# Water Resources of the Wichita Area Kansas

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1499–I

Petri and others—WATER RESOURCES OF THE WICHITA AREA, KANSAS—Geological Survey Water-Supply Paper 1499–I

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*By* L. R. PETRI, C. W. LANE, *and* L. W. FURNESS

WATER RESOURCES OF INDUSTRIAL AREAS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1499-I

*A description of the water resources of the area, their present use, and their potential for additional development*

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# WATER RESOURCES OF THE WICHITA AREA, KANSAS

By L. R. Petri, C. W. Lane, and L. W. Furness


## ABSTRACT

This report describes the quantity, quality, and availability of water, the present water use, and the potential for increased development of water resources of the Wichita area, an important industrial area of about 1,080 square miles in south-central Kansas.

Unconsolidated deposits of Tertiary(?) and Quaternary age, which provide water for most supplies, underlie a flat plain 10 to 15 miles wide, are as much as 270 feet thick, and have a water-storage capacity of about 8,000,000 acre-feet. The water table is 30 feet or less below land surface and generally slopes southeastward at 5 to 7 feet per mile. Recharge to the deposits is mainly by local precipitation; natural ground-water discharge is mainly by evapotranspiration. Natural fluctuations of the water table commonly are 2 to 4 feet, but they may be as much as 10 feet. Properly constructed wells yield 500 to 1,500 gpm and, in places, could yield 2,500 gpm.

Water from the unconsolidated deposits has less than 500 ppm of dissolved solids in most places, but it has more than 1,500 ppm in some places along the Arkansas River. Where dissolved solids are high, sodium and chloride or sulfate predominate. Most of the water is suitable for irrigation; however, it may require treatment for many nonagricultural uses because it is hard and has high iron and manganese contents. Consolidated deposits provide water for stock and domestic supplies where water from unconsolidated deposits is not available. The Wellington Formation and Ninnescah Shale of Permian age are the uppermost bedrock units and provide relatively small yields of poor-quality water.

The Arkansas and Little Arkansas Rivers, which are the principal streams in the area, have unregulated flow that varies widely. Duration curves indicate that flow of both Arkansas River near Wichita and Little Arkansas River near Valley Center exceeds 10 mgd 92 percent of the time. Arkansas River near Wichita stops flowing about 1 percent of the time, whereas Little Arkansas River at Valley Center stops flowing less than 0.1 percent of the time. Low-flow frequency curves show that an average flow of less than 10 mgd for a 30-day period may be expected at average intervals of once in 3.3 years for Arkansas River near Wichita, once in 4.5 years for Little Arkansas River at Valley Center, and once in 9 years for Arkansas River at Wichita.

Water from Arkansas River near Wichita is of poor quality for most uses because much of the time the concentrations of dissolved solids,

chloride, sulfate, iron, and manganese are high and because it is very hard. Water from Little Arkansas River near Valley Center and from North Fork Ninnescah River near Cheney, if treated to reduce the hardness and the iron and manganese contents, would be of suitable quality most of the time for public supply and most industrial uses.

Suspended-sediment concentrations in the Little Arkansas River at Valley Center generally are low; the maximum daily concentration during 1957–59 was 2,960 ppm. Generally about 85 percent of the sediment is finer than 0.004 mm.

Water rights in the area now total 232,600 acre-feet (75.8 billion gallons) per year. Current water use (1960) averages about 42.6 billion gallons per year, of which about 12.8 billion is for municipal use; 15.5, industrial use; 10.4, irrigation; and 3.9, rural-domestic use.

Development of additional large ground-water supplies will require adequate well spacing to prevent excessive drawdown of the water level. The most feasible method of artificial recharge seems to be induced infiltration of river water adjacent to the Little Arkansas River.

Future development of surface-water supplies probably will be limited to the North and South Forks of the Ninnescah River and to the Little Arkansas River. For the planned conservation pool of 144,800 acre-feet in Cheney Reservoir, from which Wichita will obtain water, chances that the net yield will be less than 104 acre-feet per day (34 mgd) are only 2 percent.

The Wichita water system can produce 112 mgd, which exceeds peak requirements by 30 mgd. The Newton water system can produce 5.7 mgd, which exceeds peak requirements by 2 mgd. Other municipal systems in the area are adequate to allow for some increase in water use. Many large-capacity wells are widely dispersed throughout the area and would be available to meet emergency water requirements in the event of a major civil disaster.

## INTRODUCTION

As industries expand to keep pace with the demands of our modern civilization, the amounts of water required increase rapidly. The extent to which the industries can expand in some areas will be limited largely by the adequacy of the water resources. Therefore, a series of reports is being prepared to summarize available information on the water resources of selected industrial areas of the Nation. This report is one of the series and provides such information for the Wichita area, Kansas.

In recent years industrial expansion, municipal growth, and irrigation in the Wichita area have been increasing considerably the amounts of water used. Development of additional supplies in some places have resulted in conflicts over water rights. Probably, the present trend toward an ever-increasing demand for water will continue for many years, and competition for the use of the water resources will increase. Therefore, information on the water resources should be readily available so that the potential for, and the limitations on, further development of these resources can be evaluated.

The water requirements, both quantitative and qualitative, differ greatly from industry to industry. To provide information for specific industries, for planning specific projects, or for solving specific problems is, therefore, beyond the scope of this report. Such detailed information can be obtained, however, from the files of the various Federal or State agencies, from other published reports, or from special investigations that might be made. This report is a general appraisal of the water resources; the information included indicates the general quantity, quality, and availability of water in the various parts of the area, the present (1960) water use, and the potential for additional development.

Most of the basic data used in preparation of this report were obtained over many years by the U.S. Geological Survey in cooperation with the following: State Geological Survey of Kansas, F. C. Foley, State geologist and director; Division of Water Resources, Kansas State Board of Agriculture, R. V. Smrha, chief engineer; Division of Sanitation, Kansas State Board of Health, D. F. Metzler, chief engineer; Kansas State Water Resources Board, R. L. Smith, executive secretary; the city of Wichita, R. H. Hess, director of Water and Sewage Treatment; and Wichita-Valley Center Flood Control Project, G. H. Wilton, Jr., director.

Other data are from interpretive studies made cooperatively by the U.S. Geological Survey with the State Geological Survey of Kansas, the Kansas Water Resources Board, or the State Highway Commission of Kansas; or they are from technical reports and records of the Corps of Engineers, U.S. Army, and the U.S. Weather Bureau. Mr. D. R. Soder, of the Layne Western Co., made available for inspection numerous logs of wells in the area. Consultation with G. J. Stramel, hydrologist of the Wichita Water Department, concerning the geology and water resources of the area was especially helpful.

This report was prepared at the request of the Water and Sewage Industry and Utility Division of the Business and Defense Services Administration of the U.S. Department of Commerce. It was prepared under the direct supervision of D. M. Culbertson, V. C. Fishel, and E. R. Leeson, district engineers of the Quality of Water, Ground Water, and Surface Water Branches, respectively, Water Resources Division of the U.S. Geological Survey.

## WICHITA AREA

The Wichita area is in south-central Kansas and consists of about 1,080 square miles in Sedgwick and Harvey Counties (fig. 1).

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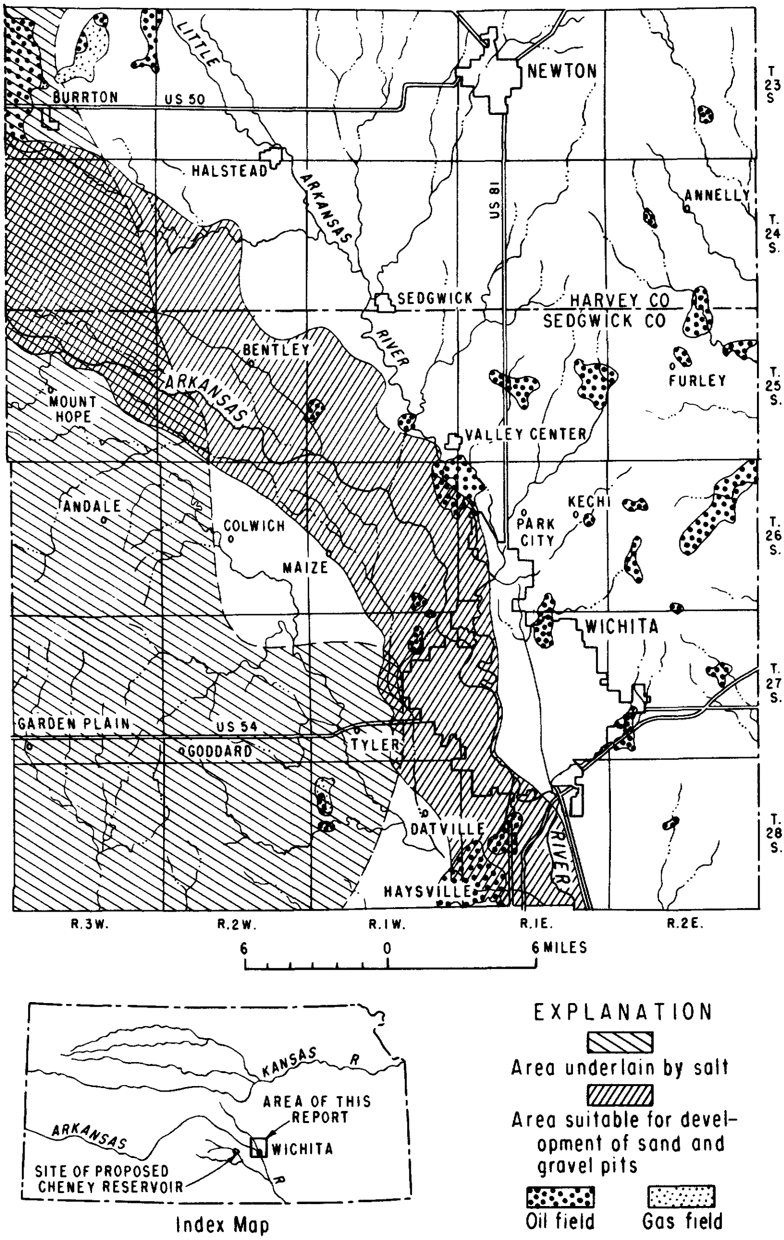


**Figure 1.**—Map showing Wichita area and locations of economic mineral resources.

It is drained by the Arkansas River, which flows southeastward. The Little Arkansas River, a tributary to the Arkansas River, drains about one-third of the report area. Low topographic relief is characteristic of the area. The highest points, near Newton and between Garden Plain and Mount Hope, are about 1,530 feet above sea level; the lowest points, along the Arkansas River south of Wichita, are about 1,260 feet above sea level.

Climate in the area is typical of the midcontinental regions of the United States. From 1889 to 1959 the temperature averaged 54.2°F, and the precipitation averaged 29.91 inches per year. The extreme and average monthly temperatures and precipitation are shown in table 1. Most of the rain falls during the growing season when it is most beneficial to crops.

TABLE 1.—*Variation in monthly temperature and precipitation in Wichita, 1889–1959*

[From records of U.S. Weather Bureau]

| Month | Mean temperature, in degrees Fahrenheit | | | Mean precipitation, in inches | | |
|---|---|---|---|---|---|---|
| | Maximum | Average | Minimum | Maximum | Average | Minimum |
| January | 42.5 | 32.0 | 16.2 | 6.29 | 0.83 | Trace |
| February | 48.6 | 35.4 | 21.2 | 4.61 | 1.18 | Trace |
| March | 58.1 | 44.8 | 33.6 | 4.55 | 1.80 | Trace |
| April | 63.7 | 56.3 | 50.0 | 12.42 | 2.96 | Trace |
| May | 71.8 | 65.3 | 58.6 | 11.22 | 4.34 | 0.97 |
| June | 83.1 | 75.2 | 68.9 | 14.43 | 4.49 | Trace |
| July | 88.2 | 80.2 | 73.5 | 13.37 | 3.33 | .10 |
| August | 89.0 | 79.4 | 71.0 | 8.50 | 2.95 | Trace |
| September | 79.4 | 71.4 | 64.8 | 10.58 | 3.13 | .03 |
| October | 68.4 | 59.6 | 49.0 | 6.13 | 2.38 | 0 |
| November | 51.2 | 45.2 | 38.0 | 6.69 | 1.49 | Trace |
| December | 46.4 | 35.3 | 24.8 | 3.98 | 1.03 | .02 |

## ECONOMIC MINERAL RESOURCES

The economic mineral resources of the area include oil, gas, salt, and sand and gravel. The distribution of these resources is shown on figure 1.

Production of oil and gas in the area started in 1923 and has continued at an increasing pace since then. The cumulative production through 1959 has been about 96 million barrels of oil and 12 million-million cubic feet of gas. Because of the many producing oil fields and gas fields in the Wichita area and vicinity, the city of Wichita has become a center for processing and distributing petroleum and related products.

Salt beds are as thick as 250 feet along the western edge of the area and thin toward the east. A series of sinks along the eastern edge of these beds indicates that solution of the salt by circulating ground water and collapse of the overlying strata are still in progress. The solution of salt along the eastern edge of the beds results in a nearly saturated brine, but neither the quantity nor exact areal extent of the brine is known. Although salt is not mined in the area, the saturated brine is used by one chemical company near Wichita as a raw material.

In the Wichita area, sand and gravel are widely distributed and have been produced for many years from numerous commerical pits. In the "area suitable for development of sand and gravel pits" (fig. 1), the overburden of soil and silt, which is 10 feet thick or less, is underlain by 20 to 40 feet of clean sand and gravel that contain few silt or clay beds; the water table is about 5 to 30 feet below the land surface. The sand and gravel are mined by hydraulic quarrying.

## INDUSTRIAL DEVELOPMENT

Wichita, the industrial center of the area, has a population of 254,698, according to the 1960 Federal census. It has large stockyards, is one of the largest milling centers in the United States, and is the largest broomcorn market; in 1950, it had about 500 diversified manufacturing establishments. However, the most important industry of Wichita, by far, is the manufacture of aircraft. Because of the large number of military and small personal aircraft made at Wichita, the city is sometimes referred to as the "Air Capital" of the world.

Industry in the area has grown rapidly since about 1940, and much of the growth was stimulated by the development for Wichita of a new well field and new treatment facilities capable of providing abundant supplies of water of good quality. According to Pfister (1952, p. 61), in 1940 the number of people employed in manufacturing in metropolitan Wichita was 8,691; but in 1944, because of the production of military aircraft for World War II, the number had increased to 54,602. In 1945, after World War II, the number dropped to 13,286. In 1952, at the close of the Korean conflict, the number was estimated to be 54,500, which represented slightly more than 40 percent of the total number of people employed in manufacturing in Kansas.

Newton, the second largest city in the area, had a population of 14,877 in 1960; it is an important trading center for the surrounding wheat country. As early as 1873 Newton was a division point of the Atchison, Topeka and Santa Fe Railway, but in 1879 the division offices were moved from Newton because of inadequate water supplies. The offices were returned to Newton about 15 years later after an abundant supply of good water had been found near the town.

Most of the industries in the area, in comparison with industries in many parts of the country, are not heavy water users. The amounts of water used per employee in 1950 in various industries in the Wichita-Hutchinson trading area (Pfister, 1952, p. 125), which is closely related to this report area, are as follows:

| *Industry* | *Water used per employee (gallons per day)* |
|---|---|
| Salt production | 30,000 |
| Petroleum refining | 8,000 |
| Dairy products | 4,000 |
| Natural gas transmission | 2,000 |
| Other chemical plants | 2,000 |
| Meat packing | 1,000 |
| Through transportation | 400 |
| Metal fabrication, including aircraft | 160 |
| Flour milling | 150 |
| Military establishments | 50 |

Agriculture is vital to the economy of the Wichita area and forms the basis for many allied industries in the cities. Field crops and livestock are raised on about 3,000 farms in the area. The chief crops are wheat, sorghum, alfalfa, and hay. Other crops include corn and barley. The livestock includes mainly beef cattle and some dairy cattle, sheep, and swine.

Irrigation, usually supplemental, is practiced in much of the area. During years of normal or above normal precipitation, irrigation is used only to assure optimum moisture conditions during critical growing periods. According to the State Board of Agriculture, irrigation water rights have been established or are pending for about 30,000 acres in the area—about 25,000 acres to utilize ground water and about 5,000 acres to utilize surface water. Both sprinkler irrigation and flood irrigation are practiced.

## WATER-BEARING DEPOSITS AND STREAMS

The availability of ground water and the flow characteristics of streams have a close relationship to the geology and climate of an area, and this relationship is pronounced in parts of the Wichita area. The generalized geology of the area is shown by the map and sections on plate 1. The stratigraphic relationship of the geologic units and a summary of their physical and water-bearing characteristics are given in table 2. These geologic units have been divided into unconsolidated deposits and consolidated deposits. The unconsolidated deposits are most significant to the water supply and include eolian sand deposits, loess and colluvium, and sand and gravel deposits. The consolidated deposits, which are not sources of large water supplies, include the Wellington Formation and the Ninnescah Shale, both of Permian age.

The eolian sand deposits, in the northwestern corner of the area, are a part of a dune tract that extends many miles to the west and displays a typical, although somewhat subdued, dune topography. The dunes are seldom active; they serve as a catchment area for precipitation, a part of which becomes recharge to the underlying water-bearing beds.

TABLE 2.—*Generalized section of geologic formations in the Wichita area and their water-bearing characteristics*

| System | Series | Stratigraphic unit used in this report | | Maximum thickness (feet) | Physical characteristics and water-bearing properties |
|---|---|---|---|---|---|
| Quaternary | Recent and Pleistocene | Unconsolidated deposits | Eolian sand deposits | 75± | Wind-deposited fine to medium sand and some silt. Yields small water supplies to a few wells. The dunes serve as a catchment for precipitation, a part of which recharges underlying water-bearing beds. |
| | | | Loess and colluvium | 75± | Wind-deposited silt (loess) underlain in parts of the area by colluvium, a mixture of silt, clay, sand, and gravel deposited on slopes. Yield small water supplies to many domestic and stock wells. |
| Quaternary; Tertiary(?) | Recent and Pleistocene; Pliocene(?) | | Sand and gravel deposits | 270± | Stream-deposited silt, clay, sand, and gravel. Many thick beds of sand and gravel yield large quantities of water to wells. Most of the water used is derived from this source and well yields of as much as 2,500 gpm are possible. |
| Permian | Lower Permian | Consolidated deposits | Ninnescah Shale | 150± | Brownish-red shale containing thin beds of siltstone and impure limestone. Yields small water supplies to domestic and stock wells in southwestern part of area. |
| | | | Wellington Formation | 550± | Gray to greenish-gray shale containing many thin beds of limestone, dolomite, and gypsum. Contains thick salt beds in subsurface in western part of area. Yields small supplies of water to domestic and stock wells in eastern part of area and locally yields as much as 350 gpm from solution zones in gypsum. |

Loess and colluvium are widespread, mantling the uplands in the eastern and southwestern parts of the area and overlapping the edges of the older valley deposits. The loess is wind-deposited silt, which in parts of the area is underlain by colluvium, a heterogeneous mixture of clay, silt, sand, and gravel deposited on slopes by sheet wash and soil creep. The loess and colluvium are not important sources of ground water except for domestic wells in the southwestern part of the area. Because of their low permeability, they do not readily absorb and transmit water.

The sand and gravel deposits of Tertiary(?) and Quaternary age form the principal ground-water reservoir and are the sources of most of the water used. These streamlaid deposits, which also include clay and silt, underlie a broad flat area 10 to 15 miles wide and fill a depression in the underlying bedrock. The bedrock depression is clearly shown by contours on figure 2; it resulted in part from stream erosion but mainly from settling of the overlying rocks by solution of salt in the Wellington Formation of Permian age. Deposition in the valley by streams crossing the area probably kept pace with the settling, and this process is still going on today. When most of the deposits were laid down, the drainage pattern was somewhat different from that of today; the ancestral Arkansas River was several miles west of the present river channel, and a major tributary from the north joined the main stream northwest of Wichita. Later, the northern tributary was abandoned, and its former course was filled with sand and gravel.

The Wellington Formation and the Ninnescah Shale are composed principally of shale, but they contain some limestone, dolomite, siltstone, sandstone, gypsum, and salt. The Wellington Formation contains thick subsurface salt beds near the middle of the formation in the western part of the area. It underlies the entire area and is overlain by the Ninnescah Shale of Permian age in the uplands in the southwestern corner.

The Little Arkansas River throughout the Wichita area and the Arkansas River downstream from its confluence with the Little Arkansas River receive ground water, and almost all the flow in these streams during low stages is from the ground-water reservoir. The Arkansas River upstream from its confluence with the Little Arkansas River is in equilibrium with the water table most of the time and receives little or no flow from the ground-water reservoir in this area. During high stages the Arkansas River recharges the ground-water reservoir.

Many short tributaries drain the uplands in the eastern part of the area. Those in the extreme eastern part are in the Walnut River drainage and contribute little to the water supply of the Wichita area. The tributaries flowing from the east to the Arkansas River are intermittent and do not add much to the ground-water supply.

Kisiwa Creek, tributary to the Little Arkansas River, and Big Slough and Cowskin Creek, tributaries to the Arkansas River, drain most of the western part of the area. Along most of their courses these streams are intermittent, but in their southern reaches Big Slough and Cowskin Creek are entrenched below the water table in the valley deposits and receive ground-water discharge.

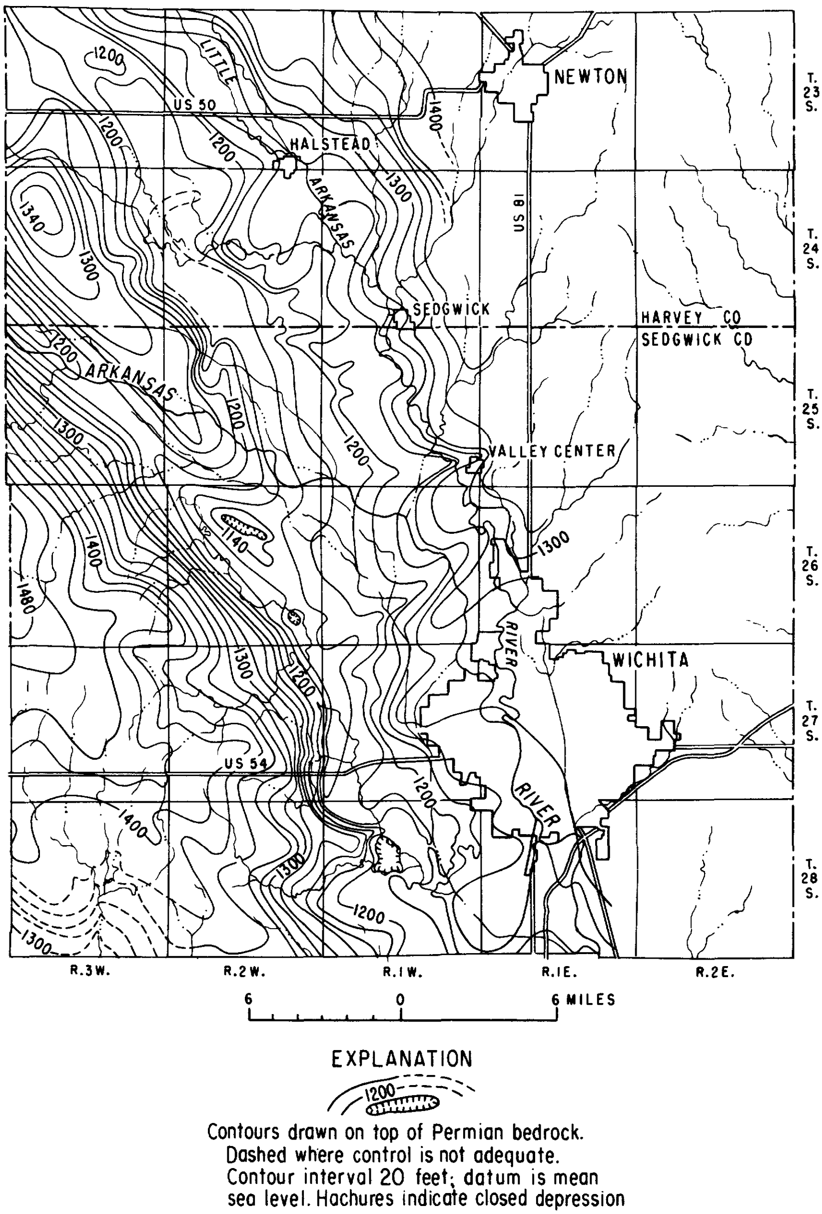


FIGURE 2.—Map showing configuration of the Permian bedrock surface.

