WATER RESOURCES OF SEDGWICK COUNTY, KANSAS

By Hugh E. Bevans

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CONVERSION FACTORS

Inch-pound units of measurements used in this report may be converted to metric (International System) units using the following conversion factors:

Multiply inch-pound unit	*By*	*To obtain metric unit*
inch	25.4	millimeter
inch per year	25.4	millimeter per year
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
mile	1.609	kilometer
mile per hour	1.609	kilometer per hour
square mile	2.590	square kilometer
cubic foot	0.02832	cubic meter
acre	0.4047	hectare
acre-foot	1,233	cubic meter
gallon	3.785	liter
gallon per minute	0.06309	liter per second
cubic foot per second	0.02832	cubic meter per second
ton	0.9072	megagram
ton per day	0.9072	megagram per day
ton per square mile	0.3502	megagram per square kilometer
cubic foot per second per square mile	0.1093	cubic meter per second per square kilometer
acre-foot per square mile	476.06	cubic meter per square kilometer
foot squared per day	0.0929	meter squared per day
pound per cubic foot	16.02	kilogram per cubic meter
degrees Fahrenheit (°F)	(1)	degrees Celsius (°C)

[1] °C = 5/9 x (°F -32).

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level."

WATER RESOURCES IN SEDGWICK COUNTY, KANSAS

By Hugh E. Bevans

ABSTRACT

The large population and diverse economic activities in Sedgwick County and its principal city, Wichita, require adequate water supplies for public, domestic, irrigation, and industrial uses. This report documents the current (1986) quantity and quality characteristics of surface- and ground-water resources, describes causes and extent of detected changes in water-resource characteristics, and evaluates water resources with respect to water-supply requirements. Interpretations of water-quality data collected from 52 stream sites, 14 impoundments, and 101 wells; of water-level measurements made at 335 wells; of historic or long-term streamflow and water-quality data from U.S. Geological Survey streamflow-gaging stations; and of water-level and water-quality data from monitoring wells were used in conjunction with results of previous investigations.

During 1985, an estimated 134,200 acre-feet of water (84 percent ground water) were used for public supplies (42 percent), irrigation (40 percent), self-supplied industrial use (14 percent), and self-supplied domestic use (4 percent). The city of Wichita used about 53,500 acre-feet of water for public supplies.

Streamflow is closely related to precipitation, and major streams are sustained by ground-water inflow. Cheney Reservoir on the North Fork Ninnescah River near Cheney, Kansas, has decreased flow downstream in the North Fork Ninnescah and the Ninnescah Rivers. The Arkansas River is in approximate equilibrium with ground water in the valley-fill deposits north of Wichita but becomes a gaining stream at Wichita. The Little Arkansas and Ninnescah Rivers are gaining streams through Sedgwick County.

Water in the Arkansas River is a sodium chloride type, with a median dissolved-solids concentration of 1,700 milligrams per liter at Hutchinson and 1,200 milligrams per liter at Derby. The Little Arkansas River at Valley Center has a calcium bicarbonate type water, with a median dissolved-solids concentration of 480 milligrams per liter. Water in the Ninnescah River is a sodium chloride type, with median dissolved-solids concentrations ranging from 640 milligrams per liter in the Ninnescah River near Peck to 760 milligrams per liter in the South Fork Ninnescah River near Murdock. The source of sodium and chloride in the Arkansas and Ninnescah Rivers is saline ground water discharged from Permian rocks upstream of Sedgwick County.

The Arkansas River basin upstream of Hutchinson has the smallest annual rates of chemical erosion (16.8 tons dissolved solids per square mile) and physical erosion (12.8 tons suspended sediment per square mile), while the South Fork Ninnescah River basin has the greatest annual rate of chemical erosion (206 tons dissolved solids per square mile) and the Little Arkansas River basin has the greatest annual rate of physical erosion (239 tons suspended sediment per square mile).

Small streams draining the county generally have water-quality characteristics that reflect the geochemical properties of aquifers providing base flow. Streams draining the Wellington Formation often have calcium sulfate type water, with concentrations of dissolved solids commonly exceeding 1,000 milligrams per liter. Streams draining the Ninnescah Shale usually have calcium bicarbonate type water, with less than 1,000 milligrams per liter dissolved solids. Streams draining unconsolidated deposits generally have a calcium bicarbonate type water, with less than 500 milligrams per liter dissolved solids.

Contamination of streams by sewage-treatment-plant effluent was indicated by increased ammonia concentrations in the Arkansas River at Derby and Mulvane, in the Little Arkansas River near Sedgwick, and in Cowskin Creek near Maize and at the Sumner County line. Contamination by oilfield brine

was detected in the Wichita-Valley Center floodway near Haysville, in Prairie Creek 4 miles southeast of Furley, and in Whitewater Creek at the Butler County line.

Agricultural pesticides (atrazine, cyanazine, and propazine) or the pesticide residue, heptachlor epoxide, were detected in 8 of 14 impoundments. An impoundment on the Little Arkansas River at Valley Center would have water with an estimated mean dissolved-solids concentration of about 220 milligrams per liter and would lose from 160 to 310 acre-feet of storage each year due to sedimentation. An impoundment on the South Fork Ninnescah River would have an estimated mean dissolved-solids concentration of 560 milligrams per liter and would lose from 59 to 110 acre-feet of storage each year due to sedimentation.

Ground water occurs in rocks throughout the area, but unconsolidated deposits of the Arkansas River valley are the principal aquifer. Wells in these unconsolidated deposits yield as much as 2,000 gallons per minute of water that generally is a calcium bicarbonate type, with less than 500 milligrams per liter dissolved solids; however, adjacent to the Arkansas River north of Wichita, sodium chloride type water with more than 1,000 milligrams per liter dissolved solids occurs. Wells in the Wellington Formation typically yield from 10 to 350 gallons per minute of calcium sulfate type water, with more than 1,000 milligrams per liter dissolved solids. Wells in the Ninnescah Shale generally yield less than 10 gallons per minute of calcium bicarbonate type water, with less than 1,000 milligrams per liter dissolved solids. Ground-water levels are closely related to cumulative departure from average precipitation; however, cones of depression have developed in local areas where large volumes of ground water are withdrawn for public or industrial supplies, especially in the Wichita well field where local declines greater than 25 feet have occurred.

Ground-water contamination by oilfield brines was indicated in 16 of 101 sampled wells. Nitrite-plus-nitrate as nitrogen concentrations exceeded 10 milligrams per liter in water from 11 of 101 sampled wells. Iron concentrations exceeded 300 micrograms per liter in water from 18 of 101 wells, and manganese concentrations exceeded 50 micrograms per liter in water from 31 of 101 wells. Herbicides (atrazine, metolachlor, propazine, and simazine) were detected in water from 5 of 19 wells, and a volatile organic compound (trichloroethylene) was detected in water from 1 of 10 wells.

Analysis of base-flow recession curves, used to estimate stream-aquifer interaction in the Arkansas and Little Arkansas River valleys, indicated hydraulic diffusivities of 1.6×10^6 feet squared per day in the Arkansas River valley and 2.2×10^6 feet squared per day in the Little Arkansas River valley.

INTRODUCTION

Purpose and Objectives

The large population and diverse economic activities in Sedgwick County and the city of Wichita require adequate water supplies for public, domestic, irrigation, and industrial uses. Water-resource management in the area has been based primarily on information contained in reports of hydrologic investigations that were published more than 20 years ago--(1) Water Resources of the Wichita Area, Kansas (Petri and others, 1964) and (2) Geohydrology of Sedgwick County, Kansas (Lane and Miller, 1965a,b). To ensure that adequate water supplies will be available in the future, current hydrologic and related information are needed for developing management strategies. In response to the need for current hydrologic information, the U.S. Geological Survey, in cooperation with Sedgwick County and the city of Wichita, conducted an investigation of areal water resources during 1984-86. The investigation provided data and interpretation needed to meet three principal objectives:

(1) Document the current quantity and quality characteristics of surface- and ground-water resources,

(2) describe causes and extent of observed changes in water-resource characteristics, and

(3) evaluate water resources with respect to water-supply requirements.

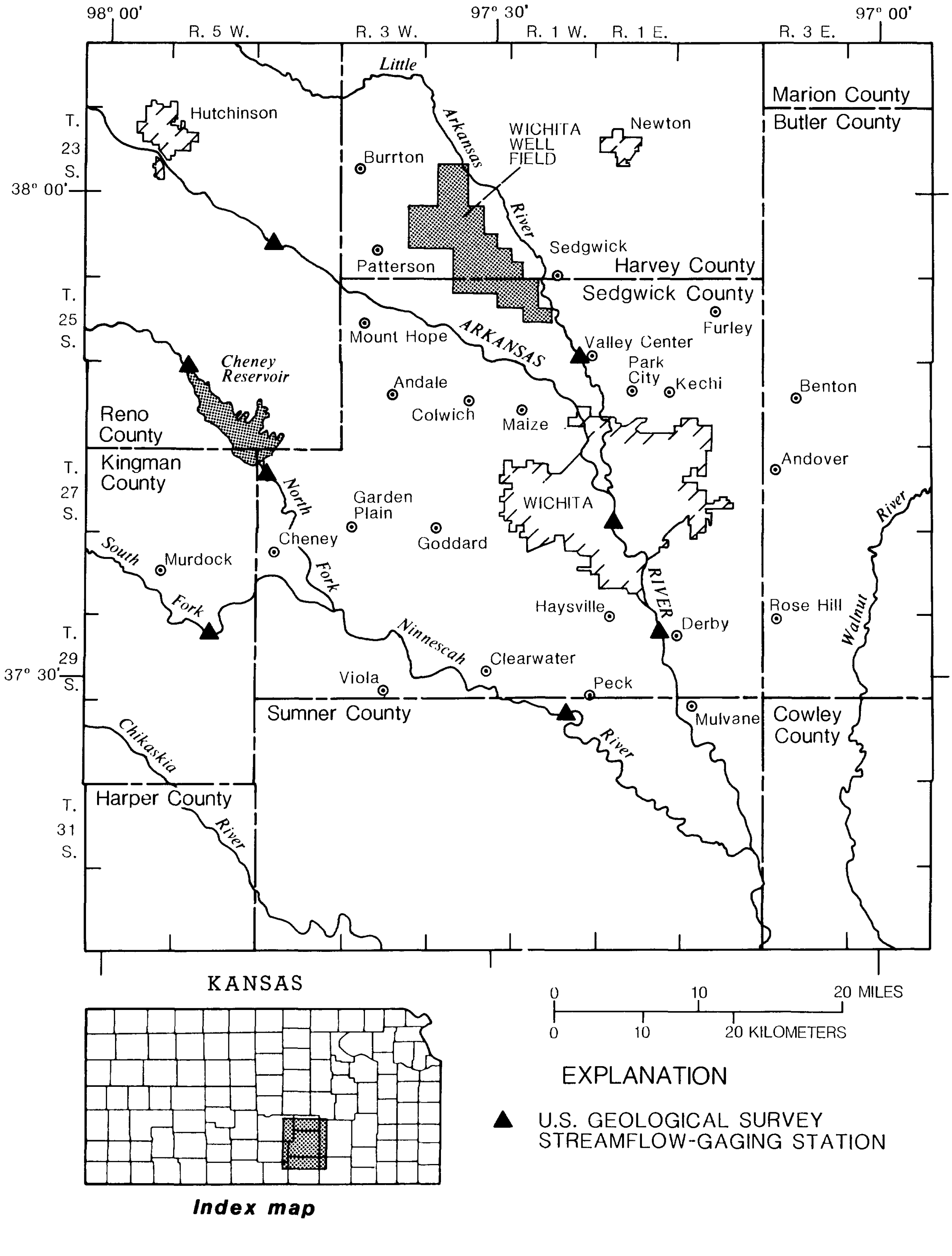


Figure 1. Location of study area.

Study Area

The study area is located in south-central Kansas and includes the city of Wichita, Sedgwick County, and adjacent areas (fig. 1). The Arkansas River and its tributary streams, including the Little Arkansas and Ninnescah Rivers, constitute the primary surface-water drainage system in the area. The eastern edge of the area is drained by east-flowing tributaries to the Walnut River in Butler County. The Wichita well field, located primarily in southwest Harvey County, and Cheney Reservoir in southeast Reno County are the principal sources of public-water supplies for Wichita, suburban areas east of Wichita, improvement districts in or adjacent to Wichita (Eastborough ,Oaklawn, and Sunview), Kechi, Park City, Rural Water Districts 1 and 2, and small towns in western Butler County (Andover, Benton, and Rose Hill) (Lorenz and others, 1985).

Previous Hydrologic Investigations

The importance of and concern about water resources in the study area are evidenced by numerous reports that have been published during the past 75 years covering a variety of hydrologic topics. Early investigations were based on very limited data and provided only brief descriptions of ground- and surface-water quality (Parker, 1911) and well yields and quality of water available for irrigation supplies (Meinzer, 1914).

Results of an investigation of the geology and ground-water resources of the *Equus* beds, the principal aquifer in the area, (Lohman and Frye, 1940) led to the location of the present Wichita well field, which is west of the Little Arkansas River in southwest Harvey County and northwest Sedgwick County (fig. 1). An estimate of ground water available for pumping from the Wichita well field was subsequently developed (Williams and Lohman, 1947). In concluding their hydrologic studies in the area, Williams and Lohman authored a comprehensive report about the geology and ground-water resources of south-central Kansas that included discussions of the Wichita well field (Williams and Lohman, 1949). Progress was made in defining the ground-water hydrology of the *Equus* beds (Stramel, 1956; 1962a; 1967), and a preliminary assessment was made of the potential for artificial ground-water recharge in the vicinity of the Wichita well field (Stramel, 1962b).

Emergency water supplies that could be utilized in the event of nuclear or biological warfare were evaluated by Lane and others (1962). Petri and others (1964) evaluated the ground- and surface-water resources of the Wichita area with respect to industrial-supply requirements.

A comprehensive report describing the geohydrology, including both availability and quality of ground water from geologic formations in Sedgwick County, was written by Lane and Miller (1965a). Logs of 369 wells and test holes used to develop interpretations for the comprehensive report were presented in a separate publication (Lane and Miller, 1965b).

Flood studies have been conducted for the Arkansas River and its tributaries (Ellis and others, 1963) and for urbanized basins in Wichita (James, 1967; Richards, 1971; Peek and Jordan, 1978; Perry and Hart, 1984). Several investigations have dealt with saline-water problems in the area (Leonard and Kleinschmidt, 1976; Gogel, 1981; Hathaway and others, 1981; Engineering Enterprises, Inc., 1982; Whittemore, 1982; Whittemore and Basel, 1982; Whittemore, 1984).

The advent of the computer has led to the development of numerical models to simulate ground-water flow (Green and Pogge, 1977) and both ground-water flow and solute transport in the *Equus* beds (Sophocleous,1983; Spinazola and others, 1985). The application of ground-water models underscored the need for accurate estimates of aquifer characteristics (Richards and Dunaway, 1972; Reed and Burnett, 1985; Sophocleous and Perry,1985).

GEOGRAPHIC SETTING

Physiography

Sedgwick County is located at the western edge of the Central Lowland physiographic province (Schoewe, 1949) (fig. 2). That part of the area drained by the Arkansas River and its tributaries, including the Ninnescah River, is included in the Arkansas River Lowlands section of the Central Lowland. The Arkansas River Lowlands section is divided into the Great Bend Lowland and the Wellington Lowland. The Great Bend Lowland includes that part of the area that is drained by the Arkansas and Little Arkansas Rivers and is described as a flat, smooth plain, with local relief ranging from 0 to 300 feet (Hammond, 1964). The Wellington Lowland includes that part of the area drained by the Ninnescah River and is described as an irregular plain, with local relief ranging from 100 to 300 feet.

The eastern edge of the county, which is drained by tributaries to the Walnut River, is included in the Osage Plains section of the Central Lowland province. This area is on the western edge of the Flint Hills Upland, the western subdivision of the Osage Plains, and is described as an irregular plain with local relief ranging from 100 to 300 feet.

The highest point in the county is in township 26 south, range 3 west, section 31 (about 5 miles southwest of Andale), with an altitude exceeding 1,545 feet above sea level. The lowest point is in township 29 south, range 1 east, section 36, where the Arkansas River flows out of the county, with an altitude of less than 1,220 feet above sea level.

The climate of an area can be expressed in terms of long-term averages of meteorologic factors; the most important factors are temperature, wind, precipitation, and evapotranspiration. Because Sedgwick County is located in the central United States, it has a continental climate and is subject to large variations in temperature because it is far away from the moderating effect of oceans. The average annual temperature at Wichita during 1888 through 1985 was 56.3 °F, according to records of the National Oceanic and Atmospheric Administration (1888-1985). Average monthly temperatures (fig. 3) range from 29.6 °F in January to 81.4 °F in July. The growing season (freeze-free period) usually exceeds 190 days. Average annual wind speeds are among the greatest in the United States, exceeding 12 miles per hour (Eagleman, 1973). The wind direction is predominantly from the south during all seasons except winter, when it is predominantly from the north.

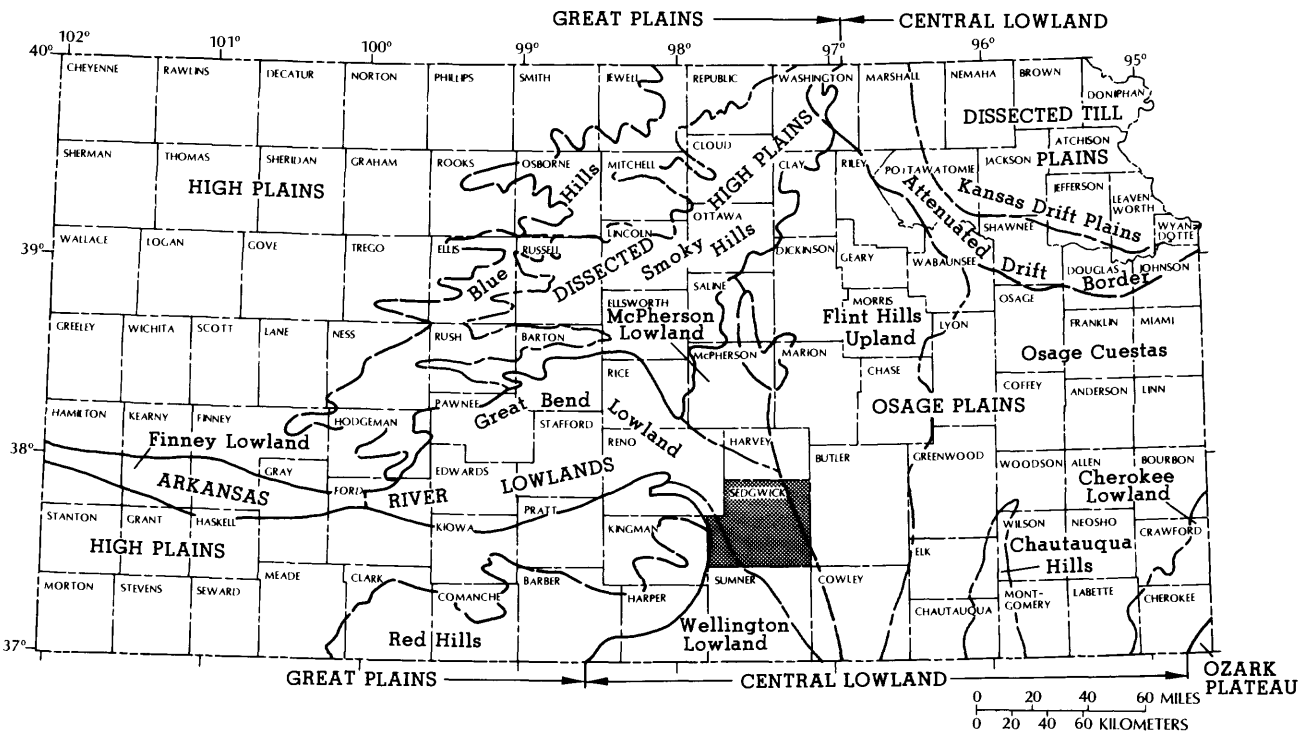


Figure 2. Physiographic provinces of Kansas (modified from Schoewe, 1949).

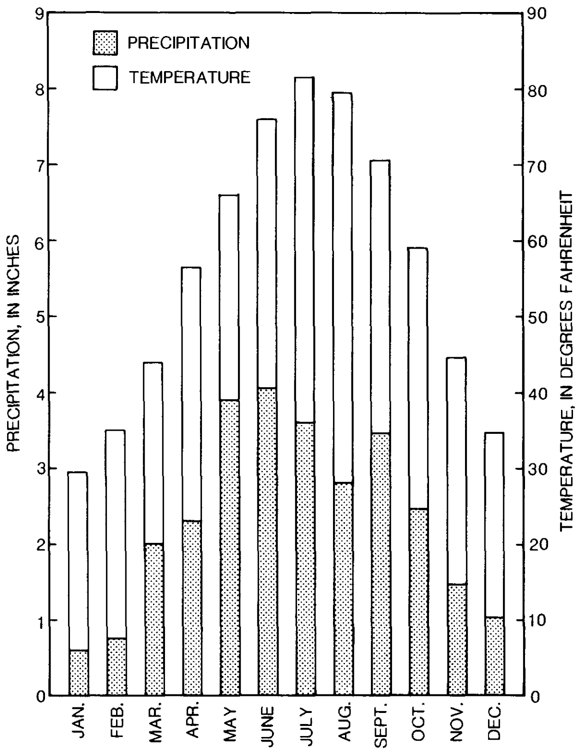


Figure 3. Average monthly precipitation and temperature at Wichita, 1888-1985.

The primary source of precipitation in the area is moisture-laden air from the Gulf of Mexico. The average annual precipitation at Wichita during 1888 through 1985 was 28.6 inches (data from National Oceanic and Atmospheric Administration, 1888-1985). Average monthly precipitation ranges from 0.68 inch in January to 4.06 inches in June (fig. 3). Most of the precipitation occurs as rain during the growing season (April through September).

Evapotranspiration, the sum of evaporation and transpiration by plants, is a function of meteorologic factors (temperature, humidity, and wind speed), soil moisture, and vegetation. During the growing season, transpiration is a major component of evapotranspiration, but during the nongrowing season transpiration ceases or is minimal. Evapotranspiration in the area ranges from 25 to 30 inches per year (Eagleman, 1973). The maximum rate of ground-water loss to evapotranspiration in the area was estimated to be 3.5 inches per year; however, this generally occurs only where the water table is within 10 feet of the land surface (Spinazola and others, 1985). Droughts can occur at any time but are most severe during the summer when evapotranspiration rates are greatest.

Soils in the county belong to the soil order Mollisol (U.S. Soil Conservation Service, 1967). Mollisols are some of the most productive agricultural soils in the world and are characterized by a surface horizon that is thick, dark, rich in organic material, dominated by divalent cations (calcium, Ca^{++}, and magnesium, Mg^{++}). Mollisols have a granular or crumb structure and are not hard when dry (Brady, 1974). Mollisols in the Arkansas River valley belong to the suborder Udoll, which is usually moist and has no horizons in which either gypsum or calcium carbonate has accumulated. Upland soil belongs to the suborder Ustoll, which is intermittently dry during the warm part of the year or has subsurface horizons in which salt or carbonate has accumulated. A soil survey of Sedgwick County was published by the U.S. Department of Agriculture, Soil Conservation Service (Penner and Wehmueller, 1979). The survey contains detailed soil maps, information about the use and management of soil, and information about engineering properties, physical and chemical properties, and soil and water features.

Population and Economic Activities

Sedgwick County had a population of 367,088 in 1980, making it the most populated county in Kansas (Murray, 1985). Wichita, with a 1980 population of 288,723, is the largest city in the State. Population in Sedgwick County during 1920-80 is shown in figure 4. During this period, the rural population has experienced slow but steady growth that has caused it to approximately double from 20,015 to 40,921. The urban population has increased by a factor of approximately 4.5, from 72,219 to 325,610 during the same period. The largest increase in county population occurred from 1940 to 1960, when the population increased by almost 200,000. Nearly all of this increase was due to a rapid increase in urban population that resulted from expansion of industries during World War II and the subsequent "baby boom" that followed the war. Since 1960, the rate of increase in urban population has moderated significantly and has been nearly equivalent to the increase in rural population. The 1990 county population is projected to be nearly 430,000 (Murray, 1985).

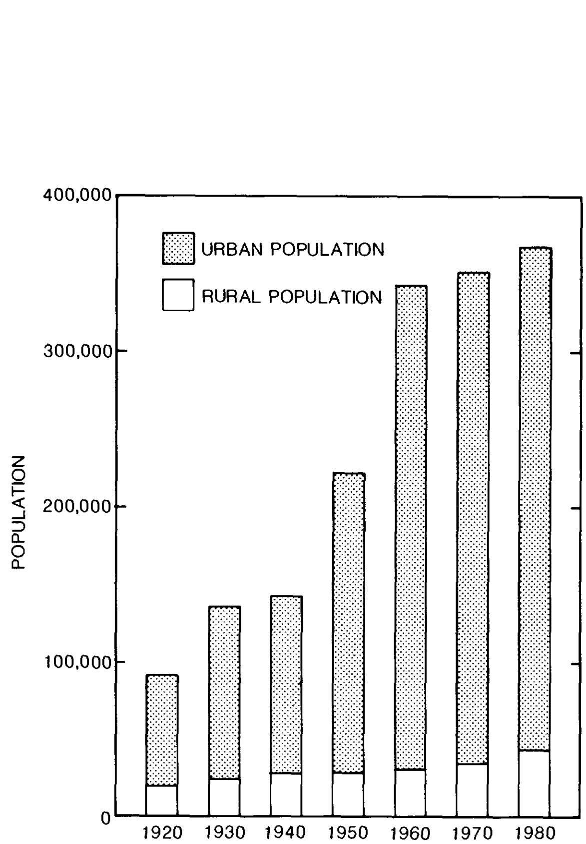


Figure 4. Population in Sedgwick County, 1920-80.

This would be an increase of about 16.5 percent over the 1980 population and the third largest increase in number of people experienced during any decade. On the basis of population trend for 1960 through 1980 (fig. 4), the 1990 population could actually be less than 400,000. The Wichita-Sedgwick County Metropolitan Area Planning Department has projected the 1990 county population to be 406,000 (Lorenz and others, 1985). Accurate population projections are important because they are used to project future water use.

In 1983, the total personal income for the county ($5,119,642,000) was the largest in the State (Murray, 1985). This personal income resulted from private nonfarm income (79.1 percent), government income disbursements (20.5 percent), and farm income (0.4 percent). These percentages underscore the importance of private nonfarm economic activities.

Private nonfarm employment data for the Wichita Standard Metropolitan Statistical Area (SMSA), which includes Sedgwick and Butler Counties, can be used to illustrate the relative importance of economic activities that are included in this category. The total private nonfarm-employed labor force for the Wichita SMSA during 1983 was 165,800. Manufacturing activities employed 30 percent of the total; trade, 27 percent; service industries, 24 percent; financial activities, 6 percent; transportation, 6 percent; construction, 5 percent; and mining (sand, gravel, oil, gas, salt), 2 percent. The aircraft industry, which employed 17 percent of the total private nonfarm labor force, was the largest employer in the manufacturing sector, which includes durable goods (fabricated metal, machinery, and transportation equipment) and nondurable goods (food products, printing and publishing, chemicals, and petroleum refining). The dominance of manufacturing in the private nonfarm employment sector is significant because manufacturing processes typically require large quantities of water.

Farm income in Sedgwick County during 1983 was $22,637,000, or only about 0.4 percent of the total personal income. However, the county is a major agricultural region, as evidenced by its 1984 ranking in the State for the number of farms (first), acres harvested (third), crop value (tenth), and livestock and poultry value (twentieth). Although agriculture is not economically as important as manufacturing, it often requires substantial quantities of water for irrigation purposes. During 1985, 45,000 acres of land in the county were irrigated for growing sorghum, corn, wheat, and soybeans (Kansas State Board of Agriculture, 1986).

Land use in the county is primarily for agriculture. In 1984, about 83 percent of the county was included in farms (Murray, 1985). Land use on farms was approximately 84-percent cropland, 15-percent pastureland, and 1-percent woodland. About 16 percent of the county is urban land (residential, commercial, and industrial), which is a very large percentage in this part of the United States. Activities associated with land-use categories often affect water resources.

WATER-SUPPLY REQUIREMENTS

Water Use

Water resources in the area are used as sources of public, irrigation, self-supplied industrial, and self-supplied domestic water supplies. Estimated water use in Sedgwick County during 1985 (Joan Kenny, U.S. Geological Survey, oral commun., 1986) and 1984 appropriated water rights (data from Kansas State Board of Agriculture, Division of Water Resources, Topeka) are presented in table 1. Appropriated water rights totaled 244,300 acre-feet in 1984, of which nearly 77 percent were ground-water rights. An estimated 134,200 acre-feet of water were used during 1985. The estimated use includes self-supplied domestic use, which does not require a water right. For those categories that require a water right (public supplies, irrigation, and self-supplied industrial use), only about 53 percent of the water rights were actually used.

Since 1960, appropriated ground-water rights have increased slightly from 185,300 acre-feet (Lane and Miller, 1965a) to 187,800 acre-feet in 1984. However, the apportionment of these rights has changed as public-supply rights have decreased by 33 percent, irrigation rights have increased by 118 percent, and self-supplied industrial rights have increased by 7 percent. An estimated 107,900 acre-feet of ground water were used during 1985 (excluding self-supplied domestic use) or about 57 percent of the ground-water rights. The principal use of ground water was for irrigation, about 45 percent of the total ground water used. The areal distribution of ground-water rights is shown in figure 5.

Surface-water rights have increased greatly from 817 acre-feet in 1960 (Petri and others, 1964), all of which was for irrigation, to 56,500 acre-feet in 1984, of which 93 percent was for public-water supplies. Of the 56,500 acre-feet of appropriated surface-water rights, only 21,500 acre-feet were used during 1985 or about 38

Table 1. *Estimated water use in Sedgwick County during 1985 and 1984 appropriated water rights, in acre-feet*

[Numbers rounded to nearest 100 acre-feet]

Use	Ground water		Surface water	
	Estimated use	Appropriated right[1]	Estimated use	Appropriated right[1]
Public supplies	38,700	73,500	18,300	52,600
Irrigation	50,400	65,900	3,100	3,800
Industrial, self-supplied[2]	18,800	48,400	100	100
Domestic, self-supplied[3]	4,800	--	0	--
Total	**112,700**	**187,800**	**21,500**	**56,500**

[1] Water-right appropriations in 1984, pending and approved; data from Kansas State Board of Agriculture, Division of Water Resources, Topeka.

[2] Includes: (1) manufacturing processes, (2) fossil-fuel power generation, (3) mining, and (4) nonirrigation agricultural activities (feedlots, dairy operations, fish farms).

[3] Water right not required.

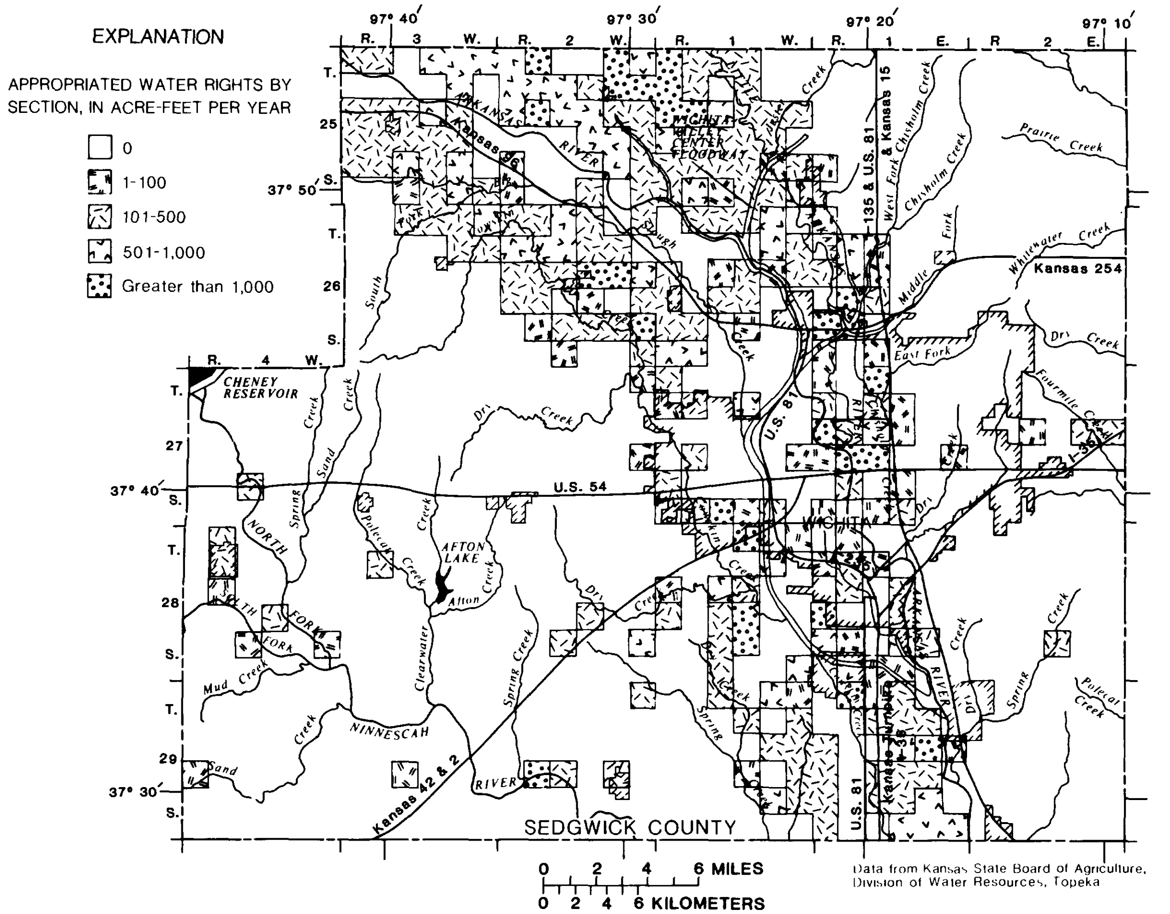


Figure 5. Distribution of 1984 appropriated water rights in Sedgwick County.

percent of the rights.

The largest category of water use in Sedgwick County during 1985 was public supply (42 percent). The 57,000 acre-feet used amounted to about 45 percent of the water rights appropriated for public supplies. The Wichita Water Utility used 53,500 acre-feet of water during 1985, or about 94 percent of the water used for public supplies. The Wichita Water Utility provides water service to Wichita, suburban areas east of Wichita, improvement areas in or adjacent to Wichita (Eastborough, Oaklawn, and Sunview), and provides wholesale water service to Park City, Kechi, Rural Water Districts 1 and 2, and small towns in western Butler County (Andover, Benton, and Rose Hill) (Lorenz and others, 1985). Public-water supplies provided by the Wichita Water Utility were used for residential (45 percent), commercial (30 percent), industrial (15 percent), and municipal and other uses (10 percent) (Lorenz and others, 1985).

All of the surface-water rights for public supplies (52,600 acre-feet per year from Cheney Reservoir) and 79 percent of the ground-water rights for public supplies (40,000 acre-feet per year from the *Equus* beds in southwest Harvey and northwest Sedgwick Counties, and 17,900 acre-feet per year from a local well field just upstream of the confluence of the Arkansas and Little Arkansas Rivers) belong to the city of Wichita. If the Wichita water-treatment plant could fully utilize this 110,500 acre-feet of water, the Wichita Water Utility should have adequate supplies through 2015, based on an extrapolation of the historic urban-population growth rate of 2.8 percent per year from 1920 through 1980 and an average urban water-use rate of 0.16 acre-foot per person per year from 1960 through 1980. From 1960 through 1980, the urban-population growth rate has been only 0.18 percent per year, which would allow water supplies to meet demand for a much longer time. Other cities or improvement districts with ground-water public-supply rights include Mount Hope, Valley Center, Kechi, Park City, Colwich, Maize, Cheney, Goddard, Clearwater, Haysville, and Derby (fig. 1). Nearly 90 percent of the population of Sedgwick County is served by water from public supplies.

The appropriation of water rights for irrigation has increased greatly during the past 25 years, from about 31,000 acre-feet in 1960 to 69,700 acre-feet in 1984. Irrigation accounted for the greatest use of ground water in the county during 1985. The estimated 50,400 acre-feet of ground water used for irrigation in 1985 accounted for 45 percent of the total ground water used. During 1985, irrigation required a greater percentage of its combined appropriated ground- and surface-water rights (77 percent or 53,500 acre-feet to irrigate 45,000 acres) than any other water use. From 1975 through 1983, 241 irrigation wells were installed in the county (data from Kansas Department of Health and Environment, Topeka). Nearly all of these wells were located in the Arkansas River valley.

Appropriated water rights for self-supplied industrial use in the county have increased slightly from 45,300 acre-feet in 1960 to about 48,500 acre-feet (48,400 acre-feet are from ground water) in 1984. Estimated water use for self-supplied industrial purposes amounted to only 39 percent of the appropriated rights. During 1985, about 15 percent of the water supplies provided by the Wichita Water Utility (about 8,000 acre-feet) were used for industrial purposes. Industry was the greatest user of water in 1960, but in 1985 it ranked a distant third behind public supplies and irrigation. Most industrial wells are located in the Arkansas River valley.

Accurate estimates for the self-supplied domestic water-use category are the most difficult to develop. Water rights are not required for self-supplied domestic water use. Because 90 percent of the population in Sedgwick County is served by public-water supplies, domestic self-supplied use is relatively minor. The 1985 estimate for this use (4,800 acre-feet of ground water) is about 13 percent less than the 1960 estimate (Lane and Miller, 1965a). A principal component of self-supplied domestic use is lawn and garden watering. From 1975 through 1983, 2,450 domestic wells and 1,070 lawn and garden wells were completed in Sedgwick County (data from Kansas Department of Health and Environment, Topeka). Most of these wells were located in the western part of Wichita and adjacent outlying areas.

Water-Quality Criteria

Water-quality characteristics are critical factors in determining the suitability of a source for water supplies. Although water can be processed to meet most water-quality criteria, the costs involved often are prohibitive. The preferred approach is to utilize water resources that require no or minimal treatment to meet required water-quality criteria. Supplies for different water-use categories are subject to different water-quality criteria. Important uses of water in Sedgwick County include public supplies, industry, and irrigation.

Domestic-water supplies provided by public utilities are included in the water-use category of public-water supplies. Although public-water supplies are used for many purposes other than drinking water, including additional domestic uses (bathing, laundering, waste disposal, and lawn and garden watering), industrial uses (steam generation, cooling, and processing), and municipal uses (firefighting, watering parks and other public areas, and street cleaning), the water is treated to meet drinking-water standards. Selected water-quality criteria for water resources used as sources of public-water supplies and self-supplied domestic water supplies are listed in table 2 (National Academy of Sciences and National Academy of Engineering, 1973; U.S. Environmental Protection Agency, 1986a, b, c). Most properties and constituents listed in table 2 either hamper or cannot be removed by conventional treatment processes.

Industrial uses of water in Sedgwick County include steam generation, cooling, and process water for manufacturing of food and beverages, chemicals, petroleum, and primary metals products. In general, water-quality criteria for industrial uses are not as stringent as those for public-water supplies. Food and beverage industries are an exception in that they often require processing water that meets drinking-water standards.

The principal industrial uses of water in the county are for steam generation and cooling processes. In general, boiler-makeup water for steam generation should be of adequate quality to: (1) Form no scale or other deposits, (2) cause no corrosion of metal components of the system, (3) not foam, and (4) not contain enough silica to form turbine-blade deposits in high-pressure boilers. Cooling water should be: (1) Non scaling with reference to limited solubility compounds, such as calcium carbonate, sulfate, and phosphate, (2) nonfouling as a result of sedimentary deposits or biological growths, and (3) noncorrosive to materials in the system (National Academy of Sciences and National Academy of Engineering, 1973).

Water used in other industrial categories (chemicals, petroleum, and primary metals) can be extremely variable in the quality required. Some chemical-processing water must meet or exceed drinking-water standards. However, usually the quantity of available water is more important than the quality in these industries. Water-quality characteristics of water resources that have been used as sources of industrial water supplies are given in table 3 (National Academy of Sciences and National Academy of Engineering, 1973).

Irrigation is a principal use of water in Sedgwick County. The water-quality criteria required for irrigation depend greatly on the type of crop and soil characteristics. The salinity of the soil-water solution available to plants is probably the most important water-quality consideration, as it affects the ability of a plant to obtain water. Most crops grown in the county (wheat, corn, and sorghum) are classified as having a medium salt tolerance or they can tolerate a soil-water solution with a specific-conductance range of 6,000 to 10,000 μS/cm (microsiemens per centimeter at 25 °C). Specific conductance is a measure of the ability of a substance to conduct an electrical current and can be directly related to the concentration of ions in solution. Fruit crops are much more sensitive to salinity, generally requiring that soil-water solutions have a specific conductance that is less than 4,000 μS/cm (National Academy of Sciences and National Academy of Engineering, 1973).

Irrigation water with less than 500 mg/L (milligrams per liter) dissolved solids usually will not have detrimental effects on crops (U.S. Environmental Protection Agency, 1986a). In relatively humid regions where irrigation is generally supplemental in nature, such as in Sedgwick County, and natural rainfall is adequate to leach salts from the soil, relatively saline water can be used. The permissible number of irrigations with saline water in humid regions that can be applied between leaching rains to crops with small (fruit crops) and medium (vegetable, field, and forage crops) salt tolerances are indicated in table 4.

The ratio of the cations sodium, calcium, and magnesium (Na^+, Ca^{++}, and Mg^{++}, respectively) in water is important in evaluating its suitability as a source of irrigation supplies. The sodium-adsorption ratio (SAR) is a measure of the adsorbable sodium in water. If too much sodium is adsorbed to clay soils, conditions result that are unfavorable for water movement and plant growth. The SAR is computed by the following formula:

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

where Na^+, Ca^{++}, and Mg^{++} are expressed in milliequivalents per liter. Generally, a SAR of 4 or less is tolerable to fruit crops, and a SAR limit of 8 to 18 is tolerable to vegetable, field, and forage crops (U.S. Environmental Protection Agency, 1986a). Sandy soils are not as susceptible to sodium hazards.

Recommended maximum concentrations of other properties and constituents in irrigation water are given in table 5 (National Academy of Sciences and National Academy of Engineering, 1973). Although the amount of water used for livestock watering is relatively small, the water-quality characteristics are important (table 5).

Table 2. *Selected water-quality criteria for water used as source of public- and domestic-water supplies*

[mg/L, milligrams per liter; µg/L, micrograms per liter]

Property or constituent	Value or concentration		Rationale
pH[1]	6.5-8.5 standard units		Secondary maximum contaminant level
Dissolved solids[1]	500	mg/L	Do.
Sodium[2]	20	mg/L	Very restricted sodium diet
	270	mg/L	Moderately restricted sodium diet
Alkalinity as $CaCO_3$[3]	≥50	mg/L	Corrosion at smaller concentrations
Sulfate[1]	250	mg/L	Secondary maximum contaminant level
Chloride[1]	250	mg/L	Do.
Fluoride	4.0[4]	mg/L	Maximum contaminant level
	2.0[1]	mg/L	Secondary maximum contaminant level
Coliform bacteria[4]	1 per 100 milliliters		Maximum contaminant level
Nitrogen (N)			
Nitrite as N[2]	1	mg/L	Adverse physiologic effects
Nitrate as N[4]	10	mg/L	Maximum contaminant level
Ammonia as N[3]	.5	mg/L	Hampers water-treatment processes
Antimony[2]	146	µg/L	Adverse physiologic effects
Arsenic[4]	50	µg/L	Maximum contaminant level
Barium[4]	1,000	µg/L	Do.
Beryllium[2,5]	.037	µg/L	Adverse physiologic effects
Cadmium[4]	10	µg/L	Maximum contaminant level
Chromium			
trivalent[2]	170,000	µg/L	Adverse physiologic effects
hexavalent[4]	50	µg/L	Maximum contaminant level
Copper[1]	1,000	µg/L	Secondary maximum contaminant level
Iron[1]	300	µg/L	Do.
Lead[4]	50	µg/L	Maximum contaminant level
Manganese[1]	50	µg/L	Secondary maximum contaminant level
Mercury[4]	2	µg/L	Maximum contaminant level
Nickel[2]	632	µg/L	Adverse physiologic effects

Table 2. *Selected water-quality criteria for water used as source of public- and domestic-water supplies*--Continued

Property or constituent	Value or concentration		Rationale
Selenium[4]	10	μg/L	Maximum contaminant level
Silver[4]	50	μg/L	Do.
Thallium[2]	13	μg/L	Adverse physiologic effects
Zinc[1]	5,000	μg/L	Secondary maximum contaminant level
Cyanide[2]	200	μg/L	Adverse physiologic effects
Chlorophenoxy herbicides			
2,4-D[4]	100	μg/L	Maximum contaminant level
2,4,5T[3]	2	μg/L	Adverse physiologic effects
Silvex[4]	10	μg/L	Maximum contaminant level
Organochlorine insecticides			
Aldrin[2,5]	.00074	μg/L	Adverse physiologic effects
Chlordane[2,5]	.0046	μg/L	Do.
DDT[2,5]	.00024	μg/L	Do.
Dieldrin[2,5]	.00071	μg/L	Do.
Endosulfan[2]	74	μg/L	Do.
Endrin[4]	.2	μg/L	Maximum contaminant level
Heptachlor[2,5]	.002	μg/L	Adverse physiologic effects
Heptachlor epoxide[3]	.1	μg/L	Do.
Lindane[4]	4	μg/L	Maximum contaminant level
Methoxychlor[4]	100	μg/L	Do.
Toxaphene[4]	5	μg/L	Do.
Organophosphorus and carbamate pesticides[3], combined	100	μg/L	Adverse physiologic effects
Diazanon	100	μg/L	Do.
Malathion	100	μg/L	Do.
Parathion	100	μg/L	Do.
Trithion	100	μg/L	Do.
Methomyl	100	μg/L	Do.
Propham	100	μg/L	Do.
Sevin	100	μg/L	Do.
Volatile organic compounds[2]			
Benzene [5]	6.6	μg/L	Do.
Benzidine[5]	.0012	μg/L	Do.
Bis(Chloromethyl)ether[5]	.0000376	μg/L	Do.
Carbon tetrachloride[5]	4	μg/L	Do.
Chloroform[5]	1.9	μg/L	Do.

Table 2. *Selected water-quality criteria for water used as source of public- and domestic-water supplies*--Continued

Property or constituent	Value or concentration		Rationale
Volatile organic compounds[2]--Continued			
1,1-Dichloroethylene[5]	.33	μg/L	Adverse physiologic effects
1,2-Dichloroethane[5]	9.4	μg/L	Do.
Ethylbenzene	1,400	μg/L	Do.
Halomethanes (total)[5]	1.9	μg/L	Do.
1,1,2,2-Tetrachloroethane[5]	1.7	μg/L	Do.
Tetrachloroethylene[5]	8	μg/L	Do.
Toluene	14,300	μg/L	Do.
1,1,1-Trichloroethane	18,400	μg/L	Do.
1,1,2-Trichloroethane[5]	6	μg/L	Do.
Trichloroethylene[5]	27	μg/L	Do.
Trihalomethane, total[4]	100	μg/L	Maximum contaminant level
Vinyl chloride[5]	20	μg/L	Adverse physiologic effects
Base-neutral extractable organic compounds[2]			
Bis(2-chloroisopropyl)ether	34.7	μg/L	Do.
Bis(2-chloroethyl)ether[5]	.3	μg/L	Do.
Dichlorobenzene	400	μg/L	Do.
Dichlorobenzidine[5]	.103	μg/L	Do.
2,4-dinitrotoluene[5]	1.1	μg/L	Do.
Diphenylhydrazine[5]	.422	μg/L	Do.
Dimethyl phthalate	313,000	μg/L	Do.
Diethyl phthalate	350,000	μg/L	Do.
Dibutyl phthalate	34,000	μg/L	Do.
Di-2-ethylhexyl phthalate	15,000	μg/L	Do.
Fluoranthene	42	μg/L	Do.
Hexachloroethane[5]	19	μg/L	Do.
Hexachlorobutadiene[5]	4.47	μg/L	Do.
Hexachlorocyclohexane[5]	.022	μg/L	Do.
Hexachlorocyclopentadiene	206	μg/L	Do.
r-Hexachloroclohexane[5]	.186	μg/L	Do.
Technical-hexachlorocyclohexane	0.052	μg/L	Do.
Isophorone	5,200	μg/L	Do.
Nitrobenzene	19,800	μg/L	Do.
N-nitrosodiethylamine[5]	.008	μg/L	Do.
N-nitrosodimethylamine[5]	.014	μg/L	Do.
N-nitrosodibutylamine[5]	.064	μg/L	Do.
N-nitrosopyrolidine[5]	.160	μg/L	Do.
N-nitrosodiphyenylamine[5]	49	μg/L	Do.
Polychlorinated biphenyls[5]	.00079	μg/L	Do.

Table 2. *Selected water-quality criteria for water used as source of public- and domestic-water supplies*--Continued

Property or constituent	Value or concentration		Rationale
Base-neutral extractable organic compounds[2]--Continued			
Polynuclear aromatic hydrocarbons[5]	.028	μg/L	Adverse physiologic effects
2,3,7,8-Tetrachloro-dibenzo-P-dioxin	0	μg/L	Do.
Acid-extractable organic compounds[2]			
Dinitrophenol	70	μg/L	Do.
2,4-Dinitro-o-cresol	13.4	μg/L	Do.
2,4-Dichlorophenol	3,090	μg/L	Do.
Pentachlorophenol	1,010	μg/L	Do.
Phenol	3,500	μg/L	Do.
2,4,5-Trichlorophenol	2,600	μg/L	Do.
2,4,6-Trichlorophenol[5]	12	μg/L	Do.
Radionuclides[4]			
Radium 226 and 228 (combined)	5 picocuries per liter		Maximum contaminant level
Gross alpha particle radioactivity	15 picocuries per liter		Do.
Gross beta particle and photon radioactivity	4 millirems per year		Do.

[1] Data from U.S. Environmental Protection Agency, 1986b. These levels are recommended standards.

[2] Data from U.S. Environmental Protection Agency, 1986a.

[3] Data from National Academy of Sciences and National Academy of Engineering, 1973.

[4] Data from U.S. Environmental Protection Agency, 1986c. These levels are enforceable standards.

[5] This concentration might result in a 0.00001 increase of cancer risk over a lifetime.

Table 3. ***Water-quality characteristics of water resources that have been used as sources for selected industrial supplies***

[Values shown in milligrams per liter (mg/L) or micrograms per liter (µg//L), unless otherwise indicated. Values represent maximum concentrations or acceptable range. Data from National Academy of Science and National Academy of Engineering (1973)]

Property or constituent	Boiler-makeup water	Cooling water		Process water		
		Fresh	Brackish[1]	Chemicals	Petroleum	Primary metals
pH, standard units (range)	--	[2]5.0-8.9; 3.5-9.1	5.8-8.4	5.5-9.0	6.0-9.0	3.0
Temperature, degrees Fahrenheit (°F)	120	[2]100; 120	[2]100; 120	--	--	100
Hydrogen sulfide, in mg/L	--	--	4	--	20	--
Chemical oxygen demand, in mg/L	[3]100; 500	[2]100	[2]100	--	--	--
Hardness as $CaCO_3$, in mg/L	5,000	850	7,000	1,000	900	1,000
Acidity as $CaCO_3$, in mg/L	1,000	[2]0; 200	0	--	--	75
Calcium, in mg/L	--	500	1,200	250	220	--
Magnesium, in mg/L	--	--	--	100	85	--
Sodium plus potassium, in mg/L	--	--	--	--	230	--
Bicarbonate, in mg/L	600	600	180	600	480	--
Alkalinity as $CaCO_3$, in mg/L	500	500	150	500	500	200
Sulfate, in mg/L	1,400	680	2,700	850	900	--
Chloride, in mg/L	19,000	[2]600; 500	22,000	500	1,600	500
Fluoride, in mg/L	--	--	--	--	1.2	--
Silica, in mg/L	150	[2]50; 150	25	--	85	--
Dissolved solids, in mg/L	35,000	1,000	35,000	2,500	3,500	1,500
Suspended solids, in mg/L	15,000	[2]5,000; 15,000	250	10,000	5,000	3,000
Nitrate (as N), in mg/L	--	7	--	--	2	--
Ammonia (NH_4), in mg/L	--	--	--	--	40	--
Phosphate (PO_4), in mg/L	[3]50	4	5	--	--	--
Aluminum, in µg/L	3,000	3,000	--	--	--	--
Iron, µg/L	80,000	[2]4,000; 80,000	1,000	10,000	15,000	--
Manganese, in µg/L	10,000	[2]2,500; 10,000	20	2,000	--	--
Carbon tetrachloride extract, in µg/L	100,000	[2]100,000	[2]100,000	--	--	3,000

[1] Defined in this report as water with more than 1,000 milligrams per liter dissolved solids.

