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GEOLOGY AND HYDROLOGY OF THE KANOPOLIS UNIT IN ELLSWORTH, MCPHERSON, AND SALINE COUNTIES, KANSAS

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GEOLOGY AND HYDROLOGY OF THE KANOPOLIS UNIT IN ELLSWORTH, MCPHERSON, AND SALINE COUNTIES, KANSAS

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With a chapter on the Chemical Quality of the Ground Water

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This report is a joint product of the Interior Department for development of the Missouri River Basin and the cooperative ground-water program of the United State Geological Survey, the State Geological Survey of Kansas, 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 HYDROLOGY OF THE KANOPOLIS UNIT IN ELLSWORTH, MCPHERSON, AND SALINE COUNTIES, KANSAS

Abstract

This report is based on a study of the geologic and hydrologic factors that affect stream flow and the occurrence and movement of ground water in the Kanopolis Unit in central Kansas. The Kanopolis Unit extends from the Kanopolis Reservoir to the City of Salina and includes an area of 303 square miles. The Bureau of Reclamation proposes to irrigate about 64 square miles of this area with surface water from the Kanopolis Reservoir.

The exposed rocks in the area are of sedimentary origin, ranging in age from late Permian to Quaternary. The Kanopolis Unit lies within the Smoky Hills Upland region of the Great Plains physiographic province and is drained by the Smoky Hill River. Part of the present course of this river was formed after Kansan time by the capture of an ancestral stream which flowed southward from Lindsborg to the Arkansas River. Subsidence caused by dissolution of salt and anhydrite in the underlying Wellington formation may have been a contributing factor to the capture. More recent subsidences have caused high water tables in some areas and makes these areas undesirable for irrigation.

The principal hydrologic features of the Kanopolis Unit form an integrated system comprised of the alluvial ground-water reservoir, the Smoky Hill River, and the Kanopolis Reservoir. The Kanopolis Dam and Reservoir exert a varying influence, both through their presence and their operation, on stream flow and ground-water levels in the area. The stream flow and ground-water levels are related as cause and effect.

Ground-water depletion curves and graphs showing the ground-water storage and discharge relation offer a method for estimating the return flow from possible future irrigation in the area.

The alluvium is the principal water-bearing formation in the area. Moderate supplies of water are available from the Dakota and Meade formations where they crop out, and a few wells obtain small supplies from the Wellington formation, Minnesoah shale, and Kiowa shale.

Maps of the area have been prepared to show the surface geology, contours of the water table, and depth to water. A panel diagram summarizes the information obtained by test drilling.

The hydrologic and geologic data upon which the report is based are given in the report and include records of 139 wells, logs of 65 test holes and 48 observation wells, and periodic measurements of the water level in 74 observation wells.

Analyses of samples of water from 40 wells in the Hanopolis unit indicated that the water would be suitable for irrigation, but water would require treatment to be satisfactory for domestic use. Four samples from the Smoky Hill River and nine samples from or just below the spillway were found to be suitable for irrigation. One sink pond containing saline water was sampled, and probably this pond and others like it would prove troublesome after irrigation of the land unless adequate drainage is provided.

INTRODUCTION

Purpose and Scope of the Investigation

This report is based upon an investigation begun in August 1950 as part of a program of the United States Department of XXInterior for development of the Missouri River basin.

The investigation was coordinated with the cooperative ground-water studies of the United State Geological Survey, the State Geological Survey of Kansas, the Division of Sanitation of the Kansas State Board of Health, and the Division of Water Resources of the Kansas State Board of Agriculture.

The purpose of the investigation was to provide basic information from which estimates can be prepared of probable effects of irrigation upon ground-water levels, and upon stream flow, in the Kanopolis-Salina reach.

The investigation was made under the general supervision of A. N. Sayre, Chief, Ground Water Branch of the Federal Geological Survey, and G. H. Taylor, Regional Engineer in charge of ground-water investigations under the Missouri River basin program. V. C. Fishel, District Engineer in charge of ground-water work in Kansas, was in immediate charge of the field studies.

Location and Extent of the Area

The Kanopolis Unit extends along the Smoky Hill River from the Kanopolis Reservoir to Salina. This area includes the southeastern part of Ellsworth County, the northwestern part of McPherson County, and the south-central section of Saline County. An area of 303 square miles, including the proposed service area of 41,000 ax acres or about 64 square miles, was investigated. The location of the unit and other areas in which ground-water studies have been made in Kansas are shown in Figure 1.

Previous Investigations

Two previous reports on the geology and ground-water resources of areas that include a part of the Kanopolis Unit have been published. The quality and availability of water in the Smoky Hill Valley were studied and discussed by Latta (1949), and a similar report concerning a part of

Fig. 1.--Area covered by this report and other areas in Kansas for which ground-water reports have been published or are in preparation.

south-central Kansas was prepared by Williams and Lohman (1949).

Many other reports and papers were consulted during the course of the study. These publications are listed in alphabetical order in the references.

Well-Numbering System

The wells and test holes discussed in this report are numbered according to their location within the subdivisions of the General Land Office survey of the area. The component parts of a well number are the township number, the range number, the section number, 160 acre tract within the section, the 40-acre tract within the quarter section, and the 10-acre tract within the quarter-quarter section. The 160-acre, 40-acre, and 10-acre tracts are designated a, b, c, and d in a counter clockwise direction beginning in the northeast quarter. Two or more wells within a 10-acre tract are numbered serially. For example, well 15-2-18da (Fig. 2) is in the SW¼ SE¼ sec. 18, T. 15 S., R. 2 W.

Acknowledgments

The preparation of this report has been made possible by the willing assistance and cooperation of many individuals and organizations. The thanks and appreciation of the author are expressed to those residents of the Kanopolis Unit who kindly supplied information concerning their wells. O. S. Fent, geologist of the Hydraulic Drilling Company gave much help on mapping the geology of the area and supplied logs and records of many wells. Acknowledgment is made to Charles Rake, resident of Salina, and Captain B. J. Nied, Commander of the Smoky Hill Air Force Base, United States Air Force, for their permission to make the pumping test.

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

The manuscript of this report has been reviewed critically by several members of the Federal and State Geological Surveys and the Bureau of Reclamation; by Robert Smrha, Chief Engineer, and George S. Knapp, Engineer, of the Division of Water Resources of the Kansas State Board of Agriculture; and by Dwight Metzler, Director, and Willard Hilton, Geologist, of the Division of Sanitation of the Kansas State Board of Health.

Geology

The rocks of the Kanopolis Unit are products of accumulation in shallow seas. Because of the stability of the area, downsinking has been small, and therefore, the sediments are thin. The strata show abrupt vertical variation, marked lateral changes, distinctive [illegible] bedding planes, and many breaks in faunal and lithologic sequence that were caused by erosion. In general, the materials are well sorted. Limestones, shales, and sandstones are common in the geologic column; whereas conglomerates are thin and rare. Contemporaneous deformation of the beds is largely absent. The rocks of the area range in age from Pre-Cambrian to Quaternary.

Geologic History

Much of the geologic history of this area must be inferred from studies of records of deep oil wells. These records indicate that the area is underlain by about 4,000 feet of sedimentary rocks including some evaporites such as salt and gypsum. These rocks, representing several geologic eras, have been deposited on a basement complex (Pre-Cambrian) that is composed of red granite or granitic gneiss. The weathered Pre-Cambrian surface is covered in some places by an arkosic rubble. The contact of this rubble or the earliest Paleozoic rocks with

underlying igneous or metamorphic rocks of Pre-Cambrian age represents a major nonconformity in the subsurface.

Paleozoic Era

The earliest Paleozoic rocks in the subsurface of the area are late Cambrian and early Ordovician in age. Silurian and Devonian rocks are absent under part of the area, and their removal was due to erosion. A principal unconformity was produced by erosion that leveled the Silurian and removed underlying formations down to the lower Ordovician dolomites. Although rocks of Devonian age were deposited by reinvading seas after the erosional interval at the close of Silurian times, they were removed later by pre-Mississippian erosion.

As compared with earlier rocks, thick sections of Mississippian, Pennsylvanian, and Permian rocks are present in the subsurface of the area. These periods are represented by cyclic deposition of limestone and shale formed by advancing and retreating seas. The Mississippian rocks are confined largely to synclinal areas, and their thickness is related to these structural features. Rocks deposited during the Pennsylvanian and Permian Periods extend across these synclines and are, therefore, widespread over central Kansas.

Some rocks of the middle Permian crop out in the area, but the rocks of the late Permian were removed by erosion prior to Cretaceous time. During the second (Leonardian) epoch of the Permian, normal sedimentation ceased, and evaporites, notably salt and gypsum, were deposited in the sea which continued to occupy the region. The "red beds" of continental origin were deposited in this area during the later part of the Permian Period.

Lee, Leatherock, and Botinelly (1948) report that four periods of major folding occurred in central Kansas during the Paleozoic Era. This folding was related to movements of the Ozark uplift, the Central Kansas uplift, and the Ouachita basin.

The first period of folding occurred during the early Ordovician and deformed upper Cambrian and lower Ordovician dolomites. This structural deformation resulted from repeated minor movements involving the subsidence of a deep basin in central Missouri. A later period of folding probably began before Mississippian rocks were deposited and resulted from then rise of the Ozark uplift from the formerly subsiding basin in Missouri.

A third period of structural movement, which was associated with the deformation of the Ouachita basin, culminated at the close of the Mississippian Period. The fourth period probably occurred at the close of Permian time. This folding involved the development of a basin in southwestern Kansas and gave the Pennsylvanian and Permian rocks of this area a southwesterly dip.

Mesozoic Era

The folding that caused a retreat of the seas near the end of the Paleozoic Era caused sedimentation to cease until the transgression of the Cretaceous seas. Because no rocks of the Triassic or Jurassic Periods occur in the area, this part of Kansas probably was above sea level during most of those periods and erosion was dominant over deposition. A zone of cobbles and pebbles formed from pre-existing rocks occurs locally on the irregular surface between the Paleozoic and Mesozoic rocks. The cobbles of this zone, which is a loosely-cemented conglomerate

X

in some places, are fragments of igneous, metamorphic, and sedimentary rocks. These cobbles may have been deposited at any time during the interval between the ~~an~~ close of the Permian and the beginning of the Cretaceous Period.

Cretaceous rocks belonging to the Middle Comanchean Series were deposited in this area by the northward advance of seas from the south. At the beginning of the Gulfian Epoch the advancing seas retreated temporarily, and the Dakota sandstone of deltaic origin was deposited over the Kiowa shale as the seas retreated.

The Upper Cretaceous shales and limestones that are present elsewhere in Kansas probably were deposited in this area, but these rocks have been removed since by erosion. Orogenic movements at the close of the Mesozoic Era formed the Rocky Mountains and also raised the rocks of this area to their present elevation.

Cenozoic Era

Erosion removed much of the Cretaceous sediments of the area and also much of the Pennsylvanian and Permian sediments east of the area after these rocks were tilted at the close of the Mesozoic Era. Although arkosic outwash from the Rocky Mountains probably extended to this area during the Tertiary Period, these materials, too, have been removed by erosion.

The only rocks of the Cenozoic Era that crop out in the Kanopolis Unit belong to the ~~XXXXXX~~ Quaternary Period. The geologic history of these rocks of relatively recent age is associated with the physiography; hence, the more recent geologic history must be interpreted from a study of the land surface.

Physiography

The Kanopolis Unit lies within the Smoky Hills Upland region of the Great Plains physiographic province. The strata in the area dip gently to the west, and the land surface slopes to the east so that successively older formations are exposed from west to east. The moderately hard sandstone of the Dakota formation forms an east-facing cuesta with numerous outlying remnants. These remnants form prominent buttes along the valley of the Smoky Hill River. Streams in the area have dissected an old erosional plain creating a rolling topography in the intervalley areas.

Smoky Hill Valley

The Smoky Hill River is an obsequent stream flowing in a direction opposite to the dip of the formations and is superimposed on that dip as far as Lindsborg; thereafter, the stream abruptly sweeps northward along a belt of soft Permian shale to Salina where it again flows eastward and becomes obsequent. The belt of soft rocks causes a marked change in the characteristics of the stream. Above Lindsborg the river is a mature stream with an average gradient of 3 feet to the mile, a somewhat meandering course, and a well-developed terrace system. The stream below Lindsborg has older characteristics in that the gradient is reduced to 2 feet to the mile; the stream has a continuous meander belt; the terraces are more obscured; and natural levees have developed. These levees cause Dry Creek to flow parallel to the Smoky Hill River from near Lindsborg to where the creek enters the Saline River north of Salina.

The older characteristics of the stream below Lindsborg result at least in part from the development of the valley along the strike of less

resistant rocks because this part of the stream is actually much younger in years than that part above Lindsborg.

Much of the present course of the Smoky Hill River in the Kanopolis Unit was formed through the capture of the Smoky Hill from its former course by a tributary to the Saline River. The Smoky Hill formerly flowed southward from an area near Lindsborg to the Arkansas River system. The gravel deposits of Kansan age near Marquette and south of Lindsborg were deposited by this stream that flowed at a much higher elevation than at present.

The capturing stream probably was aided in its headward erosion by subsidence caused by the removal of salt and anyhdrite. The subsidence gave the capturing stream the advantage of a lower position. In discussing the salt removal, Lee and others (1948, p. 111) stated:

> .....the salt and most of the associated anhydrite have been dissolved by surface waters for a distance of 20 or 30 miles down dip from the belt in which it normally should outcrop. The removal of the salt has allowed the overlying deposits to slump into a zone of steep dips and confused bedding.

The present valley of the Smoky Hill River below the elbow of capture occupies a part of that area where salt once occurred below the surface, and the greatest depth of the valley is about midway between Lindsborg and Salina (Pl. 5). Further evidence of the slumping can be seen in the vally of Gypsum Creek, which drains an area east of the Kanopolis Unit. In this valley the Carlton limestone member of the Wellington shale has slumped on both sides of the valley because of the removal by ground water of part of an underlying gypsum bed. This gypsum bed is lower stratigraphically than the salt and anhydrite beds

mentioned by Lee and others, and the present slumping may be a second stage of subsidence caused by dissolution of gypsum rather than salt. The sink holes and subsidence structures that are discussed later in this report are other effects of the salt removal.

The abandoned part of the former Smoky Hill River lost much of its volume after the capture and became an underfit stream. The former valley was filled with gravity deposits and alluvial fans built by tributaries because the stream in its shrunken condition no longer could transport the normal load. Thus, the only obvious evidence of capture remaining is the angular bend or elbow of capture near Lindsborg.

Studies of the alluvial terraces along the river by Frye, Leonard, and Hibbard (1943) and Fent (1950) placed the date of capture as Middle Pleistocene and Middle Wisconsinan, respectively. A recent review by both Frye and Fent (not published) of their earlier work indicates that the capture may have occurred during the Illinoian or Sangamonian Stages.

Stream Terraces

The alluvial terraces in the Smoky Hill Valley shown on Plate 1 have resulted from the erosion of former alluvial or colluvial deposits. Erosion by a stream is significant after the stream is rejuvenated by an increase in volume of water or a decrease in load. Apparently three periods of rejuvenation have taken place above the elbow of capture of the stream; below the elbow the stream has been renewed at least once and possibly a second time although the evidence is obscured. The changes in volume or load have been gradual, and the stream has continued to maintain the characteristics of a mature stream.

The development of the terraces probably has been associated with the advance and retreat of glaciers during the several glacial stages.

Although the glaciers did not reach the area of this report, they influenced the climate and the streams of the area. Changes in climate wrought by the glaciers had a direct effect on the volume of the stream, and the streams were affected further by glacial and fluvioglacial deposits in areas remote from the Kanopolis Unit. Overloading of the Kansas and Missouri Rivers by these deposits caused such tributaries as the Smoky Hill River to aggrade their valleys. The subsequent reduction of load in the lower part of the system at the close of the glacial stages caused erosion of the valley and development of terraces. In general, the terraces along the Smoky Hill River correspond in age to the interglacial stages, although some of the terrace development may be due to other causes. These causes are generally the result of temporary damming, accelerated downcutting where soft rocks are present, or the loss or capture of tributaries in the headwater areas.

A terrace in section 3, T. 17 S., R. 5 W., has been caused by differential erosion. Underlying Niobrara shale is protected from erosion by the cobble zone which marks the contact between Paleozoic and Mesozoic rocks.

For a more complete discussion of the terraces, especially in regard to their ages, reference is made again to Frye, Leonard, and Hibbard (1943), and Fent (1950).

Sink Holes and Subsidence Structures

Many small synclines and anticlines form physiographic features in the western part of the unit. These structures have been formed comparatively recently because they have been affected very little by erosion. The anticlines form many small rounded hills along the edges of the river

valley west of Lindsborg. Some of the synclines have been partly filled, but in some places they can be recognized by the high water table caused by the structures.

The physical cause of these structures is the removal of salt by solution from the underlying Wellington formation. Bass (1926) has shown that the subsidence area approximately coincides with the present eastern margin of the salt beds of the Wellington formation.

Several sink holes, most of which have been refilled, have developed along the eastern and southern edges of the subsidence area. Apparently these sinks are the result of later stages of the subsidence because they are present where the underlying salt is removed.

Several of the structures are apparent on the depth-to-water map (Pl. 3) where they are outlined by those zones in which the water table is less than 10 feet below the surface.

Hydrology

The principal hydrologic features of the Kanopolis Unit include the alluvial ground-water reservoir, the Smoky Hill River, and the Kanopolis Reservoir. Although these features form an integrated system and each affects the operation of the others, they must be studied separately because of their different physical nature. Certain variable factors, such as precipitation and temperature, have a widely varying influence on different parts of the system.

The several hydrologic features and their relations to each other are discussed separately in this report.

The Ground-Water Reservoir

The ground-water reservoir is the part of the hydrologic system which is most subject to geologic controls. The textures, structures, and composition of rocks within the reservoir control the volume and movement of ground water.

The study of ground water in the unit has been based on data obtained from geologic interpretations, an analysis of a pumping test, the logs of many test holes, and records of 139 wells (Table 8). Measurements of water levels made on 74 of these wells are given in the table of water-level measurements (Table 9). The records of wells constructed or inventoried during the investigation and the logs of observation wells and test holes are given in this report. A panel diagram summarizing the information obtained from test drilling is shown on Plate 4.

Maps showing the locations of wells, contours of the water table, and the depths to water have been prepared from well data and are shown on Plates 2 and 3. The data upon which these maps are based were obtained during a year of unprecedented precipitation in which the normal yearly precipitation of about 27 inches was exceeded by over 23 inches. Although this abnormal rainfall produced a marked effect on ground-water levels, most of the information contained in the maps is relevant for more average conditions. The two maps were prepared from measurements made during the first week of July 1951, and at that time the rise of the water table was apparently uniform over the area except for the area immediately below the Kanopolis Dam. A map showing the thickness of saturated materials is shown on Plate 5. This map has been prepared

from bedrock data that are inadequate for some parts of the area; however, the maps give useful general information concerning the shape, thickness, and extent of the ground-water reservoir.

Source, Occurrence and Movement of Ground Water

The principles governing the source, occurrence, and movement of ground water have been discussed by O. E. Meinzer (1923), and their applications to Kansas have been summarized by R. C. Moore (1940). Only a very general discussion of the most pertinent principles will be given in this report.

The primary source of all ground water is precipitation in the form of rain or snow. Part of this water runs off directly as stream flow, but much of it is absorbed by the soil. A part of the water held by the soil is used by plants, a part evaporates, and the remaining small part moves by gravity through rock pores to the zone of saturation.

The permeable rocks that lie below the zone of saturation are generally saturated with water, and these rocks form the ground-water reservoir. Rocks may be permeable by virtue of containing voids larger than capillary size or secondary openings such as joints, fractures, solution cavities, and weathered bedding planes.

Water reaching the zone of saturation moves through the rocks into other areas or to places of discharge from the ground-water reservoir. The ground water generally moves in a direction oblique to the course of the major stream; the water moves down the gradient and toward the stream from the point where the water joined the water table. However, this movement is altered considerably during high stream stages.

The water table, which is the surface of the ground-water reservoir, is not a level surface, but has irregularities that are a modified expression of the topography. Furthermore, the water table does not remain at a constant level but, like surface reservoirs, fluctuates up and down in response to recharge or discharge. Measurements of the fluctuations of the water table are given in Table 9. The hydrographs of five wells are shown in Figure 3. These hydrographs show the fluctuations of water levels caused by precipitation, influent seepage from the river, and recharge from flood water on the flood plain. Measurements of the water levels in these wells were started in 1946. From 1946 through 1951 the water levels fluctuated from 2 to 4 feet annually because of precipitation and some influent seepage from the river during flood periods. During the summer of 1951 the water levels rose an average of about 12 feet because of heavy rains on the flood plain, by influent seepage from the river, and by recharge from flood water on the flood plain. During the last quarter of 1951, the water levels declined sharply, but at the end of 1951 the water levels were still at higher levels generally than at any time prior to 1951. From 1951 through 1955 the water levels in this area declined steadily. The water levels in some wells with consistently high levels have relatively minor fluctuations. These wells penetrate water bodies that are isolated from the main ground-water reservoir by the subsidence structures mentioned earlier in this report. The water table in some of these areas is kept below the surface only through use of the water by plants. These conditions exist in those areas west of Lindsborg in which the water table is less than 10 feet below the surface. The

Fig. 3.---Hydrographs of five observation wells in the Kanopolis Unit,

perched water bodies are recharged in the same manner as the major alluvial reservoir, but discharge, other than by evaporation and transpiration, is inhibited by the rock structure.

Ground-water Recharge

Recharge to the ground-water reservoir of the area must occur through percolation of excess soil moisture to the zone of saturation and through influent seepage from streams. Recharge is generally at a maximum during the early spring when rainfall amounts are large and before the demands of evaporation and transpiration by plants are great.

Influent seepage from streams is an important source of recharge in the area during floods or when high stream levels are maintained by the operation of the Kanopolis Reservoir. High stream levels have the additional effect of reducing effluent seepage and thereby damming ground water. The extremely high ground-water levels observed during the late summer and fall of 1951 were caused by this damming effect which resulted from the excessive stream flows required to reduce the Kanopolis Reservoir to conservation level after the record breaking floods of June and July (Water Resources Division, 1951). As shown in Figure 4, ground-water levels fall rapidly when the river stage is lowered.

Subsurface-Water Discharge

Much of the water below the zone of saturation eventually returns to the surface through discharge by wells, springs, and seeps through transpiration by plants, or through evaporation directly from the soil where the water table is near the surface. Much ground water is discharged by percolation to surface streams. This form of discharge from the ground-water reservoir is effluent seepage. Large demands on ground

Fig. 4.--Records of precipitation and ground-water levels at well 17-3-3cca and river stages at the Lindsborg and Langley gages for the year beginning April 1, 1951. The ground-water levels and the river stage at Lindsborg are referred to a common datum.

water are made by plants during the growing season and especially during droughts when depletion of soil moisture induces a transfer of water by capillary action from the zone of saturation. Such deep-rooted plants as alfalfa and cottonwood trees can draw water directly from the water table over much of the area where the depth to water is less than 20 feet.

Springs and seeps from the alluvium of the region are limited largely to the beds of intermittent streams tributary to the Smoky Hill and Saline Rivers. Large withdrawals from the Salina and Camp Phillips well fields produce local depressions in the water table.

Effect of Irrigation on the Water Table

An estimate of the effect of irrigation with surface water on ground-water levels in this area is necessarily approximate because of the short record of water-level measurements and because of numerous indeterminate variables which affect the estimate. The amounts of irrigation water that would be used by the service area during different growing seasons are themselves variable. The additional factors of efficiency of application, absorption capacity of ~~in~~ the soil, evaporation losses, and even the water requirements of crops have a varying influence on accretion to the water table. The variables listed above are dependent in turn upon changes in weather, climate, and soil.

In order to minimize the effect of these variations, deviations from average precipitation have been correlated with corresponding changes in ground-water levels. The cumulative changes in precipitation and water levels are shown in Figures 5 and 6, respectively.

Fig. 5.—Graph of cumulative deviation from normal of monthly precipitation at Lindsborg.

Fig. 6.—Graph of average cumulative net change of water levels in four observation wells (15-2-17cd, 15-2-18cd, 16-3-4a, and 16-3-34dd).

The trends of these two curves are parallel until late in 1948 when the release of water from storage from the Kanopolis Reservoir caused some divergence of the curves. A comparison of the departure curves for the earlier part of the record indicates that a deviation of one inch from normal rainfall will produce a cumulative change of about one-third foot in water-table elevation after a time lag of about six weeks. These are average values, however, and large changes in the ratio of rainfall to recharge can be expected under some conditions.

The use of this ratio permits an estimation of the effect of irrigation on the ground-water reservoir. Table 1 shows the water requirements of crops in feet of water in the Kanopolis Unit as estimated by the Bureau of Reclamation. This table indicates that about 1.89 feet or 22.68 inches of water on the irrigated acreage will be diverted from the Kanopolis Reservoir to the proposed irrigation district.

Table 1.--Average annual water requirements of crops in the Kanopolis Unit as estimated by the Bureau of Reclamation 1/

	Feet of water, per acre	
Consumptive use requirements	2.71	
Farm loss	.31	
Canal loss	.66	
Effective precipitation		1.79
Diversion requirement		1.89
Total	3.68	3.68

1/ Data provided by Bureau of Reclamation

The application of water will cause a rise in ground water level which will vary both with time and location in the service area. The application of 1.89 feet of water in excess of normal rainfall may cause a rise in the ground water level of about 7 feet.

The Smoky Hill River

The Smoky Hill River is an important hydrologic feature of the Kanopolis Unit. The flow of the river in this area depends upon discharge from the Kanopolis Reservoir, discharge from the ground-water reservoir, and surface runoff from precipitation in the area.

The discharge from each of these sources varies as conditions within the hydrologic system change. In general, the peak flows of the river are caused by surface runoff, and the lesser flows are maintained by ground-water discharge. The Kanopolis Reservoir normally serves to reduce peak flows and increase minimum flows of the xx river.

The flow in general and the estimates of the amounts of water supplied to the stream by the several sources were determined through analyses of records from the three gages. These gages are located strategically within the area. The Langley gage is near the outlet of the dam; the Lindsborg gage is near the center of the area; and the Mentor gage, which is one mile south of Salina, is near the northern end of the area. The analyses of these gage records indicate that the Smoky Hill River is a gaining stream throughout the length of the Kanopolis Unit.

Stream levels and ground-water levels in the area are related as cause and effect. The level of one of the hydrologic features may be dependent entirely or in part on conditions existing in the other.

Although the water table fluctuates with a rise or fall in stream level, that fluctuation alone will affect stream flow. An illustration of the relation between stream flow and ground-water levels is shown in Figure 4, which gives the stream stages at the Lindsborg gage and the fluctuations in the water table for the year beginning April 1, 1951. Changes in ground-water level were measured by a water-level recorder installed on well 17-3-3caa, about 200 yards from the Smoky Hill River. The precipitation record, obtained from a U. S. Weather Bureau rain gage near well 17-3-3caa, and the discharge from the Kanopolis Reservoir during that same period have been included to show their effects on ground-water levels and stream flow.

The curves in Figure 4 show that high stream stages cause, in part at least, a rise in the water table; whereas, the stream stage is lower than the water table during depletion of the ground-water reservoir. The time lag between related changes within the system also is apparent from the figure. Both rainfall and discharge from the Kanopolis Reservoir affect stream flow and ground-water levels, but only the discharge through the dam can be controlled.

The Kanopolis Dam and Reservoir

The most impressive feature of the hydrologic system is the Kanopolis Dam and Reservoir. The earth-filled embankment rises 131 feet above the stream bed, has a total length of 15,810 feet, and required the placing of 14,668,000 cubic yards of six selected earth materials. The width of the top of the dam is 25 feet, and the average base width is 730 feet. The riprap protection against wave action on the upstream face of the dam entailed the placement of 173,400 cubic

yards of stone. The downstream face of the dam has been planted to erosion-resistant grasses.

Water is released from the reservoir through a reinforced concrete tunnel that is 14 feet in diameter and 2,443 feet long. Flow through the tunnel is regulated by two gates at the upstream end of the conduit. The capacity of the tunnel has been designed to approximately equal the channel capacity of the river downstream from the dam.

The reservoir normally is maintained at a conservation pool of 50,000 acre-feet that covers an area of 3,550 acres and provides a lake 12 miles long with a shoreline of 30 miles. During periods of heavy rainfall, the lake may enlarge to cover 13,900 acres and store 450,000 acre-feet of water. The reservoir has an external spillway which limits the volume of the reservoir to the 450,000 acre-feet.

Flood detention by the dam began by diverting the river through the tunnel outlet in July 1946. Flows in excess of 4,000 cubic feet per second were temporarily impounded until February 1948, when storage for filling the conservation pool began. The capacity of the reservoir was nearly reached during July 1951, because of the heavy rains in the Kansas River basin.

The dam and reservoir exert a varying influence, both through their presence and their operation, on stream flow and ground-water levels in the area.

Effect on Stream Levels

Except for surface runoff and ground-water discharge from areas below its outlet, the Kanopolis Dam controls the flow of the Smoky Hill River. Before the construction of the dam, the maximum and minimum flow at the Langley gage was 61,000 and 2 cubic feet per second, respectively.

Since the completion of the dam, the flow generally has been regulated between 4,000 and 67 cubic feet per second.

Although this control by the dam reduces the peak flows of the stream, the changes in discharge from the dam are much more abrupt than a natural rise and fall of the stream (Fig. 4). Sudden large reductions in stream flow, as on November 1, 1951, cause considerable slumping of the stream banks which has a serious effect on bridge foundations and roads near the river. A more uniform operation of the outlet would reduce the slumping materially.

Effect on Ground-Water

The dam and reservoir have an indirect influence on ground-water levels through their control of stream flow. The dam has a more direct but less obvious effect in that it also serves as a barrier to ground-water movement as well as surface-water flow. The earth embankment forming the dam is keyed to impermeable bedrock across the width of the valley and therefore bars the movement of ground water down gradient in the alluvium. The water-table contour map on Plate 2 shows that the part of the reservoir immediately below k the dam receives recharge only from rainfall and influent seepage. These sources of recharge should compensate for the loss of ground water moving into the ground-water reservoir; however, low stages of the stream cannot be sustained for long by this part of the ground-water reservoir because of its influent nature.

Above the dam, ground-water levels in the alluvium are higher than those before the construction of the dam by amounts corresponding to the levels of the reservoir.

Hydrologic Properties of the Alluvium

The quantity and movement and, to an extent, the quality of water within an q aquifer depend upon the physical and hydrologic properties of the materials composing the aquifer. Geologic examinations of outcrops and of materials penetrated by drilling permit an estimate of the quantity of water available in an area, but more quantitative measures of a formation, such as permeability, transmissibility, and storage coefficient, are based on analyses of the materials by laboratory and discharging-well methods. The physical and hydrologic properties of the alluvium of the Kanopolis Unit have been determined by these methods.

The laboratory studies included mechanical analysis and determinations of the coefficients of permeability, porosity, specific retention, and specific yield. As a part of these studies, further tests were made to determine the specific gravity of the materials, the apparent specific gravity or dry unit weight, and the centrifuge moisture equivalent.

Laboratory Methods and Determinations

During the period of August 29 to September 14, 1950, samples of water-bearing materials were collected in the area. Most of these samples were obtained in an essentially undisturbed condition by means of a driven tool which obtained 1 by 6-inch core samples in brass cylinders. Some additional disturbed samples were collected with hand augers. Quantitative analyses of these samples were made under the direction of A. I. Johnson in the Hydrologic Laboratory of the Federal Geological Survey at Lincoln, Nebraska.

The results of these analyses are summarized in Table 2. The locations where the samples were collected are designated in the table according to the well-numbering system described in this report.

Mechanical analysis.—A mechanical analysis is the determination of the distribution of various particle sizes within a sample. Samples as received were prepared for analysis, after being air-dried, by separating lumps of the material into individual particles with a mortar and rubber-covered pestle. Care was taken to merely separate, not crush, the individual particles.

Particle sizes smaller than 0.0625 mm were determined by the hydrometer method of wet analysis, and the larger sizes were determined by the wet sieve method. In the hydrometer method of mechanical analysis, a representative portion of the sample is dispersed in one liter of water with a suitable deflocculating agent, and the density of the suspension is measured at various times with a soil hydrometer. At any given time, the size of the largest particles remaining in suspension at the level of the hydrometer may be computed from Stoke's Law. The fraction of the sample that was less than 0.0625 mm in size was separated from the rest of the sample by washing through a sieve with that size openings. The material retained on the sieve was dried and then placed in a set of standard 8-inch sieves, and the sample was shaken in the sieves by a mechanical shaker for 15 minutes. The fractions of the sample retained by each sieve were weighed on a torsion balance.

The percentage of particles smaller than a given size was determined by making a semi-logarithmic plot of particle size in

millimeters against accumulative percentages by weight of the size groups. The percentage in various size ranges then was determined from this curve. The classification of size ranges used for these analyses is Wentworth's grain-size definition for sedimentary materials.

Permeability.--The permeability of water-bearing material is defined as the capacity of the material for transmitting water under a hydraulic head. Permeability is determined in the laboratory by observing the rate of percolation of water through a sample.

The coefficient of permeability as used by the Ground Water Branch of the Geological Survey is reported in Meinzer's units. Meinzer's unit is defined as the rate of flow of water in gallons per day through a cross-sectional area of one square foot under a 100 percent hydraulic gradient at a temperature of 60 degrees Fahrenheit. The permeability of water-bearing materials varies over a wide range, depending in general upon the degree of assortment and the arrangement and size of the particles. The permeability generally is low for clay and other fine-grained materials and high for coarse, clean gravel. Coefficients of permeability for good water-bearing materials are usually values of 200 or more above. The coefficient of transmissibility defined by Theis (1935) is equal to the coefficient of permeability multiplied by the saturated thickness of the water-bearing materials.

Coefficients of permeability were determined for all the core samples collected. The samples were tested while still in the brass cylinders in variable-head permeameters of a type similar to that used by the U. S. Geological Survey (Wenzel, 1942, pp. 59-63).

Tap water was used as a percolation fluid.

Porosity.—The porosity is the ratio of the volume of the void spaces contained in a rock or rock aggregate to the total volume of the rock. Porosity determines the total water-holding capacity of a formation; if all voids are filled with water, a rock is said to be saturated.

The pores in a rock may be either original or secondary. Original porosity was determined at the time the rock was formed and is affected by (1) uniformity of grain size, (2) shape of the grains, (3) method of deposition, and (4) compaction during and after deposition. Secondary porosity results from later changes which may increase or decrease the original porosity. Such secondary changes include fracturing, solution, and cementation. Natural sands generally have porosities varying from 25 to 45 percent; whereas clays normally have porosities of about 30 to 60 percent although some values are as high as 90 percent.

The porosity of the core samples was determined as a by-step in the permeability tests. The apparent specific gravity or the dry unit weight of the sample was determined from the ratio of the dry weight to the known volume of the filled cylinders. After determining the specific gravity of the grains, the porosity of each sample was obtained from the ratio of the specific gravity to the difference between the specific gravity and the apparent specific gravity.

Specific retention, Specific yield, and Centrifuge Moisture Equivalent.—The specific retention of a rock is that part of the pore space which

is occupied by water retained against the force of gravity by molecular attraction. The specific yield or effective porosity of a rock is the percentage of the volume of the rock that may be dewatered by pumping or draining. The total porosity of a rock is the sum of the specific yield and specific retention. The specific yield is equivalent to the coefficient of storage defined by Theis (1935) for water-table conditions. The coefficient of storage is also applicable to artesian conditions and is defined as the water released from storage from a vertical column of aquifer, one foot square and the height of the saturated portion of the aquifer, when the hydraulic pressure on the column is reduced one foot.

The centrifuge moisture equivalent of a rock is the amount of water, expressed as a percentage of the dry weight, retained by the material which has first been saturated with water and then subjected to a force equal to 1,000 times that of gravity for one hour. The centrifuge moisture equivalent is multiplied by the apparent specific gravity to obtain the moisture equivalent by volume.

The specific yields of the samples were determined by an indirect laboratory method. The centrifuge moisture equivalent by volume was determined and adjusted by a correction factor proposed by Piper (1933); this adjusted value was considered equivalent to the specific retention. The specific retention then was subtracted from the porosity to obtain the specific yield.

Discharging-Well Methods and Determinations

Methods of determining the permeability, transmissibility, and coefficient of storage of an aquifer from data obtained from pumping tests are based on the law of flow of water through sand developed by

Darcy in 1856. Darcy's law may be written: Q = PIA, in which Q is the quantity of water that moves through A, the cross-sectional area of water-bearing material at a rate dependent upon P, the coefficient of permeability, and I, the hydraulic gradient.