The southwestern part of the area is drained by tributaries to the Ninnescah River. Most of these tributaries are entrenched in the Ninnescah Shale, are intermittent, and do not contribute significantly to the ground-water supply.

## WELL-NUMBERING SYSTEM

The location of wells is shown in this report by a system of numbers and letters (fig. 3). The first number indicates the township; the second, the range; and the third, the section. The 6th principal meridian passes through Wichita; range numbers east of this meridian are followed by E, and range numbers west of this meridian are followed by W. The first lower case letter following the section number indicates the quarter section; the second, the quarter-

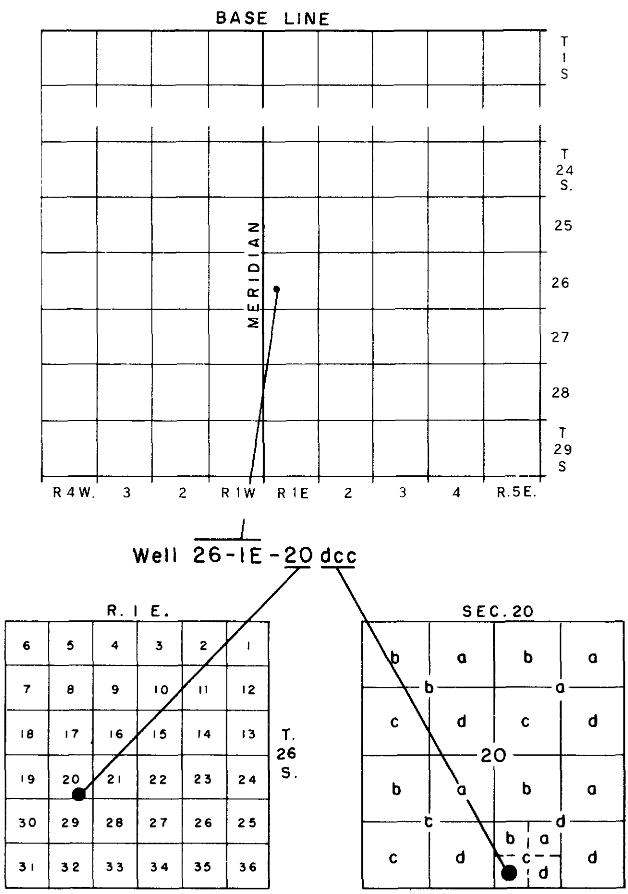


**FIGURE 3.—Sketch illustrating well-numbering system.**

quarter section; and the third, the quarter-quarter-quarter section. These letters are arranged counterclockwise and begin with "a" in the northeast quarter.

## WATER FROM UNCONSOLIDATED DEPOSITS

### GROUND-WATER HYDROLOGY

Of the three unconsolidated stratigraphic units in the area, only the sand and gravel deposits of Tertiary(?) and Quaternary age contain a large volume of water in storage. These deposits compose a ground-water reservoir that is about full and is in equilibrium with its environment except in localized areas of heavy pumping. Stratification of the deposits differs with location.

The quantity of water that might be developed at a given location depends on the thickness and permeability of saturated sand and gravel present. The percentage of sand and gravel in the deposits of Tertiary(?) and Quaternary age is shown by pattern on figure 4. The thickness of the saturated deposits is shown on figure 5. The percentage of sand and gravel was determined by the visual inspection of drill cuttings and drillers logs from more than 400 wells and test holes. In about one-third of the area underlain by these deposits, sand and gravel make up 75 percent or more of the total thickness of the deposits; in about three-fourths of the area, they make up more than 50 percent. The permeability of the sand and gravel differs considerably from place to place and decreases with depth. Most of the area south of Kisiwa Creek is underlain by a sheet of highly permeable sand and gravel that averages about 45 feet in thickness. Below the sheet in much of the area are many more layers of sand and gravel, but they are less permeable because they contain more fine sand and silt. North of Kisiwa Creek a thick bed of silt and clay lies near the surface, and the sheet of highly permeable sand and gravel is absent.

The thickness of the saturated deposits ranges from 0 to about 240 feet. About 20 percent of the volume of the saturated deposits is occupied by water in storage (Stramel, 1956). The volume of the water is about 8,000,000 acre-feet (1 acre-ft equals 325,850 gal). For practical reasons, only about half of this water could be recovered economically by wells.

The recharge and discharge characteristics of the deposits of Teritary(?) and Quaternary age affect greatly the quantity of water that ultimately can be developed from the ground-water reservoir. Recharge to the reservoir is principally by local precipitation, although some is by subsurface movement of water from the west.

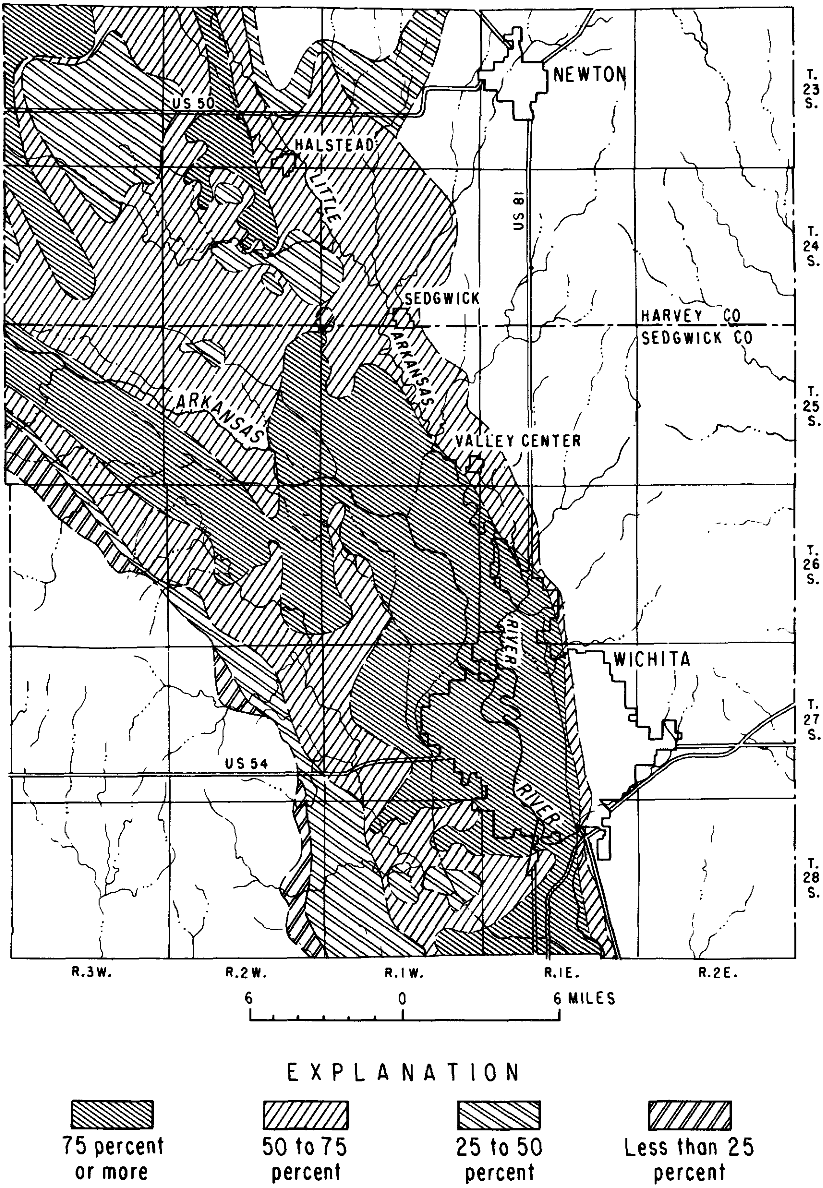


FIGURE 4.—Map showing the percentage of sand and gravel in the unconsolidated deposits of Tertiary(?) and Quaternary age.

About 20 percent of the precipitation becomes recharge, and this recharge is reflected by rapid rises of the water table. Although much ground water is discharged to the streams, a far greater quantity is discharged to the air by evaporation and plant transpiration,

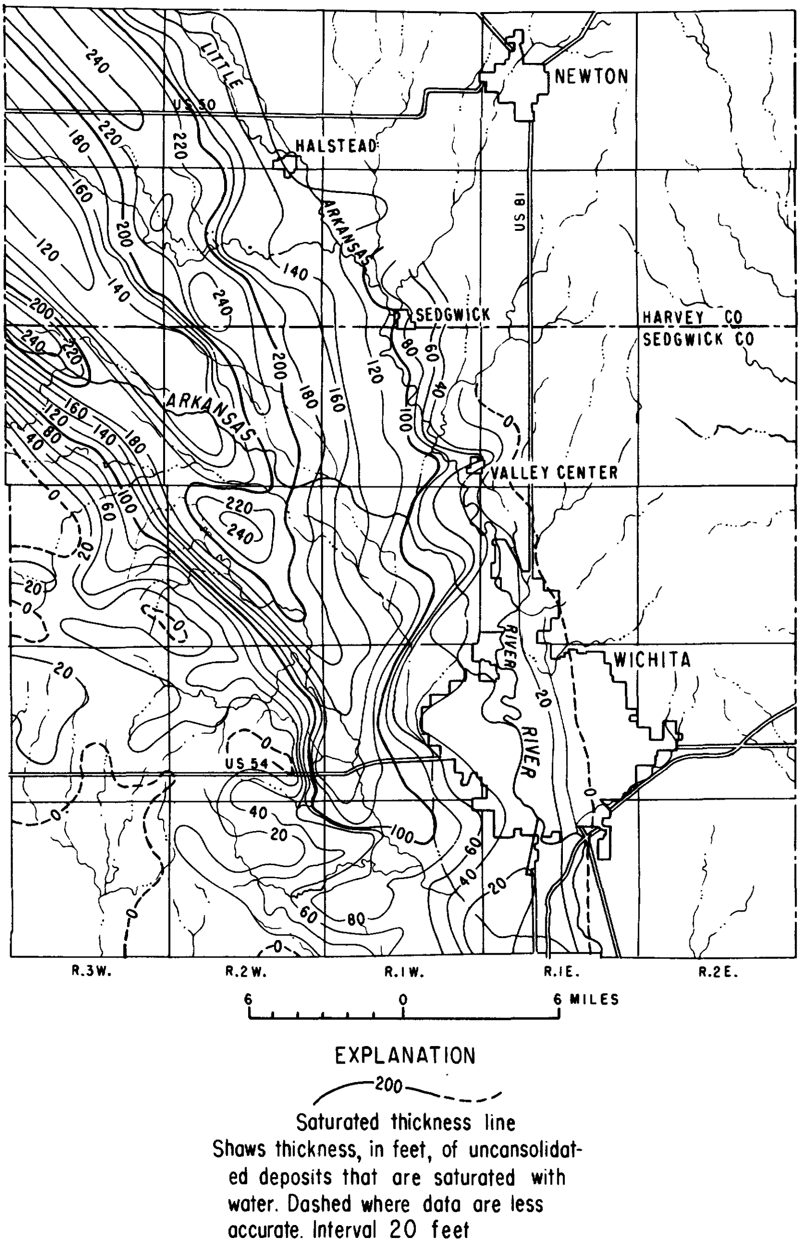


FIGURE 5.—Map showing the thickness of the saturated unconsolidated deposits in 1958.

especially where the water is less than 10 feet below the land surface. Reducing evaporation and transpiration by increased pumping to lower the water table a few feet would, in effect, add greatly to the water supply of the area.

The type of well used depends generally on the quantity of water needed. A driven sand point or shallow drilled well usually will yield a satisfactory quantity for domestic and stock use. The gravel-packed well is the most common type used if large quantities are needed. In this type of well construction a large hole, usually 30 to 42 inches in diameter, is drilled, and a casing and screen large enough to accommodate the required pumping equipment is installed. The annular space between the well casing and large hole is then filled with graded gravel and is plugged at the top with clay or cement. Generally, the total saturated thickness of the water-bearing beds need not be screened to obtain the desired well yield. Gravel-packed wells commonly yield 500 to 1,500 gpm (gallons per minute) and in much of the area would yield 1,500 to 2,500 gpm without excessive drawdown of the water level. Periodic well maintenance generally is required.

The most productive areas are, in general, those where the thickness of the saturated deposits (fig. 5) and the percentage of sand and gravel (fig. 4) are greatest. Southward from the city of Wichita the thickness of the saturated Tertiary(?) and Quaternary deposits is not great; however, the sand and gravel are very permeable, and moderately high well yields are readily obtainable.

Water cannot be withdrawn from a well without creating a drawdown or lowering of the water level in the vicinity of the well. In a multiple-well system, the drawdown at any point is affected by all wells being pumped. Excessive lowering of the water table in the vicinity of such a well system increases pumping lifts, reduces the yield of individual wells, and often creates social and economic problems concerning previously established water rights. To some extent the amount of lowering can be controlled by well spacing and distribution of pumping within the well field. Optimum well spacing to minimize drawdown effects is seldom possible, and a compromise is generally required.

Change in water level is responsive to factors such as the quantity of water pumped, the amount and distribution of precipitation, the local aquifer characteristics, and the distribution of pumping in the well field. Any large ground-water development in the area will probably experience water-level changes similar to those in the Wichita "Equus beds" well field southwest of the city of Halstead. This well field contains 55 wells and is the largest integrated water-supply development in the area. The wells are spaced about one-half mile apart. Detailed records of pumpage from each well and the drawdown in several hundred observation wells in the vicinity have been kept since operation of the well field began in 1940. The effects of pumping in this well field are shown by lines of equal change in water level on figure 6. Figure 6*A* shows the change in water level at the end of a 5-year drought; this change is the approximate maximum that has occurred in the well field. The area in which a measurable change in water level took place was about 100 square miles. Figure 6*B* shows the effect of several years of near-normal precipitation after the maximum declines were reached. By January 1960 the area of measurable change in water level had declined to about 80 miles.

The water table in the unconsolidated deposits of Tertiary(?) and Quaternary age is at the land surface in some places near the Arkansas River and is as much as 30 feet below land surface near the western edge of the deposits. Locally, near centers of heavy pumping, the water table is depressed but would recover to normal levels if pumping was discontinued. The configuration of the water table in the area is shown by contours in figure 7 and generally follows the configuration of the land but is subdued in detail. The water table in the deposits has a uniform slope to the southeast of about 5 to 7 feet per mile; the uniformity and amount of slope are indicative of the high permeability of the deposits. The movement of ground water is at right angles to the water-table contours and is toward the Little Arkansas and Arkansas Rivers. Near centers of pumping, such as the Wichita well field, the water-table contours are distorted. The upstream deflection of the contours near streams (p. I 9) indicates discharge of ground water to the streams. Along the western edge of the Tertiary(?) and Quaternary deposits, in the loess and colluvium of Quaternary age on the valley slopes and uplands, the contours indicate a gradient of the water table of about 30 feet per mile; this high gradient is caused by the low permeability of these deposits.

Fluctuations of the water level since 1938 are shown for selected wells in the vicinity of the Wichita well field in figure 8. Two of the graphs in figure 8 are for wells unaffected by pumping in the well field and show natural water-level fluctuations. These graphs resemble the graph of cumulative departure from normal precipitation near Newton, Kans. The resemblance should be expected because the reservoir is normally in equilibrium, and a significant departure from normal precipitation quickly causes a rise or fall of the water level. The graph for well 24-2W-9ccc, which is in the center of the

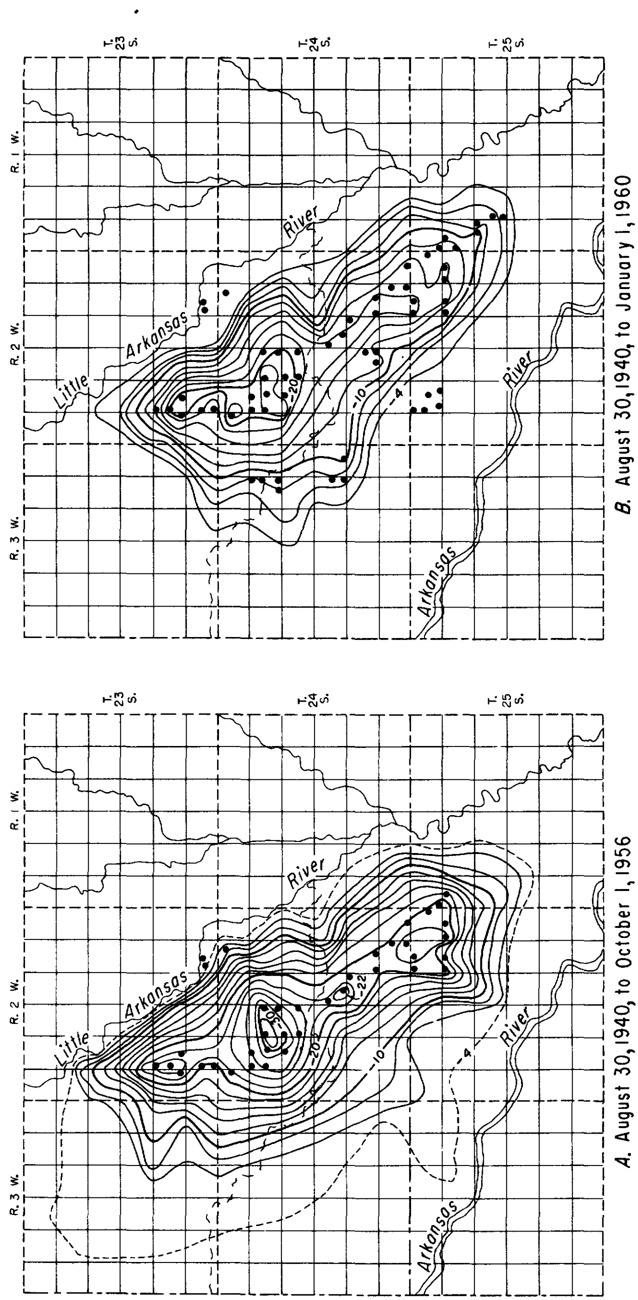


FIGURE 6.—Maps showing effects of pumping, Wichita well-field area. Dots indicate Wichita supply wells. Lines are water-level contours shown in 2-foot intervals; dashed where approximate.

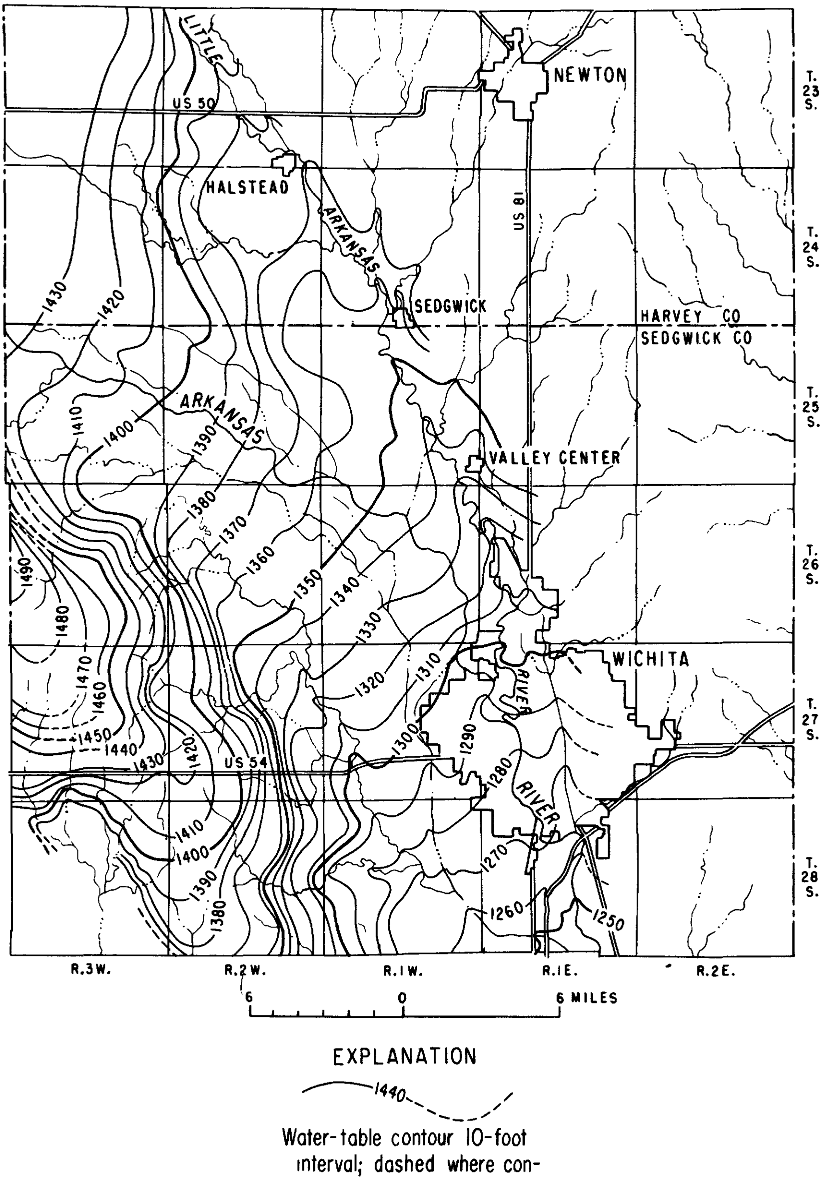


FIGURE 7.—Map showing configuration of the water table, fall of 1958.