[2] For makeup recycle water.

[3] For utilities.

Table 4. *Permissible number of irrigations with saline water in humid regions between leaching rains for indicated crops*

[Data from National Academy of Sciences and National Academy of Engineering (1973)]

Irrigation water		Number of irrigations for general crop type	
Dissolved solids, in milligrams per liter	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Fruit	Vegetables, field crops, and forage crops
640	1,000	7	15
1,280	2,000	4	7
1,920	3,000	2	4-5
2,560	4,000	2	3
3,200	5,000	1	2-3
3,840	6,000	1	2
4,480	7,000	--	1-2
5,120	8,000	--	1

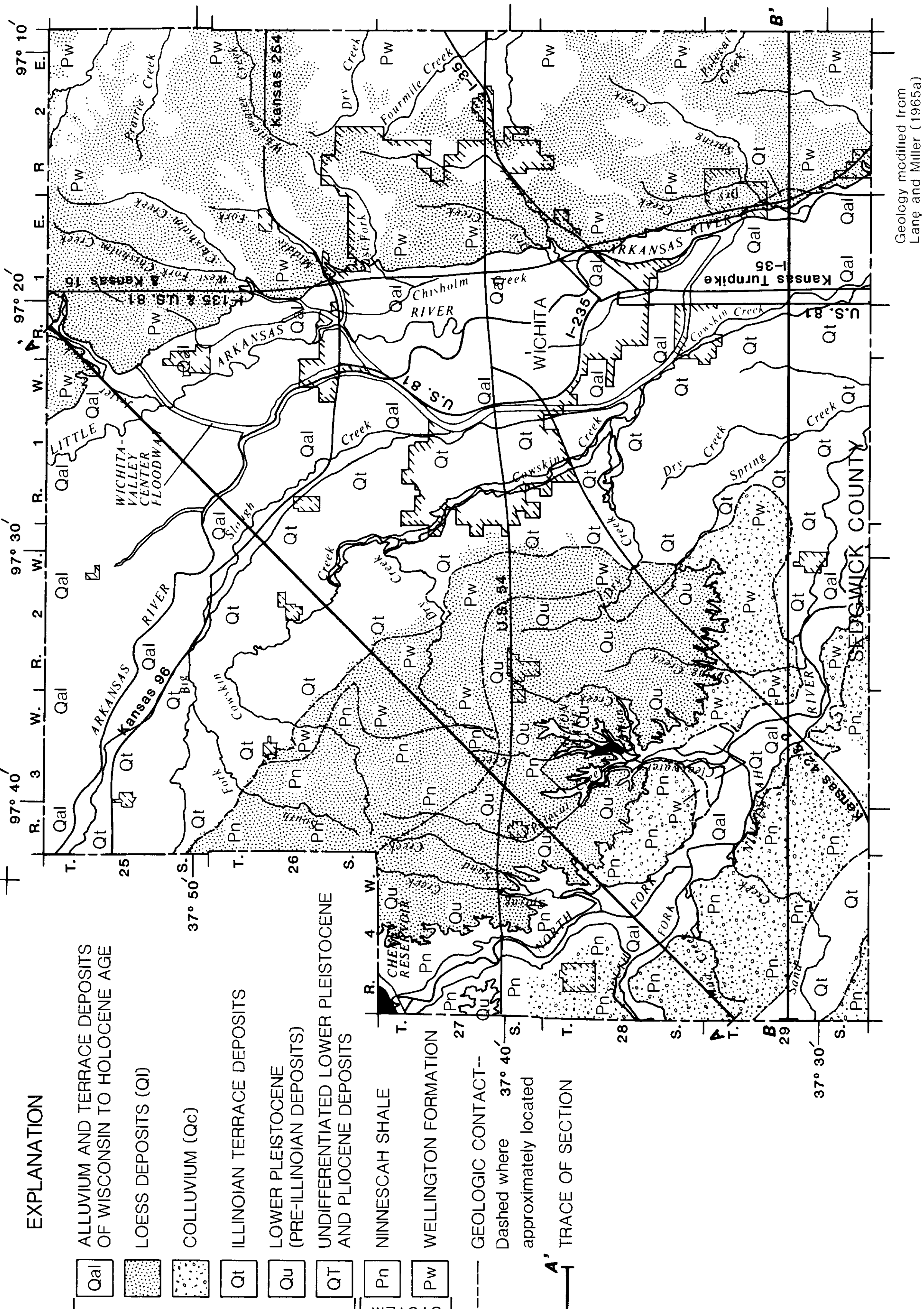
Instream use of water for recreation and aquatic life are nonconsumptive. However, water-quality characteristics are important for maintaining aquatic habitats. Specific criteria for aquatic life are available (U.S. Environmental Protection Agency, 1986a) but are not included in this report.

GEOLOGIC SETTING

Rocks that occur at the surface in Sedgwick County are classified as sedimentary. The surface geology of Sedgwick County and selected geologic cross sections are shown in figure 6 (Lane and Miller, 1965a). Consolidated rocks generally do not occur at the surface in the county because most of the bedrock is Permian shale, which is easily eroded, and unconsolidated colluvial, fluvial, and eolian deposits occur over bedrock in most of the area. The reader is referred to Lane and Miller (1965a) for a detailed description of geology from which the following discussion is summarized.

The oldest rocks that crop out in the county belong to the Wellington Formation of the Permian System. These rocks occur at or near the surface east of the Arkansas River valley and are the bedrock surface for the eastern two-thirds of the county. Rocks of the Wellington Formation are primarily gray and blue shale, with small, thin beds of maroon shale, impure limestone, gypsum, and anhydrite. A thick salt bed (Hutchinson Salt Member of the Wellington Formation) is present in the subsurface. The Hutchinson Salt Member occurs near the surface in the area of the Arkansas River valley, and its easily erodible nature was the major factor affecting the location of the river. The Wellington Formation ranges in thickness from a minimum of about 80 feet in some areas along the eastern edge of the county to a maximum of about 550 feet along the western edge. The Wellington Formation dips gently towards the west at about 10 feet per mile from its outcrop areas and occurs at a depth of about 180 feet along the western edge of the county.

The Ninnescah Shale of the Permian System occurs at or near the surface in the western one-third of the county and is the bedrock surface in that area. Rocks of the


EXPLANATION
PLEISTOCENE SERIES
Qal ALLUVIUM AND TERRACE DEPOSITS OF WISCONSIN TO HOLOCENE AGE
LOESS DEPOSITS (Ql)
COLLUVIUM (Qc)
Qt ILLINOIAN TERRACE DEPOSITS
Qu LOWER PLEISTOCENE (PRE-ILLINOIAN DEPOSITS)
QT UNDIFFERENTIATED LOWER PLEISTOCENE AND PLIOCENE DEPOSITS
PERMIAN SYSTEM
Pn NINNESCAH SHALE
Pw WELLINGTON FORMATION
GEOLOGIC CONTACT-- Dashed where approximately located
A A' TRACE OF SECTION
Geology modified from Lane and Miller (1965a)
SEDGWICK COUNTY
WICHITA
ARKANSAS RIVER
LITTLE ARKANSAS RIVER
WICHITA-VALLEY CENTER FLOODWAY
CHENEY RESERVOIR
NORTH FORK
NINNESCAH
Cowskin Creek
Chisholm Creek
Kansas Turnpike
I-35
I-135 & U.S. 81
& Kansas 15
I-235
U.S. 81
U.S. 54
Kansas 96
Kansas 254
Kansas 42
97° 40′
97° 30′
97° 20′
97° 10′
37° 50′
37° 40′
37° 30′
R. 3 W.
R. 2 W.
R. 1 W.
R. 1 E.
R. 2 E.
R. 4 W.
T. 25 S.
T. 26 S.
T. 27 S.
T. 28 S.
T. 29 S.

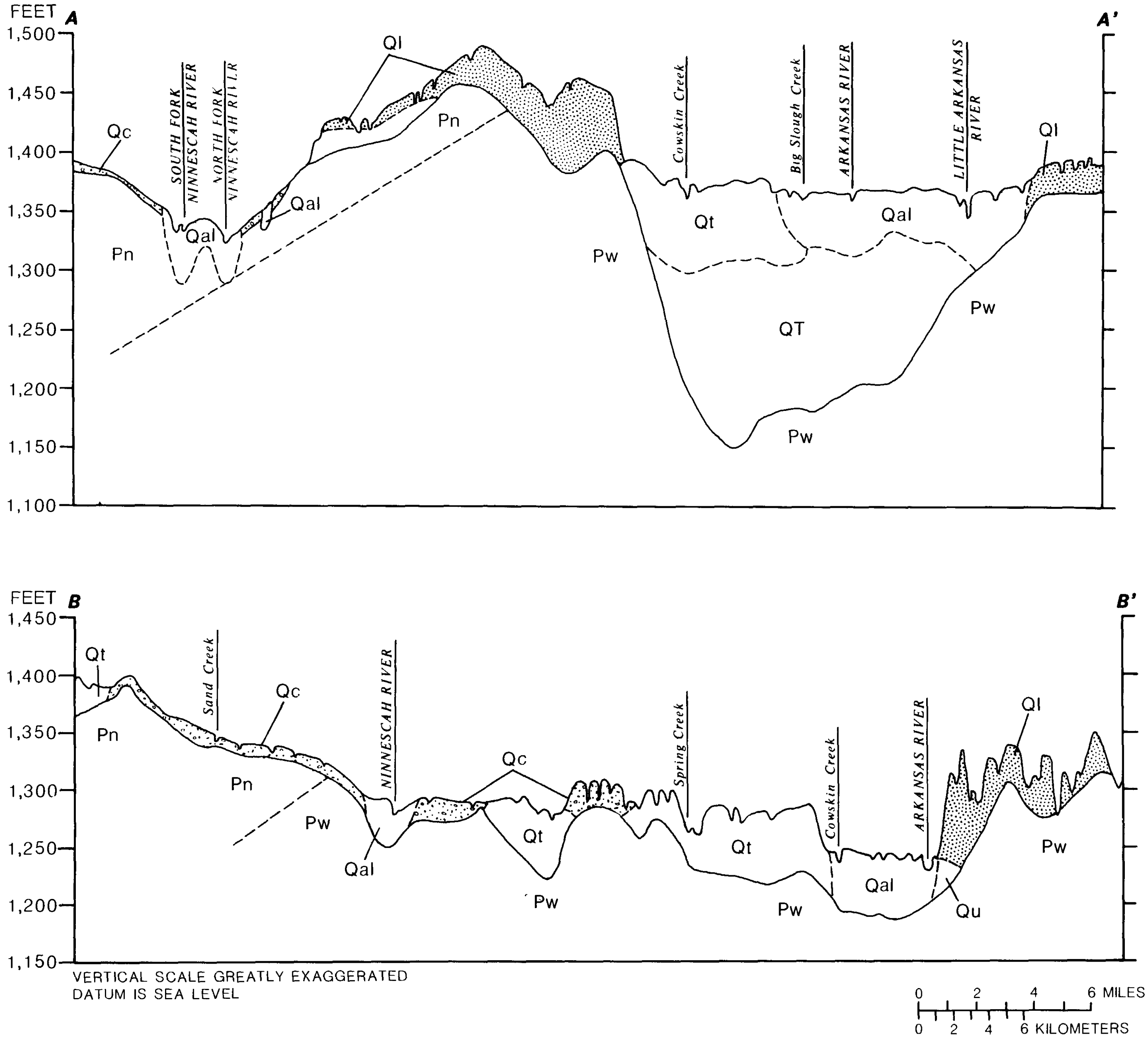


Figure 6. Surface geology and selected geologic cross sections in Sedgwick County.

Table 5. *Criteria for maximum values of selected water-quality properties and constituents in agricultural water*

[From National Academy of Sciences and National Academy of Engineering (1973). Values in milligrams per liter (mg/L) or micrograms per liter (µg/L), unless otherwise noted]

Property or constituent	Irrigation[1]	Livestock
pH, standard units	[2]4.5-9.0	--
Fluoride, mg/L	1.0	2.0
Dissolved solids, in mg/L	see table 4	3,000
Nitrite as N, in mg/L	--	10
Nitrite + nitrate as N, in mg/L	--	100
Aluminum, in µg/L	5,000	5,000
Arsenic, in µg/L	100	200
Beryllium, in µg/L	100	--
Boron, in µg/L	750	5,000
Cadmium, in µg/L	10	50
Chromium, in µg/L	100	1,000
Cobalt, in µg/L	50	1,000
Copper, in µg/L	200	500
Iron, in µg/L	5,000	--
Lead, in µg/L	5,000	100
Lithium, in µg/L	2,500	--
Manganese, in µg/L	200	--
Mercury, in µg/L	--	10
Molybdenum, in µg/L	10	--
Nickel, in µg/L	200	--
Selenium, in µg/L	20	50
Vanadium, in µg/L	100	100
Zinc, in µg/L	2,000	25,000
Fecal coliform bacteria	1,000 per 100 milliliters of water	--
Radionuclides, see table 2	see table 2	see table 2
Pesticides, in µg/L	--	Do.

[1] Continuous use on all soil types.

[2] Acceptable range.

Ninnescah Shale are primarily brownish-red silty shale and siltstone, with some thin beds of grayish-green shale, dolomite, and fine-grained sandstone. The Ninnescah Shale ranges in thickness from near zero at the outcrop of its geologic contact with the Wellington Formation to about 180 feet along the western edge of the county.

Unconsolidated deposits occur over bedrock in most of the county. Undifferentiated Pliocene deposits (calcareous, gray-to-pinkish tan silt and clay, fine-to-coarse sand, and fine-to-coarse gravel; believed to be erosional remnants of the Miocene Ogallala Formation) and lower Pleistocene deposits (pre-Illinoian time) as much as 160 feet thick occur in the basal part of the Arkansas River valley fill north of Wichita. Lower Pleistocene deposits occur in the basal part of the Arkansas River valley south of Wichita at thicknesses of as much as 70 feet and on the southward-sloping uplands north of the Ninnescah River at thicknesses of as much as 20 feet. Illinoian terrace deposits (primarily fine-to-coarse sand and fine-to-coarse gravel with silty sand in the upper part and local clay and silt lenses) occur over Permian bedrock and (or) undifferentiated Pliocene and lower Pleistocene deposits along the western side of the Arkansas River valley at thicknesses of as much as 75 feet. Colluvium (heterogeneous mixture of silt, clay, sand, gravel, and bedrock fragments deposited by local slope erosional processes) of Illinoian to Holocene age occurs over Permian bedrock on both sides of the Ninnescah River valley at thicknesses of as much as 30 feet. Loess deposits (tan to pinkish-tan calcareous silt with zones of caliche nodules and sand) of Illinoian to Holocene age occur over bedrock and lower Pleistocene deposits in most upland areas at thicknesses of as much as 75 feet. Alluvium and terrace deposits (primarily fine-to-coarse sand and fine-to-coarse gravel with clayey silt in the upper part) of Wisconsin to Holocene age occur over Permian bedrock, undifferentiated Pliocene and lower Pleistocene deposits, and (or) lower Pleistocene deposits in the Arkansas River valley (as much as 60 feet thick) and in the Ninnescah River valley (as much as 50 feet thick). The total thicknesses of unconsolidated deposits range from near zero to about 80 feet in the upland areas, to as much as 50 feet in the Ninnescah River valley, and to as much as 250 feet in the Arkansas River valley.

Unconsolidated deposits of clay, silt, sand, and gravel, ranging in age from Pliocene to Pleistocene, occur in the study area over a large triangular-shaped area delineated approximately by imaginary lines connecting the cities of Hutchinson, Newton, and Wichita. These deposits form part of what is referred to as the *Equus* beds aquifer.

SURFACE-WATER RESOURCES

Rivers and Streams

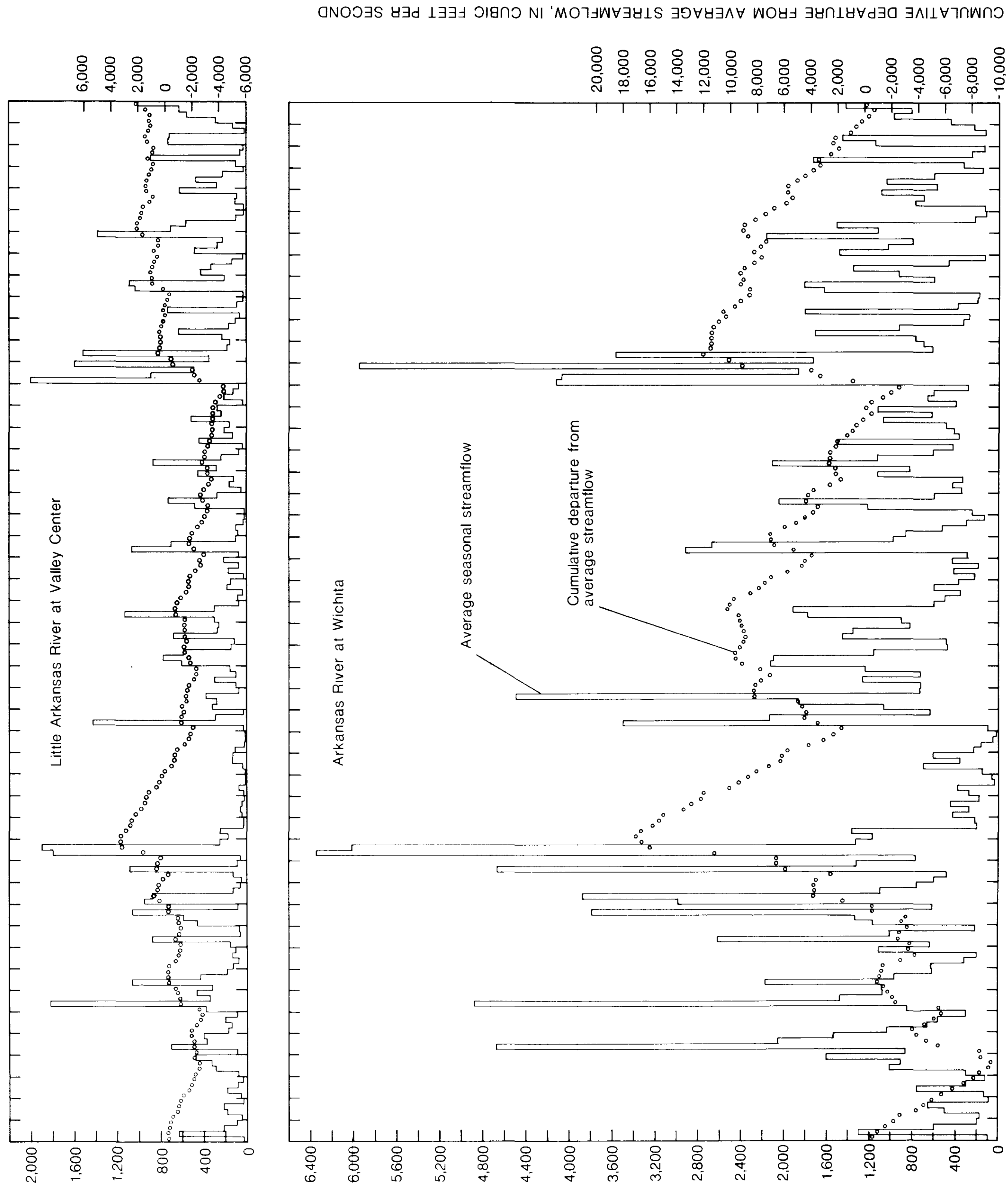
The Arkansas River and its tributary streams, including the Little Arkansas and Ninnescah Rivers, constitute the principal surface-drainage system in the study area. The eastern edge of the area is drained by east-flowing tributaries to the Walnut River (fig. 1).

Streamflow Characteristics

The determination of streamflow characteristics requires relatively long-term streamflow records. Streamflow data collected at U.S. Geological Survey streamflow-gaging stations in the study area (fig. 1) are available for the Arkansas, Little Arkansas, North Fork Ninnescah, South Fork Ninnescah, and Ninnescah Rivers. Data from these stations were analyzed to determine historic streamflow trends, flow duration, and low- and high-flow characteristics.

Historic streamflow

Examination of historic or long-term streamflow records is useful in providing a perspective of streamflow during any selected period and for detecting trends in streamflow. Very long-term streamflow records are available for the three principal streams in the study area. Mean daily streamflow data have been collected by the U.S. Geological Survey for the Arkansas River at Wichita since 1934, for the Little Arkansas River at Valley Center since 1922, and for the Ninnescah River near Peck since 1938. Average seasonal streamflow, computed from mean daily streamflow data, for these three rivers from 1938 through 1985 is shown in figure 7. Also shown in figure 7 are cumulative departures from average streamflow (for station periods of record)., seasonal precipitation at Wichita, and cumulative departure from average precipitation (1888-1985). Precipitation at


Little Arkansas River at Valley Center
Arkansas River at Wichita
Average seasonal streamflow
Cumulative departure from average streamflow
CUMULATIVE DEPARTURE FROM AVERAGE STREAMFLOW, IN CUBIC FEET PER SECOND
AVERAGE SEASONAL STREAMFLOW, IN CUBIC FEET PER SECOND

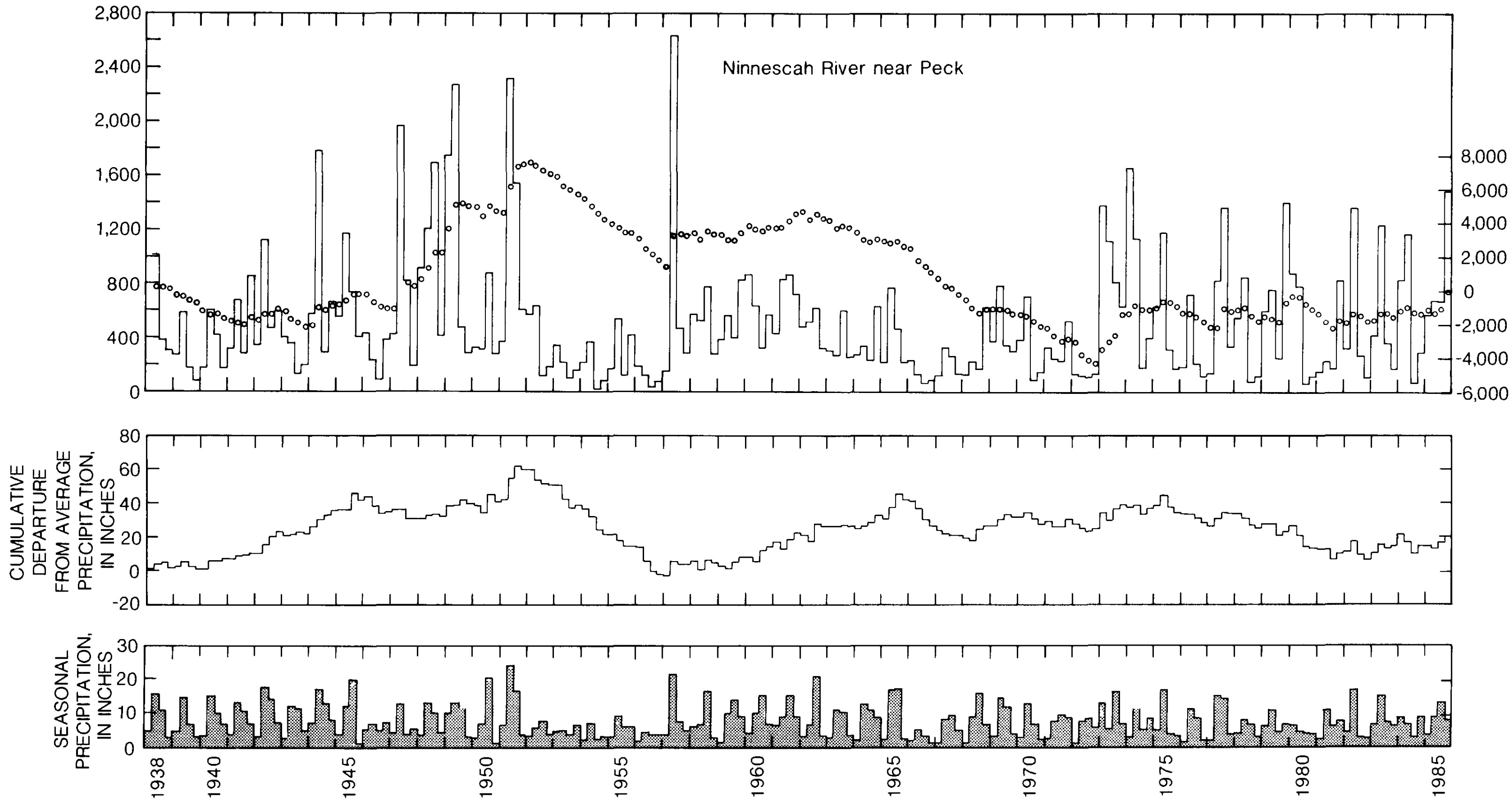


Figure 7. Average seasonal streamflow (1938-85) and cumulative departure from average streamflow (during indicated period of record) for Little Arkansas River at Valley Center (1922-85), Arkansas River at Wichita (1934-85), and Ninnescah River near Peck (1938-85), and seasonal precipitation (1938-85) and cumulative departure from average precipitation (1888-1985) at Wichita.

Wichita probably is not equal to that which occurs in the drainage basins of these rivers, but the trends probably are representative.

Streamflow in the study area occurs primarily in response to precipitation. Although large quantities of rainfall and corresponding large rates of streamflow can occur at any time during the year, they generally occur during the spring, as indicated by histograms of seasonal precipitation and average seasonal streamflow shown in figure 7. The smallest quantities of precipitation and rates of streamflow typically occur during the winter.

The plots of cumulative departure from average precipitation and streamflow (fig. 7) are similar, indicating the direct relationship between precipitation and streamflow. When the slopes of the cumulative departure curves are flat, the values represented are average; when the slopes are positive, the values represented are greater than average; and, when the slopes are negative, the values represented are less than average.

Prior to 1938, drought conditions had existed in the study area for several years, and, although precipitation was about average from 1938 through 1941, streamflow was less than average. Precipitation and streamflow generally were greater than average from 1942 through 1951, except during 1943, 1946, and 1950. The wettest year on record in the area was 1951, when more than 50 inches of precipitation fell at Wichita and the highest average streamflows on record for the Arkansas River at Wichita occurred during the spring and summer. From 1952 through 1956, a severe drought occurred in the area, and precipitation and streamflow were much less than average. In 1956, the lowest average seasonal streamflow on record for the Arkansas River at Wichita occurred during the fall. The drought ended in 1957, and the highest average seasonal streamflow on record for the Ninnescah River near Peck occurred during the spring. From 1958 through 1962, precipitation and streamflow generally were average or greater than average, except during 1959. From 1963 through 1972, precipitation and streamflow generally were less than average, except during 1965 and 1969. As a result of the construction of Cheney Reservoir in 1965, cumulative departure from average seasonal streamflow for the Ninnescah River near Peck experienced a much larger proportional decline than streamflow for the Arkansas River at Wichita and the Little Arkansas River at Valley Center during this period. In 1973 and 1974, precipitation and streamflow were greater than average as the Little Arkansas River had the highest average seasonal streamflow on record during the winter of 1973, and the Arkansas River had the third-highest average seasonal streamflow on record during the fall of 1973. From 1975 through 1985, precipitation and streamflow generally have been average or less than average, except during 1977 and 1979. The decline in streamflow for the Arkansas River since 1980 may be caused by less precipitation in western parts of its basin, effects of John Martin Reservoir in Colorado, increased ground-water withdrawals for irrigation, or agricultural practices, such as terracing, that decrease runoff.

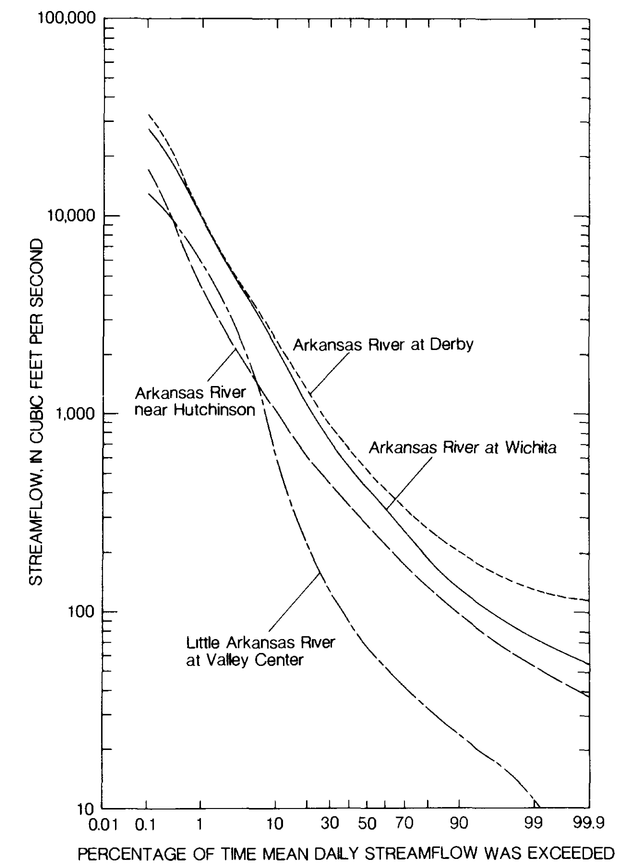


Figure 8. Flow-duration curves for Arkansas River near Hutchinson, at Wichita, and at Derby; and for Little Arkansas River at Valley Center, October 1965-September 1985.

Flow duration

Flow-duration curves graphically display the distribution of streamflow rates through time by showing the percentage of time that a given streamflow rate is equaled or exceeded. Flow-duration curves for streamflow-gaging stations in the study area were computed from mean daily streamflow data collected during October 1965 through September 1985. This period of record was selected because: (1) Data are available for all of the gaging stations (except the Arkansas River at Derby, which was established in October 1968); (2) high-, normal-, and low-flow conditions are adequately represented; and (3) the period is representative of current conditions.

Flow-duration curves for the Arkansas River at Hutchinson, Wichita,and Derby (fig. 8) are similar in shape. The relatively flat slopes of these curves for streamflow that was exceeded 50 percent or more of the time indicate that the Arkansas River is well sustained by ground-water inflow from Permian rocks northwest of Sedgwick County and from the *Equus* beds aquifer (Pliocene and Pleistocene deposits of clay, silt, sand, and gravel that occur in a triangular shaped area approximately delineated by imaginary lines connecting the cities of Hutchinson, Newton, and Wichita) in Sedgwick, Harvey, and southern McPherson Counties during low-flow conditions. The higher flows in the Arkansas River at Wichita and Derby in relation to the Arkansas River near Hutchinson result primarily from streamflow contributed by the Little Arkansas River. The flatter slope of the curve representing the Arkansas River at Derby that occurs between about 50 and 99.9 percent of the time is due mainly to effluent from Wichita sewage-treatment plants. During 1982, effluent from Wichita sewage-treatment plants averaged about 60 cubic feet per second (data from Wichita Water Pollution Control Division), which is approximately equal to the difference in streamflow observed at the lower end of the curves for Wichita and Derby.

The flow-duration curve for the Little Arkansas River at Valley Center (fig. 8) has a steeper slope in the part that represents streamflow provided by surface runoff, generally less than 50 percent of the time. The relatively steep slope is a function of basin characteristics. The Little Arkansas River basin is smaller, has steeper land-surface slopes, and bedrock occurs at or near the surface throughout much of its drainage area. These factors result in more surface runoff, which reaches the channel in a relatively short time during rainstorms. The lower end of the curve for the Little Arkansas River is relatively flat, indicating that the river is well sustained by ground-water inflow from the *Equus* beds aquifer in northern Sedgwick, Harvey, and southern McPherson Counties. The steeper slope of the curve that occurs after about

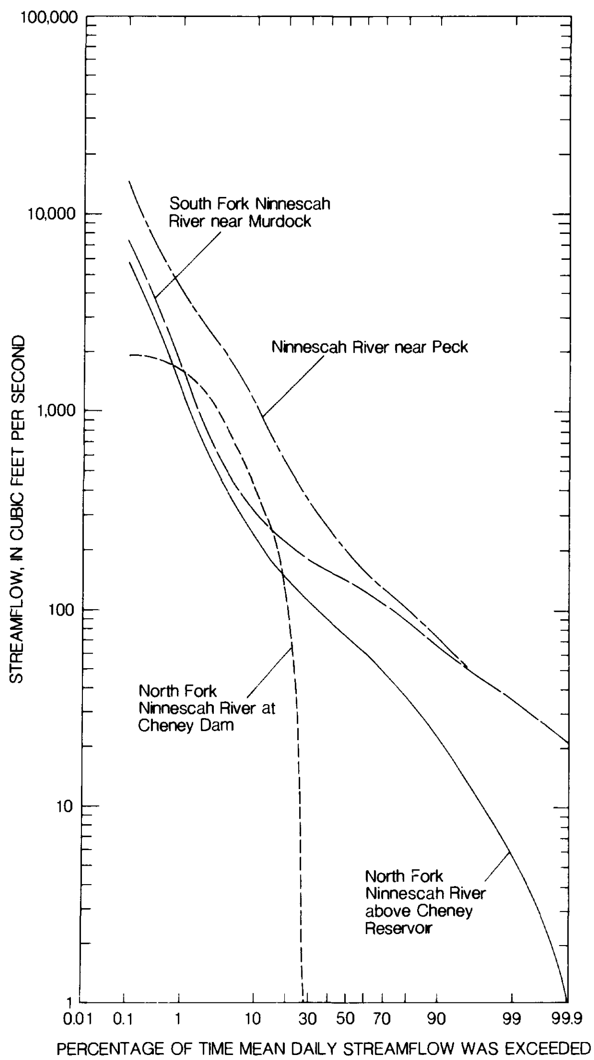


Figure 9. Flow-duration curves for North Fork Ninnescah River above Cheney Reservoir and at Cheney Dam, South Fork Ninnescah River near Murdock, and Ninnescah River near Peck, October 1965-September 1985.

95 percent of the time might be due to ground-water withdrawals from the Wichita well field upstream from Valley Center, which result in smaller rates of ground-water inflow to the stream, or in the stream losing water.

Flow-duration curves for the North Fork Ninnescah River above Cheney Reservoir and at Cheney Dam, the South Fork Ninnescah River near Murdock, and the Ninnescah River near Peck are shown in figure 9. The curve for the North Fork Ninnescah River above Cheney Reservoir has a relatively steep slope, indicating that streamflow is provided primarily by surface runoff and that the stream is not well sustained by ground-water inflow. The curve for the North Fork Ninnescah River at Cheney Dam illustrates the regulating effect of Cheney Reservoir. The reservoir impounds the extreme high flows (those exceeded less than about 0.7 percent of the time) and releases most of the water at relatively large rates of flow between 0.7 and 20 percent of the time. After about 30 percent of the time, most of the flow is held in storage, and releases are minimal. The slope of the flow-duration curve for the South Fork Ninnescah River near Murdock is much flatter at the lower end than that of the North Fork Ninnescah River, indicating that flow is well sustained by ground-water inflow from Permian rocks west of Sedgwick County. The flow-duration curve for the Ninnescah River near Peck is affected also by Cheney Reservoir. The "hump" that occurs between about 1 percent and 20 percent of the time is caused by releases from Cheney Reservoir. After about 20 percent of the time, the curve for the Ninnescah River near Peck begins to merge with that of the South Fork Ninnescah River near Murdock as less water is released from Cheney Reservoir. During smaller rates of flow, those that were equaled or exceeded more than 50 percent of the time, most of the flow in the Ninnescah River near Peck is provided by the South Fork Ninnescah River as water generally is not released from Cheney Reservoir during low-flow periods.

Low-flow characteristics

Low-flow characteristics of streams are important in evaluating their adequacy for maintaining aquatic life, providing water supplies, and abating water contamination from human activities, such as sewage disposal. Because low flow generally is sustained by ground-water inflow, low-flow characteristics are useful also for estimating ground-water inflow.

Low-flow magnitude and frequency can be estimated from curves shown for the Arkansas River (near Hutchinson, at Wichita, and at Derby) and the Little Arkansas River at Valley Center (fig. 10) and for the North Fork Ninnescah River above Cheney Reservoir, the South Fork Ninnescah River near Murdock, and the Ninnescah River near Peck (fig. 11). The curves were manually fitted to actual data points (also shown) representing mean daily streamflow recorded from October 1965 through September 1985 and probably are representative of current (1986) conditions. Streamflow values on the curves represent the lowest mean streamflow, in cubic feet per second, that occurred during the indicated number of consecutive days (7, 30, and 90 days) at recurrence intervals of from 1.05 to 20 years. The periods of 7, 30, and 90 consecutive days were selected because they represent weekly, monthly, and seasonal low flows.

Although the low-flow curves are presented primarily to describe low-flow magnitude and frequency during approximately the last 20 years, they can be used for prediction purposes. The error involved in using the curves for prediction purposes is estimated from visual inspection to be generally less than 25 percent. The extreme flatness at the lower ends of the low-flow curves for the Arkansas River at Derby probably is caused by effluent from Wichita sewage-treatment plants, which averaged about 60 cubic feet per second during 1982 (data from Wichita Water Pollution Control Division).

High-flow characteristics

High-flow characteristics of streams are used primarily to determine flood-control storage for reservoirs. Whereas low-flow characteristics generally describe streamflow that results from ground-water inflow, high-flow characteristics describe streamflow that results from surface runoff.

Curves showing frequency and magnitude of high flows for the Arkansas River (near

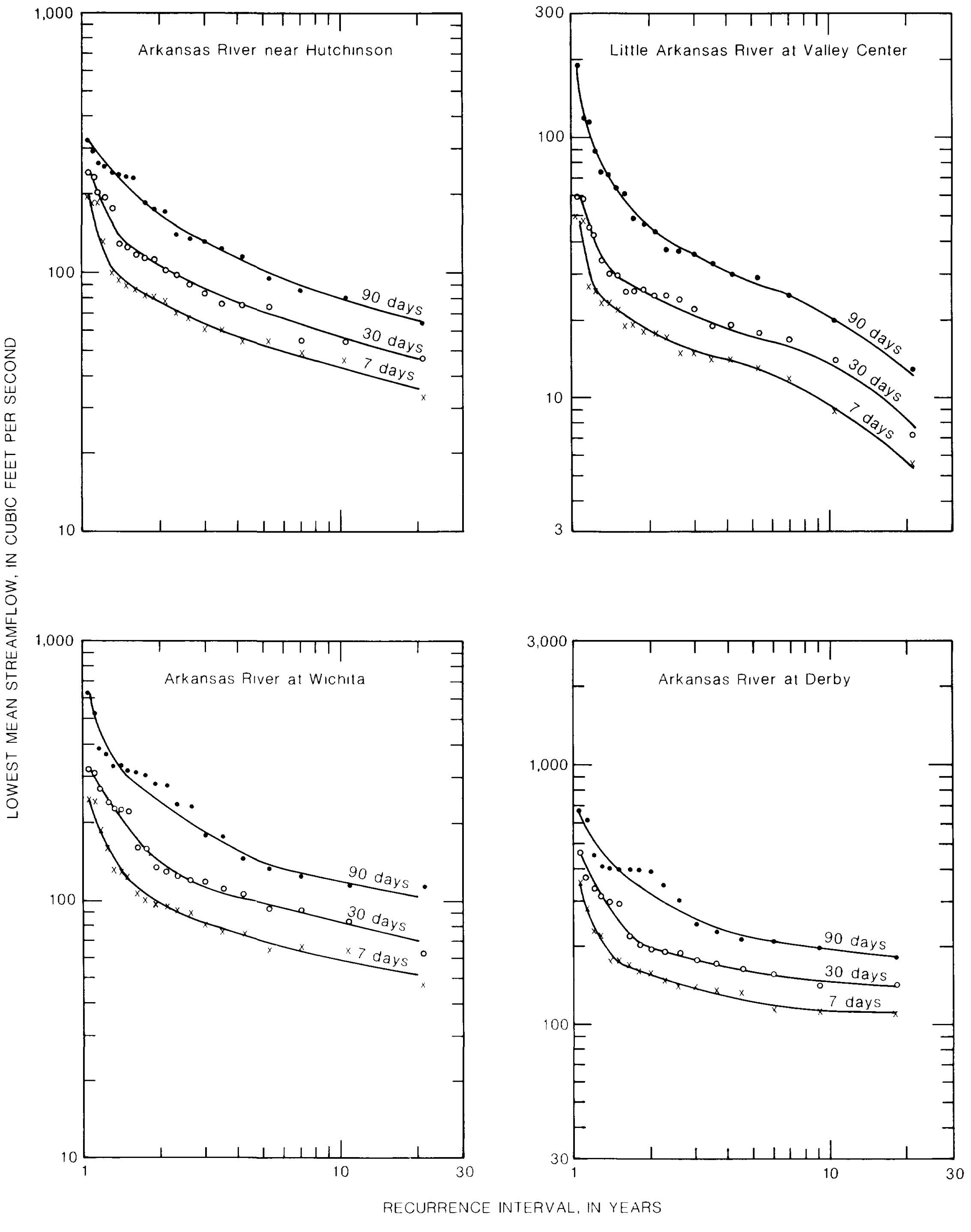


Figure 10. Low-flow frequency curves (7, 30, and 90 consecutive days) for Arkansas River near Hutchinson, at Wichita, and at Derby; and for Little Arkansas River at Valley Center, October 1965-September 1985.

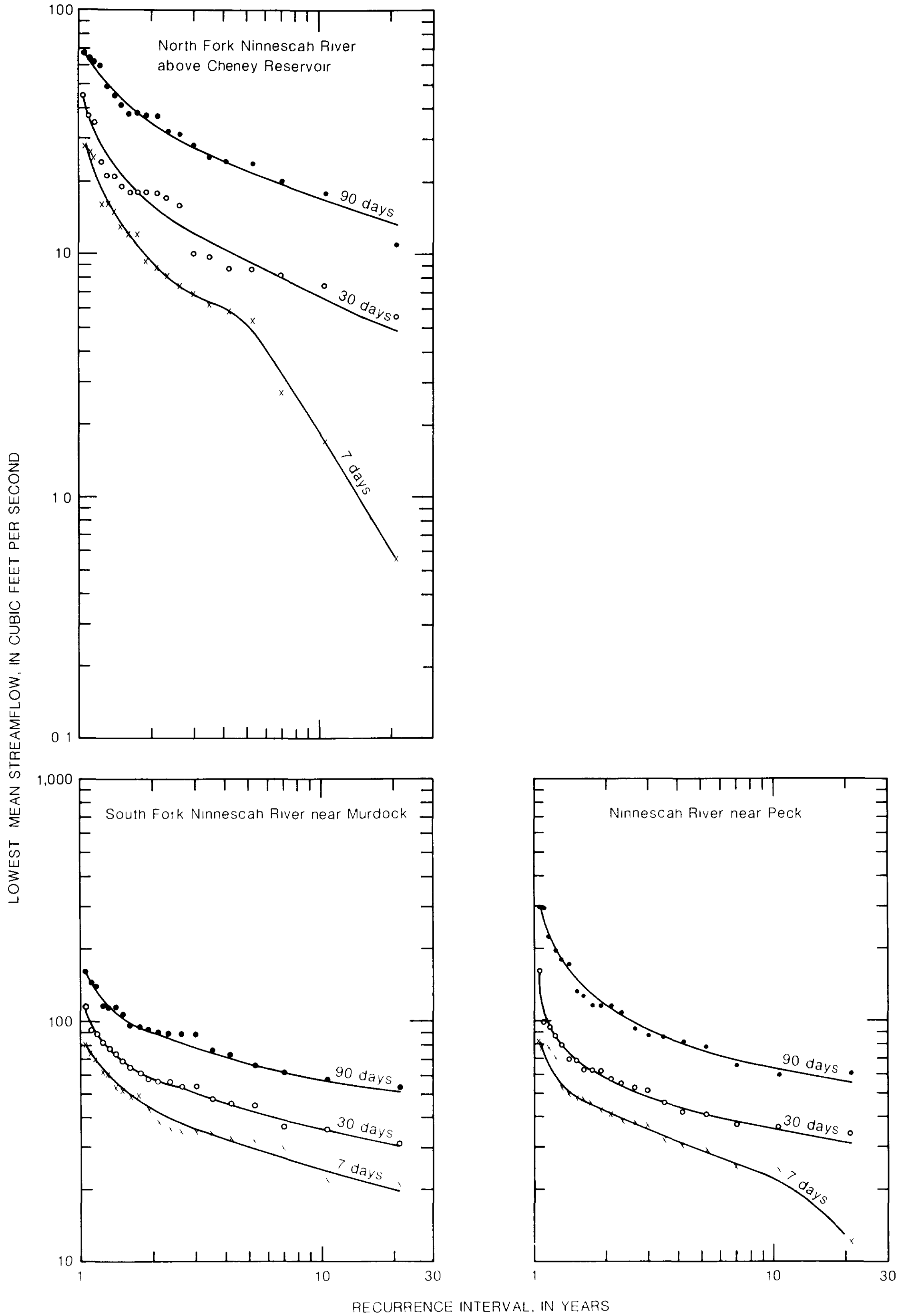


Figure 11. Low-flow frequency curves (7, 30, and 90 consecutive days) for North Fork Ninnescah River above Cheney Reservoir, South Fork Ninnescah River near Murdock, and Ninnescah River near Peck, October 1965-September 1985.

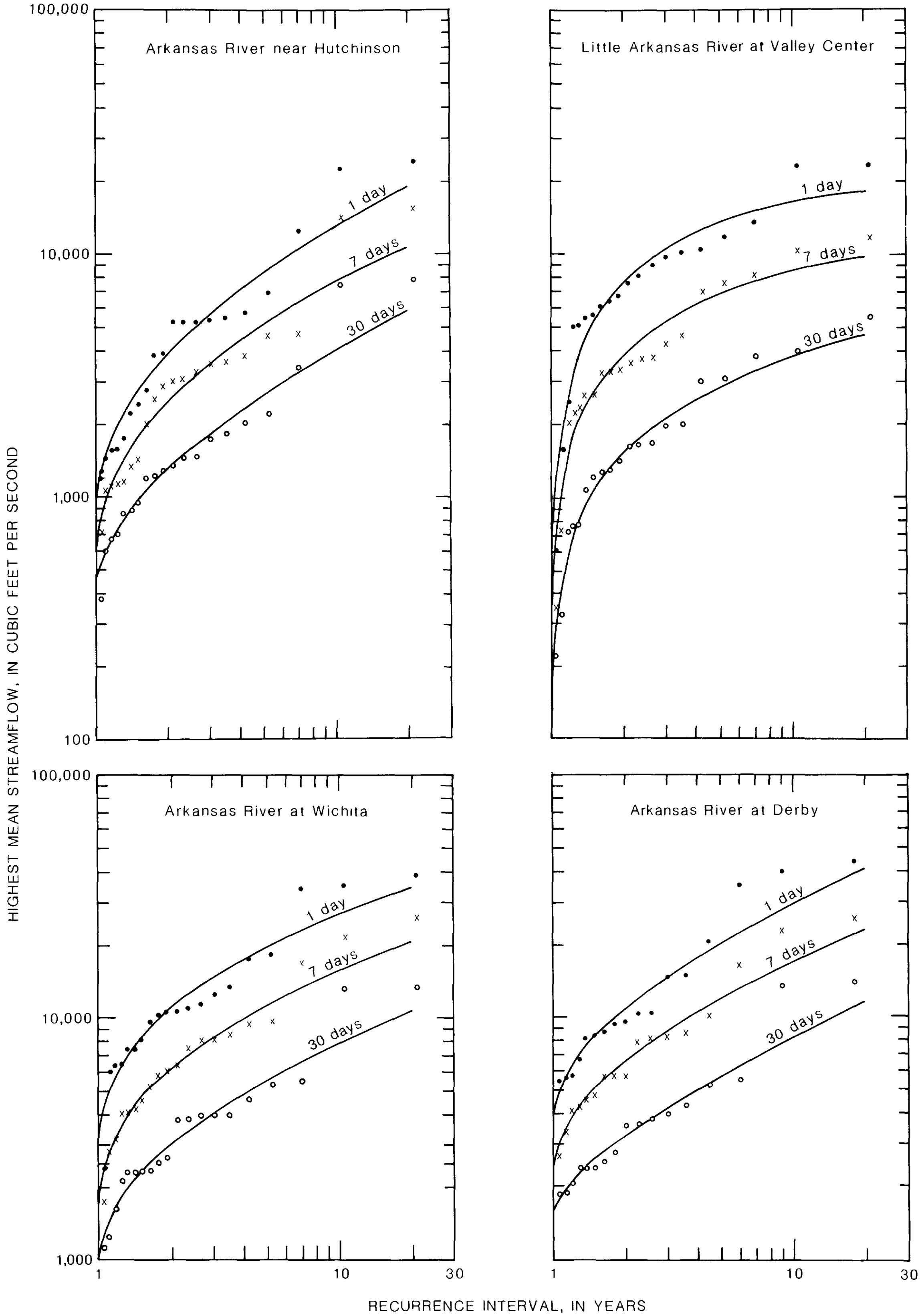


Figure 12. High-Flow frequency curves (1, 7, and 30 consecutive days) for Arkansas River near Hutchinson, at Wichita, and at Derby; and for Little Arkansas River at Valley Center, October 1965-September 1985.

Hutchinson, at Wichita, and at Derby) and the Little Arkansas River at Valley Center (fig. 12) River near Murdock, and the Ninnescah River near Peck (fig. 13) were developed by fitting log-Pearson Type III distributions to data points (also shown) representing streamflow data collected during the same period of record used to develop the flow-duration and low-flow curves in the preceding sections. The log-Pearson Type III distribution has been approved by the U.S. Water Resources Council (1981) for frequency analysis of high flows. Streamflow values on the curves represent the highest mean streamflow, in cubic feet per second, that occurred during the indicated number of consecutive days (1, 7, and 30 days) at recurrence intervals of from 1 to 20 years.

Although the high-flow curves were developed primarily to describe conditions that have occurred during approximately the last 20 years, they can be used also for prediction purposes. Errors that might result from using the curves for prediction, as estimated from visual inspection, are generally less than 30 percent for recurrence intervals of 5 years or less but can be greater than 50 percent for longer recurrence intervals.

Streamflow gains and losses

A low-flow seepage survey of area streams was conducted during March 11-14, 1985. The purpose of this survey was to determine reaches of streams that were gaining or losing flow as a result of the interaction of ground and surface water or as a result of human activities, principally withdrawals of water for public supplies and self-supplied industrial use and subsequent return flows. The survey was conducted during winter to minimize the effects of evapotranspiration and the effects of withdrawals for irrigation. Streamflow was relatively low and steady in the major streams, and no surface runoff was occurring.

Streamflow measurements taken during the seepage survey are given with concurrently collected water-quality data (discussed later in the water-quality section) in table 11 of the "Results of Low-Flow Water-Quality Reconnaissance" section. Results of the seepage survey are summarized as follows:

(1) The Ninnescah River is a gaining stream throughout its reach in Sedgwick County. However, in its downstream reach between the Kansas Highway 42 bridge and near Clearwater, the gain in streamflow is very small, possibly because of appropriated rights for ground-water withdrawals (1,772 acre-feet per year) for industrial use about 2 miles east of Clearwater.

(2) The Little Arkansas River is a gaining stream throughout its reach in Sedgwick County. The streamflow gain between Valley Center and 37th Street in Wichita was only about one-half of that observed between Sedgwick (near the Sedgwick-Harvey County line) and Valley Center, even though the Valley Center sewage-treatment plant was providing some of the flow south of Valley Center. Large volumes of appropriated rights for ground-water withdrawals for public supplies (3,420 acre-feet per year) and industrial use (3,470 acre-feet per year) in the reach of the Little Arkansas River from Valley Center south to 37th Street in Wichita probably is the cause of the relatively small streamflow gain. Results of an earlier hydrologic investigation in the Wichita area indicate that induced infiltration of river water from the Little Arkansas and Arkansas Rivers has occurred in northern parts of the city because ground-water levels have been lowered by withdrawals for industrial use (Petri and others, 1964).