The coefficients of transmissibility and storage determined by these methods are the formational constants which control the availability of ground water. The storage coefficient may be defined as the cubic feet of water discharged from each vertical column of the aquifer with a base one foot square as the water level falls one foot. The transmissibility coefficient is the discharge in gallons per day through each one-foot strip extending the height of the aquifer under a hydraulic gradient of 100 percent (Theis, 1935, p. 520). The coefficient of transmissibility is equal to the coefficient of permeability multiplied by the saturated thickness of the aquifer.

In order to determine these hydrologic properties for the alluvium of the Kanopolis Unit, a pumping test was made on well 2 of the Camp ~~XXX~~Phillips well field in the NW¼ NW¼ NE¼ sec. 7, T. 15 S., R. 2 W., in the Smoky Hill Valley near Salina. The position of the well with respect to the river is shown in Figure 7. The distance from the well to the river at its nearest point is about 1,000 feet, and a terrace, which is the boundary of the river floodplain, lies 300 feet west of the pumped well. The geologic map (Pl. 1) indicates that the alluvium is quite extensive in this area.

The alluvium at the pumped well consists of coarse sand and gravel from 19 to 28 feet, clay from 28 to 31 feet, and coarse sand and gravel from 31 to 57.5 feet. (Table 11). The well was equipped

Fig. 7.--Location of Camp Phillips well and observation wells used during pumping test.

with a Layne turbine pump powered by an electric motor. The well was pumped at a rate of about 1,080 gallons a minute throughout the test.

The 12 observation wells in which water levels were measured during the test were located as shown in Figure 7. These wells were 30 feet deep except for well D-2 which was 26 feet deep. None of the observation wells penetrated the clay lens, but this lens may extend to or beyond some or all of the wells at a depth below 30 or 31 feet. The water table in the area of the pumping test was about 1,225 feet above mean sea level and about 17.5 feet below the land surface. The slope of the water table was northeast toward the river.

The data obtained from the pumping test were analyzed by both the Theis and the Thiem methods. For a detailed discussion of these methods and a general derivation of their formulae, the reader is referred to Wenzel (1942). Much of the following analysis of the data by the Theis method has been prepared by Mrs. Alice Bentall of the Federal Geological Survey.

Inspection of the pumping test data (Table 10) indicates that in the C- and D-lines of wells some of the drawdowns in wells farthest from the pumped well are greater than corresponding drawdowns in nearer wells. This abnormal behavior also may be seen in the arithmetric distance-drawdown plots (Fig. 8) that show the shape of the cone of depression at given times, In the D-line of wells, the drawdowns in well D-2 are greater than the corresponding drawdown in well D-1 for the entire period of pumping. In the C-line of wells, the drawdowns in well C-3 are greater than those in well C-2 for only 420 minutes after pumping started. Where the drawdown at a farther well is greater,

Fig. 8.---Cross-sectional drawdown diagram of Smoky Hill pumping test.

at a given time, than the drawdown in a well nearer to the pump, the ground-water flow is necessarily in a direction away from rather than toward the pumped well. This phenomenon may be caused by the clay lens that may underlie the observation wells and that is penetrated by the pumped well. Until that time when the water would be derived from beyond the edge of the clay lens, the alluvium in this small area essentially is divided into two aquifers by the lens. This premise suggests that the water supplied to XX the pump from sand above the clay must travel a devious route around the outer edge of the lens to the pumped well. However, the gravel packing of the pumped well provides a connection of limited capacity between the upper and lower sands.

Analysis by the Theis method.--The hydrologic conditions described above make the problem of determining the formational constants somewhat complex because the discharging-well methods require an assumption of ideal conditions. The Theis method is based on the analogy that exists between Darcy's law and the law of the flow of heat by conduction; thus, the mathematical theory of heat conduction is largely applicable to hydraulic theory where an extensive aquifer of homogeneous materials exists.

The following Theis formula is one of those used in computing the formational constants:

$$s = \frac{114.6\, q\, W(u)}{T}$$

$$W(u) = \int_u^\infty \frac{e^{-u}}{u}\, du$$

$$u = \frac{1.87\, r^2 s}{Tt}$$

The formula is the mathematical expression of the conditions existing in an aquifer in which s is the drawdown in feet at any point in the vicinity of a well discharging at a uniform rate, q, in gallons per minute; T is the coefficient of transmissibility of the aquifer; r is the distance of the discharge well from the point of observation in feet; S is the coefficient of storage (a decimal fraction); and t is the time the well has been pumped in days.

The values for S and T are determined by plotting observed data for each observation well on log-log paper and adjusting these graphs horizontally to coincide with the logarithmic graph of the well-function type curve given in Figure 9. The coordinate values at a point of coincidence of the two curves than are substituted into the Theis formula. The observed data curves are made by plotting drawdown as ordinates and r^2/t values as abscissas.

The observed data graphs for each of the observation wells gives tri-artite curve that indicates the existence of two sources of interference. One of the sources may be the edge of the clay lens, and the other is the influence of the river.

The Theis method analyses indicate that the transmissibility of the alluvial aquifer is 170,000 gallons per day per foot; the permeability is 4,250 gallons per day per square foot; and the storage coefficient is between .002 and .008. Amounts of water exceeding 1,000,000 gallons per day could be withdrawn indefinitely from wells penetrating an aquifer with these hydrologic properties.

Analysis by the Thiem method:--The Thiem method of determining the transmissibility of water-bearing materials is based on the assumption

Fig. 9.—Logarithmic graph of the well-function type curve.

that water moves toward a pumped well equally from all directions, and that the same quantity of water moves toward the pumped well through each of an indefinite series of concentric cylindrical sections around the pumped well. The velocity of the ground water passing through each of the cylindrical sections is directly proportional to the areas of the cylinders, and the hydraulic gradient is inversely proportional to those areas.

C. E. Jacob has developed a convenient formula for determining transmissibility by the Thiem method:

$$T = \frac{2.30\,Q}{(2\pi)\,\Delta s'}$$

and $s' = s - \frac{s^2}{2m}$ approx

in which T is the coefficient of transmissibility; Q is the rate of pumping in gallons per day; s is the drawdown at a particular time; and m is the average saturated thickness of the water-bearing material.

Values of $\Delta s'$ are the changes in drawdown over one cycle of semi-logarithmic paper when s' is plotted on the natural scale against the distances of the observation wells from the pumped well on the logarithmic scale. Values of $\Delta s'$ are dependent on the slope of a straight line. The transmissibility is computed separately for each line of observation wells.

A summary of the Thiem method analyses for three lines of wells with valid data is given in Table 3. The average of those transmissibilities given in the summary is about 158,000 gallons per day. This value is somewhat less than that obtained from the Theis analysis, and the storage coefficient is correspondingly higher. However, the results

Table 3.—Summary of Thiem method analyses

Line A

Well No.	Date	Time	Hours Pumping	t Days Pumping	s Drawdown	$\frac{s^2}{2M}$	$\frac{s'}{s-\frac{s^2}{2M}}$	$\Delta s'$	$\frac{T}{\frac{270,000}{\Delta s'}}$
A-1					2.15	0.0594	2.09	5.20-2.03	
A-2	Jan. 9, 1951	12:30 P.M.	2 2/3	0.111	1.03	0.0136	1.02	3.17	179,000
A-3					0.17	0.0005	0.17		
A-1					2.35	0.0708	2.28	5.62-2.26	
A-2	Jan. 9, 1951	3:30 P.M.	5 2/3	0.236	1.26	0.0204	1.24	3.36	169,000
A-3					0.25	0.0008	0.25		
A-1					2.61	0.0875	2.52	6.15-2.55	
A-2	Jan. 9, 1951	8:00 P.M.	10 1/6	0.424	1.58	0.0320	1.55	3.60	158,000
A-3					0.33	0.0014	0.33		
A-1					2.79	0.0999	2.69	6.33-2.73	
A-2	Jan. 9, 1951	12:00 M.	14 1/6	0.590	1.75	0.0393	1.71	3.60	158,000
A-3					0.53	0.0036	0.53		
A-1					2.96	0.1123	2.85	6.63-2.92	
A-2	Jan. 10, 1951	4:00 A.M.	18 1/6	0.757	1.91	0.0468	1.86	3.71	154,000
A-3					0.62	0.0049	0.61		
A-1					3.17	0.1260	3.04	6.90-3.10	
A-2	Jan. 10, 1951	8:00 A.M.	22 1/6	0.923	2.09	0.0560	2.03	3.80	150,000
A-3					0.75	0.0067	0.74		
A-1					3.32	0.1426	3.18	7.05-3.26	
A-2	Jan. 10, 1951	2:00 P.M.	28 1/6	1.172	2.27	0.0663	2.20	3.79	150,000
A-3					0.91	0.0109	0.90		
A-1					3.40	0.1482	3.25	7.15-3.35	
A-2	Jan. 10, 1951	6:00 P.M.	32 1/6	1.338	2.37	0.0720	2.30	3.80	150,000
A-3					1.00	0.0128	0.99		
A-1					3.47	0.1542	3.32	7.22-3.45	
A-2	Jan. 10, 1951	10:00 P.M.	36 1/6	1.506	2.46	0.0775	2.38	3.77	161,000
A-3					1.20	0.0189	1.18		

Table 3 (Continued)

Line A

Well No.	Date	Time	Hours Pumping	t Days Pumping	s Drawdown	$\frac{s^2}{s2\ M}$	$\frac{s'}{s-s^2/2M}$	$\Delta s'$	$\frac{T}{\frac{270,000}{\Delta s'}}$
A-1					3.61	0.1670	3.44	7.35-3.57	
A-2	Jan. 11, 1951	6:00 A.M.	44 1/6	1.842	2.65	0.0910	2.56	3.78	151,000
A-3					1.25	0.0201	1.23		
A-1					3.69	0.1745	3.52	7.45-3.71	
A-2	Jan. 11, 1951	9:30 A.M.	47 2/3	1.988	2.75	0.0970	2.65	3.74	152,000
A-3					1.34	0.0230	1.32		
Line B									
B-1					4.22	0.230	3.99	6.77-2.89	
B-2	Jan. 9, 1951	3:30 P.M.	5 2/3	0.236	1.81	0.042	1.77	3.88	147,000
B-3					0.47	0.0028	0.47		
B-1					4.50	0.260	4.24	7.10-3.12	
B-2	Jan. 9, 1951	8:00 P.M.	10 1/6	0.424	2.07	0.0540	2.02	3.98	143,000
B-3					0.61	0.0048	0.60		
B-1					4.67	0.285	4.38	7.32-3.27	
B-2	Jan. 9, 1951	12:00 M.	14 1/6	0.590	2.23	0.066	2.16	4.05	140,000
B-3					0.75	0.0067	0.74		
B-1					4.80	0.299	4.50	7.40-3.40	
B-2	Jan. 10, 1951	4:00 A.M.	18 1/6	0.757	2.35	0.0708	2.28	4.00	142,000
B-3					0.83	0.009	0.82		
B-1					4.91	.310	4.60	7.48-3.50	
B-2	Jan. 10, 1951	8:00 A.M.	22 1/6	0.923	2.50	.080	2.42	3.98	143,000
B-3					0.97	.010	0.96		
B-1					5.07	.329	4.74	7.62-3.63	
B-2	Jan. 10, 1951	2:00 P.M.	28 1/6	1.172	2.65	0.0910	2.56	3.99	142,000
B-3					1.08	0.015	1.06		
B-1					5.17	.348	4.82	7.78-3.75	
B-2	Jan. 10, 1951	6:00 P.M.	32 1/6	1.338	2.75	0.0970	2.65	4.03	141,000
B-3					1.16	0.017	1.14		

Table 3 (Continued)

Well No.	Date	Time	Hours Pumping	t Days Pumping	s Drawdown	$\frac{s^2}{2M}$	$\frac{s'}{s-\frac{s^2}{2M}}$	$\Delta s'$	$\frac{T}{\frac{570,000}{\Delta s'}}$
Line B									
B-1					5.25	0.354	4.90	7.84-3.85	
B-2	Jan. 10, 1951	10:00 P.M.	36 1/6	1.506	2.85	0.106	2.74	3.99	143,000
B-3					1.25	0.0201	1.23		
B-1					5.38	0.372	5.01	7.93-3.95	
B-2	Jan. 11, 1951	6:00 A.M.	44 1/6	1.842	2.99	0.115	2.87	3.98	143,000
B-3					1.40	0.026	1.37		
B-1					5.45	0.381	5.07	8.01-4.01	
B-2	Jan. 11, 1951	9:30 A.M.	47 2/3	1.988	3.05	0.119	2.93	4.00	142,000
B-3					1.47	0.028	1.44		
Line C									
C-1					4.55	.251	4.30	6.55-3.35	
C-2	Jan. 9, 1951	3:30 P.M.	5 2/3	0.236	2.40	.074	2.33	3.20	178,000
C-3					2.47	.078	2.39		
C-1					4.79	.295	4.49	6.71-3.54	
C-2		8:00	10 1/6	0.424	2.64	.089	2.55	3.17	XX180,000
C-3					2.67	.092	2.58		
C-1					4.99	.315	4.67	7.05-3.67	
C-2		12:00 M.	14 1/6	0.590	2.82	.102	2.72	3.38	169,000
C-3					2.69	.093	2.60		
C-1					5.10	.334	4.77	7.11-3.77	
C-2	Jan. 10, 1951	4:00 A.M.	16 1/6	0.757	2.99	.114	2.88	3.34	170,000
C-3					2.88	.105	2.77		
C-1					5.17	.344	4.83	7.12-3.84	
C-2	Jan. 10, 1951	8:00 A.M.	22 1/6	0.923	3.11	.124	2.99	3.28	173,000
C-3					3.05	.120	2.85		
C-1					6.31	.365	4.94	7.25-3.93	
C-2		2:00 P.M.	28 1/6	1.172	3.21	.132	3.08	3.42	168,000
C-3					3.04	.118	2.92		

Table 3 (Continued)

Line C

Well No.	Date	Time	Hours Pumping	t Days Pumping	s Drawdown	$\frac{s^2}{2M}$	$\frac{s'}{s-\frac{s^2}{2M}}$	$\Delta s'$	$\frac{T}{\frac{270,000}{\Delta s'}}$
C-1					6.40	0.374	5.03	7.25-4.06	
C-2		6:00 P.M.	32 1/6	1.338	3.29	.139	3.15	3.19	178,000
C-3					3.25	.135	3.11		
C-1					5.52	.392	5.13	7.45-4.13	
C-2		10:00 P.M.	36 1/6	1.506	3.41	.149	3.26	3.32	172,000
C-3					3.25	.135	3.11		
C-1					5.61	.405	5.21	7.45-4.25	
C-2	Jan. 11, 1951	6:00 A.M.	44 1/6	1.842	3.54	.161	3.38	3.20	178,000
C-3					3.44	.152	3.29		
C-1					5.67	.412	5.26	7.49-4.35	
C-2		9:30 A.M.	47 2/3	1.988	3.63	.169	3.46	3.14	181,000
C-3					3.54	.161	3.38		

obtained by the two methods are in general agreement, and the conclusions concerning the aquifer that were derived from the Theis analyses are supported by the results of the Thiem method.

Estimation of Effect of Irrigation on Stream Flow

A determination of the probable effect of proposed irrigation of the unit on the flow of the Smoky Hill River has required a study of the discharge from the ground-water reservoir to the stream. The amounts and rates of effluent seepage depend on: (1) constant controlling factors such as the size, shape, thickness, and slope of the alluvial aquifer and its coefficients of storage and permeability; and (2) controlling factors having seasonal variation which include evaporation and transpiration.

The effects of all of these factors—as well as surface runoff from precipitation and the operation of the Kanopolis Reservoir—are integrated in the stream-flow records or hydrographs obtained for the Smoky Hill River at the gaging stations within the area. Depletion curves (Fig. 10), which are the basis for separating ground-water flow from surface runoff, were prepared from the records at the Lindsborg gage. No curves were prepared for the Mentor gage because of the short record, and the Langley gage, immediately below the Kanopolis Dam, does not record any appreciable effluent seepage.

As described by Johnstone and Cross (1949), depletion curves are plotted as a combination of several arcs of the hydrograph with the arcs coinciding or overlapping in their lower parts. The hydrographs are plotted on semi-log paper with discharges on the logarithmic scale and days on the linear scale. The lowest arcs of these hydrographs

Fig. 10.—Ground-water depletion curves for Smoky Hill River based on records of the Lindsborg gage.

(representing ground-water flow) were transferred to tracing paper, using the same MX horizontal and vertical scales and working backward in time from the lowest discharge to a period of surface-water runoff. The tracing paper then was moved horizontally until another arc of the hydrograph coincided in its lower part with the arc already traced, and the second arc was plotted on top of the first. This process was continued until all of the available arcs were plotted as shown in Figure 10. The upcurving part of the individual arcs is affected by surface runoff and is, therefore, disregarded. The remaining continuous arc is the depletion curve that presumably represents the hydrograph that would result from the flow of ground water over a protracted dry period. The two curves shown in Figure 10 show the variation between winter and summer flow that is caused by evapotranspiration. These curves have been prepared from data gathered prior to the completion of the Kanopolis Dam and represent the more natural conditions existing at that time.

The depletion curves indicate that as the water table is lowered the rate of effluent seepage gradually diminishes. Ground water is capable of sustaining a flow in the river for a length of time that is dependent on the season and the water level in the ground-water reservoir at the time surface flow ceases.

An integration of the depletion curves (Fig. 11) above a selected base flow shows the relation between the rate of ground-water flow and the volume of water in storage above the base in the ground-water reservoir. The storage in the figure is summed above 23 cubic feet per second and does not represent total ground-water storage. This curve is an integration of the depletion curve representing ground-water discharge

Fig. 11.--Graph showing the ground-water storage-discharge relationship. Curve A is an integration of the summer depletion curve of Figure 10; storage is summed above a discharge of 23 cubic feet per second and does not represent total storage. Curve B is an integration of the winter depletion curve summed above 66 cubic feet per second.

during the part of the year from April 1 to September 30.

The storage curve makes it possible to estimate the increase in stream flow that would result from accretion to the ground-water reservoir through irrigation. Earlier in this report, a deviation of one inch from normal precipitation was shown to produce a change of as much as 4 inches in the level of the water table after a significant time lag. The pumping test analyses and the laboratory determinations indicate that the average effective porosity or specific yield of the sand and gravel below the water table in the area is probably about 12 percent. If these estimates are correct, the addition of one inch of irrigation water at 65 percent application efficiency to the 41,000 acres of the proposed service area would raise the water table 2.6 inches and thereby add about 1,000 acre-feet of water to the ground-water reservoir. This increase in storage could result either from direct accretion or through reduced drafts from the reservoir by evapotranspiration where irrigation water is added. The storage curve shows that an increase of 1,000 acre-feet in ground-water storage would increase stream flow as much as 12 cubic feet per second after the water table is affected.

Crops in the service area may require about 23 inches per acre or about 78,500 acre-feet of irrigation water in an average year. Probably no more than 24,000 acre-feet of this water would reach the water table and thereby return to the stream, especially as increased crop yields through irrigation will result in increased transpiration and water use by the crops. However, it should be emphasized that the above figures apply only to increased return flow from the application of irrigation water and not to total flow from the ground-water reservoir.

The depletion and storage curves shown in the figures measure only the conditions upstream from the Lindsborg gage. However, the curves may be considered representative of conditions existing throughout the area because the alluvial aquifer is continuous [illegible] below Kanopolis Dam and nearly uniform. If curves could have been prepared for areas further downstream, they would have shown greater daily discharges and greater ground-water storage, but their form would have been approximately the same as those included in this report.

The accuracy of this method of estimating the effect of future irrigation is limited by some assumptions. Perhaps the most inaccurate of these is the estimation of the effect of irrigation on the water table because that effect is dependent on a large number of varying factors. However, all other methods considered were subject to the same limitations. The depletion curves permitted direct observations of actual conditions and the projection of [illegible] those observations to possible future conditions.

Geologic Formations and their Hydrologic Properties

The stratigraphic section exposed in the Kanopolis Unit consists of sedimentary rocks that are principally shales. These shales are poor aquifers, but the younger, unconsolidated rocks produce moderate to large supplies of water. Generalized data pertaining to the lithology and water-bearing characteristics of the formations are shown in Table 4. Areas of outcrops of the formations are shown in Plate 1.

Permian System

Leonardian Series

The Permian System is represented in the area by two formations

Table 4.—Generalized section of the geologic formations in the Kanopolis Unit.

				Thickness, in feet	Physical Character	Water Supply
Quaternary	Pleistocene Series		Alluvium	0-94±	Silt, clay, sand, and gravel in various proportions. Fine materials near surface grade to coarse at depth.	Large to very large supplies of relatively hard water are available from the Smoky Hill Valley.
			Meade fm.	0-80±	Sand and gravel, locally cemented in lower Grand Island member. Massive silt in upper Sappa member; contains volcanic ash in places.	Yields small supplies of moderately hard water to wells from the small irregular outcrops in the area.
Cretaceous System	Comanchean Series	Gulfian S.	Dakota fm.	0-150±	Brown, yellow-brown, and gray medium-grained sandstone and gray and red- and white mottled clays; contains hematite, limonite and pyrite concretions.	Yields moderate to large supplies of good water in the outcrop area.
			Kiowa shale	0-75±	Dark gray to black fissile shale in lower part light gray and sandy shale in upper part, contains ecca-in-ecca and selenite.	Yields small amounts of very hard water from sandy shale in upper part to farm wells and small springs.
Permian System	Leonardian Series		Ninnescah shale	0-150±	Soft to hard, brick-red shale, contains thin beds of gray-green shale, thin argillaceous limestones, and selenite crystals.	Yields meager supplies of mineralized water from weathered surface limestones, and crevices to farm wells in area of outcrop.
			Wellington fm.	0-200± Exposed	Soft, gray, calcareous shale; contains some red zones and thin argillaceous limestones; contains gypsum, anhydrite, and salt in the subsurface.	Yields small quantities of highly mineralized water to farm wells.

belonging to the Sumner group of the Leonardian Series. The oldest of these formations, the Wellington, is conformably overlain by the Ninnescah shale.

Wellington formation

A study of the Wellington formation has been made by Ver Wiebe (1937), who distinguished five zones on the basis of lithologic changes. These five zones in ascending order are: anhydrite beds, salt beds, middle gray beds, red beds, and upper gray beds. Only the upper two beds, a thickness of 150 to 200 feet, is exposed in the Kanopolis Unit.

The anhydrite zone at the base of the Wellington formation comprises an alternating sequence of gray shale and anhydrite beds. The Hollenberg limestone member in this zone lies about 20 to 40 feet above the base. The salt zone, known as the Hutchinson salt member, consists mainly of salt and thin laminae of shale and anhydrite. This zone is 350 feet thick below the western part of the area. The three upper zones are composed mainly of shale and a few thin argillaceous limestones.

The Wellington formation crops out in the eastern and northern parts of the area and forms more than two-thirds of the bedrock floor of the area. Erosion of the soft shales and evaporites of the formation produces gently rounded, rolling hills. The formation in this region has been locally deformed.

Only meager supplies of water are available from the Wellington formation because of the materials comprising the formation. Wells penetrating the thin limestone beds in the formation produce somewhat larger amounts of very hard water, but even these wells may fail during periods of drought.

Ninnescah shale

The Ninnescah shale in the area of outcrop is composed of shale and silty shale which is predominantly brick-red in color. The formation contains a few beds of gray-green shale and some thin impure limestones. The intersecting veins of gypsum and crystals of selenite that occur at a few outcrops are probably of secondary origin. The formation has a maximum thickness of about 425 feet in southern Kansas but thins northward to about 150 feet in the area of this report.

The Ninnescah shale crops out and forms the bedrock below unconsolidated rocks in the western and southwestern parts of the area. Erosion by small streams in this area produces a highly dissected topography with small buttes and box canyons. The water-bearing properties of the Ninnescah shale are very much like the Wellington formation. The weathered zone at the surface of the shale forms an intermittent aquifer, and those wells penetrating the thin limestones are somewhat more permanent.

Cretaceous System

The transition from the Permian to the Cretaceous System is marked by a major unconformity and in some places by the presence of a cobble zone or conglomerate. The cobble zone is composed of uniformly large, well-rounded cobbles derived from igneous, metamorphic, and sedimentary rocks. The cobbles lie at relatively high positions on the erosional surface where they protected underlying Permian rocks from additional erosion before the encroachment of the Cretaceous seas. The cobbles serve as

the same protection today where the overlying Kiowa shale has been removed.

The two formations of Cretaceous age that crop out in the area are the Kiowa shale of the Comanchean Series and the Dakota formation of the Colorado group, Gulfian Series. These rocks form the high hills which border the Smoky Hill Valley in the area.

Comanchean Series

Kiowa shale

The Kiowa shale is a marine shale and is black to dark gray in the lower part and light gray in the uppermost part where the shale is sandy in some places. The rock contains marine XXXXshells, pyrite, glauconite, and well-developed crystals of selenite. Thin ecquinoid limestones, beds of cone-in-cone, and thin seams of alabaster are present irregularly within the formation. Outcrops of the shale may be stained with the yellow iron XXXXXX sulfate, melanterite. Although the thickness of the Kiowa shale varies considerably from place to place XXXXX the greatest thickness in this area is about 75 feet.

The soft shale of the Kiowa shale weathers rapidly and produces either a flat or gently rounded topography. Where the shale is overlain by sandstones of the Dakota formation, the shale forms a steep bluff below the overhanging ledges of sandstone. Under these conditions the shale is subject to much slumping and mass-wasting.

Only small amounts of water of very poor quality can be obtained from the Kiowa shale, and this can be obtained only where

the shale is somewhat sandy.

Gulfian Series

Dakota formation

The Kiowa shale is overlain by the Terra Cotta member of the Dakota formation, which is composed chiefly of gray, tan, and red-and-white mottled clay and brown sandstone. The clays in some places are kaolinitic in composition and normally contain "ironstone" pellets of hematite or limonite. The sandstones in the lower part of the formation may be either marine or continental according to the present classification. Earlier investigators have placed the marine sandstones within the Kiowa shale; however, this writer has included all the sandstones near the XXX contact within the Dakota formation because (1) the former units were not mappable units where continental sandstone occurred below marine sandstone; (2) the interfingering of the marine and continental sands suggests that they were deposited under deltaic conditions and are, then, genetically related; and (3) the sandstones are not significantly different in either age or lithology.

The higher sandstones are channel sands that are irregularly distributed both vertically and horizontally within the member. The sandstones are coarse-grained to fine-grained and contain abundant limonite and hematite XX concretions. The Terra Cotta member is about 150 feet thick in the extreme western part of the area.

Erosion of the Dakota formation produces prominent ledges and flat-topped hills where the sandstones are tightly cemented. Elsewhere, the sandstones weather readily and form rounded hills. In both cases

the resulting topography is one of moderate relief.

The Dakota formation is by far the best consolidated aquifer in the region. Moderate supplies of good water generally can be developed from the Dakota formation in this area.

Quaternary System

Pleistocene Series

The Quaternary deposits of this area are of alluvial, colluvial, and eolian origin. Although none of these sediments are glacial, their deposition was influenced considerably by glaciation. All these deposits are unconsolidated.

Two distinct deposits of the Quaternary Period crop out in the area. These rocks are the Meade formation of Kansan and Yarmouthian Ages and the alluvium. The alluvium includes all the alluvial deposits of Recent and older age because the Wisconsinan-Recent boundary is not clearly recognisable and the two stages were not differentiated during the geologic mapping.

Meade formation

The Meade formation is composed of gravel, sand, silt, clay, and volcanic ash, and lies in an upper terrace position along the Smoky Hill River. In some places a conglomeratic bed, which is 1 to 6 feet thick, occurs in the lower part of the formation. This bed is composed of shale and sandstone fragments and igneous pebbles and is cemented with an impure calcium carbonate. This conglomerate and the overlying cross-bedded sands and gravels make up the Grand Island member that is probably late Kansan in age.

The Sappa member of the Meade formation may be latest Kansan and earliest Yarmouthian in age. This member is composed chiefly

of silt associated with some sand and clay and contains the Pearlette volcanic ash bed. Landes (1928, p. 19) suggested that the ash was carried to this area by wind from the Capulin group of volcanoes in northeastern New Mexico. The maximum thickness of the Meade in the area of this investigation is about 80 feet.

Outcrops of this formation are restricted to the area of its deposition along the ancestral river mentioned previously in this report. The present Smoky Hill River has cut below the older channel and removed all the formation except those irregular patches shown on Plate 1. Most of the remaining deposits crop out at the tops of the higher hills in the area, and generally the Sappa member has been removed from the outcrops.

The Meade formation is the principal source of water for several cities south of the area of this report. The Wichita municipal water supply is derived from 35 wells, most of which yield 1,000 gallons a minute or more from the Meade formation. The importance of the aquifer in the Kanopolis Unit is ~~XXXX~~ reduced by its small extent, although supplies of water adequate for domestic and stock uses are available to wells in most of the outcrop areas.

Alluvium

Alluvium of late Quaternary age is present in the valleys of the Smoky Hill River and its tributaries. The alluvium is composed of clay, silt, sand, and gravel in various proportions. A description of the material is given in the table of hydrologic

and physical properties of the alluvium. Because of an increased gradient in the upper part of the river, the alluvium is coarser above Lindsborg than below.

The maximum thickness of the alluvium that was penetrated by a test hole was 94 feet in test hole 15-2-19cdd, 1 mile southeast of Mentor. As stated by Latta (1949) the maximum thickness of alluvium that will be found in a section across the valley cannot be predicted. In some places the channel of the river nearly coincides with the deepest place in the bedrock floor, but in other places the deepest part of the bedrock floor is on the opposite side of the valley from the present stream channel.

Much of the alluvium of the area was derived from former deposits of the Meade formation and from loess deposits on the Great Plains in the headwaters area of the Smoky Hill River. Cretaceous and Permian rocks adjacent to the valley also have contributed some of the material composing the alluvium.

As shown in the hydrology section of this report, very large supplies of water are available from the alluvium of the Smoky Hill Valley. Somewhat larger supplies can be developed in the lower part of the valley than near the Kanopolis Dam. However, the supply is adequate everywhere in the valley for domestic, industrial, or public use. All the cities in the Kanopolis Unit utilizes the alluvial aquifer for their public supply. Water from the alluvium is hard, and in some places iron makes the water undesirable.

CHEMICAL QUALITY OF THE WATER

by

Robert A. Krieger

INTRODUCTION

As part of the ground-water investigation in the Kanopolis Unit, quality-of-water studies were made of the water from wells and streams in the area. The chemical quality-of-water data will serve as a reference for changes in the quality of the ground water after irrigation has begun. It will also serve in the further development of the use of ground water.

In April 1952, water samples were collected mainly from the alluvium in the Smoky Hill River valley. Additional samples were collected from Kanopolis Reservoir, the Smoky Hill River, and one sample each from the Meade and Wellington formations and Kiowa shale. Data from Kansas Geological Survey Bulletins 79 (Williams and Lohman, 1946) and 84 (Latta, 1949) are also used to augment the recent sampling program.

The study of the quality of water was under the direction of S. K. Love, Chief, Quality of Water Branch, and P. C. Benedict, Regional Engineer, Missouri River basin.

The points of collection of the 88 water samples are shown in Figure 12. The results of the chemical and physical analyses are given in Table 5. The wells are listed by well-location number and water-bearing formation. The results in equivalents per million are given in Table 6.

Hardness

Calcium is the principal cation found in the ground waters of the area. Calcium and magnesium are the principal causes of hardness of water. These two ions combine with soap to form an objectionable insoluble curd and are the active agents in forming boiler scale. In waters from the alluvium, the calcium content ranged from 89 to ~~XX~~ 522 ppm, but only 6 of 33 samples contained more than 200 ppm calcium. Magnesium content of the 33 samples ranged from 16 to 82 ppm and had an average of 38 ppm. Bicarbonate ion, which is the principal anion in waters from the alluvium, ranged from 293 to 575 ppm and averaged 430 ppm. Hardness caused by the calcium and magnesium equivalent of the bicarbonate is called carbonate hardness or temporary hardness (removed by boiling). The remaining calcium and magnesium that would not be precipitated on boiling is called noncarbonate or permanent hardness. Total hardness expressed as calcium carbonate ranged from 335 to 1,640 ppm in water from the alluvium. Water containing more than 200 ppm of hardness is considered very hard and requires some treatment before use for most purposes.

Sulfate

In most samples of water, sulfate ion was the second most predominant anion. Sulfate, in combination with calcium and magnesium, causes the formation of a hard scale in steam boilers. Sulfate in waters from the alluvium ranged in concentration from 45 to 1,470 ppm, but ~~XX~~ only five samples contained 250 ppm or more of sulfate. Samples of water from wells 17-3-15abb and 17-4-29aaa contained more sulfate than bicarbonate. These samples

also contained the most calcium, which indicated that the water had been in contact with XXXX gypsum at sometime.

Chloride

Chloride has little effect on the domestic use of the water unless present in larger quantities, but a chloride content of more than 550 ppm may affect the taste of the water. For some industrial purposes chloride concentration below 100 ppm may be required. The chloride in the water from the alluvium ranged from 11 to 380 ppm, but only six samples contained more than 75 ppm chloride.

Fluoride

The quantity of fluoride in natural waters is generally less than the quantity of chloride. Fluoride in concentrations of 1.0 to 1.5 ppm is known to lower ~~the~~ the incidence of a dental caries. Recently, there is a trend to fluoridate fluoride-deficient drinking water. An excess of fluoride in the water (above 1.5 ppm) may cause mottling of teeth in young children during formation of the teeth. One sample from the alluvium contained no fluoride; 32 samples from the alluvium contained from 0.1 to 0.6 ppm fluoride.

Nitrate

Nitrate in water may indicate contamination from sewage or other organic matter. Quantities of nitrate above 45 ppm may cause methemoglobinemia in some infants (Comly, 1945). Nitrate in waters from the alluvium ranged XXX from 0.4 to 416 ppm. Seven samples contained more than the suggested limit of 45 ppm of nitrate.

Boron

Boron is one of the essential elements for plant growth, but it is beneficial only within narrow limits. About 1 to 2 ppm boron in the soil is optimum for good growth of crops. Magistad and Christiansen (1944) recommended for irrigation, waters containing less than 0.5 ppm boron for sensitive crops and 0.5 to 2.0 ppm for tolerant crops. Waters containing more than 2.0 ppm boron ultimately may be harmful to most crops. The samples obtained from wells in the alluvium contained 0.09 to 0.49 ppm of boron.

CHEMICAL QUALITY IN RELATION TO GEOLOGIC SOURCE

Water in the Alluvium

Ground water in the alluvium will be affected most by irrigation. Of the 40 samples of ground water used in this study, 33 are from the alluvium. The alluvial water is slightly alkaline, as indicated by pH values ranging from 7.2 to 7.7. The water from the alluvium is very hard and in some places is gypsiferous, but as shown in Table 1, is generally of better quality than water from the Wellington formation, Minnesoah shale, or Kiowa shale.

If the wells are arranged in a downstream order as in Figure 13, no significant trend or change in water quality is noticeable. The wells sampled in McPherson County yielded water more variable in the amount of dissolved material than the samples obtained in Saline County.

Chemical quality samples were collected in cross section at two locations in Smoky Hill River valley. Cross section A (Fig. 12)

is composed of wells 17-4-20aae, 17-4-29aaa, and 17-4-28cbb; the latter is nearest the Smoky Hill River. Water from well 17-4-29aaa, in the middle, was decidedly gypsiferous, whereas the other two were dolomitic waters. Waters represented in cross section B near the downstream end of the project did show a decline in the amount of dissolved material nearer the Smoky Hill River as shown below.

Decline in dissolved material in cross section B

Well No.	Date	Sodium and potassium (epm)	Chloride and fluoride and nitrate (epm)	Dissolved solids (ppm)
14-3-28ddd	7-30-39	5.84	10.22	1,202
14-3-26cdd	5-27-44	4.90	4.07	843
14-2-30ded	4-8-52	2.81	1.75	714
14-2-30dcd	5-27-44	1.82	2.13	622

Associated with the decline in dissolved solids was a decrease in the amount of sodium plus potassium and of chloride plus fluoride plus nitrate. The more upland wells may be more subject to contamination by sodium and chloride from underlying bedrock.

Certain basic relations exist between various ions in samples of water from the alluvium. The relation between sulfate and dissolved solids is shown in Figure 14A. The change in slope of the curve indicates that sulfate occupies an increasingly larger part of the dissolved material as the concentration of salts increases. There seems to be no difference in the ratio of sulfate to dissolved solids in the samples collected in 1952 and in the samples taken earlier.

The relation between bicarbonate and dissolved solids, as shown in Figure 14 B, is not very definite; instead, the curve as

Fig. 13.—Principal mineral constituents in the ground water.

Fig. 14.—Relation between various ions in waters from the alluvium.

drawn indicates only a trend. The chloride-dissolved solids relation is plotted in Figure 14C. The relation is similar to that found between sulfate and dissolved solids except the relation is not as clear because the points are more scattered. No change in the over-all composition of the samples collected in 1952 and the samples collected previously is apparent. The correlation between sulfate and hardness indicates that sulfate was dissolved chiefly as the calcium or magnesium salt. (Fig. 14D) XXThe bar graphs in Figure 13 tend to corroborate this because the samples high in sulfate also have large amounts of calcium and sometimes magnesium.