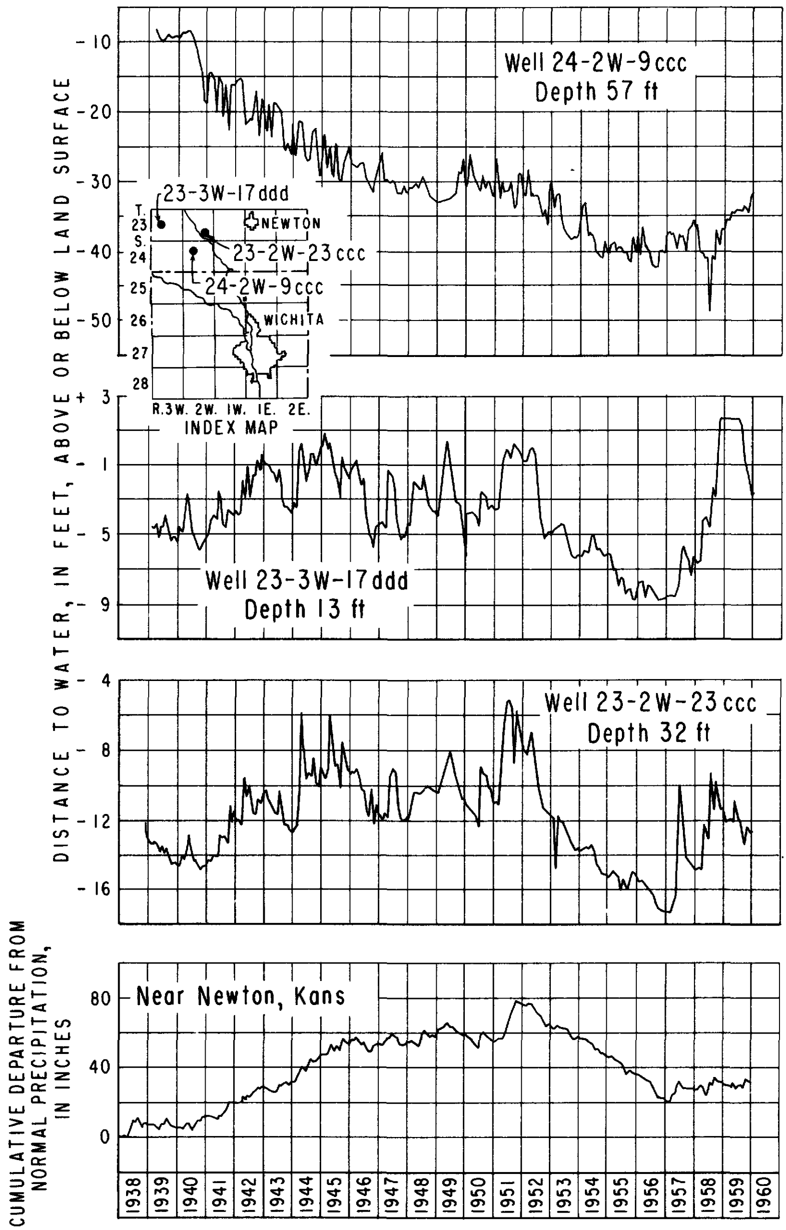


FIGURE 8.—Fluctuations of the water levels in selected wells in the Wichita well-field area and cumulative departure from normal precipitation near Newton, Kans.

well field, shows fluctuations whose pattern is influenced mainly by changes in pumping rate. As the rate increases, the water level declines; as the rate becomes stabilized, the reservoir attains a near equilibrium between recharge and discharge and the water level becomes stabilized at a lower elevation. The reservoir equilibrium under pumping conditions can be reestablished only by reducing the natural discharge from the reservoir or by intercepting a source of additional recharge. Pumping was started in the Wichita well field in 1940, and water levels declined steadily except for seasonal fluctuations until the late 1940's. Lowering the water table decreased the natural discharge to the Little Arkansas River and, even more important, decreased the natural discharge by evaporation and transpiration; a near-equilibrium condition was reestablished. Ten new wells were added to the field in 1949; and during the drought years from 1952 through 1956, pumpage from the field increased greatly and water levels again declined steadily. Since 1956, precipitation has been near normal, pumpage from the well field has decreased, and water levels in the field have risen. Twenty new wells were added to the field in 1959, and the distribution of pumpage from the field has been spread over a larger area. If precipitation remains near normal and if pumpage does not increase, water levels will continue to rise until a new equilibrium is established.

### CHEMICAL QUALITY

The dissolved-solids content of water from unconsolidated deposits in most of the area is less than 500 ppm (parts per million). However, it is more than 750 ppm in an extensive area (part *D*, fig. 9) and is more than 1,500 ppm in some of the alluvium along the Arkansas River. In parts *B*, *C*, and the western part of *D* (fig. 9), the dissolved-solids content commonly increases with depth, more than 200 percent in some places. For example, during test drilling of well 24–2W–35a, it was 199 ppm at 28 feet, 430 ppm at 59 feet, and 589 ppm at 190 feet. However, in many places near the western boundary of parts *A* and *C*, it decreased with depth in 1939. The higher dissolved-solids contents near the land surface were attributed by Williams and Lohman (1949, p. 176) to contamination by brines that had been pumped from oil wells into sump ponds.

Differences in the dissolved-solids content of the ground water are accompanied by differences in the relative proportions of some of the individual constituents. In water having low dissolved solids, calcium and bicarbonate are by far the predominant constitutents; in water having high dissolved solids, sodium and chloride or sulfate are ordinarily the predominant constituents.

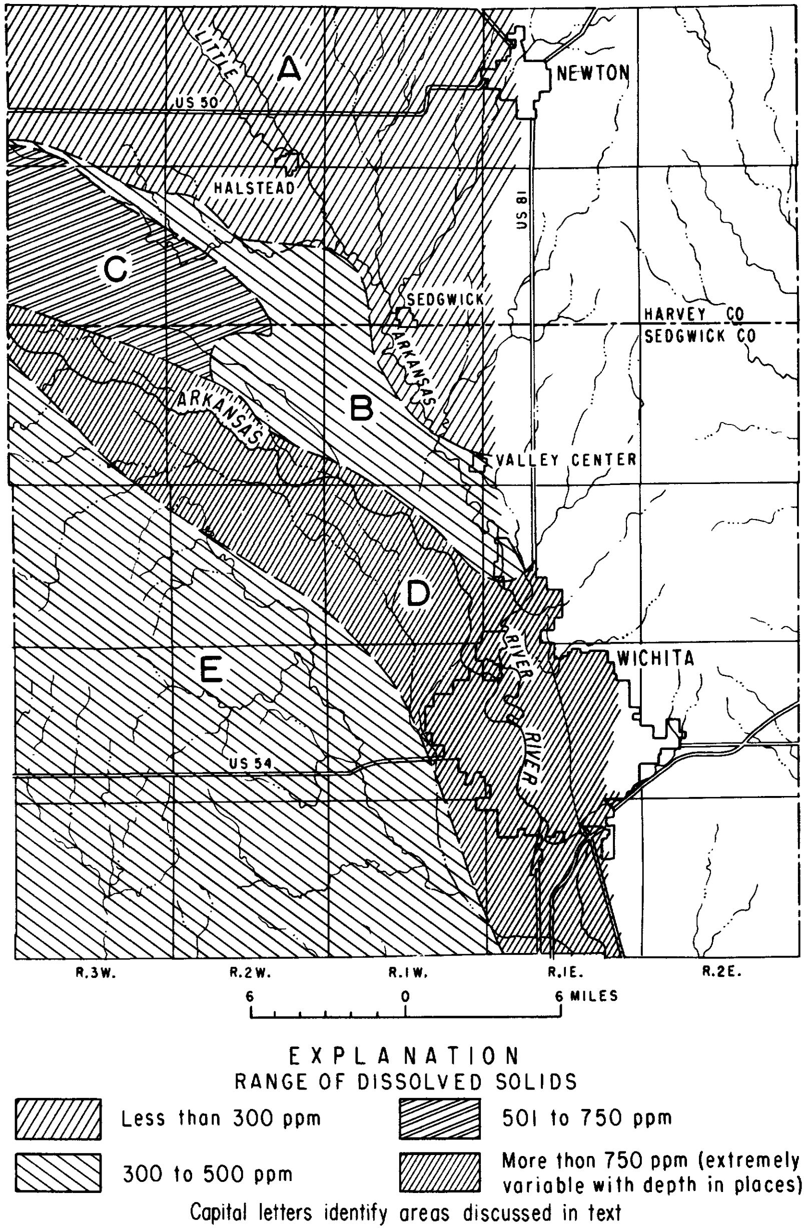


FIGURE 9.—Map showing the dissolved-solids content of water from unconsolidated deposits.

The chemical quality of the water most common in the different parts of the area is represented by selected analyses given in table 3. These analyses were from records available for about 340 wells (fig. 10); the water from some of the wells has been analyzed periodically for many years. Analyses for most of the wells have been published either by Williams and Lohman (1949) or by the Kansas State Board of Health in periodicals entitled "Chemical Analyses, Kansas Municipal Water Supplies," and analyses for many of the wells will be published in a report in preparation by the State and U.S. Geological Surveys on Sedgwick County.

### CONTAMINATION BY BRINES

Generally, the unconsolidated deposits have been well leached and contain only small amounts of chloride. However, intrusion of brines from the consolidated deposits and disposal of brines through sump ponds in oil fields have contaminated the water in the unconsolidated deposits in some places. Because chloride is one of the principal constituents in the brines, high concentrations of it in water from the unconsolidated deposits indicate that contamination has taken place (fig. 11).

Chloride concentrations are particularly high near the Arkansas River and Big Slough. During much of the year, concentrations of chloride in the Arkansas River are high, and some of the chloride in the ground water probably comes from the river.

The high chloride concentrations in the vicinity of Burrton are the results of the disposal of brines through sump ponds and shallow disposal wells in the 1930's and early 1940's. In 1947, according to Lohman and Williams (1949), chloride concentrations were several thousand parts per million; but according to the data from 1954 to 1960, they are less than 1,100 ppm. Most of the oil-well brines are now injected into deep wells; therefore, the brines except in a few places are no longer active sources of contamination to water in the unconsolidated deposits. Data from the State Board of Health indicate that as of November 1958, in Sedgwick and Harvey Counties combined, only about 38 barrels of brine per day was being discharged into 5 surface ponds, whereas about 57,000 barrels per day was being discharged into deep wells.

Jones (1938) reported severe contamination in the unconsolidated deposits in the north industrial area of Wichita by seepage of high-chloride water from the large drainage canal that flows through the city. Restrictions on the use of the drainage canal for industrial waste disposal probably have eliminated contamination from this source.

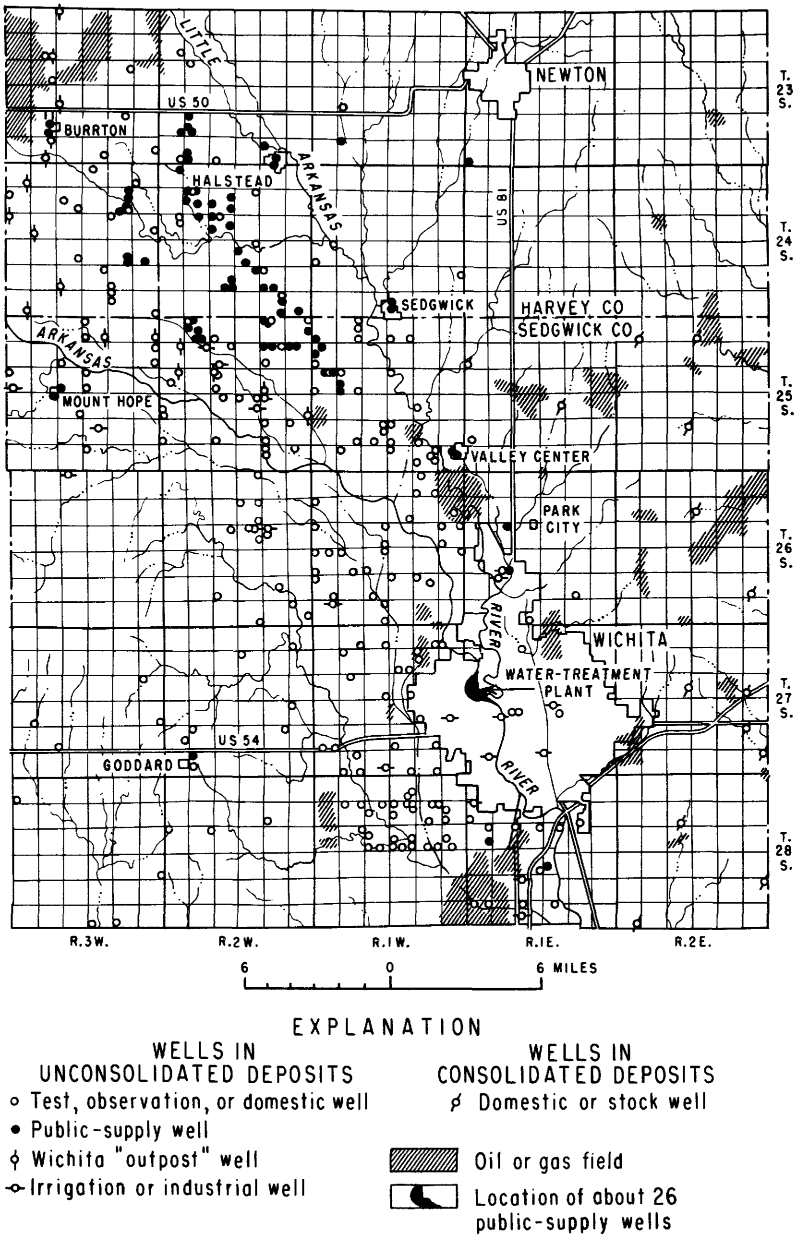


FIGURE 10.—Map showing location of wells for which chemical analyses of water are available.

TABLE 3.—*Selected chemical analyses, in parts per million, of water from unconsolidated deposits, Wichita area, Kansas*

[Analyses by Kansas State Board of Health unless footnoted]

| Well | Well depth (ft) | Date of collection | Temperature (°F) | Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | Alkalinity as $CaCO_3$ | Percent sodium | Sodium-adsorption ratio | Specific conductance (micromhos per cm at 25°C) | Classification for irrigation [1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Part A (See fig. 9.)** | | | | | | | | | | | | | | | | | | | | | | | |
| 23-1E-31ccc | ------ | 6-25-52 | ------ | 20 | 0.90 | 0.13 | 53 | 8.4 | 29 | | 199 | 37 | 15 | 0.2 | 7.5 | 270 | 166 | 3 | 163 | 28 | 1.0 | ------ | $C_2$, $S_1$ |
| 23-1W-32bb | 130 | 11-15-40 | ------ | ------ | .01 | ------ | 53 | 8.7 | 24 | | 220 | 24 | 9 | .1 | 2.0 | 272 | 168 | 0 | 180 | 24 | .8 | ------ | $C_2$, $S_1$ |
| 23-2W-7d | [2] 40 | 11-18-38 | 57 | ------ | .85 | ------ | 45 | 5.6 | 19 | | 198 | 3.7 | 5.5 | .2 | 2.2 | 181 | 138 | 0 | 162 | 23 | .7 | ------ | $C_2$, $S_1$ |
| 29bbb [3] | 226 | 1- -60 | ------ | [4] 13 | .30 | .18 | 36 | 6.0 | 21 | | 171 | 18 | 10 | [4] .2 | .4 | 186 | 114 | 0 | 140 | 26 | .9 | ------ | $C_2$, $S_1$ |
| 23-3W-34dda | 13 | 11-18-38 | 62 | ------ | <.15 | ------ | 46 | 11 | 45 | | 220 | 33 | 26 | .4 | 7.1 | 278 | 160 | 0 | 180 | 38 | 1.5 | ------ | $C_2$, $S_1$ |
| 24-1W-19a | [2] 40 | 9- 8-38 | 58 | ------ | 1.0 | ------ | 56 | 7.0 | 29 | | 259 | 8.2 | 5.5 | .1 | 2.2 | 239 | 171 | 0 | 212 | 27 | 1.0 | ------ | $C_2$, $S_1$ |
| 34bcd | [2] 46 | 3-21-41 | [4] 59 | ------ | .82 | ------ | 103 | 17 | 13 | | 320 | 64 | 17 | .2 | 2.7 | 424 | 327 | 65 | 262 | 8 | .3 | ------ | $C_2$, $S_1$ |
| **Part B** | | | | | | | | | | | | | | | | | | | | | | | |
| 24-2W-8bcc [3] | 230 | 1- -60 | ------ | [4] 13 | 1.4 | 0.02 | 66 | 10 | 45 | | 276 | 48 | 25 | [4] 0.4 | 0.0 | 340 | 204 | 0 | 226 | 31 | 1.4 | ------ | $C_2$, $S_1$ |
| 22aa | [2] 28 | 8- 3-38 | ------ | ------ | 1.9 | ------ | 63 | 13 | 54 | | 315 | 21 | 32 | .7 | 2.2 | 343 | 216 | 0 | 258 | 36 | 1.6 | ------ | $C_2$, $S_1$ |
| 26dcc [3] | 80 | 1- -60 | [4] 58 | [4] 14 | 1.4 | .01 | 53 | 9 | 59 | | 232 | 64 | 42 | [4] .4 | .1 | 350 | 171 | 0 | 190 | 43 | 2.0 | ------ | $C_2$, $S_1$ |
| 25-1W-18abb [3] | 170 | 1- -60 | ------ | ------ | .02 | .05 | 78 | 16 | 68 | | 327 | 49 | 70 | ------ | .3 | 464 | 258 | 0 | 268 | 36 | 1.8 | ------ | $C_3$, $S_1$ |
| 36acd [3] | [2] 52 | 2- 1-60 | ------ | 17 | .60 | .13 | 91 | 21 | 32 | | 356 | 74 | 9.0 | .4 | 1.0 | 420 | 314 | 22 | 292 | 18 | .8 | ------ | $C_3$, $S_1$ |
| 25-2W-23bbc | 35 | 3-14-58 | 62 | 17 | .04 | ------ | 66 | 12 | 61 | ------ | 246 | 47 | 58 | .5 | 15 | 398 | 214 | 12 | 202 | 38 | 1.8 | 726 | $C_2$, $S_1$ |
| **Part C** | | | | | | | | | | | | | | | | | | | | | | | |
| 24-3W-7bc | 35 | 8- 3-38 | ------ | ------ | 0.75 | ------ | 115 | 23 | 107 | | 368 | 113 | 136 | ------ | 2.2 | 680 | 384 | 82 | 302 | 38 | 2.4 | ------ | $C_3$, $S_1$ |
| 11dcc [3] | 143 | 1- -60 | ------ | ------ | 2.7 | 0.01 | 110 | 23 | 94 | | 298 | 124 | 106 | ------ | .0 | 654 | 368 | 124 | 244 | 36 | 2.1 | ------ | $C_3$, $S_1$ |
| 25-2W-5dcd [3] | 57 | 1- -60 | ------ | ------ | .06 | .00 | 70 | 15 | 62 | | 259 | 67 | 80 | ------ | 4.0 | 516 | 238 | 26 | 212 | 36 | 1.7 | ------ | $C_2$, $S_1$ |

**Part D**

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25-2W-36bab | [2] 12 | 11- 7-37 | ------ | ------ | <0.15 | ------ | 204 | 43 | 431 | | 239 | 312 | 775 | ------ | 8.9 | 1,890 | 685 | 489 | 196 | 58 | 7.2 | ------ | $C_4$, $S_2$ |
| 26-1E-20dcc | 40 | 5-22-59 | 58 | 16 | .14 | 0.12 | 141 | 42 | 45 | ------ | 383 | 200 | 70 | 0.2 | 2.4 | 705 | 524 | 210 | 314 | 16 | .9 | 1,160 | $C_3$, $S_1$ |
| 26-2W-14b | 255 | 11-13-44 | 60 | ------ | <.15 | ------ | 50 | 13 | 481 | | 333 | 167 | 550 | .4 | 1.3 | 1,430 | 178 | 0 | 310 | 68 | 16 | ------ | ------ |
| 15abb | 70 | 4- 8-57 | ------ | 22 | ------ | ------ | 108 | 40 | ------ | ------ | 317 | 40 | 90 | ------ | ------ | 499 | 148 | 0 | 260 | ------ | ------ | ------ | ------ |
| 15abb | 230 | 4- 8-57 | ------ | 22 | ------ | ------ | 100 | 44 | ------ | ------ | 356 | 136 | 400 | ------ | ------ | 1,270 | 144 | 0 | 292 | ------ | ------ | ------ | ------ |
| 27-1E-18ccd [3] | (2) | 5- -60 | ------ | ------ | .00 | .00 | 118 | ------ | 306 | ------ | 257 | 270 | 503 | ------ | 4.0 | 1,460 | 409 | 198 | 211 | 55 | 6.6 | ------ | $C_4$, $S_2$ |
| 18 [3] | (2) | 5- -60 | ------ | ------ | .00 | .00 | 128 | ------ | 150 | ------ | 289 | 139 | 270 | ------ | .6 | 916 | 411 | 174 | 237 | 43 | 3.2 | ------ | $C_3$, $S_1$ |
| 34bbc | [2] 27 | 9-24-57 | 59 | 11 | .54 | ------ | 229 | 37 | 131 | ------ | 329 | 428 | 205 | .6 | 4.4 | 1,210 | 724 | 454 | 270 | 28 | 2.1 | 1,840 | $C_3$, $S_1$ |
| 28-1E-7bab | 48 | 9-24-57 | ------ | 13 | 2.4 | ------ | 130 | 25 | 265 | ------ | 351 | 149 | 396 | .4 | .7 | 1,150 | 428 | 140 | 288 | 58 | 5.5 | 2,120 | $C_3$, $S_2$ |
| 28bbd | 36 | 8-15-58 | 65 | 16 | .66 | ------ | 99 | 19 | 131 | ------ | 336 | 114 | 150 | .8 | 1.7 | 697 | 325 | 49 | 276 | 47 | 3.2 | 1,160 | $C_3$, $S_1$ |

**Part E**

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25-3W-18cdc | 100 | 8-14-58 | 65 | 22 | 0.01 | ------ | 80 | 16 | 35 | ------ | 315 | 43 | 16 | 0.2 | 19 | 386 | 266 | 8 | 258 | 22 | 0.9 | 682 | $C_2$, $S_1$ |
| 26-3W-4baa | 100 | 8-15-58 | 64 | 23 | .03 | 0.00 | 74 | 14 | 45 | ------ | 331 | 30 | 18 | .1 | 15 | 382 | 242 | 0 | 272 | 29 | 1.3 | 660 | $C_2$, $S_1$ |
| 27-1W-32abb | 56 | 5-22-59 | 62 | 18 | .17 | .00 | 48 | 12 | 71 | ------ | 324 | 14 | 25 | .1 | 9.3 | 357 | 170 | 0 | 266 | 48 | 2.4 | 630 | $C_2$, $S_1$ |
| 27-2W-32bbb | ------ | 6-29-59 | ------ | 20 | .03 | .00 | 94 | 14 | 39 | | 339 | 13 | 57 | .2 | 6.2 | 410 | 292 | 14 | 278 | 23 | 1.0 | ------ | $C_2$, $S_1$ |
| 28-1W-11cddc | 114 | 1955 | ------ | 19 | .04 | .00 | 32 | 6.8 | 146 | ------ | 334 | 36 | 78 | .2 | 4.4 | 489 | 108 | 0 | 274 | 75 | 6.1 | ------ | $C_3$, $S_2$ |

[1] From U.S. Salinity Laboratory Staff (1954).
[2] Water from alluvium.
[3] Analysis by Wichita Water Department.
[4] Result from a previous analysis.