(3) The Arkansas River generally is a gaining stream within Sedgwick County. North of Wichita, in the reach between Mount Hope and 4 miles east of Maize, the Arkansas River gained about 20 cubic feet per second. In this reach, the river is in approximate equilibrium with the ground water and does not serve as the main drain for ground-water

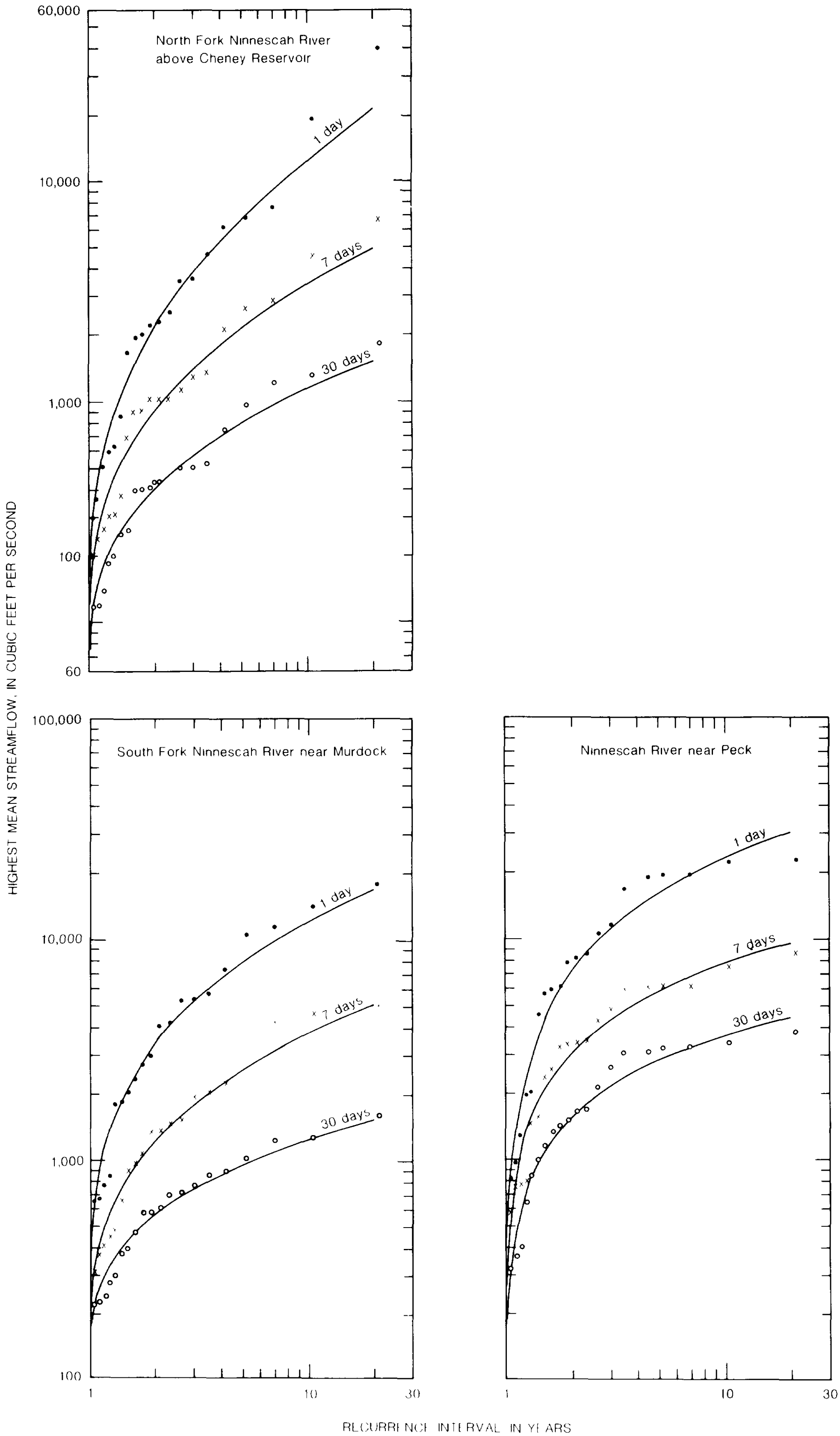


Figure 13. High-flow frequency curves (1, 7, and 30 consecutive days) for North Fork Ninnescah River above Cheney Reservoir, South Fork Ninnescah River near Murdock, and Ninnescah River near Peck, October 1965-September 1985.

discharge; the Little Arkansas River serves as the primary drain for ground-water discharge. In north Wichita in the reach between 4 miles east of Maize and 21st Street, the Arkansas River is losing water, probably because of ground-water withdrawals for public supplies and industrial use that also affect the Little Arkansas River or because water is being lost to the Little Arkansas River, which is the primary ground-water drain. South of the confluence of the Arkansas and Little Arkansas Rivers at Pawnee Street in Wichita, flow in the Arkansas River had increased by about 70 percent from flow contributed by the Little Arkansas River and some local ground-water discharge. In the reach between Pawnee Street and Derby, flow in the Arkansas River increased by about 30 percent. About one-half of this increase probably was due to discharge from Wichita sewage-treatment plants, which averaged about 60 feet per second during 1982. In the reach between Derby and Mulvane, there was a slight loss of streamflow that could be caused by withdrawal of ground water for public supplies along this reach (appropriated water rights = 2,060 acre-feet per year).

Water-Quality Characteristics

Statistical summary of water-quality properties and constituents

Water-quality data collected at U.S. Geological Survey streamflow-gaging stations on the Arkansas River (near Hutchinson, at Wichita, and at Derby), the Little Arkansas River at Valley Center, the North Fork Ninnescah River (above Cheney Reservoir and at Cheney Dam), the South Fork Ninnescah River near Murdock, and the Ninnescah River near Peck during October 1965 through September 1985 are summarized statistically in table 6. These data represent water-quality characteristics observed in the streams during the same period of record represented in the flow-duration, low-flow, and high-flow sections of this report (1965-85) and probably are representative of current (1986) conditions.

Streamflow values shown in table 6 are instantaneous measurements made during the collection of water-quality samples. Although all of the listed properties and constituents were not analyzed for each sample collected, the range of streamflows and the median streamflow for which samples were collected are reasonably representative of streamflows that occurred during 1965 through 1985, as indicated by previously shown flow-duration curves, except for the Arkansas River at Wichita. With the exception of specific conductance and suspended-sediment data, the small amount of water-quality data available for the North Fork Ninnescah River above Cheney Reservoir may not be representative. Streamflow in the Ninnescah River at Cheney Dam is provided primarily by releases from Cheney Reservoir, and the water-quality data should represent the water-quality characteristics of Cheney Reservoir. Only a small amount of iron, manganese, and trace-element data are available for the stream stations. Suspended-sediment data generally are not available for the Arkansas River at Wichita and at Derby and for the Ninnescah River at Cheney Dam.

Water in the Arkansas River near Hutchinson has a median hardness concentration of 420 mg/L as calcium carbonate and a median dissolved-solids concentration of 1,700 mg/L. The principal dissolved constituents are sodium (median concentration, 380 mg/L) and chloride (median concentration, 540 mg/L). Sulfate concentrations can be very large at times, as indicated by the observed maximum of 920 mg/L. Most of the sodium, chloride, and sulfate result from saline ground water in Permian shale of eastern Stafford and western Reno Counties that is discharged into the Arkansas River as base flow and by Rattlesnake, Peace, and Salt Creeks (Hargadine and Luehring, 1978).

The Little Arkansas River at Valley Center contains water that has a median hardness concentration of 280 mg/L as calcium carbonate and a median dissolved-solids concentration of 480 mg/L. Calcium is normally the principal cation in solution, with a median concentration of 85 mg/L, and bicarbonate is the principal anion, with a median concentration of 270 mg/L. However, median concentrations of sodium (70 mg/L) and chloride (100 mg/L) indicate that they are also principal dissolved constituents and sometimes might be

Table 6. *Statistical summary of selected water-quality properties and constituents for major streams, October 1965-September 1985*

[mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft³/s, cubic feet per second; and <preceding a value indicates the constituent was not detected at that level]

Property or constituent	Number of samples	Median	Mean	Maximum	Minimum	Standard deviation
		Arkansas River near Hutchinson				
Streamflow[1], ft^3/s	302	315	703	16,200	60	1,620
Specific conductance, µS/cm	222	2,760	2,650	5,100	370	924
pH, standard units	196	7.7	7.7	8.7	7.1	.3
Hardness as $CaCO_3$, mg/L	121	420	430	810	0	180
Hardness, noncarbonate as $CaCO_3$, mg/L	121	230	240	580	0	140
Bicarbonate as HCO_3, mg/L	188	240	230	340	98	48
Calcium, dissolved as Ca, mg/L	120	120	120	210	32	42
Magnesium, dissolved as Mg, mg/L	120	34	34	72	3.5	17
Sodium, dissolved as Na, mg/L	120	380	380	880	23	170
Potassium, dissolved as K, mg/L	120	12	11	18	6	2
Sulfate, dissolved as SO_4, mg/L	157	240	310	920	18	210
Chloride, dissolved as Cl, mg/L	157	540	560	1,400	34	280
Fluoride, dissolved as F, mg/L	120	.6	.6	1.2	.3	.1
Silica, dissolved as SiO_2, mg/L	120	13	13	28	5.6	4.0
Solids, dissolved, mg/L	157	1,700	1,580	3,000	210	607
Nitrate, dissolved as N, mg/L	120	1.2	1.2	3.2	.02	.59
Phosphate, total as PO_4, mg/L	120	1.2	1.3	3.0	.50	.55
Arsenic, dissolved as As, µg/L	1	--	--	2	--	--
Boron, dissolved as B, µg/L	114	240	230	570	60	80
Cadmium, dissolved as Cd, µg/L	1	--	--	<10	--	--
Chromium, total as Cr, µg/L	1	--	--	<1	--	--
Iron, dissolved as Fe, µg/L	13	80	110	290	20	80
Lead, dissolved as Pb, µg/L	1	--	--	5	--	--
Manganese, dissolved as Mn, µg/L	11	<10	<10	20	<10	<10
Mercury, total as Hg, µg/L	1	--	--	2.1	--	--
Zinc, dissolved as Zn, µg/L	1	--	--	200	--	--
Sediment, suspended, mg/L	124	108	369	4,700	5	664
		Little Arkansas River at Valley Center				
Streamflow[1], ft^3/s	274	112	652	14,000	3.0	1,710
Specific conductance, µS/cm	220	832	842	1,960	91	357
pH, standard units	214	7.6	7.6	8.7	6.6	.4
Hardness as $CaCO_3$, mg/L	130	280	260	470	1	100
Hardness, noncarbonate as $CaCO_3$, mg/L	130	52	68	220	0	47
Bicarbonate as HCO_3, mg/L	197	270	240	360	37	82
Calcium, dissolved as Ca, mg/L	129	85	81	140	11	31
Magnesium, dissolved as Mg, mg/L	129	15	15	32	.6	6.5
Sodium, dissolved as Na, mg/L	129	70	75	220	3.0	40
Potassium, dissolved as K, mg/L	129	6	6	10	4	1
Sulfate, dissolved as SO_4, mg/L	167	52	52	110	5.0	22
Chloride, dissolved as Cl, mg/L	167	100	120	420	5.0	76
Fluoride, dissolved as F, mg/L	129	.4	.4	.8	.2	.1
Silica, dissolved as SiO_2, mg/L	128	17	17	39	6.2	5.1
Solids, dissolved, mg/L	167	480	493	1,100	62	196
Nitrate, dissolved as N, mg/L	129	.86	.95	3.6	.04	5.9
Phosphate, total as PO_4, mg/L	129	1.9	2.1	6.7	.50	.9
Arsenic, dissolved as As, µg/L	1	--	--	<1	--	--
Boron, dissolved as B, µg/L	125	150	140	270	20	50
Cadmium, dissolved as Cd, µg/L	1	--	--	<1	--	--
Chromium, total as Cr, µg/L	1	--	--	<1	--	--
Iron, dissolved as Fe, µg/L	18	95	100	230	10	60
Lead, dissolved as Pb, µg/L	1	--	--	6	--	--
Manganese, dissolved as Mn, µg/L	16	10	70	280	<10	100
Mercury, total as Hg, µg/L	1	--	--	3.7	--	--
Zinc, dissolved as Zn, µg/L	1	--	--	61	--	--
Sediment, suspended, mg/L	58	745	962	9,990	50	1,340

Table 6. *Statistical summary of selected water-quality properties and constituents for major streams, October 1965-September 1985*--Continued

Property or constituent	Number of samples	Median	Mean	Maximum	Minimum	Standard deviation
		Arkansas River at Wichita				
Streamflow[1], ft^3/s	24	409	1,080	6,340	1.7	1,540
Specific conductance, µS/cm	16	1,780	1,640	2,240	775	489
pH, standard units	13	8.0	7.8	8.9	6.8	.6
Sediment, suspended, mg/L	2	--	--	1,230	459	--
		Arkansas River at Derby				
Streamflow[1], ft^3/s	215	554	1,330	30,100	118	2,880
Specific conductance, µS/cm	209	2,050	1,920	3,560	290	680
pH, standard units	211	7.5	7.6	8.9	6.8	.4
Hardness as $CaCO_3$, mg/L	130	370	370	720	80	130
Hardness, noncarbonate as $CaCO_3$, mg/L	130	180	190	490	16	99
Bicarbonate as HCO_3, mg/L	197	230	220	340	66	54
Calcium, dissolved as Ca, mg/L	130	100	100	190	25	34
Magnesium, dissolved as Mg, mg/L	130	27	27	64	3.4	12
Sodium, dissolved as Na, mg/L	130	300	270	540	22	110
Potassium, dissolved as K, mg/L	130	11	10	15	4	2
Sulfate, dissolved as SO_4, mg/L	168	180	220	740	20	150
Chloride, dissolved as Cl, mg/L	169	380	370	760	33	150
Fluoride, dissolved as F, mg/L	130	.6	.6	1.0	.3	.1
Silica, dissolved as SiO_2, mg/L	130	13	12	25	1.0	3.9
Solids, dissolved, mg/L	168	1,200	1,130	2,100	180	420
Nitrate, dissolved as N, mg/L	129	1.6	2.0	13	.32	1.4
Phosphate, total as PO_4, mg/L	126	2.4	3.5	55	.40	5.2
Boron, dissolved as B, µg/L	123	230	220	380	30	80
Iron, dissolved as Fe, µg/L	17	110	100	270	20	60
Manganese, dissolved as Mn, µg/L	14	10	14	130	<10	34
Sediment, suspended, mg/L	2	--	--	1,560	1,340	--
		North Fork Ninnescah River above Cheney Reservoir[2]				
Streamflow[1], ft^3/s	247	72	198	12,500	0.90	862
Specific conductance, µS/cm	85	1,100	1,060	1,560	152	247
pH, standard units	22	8.0	8.0	8.6	7.2	0.4
Hardness as $CaCO_3$, mg/L	12	240	230	270	190	25
Hardness, noncarbonate as $CaCO_3$, mg/L	12	50	49	66	25	12
Bicarbonate as HCO_3, mg/L	12	230	220	260	170	29
Calcium, dissolved as Ca, mg/L	12	74	73	83	54	8.8
Magnesium, dissolved as Mg, mg/L	12	13	12	16	9.1	1.9
Sodium, dissolved as Na, mg/L	12	180	180	190	140	14
Potassium, dissolved as K, mg/L	12	5	5	8	4	1
Sulfate, dissolved as SO_4, mg/L	12	66	67	88	49	12
Chloride, dissolved as Cl, mg/L	12	260	260	280	200	22
Fluoride, dissolved as F, mg/L	12	.4	.4	.5	.4	<.1
Silica, dissolved as SiO_2, mg/L	12	12	13	24	8.4	4.2
Solids, dissolved, mg/L	12	730	718	770	610	45
Nitrate, dissolved as N, mg/L	12	.73	.68	1.2	.01	.34
Phosphate, total as PO_4, mg/L	12	.18	.21	.47	.08	.11
Boron, dissolved as B, µg/L	9	90	100	150	60	30
Iron, dissolved as Fe, µg/L	3	20	50	110	10	60
Sediment, suspended, mg/L	225	77	163	2,460	1	324
		North Fork Ninnescah River at Cheney Dam				
Streamflow[1], ft^3/s	65	0.43	155	1,600	0.13	369
Specific conductance, µS/cm	52	1,010	992	1,360	660	156
pH, standard units	44	7.8	7.8	8.5	7.1	.3
Hardness as $CaCO_3$, mg/L	37	220	300	580	140	130
Hardness, noncarbonate as $CaCO_3$, mg/L	37	100	140	370	17	120
Bicarbonate as HCO_3, mg/L	37	190	200	260	140	29
Calcium, dissolved as Ca, mg/L	37	58	78	150	38	32
Magnesium, dissolved as Mg, mg/L	37	21	25	50	9.0	12
Sodium, dissolved as Na, mg/L	37	88	95	160	39	34
Potassium, dissolved as K, mg/L	37	5	6	10	3	2
Sulfate, dissolved as SO_4, mg/L	37	80	120	280	35	77
Chloride, dissolved as Cl, mg/L	37	160	160	230	98	38
Fluoride, dissolved as F, mg/L	37	.4	.4	.5	.2	.1
Silica, dissolved as SiO_2, mg/L	37	6.2	6.4	26	1.1	4.3
Solids, dissolved, mg/L	37	590	586	840	350	115

Table 6. *Statistical summary of selected water-quality properties and constituents for major streams, October 1965-September 1985*--Continued

Property or constituent	Number of samples	Median	Mean	Maximum	Minimum	Standard deviation
North Fork Ninnescah River at Cheney Dam--Continued						
Nitrate, dissolved as N, mg/L	37	0.18	0.21	0.86	<0.01	0.18
Phosphate, total as PO_4, mg/L	37	.14	.17	.80	<.01	.17
Boron, dissolved as B, μg/L	37	120	160	380	60	90
Iron, dissolved as Fe, μg/L	15	80	90	230	30	60
Manganese, dissolved as Mn, μg/L	12	10	36	220	<10	71
South Fork Ninnescah River near Murdock						
Streamflow[1], ft^3/s	396	134	266	15,000	30	937
Specific conductance, μS/cm	328	1,350	1,340	1,950	230	308
pH, standard units	135	7.8	7.8	8.8	7.1	.4
Hardness as $CaCO_3$, mg/L	121	220	210	320	100	38
Hardness, noncarbonate as $CaCO_3$, mg/L	121	47	46	80	1	14
Bicarbonate as HCO_3, mg/L	121	210	200	320	120	39
Calcium, dissolved as Ca, mg/L	121	69	67	110	35	14
Magnesium, dissolved as Mg, mg/L	121	11	11	19	3.8	2.7
Sodium, dissolved as Na, mg/L	121	200	190	310	16	61
Potassium, dissolved as K, mg/L	121	5	5	8	3	1
Sulfate, dissolved as SO_4, mg/L	121	48	47	70	9.9	11
Chloride, dissolved as Cl, mg/L	287	290	300	500	12	91
Fluoride, dissolved as F, mg/L	121	.3	.3	.6	.2	.1
Silica, dissolved as SiO_2, mg/L	121	15	14	32	2.8	4.6
Solids, dissolved, mg/L	121	760	730	1,000	190	163
Nitrate, dissolved as N, mg/L	121	.82	.86	2.0	.02	.5
Phosphate, total as PO_4, mg/L	121	.46	.49	5.4	.18	.48
Boron, dissolved as B, μg/L	120	120	110	240	20	30
Iron, dissolved as Fe, μg/L	19	90	110	470	<10	110
Manganese, dissolved as Mn, μg/L	15	<10	4	10	<10	<10
Sediment, suspended, mg/L	131	92	265	3,280	11	514
Ninnescah River near Peck						
Streamflow[1], ft^3/s	233	170	787	31,800	23	2,820
Specific conductance, μS/cm	179	1,110	1,080	1,740	170	324
pH, standard units	149	7.7	7.7	8.5	6.8	.4
Hardness as $CaCO_3$, mg/L	128	220	220	320	48	48
Hardness, noncarbonate as $CaCO_3$, mg/L	128	54	52	110	0	18
Bicarbonate as HCO_3, mg/L	128	200	200	300	56	44
Calcium, dissolved as Ca, mg/L	128	62	63	99	14	15
Magnesium, dissolved as Mg, mg/L	128	15	14	22	3.2	3.8
Sodium, dissolved as Na, mg/L	128	150	150	270	7.5	56
Potassium, dissolved as K, mg/L	128	5	5	8	2	1
Sulfate, dissolved as SO_4, mg/L	128	57	55	82	6.0	15
Chloride, dissolved as Cl, mg/L	129	230	230	420	12	89
Fluoride, dissolved as F, mg/L	127	.4	.4	.7	.2	.1
Silica, dissolved as SiO_2, mg/L	127	11	12	28	1.0	4.5
Solids, dissolved, mg/L	127	640	627	920	84	174
Nitrate, dissolved as N, mg/L	128	.54	.64	2.0	<.01	.43
Phosphate, total as PO_4, mg/L	119	.40	.62	23	<.01	2.1
Arsenic, dissolved as As, μg/L	1	--	--	<1	--	--
Boron, dissolved as B, μg/L	118	120	120	260	30	30
Cadmium, dissolved as Cd, μg/L	1	--	--	<1	--	--
Chromium, total as Cr, μg/L	1	--	--	4	--	--
Iron, dissolved as Fe, μg/L	19	80	90	190	20	40
Lead, dissolved as Pb, μg/L	1	--	--	<1	--	--
Manganese, dissolved as Mn, μg/L	15	<10	4	10	<10	5
Mercury, total as Hg, μg/L	1	--	--	4.3	--	--
Zinc, dissolved as Zn, μg/L	1	--	--	65	--	--
Sediment, suspended, mg/L	135	87	232	2,190	11	380

[1] Instantaneous streamflow measured in conjunction with the collection of water-quality data.

[2] Water-quality constituents, for which 12 samples are available, were collected during streamflows that ranged only from 10 to 250 ft^3/s. However, the median streamflow measured during collection of the samples was approximately equivalent to the long-term median streamflow.

predominant if their maximum concentrations exceed those of calcium and bicarbonate. The median concentration of suspended sediment (745 mg/L) is the largest for the major streams in Sedgwick County. Relatively large concentrations of suspended sediment occur in the Little Arkansas River because much of the streamflow is provided by surface runoff from loess-mantled upland areas in McPherson and Harvey Counties.

Water-quality characteristics of the Arkansas River at Derby are somewhat different from those at the Arkansas River at Hutchinson primarily because of streamflow contributed by the Little Arkansas River, ground-water inflow in the reach between the confluence of the Arkansas and Little Arkansas Rivers and Derby, and effluent from Wichita sewage-treatment plants. The water has a median hardness concentration of 370 mg/L as calcium carbonate and a median dissolved-solids concentration of 1,200 mg/L. Sodium (median concentration, 300 mg/L) and chloride (median concentration, 380 mg/L) are the principal dissolved constituents. Median concentrations of these constituents and most of the other constituents are intermediates of median concentrations in the Arkansas River near Hutchinson and the Little Arkansas River at Valley Center. Maximum concentrations of nitrate as nitrogen (13mg/L) and phosphate (55 mg/L) are much larger than those at the other streamflow-gaging stations and probably result from Wichita sewage-treatment plant effluent.

Water-quality data are relatively few for the North Fork Ninnescah River above Cheney Reservoir, and most of the data (those constituents with 12 samples) represent a range in streamflow from about 10 to 250 cubic feet per second. However, the median streamflow of about 72 cubic feet per second that occurred during collection of the 12 samples is equivalent to the median streamflow represented by the flow-duration curves (fig. 9). The water has a median hardness concentration of 240 mg/L as calcium carbonate and a median dissolved-solids concentration of 730 mg/L. Sodium (median concentration, 180 mg/L) and chloride (median concentration, 260 mg/L) are the principal dissolved constituents. Most of the sodium and chloride are contributed by ground water discharged from Permian shale in southeastern Stafford, northeastern Pratt, and southwestern Reno Counties, where the head-waters of the North Fork Ninnescah River are located. This area is the same general area that contributes saline water to the Arkansas River. Water-quality data for specific conductance and suspended sediment correspond to the full range of streamflow shown on the flow-duration curve (fig. 9) and should be representative of all flow conditions.

Water-quality characteristics of the North Fork Ninnescah River at Cheney Dam are affected primarily by Cheney Reservoir. As indicated by the flow-duration curve (fig. 9), streamflow that is equaled or exceeded more than 28 percent of the time is provided by local ground-water inflow because water is not being released from the reservoir. The water has a median hardness concentration of 220 mg/L as calcium carbonate and a median dissolved-solids concentration of 590 mg/L. Sodium (median concentration, 88 mg/L) and chloride (median concentration, 160 mg/L) are the principal dissolved constituents, but their median concentrations are much less than those upstream from the reservoir.

Water in the South Fork Ninnescah River near Murdock has a median hardness concentration of 220 mg/L as calcium carbonate and a median dissolved-solids concentration of 760 mg/L. Sodium (median concentration, 200 mg/L) and chloride (median concentration, 290 mg/L) are the principal dissolved constituents. The source of sodium and chloride is saline ground water that is discharged from Permian shale into the river in the vicinity of the Pratt-Kingman County line (Hargadine and Luehring, 1978). On the basis of available data, median concentrations of water-quality properties and constituents occurring in the South Fork Ninnescah River near Murdock are very similar to those in the North Fork Ninnescah River above Cheney Reservoir.

Water quality in the Ninnescah River near Peck is slightly less mineralized than that observed in either the North Fork Ninnescah River above Cheney Reservoir or the South Fork Ninnescah River near Murdock. The water has a median hardness concentration of 220 mg/L as calcium carbonate and a median dissolved-solids concentration of 640 mg/L. Sodium (median

Table 7. *Results of correlation and regression analysis relating selected water-quality properties and constituents (as defined in table 6) to streamflow (Q), in cubic feet per second, for major streams in Sedgwick County, October 1965-September 1985*

[Dependent variable is shown if correlation coefficient is significant at 0.0001 level; regression equation shown if correlation coefficient is equal to or greater than +0.70; units of measurement are same as those shown in table 6]

Dependent variable		Equation	Number of samples	Correlation coefficient	Range of streamflow for equation, in cubic feet per second	Standard error of estimate, in percent of predicted value: Above	Below
Arkansas River near Hutchinson							
Specific conductance	=	$30,414Q^{-0.43088}$	223	-0.76	60-16,200	25.7	19.3
Hardness	=	--	119	-.60	--	--	--
Hardness, noncarbonate	=	--	119	-.63	--	--	--
Bicarbonate	=	--	187	-.58	--	--	--
Calcium	=	--	119	-.60	--	--	--
Magnesium	=	--	119	-.61	--	--	--
Sodium	=	$11,206Q^{-0.58623}$	119	-.82	60-16,200	26.7	21.1
Potassium	=	--	119	-.35	--	--	--
Sulfate	=	--	156	-.46	--	--	--
Chloride	=	$17,619Q^{-0.61070}$	156	-.83	60-16,200	24.9	20.0
Fluoride	=	--	119	-.48	--	--	--
Silica	=	--	119	+.43	--	--	--
Solids, dissolved	=	$19,807Q^{-0.44562}$	156	-.78	60-16,200	24.4	19.6
Phosphate	=	--	119	-.55	--	--	--
Boron	=	--	113	-.63	--	--	--
Sediment, suspended	=	$0.27228Q^{1.0298}$	124	+.78	60-16,200	77.8	43.8

Table 7. *Results of correlation and regression analysis relating selected water-quality properties and constituents (as defined in table 6) to streamflow (Q), in cubic feet per second, for major streams in Sedgwick County, October 1965-September 1985*--Continued

Dependent variable		Equation	Number of samples	Correlation coefficient	Range of streamflow for equation, in cubic feet per second	Standard error of estimate, in percent of predicted value	
						Above	Below
			Little Arkansas River at Valley Center				
Specific conductance	=	--	230	-0.67	--	--	--
pH	=	--	214	-.56	--	--	--
Hardness	=	--	130	-.52	--	--	--
Bicarbonate	=	$916.95Q^{-0.31154}$	196	-.79	3.0-14,000	20.1	16.8
Calcium	=	$305.66Q^{-0.31457}$	129	-.76	18-14,000	25.7	20.5
Magnesium	=	--	129	-.66	--	--	--
Sodium	=	--	129	-.69	--	--	--
Sulfate	=	--	167	-.69	--	--	--
Chloride	=	--	167	-.50	--	--	--
Solids, dissolved	=	--	167	-.68	--	--	--
Nitrate	=	--	129	+.33	--	--	--
Phosphate	=	--	129	-.62	--	--	--
Boron	=	$412.34Q^{-0.24949}$	125	-.74	18-14,000	22.4	18.3

Table 7. *Results of correlation and regression analysis relating selected water-quality properties and constituents (as defined in table 6) to streamflow (Q), in cubic feet per second, for major streams in Sedgwick County, October 1965-September 1985*--Continued

Dependent variable		Equation	Number of samples	Correlation coefficient	Range of streamflow for equation, in cubic feet per second	Standard error of estimate, in percent of predicted value: Above	Standard error of estimate, in percent of predicted value: Below
Arkansas River at Derby							
Specific conductance	=	$24{,}502Q^{-0.4036}$	203	-0.76	118-30,100	23.2	18.8
Hardness	=	$2{,}753.3Q^{-0.31962}$	125	-.70	155-30,100	26.7	21.1
Hardness, noncarbonate	=	--	125	-.69	--	--	--
Bicarbonate	=	--	191	-.67	--	--	--
Calcium	=	$631.62Q^{-0.28801}$	125	-.70	155-30,100	24.0	19.3
Magnesium	=	$360.92Q^{-0.41373}$	125	-.70	155-30,100	36.6	26.8
Sodium	=	$8{,}033.4Q^{-0.53825}$	125	-.84	155-30,100	21.6	17.8
Potassium	=	--	125	-.57	--	--	--
Sulfate	=	--	163	-.57	--	--	--
Chloride	=	$9{,}439.6Q^{-0.51760}$	163	-.81	118-30,100	26.6	19.1
Fluoride	=	--	125	-.56	--	--	--
Solids, dissolved	=	$14{,}960Q^{-0.41250}$	163	-.78	118-30,100	22.9	18.7
Nitrate	=	--	125	-.48	--	--	--
Phosphate	=	--	125	-.68	--	--	--
Boron	=	$2{,}100.6Q^{-0.35734}$	120	-.78	175-30,100	20.6	17.1
North Fork Ninnescah River above Cheney Reservoir							
Specific conductance	=	--	83	-0.68	--	--	--
Sediment, suspended	=	--	225	+.51	--	--	--

Table 7. *Results of correlation and regression analysis relating selected water-quality properties and constituents (as defined in table 6) to streamflow (Q), in cubic feet per second, for major streams in Sedgwick County, October 1965-September 1985*--Continued

Dependent variable		Equation	Number of samples	Correlation coefficient	Range of streamflow for equation, in cubic feet per second	Standard error of estimate, in percent of predicted value: Above	Below
South Fork Ninnescah River near Murdock							
Specific conductance	=	$6,806.8Q^{-0.34225}$	328	-0.89	30-15,200	6.6	6.2
Hardness, noncarbonate	=	--	121	-.66	--	--	--
Magnesium	=	--	121	-.65	--	--	--
Sodium	=	$2,224.7Q^{-0.51653}$	121	-.86	30- 6,600	13.8	12.1
Sulfate	=	$232.52Q^{-0.33257}$	121	-.84	30- 6,600	10.1	9.2
Chloride	=	$3,261.8Q^{-0.51140}$	287	-.91	30-15,200	8.0	7.4
Silica	=	--	121	+.35	--	--	--
Boron	=	--	120	-.62	--	--	--
Solids, dissolved	=	$3,579.7Q^{-0.32994}$	121	-.91	30- 6,600	5.0	4.8
Sediment, suspended	=	$0.98734Q^{0.93500}$	131	+.73	30- 6,600	70.0	40.1
Ninnescah River near Peck							
Specific conductance	=	$4,924.2Q^{-0.28545}$	178	-0.86	20-31,800	11.9	10.6
Hardness	=	--	127	-.62	--	--	--
Hardness, noncarbonate	=	$249.27Q^{-0.30660}$	126	-.73	20-31,800	27.4	21.6
Bicarbonate	=	--	127	-.49	--	--	--
Calcium	=	--	127	-.57	--	--	--
Magnesium	=	--	127	-.63	--	--	--
Sodium	=	$1,545.5Q^{-0.46092}$	127	-.91	20-31,800	11.9	10.6
Sulfate	=	$221.86Q^{-0.27224}$	127	-.77	20-31,800	19.6	16.4
Chloride	=	$2,369.6Q^{-0.46259}$	128	-.91	20-31,800	11.2	10.1
Solids, dissolved	=	$2,860.0Q^{-0.29472}$	127	-.89	20-31,800	8.8	8.1
Boron	=	--	118	-.53	--	--	--
Sediment, suspended	=	--	135	+.61	--	--	--

concentration, 150 mg/L) and chloride (median concentration, 230 mg/L) are the principal dissolved constituents. The decreased concentrations of sodium, chloride, and dissolved solids that occur in the Ninnescah River near Peck relative to those that occur in the North Fork Ninnescah River above Cheney Reservoir and the South Fork Ninnescah River near Murdock probably result from dilution by local ground-water discharge and releases from Cheney Reservoir.

Results of trend analysis for dissolved-solids concentrations in the Arkansas River near Hutchinson and the Ninnescah River near Peck for 1968-82 indicate no apparent trend (Stoner, 1985). However, this period of record is after the completion of Cheney Reservoir.

Relationships between streamflow and water-quality properties and constituents

Correlation and regression analyses were performed on the data presented in the preceding "Statistical Summary" section to evaluate and develop relationships between streamflow and water-quality properties and constituents. The results of the correlation and regression analyses are given in table 7. Streamflow, in cubic feet per second, was designated as the independent variable, and the water-quality properties and constituents were designated as dependent variables. The properties and constituents listed in table 7 are those which are correlated with streamflow at the 0.0001 level of significance, as determined by an F-test. There were no significant correlations between streamflow and water-quality properties and constituents for the Ninnescah River at Cheney Dam because the streamflow is provided primarily by releases from Cheney Reservoir.

The square of a correlation coefficient, R^2, is that part of the variance of the dependent variable that is explained by or due to variance of the independent variable. A correlation coefficient, R, of $\pm$ 0.70 means that 49 percent (0.7 X 0.7 = 49 percent) of the variance of the water-quality property or constituent is due to the variance of streamflow. The sign (+ or -) of a correlation coefficient indicates whether the independent and dependent variables are directly or inversely related. If the correlation coefficient is positive (+), the variables are directly related, or as streamflow increases the value of the dependent variable also increases. If the correlation coefficient is negative (-), the variables are inversely related, or as streamflow increases the value of the dependent variable decreases.

Water-quality properties and constituents that are introduced into streams by surface runoff are positively correlated with streamflow. Properties and constituents that are introduced into a stream by ground-water discharge or point sources, such as effluent from sewage-treatment plants, are negatively correlated with streamflow because of dilution during surface runoff.

Nearly all of the dissolved constituents and properties that are directly related to concentrations of dissolved constituents (specific conductance, hardness, and noncarbonate hardness) in the major streams of Sedgwick County are negatively correlated with streamflow, indicating that they are introduced into the streams primarily by ground-water discharge. Exceptions are silica (SiO_2), which is positively correlated with streamflow in the Arkansas River near Hutchinson and the South Fork Ninnescah River near Murdock, and nitrate (NO_3), which is positively correlated with streamflow in the Little Arkansas River at Valley Center.

Suspended sediment is positively correlated with streamflow at all sites with available data. Suspended sediment is introduced into streams by surface runoff and is also increased by bank and channel erosion during high streamflow.

Regression equations presented in table 7 are of the form:

$$Y = aQ^b, \qquad (1)$$

where

Y is the water-quality property or constituent, in units given in table 6;

a is the Y-intercept value, in units of Y;

Q is streamflow, in cubic feet per second; and *b* is the slope of the regression line, in $\log_{10}$ units.

Equations are given only for those relationships that were correlated at the 0.0001 level of significance and had correlation coefficients that were equal to or greater than $\pm$ 0.70.

Generally, specific conductance, dissolved solids and dissolved constituents that are major components of the dissolved-solids concentration, and suspended sediment were the only constituents that were correlated with streamflow to the degree required for developing regression equations.The ranges of streamflow for which the equations were developed and the standard errors of estimate that apply to predicting values of the dependent variables with the equations are also given in table 7.

Discharge of sodium, sulfate, chloride, dissolved solids, and suspended sediment

Discharges of major ions, dissolved solids, and suspended sediment are useful for estimating chemical and physical erosion of upstream basins. Except for the Little Arkansas River, the major streams have median concentrations of dissolved solids that exceed 500 mg/L (table 6). In the Arkansas River, median concentrations of dissolved solids equal or exceed 1,200 mg/L. These relatively large concentrations of dissolved solids are due to ground-water discharge with large concentrations of sodium, chloride, and occasionally, sulfate that enter the streams upstream from Sedgwick County. Although the median concentration of dissolved solids in the Little Arkansas River is less than 500 mg/L, the median concentration of suspended sediment (745 mg/L) was larger than at any other site (table 6).

Regression equations relating streamflow (independent variable), in cubic feet per second, to instantaneous discharges of sodium, sulfate, chloride, dissolved solids, and suspended sediment (dependent variables), in tons per day, are presented in table 8. These equations are of the same form as those presented in the preceding section. Instantaneous discharge of constituents was computed by multiplying the constituent concentration, in milligrams per liter, by the corresponding instantaneous streamflow, in cubic feet per second, and then multiplying by 0.0027 to convert to tons per day. Constituents (dependent variables) listed in table 8 were positively correlated (directly related) to streamflow at the 0.0001 level of significance, as determined by an F-test. Equations are given for those relationships that had correlation coefficients equal to or greater than + 0.70. Ranges of streamflow for which the equations were developed and standard errors that would result from using the equations for prediction purposes also are presented in table 8.

Annual discharges of dissolved solids and suspended sediment were estimated by a computational procedure that utilized the regression equations in table 8 in conjunction with flow-duration curves (figs. 8 and 9) in the following manner:

(1) The regression equations were used to compute instantaneous discharges of constituents, in tons per day, for streamflows representing selected percentages of time on the flow-duration curves.

(2) Discharges of constituents computed for the beginning and end of each time interval (period between each percentage of time and the succeeding percentage of time) were summed and divided by two to compute the mean discharge during each time interval.

(3) Mean constituent discharge for each time interval was multiplied by the percentage of time in that interval, expressed as a decimal, to compute discharge during the interval.

(4) Discharges of constituents for all time intervals then were summed to compute mean discharge, in tons per day.

(5) Mean discharge of constituents, in tons per day, then was multiplied by 365 to compute mean annual discharge.

Table 8. *Results of correlation and regression analysis relating discharge of sodium, sulfate, chloride, dissolved solids, and suspended sediment, in tons per day, to streamflow (Q), in cubic feet per second, for major streams, October 1965-September 1985*

[Dependent variable shown if correlation coefficient is significant at the 0.0001 level; regression equation shown if correlation coefficient is equal to or greater than ± 0.70]

Dependent variable, in tons per day	=	Equation	Number of samples	Correlation coefficient	Range of streamflow for equation, in cubic feet per second	Standard error of estimate, in percent of predicted value: Above	Standard error of estimate, in percent of predicted value: Below
				Arkansas River near Hutchinson			
Sodium	=	$30.258Q^{0.41377}$	119	+0.71	60-16,200	33.7	25.2
Sulfate	=	--	156	+ .66	--	--	--
Chloride	=	$47.572Q^{0.38929}$	156	+ .70	60-16,200	33.7	25.2
Solids, dissolved	=	$53.479Q^{0.55438}$	156	+ .84	60-16,200	20.8	17.2
Sediment, suspended	=	$0.00073Q^{2.0284}$	124	+ .92	60-16,200	45.1	31.1
				Little Arkansas River at Valley Center			
Sodium	=	$0.97368Q^{0.61381}$	129	+0.84	18-14,000	33.6	25.2
Sulfate	=	$0.51805Q^{0.68176}$	167	+ .90	3.0-14,000	20.5	17.0
Chloride	=	$1.0160Q^{0.70896}$	167	+ .82	3.0-14,000	43.2	30.2
Solids, dissolved	=	$4.2256Q^{0.72177}$	167	+ .92	3.0-14,000	15.4	13.4
Sediment, suspended	=	$0.25212Q^{1.2825}$	55	+ .91	18-14,000	48.1	32.5
				Arkansas River at Derby			
Sodium	=	$21.690Q^{0.46175}$	125	+0.80	155-30,100	24.2	19.5
Sulfate	=	--	163	+ .69	--	--	--
Chloride	=	$25.487Q^{0.48240}$	163	+ .79	118-30,100	24.8	19.9
Solids, dissolved	=	$40.394Q^{0.58750}$	163	+ .87	118-30,100	17.6	15.0

Table 8. *Results of correlation and regression analysis relating discharge of sodium, sulfate, chloride, dissolved solids, and suspended sediment, in tons per day, to streamflow (Q), in cubic feet per second, for major streams, October 1965-September 1985*--Continued

Dependent variable, in tons per day	=	Equation	Number of samples	Correlation coefficient	Range of streamflow for equation, in cubic feet per second	Standard error of estimate, in percent of predicted value: Above	Standard error of estimate, in percent of predicted value: Below
		North Fork Ninnescah River above Cheney Reservoir					
Sodium	=	$0.56596Q^{0.95887}$	12	+0.99	10-250	0.9	0.9
Sulfate	=	$0.29404Q^{0.88121}$	12	+ .98	10-250	3.5	3.4
Chloride	=	$0.82375Q^{0.95961}$	12	+ .99	10-250	1.2	1.2
Solids, dissolved	=	$1.9747Q^{0.99526}$	12	+1.0	10-250	0.6	0.6
Sediment, suspended	=	$0.02948Q^{1.4581}$	225	+ .88	1-12,500	55.5	35.7
		North Fork Ninnescah River at Cheney Dam					
Sodium	=	$0.21869Q^{1.0635}$	37	+1.0	0.15-1,600	3.1	3.0
Sulfate	=	$0.31969Q^{0.84070}$	37	+ .99	.15-1,600	5.5	5.2
Chloride	=	$0.41738Q^{1.0175}$	37	+1.0	.15-1,600	1.7	1.7
Solids, dissolved	=	$1.6239Q^{0.96943}$	37	+1.0	.15-1,600	1.0	1.0
		South Fork Ninnescah River near Murdock					
Sodium	=	$6.0066Q^{0.48347}$	121	+0.84	30- 6,600	14.5	12.6
Sulfate	=	$0.62782Q^{0.66743}$	121	+ .95	30- 6,600	5.4	5.1
Chloride	=	$8.8069Q^{0.48860}$	287	+ .90	30-15,200	8.3	7.6
Solids, dissolved	=	$9.6651Q^{0.67006}$	121	+ .98	30- 6,600	2.6	2.6
Sediment, suspended	=	$0.00268Q^{1.9339}$	131	+ .91	30- 6,600	36.1	26.5
		Ninnescah River near Peck					
Sodium	=	$4.1725Q^{0.53908}$	127	+0.93	20-31,800	10.4	9.4
Sulfate	=	$0.59902Q^{0.72776}$	127	+ .96	20-31,800	8.6	8.0
Chloride	=	$0.01231Q^{1.0076}$	127	+ .98	20-31,800	4.0	3.8
Solids, dissolved	=	$7.7219Q^{0.70528}$	127	+ .98	20-31,800	4.0	3.8
Sediment, suspended	=	$0.01380Q^{1.5459}$	135	+ .91	20-31,800	45.0	31.1

Table 9. *Computation of mean suspended-sediment discharge for Arkansas River near Hutchinson, October 1965-September 1985*

Percentage of time	Streamflow[1] equaled or exceeded, in cubic feet per second	Discharge[2] of suspended sediment, in tons per day	Interval between succeeding percentage of time, expressed as a decimal	Mean discharge of suspended sediment during time interval, in tons per day	Discharge of suspended sediment during time interval, in tons per day
0.1	17,000	278,000	0.001	208,000	208
.2	12,000	137,000	.003	90,800	272
.5	6,900	44,700	.005	30,900	154
1.0	4,300	17,100	.01	12,400	124
2	2,900	7,700	.03	5,000	150
5	1,600	2,300	.05	1,640	82.5
10	1,050	981	.1	648	64.8
20	600	315	.1	242	24.2
30	440	168	.1	134	13.4
40	340	100	.1	81.2	8.12
50	270	62.4	.1	51.8	5.18
60	220	41.2	.1	33.6	3.36
70	175	25.9	.1	20.6	2.06
80	135	15.3	.1	11.6	1.16
90	98	7.98	.1	4.30	0.430
100	[3]28	.629	--	--	--

Mean daily discharge = 1,113 tons
x365 days

Mean annual discharge = 406,000 tons
Drainage area = ÷31,174 square miles

Mean annual discharge per square mile of drainage area = 12.8 tons

[1] Streamflow from flow-duration curve in figure 8.

[2] Instantaneous value computed with regression equation in table 8.

[3] One day mean low-flow value with a recurrence interval of 20 years.

Table 10. *Mean annual discharges of dissolved and suspended sediment for major streams, October 1965-September 1985.*

Streamflow-gaging station	Contributing drainage area, in square miles	Mean annual dissolved-solids discharge, in tons		Mean annual suspended-sediment discharge, in tons	
		Total	Per square mile	Total	Per square mile
Arkansas River near Hutchinson	31,724	533,000	16.8	406,000	12.8
Little Arkansas River at Valley Center	1,250	79,600	63.7	299,000	239
Arkansas River at Derby[1]	33,567	770,000	22.9	--	--
North Fork Ninnescah River above [2] Cheney Reservoir	550	91,200	166	22,900	41.6
North Fork Ninnescah River at Cheney Dam[1]	664	57,300	86.3	--	--
South Fork Ninnescah River near Murdock	543	112,000	206	107,000	197
Ninnescah River near Peck	1,785	182,000	102	130,000	72.8

1 Sediment data not available.

2 Dissolved-solids data available only for streamflow from 10 to 250 cubic feet per second.

An example of this procedure, as used to compute mean annual suspended-sediment discharge for the Arkansas River near Hutchinson, is shown in table 9.

Mean annual discharges of dissolved solids and suspended sediment, in tons, for major streams are given in table 10. The Arkansas River has the largest mean annual discharges of dissolved solids (770,000 tons) at Derby and suspended sediment (405,000 tons) near Hutchinson principally because it carries much more flow than the other streams. The North Fork Ninnescah River has the smallest mean annual discharge of dissolved solids (57,300 tons) at Cheney Dam and the smallest mean annual discharge of suspended sediment (22,900 tons) above Cheney Reservoir principally because the North Fork Ninnescah River has the smallest annual flow, especially at Cheney Dam because of the regulating effect of Cheney Reservoir (see "Flow Duration" section). The computed value of mean annual dissolved-solids discharge for the North Fork Ninnescah River above Cheney Reservoir is considered as a very rough estimate because the regression equation used to compute instantaneous discharges of dissolved solids was developed for streamflow that ranged from 10 to only 250 cubic feet per second.

Estimates of rates of chemical and physical erosion were developed by dividing the mean annual discharges of dissolved solids and suspended sediment by the contributing drainage areas of the streams. These estimates are given also in table 10. The Arkansas River basin upstream of Hutchinson has the smallest annual rates of chemical and physical erosion, yielding an average of 16.8 tons of dissolved solids per square mile and 12.8 tons of suspended sediment per square mile, principally because of the relatively small quantities of precipitation and resultant streamflow that occur in this basin in eastern Colorado and western Kansas. The South Fork Ninnescah River basin (206 tons of dissolved solids per square mile) and the North Fork Ninnescah River basin upstream of Cheney Reservoir (166 tons of dissolved solids per square mile) have the largest rates of chemical erosion, which occur predominantly in Permian rocks west of Sedgwick County. The Little Arkansas River basin (239 tons of suspended sediment per square mile) and the South Fork Ninnescah River basin (197 tons of suspended sediment per square mile) have the largest rates of physical erosion probably because of extensive loess deposits in upland areas of their basins.

Results of low-flow water-quality reconnaissance

Water samples for water-quality analysis were collected during low flow at 52 stream sites (plate 1) in Sedgwick County on March 11-14, 1985. These samples were collected in addition to concurrent streamflow measurements discussed in the "Streamflow Characteristics" section. The purpose of the low-flow water-quality survey was to provide information about the water-quality characteristics of streams as they relate to geology and human activities (sewage-treatment plant effluent and contamination from oilfield activities, for example). The streams were sampled during low flow so that geologic and human effects would not be obscured by dilution from surface runoff. The chemical analyses of these water samples are presented in table 11.

The column in table 11 that is labeled "local identifier" provides the location of the sampling sites according to a modification of the U.S.Bureau of Land Management's system of land subdivision. The first pair of numbers is the township south (S) of the 40th parallel; the second pair of numbers is the range east (E) or west (W) of the sixth principal meridian; and the third set of numbers indicates the section (1-36). The letters following the section number designate the part of the section in which the site is located. The first letter denotes the quarter section (160-acre tract), the second letter denotes the quarter-quarter section (40-acre tract); and the third letter denotes the quarter-quarter-quarter section (10-acre tract). The letters A, B, C, or D, divide each quarter, quarter-quarter, and quarter-quarter-quarter section into four equal parcels with the letter A designating the northeast quarter, B designating the northwest quarter, C designating the southwest quarter, and D designating the southeast quarter. This system is illustrated in figure 14, which depicts the location of site 27S-02E-36ADA.

Pie diagrams illustrating the range of dissolved-solids concentrations and proportions of major dissolved ions (based on milliequivalents per liter) in table 11 samples are plotted on plate 1.