Water in Other Formations

Other water-bearing formations were sampled in the area because these formations supply water to and receive water from the alluvium. Irrigation may raise the water table and alter the chemical quality of water in the alluvium to such an extent that the dissolved material in the water in other formations may be affected.

Waters from the Ninnescah shale, Wellington formation, and Kiowa shale were higher in dissolved material than water samples obtained from the alluvium, as shown in Figure 13. XXXWater from the Meade formation contained the least dissolved material.

The one sample of water obtained from the Ninnescah shale contained large amounts of calcium, magnesium, and sulfate. Calcium, magnesium, and sulfate concentrations were 428 ppm, 198 ppm, and 1,386 ppm, respectively. One sample was obtained from

the Wellington formation in 1944 and another in 1952, (well 18-3-5ddd in 1944 and well 17-3-11ccc in 1952). The 1944 and 1952 samples contained 2,044 ppm and 1,890 ppm dissolved solids respectively. The sample of water from the Kiowa shale is largely a sodium-magnesium-bicarbonate water with large amounts of nitrate and chloride present, as shown in Table 6. The sample of water contained 1,050 ppm of dissolved solids, whereas the samples from the Ninnescah shale and Wellington formation were about twice as concentrated. Water from a spring in the Meade formation, which was the least concentrated of all the samples analyzed, contained 372 ppm dissolved solids and consisted principally of calcium bicarbonate.

EFFECT OF APPLICATION OF IRRIGATION WATER ON THE QUALITY OF THE GROUND WATER

Surface-water samples were obtained from two principal sources, Kanopolis Reservoir and Smoky Hill River. The points of sampling are shown in Figure 12. The water applied to the soil will vary in quality and will have a varying effect on the quality of the water in the alluvium. The data in Table 7 indicate that the mineral content of the water will be less concentrated at high levels of water in the reservoir. It is the dilute water that probably will be used for irrigation because of the method of operating the reservoir.

The water used for irrigation will contain approximately 300 to 600 ppm dissolved solids. This water is more dilute than the samples of water from the alluvium, but it is unlikely that much dilution of water in the alluvium will occur in the first years of irrigation. It will depend on how much water is applied to the soil.

At the time of sampling (Apr. 7-8, 1952), the water in the Smoky

Hill River varied but slightly in quality from the water in the reservoir.

A sink pond near Lindsborg probably became salty (Table 7) from seepage from a nearby oil well evaporation pond. Application of irrigation water to the land will either increase the flow of ground water into the sink pond or retard the movement of water from the sink pond into the ground. In either event, the increase in the amount of ground water will enlarge the size of the saline sink pond.

CHEMICAL QUALITY OF THE WATER IN RELATION TO USE

Irrigation

Wilcox (1948) devised a system of classification of water for irrigation of an average soil based on specific conductance and percentage of sodium. This classification is empirical and would, therefore, depend on the soil, surface and subsurface drainage, crops grown, and the amount of water available. The classification of the waters in the Kanopolis Reservoir, in the Smoky Hill River, and in the alluvium is shown in Figure 15. The water samples from the alluvium were lower in percentage of sodium than the surface water intended for irrigation, but the wide range in specific conductance of the water from the alluvium caused the water to be classified from excellent to doubtful. The water from wells in the alluvium is generally of poorer quality for irrigation than that supplied from the reservoir. Moreover, the irrigation quality of the ground water may decrease after irrigation with surface water because of the removal of soluble material from the soil.

Fig. 15.—Classification of waters for irrigation use.

Domestic

The U. S. Public Health Service (1946) has established the following drinking water standards for interstate carriers.

Ion	Upper limit (ppm)
Iron	0.3
Magnesium	125
Chloride	250
Sulfate	250
Fluoride	1.5

The standards are not necessarily limits above which water is unsafe for human consumption, but they are a measure of the suitability of water for domestic use.

Over an one-half of the samples from the alluvium contain more than 0.3 ppm iron. The high iron content in some of the waters undoubtedly would cause staining of clothing during washing and discoloration of cooking utensils. Limits for magnesium were not exceeded. Water having high magnesium sulfate content, such as that from the Minnesoah shale, may have an undesirable physiological effect. Three samples exceeded the chloride standard and the remainder contained less than 100 ppm chloride. The three samples that exceeded the standard contained 380, 355, and 340 ppm chloride; however, the palatableness of the water did not seem to be affected. Sulfate content of the water from the alluvium equaled or exceeded the standard in five samples. The sample from well 17-4-29aaa would have a decided gypsiferous taste. To be effective in assisting in the prevention of dental caries, the fluoride content of the water from all the wells would have to be increased. No samples were found to contain the optimum of 1.0 to 1.5 ppm fluoride.

All the samples exceeded the 200 ppm hardness limit; the range in the alluvium was from 335 to 1,640 ppm hardness, and

about three-fourths of the samples contained less than 600 ppm hardness. However, all the water would require softening for satisfactory use.

SUMMARY

Ground-water conditions in formations other than the alluvium of the area preclude the development of large supplies of water. However, moderately large supplies, up to 1,000,000 gallons a day, can be developed from wells in the alluvium of the Smoky Hill Valley. In general, the alluvium is progressively less productive from Salina to the Kanopolis Dam.

The chemical character of the water in the Smoky Hill Valley is such that treatment is required for many industrial purposes and desirable for municipal supplies. The water is very hard and contains a considerable amount of iron, which is detrimental for some industrial uses. The temperature of the water, about 60° F, is suitable for air-conditioning.

Ground-water conditions in most parts of the proposed service area are favorable for irrigation with surface water. Most of the service area is underlain by alluvial materials which are sufficiently permeable to provide underdrainage if effluent seepage is not retarded by continued high stages of the Smoky Hill River. Accumulations of silt and clay in meander scars of the river may reduce the permeability and thereby lessen the drainage capacity of the alluvium where those scars are present. Some areas west of Lindsborg are unfavorable for irrigation because of tight soils and synclinal rock structures that inhibit drainage. Plate 3 indicates that the water table is less than 10 feet below the

surface in these areas.

About 1,000 acre-feet of return flow can be expected from the application of 1 inch of surface water to the proposed service area of 41,000 acres. Because only about 23 inches per acre of irrigation water would be used in a normal year, the increase in effluent seepage from irrigation probably would amount to about 23,000 acre-feet of return flow.

Data on the ground waters of the Kanopolis Unit were obtained from samples taken in April 1952 and from Kansas State Geological Survey Bulletins 79 and 84. Most of the samples were from the alluvium because it is this area that will be most affected by irrigation. Additional data were obtained from water samples from the Smoky Hill River, Kanopolis Reservoir, and a saline sink pond.

The data will serve as a guide to future use of ground water in the area and as a basis for determination of the effect of irrigation on the chemical quality of water in the alluvium. The concentration of dissolved material in water of the alluvium probably will increase temporarily with irrigation and make the water less desirable for supplemental irrigation and domestic use. However, the chemical quality of the water in the alluvium may eventually improve with irrigation.

The sink pond near Lindsborg became saline from seepage from an oil well evaporation pond. This pond and others like it will be troublesome after irrigation starts unless adequate drainage is provided.

RECORDS OF WELLS

Information pertaining to 139 wells inventoried or constructed in the Kanopolis Unit is tabulated on the following pages (Table 8). The well numbers used in this table give the location of wells according to General Land Office surveys as described in the introduction. The wells are listed in order by townships from north to south and by ranges from east to west. Within a township the wells are listed in the order of the sections and the range and township numbers are not repeated.

RECORD OF WATER-LEVEL MEASUREMENTS

Water-level measurements, in feet below land surface, in the Kanopolis Unit are tabulated on the ~~XXXXXXXX~~ following pages. An observation-well program was begun in the Kanopolis Unit in the spring of 1946 with the construction of 15 driven wells. During 1950 and 1951, 59 additional wells were constructed by a jetting method.

The location of these wells is shown in Plates 2 and 3 and data pertaining to them is given in Table 9. The wells are listed in order by townships from north to south and by ranges from east to west. Within a township they are listed serially in the order of the sections.

Table 9.--Record of water-level measurements

14-2-19dc.

Date	Water level	Date	Water level	Date	Water level
Jan. 24, 1951	12.38	Feb. 26, 1952	14.15	July 23,	13.40
July 2	16.36	June 9	13.50	Apr. 7, 1955	20.15
Aug. 17	4.11	Sept. 22	14.98	Aug. 19	20.47
Oct. 1	4.29	Jan. 10, 1953	16.54		
Nov. 9	5.86	Mar. 13	17.15		

14-2-30cd.

Jan. 24, 1951	13.50	Feb. 26, 1952	11.13	July 23	14.46
July 2	11.67	June 9	9.51	Apr. 7, 1955	15.97
Aug. 17	2.52	Sept. 22	12.58	Aug. 19	17.77
Oct. 1	1.13	Jan. 10, 1953	14.07		
Nov. 9	5.27	Mar. 13	14.13		

14-2-31cc.

Oct. 17, 1950	6.10	Feb. 26, 1952	10.79	July 23	Dry
July 2, 1951	9.57	June 9	12.79	Apr. 7, 1955	Dry at 17.5
Aug. 17	10.06	Sept. 22	13.47	Aug. 19	Dry
Oct. 1	9.57	Jan. 10, 1953	14.12		
Nov. 9	9.40	Mar. 13	16.17		

14-3-25ad.

Jan. 24, 1951	13.94	Feb. 26, 1952	7.16	July 23	12.84
July 2	11.97	June 9	7.89	Apr. 7, 1955	16.19
Aug. 17	.08	Sept. 22	9.58	Aug. 19	16.25
Oct. 1	.62	Jan. 10, 1953	11.68		
Nov. 9	1.44	Mar. 13	12.44		

14-3-36abb.

Oct. 13, 1950	17.35	Nov. 9	2.06	Mar. 13	5.36
July 2, 1951	16.11	Feb. 26, 1952	2.83		
Aug. 17	.85	June 9	2.32		
Oct. 1	1.53	Jan. 10, 1953	5.12		

15-2-6aa.

Jan. 24, 1951	17.04	Feb. 26, 1952	15.03	July 23	18.82
July 2	14.11	June 9	13.34	Apr. 7, 1955	Dry at 19.5
Aug. 17	6.30	Sept. 22	16.70	Aug. 19	Dry
Oct. 1	5.90	Jan. 10, 1953	18.14		
Nov. 9	8.31	Mar. 13	18.44		

Table 9.---(Continued)

15-2-6dd.

Date	Water level	Date	Water level	Date	Water level
Jan. 24, 1951	16.75	Nov. 9	8.16	Jan. 10, 1953	17.96
July 2	10.74	Feb. 26, 1952	16.39	Mar. 13	18.15
Aug. 17	4.68	June 9	12.61	July 23	18.09
Oct. 1	4.25	Sept. 22	17.01		

15-2-17cd.

Mar. 28, 1946	23.73	Jan. 6, 1948	25.44	Jan. 24, 1951	22.97
July 3	24.56	Apr. 7	24.43	Mar. 15	23.63
Aug. 1	24.75	May 28	24.87	May 18	23.34
Sept. 5	24.49	Aug. 6	22.33	June 22	20.25
Nov. 1	23.92	Sept. 30	23.32	July 24	10.22
Nov. 4	22.79	Dec. 3	23.98	Aug. 17	10.50
Dec. 2	22.72	Apr. 27, 1949	22.15	Oct. 1	9.58
Dec. 23	23.08	July 1	21.41	Nov. 9	12.45
Jan. 26, 1947	23.56	Aug. 22	22.42	Feb. 26, 1952	18.76
Feb. 28	23.96	Oct. 24	23.12	June 9	18.43
Mar. 31	24.07	Dec. 22	23.49	Sept. 22	22.39
May 8	23.60	Feb. 4, 1950	23.95	Jan. 10, 1953	24.04
July 21	22.76	Mar. 6	24.20	Mar. 13	24.37
Sept. 9	23.99	Apr. 11	24.53	July 23	24.89
Oct. 2	24.49	May 31	24.10	Apr. 19, 1954	26.00
Oct. 30	24.99	Sept. 19	21.61	Apr. 7, 1955	26.60
Dec. 1	25.27	Nov. 20	20.89	Aug. 19	25.67

15-2-18cdd

Mar. 29, 1946	24.12	July 1	22.12	Nov. 18	14.99
July 3	24.73	Aug. 22	24.29	Nov. 23	15.52
Aug. 1	24.82	Oct. 24	23.98	Nov. 29	15.66
Sept. 5	24.98	Dec. 22	24.01	Dec. 7	15.27
Oct. 1	24.25	Feb. 4, 1950	24.59	Dec. 14	17.10
Nov. 4	22.90	Mar. 6	24.28	Jan. 19, 1952	18.79
Dec. 2	22.92	Apr. 11	24.70	Feb. 23	19.28
Dec. 23	23.27	May 31	24.40	Feb. 26	19.34
Jan. 26, 1947	23.70	Sept. 19	21.86	Mar. 19	18.97
Feb. 28	24.09	Oct. 16	21.33	Apr. 23	18.55
~~MXMar~~ 31	24.58	Nov. 18	20.96	May 20	17.98
May 8	24.00	Dec. 19	21.91	June 9	18.42
July 21	23.26	Jan. 19, 1951	23.55	June 30	19.68
Sept. 9	24.43	Feb. 24	24.10	Aug. 16	21.35
Oct. 2	24.86	Mar. 16	24.25	Sept. 22	22.00
Oct. 10	24.98	Apr. 20	24.45	Nov. 3	22.88
Dec. 1	25.39	May 16	23.96	Nov. 27	23.02
Jan. 6, 1948	25.50	June 22	21.15	Dec. 15	23.25
Apr. 7	24.83	July 19	13.96	Jan. 10, 1953	24.40
May 28	25.18	July 24	14.73	Mar. 13	23.79
Aug. 6	23.70	Aug. 17	14.29	Apr. 13	23.53
Sept. 30	24.16	Sept. 18	11.50	June 20	23.87
Dec. 3	24.67	Oct. 1	11.72	July 23	24.16
Apr. 27, 1949	23.20	Oct. 16	12.13	Sept. 26	24.62

15-2-18cdd.(Continued)
Table 9.—(Continued)

Date	Water level	Date	Water level	Date	Water level
Nov. 23, 1953	25.00	Apr. 7, 1955	26.26	Aug. 19	26.70
Apr. 19, 1954	25.35				

15-2-19bb.

Jan. 24, 1951	18.05	Feb. 26, 1952	11.34	Mar. 13	16.70
July 2	20.06	June 9	13.79	July 23	18.03
Aug. 17	13.70	Sept. 22	14.06	Apr. 7, 1955	22.40
Nov. 9	11.56	Jan. 10, 1953	15.98	Aug. 19	22.91

15-2-30ccc.

Oct. 4, 1950	25.80	Nov. 9	14.25	Jan. 10, 1953	15.51
July 2, 1951	21.65	Feb. 26, 1952	11.89	Mar. 13	16.70
Aug. 17	16.64	June 9	12.12	July 23	18.19
Oct. 1	13.37	Sept. 22	12.27	Apr. 7, 1955	19.72

15-2-30ddd.

Mar. 27, 1946	21.38	Jan. 6, 1948	22.41	Mar. 15	21.58
July 3	22.05	Apr. 7	20.85	May 18	21.24
Aug. 1	22.35	May 28	21.38	July 2	19.27
Sept. 5	22.42	Aug. 6	19.58	July 24	6.56
Oct. 1	21.89	Sept. 30	20.60	Aug. 17	9.75
Nov. 4	20.99	Dec. 3	21.08	Nov. 9	14.93
Dec. 2	20.96	Apr. 27, 1949	19.72	Feb. 26, 1952	16.45
Dec. 23	21.21	July 1	19.06	June 9	15.64
Jan. 26, 1947	21.43	Aug. 22	20.11	Sept. 22	18.80
Feb. 28	21.36	Oct. 24	20.95	Jan. 10, 1953	20.17
Mar. 31	21.73	Dec. 22	21.05	Mar. 13	20.53
May 6	21.44	Feb. 4, 1950	21.52	July 23	21.24
July 21	21.13	Mar. 6	21.80	Apr. 7, 1955	23.29
Sept. 9	21.41	Apr. 11	21.35	Aug. 19	23.45
Oct. 2	21.91	May 31	21.90		
Oct. 30	22.24	Sept. 19	19.64		
Dec. 1	22.32	Jan. 24, 1951	21.15		

15-2-31ccc.

Oct. 19, 1950	13.70	Feb. 26, 1952	8.52	July 23	10.11
July 2, 1951	16.36	June 9	8.61	Apr. 7, 1955	14.07
Aug. 17	12.12	Sept. 22	8.81	Aug. 19	14.75
Oct. 1	8.88	Jan. 10, 1953	9.40		
Nov. 9	7.92	Mar. 13	9.45		

Table 9.---(Continued)

15-2-32baa.

Date	Water level	Date	Water level	Date	Water level
Oct. 5, 1950	E27.60	Feb. 26, 1952	21.90	July 23	24.93
July 2, 1951	22.44	Sept. 22	24.14	Apr. 7, 1955	24.85
Aug. 17	13.72	Jan. 10, 1953	23.83		
Nov. 9	16.92	Mar. 13	24.78		

15-3-1ccc.

Oct. 19, 1950	5.34	Nov. 9	4.47	Jan. 10, 1953	6.84
July 2	16.52	Feb. 26, 1952	5.55	Mar. 13	7.40
Aug. 17	5.78	June 9	5.25	July 23	8.12
Oct. 1	4.30	Sept. 22	5.48	Apr. 7, 1955	15.80

15-3-12ab.

Jan. 24, 1951	19.13	Feb. 26, 1952	11.56	July 23	18.87
July 2	18.00	June 9	10.89	Apr. 7, 1955	22.69
Aug. 17	10.21	Sept. 22	14.65	Aug. 19	23.32
Oct. 1	6.31	Jan. 10, 1953	16.74		
Nov. 9	7.30	Mar. 13	17.50		

15-3-12cd.

Jan. 19, 1951	16.20	Oct. 1	15.83	Sept. 22	17.70
July 2	19.94	Nov. 9	14.25		
Aug. 17	19.08	June 9, 1952	14.13		

15-3-12dd.

Jan. 17, 1951	14.06	Feb. 26, 1952	14.85	July 23	20.05
July 2	18.87	June 9	15.10	Apr. 7, 1955	23.12
Aug. 17	12.74	Sept. 22	18.11	Aug. 19	22.50
Oct. 1	10.38	Jan. 10, 1953	19.20		
Nov. 9	10.02	Mar. 13	19.43		

15-3-13cc.

Jan. 24, 1951	16.02	Feb. 26, 1952	13.05	July 23	20.24
July 2	20.04	June 9	12.71	Apr. 19, 1954	23.35
Aug. 17	13.09	Sept. 22	14.19	Apr. 7, 1955	25.80
Oct. 1	10.75	Jan. 10, 1953	18.20		this line out
Nov. 9	11.99	Mar. 13	18.54		

Table 9.—(Continued)
15-3-24ddd.

Date	Water level	Date	Water level	Date	Water level
Mar. 27, 1946	18.90	Jan. 6, 1948	20.64	Jan. 24, 1951	20.13
July 1	19.48	Apr. 7	18.93	Mar. 15	20.30
Aug. 1	19.88	May 28	19.44	May 18	20.45
Sept. 5	19.75	Aug. 6	17.49	July 2	18.95
Oct. 1	20.50	Sept. 30	18.75	July 24	4.30
Nov. 4	19.76	Dec. 3	19.18	Aug. 17	9.47
Dec. 2	19.19	Apr. 27, 1949	17.72	Oct. 1	6.83
Dec. 23	19.28	July 1	18.12	Nov. 9	8.74
Jan. 26, 1947	19.20	Aug. 22	18.88	Feb. 26, 1952	12.43
Feb. 28	19.69	Oct. 24	19.63	June 9	12.55
Mar. 31	19.76	Dec. 22	19.89	Sept. 22	15.37
May 8	19.41	Feb. 4, 1950	18.60	Jan. 10, 1953	17.05
July 21	19.24	Mar. 6	19.59	Mar. 13	17.59
Sept. 9	19.81	Apr. 11	20.29	July 23	18.27
Oct. 2	20.06	May 31	19.65	Apr. 7, 1955	22.25
Oct. 30	20.20	Sept. 19	19.95	Aug. 19	22.59
Dec. 1	20.47	Nov. 20	19.51		

15-3-25ccd.

Oct. 4, 1950	12.64	Feb. 26, 1952	7.67	Mar. 13	10.73
July 2, 1951	9.84	June 9	7.86	July 23	12.92
Aug. 17	7.20	Sept. 22	10.39	Apr. 7, 1955	16.23
Nov. 9	7.34	Jan. 10, 1953	10.78	Aug. 19	16.85

15-3-36abb.

Mar. 26, 1946	25.30	Jan. 6, 1948	27.35	Jan. 24, 1951	26.47
July 1	26.70	Apr. 7	25.48	Mar. 15	26.74
Aug. 3	27.12	May 28	25.74	May 18	25.03
Sept. 5	27.16	Aug. 6	23.54	July 2	25.71
Oct. 1	26.96	Sept. 30	24.98	July 24	20.22
Nov. 4	26.81	Dec. 3	25.40	Aug. 17	19.65
Dec. 2	26.62	Apr. 27, 1949	24.22	Nov. 9	17.57
Dec. 23	26.64	July 1	24.58	Feb. 26, 1952	19.38
Jan. 26, 1947	26.64	Aug. 22	25.49	June 9	19.00
Feb. 28	26.66	Oct. 24	26.07	Sept. 22	21.85
Mar. 31	26.77	Dec. 22	26.37	Jan. 10, 1953	23.34
May 8	26.52	Feb. 4, 1950	26.60	Mar. 13	24.05
July 21	26.64	Mar. 6	26.73	July 23	25.08
Sept. 9	26.93	Apr. 11	26.65	Apr. 7, 1955	29.03
Oct. 2	27.22	May 31	26.70	Aug. 19	30.35
Oct. 30	27.28	Sept. 19	26.02		
Dec. 1	27.30	Nov. 20	19.44		

Table 9.--(Continued)
16-2-7bbb.

Date	Water level	Date	Water level	Date	Water level
Mar. 21, 1946	20.20	Jan. 6, 1948	21.14	Jan. 24, 1951	19.35
July 3	20.84	Apr. 7	19.75	Mar. 15	19.82
Aug. 1	22.08	May 28	20.13	May 18	19.89
Sept. 5	21.25	Aug. 6	18.30	July 2	18.73
Oct. 1	20.84	Sept. 30	19.05	July 24	10.29
Nov. 4	20.22	Dec. 3	19.72	Aug. 17	12.11
Dec. 2	19.97	Apr. 27, 1949	18.60	Oct. 1	10.54
Dec. 23	20.09	July 1	18.38	Nov. 9	11.70
Jan. 26, 1947	20.18	Aug. 22	18.96	Feb. 26, 1952	15.71
Feb. 28	20.40	Oct. 24	19.60	June 9	15.19
Mar. 31	20.50	Dec. 22	19.72	Sept. 22	17.53
May 8	20.18	Feb. 4, 1950	20.17	Jan. 10, 1953	19.11
July 21	19.81	Mar. 6	20.20	Mar. 13	19.64
Sept. 9	20.20	Apr. 11	20.70	July 23	20.58
Oct. 2	20.49	May 31	20.05	Apr. 7, 1955	22.32
Oct. 30	20.76	Sept. 19	18.67	Aug. 19	22.25
Dec. 1	20.95	Nov. 20	19.27		

16-2-8ccc.

Oct. 20, 1950	7.94	Feb. 26, 1952	20.50	July 23	14.09
July 2, 1951	22.62	June 9	19.85	Apr. 19, 1954	23.38
Aug. 17	12.55	Sept. 22	21.80	Apr. 7, 1955	25.10
Oct. 1	11.80	Jan. 10, 1953	23.28	Aug. 19	25.10
Nov. 9	13.64	Mar. 13	23.70		

16-2-18abb.

Oct. 20, 1950	26.50	Feb. 26, 1952	25.40	July 23	Dry at 29.5
July 2, 1951	25.42	June 9	14.42	Apr. 7, 1955	Dry
Aug. 17	18.58	Sept. 22	21.20	Aug. 19	Dry
Oct. 1	18.28	Jan. 10, 1953	28.42		
Nov. 9	20.28	Mar. 13	Dry		

16-2-18ccc.

Mar. 21, 1946	25.80	Oct. 30	26.43	Apr. 11	25.20
July 3	26.30	Dec. 1	26.52	May 31	25.10
Aug. 1	26.18	Jan. 6, 1948	26.52	Sept. 19	20.31
Sept. 5	26.35	Apr. 7	25.54	Nov. 20	21.56
Oct. 1	25.32	May 28	26.18	Jan. 24, 1951	24.69
Nov. 4	23.39	Aug. 6	24.83	Mar. 15	25.13
Dec. 2	23.74	Sept. 30	25.47	May 18	22.50
Dec. 23	24.36	Dec. 3	25.78	July 2	18.21
Jan. 26, 1947	24.91	Apr. 27, 1949	24.27	July 24	13.03
Feb. 28	25.29	July 1	22.28	Aug. 17	11.76
Mar. 31	25.34	Aug. 22	24.55	Oct. 1	12.44
May 8	24.98	Oct. 24	24.63	Nov. 9	18.97
July 21	24.49	Dec. 22	24.40	Feb. 26, 1952	22.54
Sept. 9	25.81	Feb. 4, 1950	25.30	June 9	21.78
Oct. 2	26.20	Mar. 6	25.00	Sept. 22	25.01

Table 9.—(Continued)
16-2-18ccc(Continued)

Date	Water level	Date	Water level	Date	Water level
Jan. 10, 1953	25.45	July 23	25.31	Aug. 19	26.26
Mar. 13	25.58	Apr. 7, 1955	26.90		

16-2-19ab.

Mar. 21, 1946	23.90	Dec. 1	24.67	Nov. 20	18.66
July 3	23.38	Jan. 6, 1948	24.66	Jan. 24, 1951	22.75
Aug. 1	24.18	Apr. 7	23.62	Mar. 15	23.16
Sept. 5	24.35	May 28	24.41	May 18	20.21
Oct. 1	23.18	Aug. 6	22.98	July 2	16.10
Nov. 4	21.00	Sept. 30	23.70	July 24	11.68
Dec. 2	21.59	Dec. 3	23.94	Aug. 17	10.03
Dec. 23	22.39	Apr. 27, 1949	22.24	Oct. 1	11.46
Jan. 26, 1947	22.98	July 1	19.94	Nov. 9	16.69
Feb. 28	23.29	Aug. 22	22.48	Feb. 26, 1952	21.10
Mar. 31	23.36	Oct. 24	22.54	June 9	19.72
May 8	22.91	Dec. 22	22.21	Sept. 22	22.14
July 21	22.53	Feb. 4, 1950	23.35	Jan 10, 1953	23.56
Sept. 9	24.04	Mar. 6	22.09	Mar. 13	23.74
Oct. 2	24.43	Apr. 11	23.58	Apr. 7, 1955	24.78
Oct. 10	24.64	Sept. 19	17.99	Aug. 19	24.50

16-3-12bcb.

Nov. 21, 1950	23.10	Feb. 26, 1952	7.08	July 23	12.29
July 2, 1951	12.40	June 9	7.32	Apr. 7, 1955	14.40
Aug. 17	8.48	Sept. 22	8.99	Aug. 19	14.18
Oct. 1	6.10	Jan. 10, 1953	10.92		
Nov. 9	6.89	Mar. 13	11.63		

16-3-13aaa.

Oct. 20, 1950	21.30	Feb. 26, 1952	18.29	July 23	20.96
July 2, 1951	20.33	June 9	17.91	Apr. 19, 1954	22.08
Aug. 17	15.45	Sept. 22	20.16	Apr. 7, 1955	22.07
Oct. 1	13.18	Jan. 10, 1953	21.22	Aug. 19	22.09
Nov. 9	13.63	Mar. 13	21.64		

16-3-13abb.

Oct. 19, 1950	21.10	Oct. 1	15.94	Sept. 22	20.10
July 2, 1951	21.50	Nov. 9	15.00	Apr. 7, 1955	25.52
Aug. 17	18.16	Feb. 26, 1952	17.74		

Table 9.--(Continued)
16-3-13cdd.

Date	Water level	Date	Water level	Date	Water level
Apr. 1, 1946	20.70	Jan. 6, 1948	24.38	Jan. 24, 1951	21.38
July 3	23.96	Apr. 7	23.32	Mar. 15	22.10
Aug. 1	24.17	May 28	23.56	May 18	22.19
Sept. 5	24.33	Aug. 6	21.78	July 2	20.80
Oct. 1	23.92	Sept. 30	22.44	July 24	15.06
Nov. 4	23.14	Dec. 3	23.06	Aug. 17	13.76
Dec. 2	22.77	Apr. 27, 1949	21.84	Oct. 1	11.64
Dec. 23	22.78	July 1	21.67	Nov. 9	12.83
Jan. 26, 1947	22.96	Aug. 22	21.92	Feb. 26, 1952	18.13
Feb. 28	23.24	Oct. 24	22.63	June 9	17.84
Mar. 31	23.39	Dec. 22	22.99	Sept. 22	21.20
May 8	22.87	Feb. 4, 1950	23.10	Jan. 10, 1953	22.36
July 21	22.16	Mar. 6	22.90	Mar. 13	22.75
Sept. 9	23.12	Apr. 11	23.35	July 23	22.57
Oct. 2	23.49	May 31	22.95	Apr. 7, 1955	25.38
Oct. 30	23.92	Sept. 19	21.15	Aug. 19	25.39
Dec. 1	24.20	Nov. 20	20.43		

16-3-24ddd.

Nov. 17, 1950	9.62	Nov. 9	10.38	July 23, 1953	20.40
July 2, 1951	17.11	Feb. 26, 1952	17.79	Apr. 7, 1955	Dry at 20.6
Aug. 17	4.92	June 9	18.04		
Oct. 1	8.60	Sept. 22	19.31		

16-3-26aad.

Nov. 30, 1950	8.49	Nov. 9	2.74	Jan. 10, 1953	14.72
July 2, 1951	12.73	Feb. 26, 1952	7.24	Mar. 13	15.70
Aug. 17	.14	June 9	10.26		
Oct. 1	1.44	Sept. 22	12.31		

16-3-26dod.

Apr. 9, 1946	20.60	Jan. 6, 1948	21.60	Jan. 24, 1951	18.76
July 3	21.13	Apr. 7	20.17	Mar. 15	19.50
Aug. 1	21.27	May 28	20.75	May 18	19.64
Sept. 5	21.39	Aug. 6	19.50	July 2	16.23
Oct. 1	20.57	Sept. 30	20.28	July 24	4.96
Nov. 4	19.06	Dec. 3	20.74	Aug. 17	8.29
Dec. 2	19.00	Apr. 27, 1949	19.06	Oct. 1	9.02
Dec. 23	19.35	July 1	18.04	Nov. 9	11.37
Jan. 26, 1947	19.79	Aug. 22	19.11	Feb. 26, 1952	16.94
Feb. 28	20.11	Oct. 24	19.74	June 9	16.06
Mar. 31	20.18	Dec. 22	19.94	Sept. 22	20.49
May 8	19.73	Feb. 4, 1950	20.29	Jan. 10, 1953	20.19
July 21	19.25	Mar. 6	20.43	Mar. 13	20.31
Sept. 9	20.55	Apr. 11	20.65	July 23	21.41
Oct. 2	21.01	May 31	20.55	Apr. 19, 1954	21.73
Oct. 10	21.37	Sept. 19	16.87	Apr. 7, 1955	22.22
Dec. 1	21.54	Nov. 20	16.32	Aug. 19	22.45

Table 9.--(Continued)
16-3-33ddd.

Date	Water level	Date	Water level	Date	Water level
July 2, 1951	14.23	Feb. 26, 1952	10.97	Mar. 13	14.90
Aug. 17	10.11	June 9	10.71	July 23	15.80
Oct. 1	8.77	Sept. 22	13.20	Apr. 7, 1955	18.89
Nov. 9	9.05	Jan. 10, 1953	14.53	Aug. 19	19.89

16-3-34ddd.

July 3, 1946	22.56	Jan. 6, 1948	23.15	Nov. 20	18.14
Aug. 1	22.74	Apr. 7	21.84	Jan. 24, 1951	20.10
Sept. 5	22.98	May 28	22.36	Mar. 15	20.90
Oct. 1	22.31	Aug. 6	21.57	May 18	20.77
Nov. 4	21.14	Sept. 30	21.90	July 2	18.39
Dec. 2	20.92	Dec. 3	22.09	July 24	5.80
Dec. 23	21.19	Apr. 27, 1949	20.40	Aug. 17	9.45
Jan. 26, 1947	21.64	July 1	19.76	Oct. 1	9.30
Feb. 28	21.94	Aug. 22	20.31	Nov. 9	11.43
Mar. 31	22.08	Oct. 24	21.22	Feb. 26, 1952	17.86
May 8	21.76	Dec. 22	21.47	June 9	17.29
July 21	21.15	Feb. 4, 1950	21.61	Sept. 22	20.16
Sept. 9	22.23	Mar. 6	22.01	Jan. 10, 1953	21.29
Oct. 2	22.62	Apr. 11	21.15	Mar. 13	21.90
Oct. 10	22.94	May 31	22.00		
Dec. 1	23.07	Sept. 19	18.76		

16-6-36bdd.

Oct. 11, 1950	20.40	Feb. 26, 1952	18.42	July 23	19.95
July 2, 1951	16.35	June 9	18.85	Apr. 18	20.42
Aug. 20	24.31	Sept. 22	19.09	Apr. 7, 1955	20.67
Oct. 1	15.18	Jan. 10, 1953	19.54	Aug. 19	20.67
Nov. 9	15.42	Mar. 13	19.61		

17-3-2add.

Sept. 17, 1951	5.00	Feb. 26, 1952	10.65	Jan. 10, 1953	13.55
Oct. 1	6.41	June 9	11.18	Mar. 13	13.85
Nov. 9	7.32	Sept. 22	12.85	Apr. 7, 1955	Dry at 16.1

17-3-3ddd.

Nov. 18, 1950	9.42	Nov. 9	13.39	Sept. 22	21.23
July 2, 1951	17.83	Feb. 26, 1952	18.06	Apr. 7, 1955	Dry at 23.3
Aug. 17	13.53	Mar. 13	Dry at 18.1		
Oct. 1	13.41	June 9	19.78		

Table 9.---(Continued)
17-3-4bbb.

Date	Water level	Date	Water level	Date	Water level
Nov. 9, 1950	18.90	Feb. 26, 1952	17.96	July 23	17.22
July 2, 1951	21.20	June 9	17.39	Apr. 7, 1955	17.28
Aug. 17	20.09	Sept. 22	17.05	Aug. 19	17.29
Oct. 1	19.22	Jan. 10, 1953	17.33		
Nov. 9	19.24	Mar. 13	17.10		

17-3-5ccc.

Aug. 18, 1951	222	Feb. 26, 1952	3.94	Jan. 10, 1953	4.74
Oct. 1	2.00	June 9	4.35	Mar. 13	4.13
Nov. 9	2.55	Sept. 22	4.81	Apr. 7, 1955	7.05

17-3-9bcc.

Oct. 11, 1950	8.99	Nov. 9	14.54	Mar. 13	15.97
July 2, 1951	11.55	Feb. 26, 1952	14.24	July 23	17.05
Aug. 17	15.50	Sept. 22	14.67	Apr. 7, 1955	19.67
Oct. 1	15.00	Jan. 10, 1953	15.67	Aug. 19	19.75

17-3-9ddd.

Aug. 17, 1951	19.18	June 9	17.86	July 23	Dry at 22.2
Oct. 1	16.97	Sept. 22	18.37	Apr. 7, 1955	23.50
Nov. 9	16.22	Jan. 10, 1953	19.70		
Feb. 26, 1952	16.86	Mar. 13	20.28		

17-3-10bbb.

Mar. 1, 1951	17.74	Feb. 26, 1952	14.78	July 23	18.53
July 2	14.63	June 9	13.76	Apr. 7, 1955	20.35
Aug. 17	6.65	Sept. 22	16.55	Aug. 19	20.59
Oct. 1	6.86	Jan. 10, 1953	17.66		
Nov. 9	9.23	Mar. 13	18.19		

17-3-16ddd.

July 2, 1951	22.72	Feb. 26, 1952	20.71	Mar. 13	24.70
Aug. 18	15.58	June 9	21.65	Apr. 7, 1955	26.56
Oct. 1	14.41	Sept. 22	22.71		
Nov. 9	15.40	Jan. 10, 1953	24.03		

Table 9.—(Continued)
17-3-17dd.