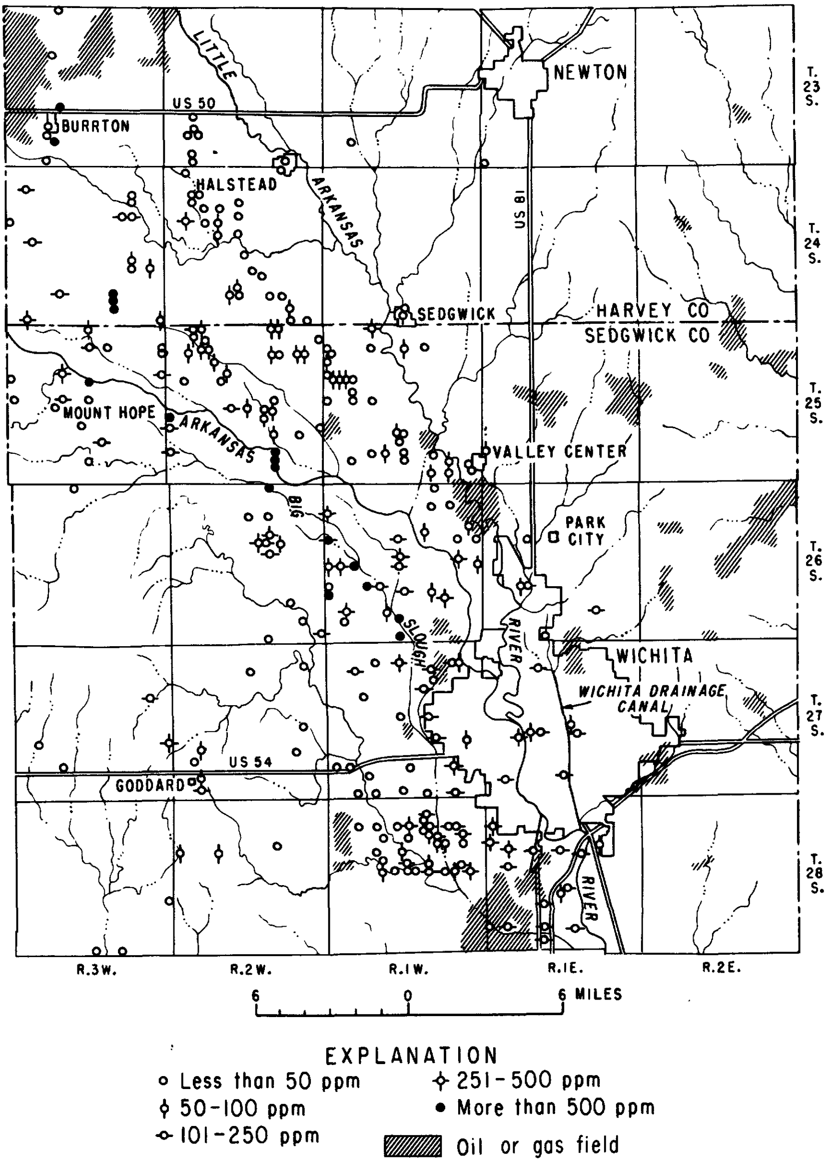


FIGURE 11.—Chloride concentrations in water from unconsolidated deposits, 1954–60.

Water having high concentrations of chloride might, under certain hydraulic conditions, move into the vicinity of the Wichita city wells southwest of Halstead and Sedgwick. Therefore, the Wichita Water Department established outpost wells from which samples of water are analyzed annually, or more frequently, for chloride content. No significant movement of high-chloride water toward the city wells has been detected as of 1961.

## SUITABILITY OF THE WATER FOR USE

The suitability of water for use is dependent largely on the dissolved chemical constituents in the water. The concentrations of the various constituents that can be tolerated differ according to the use of the water. Consequently, water suitable for one use may be unsuitable for another.

The suitability of water for public supply or domestic use commonly is judged in relation to standards established for drinking water by the U.S. Public Health Service. The standards, adopted in 1914 to protect the health of the traveling public, were revised several times in subsequent years. The latest revisions by the U.S. Public Health Service (1962), approved by the Secretary of Health, Education, and Welfare, are, in part, as follows:

| *Constituent* | *Maximum concentration (ppm)* |
|---|---|
| Iron (Fe) | 0.3 |
| Manganese (Mn) | .05 |
| Sulfate ($SO_4$) | 250 |
| Chloride (Cl) | 250 |
| Fluoride (F) | [a] 1.0 |
| Dissolved solids | 500 |

[a] Varies for different parts of the United States.

Iron and manganese are objectionable in water mostly because they stain laundry, porcelain fixtures, and cooking utensils, and because they contribute an unpalatable flavor to the water and to coffee, tea, and some foods cooked with the water. Also, iron and manganese stimulate the growth of Crenothrix and similar organisms that are troublesome in wells and distribution systems. Sulfate in high concentrations is objectionable principally because it has cathartic effects, especially if magnesium is also present, and because it helps form deposits in heat exchangers. Chloride in high concentrations imparts a salty taste to water, but the threshold of detection differs with individuals.

Water from properly constructed wells in the unconsolidated deposits has little turbidity or color, has no offensive taste or odor, and ranges in temperature from about 55° to 65°F. Concentrations of magnesium and fluoride are much less than the maximums of the standards, and concentrations of sulfate, chloride, and dissolved solids exceed the maximums only in part *D* (fig. 9) and in a few other places. Concentrations of iron and manganese, however, exceed the maximums in nearly the entire area. (See table 3.)

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The following gradations for hardness generally are recognized:

| Hardness as $CaCO_3$ (ppm) | Rating | Suitability |
|---|---|---|
| 0–60 | Soft | Suitable for many uses without further softening. |
| 61–120 | Moderately hard | Usable except in some industrial applications. |
| 121–180 | Hard | Softening required by laundries and some other industries. |
| 181+ | Very hard | Requires softening for many uses. |

Water from the unconsolidated deposits at most places is hard or very hard. Water from the alluvium in the Arkansas River valley is extremely hard (more than 400 ppm); however, in some places it contains little iron or manganese.

Industries use water principally for waste removal, sanitation, in heat exchangers, or as process water—water that comes into contact with, or is incorporated into, a product. Water used strictly for sanitation should preferably be soft and should contain less than 0.3 ppm of iron and manganese; for laundering, the hardness should not exceed 50 ppm and the iron and manganese together, 0.2 ppm. If water for sanitation and for drinking is from a common distribution system, it must, of course, meet the quality requirements for drinking.

Water used in heat exchangers should be relatively free of organisms that form slime. The high concentrations of iron in water from the unconsolidated deposits tend to favor the growth of several species of such organisms.

A thin layer of scale in heat exchangers and pipes is beneficial in that the scale protects the metal from corrosive attack by the water. If, however, much scale is formed, the heat-insulating properties of the scale may decrease the efficiency of the heat exchangers. Also, the scale may eventually clog pipes and radiators. Scale from untreated water is mostly calcium carbonate, and the tendency of water to deposit scale or to corrode metal can be estimated from chemical analyses. The analyses in table 3 indicate that the water is slightly undersaturated with respect to calcium bicarbonate and has neither a strong tendency for scale formation nor for corrosiveness.

The tolerances for process water differ with the type of industry. In the food industry, the tolerances are the same as those for drinking water except for iron and manganese, which are 0.1 or 0.2 ppm. In most manufacturing industries, tolerances have been established principally for turbidity, color, hardness, and iron and manganese.

Water from parts *A*, *B*, and *E* of the area (fig. 9), if softened and if treated for iron removal, will meet the requirements for most industrial purposes. (See table 3.) Water from some places in part *D*—where most of the industrial establishments are located—will not meet the requirements for process water even if softened and treated for iron removal because the dissolved solids are too high.

Water for irrigation should be of such quality that continued use of it will not adversely affect the productivity of the land. High dissolved-solids content may cause undesirable accumulations of salts in the root zone of the soil, and disproportionately high concentrations of sodium in the water may cause the soil structure to deteriorate. Concentrations of bicarbonate too much in excess of the concentrations of calcium and magnesium may cause the pH of the soil to become high and may cause a soil condition known as "black alkali."

According to a system of classifying water proposed by the U.S. Salinity Laboratory Staff (1954), the tendency of water to cause accumulations of salt in the root zone of the soil is designated by the term "salinity hazard" of the water and is indicated by the letter "C" and subscripts from 1 to 4; the higher the salinity hazard, the higher the subscript. The tendency of water to cause deterioration of the soil structure because of too much sodium is designated by the term "sodium hazard" of the water and is indicated by the letter "S" and subscripts from 1 to 4; the higher the "sodium hazard," the higher the subscript.

In part *A* and in most of parts *B* and *E* of the area, the water is of the $C_2$–$S_1$ classification. (See table 3.) Such water is unlikely to cause accumulations of salt or to cause deterioration of the soil structure if a moderate amount of leaching is provided. In most of parts *C* and *D* the water is of the $C_3$–$S_1$ classification, and in some of part *D* the water is of the $C_4$–$S_2$ classification. Considerable caution should be exercised in using such water on soils with restricted drainage. Generally, in all parts of the area the concentrations of bicarbonate either are less than those of calcium plus magnesium or are more by only a small amount. Thus, use of water from the unconsolidated deposits is unlikely to cause the pH of the soil to become high.

## QUANTITY IN RELATION TO USE

All but a small part of the water used in the area is ground water. The quantity of water used for specific purposes changes greatly from year to year and depends on the quantity and distribution of precipitation throughout the year; for some purposes it cannot be determined accurately.

The annual quantities of water, by use, for which rights are approved or are pending approval by the State are shown in figure 12 and allow for considerable fluctuation, particularly in municipal use. The total of these quantities probably exceed average actual water use by more than 75 percent in years of normal precipitation. Municipal water rights account for about 60 percent of the total, most of which is for the city of Wichita and its suburbs. About 25 percent of the water actually used by Wichita is for industries located within the city. Industries providing their own water supplies account for about 20 percent of the total. Irrigation and rural-domestic water rights including stock watering account for the remaining 20 percent, of which 15 percent is for irrigation. During many years the distribution of precipitation is near optimum for crop production, and little water is used for irrigation.

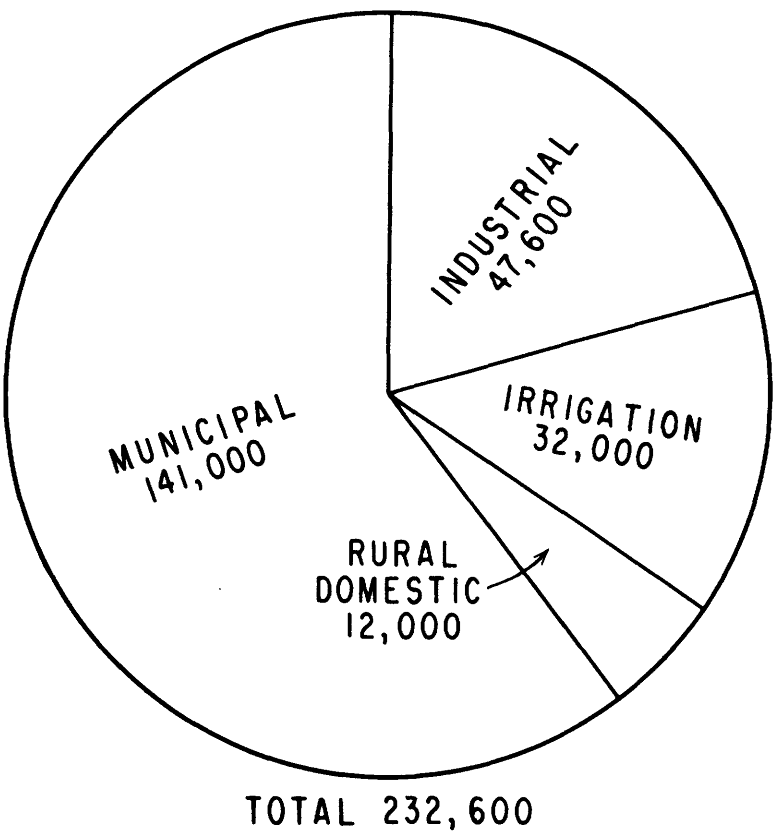



FIGURE 12.—Chart showing annual quantities of ground water in acre-feet, by use, for which rights are approved or are pending approval by the State, July 1, 1960.

The major areas of water withdrawal are widely dispersed, but they are all in the area underlain by valley deposits. The annual volumes of water for which water rights are approved or are pending approval are shown, by township, in figure 13. The larger volumes are for the townships that provide municipal and industrial water supplies, and the smaller volumes are for townships that provide mainly irrigation water supplies. Domestic water supplies are con-

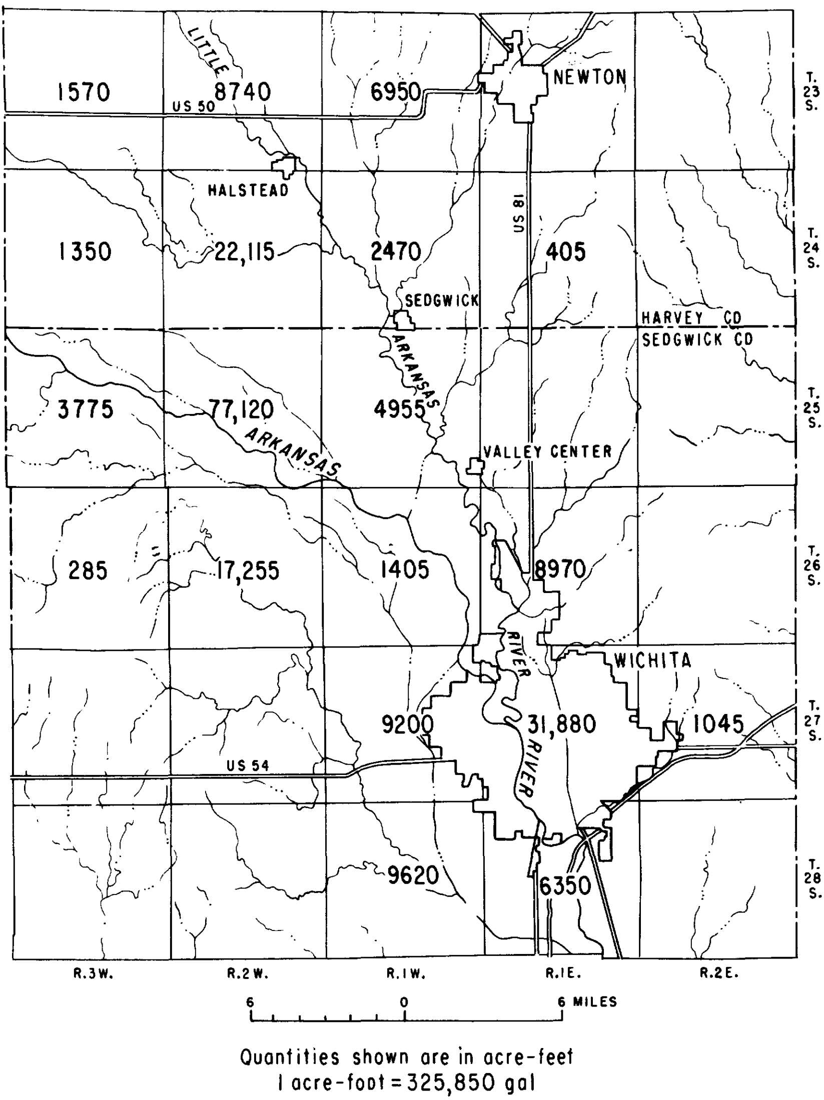



**Figure 13.**—Map showing annual volume of ground water, by township, for which rights are approved or are pending approval, July 1, 1960.

sidered as vested rights by the State and do not require filing of a water right and thus are not included in the totals shown on figure 13.

As growth in the Wichita area continues and the demand for water increases, conservation measures to augment the ground-water supply may become necessary. Artificial recharge, whereby surplus surface water is diverted underground, and induced infiltration of water from rivers to nearby wells are two methods that might be successful. The city of Wichita is conducting pilot investigations of both methods, and preliminary results indicate that as of 1960 induced infiltration of river water is the only method that may be economically justifiable.

Figure 14 shows where artificial recharge or induced infiltration of river water is possible and where induced infiltration of river water now takes place. The area where recharge pits might be successfully operated is that in which the permeable sand and gravel have less than 10 feet of overburden. In most of this area, water levels are relatively high and little storage space is available for additional water. Along the Arkansas River, conditions are highly favorable for induced infiltration of the river water to properly located wells, but the quality of the river water is so poor that the water thus obtained would have only limited use. Along the Little Arkansas River, conditions are less favorable locally for induced infiltration because of the low permeability of the riverbed and banks; but along much of its course, where the river channel cuts into permeable sand and gravel, pumping of properly located wells could induce infiltration of river water. The water quality of the Little Arkansas River generally is good; therefore, the water thus obtained would be satisfactory for most uses. The floodway west of Wichita carries water only at high stages of the Arkansas and Little Arkansas Rivers, but it offers good possibilities as a source of recharge. Along the reach of the floodway (fig. 14) the channel cuts into permeable sand and gravel near the level of the water table, except for one area southwest of Wichita where the channel cuts into clayey silt. Although little storage space for additional water is available, pumping of properly located wells along the floodway could lower the water table and create storage space for recharge at high stages of the Arkansas and Little Arkansas Rivers.

Induced infiltration of river water takes place in Wichita and in the southeastern part of T. 25 S., R. 2 W. (See fig. 14.) Many industrial and air-conditioning wells in the business district of Wichita have pumped large quantities of water for many years. Thus, water levels have been lowered, and water from the Little Arkansas and Arkansas Rivers and from the Wichita drainage canal has

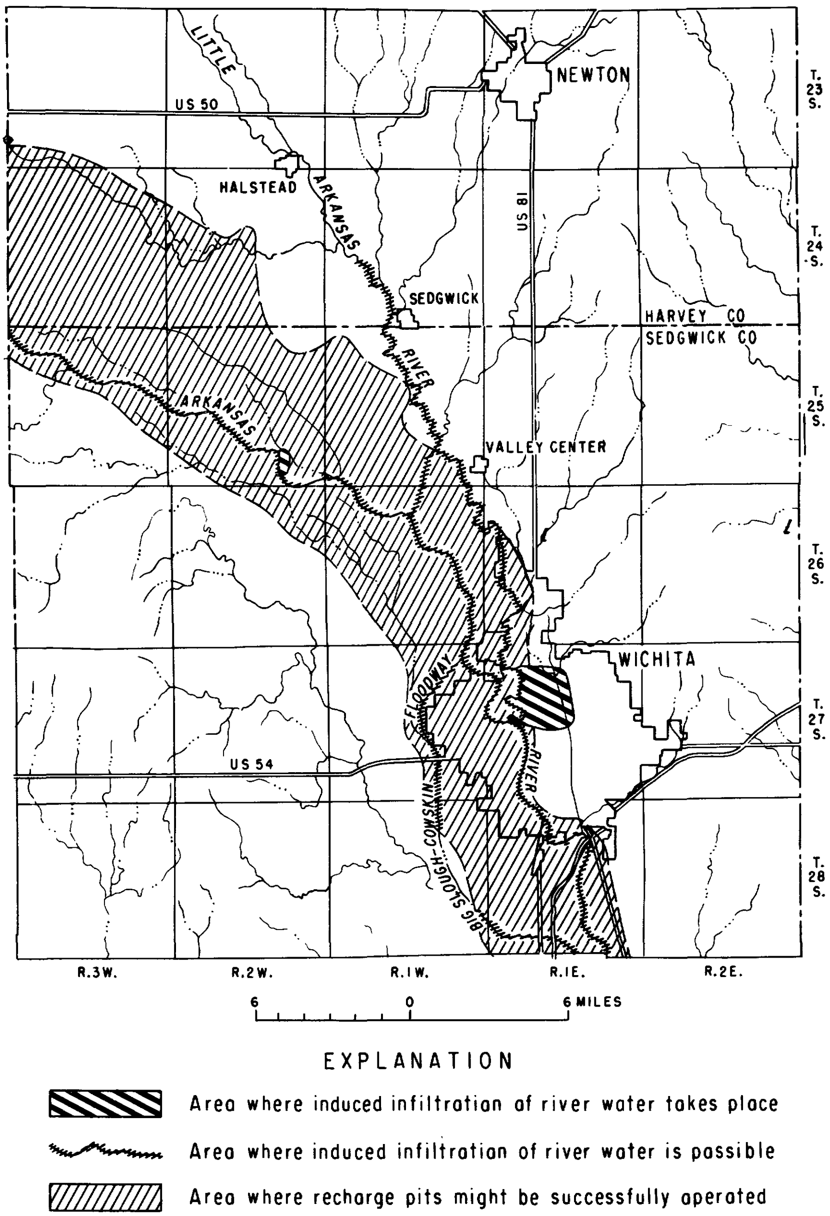



FIGURE 14.—Map showing areas where induced infiltration of river water or artificial recharge is possible.

moved into the area. The Wichita "local" well field, adjacent to the business district, is in the triangular area formed by the junction of the Arkansas and Little Arkansas Rivers and causes infiltration of river water when the wells are pumped. The Wichita "Bentley reserve" well field in T. 25 S., R. 2 W., consists of six wells designed to cause infiltration of water from the Arkansas River. Water from these wells is of unsatisfactory chemical quality when used alone, but it can be used when mixed with better quality water from the Wichita "Equus beds" well field to the north. The "reserve" well field generally is used only during periods of peak water demand or when power or pipeline failures restrict withdrawals of water from other sources.

## WATER FROM CONSOLIDATED DEPOSITS

The consolidated deposits—the Wellington Formation and the Ninnescah Shale—are not sources of large water supplies in most of the area. Where present near the surface in the southwestern and eastern parts of the area (pl. 1), they supply water to most domestic and stock wells and are the only sources of usable ground water.

The Wellington Formation yields water to all domestic and stock wells east of the Tertiary(?) and Quaternary deposits; but the amount is usually small, and the wells often fail during dry periods. In a narrow zone 1 to 3 miles in width along the eastern edge of the area, thin gypsum beds that contain many solution openings yield highly mineralized water. Large springs issue from these beds where exposed, and many of the creeks fed by these springs have been impounded to form stock ponds and small recreational lakes. Wells penetrating these beds yield as much as 350 gpm, and one industry utilizes the water for cleaning after dilution with good-quality surface water.

Locations of wells producing from the Wellington Formation for which chemical-quality records are available are indicated on figure 10. All the wells are near the eastern border of the area where no water can be obtained from the unconsolidated deposits mantling the shale. The selected chemical analyses given in table 4 indicate that the water is of poor quality for most uses. The water is very hard and generally contains excessive amounts of dissolved solids. Most of the water contains iron and sulfate, and some of the water also contains chloride in excess of recommended standards. (See p. I 27.) Concentrations of nitrate in much of the water are far in excess of the 44 ppm suggested by some investigators (Maxcy, 1950) as the safe upper limit for drinking water for infants.

TABLE 4.—*Selected chemical analyses, in parts per million, of water from consolidated deposits, Wichita area, Kansas*

[Analyses by Kansas State Board of Health]

| Well | Well depth (ft) | Date of collection | Temperature (°F) | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | Alkalinity as $CaCO_3$ | Percent sodium | Sodium-adsorption ratio | Specific conductance (micromhos per cm at 25°C) | Classification for irrigation [1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wellington Formation** | | | | | | | | | | | | | | | | | | | | | | |
| 23-1W-3ac | 84 | 11-19-38 | 60 | ------ | 1.0 | 197 | 79 | 84 | | 190 | 663 | 106 | ------ | 3.3 | 1,230 | 819 | 663 | 232 | 18 | 1.3 | ------ | $C_3$, $S_1$ |
| 24-1E-7aab | 100 | 11-19-38 | 59 | ------ | .40 | 170 | 68 | 106 | | 276 | 282 | 194 | ------ | 173 | 1,130 | 705 | 479 | 337 | 25 | 1.7 | ------ | $C_3$, $S_1$ |
| 25-2E-3ccc | [2] 19 | 11-22-58 | 58 | 18 | .36 | 592 | 79 | 83 | ------ | 316 | 1,550 | 77 | 0.8 | 1.9 | 2,560 | 1,800 | 1,540 | 259 | 9 | .9 | 2,920 | $C_4$, $S_1$ |
| 26-2E-10cbb | 30 | 11-25-58 | 56 | 18 | .03 | 223 | 94 | 49 | ------ | 451 | 269 | 121 | .2 | 283 | 1,280 | 943 | 573 | 370 | 10 | .7 | 2,050 | $C_3$, $S_1$ |
| 27-2E-13ccc | ([3]) | 5-18-59 | 55 | 12 | .33 | 624 | 74 | 152 | ------ | 332 | 1,370 | 345 | .8 | 2.2 | 2,750 | 1,860 | 1,590 | 272 | 15 | 1.5 | 3,800 | $C_4$, $S_1$ |
| 28-2E-25aaa | 35 | 11-26-58 | 60 | 16 | .03 | 202 | 49 | 15 | ------ | 386 | 23 | 105 | .3 | 310 | 910 | 706 | 390 | 316 | 5 | .3 | 1,570 | $C_3$, $S_1$ |
| **Ninnescah Shale** | | | | | | | | | | | | | | | | | | | | | | |
| 27-4W-12ccb [4] | 49 | 12-17-58 | 53 | 16 | 0.48 | 152 | 37 | 14 | ------ | 237 | 13 | 68 | 0.2 | 319 | 736 | 531 | 337 | 194 | 5 | 0.3 | 1,230 | $C_3$, $S_1$ |
| 26ccd [4] | 50 | 12-17-58 | 52 | 16 | .28 | 110 | 26 | 27 | ------ | 83 | 72 | 90 | .1 | 212 | 594 | 382 | 314 | 68 | 13 | .6 | 1,010 | $C_3$, $S_1$ |
| 28-4W-32ddd [4] | 64 | 1-22-59 | 62 | 17 | [5] .08 | 75 | 41 | 55 | ------ | 373 | 89 | 32 | .1 | 40 | 533 | 356 | 50 | 306 | 25 | 1.3 | 879 | $C_3$, $S_1$ |

[1] From U.S. Salinity Laboratory Staff (1954).
[2] Flowing well.
[3] Spring.
[4] Outside report area.
[5] Manganese, 0.00 ppm.