Table 11. *Streamflow and water-quality data collected during low-flow reconnaissance in Sedgwick County, March 11-14, 1985*

[A < preceding a value indicates the constituent was not detected at that level]

Local identifier (township-range-section, plate 1)	Stream sampling site (downstream order)	Date	Time (24-hour)	Streamflow, instantaneous (cubic feet per second)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)
25S-03W-09BBC	Arkansas River near Mount Hope	03-11-85	1230	169	3,280
25S-02W-26CCB	Arkansas River 4 miles northeast of Colwich	03-11-85	1430	173	2,950
26S-01W-14DDB	Arkansas River 4 miles east of Maize	03-11-85	1550	189	2,820
27S-01W-12BAD	Arkansas River at 21st Street, Wichita	03-11-85	1740	180	2,800
25S-01W-15BBB	Little Arkansas River near Sedgwick	03-11-85	1230	83	640
25S-01W-23DBB	Jester Creek near Valley Center	03-11-85	1430	4.3	770
25S-01W-36CBA	Little Arkansas River at Valley Center	03-11-85	1600	96	595
26S-01E-29CCC	Little Arkansas River at 37th Street, Wichita	03-12-85	1200	103	700
28S-01E-05ABB	Arkansas River at Pawnee Street, Wichita	03-12-85	0815	309	1,540
26S-01E-16BAB	West Fork Chisholm Creek near Park City	03-12-85	0800	3.6	1,200
26S-01E-17BAB	West Fork Chisholm Creek tributary near Park City	03-12-85	0930	.82	745
26S-01E-29DDD	Middle Fork Chisholm Creek at Broadway Street, Wichita	03-12-85	1100	1.0	940
27S-01E-09BBB	Chisholm Creek at 21st Street, Wichita	03-12-85	1500	1.0	760
27S-01E-04DDD	East Fork Chisholm Creek at 21st Street, Wichita	03-12-85	1410	2.6	1,200
28S-01E-02BBA	Dry Creek at Pawnee Street, Wichita	03-12-85	1730	.08	565
28S-01E-02AAC	Gypsum Creek at George Washington Boulevard, Wichita	03-12-85	1615	3.2	1,850
28S-01E-10ACB	Chisholm Creek above Arkansas River	03-12-85	1845	10	1,340
28S-01E-27BCB	Big Slough Creek at Hydraulic Street, Wichita	03-12-85	1750	1.5	1,590
28S-01E-35BAA	Arkansas River tributary 1 mile northwest of Derby	03-12-85	1705	.73	660
27S-01W-10CDC	Big Slough Creek at 13th Street, Wichita	03-12-85	0920	.55	868
28S-01W-11CCD	Wichita-Valley Center floodway at MacArthur Road, Wichita	03-12-85	1035	2.7	738
28S-01E-33DAD	Wichita-Valley Center floodway near Haysville	03-12-85	1150	5.9	2,290
29S-01E-12BCD	Arkansas River at Derby	03-12-85	1315	404	1,810
29S-01E-13DBC	Spring Creek at K-15 highway	03-12-85	1450	2.8	1,470
29S-02E-31CCC	Arkansas River at Mulvane	03-12-85	1605	398	1,860
29S-02E-33CDC	Dog Creek near Mulvane	03-13-85	1730	.75	2,700
26S-02W-26DAD	Cowskin Creek near Maize	03-14-85	0735	.90	1,130
27S-02W-01BCB	Dry Creek near Maize	03-14-85	0825	.67	1,020
28S-01W-05BAA	Cowskin Creek at Pawnee Street, Wichita	03-14-85	0935	7.2	713
28S-01W-16CCB	Dry Creek at Tyler Street, Wichita	03-14-85	1025	.68	990
28S-01W-23CBB	Cowskin Creek at 47th Street, Wichita	03-14-85	1120	7.7	802
29S-01E-06AAB	Cowskin Creek at Haysville	03-14-85	1240	15	848
29S-01E-34CCC	Cowskin Creek at Sumner County line	03-14-85	1345	17	867
27S-04W-17BBD	North Fork Ninnescah River at K-251 highway	03-13-85	0855	7.2	700
28S-04W-14BAB	Spring Creek near Cheney	03-13-85	0900	4.5	555
28S-04W-22ABA	North Fork Ninnescah River near Cheney	03-13-85	1025	54	855
28S-04W-26CCC	South Fork Ninnescah River near Cheney	03-13-85	1130	234	1,130
28S-04W-34DAD	Mud Creek 4 miles southeast of Cheney	03-13-85	1015	.72	1,050
29S-03W-06BAB	Ninnescah River 6 miles southeast of Cheney	03-13-85	1250	306	1,030
29S-04W-01DDD	Sand Creek 5 miles northwest of Viola	03-13-85	1115	9.0	610
29S-03W-07DDA	Tributary to Ninnescah River 3 miles northwest of Viola	03-13-85	1230	.54	1,260
29S-03W-03BAA	Clearwater Creek 3 miles south of Lake Afton	03-13-85	1400	6.3	710
29S-03W-23AAA	Ninnescah River at K-42 highway bridge	03-13-85	1420	356	1,040
29S-02W-19AAB	Spring Creek 4 miles west of Clearwater	03-13-85	1515	1.6	715
29S-02W-26CCC	Ninnescah River near Clearwater	03-13-85	1535	359	1,070
29S-01W-35CDC	Spring Creek at Sumner County line	03-13-85	1645	1.0	715
25S-02E-13ACA	Wildcat Creek 3 miles east of Furley	03-14-85	1515	5.0	1,280
25S-02E-25ADD	Prairie Creek 4 miles southeast of Furley	03-14-85	1415	1.5	2,950
26S-02E-01DDD	Whitewater Creek at Butler County line	03-14-85	1315	1.0	3,450
26S-02E-36DAD	Dry Creek at Butler County line	03-14-85	1200	.15	390
27S-02E-25DAA	Fourmile Creek near Butler County line	03-14-85	1050	2.4	1,900
27S-02E-36ADA	Spring Branch Creek at Butler County line	03-14-85	0930	3.6	1,850

Table 11. *Streamflow and water-quality data collected during low-flow reconnaissance in Sedgwick County, March 11-14, 1985*--Continued

Local identifier (township-range-section, plate 1)	pH (standard units)	Water temperature (degrees Celsius)	Hardness, (milligrams per liter as $CaCO_3$)	Hardness, noncarbonate (milligrams per liter as $CaCO_3$)	Calcium, dissolved (milligrams per liter as Ca)	Magnesium, dissolved (milligrams per liter as Mg)	Sodium, dissolved (milligrams per liter as Na)	Potassium, dissolved (milligrams per liter as K)	Alkalinity, (milligrams per liter as $CaCO_3$)
25S-03W-09BBC	8.3	16.0	350	150	100	24	520	6.4	200
25S-02W-26CCB	8.4	17.5	340	140	100	23	480	6.5	200
26S-01W-14DDB	8.4	15.0	340	130	100	23	450	6.7	210
27S-01W-12BAD	8.4	14.5	340	140	100	23	440	6.7	200
25S-01W-15BBB	7.9	14.5	220	67	64	14	43	6.5	150
25S-01W-23DBB	8.6	15.0	350	92	98	26	40	4.6	260
25S-01W-36CBA	7.9	14.0	220	61	67	13	38	6.1	160
26S-01E-29CCC	7.9	9.0	240	82	72	15	53	6.2	160
28S-01E-05ABB	8.5	12.5	310	120	93	19	280	6.6	190
26S-01E-16BAB	8.1	8.5	430	140	110	38	78	4.4	290
26S-01E-17BAB	7.8	8.0	320	94	95	21	39	2.2	230
26S-01E-29DDD	8.4	8.0	470	230	110	47	39	5.6	240
27S-01E-09BBB	9.1	9.0	190	6	45	18	98	4.1	180
27S-01E-04DDD	8.5	9.0	580	420	130	61	61	5.1	160
28S-01E-02BBA	9.0	8.0	150	9	48	7.1	66	5.1	140
28S-01E-02AAC	8.5	9.5	780	630	240	44	120	5.0	150
28S-01E-10ACB	8.5	9.5	510	310	140	40	96	5.4	200
28S-01E-27BCB	8.6	9.5	370	140	120	18	180	6.7	230
28W-01E-35BAA	8.7	9.0	270	110	81	16	39	3.6	160
27S-01W-10CDC	8.2	10.5	130	--	41	7.8	130	3.8	150
28S-01W-11CCD	8.3	8.0	150	--	46	7.8	96	3.2	170
28S-01E-33DAD	7.9	9.0	480	240	150	25	280	4.9	240
29S-01E-12BCD	8.0	10.5	300	110	87	19	250	7.1	190
29S-01E-13DBC	8.1	10.0	930	680	300	45	52	4.9	250
29S-02E-31CCC	7.9	10.5	300	110	89	20	250	7.1	190
29S-02E-33CDC	8.0	11.5	1,800	1,500	540	100	66	5.4	270
26S-02W-26DAD	8.3	7.0	240	67	72	14	140	8.2	170
27S-02W-01BCB	9.1	6.0	320	35	90	22	110	7.5	280
28S-01W-05BAA	8.1	8.0	200	--	62	12	69	5.3	220
28S-01W-16CCB	8.4	8.0	330	90	91	25	98	5.2	240
28S-01W-23CBB	8.4	9.0	210	--	61	13	66	5.3	210
29S-01E-06AAB	8.2	11.0	190	--	58	12	93	4.4	200
29S-01E-34CCC	8.0	12.0	210	--	63	12	96	4.9	220
27S-04W-17BBD	8.3	7.5	200	47	54	15	64	3.2	150
28S-04W-14BAB	8.1	7.5	270	51	77	19	26	2.8	220
28S-04W-22ABA	8.3	7.5	240	51	65	19	84	4.0	190
28S-04W-26CCC	8.6	8.0	250	47	74	15	130	2.6	200
28S-04W-34DAD	8.3	7.5	410	130	77	54	83	3.0	280
29S-03W-06BAB	8.6	9.0	240	43	71	16	120	3.0	200
29S-04W-01DDD	8.3	8.5	240	57	57	23	42	2.3	180
29S-03W-07DDA	8.4	9.5	530	280	100	68	84	3.1	250
29S-03W-03BAA	8.0	9.5	310	93	84	25	34	4.1	220
29S-03W-23AAA	8.5	10.5	240	43	71	16	120	3.3	200
29S-02W-19AAB	8.3	13.0	300	82	73	29	41	6.0	220
29S-02W-26CCC	8.3	11.0	240	55	70	17	120	3.5	190
29S-01W-35CDC	8.7	12.0	280	71	73	24	45	3.9	210
25S-02E-13ACA	8.3	11.0	660	460	170	56	38	4.2	200
25S-02E-25ADD	8.1	12.0	1,500	1,200	430	93	160	3.4	240
26S-02E-01DDD	7.9	12.0	1,300	1,100	390	86	250	3.8	250
26S-02E-36DAD	8.1	8.0	190	40	58	11	8.7	6.1	150
27S-02E-25DAA	8.0	9.5	1,000	790	320	52	64	3.8	220
27S-02E-36ADA	7.6	9.5	1,000	780	320	48	53	3.3	220

Table 11. *Streamflow and water-quality data collected during low-flow reconnaissance in Sedgwick County, March 11-14, 1985*--Continued

Local identifier (township-range-section, plate 1)	Sulfate, dissolved (milligrams per liter as SO_4)	Chloride, dissolved (milligrams per liter as Cl)	Fluoride, dissolved (milligrams per liter as F)	Bromide, dissolved (milligrams per liter as Br)	Iodide, dissolved (milligrams per liter as I)	Silica, dissolved (milligrams per liter as SiO_2)	Solids, dissolved, sum of constituents (milligrams per liter)
25S-03W-09BBC	200	780	0.5	0.19	0.015	12	1,760
25S-02W-26CCB	190	730	.5	.19	.011	12	1,660
26S-01W-14DDB	210	680	.5	.18	.01	12	1,600
27S-01W-12BAD	200	660	.5	.18	.012	11	1,560
25S-01W-15BBB	55	64	.3	.056	.011	12	350
25S-01W-23DBB	120	31	.3	.012	.006	10	490
25S-01W-36CBA	57	54	.3	.055	.007	12	340
26S-01E-29CCC	66	74	.3	.094	.009	12	400
28S-01E-05ABB	120	420	.4	.16	.012	11	1,060
26S-01E-16BAB	170	95	.4	.090	.006	10	680
26S-01E-17BAB	100	53	.3	.21	.005	18	470
26S-01E-29DDD	210	42	.3	<.01	.012	3.5	600
27S-01E-09BBB	86	96	.4	.33	.008	12	450
27S-01E-04DDD	410	73	.3	.055	.009	4.4	840
28S-01E-02BBA	67	66	.2	.043	.009	5.5	340
28S-01E-02AAC	560	210	.3	.48	.022	4.8	1,300
28S-01E-10ACB	290	140	.3	.23	.020	10	840
28S-01E-27BCB	110	290	.6	.73	.020	11	880
28S-01E-35BAA	150	29	.2	.074	.031	6.2	410
27S-01W-10CDC	87	130	.4	.044	.009	4.0	490
28S-01W-11CCD	62	89	.6	.061	.006	5.3	410
28S-01E-33DAD	110	530	.4	1.9	.039	10	1,250
29S-01E-12BCD	140	370	.4	.17	.018	12	1,000
29S-01E-13DBC	690	56	.3	.15	.010	13	1,310
29S-02E-31CCC	150	380	.4	.17	.017	12	1,020
29S-02E-33CDC	1300	77	.3	.24	.009	9.2	2,260
26S-02W-26DAD	230	96	.5	.013	.011	9.4	670
27S-02W-01BCB	110	140	.3	.050	.011	3.3	660
28S-01W-05BAA	62	52	.3	.027	.015	17	420
28S-01W-16CCB	160	120	.3	.19	.009	2.8	640
28S-01W-23CBB	67	50	.3	.040	.012	15	410
29S-01E-06AAB	97	74	.3	.055	.010	14	470
29S-01E-34CCC	96	77	.3	.052	.012	15	500
27S-04W-17BBD	52	85	.3	.043	.007	10	380
28S-04W-14BAB	55	22	.3	.038	.004	7.0	340
28S-04W-22ABA	64	120	.4	.052	.009	9.4	480
28S-04W-26CCC	57	200	.4	.085	.006	10	610
28S-04W-34DAD	210	51	.3	.037	.009	3.6	650
29S-03W-06BAB	59	180	.4	.079	.006	10	580
29S-04W-01DDD	94	27	.3	.051	.005	8.9	370
29S-03W-07DDA	330	82	.3	.052	.006	<1.0	820
29S-03W-03BAA	110	33	.3	.046	.008	<1.0	420
29S-03W-23AAA	63	170	.4	.071	.009	9.9	570
29S-02W-19AAB	110	35	.4	.054	.006	9.2	440
29S-02W-26CCC	68	170	.4	.095	.008	9.4	570
29S-01W-35CDC	99	40	.3	.056	.006	9.6	430
25S-02E-13ACA	400	50	.3	.10	.008	6.5	850
25S-02E-25ADD	1100	270	.3	.97	.027	8.0	2,210
26S-02E-01DDD	620	660	.3	2.4	.020	10	2,170
26S-02E-36DAD	39	15	.2	<.01	.005	10	240
27S-02E-25DAA	730	110	.5	.24	.013	10	1,420
27S-02E-36ADA	780	79	.5	.22	.011	10	1,420

Table 11. *Streamflow and water-quality data collected during low-flow reconnaissance in Sedgwick County, March 11-14, 1985*--Continued

Local identifier (township-range-section, plate 1)	Nitrogen ammonia, dissolved (milligrams per liter as N)	Nitrogen NO_2+NO_3, dissolved (milligrams per liter as N)	Phosphorus, dissolved (milligrams per liter as P)	Iron, dissolved (micrograms per liter as Fe)	Manganese, dissolved (micrograms per liter as Mn)	Carbon, organic, total (milligrams per liter as C)
25S-03W-09BBC	0.20	1.90	0.37	30	20	6.1
25S-02W-26CCB	.07	1.70	.31	60	20	4.7
26S-01W-14DDB	.05	1.70	.30	40	10	5.3
27S-01W-12BAD	.10	1.70	.26	40	20	6.4
25S-01W-15BBB	.62	2.20	.55	18	48	13
25S-01W-23ACD	.03	2.00	.16	18	64	5.8
25S-01W-36CBA	.37	2.10	.46	83	47	14
26S-01E-29CCC	.29	2.70	.58	92	38	12
28S-01E-05ABB	.19	1.70	.30	18	20	5.6
26S-01E-16BAB	.39	1.30	.79	15	140	7.4
26S-01E-17BAB	.04	< .10	.01	11	210	1.0
26S-01E-29DDD	.04	.75	.04	20	28	7.4
27S-01E-09BBB	.04	.52	1.90	40	42	7.2
27S-01E-04DDD	.05	.31	.06	220	110	7.6
28S-01E-02BAA	.02	.13	.08	19	11	6.6
28S-01E-02AAC	.10	<.10	.04	15	140	5.8
28S-01E-10ACB	.17	1.30	.12	15	65	5.0
28S-01E-27BCB	.06	<.10	.03	14	380	3.7
28S-01E-35BAA	.08	.51	.06	10	100	8.3
27S-01W-10CDC	.01	1.00	.01	23	2	2.8
28S-01W-11CCD	.01	<.10	.01	31	7	4.8
28S-01E-33DAD	.08	.22	.03	30	560	3.0
29S-01E-12BCD	1.70	1.70	.92	22	29	6.0
29S-01E-13DBC	.13	.62	.07	8	340	4.2
29S-02E-31CCC	1.50	2.00	.95	14	34	7.8
29S-02E-33CDC	.28	.27	.03	40	270	3.3
26S-02W-26DAD	.74	1.20	.79	25	43	5.7
27S-02W-01BCB	.03	<.10	.66	11	46	11
28S-01W-05BAA	.34	1.20	.27	34	100	5.7
28S-01W-16CCB	.03	<.10	.06	10	44	6.8
28S-01W-23CBB	.23	1.10	.24	29	22	6.3
29S-01E-06AAB	.13	1.00	.17	17	75	5.5
29S-01E-34CCC	1.20	1.50	.81	18	83	7.0
27S-04W-17BBD	.04	3.70	.04	12	28	3.3
28S-04W-14BAB	.02	3.40	.03	18	24	4.0
28S-04W-22ABA	.06	1.10	.05	12	35	3.6
28S-04W-26CCC	.02	1.70	.05	10	2	2.9
28S-04W-34DAD	.02	.71	.01	8	25	5.6
29S-03W-06BAB	.02	1.50	.05	8	9	3.1
29S-04W-01DDD	.02	2.20	.02	21	40	3.7
29S-03W-07DDA	.04	.53	.02	6	55	4.2
29S-03W-03BAA	.06	1.90	.04	5	78	4.8
29S-03W-23AAA	.03	1.50	.06	29	4	3.1
29S-02W-19AAB	.03	3.60	.17	15	49	5.8
29S-02W-26CCC	.03	1.30	.06	10	3	3.7
29S-01W-35CDC	.03	1.40	.06	5	59	5.2
25S-02E-13ACA	.08	1.40	.04	9	120	5.4
25S-02E-25ADD	.19	.59	.01	40	430	3.2
26S-02E-01DDD	.15	.49	<.01	40	540	2.8
26S-02E-36DAD	.02	.52	.04	63	22	7.9
27S-02E-25DAA	.25	.55	.25	5	160	4.3
27S-02E-36ADA	.13	<.10	<.01	20	190	3.4

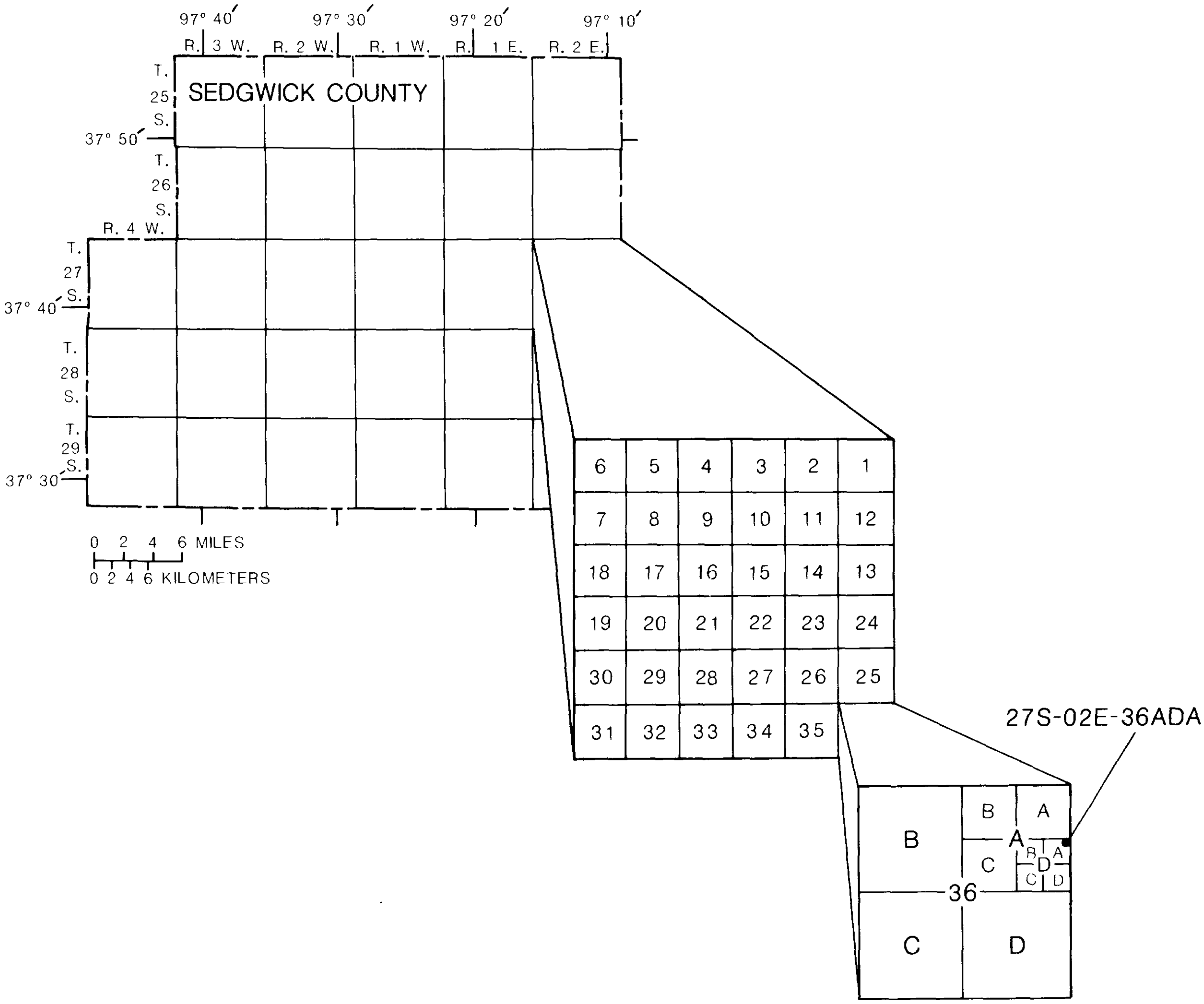


Figure 14. Method used to describe location of sampling sites.

Water in the Arkansas River was a sodium chloride type throughout its reach in Sedgwick County as a result of saline ground-water discharge from Permian shale upstream. Concentrations of dissolved solids decreased downstream from 1,760 mg/L near Mount Hope to 1,660 mg/L 4 miles east of Maize, which indicates that the stream water was being diluted by ground-water discharge with smaller concentrations of dissolved solids. Streamflow measurements discussed in the "Streamflow Characteristics" section also indicate the stream was gaining through this reach. Concentrations of dissolved solids remained nearly constant in the reach from 4 miles east of Maize to 21st Street in Wichita. Streamflow measurements indicate that the stream was losing through this reach.

Downstream from the confluence with the Little Arkansas River, concentrations of dissolved solids in the Arkansas River at Pawnee Street in Wichita decreased to 1,060 mg/L due to dilution from the Little Arkansas River, which increased the flow in the Arkansas River by about 70 percent. At Derby, concentrations of dissolved solids had decreased slightly to 1,000 mg/L as flow increased by 95 cubic feet per second. Effluent from the Wichita sewage-treatment plant, which in 1982 emitted an average flow of about 60 cubic feet per second (data from Wichita Water Pollution Control Division), probably was diluting the stream water. The concentration of dissolved chloride was 420 mg/L at Pawnee Street, 370 mg/L at Derby, and only averaged 180 mg/L in Wichita sewage-treatment plant effluent during 1982 (data from Wichita Water Pollution Control Division). Although treated sewage effluent slightly decreased concentrations of dissolved solids and major ions, the concentration of ammonia as nitrogen had increased at Derby to a concentration (1.70 mg/L) that exceeded criterion for sources of public-water supplies (0.50 mg/L). The concentration of dissolved solids at Mulvane was almost the same as that at Derby (1,020 mg/L), and the concentration of ammonia as nitrogen (1.50 mg/L) still exceeded the criterion for sources of public-water supplies. The constancy of dissolved-solids concentrations in this reach helps substantiate that the stream was losing through this reach, as indicated by streamflow measurements.

The Little Arkansas River contained water that was a calcium bicarbonate type and had a dissolved-solids concentration of 350 mg/L near Sedgwick where it enters the county. The calcium and bicarbonate are derived from calcareous shale and limestone of the Wellington Formation. The concentration of ammonia as nitrogen (0.62 mg/L) exceeded criterion for sources of public-water supplies and might indicate contamination by sewage-treatment plant effluent from Sedgwick. At Valley Center, the chemical type of water and the dissolved-solids concentration (340 mg/L) were virtually the same as observed at Sedgwick, but the ammonia-as-nitrogen concentration did not exceed criterion for sources of public-water supplies. The sampling site at Valley Center was upstream of the sewage-treatment plant effluent. Farther downstream at 37th Street in Wichita, water in the Little Arkansas River was a mixed calcium sodium bicarbonate chloride type, with 400 mg/L dissolved solids. Sodium and chloride accounted for most of the increase in dissolved-solids concentration. The Little Arkansas River probably is gaining some sodium chloride type ground water in this area.

Cowskin Creek, a tributary to the Arkansas River, undergoes several changes in water quality as it flows through the county. Cowskin Creek near Maize had a mixed sodium sulfate bicarbonate type water, with a dissolved-solids concentration of 670 mg/L. The ammonia-as-nitrogen concentration (0.74 mg/L) exceeded water-quality criteria for sources of public supplies and might indicate contamination by sewage-treatment plant effluent from Colwich. The water in Dry Creek near Maize, a tributary to Cowskin Creek, had a mixed sodium calcium bicarbonate chloride type water, with a dissolved-solids concentration of 660 mg/L. The water may be from the Wellington Formation, which has limestone (source of calcium and bicarbonate) and shale (source of sodium and chloride). Dry Creek probably receives some flow from sewage lagoons at Goddard, which may be the source of some of the mixed-ion type water. The concentration of ammonia as nitrogen was small, but the concentration of phosphorus was relatively large (0.66 mg/L) and in the same range as other stream sites in the county that are affected by sewage effluent.

Farther downstream, in Cowskin Creek at Pawnee Street in Wichita, the water is a calcium sodium bicarbonate type, with a dissolved-solids concentration of 420 mg/L. Small tributaries that drain areas underlain by the Wellington Formation and terrace deposits to the west probably are diluting the water from upstream reaches of Cowskin Creek with a calcium bicarbonate type water that has relatively small concentrations of dissolved solids. Dry Creek at Tyler Street in Wichita, no relation to Dry Creek near Maize, flows from the west into Cowskin Creek. Dry Creek at Tyler Street has a mixed-ion type water, with a dissolved-solids concentration of 640 mg/L. This mixed-ion type water may be from the Wellington Formation, which has gypsum and anhydrite deposits (sources of calcium and sulfate) in addition to limestone and shale.

Downstream from the confluence of Cowskin Creek and Dry Creek, the water in Cowskin Creek at 47th Street in Wichita was a calcium sodium bicarbonate type, with 410 mg/L of dissolved solids. At Haysville, the water in Cowskin Creek was a sodium bicarbonate chloride sulfate type, with a dissolved-solids concentration of 470 mg/L. Upstream from Haysville, Cowskin Creek mixes with water in the Wichita-Valley Center floodway, which may cause the change in water type. At the Sumner County line, water in Cowskin Creek was a mixed-ion type, with a dissolved-solids concentration of 500 mg/L. The concentration of ammonia as nitrogen (1.20 mg/L) exceeds criterion for sources of public-water supplies and might be due to sewage-treatment plant effluent at Haysville.

Big Slough Creek will be discussed in conjunction with the Wichita-Valley Center floodway because the creek is diverted into the floodway near Maple Street in Wichita. The downstream reach of Big Slough Creek that flows into the Arkansas River receives only local drainage south of 31st Street in Wichita. When samples were collected, the farthest upstream site where flow was detected was at 13th Street in Wichita. At this site the water was a sodium chloride bicarbonate type, with a dissolved-solids concentration of 490 mg/L. The sodium and chloride probably result from saline water from the Arkansas River that has moved into alluvial deposits in this area. In the Wichita-Valley Center floodway at MacArthur Road, the water was a sodium bicarbonate chloride type, with a dissolved-solids concentration of 410 mg/L.

Water quality in the floodway near Haysville was much different than at upstream sites. The water was a sodium chloride type, with a dissolved-solids concentration of 1,250 mg/L. The sodium:chloride ratio computed by dividing the concentration of sodium by the concentration of chloride was about 0.53. A sodium:chloride ratio of less than 0.60 may indicate contamination by oilfield brine (Whittemore, 1982). The Gladys oilfield is located upstream of this site. The downstream reach of Big Slough Creek was sampled at Hydraulic Street in Wichita where the water was a sodium chloride type, with a dissolved-solids concentration of 880 mg/L. The sodium:chloride ratio at this site was 0.62, indicating the source probably is dissolved salt from Permian rocks provided by ground water in the alluvium, which has infiltrated from the Arkansas River. However, there is an oilfield upstream of this site, and some of the sodium and chloride may be from oilfield brine.

Water-quality samples also were collected from Chisholm Creek and its tributaries. Water in West Fork Chisholm Creek near Park City was a mixed-ion type, with a dissolved-solids concentration of 680 mg/L. The Park City sewage-treatment plant discharges effluent upstream of this site. The concentration of ammonia as nitrogen (0.39 mg/L) was relatively large but did not exceed criterion for sources of public-water supplies. The concentration of phosphorus (0.79 mg/L) was in the same range as in other streams in the county that receive sewage-treatment plant effluent. Flow in a tributary to West Fork Chisholm Creek near Park City was provided by effluent from a Derby Oil Company facility upstream. The water was a calcium bicarbonate type, with 470 mg/L dissolved solids.

Middle Fork Chisholm Creek was sampled at Broadway Street in Wichita where the water was a calcium bicarbonate sulfate type, with 600 mg/L dissolved solids. The source of these constituents probably is natural dissolution of minerals (gypsum, anhydrite, and limestone) in the Wellington Formation.

Chisholm Creek at 21st Street in Wichita had a sodium bicarbonate chloride type water, with 450 mg/L dissolved solids. The pH (9.1) was very high, and the concentration of phosphorus (1.9 mg/L) was also very large, indicating possible contamination from an unknown source. Chisholm Creek receives only local drainage at this site because West Fork and Middle Fork Chisholm Creeks are diverted into the Wichita-Valley Center floodway.

East Fork Chisholm Creek was sampled at 21st Street in Wichita, where the water was a calcium magnesium sulfate type, with 840 mg/L of dissolved solids. The concentration of dissolved iron (220 μg/L) was the largest observed at any stream site in the county. The calcium and sulfate probably result from the dissolution of gypsum in the Wellington Formation.

Dry Creek at Pawnee Street in Wichita, a tributary to Chisholm Creek, had a mixed-ion type water, with a dissolved-solids concentration of 340 mg/L. Gypsum Creek at George Washington Boulevard in Wichita, also a tributary to Chisholm Creek, had a calcium sulfate type water, with 1,300 mg/L dissolved solids. As the name of Gypsum Creek suggests, flow in the creek probably results from a spring developed in an easily erodible gypsum deposit. Chisholm Creek upstream from its confluence with the Arkansas River had a mixed-ion type water, with calcium and sulfate as the principal dissolved constituents. The concentration of dissolved solids at this site was 840 mg/L. Water quality at this site represents the combined characteristics of Chisholm Creek at 21st Street, East Fork Chisholm Creek at 21st Street, and Gypsum Creek at George Washington Boulevard.

Small streams that originate in the area underlain by the Wellington Formation and flow west to the Little Arkansas River (Jester Creek near Valley Center, a small tributary that flows through the southeast corner at McConnell Air Force Base and enters the Arkansas River 1 mile northwest of Derby, Spring Creek at Kansas Highway 15 south of Derby, and Dog Creek near Mulvane) were also sampled. Jester Creek near Valley Center had a calcium bicarbonate type water, with 490 mg/L dissolved solids. The Arkansas River tributary 1 mile northwest of Derby had a calcium sulfate bicarbonate type water, with 410 mg/L dissolved solids. Spring Creek at Kansas Highway 15 had a calcium sulfate type water, with 1,340 mg/L dissolved solids. Dog Creek near Mulvane had a calcium sulfate type water, with 2,260 mg/L dissolved solids.

Small streams that originate in the area underlain by the Wellington Formation in eastern Sedgwick County and flow to the east as tributaries to the Walnut River include Wildcat, Prairie, Whitewater, Dry, Fourmile, and Spring Branch Creeks. Wildcat Creek had a calcium sulfate type water, with 850 mg/L dissolved solids. Prairie Creek had a calcium sulfate type water, with 2,210 mg/L dissolved solids. A sodium:chloride ratio of 0.59 indicates possible contamination of Prairie Creek by oilfield brine. Whitewater Creek had a calcium chloride type water, with 2,170 mg/L dissolved solids. A sodium:chloride ratio of 0.38 indicates that Whitewater Creek is contaminated by oilfield brine. Dry Creek at the Butler County line had calcium bicarbonate type water, with only 240 mg/L dissolved solids. Fourmile Creek had a calcium sulfate type water, with 1,420 mg/L dissolved solids. The sodium:chloride ratio of 0.58 indicates possible contamination of Fourmile Creek by oilfield brine. Spring Branch Creek at the Butler County line had a calcium sulfate type water, with 1,420 mg/L dissolved solids.

Water was not being released from Cheney Reservoir during the time that samples were collected from the Ninnescah River system but had been released for 21 consecutive days prior to sample collection. Consequently, flow in the North Fork Ninnescah River was provided primarily by seepage from water in the alluvium that had been stored during the period of release from Cheney Reservoir.

The North Fork Ninnescah River at Kansas Highway 251 (downstream of Cheney Reservoir) had a sodium calcium bicarbonate chloride type water, with 380 mg/L dissolved solids. Downstream near Cheney the water type was the same, and the dissolved-solids concentration had increased to 480 mg/L. Some of the flow at this site was from sewage-treatment plant effluent at Cheney, but concentrations of ammonia as nitrogen (0.06 mg/L) and phosphorus (0.05 mg/L) were small. In the South Fork Ninnescah River near Cheney, the water was a sodium chloride type, with 610 mg/L dissolved solids. The sodium chloride water is discharged to the stream from Permian shale west of Sedgwick County. Downstream from the confluence of the North and South Forks of the Ninnescah River, in the Ninnescah River 6 miles southeast of Cheney, the water was a sodium chloride type, with 580 mg/L dissolved solids. The South Fork Ninnescah River provided about 76 percent of the flow at this site.

In the Ninnescah River at Kansas Highway 42, the water was a sodium chloride bicarbonate type, with a dissolved-solids concentration of 570 mg/L. At Clearwater, the water was a sodium chloride bicarbonate type, with 570 mg/L dissolved solids. Streamflow measurements indicate that the flow at Kansas Highway 42 and at Clearwater was about the same, and the fact that water-quality characteristics at the two sites were essentially the same indicates that the stream was not gaining in this reach, possibly because of ground-water withdrawals for industrial use west of Clearwater.

Small streams draining areas north of the Ninnescah River that were sampled include Spring Creek near Cheney, Clearwater Creek 3 miles south of Lake Afton, Spring Creek 4 miles west of Clearwater, and Spring Creek at the Sumner County line. Spring Creek near Cheney had a calcium bicarbonate type water, with 340 mg/L dissolved solids. This stream drains areas underlain by lower Pleistocene deposits (pre-Illinoian age) and the Ninnescah Shale. Clearwater Creek had a calcium bicarbonate type water, with 420 mg/L dissolved solids. Clearwater Creek drains areas underlain by lower Pleistocene deposits, the Ninnescah Shale, and the Wellington Formation. Spring Creek, 4 miles west of Clearwater drains areas underlain by lower Pleistocene deposits and the Wellington Formation. The water in this stream was a calcium magnesium bicarbonate type, with 440 mg/L dissolved solids. Spring Creek at the Sumner County line drains an area underlain by terrace deposits of Illinoian age. This stream had a calcium magnesium sodium bicarbonate type water, with 430 mg/L dissolved solids.

Small streams draining areas south of the Ninnescah River that were sampled include Mud Creek, Sand Creek, and an unnamed tributary 3 miles northwest of Viola. These streams drain areas underlain by the Ninnescah Shale. Mud Creek had a mixed-ion type water, with 650 mg/L dissolved solids. Sand Creek originates in an area underlain by a buried valley containing terrace deposits of Illinoian age. Sand Creek had a calcium magnesium sodium bicarbonate type water, with 370 mg/L dissolved solids. The unnamed tributary 3 miles northwest of Viola had a mixed-ion type water, with 820 mg/L dissolved solids.

Impoundments

Storage Requirements

The storage requirement of an

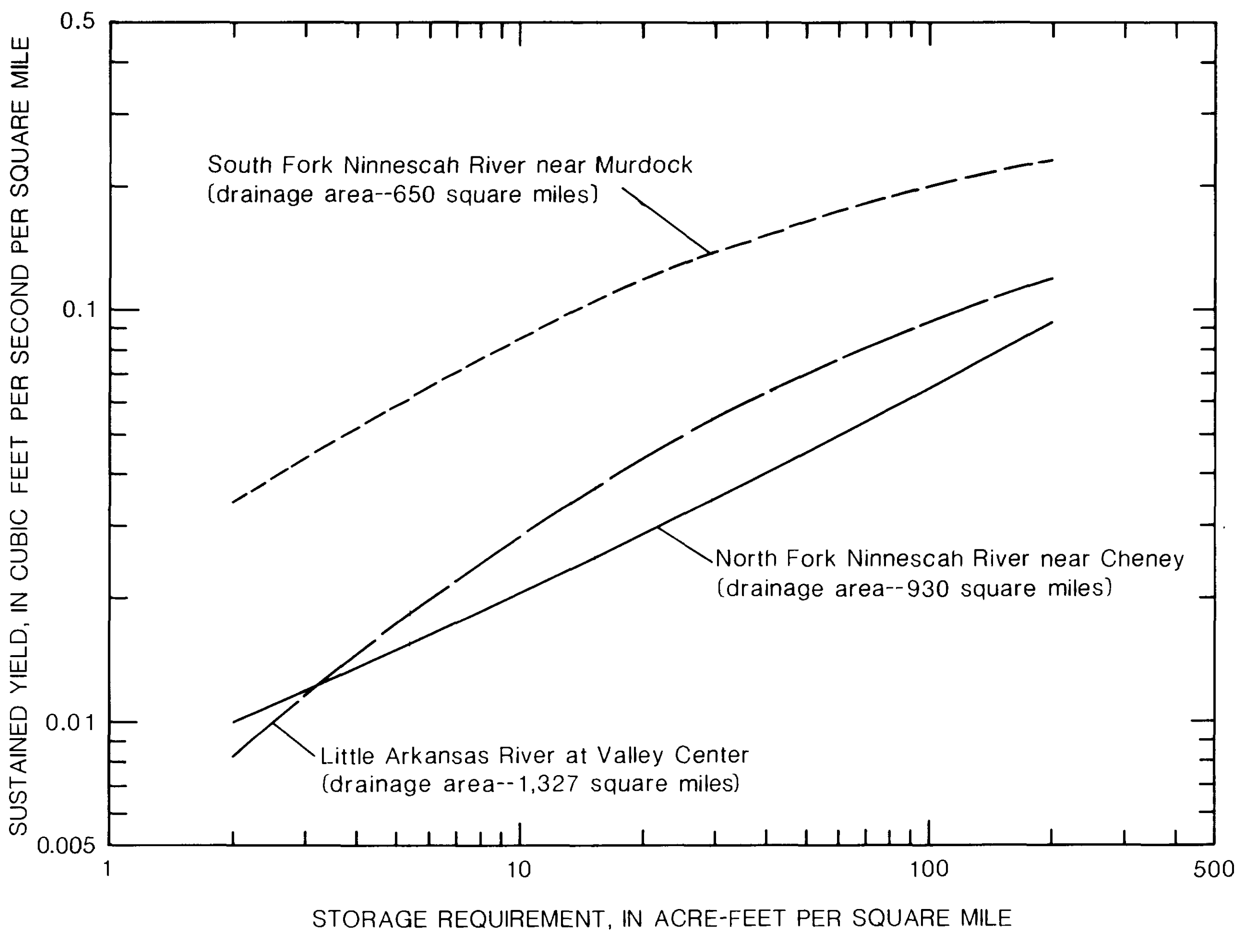


Figure 15. Storage-yield curves for Little Arkansas River at Valley Center, North Fork Ninnescah River near Cheney, and South Fork Ninnescah River near Murdock, representing a 2-percent chance of deficiency (modified from Furness, 1962).

impoundment is defined as the volume of water that must be stored in order to provide a sustained yield from the impoundment with a selected chance of deficiency. The sustained yield is equivalent to the volume of water withdrawn or released for selected uses in addition to natural losses due to evapotranspiration, seepage, and loss of storage in the impoundment due to sedimentation. Previous investigations have presented methods used to develop storage-yield curves for gaged and ungaged basins in Kansas with drainage areas greater than 100 square miles (Furness, 1962) and for basins with drainage areas less than 300 square miles (Carswell, 1982).

Storage-yield curves presented by Furness (1962) were developed from continuous streamflow records that were 6 years or more in length and were extended by correlation with long-term records to a base period of 37 years (1920-56). It is beyond the scope of this report to update the analysis by Furness. A detailed storage-yield investigation should be conducted using a data base that includes data collected since the Furness study (since 1956) for any site at which the construction of a major impoundment is being considered. Storage-yield curves developed by Furness (1962) for the Little Arkansas River at Valley Center, the North Fork Ninnescah River near Cheney (a discontinued station), and the South Fork Ninnescah River near Murdock with a 2-percent chance of deficiency are shown in figure 15 for comparison purposes. In general, less storage would be required for an impoundment on the South Fork Ninnescah River to provide a selected sustained yield than would be required for impoundments on either the Little Arkansas River or the North Fork Ninnescah River.

In a more recent investigation, Carswell (1982) used streamflow data for all streamflow-gaging stations in Kansas that had drainage areas of less than 300 square miles and that had more than 10 years of continuous streamflow record to develop regional storage-yield curves for estimating storage requirements to sustain yields from impoundments on small ungaged streams. Although no data from Sedgwick County were used to develop the regional curves, the curves and procedure developed by Carswell (1982) can be applied in the area and are presented in the following discussion.

The regional storage-yield curves for a 2-percent chance of deficiency developed by Carswell (1982) are shown in figure 16. This three-parameter plot relates sustained yield (in cubic feet per second per square mile), mean annual runoff (in inches), and storage (in acre-feet per square mile). For ungaged basins, mean annual runoff can be determined from figure 17 (Carswell, 1982) by interpolating to the centroid of the basin. Mean annual runoff then is used in figure 16 to determine the sustained yield that would result from storage of 30, 100, 250, 500, or 1,000 acre-feet per square mile with a 2-percent chance of deficiency.

Storage-yield curves and procedures presented in this section should only be used for developing estimates of impoundment yield. Detailed site studies should be conducted before the construction of an impoundment. Estimates of water lost to seepage, evapotranspiration, and of storage loss due to sedimentation should be included in the site study. Continuous streamflow records should be collected at sites for major impoundments if data are not available.

Water-Quality Characteristics

Results of water-quality reconnaissance

Water-quality samples and measurements of physical properties were collected from 14 impoundments in Sedgwick County during October 21-24,1985. These data are presented in table 12. Pie diagrams indicating the concentration of dissolved solids and the proportions of major dissolved ions are shown on plate 1. The impoundments generally were small; Lake Afton, with a surface area of approximately 320 acres, was by far the largest impoundment sampled. The impoundments were used for recreational purposes (fishing, swimming, waterfowl hunting) or for stock watering. The impoundments were selected to provide areal coverage of the county and to represent the varying surface geology. Their locations are identified by an abbreviated land-line description, which indicates the township, range, and section in which they are located (see fig. 14). Approximately 2 weeks prior to sampling, a large storm produced significant rainfall and considerable runoff in the county, and the impoundments were relatively full.

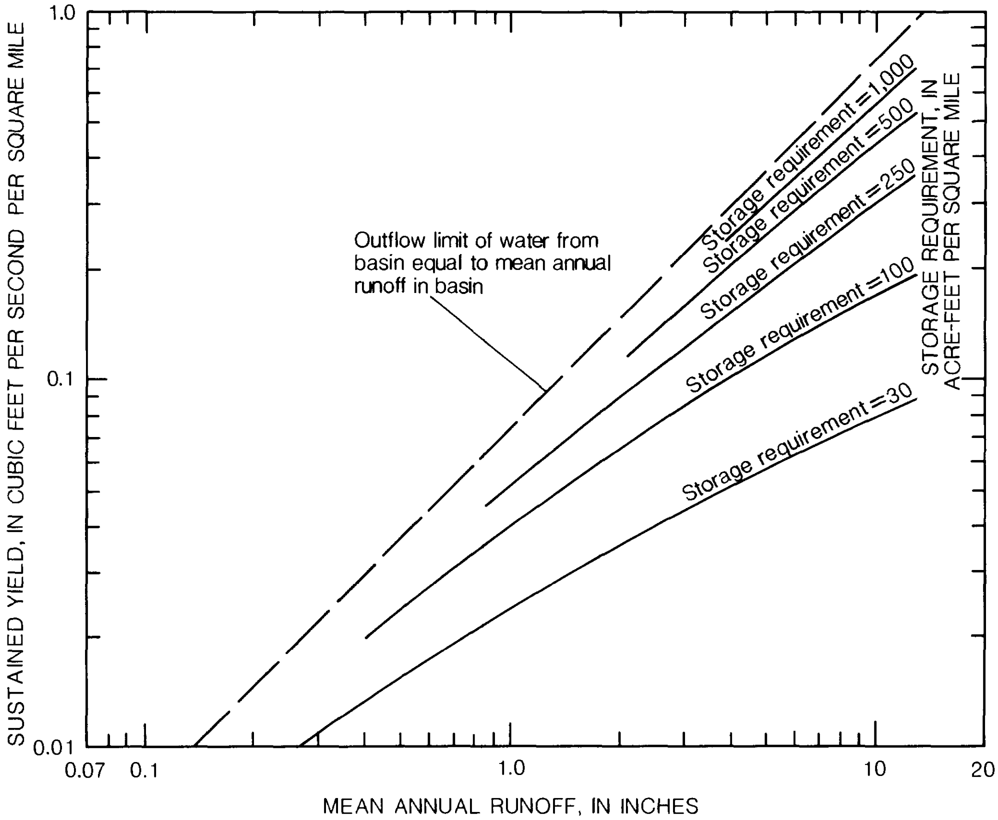


Figure 16. Regional storage-yield curves for unregulated streams with drainage areas less than 300 square miles, representing a 2-percent change of deficiency (modified from Carswell, 1982).

Six lakes were sampled in parts of the county where the Wellington Formation occurs at or near the surface (25S-02E-4AC, 25S-01E-27CB, 26S-02E-10AD, 27S-02E-11BD, 28S-02E-24AC, and 29S-02W-15AC). All of these lakes were relatively shallow, with maximum depths ranging from 5.0 feet (26S-02E-10AD) to 10.5 feet (25S-01E-27CB and 28S-02E-24AC). The lakes were relatively turbid, with transparencies (as depth below surface at which a secchi disk could no longer be seen) generally 11.0 inches or less. Lake 28S-02E-24AC had a transparency of 21.5 inches. This lake is supplemented with ground water from a well, which is probably the reason for its relative clarity. Concentrations of dissolved solids in the four lakes where calcium and bicarbonate were the principal dissolved ions ranged from 41 mg/L (25S-01E-27CB) and 61 mg/L (27S-02E-11BD) to 110 mg/L (28S-02E-24AC and 29S-02W-15AC). The other two lakes had calcium and sulfate as the principal dissolved constituents and concentrations of dissolved solids of 140 mg/L (26S-02E-10AD) and 170 mg/L (25S-02E-4AC).

Concentrations of the herbicide atrazine were detected in lakes 25S-02E-4AC (0.1 µg/L), 26S-02E-10AD (0.9 µg/L), 27S-02E-11BD (1.8 µg/L), 28S-02E-24AC (0.3 µg/L), and 29S-02W-15AC (0.1 g/L). Atrazine is sold under the trade names AAtrex, Atrazine, and Atratol[1] and is used primarily to control broadleaf weeds in corn and grain sorghum. It is relatively soluble in water at 33 mg/L (Meister and others, 1984) and persists in soil for 1 year or longer. The U.S. Environmental Protection Agency has issued a lifetime health advisory level of 3.0 µg/L for atrazine (U.S. Environmental Protection Agency, written commun., September 1987).

[1] Use of trade names in this report is for identification purposes only and does not constitute an endorsement by the U.S. Geological Survey.

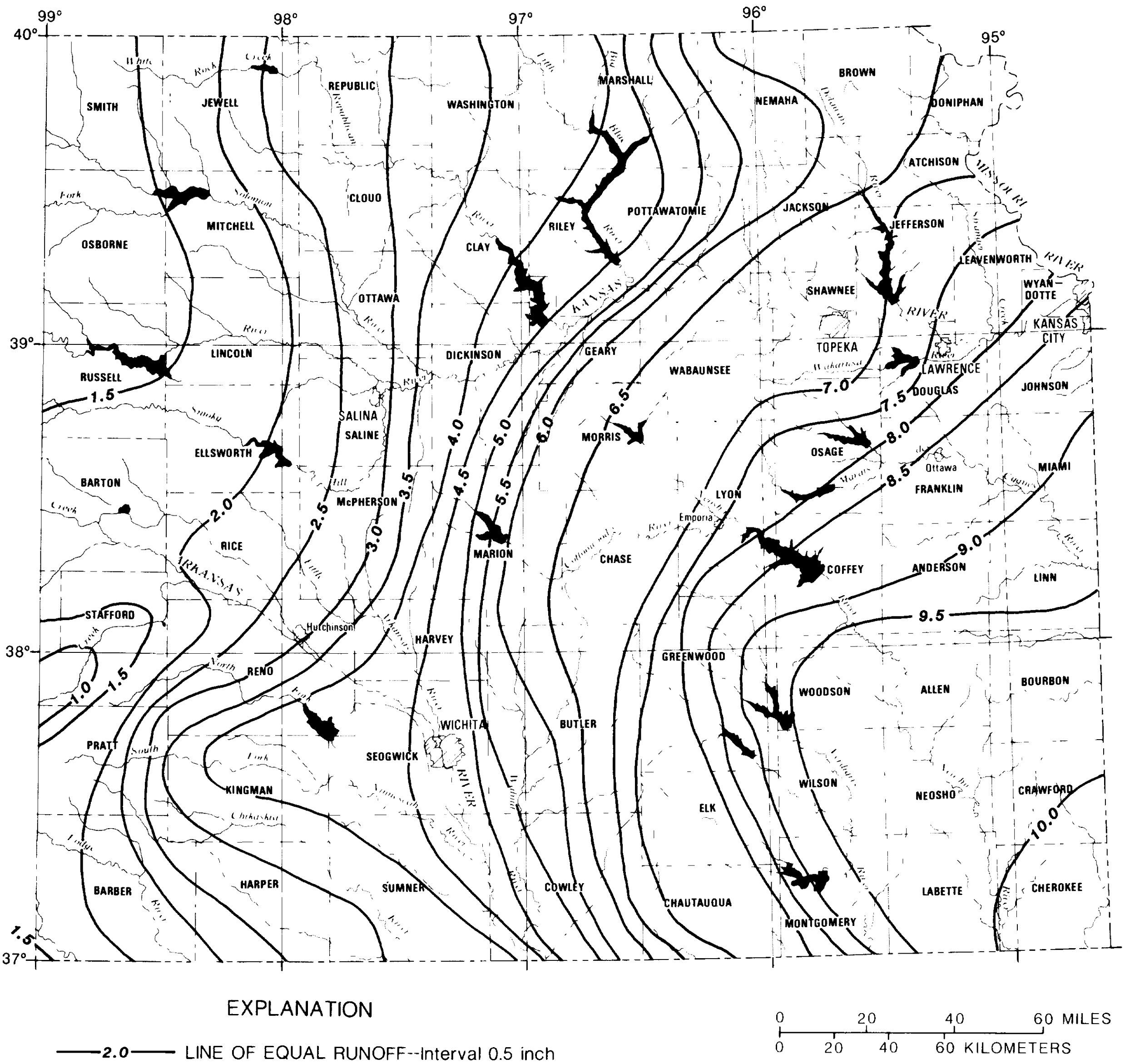


Figure 17. Mean annual runoff in eastern Kansas (modified from Carswell, 1982).

The herbicide cyanazine also was detected in the lake 27S-02E-11BD (0.3 µg/L). Cyanazine is sold under the trade name Bladex and is used as a preplant, preemergent, or postemergent herbicide for the control of weeds in field corn or for preemergent control of weeds in sorghum. Cyanazine is very soluble in water at 171 mg/L and persists in soil for about 1 year. The U.S. Environmental Protection Agency has issued a lifetime health advisory level of 9.0 µg/L for cyanazine (U.S. Environmental Protection Agency, written commun., August 1987).

Two lakes were sampled in parts of the county where the Ninnescah Shale occurs at or near the surface (26S-03W-19AC and 29S-04W-4DC). These lakes were less than 9 feet deep and were very turbid, with transparencies of 2.5 inches. Calcium and bicarbonate were the principal dissolved constituents, and concentrations of dissolved solids were less than 45 mg/L. The herbicides atrazine (1.1 µg/L), propazine (0.1 µg/L), and a degradation product of the insecticide heptachlor (heptachlor epoxide = 0.01 µg/l) were detected in lake 26S-03W-19AC.