Date	Water level	Date	Water level	Date	Water level
Apr. 17, 1946	26.96	Apr. 7	27.35	May 18	24.93
July 3	27.34	May 28	27.77	July 2	22.33
Aug. 1	27.57	Aug. 6	27.10	July 24	16.75
Sept. 5	27.86	Sept. 30	27.54	Aug. 17	17.49
Oct. 1	27.38	Dec. 3	27.48	Oct. 1	17.60
Nov. 4	26.24	Apr. 27, 1949	25.88	Nov. 9	19.94
Dec. 2	26.28	July 1	24.98	Feb. 26, 1952	22.89
Dec. 23	26.50	Aug. 22	26.10	June 9	22.57
Jan. 26, 1947	26.86	Oct. 24	26.33	Sept. 22	25.37
Feb. 28	27.07	Dec. 22	26.17	Jan. 18, 1953	25.65
Mar. 31	27.10	Feb. 4, 1950	24.96	Mar. 13	25.89
May 8	26.93	Mar. 6	26.39	July 23	26.97
July 21	26.52	Apr. 11	26.30	Apr. 7, 1955	27.73
Sept. 9	27.57	May 31	26.28	Aug. 19	27.97
Oct. 2	27.85	Sept. 19	23.17		
Oct. 30	28.15	Nov. 20	22.95		
Dec. 1	28.18	Jan. 24, 1951	25.10		
Jan. 6, 1948	28.16	Mar. 15	25.58		

17-3-18ddc.

Apr. 19, 1946	27.44	Jan. 6, 1948	28.40	Jan. 24, 1951	25.08
July 3	27.98	Apr. 7	27.49	Mar. 15	25.65
Aug. 1	27.29	May 28	27.80	May 16	25.01
Sept. 5	28.37	Aug. 6	26.52	July 2	21.80
Oct. 1	28.04	Sept. 30	27.14	July 24	17.60
Nov. 4	27.22	Dec. 2	27.40	Aug. 20	17.38
Dec. 2	26.97	Apr. 27, 1949	26.02	Oct. 1	17.25
Dec. 23	27.07	July 1	25.08	Nov. 9	18.88
Jan. 26, 1947	27.24	Aug. 22	25.93	Feb. 26, 1952	22.75
Feb. 28	27.42	Oct. 24	26.34	June 9	22.52
Mar. 31	27.37	Dec. 22	26.45	Sept. 22	25.14
May 8	27.00	Feb. 4, 1950	26.78	Jan. 10, 1953	25.97
July 21	26.42	Mar. 6	25.90	Mar. 13	26.41
Sept. 9	27.57	Apr. 11	26.05	July 23	27.02
Oct. 2	27.95	May 31	26.45	Apr. 19, 1954	27.89
Oct. 30	28.22	Sept. 19	23.33	Apr. 7, 1955	28.60
Dec. 1	28.31	Nov. 20	24.01	Aug. 19	28.18

17-3-19ddd.

July 2, 1951	20.40	June 9	19.84	Apr. 19, 1954	24.20
Aug. 20	12.65	Sept. 22	21.73	Apr. 7, 1955	24.72
Oct. 1	12.60	Jan. 10, 1953	22.83	Aug. 19	24.65
Nov. 9	13.01	Mar. 13	23.20		
Feb. 26, 1952	19.75	July 23	21.60		

Table 9.—(Continued)
17-3-17dd.

Date	Water level	Date	Water level	Date	Water level
Apr. 17, 1946	26.96	Apr. 7	27.35	May 18	24.93
July 3	27.34	May 28	27.77	July 2	22.33
Aug. 1	27.57	Aug. 6	27.10	July 24	16.75
Sept. 5	27.86	Sept. 30	27.54	Aug. 17	17.49
Oct. 1	27.38	Dec. 3	27.48	Oct. 1	17.60
Nov. 4	26.24	Apr. 27, 1949	25.88	Nov. 9	19.94
Dec. 2	26.28	July 1	24.98	Feb. 26, 1952	22.89
Dec. 23	26.50	Aug. 22	26.10	June 9	22.57
Jan. 26, 1947	26.86	Oct. 24	26.33	Sept. 22	25.37
Feb. 28	27.07	Dec. 22	26.17	Jan. 10, 1953	25.65
Mar. 31	27.10	Feb. 4, 1950	24.96	Mar. 13	25.89
May 8	26.93	Mar. 6	26.39	July 23	26.97
July 21	26.52	Apr. 11	26.30	Apr. 7, 1955	27.73
Sept. 9	27.57	May 31	26.28	Aug. 19	27.97
Oct. 2	27.85	Sept. 19	23.17		
Oct. 30	28.15	Nov. 20	22.95		
Dec. 1	28.18	Jan. 24, 1951	25.10		
Jan. 6, 1948	28.16	Mar. 15	25.58		

17-3-18dda.

Apr. 19, 1946	27.44	Jan. 6, 1948	28.40	Jan. 24, 1951	25.06
July 3	27.98	Apr. 7	27.49	Mar. 15	25.65
Aug. 1	27.29	May 28	27.80	May 16	25.01
Sept. 5	28.37	Aug. 6	26.52	July 2	21.80
Oct. 1	28.04	Sept. 30	27.14	July 24	17.60
Nov. 4	27.22	Dec. 2	27.40	Aug. 20	17.38
Dec. 2	26.97	Apr. 27, 1949	26.02	Oct. 1	17.25
Dec. 23	27.07	July 1	25.08	Nov. 9	18.88
Jan. 26, 1947	27.24	Aug. 22	25.93	Feb. 26, 1952	22.75
Feb. 28	27.42	Oct. 24	26.34	June 9	22.52
Mar. 31	27.37	Dec. 22	26.45	Sept. 22	25.14
May 8	27.00	Feb. 4, 1950	26.78	Jan. 10, 1953	25.97
July 21	26.42	Mar. 6	25.90	Mar. 13	26.41
Sept. 9	27.57	Apr. 11	26.05	July 23	27.02
Oct. 2	27.95	May 31	26.45	Apr. 19, 1954	27.89
Oct. 30	28.22	Sept. 19	23.33	Apr. 7, 1955	28.60
Dec. 1	28.31	Nov. 20	24.01	Aug. 19	28.18

17-3-19ddd.

July 2, 1951	20.40	June 9	19.84	Apr. 19, 1954	24.20
Aug. 20	12.65	Sept. 22	21.73	Apr. 7, 1955	24.72
Oct. 1	12.60	Jan. 10, 1953	22.83	Aug. 19	24.65
Nov. 9	13.01	Mar. 13	23.20		
Feb. 26, 1952	19.75	July 23	23.60		

Table 9.--(Continued)
17-3-21cbb.

Date	Water level	Date	Water level	Date	Water level
Oct. 11, 1950	9.05	Nov. 9	12.95		
July 2, 1951	15.96	Feb. 26, 1952	13.30		
Aug. 18	14.76	June 9	14.25		
Oct. 2	14.20				

17-3-23dd.

Apr. 23, 1946	30.53	Jan. 6, 1948	31.36	Jan. 24, 1951	28.33
July 3	30.94	Apr. 7	30.72	Mar. 15	29.04
Aug. 1	31.05	May 28	31.02	May 16	29.70
Sept. 5	31.23	Aug. 6	30.46	July 2	25.90
Oct. 1	30.69	Sept. 3	30.77	July 24	19.09
Nov. 4	29.50	Dec. 2	30.92	Aug. 20	19.25
Dec. 2	29.40	Apr. 27, 1949	29.39	Oct. 1	19.54
Dec. 23	29.63	July 1	28.49	Nov. 9	20.82
Jan. 26, 1947	29.96	Aug. 22	29.08	Feb. 26, 1952	25.96
Feb. 28	30.13	Oct. 24	29.54	June 9	26.60
Mar. 31	29.98	Dec. 22	29.58	Sept. 22	28.54
May 8	30.17	Feb. 4, 1950	29.85	Jan. 10, 1953	29.59
July 21	29.77	Mar. 6	29.90	Mar. 13	29.76
Sept. 9	30.68	Apr. 11	29.55	July 23	30.53
Oct. 2	31.00	May 31	29.90	Apr. 19, 1954	30.98
Oct. 30	31.25	Sept. 19	26.61	Apr. 7, 1955	31.73
Dec. 1	31.33	Nov. 20	21.59	Aug. 19	31.28

17-4-20ddd.

Oct. 11, 1950	3.65	Feb. 26, 1952	4.64	July 23	8.83
July 2, 1951	1.73	June 9	3.94	Apr. 19, 1954	11.68
Aug. 20	3.49	Sept. 22	9.24	Apr. 7, 1955	13.24
Oct. 1	3.63	Jan. 10, 1953	8.48	Aug. 19	13.70
Nov. 9	3.13	Mar. 13	9.30		

17-4-21bcc.

Oct. 11, 1950	6.74	Feb. 26, 1952	7.10	July 23	9.44
July 2, 1951	3.78	June 9	6.49	Apr. 19, 1954	Dry at 10.6
Aug. 20	6.16	Sept. 22	9.51	Apr. 7, 1955	Dry at 10.5
Oct. 1	6.03	Jan. 10, 1953	9.13		
Nov. 9	6.50	Mar. 13	8.80		

Table 9.—(Continued)
17-4-25ddd.

Date	Water level	Date	Water level	Date	Water level
Apr. 23, 1946	24.30	Dec. 1	25.64	Nov. 20	26.15
July 3	24.96	Jan. 6, 1948	25.80	Jan. 24, 1951	22.68
Aug. 1	25.30	Apr. 7	25.05	Mar. 15	23.01
Sept. 5	25.49	May 28	25.23	May 16	22.72
Oct. 1	25.34	Aug. 6	24.40	July 2	20.44
Nov. 4	24.82	Sept. 3	24.86	July 24	15.11
Dec. 2	24.74	Dec. 2	24.97	Aug. 20	15.44
Dec. 23	24.82	Apr. 27, 1949	24.02	Oct. 1	15.52
Jan. 26, 1947	24.91	July 1	23.46	Nov. 9	16.42
Feb. 28	25.09	Aug. 22	23.43	Feb. 26, 1952	19.47
Mar. 31	25.17	Oct. 24	23.84	June 9	19.82
May 8	25.03	Dec. 22	24.09	Sept. 22	21.78
July 21	24.67	Feb. 4, 1950	24.09	Mar. 13, 1953	23.46
Sept. 9	24.80	Mar. 6	24.15	July 23	24.26
Oct. 2	25.63	Apr. 11	25.49	Apr. 7, 1955	26.55
Oct. 30	25.72	Sept. 19	21.31	Aug. 19	26.70

17-4-26ddd.

July 2, 1951	20.58	Feb. 26, 1952	22.93	Mar. 13	25.64
Aug. 20	21.22	June 9	23.13	July 23	25.96
Oct. 1	21.67	Sept. 22	23.48	Apr. 7, 1955	29.40
Nov. 9	21.95	Jan. 10, 1953	24.99		

17-4-29ccc.

Nov. 30, 1950	12.90	Nov. 9	9.52	Jan. 10, 1953	19.30
July 2, 1951	15.40	Feb. 26, 1952	17.97	Mar. 13	19.59
Aug. 20	6.52	June 9	20.51	Apr. 7, 1955	20.17
Oct. 1	7.96	Sept. 22	18.40	Aug. 19	19.68

17-4-31baa.

Oct. 23, 1950	19.60	Oct. 1	13.26	Apr. 7, 1955	24.50
July 2, 1951	17.02	Sept. 22, 1952	23.30	Aug. 19	18.47
Aug. 20	13.06	July 23, 1953	16.34		

17-4-32baa.

Oct. 26, 1950	16.90	Feb. 26, 1952	18.73	July 23	21.32
July 2, 1951	20.01	June 9	19.56	Apr. 7, 1955	23.07
Aug. 20	8.80	Sept. 22	19.64	Aug. 19	23.15
Oct. 1	10.52	Jan. 10, 1953	11.59		
Nov. 9	11.71	Mar. 13	21.05		

Table 9.—(Continued)

17-4-33abb.

Date	Water level	Date	Water level	Date	Water level
Oct. 27, 1950	18.79	Feb. 26, 1952	19.53	July 23	Dry
July 2, 1951	21.18	June 9	20.38	Apr. 7, 1955	Dry at 24.5
Aug. 20	17.72	Sept. 22	22.79	Aug. 19	Dry
Oct. 1	17.04	Jan. 10, 1953	23.55		
Nov. 9	16.92	Mar. 13	23.82		

17-4-33bbb.

Oct. 11, 1950	13.60	Feb. 26, 1952	19.16	July 23	22.82
July 2, 1951	16.89	June 9	19.53	Apr. 7, 1955	Dry at 25.0
Aug. 20	11.05	Sept. 22	20.79	Aug. 19	Dry
Oct. 1	12.51	Jan. 10, 1953	21.93		
Nov. 9	13.70	Mar. 13	22.38		

17-4-34add.

July 2, 1951	19.64	Feb. 26, 1952	22.06	Mar. 13	24.97
Aug. 20	13.11	June 9	21.51	July 23	24.85
Oct. 1	14.31	Sept. 22	23.46	Apr. 7, 1955	25.75
Nov. 9	16.21	Jan. 10, 1953	24.51	Aug. 19	25.69

17-4-36abb.

July 2, 1951	20.08	Feb. 26, 1952	18.69	Mar. 13	22.35
Aug. 20	15.23	June 9	19.07	July 23	23.00
Oct. 1	15.38	Sept. 22	21.58	Apr. 7, 1955	25.85
Nov. 9	16.00	Jan. 10, 1953	21.88	Aug. 19	26.90

17-5-4ddd.

Apr. 8, 1951	15.34	Nov. 9	14.90	Jan. 10, 1953	16.41
July 2	13.82	Feb. 26, 1952	16.04	Mar. 13	16.53
Aug. 20	14.67	June 9	15.41	July 23	Dry
Oct. 1	14.00	Sept. 22	15.97	Apr. 7, 1955	Dry at 20.5

17-5-5edd.

Apr. 8, 1951	17.49	Nov. 9	14.10	Jan. 10, 1953	Dry
July 2	18.50	Feb. 26, 1952	Dry	Mar. 13	Dry
Aug. 20	16.25	June 9	Dry	July 13	Dry
Oct. 1	14.90	Sept. 22	Dry	Apr. 7, 1955	Dry at 20.0

17-5-7add.

Mar. 16, 1951	14.30	Feb. 26, 1952	12.89	July 23, 1953	15.18
July 2	10.44	June 9	11.94	Apr. 7	15.50
Aug. 20	6.06	Sept. 22	14.55	June 19	15.89
Oct. 1	6.01	Jan. 10, 1953	14.99		
Nov. 9	8.40	Mar. 13	14.95		

Table 9.—(Continued)
17-5-7bbb.

Date	Water level	Date	Water level	Date	Water level
Dec. 17, 1950	20.00	Feb. 26, 1952	20.63	July 23	24.28
July 2, 1951	17.88	June 9	21.70	Apr. 7, 1955	25.94
Aug. 20	18.92	Sept. 22	21.96	Aug. 19	25.57
Oct. 1	19.24	Jan. 10, 1953	22.84		
Nov. 9	19.55	Mar. 13	22.64		

17-5-8ccc.

Dec. 9, 1950	8.44	Feb. 26, 1952	4.74	July 23	9.30
July 2, 1951	7.85	June 9	4.74	Apr. 7, 1955	11.48
Aug. 20	4.34	Sept. 22	7.16	Aug. 19	11.76
Oct. 1	3.42	Jan. 10,1953	8.79		
Nov. 9	3.33	Mar. 13	8.93		

17-5-8ddd.

Dec. 9, 1950	7.22	Feb. 26, 1952	7.85	July 23	10.25
July 2, 1951	2.79	June 9	6.56	Apr. 7, 1955	11.72
Aug. 20	1.23	Sept. 22	9.92	Aug. 19	11.75
Oct. 1	.90	Jan. 10, 1953	8.72		
Nov. 9	1.98	Mar. 13	10.75		

17-5-11bbb.

Dec. 10, 1950	5.10	Feb. 26, 1952	4.72	July 23	9.75
July 2, 1951	5.08	June 9	3.96	Apr. 7, 1955	13.79
Aug. 20	2.67	Sept. 22	7.77	Aug. 19	14.89
Oct. 1	1.87	Jan. 10, 1953	8.64		
Nov. 9	2.68	Mar. 13	9.15		

17-5-16aaa.

Mar. 16, 1951	19.20	Feb. 26, 1952	17.04	July 23	19.85
July 2	15.19	June 9	15.96	Apr. 7, 1955	20.03
Aug. 20	10.57	Sept. 22	18.80	Aug. 19	19.56
Oct. 1	10.39	Jan. 10, 1953	19.53		
Nov. 9	12.45	Mar. 13	19.72		

17-5-21dad.

Dec. 17, 1950	9.30	Nov. 9	9.31	Apr. 7, 1955	18.90
July 2, 1951	12.37	Feb. 26, 1952	15.48		
Aug. 20	7.01	June 9	14.18		
Oct. 1	6.51	Sept. 22	16.81		

Table 9.---(Continued)
17-5-23ccc.

Date	Water level	Date	Water level	Date	Water level
Dec. 17, 1950	9.61	Feb. 26, 1952	Dry	July 23	Dry
July 2, 1951	15.05	June 9	Dry	Apr. 7, 1955	22.91
Aug. 20	11.71	Sept. 22	Dry	Aug. 19	Dry
Oct. 1	12.30	Jan. 10, 1953	Dry		
Nov. 9	17.30	Mar. 13	Dry		

17-5-25aaa.

Oct. 23, 1950	20.90	Feb. 26, 1952	8.60	Apr. 18	13.47
July 2, 1951	11.39	June 9	9.18	July 23	11.06
Aug. 20	9.35	Sept. 22	8.45	Apr. 7, 1955	15.41
Oct. 1	7.51	Jan. 10, 1953	10.25	Aug. 19	15.96
Nov. 9	7.62	Mar. 13	11.12		

17-5-26ddd.

Oct. 25, 1950	19.73	Feb. 26, 1952	14.80	July 23	19.70
July 2, 1951	13.87	June 9	15.56	Apr. 18, 1954	20.54
Aug. 20	5.00	Sept. 22	17.48	Apr. 7, 1955	21.14
Oct. 1	7.33	Jan. 10, 1953	19.09	Aug. 19	21.34
Nov. 9	8.62	Mar. 13	19.44		

17-6-13aaa.

Dec. 9, 1950	16.34	Feb. 26, 1952	21.85	July 23	22.38
July 2, 1951	22.80	June 9	21.66	Apr. 18	22.98
Aug. 20	22.61	Sept. 22	21.58	Apr. 7, 1955	23.70
Oct. 1	22.36	Jan. 10, 1953	22.18	Aug. 19	Dry
Nov. 9	22.18	Mar. 13	22.27		

Table 10.--Water-level measurements collected during the Camp Phillips pumping test.

Camp Phillips well 2 (pumped well) altitude of measuring point, 1,246.7 feet.

Date	Time	Depth to water level feet	Drawdown, feet
Jan. 6, 1951	1:55	20.19	
7	2:25	21.17	
9	Pump started at 9:50 A.M. Jan. 9, 1951		
	9:50 A.M.	21.19	0.00
	9:55	32.94	11.75
	9:57	33.04	11.85
	10:00	33.10	11.91
	10.06	33.11	11.92
	10:13	33.22	12.03
	10:20	33.26	12.07
	10:36	33.30	12.11
	11:02	33.38	12.19
	11:30	33.40	12.21
	12:00 Noon	33.44	12.25
	1:00	33.52	12.33
	2:00	33.58	12.39
	3:00	33.66	12.47
	4:00	33.71	12.52
	5:00	33.75	12.56
	6:00	33.80	12.61
	8:00	33.90	12.71
	12:00 Midnight	34.05	12.86
January 10, 1951	4:00 A.M.	34.18	12.99
	8:00 A.M.	34.29	13.10
	10:00 A.M.	34.34	13.15
	1:50 P.M.	34.42	13.23
	5:50 P.M.	34.51	13.32
	9:50 P.M.	34.60	13.41
Jan. 11, 1951	5:50 A.M.	34.69	13.50
	9:50 A.M.	34.75	13.56

Pump stopped at 9:50 A.M. Drawdown column is residual drawdown

Table 10 (Continued)

Date	t_m	t'_m	Time	Depth to water level feet	Drawdown, feet	t_m/t'_m
	2882	2	9:52	23.49	2.30	1.44×10^3
	2884	4	9:54	23.02	1.83	7.21×10^2
	2885	5	9:55	22.95	1.76	5.77
	2887	7	9:57	22.88	1.69	4.12
	2890	10	10:00	22.83	1.64	2.89
	2895	15	10:05	22.79	1.60	1.92
	2900	20	10:10	22.77	1.58	1.45
	2910	30	10:20	22.73	1.54	9.70×10^1
	2920	40	10:30	22.69	1.50	7.30
	2930	50	10:40	....	....	
	2940	60	10:50	22.65	1.46	4.90
	2950	70	11:00	22.63	1.44	4.21
	2980	100	11:30	22.57	1.38	2.98
	3010	130	12:00 Noon	22.51	1.32	2.31
	3060	180	12:50	22.46	1.27	1.70
	3120	240	1:50 P.M.	22.41	1.22	1.30
	3180	300	2:50	22.36	1.17	1.06
	3240	360	3:50	22.32	1.13	$9:00 \times 10^0$
	3300	420	4:50	22.28	1.09	7.85
	3360	480	5:50	22.29	1.10	7.00
	3600	720	9:50 P.M.	22.14	0.95	5:00
Jan. 12 1951	4320	1440	9:50 A.M.	21.94	0.75	$3:00 \times 10^0$
	4560	1680	1:50 P.M.	....	....	2.72
	4800	1920	5:50 P.M.	21.85	0.66	2.50
Jan. 13 1951	5750	2880	9:50 A.M.	21.75	0.56	2.00

Table 10 (Continued)

Well Line A

Date	Time	Well A1 100 feet east altitude 1,244.1 Depth to water level, feet	Drawdown feet	Well A2 200 feet east altitude 1,244.0 Depth to water level, feet	Drawdown, feet	Well A3 400 feet east altitude 1,244.3 Depth to water level, feet	Draw-down f
Jan. 1, 1951	11:20 P.M.	17.29		13.58) void, well		18.82	
2,	4:40 P.M.	17.37		13.68) developed on		18.82	
4,	9:00 A.M.	17.44		13.75) 1-5-51		18.86	
6,	2:20 P.M.	17.36		18.31		18.76	
7,	2:27 P.M.	Void 1550(well devel-		17.69		18.66	
9,	9:30 A.M.	18.47 .	oped)	18.45		18.85	
	Pump started at 9:50 A.M.						
	9:50 :30 A.M.	18.47	0.00	18.45	0.0	18.82	0.0
	9:51 :00	18.47	0.00	18.50	0.05	18.82	0.0
	9:51 :30	18.70	0.23	18.50	0.05	18.84	0.0
	9:52 :00	18.83	0.36	18.58	0.13	18.84	0.0
	9:52 :30	18.92	0.45	18.70	0.25	18.85	0.0
	9:53 :00	18.98	0.51	18.71	0.26	18.88	0.03
	9:53 :30	19.11	0.64	18.74	0.29	18.86	0.01
	9:54	19.17	0.70	18.79	0.34	18.86	0.01
	9:55	19.22	0.75	18.83	0.38	18.86	0.01
	9:56	19.31	0.81	18.84	0.39	18.86	0.01
	9:57	19.44	0.97	18.85	0.40	18.85	0.00
	9:58	19.51	1.04	18.86	0.41	18.85	0.00
	9:59	19.57	1.10	18.87	0.42	18.85	0.00
	10:00	19.62	1.15	18.90	0.45	18.84	0.00
	10:01	19.75	1.28	18.90	0.45	18.85	0.00
	10:02	19.85	1.38	18.95	0.50	18.86	0.01
	10:04	19.89	1.42	18.96	0.51	18.87	0.02
	10:06	19.97	1.50	18.99	0.54	18.87	0.02
	10:08	20.01	1.54	19.01	0.56	18.87	0.02
	10:10	20.07	1.60	19.04	0.59	18.87	0.02
	10:13	20.11	1.64	19.10	0.65	18.88	0.03
	10:16	20.14	1.67	19.11	0.66	18.88	0.03
	10:19	20.18	1.71	19.12	0.67	18.89	0.04
	10:22	20.20	1.73	19.13	0.68	18.89	0.04
	10:25	20.22	1.75	19.14	0.69	18.91	0.06
	10:28	20.22	1.75	19.15	0.70	18.91	0.06
	10:30	20.23	1.76	19.16	0.73	18.92	0.07
	10:35	20.26	1.79	19.20	0.75	18.92	0.07
	10:40	20.30	1.83	19.22	0.77	18.90	0.05
	10:45	20.30	1.83	19.22	0.77	18.91	0.06
	10:50	20.32	1.85	19.23	0.78	18.90	0.05
	10:55	20.34	1.87	19.27	0.82	18.91	0.06

Table 10 (Continued)

Well Line A

Date	Time	Well A1 100 feet east altitude 1,244.1 Depth to water level, feet	Drawdown, feet	Well A2 200 feet east altitude 1,244.0 Depth to water level, feet	Drawdown, feet	Well A3 400 feet east altitude 1,244.3 Depth to water level, feet	Drawdown, feet
	11:00	20.34	1.87	19.28	0.83	18.92	0.07
	11:10	20.36	1.89	19.31	0.86	18.92	0.07
	11:20	20.38	1.91	19.37	0.92	18.92	0.07
	11:30	20.44	1.97	19.38	0.93	18.93	0.08
	11:50	20.49	2.02	19.40	0.95	18.92	0.07
	12:10P.M.	20.49	2.02	19.44	0.99	18.95	0.10
	12:30	20.52	2.05	19.51	1.06	18.96	0.11
	12:50	20.52	2.10	19.57	1.12	18.96	0.11
	1:20	20.71	2.25	19.60	1.15	18.98	0.13
	1:50	20.78	2.31	19.71	1.26	19.05	0.20
	22:20	20.79	2.32	19.71	1.26	19.08	0.23
	2:50	20.79	2.32	19.78	1.33	19.04	0.19
	3:30	20.82	2.35	19.82	1.37	19.05	0.20
Jan. 9, 1951	4:10	20.82	2.35	19.89	1.44	19.07	0.22
	4:50	20.93	2.45	19.89	1.44	19.13	0.28
	5:30	20.86	2.39	19.96	1.54	19.14	0.29
	6:10	20.90	2.43	20.20	1.75	19.17	0.32
	8:00	20.98	2.51	20.36	1.91	19.22	0.37
Jan. 10, 1951	12:00 M	21.24	2.77	20.54	2.09	19.39	0.54
	4:00 A.M.	21.40	2.93	20.63	2.18	19.47	0.62
	8:00	21.63	3.16	20.69	2.24	19.63	0.78
	9:50	21.70	3.23	20.87	2.42	19.67	0.82
	1:50P.M.	21.75	3.28	20.95	2.50	19.74	0.89
	5:50	21.90	3.43	20.99	2.54	19.89	1.04
	9:50	21.97	3.50	21.08	2.63	19.94	1.09
Jan. 11, 1951	5:50A.M.	22.16	3.69	21.12	2.67	20.12	1.27
	9:30	22.20	3.73	21.20	2.75	20.19	1.34
	Pump stopped at 9:50 A.M. Drawdown column is residual drawdown						
Jan. 11, 1951	9:50A.M.						
	9:51	22.12	3.65			20.16	1.32
	9:52	21.88	3.41			20.14	1.30
	9:53	21.60	3.13			20.15	1.31
	9:54	21.32	2.85			20.14	1.30
	9:55	21.10	2.63			20.13	1.29
	9.56	21.01	2.54	20.70	2.25	20.13	1.29
	9:57	20.81	2.34	20.69	2.24	20.13	1.29
	9:58	20.63	2.16	20.68	2.23	20.12	1.27
	9:59	20.56	2.09	20.68	2.23	20.11	1.26

Table 10 (Continued)

Well Line A

Date	Time	Well A1 100 feet east altitude 1,244.1 Depth to water level, feet	Drawdown, feet	Well A2 200 feet east altitude 1,244.0 Depth to water level, feet	Drawdown, feet	Well A3 400 feet east altitude 1,244.3 Depth to water level, feet	Drawdown, feet
	[illegible]						
	10:00	20.49	2.02	20.67	2.22	20.09	1.24
	10:02	20.39	1.92	20.67	2.22	20.09	1.24
	10:04	20.33	1.84	20.66	2.21	20.19	1.34
	10:06	20.31	1.82	20.65	2.20	20.19	1.34
	10:08	20.29	1.80	20.65	2.20	20.19	1.34
	10:10	20.26	1.77	20.64	2.19	20.13	1.28
	10:13	20.25	1.76	20.62	2.17	20.13	1.28
	10:16	20.23	1.74	20.60	2.15	20.15	1.30
	10:19	20.23	1.74	20.58	2.13	20.16	1.31
	10:20	20.22	1.743	20.58	2.13	20.18	1.33
	10:30	20.22	1.73	20.52	2.107	20.14	1.29
	10:40	20.15	1.67	20.52	28.07	20.11	1.26
	10:50	20.11	1.63	20.51	2.06	20.12	1.27
	11:00	20.09	1.61	20.45	2.00	20.11	1.26
	11:30A.M.	19.99	1.51	20.39	1.94	20.12	1.27
	12:00Noon	19.93	1.46	20.34	1.89	20.11	1.26
	1:50P.M.	19.86	1.39	20.28	1.83	20.07	1.22
	2:50	19.80	1.33	20.17	1.72	20.05	1.20
	3:50	19.76	1.29	20.09	1.64	20.05	1.20
	4:50	19.72	1.25	20.02	1.57	20.07	1.22
	5:50	19.67	1.20	19.96	1.51	20.02	1.17
	9:50	19.56	1.09	19.81	1.36	19.97	1.12
Jan. 12, 1951	9:50A.M.	19.38	0.93	19.48	1.03	19.79	0.94
	1:50P.M.	19.27	0.82	19.40	0.95	19.76	0.91
	5:50	19.25	0.80	19.31	0.86	19.74	0.889
Jan. 13, 1951	9:50A.M.	19.08	0.61	19.10	0.65	19.56	0.71

Recovery measurements stopped at 9:50 A.M., January 13, 1951

Table 10.—Water-level measurements collected during the Camp Phillips pumping test.

Well Line B

Date	Time	Well B1 50 feet south altitude 1,243.8 Depth to water level, feet	Drawdown, feet	Well B2 200 feet south altitude 1,243.6 Depth to water level, feet	Drawdown, feet	Well B3 400 feet south altitude 1,244.5 Depth to water level, feet	Drawdown, feet
Jan. 1, 1951	11:20P.M.			17.56		17.00	
2,	4:40P.M.			17.60		17.06	
4,	9:00 A.M.	18.31		17.66		17.10	
6,	2:20P.M.	18.36		17.68		17.16	
7,	2.27P.M.	18.04		17.65	XX	18.54	
9,	9:30A.M.	18.13		17.80		18.50	
	Pump started at 9:50 A.M.						
	9:50:30A.M.	19.19	1.06	17.92	0.12	18.50	0.00
	9:51:00	20.09	1.96	18.18	0.38	18.50	0.00
	9:51:30	20.79	2.66	18.35	0.55	18.51	0.01
	9:52:00	21.39	3.26	18.51	0.71	18.52	0.02
	9:52:30	21.51	3.38	18.60	0.80	18.54	0.04
	9:53:00	21.53	3.40	18.68	0.88	18.56	0.06
	9:53:30	21.53	3.40	18.70	0.91	18.58	0.08
	9:54:00	21.54	3.41	18.73	0.93	18.59	0.09
	9:55	21.56	3.43	18.80	1.00	18.61	0.11
	9:56	21.63	3.53	18.83	1.03	18.62	0.12
	9:57	21.73	3.60	18.85	1.05	18.63	0.13
	9:58	21.74	3.61	18.88	1.08	18.65	0.15
	9:59	21.77	3.64	18.90	1.10	18.66	0.16
	10:00	21.79	3.66	18.91	1.11	18.66	0.16
	10:01	21.79	3.66	18.92	1.12	18.66	0.16
	10:02	21.79	3.66	18.93	1.13	18.66	0.16
	10:04	21.80	3.67	18.95	1.15	18.64	0.14
	10:06	21.80	3/67	18.97	1.17	18.65	0.15
	10:08	21.81	3.68	18.98	1.18	18.66	0.16
	10:10	21.83	3.70	18.99	1.19	18.66	0.16
	10:13	21.84	3.71	19.00	1.20	18.69	0.19
	10:16	21.85	3.72	19.01	1.21	18.69	0.19
	10:19	21.88	3.75	19.02	1.22	18.69	0.19
	10:22	21.89	3.76	19.04	1.24	18.69	0.19
	10:25	21.90	3.77	19.06	1.26	18.71	0.21
	10:28	21.90	3.77	19.07	1.27	18.71	0.21
	10:30	21.91	3.78	19.08	1.28	18.70	0.20
	10:35	21.93	3.80	19.08	1.28	18.70	0.20

Table 10 (Continued)

Well Line B

Date	Time	Well B1, 50 feet south, altitude 1,243.8		Well B2, 200 feet south, altitude 1,243.6		Well B3, 400 feet south, altitude 1,244.5	
		Depth to water level, feet	Drawdown, feet	Depth to water level, feet	Drawdown, feet	Depth to water level, feet	Drawdown, feet
	10:40	21.95	3.82	19.08	1.28	18.70	0.20
	10:45	21.99	3.86	19.08	1.28	18.71	0.21
	10:50	22.01	3.88	19.12	1.32	18.75	0.25
	10:55	22.03	3.90	19.12	1.32	18.74	0.24
	11:00	22.04	3.91	19.17	1.37	18.75	0.25
	11:10	22.01	3.92	19.22	1.42	18.78	0.28
	11:20	22.05	3.92	19.23	1.43	18.80	0.30
	11:30	22.05	3.92	19.23	1.43	18.80	0.30
	11:50	22.06	3.93	19.28	1.48	18.81	0.31
	12:10P.M.	22.06	3.93	19.32	1.52	18.62	0.32
	12:30	22.12	3.99	19.35	1.55	18.84	0.34
	12:50	22.17	4.04	19.38	1.58	18.81	0.31
Jan. 9, 1951	1:30P.M.	22.21	4.08	19.41	1.61	18.84	0.34
	1:50	22.23	4.10	19.42	1.62	18.88	0.38
	2:20	22.29	4.16	19.49	1.69	18.90	0.40
	2:50	22.33	4.20	19.52	1.72	18.92	0.42
	3:30	22.36	4.23	19.55	1.75	18.96	0.46
	4:10	22.40	4.27	19.60	1.80	18.97	0.47
	4:50	22.49	4.36	19.68	1.88	19.03	0.53
	5:30	22.49	4.36	19.70	1.90	19.02	0.52
	6:10	22.53	4.40	19.77	1.97	19.05	0.55
	8:00	22.63	4.50	19.86	2.06	19.11	0.61
Jan. 10, 1951	12:00 M	22.79	4.66	20.01	2.21	19.25	0.75
	4:00A.M.	22.94	4.79	20.15	2.35	19.34	0.84
	8:00	23.05	4.92	20.30	2.50	19.48	0.98
	9:50	23.11	4.98	20.35	2.55	19.50	1.00
	1:50P.M.	23.19	5.06	20.44	2.64	19.56	1.06
	5:50	23.29	5.16	20.55	2.75	19.65	1.15
	9:50	23.38	5.25	20.64	2.84	19.78	1.28
	5:50A.M.	22.53	5.40	20.79	2.99	19.91	1.41
	9:30	23.58	5.44	20.85	3.05	19.96	1.46
Pump stopped at 9:50 A.M. Drawdown column is residual drawdown							
Jan. 11, 1951	9:50A.M.						
	9:51	21.22	3.09	20.58	2.78	19.96	1.46
	9:52	20.63	2.50	20.14	2.34	19.94	1.44
	9:53	20.34	2.21	20.06	2.26	19.92	1.42
	9:54	20.24	2.11	19.99	2.19	19.87	1.37

Table 10 (Continued)