In the Ninnescah Shale, water that can be recovered by wells generally is found only at relatively shallow depths where weathering has created small openings by solution of material. The yield of most wells is 1 to 5 gpm. No deep wells in the Ninnescah are known to produce water.

No records of the quality of the water from the Ninnescah Shale in the area are available. However, several analyses for water from wells just outside the western boundary are given in table 4. The water is of much better quality than that from the Wellington Formation, but it also is extremely hard and has high concentrations of nitrate.

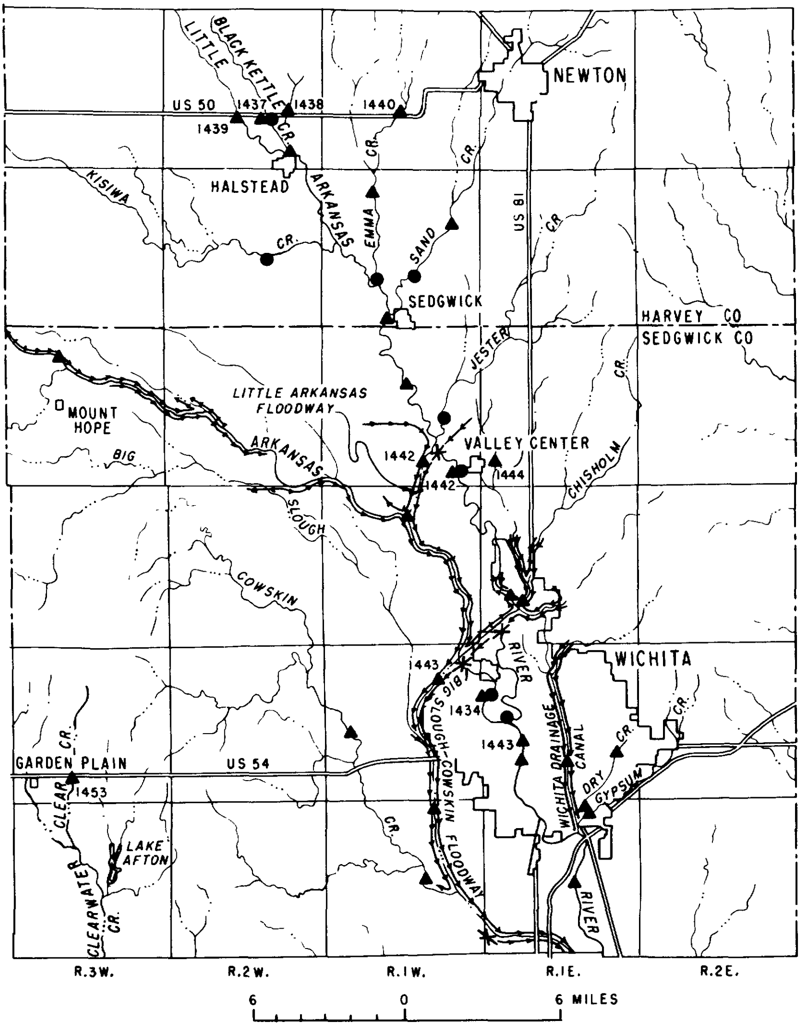
## SURFACE WATER

Only a small part of the water withdrawn for use in the area is surface water, mostly from the Arkansas and Little Arkansas Rivers that join in downtown Wichita (fig. 15). However, development of potential surface supplies will be necessary if the water demand continues to increase. The Arkansas River upstream from the Little Arkansas River drains 39,076 square miles, which includes most of the southeast quarter of Colorado and most of the southern half of Kansas (fig. 1). John Martin Reservoir regulates headwater flow for irrigation in eastern Colorado and extreme western Kansas, but it is too far upstream to have a significant effect on the flow at Wichita. The Little Arkansas River, which originates 75 miles northwest of Wichita, drains 1,343 square miles. Minor tributaries in the area include Emma, Sand, Cowskin, Big Slough, and Chisholm Creeks (fig. 15).

Continuous stage and discharge records have been obtained for long periods at gaging stations on the Little Arkansas River at Valley Center and on the Arkansas River just upstream from the Little Arkansas River near Wichita and just downstream from the Little Arkansas River at Wichita. These records have been extended, by correlation, to estimate streamflow for the base period 1921–56. Stage and discharge records have been obtained also at other places in the area. (See table 5.)

### USE OF THE WATER

Withdrawal of streamflow for industry in the Wichita area is small and is mostly nonconsumptive; the water is returned nearly undiminished in quantity to the streams. Withdrawal of streamflow for irrigation and some recreation is consumptive, and little of the water is returned to the streams. Withdrawal for irrigation is usually greatest when rainfall is deficient during the growing season.




EXPLANATION

Ungated control structure

Levee

▲ Stage and discharge records

● Water-quality records

*Station numbers correspond to those in Geological Survey water-supply papers on surface-water records*

FIGURE 15.—Map showing floodways and sites for which surface-water records are available.

TABLE 5.—*Stations for which stage and discharge records are available and period of records*

[Collecting agency: KBA, Kansas Board of Agriculture, Division of Water Resources; USGS, U.S. Geological Survey; USWB, U.S. Weather Bureau; and WDPW, Wichita Department of Public Works]

| Station no. on fig. 15 | Station name | Location | | | Total drainage area (sq mi) | Water years of record | Collecting agency | Type of record |
|---|---|---|---|---|---|---|---|---|
| | | Sec. | T. | R. | | | | |
| ------ | Arkansas River near Mount Hope. | 9 | 25 S. | 3 W. | ---------- | 1951, 1957– | WDPW | Occasional peak stage and discharge. |
| ------ | Arkansas River at Wilson Bridge. | 10 | 26 S. | 1 W. | ---------- | 1957– | WDPW | Do. |
| 1434 | Arkansas River near Wichita | 18 | 27 S. | 1 E. | 39, 072 | 1921–35<br>1958– | USGS<br>WDPW | Daily stage and discharge.<br>Occasional peak stage and discharge. |
| 1437 | Black Kettle Creek near Halstead. | 27 | 23 S. | 2 W. | 60 [1] | 1954– | KBA | Occasional low-period discharge. |
| 1438 | Black Kettle Creek tributary near Halstead. | 23 | 23 S. | 2 W. | 1. 6 [1] | 1957– | USGS | Annual peak stage and discharge. |
| 1439 | Little Arkansas River near Halstead. | 28 | 23 S. | 2 W. | 730 [1] | 1954–59 [2] | KBA | Occasional low-period discharge. |
| ------ | Little Arkansas River at Halstead. | 35 | 23 S. | 2 W. | 850 [1] | 1904–44, 1957– | WDPW | Occasional peak stage and discharge. |
| 1440 | East Emma Creek near Halstead. | 21 | 23 S. | 1 W. | 60 [1] | 1957– | USGS | Annual peak stage and discharge. |
| ------ | Emma Creek at Rd. 578 | 4 | 24 S. | 1 W. | ---------- | 1959– | WDPW | Occasional peak stage and discharge |
| ------ | Sand Creek at Rd. 580 | 14 | 24 S. | 1 W. | 90 [1] | 1959– | WDPW | Do. |
| ------ | Little Arkansas River: | | | | | | | |
| ------ | At Sedgwick | 33 | 24 S. | 1 W. | 1, 252 | 1916– | USWB | Daily stage during high water. |
| ------ | At Fry Bridge | 15 | 25 S. | 1 W. | ---------- | 1957– | WDPW | Occasional peak stage and discharge. |
| 1442 | At Valley Center [3] | 36 | 25 S. | 1 W. | 1, 327 | 1922– | USGS | Daily stage and discharge. |
| ------ | At Ripley Station | 29 | 26 S. | 1 E. | 1, 335 | 1944– | USWB | Daily stage. |
| ------ | At Hellers Grove | 29 | 26 S. | 1 E. | 1, 335 | 1920–29 | USWB | Daily stage, fragmentary. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1444 | West Fork Chisholm Creek tributary at Valley Center. | 31 | 25 S. | 1 E. | [1] 6.5 | 1957– | USGS | Annual peak stage and discharge. |
| ------ | Chisholm Creek at Arkansas Ave. | 29 | 26 S. | 1 E. | [1] 61 | 1958–59 | WDPW | Occasional peak stage and discharge. |
| 1443 | Arkansas River at Wichita [4] | 20 | 27 S. | 1 E. | [5] 40,420 | {1934– | USGS | Daily stage and discharge. |
| | | | | | | {1897– | USWB | Daily stage, fragmentary. |
| ------ | Arkansas River at Harry St | 29 | 27 S. | 1 E. | ---------- | 1958–59 | WDPW | Occasional peak stage and discharge. |
| ------ | Wichita drainage canal at Lincoln St. | 27 | 27 S. | 1 E. | 28.7 | 1944, 1957– | WDPW | Do. |
| ------ | Gypsum Creek at Wassal St | 3 | 28 S. | 1 E. | ---------- | 1958– | WDPW | Do. |
| ------ | Dry Creek at Lincoln St | 25 | 27 S. | 1 E. | ---------- | 1958 | WDPW | Do. |
| ------ | Dry Creek at Hillside Ave | 3 | 28 S. | 1 E. | ---------- | 1959 | WDPW | Do. |
| ------ | Arkansas River at Stuckey Rd | 22 | 28 S. | 1 E. | ---------- | 1958, 1960 | WDPW | Do. |
| ------ | Big Slough-Cowskin floodway at State Route 42. | 2 | 28 S. | 1 W. | ---------- | 1958, 1960 | WDPW | Do. |
| ------ | Cowskin Creek at Maize Rd | 19 | 27 S. | 1 W. | ---------- | 1959 | WDPW | Do. |
| ------ | Cowskin Creek at 47th St. South. | 22 | 28 S. | 1 W. | [1] 110 | 1955, 1959 | WDPW | Do. |
| 1453 | Clear Creek near Garden Plain | 33 | 27 S. | 3 W. | [1] 5.5 | 1957– | USGS | Annual peak stage and discharge. |

[1] Approximate.
[2] Gaged below Black Kettle Creek since November 1959.
[3] Includes discharge at floodway, sec. 34, T. 25 S., R. 1 W.
[4] Includes discharge at floodway, sec. 11, T. 27 S., R. 1 W.
[5] Prior to diversion of Chisholm Creek, July 1958.

As of July 1, 1960, no applications have been filed to appropriate water from the main stem of the Arkansas River in the area. The water is used only to dilute industrial and municipal wastes. Records of the Divison of Water Resources, Kansas State Board of Agriculture, show the following established and pending rights as of July 1, 1960, for use of water from the Little Arkansas River basin.

The following appropriated or pending water rights as of July 1, 1960, are filed for the small streams of the area: Industrial and recreation use, none; and irrigation from tributaries west of Wichita, 284 acre-feet per year.

| *Little Arkansas River basin* | *Use* | *Acre-feet per year* |
|---|---|---|
| Upstream from Halstead | Industrial | 47 |
| | Irrigation | 2, 737 |
| | Recreation | 52 |
| Upstream from Sedgwick | Industrial | 47 |
| | Irrigation | 4, 690 |
| | Recreation | 52 |
| Upstream from mouth | Industrial | 47 |
| | Irrigation | 5, 507 |
| | Recreation | 52 |

Waste disposal is the only important nonwithdrawal use of water in the area. Significant amounts of wastes comes from municipal sewage, the aircraft industries near Wichita, the oil refineries at Wichita and in the headwaters of Little Arkansas River at McPherson, the salt plants and paper-product plants at Hutchinson, and the many slaughterhouses and milk-product plants. Formerly, considerable quantities of brines came from the operation of salt mines near Hutchinson and from separation processes in the production of crude oil; but in recent years, changes in disposal methods have reduced pollution from these sources.

Each municipality in the area applies secondary treatment to its sewage, and the effluent is discharged into the Arkansas River or its tributaries. Data in table 6 have been compiled by the Kansas State Board of Health, Division of Sanitation, which has the basic responsibility for pollution control in Kansas. For the present degree of sewage treatment, the desirable minimum flows in table 6 indicate the amount of water needed to maintain a satisfactory dissolved oxygen level and to dilute wastes to the point that nuisance conditions will not be created. In the two largest cities, Wichita and Newton, sewage plants have more than adequate capacity; but in many of the smaller towns, sewage plants are overloaded and at times release only partly treated sewage to the streams.

TABLE 6.—*Data on sewage disposal*

| Cities and towns | Population [1] (1960) | Design capacity of plant (mgd) | Average treatment in 1959 (mgd) | Desirable minimum streamflow (mgd) | Stream receiving effluent |
|---|---|---|---|---|---|
| Andale | 432 | 0. 05 | 0. 04 | 0. 3 | Cowskin Creek tributary. |
| Burrton | 774 | . 09 | . 09 | . 3 | Kisiwa Creek. |
| Colwich | 703 | . 06 | . 07 | . 3 | Cowskin Creek. |
| Garden Plain | 560 | . 03 | . 05 | . 3 | Polecat Creek. |
| Goddard | 533 | . 03 | . 04 | . 3 | Cowskin Creek tributary. |
| Halstead | 1, 598 | . 25 | . 16 | 1. 0 | Little Arkansas River. |
| Haysville | 5, 836 | . 40 | . 56 | 1. 7 | Cowskin Creek. |
| Maize | 623 | . 04 | . 08 | . 3 | Big Slough Creek. |
| Mount Hope | 539 | . 05 | . 05 | . 3 | Arkansas River. |
| Newton | 14, 877 | 2. 0 | 1. 5 | 8 | Sand Creek. |
| Park City | (2) | . 50 | . 50 | 2. 3 | Chisholm Creek. |
| Sedgwick | 1, 095 | . 14 | . 10 | 1. 0 | Little Arkansas River. |
| Valley Center | 2, 570 | . 45 | . 22 | 1. 6 | Do. |
| Wichita | 254, 698 | 36. 0 | 26 | 130 | Arkansas River. |

[1] U.S. Federal census.
[2] Unincorporated.

As the population and industry of the area increase, the amounts of wastes also increase. Provision for adequate disposal of additional wastes will be a serious problem because even now the amount of water available for dilution is insufficient at times. About a third of the time, flow in the Arkansas River is less than the 130 mgd (million gallons per day) needed for dilution of effluent from the Wichita sewage plant. (See p. I 43.) Probably tertiary treatment of sewage will be required eventually if nuisance conditions in the stream are to be avoided.

## VARIATIONS IN FLOW

Streamflow in the area is defined from records for the following sites (fig. 15):

Station 1434, Arkansas River near Wichita (at 16th St. just upstream from Little Arkansas River).

Station 1442, Little Arkansas River at Valley Center (16 miles upstream from mouth).

Station 1443, Arkansas River at Wichita (at Douglas Ave. just downstream from Little Arkansas River).

The variations in monthly discharge at these three sites are shown in figure 16. The mean discharge at each site is highest from April to August when average rainfall is high. The mean discharge is more constant during the year on the Arkansas River than on the

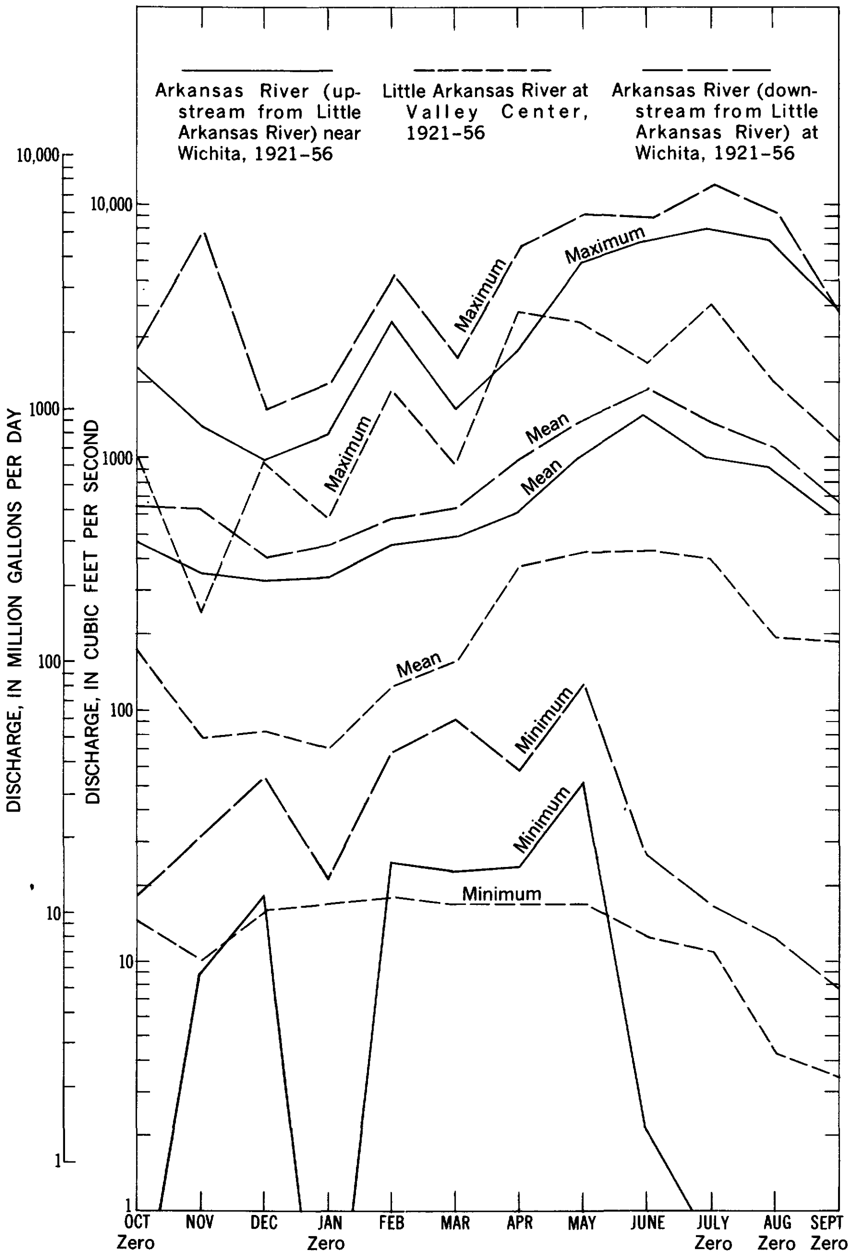



FIGURE 16.—Variations in monthly discharge—Arkansas River, near Wichita, 1921–56, Little Arkansas River at Valley Center, 1921–56, Arkansas River, at Wichita, 1921–56.

Little Arkansas River, but the minimum flow is markedly more erratic. In fact, during 5 of the 12 months the discharge of the Arkansas River just upstream from the Little Arkansas River has been zero, and flow at Wichita has been sustained by inflow from the Little Arkansas River. Effluent from the Wichita sewage-treatment plant enters the Arkansas River at the south side of the city 6 miles downstream from the gaging station at Wichita and increases the discharge of the river. In 1959 the average increase was 26 mgd (records of Kansas State Board of Health). This increment to the flow of the Arkansas River, as delineated in figure 16, is an appreciable addition during low-water periods.

Variation in flow of the small streams in the Wichita area has not been defined. However, from a study of the mean discharge of large streams in Kansas for the base period 1921–56 (Furness, 1960, fig. 124), the mean discharge of the small streams over a long-term period is estimated to be from 0.1 to 0.2 mgd from each square mile of drainage. However, considerable variation from the estimate can be expected for individual small streams.

Records of average and extreme flows show seasonal trends, but they do not show the percentage of time that given rates of flow are maintained; therefore, flow-duration curves were prepared for four points on the Arkansas and Little Arkansas Rivers. (See fig. 17.) The curve for a site 2 miles northwest of Halstead (sta. 1439, fig. 15), where periodic low-flow discharges were measured during 1954–59, was estimated with methods developed by Furness (1959, p. 186–211). All curves define the total runoff upstream from the sites, which includes flow diverted into floodways. The duration curves may be used to estimate the future availability of streamflow at each site. For example, during 92 percent of the time, the flow of both Arkansas River near Wichita and Little Arkansas River at Valley Center may be expected to exceed 10 mgd. The Arkansas River near Wichita would stop flowing about 1 percent of the time, whereas the Little Arkansas River at Valley Center would stop flowing less than 0.1 percent of the time. The accuracy of such estimates depends on how well the records used to prepare the curves represent flow over long periods. For added reliability the flow-duration data for the three gaged sites have been correlated with selected long-term records for sites outside the area to reflect regional rather than local conditions. The period 1921–56 is one in which both wet and dry periods are well represented and, therefore, is a reasonable base for prediction.

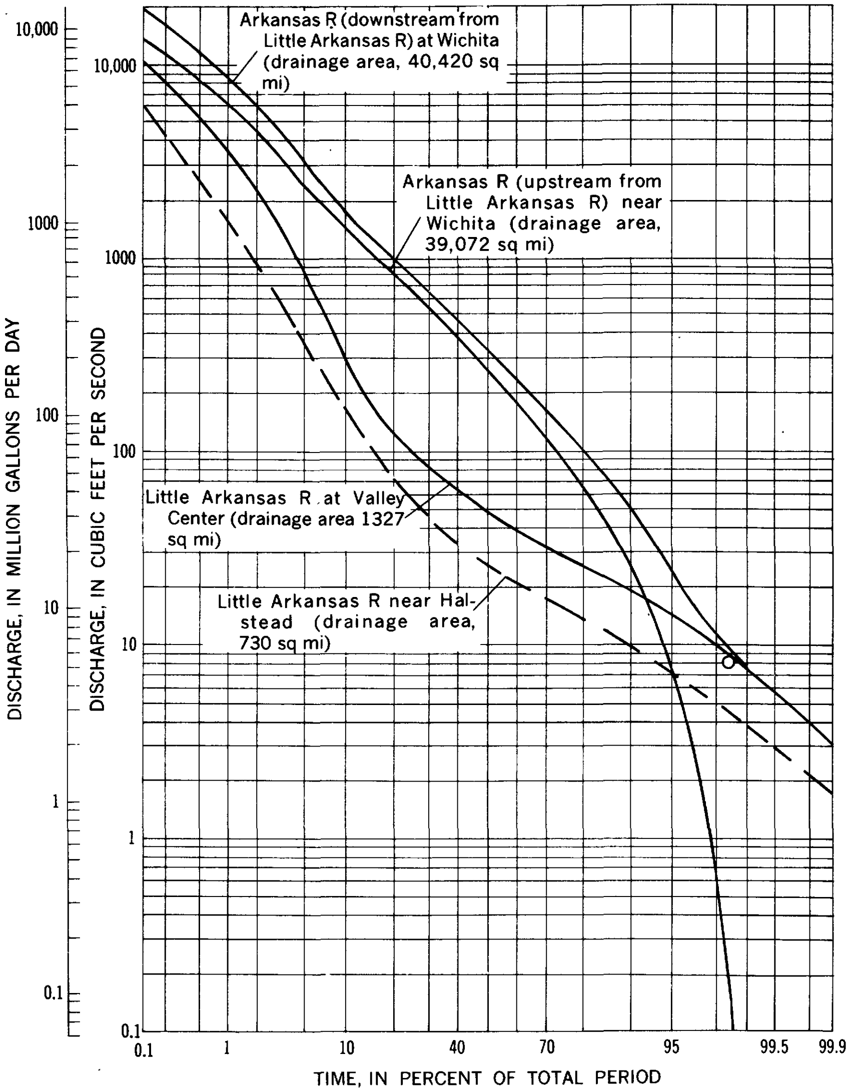



FIGURE 17.—Duration curves of daily flow, Arkansas and Little Arkansas Rivers.