Propazine is sold under the trade names Milogard and Propazine and is used as a preemergent and preplant incorporated

Table 12. *Water-quality data for selected impoundments in Sedgwick County, October 21-24, 1985*

[A < sympol preceding a value means that the constituent was not detected at that detection level]

Impoundment sampling site (township-range-section, plate 1)	Owner or tenant	Surface geology[1] of drainage area	Maximum depth of lake (feet)	Water use	Estimated age (years)	Date sampled (month-day-year)	Time (24-hour)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)	pH (standard units)
25S-02E-04AC	Mark Schoenecker	Pw	9.5	Fishing	8	10-21-85	1745	289	7.6
25S-01E-27CB	Lloyd Patterson	do.	10.5	Fishing	30	10-22-85	1130	53	6.8
25S-03W-24AB	Sherman Sampson	Qal	15.0	Fishing	30	10-22-85	1530	2,350	8.3
26S-02E-10AD	Unknown	Pw	5.0	Recreation	20	10-21-85	1600	249	7.4
26S-03W-19AC	A. N. Reichenberger	Pn	8.5	Fishing	27	10-23-85	0930	65	7.5
27S-02E-11BD	Marni Bryan	Pw	6.1	Stock,fishing	25	10-21-85	1330	90	7.5
27S-01W-10AB	City of Wichita	Qal	26.0	Fishing	--	10-22-85	0930	1,110	8.8
27S-02W-20BD	Harold Strunk	Qu, Pw	6.5	Stock,fishing	50	10-23-85	1115	53	7.3
27S-04W-25CA	Sheldon Brandis	Qu	12.5	Fishing	20	10-23-85	1315	82	7.5
28S-02E-24AC	Joan E. Ash	Pw	10.5	Fishing	20	10-24-85	1030	186	7.6
28S-01E-05DC	Sedgwick County	Qal	16.0	Fishing	60	10-24-85	1640	1,680	8.9
28S-03W-15DC	Lake Afton	Qu, Pn	25.5	Recreation	43	10-23-85	1745	175	7.5
29S-02W-15AC	John Struthers	Pw	6.5	Stock,fishing	30	10-24-85	1515	211	7.3
29S-04W-04DC	Unknown	Pn	5.5	Stock	--	10-23-85	1530	52	7.6

Table 12. *Water-quality data for selected impoundments in Sedgwick County, October 21-24, 1985*--Continued

Impoundment sampling site (township-range-section, plate 1)	Water temperature (degrees Celsius)	Transparency, secchi disk (inches)	Oxygen, dissolved (milligrams per liter)	Hardness (milligrams per liter as $CaCO_3$)	Hardness, noncarbonate (milligrams per liter as $CaCO_3$)	Calcium, dissolved (milligrams per liter as Ca)	Magnesium, dissolved (milligrams per liter as Mg)	Sodium, dissolved (milligrams per liter as Na)	Potassium dissolved (milligrams per liter as K)	Alkalinity, (milligrams per liter as $CaCO_3$)
25S-02E-04AC	15.5	7.00	6.1	130	71	32	13	5.2	4.4	62
25S-01E-27CB	15.5	11.0	5.1	19	--	5.3	1.4	3.0	4.9	20
25S-03W-24AB	17.0	43.0	10.0	250	110	63	23	360	7.3	140
26S-02E-10AD	16.5	3.50	4.6	93	48	19	11	8.0	5.0	45
26S-03W-19AC	16.5	2.50	8.0	25	3	8.0	1.2	1.0	4.9	22
27S-02E-11BD	17.0	5.00	7.0	39	3	12	2.1	2.0	4.3	36
27S-01W-10AB	16.0	45.5	10.2	120	--	33	8.1	180	3.2	170
27S-02W-20BD	16.0	3.50	7.3	17	4	5.0	1.1	2.0	3.3	13
27S-04W-25CA	16.0	3.50	7.7	46	14	15	2.0	2.4	3.2	32
28S-02E-24AC	17.0	21.5	6.4	77	9	24	4.1	4.0	4.4	68
28S-01E-05DC	19.0	18.0	13.2	210	79	44	24	240	8.0	130
28S-03W-15DC	16.5	2.50	7.5	58	3	16	4.5	8.0	4.0	55
29S-02W-15AC	20.0	5.00	6.5	80	20	17	9.0	8.3	3.6	60
29S-04W-04DC	19.5	2.50	7.8	21	3	4.5	2.3	1.0	2.2	18

Table 12. *Water-quality data for selected impoundments in Sedgwick County, October 21-24, 1985*--Continued

Impoundment sampling site (township-range-section, plate 1)	Sulfate, dissolved, (milligrams per liter as SO_4)	Chloride, dissolved (milligrams per liter as Cl)	Fluoride, dissolved (milligrams per liter as F)	Silica, dissolved (milligrams per liter as SiO_2)	Solids, dissolved sum of constituents, (milligrams per liter)	Nitrogen, NO_2+NO_3 total (milligrams per liter as N	Phosphorus, ortho, total (milligrams per liter as P)	Iron, dissolved (micrograms per liter as Fe)	Manganese, dissolved (micrograms per liter as Mn)	Carbon, organic, total (milligrams per liter as C)
25S-02E-04AC	67	3.1	0.2	8.0	170	0.70	0.16	21	43	5.8
25S-01E-27CB	8.6	1.4	<.1	4.3	41	3.80	.12	110	40	5.7
25S-03W-24AB	210	550	.7	6.2	1,300	.10	<.01	6	18	4.6
26S-02E-10AD	54	7.7	.2	12	140	2.80	.10	46	54	11
26S-03W-19AC	5.3	2.5	.1	8.0	44	1.40	.32	64	9	14
27S-02E-11BD	6.8	2.3	.2	10	61	.50	.11	40	16	10
27S-01W-10AB	94	200	.6	7.0	630	<.10	<.01	6	3	4.4
27S-02W-20BD	8.8	2.5	<.1	5.0	36	.60	.13	71	22	11
27S-04W-25CA	8.2	2.0	.1	5.1	57	.60	.16	48	18	9.5
28S-02E-24AC	20	5.4	.2	9.4	110	.20	.07	100	50	7.6
28S-01E-05DC	150	360	.5	10	910	<.10	.01	<3	3	8.7
28S-03W-15DC	16	9.8	.2	4.0	96	.80	.13	19	9	11
29S-02W-15AC	25	8.7	.1	6.4	110	.80	.08	68	36	6.9
29S-04W-04DC	6.6	.7	<.1	6.0	34	1.60	.17	85	7	25

Table 12. *Water-quality data for selected impoundments in Sedgwick County, October 21-24, 1985*--Continued

Impoundment sampling site (township-range-section, plate 1)	PCB, total (micrograms per liter)	Aldrin, total (micrograms per liter)	Chlordane, total (micrograms per liter)	DDD, total (micrograms per liter)	DDE, total (micrograms per liter)	DDT, total (micrograms per liter)	Dieldrin, total (micrograms per liter)	Endosulfan, total (micrograms per liter)	Endrin, total (micrograms per liter)
25S-02E-04AC	<0.1	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
25S-01E-27CB	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
25S-03W-24AB	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
26S-02E-10AD	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
26S-03W-19AC	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
27S-02E-11BD	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
27S-01W-10AB	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
27S-02W-20BD	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
27S-04W-25CA	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
28S-02E-24AC	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
28S-01E-05DC	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
28S-03W-15DC	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
29S-02W-15AC	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01
29S-04W-04DC	<.1	<.01	<.1	<.01	<.01	<.01	<.01	<.01	<.01

Table 12. *Water-quality data for selected impoundments in Sedgwick County, October 21-24, 1985*--Continued

Impoundment sampling site (township-range-section, plate 1)	Heptachlor, total (micrograms per liter)	Heptachlor epoxide, total (micrograms per liter)	Lindane, total (micrograms per liter)	Methoxychlor, total (micrograms per liter)	Toxaphene, total (micrograms per liter)	Ametryne, total (micrograms per liter)	Atrazine, total (micrograms per liter)	Cyanazine, total (micrograms per liter)	Mirex, total (micrograms per liter)
25S-02E-04AC	<0.01	<0.01	<.01	<0.01	<1	<0.1	0.1	<0.1	<.01
25S-01E-27CB	<.01	<.01	<.01	<.01	<1	<.1	<.1	<.1	<.01
25S-03W-24AB	<.01	<.01	<.01	<.01	<1	<.1	<.1	<.1	<.01
26S-02E-10AD	<.01	<.01	<.01	<.01	<1	<.1	.9	<.1	<.01
26S-03W-19AC	<.01	.01	<.01	<.01	<1	<.1	1.1	<.1	<.01
27S-02E-11BD	<.01	<.01	<.01	<.01	<1	<.1	1.8	0.3	<.01
27S-01W-10AB	<.01	<.01	<.01	<.01	<1	<.1	<.1	<.1	<.01
27S-02W-20BD	<.01	<.01	<.01	<.01	<1	<.1	.1	<.1	<.01
27S-04W-25CA	<.01	<.01	<.01	<.01	<1	<.1	<.1	<.1	<.01
28S-02E-24AC	<.01	<.01	<.01	<.01	<1	<.1	.3	<.1	<.01
28S-01E-05DC	<.01	<.01	<.01	<.01	<1	<.1	<.1	<.1	<.01
28S-03W-15DC	<.01	<.01	<.01	<.01	<1	<.1	.1	<.1	<.01
29S-02W-15AC	<.01	<.01	<.01	<.01	<1	<.1	.1	<.1	<.01
29S-04W-04DC	<.01	<.01	<.01	<.01	<1	<.1	<.1	<.1	<.01

Table 12. *Water-quality data for selected impoundments in Sedgwick County, October 21-24, 1985*--Continued

Impoundment sampling site (township-range-section, plate 1)	Naphthalenes, polychlorinated, (micrograms per liter)	Perthane, total (micrograms per liter)	Prometone, total (micrograms per liter)	Prometryne, total (micrograms per liter)	Propazine, total (micrograms per liter)	Simazine, total (micrograms per liter)	Simetryne, total (micrograms per liter)	Chlorophyll *a*, phytoplankton (micrograms per liter)	Chlorophyll *b*, phytoplankton (micrograms per liter)
25S-02E-04AC	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	7.70	0.20
25S-01E-27CB	<.1	<.1	<.1	<.1	<.1	<.1	<.1	3.80	.40
25S-03W-24AB	<.1	<.1	<.1	<.1	<.1	<.1	<.1	7.00	1.10
26S-02E-10AD	<.1	<.1	<.1	<.1	<.1	<.1	<.1	3.10	.80
26S-03W-19AC	<.1	<.1	<.1	<.1	.1	<.1	<.1	.30	<.10
27S-02E-11BD	<.1	<.1	<.1	<.1	<.1	<.1	<.1	23.0	1.00
27S-01W-10AB	<.1	<.1	<.1	<.1	<.1	<.1	<.1	26.0	1.90
27S-02W-20BD	<.1	<.1	<.1	<.1	<.1	<.1	<.1	.40	<.10
27S-04W-25CA	<.1	<.1	<.1	<.1	<.1	<.1	<.1	.60	<.10
28S-02E-24AC	<.1	<.1	<.1	<.1	<.1	<.1	<.1	6.20	<.20
28S-01E-05DC	<.1	<.1	<.1	<.1	<.1	<.1	<.1	80.0	2.70
28S-03W-15DC	<.1	<.1	<.1	<.1	<.1	<.1	<.1	.50	<.10
29S-02W-15AC	<.1	<.1	<.1	<.1	<.1	<.1	<.1	2.80	.20
29S-04W-04DC	<.1	<.1	<.1	<.1	<.1	<.1	<.1	.20	<.10

[1] Surface geology--Qal, alluvium and terrace deposits of Wisconsin to Holocene age; Qu, lower Pleistocene (undifferentiated pre-Illinoian age) deposits; Pn, Ninnescah Shale; Pw, Wellington Formation.

sorghum. Propazine is soluble in water at 8.6 mg/L and persists in soil for 1 year or longer. The U.S. Environmental Protection Agency has issued a lifetime health advisory level of 14 µg/L for herbicide for the control of most annual broadleaf weeds and grasses in milo and sweet propazine (U.S. Environmental Protection Agency, written commun., August 1987).

Heptachlor is sold under the trade names Drinox H-34, Gold Crest H-60, Heptamul, and Heptox. It is used as an insecticide for subterranean termite control and some agricultural applications. Heptachlor is practically insoluble in water and persists in soil for as long as 3 years. The public-water supply criteria for heptachlor is 0.002 µg/L and for heptachlor epoxide is 0.1 µg/L (see table 2).

Three of the sampled lakes (27S-02W-20BD, 27S-04W-25CA, and 28S-03W-15DC or Lake Afton) receive most of their drainage from areas underlain by lower Pleistocene (undifferentiated pre-Illinoian age) deposits. These lakes ranged in depth from 6.5 feet (27S-02W-20BD) to 25.5 feet (Lake Afton) and were turbid, with transparencies of 3.5 inches or less. Calcium and bicarbonate were the principal dissolved constituents, and concentrations of dissolved solids ranged from 36 mg/L (27S-02W-20BD) and 57 mg/L (27S-04W-25CA) to 96 mg/L (Lake Afton). Lake Afton probably receives more ground-water discharge, which results in a larger concentration of dissolved solids. The herbicide atrazine was detected in lake 27S-02W-20BD (0.1 µg/L) and in Lake Afton (0.1 µg/L).

Three sandpit lakes (25S-03W-24AB, 27S-01W-10AB, and 28S-01E-05DC) were sampled in the vicinity of the Arkansas River. These lakes occur in areas underlain by alluvium and terrace deposits of Wisconsin to Holocene age. The sandpit lakes were quite different from other lakes sampled in the county. All of the other lakes that were sampled were formed by the construction of earthfill dams across stream channels, whereas the sandpit lakes were dug in areas where the ground water was shallow. Consequently, the sandpit lakes receive little surface runoff and contain mostly ground water. These lakes generally were deeper than most of the other lakes sampled, with depths ranging from 15 to 26 feet, and were relatively clear, with secchi disk depths ranging from 18 to 45.5 inches. The transparency values of these sandpit lakes are large because they receive little surface runoff to transport suspended sediment into them. The lake with the smallest transparency value (28S-01E-05DC) had a very significant density of phytoplankton, as evidenced by the chlorophyll-*a* concentration of 80 µg/L, which was three times larger than any other sampled lake and caused the decreased transparency. The sandpit lakes contained sodium chloride type water, with concentrations of dissolved solids that ranged from 630 mg/L (27S-01W-10AB) to 1,300 mg/L (25S-03W-24AB). Concentrations of nitrite plus nitrate as nitrogen and orthophosphorus were smaller in the sandpit lakes than in the other lakes sampled possibly because these nutrients often are introduced by surface runoff or because of nutrient uptake by phytoplankton and macrophytes. No pesticides were detected in these lakes.

Estimated water-quality characteristics of hypothetical impoundments on Little Arkansas and South Fork Ninnescah Rivers

The Little Arkansas and South Fork Ninnescah Rivers have long been considered as sources of water supplies for residents of the city of Wichita and Sedgwick County. Although the median and ranges of constituent concentrations that occur in these streams as presented in the section on "Statistical Summary of Water-Quality Properties and Constituents" are adequate for describing the water-quality characteristics of streams, those values are not representative of water-quality characteristics for impoundments that might be constructed on the streams. The maximum and minimum values of constituent concentrations observed in the streams would not occur in impoundments because they would be integrated with the continum of stream constituent concentrations as the water is impounded. The median constituent concentrations observed in the stream would correspond to values that occur during median streamflow if the data are representative. However, most of the impounded water would result from high streamflow.

The water-quality characteristics that can be used for determining the adequacy of an impoundment for water supplies are the mean concentration of dissolved solids and the rate of sediment deposition. The mean concentration of dissolved solids is a good general indicator of the quality of the impounded water.

An estimate of the mean concentration of dissolved solids that would occur in impoundments on the Little Arkansas River at Valley Center and the South Fork Ninnescah River near Murdock can be calculated by dividing the mean annual discharge of dissolved solids (provided in table 10) by the corresponding mean annual streamflow. The mean annual discharge of dissolved solids for the Little Arkansas River at Valley Center of 79,600 tons (7.22×10^{13} milligrams) divided by the mean annual streamflow of 1.15×10^{10} cubic feet (3.26×10^{11} liters) gives a mean annual dissolved-solids concentration of about 220 mg/L that would occur in an impoundment, assuming that all the streamflow is impounded. The mean annual discharge of dissolved solids for the South Fork Ninnescah River near Murdock of 112,000 tons (1.02×10^{14} milligrams) divided by the mean annual streamflow of 6.46×10^{9} cubic feet (1.83×10^{11} liters) gives a mean annual dissolved-solids concentration of about 560 mg/L. These computed concentrations are significantly smaller than the observed median concentrations for the Little Arkansas River at Valley Center (480 mg/L) and the South Fork Ninnescah River near Murdock (760 mg/L). Of course not all of the flow will be impounded, but regulation of the impoundments can cause concentrations of dissolved solids to remain smaller than median concentrations in the contributing streams.

The mean annual discharge of suspended sediment for the Little Arkansas River at Valley Center (299,000 tons) and the South Fork Ninnescah River near Murdock (107,000 tons), presented in table 10, can be used to estimate the sedimentation rate of impoundments on these streams. Sedimentation decreases the amount of storage in an impoundment and, in Kansas, is the limiting factor in determining the duration of the impoundment's effective use for storage of water supplies. Assuming a 90-percent sediment-trap efficiency, an impoundment on the Little Arkansas River at Valley Center would accumulate sediment at a rate of about 269,000 tons per year, and an impoundment on the South Fork Ninnescah River near Murdock would accumulate sediment at a rate of about 96,300 tons per year. Assuming that most of the sediment in these streams is clay and silt, the specific weight of the sediments would range between about 40 and 75 pounds per cubic foot after 50 years of accumulation (Linsley and others, 1975). Therefore, an impoundment on the Little Arkansas River at Valley Center could lose about 160 to 310 acre-feet of storage per year, and an impoundment on the South Fork Ninnescah River near Murdock could lose about 59 to 110 acre-feet of storage per year.

Cheney Reservoir

Cheney Reservoir, which is located on the North Fork Ninnescah River primarily in southeastern Reno County (fig. 1), is a principal source of public-water supplies for Wichita and for adjacent communities and rural water districts served by the Wichita Water Utility. The reservoir was completed in 1964 by the U.S. Bureau of Reclamation. The dam is approximately 20 miles west of Wichita and controls runoff from 901 square miles, of which probably only 664 square miles contribute. The reservoir has a total storage capacity of 566,300 acre-feet of water. The controlled storage total is 247,950 acre-feet and is allocated for sediment storage (980 acre-feet), fish and wildlife (14,310 acre-feet), conservation pool (151,800 acre-feet), and flood-control pool (80,860 acre-feet). When the reservoir is filled to the top of the conservation pool, it has a surface area of 9,540 acres; at the top of the flood-control pool, the reservoir has a surface area of 12,420 acres (U.S. Army Corps of Engineers, 1973). The capacity table for this reservoir, which relates the elevation of water to reservoir content, is based on a 1965 survey by the U.S. Bureau of Reclamation. More than 20 years of sediment deposition undoubtedly has changed this rating. If the same assumptions are used as in the preceding section concerning hypothetical reservoirs, approximately 290 to 530 acre-feet of storage may have been lost due to sedimentation during 1965 through 1986 (22 years). This is only a rough approximation, and a new survey would be required to accurately determine the amount of sediment deposition.

The city of Wichita has appropriated rights to annually withdraw as much as 52,600 acre-feet of water from Cheney Reservoir for public-water supplies. During 1985, Wichita withdrew about 18,300 acre-feet of water from the reservoir (data from city of Wichita). From 1966, when Wichita began withdrawing water from the reservoir, through 1985, the city of Wichita had withdrawn a total of about 322,610 acre-feet of water from Cheney Reservoir. It is estimated that during a 2-year drought the yield from the reservoir would be limited to about 42,600 acre-feet per year (Lorenz and others, 1985).

Raw water from Cheney Reservoir and the Wichita well field are mixed prior to treatment at the Wichita water-treatment plant. Because of the relatively high turbidity of water from Cheney Reservoir, a mixture of 30-percent Cheney Reservoir water and 70-percent Wichita well field water is considered the optimum blend prior to treatment (Lorenz and others, 1985). The appropriated water right from the well field is about 40,000 acre-feet per year. To achieve the optimum blend of water at the water-treatment plant requires that only about 17,000 acre-feet of water from Cheney Reservoir be used on an annual basis if the total appropriated right from the well field is used. This is the current (1986) situation. A pretreatment facility to remove sediment from Cheney Reservoir water prior to blending with well-field water would allow much more of the appropriated water right from the reservoir to be used.

The water-quality characteristics of Cheney Reservoir are indicated by the mean values of selected water-quality properties and constituents given in table 13. The U.S. Geological Survey data are analyses of 14 samples collected from the North Fork Ninnescah River at Cheney Dam while water was being released from Cheney Reservoir during October 1965 through September 1985. The city of Wichita data are analyses of weekly composite samples (52) collected from the water-supply intake at Cheney Reservoir during 1985. The mean values of chemical constituents for the two data sets are very similar. The water is a sodium chloride type. An estimate of the mean concentration of dissolved solids, based on the mean values of major constituents shown in table 13, is about 500 mg/L. Potassium, fluoride, and nitrate are not included in the estimate of dissolved-solids concentration; however, concentrations of these constituents generally are very small, and the error introduced by excluding them probably is very small.

GROUND-WATER RESOURCES

Occurrence and Availability

Although ground water is present in the subsurface throughout Sedgwick County, the hydrogeologic properties of rocks determine the availability of water. In general, saturated unconsolidated deposits yield much greater quantities of water than saturated bedrock in the county. Most of the bedrock consists of fine-grained shale, silty shale, and siltstone. The fine-grained consolidated nature of the bedrock hinders the movement of water and limits recharge and yields to wells.

The Wellington Formation of Permian age is present throughout the county. Where it occurs at or near the surface, on both sides of the Arkansas River valley, it is utilized as a source of self-supplied domestic and stock water. Wells completed in shale of the Wellington Formation generally yield less than 10 gallons per minute. However, in areas where the weathered upper surface of the Wellington Formation is saturated, yields may be greater. Moderately large yields, as much as 350 gallons per minute, can be obtained from wells penetrating gypsum or anhydrite solution channels (Lane and Miller, 1965a). Water in solution channels is usually confined (artesian).

In the area underlying the Arkansas River valley, the Hutchinson Salt Member of the Wellington Formation has been removed by dissolution processes resulting in solution cavities and greatly fractured collapsed beds. This part of the formation has been referred to as the Wellington aquifer and can yield large quantities of very saline water (Gogel, 1981).

The Ninnescah Shale, also of Permian age, occurs at or near the surface in the western one-third of the county. Wells completed in the Ninnescah Shale generally yield only small quantities of water, less than 10 gallons per minute. However, in areas where the upper weathered surface of the Ninnescah Shale is saturated, yields to wells may be greater. The Ninnescah Shale is utilized as a source of self-supplied domestic and stock water in the western

Table 13. *Mean values of selected properties and concentrations of chemical constituents in water from Cheney Reservoir*

[U.S. Geological Survey samples (14) were collected from the Ninnescah River at Cheney Dam during releases from Cheney Reservoir October 1965-September 1985; City of Wichita samples (52) were collected from the water-supply intake at Cheney Reservoir, near the dam, during 1985 and are weekly composite samples]

Source of analyses	Specific-conductance, in microsiemens per centimeter at 25 degrees Celsius	pH, standard units	Concentration of chemical constituents, in milligrams per liter						
			Calcium	Magnesium	Sodium	Bicarbonate	Sulfate	Chloride	Silica
U.S. Geological Survey	956	7.8	52	15	120	190	51	180	6.2
City of Wichita	788	7.4	54	16	--	200	51	150	10

part of Sedgwick County where it is not overlain by saturated unconsolidated alluvium, terrace deposits, or lower Pleistocene deposits (undifferentiated pre-Illinoian age) that are better sources of water (Lane and Miller, 1965a). Lower Pleistocene deposits (undifferentiated pre-Illinoian age) that occur on the southward-sloping uplands north of the Ninnescah River are utilized as sources of self-supplied domestic and stock water and as a source of public-water supplies for the city of Goddard. These deposits can yield as much as 50 gallons per minute (Lane and Miller, 1965a). Lower Pleistocene deposits that occur in the Arkansas River valley will be discussed in conjunction with other unconsolidated deposits in the valley.

Unconsolidated deposits in the Arkansas River valley range in age from Pliocene to Holocene. Undifferentiated Pliocene and lower Pleistocene (pre-Illinoian age) deposits generally occur under Illinoian terrace deposits and alluvium and terrace deposits of Wisconsin to Holocene age. Wells that are completed through the entire thickness of the deposits and screened in the more permeable sections can yield as much as 2,000 gallons per minute (Lane and Miller, 1965a). Shallower irrigation, stock, or domestic wells screened only in the Illinoian terrace deposits yield from 500 to 1,000 gallons per minute (Lane and Miller, 1965a). Unconsolidated alluvium and terrace deposits of Wisconsin to Holocene age that occur in the Ninnescah River valley are thinner and generally less permeable than those in the Arkansas River valley (Lane and Miller, 1965a). Public-supply wells in Illinoian terrace deposits at Clearwater can yield about 270 gallons per minute, and wells in the buried valley located in the southwest corner of Sedgwick County can yield an estimated 50 to 100 gallons per minute.

Unconsolidated deposits of loess and colluvium generally are above the water table. Loess is very fine-grained, well-sorted, and has a small permeability but can yield small quantities of water if it lies below the water table. Colluvium (mainly silt but may contain sand, gravel, and bedrock fragments) can yield small quantities of water if it lies below the water table.

Water Levels and Ground-Water Flow

Water levels were measured at 335 wells in Sedgwick County during December 1985 and January 1986. The location, depth to water, land-surface elevation, ground-water elevation, and supporting information (owner or tenant, water use, depth of well, geologic source, and pertinent remarks) for these wells are given in table 14. The wells are plotted on plate 2. Plate 2 also shows depth to water and the ground-water elevation for each measured well and has ground-water-level contours (lines of equal ground-water elevation) that were drawn from interpretations of individual well measurements, geology, and topography.

Table 14. *Records of wells where water-level measurements were made during December 1985 and January 1986*

				Principal water-bearing units						
Well number (township-range-section, plate 2)	Owner or tenant	Water use[1]	Depth of well (feet)	Character of material	Geologic source[2]	Date of measurement (month-day-year)	Land-surface elevation (feet above sea level)	Depth to ground-water (feet)	Ground-water level (feet above sea level)	Remarks (MW = owner or tenant monitor wells; QW = water-quality data in table 15; gal/min = gallons per minute)
25S-02E-22BBB	Eugene Thompson	D	90.0	Shale	Pw	12-06-85	1,400	44.3	1,356	
25S-02E-31DDA	Harry Newsum	D	85.0	Sand, shale	Ql, Pw	12-06-85	1,440	15.2	1,425	
25S-01E-15DDC	Wayne E Means	S	45.0	do.	do.	12-06-85	1,432	15.2	1,417	
25S-01E-18CDC	Lyle Kalp	D	45.0	do.	do.	12-06-85	1,382	16.7	1,365	
25S-01E-24DCD	Don Tideman	D	78.0	Shale	Pw	12-06-85	1,400	8.7	1,391	Yields 10 gal/min; QW
25S-01E-29CBC	George Bradshaw	D	65.0	Sand, shale	Ql, Pw	12-06-85	1,390	36.9	1,353	
25S-01E-31CDB	Lynn Ireland	L&G	--	Sand	Qal	12-06-85	1,341	13.9	1,327	
25S-01W-03AAA	City of Wichita	O	25.1	Sand, gravel	do.	01-01-86	1,383	8.3	1,375	MW 825
25S-01W-05AAA	do.	O	18.2	do.	do.	01-01-86	1,368	10.2	1,358	MW 826
25S-01W-05CCC	do.	O	32.5	do.	do.	01-01-86	1,375	22.6	1,352	MW 1176
25S-01W-05DDD	do.	O	70.0	do.	Qal, QT	01-01-86	1,371	19.5	1,351	MW 124
25S-01W-06CCC	do.	O	85.0	do.	do.	01-01-86	1,380	28.3	1,352	MW M34b
25S-01W-06CDD	do.	O	86.0	do.	do.	01-01-86	1,382	31.4	1,351	MW M35b
25S-01W-07BCC	do.	O	51.0	do.	Qal	01-01-86	1,381	30.3	1,351	MW M36b
25S-01W-07CCC	do.	O	31.1	do.	do.	01-01-86	1,381	28.6	1,352	MW 816
25S-01W-10CCC	do.	O	68.5	do.	Qal, QT	01-01-86	1,361	11.6	1,349	MW 125
25S-01W-17AAA	do.	O	30.7	do.	Qal	01-01-86	1,370	21.3	1,349	MW 815
25S-01W-17CBB	do.	O	52.0	do.	do.	01-01-86	1,371	21.8	1,349	MW M39b
25S-01W-17CCC	do.	O	43.0	do.	do.	01-01-86	1,370	20.1	1,350	MW M40b
25S-01W-18AAA	do.	O	48.0	do.	do.	01-01-86	1,375	28.5	1,346	MW M38b
25S-01W-18ABB	do.	O	52.5	do.	do.	01-01-86	1,375	26.1	1,349	MW M37b
25S-01W-20CCC	do.	O	38.5	do.	do.	01-01-86	1,371	15.8	1,355	MW 117
25S-01W-22BBB	do.	O	40.4	do.	do.	01-01-86	1,359	13.1	1,346	MW 126
25S-01W-25DDA	Valley Center School	NU	45.0	do.	do.	12-05-85	1,348	12.4	1,336	
25S-01W-26DBD	City of Wichita	O	54.0	do.	do.	01-01-86	1,352	17.9	1,334	MW 12
25S-01W-27BBB	do.	O	25.3	do.	do.	01-01-86	1,362	16.7	1,345	MW 812
25S-01W-31AAA	Mike Rajewski	D	35.0	do.	do.	12-05-85	1,365	12.3	1,353	Yields 100 gal/min
25S-01W-34DCC	Louis Hendy	D	--	do.	do.	12-05-85	1,352	11.6	1,340	
25S-01W-35DAA	City of Wichita	O	24.8	do.	do.	01-01-86	1,347	15.9	1,331	MW 810
25S-01W-36AAB	Leland Johnson	L&G	50.0	Sand	do.	12-05-85	1,347	16.3	1,331	
25S-02W-01ADD	City of Wichita	O	75.0	Sand, gravel	Qal, QT	01-01-86	1,379	27.0	1,352	MW M33b
25S-02W-01BAA	do.	O	51.0	do.	Qal	01-01-86	1,384	28.2	1,356	MW M25b
25S-02W-01CBB	do.	O	92.0	do.	Qal, QT	01-01-86	1,388	31.5	1,356	MW 307
25S-02W-02ABB	do.	O	82.0	do.	do.	01-01-86	1,390	34.2	1,356	MW M28b
25S-02W-03AAA	do.	O	80.0	do.	do.	01-01-86	1,393	32.8	1,360	MW M27b
25S-02W-03CCC	City of Wichita	O	26.0	Sand, gravel	Qal	01-01-86	1,395	16.3	1,379	MW 840
25S-02W-04AAA	do.	O	20.1	do.	do.	01-01-86	1,400	25.3	1,375	MW 1171
25S-02W-05BBB	do.	O	39.0	do.	do.	01-01-86	1,408	11.9	1,396	MW M51b
25S-02W-05BCC	do.	O	40.3	do.	do.	01-01-86	1,408	13.8	1,394	MW M52b
25S-02W-05CCD	do.	O	37.0	do.	do.	01-01-86	1,402	12.6	1,389	MW M53b
25S-02W-05DBB	do.	O	40.0	do.	do.	01-01-86	1,404	17.8	1,386	MW M54b
25S-02W-05DCD	do.	O	40.0	do.	do.	01-01-86	1,402	15.8	1,386	MW M55b
25S-02W-07AAA	do.	O	32.0	do.	do.	01-01-86	1,402	10.0	1,392	MW 114
25S-02W-11ABB	do.	O	61.0	do.	do.	01-01-86	1,387	29.5	1,357	MW M30b
25S-02W-11BBB	do.	O	103.0	do.	Qal, QT	01-01-86	1,391	27.0	1,364	MW M29b
25S-02W-12BBA	do.	O	62.0	do.	Qal	01-01-86	1,386	30.2	1,356	MW M31b
25S-02W-12BAA	do.	O	61.0	do.	do.	01-01-86	1,383	30.3	1,353	MW M32b
25S-02W-13BBC	do.	O	65.0	do.	do.	01-01-86	1,383	19.1	1,364	MW 3045
25S-02W-14CCC	do.	O	24.0	do.	do.	01-01-86	1,384	7.7	1,376	MW 3044
25S-02W-16BBB	do.	O	15.0	do.	do.	01-01-86	1,397	9.7	1,387	MW 842
25S-02W-18AAB	do.	O	19.0	do.	do.	01-01-86	1,404	12.2	1,392	MW 870
25S-02W-22BBB	do.	O	32.0	do.	do.	01-01-86	1,389	7.8	1,381	MW 115
25S-02W-22DAA	David Jacob	D	32.0	do.	do.	12-04-85	1,384	6.2	1,378	
25S-02W-24DDD	City of Wichita	O	20.0	do.	do.	01-01-86	1,373	10.9	1,362	MW 3050
25S-02W-26BAB	Noel Ramey	D	130.0	do.	Qal, QT	12-04-85	1,381	6.9	1,374	

Table 14. *Records of wells where water-level measurements were made during December 1985 and January 1986*--Continued

Well number (township-range-section, plate 2)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing units: Character of material	Principal water-bearing units: Geologic source[2]	Date of measurement (month-day-year)	Land-surface elevation (feet above sea level)	Depth to ground-water (feet)	Ground-water level (feet above sea level)	Remarks (MW = owner or tenant monitor wells; QW = water-quality data in table 15; gal/min = gallons per minute
25S-02W-26DDB	MLF Razier	I	---	Sand, gravel	Qal	12-05-85	1,374	6.4	1,368	
25S-02W-30CCC	City of Wichita	O	57.0	do.	Qt	01-01-86	1,418	28.9	1,389	MW 830
25S-02W-34C	Harold Korte	I	---	do.	do.	12-04-85	1,381	9.0	1,372	
25S-03W-01DDD	City of Wichita	O	20.0	do.	Qal	01-01-86	1,409	10.8	1,398	MW 3004
25S-03W-03DDD	do.	O	17.2	do.	do.	01-01-86	1,423	10.1	1,413	MW 3041
25S-03W-05BAB	Ronnie Young	I	80.0	do.	Qal, QT	12-03-85	1,435	6.7	1,428	QW
25S-03W-08DDD	Dale McCurry	D	65.0	do.	Qt	12-03-85	1,430	6.5	1,424	Yields 50 gal/min
25S-03W-09CCC	City of Wichita	O	18.5	do.	do.	01-01-86	1,430	10.3	1,420	MW 834
25S-03W-14CCC	Mt. Hope Trucking	D	59.0	do.	do.	12-02-85	1,425	18.1	1,407	Yields 50 gal/min
25S-03W-15CCC	Bob & Rayle Elliott	I	106.0	do.	Qt, QT	12-02-85	1,428	19.9	1,408	Yields 2,000 gal/min
25S-03W-17BBC	Irwin Beal	I	104.0	do.	do.	12-04-85	1,443	19.7	1,423	Yields 1,200
25S-03W-21BAB	Roger Christenson	D	60.0	do.	Qt	12-03-85	1,437	19.2	1,418	QW; Yields 80 gal/min
25S-03W-30BBA	Steve Beal	I	71.0	do.	do.	12-04-85	1,467	41.3	1,426	Yields 900 gal/min
25S-03W-34AAA	Tony and Phil Dozien	I	126.0	do.	Qt, QT	12-04-85	1,415	17.3	1,398	Yields 550 gal/min
25S-03W-36BBB	Joe Raple	I	97.0	do.	do.	12-04-85	1,406	12.8	1,393	QW; yields 1,200 gal/min
26S-02E-10ABB	R. A. Bagshaw	L&G	55.0	Shale	Pw	12-06-85	1,370	22.1	1,348	
26S-02E-29ADA	John Tolbert	L&G	80.0	do.	do.	12-06-85	1,420	19.3	1,401	
26S-02E-35ADA	Tommy Cagle	L&G	--	do.	do.	12-06-85	1,353	19.0	1,334	
26S-02E-36DDA	Lloyd Creed	D	45.0	do.	do.	12-06-85	1,340	15.0	1,325	
26S-01E-07CBC	Continental Pipeline Company	D	35.0	Sand	Qal	12-06-85	1,340	18.4	1,322	QW
26S-01E-11DDB	Gene Washington	L&G	75.0	Sand, shale	Ql, Pw	12-07-85	1,393	13.1	1,380	
26S-01E-17CDA	Ted Hollis	D	40.0	Sand	Qal	12-07-85	1,328	12.4	1,316	
26S-01E-18CBD	Bob Burgan	L&G	34.0	do.	do.	12-07-85	1,333	15.2	1,318	Yields 50 gal/min
26S-01E-19ABD	Micheal Owens	D	25.0	do.	do.	12-07-85	1,330	13.4	1,317	QW
26S-01E-20BCC	Dr. J. C. Short	L&G	45.0	do.	do.	12-07-85	1,330	16.2	1,314	
26S-01E-29ABD	Junior Pruitt	L&G	40.0	do.	do.	12-07-85	1,321	9.8	1,311	
26S-01E-30DDD	Tom Eddy	L&G	40.0	do.	do.	12-08-85	1,321	12.5	1,308	
26S-01E-31ADC	Joseph R. Blaha	L&G	40.0	do.	do.	12-08-85	1,320	19.3	1,301	QW
26S-01E-32BDA	Keith Wirths	L&G	45.0	do.	do.	12-08-85	1,320	14.1	1,306	
26S-01E-33CCC	KDHE[3]	O	17.0	do.	do.	12-06-85	1,315	9.0	1,306	
26S-01W-01DBB	Gary Bolton	D	50.0	do.	do.	12-08-85	1,345	18.8	1,326	
26S-01W-02ABB	Charles Frazee	I	64.0	do.	do.	12-06-85	1,348	10.2	1,338	
26S-01W-05CAA	Nolan Davis	O	--	do.	do.	12-05-85	1,357	10.8	1,346	
26S-01W-06DDC	Hugh Shaft	S	40.0	do.	do.	12-05-85	1,358	5.7	1,352	
26S-01W-07CBC	Dennis Meyer	L&G	50.0	Sand, gravel	do.	12-05-85	1,360	7.0	1,353	Yield 100 gal/min
26S-01W-09AAD	City of Wichita	O	16.2	Sand	do.	12-05-85	1,347	6.9	1,340	MW Wilson
26S-01W-10BCB	do.	O	15.3	do.	do.	12-06-85	1,348	8.7	1,339	MW York
26S-01W-12DCA	J. A. Wilson	L&G	50.0	do.	do.	12-06-85	1,338	15.0	1,323	
26S-01W-15BCD	George Nicholson	L&G	90.0	Sand, gravel	Qal, QT	12-06-85	1,345	10.4	1,335	
26S-01W-16DDD	City of Wichita	O	24.9	do.	Qal	01-01-86	1,342	5.9	1,336	MW TW804
26S-01W-18BCB	Leo R. Wetta	D	44.0	do.	do.	12-05-85	1,358	8.4	1,350	Yields 50 gal/min
26S-01W-22BAA	Sam Cox	L&G	30.0	Gravel	do.	12-06-85	1,340	2.5	1,337	Yields 60 gal/min
26S-01W-23AAB	City of Wichita	O	17.7	Sand	do.	12-05-85	1,334	9.7	1,324	MW House
26S-01W-24BBC	do.	O	19.7	do.	do.	12-06-85	1,332	11.4	1,321	MW N. Miles
26S-01W-25ABC	do.	O	14.5	do.	do.	12-05-85	1,328	10.0	1,318	MW Zleschis
26S-01W-27AAB	Dick Helt	L&G	28.0	do.	do.	12-05-85	1,336	9.4	1,327	Yields 85 gal/min
26S-01W-31DAA	G. L. Manns	D	60.0	do.	Qt	12-05-85	1,352	19.7	1,332	QW
26S-01W-36ADA	William Reece	L&G	--	do.	Qal	12-08-85	1,320	12.1	1,308	
26S-02W-04DDA	Tim Stolz	I	92.0	Sand, gravel	Qt, QT	12-04-85	1,395	30.1	1,365	Yields 1,000 gal/min
26S-02W-14CAA	Kansas Gas and Electric Company	O	185.0	do.	do.	12-04-85	1,370	13.2	1,357	

Table 14. *Records of wells where water-level measurements were made during December 1985 and January 1986*--Continued

Well number (township-range-section, plate 2)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing units: Character of material	Principal water-bearing units: Geologic source[2]	Date of measurement (month-day-year)	Land-surface elevation (feet above sea level)	Depth to ground-water (feet)	Ground-water level (feet above sea level)	Remarks (MW = owner or tenant monitor wells; QW = water-quality data in table 15; gal/min = gallons per minute)
26S-02W-16DAD	Cons Farm Mutual Ins.	AC	60.0	Sand	Qt	12-04-85	1,384	24.9	1,359	
26S-02W-24CDC	Paul Ewertz	D	40.0	do.	do.	12-04-85	1,362	19.6	1,342	
26S-02W-28DCD	Tom Strunk	S	32.0	do.	do.	12-04-85	1,371	19.7	1,351	Windmill
26S-03W-01DAD	Alvin Winter	D	—	do.	do.	12-03-85	1,403	22.9	1,380	
26S-03W-03DAA	Rohm Hass Seeds,Inc.	L&G	79.0	do.	Qt, QT	12-03-85	1,420	29.5	1,391	Yields 75 gal/min
26S-03W-08CDD	Damon L. Horsch	L&G	65.0	Shale	Pn, Pw	12-03-85	1,470	18.9	1,451	
26S-03W-10AAA	Oran Winter	D	80.0	Sand	Qt, QT	12-03-85	1,420	31.5	1,388	Yields 40 gal/min
26S-03W-15ABA	Ray Renner	D	62.0	do.	Qt	12-03-85	1,435	45.8	1,389	Yields 10 gal/min
26S-03W-26CBC	Gerald Kerschen	NU	40.0	Shale	Pn	12-03-85	1,465	10.8	1,454	
26S-03W-30CDC	F. N. Reichenberger	D	70.0	do.	do.	12-03-85	1,530	21.6	1,508	QW
27S-02E-10BAA	Dr. Dillis Hart	NU	—	do.	Pw.	12-11-85	1,370	32.9	1,337	
27S-02E-10DCC	Continental Mgmt.	L&G	70.0	do.	do.	12-11-85	1,370	42.9	1,327	
27S-02E-13CCC	Beech Aircraft Co.	L&G	40.0	do.	do.	12-11-85	1,315	7.1	1,308	
27S-02E-17CCC	Trans American Inv.	L&G	50.0	do.	do.	12-11-85	1,350	15.1	1,335	
27S-02E-22BDB	Keith Petty	L&G	67.0	do.	do.	12-11-85	1,370	43.7	1,326	
27S-02E-24BAD	Ken Helmer	L&G	90.0	do.	do.	12-11-85	1,322	22.4	1,300	
27S-02E-26DAD	James Garvey	L&G	80.0	do.	do.	12-11-85	1,295	8.9	1,286	
27S-02E-34BBB	Terry Smith	L&G	55.0	do.	do.	12-11-85	1,342	15.1	1,327	
27S-01E-03CDB	Willie Smith	L&G	25.0	Gravel	Qal	12-11-85	1,313	16.1	1,297	Yields 50 gal/min
27S-01E-06DAD	Twin Rivers Apts	L&G	50.0	Sand, gravel	do.	12-12-85	1,310	15.9	1,294	
27S-01E-07BAC	City of Wichita	O	24.0	do.	do.	12-06-85	1,312	15.7	1,296	MW Marina Lakes; yields 500 gal/min
27S-01E-07BCB	Jim Keely	L&G	36.0	Sand	do.	12-11-85	1,311	19.6	1,291	Yields 20 gal/min
27S-01E-07CDD	City of Wichita	O	24.0	do.	do.	12-06-85	1,308	18.7	1,289	MW TW40
27S-01E-08CCD	Robert Dyer	L&G	30.0	Sand, gravel	do.	12-12-85	1,305	14.4	1,291	Yields 50 gal/min
27S-01E-09ABC	Tramco	L&G	35.0	Sand	do.	12-12-85	1,305	12.9	1,292	Yields 80 gal/min
27S-01E-10BDB	Ulysses Stokes	L&G	40.0	do.	do.	12-12-85	1,310	16.8	1,293	
27S-01E-12BBB	Univ. Baptist Church	NU	28.0	Shale	Pw	12-12-85	1,410	12.0	1,398	
27S-01E-17ABA	Cecil Brady	L&G	39.0	Sand, gravel	Qal	12-12-85	1,305	17.2	1,288	Yields 60 gal/min
27S-01E-18BBA	Bill Oler	L&G	50.0	do.	do.	12-11-85	1,305	16.2	1,289	
27S-01E-18CCB	City of Wichita	O	23.3	Sand	do.	12-05-85	1,303	16.3	1,287	MW TW38
27S-01E-20BDD	City of Wichita	O	26.4	Sand, gravel	Qal	12-06-85	1,303	19.1	1,284	MW TW35
27S-01E-19BAA	do.	O	23.2	do.	do.	12-06-85	1,304	18.8	1,285	MW TW37
27S-01E-19CAA	W. Side Christian Ch.	L&G	40.0	do.	do.	12-11-85	1,300	15.4	1,285	
27S-01E-20ADB	Farm Credit Bank	AC	38.0	do.	do.	12-12-85	1,300	10.4	1,290	
27S-01E-20BBC	City of Wichita	O	26.4	do.	do.	12-06-85	1,298	14.2	1,284	MW TW36
27S-01E-20DAB	City of Wichita	O	---	do.	do.	12-06-85	1,302	17.5	1,284	MW TW21
27S-01E-20DCC	do.	O	22.2	do.	do.	12-06-85	1,294	11.4	1,283	MW TW34
27S-01E-22CBD	Clyde Daniels	L&G	28.0	Sand	do.	12-12-85	1,295	15.3	1,280	
27S-01E-25ABC	James Haigh	L&G	58.0	Sand, shale	Ql, Pw	12-13-85	1,350	16.8	1,333	
27S-01E-29AAD	W. F. Shauf	L&G	37.0	Sand	Qal	12-12-85	1,295	14.9	1,280	Yields 30 gal/min
27S-01E-29ACD	City of Wichita	O	23.3	do.	do.	12-05-85	1,295	16.2	1,279	MW TW30
27S-01E-29BDD	do.	O	15.9	do.	do.	12-05-85	1,288	8.1	1,280	MW TW33
27S-01E-29CDC	do.	O	18.2	do.	do.	12-05-85	1,288	12.8	1,275	MW TW28
27S-01E-30CCC	Ferguson	L&G	30.0	do.	do.	12-11-85	1,295	12.2	1,283	
27S-01E-31CDD	D. E. Porter	L&G	28.0	do.	do.	12-11-85	1,288	10.7	1,277	
27S-01E-32BCD	City of Wichita	O	19.7	do.	do.	12-06-85	1,284	11.2	1,273	MW TW27
27S-01E-32CAA	Jerry West	D	40.0	do.	do.	12-12-85	1,288	14.4	1,274	
27S-01E-32CDC	City of Wichita	O	17.6	do.	do.	12-06-85	1,284	12.7	1,271	MW TW25
27S-01E-32CDD	do.	O	23.6	do.	do.	12-06-85	1,288	16.9	1,271	MW TW24
27S-01E-33BBC	Peterson	L&G	40.0	do.	do.	12-12-85	1,290	17.1	1,273	
27S-01E-35BDB	Jeanne Parish	AC	95.0	Shale	Pw	12-12-85	1,323	19.8	1,303	
27S-01W-01ADD	Donald Butler	L&G	40.0	Sand	Qal	12-11-85	1,316	12.4	1,304	QW
27S-01W-02CAC	KDHE	O	--	do.	do.	12-11-85	1,325	12.0	1,313	
27S-01W-03DAA	Billy Nida	D	40.0	do.	do.	12-11-85	1,325	8.9	1,316	QW
27S-01W-07DDC	Kevin McWhorter	L&G	60.0	do.	Qt	12-10-85	1,346	22.7	1,323	

Table 14. *Records of wells where water-level measurements were made during December 1985 and January 1986*--Continued

Well number (township-range-section, plate 2)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing units: Character of material	Principal water-bearing units: Geologic source[2]	Date of measurement (month-day-year)	Land-surface elevation (feet above sea level)	Depth to ground-water (feet)	Ground-water level (feet above sea level)	Remarks (MW = owner or tenant monitor wells; QW = water-quality data in table 15; gal/min = gallons per minute)
27S-01W-09BCC	John Collins	L&G	67.0	Sand	Qt.	12-11-85	1,360	42.6	1,317	QW
27S-01W-11BBD	City of Wichita	O	20.1	Sand, gravel	Qal	12-05-85	1,322	14.1	1,308	MW TW8
27S-01W-11DBC	do.	O	32.3	do.	do.	12-05-85	1,322	19.5	1,303	MW TW1
27S-01W-12ACA	do.	O	--	Sand	do.	12-06-85	1,311	16.9	1,294	MW TW42; well
27S-01W-13AAB	Johnson Garden Center	L&G	43.0	do.	do.	12-12-85	1,309	16.8	1,292	
27S-01W-13BBC	City of Wichita	O	14.7	do.	do.	12-06-85	1,312	17.6	1,294	MW TW17
27S-01W-15CCD	Union National Bank	L&G	50.0	do.	do.	12-11-85	1,312	10.2	1,302	
27S-01W-17CDB	Larry Biggs	L&G	65.0	do.	Qt	12-11-85	1,339	27.8	1,311	
27S-01W-19CCB	John Esposito	L&G	65.0	do.	do.	12-11-85	1,340	28.0	1,312	
27S-01W-21CCC	John Rice	D	140.0	Sand, gravel	Qt, QT	12-11-85	1,332	29.7	1,302	QW
27S-01W-23CDC	Lester Malone	D	50.0	Sand	Qal	12-11-85	1,310	14.0	1,296	QW
27S-01W-24AAD	Nellie Allspaugh	L&G	28.0	do.	do.	12-11-85	1,305	17.6	1,287	Yields 25 gal/min
27S-01W-26DDC	Tweeco Products	L&G	35.0	Sand, gravel	do.	12-12-85	1,300	14.0	1,286	QW; yields 75 gal/min
27S-01W-28CCB	Sharpline Converting	L&G	120.0	Sand	Ot, QT	12-10-85	1,327	30.8	1,296	
27S-01W-29BCD	Jerry Blue	L&G	50.0	Sand, gravel	Qt	12-10-85	1,314	7.9	1,306	
27S-01W-31BAA	Blasi	L&G	120.0	Sand	Qt, QT	12-10-85	1,328	23.1	1,305	
27S-02W-01CCC	Terry Irwin	L&G	90.0	do.	do.	12-11-85	1,354	21.8	1,332	
27S-02W-04BBB	Jerry Martin	D	65.0	Sand, shale	Qt, Pw	12-10-85	1,398	51.3	1,347	Yields 20 gal/min
27S-02W-11AAB	G. Kozera	L&G	87.0	Shale	Pw	12-11-85	1,359	28.2	1,331	
27S-02W-13ABC	Lou Sheets	L&G	67.0	Sand	Qt	12-10-85	1,350	22.9	1,327	
27S-02W-15DCA	Eugene Falkowski	L&G	115.0	Shale	Pw	12-10-85	1,390	18.7	1,371	
27S-02W-20BCB	Mike Moltz	D	105.0	do.	do.	12-10-85	1,433	15.2	1,418	
27S-02W-31ADD	Ott Dickerson	L&G	80.0	Sand, shale	Qu, Pw	12-09-85	1,465	32.0	1,433	
27S-02W-34BDB	Gregg Menges	L&G	110.0	Shale	Pw	12-07-85	1,400	4.6	1,395	
27S-03W-03DCD	Mark Helten	NU	--	do.	Pn	12-09-85	1,485	16.2	1,469	Hand-dug well
27S-03W-11ADA	Lawrence Weber	D	--	do.	Pw	12-09-85	1,450	11.5	1,438	
27S-03W-12ADB	Martin Lindwehr	D	80.0	do.	do.	12-09-85	1,430	18.2	1,412	
27S-03W-18CBB	Ivan Lange	L&G	90.0	Sand, shale	Qu, Pn	12-09-85	1,477	21.9	1,455	
27S-03W-21ADD	Eugene J. Scheer	D	--	Shale	Pn	12-09-85	1,480	22.7	1,457	
27S-03W-24AAA	Gary Mies	D	130.0	do.	Pw	12-09-85	1,458	24.2	1,434	
27S-03W-27BBB	David Kershen	D	110.0	Sandy clay, shale	Ql, Pw	12-09-85	1,468	17.3	1,451	
27S-03W-32BCB	City of Garden Plain	L&G	100.0	Sand, shale	Qu, Pn	12-09-85	1,452	12.6	1,439	
27S-04W-06DDA	Unknown	D	--	Shale	Pn	12-09-85	1,402	21.3	1,381	New residence
27S-04W-10CDC	Thomas Hopper	D	65.0	Sand, shale	Qu, Pn	12-09-85	1,463	7.9	1,455	
27S-04W-12CDC	Leon Siewert	D	85.0	Shale	Pn	12-09-85	1,468	17.9	1,450	QW; yields 40 gal/min
27S-04WADB	Fidelity Investment	D	75.0	do.	do.	12-09-85	1,435	30.1	1,405	Yields 30 gal/min
27S-04W-33BBB	Manufacturing Dev.	NU	--	do.	do.	12-09-85	1,372	19.4	1,353	
27S-04W-36ABB	Barry Smith	D	65.0	Sand, shale	Qu, Pn	12-09-85	1,450	12.9	1,437	
28S-02E-01DCA	Jack Wagner	L&G	85.0	Shale	Pw	12-02-85	1,338	18.5	1,320	QW
28S-02E-09BAD	John Hayworth Sr.	L&G	70.0	do.	do.	12-02-85	1,358	28.0	1,330	Yields 30 gal/min
28S-02E-19BBB	Jeanette Barber	L&G	90.0	do.	do.	12-02-85	1,321	12.9	1,308	
28S-02E-28BBB	Dewey Shulda	L&G	72.0	do.	do.	12-02-85	1,338	15.7	1,322	
28S-02E-30DCB	J. A. Fisher	AC	111.0	do.	do.	12-02-85	1,325	27.0	1,298	
28S-02E-36BAA	Gary Rowles	S	100.0	do.	do.	12-08-85	1,340	41.5	1,298	
28S-01E-01ACB	Cessna Aircraft Co.	O	35.8	do.	do.	12-03-85	1,328	29.0	1,299	
28S-01E-03ABC	W. D. Grishmore	L&G	25.0	Sand, gravel	Qal	12-03-85	1,282	7.2	1,275	Yields 30 gal/min
28S-01E-04BDD	Wilnerd	L&G	30.0	Sand	do.	12-03-85	1,284	14.4	1,270	
28S-01E-05BAB	Duane Hickerson	L&G	37.0	Sand, gravel	do.	12-03-85	1,287	16.0	1,271	Yields 60 gal/min
28S-01E-05DAA	City of Wichita	O	21.2	do.	do.	12-05-85	1,284	15.5	1,269	MW TW23
28S-01E-06BAA	City of Wichita	O	17.6	do.	do.	12-07-85	1,289	10.1	1,279	MW TW10
28S-01E-06CDD	City of Wichita	O	13.3	do.	do.	12-05-85	1,282	5.5	1,277	MW TW18
28S-01E-07BDD	do.	O	12.2	do.	do.	12-06-85	1,280	7.0	1,273	MW TW13
28S-01E-07CAD	C&J Construction	L&G	50.0	do.	do.	12-03-85	1,280	7.4	1,273	
28S-01E-08CCD	Cities Service	O	20.0	do.	do.	12-04-85	1,275	8.4	1,267	MW 1-85
28S-01E-09ACD	James Carns	L&G	30.0	do.	do.	12-03-85	1,278	12.7	1,265	