Well Line B

Date	Time	Well B1 50 feet south altitude 1,243.8 Depth to water level, feet	Drawdown, feet	Well B2 200 feet south altitude 1,243.6 Depth to water level, feet	Drawdown, feet	Well B3 400 feet south altitude 1,244.5 Depth to water level, feet	Drawdown, feet
	9:55	20.19	2.06	19.86	2.06	19.86	1.36
	9:56	20.11	1.98	19.86	2.06	19.86	1.36
	9:57	20.17	2.04	19.85	2.05	19.86	1.36
	9:58	20.09	1.96	19.82	2802	19.86	1.36
	9:59	20.07	1.94	19.77	1.97	19.87	1.37
	10:00	20.05	1.92	19.77	1.97	19.87	1.37
	10:082	20.02	1.89	19.77	1.97	19.86	1.36
	10:04	20.00	1.87	19.76	1.96	19.86	1.36
	10:06	19.98	1.85	19.76	1.96	19.86	1.36
	10:08	19.97	1.84	19.75	1.96	19.84	1.34
	10:10	19.97	1.84	19.73	1.93	19.84	1.34
	10:13	19.96	1.83	19.71	1.91	19.84	1.34
	10:16	19.95	1.82	19.71	1.91	19.83	1.33
	10:19	19.94	1.81	19.70	1.90	19.81	1.31
	10:20	19.94	1.81	19.70	1.90	19.81	1.31
	10:30	19.89	1.76	19.66	1.86	19.81	1.31
	10:40	19.86	1.73	19.61	1.81	19.80	1.30
	10:50	19.86	1.73	19.56	1.76	19.79	1.29
	11:00	19.84	1.71	19.54	1.74	19.78	1.28
	11:30A.M.	19.79	1.66	19.50	1.70	19.75	1.25
	12:00Noon	19.73	1.60	19.43	1.63	19.73	1.23
	1:50P.M.	19.57	1.44	19.29	1.49	19.61	1.11
	2:50	19.51	1.38	19.21	1.41	19.57	1.07
	3:50	19.45	1.32	19.15	1.35	19.57	1.07
	4:50	19.41	1.28	19.09	1.29	19.52	1.02
	5:50	19.38	1.25	19.07	1.27	19.50	1.00
	9:50	19.25	1.12	18.94	1.14	19.47	.97
Jan. 12, 1951	9:50A.M.	18.98	0.85	18.68	0.88	19.30	.80
	1:50P.M.	18.95	0.82	18.64	0.84	19.26	.76
	5:50	18.90	0.76	18.57	0.77	19.26	.76
Jan. 13, 1951	9:50A.M.	18.74	0.50	18.44	0.64	19.13	.63

Table 10 (Continued)

Well Line G

Date	Time	Well G1 50 feet west altitude 1,244.3 Depth to water level, feet	Drawdown, feet	Well G2 100 feet west altitude 1,243.3 Depth to water level, feet	Drawdown, feet	Well G3 200 feet west altitude 1,244.6 Depth to water level, feet	Drawdown, feet
Jan. 1, 1951							
2,	4:54						
4,	9:28						
6,	2:39						
7,	2:37						
8,	9:30						
Pump started at 9:50 A.M.							
	9:50:30AM	19.46	1.8	17.97	0.34	19.14	0.23
	9:51:00	20.76	2.1	18.26	0.63	19.37	0.46
	9:51:30	21.56	2.9	18.47	0.84	19.60	0.69
	9:52:00	21.89	3.23	18.71	1.08	19.83	0.92
	9:52:30	22.06	3.4	18.82	1.19	20.06	1.15
	9:53:00	22.16	3.5	18.92	1.29	20.31	1.40
	9:53:30	22.36	3.7	19.04	1.41	20.40	1.49
	9:54	22.46	3.8	19.11	1.48	20.849	1.58
	9:55	22.51	3.85	19.18	1.55	20.68	1.77
	9:56	22.52	3.86	19.35	1.72	20.72	1.81
	9:57	22.57	3.91	19.32	1.69	20.77	1.86
	9:58	22.57	3.91	19.38	1.75	20.79	1.88
	9:59	22.61	3.95	19.41	1.78	20.82	1.91
	10:00	22.61	3.95	19.45	1.82	20.81	1.91
	10:01	22.61	3.95	19.48	1.85	20.82	1.92
	10:02	22.61	3.95	19.49	1.86	20.84	1.93
	10:04	22.64	3.98	19.53	1.90	20.83	1.92
	10:06	22.67	4.01	19.49	1.86	20.90	1.99
	10:08	22.69	4.03	19.51	1.88	20.91	2.00
	10:10	22.74	4.08	19.54	1.91	20.91	2.00
	10:13	22.74	4.08	19.56	1.93	20.91	2.00
	10:16	22.786	4.10	19.56	1.93	20.95	2.04
	10:19	22.77	4.11	19.57	1.94	20.97	2.06
	10:22	22.78	4.12	19.57	1.94	20.99	2.08
	10:25	22.79	4.13	19.57	1.94	20.99	2.08
	10:28	22.81	4.135	19.57	1.94	20.99	2.08
	10:30	22.82	4.16	19.61	1.98	21.01	2.10
	10:35	22.63	4.17	19.62	1.99	21.02	2.11
	10:40	22.84	4.18	19.62	1.99	20.98	2,07
	10:45	22.85	4.19	19.63	2.00	21.06	2.15
	10:50	22.86	4.20	19.64	2.01	21.07	2.16

Table 10 (Continued)

Well Line C

Date	Time	Well C1 50 feet west altitude 1,244.3 Depth to water level, feet	Drawdown, feet	Well C2 100 feet west altitude 1,243.3 Depth to water level, feet	Drawdown, feet	Well C3 200 feet west altitude 1,244.6 Depth to water level, feet	Drawdown, feet
	10:55	22.91	4.25	19.66	2.03	21.09	2.18
	11:00	22.91	4.25	19.70	2.07	21.09	2.18
	11:10	22.94	4.28	19.73	2.10	21.10	2.19
	11:20	22.94	4.28	19.73	2.10	21.10	2.19
	11:30	22.94	4.28	19.73	2.10	21.12	2.21
	11:50	23.01	4.35	19.76	2.13	21.15	2.24
	12:10P.M.	23.01	4.35	19.80	2.17	21.16	2.25
	12:30	23.01	4.35	19.82	2.19	21.16	2.25
Jan. 9, 1951	12:50	23.06	4.40	19.83	2.20	21.21	2.30
	1:20	23.07	4.41	19.87	2.24	21.26	2.35
	1:50	23.08	4.42	19.93	2.30	21.28	2.37
	2:20	23.12	4.46	19.99	2.36	21.31	2.40
	2:50	23.19	4.53	19.99	2.36	21.34	2.43
	3:30	23.21	4.55	19.93	2.30	21.38	2.47
	4:10	23.23	4.57	19.95	2.32	21.39	2.48
	4:50P.M.	23.30	4.64	20.11	2.48	21.41	2.50
	5:30	23.34	4.68	20.40	2.77	21.42	2.51
	6:10	23.36	4.70	20.37	2.74	21.48	2.57
	8:00	23.48	4.79	20.27	2.64	21.58	2.67
Jan. 10, 1951	12:00 M	23.65	4.99	20.45	2.82	21.60	2.69
	4:00A.M.	23.76	5.10	20.62	2.99	21.79	2.88
	8:00	23.84	5.17	20.74	3.11	21.96	3.05
	9:50	23.87	5.21	20.82	3.19	21.96	3.05
	1:50P.M.	23.97	5.31	20.84	3.21	22.05	3.14
	5:50	23.06	5.40	20.92	3.29	22.16	3.25
	9:50	23.18	5.52	21.04	3.41	22.16	3.25
Jan. 11, 1951	5:50A.M.	23.27	5.61	21.17	3.54	22.35	3.44
	9:30	23.34	5.67	21.26	3.63	22.37	3.46
	Pump stopped at 9:50 A.M. Drawdown column is residual drawdown.						
Jan. 11, 1951	9:50A.M.	24.41	5.75				
	9:51	22.11	3.45	20.56	2.93	22.27	3.36
	9:52	21.21	2.55	20.21	2.58	20.98	2.07
	9:53	20.19	2.25	19.98	2.35	20.97	2.06
	9:54	20.69	2.03	19.85	2.22	20.91	2.00

Table 10 (Continued)

Well Line C

Date	Time	Well C1, 50 feet west, altitude 1,244.3: Depth to water level, feet	Well C1: Drawdown, feet	Well C2, 100 feet west, altitude 1,243.3: Depth to water level, feet	Well C2: Drawdown	Well C3, 200 feet west, altitude 1,244.6: Depth to water level, feet	Well C3: Drawdown, feet
	9:55	20.66	2.00	19.79	2.16	20.50	1.59
	9:56	20.63	1.97	19.77	2.14	20.48	1.57
	9:57	20.59	1.93	19.70	2.07	20.45	1.54
	9:58	20.56	1.90	19.68	2.05	20.43	1.52
	9:59	20.51	1.85	19.65	2.02	20.40	1.49
	10:00	20.48	1.82	19.61	1.98	20.38	1.47
	10:02	20.47	1.81	19.61	1.98	20.35	1.44
	10:04	20.46	1.80	19.61	1.98	20.34	1.43
	10:06	20.50	1.84	19.63	2.00	20.33	1.42
	10:08	20.49	1.83	19.59	1.96	20.32	1.41
	10:10	20.48	1.82	19.58	1.95	20.31	1.40
	10:13	20.46	1.80	19.55	1.92	20.29	1.38
	10:16	20.46	1.80	19.55	1.92	20.29	1.38
	10:19	20.46	1.80	19.54	1.91	20.28	1.37
	10:20	20.46	1.80	19.54	1.91	20.27	1.36
	10:30	20.40	1.74	19.53	1.90	20.24	1.33
	10:40	20.33	1.67	19.48	1.85	20.16	1.25
	10:50	20.32	1.66	19.44	1.81	20.19	1.28
	11:00	20.30	1.64	19.43	1.80	20.18	1.27
	11:30	20.22	1.56	19.37	1.74	20.13	1.22
	12:00Noon	20.18	1.52	19.34	1.71	20.08	1.17
	1:50P.M.	20.08	1.42	19.20	1.57	19.99	1.08
	2:50	20.01	1.35	19.13	1.50	19.93	1.02
	3:50	19.95	1.29	19.09	1.46	19.89	0.98
	4:50	19.91	1.25	19.04	1.41	19.90	0.99
	5:50	19.88	1.22	18.97	1.33	19.84	0.93
	9:50	19.84	1.18	18.84	1.20	19.74	0.83
Jan. 12, 1951	9:50A.M.	19.50	0.84	18.57	.94	19.59	0.68
	1:50P.M.	19.44	0.78	18.50	.87	19.54	0.63
	5:50	19.39	.73	18.46	.83	19.49	0.58
Jan. 13, 1951	9:50A.M.	19.25	.59	18.29	.66	19.41	0.50

Table 10 (Continued)

Well Line D

Date	Time	Well D1 100 feet north altitude 1,244.4 Depth to water level, feet	Drawdown, feet	Well D2 200 feet north altitude 1,243.9 Depth to water level, feet	Drawdown, feet	Well D3 400 feet north altitude 1,243.7 Depth to water level, feet	Drawdown, feet
Jan. 1, 1951	11:42	18.45		18.39		18.41	
2,	4:59	18.52		18.30		18.43	
4,	9:32	18.86		18.66		18.34	
6,	3:10	18.86		18.65		18.35	
7,	2:39	18.90		18.64		18.34	
	Pump started at 9:50 A.M.						
	9:50:30AM	19.22	0.04	18.67	0.00	18.39	0.08
	9:51:00	19.27	0.09	18.67	0.00	18.47	0.16
	9:51:30	19.30	0.12	18.67	0.00	18.56	0.25
	9:52:00	19.33	0.15	18.67	0.00	18.63	0.32
	9:52:30	19.34	0.16	18.67	0.00	18.66	0.35
	9:53:00	19.35	0.17	18.67	0.00	18.68	0.37
	9:53:30	19.35	0.17	18.67	0.00	18.70	0.39
	9:54	19.36	0.18	18.67	0.00	18.72	0.41
	9:55	19.37	0.19	18.67	0.00	18.75	0.44
	9:56	19.39	0.21	18.67	0.00	18.76	0.45
	9:57	19.40	0.22	18.67	0.00	18.77	0.46
	9:58	19.40	0.22	18.67	0.00	18.78	0.47
	9:59	19.41	0.23	18.67	0.00	18.79	0.48
	10:00	19.42	0.24	18.67	0.00	18.80	0.49
	10:01	19.42	0.24	18.68	0.01	18.81	0.50
	10:02	19.43	0.25	18.68	0.01	18.82	0.51
	10:04	19.45	0.27	18.68	0.01	18.84	0.53
	10:06	19.48	0.30	18.68	0.01	18.85	0.54
	10:08	19.50	0.32	18.68	0.01	18.87	0.56
	10:10	19.50	0.32	18.68	0.01	18.89	0.58
	10:13	19.54	0.36	18.68	0.01	18.90	0.59
	10:16	19.54	0.36	18.68	0.01	18.91	0.60
	10:19	19.59	0.41	18.68	0.01	18.94	0.63
	10:22	19.60	0.42	18.69	0.02	18.94	0.63
	10:25	19.62	0.44	18.69	0.02	18.95	0.64
	10:28	19.62	0.44	18.69	0.02	18.96	0.65
	10:30	19.63	0.45	18.69	0.02	18.97	0.66
	10:35	19.65	0.47	18.70	0.03	18.99	0.68
	10:40	19.66	0.48	18.71	0.04	19.01	0.70
	10:45	19.67	0.49	18.72	0.05	19.02	0.71
	10:50	19.67	0.49	18.72	0.05	19.02	0.72

Table 10 (Continued)

Well Line D

Date	Time	Well D1 100 feet north altitude 1,244.4 Depth to water level, feet	Drawdown, feet	Well D2 200 feet north altitude 1,243.9 Depth to water level, feet	Drawdown, feet	Well D3 400 feet north altitude 1,243.7 Depth to water level, feet	Drawdown, feet
	10:55	19.67	0.49	18.76	0.09	19.05	0.74
	11:00	19.71	0.53	18.85	0.18	19.06	0.75
	11:10	19.76	0.58	18.85	0.18	19.07	0.76
	11:20	19.78	0.60	18.85	0.18	19.10	0.79
	11:30	19.79	0.61	18.87	0.20	19.11	0.80
	11:50	19.79	0.61	18.88	0.21	19.16	0.85
	12:10P.M.	19.83	0.65	18.89	0.22	19.20	0.89
	12:30	19.87	0.69	18.89	0.22	19.26	0.95
Jan. 9, 1951	12:50	19.90	0.72	18.90	0.23	19.27	0.96
	1:20	19.97	0.79	18.94	0.27	19.30	0.99
	1:50	19.99	0.81	18.95	0.28	19.33	1.02
	2:20	20.04	0.86	18.91	0.24	19.35	1.04
	2:50	20.10	0.92	18.92	0.25	19.38	1.07
	3:30	20.14	0.96	18.93	0.26	19.42	1.11
	4:10	20.20	1.02	18.93	0.26	19.45	1.14
	4:50P.M.	20.13	0.95	Developed well D_2		19.50	1.19
	5:30	20.38	1.20	19.47	0.30	19.54	1.23
	6:10	20.43	1.25	19.54	0.87	19.58	1.27
	8:00	20.55	1.37	19.69	1.02	19.69	1.38
Jan. 10, 1951	12:00 M	20.74	1.56	19.87	1.20	19.78	1.47
	4:00A.M.	20.97	1.79	20.09	1.42	19.89	1.58
	8:00	21.08	1.90	20.20	1.53	19.98	1.67
	9:50	21.15	1.97	20.28	1.61	20.03	1.72
	1:50P.M.	21.29	2.11	20.41	1.74	20.12	1.81
	5:50	21.40	2.22	20.54	1.97	20.18	1.87
	9:50	21.54	2.36	20.64	2807	20.23	1.92
Jan. 11, 1951	5:50A.M.	21.69	2.51	20.81	2.14	20.35	2.04
	9:30	21.63	2.65	20.90	2.23	20.40	2.09
	Pump stopped at 9:50 A.M. Drawdown column is residual drawdown.						
Jan. 11, 1951	9:50A.M.	21.83	2.65	20.90	2.23	20.40	2.09
	9:51	21.52	2.34	20.89	2.22	20.36	2.05
	9:52	21.41	2.23	20.88	2.21	20.18	1.87
	9:53	21.36	2.18	20.85	2.18	20.09	1.78
	9:54	21.34	2.16	20.84	2.17	20.04	1.73
	9:55	21.32	2.14	20.83	2.16	19.99	1.68
	9:56	21.30	2.12	20.81	2.14	19.96	1.65
	9:57	21.27	2.09	20.80	2.13	19.94	1.63
	9:58	21.26	2.08	20.80	2.13	19.93	1.62
	9:59	21.26	2.08	20.79	2.12	19.92	1.61
	10:00	21.25	2.07	20.78	2.11	19.90	1.59

Table 10 (Continued)

Well Line D

Date	Time	Well D1 100 feet north altitude 1,244.4 Depth to water level, feet	Drawdown, feet	Well D2 200 feet north altitude 1,243.9 Depth to water level, feet	Drawdown, feet	Well D3 200 feet north altitude 1,243.7 Depth to, water level, feet	Drawdown, feet
	10:02	21.21	2.03	20.77	2.10	19.89	1.58
	10:04	21.20	2.02	20.74	2.07	19.87	1.56
	10:06	21.20	2.02	20.74	2.07	19.86	1.55
	10:08	21.19	2.01	20.72	2.05	19.85	1.54
	10:10	21.16	1.98	20.71	2.04	19.84	1.53
	10:13	21.15	1.97	20.68	2.01	19.82	1.51
	10:16	21.15	1.97	20.67	2.00	19.81	1.50
	10:19	21.14	1.96	20.66	1.99	19.80	1.49
	10:20	21.14	1.96	20.66	1.99	19.79	1.48
	10:30	21.12	1.94	20.62	1.95	19.75	1.44
	10:40	21.11	1.93	20.59	1.92	19.72	1.41
	10:50	21.12	1.94	20.57	1.90	19.69	1.38
	11:00	21.13	1.95	20.55	1.88	19.67	1.36
	11:30A.M.	20.98	1.80	20.48	1.81	19.61	1.30
	12:00Noon	20.95	1.77	20.42	1.75	19.55	1.24
	1:50P.M.	20.82	1.64	20.27	1.60	19.42	1.11
	2:50	20.75	1.57	20.25	1.58	19.236	1.05
	3:50	20.69	1.51	20.14	1.47	19.32	1.01
	4:50	20.62	1.44	20.11	1.44	19.27	0.96
	5:50	20.57	1.39	20.05	1.38	19.24	0.93
	9:50	20.43	1.25	19.92	1.25	19.14	0.83
Jan. 12, 1951	9:50A.M.	20.05	0.87	19.56	0.89	18.97	0.66
	1:50P.M.	19.97	0.79	19.46	0.79	18.93	0.62
	5:50	19.88	0.70	19.41	0.74	18.89	0.58
Jan. 13, 1951	9:50A.M.	19.71	0.53	19.24	0.57	18.81	0.50

Table 11.--Logs of wells observed during the Camp Phillips pumping test.

Log of Camp Phillips well 2 (pumped well).

	Thickness, feet	Depth, feet
Clay, brown.....	19	19
Sand, coarse, contains clay streaks	6	25
Sand, coarse, and gravel	3	28
Clay, soft, blue	3	31
Sand and gravel	19	50
Sand, coarse, and gravel	7.5	57.5

Well Line A

Log of well A1 located 100 feet east of pumped well.

Silt, gray.....	3	3
Silt, buff.....	4	7
Clay, cream, silty	1.5	8.5
Silt, sandy, red-brown	1.5	10.5
Sand, fine to medium	14.5	25
Sand, coarse to coarse gravel	5	30

Log of well A2 located 200 feet east of pumped well.

Silt, gray.....	3	3
Silt, buff	4	7
Clay, silty, cream-colored	10	17
Sand, fine to medium, silty	9	26
Sand, coarse to coarse gravel	4	30

Table 11 (Continued)

Log of well A3 located 400 feet east of pumped well.

	Thickness, feet	Depth, feet
Silt, gray.....	2.5	2.5
Silt, buff	4.5	7
Clay, silty, cream-colored	1.5	8.5
Sand, fine to medium, silty	16.5	25
Sand, coarse to coarse gravel	5	30

Well Line B

Log of well B1 located 50 feet south of pumped well.

Silt, gray.....	3	3
Silt, buff	5	8
Clay, silty, cream-colored	1	9
Sand, fine to medium, silty	17	26
Sand, coarse to coarse gravel	4	30

Log of well B2 located 200 feet south of pumped well.

Silt, gray.....	3	3
Silt, buff	5	8
Clay, silty, cream-colored	1	9
Sand, fine to medium, silty	17	26
Sand, coarse to coarse gravel	4	30

Log of well B3 located 400 feet south of pumped well.

Silt, gray.....	3	3
Silt, buff	4.5	7.5
Clay, silty, cream-colored	1.5	9
Sand, fine to medium, silty	17	26
Sand, coarse to coarse gravel	4	30

Table 11 (Continued)

Well Line C

Log of well C1 located 50 feet west of pumped well.

	Thickness, feet	Depth, feet
Silt, gray.....	2.5	2.5
Silt, mugg buff	4.5	7
Clay, silty, cream-colored	1.5	8.5
Sand, fine to medium, silty	16.5	25
Sand, coarse to coarse gravel	5	30

Log of well C2 located 100 feet west of pumped well.

Silt, gray.....	2.5	2.5
Silt, buff	4.5	7
Clay, silty, cream-colored	1.5	8.5
Sand, fine to medium, silty	16.5	25
Sand, coarse to fine gravel	5	30

Log of well C3 located 200 feet west of pumped well.

Silt, gray.....	3	3
Silt, buff	4	7
Clay, silty, cream-colored	1.5	8.5
Sand, fine to medium, silty	17.5	26
Sand, coarse to coarse, gravel	4	30

Table 11 (Continued)

Well Line D

Log of well D1 located 100 feet north of pumped well.

	Thickness, feet	Depth, feet
Silt, gray.....	3	3
Silt, buff	4	7
XClay, silty, cream-colored	1.5	8.5
Silt, sandy, red-brown	2.5	11
Sand, fine to medium	15	26
Sand, coarse to coarse gravel	4	30

Log of well D2 located 200 feet north of pumped well.

Silt, gray.....	3	3
Silt, buff	4	7
Clay, silty, cream-colored	1.5	8.5
Silty, sandy, red-brown	2.5	11
Sand, fine to medium	17	28
Sand, coarse to coarse gravel, blue shale particles	2	30

Log of well D3 located 300 feet north of pumped well.

Silt, gray.....	3	3
Silt, buff	4	7
Clay, silty, cream-colored	1.5	8.5
Silty, red-brown, sandy	2.5	11
Sand, fine to medium	15	26
Sand, coarse to coarse gravel	4	30

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Table 12.--Logs of jetted observation wells

Logs of 48 jetted observation wells constructed by the Federal Geological Survey in the Kanopolis Unit are given on the following pages. Although these wells rarely penetrate the entire thickness of alluvium, their logs give pertinent information concerning the materials that overlie the water table. The logs also are useful for interpreting water-level changes in the observation wells.

Logs of the wells are listed in order by townships from north to south and by ranges from east to west. Within a township they are arranged in the numerical order of the sections.

14-2-19dc

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	2.0	2.0
Silt, buff	6.0	8.0
Clay, silty, gray	1.5	9.5
Silt, buff	9.5	19.0
Sand, medium to coarse	9.0	28.0
Gravel, fine	2.0	30.0

14-2-30cd

QUATERNARY--Pleistocene		
Topsoil	1.5	1.5
Silt, buff	9.5	11.0
Clay, silty, gray	3.0	14.0
Silt, buff	7.5	21.5
Sand, medium to coarse	8.5	30.0

14-2-31cc

QUATERNARY--Pleistocene		
Topsoil	1.5	1.5
Silt, buff	6.5	8.0
Clay, gray	1.5	9.5
Silt, loose, buff	18.5	28.0

14-3-25ad

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	1.0	1.0
Silt, buff	8.0	9.0
Clay, sandy, gray	1.5	10.5
Silt, buff	5.5	16.0
Sand, fine	9.0	25.0
Sand, medium to coarse	5.0	30.0

14-3-36abb

QUATERNARY--Pleistocene		
Soil	1.0	1.0
Silt, buff	7.5	8.5
MClay, sandy, gray	1.5	10.0
Silt, buff	5.0	15.0
Sand, fine	10.0	25.0
Sand, medium to coarse	2.0	27.0

15-2-6aa

QUATERNARY--Pleistocene		
Silt, gray	65.0	5.0
Silt, buff	3.5	8.5
Clay, cream	1.5	10.0
Silt, buff	4.0	14.0
Sand, fine to medium	14.0	28.0
Sand, coarse, and gravel	2.0	30.0

15-2-19bb

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Silt, buff	10.5	10.5
Sand, fine	8.5	19.0
Clay, silty, white	4.0	23.0
Silt, buff	7.0	30.0

15-2-30ccc

QUATERNARY--Pleistocene		
Soil (loam), black	1.5	1.5
Silt, sandy, buff	8.5	10.0
Silt, dark-buff	7.0	17.0
Sand, silty, fine, tan	3.0	20.0
Sand, medium to coarse, tan	7.3	27.3

15-2-31ccc

QUATERNARY--Pleistocene		
Soil, (loam) black	1.8	1.8
Silt, sandy, very fine, buff	8.2	10.0
Silt, dark-buff	6.5	16.5
Sand, silty, very fine buff	4.0	20.5
Sand, medium to coarse	6.9	27.4

15-2-32baa

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Soil.....	3.5	3.5
Clay, silty, buff (1-foot soil zone at 11.5 feet beneath surface)	10.5	14.0
Silt, clayey, brown	3.5	17.5
Sand, silty, brown	2.2	19.7
Clay, silty, buff	8	20.5
Sand, silty, fine	10.5	31.0

15-3-1ccc

QUATERNARY--Pleistocene		
Topsoil	2.5	2.5
Silt, buff	4.5	7.0
Clay, silty, gray	1.0	8.0
Silt, slightly sandy hair	16.4	24.4

15-3-12ab

QUATERNARY--Pleistocene		
Top soil	2.0	2.0
Silt, buff	5.0	7.0
Clay, silty, gray	1.5	8.5
Silt, buff, sandy	6.5	15.0
Sand, medium	11.0	26.0
Sand, coarse and gravel	4.0	30.0

[illegible]
. 15-3-12cd

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil.....	3.0	3.0
Silt, buff	16.0	19.0
Clay, cream	3.0	21.0
Silt, granular, buff	9.0	30.0
15-3-13cc		
QUATERNARY--Pleistocene		
Silt, fine, buff	17.0	17.0
Silt, granular, buff	11.0	28.0
15-3-25ccd		
QUATERNARY--Pleistocene		
Soil (loam) black	6.5	6.5
Silt, clayey, tan	1.5	8.0
Silt, slightly sandy, brown	5.0	13.0
Sand, fine to medium	12.0	25.0
16-2-8ccc		
QUATERNARY--Pleistocene		
Topsoil	2.2	2.2
Silt, clayey, buff	5.0	7.2
Clay, slightly silty, gray	3.0	10.2
Silt, nodular, buff	4.0	14.2
Sand, medium, tan	16.0	30.2

16-2-18abb

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	1.5	1.5
Silt, nodular, buff	15.5	17.0
Sand, silty, fine, tan	13.0	30.0

XXXXXXX
16-3-12bcb

QUATERNARY--Pleistocene		
Topsoil	1.5	1.5
Silt, loose, buff	7.5	9.0
Clay, silty	1.5	10.5
Silt, loose, reddish	17.1	27.6
Clay, compact, hard	2.6	30.2

16-3-13abb

QUATERNARY--Pleistocene		
Topsoil	2.2	2.2
Silt, nodular, buff	28.8	31.0

16-3-24ddd

QUATERNARY--Pleistocene		
Topsoil	1.5	1.5
Clay, silty, buff	13.5	15.0
Silt	14.0	29.0
Sand, coarse	2.0	31.0

16-3-26aad

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Soil	1.5	1.5
Clay, gray	16.5	18.0
Silt, sandy, buff	12.2	30.2

16-3-33ddd

QUATERNARY--Pleistocene		
Topsoil	2.0	2.0
Clay, dark	2.5	4.5
Silt, buff; lower part fine sandy	28.5	33.0
Sand, very coarse, and gravel	7.0	40.0

16-6-35bdd

QUATERNARY--Pleistocene		
Topsoil	1.5	1.5
Silt, clayey, brown	4.0	5.5
Clay, slightly silty, brown	8.2	13.7
Silt, sandy, buff	3.3	17.0
Sand, medium, tan	5.0	22.0
Sand, coarse, tan	4.6	26.6

17-3-3ddd

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Soil	1.5	1.5
Clay, silty	21.5	23.0
Clay, red-brown	2.0	25.0
Silt	5.7	30.7

17-3-4bbb

QUATERNARY—Pleistocene		
Topsoil	1.8	1.8
Silt, clayey, brown	8.4	10.2
Silt, clayey, red-brown	16.3	26.5
Clay, green		26.5+

17-3-[illegible]bcc

QUATERNARY—Pleistocene		
Silt, sandy, very fine	3.2	3.2
Clay, silty	3.8	7.0
Clay, slightly silty, gray-brown	1.7	8.7
Sand, silty, very fine	5.8	14.5
Sand, medium	4.5	19.0

17-3-10bbb

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	2.5	2.5
Clay, tan	6.0	8.5
Silt, fine, sandy	14.0	22.5
Sand, coarse	7.0	29.5
Gravel, fine, and clay balls	1.5	31.0

17-3-16ddd

QUATERNARY--Pleistocene		
Topsoil	2.0	2.0
Clay, silty, gray	18.0	20.0
Silt, sandy	2.0	22.0
Sand, fine to coarse	8.0	30.0

17-3-19ddd

QUATERNARY--Pleistocene		
Topsoil	2.5	2.5
Silt, gray, clayey	5.5	8.0
Silt, fine sandy, iron stains	16.0	24.0
Sand, fine, silty, iron stains	8.0	32.0

17-3-21cbb

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	2.0	2.0
Silt, clayey, buff	9.0	11.0
Clay, silty, dense, gray	4.0	15.0
Silt, nodular, buff	3.6	18.6
Sand, medium to very coarse	11.4	30.0

17-4-20ddd

QUATERNARY--Pleistocene		
Topsoil, reddish	1.9 ±	1.9
Clay, silty, red-brown	10.1	12.0
Sand, coarse, and gravel, fine; contains shale fragments	9.0	21.0

17-4-21bcc

QUATERNARY--Pleistocene		
Soil (loam) black	1.8	1.8
Clay, silty, dark red	6.2	8.0
Sand, very coarse, and gravel, fine	3.0	11.0

17-4-26ddd

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil.....	2.0	2.0
Silt, loose, contains occasional thin clay zones, gray	33.0	35.0
Sand, coarse	7.0	42.0

17-4-29ccc

QUATERNARY--Pleistocene		
Topsoil	1.9	1.9
Silt, clayey, buff	9.0	11.0
(No recovery of samples)	20.5	31.5

17-4-31baa

QUATERNARY--Pleistocene		
Topsoil	2.8	2.8
Silt, nodular, buff	22.2	25.0
Sand, medium to coarse, tan	6.5	31.5

17-4-32baa

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	2.5	2.5
Silt, clayey, gray	5.5	8.0
Silt, nodular, buff	7.4	15.4
Sand, silty, very fine	4.2	19.6
Sand, fine to medium	2.4	22.0
Sand, medium to coarse	4.0	26.0

17-4-33abb

QUATERNARY--Pleistocene		
Topsoil	3.0	3.0
Silt, clayey, gray	13.5	16.5
Silt, nodular, buff	3.9	20.4
Sand, silty, fine	3.6	24.0

~~17-4-33bbb~~

17-4-33bbb

QUATERNARY--Pleistocene		
Topsoil	2.5	2.5
Silt, clayey, gray	5.5	8.0
Silt, nodular, buff	7.4	15.4
Sand, silty, very fine	4.2	19.6
Sand, fine to medium	2.4	22.0
Sand, medium to coarse	4.0	26.0

17-4-36abb

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	2.0	2.0
Silt, clayey, nodular	23.0	25.0
Sand, medium to fine	6.0	31.0

17-5-5add

QUATERNARY--Pleistocene		
Topsoil	1.5	1.5
Silt, clayey, gray	11.5	13.0
Silt, fine sandy, red-brown	17.0	30.0

17-5-7add

QUATERNARY--Pleistocene		
Silt, sandy	8.0	8.0
Sand, fine to medium	11.0	19.0
Sand, coarse, and gravel	8.0	27.0

17-5-8ccc

QUATERNARY--Pleistocene		
Topsoil	1.1	1.1
Sand, silty, very fine to fine	12.9	14.0
Sand, coarse, and gravel, fine to medium	6.0	20.0

17-5-8ddd

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Topsoil	1.3	1.3
Silt, sandy, very fine, buff	8.0	9.3
Sand, fine to medium	5.7	15.0
Sand, coarse and gravel, fine	2.9	17.9

17-5-16aaa

QUATERNARY--Pleistocene		
Clay, dark gray, silty	8.0	8.0
Clay, buff, silty and slightly sandy	15.85	23.5
Sand, fine to coarse	1.0	24.5
Gravel, fine to medium	1.0	25.5
PERMIAN--Leonardian		
Winnesoah shale		
Shale, mottled, red-brown and gray-green	1.0	26.5

17-5-23ccc

QUATERNARY--Pleistocene		
Top soil	3.0	3.0
Silt, clayey, gray	9.2	12.2
Silt, nodular, buff	5.3	17.5
Sand, fine to medium	7.5	25.0

XXXXXXXXX
17-5-25aaa

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Top soil.....	2.5	2.5
Clay, silty, gray	4.4	6.9
Silt, clayey, buff	12.1	19.0
Sand, silty, fine	3.5	22.5
Sand, silty, medium	9.0	31.5
17-5-26ddd		
QUATERNARY—Pleistocene		
Topsoil	3.1	3.1
Silt, clayey, gray	8.1	11.2
Clay, silty, dense, gray	2.2	13.4
Silt, nodular, buff	9.6	23.0
Sand, silty, fine to medium	7.5	30.5
17-6-13aaa		
Road fill	7.0	7.0
QUATERNARY—Pleistocene		
Silt, clayey, buff	7.0	14.0
Sand, silty, very fine	5.0	19.0
Sand, very coarse, well-sorted	7.6	26.6

Logs of Test Holes

Listed on the following pages are logs of 65 test holes and wells of which 51 were drilled by the State Geological Survey of Kansas and 14 were drilled by the Layne-Western Company for the city of Salina and the U. S. Army. The logs entitled sample logs were drilled by the State Geological Survey, and the samples collected from these holes were studied both in the field and microscopically in the office.

The locations of 64 test holes are shown on Plate 3. Test hole 15-4-25bab is just outside the map area. All but 4 test holes (15-3-16bbb, bbc, ccc, and 15-4-25bab) are shown on Plate 4. The test holes are listed in numerical order according to their location within townships, ranges, sections, and parts of sections.

14-2-1bccd. Driller's log of test hole in the SE¼ SW¼ SW¼ sec. 19, T. 14 S., R. 2 W., Saline County, drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,229 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY—Pleistocene		
Alluvium		
Clay	21	24
Sand, fine	5	29
Sand, coarse and gravel	19	48
Clay	1	49
PERMIAN—Leonardian		
Wellington formation		
Rock	1	50

14-2-30aab. Driller's log of test hole in the NW¼ NW¼ NE¼ sec. 30, T. 14 S., R. 2 W., Saline County; drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,227 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY--Pleistocene		
Alluvium		
Clay	12	15
Sand and gravel	40	55
PERMIAN--Leonardian		
Wellington formation		
Shale	1	56

14-2-30bbb. Driller's log of test hole at the NW cor. sec. 30, T. 14S., R. 2 W., Saline County, drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,225 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY—Pleistocene		
Alluvium		
Clay	30	33
Sand and gravel	22	55
PERMIAN—Leonardian		
Wellington formation		
Shale	1	56

14-3-22dcc. Sample log of test hole at the SW cor. SE¼ sec. 22, T. 14 S., R. 3 E., Saline County; drilled by the State Geological Survey, 1945. Surface altitude, 1,232 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt, clayey, gray, gray-black, and brown.....	10	10
Silt, light-buff and light-gray	18	28
Sand and gravel, fine to coarse; gravels derived from sandstone and shale	7	35
PERMIAN--Leonardian		
Wellington		
Shale, laminated, gray to blue-gray	5	40

14-3-23ccc. Driller's log of test hole at the SW cor. sec. 23, T. 14 S., R. 3 W., Saline County; drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,234 feet.

	Thickness, feet	Depth, feet
Soil	4	4
QUATERNARY—Pleistocene		
Alluvium		
Clay	42	46
PERMIAN—Leonardian		
Wellington formation		
Shale	1	47

14-3-23odd. Driller's log of test hole at the SE cor. SW¼ sec. 23, T. 14 S., R. 3 W., Saline County; drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,234 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY--Pleistocene		
Alluvium		
Shale, soft	35	38
Sand and gravel	4	42
PERMIAN--Leonardian		
Wellington formation		
Shale	1	43

14-3-23aod. Driller's log of test hole in the SE¼ SW¼ SW¼ sec. 23, T. 14 S., R. 3 E., Saline County; drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,230 feet.