The flow-duration curves for the two sites on the Arkansas River are applicable to other sites along the river. The curve for Arkansas River near Wichita is representative of the flow of the Arkansas River from the western boundary of the report area to the confluence with the Little Arkansas River. The curve for Arkansas River at Wichita is representative of the flow from the confluence with the Little Arkansas River to the Wichita sewage-treatment plant.

Downstream from the sewage-treatment plant the flow is increased by the sewage effluent, which averaged 28.7 mgd in 1960. The minimum desirable flow of 130 mgd at the Wichita sewage-treatment plant, recommended by the Kansas State Board of Health, would provide a total streamflow of 158 mgd downstream from the plant. The curve for the Arkansas River at Wichita (fig. 17) shows that the recommended flow will be equaled or exceeded only 64 percent of the time.

The two flow-duration curves for the Little Arkansas River are relatively similar, and accordingly they may be used to estimate curves for other points on the river by prorating between the two curves in accordance with differences in drainage area. For example, assume that an industrial plant is to be located adjacent to the Little Arkansas River in Sedgwick where the drainage area is 1,252 square miles, that construction of a storage dam is not planned, and that 5 mgd is required for plant operation. Because the observed minimum flow is less than the required flow, it is necessary to know the probable number of days per year that there will be a shortage of water. The drainage area between Valley Center and Sedgwick is 1,327 minus 1,252, or 75 square miles, as compared with 1,327 minus 730, or 597 square miles, between Valley Center and Halstead. Because 75 square miles is about one-eighth of the 597 square miles, the position of the duration curve at Sedgwick may be estimated to be one-eighth of the interval between the curves for Valley Center and Halstead and thus flow can be estimated. The resulting estimate cannot be used if manmade regulation modifies the distribution of flow. From figure 17, a flow of 5 mgd at Sedgwick is determined to be available 98.4 percent of the time on the average. The plotting position is shown by an open circle on figure 17. Streamflow will fail to meet the demand 1.6 percent of the time, or 6 days per year on the average.

## MINIMUM FLOW AND STORAGE

Low-flow frequency curves show how often, on the average, a stream may fail to provide various average rates of flow for given periods of consecutive days under existing conditions. Figures 18 to 21 show the curves for four sites in the area. The curves are for the long-term base period 1920–56 and have been adjusted, by correlation with selected long-term records outside the area, to reflect regional rather than local conditions. The curves for Little Arkansas River near Halstead (fig. 21) were estimated with methods developed by Furness (1960, p. 160–177).

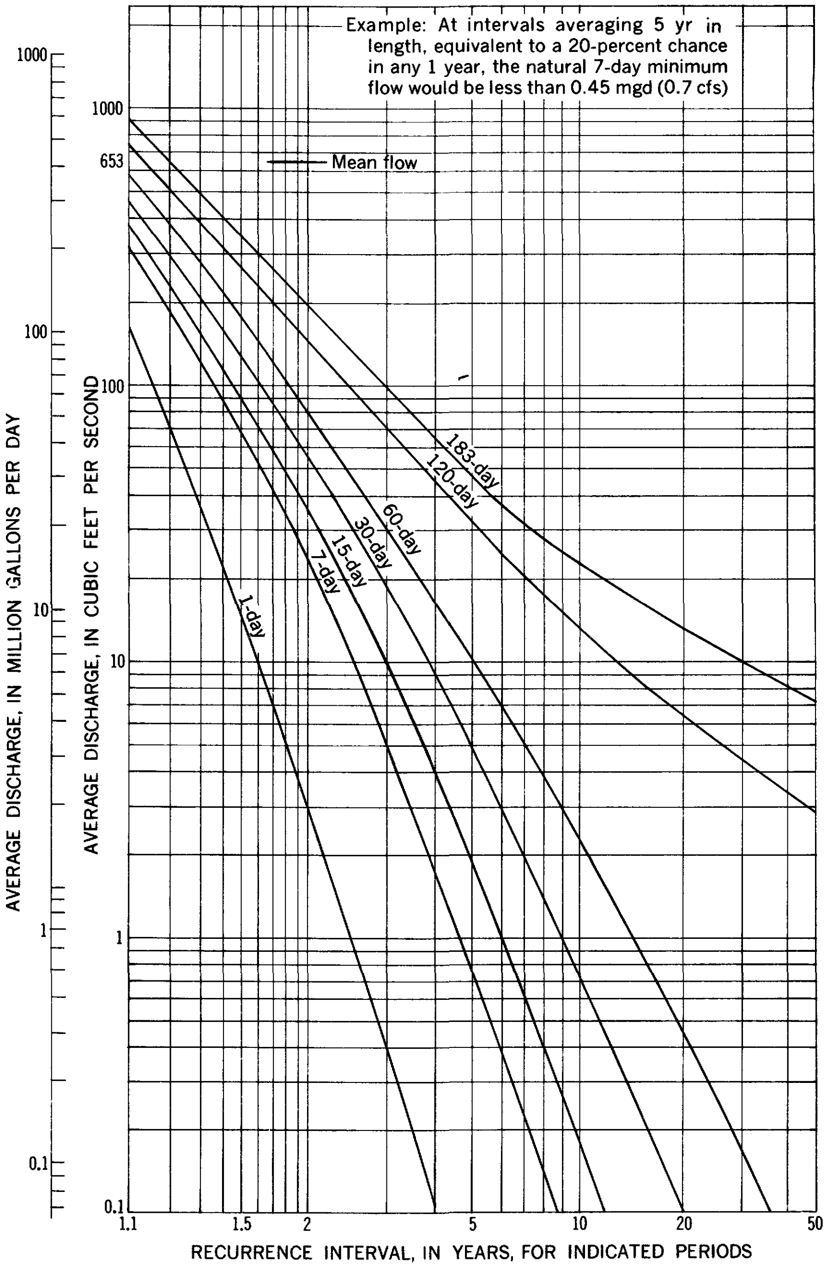



FIGURE 18.—Low-flow frequency curves for Arkansas River (upstream from Little Arkansas River) near Wichita (drainage area 39,072 square miles).

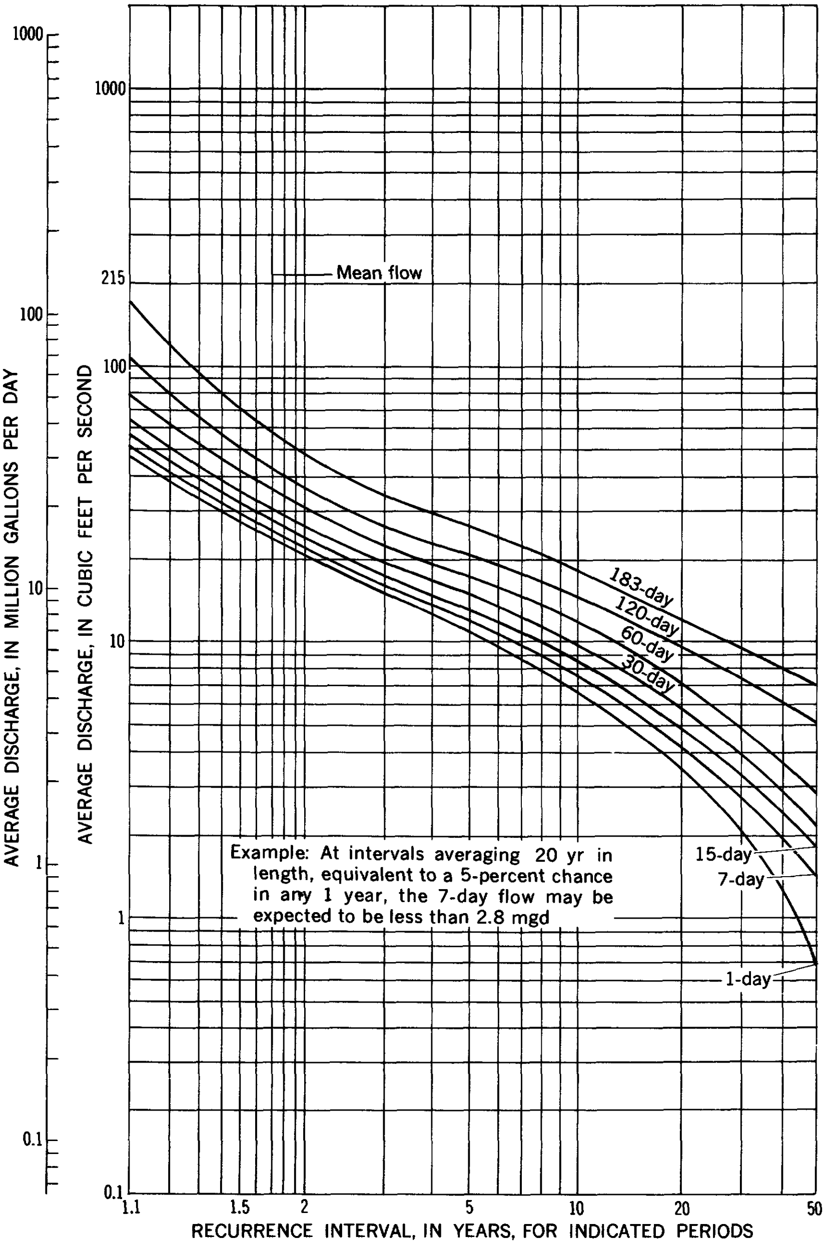



FIGURE 19.—Low-flow frequency curves for Little Arkansas River at Valley Center (drainage area 1,327 square miles).

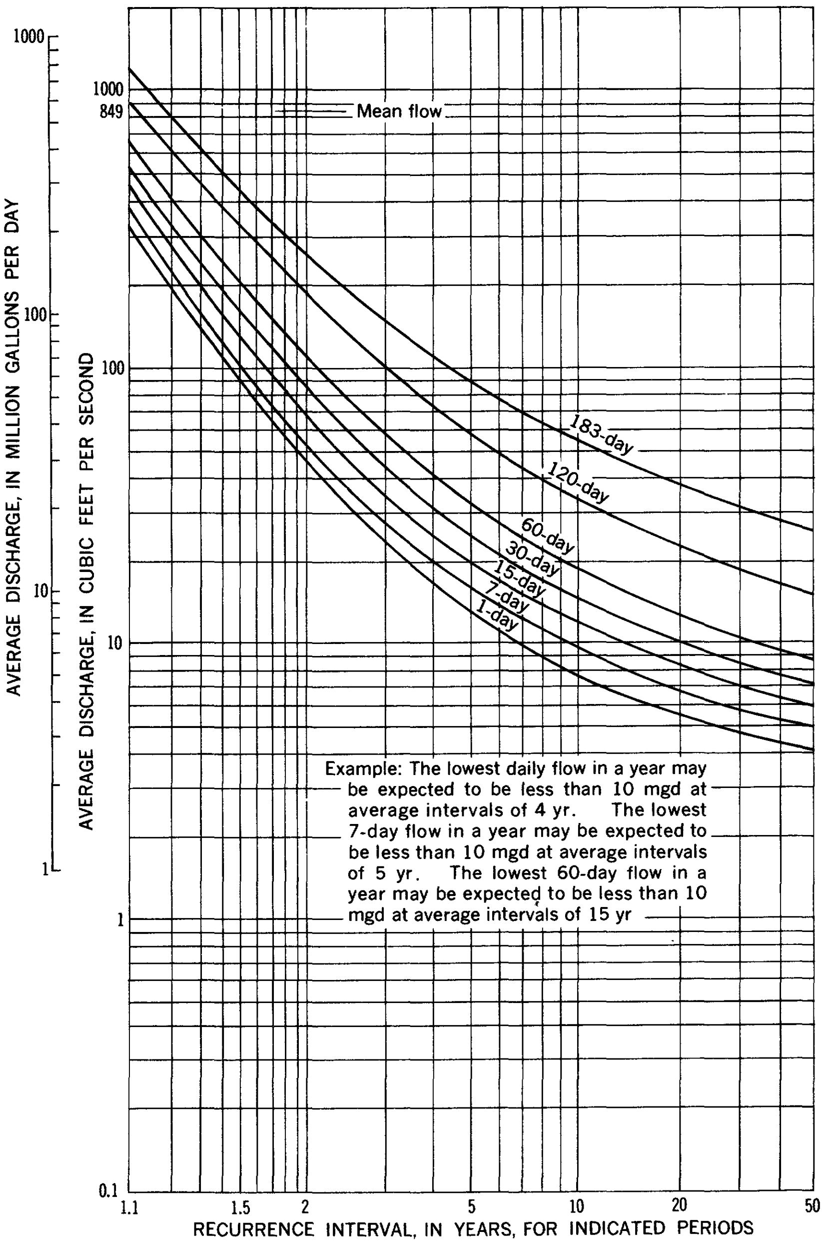



FIGURE 20.—Low-flow frequency curves for Arkansas River (downstream from Little Arkansas River) at Wichita (drainage area 40,420 square miles).

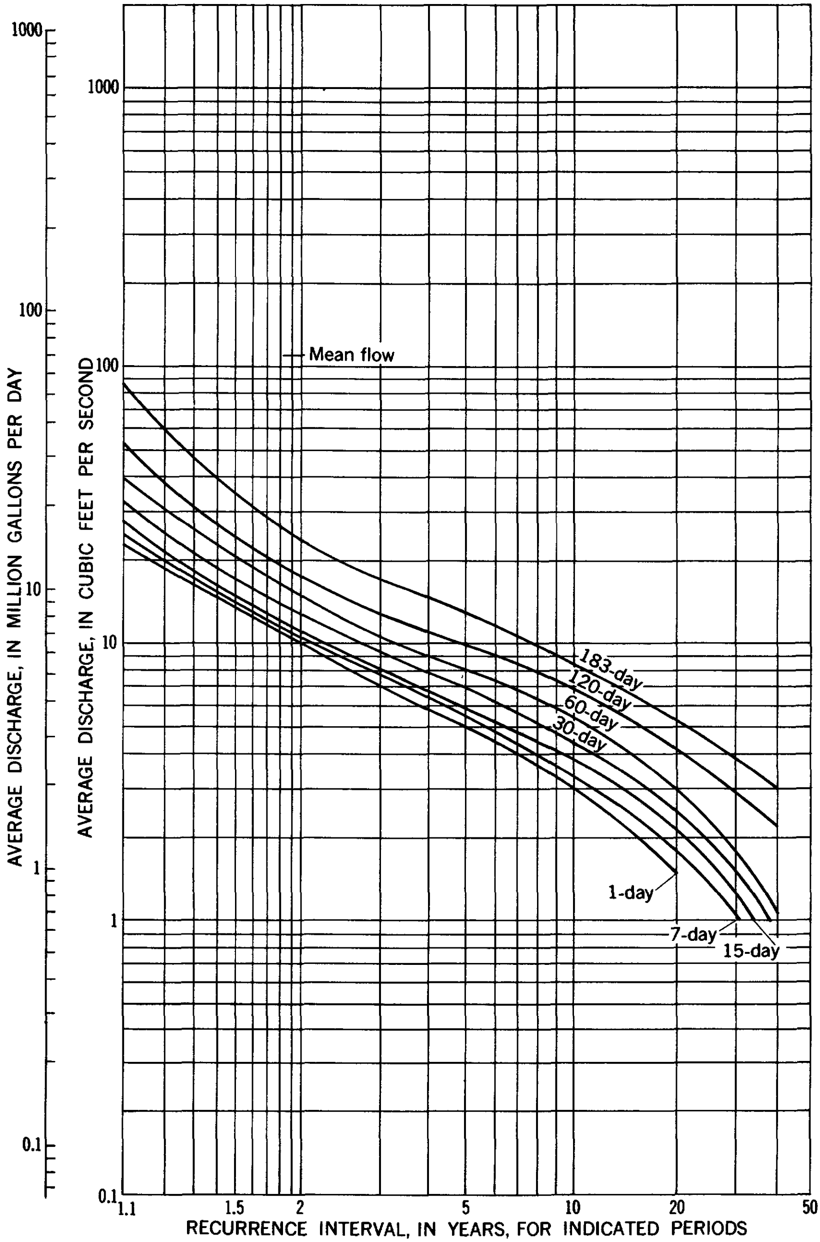



FIGURE 21.—Low-flow frequency curves for Little Arkansas River near Halstead (drainage area 730 square miles).

The figures show that an average flow of less than 10 mgd for a 30-day period may be expected at average intervals of 3.3 years for Arkansas River near Wichita, of 4.5 years for Little Arkansas River at Valley Center, and of 9 years for Arkansas River at Wichita. If the flow could be maintained at a continuous rate, it would be that shown by the line designated "Mean flow" on each of the figures.

The two low-flow curves (figs. 19, 21) for the Little Arkansas River may be used to estimate the recurrence interval of minimum flows to be expected at intervening points or at nearby points within the area if manmade regulation does not modify the distribution of flow. Suppose the hypothetical industry requiring 5 mgd at Sedgwick could schedule its withdrawals or construct a small channel dam so that the average 7-day flow would fulfill its needs. Superimposing the 7-day curve of figure 19 onto figure 21 and prorating in accordance with drainage area indicate that the 7-day flow would fall below 5 mgd only once in every 8½ years on the average.

No suitable sites for storage reservoirs are available on the Arkansas River between Great Bend and the Oklahoma State line (U.S. Corps of Engineers, 1951). However, construction of reservoirs has received some consideration in the upper reaches of the Little Arkansas River. For a potential reservoir site on Little Arkansas River near Halstead, the relation of storage requirements to different sustained rates of draft depends on the percentage chance of deficiency in any one year (fig. 22). For example, for a drought that has a 2-percent chance of occurring in any one year or that may be expected to recur on the average of once in 50 years, a storage of 50,000 acre-feet would be required for a continuous release of 23 mgd, less evaporation and seepage losses. The relation is based on low-flow frequency data. Any reservoir in this area would be so broad and shallow that evaporation losses would be large. Unpublished studies by the Kansas Water Resources Board indicate that evaporation losses might average as much as 65 percent in this vicinity so that a storage of 50,000 acre-feet would permit a continuous release of only about 8 mgd instead of 23 mgd.

## FLOOD-STAGE EXPECTANCY

The Arkansas and Little Arkansas Rivers have caused extensive flood damage in previous years, and areas near Wichita were particularly vulnerable. The Wichita-Valley Center flood-control project was authorized in 1936 as a cooperative project of the city of Wichita, the county of Sedgwick, and the U.S. Army Corps of Engineers. Construction on the project began in 1950 and was completed in November 1958 at a cost of about $18,980,000 ([U.S.] Chief

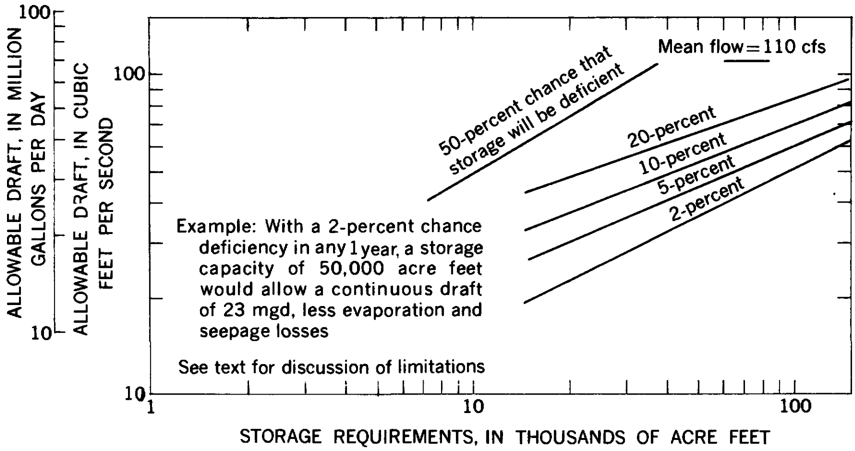



**Figure 22.**—Draft-storage relations for Little Arkansas River near Halstead (drainage area 730 square miles).

of Engineers, 1958). The project as illustrated in figure 15 incorporates earlier flood-protective measures and includes the following diversions of flood runoff: From the headwaters of Big Slough Creek into the Arkansas River 10 miles northwest of Wichita, from the Little Arkansas River upstream from Valley Center into the Little Arkansas River Floodway and thence into the Arkansas River 6 miles northwest of Wichita, from the major portion of Chisholm Creek into the Arkansas River just north of Wichita (flow from only 19 square miles is retained in the Wichita drainage canal), and from the combined diversions into Big Slough-Cowskin Floodway around the western edge of the city and then back to the Arkansas River 5 miles south of Wichita. Ungated structures having fixed openings permit low flow and a portion of floodflow up to the channel capacity to continue down the original channels.

The floodways and existing channels were constructed or improved to retain within their banks a design flood that exceeds any flood on record. (See table below.) Statistical studies show that the design flood should recur less frequently than once in 50 years on the average.

The structures and floodways for controlling the design flood are described by the U.S. Corps of Engineers (1945). The 50-year flood discharges on the Arkansas and Little Arkansas Rivers are based on a correlative frequency study by Ellis and Edelen (1960) of all floods on record at all gaging stations in Kansas. Although the flood-protective works were designed to retain flows greater than any on record, absolute protection cannot be assumed. An adverse combination of flood-producing conditions could cause a flood even greater than the design flood; such conditions nearly occurred in August 1960 on the Wichita drainage canal when the design flood discharge was equaled and the water reached the top of the levee in one place.

*Flood-control data*

| Floodways and channels | Design flood (cfs) | Maximum flood | | 50-year flood (cfs) |
|---|---|---|---|---|
| | | During period— | Discharge (cfs) | |
| Little Arkansas River Floodway | 55, 000 | | | |
| Existing Little Arkansas River channel | 4, 000 | | | |
| Floodway plus channel | 59, 000 | 1887–1960 | 32, 000 | 36, 000 |
| Chisholm Creek diversion | 20, 000 | | | |
| Big Slough-Cowskin Floodway | 46, 000 | | | |
| Existing Arkansas River channel | 20, 000 | | | |
| Floodway plus channel | 66, 000 | 1878–1960 | 39, 000 | 59, 000 |
| Wichita drainage canal | 6, 000 | 1959–60 | 6, 000 | 4, 800 |

The Flood Control and Maintenance Division of the Department of Public Works in Wichita is responsible for the administration and maintenance of the Wichita-Valley Center flood-control project. A network of rainfall stations in the headwaters and of stage stations on the streams is constantly maintained to forewarn of approaching floods. Floodflows are measured as they approach the project, and levees and structures are patrolled to assure successful operation.

Upstream from the Wichita-Valley Center project, flood protection consists only of farm levees, which are inadequate at times.

The U.S. Weather Bureau has collected river-stage data on Little Arkansas River at Sedgwick since 1916 and has established a flood stage of 18 feet, gage datum, at which floodwater first encroaches upon lowlands in the vicinity to cause damage. Figure 23 shows how the floods since 1916 have been distributed by months; floods have been most prevalent during June.