Table 14. *Records of wells where water-level measurements were made during December 1985 and January 1986*--Continued

Well number (township-range-section, plate 2)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing units		Date of measurement (month-day-year)	Land-surface elevation (feet above sea level)	Depth to ground-water (feet)	Ground-water level (feet above sea level)	Remarks (MW = owner or tenant monitor wells; QW = water-quality data in table 15; gal/min = gallons per minute)
				Character of material	Geologic source[2]					
28S-01E-10CCC	Landmark Drive In	L&G	40.0	Sand, gravel	Qal	12-03-85	1,273	8.2	1,265	
28S-01E-11BCD	Victor Gardner	L&G	40.0	Sand, shale	Qal, Pw	12-08-85	1,312	22.6	1,289	
28S-01E-15BBC	Superior Nursery	I	35.0	Sand	Qal	12-04-85	1,273	7.6	1,265	
28S-01E-16DDA	Vernon Richardson	L&G	40.0	do.	do.	12-04-85	1,273	10.2	1,263	
28S-01E-17CAC	Don Pack	L&G	28.0	Sand	do.	12-04-85	1,276	10.5	1,266	
28S-01E-20BCD	Jim Browser	L&G	30.0	Sand, gravel	do.	12-05-85	1,271	5.5	1,265	Yields 10 gal/min
28S-01E-21ACC	KDHE[3/]	O	26.5	do.	do.	12-04-85	1,265	3.8	1,261	MW 1
28S-01E-23ABA	Jess Matheny	L&G	82.0	Sand, shale	Qal, Pw	12-07-85	1,302	24.4	1,278	
28S-01E-27CBB	Lynn Harris	L&G	26.0	Sand, gravel	Qal	12-05-85	1,265	14.5	1,251	
28S-01E-29ACC	KDHE[3/]	O		do.	do.	12-09-85	1,267	10.7	1,256	MW K4
28S-01E-31CBC	Randy Hall	L&G	65.0	Sand	Qt	12-05-85	1,290	36.8	1,253	
28S-01E-32CAA	KDHE[3/]	O	48.0	do.	Qal	12-05-85	1,262	11.1	1,251	MW 7
28S-01E-33BDA	do.	O	49.0	do.	do.	12-05-85	1,267	17.0	1,250	MW 11A
28S-01E-36CCB	Nick Belcher	L&G	65.0	Sand, shale	Qal, Pw	12-02-85	1,292	30.5	1,262	
28S-01W-01CDD	City of Wichita	O	18.0	Sand	Qal	12-06-85	1,288	8.8	1,279	MW TW14
28S-01W-02DDC	do.	O	25.9	do.	do.	12-05-85	1,293	14.1	1,279	MW TW16
28S-01W-03DCB	Cessna Aircraft Co.	L&G	125.0	do.	Qt	12-06-85	1,305	20.6	1,284	
28S-01W-09AAA	Wichita Police Dept.	L&G	80.0	do.	do.	12-06-85	1,314	27.4	1,287	
28S-01W-10CAC	Bill McCarthy	L&G	60.0	do.	do.	12-06-85	1,307	30.2	1,277	
28S-01W-12ABA	Fonken	L&G	28.0	Sand, gravel	Qal	12-06-85	1,287	9.8	1,277	Yields 50 gal/min
28S-01W-17AAD	Ed Birdwell	L&G	95.0	do.	Qt	12-06-85	1,315	42.4	1,273	Yields 80 gal/min
28S-01W-19ADA	Emmett Simon	I	104.0	Sand	do.	12-06-85	1,322	30.3	1,292	Yields 700 gal/min
28S-01W-21CDB	Roman Thome	L&G	80.0	do.	do.	12-06-85	1,315	46.9	1,268	
28S-01W-23CCB	Vulcan Materials	O	35.0	Sand, gravel	do.	12-03-85	1,291	24.4	1,267	MW 11S-AD
28S-01W-23DCD	do.	O	61.0	do.	do.	12-07-85	1,288	23.7	1,264	MW 4S-AD
28S-01W-24BBA	James Wilson	D	57.0	Sand	Qal	12-06-85	1,278	10.5	1,268	QW
28S-01W-26BBC	Steven Peterson	L&G	60.0	do.	Qt	12-07-85	1,300	37.2	1,263	
28S-01W-27DAA	Vulcan Materials	O	57.5	Sand, gravel	do.	12-04-85	1,300	35.7	1,264	MW 10S-AD
28S-01W-28ABA	Tom Bergkamp	I	127.0	do.	do.	12-06-85	1,309	42.4	1,267	
28S-01W-33ADA	Vulcan Materials	O	82.0	do.	Qt	12-04-85	1,306	48.5	1,258	MW 9S-AD
28S-01W-34AAD	do.	O	51.0	do.	do.	12-03-85	1,301	42.1	1,259	MW 13S-AD
28S-02W-03BCC	Ron Nelson	D	36.0	Sand	Qu	12-07-85	1,428	30.1	1,398	Yields 30 gal/min
28S-02W-07CCB	Jim Cooper	D	130.0	Sand, shale	Qu, Pw	12-07-85	1,420	14.1	1,406	
28S-02W-11DCC	Ed Osterman	D	95.0	do.	01, Pw	12-08-85	1,370	33.7	1,336	
28S-02W-17BDA	Craig Page	D	60.0	do.	Qu, Pw	12-07-85	1,420	6.7	1,413	Yields 30 gal/min
28S-02W-19DDC	John Wells	S	40.0	Sand	Qu	12-07-85	1,405	10.1	1,395	
28S-02W-22CDB	Leroy Webber	L&G	50.0	do.	do.	12-07-85	1,385	12.0	1,373	Yields 11 gal/min
28S-02W-25AAD	Roman Klausmeyer	I	138.0	Sand, gravel	Qt, QT	12-07-85	1,343	31.2	1,312	QW
28S-02W-32AAA	Bill Gorges	L&G	95.0	Shale	Pw	12-07-85	1,398	17.4	1,381	QW; yields 20 gal/min
28S-03W-10DAD	Lake Afton Observ.	P	90.0	Sand, shale	Qu, Pw	12-09-85	1,393	12.6	1,380	
28S-03W-12AAA	Rebecca Cunningham	D	50.0	Sand, gravel	Qu	12-09-85	1,432	9.1	1,423	
28S-03W-14BAD	Camp Fellowship	D	110.0	Shale	Pw	12-09-85	1,390	8.5	1,382	
28S-03W-18CBC	Norbert Berkamp	S	128.0	do.	Pn, Pw	12-09-85	1,382	34.7	1,347	Yields 11 gal/min
28S-03W-21DDD	Chris Mountain	D	110.0	do.	do.	12-09-85	1,365	10.3	1,355	
28S-03W-23ACA	Tipton	L&G	125.0	Sand, shale	Qu, Pw	12-09-85	1,395	16.0	1,379	
28S-04W-05CDC	Unified Sch. Dist.2	L&G	88.0	Shale	Pn	12-09-85	1,385	15.0	1,370	
28S-04W-08BDD	Todd Rosenhagen	L&G	74.0	Sand, shale	Qc, Pn	12-09-85	1,385	14.7	1,370	
28S-04W-09ADB	City of Cheney	O	20.0	do.	do.	12-10-85	1,344	6.0	1,338	
28S-04W-15BCB	C. W. Sebits	D	50.0	Shale	Pn	12-10-85	1,345	10.7	1,334	QW
28S-04W-20ABA	R. L. Blakely	D	74.0	Sand, shale	Qal, Pn	02-27-86	1,340	7.9	1,332	QW
28S-04W-20ABD	R. L. Blakely	D	65.0	do.	do.	02-27-86	1,337	4.0	1,333	QW
29S-02E-04AAD	Elwood Jones	D	84.0	Shale	Pw	12-10-85	1,308	41.1	1,267	
29S-02E-18ADD	George Wayman	D	90.0	do.	do.	12-09-85	1,310	53.2	1,257	
29S-02E-18CBC	Harold Matheny	D	80.0	Sand, shale	Qt, Pw	12-09-85	1,280	43.9	1,236	QW; good yield ?
29S-02E-19CCD	Meyers Nut Farm	S	—	Shale	Pw	12-10-85	1,263	38.5	1,225	Good yield ?

Table 14. *Records of wells where water-level measurements were made during December 1985 and January 1986*--Continued

Well number (township-range-section, plate 2)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing units: Character of material	Principal water-bearing units: Geologic source[2]	Date of measurement (month-day-year)	Land-surface elevation (feet above sea level)	Depth to ground-water (feet)	Ground-water level (feet above sea level)	Remarks (MW = owner or tenant monitor wells; QW = water-quality data in table 15; gal/min = gallons per minute)
29S-02E-22BCB	Unknown	--	--	Shale	Pw	12-10-85	1,315	29.2	1,286	
29S-02E-23ABA	Howard Humboldt	S	--	do.	do.	12-10-85	1,318	39.1	1,279	
29S-02E-25BCC	Bill Reager	D	78.0	do.	do.	12-10-85	1,330	49.4	1,281	Yields 20 gal/min
29S-02E-27BBB	Wright	--	--	do.	do.	12-10-85	1,300	31.8	1,268	
29S-02E-31DDD	Roy Dudley	L&G	35.0	Sand	Qal	12-10-85	1,250	14.6	1,235	Yields 50 gal/min
29S-02E-32BAB	Jack Farber	--	--	Shale	Pw	12-10-85	1,281	38.9	1,242	
29S-01E-01BDC	Happy Plant-Garden Center	L&G	60.0	Sand, shale	Ql, Pw	12-09-85	1,295	40.1	1,255	
29S-01E-01DDA	Kermit McGreger	L&G	60.0	do.	do.	12-09-85	1,295	26.4	1,269	
29S-01E-02BBD	N. S. Cornelson	--	--	Sand, gravel	Qal	12-08-85	1,255	10.2	1,245	
29S-01E-03AAD	KDHE[3]	O	22.5	do.	do.	12-08-85	1,250	8.0	1,242	
29S-01E-04ABB	Valgene Smith	L&G	30.0	Sand	Qal	12-07-85	1,259	13.1	1,246	
29S-01E-05BBA	Haysville State Bank	L&G	35.0	do.	do.	12-07-85	1,260	13.4	1,247	Yields 60 gal/min
29S-01E-07BAB	Vivian Howell	D	59.0	Sand, gravel	Qt	12-06-85	1,290	37.1	1,253	
29S-01E-09DAC	Unknown	NU	--	do.	Qal	12-07-85	1,250	7.1	1,243	
29S-01E-10DDD	Linden Benson	L&G	40.0	do.	do.	12-08-85	1,247	11.0	1,236	
29S-01E-11ABC	Bob Smith	L&G	--	Sand	do.	12-08-85	1,250	12.0	1,238	
29S-01E-12AAC	Mark Ellis	L&G	--	Shale	Pw	12-09-85	1,275	15.3	1,260	
29S-01E-13DBC	Derby Wastewater Treatment Facility	NU	--	Sand, gravel	Qal	12-09-85	1,250	14.8	1,235	
29S-01E-14CDA	Lillian Harmon	D	--	do.	do.	12-07-85	1,240	12.4	1,228	
29S-01E-16DBA	P. V. Brooks	L&G	--	do.	do.	12-07-85	1,245	8.1	1,237	
29S-01E-17ADD	Jack Henry	--	--	Sand	do.	12-06-85	1,245	8.8	1,236	
29S-01E-21BBC	James Oliphant	L&G	40.0	do.	do.	12-07-85	1,244	8.1	1,236	
29S-01E-23BBB	Ed Bachman	I	50.0	do.	do.	12-08-85	1,242	11.2	1,231	
29S-01E-25DCC	Larry W. Bryan	D	30.0	do.	do.	12-09-85	1,229	7.1	1,222	
29S-01E-26DAA	Oliver Laurie	I	45.0	do.	do.	12-08-85	1,233	12.1	1,221	
29S-01E-27AAA	John Robertson	L&G	--	Sand, gravel	do.	12-07-85	1,235	9.0	1,226	
29S-01E-29CBD	Charles Ott	I	51.0	do.	Qt	12-07-85	1,270	27.5	1,242	Yields 900 gal/min
29S-01E-32CBC	Heilberg	I	--	do.	do.	12-07-85	1,266	30.0	1,236	
29S-01E-34DAD	Juanita Bradford	--	--	do.	Qal	12-07-85	1,230	11.0	1,219	
29S-01E-35BBB	Galen Gerlach	D	50.0	Sand	do.	12-08-85	1,232	10.7	1,221	Yields 800 gal/min
29S-01E-36CBC	Melvin Lentz	D	54.0	do.	do.	12-09-85	1,225	8.2	1,217	Yields 1,150 gal/min
29S-01W-03DBA	M. W. Briley	D	60.0	do.	Qt	12-05-85	1,291	35.1	1,256	
29S-01W-06DBB	L. E. Soupene	D	33.0	Sand, gravel	do.	12-05-85	1,320	12.3	1,308	
29S-01W-08BAA	Alma Mae Hasler	--	--	Sand	do.	12-05-85	1,295	14.5	1,280	
29S-01W-11ADD	Angie Hutchinson	D	65.0	do.	do.	12-06-85	1,287	32.4	1,255	QW
29S-01W-20CCD	J. Bruce Learmont	--	--	Sand, gravel	do.	12-05-85	1,270	14.9	1,255	
29S-01W-24ACA	Gressell Corporation	NU	60.0	do.	do.	12-05-85	1,275	33.8	1,241	
29S-01W-25BBB	Tony Lies	I	66.0	do.	do.	12-06-85	1,276	35.2	1,241	
29S-01W-27BBB	Glenn Luckner	L&G	44.0	Sand	do.	12-06-85	1,258	9.8	1,248	QW
29S-01W-34CDD	Leonard Schmeissner	D	45.0	do.	do.	12-06-85	1,248	11.0	1,237	
29S-01W-36DDD	Ira Dietrich	D	60.0	do.	do.	12-05-85	1,252	21.0	1,231	
29S-02W-03BBB	Herman Seiter	D	60.0	Sand, shale	Qu, Pw	12-04-85	1,386	18.8	1,367	Yields 35 gal/min
29S-02W-16ABC	Cecil Pietz	NU	--	Shale	Pw	12-04-85	1,310	9.7	1,300	
29S-02W-17CBB	Delbert Townsend	D	44.0	Sand, shale	Qc, Pw	12-04-85	1,308	18.0	1,290	
29S-02W-19DBB	Vulcan Materials	O	34.0	Sand, gravel	Qal	12-05-85	1,280	9.6	1,273	
29S-02W-20DDA	Vulcan Materials	O	38.0	do.	do.	12-05-85	1,266	3.5	1,262	
29S-02W-24CBC	Bill Machart	L&G	66.0	Sand	Qt	12-05-85	1,290	26.2	1,264	
29S-02W-26ABB	Louise Wise	L&G	52.0	do.	Qal	12-04-85	1,285	23.8	1,261	
29S-02W-30ABC	Vulcan Materials	O	38.0	Sand, gravel	do.	12-05-85	1,273	5.1	1,268	
29S-02W-30ADD	Doana Parsons	S	--	Shale	Pw	12-04-85	1,300	25.0	1,275	
29S-02W-35BCC	Delbert McMillian	--	--	Sand	Qal	12-04-85	1,260	11.6	1,248	
29S-03W-09ABA	Roy Holder	L&G	45.0	do.	do.	12-03-85	1,297	2.8	1,294	QW
29S-03W-14CCD	Elaine Nighswanger	S	45.0	do.	do.	12-04-85	1,290	5.3	1,285	
29S-03W-21DDA	Gary Porter	L&G	--	Shale	Pn	12-07-85	1,317	8.3	1,309	
29S-03W-23ABB	Roger Lemon	--	--	Sand	Qal	12-04-85	1,286	11.0	1,275	

Table 14. *Records of wells where water-level measurements were made during December 1985 and January 1986*--Continued

Well number (township-range-section, plate 2)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing units: Character of material	Principal water-bearing units: Geologic source[2]	Date of measurement (month-day-year)	Land-surface elevation (feet above sea level)	Depth to ground-water (feet)	Ground-water level (feet above sea level)	Remarks (MW = owner or tenant monitor wells; QW = water-quality data in table 15; gal/min = gallons per minute)
29S-03W-25ADB	Vulcan Materials	O	48.0	Sand, gravel	Qal	12-05-85	1,280	10.7	1,269	
29S-03W-26CBC	Larry & Earl Paulg	S	--	Shale	Pn	12-04-85	1,330	18.2	1,302	
29S-03W-33ABA	Hadwiger	D	--	do.	do.	12-03-85	1,335	15.7	1,319	
29S-04W-02CDD	Milton Blocker	D	--	do.	do.	12-02-85	1,333	24.4	1,309	
29S-04W-10DCA	Albert Olthoff	D	65.0	do.	do.	12-02-85	1,347	7.8	1,339	
29S-04W-16BCC	William Ruckle	D	70.0	do.	do.	12-02-85	1,385	18.8	1,366	QW
29S-04W-19BCC	Jesse Allen	D	40.0	Gravel	Qt	12-02-85	1,406	6.2	1,400	Yields 25 gal/min
29S-04W-25CDC	Steve Dick	D	--	Sand, gravel	do.	12-02-85	1,378	22.0	1,356	
29S-04W-32CCD	Bonnie Gable	D	70.0	Shale	Pn	12-02-85	1,418	16.1	1,402	Windmill
29S-04W-36DAD	Don Ewing	S	--	Sand, gravel	Qt	12-07-85	1,380	19.8	1,360	Do.

[1] Use: AC, air conditioner; D, domestic; I, irrigation; L&G, lawn and garden; NU, not used; O, observation; S, stock watering.

[2] Geologic source: Qal, alluvium and terrace deposits of Wisconsin to Holocene age; Ql, loess deposits; Qc, colluvium; Qt, Illinoian terrace deposits; Qu, lower Pleistocene (undifferentiated pre-Illinoian deposits); QT, undifferentiated lower Pleistocene and Pliocene deposits; Pn, Ninnescah Shale; Pw, Wellington Formation.

[3] KDHE, Kansas Department of Health and Environment.

Ground-water-level contours are dashed on plate 2 in areas where either the saturated thickness of unconsolidated deposits is less than 20 feet or where the ground-water elevation is below the bedrock surface. Although shale bedrock that occurs near or at the surface in the eastern part of the county as the Wellington Formation and in the western part of the county as the Ninnescah Shale is not a good aquifer because the fine-grained consolidated rock does not readily transmit water, the bedrock generally is saturated below the ground-water-level contours that are shown. Contours are omitted in areas where water-level measurements were not available, such as in the extreme northeast part of the county.

Unconfined ground water flows from higher to lower elevations in the direction that is perpendicular to the ground-water-level contours. The water-level contours generally mirror the surface topographic contours but are more subdued. In upland areas between the Arkansas and Ninnescah Rivers and east of the Little Arkansas River and the Arkansas River south of Wichita, the ground-water divides correspond to the topographic divides and are equivalent to surface-drainage divides between the Ninnescah and Arkansas Rivers and between streams that flow west toward the Little Arkansas and Arkansas Rivers and streams that flow east to the Walnut River in Butler County.

In the North Fork Ninnescah, South Fork Ninnescah, Ninnescah, and Little Arkansas River valleys, ground water flows primarily toward the streams, indicating that these are gaining streams. In the Arkansas River valley, ground water flows primarily down the valley parallel to the stream. Where the water-level contours cross the Arkansas River north of Wichita, they have relatively small random inflections, indicating the stream is approximately in equilibrium with the ground water and is neither gaining nor losing. From Wichita south to the Sumner County line, the water-level contours are inflected in an upstream direction as they cross the Arkansas River, indicating that the stream is gaining water through this reach.

At several locations in the county, the inflection of water-level contours indicates cones of depression caused by ground-water withdrawals for industrial and public supplies. The wells were measured in December and January, and the effects of withdrawals for irrigation are not evident. Withdrawals for public supplies from the Wichita well field have created the largest cone of depression, as evidenced by large inflections of water-level contours in the northern one-half of township 25 south, range 2 west and in the northwest quarter of range 1 west. Slight cones of depression from withdrawals for public supplies appear to be present just east of Mount Hope, in the vicinity of Valley Center on the east side of the Little Arkansas River, about 1 mile southwest of Maize, and west of Derby on the west side of the Arkansas River. Withdrawals for public supplies and self-supplied industrial use appear to have caused cones of depression on the east side of the Little Arkansas River about 4 miles southwest of Kechi, and in the southeast part of Haysville. Withdrawals by industry appear to have caused cones of depression northwest of Colwich, between the Arkansas and Little Arkansas Rivers about 4 miles upstream of their confluence with the Arkansas River to about 3 miles upstream, on the east side of the Arkansas River about 2 miles southeast of its confluence with the Little Arkansas River, about 3 miles west of Haysville, about 3 miles south of the Wichita airport, and in the vicinity of the Wichita airport. Most of the cones of depression are not well defined because the spacing between measured wells is too great.

In contrast to the cones of depression caused by ground-water withdrawals, a low-head dam on the Little Arkansas River just upstream from its confluence with the Arkansas River appears to have caused the formation of a mound of ground water under the Little Arkansas River.

Historic Fluctuations in Water Levels

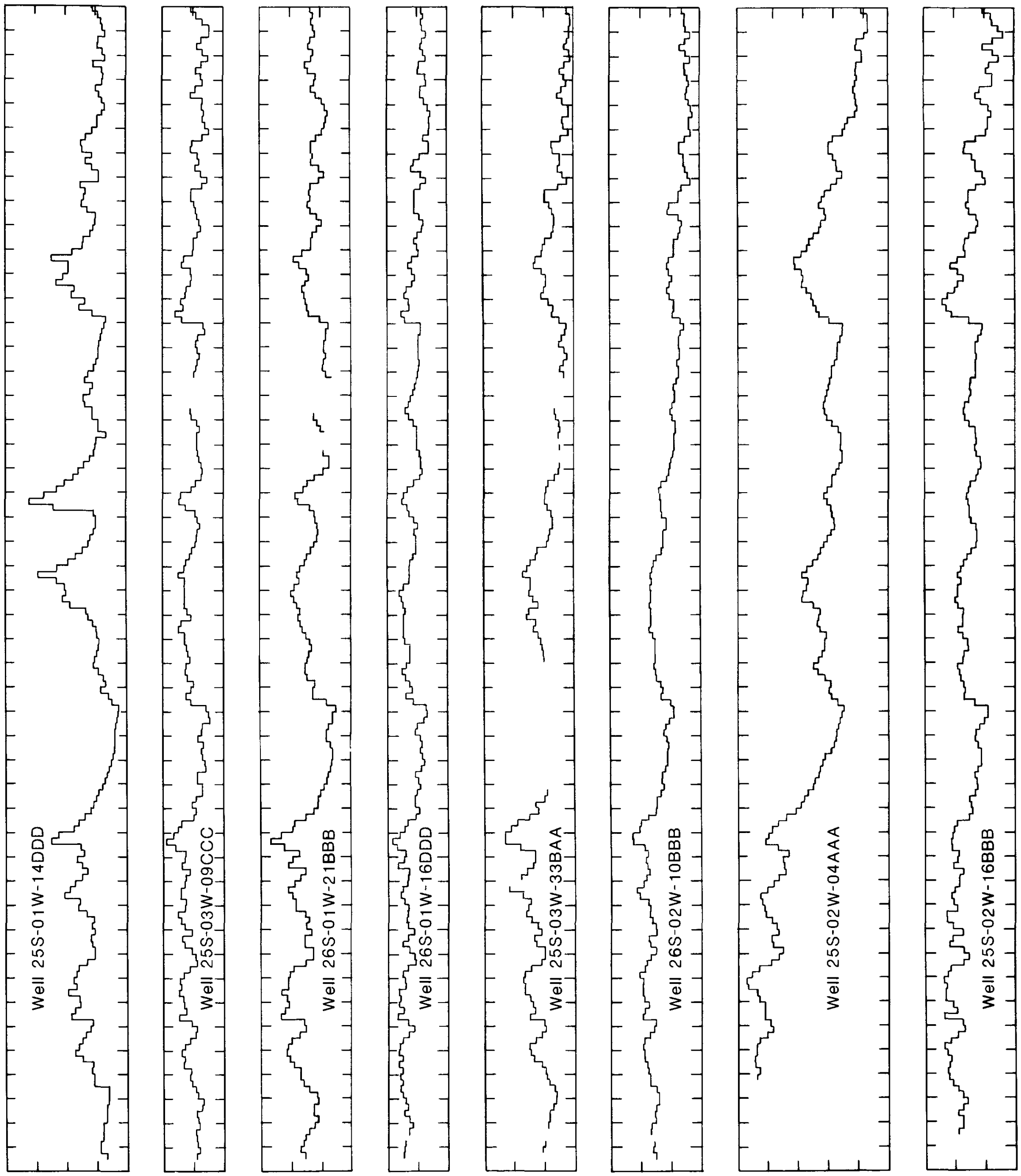
Water-level measurements have been made at monitoring wells in Sedgwick County on a regular basis since 1938. These long-term monitoring wells were established to observe effects of the Wichita well field on ground-water levels in alluvium and terrace deposits of the Arkansas and Little Arkansas Rivers in northern Sedgwick County. However, a few monitoring wells were established in southern parts of the Arkansas River valley during the mid-1960's. One of these southern wells (well 28S-01W-11BCB) has a continuous record of water-level measurements and is included in this discussion of historic water-level fluctuations.

Well hydrographs for selected monitoring wells, showing the average seasonal depth to water from 1938 through 1985, are shown in figure 18 in conjunction with graphs showing seasonal precipitation and cumulative departure from average precipitation at Wichita, irrigated acres in Sedgwick County, and annual ground-water withdrawals for public supplies from the Wichita well field. Several of these wells are located far enough from areas where large volumes of ground water are withdrawn that they probably are unaffected by the withdrawals and should be representative of natural fluctuations in ground-water levels. The wells that are not affected by ground-water withdrawals are 25S-01W-14DDD and 25S-03W-9CCC. Water levels in these wells are related directly to the cumulative departure from average precipitation. Evidence that water levels are not affected by ground-water withdrawals is given by the observation that these were the only wells with higher water levels in 1985 than in 1938; cumulative departure from average precipitation was also greater in 1985 than in 1938. All of the other wells had lower water levels in 1985 than in 1938.

Well 26S-01E-21BBB is adjacent to areas where large volumes of ground water are withdrawn for public and industrial supplies. However, the water level appears to have been only slightly affected. Wells 26S-01W-16DDD, 25S-03W-33BAA, and 26S-02W-10BBB are located in areas where the ground-water levels have been lowered by irrigation, primarily during the last 20 years. Well 26S-02W-10BBB is also adjacent to an area where ground water is withdrawn for industrial use and has experienced only a slight decline in the water level.

Wells 25S-02W-04AAA, 25S-02W-16BBB, and 25S-01W-17AAA are located in or adjacent to the Wichita well field. The water level in well 25S-02W-04AAA has declined more than 20 feet since 1941. Water levels in these wells probably are affected also by withdrawals for irrigation.

Well 28S-01W-11BCB has a much shorter


Well 25S-01W-14DDD
Well 25S-03W-09CCC
Well 26S-01W-21BBB
Well 26S-01W-16DDD
Well 25S-03W-33BAA
Well 26S-02W-10BBB
Well 25S-02W-04AAA
Well 25S-02W-16BBB
AVERAGE SEASONAL DEPTH TO WATER, IN FEET

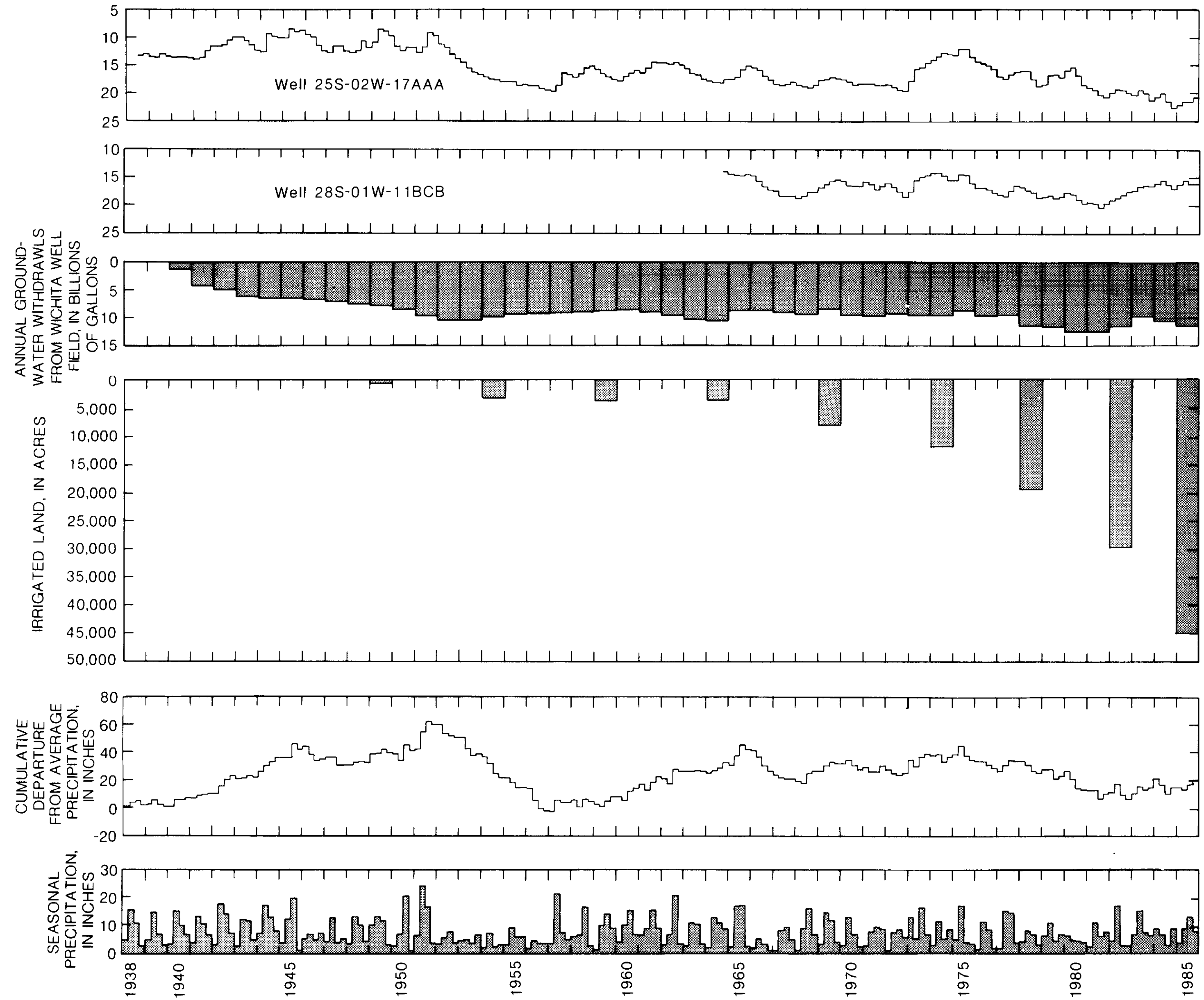


Figure 18. Hydrographs of selected wells in Sedgwick County, seasonal precipitation at Wichita, irrigated acres in Sedgwick County, and annual ground-water withdrawals from Wichita well field, 1938-85, and cumulative departure from average precipitation (1888-1985) at Wichita.

period of record (1965-85) than the wells in the northern part of the county. Although it is located in an area where ground water is withdrawn for industrial supplies, the water level is closely related to cumulative departure from average precipitation and does not appear to have been affected significantly by ground-water withdrawals.

In general, ground-water levels in the area are directly related to cumulative departure from average precipitation. However, those wells located in and adjacent to the Wichita well field and in areas where large volumes of ground water are withdrawn for irrigation supplies have 1985 water levels that are the lowest observed during the period of record. Most of these declines are attributed to ground-water withdrawals. However, cumulative departure from average precipitation has declined also in recent years (since about 1975). An extended period of above-average precipitation, such as occurred during 1940-45, 1948-51, 1957-65, and 1973-75, probably would cause a substantial rise in ground-water levels. An extensive drought, such as occurred during 1952-56, probably would lower ground-water levels substantially.

Depth to Water and Saturated Thickness

The depth to water at any location is a function of both the ground-water elevation and local topography. The depth to water generally is least in areas adjacent to the Arkansas and Ninnescah Rivers where depth to water is often less than 10 feet and occasionally is less than 5 feet (plate 2). However, in areas adjacent to the Arkansas River in Wichita, depths are greater in areas where ground-water withdrawals have caused cones of depression to develop. In upland areas, the depth to water is greater, exceeding 40 feet in several of the measured wells.

The saturated thickness of unconsolidated deposits in Sedgwick County is shown in figure 19. The saturated-thickness map was developed by subtracting the altitude of the Permian (Wellington Formation or Ninnescah Shale) bedrock surface (from Lane and Miller, 1965a, plate 3) from the altitude of the ground-water surface, as shown on plate 2 of this report. Lines of equal saturated thickness in figure 19 are shown at 40-foot intervals for saturated thickness ranging from 20 to 220 feet. Areas where the saturated thickness is less than 20 feet are shaded. In the shaded areas, the unconsolidated deposits are thin or absent.

Saturated thickness is greatest in the northwest part of the county in the Arkansas River valley where it exceeds 220 feet in a few areas. Solution of the Hutchinson Salt Member of the Wellington Formation caused collapses and settling of the bedrock surface, resulting in a large closed depression that was subsequently filled with unconsolidated deposits (Lane and Miller, 1965a). Saturated thickness of unconsolidated deposits in the Arkansas River valley south of Wichita generally is less than 60 feet. Saturated thickness of unconsolidated deposits in the Ninnescah River valley ranges from about 40 feet along the river south of Clearwater to about 20 feet in alluvium of the North and South Forks of the Ninnescah River.

Recharge, Storage, and Discharge

Ground-water recharge occurs from precipitation, ground-water inflow from adjacent areas, and losing stream reaches. Precipitation is the primary source of ground-water recharge in the area. The quantity of recharge from precipitation in any area is a function of the quantity of precipitation, vegetation (interception and subsequent evaporation), seasonal factors (evaporation and evapotranspiration), topography (slope), soil conditions (permeability and antecedent soil moisture), and aquifer characteristics (permeability, porosity, depth to water, and capacity to store the recharge).

The Arkansas River valley unconsolidated aquifer in Sedgwick County is readily recharged by precipitation. The valley receives adequate precipitation (about 28.6 inches per year), is primarily grassland and cropland that intercepts less precipitation than forest vegetation, is relatively flat, which allows for less runoff and more infiltration, has sandy soil that is permeable, and has excellent aquifer characteristics provided by deep deposits of unconsolidated sand and gravel.

An investigation of recharge from precipitation in Harvey County, near Burrton (fig. 1), determined that effective recharge generally occurs only during late winter and spring (these are periods with relatively large amounts of precipitation and slow rates of evapotranspiration) (Sophocleous and Perry,

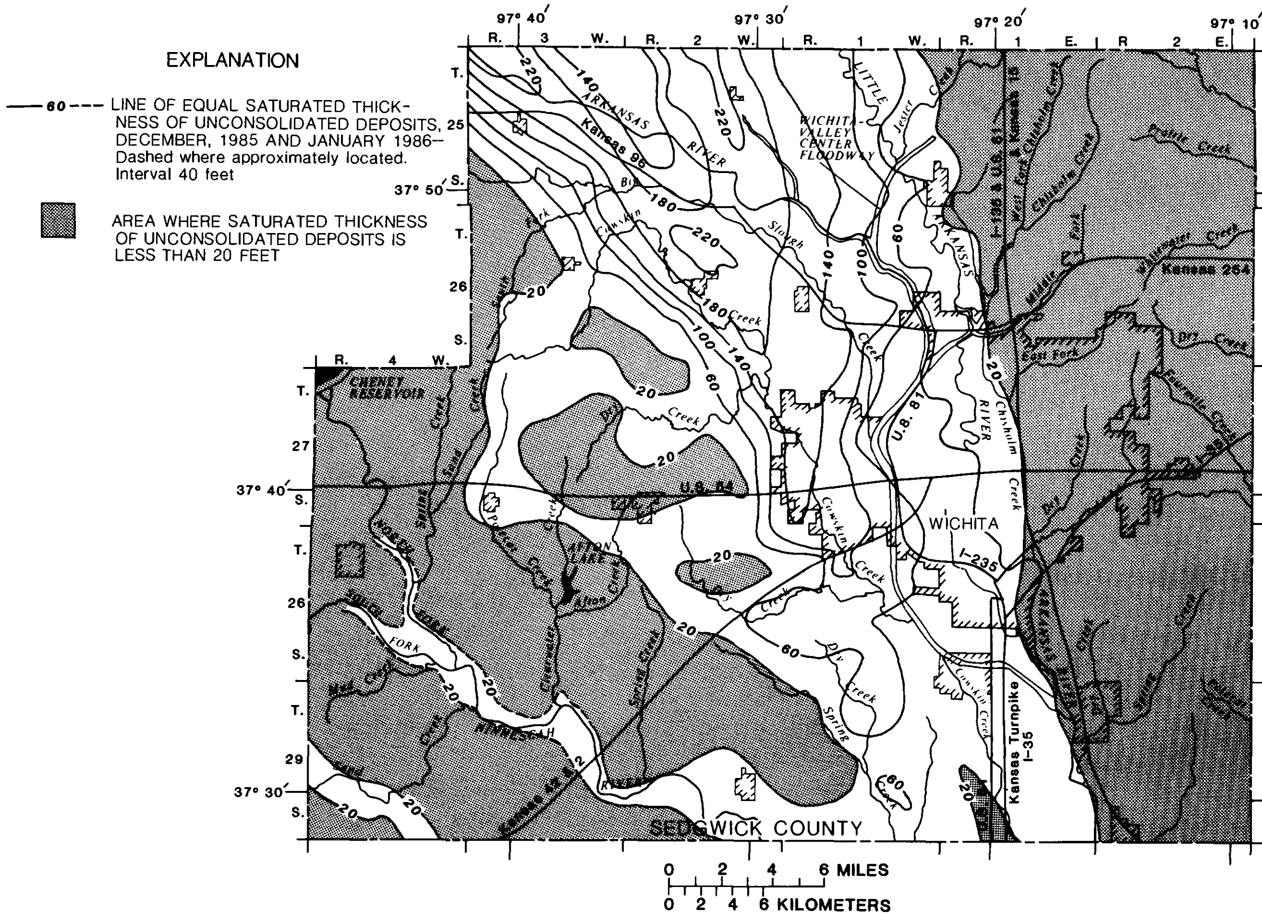


Figure 19. Saturated thickness of unconsolidated deposits in Sedgwick County.

1985). This same investigation indicated that the greater the thickness of the unsaturated zone (or the greater the depth to water) and the less available soil moisture (hydraulic conductivity decreases with decreasing soil moisture), the less recharge occurs (Sophocleous and Perry,1985). The areas investigated by Sophocleous and Perry were obvious recharge areas, sand-dune areas with no surface drainage patterns. In areas where surface runoff occurs, high levels of antecedent soil moisture can impede recharge by precipitation if the soil is near saturation. Recharge from precipitation in the Arkansas River valley of Sedgwick County and adjacent areas was estimated by Williams and Lohman (1949) at 5.32 to 8.37 inches per year, by Stramel (1956) at 3.75 to 8.80 inches per year, by Sophocleous (1983) at 1.6 to 6.4 inches per year, by Sophocleous and Perry (1985) at 6.06 inches per year, and by Spinazola and others (1985) at 0.1 to 5.5inches per year.

Recharge from ground-water inflow is minimal in Sedgwick County. Water-level contours on plate 2 show that little ground-water inflow occurs along the northern boundary of the county because the contours are approximately normal to the boundary. Ground-water inflow to the Arkansas River valley does occur from uplands to the east and west, as indicated by the water-level contours. However, inflow is probably equal to the outflow indicated by water-level contours along the southern boundary of the county.

Recharge by losing streams generally does not occur in the area except during extended periods of high streamflow. The water-level contours on plate 2 indicate that the streams normally are either in relative equilibrium with the ground water (as the Arkansas River north of Wichita) or are gaining. Recharge from streams can occur in areas near the streams where ground-water withdrawals have created cones of depression.

Storage of ground water with less than 1,000 mg/L dissolved solids in unconsolidated deposits of the Arkansas, Little Arkansas, and Ninnescah River valleys in Sedgwick County has been estimated to be about 2.88 million acre-feet (Hansen, 1987).

Ground-water discharge in the area is due primarily to gaining streams, evapotranspiration, and ground-water withdrawals. In general, over a long period, ground-water discharge is approximately equal to ground-water recharge, although ground-water withdrawals can upset this balance locally in areas of intensive pumping. In a natural setting (excluding ground-water withdrawals), most of the ground-water discharge occurs through gaining streams followed by evapotranspiration, which generally occurs only in areas where the depth to water is less than 10 feet (Spinazola and others, 1985). Spinazola and others estimated the maximum rate of ground-water discharge by evapotranspiration to be about 3.5 inches per year. In recent years, large ground-water withdrawals (about 112,700 acre-feet in 1985) may be approaching discharge to streams as a primary means of ground-water discharge.

During a low-flow seepage survey in March 1985, the Arkansas River gained only about 126 cubic feet per second between Mount Hope and Mulvane (excluding streamflow provided by the Little Arkansas River, table 11). However, part of the gain was due to sewage-treatment plant effluent from Wichita (probably about 60 cubic feet per second), so only about 66 cubic feet per second were gained. Ground-water withdrawals in Wichita and near Derby probably are decreasing the gain to some extent. The Little Arkansas River gained about 20 cubic feet per second between Sedgwick and 37th Street in Wichita (table 11), although the river is affected by ground-water withdrawals for public and industrial supplies. The Ninnescah River system experienced a gain of about 118 cubic feet per second in its reach through Sedgwick County. If these rates of gain are extrapolated to 1 year, the amount of ground-water loss to major streams in the county would be approximately 148,000 acre-feet per year.

Water-Quality Characteristics

Water samples for chemical analysis were collected from 99 wells during an areal reconnaissance of ground-water quality in August 1985. Two additional wells were sampled during February 1986. Wells in the reconnaissance network were selected to provide areal coverage and to represent the geology of the county. Where possible, wells with driller's logs describing the stratigraphy and providing other information, such as depth of well, water use, and estimated yield, were sampled. The results of chemical analysis of these samples and other information are provided in table 15. Pie diagrams showing the concentration of dissolved solids and the chemical composition of the water (based on milliequivalents per liter) for each well are plotted on plate 1.

Relationship Between Ground-Water Quality and Geology

Water-quality characteristics of ground water generally are functions of the mineralogy of the geologic formation containing the water and of the duration of contact between the water and minerals.