	Thickness, feet	Depth, feet
Soil	2	2
QUATERNARY--Pleistocene		
Alluvium		
Clay	33	35
Sand, fine	8	43
Clay, sandy	2	45
Sand, fine	3	48
Sand, coarse	8	56
Clay	15	71
Sand, coarse	5	76
PERMIAN--Leonardian		
Wellington formation		
Shale	1	77

14-3-24aa. Driller's log of test hole at the NE cor. sec. 24, T. 14 S., R. 3 W., Saline County; drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,229 feet.

	Thickness, feet	Depth, feet
Soil	4	4
QUATERNARY—Pleistocene		
Alluvium		
Shale, soft	18	22
Sand and gravel	31	53
PERMIAN—Leonardian		
Wellington formation		
Shale	1	54

14-3-24add. Driller's log of test hole at the SE cor. NE¼ sec. 24, T. 14 S., R. 3 E., Saline County; drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,231 feet.

	Thickness, feet	Depth, feet
Soil.....	3	3
QUATERNARY--Pleistocene		
Alluvium		
Clay	23	26
Sand, fine	4	30
Sand, xtcoarse	10	40
Sand and gravel	8	48
Sand, coarse	4	52
Clay	1	53
PERMIAN--Leonardian		
Wellington formation		
Rock	1	54

14-3-24dcd. Sample log of test hole at the SE cor. SW¼ SE¼ sec. 24, T. 14 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,232 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Alluvium		
Silt, clayey, buff and brown; contains few caliche nodules	9	10
Silt, sandy, buff and gray; contains a little fine to medium gravel	17	27
Sand and gravel, fine to coarse	19	46
Silt, grey	8	54
PERMIAN—Leonardian		
Wellington formation		
Shale, green and gray	3	57

14-3-25bb. Driller's log of test hole in the NE¼ NW¼ sec. 25, T. 14 S., R. 3 W., Saline County, drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,232 feet.

	Thickness, feet	Depth, feet
Soil	2	2
QUATERNARY—Pleistocene		
Alluvium		
Shale, soft	39	41
Sand and gravel	31	72
PERMIAN—Leonardian		
Wellington formation		
Shale	1	73

14-3-26aa. Driller's log of test hole in the NE¼ NE¼ sec. 26, T. 14 S., R. 3 W., Saline County; drilled by the Layne-Western Company for the City of Salina. Surface altitude, 1,238 feet.

	Thickness, feet	Depth feet
Soil	5	5
QUATERNARY--Pleistocene		
Alluvium		
Shale, soft	19	24
Shale, sandy	18	42
Sand and gravel	20	62
PERMIAN--Leonardian		
Wellington formation		
Shale	1	63

15-2-7aa. Driller's log of well (camp well 3) for Camp Phillips, Kansas, in the NE¼ NE¼ NW¼ sec. 7, T. 15 S., R. 2 W., Saline County; drilled by the Layne-Western Company for the U. S. Army, 1942.

	Thickness, feet	Depth, feet
Soil	1	1
QUATERNARY		
Alluvium		
Clay	20	21
Sand, fine	5	26
Sand, gravel, and clay balls	3	29
Sand, gravel, and a few boulders	31	60
PERMIAN—Leonardian		
Wellington formation		
Shale	2	62

15-2-7bca. Driller's log of well (camp well 2) for Camp Phillips, Kansas, in the NE¼ SW¼ NW¼ sec. 7, T. 15 S., R. 2 E., Saline County; drilled by the Layne-Western Company for the U. S. Army, 1942.

	Thickness, feet	Depth, feet
QUATERNARY		
Alluvium		
Clay, brown	19	19
Sand, coarse; contains clay streaks	6	25
Sand, coarse, and gravel	3	28
Clay, soft, blue	3	31
Sand and gravel	19	50
Sand, coarse, and gravel	7.5	57.5
PERMIAN--Leonardian		
Wellington formation		
Shale	3.5	61

15-2-7bbb. Driller's log of well (camp well 1) for Camp Phillips, Kansas, at the NW cor. sec. 7, T. 15S., R. 2 W., Saline County; drilled by the Layne-Western Company for the U. S. Army, 1942.

	Thickness, feet	Depth, feet
Soil	2	2
QUATERNARY		
Alluvium		
Clay	29	31
Sand, coarse, and gravel; contains clay balls	6	37
Sand, coarse, and gravel; contains a few boulders at base	22	59
Rock, chipped, brown and streaks of yellow clay	4	63
PERMIAN—Leonardian		
Wellington formation		
Shale	2	65

15-2-8baa. Sample log of test hole in the NE¼ NE¼ NE¼ sec. 8, T. 15 S., R. 2 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,301.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY		
Slope deposits		
Silt, clayey, brown	3.5	3.5
Gravel, medium to very coarse; derived from Cretaceous material; contains silt, some fine gravel and sand	4.5	8
PERMIAN—Leonardian		
Wellington formation		
Shale, gray-green and yellow-green	4	12
Shale, red-brown, yellow-green, and blue-gray; contains a little calcite	8	20

15-2-33b. Driller's log of well (camp well 4) for Camp Phillips, Kansas, in the NE¼ NW¼ sec. 8, T. 18 S., R. 2 W., Saline County; drilled by the Layne-Western Company for the U. S. Army, 1942.

	Thickness, feet	Depth, feet
Soil	1	1
QUATERNARY		
Alluvium		
Clay	18	19
Sand, fine, clayey	3	22
Sand, gravel, and clay balls	11	33
Sand and gravel	17	50
PERMIAN--Leonardian		
Wellington formation		
Shale	5	55

15-2-3cc. Sample log of test hole in the SW¼ SW¼ sec. 3, T. 15 S., R. 3 E., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,296.8 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY		
Slope deposits		
Silt, clayey, light gray-green; contains few caliche nodules	2	4
Silt, clayey, brown and yellow buff	6	10
Volcanic ash, white	2	12
Clay, silty, yellow and dark-gray	15	27
PERMIAN—Leonardian		
Wellington formation		
Shale, red-brown and gray-green	3	30

15-2-19cdd. Sample log of test hole at the SE cor. SW¼ sec. 19, T. 15 S., R. 2 E., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,268.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, light-gray	10	10
Silt, sandy, light-gray to gray	15	25
Sand, fine, to gravel, coarse; gravel composed mostly of shale fragments	10	36
Sand, fine to gravel, very coarse; granitic	19.5	54.5
Silt and clay; sandy, yellow-gray	8.5	63
Gravel, fine to very coarse; composed of shale, limestone, and sandstone fragments; contains some sand and clay	4.5	67.5
Clay, silty, blue-gray	10.5	78
Sand, fine to gravel, coarse	7	85
Silt and clay; dark-gray to blue-gray	9	94
PERMIAN—Leonardian		
Wellington formation		
Shale, light to dark blue-gray	6	100

16-2-19dd$_4$. Sample log of test hole in the 38½ SE¼ sec. 19, T. 15 S., R. 2 W., Saline County; drilled by the State Geological Survey, 1945. Surface altitude, 1,288.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, yellow-gray; contains much fine to medium gravel at bottom.....	30	30
Sand, fine, to gravel, coarse; mostly granitic	8	38
Silt, clayey, blue-gray	2.5	40.5
Sand, fine, to gravel, coarse	13.5	54
PERMIAN—Leonardian		
Wellington formation		
Shale, light to dark-gray	4	58

15-2-20cdc. Sample log of test hole in the SW¼ SE¼ SW¼ sec. 20, T. 15 S., R. 2 E., Saline County: drilled by the State Geological Survey, 1943. Surface altitude, 1,263.3 feet.

	Thickness, feet	Depth, feet
Soil, dark gray-brown	2	2
QUATERNARY--Pleistocene		
Alluvium		
Silt, clayey, gray	8	10
Silt, sandy, yellow-gray and gray; contains some gravel	10	20
Silt, sandy and gravel	10	20
Sand and gravel, fine; contains little gravel, medium to coarse; composed partly of Cretaceous and Permian-derived material	13	43
Silt, sandy, buff and gray	3	46
Sand, fine to gravel, coarse; mostly granitic	6.5	52.5
PERMIAN--Leonardian		
Wellington formation		
Shale, light to dark-gray	2.5	55

15-3-10aaa. Sample log of test hole at the SE cor. sec. 10, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,256.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY		
Alluvium		
Silt, partly clayey, gray, yellow-brown, dark-brown, and tan	20	20
Silt, sandy, yellow-buff	5	25
Sand and gravel, fine to very coarse; composed of sandstone and shale fragments	5	30
PERMIAN--Leonardian		
Wellington formation		
Shale, gray-green and red-brown	10	40

15-3-10abb. Sample log of test hole at the NE cor. NE¼ sec. 10, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,209.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY		
Slope deposits		
Silt, clayey, light-gray to gray.....	3	3
Silt, clayey, dark-brown to red	5	8
PERMIAN—Leonardian		
Wellington formation		
Shale, yellow-green, blue-gray, and red-brown	22	30

16-3-11aaa. Sample log of test hole at the NW cor. sec. 11, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,248.6 feet.

	Thickness, feet	Depth, feet
Road fill and soil, gray-black.....	2	2
QUATERNARY		
Alluvium		
Silt, and clay; tan, brown, and grey	25.5	27.5
Sand, fine to coarse; contains some fine to medium gravel	2.5	30
Sand and gravel, fine to coarse	25.5	55.5
PERMIAN--Leonardian		
Wellington formation		
Shale, light to dark gray	4.5	60

15-3-11abb. Sample log of test hole at the NW cor. NE¼ sec. 11, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,250.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY		
Alluvium		
Silt, gray black	5	5
Silt, clayey, light-gray to gray, brown, and buff	23	28
Sand and gravel, fine to medium	2	28
PERMIAN—Leonardian		
Wellington formation		
Shale, light-gray to gray	9	37

15-3-12abc. Sample log of test hole at the NE¼ SE¼ NE¼ sec. 12, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,247.7 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY		
Alluvium		
Silt, clayey, brown and brown-gray	13	15
Sand, fine to medium, silty; contains many shells	14	29
Silt, gray	3	32
Sand and gravel, fine to coarse; contains some silty dark blue-gray clay	18	50
Gravel, fine to coarse, brown; contains many sandstone and ironstone fragments	10	60
Gravel, medium to very coarse; composed mostly of Cretaceous-derived material; contains some fine gravel, sand and silt	11.5	71.5
PERMIAN—Leonardian		
Wellington formation		
Shale, blue-gray, gray-green, and brown	18.5	90

15-3-12 abb. Sample log of test hole at the NW cor. NW¼ sec. 12, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,247.1 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY		
Alluvium		
Silt, clayey, gray	8	10
Sand, fine to coarse, soft gray silt, a little fine gravel	7	17
Silt, soft, gray	5	22
Sand and gravel, fine	2	24
Silt, gray	6	30
Sand, fine to coarse	7.5	37.5
Silt, sandy, dark blue-gray	14.5	52
Gravel, fine to very coarse; composed largely of sandstone, shale and ironstone fragments; contains a little sand	6	58
PERMIAN—Leonardian		
Wellington formation		
Shale, silty, blue gray	12	70

15-3-16bbb. Sample log of test hole at the NW cor. sec. 16, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,287.2 feet.

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY		
Slope deposits		
Silt, gray, brown, and yellow tan; contains few limonite nodules	13.5	15
Silt, yellow-gray; contains some sand and a little gravel	12	27
Gravel, fine to coarse; derived from sandstone and shale	4	31
PERMIAN--Leonardian		
Wellington formation		
Shale, red-brown and gray-green	4	35

15-3-16bbc. Sample log of test hole at the SE¼ NW¼ NW¼ sec. 16, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,277.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY		
Alluvium		
Silt, clayey, dark-gray; contains some fine to coarse gravel and sand	5	5
Silt, clayey, blue-gray, green-gray, and yellow-brown	7	12
Silt, sandy, limonitic, yellow-brown	3	15
Sand, fine to medium, and yellow-buff silt	5	20
Silt, sandy, yellow-buff	5.5	25.5
Sand, fine, to very coarse gravel	9.5	35
Silt, sandy-buff	4	39
Silt, sandy, and gravel, fine to medium; grades downward to sandy blue-gray silt, interbedded with sand and fine to medium gravel	14	53
PERMIAN--Leonardian		
Wellington formation		
Shale, blue-green and red-brown	7	60

15-3-16ccc. Sample log of test hole at the SE cor. sec. 16, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,269.1 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY		
Alluvium		
Silt and clay; tan, gray-brown, and yellow-buff; contains some fine sand in lower part	16	17
Sand, fine, to very coarse gravel; derived from Cretaceous and Permian rocks; contains yellow and light-gray silt.	14	31
PERMIAN--Leonardian		
Wellington formation		
Shale, red-brown and gray-green	9	40

15-3-22ccc. Sample log of test hole at the SW cor. sec. 22, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,264.2 feet.

	Thickness, feet	Depth, feet
Soil, dark gray-brown	2	2
QUATERNARY--Pleistocene		
Alluvium		
Silt and clay; green-gray, yellow-brown, and gray-brown	8	10
Silt, light yellow-tan	6	16
Gravel, coarse; composed of shale, sandstone and and caliche pebbles; contains much silt, yellow-tan	1	17
PERMIAN--Leonardian		
Wellington formation		
Shale, blocky, gray-green	3	20

15-3-23ccc. Sample log of test hole at the SW cor. sec. 23, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,366.6 feet.

	Thickness, feet	Depth, feet
Soil, gray-brown	1.5	1.5
QUATERNARY--Pleistocene		
Alluvium		
Silt and clay, tan and light-gray	18.5	20
Clay, silty, tan; contains little gravel, fine to medium, and caliche nodules	10	30
Silt, greenish tan; contains sand and gravel and fragments of snails	10	40
Sand, fine, to gravel, medium; composed of Permian and Cretaceous fragments	2	42
PERMIAN--Leonardian		
Wellington formation		
Shale, light green, gray, and blue-gray	14	56
Shale, light to dark-gray and thin beds of limestone, hard	4	60

15-3-23ddd. Sample log of test hole at the SE cor. sec. 23, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,277.7 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
TERTIARY and/or QUATERNARY—Pleistocene		
Slope and terrace deposits		
Silt, clayey, tan-brown and yellow-gray; contains fine sand in lower part	4	5
Gravel, fine to coarse silty, sandy composed of Permian- and Cretaceous-derived material; hard lime-cemented beds occur between 8 and 10 feet and 14 and 15 feet	10	15
Clay, silty, sandy, yellow-gray; contains little gravel, fine to coarse	11	26
Gravel, fine to coarse; composed of Permian- and Cretaceous-derived material; contains some sand and silt	4	30
Clay, light-gray to blue-gray	10	40
PERMIAN—Leonardian		
Wellington formation		
Shale, blue-green and red-brown	5	45

15-3-24cad. Sample log of test hole in the SE¼ SW¼ SW¼ sec. 24, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,256.5 feet.

	Thickness, feet	Depth, feet
Road fill	4	4
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, buff; contains caliche	6	10
Silt and clay, gray, gray-buff, and blue-gray	20	30
Silt and clay, sandy, blue-gray	7	37
Sand, fine, to gravel, coarse	20	57
PERMIAN—Leonardian		
Wellington formation		
Shale, hard, light to dark-gray	3	60

15-3-24dcc. Sample log of test hole at the SW cor. SE¼ sec. 24, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,257.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt and clay; gray, blue-green, and green-gray; contains few snails near base.....	40	40
Sand, fine, to gravel, coarse; contains little clay in upper part	22	62
PERMIAN—Leonardian		
Wellington formation		
Shale, light to dark blue-gray; contains much gypsum between 66 and 70 feet	8	70

15-3-26aaa. Sample log of test hole at the NE cor. sec. 26, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,283.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt, clayey, brown-gray to gray buff.....	10	10
Silt, sandy, gray-buff; contains caliche	16	26
Silt and clay; light green-gray mottled yellow-brown	5	31
Sand, fine, to gravel, coarse; contains little silt in upper part	26	57
Gravel, fine to very coarse; composed of limestone, sandstone, and shale fragments; contains some sand and silt	5	62
PERMIAN--Leonardian		
Wellington formation		
Shale, light to dark blue-gray	3	65

15-3-28bbb. Sample log of test hole at the NW cor. sec. 28, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,287.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt and clay; light to dark-gray and blue-gray...	17	17
Silt, tan; contains little medium to coarse gravel between 18 and 20 feet	13	30
Silt, dark-buff; contains some sand and gravel, fine to coarse	8	38
Clay, silty, blue-gray, interbedded with some sand, fine to coarse, and gravel, fine to medium	16	54
PERMIAN--Leonardian		
Wellington formation		
Shale, light to dark blue-gray	2	56

15-3-30aaa. Sample log of test hole at the NE cor. sec. 30, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,273.6 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY--Pleistocene		
Alluvium		
Silt, light-gray, and yellow-brown	13	15
Silt, sandy, yellow-buff	18.5	33.5
Sand and gravel, medium to coarse; composed of sandstone, ironstone, and "mortar bed" pebbles	5.5	39
Silt, buff	5	44
Sand and gravel, fine to coarse; composed of sandstone, ironstone, and "mortar bed" pebbles	3	47
PERMIAN--Leonardian		
Wellington formation		
Shale, red and gray-green	3	50

15-3-32aac. Sample log of test hole at the SE cor. sec. 32, T. 15 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,277.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt, clayey, light to dark-gray, tan, and brown; contains caliche.....	25	25
Sand, fine, to gravel, coarse; brown; composed of Cretaceous and Permian derived material	3	28
PERMIAN--Leonardian		
Wellington formation		
Shale, green and red-brown	2	30

15-4-4Saa. Sample log of test hole at the NE cor. sec. 25, T. 15 S., R. 4 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,290.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt, clayey, tan and light to dark-gray.....	20	20
Silt and clay; sandy; tan-gray; contains some caliche	14.5	34.5
Sand, fine, to gravel, very coarse; [illegible]	3	37.5
Silt, sandy, buff and gray	9.5	47
Sand, fine, to gravel, very coarse; brown; composed of shale and sandstone fragments	3	50
PERMIAN--Leonardian		
Wellington formation		
Shale, red-brown	3	53

15-4-25bab. Sample log of test hole in the NE¼ NE¼ NW¼ sec. 25, T. 15 S., R. 4 W., Saline County; drilled by the State Geological Survey, 1945. Surface altitude, 1,282.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, clayey, gray and gray-black.....	6	6
Silt, clayey, yellow and yellow-tan; contains sand, few caliche nodules, and some gravel medium to coarse	19	25
Gravel, fine to coarse, silty	2.5	27.5
Silty, clayey, sandy, yellow-gray and gray	10.5	38
Sand and gravel, fine to coarse; contains few soft limonite concretions	5	43
Silt, yellow-buff and gray	7	50
Silt and sand, medium; yellow-buff; contains little gravel, medium to coarse	3.5	53.5
PERMIAN—Leonardian		
Wellington formation		
Shale, gray-green and purple	2.5	56

14-2-18cde. Sample log of test hole in the SW¼ SE¼ SW¼ sec. 18, T. 16 S., R. 2 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,279.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt, sandy, gray-brown to yellow-gray	10	10
Silt, sandy, gray; contains sand and gravel in lower part	10	20
Sand, fine, to gravel, medium; silty; contains a few pebbles	16	36
Clay, sandy, blue-gray; contains a few pebbles	4	40
Sand, fine, to gravel, coarse	49.5	89.5
PERMIAN--Leonardian		
Wellington formation (?)		
Shale, light to dark-gray	4.5	94

16-2-19aad. Sample log of test hole in the SE¼ NE¼ NE¼ sec. 19, T. 16 S., R. 2 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,287.9 feet.

	Thickness, feet	Depth, feet
Soil, gray brown	2	2
QUATERNARY--Pleistocene		
Alluvium		
Silt and clay; light to dark-gray and light brown	36	38
Sand, fine, to gravel, coarse	18	56
PERMIAN--Leonardian		
Wellington formation (?)		
Shale, hard, light and dark blue-gray	4	60

16-2-15abb. Sample log of test hole at the NW cor. NE¼ sec. 19, T. 16 S., R. 2 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,270.9 feet.

	Thickness, feet	Depth, feet
Soil, gray black	3	3
QUATERNARY--Pleistocene		
Alluvium		
Silt and clay; yellow-gray	13	16
Sand and gravel, fine	2	18
Silt, sandy, light-brown	4	22
Sand, fine to coarse, grading downward to gravel, fine to coarse	8	30
Sand, fine to gravel, coarse; silty; contains few lenses of clay	58	88
PERMIAN--Leonardian		
Wellington formation (?)		
Shale, light to dark blue-gray	4	92

16-3-13ada. Sample log of test hole in the SW¼ SW¼ SW¼ sec. 13, T. 16 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,282.0 feet.

	Thickness, feet	Depth feet
QUATERNARY—Pleistocene		
Alluvium		
Silt and clay; tan to gray.....	5	5
Clay, silty, sandy, light to dark-gray	5	10
Silt, clayey, gray	10	20
Silt, sandy, gray and blue-gray; contains few small shells	14	34
Sand and gravel, fine to coarse; light-gray	13	47
Silt, sandy, grey and blue-gray	5	52
Sand and gravel, fine to coarse; light-gray	21.5	73.5
PERMIAN—Leonardian		
Wellington formation (?)		
Shale, dark blue-gray	4.5	78

16-3-13ddd. Sample log of test hole in the SE¼ SE¼ SE¼ sec. 13, T. 16 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,282.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt and clay; gray, gray-brown and blue-gray	35	35
Sand, fine to gravel, coarse; silty	24	59
Silt, sandy, gray	3	62
Gravel, fine to coarse; contains little sand; gravel; contains many Permian and Cretaceous fragments	6	68
PERMIAN—Leonardian		
Wellington formation (?)		
Shale, dark-gray	2	70

16-S-23aa. Sample log of test hole in the NE¼ NE¼ sec. 23, T. 16 S., R. 3 W., Saline County, drilled by the State Geological Survey, 1943. Surface altitude, 1,271.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt, sandy, gray	1.5	1.5
Silt, clayey, gray-black	5.5	7
Silt, sandy, gray	9.5	16.5
PERMIAN--Leonardian		
Nimmescah formation		
Shale, gray, yellow-brown, blue-gray, and red-brown	3.5	20

16-3-23aba. Sample log of test hole in the NE¼ NE¼ NE¼ sec. 23, T. 16 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,267.7 feet.

	Thickness, feet	Depth, feet
TERTIARY and/or QUATERNARY		
Slope and terrace deposits		
Silt, sandy, gray and red-brown	11	11
Clay, silty, sandy, yellow-tan	4.5	15.5
Gravel, fine to coarse, silty; composed of		
Permian- and Cretaceous-derived material	5.5	21
PERMIAN--Leonardian		
Minnescah formation		
Shale, red-brown and gray-green	3	24

16-3-23baa. Sample log of test hole in the NE¼ NE¼ NW¼ sec. 23, T. 16 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1943. Surface altitude, 1,320.2 feet.

	Thickness, feet	Depth, feet
TERTIARY and/or QUATERNARY		
Slope and terrace deposits		
Clay, silty, red-brown, gray, and yellow-buff; contains ironstone pebbles in upper part....	7	7
Silt, clayey, yellow-buff	6	13
Gravel, fine to coarse, silty, brown; composed of angular sandstone and ironstone fragments; contains some sand, fine	6	19
Silt, sand, and gravel, fine to coarse	7	26
PERMIAN--Leonardian		
Minnesota formation		
Shale, gray, blue-gray, green-gray, and red-brown	14	40

16-3-24bbb. Sample log of test hole in the NW¼ NW¼ NW¼ sec. 24, T. 16 S., R. 3 W., Saline County; drilled by the State Geological Survey, 1945. Surface altitude, 1,268.9 feet.

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
TERTIARY and/or QUATERNARY		
Slope and terrace deposits		
Sand, fine to medium, yellow gray	2.5	4
Silt, sandy, gray; contains little gravel, fine to medium	6	10
Sand, fine, to gravel, coarse; silty; gravel composed of Permian- and Cretaceous-derived materials	6	16
PERMIAN--Leonardian		
Kinnescah formation		
Shale, red and green gray	4	20

17-4-22dcm. Sample log of test hole at NE cor. SE¼ SE¼ sec. 22, T. 17 S., R. 4 W., McPherson County; drilled by State Geological Survey, 1943. Surface altitude, 1,365.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt and clay, brown	6	6
Silt and clay, light-gray to buff	28	34
Clay, soft, gray-green; contains limestone and shale fragments	4	38
PERMIAN--Leonardian		
Nimmescah formation		
Shale, purple, red, and gray-green	2	40

		feet
...t clay, brown.....	4	4
Silt and clay, dark-gray to tan	30	34
Silt, soft, sandy, gray-green	9	43
Silt and clay, gray	11	54
Sand, coarse to fine, and gravel, fine	6	60
Gravel, coarse to fine, and sand	10	70
Gravel, medium to fine	9	79
PERMIAN--Leonardian		
Wellington formation		
Shale, hard laminated, blue-gray	1	80

17-4-27ada. Sample log of test hole in NE cor. SE¼ NE¼ sec. 27, T. 17 S., R. 4 W., McPherson County; drilled by State Geological Survey, 1943. Surface altitude, 1,356.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt, light-brown, and sand, fine to medium.....	5	5
Silt and clay, buff to tan	29	34
Silt and clay, blue-gray	6	40
Sand, medium to fine, containing silt, dark-gray	10	50
Gravel, medium to fine, and sand, coarse to medium	10	60
Gravel, medium to fine, and sand, coarse	12	72
PERMIAN--Leonardian		
Wellington formation		
Shale, hard brittle, gray	2	74

17-4-27ddn. Sample log of test hole in NE cor. SE¼ SE¼ sec. 27, T. 17 S., R. 4 W., McPherson County; drilled by State Geological Survey, 1943. Surface altitude, 1,358.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil	3	3
Silt, soft, gray, and sand, medium to fine	3	6
Silt and clay, light gray to tan	14	20
Silt, soft, buff, and sand, fine to coarse	7	27
Sand, coarse to fine, and gravel, fine	13	40
Silt, soft, blue-gray	6	46
Gravel, fine, and sand, coarse	4	50
Gravel, coarse to fine	13	63
PERMIAN—Leonardian		
Wellington formation		
Shale, gray	7	70

17-4-34ada. Sample log of test hole in NE cor. SE¼ NE¼ sec. 34, T. 17 S., R. 4 W., McPherson County; drilled by State Geological Survey, 1943. Surface altitude, 1,355.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Silt and clay, brown	13	13
Silt, soft, buff, and sand, fine to medium	12	25
Sand, coarse to fine, and gravel, fine	15	40
Gravel, coarse to fine, and sand, coarse	10	50
Silt, soft, blue-gray, containing sand, fine to medium	10	60
Gravel, medium to fine, and sand, coarse	12	72
PERMIAN--Leonardian		
Wellington formation		
Shale, gray and maroon	6	78

17-4-34dad. Sample log of test hole in SE cor. NE¼ SE¼ sec. 34, T. 17 S., R. 4 W., McPherson County; drilled by State Geological Survey, 1943. Surface altitude, 1,350.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, dark-gray to brown	7	7
Silt, soft, brown, containing sand, fine to medium	11	18
Sand, coarse to fine, and gravel, fine to medium	12	30
Gravel, medium to fine, and sand, coarse	5	35
Silt and clay, blue-gray-	5	40
Gravel, fine to medium, and sand, coarse	4	44
PERMIAN—Leonardian		
Wellington formation		
Shale, gray and maroon	2	46

17-5-10ccc. Sample log of test hole in the SW¼ SW¼ sec. 10, T. 17 S., R. 5 W., McPherson County; drilled by the State Geological Survey, 1950. Surface altitude, 1,384.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, silty, dark-gray	3	3
Clay, silty, buff	5	8
Clay, buff to gray, contains some gravel	2	10
Sand, medium to coarse	9	19
Sand, medium to very coarse	4	23
Gravel, fine to medium, sandy	5	28
PERMIAN—Leonardian		
Hennessah formation		
Shale, red-brown	2	30

17-5-10cdd. Sample log of test hole in the SE¼ SW¼ sec. 10, T. 17 S., R. 5 W. McPherson County; drilled by the State Geological Survey, 1950. Surface altitude, 1,395.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, slightly silty, gray	4	4
Clay, silty, buff	9	13
Sand, medium to very coarse	7	20
Sand, coarse, small amount of gravel, fine	8	28
PERMIAN—Leonardian		
Minnecoah formation		
Shale, red-brown	1.5	29.5
Shale, gray-green	.5	30

17-5-10ddd. Sample log of test hole in the SE¼ SE¼ sec. 10, T. 17 S., R. 5 W., McPherson County; drilled by the State Geological Survey, 1950. Surface altitude, 1,391.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, dark gray	4	4
Clay, silty, light-gray	2	6
Clay, silty, buff	7	13
Sand, very fine to fine	5	18
Sand, coarse to very coarse, and gravel, fine	12	30
Sand, very coarse, and gravel, fine to medium	6	36
PERMIAN—Leonardian		
Ninnescah formation		
Shale, gray-green	2	38
Shale, red-brown	2	40

17-6-14bab. Sample log of test hole in the NW¼ NW¼ NE¼ sec. 14, T. 17 S., R. 6 E., McPherson County; drilled by the State Geological Survey, 1950. Surface altitude, 1,392.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, slightly silty, dark gray	8	8
Clay, silty, buff	11	16
Sand, fine to medium	3	19
Sand, coarse, some gravel, fine	7	26
Sand, gray, medium to very coarse, some gravel, fine	14	40
Sand, gray, fine to medium	3	43
PERMIAN—Leonardian		
Hennessey formation		
Shale, red-brown	3	46

17-6-16aab. Sample log of test hole in the NW¼ NW¼ NE¼ sec. 16, T. 17 S., R. 5 W., McPherson County; drilled by the State Geological Survey, 1950. Surface altitude, 1,398.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
Alluvium		
Clay, silty, dark-gray	8	8
Clay, silty and slightly sandy, buff, some gravel, fine	15.5	23.5
Sand, fine to coarse	1.0	24.5
Gravel, fine to medium, sandy, fine	1.0	25.5
PERMIAN--Leonardian		
Ninnescah formation		
Shale, red-brown and gray-green, mottled	1.0	26.5

18-3-8bbb. Sample log of test hole in NW cor. sec. 8, T. 18 S., R. 3 W., McPherson County, drilled by State Geological Survey, 1943. Surface altitude, 1,359.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
McPherson formation		
Clay and silt, brown to tan	17	17
Silt, buff, containing some sand and gravel	5	22
Silt and clay, gray, and gravel, coarse to medium	6	28
PERMIAN—Leonardian		
Wellington formation		
Shale, gray	2	30

18-3-8bca. Sample log of test hole at NE cor. NW¼ sec. 8, T. 18 S., R. 3 W., McPherson County; drilled by State Geological Survey, 1943. Surface altitude, 1,343.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
McPherson formation		
Silt and clay, brown to gray	6	6
Silt, buff, containing nodules of calcium carbonate	21	27
Clay, gray-green	5	32
Gravel, medium to fine, and sand, coarse	11	43
PERMIAN--Leonardian		
Wellington formation		
Shale, blue-gray and maroon	4	47

18-4-1aaa. Sample log of test hole in NE cor. sec. 1, T. 18 S., R. 4 W., McPherson County, drilled by State Geological Survey, 1943. Surface altitude, 1,333.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY--Pleistocene		
McPherson formation		
Silt and clay, brown	7	7
Silt and clay, gray to tan	2	9
Silt, tan, containing sand, fine to coarse	5	14
Silt, buff, containing nodules of calcium carbonate	6	20
Gravel, medium to fine, and sand, coarse to medium	9	29
PERMIAN--Leonardian		
Wellington formation		
Shale, gray	1	30

13-4-1abb. Sample log of test hole in NW cor. NW sec. 1, T. 18 S., R. 4 W., McPherson County; drilled by State Geological Survey, 1943. Surface altitude, 1,317.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
McPherson formation		
Silt, soft, tan, containing sand, fine.....	1	1
Silt and clay, dark gray	2	3
Silt, buff, and sand, fine to coarse	7	10
Silt, buff, and sand, fine	10	20
Silt and clay, gray, containing nodules of calcium carbonate	6	26
Gravel, fine, and sand, coarse to medium	4	30
Gravel, fine to coarse, and sand, coarse to medium	16	46
PERMIAN—Leonardian		
Wellington formation		
Shale, gray	4	50

REFERENCES

Bass, N. W., 1926, Structure and limits of the Kansas salt beds; Kansas Geol. Survey, Bull. 11, pt. 4, pp. 90-95, pls. 8-9.

Comly, H. H., 1945, Cyanosis in infants caused by nitrates in well water: Jour. Am. Med. Assn., vol. 129, pp. 112-116.

Fent, O. S., 1950, Pleistocene drainage history of central Kansas: Trans. Kansas Acad. of Science, vol. 53, no. 1, pp. 81-90, figs. 1-5.

Frye, J. C., Leonard, A. B., and Hibbard, C. W., 1943, Westward extension of the Kansas "Equus beds": Jour. Geol., vol. 51, pp. 33-47, fig. 1-3.

Johnstone, Don, and Cross, W. P., 1949, Elements of Applied Hydrology: Ronald Press Co., New York, pp. 1-275.

Landes, K. K., 1928, Volcanic ash resources of Kansas: Kansas Geol. Survey, Bull. 14, pp. 1-57, fig. 1-3, pls. 1-5.

Latta, Bruce, 1949, Ground-water conditions in the Smoky Hill Valley in Saline, Dickinson, and Geary Counties, Kansas: Kansas Geol. Survey, Bull. 84, pp. 1-152, fig. 1-13, pls. 1-6.

Lee, Wallace, Leatherock, Constance, and Botinelly, Theodore, 1948, Stratigraphy and structural development of the Salina basin of Kansas: Kansas Geol. Survey, Bull. 74, pp. 1-155, fig. 1-11, pls. 1-14.

Magistad, O. C., and Christiansen, J. E., 1944, Saline soils, their nature and management: U. S. Dept. Agri., Circ. 707, p. 9.

Meinzer, O. E., 1923, The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey, Water-Supply Paper 489, pp. 1-321, fig. 1-110, pls. 1-31.

Moore, R. C., 1940, Ground-water resources of Kansas: Kansas Geol. Survey, Bull. 27, pp. 1-112, figs. 1-28, pls. 1-34.

Moore, R. C., and six others, 1951, The Kansas rock column: Kansas Geol. Survey, Bull. 89, pp. 1-132, fig. 1-52.

Piper, A. M., 1933, Notes on the relation between the moisture equivalent and the specific retention of water-bearing materials: Am. Geophysical Union Trans., 14th Ann. Meeting, pp. 481-487, fig. 1-2.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophysical Union Trans., 16th Ann. Meeting, pt. 2, pp. 519-524, fig. 1-3.

U. S. Public Health Service, 1946, Drinking water standards: U. S. Public Health Rept., vol. 61, no. 11, pp. 371-384.

Ver Wiebe, W. A., 1937, The Wellington formation of central Kansas: Wichita Municipal Univ. Studies, Bull. 2, pp. 1-18, fig. 1-2.

Water Resources Division, 1951, Kansas-Missouri floods of July 1951: U. S. Geol. Survey, Circ. 151, pp. 1-69, fig. 1-8.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials: U. S. Geol. Survey, Water-Supply Paper 887, pp. 1-192, fig. 1-17, pls. 1-6.

Wilcox, L. V., 1948, Explanation and interpretation of analyses of irrigation waters: U. S. Dept. Agri., Circ. 784.

Williams, C. C., and Lohman, S. W., 1949, Geology and ground-water resources of a part of south-central Kansas: Kansas Geol. Survey, Bull. 79, pp. 1-455, figs. 1-31, pls. 1-34.