Because the monthly distribution of floods at Sedgwick is typical for all streams in the area, figure 23 indicates seasons when floods are most likely in any part of the area. For example, if a construction project is planned in the flood plain of a stream, the chances of work interruption are much higher from April to July than during other months.

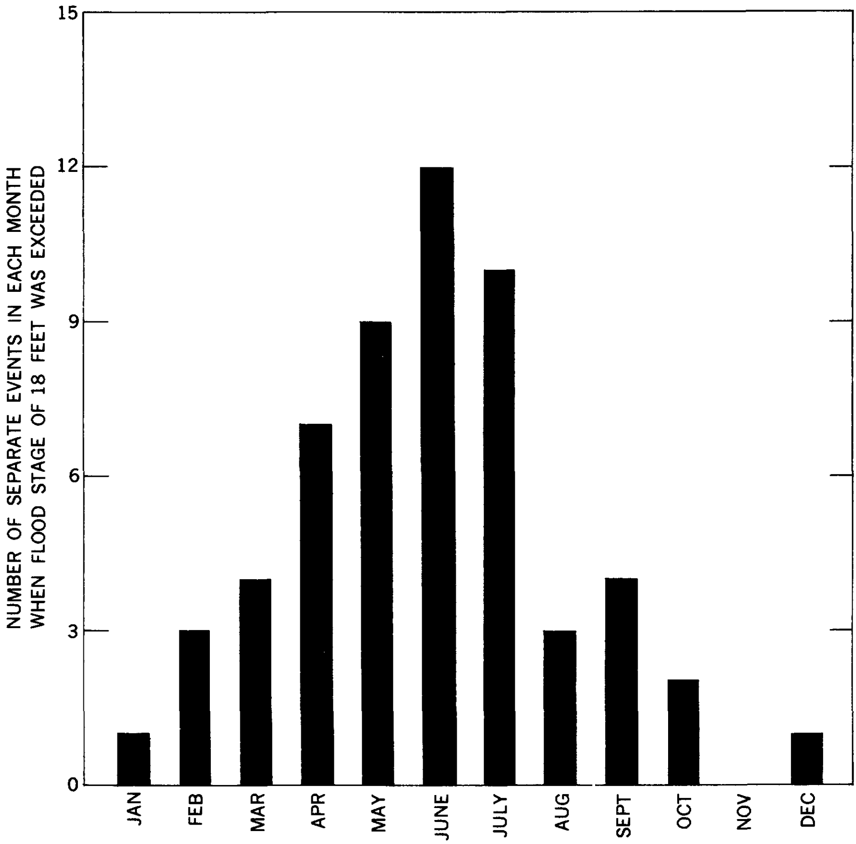



FIGURE 23.—Distribution of floods by months, Little Arkansas River at Sedgwick, 1916–60. Data from U.S. Weather Bureau.

In some years the high water does not reach flood stage, but in other years it reaches flood stage more than once. The average occurrence of flood stage, as shown in figure 24, is once every 0.8 year. Because of the broad flood plain, the maximum stage has been only 7 feet above flood stage since 1916, but the river has risen to within 2 feet of the maximum at least once every 2 years on the average.

In a cooperative study between the Wichita Department of Public Works and the Geological Survey, Ellis (1962) has prepared maps of the southeastern part of the Wichita area to show the extremities of inundation during the maximum floods on record. Because the maps delineate areas where floods have occurred in the past, they provide a basis for avoiding flood damage in the future.

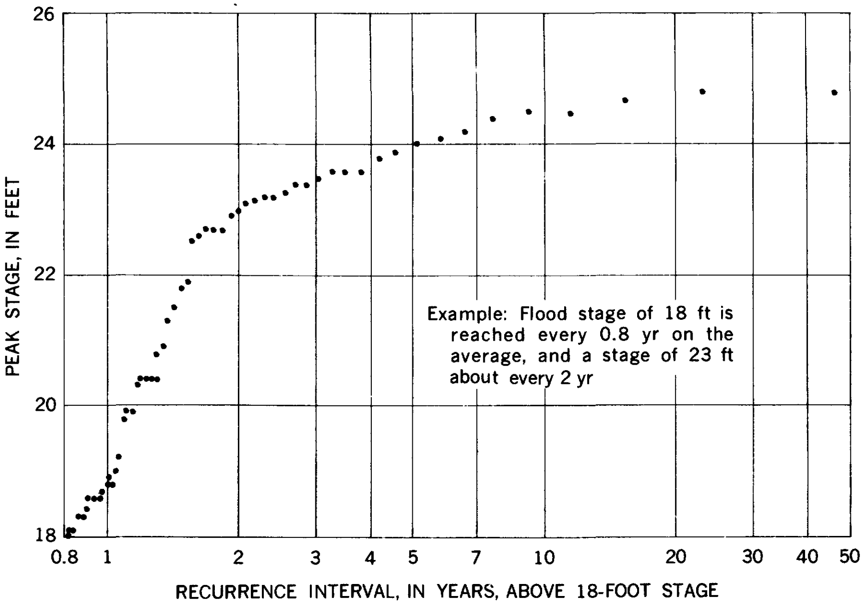



FIGURE 24.—Frequency of flood stages, Little Arkansas River at Sedgwick, 1916–60. Gage readings from U.S. Weather Bureau.

## CHEMICAL QUALITY

Records of the chemical quality of the water from the Arkansas, Little Arkansas, and North Fork Ninnescah Rivers have been obtained for several years by the Kansas State Board of Health (1960) and by the Wichita Water Department. Although the North Fork Ninnescah River is outside the area, the chemical quality of its water is important to Wichita because the river eventually will augment the city supply. Some records are also available for small tributaries in the area. (See fig. 15.)

The Arkansas River generally is highly mineralized; dissolved solids near Wichita exceeded 1,000 ppm 72 percent of the time from 1950 to 1960 (table 7) and frequently exceeded 2,000 ppm. Although the dissolved solids decrease during periods of high flow, no consistent relation between dissolved solids and flow is apparent.

The dissolved solids in the Little Arkansas River rarely exceed 1,000 ppm and at Valley Center are less than 500 ppm about 55 percent of the time, especially during periods of low flow (less than 30 cfs). During such periods most of the flow is from ground water. During periods of intermediate flow (30 to 150 cfs), dissolved solids fluctuate erratically between 300 and 1,000 ppm, mostly because of differences in storm patterns within the basin. Storm runoff flushes salts from tributary basins where there has been improper disposal of oil-field brines. As flows increase above 150 cfs, dissolved solids decrease as the result of dilution.

TABLE 7.—*Concentration-duration data for selected constituents and properties of water from the principal streams*

[Computed from analyses by Wichita Water Department and Kansas State Board of Health]

| Constituent or property | Percentage of time that concentrations (ppm) exceeded— | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 | 750 | 1,000 |
| **Arkansas River near Wichita at 13th St. Bridge** [1] | | | | | | | | | | | | | |
| Calcium (Ca) | ----- | ----- | 100 | 93 | 62 | 18 | 0 | ----- | ----- | ----- | ----- | ----- | ----- |
| Magnesium (Mg) | 94 | 89 | 60 | 5 | 0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Bicarbonate ($HCO_3$) | ----- | ----- | ----- | 100 | 98 | 84 | 61 | 31 | 3 | <1 | <1 | 0 | ----- |
| Sulfate ($SO_4$) | ----- | 100 | 99 | 97 | 89 | 82 | 75 | 66 | 43 | 24 | 10 | 1 | 0 |
| Chloride (Cl) | ----- | 100 | 99 | 98 | 90 | 84 | 80 | 74 | 68 | 58 | 44 | 15 | 2 |
| Dissolved solids | ----- | ----- | ----- | ----- | ----- | 100 | 99 | 97 | 96 | 93 | 88 | 81 | 72 |
| Hardness as $CaCO_3$ | ----- | ----- | ----- | 100 | 99 | 92 | 85 | 78 | 71 | 46 | 22 | 0 | ----- |
| **Little Arkansas River at Valley Center** [2] | | | | | | | | | | | | | |
| Calcium (Ca) | 100 | 99 | 87 | 70 | 29 | 0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Magnesium (Mg) | 89 | 67 | 4 | 1 | 0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Bicarbonate ($HCO_3$) | 100 | 98 | 96 | 91 | 80 | 65 | 51 | 39 | 17 | 0 | ----- | ----- | ----- |
| Sulfate ($SO_4$) | 99 | 99 | 92 | 41 | 0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Chloride (Cl) | 100 | 99 | 93 | 80 | 52 | 37 | 24 | 13 | 10 | 2 | 1 | 0 | ----- |
| Dissolved solids | ----- | ----- | ----- | 100 | 98 | 94 | 90 | 83 | 79 | 63 | 45 | 19 | 3 |
| Hardness as $CaCO_3$ | ----- | 100 | 99 | 95 | 82 | 68 | 57 | 35 | 18 | 4 | 0 | ----- | ----- |
| **North Fork Ninnescah River near Cheney** [3] | | | | | | | | | | | | | |
| Calcium (Ca) | ----- | 100 | 99 | 87 | 1 | 0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Magnesium (Mg) | 96 | 84 | 2 | 0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Bicarbonate ($HCO_3$) | ----- | ----- | 100 | 99 | 99 | 96 | 70 | 25 | 1 | 0 | ----- | ----- | ----- |
| Sulfate ($SO_4$) | ----- | 100 | 99 | 99 | 93 | 5 | 2 | 2 | 1 | 1 | <1 | <1 | 0 |
| Chloride (Cl) | ----- | 100 | 98 | 96 | 91 | 78 | 52 | 19 | 4 | 1 | <1 | <1 | 0 |
| Dissolved soilds | ----- | ----- | ----- | ----- | 100 | 99 | 99 | 99 | 96 | 93 | 83 | 14 | <1 |
| Hardness as $CaCO_3$ | ----- | ----- | ----- | 100 | 98 | 89 | 58 | 17 | 3 | 0 | ----- | ----- | ----- |

[1] From records obtained November 1950 to June 1960.
[2] From records obtained December 1956 to June 1960.
[3] From records obtained November 1950 to October 1959.

The dissolved solids in the North Fork Ninnescah River generally range from 500 to 750 ppm. Only on rare occasions, usually during periods of very low flow, do the dissolved solids exceed 1,000 ppm. They tend to vary inversely as the water discharge varies.

The relative concentrations of the major constituents in water from the principal streams are shown in figure 25 for a 1-year period. The samples for the period represent a wide range in flow. For the Arkansas River near Wichita, the principal cation in all samples was sodium and the principal anion in most samples was chloride. Sulfate, however, was the principal anion in several samples and was in relatively high concentrations in nearly all the samples. No consistent relation between the concentrations of the different constituents and water discharge is apparent.

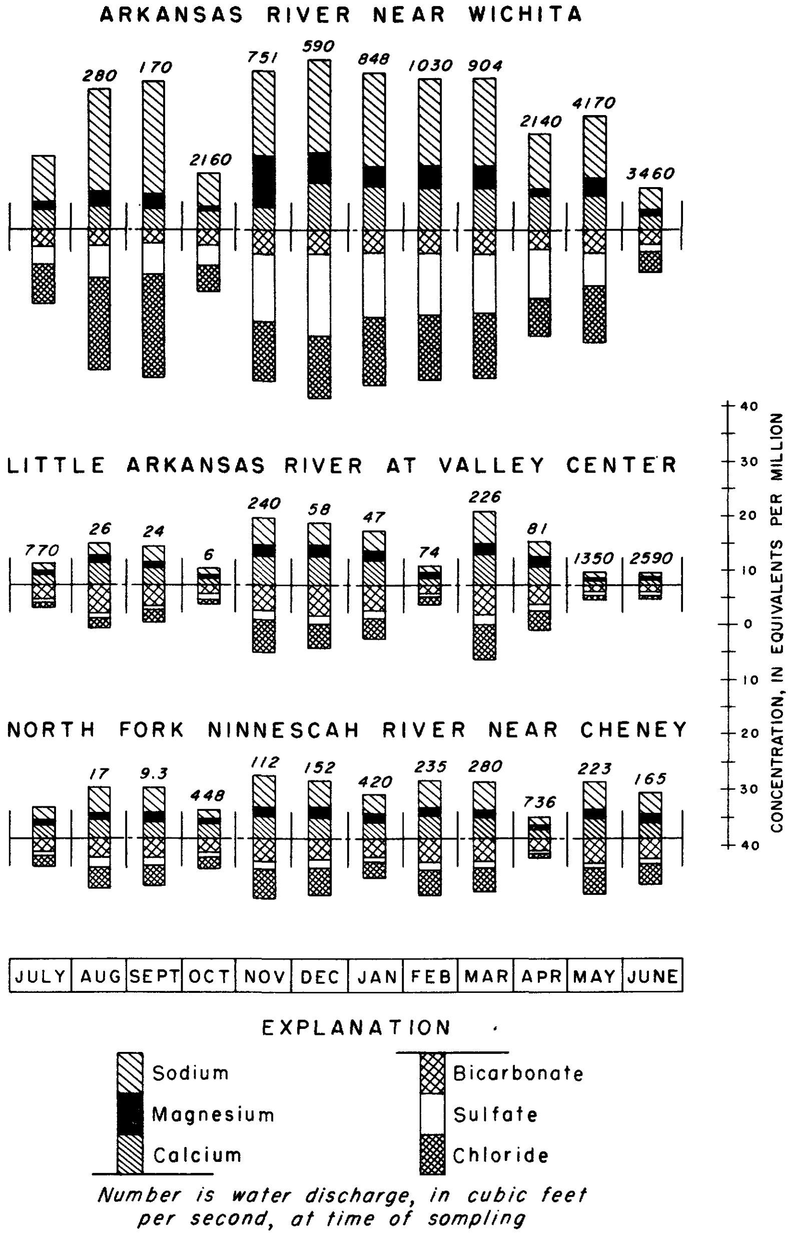



FIGURE 25.—Graph showing major constituents in water from the principal streams, July 1959 to June 1960.

Water from the Little Arkansas River at Valley Center generally contains calcium and bicarbonate as the principal constituents, although at times chloride is the principal anion. Sulfate in the Little Arkansas River, unlike that in the Arkansas River, is seldom, if ever, the principal anion. The chemical composition of the water during low flow is similar to that during high flow.

Water from the North Fork Ninnescah River near Cheney contains sodium as the principal cation and either bicarbonate or chloride as the principal anion. The chemical composition of the water is much more constant than that of either the Arkansas or Little Arkansas Rivers.

Concentration-duration data for selected constituents in the principal streams are given in table 7. Silica, nitrate, and fluoride concentrations, not included in the table, generally are less than 20, 10, and 0.8 ppm, respectively. Iron and manganese concentrations, also not included in the table, frequently exceed 0.5 ppm each in water from Arkansas River near Wichita and Little Arkansas River at Valley Center, and iron frequently exceeds 0.5 ppm in water from Ninnescah River near Cheney.

Water from Arkansas River near Wichita is of poor quality for public supply or domestic use, for irrigation, and for most industrial uses much of the time; concentrations of dissolved solids, chloride, sulfate, iron, and manganese are high, and the water is hard (table 7). Water from Little Arkansas River near Valley Center, if treated to reduce the hardness and the iron and manganese content, would be of suitable quality most of the time for public supply, domestic use, and most industrial uses; and water from Ninnescah River near Cheney, if similarly treated, would be of suitable quality nearly all the time. During most of the growing season, water from both the Little Arkansas River and the Ninnescah River is of the $C_2$–$S_1$ classification for irrigation. (See section on "Suitability of the water for use.") Such water can be used on almost all soils if a moderate amount of leaching of the soils takes place.

Most of the time the dissolved-solids content of water from the small streams is less than 600 ppm; the water contains principally calcium and bicarbonate and contains little fluoride, nitrate, or boron. However, some of the streams are subject to sudden change in water quality. This sudden change is due to flushing out contaminants, both organic and inorganic, which have concentrated during periods of extremely low flow. Miscellaneous chemical analyses of water from the small streams are included in table 8.

TABLE 8.—*Chemical analyses, in parts per million, of water from small streams*

[Analyses by U.S. Geol. Survey]

| Date of collection | Discharge (cfs) | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Boron (B) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | Percent sodium | Sodium-adsorption-ratio | Specific conductance (micromhos per cm at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Black Kettle Creek near Halstead (sec. 27, T. 23 S., R. 2 W.)** | | | | | | | | | | | | | | | | | | | | | |
| May 3, 1960 | 1.1 | 8.9 | 0.37 | 9.8 | 2.6 | 8.3 | 6.8 | 40 | 0 | 11 | 7.6 | 0.3 | 1.2 | 0.05 | 135 | 35 | 2 | 29 | 0.6 | 126 | 6.5 |
| **Kisiwa Creek near Halstead (sec. 22, T. 24 S., R. 2 W.)** | | | | | | | | | | | | | | | | | | | | | |
| May 4, 1960 | [1] 5 | 8.1 | 0.32 | 5.5 | 0.1 | 5.0 | 6.1 | 16 | 0 | 9.7 | 1.4 | 0.2 | 5.4 | 0.04 | ------- | 14 | 1 | 33 | 0.6 | 61 | 6.8 |
| **Emma Creek near Sedgwick (sec. 28, T. 24 S., R. 1 W.)** | | | | | | | | | | | | | | | | | | | | | |
| Dec. 18, 1959 | 5.53 | 3.9 | 0.00 | 81 | 14 | 74 | 3.5 | 272 | 0 | 40 | 120 | 0.4 | 0.1 | 0.05 | 478 | 261 | 38 | 38 | 2.0 | 852 | 7.5 |
| May 4, 1960: | | | | | | | | | | | | | | | | | | | | | |
| 9:00 a.m. | 130 | 14 | .08 | 58 | 7.4 | 31 | 5.1 | 204 | 0 | 34 | 36 | .4 | 3.1 | .04 | 312 | 175 | 8 | 27 | 1.0 | 498 | 7.6 |
| 10:45 a.m. | [1] 3,000 | 14 | .06 | 18 | 3.4 | 13 | 6.2 | 62 | 0 | 13 | 15 | .7 | 7.1 | .03 | 144 | 59 | 8 | 30 | .7 | 203 | 7.2 |
| **Sand Creek near Sedgwick (sec. 27, T. 24 S., R. 1 W.)** | | | | | | | | | | | | | | | | | | | | | |
| Dec. 18, 1959 | 7.85 | ------ | ------ | 105 | 35 | 50 | | 294 | 0 | 200 | 47 | ------ | ------ | ------ | 640 | 407 | 166 | 21 | 1.1 | 964 | 7.1 |
| May 4, 1960: | | | | | | | | | | | | | | | | | | | | | |
| 10:35 a.m. [2] | (3) | ------ | ------ | ------ | ------ | 16 | ------ | 114 | 0 | 53 | 15 | ------ | ------ | ------ | ------- | 141 | 48 | 20 | .6 | 366 | 7.5 |
| 11:35 a.m. [2] | (4) | 24 | 0.05 | 56 | 11 | 11 | 5.4 | 175 | 0 | 54 | 5.5 | 0.5 | 2.4 | 0.07 | 276 | 186 | 42 | 11 | .4 | 408 | 7.8 |
| **Jester Creek near Valley Center (sec. 23, T. 25 S., R. 1 W.)** | | | | | | | | | | | | | | | | | | | | | |
| Dec. 18, 1959 | 2.15 | 7.4 | 0.01 | 104 | 27 | 33 | 4.9 | 362 | 0 | 116 | 22 | 0.2 | 0.2 | 0.06 | 501 | 370 | 73 | 16 | 0.7 | 791 | 7.6 |
| May 4, 1960 | [1] 150 | ------ | ------ | ------ | ------ | 5.9 | ------ | 37 | 0 | 18 | 4.6 | ------ | ------ | ------ | ------- | 42 | 12 | 23 | .4 | 132 | 7.4 |

[1] Estimated.
[2] Sampled at sec. 14, T. 24 S., R. 1 W.
[3] Staff gage reading 4.00 ft.
[4] Staff gage reading 10.02 ft.

## SUSPENDED SEDIMENT

Suspended sediment transported by a stream may affect considerably the economics involved in using water from the stream for industrial or public supply. The sediment must be removed, commonly by settling basins, before the water can be used; and the higher the concentrations of fine material, the greater the difficulties in clarifying the water. Impoundment of sediment-laden water in reservoirs may simplify the process of clarifying the water by allowing the sediment to settle to the bottom of the reservoir, but the sediments that settle decrease the storage capacity of the reservoirs.

Practically no data are available from the area on the quantity or characteristics of sediment transported by the Arkansas River. Data obtained at Great Bend, about 110 miles upstream from Wichita, indicate that most of the suspended sediment is extremely fine and has a settling velocity in distilled water similar to that of colloidal clay (0.002 mm).

Data on the suspended-sediment transported by Little Arkansas River at Valley Center have been obtained by the Geological Survey since 1957 because the Little Arkansas River is being considered as an eventual supplement to the Wichita city supply. Water from the river may be used directly, or it may be used to recharge the ground-water reservoir. Suspended sediment might seriously interfere with the success of a ground-water recharge project by plugging up the interstices through which water from the stream would have to percolate, especially if the sediment were very fine.

The Little Arkansas River is sluggish most of the time, and the concentrations of suspended sediment generally are low. The maximum daily concentration for the period October 1957 to September 1959 was 2,960 ppm, and discharge-weighted mean concentrations for 1958 and 1959 were 687 and 779 ppm, respectively. (See table 9.) The sediment generally is very fine; measurements of the fall velocity in distilled water indicate that about 95 percent is finer than 0.062 mm in diameter, about 85 percent is finer than 0.004 mm, and about 80 percent is finer than 0.002 mm. Detailed records on sediment in the Little Arkansas River will be given in the annual series of U.S. Geological Survey water-supply papers entitled "Quality of Surface Waters of the United States."

TABLE 9.—*Monthly and annual summary of water and suspended-sediment discharge, October 1957 to September 1959, Little Arkansas River at Valley Center* [1]

| Month | Discharge (cfs-days) | Runoff (acre-feet) | Suspended sediment | | | | |
|---|---|---|---|---|---|---|---|
| | | | Load (tons) | Daily load (tons) | | Concentration (ppm) | |
| | | | | Maximum | Minimum | Weighted mean | Maximum daily |
| *1957* | | | | | | | |
| October | 1,316 | 2,610 | 1,207.7 | 598 | 3.3 | 340 | 1,160 |
| November | 1,341 | 2,660 | 410.3 | 83 | 1.4 | 113 | 297 |
| December | 1,131 | 2,240 | 68.1 | 5.5 | 1.0 | 22 | 46 |
| *1958* | | | | | | | |
| January | 1,125 | 2,230 | 58.5 | 4.2 | .8 | 19 | 39 |
| February | 1,110 | 2,200 | 58.6 | 9.8 | .3 | 20 | 65 |
| March | 26,466 | 52,490 | 69,523.6 | 10,520 | 4.3 | 973 | 1,920 |
| April | 6,793 | 13,470 | 14,560 | 9,900 | 10 | 794 | 1,730 |
| May | 14,437 | 28,640 | 30,132 | 7,500 | 49 | 773 | 1,320 |
| June | 1,841 | 3,650 | 1,478 | 651 | 10 | 297 | 818 |
| July | 43,556 | 86,410 | 68,015.2 | 7,280 | 9.2 | 578 | 1,430 |
| August | 7,094 | 14,070 | 6,484 | 2,840 | 18 | 339 | 720 |
| September | 16,947 | 33,610 | 36,325 | 10,800 | 32 | 794 | 1,250 |
| Water year 1957-58 | 123,137 | 244,300 | 228,321.0 | 10,800 | 0.3 | 687 | 1,920 |
| October | 2,919 | 5,790 | 3,623.4 | 1,730 | 1.8 | 460 | 2,320 |
| November | 1,763 | 3,500 | 156.1 | 27 | 1.2 | 33 | 92 |
| December | 1,701 | 3,370 | 31 | ------ | ------ | 6.7 | ------ |
| *1959* | | | | | | | |
| January | 2,066 | 4,100 | 46 | ------ | ------ | 5.6 | ------ |
| February | 2,842 | 5,640 | 600.4 | ------ | ------ | 102 | ------ |
| March | 3,918 | 7,770 | 7,738.9 | 4,450 | 1.2 | 732 | 2,380 |
| April | 2,590 | 5,140 | 1,661.4 | 419 | 8.0 | 238 | 746 |
| May | 19,160 | 38,000 | 56,086.8 | 9,480 | 8.8 | 1,084 | 1,930 |
| June | 2,751 | 5,460 | 5,040 | 2,880 | 10 | 679 | 2,100 |
| July | 7,260 | 14,400 | 25,788.5 | 5,420 | 4.8 | 1,316 | 2,960 |
| August | 910 | 1,800 | 139.8 | 13 | 1.4 | 57 | 100 |
| September | 1,141 | 2,260 | 1,548.6 | 496 | 1.2 | 503 | 1,370 |
| Water year 1958-59 | 49,021 | 97,230 | 102,460.9 | 9,480 | ------ | 775 | 2,960 |

[1] Data from U.S. Geol. Survey, Lincoln, Nebr.