Water from wells in the Wellington Formation of Permian age generally is either a calcium sulfate, a calcium bicarbonate sulfate, or a calcium bicarbonate type. Calcium and bicarbonate are derived from the dissolution of impure limestone beds that occur in this formation. Calcium and sulfate are derived from the dissolution of gypsum and anhydrite beds. Concentrations of dissolved solids in the ground water generally increase with depth as the duration of contact between the water and minerals increases. In the Wellington Formation, calcium sulfate type water usually has concentrations of dissolved solids that exceed 1,000 mg/L; calcium bicarbonate sulfate type water has concentrations of dissolved solids ranging from 500 to 1,000 mg/L; and calcium bicarbonate type water has concentrations of dissolved solids that are less than 500 mg/L. Calcium sulfate type water obtained from solution openings in gypsum and anhydrite beds in the extreme eastern part of the county, generally that part drained by eastward-flowing tributaries to the Walnut River, commonly is the most mineralized in the county, with concentrations of dissolved solids sometimes exceeding 2,000 mg/L. Ground water from the

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986*

[< preceding a value indicates the constituent was not detected at that detection level]

WELL CHARACTERISTICS

Well number (township-range-section, plate 1)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source[2]	Date sampled (month-day-year)	Remarks (WL = water-level data in table 14; gal/min = gallons per minute)
25S-01E-24DCD	Don Tidemann	D	78.0	Shale	Pw	08-12-85	WL; yields 10 gal/min
25S-01W-07BAA[3]	City of Wichita	P	132.5	Sand and gravel	Qal, QT	08-14-85	Well M35; yields 1,500 gal/min
25S-01W-15AAB	Bill Wilbur	I	56.0	Gravel	Qal	08-12-85	Yields 1,200 gal/min
25S-01W-24CDC	William Congdon	D	42.0	Sand	do.	08-12-85	
25S-01W-27CCC	Keith W. Dillinger	D	40.0	Gravel	do.	08-13-85	Yields 60 gal/min
25S-01W-30ABB[3]	Homer Jacob	D	32.0	Sand and gravel	do.	08-13-85	
25S-01W-35AAC	Marilyn Moeder	D	37.0	Sand	do.	08-13-85	
25S-01W-36ACB[4]	City of Valley Center	P	52.0	Sand and gravel	do.	08-13-85	
25S-02W-02BAA	City of Wichita	P	218.0	do.	Qal, QT	08-14-85	Well M28; yield 1,050 gal/min
25S-02W-15DDD[3]	Owner unknown	I	--	do.	Qal	08-12-85	
25S-02W-17ABB	Larry Williams	I	45.0	Sand	do.	08-14-85	Yields 1,400 gal/min
25S-02W-34CCB	Bill Majerus	D	50.0	Gravel	do.	08-15-85	
25S-03W-02BBC	Odell McCurry	I	52.0	Sand	do.	08-14-85	Yields 900 gal/min
25S-03W-05BAB[3]	Ronnie Young	I	80.0	Sand and gravel	Qal, QT	08-14-85	WL
25S-03W-14CCB[3]	Jack Kountz	D	64.0	do.	Qt	08-14-85	Yields 100 gal/min
25S-03W-21BAB	Roger Christenson	D	60.0	do.	do.	08-14-85	WL; yields 80 gal/min
25S-03W-36BBB[3]	Joe Raple	I	97.0	do.	Qt, QT	08-15-85	WL; yields 1,200 gal/min
26S-02E-09DAA	B. B. Johnson	D	58.0	Shale	Pw	08-12-85	
26S-01E-07CBC[4]	Continental Pipeline Co	D	35.0	Sand	Qal	08-12-85	WL
26S-01E-11CDD	Larry McRae	D	60.0	Sand and shale	Ql, Pw	08-12-85	
26S-01E-17AAB	Park City	D	42.0	Sand and gravel	Qal	08-12-85	Well 7; yields 200 gal/min
26S-01E-19ABD	Micheal Owens	D	25.0	Sand	do.	08-12-85	WL
26S-01E-21BBA	L&E Machine	L&G	40.0	Sand and shale	Qal, Pw	08-12-85	
26S-01E-31ADC[4]	Joseph Blaha	L&G	40.0	Sand	Qal	08-12-85	WL
26S-01W-01DAD	Dan Ackerman	D	44.0	do.	do	08-12-85	
26S-01W-05BAB	Robert Ulbrick	I	156.0	do.	Qal, QT	08-13-85	Yields 2,500 gal/min
26S-01W-15BBB	Steve Simon	D	40.0	Sand	Qal	08-13-85	
26S-01W-18AAA[3]	Edward Drollinger	D	28.0	do.	do.	08-14-85	
26S-01W-22CBD	Gary Grimes	D	56.0	do.	do.	08-13-85	
26S-01W-31DAA	G. L. Manns	D	60.0	do.	Qt	08-13-85	WL
26S-02W-04BBD	Louis Gruenbacker	I	91.0	Sand and gravel	Qt, QT	08-15-85	Yields 1,000 gal/min
26S-02W-16BBD[3]	Herbert L. Winter Jr.	I	85.0	do.	do.	08-15-85	Yields 1,000 gal/min
26S-02W-18ADD	Walter Gruenbacker	D	56.0	Sand	Qt	08-15-85	Yields 50 gal/min
26S-02W-33CDD	St. Marks Parish	P	--	do.	do.	08-15-85	
26S-03W-08DCB	Paul Blick	D	80.0	Shale	Pn, Pw	08-12-85	Yields 20 gal/min
26S-03W-10DDB	Monte Peltz	D	58.0	Sand and shale	Qt, Pw	08-12-85	Yields 30 gal/min
26S-03W-30CDC	F. N. Reichenberger	D	70.0	Shale	Pn	08-13-85	WL
27S-02E-13CCC	Beech Aircraft	L&G	40.0	Shale and gypsum	Pw	08-15-85	Yields 300 gal/min
27S-01E-08CCD	Robert Dyer	L&G	30.0	Sand and gravel	Qal	08-14-85	
27S-01E-13DAC	Sol Bachos	L&G	90.0	Shale	Pw	08-14-85	
27S-01E-18CDD	Wichita Water Works	P	51.0	Sand and gravel	Qal	08-14-85	Well S1; yields 1,690 gal/min
27S-01W-01ADD	Donald Butler	L&G	40.0	Sand	do.	08-12-85	WL
27S-01W-03DAA[3]	Billy Nida	D	40.0	do.	do.	08-12-85	WL
27S-01W-09BCC	John Collins	L&G	67.0	do.	Qt	08-13-85	WL
27S-01W-12DAA[4]	Larry Dickson	L&G	40.0	do.	Qal	08-13-85	
27S-01W-13AAB	David Cadmus	L&G	40.0	do.	do.	08-13-85	

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986*--Continued

WELL CHARACTERISTICS--Continued

Well number (township-range-section, plate 1)	Owner or tenant	Water use[1]	Depth of well (feet)	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source[2]	Date sampled (month-day-year)	Remarks (WL = water-level data in table 14; gal/min = gallons per minute)
27S-01W-15BDC	James Wall	L&G	55.0	Sand	Qal	08-13-85	
27S-01W-17BCD	Marie Corns	L&G	60.0	Sand and gravel	Qt	08-13-85	
27S-01W-21CCC	John Rice	D	140.0	do.	Qt, QT	08-13-85	WL
27S-01W-23CDC[4]	Lester Malone	D	50.0	Sand	Qal	08-13-85	WL
27S-01W-26DDC	Tweeco Products	L&G	35.0	Sand and gravel	do.	08-14-85	WL; yields 75 gal/min
27S-01W-27BBD	Ray Dohrer	D	67.0	do.	Qt	08-13-85	
27S-01W-29DBD[4]	Tom Linam	D	56.0	Sand	do.	08-13-85	
27S-01W-33AAA	U.S. Postal Service	L&G	65.0	do.	do.	08-14-85	
27S-02W-01DBD[3]	Ernie Nickens	L&G	80.0	do.	Qt, QT	08-12-85	
27S-02W-10ADA	Mark Dickerson	D	100.0	do.	do.	08-12-85	
27S-02W-13ABB	Richard Moore	D	95.0	do.	do.	08-13-85	
27S-02W-32BBB[3]	City of Goddard	P	54.0	Sand and gravel	Qu	08-13-85	Well 4; yields 50 gal/min
27S-03W-03DCC	Mark Helten	D	66.0	Shale	Pn, Pw	08-13-85	Yields 15 gal/min
27S-03W-12DCC	A. E. Zenner	D	80.0	Sand and shale	Ql, Pw	08-13-85	Yields 25 gal/min
27S-03W-31DCD	M. L. Duren	D	65.0	do.	Qu, Pn	08-13-85	
27S-04W-12CDC	Leon Siewert	D	85.0	Shale	Pn	08-13-85	WL; yields 40 gal/min
28S-02E-01DCA	Jack Wagner	L&G	85.0	do.	Pw	08-14-85	WL
28S-02E-34CAC	John R. Keck	D&S	65.0	do.	do.	08-16-85	
28S-01E-05BAB	Charles L. Byfield	L&G	37.0	Sand and gravel	Qal	08-13-85	Yields 30 gal/min
28S-01E-07DDD	CJ Mobile Home Sales	L&G	50.0	do.	do.	08-13-85	
28S-01E-17DDB	William Gale	L&G	40.0	Sand	do.	08-13-85	
28S-01E-29CBB	Carl Ballinger	L&G	49.0	do.	do.	08-13-85	
28S-01E-31CAB	Marvin Hoover	L&G	75.0	do.	do.	08-13-85	
28S-01W-10CCB[4]	Jerry Weber	D	65.0	do.	Qt	08-14-85	
28S-01W-11CBC	Ron Schaeffer	L&G	95.0	do.	Qt, QT	08-14-85	Yields 40 gal/min
28S-01W-17ADD	Phil Nelson	D	130.0	do.	do.	08-14-85	
28S-01W-24BBA[4]	James Wilson	D	57.0	do.	Qal	08-14-85	WL
28S-01W-32DDD	Carl Jaax	D	25.0	do.	Qt	08-14-85	
28S-02W-11CDD	Jewel Davis	D	105.0	Shale	Pw	08-14-85	
28S-02W-21CDD	Frank Rohmeyer	D	45.0	Sand and shale	Qu, Pw	08-14-85	
28S-02W-25AAD[3]	Roman Klausmeyer	I	138.0	Sand and gravel	Qt, QT	08-16-85	WL
28S-02W-32AAA	Bill Gorges	L&G	95.0	Shale	Pw	08-14-85	WL
28S-03W-01ACC	Larry Newby	D	50.0	Sand	Qu	08-14-85	
28S-03W-23DDB	R. S. Hagan	D	55.0	Shale	Pw	08-14-85	
28S-04W-05BCC[3]	City of Cheney	P	40.0	Sand and gravel	Qc	08-14-85	Well 8; yields 100 gal/min
28S-04W-15BCC	C. W. Sebits	D	50.0	Shale	Pn	08-14-85	WL
28S-04W-20ABA	R. L. Blakely	D	74.0	do.	do.	02-27-86	WL
28S-04W-20ABD	R. L. Blakely	D	65.0	do.	do.	02-27-86	WL
28S-04W-35ABD[3]	Marvin Zogelman	I	40.0	Sand and gravel	Qal	08-15-85	
29S-02E-18CBC	Harold Matheny	D	80.0	Sand and shale	Qt, Pw	08-15-85	WL
29S-01E-03DCC	Brian Simpson	L&G	40.0	Sand	Qal	08-14-85	
29S-01E-05CAA[4]	City of Haysville	P	54.0	Sand and gravel	do.	08-15-85	Well 2; yields 300 gal/min
29S-01E-14DCC	El Paso Water Co	P	37.5	do.	do.	08-14-85	Well 8; yields 650 gal/min
29S-01E-21CBC[4]	Southgate Bapt. Church	D	43.0	do.	do.	08-15-85	
29S-01E-23CCC[3]	Tom McElroy	D	45.0	do.	do.	08-15-85	
29S-01E-31BAB[3]	Clyde Hudspeth	D	60.0	do.	Qt	08-15-85	
29S-01E-34CCB	John R. Grother	D	--	do.	Qal	08-15-85	
29S-01E-36CCD	City of Mulvane	P	55.0	do.	do.	08-15-85	Well 4; yields 1,000 gal/min
29S-01W-06DAA	Roeder	S	25.0	Sand	Qt	08-13-85	
29S-01W-11ADD[3]	Angie Hutchinson	D	65.0	do.	do.	08-13-85	WL
29S-01W-27BBB	Glen Luckner	L&G	44.0	do.	do.	08-15-85	WL
29S-02W-23DDA[3]	City of Clearwater	P	54.0	Sand and gravel	do.	08-15-85	Well 5
29S-03W-09ABA[3]	Roy Holder	L&G	45.0	Sand	Qal	08-15-85	WL
29S-04W-16BCC	William Ruckle	D	70.0	Shale	Pn	08-15-85	WL
29S-04W-35BDC	Sam Wolf	D	78.0	Sand and shale	Qt, Pn	08-15-85	

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986*--Continued

PHYSICAL PROPERTIES AND INORGANIC CONSTITUENTS

Well number (township-range-section, plate 1)	Time (24-hour)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius	pH (standard units)	Water temperature (degrees Celsius)	Hardness, (milligrams per liter as $CaCO_3$)	Hardness, noncarbonate (milligrams per liter as $CaCO_3$)	Calcium, dissolved (milligrams per liter as Ca)	Magnesium, dissolved (milligrams per liter as Mg)	Sodium, dis solved (milligrams per liter as Na)	Sodium-adsorption ratio	Potassium, dissolved (milligrams per liter as K)
25S-01E-24DCD	1515	570	7.6	23.5	290	39	91	15	29	0.8	0.5
25S-01W-07BAA	1045	622	7.3	15.5	250	42	81	12	38	1	2.6
25S-01W-15AAB	1400	628	7.5	14.5	240	--	75	14	24	.7	1.8
25S-01W-24CDC	1315	630	7.5	17.0	340	44	100	23	35	.9	3.7
25S-01W-27CCC	1120	615	7.3	15.5	250	37	79	12	37	1	2.4
25S-01W-30ABB	1215	805	7.2	15.0	280	86	89	13	51	1	9.7
25S-01W-35AAC	0940	940	7.2	17.5	460	170	150	20	38	.8	2.6
25S-01W-36ACB	1030	822	7.2	16.0	320	26	91	22	33	.8	2.0
25S-02W-02BAA	1030	785	7.5	16.0	240	--	76	13	78	2	2.9
25S-02W-15DDD	1530	626	8.1	25.0	200	37	59	12	40	1	3.1
25S-02W-17ABB	1200	960	7.2	14.5	300	120	94	17	77	2	3.4
25S-02W-34CCB	1120	2,990	7.6	16.0	27	--	8.3	1.5	600	52	3.0
25S-03W-02BBC	1245	986	7.2	15.0	330	48	100	19	88	2	3.0
25S-03W-05BAB	1330	1,180	7.5	15.0	190	--	57	11	140	5	2.9
25S-03W-14CCB	1510	2,350	7.5	15.0	420	220	120	29	270	6	5.5
25S-03W-21BAB	1415	592	7.0	16.0	210	--	64	13	50	2	2.9
25S-03W-36BBB	1345	1,100	7.5	15.0	190	--	58	11	150	5	2.6
26S-02E-09DAA	1300	3,100	7.0	22.0	1,800	1,600	570	96	89	.9	4.8
26S-01E-07CBC	1200	890	6.7	22.0	330	--	100	20	61	2	3.4
26S-01E-11CDD	1400	675	7.6	19.0	300	22	96	15	35	.9	1.2
26S-01E-17AAB	1300	1,060	7.1	15.0	390	36	100	33	48	1	2.3
26S-01E-19ABD	1400	1,450	6.9	16.5	340	66	100	21	150	4	4.0
26S-01E-21BBA	1620	1,160	7.4	15.0	460	100	120	40	91	2	2.0
26S-01E-31ADC	1745	1,910	7.2	16.5	340	91	97	24	240	6	5.4
26S-01W-01DAD	1220	653	7.3	17.0	280	7	88	14	53	1	2.3
26S-01W-05BAB	1300	2,090	7.4	15.0	420	230	130	24	280	6	4.6
26S-01W-15BBB	1410	2,550	7.6	19.0	480	270	140	32	370	8	6.6
26S-01W-18AAA	1600	2,130	7.4	16.0	560	330	180	26	230	4	6.1
26S-01W-22CBD	1440	2,020	7.3	17.0	550	350	170	31	200	4	4.9
26S-01W-31DAA	1510	580	7.2	16.0	120	--	37	6.9	76	3	2.4
26S-02W-04BBD	1030	1,730	7.4	15.0	480	230	150	25	170	4	3.7
26S-02W-16BBD	1230	708	7.6	15.0	270	--	85	14	50	1	2.4
26S-02W-18ADD	1630	515	7.1	16.0	210	--	65	11	35	1	1.8
26S-02W-33CDD	1530	750	7.3	15.0	230	--	63	18	61	2	2.0
26S-03W-08DCB	1220	2,250	6.9	15.0	1,000	790	300	72	120	2	2.4
26S-03W-10DDB	1320	665	7.2	16.0	290	16	85	18	43	1	1.8
26S-03W-30CDC	1120	1,050	7.3	15.5	370	49	100	29	72	2	1.7
27S-02E-13CCC	1100	2,800	7.4	15.0	1,900	1,600	600	89	68	.7	4.0
27S-01E-08CCD	1145	1,150	7.5	20.0	300	45	89	20	120	3	4.1
27S-01E-13DAC	1300	1,630	7.3	16.5	780	400	210	61	97	2	1.2
27S-01E-18CDD	1100	1,570	7.6	15.5	480	160	140	31	170	4	6.4
27S-01W-01ADD	1600	1,950	7.4	15.0	280	80	79	20	280	8	6.0
27S-01W-03DAA	1700	1,610	7.3	15.5	270	130	82	15	210	6	4.2
27S-01W-09BCC	0945	407	6.8	17.5	120	--	38	6.6	44	2	4.6
27S-01W-12DAA	1030	1,220	7.2	17.0	320	150	95	21	120	3	4.2
27S-01W-13AAB	1115	1,460	7.3	16.0	350	130	110	18	190	5	3.1
27S-01W-15BDC	1315	663	6.8	16.0	160	--	51	8.1	93	3	2.6
27S-01W-17BCD	1230	691	7.0	17.0	240	--	76	13	61	2	3.2
27S-01W-21CCC	1500	730	6.8	15.5	230	--	71	13	77	2	2.4
27S-01W-23CDC	1545	964	7.3	16.0	140	--	44	8.4	140	5	2.5

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986--* Continued

PHYSICAL PROPERTIES AND INORGANIC CONSTITUENTS--Continued

Well number (township-range-section, plate 1)	Time (24-hour)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)	pH (standard units)	Water temperature (degrees Celsius)	Hardness noncarbonate (milligrams per liter as $CaCO_3$)	Hardness (milligrams per liter as $CaCO_3$)	Calcium, dissolved (milligrams per liter as Ca)	Magnesium, dissolved (milligrams per liter as Mg)	Sodium, dissolved (milligrams per liter as Na)	Sodium-adsorption-ratio	Potassium, dissolved (milligrams per liter as K)
27S-01W-26DDC	1115	888	7.3	17.0	220	--	70	12	110	3	3.0
27S-01W-27BBD	1800	845	7.1	16.0	160	--	49	8.6	140	5	2.4
27S-01W-29DBD	1700	1,770	6.8	16.0	410	130	130	21	210	5	2.8
27S-01W-33AAA	1000	639	7.2	15.5	110	--	34	6.1	100	4	2.1
27S-02W-01DBD	1440	1,400	7.1	16.5	400	140	120	25	120	3	3.1
27S-02W-10ADA	1525	720	7.3	14.5	230	--	65	16	74	2	2.1
17S-02W-13ABB	0850	765	7.1	20.0	250	--	73	16	67	2	2.2
27S-02W-32BBB	1515	849	7.4	14.5	290	--	83	20	50	1	1.8
27S-03W-03DCC	1245	1,190	7.1	16.5	510	140	170	20	56	1	1.6
27S-03W-12DCC	1015	1,290	7.2	16.0	420	130	130	24	100	2	1.2
27S-03W-31DCD	1345	355	7.4	14.5	140	57	41	8.5	17	.7	1.8
27S-04W-12CDC	1210	1,950	7.2	15.5	750	530	180	72	150	2	2.9
28S-02E-01DCA	1530	1,890	7.1	15.5	1,200	1,000	380	67	45	.6	1.9
28S-02E-34CAC	1030	1,050	7.5	19.0	610	290	180	40	27	.5	1.9
28S-01E-05BAB	1730	1,900	7.2	16.5	420	59	130	23	240	5	4.2
28S-01E-07DDD	1030	1,550	7.1	15.0	450	130	140	25	180	4	4.7
28S-01E-17DDB	1130	1,240	7.3	15.5	240	38	69	16	160	5	3.8
28S-01E-29CBB	1230	1,070	7.3	16.0	340	61	110	16	110	3	4.7
28S-01E-31CAB	1300	1,000	6.9	15.5	400	300	120	24	45	1	1.7
28S-01W-10CCB	1215	545	7.1	15.5	150	--	47	8.4	61	2	2.1
28S-01W-11CBC	1300	841	7.5	15.5	83	--	26	4.3	160	8	1.9
28S-01W-17ADD	1330	960	7.3	16.0	410	270	110	32	37	.8	3.1
28S-01W-24BBA	1430	1,320	7.3	15.0	300	7	94	15	180	5	3.1
28S-01W-32DDD	1600	690	7.0	15.0	280	31	91	13	58	2	2.2
28S-02W-11CDD	0915	2,450	7.2	15.5	1,400	1,100	460	56	83	1	2.9
28S-02W-21CDD	1020	390	7.4	15.5	130	--	39	7.9	31	1	2.0
28S-02W-25AAD	0900	1,030	7.4	15.5	350	73	110	19	49	1	3.5
28S-02W-32AAA	1215	1,850	7.4	16.0	770	560	210	59	140	2	3.1
28S-03W-01ACC	1510	600	7.1	14.5	360	1	120	15	39	.9	2.3
28S-03W-23DDB	1250	1,010	7.3	17.0	330	150	100	19	81	2	1.6
28S-04W-05BCC	1600	895	7.3	16.0	390	250	120	21	23	.5	3.8
28S-04W-15BCC	1640	680	7.4	18.0	320	87	74	32	24	.6	2.8
28S-04W-20ABA	1315	1,740	7.3	16.0	810	690	240	52	75	1	3.3
28S-04W-20ABD	1330	1,870	7.5	14.0	950	830	290	55	77	1	3.2
28S-04W-35ABD	1420	1,390	7.6	14.5	530	340	140	45	60	1	2.1
29S-02E-18CBC	1345	650	7.5	19.5	270	12	86	14	47	1	1.4
29S-01E-03DCC	1730	970	7.3	15.0	470	160	150	22	38	.8	2.0
29S-01E-05CAA	1045	1,080	7.2	15.0	330	38	100	19	85	2	3.3
29S-01E-14DCC	1630	900	6.8	15.0	400	120	130	19	61	1	3.1
29S-01E-21CBC	1215	636	7.2	16.0	250	--	79	12	44	1	1.9
29S-01E-23CCC	1800	630	7.2	17.0	270	49	88	12	36	1	3.3
29S-01E-31BAB	1315	662	7.1	16.0	220	26	65	13	41	1	2.8
29S-01E-34CCB	1700	920	7.0	18.0	440	140	140	22	26	.6	3.7
29S-01E-36CCD	1620	780	7.2	15.0	300	7	96	14	50	1	3.1
29S-01W-06DAA	1620	900	7.3	15.0	430	340	130	25	39	.9	2.0
29S-01W-11ADD	1400	345	7.0	21.0	150	--	47	8.7	36	1	2.4
29S-01W-27BBB	1415	698	7.1	16.0	250	11	66	21	39	1	1.2
29S-02W-23DDA	1010	665	7.4	16.0	270	57	74	20	42	1	2.3
29S-03W-09ABA	1100	570	7.7	14.5	270	70	70	23	22	.6	1.0
29S-04W-16BCC	1315	850	7.7	17.0	5	--	1.5	.4	180	35	.6
29S-04W-35BDC	1230	760	7.7	17.0	280	95	63	31	42	1	1.8

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986*--Continued

PHYSICAL PROPERTIES AND INORGANIC CONSTITUENTS--Continued

Well number (township-range-section, plate 1)	Alkalinity, (milligrams per liter as $CaCO_3$)	Sulfate, dissolved (milligrams per liter as SO_4)	Chloride, dissolved (milligrams per liter as Cl)	Fluoride, dissolved (milligrams per liter as F)	Bromide, dissolved (milligrams per liter as Br)	Silica, dissolved (milligrams per liter as SiO_2)	Solids, dissolved, sum of constituents (milligrams per liter)	Nitrogen, NO_2+NO_3, dissolved (milligrams per liter as N)	Phosphorus, ortho, dissolved (milligrams per liter as P)	Iron, dissolved (micrograms per liter as Fe)	Manganese, dissolved (micrograms per liter as Mn)
25S-01E-24DCD	250	41	14	0.5	0.074	22	370	2.10	0.07	23	9
25S-01W-07BAA	210	66	18	.4	.043	18	370	6.30	.04	7	44
25S-01W-15AAB	260	62	7.5	.3	.072	18	360	1.80	.07	150	120
25S-01W-24CDC	300	91	19	.3	.095	17	470	<0.10	<.01	4,300	120
25S-01W-27CCC	210	82	16	.6	.068	16	370	.95	.02	<3	5
25S-01W-30ABB	190	60	47	.5	.087	15	420	21.0	.02	<3	<1
25S-01W-35AAC	290	170	25	.5	.038	21	600	<.10	<.01	130	75
25S-01W-36ACB	292	120	17	.4	.1	18	480	1.40	.02	240	89
25S-02W-02BAA	250	78	60	.4	.052	23	480	.23	.02	190	210
25S-02W-15DDD	160	46	45	.5	.043	16	330	9.20	.03	5	7
25S-02W-17ABB	180	97	110	.5	.081	18	530	9.50	.02	25	8
25S-02W-34CCB	260	340	580	.8	.34	15	1,700	<.10	.05	8	41
25S-03W-02BBC	280	110	89	.7	.12	18	600	1.60	<.01	350	110
25S-03W-05BAB	200	80	200	.7	.088	16	630	2.40	.03	13	7
25S-03W-14CCB	200	190	510	.5	.31	16	1,270	3.00	.03	21	5
25S-03W-21BAB	230	26	41	.4	.11	23	360	.89	.04	4	190
25S-03W-36BBB	200	72	200	.6	.088	18	630	1.20	.11	10	4
26S-02E-09DAA	190	1,700	120	.5	.5	13	2,770	<.10	<.01	540	48
26S-01E-07CBC	420	4.6	65	.4	.077	32	550	<.10	<.01	3,800	4,400
26S-01E-11CDD	280	48	14	.2	.036	23	400	6.50	.01	8	3
26S-01E-17AAB	350	150	42	.3	.19	18	600	.68	.04	48	63
26S-01E-19ABD	270	150	220	.5	.2	17	840	9.10	.04	8	2
26S-01E-21BBA	360	95	140	.5	.41	26	730	.26	.10	240	680
26S-01E-31ADC	250	140	410	.5	.26	13	1,080	.15	<.01	200	24
26S-01W-01DAD	270	89	34	.3	.17	16	460	<.10	.02	380	120
26S-01W-05BAB	190	170	490	.6	.32	15	1,230	.89	.01	48	49
26S-01W-15BBB	210	250	630	.6	.4	15	1,570	<.10	.03	69	9
26S-01W-18AAA	230	230	410	.6	.24	16	1,240	<.10	<.01	1,100	430
26S-01W-22CBD	200	220	400	.5	.18	18	1,160	<.10	<.01	550	690
26S-01W-31DAA	160	30	48	.5	.099	21	320	5.60	.17	10	4
26S-02W-04BBD	250	170	310	.5	.16	16	1,000	1.30	.11	38	400
26S-02W-16BBD	300	24	23	.3	.074	24	400	2.20	.15	4	6
26S-02W-18ADD	220	15	12	.2	.051	26	300	2.90	.13	9	7
26S-02W-33CDD	270	43	37	.2	.12	22	420	5.60	.11	<3	3
26S-03W-08DCB	260	880	130	.3	.14	21	1,690	6.30	<.01	18	15
26S-03W-10DDB	270	44	18	.2	.13	23	400	5.60	.09	17	2
26S-03W-30CDC	320	28	94	.5	.17	23	550	11.0	<.01	110	2
27S-02E-13CCC	270	1,500	91	.6	.025	15	2,530	.11	<.01	630	4
27S-01E-08CCD	260	100	150	.5	.23	16	660	.73	<.01	1,700	46
27S-01E-13DAC	380	360	160	.3	.21	15	1,130	.84	<.01	51	87
27S-01E-18CDD	320	190	240	.3	.32	19	990	2.00	.03	13	12
27S-01W-01ADD	200	140	430	.6	.27	13	1,090	.14	.02	19	180
27S-01W-03DAA	140	120	350	.5	.11	8.2	870	.20	.02	35	28
27S-01W-09BCC	140	20	12	.2	.089	27	240	5.10	.21	25	6
27S-01W-12DAA	170	150	240	.4	.15	15	750	.84	.01	13	150
27S-01W-13AAB	220	110	300	.5	.41	16	880	1.80	<.01	42	69
27S-01W-15BDC	170	43	61	.3	.14	26	400	9.00	.16	78	12
27S-01W-17BCD	290	36	49	.3	.11	20	440	6.20	.18	10	5
27S-01W-21CCC	270	31	43	.3	.14	23	430	7.10	.18	50	1
27S-01W-23CDC	200	76	150	.6	.23	18	560	< .10	.09	570	170

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986*--Continued

PHYSICAL PROPERTIES AND INORGANIC CONSTITUENTS--Continued

Well number (township-range-section, plate 1)	Alkalinity, (milligrams per liter as $CaCO_3$)	Sulfate, dissolved (milligrams per liter as SO_4)	Chloride, dissolved (milligrams per liter as Cl)	Fluoride, dissolved (milligrams per liter as F)	Bromide, dissolved (milligrams per liter as Br)	Silica, dissolved (milligrams per liter as SiO_2)	Solids, sum of constituents, dissolved (milligrams per liter)	Nitrogen, NO_2+NO_3 dissolved (milligrams per liter as N)	Phosphorus, ortho, dissolved (milligrams per liter as P)	Iron, dissolved (micrograms per liter as Fe)	Manganese, dissolved (micrograms per liter as Mn)
27S-01W-26DDC	240	68	120	0.8	0.13	19	550	<0.10	0.03	29	440
27S-01W-27BBD	290	45	76	.4	.096	21	520	6.10	—	20	4
27S-01W-29DBD	280	61	350	.2	.18	25	990	16.0	.14	15	5
27S-01W-33AAA	220	28	46	.4	.1	22	370	2.80	.18	9	1
27S-02W-01DBD	260	370	100	.3	.099	24	920	.53	.09	4	1
27S-02W-10ADA	300	34	28	.3	.092	22	420	4.50	.09	5	2
27S-02W-13ABB	290	44	38	.2	.1	25	450	7.20	.12	7	3
27S-02W-32BBB	320	85	27	.3	.058	22	480	.98	.06	4	2
27S-03W-03DCC	370	25	110	.5	.44	25	650	20.0	--	29	2
27S-03W-12DCC	290	71	180	.6	.67	20	710	16.0	<.01	4	1
27S-03W-31DCD	80	20	9.9	.2	.075	23	180	12.0	.11	9	3
27S-04W-12CDC	220	600	180	.6	.21	17	1,340	8.90	.01	6	5
28S-02E-01DCA	200	1,000	69	1.0	.083	5.6	1,690	.17	<.01	7	6
28S-02E-34CAC	320	290	49	.4	.13	15	800	3.20	<.01	330	5
28S-01E-05BAB	360	210	320	.5	.21	17	1,160	<.10	<.01	650	240
28S-01E-07DDD	320	180	260	.6	.17	18	1,000	<.10	<.01	420	540
28S-01E-17DDB	200	88	220	.8	.21	14	690	<.10	.08	1,200	330
28S-01E-29CBB	280	120	130	.7	.11	15	680	<.10	<.01	25	330
28S-01E-31CAB	100	160	150	.2	.24	25	600	8.50	.06	<3	8
28S-01W-10CCB	220	24	27	.3	.068	22	330	4.90	.11	5	6
28S-01W-11CBC	300	43	77	.3	.059	20	510	.54	.10	20	3
28S-01W-17ADD	140	230	28	.4	.072	27	550	.23	.10	53	34
28S-01W-24BBA	290	150	200	.5	.17	18	830	<.10	.08	20	230
28S-01W-32DDD	250	28	9.5	.3	.077	33	390	7.20	.04	11	8
28S-02W-11CDD	240	1,100	130	.3	.2	20	2,000	3.00	<.01	9	6
28S-02W-21CDD	130	21	18	.3	.075	26	230	5.10	.18	<3	4
28S-02W-25AAD	280	36	90	.3	.63	29	530	25.0	.04	7	3
28S-02W-32AAA	210	650	190	.3	.2	16	1,400	5.30	<.01	13	3
28S-03W-01ACC	360	39	32	.3	.31	23	490	.89	.01	18	2
28S-03W-23DDB	180	110	160	3	.12	21	600	4.30	.04	7	4
28S-04W-05BCC	140	18	170	.4	.59	56	510	9.30	.19	<3	6
28S-04W-15BCC	230	51	9.6	.4	.054	16	360	12.0	.10	29	1
28S-04W-20ABA	120	870	38	.4	.075	18	1,370	4.30	<.01	12	4
28S-04W-20ABD	120	830	42	.3	.079	17	1,390	4.40	<.01	510	5
28S-04W-35ABD	190	470	74	.4	.098	16	920	.33	<.01	510	600
29S-02E-18CBC	260	27	20	.2	.1	25	390	12.0	.02	9	7
29S-01E-03DCC	310	74	80	.6	.18	18	570	5.00	.03	5	4
29S-01E-05CAA	290	160	100	.6	.19	15	660	.36	<.01	320	170
29S-01E-14DCC	280	130	71	.7	.084	16	600	1.20	.04	5	180
29S-01E-21CBC	250	64	14	.4	.071	16	380	<.10	<.01	560	41
29S-01E-23CCC	220	76	28	.6	.036	15	390	.31	.01	50	220
29S-01E-31BAB	190	46	52	.3	.17	23	360	4.50	.11	29	4
29S-01E-34CCB	300	130	32	.6	.099	13	550	5.10	<.01	72	140
29S-01E-36CCD	290	84	47	.6	.039	16	480	.56	.03	13	440
29S-01W-06DAA	92	270	64	.2	.095	22	620	9.40	.02	27	4
29S-01W-11ADD	190	23	13	.3	.046	25	270	1.70	.14	6	<1
29S-01W-27BBB	240	56	20	.3	.14	24	370	11.0	.13	8	3
29S-02W-23DDA	210	53	43	.5	.091	25	390	6.60	.11	16	4
29S-03W-09ABA	200	77	13	.5	.061	18	350	1.30	.07	16	35
29S-04W-16BCC	250	83	33	.4	.11	19	480	7.20	<.01	5	<1
29S-04W-35BDC	190	51	51	.2	.12	19	390	15.0	.02	5	1

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986--* Continued

ORGANIC CONSTITUENTS - HERBICIDES

Well number (township-range-section, plate 1)	Ametryne, total (micrograms per liter)	Atrazine, total (micrograms per liter)	Cyanazine, total (micrograms per liter)	Metolachlor, total (micrograms per liter)	Prometone, total (micrograms per liter)	Prometryne, total (micrograms per liter)	Propazine, total (micrograms per liter)	Simazine, total (micrograms per liter)	Simetryne, total (micrograms per liter)
25S-01W-07BAA	<0.1	0.3	<0.1	6	<0.1	<0.1	<0.1	<0.1	<0.1
25S-01W-30ABB	<.1	.2	<.1	--	<.1	<.1	<.1	<.1	<.1
25S-02W-15DDD	<.1	.4	<.1	--	<.1	<.1	<.1	<.1	<.1
25S-03W-05BAB	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
25S-03W-14CCB	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
25S-03W-36BBB	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
26S-01W-18AAA	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
26S-02W-16BBD	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
27S-01W-03DAA	<.1	.2	<.1	--	<.1	<.1	.2	.1	<.1
27S-02W-01DBD	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
27S-02W-32BBB	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
28S-02W-25AAD	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
28S-04W-05BCC	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
28S-04W-35ABD	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
29S-01E-23CCC	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
29S-01E-31BAB	<.1	.1	<.1	--	<.1	<.1	<.1	<.1	<.1
29S-01W-11ADD	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
29S-02W-23DDA	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1
29S-03W-09ABA	<.1	<.1	<.1	--	<.1	<.1	<.1	<.1	<.1

ORGANIC CONSTITUENTS - VOLATILE ORGANIC COMPOUNDS

Well number (township-range-section, plate 1)	Benzene, total (micrograms per liter)	Bromoform, total (micrograms per liter)	Carbontetrachloride, total (micrograms per liter)	Chlorodibromomethane, total (micrograms per liter)	Chloroethane, total (micrograms per liter)	Chloroethylene, total (micrograms per liter)	2-chloroethylvinylether, total (micrograms per liter)	Chloroform, total (micrograms per liter)	Dichlorobromomethane, total (micrograms per liter)
25S-01W-36ACB	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
26S-01E-07CBC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
26S-01E-31ADC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-12DAA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-23CDC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-29DBD	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
28S-01W-10CCB	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
28S-01W-24BBA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
29S-01E-05CAA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
29S-01E-21CBC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0	<3.0

Table 15. *Water-quality data for selected wells in Sedgwick County, August 1985 and February 1986--* **Continued**

ORGANIC CONSTITUENTS - VOLATILE ORGANIC COMPOUNDS--Continued

Well number (township-range-section, plate 1)	1,1-Dichloroethane, total (micrograms per liter)	1,2-Dichloroethane, total (micrograms per liter)	1,1-Dichloroethylene, total (micrograms per liter)	Dichlorodifluoromethane, total (micrograms per liter)	1,2-Dichloropropane, total (micrograms per liter)	1,3-Dichloropropane, total (micrograms per liter)	Ethylbenzene, total (micrograms per liter)	Methylbromide, total (micrograms per liter)	Methylene chloride, total (micrograms per liter)
25S-01W-36ACB	<3.0	<3.0	<3.0	--	<3.0	<3.0	<3.0	<3.0	<3.0
26S-01E-07CBC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
26S-01E-31ADC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-12DAA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-23CDC	<3.0	<3.0	<3.0	--	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-29DBD	<3.0	<3.0	<3.0	--	<3.0	<3.0	<3.0	<3.0	<3.0
28S-01W-10CCB	<3.0	<3.0	<3.0	--	<3.0	<3.0	<3.0	<3.0	<3.0
28S-01W-24BBA	<3.0	<3.0	<3.0	--	<3.0	<3.0	<3.0	<3.0	<3.0
29S-01E-05CAA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
29S-01E-21CBC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

Well number (township-range-section, plate 1)	1,1,2,2 tetrachloroethane, total (micrograms per liter)	Tetrachloroethylene, total (micrograms per liter)	Toluene, total (micrograms per liter)	1,1,1-Trichloroethane, total (micrograms per liter)	1,1,2-Trichloroethane, total (micrograms per liter)	Trichloroethylene, total (micrograms per liter)	Trichlorofluoromethane, total (micrograms per liter)	Vinyl chloride, total (micrograms per liter)
25S-01W-36ACB	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
26S-01E-07CBC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
26S-01E-31ADC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-12DAA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-23CDC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
27S-01W-29DBD	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
28S-01W-10CCB	<3.0	<3.0	<3.0	<3.0	<3.0	8.2	<3.0	<3.0
28S-01W-24BBA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
29S-01E-05CAA	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
29S-01E-21CBC	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

[1] Water use: D, domestic; I, irrigation; L&G, lawn and garden; P, public supply; S, stock.

[2] Geologic source: Qal, Holocene alluvium and Wisconsin terrace deposits; Ql, loess deposits; Qc, colluvium; Qt, Illinoian terrace deposits; Ou, lower Pleistocene (undifferentiated pre-Illinoian) deposits; QT, undifferentiated lower Pleistocene and Pliocene deposits; Pn, Ninnescah Shale; Pw, Wellington Formation.

[3] Samples analyzed for selected herbicides.

[4] Samples analyzed for selected volatile organic compounds.

the Burrton oilfield adjacent to the Arkansas River, about 2 miles upstream of Sedgwick County in Reno County, could have contributed brine to the Arkansas River, which subsequently infiltrated into the alluvium sometime in the past. Water samples collected from the Arkansas River during this investigation (see stream water-quality data, table 11) did not have sodium:chloride ratios that indicate contamination by oilfield brine.

A sodium:chloride ratio less than 0.60 was detected in water from well 26S-01E-31ADC, which is adjacent to the Little Arkansas River in north Wichita. There are oilfield activities upgradient (north) of this well. South of Wichita, sodium:chloride ratios less than 0.60 are present in wells 28S-01E-31CAD and 29S-01E-03DCC. These wells are in alluvium and terrace deposits of Wisconsin to Holocene age in an area known to be contaminated by oilfield activities in the Gladys oilfield, which is just north of Haysville (Whittemore, 1982). Well 28S-04W-05BCC, just north of Cheney, is adjacent to an oilfield and had a sodium:chloride ratio that was less than 0.60. Other wells with sodium:chloride ratios less than 0.60 were in areas with no apparent oilfield activities (27S-03W-03DCC, 27S-03W-12DCC, 28S-02E-34CAC, 28S-02W-25AAD, and 28S-03W-23DDB).

Nitrogen

Nitrogen can be introduced into ground water by the leaching of fertilizers, by sewage disposal (septic fields and infiltration of sewage-treatment plant effluent), and by surface runoff with fertilizer residues or animal wastes entering improperly constructed wells. Nitrite-plus-nitrate as nitrogen concentrations that exceed 10 mg/L, the water-quality criterion for nitrate as nitrogen (U.S. Environmental Protection Agency, 1986c) were detected in 11 wells (25S-01W-30ABB, 26S-03W-30CDC, 27S-01W-29DBD, 27S-03W-03DCC, 27S-03W-12DCC, 27S-03W-31DCD, 28S-02W-25AAD, 28S-04W-15BCB, 29S-02E-18CBC, 29S-01W-27BBB, and 29S-04W-35BDC). The criterion for nitrate as nitrogen was used because nitrite is unstable and is oxidized to nitrate and because the criteria for nitrite is more strict than for nitrate. Exceedences of the nitrate-as-nitrogen criterion occur randomly throughout the county and probably result from local sources of contamination, such as surface runoff into improperly constructed wells or infiltration from septic fields.

Iron and manganese

Concentrations of iron that exceed the water-quality criterion of 300 µg/L (U.S. Environmental Protection Agency, 1986b) were detected in samples from 18 wells (see table 15). These wells are scattered randomly throughout the county, and the large concentrations of iron may be due to corroded steel or galvanized well casings. Iron causes no significant health effects but can be objectionable because of taste, staining of laundry and porcelain fixtures, and deposits in plumbing.

Concentrations of manganese that exceed the water-quality criterion of 50 µg/L (U.S. Environmental Protection Agency, 1986b) were detected in 31 wells. All but one of the wells are located in alluvium or terrace deposits. This indicates that the manganese probably is derived from organic matter in soil and then is leached by percolation of precipitation through the unconsolidated sand and gravel into the ground water. Manganese produces no significant health effects but can be objectionable because of taste, staining of porcelain fixtures, and deposits in plumbing.

Herbicides

Water-quality samples from 19 wells in alluvium and terrace deposits of the Ninnescah and Arkansas River valleys were analyzed for selected herbicides (ametryne, atrazine, cyanazine, metolachlor, prometone, prometryne, propazine, simazine, and simetryne) (see table 15). None of the herbicides were detected in water samples from the four wells in the Ninnescah River valley. However, of the 15 wells sampled in the Arkansas River valley, herbicides were detected in five. Atrazine (0.3 µg/L) and metolachlor (6 µg/L) were detected in well 25S-01W-07BAA. Atrazine also was detected in wells 25S-01W-30ABB (0.2 µg/L), 25S-02W-15DDD (0.4 µg/L), and 29S-01E-31BAB (0.1 µg/L). Atrazine (0.2 µg/L), propazine (0.2 µg/L), and simazine (0.1 µg/L) were detected in well 27S-01W-03DAA. These herbicides may have entered the ground water either by being leached from the surface, through runoff into improperly constructed wells, or, if the process of chemigation is practiced (chemicals applied in irrigation water), they may have been siphoned down the well.

The uses of atrazine and propazine and the implications of their occurrence in water were discussed previously in the "Results of Water-Quality Reconnaissance" part of the "Impoundment" section. The U.S. Environmental Protection Agency has issued a lifetime health advisory level of 3 µg/L for atrazine and 14 µg/L for propazine (U.S. Environmental Protection Agency, written commun., August and September 1987).

Metolachlor is used as a preemergent and preplant incorporated weed control in corn, soybeans, and grain sorghum. It is soluble in water at 530 mg/L and has a half-life in soil of from 15 to 50 days. The U.S. Environmental Protection Agency has issued a lifetime health advisory level of 10.0 µg/L for metolachlor (U.S. Environmental Protection Agency, written commun., August 1987).

Simazine is is used to control most annual broadleaf weeds and grasses in corn, alfalfa, fruits, nursery stock, and turf-grass production. It is soluble in water at 3.5 mg/L and persists in soil for 1 year or longer. The U.S. Environmental Protection Agency has issued a lifetime health advisory level of 35 µg/L for simazine (U.S. Environmental Protection Agency, written commun., August 1987).

Although the detected concentrations of these herbicides were quite small, they may pose health threats because of the mutagens and degradation products that they produce, the possible synergistic effects that might result from the occurrence of more than one of the herbicides, and the widespread nature of herbicide application. Many other pesticides (both insecticides and herbicides) probably are used in Sedgwick County. The insecticide chlordane has been detected in tissue of bottom-feeding fish in the Arkansas River at Wichita (Fromm and Daley, 1986).

Volatile organic compounds

Analysis of volatile organic compounds (also known as purgeable organic compounds) was made on water samples from 10 wells in the Little Arkansas and Arkansas River valleys (see table 15). Volatile organic compounds are ingredients in many household, commercial, and industrial products, including spot removers, drain openers, solvents, and degreasers; and may enter ground water through septic fields, spills, leaks, or disposal from industrial processes. The volatile organic compound trichloroethylene was detected in well 28S-01W-10CBB at a concentration of 8.2 µg/L; the water-quality criterion is 27 µg/L (U.S. Environmental Protection Agency, 1986a). Trichloroethylene is a suspected carcinogen and can cause central-nervous-system depression and heart damage.

Volatile organic compounds also have been detected by the U.S. Geological Survey (Hart and Spruill, 1988), the Kansas Department of Health and Environment (Wichita-Eagle Beacon, June 11, 1985; Sept. 9, 1985; Jan. 15, 1986), and the U.S. Environmental Protection Agency (Wichita-Eagle Beacon, Jan. 18, 1985). Although volatile organic compounds have been detected in ground water at several sites in Sedgwick County, the contaminated areas are localized and do not represent a widespread water-quality problem.

Statistical Summary of Historic Water-Quality Data for Selected Wells

There are several wells in Sedgwick County where water-quality data have been collected for a relatively long time, generally during the last 30 years. Statistical summaries of water-quality data for six of these wells are presented in table 16. Five of the wells are public-supply wells (Valley Center, Wichita, Park City, Goddard, and Clearwater). All of the wells produce water from unconsolidated deposits ranging in age from Pliocene to Holocene.

The Valley Center public-supply well 5 (25S-01W-36ACB) is 52.0 feet deep and yields water from alluvium of the Little Arkansas River valley. Water from this well is a calcium bicarbonate type, with a median dissolved-solids concentration of 524 mg/L. The water has a median concentration of hardness as calcium carbonate of 380 mg/L. Concentrations of manganese (median concentration, 130 µg/L)

Wellington Formation generally has hardness as calcium carbonate approaching or exceeding 1,000 mg/L (most of which is noncarbonate hardness) in calcium sulfate type water.

Water from wells in the Ninnescah Shale of Permian age, which occurs in the western part of the county, generally is not as mineralized as water from the Wellington Formation because the Ninnescah Shale does not contain as many readily soluble minerals and because the occurrence of unconsolidated loess, colluvium, or lower Pleistocene (undifferentiated pre-Illinoian age) deposits over the Ninnescah Shale improves recharge conditions and probably allows dilution of water in the bedrock (Lane and Miller, 1965a). Shallow wells in the upper weathered part of the Ninnescah Shale generally yield calcium bicarbonate water, with dissolved-solids concentrations less than 1,000 mg/L. Mineralization of water increases with depth in the Ninnescah Shale, and where thin beds of gypsum are encountered, the water is a calcium sulfate type, with concentrations of dissolved solids often exceeding 1,000 mg/L. Water samples from the Ninnescah Shale had from 5 to 1,000 mg/L of hardness as calcium carbonate. The largest concentrations of hardness occur primarily as noncarbonate hardness in calcium sulfate type water.

Unconsolidated deposits ranging in age from Pliocene to Holocene generally are the best sources of ground water in the county with respect to both the quantity and quality of water available. These deposits of clay, silt, sand, and gravel are erosional remnants that have few readily soluble minerals; they are recharged rapidly by precipitation and transmit ground water at a faster rate than bedrock. However, unconsolidated deposits generally are more susceptible to contamination.

Lower Pleistocene (undifferentiated pre-Illinoian age) deposits that occur in upland areas north of the Ninnescah River yield calcium bicarbonate type water, with less than 500 mg/L dissolved solids. Hardness as calcium carbonate in water samples ranges from 130 to 360 mg/L. Terrace deposits of Illinoian age that occur along the western side of the Arkansas River valley, in the vicinity of Clearwater, and in a small buried valley in the southwest corner of the county generally yield calcium bicarbonate water, with less than 500 mg/L dissolved solids. Northwest of Wichita, Illinoian terrace deposits occur over unconsolidated lower Pleistocene and Pliocene and deposits (Lane and Miller, 1965a). Along the eastern edge of the Illinoian terrace deposits, generally between Cowskin Creek and Big Slough Creek from about 6 miles southeast of Mount Hope to where Cowskin Creek intersects the Wichita-Valley Center floodway, there is an area where calcium bicarbonate water from the Illinoian terrace deposits is mixing with sodium chloride water from the Arkansas River terrace and alluvial deposits of Holocene age. In this mixing zone, water types include calcium bicarbonate, calcium sodium bicarbonate, calcium sodium chloride, sodium bicarbonate, sodium bicarbonate chloride, and sodium chloride. In this area, concentrations of dissolved solids are less than 1,000 mg/L and usually less than 500 mg/L. Hardness as calcium carbonate in water samples from Illinoian terrace deposits ranges from 83 to 480 mg/L.

Alluvium and terrace deposits of Wisconsin to Holocene age occur in the Ninnescah, Little Arkansas, and Arkansas River valleys. Older unconsolidated deposits of undifferentiated early Pleistocene and Pliocene age occur at the basal part of the valley-fill deposits northwest of Wichita (Lane and Miller, 1965a). Water-quality data are limited for the alluvium and terrace deposits of the Ninnescah River. The Ninnescah River is a gaining stream throughout its reach, and water in the alluvium may be similar to that in adjacent bedrock, probably calcium sulfate or calcium bicarbonate type water with less than 1,000 mg/L dissolved solids. Large-capacity wells could induce infiltration of stream water into the alluvium and yield sodium chloride type water with less than 1,000 mg/L dissolved solids.

Water in alluvium and terrace deposits of Wisconsin to Holocene age in the Little Arkansas River valley north of Wichita generally is a calcium bicarbonate type, with less than 500 mg/L dissolved solids although concentrations of dissolved solids can exceed 500 mg/L. In northern Wichita, the Little Arkansas River alluvium and terrace deposits contain sodium calcium chloride bicarbonate type water, with concentrations of dissolved solids exceeding 500 mg/L, or sodium chloride type water, with concentrations of dissolved solids exceeding

1,000 mg/L. The Little Arkansas River is the primary drain for ground water in alluvium and terrace deposits in northern Sedgwick County. Sodium chloride type water from the Arkansas River has moved through the alluvium to areas adjacent to the Little Arkansas River in northern Wichita.

Sodium chloride type water generally is present in alluvium and terrace deposits of Wisconsin to Holocene age that occur along the west side of the Arkansas River in Sedgwick County north of the confluence of the Arkansas River and the Wichita-Valley Center floodway. The source of this sodium chloride type water is the Arkansas River. From Mount Hope to Wichita, concentrations of dissolved solids generally exceed 1,000 mg/L. Concentrations of dissolved solids generally are less than 1,000 mg/L from north Wichita to the confluence of the Arkansas River and the Wichita-Valley Center floodway near Derby.

A narrow band (probably less than 2 miles wide) of sodium chloride type water, with dissolved-solids concentrations exceeding 1,000 mg/L, occurs along the east side of the Arkansas River north of Wichita. However, most of the area of alluvium and terrace deposits between the Arkansas and Little Arkansas Rivers north of Wichita has calcium bicarbonate type water, with less than 500 mg/L dissolved solids.

South of Wichita, alluvium and terrace deposits of Wisconsin to Holocene age contain calcium bicarbonate water, with concentrations of dissolved solids less than 1,000 mg/L and sometimes less than 500 mg/L. Although sodium chloride water was not observed in wells sampled within one-half mile of the Arkansas River south of Wichita, primarily because the river is gaining, large-capacity wells adjacent to the river could induce the infiltration of saline river water and yield sodium chloride water. Water samples from alluvium and terrace deposits of Wisconsin to Holocene age had hardness as calcium carbonate ranging from 27 to 560 mg/L.

Contaminants in Ground Water

Contaminants can be introduced into ground water by natural process, human activities, and sometimes are introduced into wells by surface runoff or materials used in constructing the well. Analyses of a limited number of constituents for water-quality samples (table 15) collected from only 101 wells are not adequate for determining all types and areas of contamination in Sedgwick County. However, many of the representative types of ground-water contaminants in the county were detected.

Salinity

Sources of salinity in Sedgwick County include dissolution of naturally occurring soluble minerals in rocks of the county, infiltration of sodium chloride water from the Arkansas River into adjacent alluvium and terrace deposits, and the disposal of brine recovered during the production of oil.

All water samples from wells in the Wellington Formation and Ninnescah Shale that had concentrations of dissolved solids equal to or greater than 1,000 mg/L were calcium sulfate type water (table 15 and plate 1). These wells are producing water from stratigraphic beds with deposits of gypsum and anhydrite.

Water samples from alluvium and terrace deposits of Wisconsin to Holocene age adjacent to the Arkansas River north of Wichita had sodium chloride type water, with 1,000 mg/L or more dissolved solids. The source of this sodium chloride type water is the Arkansas River, which receives saline ground water discharged from Permian rocks (primarily contributed by Rattlesnake Creek in Reno County) and has received brine from salt and oil production.