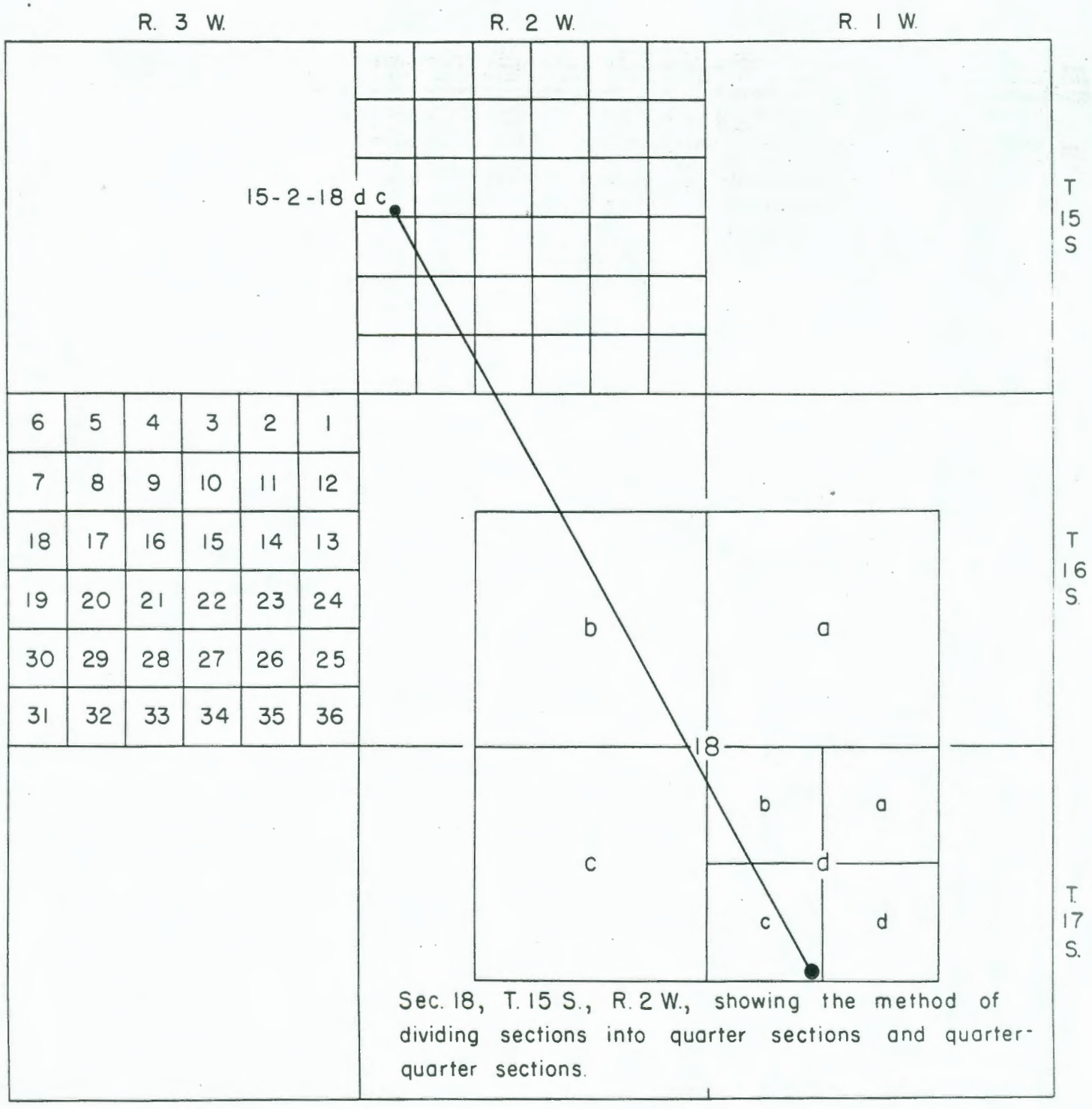

R. 3 W.
R. 2 W.
R. 1 W.
T 15 S
T 16 S
T 17 S.
15-2-18 d c
6 5 4 3 2 1
7 8 9 10 11 12
18 17 16 15 14 13
19 20 21 22 23 24
30 29 28 27 26 25
31 32 33 34 35 36
b
a
18
b
a
c
d
c
d
Sec. 18, T. 15 S., R. 2 W., showing the method of dividing sections into quarter sections and quarter-quarter sections.

Figure 2

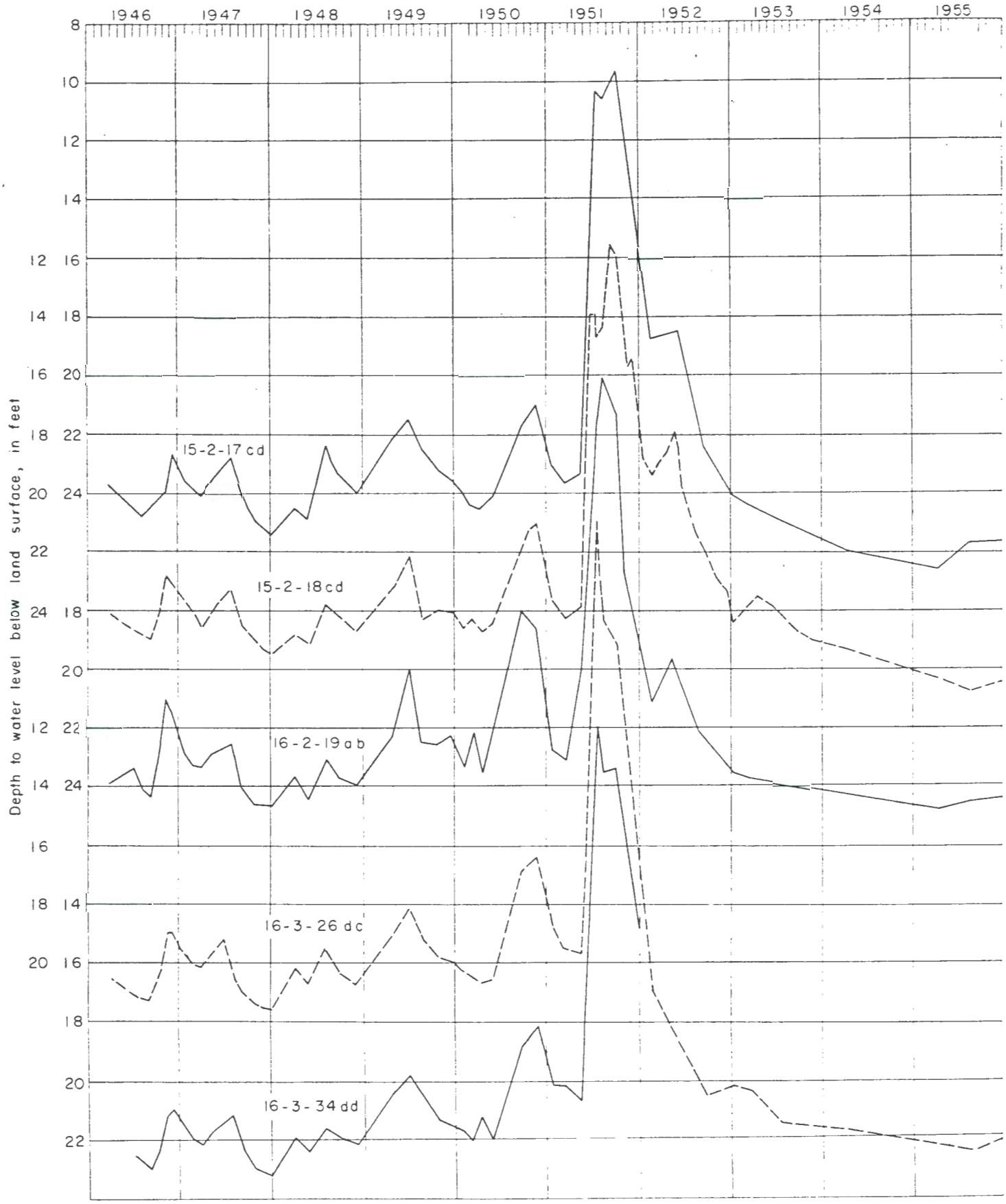

1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
Depth to water level below land surface, in feet
15-2-17 cd
15-2-18 cd
16-2-19 ab
16-3-26 dc
16-3-34 dd

Figure 3

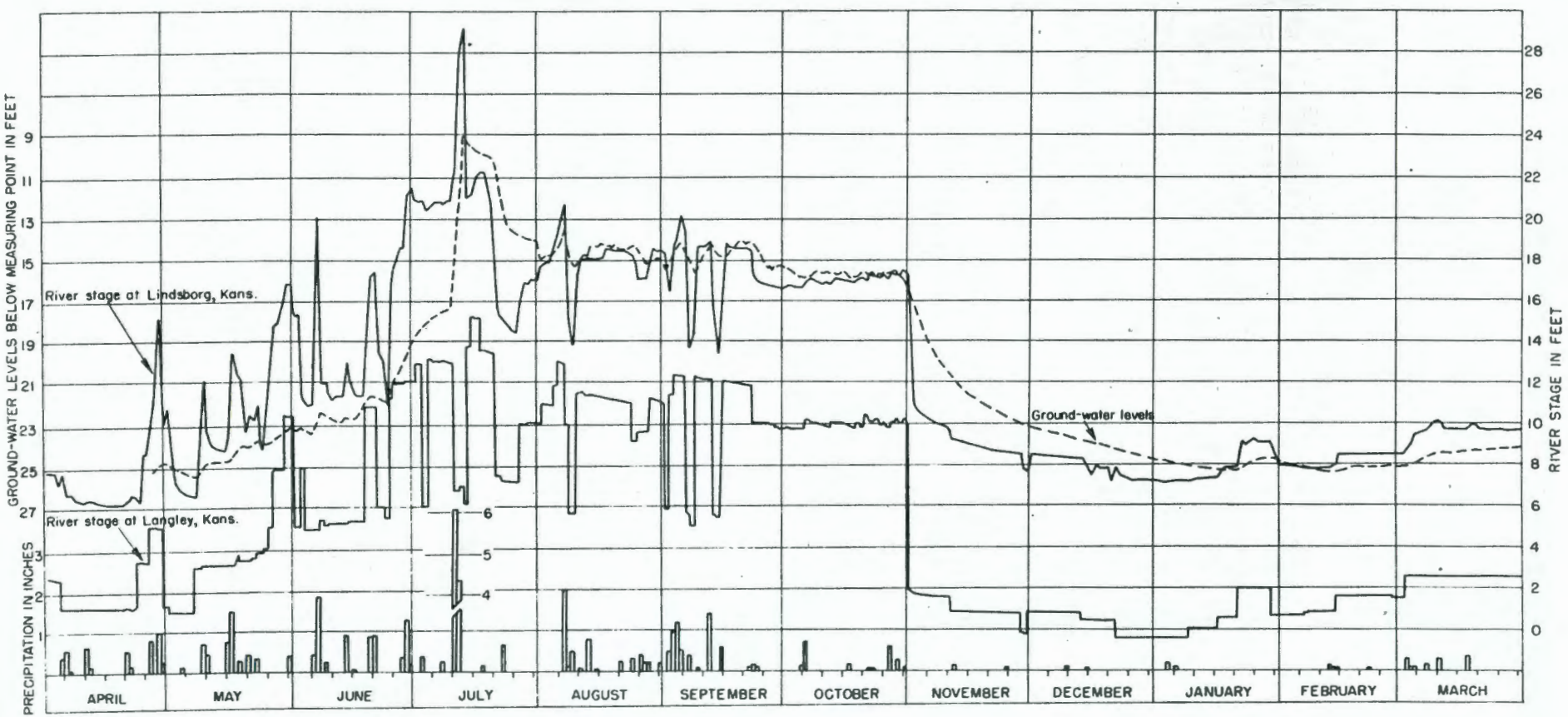

GROUND-WATER LEVELS BELOW MEASURING POINT IN FEET
RIVER STAGE IN FEET
PRECIPITATION IN INCHES
River stage at Lindsborg, Kans.
River stage at Langley, Kans.
Ground-water levels
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH

Figure 4

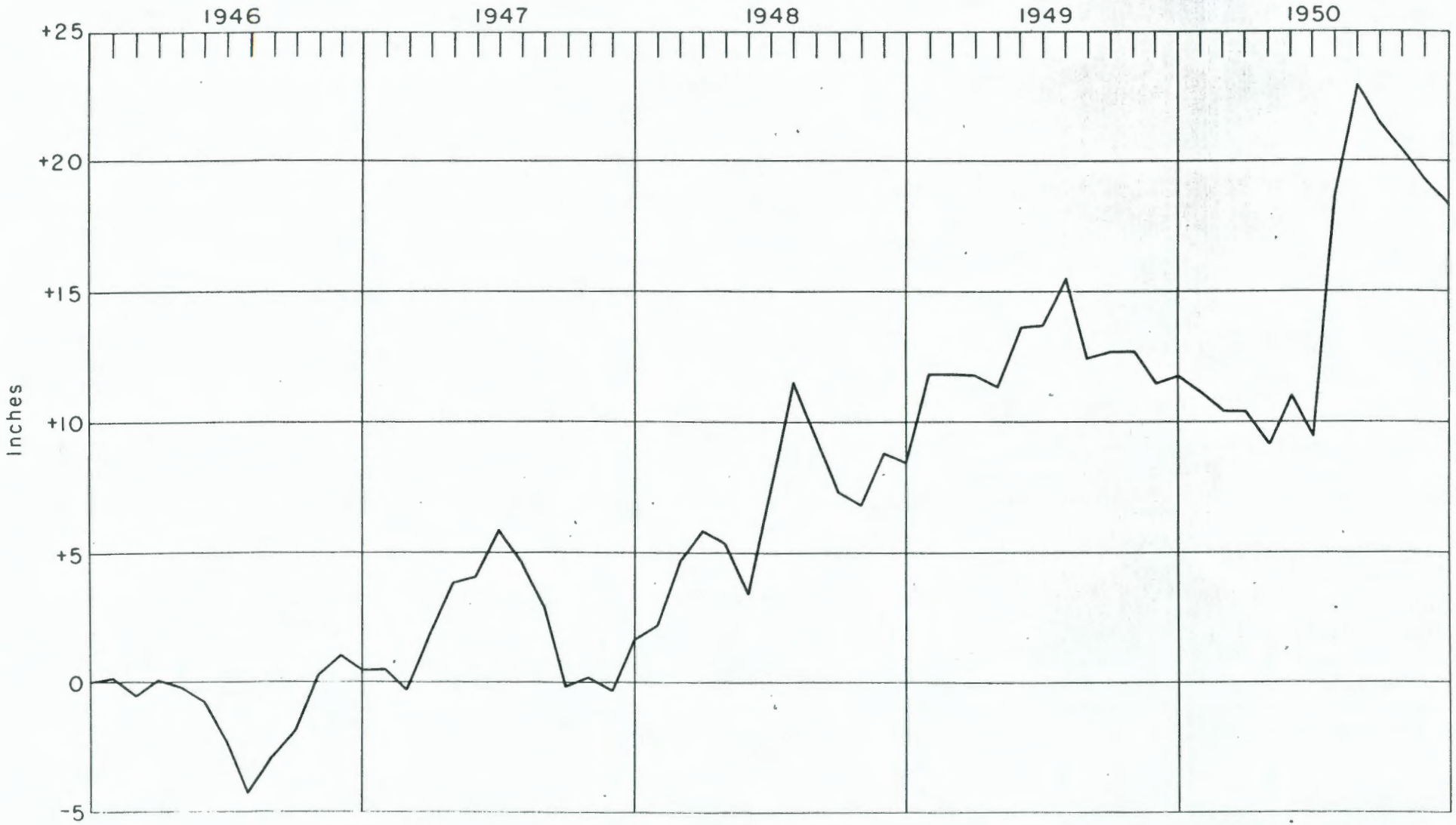


Figure 5

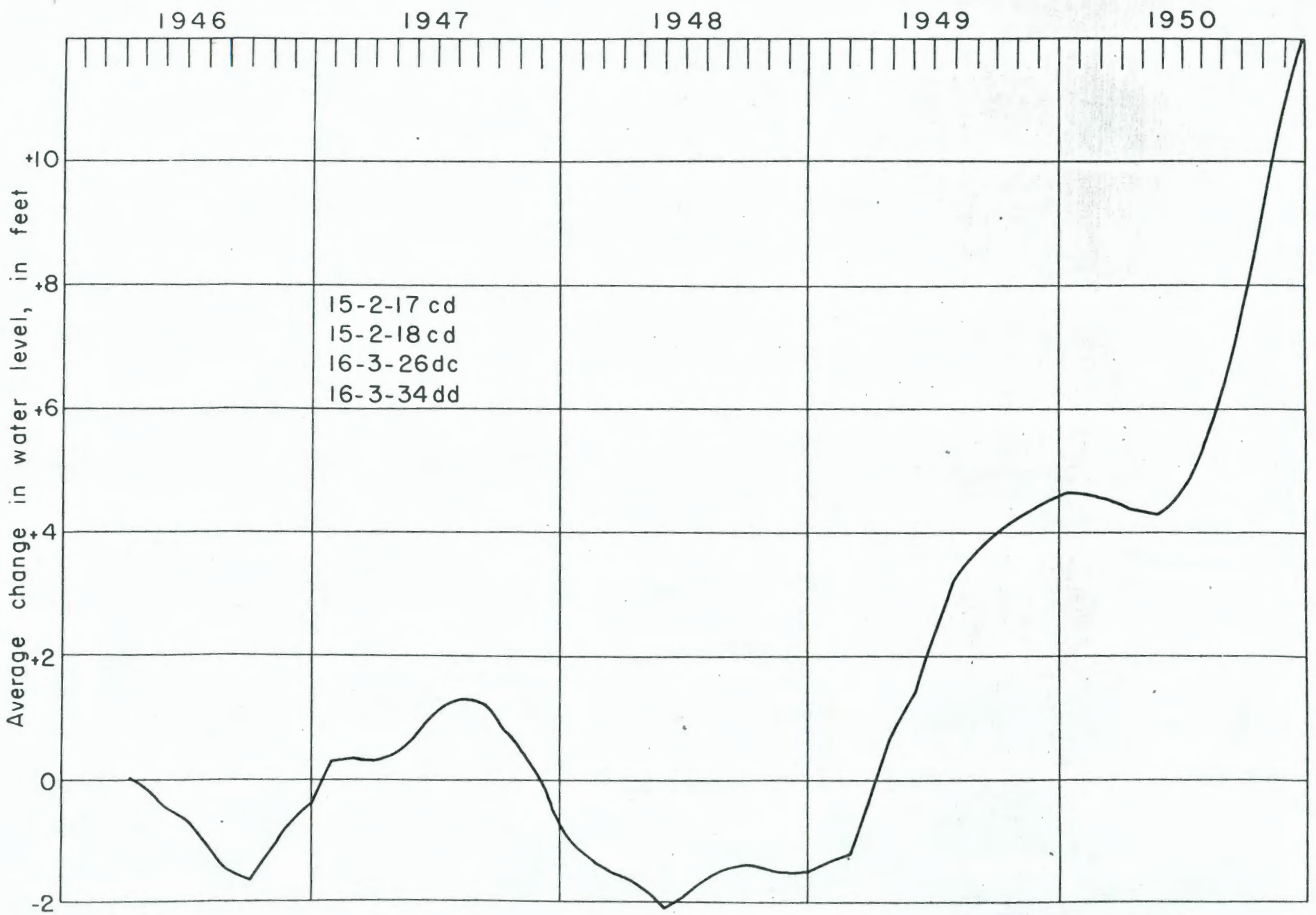

1946
1947
1948
1949
1950
+10
+8
+6
+4
+2
0
-2
Average change in water level, in feet
15-2-17 cd
15-2-18 cd
16-3-26 dc
16-3-34 dd

Figure 6

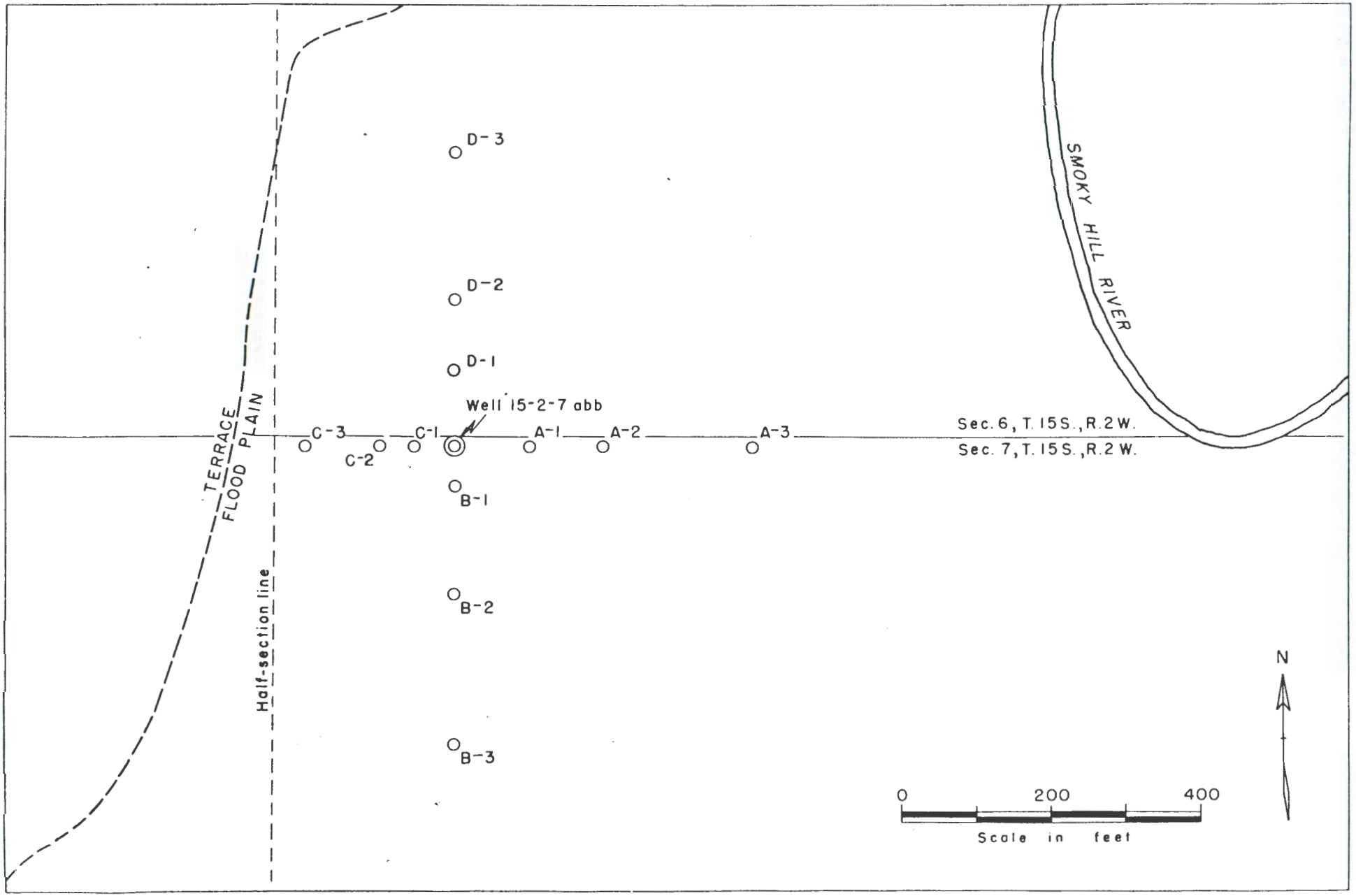

D-3
D-2
D-1
Well 15-2-7 abb
C-3
C-2
C-1
A-1
A-2
A-3
B-1
B-2
B-3
TERRACE
FLOOD PLAIN
Half-section line
SMOKY HILL RIVER
Sec. 6, T. 15S., R. 2W.
Sec. 7, T. 15S., R. 2W.
N
0
200
400
Scale in feet

Figure 7

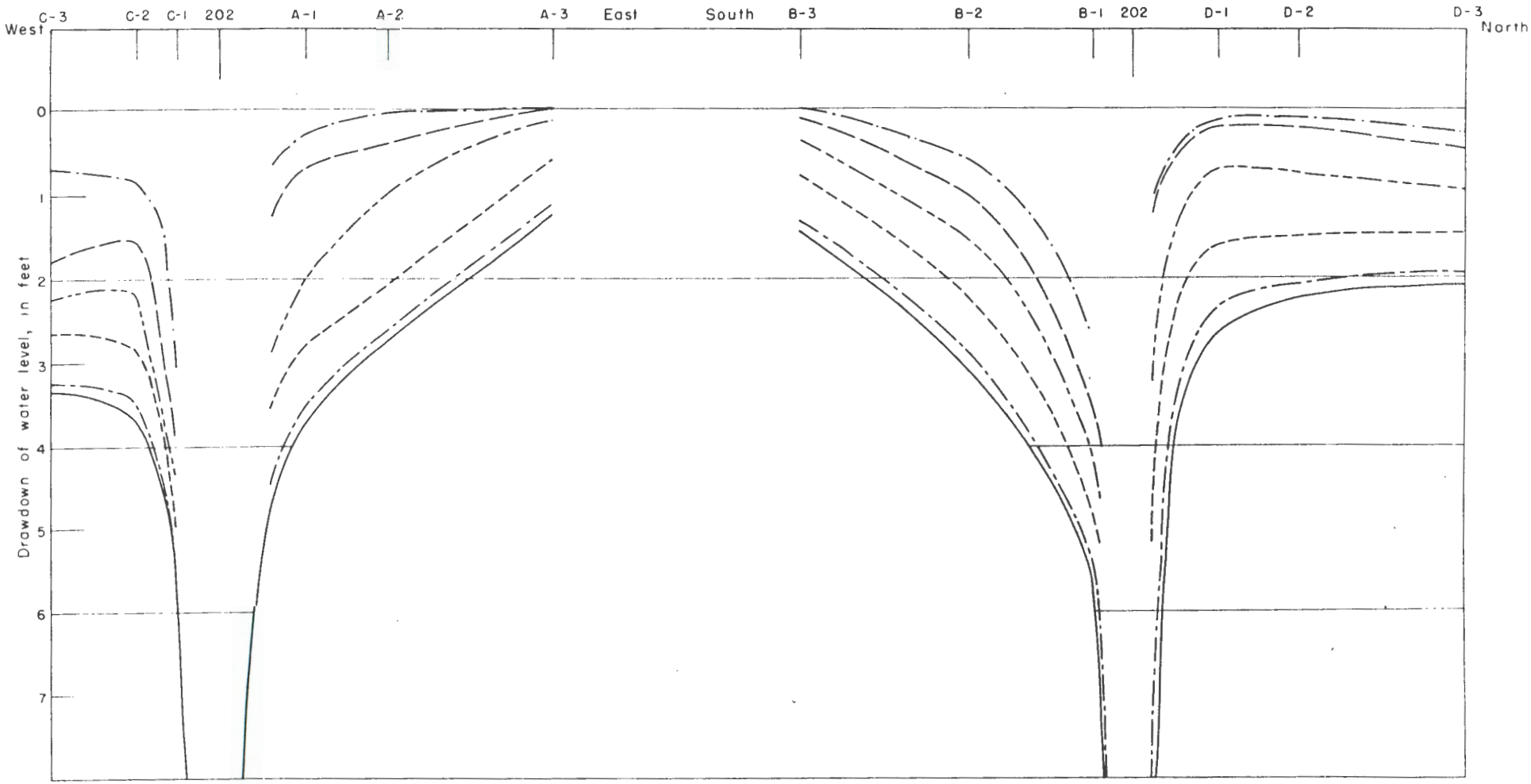

West
C-3
C-2
C-1
202
A-1
A-2
A-3
East
South
B-3
B-2
B-1
202
D-1
D-2
D-3
North
0
1
2
3
4
5
6
7
Drawdown of water level, in feet

Figure 8

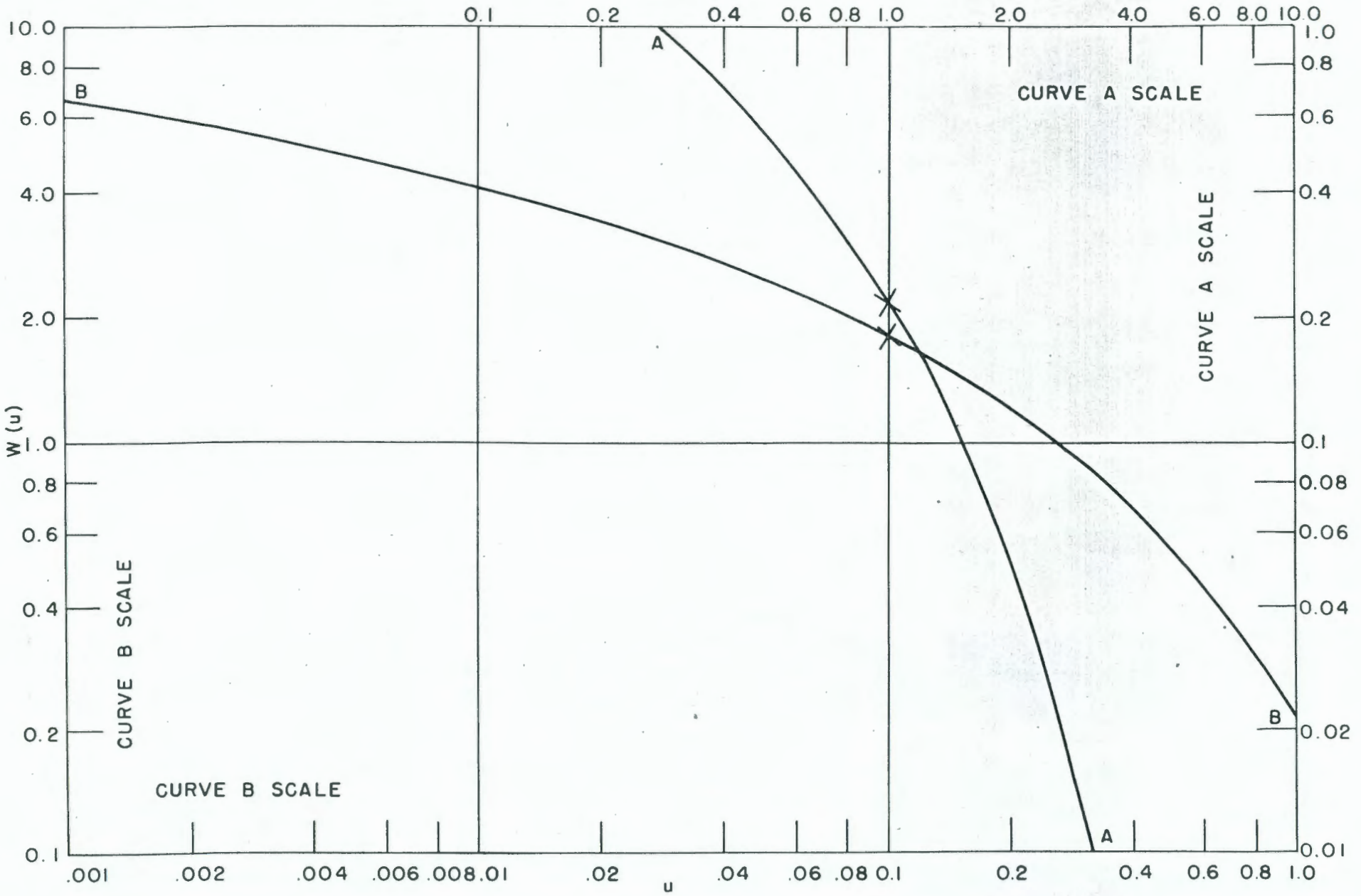

0.1
0.2
0.4
0.6
0.8
1.0
2.0
4.0
6.0
8.0
10.0
A
B
CURVE A SCALE
CURVE A SCALE
10.0
8.0
6.0
4.0
2.0
1.0
0.8
0.6
0.4
0.2
0.1
W(u)
1.0
0.8
0.6
0.4
0.2
0.1
0.08
0.06
0.04
0.02
0.01
B
CURVE B SCALE
CURVE B SCALE
A
.001
.002
.004
.006
.008
.01
.02
.04
.06
.08
0.1
0.2
0.4
0.6
0.8
1.0
u

Figure 9

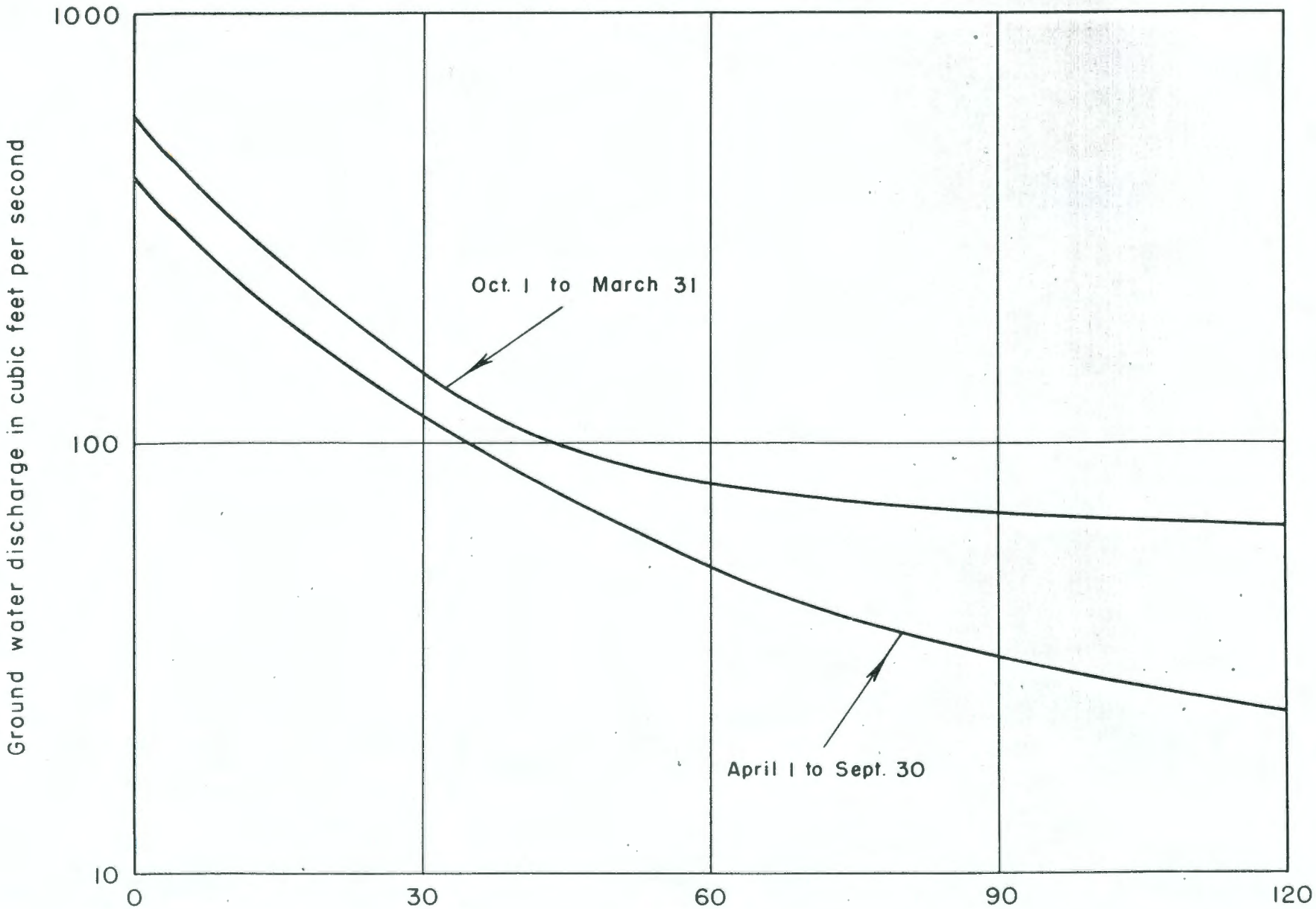

1000
100
10
0
30
60
90
120
Ground water discharge in cubic feet per second
Time, in days
Oct. 1 to March 31
April 1 to Sept. 30

Figure 10

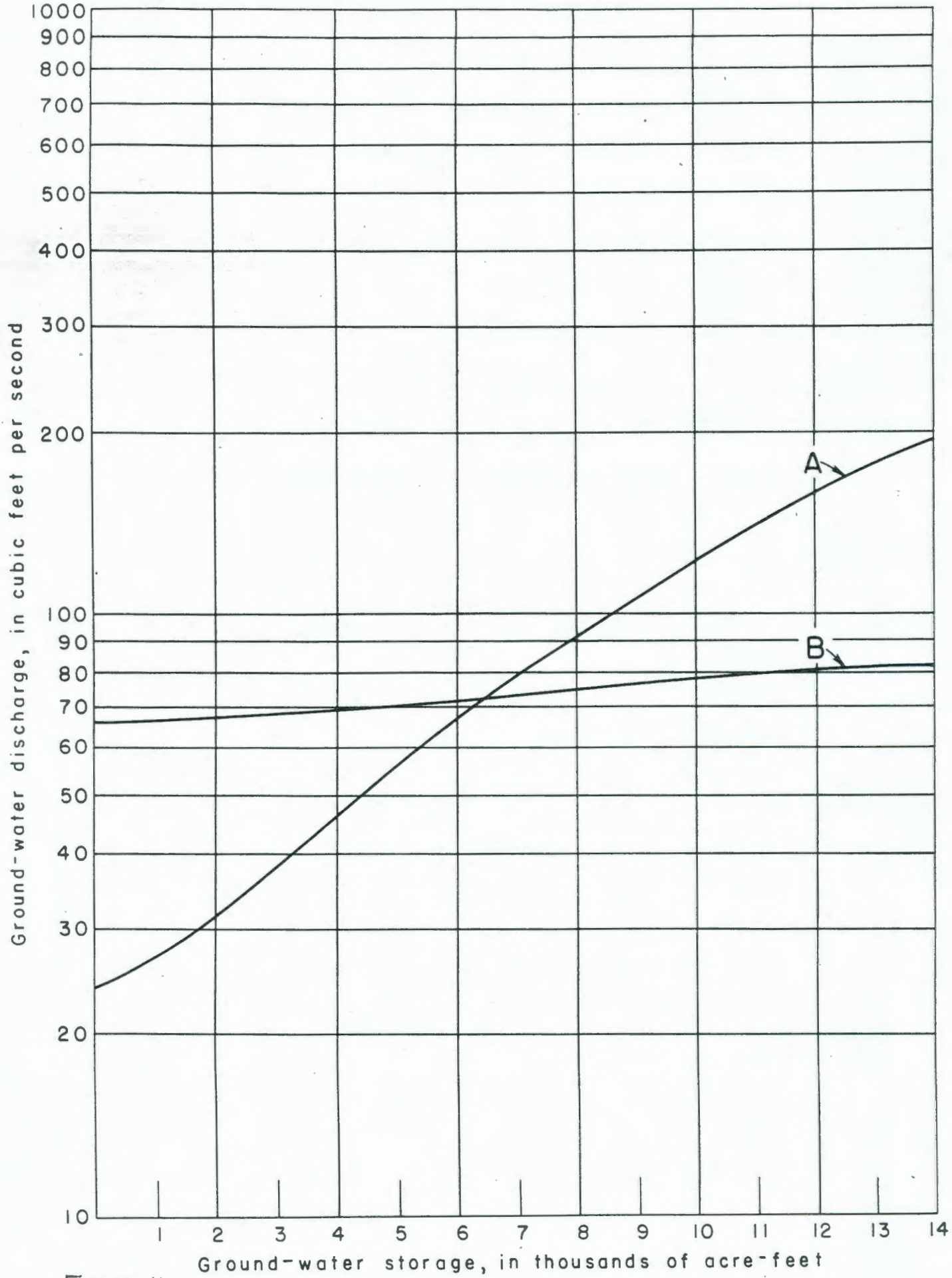

1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
Ground-water discharge, in cubic feet per second
A
B
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Ground-water storage, in thousands of acre-feet