## PUBLIC WATER-SUPPLY SYSTEMS

Seven municipal systems provide water for most of the towns in the area, and nine suburban systems provide water for the immediate vicinity of Wichita. Data on the municipal systems are presented in table 10.

The water-supply system for Wichita is the largest in the State. It is complex but very flexible in operation. The 55 wells in the "Equus beds" well field, the 6 wells in the "Bentley reserve" well field, and the 27 wells in the "local" well field have a maximum combined pumping capacity of about 95 mgd. The "Equus beds" well field is the principal source of water and has a pumping capacity of 55 mgd. The "Bentley reserve" well field, capable of pumping 10 mgd, and the "local" well field, capable of pumping 30 mgd, are used mainly to meet peak demands.

TABLE 10.—*Municipal water systems in the area*

| City | Population 1960[1] | Number of wells | Water-plant capacity (mgd) | Water treatment | Storage (mg) | | Daily water use (mgd) | | Unused capacity in excess of peak requirements (mgd) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Elevated | Surface | Average | Maximum | |
| Burrton | 774 | 3 | 0.94 | Chlorination | 0.05 | | 0.07 | [2] 0.14 | 0.8 |
| Halstead | 1,598 | 5 | .96 | do | .05 | | .30 | [2] .70 | .25 |
| Mount Hope | 539 | 4 | .37 | do | .05 | | .05 | [2] .11 | .25 |
| Newton | 14,877 | 10 | 5.7 | do | .70 | 3.6 | 2.0 | 3.7 | 2 |
| Sedgwick | 1,095 | 5 | .72 | do | .06 | | .25 | [2] .50 | .20 |
| Valley Center | 2,570 | 3 | .72 | do | .28 | | .14 | [2] .30 | .40 |
| Wichita | 254,698 | 88 | 112.0 | (3) | 2.3 | 4.0 | 25.0 | 61.0 | 30 |

[1] U.S. Federal census.
[2] Estimated.
[3] Includes aeration. flocculation, sedimentation, filtration, adjustment of pH, and chlorination.

Water from the "Equus beds" and "Bentley reserve" well fields is delivered to the treatment plant through 66-inch and 48-inch pipelines, which are cross connected with a 42-inch pipeline in the middle of the well field. The pipelines extend about 25 miles northwest of the city. The combined capacity of these pipelines is about 100 mgd. Water that is stored in the 3-million gallon surge tank in the "Equus beds" well field and in the pipelines and treatment basins would provide about 2 days water supply for the city. From the treatment plant, water is distributed through about 800 miles of mains at a pressure of 95 pounds per square inch by pumps powered by diesel, natural-gas, and electric motors. With present (1960) facilities the Wichita water system could provide 30 mgd in excess of peak requirements.

The water system for Newton is the second largest in the area and is more than adequate to supply the city's needs. The water is supplied by 10 wells about 7 miles southwest of Newton in sec. 32, T. 23 S., R. 1 W., and sec. 5, T. 24 S., R. 1 W.; the wells have a combined capacity of 9 mgd. Water is pumped to a 1-million-gallon surface storage reservoir at the waterplant in the well field. The water is chlorinated at the waterplant and pumped into 12-inch and 14-inch pipelines for transmission to the city. Pumps at the waterplant have a capacity of about 10 mgd. A booster station about 4 miles from the well field, having a capacity of 5.7 mgd, maintains the pressure in the pipelines the remaining distance to the city. The pipelines from the well field terminate at a 3.6-million-gallon surface reservoir in the city. From this reservoir the water is pumped into the distribution system, which includes a 700,000-gallon elevated storage tank. All pumping equipment in the system is powered by electricity, and no auxiliary power source is available. With present (1960) facilities the Newton water system could provide an additional 2 mgd.

The dissolved solids in water from the public supplies are less than 600 ppm; and the concentrations of all constituents, except iron and manganese for some supplies, are well below the standards of the U.S. Public Health Service (1962). Table 11 shows the chemical quality of several supplies; table 12 shows the average chemical quality of the Wichita supply, which is the only supply that is significantly altered by treatment. The analyses in table 12 represent composites of daily samples after treatment. Hardness as $CaCO_3$ is maintained at about 110 ppm, and iron and manganese are removed completely. The increases in dissolved solids, chloride, and sulfate from July to September result from blending with poor-quality water from the "local" well field or the "Bentley reserve" well field.

Analyses by the Wichita Water Department indicate that the average quality of the water from the original 25 public-supply wells in the "Equus beds" well field has changed little since pumping began. The average concentrations in 1941 and 1960 were as follows: Dissolved solids, 298 and 291 ppm; hardness, 163 and 171 ppm; chloride, 24 and 26 ppm. However, this well field has been expanded several times since 1941; and as the number of wells increased, the dissolved solids also increased. The average concentration was 298 ppm for water from 25 wells in 1941, 345 ppm for water from 35 wells in 1950, and 378 ppm for water from 55 wells in 1960. Apparently the quality of the water in the vicinity of the new wells is poorer than that in the vicinity of the original wells.

TABLE 11.—*Chemical analyses, in parts per million, of water from several public supplies*

[Analyses by Kansas State Board of Health]

| Municipality | Burrton | Goddard | Halstead | Mount Hope | Park City | Sedgwick | Valley Center | Newton | Haysville |
|---|---|---|---|---|---|---|---|---|---|
| Date | 1941 | 1959 | 1960 | 1960 | 1960 | 1960 | 1960 | 1960 | 1960 |
| Iron (Fe) | 0.8 | 0.03 | 0.51 | 0.06 | 4.1 | 0.04 | 0.60 | 0.04 | 0.05 |
| Manganese (Mn) | -------- | .00 | .33 | .0 | .32 | .2 | .13 | .0 | .00 |
| Silica ($SiO_2$) | -------- | 20 | 17 | 14 | 16 | 15 | 17 | 24 | 12 |
| Calcium (Ca) | 46 | 94 | 44 | 59 | 77 | 137 | 91 | 53 | 33 |
| Magnesium (Mg) | 11 | 14 | 13 | 15 | 17 | 25 | 21 | 11 | 12 |
| Sodium (Na) | 29 | 39 | 41 | 128 | 29 | 37 | 32 | 22 | 127 |
| Potassium (K) | | | | | | | | | |
| Bicarbonate ($HCO_3$) | 154 | 339 | 251 | 246 | 256 | 393 | 356 | 217 | -------- |
| Sulfate ($SO_4$) | 45 | 13 | 25 | 60 | 83 | 119 | 74 | 25 | 149 |
| Chloride (Cl) | 21 | 57 | 13 | 155 | 20 | 51 | 9 | 10 | 154 |
| Fluoride (F) | .3 | .2 | .3 | .5 | .3 | .2 | .4 | .2 | .1 |
| Nitrate ($NO_3$) | 25 | 6.2 | 2.4 | 4.2 | .5 | 7.5 | 1.0 | 7.5 | 2.8 |
| Dissolved solids | 342 | 410 | 279 | 562 | 369 | 585 | 420 | 260 | 510 |
| Hardness as $CaCO_3$ | 160 | 292 | 164 | 208 | 262 | 445 | 314 | 177 | 132 |
| Noncarbonate hardness as $CaCO_3$ | 34 | 14 | 0 | 6 | 51 | 123 | 22 | 0 | 98 |
| Alkalinity as $CaCO_3$ | 126 | 278 | 206 | 202 | 210 | 322 | 292 | 178 | 34 |

TABLE 12.—*Chemical analyses, in parts per million, of treated water, Wichita public supply, 1959*

[Analyses by Wichita Water Department]

| Constituent or property | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iron (Fe) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Manganese (Mn) | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Calcium (Ca) | 25 | 27 | 26 | 23 | 23 | 26 | 27 | 27 | 18 | 17 | 21 | 21 |
| Magnesium (Mg) | 10 | 9 | 11 | 11 | 11 | 11 | 11 | 12 | 14 | 13 | 13 | 13 |
| Sodium (Na) | 72 | 66 | 80 | 68 | 71 | 84 | 82 | 102 | 100 | 68 | 68 | 66 |
| Bicarbonate ($HCO_3$) | ---------- | 122 | 115 | 122 | 124 | 124 | 115 | 105 | 100 | 117 | 113 | 122 |
| Sulfate ($SO_4$) | 88 | 80 | 86 | 70 | 67 | 77 | 86 | 105 | 91 | 52 | 73 | 68 |
| Chloride (Cl) | 75 | 75 | 90 | 65 | 70 | 80 | 90 | 85 | 115 | 80 | 70 | 75 |
| Dissolved solids | 350 | 332 | 382 | 334 | 336 | 382 | 422 | 486 | 468 | 386 | 304 | 286 |
| Hardness as $CaCO_3$ | 105 | 106 | 112 | 102 | 103 | 110 | 110 | 115 | 102 | 97 | 103 | 102 |
| Alkalinity as $CaCO_3$ | 102 | 100 | 94 | 100 | 102 | 102 | 94 | 86 | 82 | 96 | 93 | 100 |
| pH | 8.8 | 8.8 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.7 | 8.8 |

## SUMMARY OF WATER USE

The total quantity of water used in the area cannot be determined accurately because of seasonal and annual variations and because of a lack of records by many water users. The greatest variations are in the quantities used for irrigation. A summary of annual quantities of water used is given in the table below; quantities shown for municipal and rural-domestic uses are averages, and those for industrial uses and irrigation are probable maximums.

| Use | Annual quantities [1] | |
|---|---|---|
| | Million gallons | Acre-feet |
| Municipal [2] | 12, 770 | 39, 200 |
| Industrial | 15, 510 | 47, 600 |
| Irrigation | 10, 430 | 32, 000 |
| Rural domestic | 3, 910 | 12, 000 |
| Total | 42, 620 | 130, 800 |

[1] All municipal and industrial water supplies are derived from ground water. Irrigation and rural domestic supplies are derived in part from surface water.
[2] Includes about 8,000 acre-ft per yr supplied to industry by Wichita.

## EMERGENCY SUPPLIES FOR CIVIL DEFENSE

The area is favorably situated for obtaining water for domestic and sanitary uses in the event of civil disaster because the water supplies are abundant at relatively shallow depths. Unless the Wichita treatment and distribution pumping plants are destroyed completely, the city system could continue to supply water for emergency use. Water from the "Equus beds" well field can be delivered to the city by gravity flow and would be of satisfactory quality for use with no treatment other than chlorination. Should there be destruction in the "Equus beds" well field or breaks in the transmission lines to the city, the "local" well field near the treatment plant could supply emergency demands of the city adequately. The water from the "local" well field is inferior in quality to that from the "Equus beds" well field, but it could be used in an emergency with no treatment other than chlorination. The distribution pumping plant can deliver about 30 mgd independent of electric power.

Numerous industrial and air-conditioning wells and a dozen or more city-park wells are widely dispersed throughout the city and could be utilized for emergency water supplies. Many residences in the western half of the city have small-capacity wells ordinarily used to water lawns and gardens. In an emergency, pumps on these wells, believed to number in the thousands, could be powered by small gasoline engines. The smaller cities and most residents outside the Wichita metropolitan area provide their own water supplies from wells. Several hundred irrigation wells are rather uniformly distributed throughout the area underlain by valley deposits and would be a valuable emergency source. Most of these wells are pumped with internal-combustion engines and could supply a quantity of water adequate to meet emergency needs in the entire area. Lane, Reavis, and Stramel (1962) show by maps and tables the existing large ground-water supplies and areas where ground-water supplies could be readily developed for emergency use within a 50-mile radius of Wichita.

In the event of warfare the water supplies of all cities could be threatened by radioactive fallout and by harmful chemical or biological contaminants. According to Lane, Reavis, and Stramel (1962), ground-water supplies would be less subject to contamination than surface-water supplies. They indicate that contamination of ground water in the Wichita area by radioactive fallout or by chemical or biological agents probably would not pose a serious problem in the immediate post-attack period except in localized areas. However, the long-term effects of such contamination are not known at this time.

## POSSIBILITIES FOR FUTURE DEVELOPMENT OF WATER SUPPLIES

The development of additional large supplies of water from the sand and gravel deposits of Tertiary(?) and Quaternary age is possible. Withdrawals from wells properly spaced throughout the area could be increased appreciably without causing an excessive lowering of the water table or a progressive depletion of the quantity of water in storage. However, large withdrawals of water from wells improperly spaced could cause excessive lowering of the water table locally and could decrease efficiency of pumping for present water users, and the excessive lowering of the water table might induce the movement of poor-quality water toward the wells.

The amount of ground water that might ultimately be withdrawn safely cannot be estimated too accurately from the information now available. Certainly the amount would be only a small fraction of the 8,000,000 acre-feet estimated to be in storage in the sand and gravel deposits, but it is probably at least several times the estimated 130,800 acre-feet (including surface water) per year now being withdrawn. Limits on the quantities that might be withdrawn are more likely to be set by water quality considerations than by the amount of water available.

The parts of the area having the greatest potential for future development without a progressive depletion of the available water supply generally are those where the thickness of the saturated water-bearing materials is the greatest. (See fig. 5.) They are shown in a general way by figure 13 and include parts of Tps. 23–28 S., R. 1 W., and Tps. 23–26 S., R. 3 W. Pumping of wells adjacent to the Arkansas and Little Arkansas Rivers could cause infiltration of river water and thereby greatly augment the available ground-water supply in the area. Such wells along the Arkansas River would produce inferior water, but such water should be usable for some purposes.

The Arkansas River has little potential for development because the quality of the water is poor and because upstream from the confluence with the Little Arkansas River flow ceases, or nearly ceases, every few years. Also, no suitable sites for storage reservoirs to stabilize flow exist in or near the Wichita area.

The Little Arkansas River has some potential for further development. The quality of the water most of the time is good, and the average flow for a period of 7 consecutive days is unlikely to be less than 8 mgd more frequently than once every 5 years on the average. Consideration is being given to a plan for diverting flow from the Little Arkansas River for municipal use by Wichita during such periods as water of suitable quality is available. Such diversion of surface water would reduce ground-water pumping and thereby conserve ground-water supplies. Some consideration also has been given to construction of reservoirs in the headwaters of the Little Arkansas River; however, evaporation losses from such reservoirs probably would be large.

In any development for which water supply is essential, careful consideration should be given to the water rights that may be involved. In 1945 the legislature enacted the Kansas Water Appropriation Act, the State's basic water law, which establishes procedures for acquisition of legal rights to appropriate ground and surface waters. The act provides that, subject to vested rights (rights perfected on or before June 28, 1945, or reasonably soon thereafter), water may be appropriated by anyone desiring beneficial use of it as long as such appropriation neither impairs existing water rights nor unreasonably affects the public interest (Kansas Water Resources Board, 1960a, p. 52–57). The act is administered principally by the Division of Water Resources of the State Board of Agriculture. An appropriation right to the use of water, other than for domestic use, can be acquired only by filing an application with, and receiving the approval of, the chief engineer of the Division of Water Resources. Priorities for appropriation rights conform to the premise that first in time is first in right. The dates of the appropriation rights—not the type of use—determine who is entitled to a supply that is limited; however, all appropriated rights are subject to vested rights, which have first priority. At present (1961) the law expresses the following order of preference for various water uses: Domestic, municipal, irrigation, industrial, recreation, and water power. Where conflicts in the use of water exist, preference in use is to conform to the order indicated. However, as long as water is being used properly under the terms of the rights and the laws of Kansas, holders of water rights for "inferior" beneficial use cannot be deprived of their use of water, either temporarily or permanently, other than through condemnation.

Obtaining an appropriation right is not a mandatory prerequisite to the use of water in the State. However, the wisdom of obtaining one for any significant water development is obvious. As competition for water increases and conflicts in the use of water arise, those who have not protected themselves with the legal rights to water may find themselves without water.

Streamflow is now used principally for the very necessary function of diluting and transporting waste. As the population and industry of the area grow, the need for water for waste disposal also is likely to grow. Before further withdrawals for consumptive uses of water from the streams are made, the value of the water for such uses should be weighed against the need of the water for dilution of wastes—a need that even now is not always adequately met.

At present, Wichita is concentrating on obtaining a supplemental supply from the proposed Cheney Reservoir to be built on the North Fork Ninnescah River, 24 miles west of the city (fig. 1). In 1956 Wichita was authorized by the city electorate to contract with the Federal Government for a water supply from the reservoir, and in 1960 the U.S. Bureau of Reclamation was authorized by the 86th Congress to construct the reservoir. Draft-storage relations similar to those on figure 22 have been computed from daily streamflow records collected near Cheney. For the planned conservation pool of 144,800 acre-ft, the curves show that a gross yield of 63 mgd (193 acre-ft per day) may be expected from the reservoir with only a 2-percent chance of failure. According to the Kansas Water Resources Board (1960b), this gross yield would correspond to a net yield of 34 mgd (104 acre-ft per day) after adjustment for evaporation.

Future opportunities for public water supply may also be found in other adjoining streams, such as in the Walnut River basin on the east and the South Fork Ninnescah on the west. Development of all sites would provide a water supply greater than any anticipated needs in the foreseeable future.

## SELECTED REFERENCES


American Water Works Association, 1950, Water quality and treatment 2d ed.: Am. Water Works Assoc. Manual, p. 53.

American Water Works Service Co., Inc., 1955, Report on water supply plan for city of Wichita: Philadelphia, Pa., Eng. rept. to Wichita Water Co.

Black and Veatch Consulting Engineers, 1952, Long range water supply plan, Wichita, Kansas: Kansas City, Mo.

——— 1955, Wichita, Kansas, Report on feasibility of proposed Cheney Reservoir: Kansas City, Mo.

Ellis. D. W., 1963, Floods at Wichita, Kansas: U.S. Geol. Survey Hydrol. Inv. Atlas 63.

Ellis. D. W., and Edelen, G. W., Jr., 1960, Flood frequency, pt. 3 *of* Kansas streamflow characteristics: Kansas Water Resources Board Tech. Rept. 3.

Fishel, V. C., and Broeker, M. E., 1960, Ground-water levels in observation wells in Kansas, 1959: Kansas Geol. Survey Bull. 146, 174 p.

Fishel, V. C., and Mason, B. J., 1957, Ground-water levels in observation wells in Kansas, 1956: Kansas Geol. Survey Bull. 125, 158 p.

——— 1958, Ground-water levels in observation wells in Kansas, 1957: Kansas Geol. Survey Bull. 131, 146 p.

Fishel, V. C., Gulley, E. L., and Reavis, E. L., 1959, Ground-water levels in observation wells in Kansas, 1958: Kansas Geol. Survey Bull. 141, 126 p.

Foley, F. C., Smrha, R. V., and Metzler, D. F., 1955, Water in Kansas: Kansas Water Resources Fact-Finding and Research Comm.

Frye, J. C., and Leonard, A. B., 1952, Pleistocene geology of Kansas: Kansas Geol. Survey Bull. 99, 230 p.

Furness, L. W., 1959, Flow duration, pt. 1 *of* Kansas streamflow characteristics: Kansas Water Resources Board Tech. Rept. 1.

——— 1960, Low-flow frequency, pt. 2 *of* Kansas streamflow characteristics: Kansas Water Resources Board Tech. Rept. 2.

Jeffords, R. M., 1948, Graphic representation of oil-field brines in Kansas: Kansas Geol. Survey Bull. 76, pt. 1, 12 p.

Jones, O. S., 1938, Chloride survey in the north portion of Wichita, Kansas: Kansas Board of Health, 7 p.

Kansas State Board of Health, 1960, Chemical quality of surface waters in Kansas, 1957–1960: Topeka, Kans., Div. Sanitation.

Kansas Water Resources Board, 1960a, Report on the laws of Kansas pertaining to ground water: Bull. 5, 153 p.

———1960b, Lower Arkansas unit, sec. 4 *of* Preliminary appraisal of Kansas water problems, pt. A *of* State water plan studies: Kansas Water Resources Board.

Lane, C. W., Reavis, E. L., and Stramel, G. J., 1962, Emergency water supplies in the Wichita area, Kansas: U.S. Geol. Survey Hydrol. Inv. Atlas 58.

Langlier, W. F., 1946, Chemical equilibria in water technology: Am. Water Works Assoc. Jour. 38, 169 p.

Maxcy, K. F., 1950, Report on the relation of nitrate concentrations in well waters to the occurrence of methemoglobinemia: Natl. Research Council Bull., Sanitary Engineer, p. 265, app. D.

Mayor's Advisory Committee, 1955, Water report: Wichita, Kans.

Miller, G. H., Jr., 1959, Mineral and water resources, pt. 6 *of* Economic development in south-central Kansas: Lawrence, Kans., Kansas Univ., Center for Research in Business.

Pfister, Richard, 1952, Water requirements survey in the Wichita-Hutchinson trading area: Lawrence, Kans., Kansas Univ., Bur. Business Research, Business School, 148 p.

Stramel, G. J., 1956, Progress report on the ground-water hydrology of the Equus beds area, Kansas: Kansas Geol. Survey Bull. 119, pt. 1, 59 p.

Swineford, Ada, 1955, Petrography of upper Permian rocks in south-central Kansas: Kansas Geol. Survey Bull. 111, 178 p.

[U.S.] Chief of Engineers, 1958, Annual report, civil works activities: U.S. Dept. Army.

U.S. Corps of Engineers, 1945, Definite project report, Wichita and Valley Center, Arkansas River, Kansas: War Dept., U.S. Engineers Office, Tulsa, Okla.

——— 1951, Preliminary studies of navigation in the Arkansas River basin, Oklahoma and Kansas: War Dept., U.S. Engineers Office, Tulsa, Okla.

U.S. Geological Survey, Water levels and artesian pressure in observation wells in the United States, part 3, north-central States: Issued annually 1935–55 as water-supply papers.

U.S. Inter-Agency Committee on the Arkansas-White-Red River Basins, Water Use and Control Group, Oklahoma and Kansas, 1954, Brief written statement including project evaluation statements, Arkansas River basin from Great Bend, Kansas, to Keystone damsite, Oklahoma: U.S. 81st Cong., 2d sess., sec. 205 Public Law 516.

U.S. Public Health Service, 1962, Drinking water standards: Federal Register, Mar. 6, 1962, p. 2152–2155.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture, Agriculture Handb. 60, 160 p.

Williams, C. C., and Lohman, S. W., 1949, Geology and ground-water resources of a part of south-central Kansas, with special reference to the Wichita municipal water supply: Kansas Geol. Survey Bull. 79, 455 p.