Figure 11

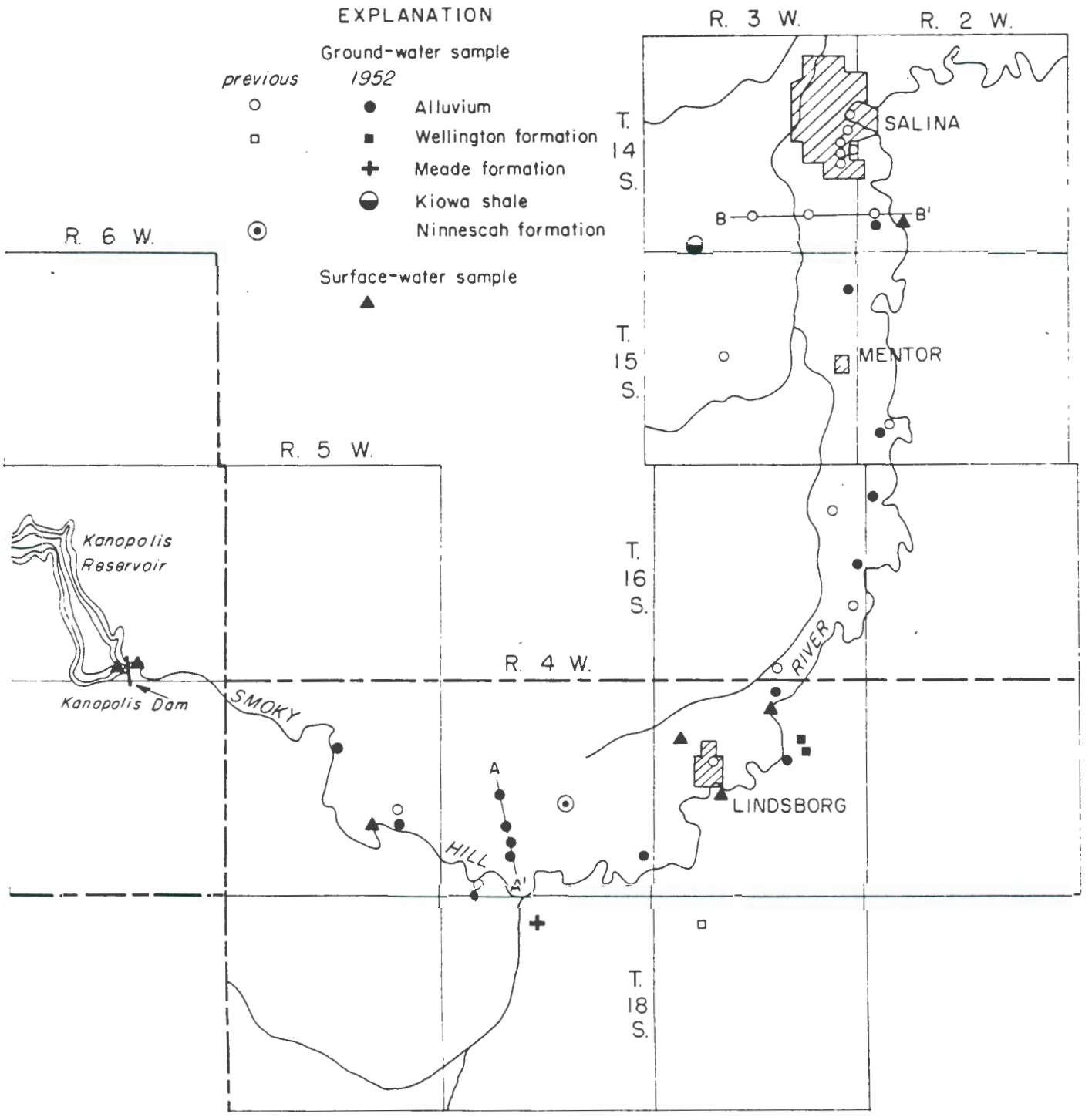

EXPLANATION
Ground-water sample
previous
1952
Alluvium
Wellington formation
Meade formation
Kiowa shale
Ninnescah formation
Surface-water sample
R. 6 W.
R. 5 W.
R. 4 W.
R. 3 W.
R. 2 W.
T. 14 S.
T. 15 S.
T. 16 S.
T. 18 S.
SALINA
MENTOR
LINDSBORG
Kanopolis Reservoir
Kanopolis Dam
SMOKY
HILL
RIVER
A
A'
B
B'

Figure 12

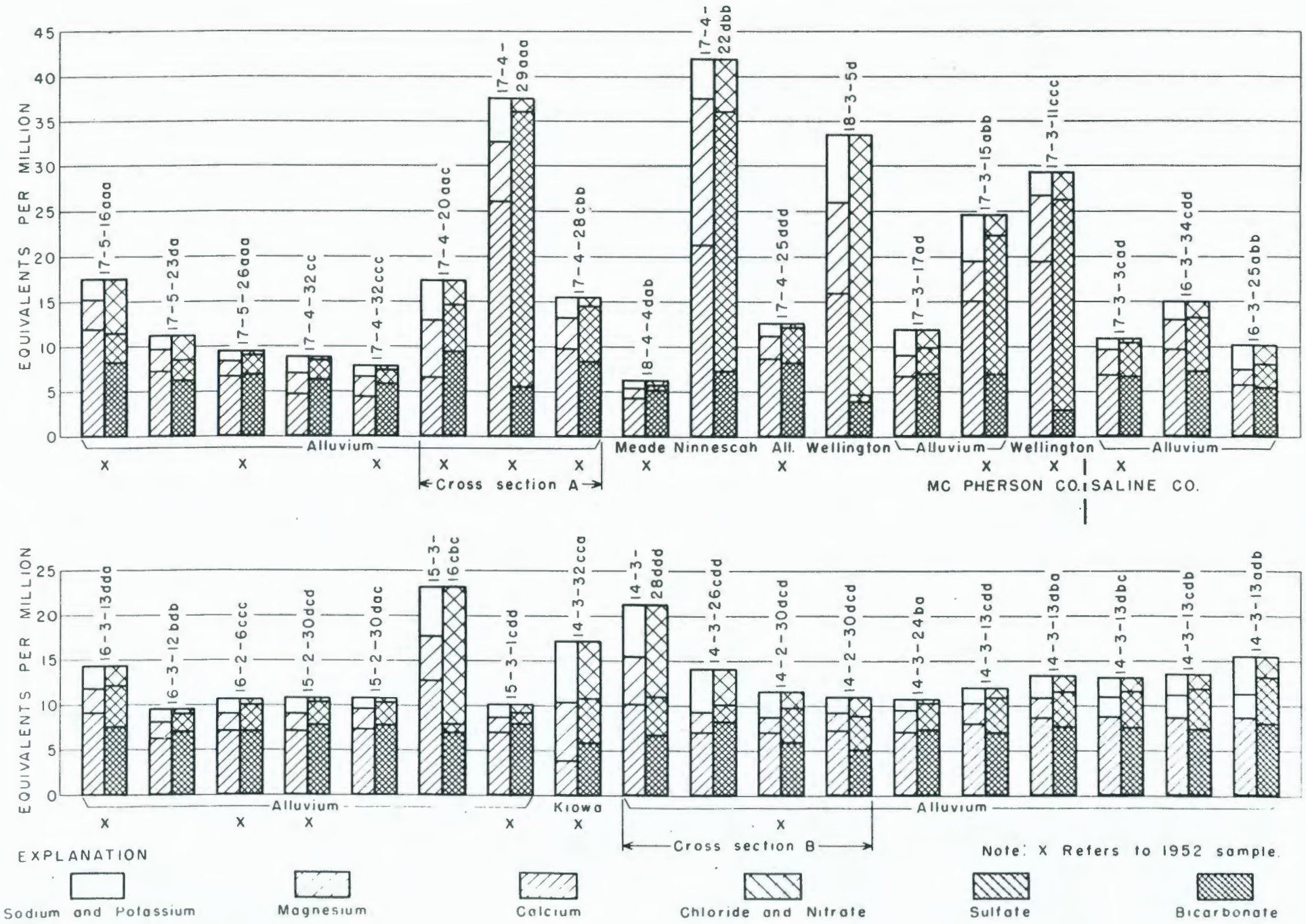
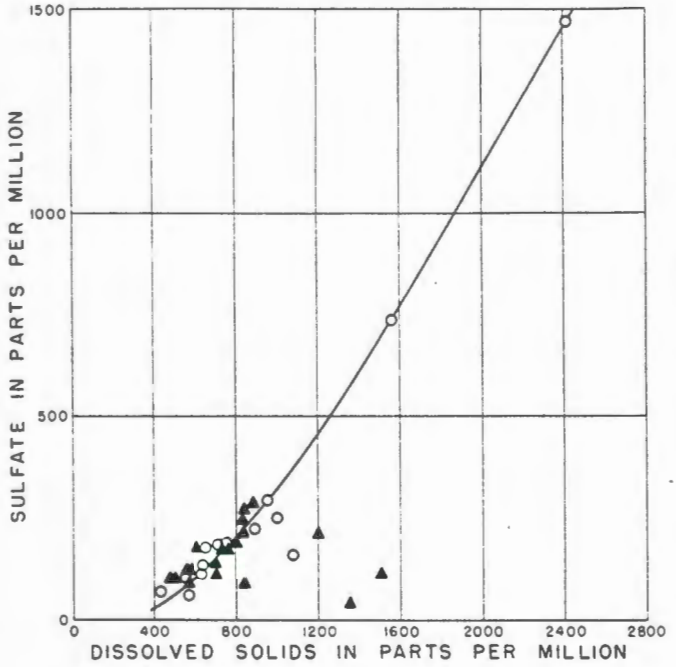
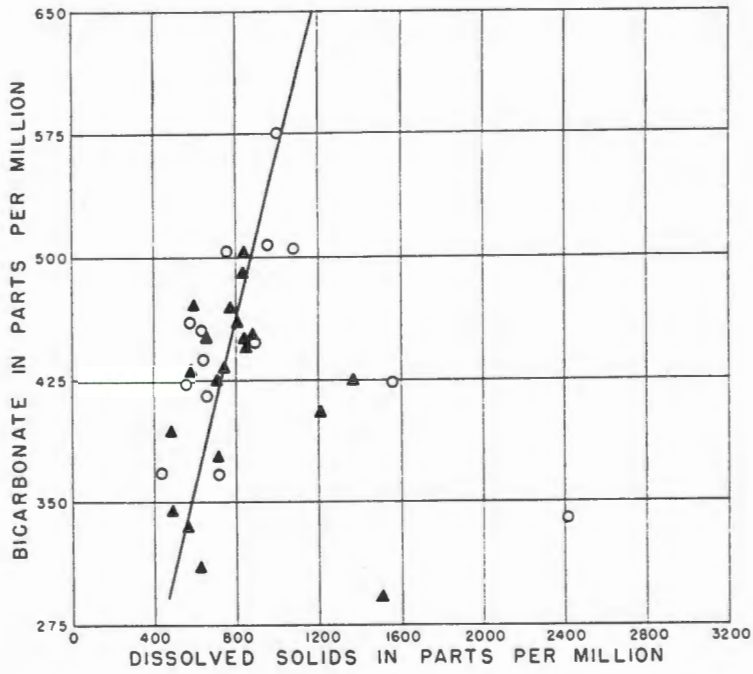


Figure 13.--Principal mineral constituents in ground water, Kanopolis Unit, Kans.



A. Sulfate – dissolved solids relation

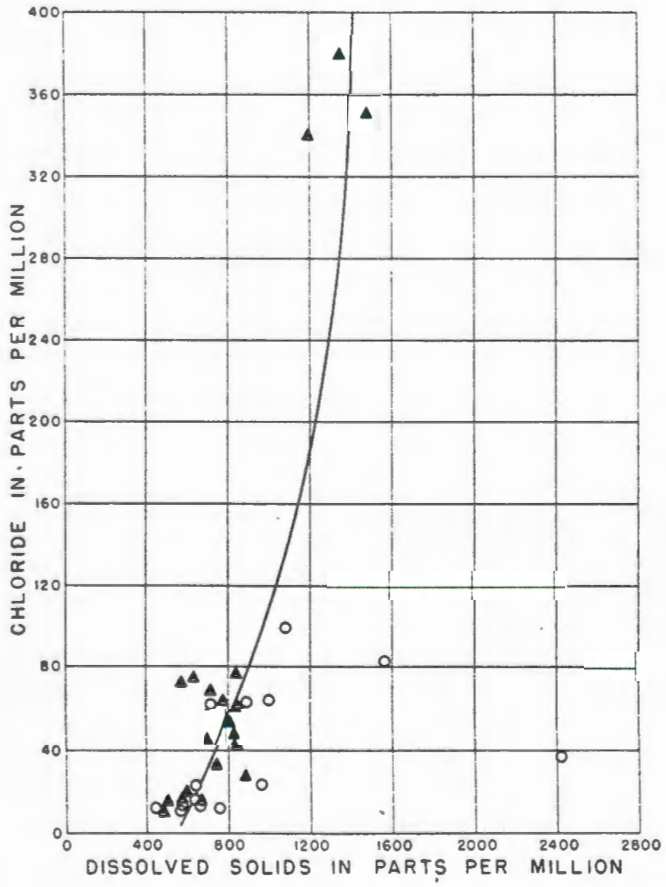


B. Bicarbonate – dissolved solids relation

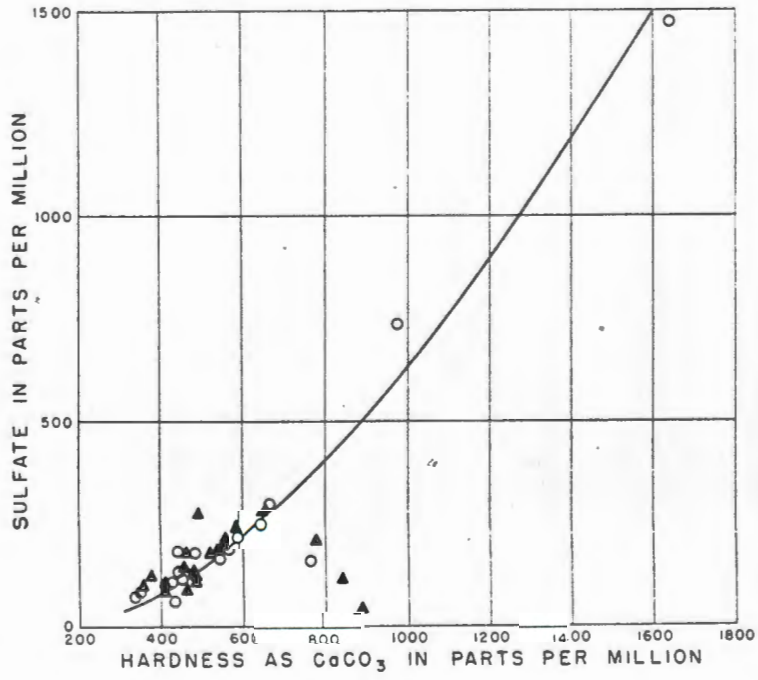
EXPLANATION

○ 1952 sample

▲ Previous sample



C. Chloride – dissolved solids relation



D. Hardness – sulfate relation

Figure 14 --Relation between various ions in waters from the alluvium, Kanopolis Unit, Kans.

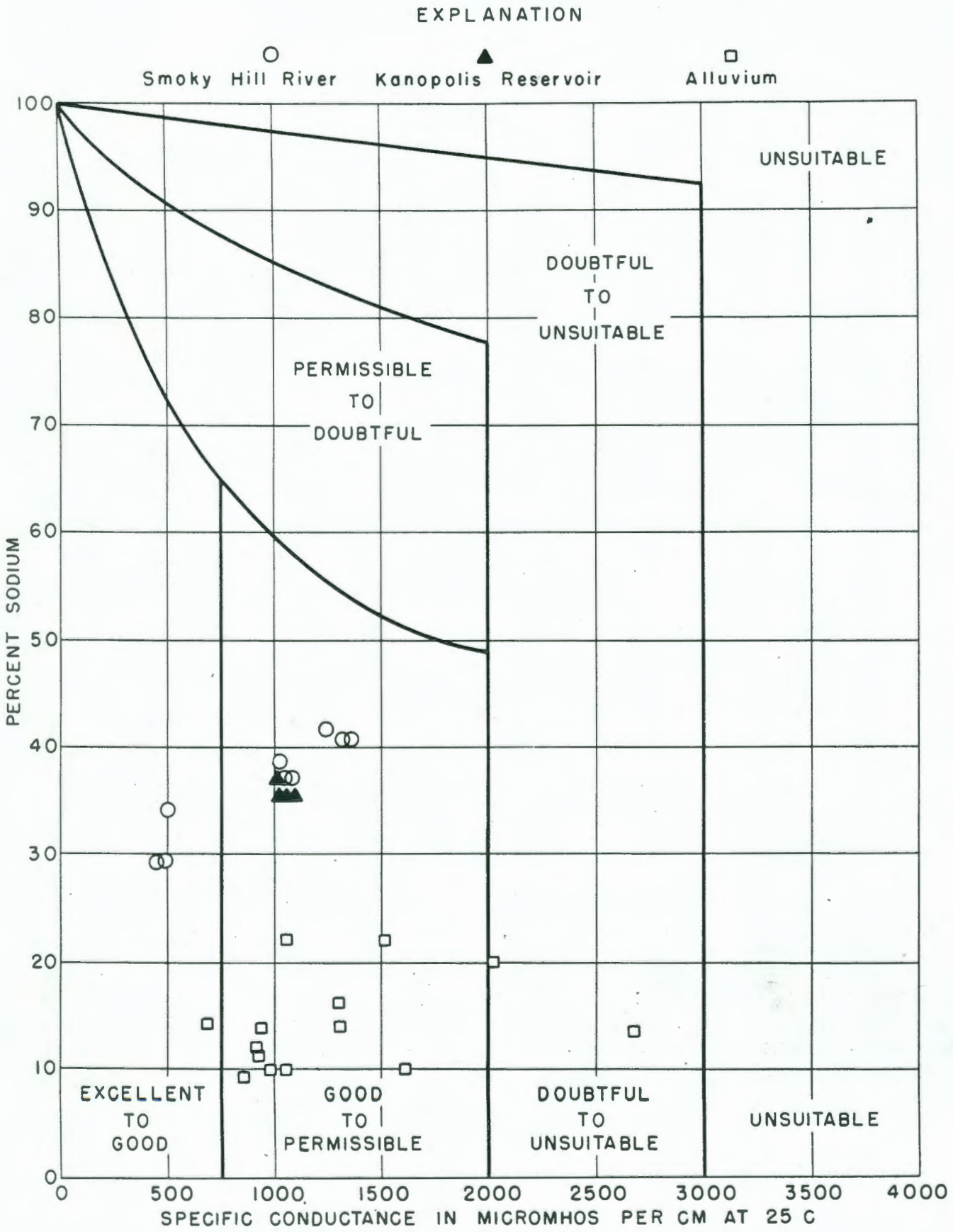


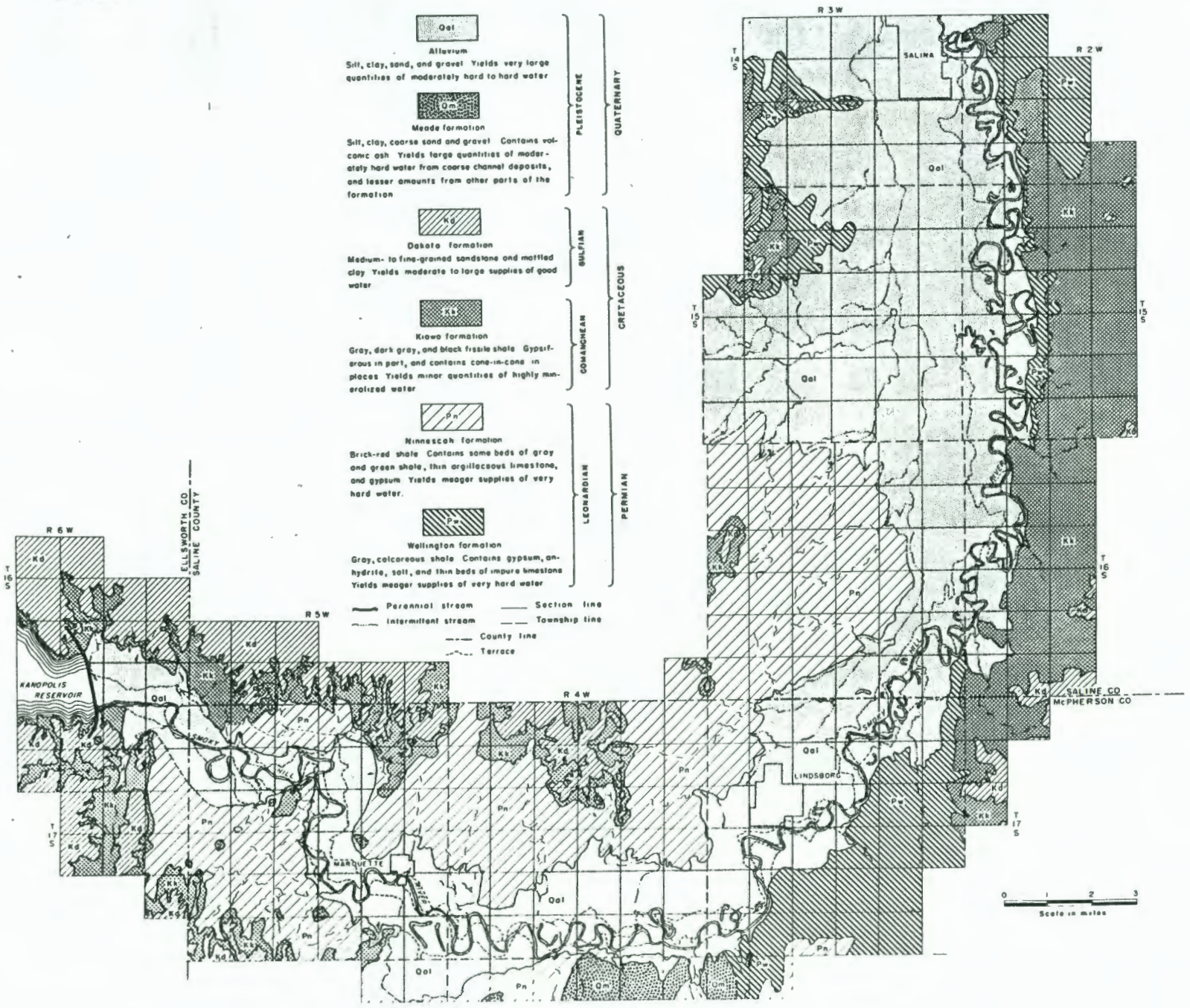
Figure 15.--Classification of waters in Kanopolis Unit for irrigation use (after Wilcox).

AREAL GEOLOGY OF THE KANOPOLIS UNIT, KANSAS

State Geological Survey of Kansas

by W. D. Waterman
1952

Bulletin
Plate I



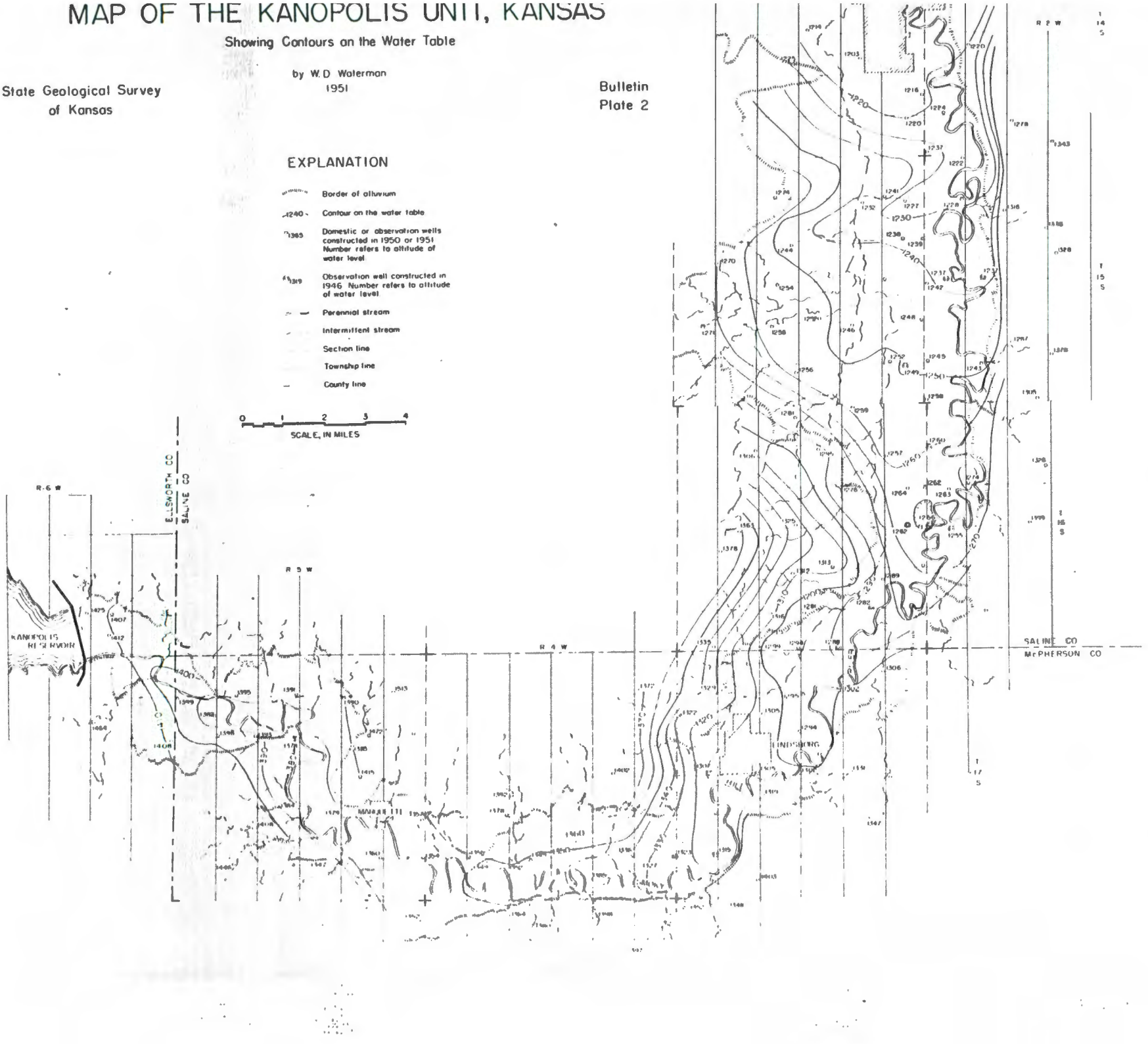
MAP OF THE KANOPOLIS UNIT, KANSAS

Showing Contours on the Water Table

by W. D. Waterman
1951

State Geological Survey
of Kansas

Bulletin
Plate 2



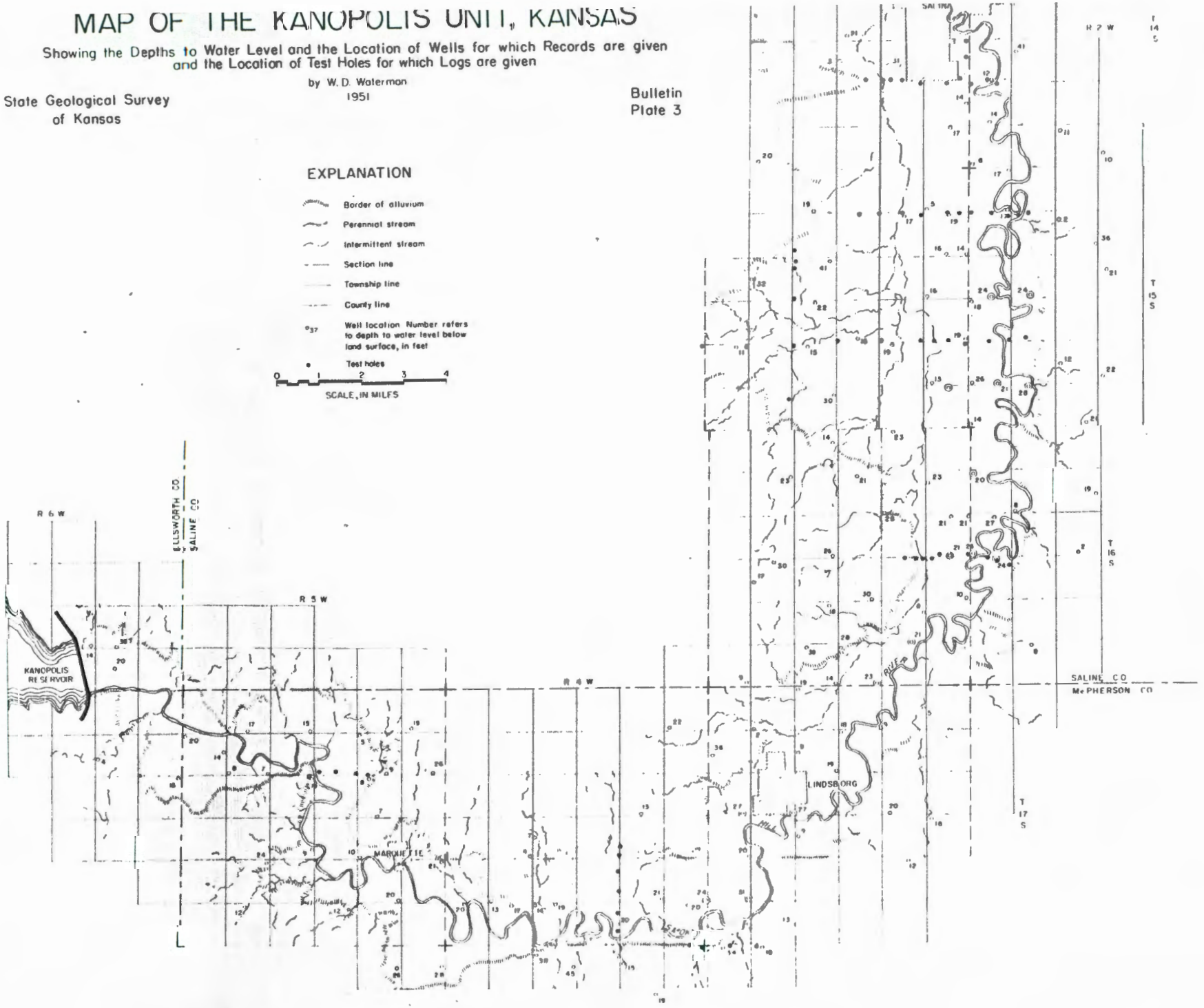
MAP OF THE KANOPOLIS UNIT, KANSAS

Showing the Depths to Water Level and the Location of Wells for which Records are given and the Location of Test Holes for which Logs are given

by W. D. Waterman
1951

State Geological Survey
of Kansas

Bulletin
Plate 3



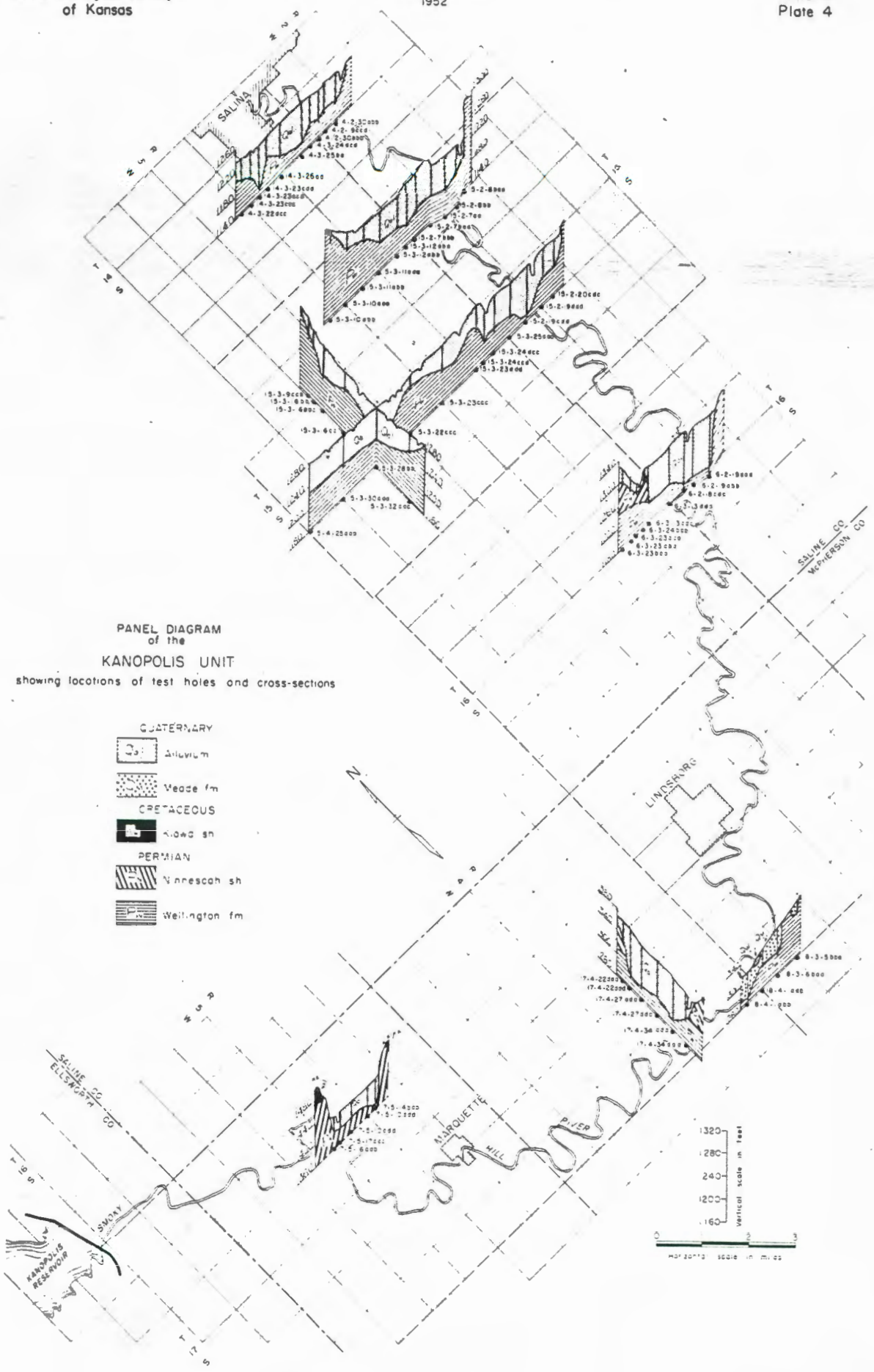
PANEL DIAGRAM OF THE KANOPOLIS UNIT, KANSAS

Showing Locations of Test Holes and Cross Sections

State Geological Survey of Kansas

by W. D. Waterman
1952

Bulletin
Plate 4



MAP OF THE KANOPOLIS UNIT, KANSAS

Showing Thickness of Saturated Material

by W. D. Waterman
1951

State Geological Survey
of Kansas

Bulletin
Plate 5