Contamination of ground water by oilfield brines often is indicated by a sodium:chloride (both in milligrams per liter) ratio that is less than 0.60. Sodium:chloride ratios less than 0.60 were detected in several wells completed in Wisconsin to Holocene alluvium and terrace deposits adjacent to the Arkansas River from Mount Hope to its confluence with the Little Arkansas River (25S-03W-14CCB, 26S-01W-05BAB, 26S-01W-15BBB, 26S-01W-18AAA, 26S-01W-22CBD, 26S-02W-04BBD, and 27S-01W-12DAA). All of these wells except 26S-01W-05BAB are on the west side of the river. There are no oilfield activities in this part of the county except just upstream of well 27S-01W-12DAA. It is possible that oilfield activities in

Table 16. *Statistical summary of water-quality data from selected wells in Sedgwick County with long-term records*

[Values are given in microsiemens per centimeter at 25 degrees Celsius, µS/cm; milligrams per liter, mg/L; and micrograms per liter, µg/L. ND means constituent was not detected]

City of Valley Center public-supply well 5

(25S-01W-36ACB, 52.0 feet deep)

Period of record: 1952, 1956-58, 1960-64, 1967, 1970, 1984-86

Property or constituent	Number of samples	Median	Maximum	Minimum
Specific conductance, µS/cm	13	822	927	700
pH, standard units	15	7.3	8.0	7.0
Hardness, as $CaCO_3$, mg/L	14	380	430	310
Hardness, noncarbonate as $CaCO_3$, mg/L	14	74	110	24
Bicarbonate as HCO_3, mg/L	11	380	400	340
Calcium, dissolved as Ca, mg/L	14	120	120	91
Magnesium, dissolved as Mg, mg/L	14	24	31	21
Sodium, dissolved as Na, mg/L	14	35	43	29
Potassium, dissolved as K, mg/L	7	2.2	2.9	1.7
Sulfate, dissolved as SO_4, mg/L	14	120	150	74
Chloride, dissolved as Cl, mg/L	14	17	21	9.0
Fluoride, dissolved as F, mg/L	14	.4	.6	.2
Silica, dissolved as SiO_2, mg/L	14	16	18	14
Solids, dissolved, mg/L	14	524	555	420
Nitrate, dissolved as N, mg/L	10	1.3	3.0	.23
Phosphate, ortho, dissolved as PO_4, mg/L	1	--	.06	--
Arsenic, dissolved as As, µg/L	2	--	13	2
Barium, dissolved as Ba, µg/L	2	--	160	80
Cadmium, dissolved as Cd, µg/L	2	--	ND	--
Chromium, dissolved as Cr, µg/L	2		30	10
Copper, dissolved as Cu, µg/L	2		20	ND
Iron, dissolved as Fe, µg/L	3	250	280	240
Lead, dissolved as Pb, µg/L	2	--	ND	--
Manganese, dissolved as Mn, µg/L	13	130	220	80
Mercury, dissolved as Hg, µg/L	2	--	ND	--
Selenium, dissolved as Se, µg/L	2	--	5	ND
Zinc, dissolved as Zn, µg/L	2	--	10	ND

Table 16. *Statistical summary of water-quality data from selected wells in Sedgwick County with long-term records*--Continued

City of Wichita public-supply well M28

(25S-02W-02BAA, 218 feet deep)

Period of record: 1948-50, 1952, 1957-68, 1971-72, 1985

Property or constituent	Number of samples	Median	Maximum	Minimum
Specific conductance, μS/cm	4	675	785	550
pH, standard units	7	7.4	8.2	7.2
Hardness, as $CaCO_3$, mg/L	19	240	250	180
Hardness, noncarbonate as $CaCO_3$, mg/L	19	0	0	0
Bicarbonate as HCO_3, mg/L	19	300	320	220
Calcium, dissolved as Ca, mg/L	13	75	80	64
Magnesium, dissolved as Mg, mg/L	13	13	16	7.5
Sodium, dissolved as Na, mg/L	13	65	78	44
Potassium, dissolved as K, mg/L	1	--	2.9	--
Sulfate, dissolved as SO_4, mg/L	16	100	100	78
Chloride, dissolved as Cl, mg/L	19	60	75	27
Fluoride, dissolved as F, mg/L	3	.4	.4	.3
Silica, dissolved as SiO_2, mg/L	6	16	37	1.0
Solids, dissolved, mg/L	13	450	520	323
Nitrate, dissolved as N, mg/L	1	--	2.3	--
Phosphate, ortho, dissolved as PO_4, mg/L	1	--	.06	--
Iron, dissolved as Fe, μg/L	1	--	190	--
Manganese, dissolved as Mn, μg/L	7	190	220	50

Table 16. *Statistical summary of water-quality data from selected wells in Sedgwick County with long-term records*--Continued

Park City public-supply well 7

(26S-01E-17AAB, 42.0 feet deep)

Period of record: 1953, 1954, 1960, 1964, 1968, 1984-86

Property or constituent	Number of samples	Median	Maximum	Minimum
Specific conductance, μS/cm	6	1,000	1,140	810
pH, standard units	8	7.3	7.4	7.1
Hardness, as $CaCO_3$, mg/L	8	400	470	260
Hardness, noncarbonate as $CaCO_3$, mg/L	8	99	210	36
Bicarbonate as HCO_3, mg/L	9	410	440	260
Calcium, dissolved as Ca, mg/L	8	110	130	77
Magnesium, dissolved as Mg, mg/L	8	32	41	17
Sodium, dissolved as Na, mg/L	8	40	51	29
Potassium, dissolved as K, mg/L	5	2.3	2.4	1.5
Sulfate, dissolved as SO_4, mg/L	8	140	170	83
Chloride, dissolved as Cl, mg/L	8	22	42	13
Fluoride, dissolved as F, mg/L	8	.3	.5	.3
Silica, dissolved as SiO_2, mg/L	7	18	19	16
Solids, dissolved, mg/L	8	572	640	369
Nitrate, dissolved as N, mg/L	5	.27	.34	.14
Phosphate, ortho, dissolved as PO_4, mg/L	1	--	.12	--
Iron, dissolved as Fe, μg/L	3	48	60	20
Manganese, dissolved as Mn, μg/L	7	150	450	60

Table 16. *Statistical summary of water-quality data from selected wells in Sedgwick County with long-term records*--Continued

City of Goddard public-supply well 4

(27S-02W-32BBB, 54.0 feet deep)

Period of record: 1960-61, 1964-66, 1969-70, 1974, 1977-81, 1983-86

Property or constituent	Number of samples	Median	Maximum	Minimum
Specific conductance, μS/cm	17	835	1,020	730
pH, standard units	16	7.4	7.6	7.1
Hardness, as $CaCO_3$, mg/L	17	320	440	290
Hardness, noncarbonate as $CaCO_3$, mg/L	15	28	140	5
Bicarbonate as HCO_3, mg/L	16	370	400	340
Calcium, dissolved as Ca, mg/L	17	100	130	83
Magnesium, dissolved as Mg, mg/L	17	19	28	8.6
Sodium, dissolved as Na, mg/L	17	52	74	35
Potassium, dissolved as K, mg/L	14	1.7	2.0	.9
Sulfate, dissolved as SO_4, mg/L	14	72	190	13
Chloride, dissolved as Cl, mg/L	17	45	130	27
Fluoride, dissolved as F, mg/L	17	.2	.4	.1
Silica, dissolved as SiO_2, mg/L	17	21	23	8.0
Solids, dissolved, mg/L	17	480	650	410
Nitrate, dissolved as N, mg/L	13	3.2	8.0	.41
Phosphate, ortho, dissolved as PO_4, mg/L	5	.10	.22	.10
Iron, dissolved as Fe, μg/L	10	20	150	7
Manganese, dissolved as Mn, μg/L	6	10	20	ND

Table 16. *Statistical summary of water-quality data from selected wells in Sedgwick County with long-term records*--Continued

Domestic well

(29S-01E-08CBB, 36.0 feet deep)

Period of record: 1959, 1978-81, 1983-84, 1986

Property or constituent	Number of samples	Median	Maximum	Minimum
Specific conductance, µS/cm	8	565	735	525
pH, standard units	7	7.1	7.9	7.0
Hardness, as $CaCO_3$, mg/L	8	200	280	170
Hardness, noncarbonate as $CaCO_3$, mg/L	6	0	24	0
Bicarboate as HCO_3, mg/L	6	280	320	260
Calcium, dissolved as Ca, mg/L	8	60	84	50
Magnesium, dissolved as Mg, mg/L	8	12	18	11
Sodium, dissolved as Na, mg/L	8	47	50	44
Potassium, dissolved as K, mg/L	7	2.0	2.0	1.5
Sulfate, dissolved as SO_4, mg/L	8	30	48	23
Chloride, dissolved as Cl, mg/L	8	18	25	14
Fluoride, dissolved as F, mg/L	8	.3	.4	.1
Silica, dissolved as SiO_2, mg/L	8	22	23	8.6
Solids, dissolved, mg/L	8	345	410	310
Nitrate, dissolved as N, mg/L	5	6.2	7.5	3.8
Arsenic, dissolved as As, µg/L	2	--	5	ND
Barium, dissolved as Ba, µg/L	1	--	110	--
Cadmium, dissolved as Cd, µg/L	2	--	ND	ND
Chromium, dissolved as Cr, µg/L	2	--	10	ND
Copper, dissolved as Cu, µg/L	2	--	ND	ND
Iron, dissolved as Fe, µg/L	5	ND	40	ND
Lead, dissolved as Pb, µg/L	2	--	ND	ND
Manganese, dissolved as Mn, µg/L	4	ND	10	ND
Mercury, dissolved as Hg, µg/L	2	--	ND	ND
Selenium, dissolved as Se, µg/L	2	--	1	ND
Zinc, dissolved as Zn, µg/L	2	--	20	20

Table 16. *Statistical summary of water-quality data from selected wells in Sedgwick County with long-term records*--Continued

City of Clearwater public-supply well 5

(29S-02W-23DDA, 54.0 feet deep)

Period of record: 1961-62, 1964-65, 1967, 1970, 1972, 1974, 1977-81, 1983-85

Property or constituent	Number of samples	Median	Maximum	Minimum
Specific conductance, µS/cm	16	725	820	550
pH, standard units	16	7.15	7.5	6.8
Hardness, as $CaCO_3$, mg/L	16	290	330	210
Hardness, noncarbonate as $CaCO_3$, mg/L	16	85	110	0
Bicarbonate as HCO_3, mg/L	14	260	300	230
Calcium, dissolved as Ca, mg/L	16	72	80	64
Magnesium, dissolved as Mg, mg/L	16	26	33	11
Sodium, dissolved as Na, mg/L	16	39	52	32
Potassium, dissolved as K, mg/L	14	2.2	6.0	2.0
Sulfate, dissolved as SO_4, mg/L	16	58	87	26
Chloride, dissolved as Cl, mg/L	16	51	85	17
Fluoride, dissolved as F, mg/L	16	.4	2.8	.1
Silica, dissolved as SiO_2, mg/L	16	24	29	8.0
Solids, dissolved, mg/L	16	425	500	340
Nitrate, dissolved as N, mg/L	13	7.2	9.1	3.3
Phosphate, ortho, dissolved as PO_4, mg/L	1	--	.34	--
Arsenic, dissolved as As, µg/L	4	4	6	ND
Barium, dissolved as Ba, µg/L	2	--	170	60
Cadmium, dissolved as Cd, µg/L	4	ND	ND	ND
Chromium, dissolved as Cr, µg/L	4	ND	10	ND
Copper, dissolved as Cu, µg/L	4	20	40	10
Iron, dissolved as Fe, µg/L	11	20	70	10
Lead, dissolved as Pb, µg/L	4	ND	ND	ND
Manganese, dissolved as Mn, µg/L	4	ND	4	ND
Mercury, dissolved as Hg, µg/L	4	ND	1.1	ND
Selenium, dissolved as Se, µg/L	4	2	5	ND
Zinc, dissolved as Zn, µg/L	4	40	80	ND

generally exceed the water-quality criterion (U.S. Environmental Protection Agency, 1986b).

City of Wichita public-supply well M28 (25S-02W-02BAA) is 218 feet deep and yields water from unconsolidated deposits in the *Equus* beds aquifer ranging in age from Pliocene to Holocene. Water from this well is a calcium sodium bicarbonate type, with a median dissolved-solids concentration of 450 mg/L. The water has a median concentration of hardness as calcium carbonate of 240 mg/L. Concentrations of manganese (median concentration, 190 µg/L) generally exceed the water-quality criterion.

Park City public-supply well 7 (26S-01E-17AAB) is 42.0 feet deep and yields water from alluvium and terrace deposits of the Little Arkansas River. The water from this well is a calcium bicarbonate type, with a median dissolved-solids concentration of 572 mg/L. The water has a median concentration of hardness as calcium carbonate of 400 mg/L. Concentrations of manganese (median concentration, 150 µg/L) generally exceed the water-quality criterion.

Goddard public-supply well 4 (27S-02W-32BBB) is 54.0 feet deep and yields water from unconsolidated deposits of pre-Illinoian age. The water is a calcium bicarbonate type, with a median dissolved-solids concentration of 480 mg/L. The water has a median concentration of hardness as calcium carbonate of 320 mg/L.

Long-term water-quality data also are available for a domestic well (29S-01E-08CBB) that is 36.0 feet deep and yields water from alluvium and terrace deposits of Wisconsin to Holocene age in the Arkansas River valley. Water from this well is a calcium bicarbonate type, with a median dissolved-solids concentration of 345 mg/L. The water has a median concentration of hardness as calcium carbonate of 200 mg/L.

Clearwater public-supply well 5 (29S-02W-23DDA) is 54.0 feet deep and yields water from terrace deposits of Illinoian age. The water is a calcium bicarbonate type, with a median dissolved-solids concentration of 425 mg/L. The water has a median concentration of hardness as calcium carbonate of 290 mg/L. Mercury (maximum concentration, 1.1 µg/L) has exceeded the water-quality criterion (U.S. Environmental Protection Agency, 1986c).

Wichita Well Field

The Wichita well field in southwest Harvey County (in parts of township 23 south, range 2 west and township 24 south, ranges 2 and 3 west) and northwest Sedgwick County (in parts of township 25 south, ranges 1 and 2 west) yields water for public supplies from the *Equus* beds aquifer. The original well field, located in Harvey County, was established in 1940when 25 wells were used to withdraw about 3,900 acre-feet of water. The current (1986) public-supply and observation-well network of the Wichita well field is shown in figure 20. During 1985, nearly 35,200 acre-feet of water were withdrawn from 55 wells in the well field. During 1940 through 1985, a total of approximately 1,268,400 acre-feet of water have been withdrawn from the well field for public supplies (data from city of Wichita). The city of Wichita currently has appropriated ground-water rights to withdraw about 40,000 acre-feet annually (Lorenz and others, 1985).

Water Yield

A previous investigation determined that the Wichita well field had a potential perennial yield of about 40,000 acre-feet (Williams and Lohman, 1947). The perennial yield was defined as being equivalent to the sum of all natural recharge (precipitation and inflow), assuming that the water table was lowered to a degree that all natural recharge could be intercepted. This estimate of potential perennial yield was used to develop the ground-water appropriation for the well field. Williams and Lohman (1947) also determined that in order for all natural recharge to be intercepted that about 200,000 acre-feet of water would have to be removed from storage. By the end of 1950, more than 200,000 acre-feet of water had been withdrawn from the well field although annual withdrawals had increased to only about 26,000 acre-feet. If the estimate of perennial yield by Williams and Lohman (1947) was accurate, the water-level declines in the well field should have stabilized by about 1950. However, this has not occurred as can be seen by comparing water-level declines in the well field during selected time intervals (fig. 20).

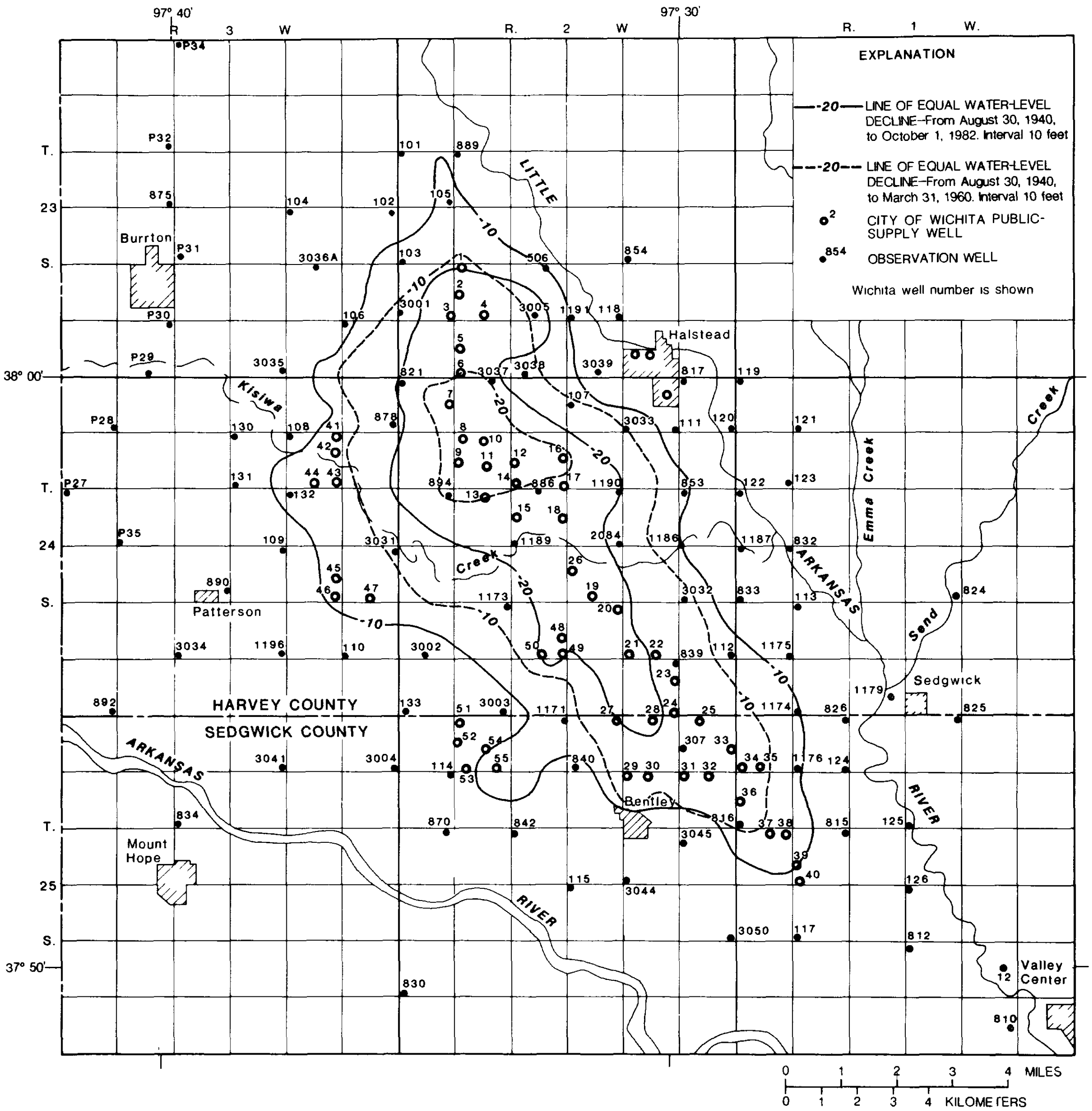


Figure 20. Wichita well field in southwest Harvey and northwest Sedgwick Counties, public-supply and observation-well network, and water-level declines from August 30, 1940, to March 31, 1960, and from August 30, 1940, to October 1, 1982.

The water-level declines shown in figure 20 represent declines that occurred from the base period of 1940 to 1960 and from 1940 to 1982. The years 1960 and 1982 were selected for comparison because the cumulative departure from average precipitation, shown previously in figure 18, indicates that precipitation was about average during 1940, 1960, and 1980, and that the cumulative departures from average precipitation were nearly equivalent. Because the climatic conditions were similar during these years, any change in water levels in the well field would be caused by withdrawals. The area where water levels had declined 20 feet or more had increased by approximately four times between 1960 and 1982, and the area where water-level declines were 10 feet or more also had increased substantially even though less than 40,000 acre-feet of ground water were withdrawn in 1982. However, increasing ground-water withdrawals for irrigation in the vicinity of the well field since 1960 probably have contributed to the decline of water levels since then.

Williams and Lohman (1947) estimated that natural recharge to the well field from precipitation was about 6 inches. A more recent ground-water modeling investigation used annual recharge from precipitation ranging from 2.5 to 4.0 inches (Spinazola and others, 1985). If a value of 3.25 inches (averaged used by Spinazola) were used in the computation by Williams and Lohman, the estimated perennial yield would decrease from 40,000 acre-feet to less than 30,000 acre-feet. This difference in recharge from precipitation may be the reason that water levels in the well field have continued to decline, although withdrawals for irrigation are also a major factor. Assuming recharge by precipitation of 3.25 inches per year, the area affected by the well field would have to exceed 155 square miles before the water levels would stabilize. By 1982, water-level declines of 2 feet or more had occurred in a 135-square-mile area in and adjacent to the well field. In recent years since 1982, the areas of water-level decline in the well field have been relatively stable.

Although water-level declines greater than 25 feet occasionally have been observed in localized parts of the well field, the saturated thickness of unconsolidated deposits ranged from about 140 to 250 feet in 1980 (Spinazola and others, 1985). Spinazola used a three-dimensional finite-difference ground-water flow model to project the effects of ground-water withdrawals in the *Equus* beds aquifer, including the Wichita well field. He estimated that continued withdrawals from the well field at the rate observed during the 1970's (about 30,000 acre-feet per year) would cause additional water-level declines of about 15 feet during 1980-2020, assuming that withdrawals for irrigation also remained constant. If withdrawals were doubled (including irrigation), water levels in the well field would decline an additional 40 feet during 1980-2020, and the saturated thickness of unconsolidated deposits would range from about 95 to 210 feet by 2020.

Water Quality

Water-quality data collected since 1980 from the vicinity of the Wichita well field are presented in table 17. These data were compiled from reports of the Kansas Geological Survey (Hathaway and others, 1981), the Burrton Task Force (1984), and from data files of the U.S. Geological Survey (including data collected during this investigation).

Water from wells in the Wichita well field generally is a calcium bicarbonate type, with less than 500 mg/L dissolved solids. Water with concentrations of dissolved solids exceeding 500 mg/L in the vicinity of the well field usually has relatively large concentrations of sodium, sulfate, or chloride. Concentrations of nitrate as nitrogen occasionally exceed the water-quality criterion of 10 mg/L (U.S. Environmental Protection Agency, 1986c), and concentrations of iron and manganese in water from many wells in the area exceed public-supply criteria of 300 and 50 µg/L (U.S. Environmental Protection Agency, 1986b), respectively.

Sodium chloride type ground water, with large concentrations of dissolved solids (exceeding 1,000 mg/L), occurs in areas adjacent to the western edge of the well field. The sodium chloride water is derived from dissolution of salt beds in Permian rocks and from past disposal of oilfield brine in the Burrton oilfield. The Wellington Formation of Permian age underlies the unconsolidated deposits in the well field. The Hutchinson Salt Member of the Wellington Formation has been dissolved by ground water in areas south and west of the well field, resulting in the formation of a discontinuous zone of solution cavities and collapsed beds that is referred to as the Wellington aquifer (Gogel, 1981). Digital flow modeling by Gogel (1981) predicted that the potentiometric surface of water in the Wellington aquifer is higher than the potentiometric surface in the overlying unconsolidated deposits in an area adjacent to Kisiwa Creek south of Burrton. Also, because less than 100 feet of shale is present between the Wellington aquifer and the unconsolidated deposits, there is potential for the upward movement of halite-solution brine into the freshwater aquifer in this area. Relatively large concentrations of chloride ions and sodium:chloride ratios greater than 0.60 in several wells in the vicinity of Patterson (fig. 1) may be due to upward movement of brine from the Wellington aquifer. However, a detailed investigation in this area is needed before any conclusions can be drawn.

The Arkansas River receives sodium chloride water from ground water discharged by

Table 17. *Water-quality data for wells in vicinity of Wichita well field, 1980-85.*

Well number (township-range-section, fig. 22)	Date sampled (month-day-year)	Depth of well, in feet	Concentration of constituent, in milligrams per liter; ND, not detected: Hardness, as $CaCO_3$	Calcium, as Ca	Sodium, as Na	Bicarbonate, as HCO_3	Sulfate, as SO_4	Chloride, as Cl	Dissolved solids	Nitrate, as N	Sodium: chloride ratio[1] (Na/Cl)	Concentration of constituent, in micrograms per liter: Iron, as Fe	Manganese, as Mn
23S-02W-29BAC[2]	07-29-80	--	110	35	31	180	18	6.0	230	0.02	--	10	260
23S-02W-29CDD[3]	08-01-85	237	120	39	26	190	21	7.8	220	.09	--	60	300
23S-03W-04BBB[4]	10-15-82	78	--	--	--	--	--	3.0	--	--	--	--	--
23S-03W-07DAA[4]	12-14-82	20	410	130	39	32	6.5	310	--	2.2	0.12	--	--
23S-03W-08BBB[4]	10-15-82	146	--	--	--	--	--	4.0	--	--	--	--	--
23S-03W-08DDD[4]	10-15-82	89	--	--	--	--	--	6.0	--	--	--	--	--
23S-03W-10BBB[4]	12-14-82	50	--	--	--	--	--	8.0	--	--	--	--	--
23S-03W-10CCA[4]	10-15-82	137	--	--	--	--	--	5.0	--	--	--	--	--
23S-03W-16DDB[2]	07-29-80	--	130	40	44	220	19	10	260	.11	--	770	350
23S-03W-17AAB[4]	12-14-82	25	12	35	13	43	28	18	--	12	--	--	--
23S-03W-19BBB[4]	10-23-82	175	--	--	--	--	--	10	--	--	--	--	--
23S-03W-19DCC[4]	01-20-83	124	470	140	130	170	36	400	--	.5	.32	--	--
23S-03W-19DDD[4]	12-14-82	110	1,670	520	490	73	54	1,830	--	ND	.27	--	--
23S-03W-20DBC[4]	12-14-82	33	--	--	--	--	--	150	--	--	--	--	--
23S-03W-21ADC[2]	07-29-80	--	440	140	97	89	21	400	780	.77	.24	2,100	190
23S-03W-21CCC[4]	12-14-82	65	820	240	480	99	32	1,220	--	ND	.39	--	--
23S-03W-22BBB[4]	12-14-82	53	530	170	240	60	25	660	--	5.00	.36	--	--
23S-03W-22DBD[2]	07-29-80	--	100	32	29	160	15	12	200	--	--	--	250
23S-03W-23BBB[4]	10-15-82	140	--	--	--	--	--	5	--	--	--	--	--
23S-03W-26BBB[4]	10-14-82	66	--	--	--	--	--	190	--	--	--	--	--
23S-03W-27BCC[4]	12-14-82	100	650	200	380	120	52	920	--	.1	.41	--	--
23S-03W-28BC[4]	12-14-82	29	270	80	77	180	163	160	--	2.6	.48	--	--
23S-03W-29DBD[3]	08-01-85	--	250	74	67	190	76	100	460	4.42	--	90	10
23S-03W-32AAA[4]	12-14-82	128	970	300	430	210	32	1,180	--	.2	.36	--	--
23S-03W-34DBB[4]	12-14-82	130	380	120	67	240	39	220	--	ND	.30	--	--
23S-03W-34DDD[4]	12-14-82	125	--	--	--	--	--	29	--	--	--	--	--
23S-03W-36ABC[2]	07-29-80	--	120	36	26	130	31	16	240	5.9	--	84	27
24S-01W-18CCA[2]	07-29-80	--	140	64	58	310	44	21	370	.04	--	1,900	480
24S-01W-29BBC[2]	07-29-80	--	270	84	98	370	140	28	570	.02	--	770	630
24S-02W-02AAC[3]	09-23-80	20	190	62	45	220	76	21	360	2.7	--	--	--
24S-02W-05DDA[2]	07-29-80	--	110	36	44	200	23	11	240	.05	--	510	250
24S-02W-06DBD[2]	07-29-80	--	160	51	34	200	61	14	310	.02	--	2,300	190
24S-02W-12CCC[2]	07-29-80	--	200	65	60	280	90	10	390	.04	--	2,200	360
24S-02W-17CAA[2]	07-29-80	--	320	100	91	280	170	73	600	.04	--	1,800	330
24S-02W-23BBC[2]	07-29-80	--	350	110	49	200	260	12	600	.75	--	4,100	530
24S-02W-23BDC[2]	07-29-80	--	200	62	35	170	93	19	340	2.1	--	3,400	430
24S-02W-23BBB[3]	09-23-80	80	340	110	48	210	240	15	560	9	--	--	--
24S-02W-27C[2]	07-29-80	--	280	86	69	280	160	22	480	.04	--	3,500	560
24S-02W-29DDB[2]	07-29-80	--	270	82	76	310	110	54	490	.04	--	660	520
24S-03W-01BBA[4]	12-14-82	90	--	--	--	--	--	71	--	--	--	--	--
24S-03W-01DDD[4]	12-14-82	44	--	--	--	--	--	35	--	--	--	--	--
24S-03W-03DDC[4]	12-14-82	31	--	--	--	--	--	63	--	--	--	--	--
24S-03W-04BAA[4]	12-14-82	63	--	--	--	--	--	52	--	--	--	--	--
24S-03W-05ACC[2]	07-29-80	--	260	76	74	230	60	110	490	.25	.67	1,100	42
24S-03W-07BCC[4]	12-13-82	35	1,050	340	120	370	230	240	--	105	.50	--	--
24S-03W-07CDD[4]	12-14-82	37	--	--	--	--	--	170	--	--	--	--	--
24S-03W-08DBB[2]	07-29-80	--	270	80	89	290	90	90	530	.61	--	910	150
24S-03W-11DDD[4]	12-14-82	54	--	--	--	--	--	92	--	--	--	--	--
24S-03W-13DAA[4]	12-13-82	130	5	2.0	230	290	150	93	--	.6	--	--	--
24S-03W-15DAA[4]	12-14-82	30	30	9.5	130	20	79	170	--	ND	.76	--	--
24S-03W-15DCD[2]	07-29-80	--	390	120	100	360	150	110	690	.45	.91	1,300	290
24S-03W-17DDD[4]	12-13-82	80	190	56	95	140	39	170	--	.9	.56	--	--
24S-03W-20BBD[2]	07-29-80	--	340	110	100	320	110	110	550	2.5	.91	87	81
24S-03W-22CBB[2]	07-29-80	--	360	110	130	330	160	140	710	.52	.93	750	200
24S-03W-24C [2]	07-29-80	--	290	89	62	310	100	46	480	1.1	--	280	43
24S-03W-26ADA[3]	08-01-85	75	170	150	120	400	250	110	880	ND	1.09	2,700	210
24S-03W-26B[2]	07-29-80	--	350	109	3.7	370	84	86	590	5.4	--	380	76
24S-03W-26CDD[4]	12-14-82	--	--	--	--	--	--	92	--	--	--	--	--
24S-03W-29BBA[4]	12-14-82	47	--	--	--	--	--	91	--	--	--	--	--
24S-03W-30CBB[4]	12-14-82	35	360	120	83	280	77	130	--	9.0	.64	--	--

Table 17. *Water-quality data for wells in vicinity of Wichita well field, 1980-85*--Continued

Well number (township-range-section, fig. 22)	Date sampled (month-day-year)	Depth of well, in feet	Hardness, as $CaCO_3$	Calcium, as Ca	Sodium, as Na	Bicarbonate, as HCO_3	Sulfate, as SO_4	Chloride, as Cl	Dissolved solids	Nitrate, as N	Sodium: chloride ratio[1] (Na/Cl)	Iron, as Fe	Manganese, as Mn
			Concentration of constituent, in milligrams per liter; ND, not detected									Concentration of constituent, in micrograms per liter	
24S-03W-32B[2]	07-29-80	--	230	70	120	280	65	150	560	1.2	0.80	<8	<3
24S-03W-33BBD[4]	12-14-82	50	--	--	--	--	--	120	--	--	--	--	--
25S-01W-06DBB[2]	07-29-80	--	230	71	55	270	88	27	400	.93	--	480	120
25S-01W-07BAA[3]	08-14-85	130	250	81	38	260	66	18	360	6.3	--	7	44
25S-01W-21B[2]	07-29-80	--	310	97	58	370	88	32	480	.04	--	250	190
25S-01W-27ABC[2]	07-29-80	--	340	100	50	350	110	30	490	.86	--	160	280
25S-01W-27CCC[3]	08-13-85	40	250	79	37	260	82	16	370	.95	--	<3	5
25S-01W-30ABB[3]	08-13-85	32	280	89	51	230	60	47	400	21.0	--	<3	<1
25S-01W-31B[2]	07-29-80	--	270	81	100	300	69	130	580	.73	.77	<8	<3
25S-01W-32BCB[2]	07-29-80	--	300	90	130	180	120	220	750	8.4	.59	<8	<3
25S-01W-32CDA[2]	07-29-80	--	360	110	110	270	79	220	710	1.2	.50	8	<3
25S-01W-35AAC[3]	08-13-85	37	460	150	38	350	170	25	600	< .10	--	130	75
25S-02W-02BAA[3]	08-14-85	218	240	76	78	300	78	60	480	.23	--	190	210
25S-02W-03DD[2]	07-29-80	--	280	90	43	290	65	26	430	7.5	--	<8	20
25S-02W-07DC[2]	07-29-80	--	220	67	86	240	62	89	490	7.3	--	<8	<3
25S-02W-10AAB[2]	07-29-80	--	260	83	47	280	45	30	430	9.1	--	<8	12
25S-02W-12DBD[2]	07-29-80	--	200	63	43	220	53	30	360	3.4	--	<8	150
25S-02W-15ABB[2]	07-29-80	--	220	68	68	300	56	39	410	.02	--	300	110
25S-02W-15C[2]	07-29-80	--	210	63	47	200	40	44	380	13	--	<8	<3
25S-02W-15DDD[3]	08-12-85	--	200	59	40	200	46	45	320	9.2	--	5	7
25S-02W-17ABB[3]	08-14-85	45	300	94	77	220	97	110	530	9.5	.70	25	8
25S-02W-22BDA[2]	07-29-80	--	390	120	120	280	110	200	770	7.0	.60	<8	<3
25S-02W-22DAA[2]	07-29-80	--	340	100	110	270	89	160	670	7.5	.69	<8	<3
25S-02W-36ABB[2]	07-29-80	--	520	160	270	270	220	480	1,330	2.0	.56	20	4
25S-03W-02BBC[3]	08-14-85	52	330	100	88	340	110	89	600	1.6	--	350	110
25S-03W-02CCB[2]	07-29-80	--	290	88	72	240	62	100	520	11	--	<8	<3
25S-03W-03D[2]	07-29-80	--	230	66	120	280	65	130	560	1.3	.92	<8	64
25S-03W-05BAB[3]	08-14-85	80	190	57	140	240	80	200	630	2.4	.70	13	5
25S-03W-06A[2]	07-29-80	--	290	87	140	270	130	170	700	1.2	.82	<8	8
25S-03W-11CBD[2]	07-29-80	--	430	130	170	340	200	220	940	.25	.77	1,000	780

[1] Sodium:chloride ratio computed if chloride concentration exceeded 100 milligrams per liter and if sodium and chloride data were available. The sodium:chloride ratio is dimensionless.

[2] Data from Hathaway and others, 1981.

[3] Data from files of U.S. Geological Survey (1980-85).

[4] Data from Burrton Task Force (1984).

Permian rocks in Reno and Stafford Counties, from salt-production activities at Lyons and Hutchinson, and from past oilfield activities. The Arkansas River alluvium contains sodium chloride type water in a narrow band that is generally less than 2 miles wide along both sides of the river and serves as a line source of sodium chloride water to adjacent unconsolidated deposits. The Burrton oilfield, which is located north and west of Burrton, is a source of sodium chloride ground water from oilfield activities, primarily the past disposal of brine in shallow evaporation pits that leaked and early attempts at pressurized disposal of brine in shallow injection wells.

Geochemical evidence based on sodium:chloride, bromide:chloride, and sulfate:chloride ratios indicates that the main source of salinity in the Burrton area is oilfield brine (Whittemore and Basel, 1982). Iodide:chloride ratios were interpreted to suggest that the saltwater originated at the surface and flowed downward through the freshwater aquifer, indicating that the shallow evaporation pits are the primary source of the oilfield brine (Burrton Task Force, 1984). The downward movement of brine in the Burrton area is illustrated in figure 21. Adjacent observation wells, located in township 23 south, range 3 west, section 21CCC, are screened at depths of 38 and 64.5 feet. Large concentrations of chloride were first observed in the shallower well and then migrated downward to the deeper well, which now has larger concentrations of chloride than the shallower well.

Concentrations of chloride from table 17 are plotted on a map of the Wichita well-field area (fig. 22). In addition to large concentrations of chloride in the Burrton area, a band of sodium chloride water along the north side of the Arkansas River is also apparent. Sodium:chloride ratios shown in table 17 for wells with water having greater than 100 mg/L of chloride generally are less than 0.60 in the vicinity of Burrton, indicating contamination from oilfield brine, and greater than 0.60 in the area adjacent to the Arkansas River, indicating contamination by halite solution from Permian rocks upstream.

A two-dimensional solute-transport model was used to simulate the movement of chloride ions in this area (Spinazola and others, 1985). The model was used to project the effects of three rates of ground-water withdrawals (one-half of the 1971-79 withdrawal rate, the 1971-79 withdrawal rate, and two times the 1971-79 withdrawal rate) on the distribution of chloride concentrations. Results indicated that chloride concentrations would increase in direct proportion to projected withdrawal rates. Changes in chloride concentrations projected by withdrawal rates at one-half and equal to the 1971-79 rate were relatively small for the northern part of the well field that is affected by oilfield brine. However, the southern part of the well field experienced much greater increases in chloride concentrations for these withdrawal rates, indicating that the continuous line source of chloride from the Arkansas River will have a greater effect on increasing chloride concentrations in the well field than residual oilfield brines north and west of the well field. Lines of equal chloride concentration projected for ground-water-withdrawal rates of twice the 1971-79 rate are shown for 2020 in figure 22 (Spinazola and others, 1985).

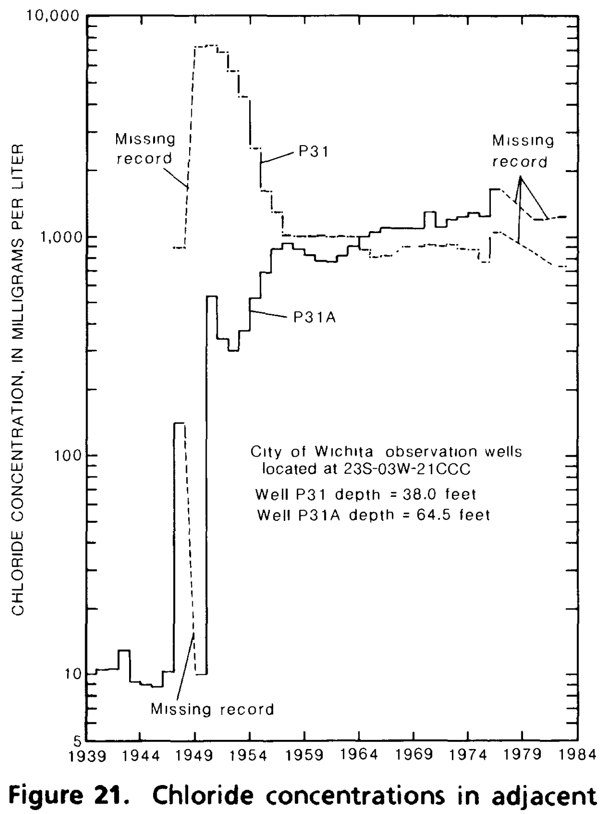


Figure 21. Chloride concentrations in adjacent wells indicating downward movement of brine from shallow evaporation pits in vicinity of Wichita well field, 1939-83.

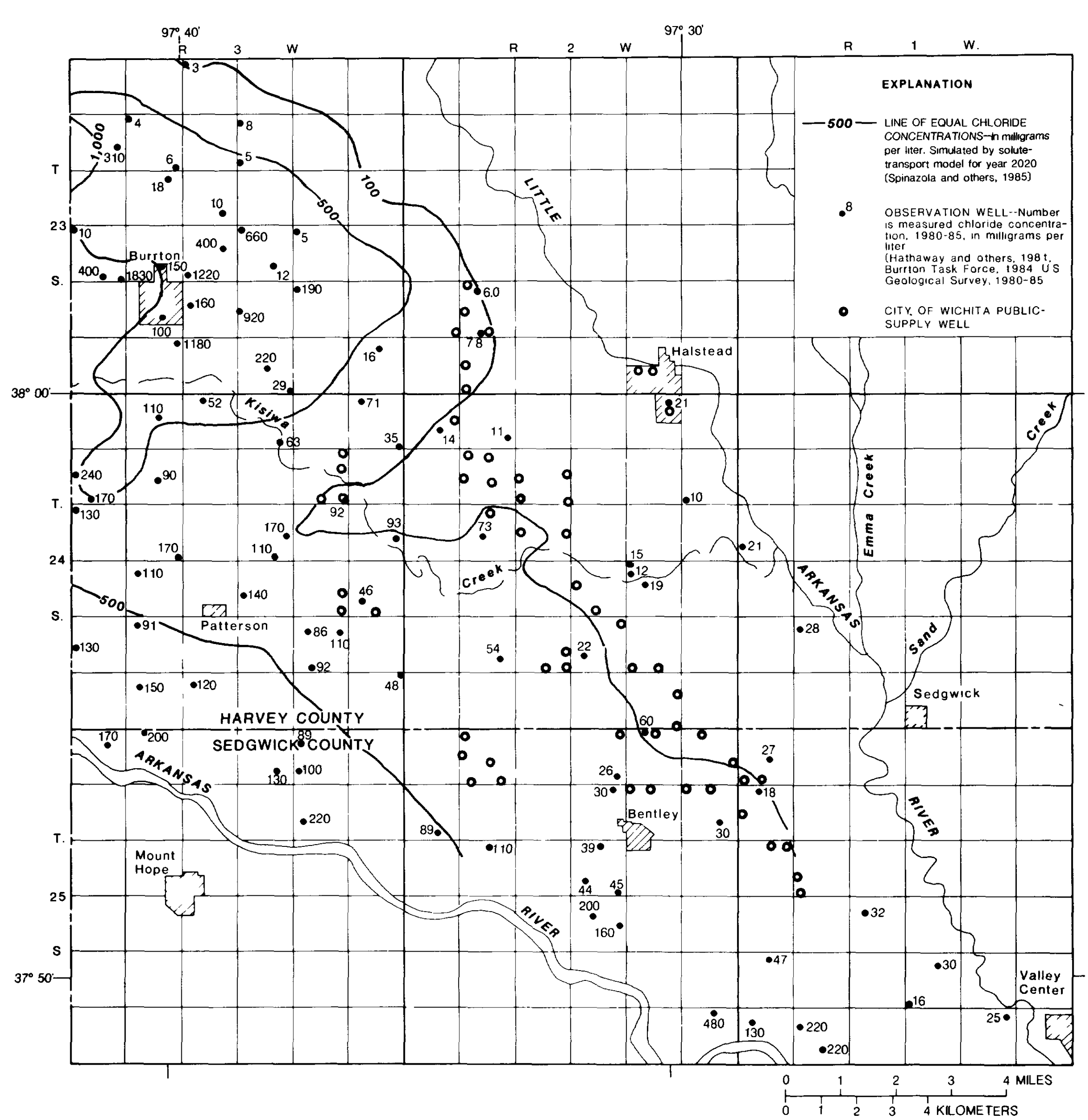


Figure 22. Chloride concentrations in vicinity of Wichita well field, 1980-85.

STREAM-AQUIFER INTERACTION IN ARKANSAS AND LITTLE ARKANSAS RIVER BASINS NEAR WICHITA

Rationale for Evaluating Stream-Aquifer Interaction

Unconsolidated valley-fill deposits that occur in the Arkansas and Little Arkansas River valleys north of Wichita are primary sources of ground water for public, irrigation, and industrial supplies. Although the rivers generally are not used as sources of water supplies, instream uses of water for wildlife habitat, recreation, and assimilation of municipal and industrial wastes are important; also, the rivers are potential sources of future water supplies.

A principal limiting factor in determining the suitability of rivers as sources of water supplies, or for selected instream uses, is the availability of base flow. The availability of base flow, or streamflow provided by ground-water discharge that sustains streamflow during periods of little or no surface runoff, is a function of both the hydrogeologic characteristics (hydraulic properties and extent) of the aquifer providing the base flow and the interaction between the stream and the aquifer.

Although digital models can be used to quantify stream-aquifer interaction, representative values of aquifer properties are needed to calibrate the models. Traditional methods of obtaining values of aquifer properties by pump or slug tests of wells generally are not applicable to definitions of stream-aquifer interaction because (1) the values represent only local conditions in the vicinity of the test wells and (2) stream-channel characteristics, such as depth and particle size of sediments forming the banks and bed, also affect stream-aquifer interaction. An alternative method for defining stream-aquifer interaction is based on the evaluation of base-flow recession.

A quantitative analytical method of determining stream-aquifer interaction by evaluating the slopes of selected base-flow recession curves was used to develop representative areal values of aquifer properties as they relate to stream-aquifer interaction in the Arkansas and Little Arkansas River valleys near Wichita.

Definition of Selected Ground-Water Terms

Ground-water terms used in the evaluation of stream-aquifer interaction are defined in the following paragraphs to aid in the understanding of the concepts presented (Lohman and others, 1972).

Hydraulic conductivity *(K)*--The volume of water at the existing viscosity that will move during a unit time under a unit hydraulic gradient through a unit area of the aquifer that is normal to the direction of flow, expressed in units of length per time (feet per day).

Hydraulic diffusivity *(T/S)*--The conductivity of the saturated aquifer when the unit volume of water moving horizontally is that involved in changing the hydraulic head a unit amount in a unit volume of aquifer, expressed in units of area per time (feet squared per day). In any isotropic homogeneous aquifer, the time involved for a given head change to occur at a particular point in response to a greater change in head at another point, such as an observation well affected by a pumping well, is inversely proportional to the hydraulic diffusivity of the aquifer.

Specific yield *(Sy)*--The volume of water an unconfined aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head, expressed as a dimensionless value. Specific yield is only an approximate measure of the relation between storage and hydraulic head in an unconfined aquifer because its definition implies that gravity drainage is complete.

Storage coefficient *(S)*--The volume of water released from or taken into storage per unit surface area of the aquifer per unit change in head,expressed as a dimensionless value. In an unconfined aquifer, the storage coefficient is virtually equal to the specific yield.

Transmissivity *(T)*--The rate at which water at the existing viscosity will move through a unit width of the aquifer under a unit hydraulic gradient, expressed in units of area per time (feet squared per day). Transmissivity is equal to an integration of hydraulic-conductivity values across the saturated part of the aquifer that is normal to the direction of flow and can be computed by multiplying the hydraulic conductivity by the saturated thickness.

Relationship Between Stream-Aquifer Interaction and Base-Flow Recession

The methodology used to define stream-aquifer interaction by evaluating base-flow recessions of streams is based on an equation developed to determine the hydraulic diffusivity (*T/S*) of an aquifer from the slope of a water-level recession in an observation well (Rorabaugh, 1960).

$$\frac{T}{S} = \frac{0.933\, a^2 \log(h_1 - h_2)}{t_2 - t_1} \qquad (2)$$

where

T = transmissivity, in feet squared per day;

S = storage coefficient, dimensionless;

a = half-width of the aquifer, in feet;

h_1 = initial water level, in feet, at time t_1, in days; and

h_2 = water level, in feet, at time t_2, in days.

Because base flow in a stream is provided by ground-water discharge, equation 2 can be modified to determine stream-aquifer interaction from the slope of a base-flow recession curve. After overland runoff has ceased and streamflow has declined to a point where it is being provided only by ground-water discharge, the base-flow recession curve will decline exponentially with time. If streamflow is plotted on a log scale and time on an arithmetic scale, the base-flow recession will plot as a straight line that declines through time. Furthermore, if the time required for base flow to decline exponentially through one log cycle is determined, equation 2 can be rewritten as (Rorabaugh and Simmons, 1966):

$$\frac{T}{S} = \frac{a^2 (0.933)}{\Delta t/\text{log cycle}} \qquad (3)$$

where

Δt/log cycle = the time required for the base flow to decline through one log cycle, in days; and

a = the aquifer half-width (which is equivalent to the average distance from the stream to the ground-water divides), in feet.

In order to apply equation 3 for the purpose of defining stream-aquifer interaction, it is necessary to determine slopes of base-flow recession curves that result from the interaction of the stream and aquifer and are not being affected by extraneous natural or human-induced factors. Extraneous natural factors include runoff from precipitation or snowmelt and water loss by evapotranspiration or leakage. Extraneous human-induced factors include regulation by reservoirs, withdrawals of ground or surface water for water supplies, and return flows.

Estimating Hydraulic Diffusivity

Hydraulic diffusivity can be estimated from equation 3 if adequate streamflow records are available for determining the slope of the base-flow recession within the framework of required assumptions and if a reasonable value of the aquifer half-width can be determined. If periods of record are selected that are not affected by runoff, evapotranspiration, or human-induced factors and the base flow declines exponentially with time, forming a straight line on semilog graph paper, the required assumptions have been met. If the aquifer is leaky, the recession will not decline as a straight line, but the slope will increase with time, and the curve will bend downward.

Determining Slope of Base-Flow Recession

Proper selection of streamflow records can eliminate the effects of natural and human-induced extraneous factors on base-flow recession. Streamflow regulation by reservoirs is not a factor in the area because the only reservoirs in the Arkansas River basin upstream from Wichita are in Colorado, and the Little Arkansas River basin has no large reservoirs. Small scattered ponds and lakes have little effect on base flow. Effects of runoff were avoided by examining climatological records in the area to determine that significant precipitation or snowmelt had not occurred during the base-flow recessions. Effects of irrigation (withdrawals and return flows) and evapotranspiration were avoided by evaluating base-flow recessions that occurred during periods of record prior to large-scale development of irrigation and during the nongrowing season.

Effects of withdrawals for industrial and municipal supplies and subsequent return flows were harder to avoid because they had been occurring for a long time in the vicinity of Wichita and are not seasonal. Records of streamflow-gaging stations in Wichita and Derby were not used because of these effects.

Periods of streamflow for the Arkansas River near Hutchinson and the Little Arkansas River at Valley Center were adequate for analysis. Streamflow records for the Arkansas River near Hutchinson were evaluated from the beginning of record (1959) through 1965. Irrigation in the area increased rapidly after 1965, so streamflow records after 1965 were avoided. There probably is a slight effect on the base-flow recessions caused by sewage-treatment plant effluent from Hutchinson and other upstream municipalities. However, these towns are not large, and the slopes of recessions that were examined did not appear to be affected significantly. Streamflow records for the Little Arkansas River at Valley Center were evaluated from the beginning of record (1921) through 1939. The Wichita well field began operation in 1940 and probably affects base-flow recession. Sedgwick and a few other small towns discharge sewage-treatment plant effluent into the Little Arkansas River, but the effects are minimal.

Analysis of base-flow recessions during periods of record selected according to guidelines presented in the preceding discussion determined that the slopes of the base-flow recessions were approximately 750 days per log cycle for the Arkansas River near Hutchinson and 1,000 days per log cycle for the Little Arkansas River at Valley Center. Although these values appear to be very large, it should be remembered that they represent base-flow recessions that result only from interaction between the streams and their aquifers and are not affected by extraneous natural or human-induced factors. The lesser slope of the base-flow recession in the Little Arkansas River is due primarily to the deeper channel of that stream compared to the Arkansas River.

Determining Aquifer Half-Width

The aquifer half-width, or average distance from the stream to the ground-water divide, was determined for the Arkansas and Little Arkansas Rivers from water-level maps for the periods of streamflow record that were analyzed. The unconsolidated aquifer of the Arkansas River near Hutchinson was delineated from a map showing water-level contours in the High Plains aquifer during 1965 (Pabst and Stullken, 1982). The upstream extent of the Arkansas River unconsolidated aquifer was determined to be at Garden City, about 200 miles west of Wichita, where it became a gaining stream, as indicated by the water-level contours. The width of the Arkansas River unconsolidated aquifer was limited either to ground-water divides shown by the water-level contours, to points where the saturated thickness approaches zero, or to the extent of the unconsolidated deposits (also shown on the water-level map).

The unconsolidated aquifer of the Little Arkansas River at Valley Center was delineated from a map showing pre-1950 water levels in the High Plains aquifer (Stullken and Pabst, 1982). The upstream extent of the Little Arkansas River unconsolidated aquifer was determined to be about 6 miles northeast of Hutchinson where the saturated thickness approaches zero. The aquifer width was limited either to ground-water divides, as shown by water-level contours, to points where the saturated thickness approaches zero, or to the extent of the unconsolidated deposits.

Measurements of the aquifer widths, at right angles to the streams, were made at regular intervals along the unconsolidated stream aquifers. The average half-width (a) of the Arkansas River unconsolidated aquifer was determined to be about 37,000 feet, and the average half-width of the Little Arkansas River unconsolidated aquifer was determined to be about 50,000 feet. The greater width of the Little Arkansas River unconsolidated aquifer is caused by the inclusion of *Equus* beds aquifer in Harvey and southern McPherson Counties.

Computation of Hydraulic Diffusivity

Hydraulic diffusivity was computed by entering values of the base-flow recession slopes and aquifer half-widths determined in the preceding sections into equation 3. The computed hydraulic diffusivity is approximately 1.6×10^6 feet squared per day for the unconsolidated aquifer of the Arkansas River near Hutchinson and 2.2×10^6 feet squared per day for the unconsolidated aquifer of the Little Arkansas River at Valley Center. The greater hydraulic diffusivity for the Little Arkansas River unconsolidated aquifer is primarily the result of its greater aquifer half-width.

Comparison of Stream-Aquifer Properties with Aquifer Properties Determined by Previous Investigations

Values of transmissivity, storage coefficient, and hydraulic diffusivity for unconsolidated aquifers of the Arkansas and Little Arkansas River that were determined by previous investigations or developed from information provided by previous investigations are presented in table 18. Williams and Lohman (1949) determined values of transmissibility, an obsolete term, for 25 selected wells in the Wichita well field. The transmissibility values were converted to transmissivity (divided by 7.48) and ranged from 6,100 to 44,000 feet squared per day. Specific-yield values provided by Williams and Lohman were determined by laboratory tests of core samples from test holes. These specific-yield values were assumed to be equivalent to storage coefficients and ranged from 0.08 to 0.38. The range of hydraulic diffusivity values shown by Williams and Lohman (1.6×10^4 to 5.5×10^5 feet squared per day) was computed by dividing the minimum transmissivity by the maximum storage coefficient and vice versa.

Values of transmissibility shown on a map of Sedgwick County by Lane and Miller (1965a) were determined from permeability values obtained from pump tests in conjunction with sand and gravel thickness determined from well logs. The transmissibility values were converted to transmissivity, which ranged from 3,300 to 33,000 feet squared per day. The transmissivity values were divided by an average value of specific yield (0.20), assumed to be equivalent to the storage coefficient given in the text, to compute the range of hydraulic diffusivity shown (1.6×10^4 to 1.6×10^5 feet squared per day).

Values of transmissivity and storage coefficient presented by Reed and Burnett (1985) were determined by pump tests in unconsolidated aquifers of the Arkansas and Little Arkansas Rivers in Reno, Harvey, and Sedgwick Counties although some of the storage coefficients were estimated. The very small minimum storage coefficient (0.0004) represents confined conditions in deeper parts of the aquifers. The range in hydraulic-diffusivity values (4.1×10^4 to 4.2×10^7 feet squared per day) represents actual observed values because the storage-coefficient (0.0004 to 0.16) and transmissivity (4,900 to 34,000 feet squared per day) values were from the same pump tests.

Spinazola and others (1985) presented maps of hydraulic conductivity and saturated thickness. Transmissivity values ranging from 500 to 200,000 feet squared per day were determined from these maps. The transmissivity values then were divided by an average value of specific yield presented in the text (0.15) that was assumed to be equal to the storage coefficient. The range in hydraulic diffusivity (2.5×10^3 to 1.3×10^6 feet squared per day) was estimated by dividing the minimum and maximum transmissivity values by the average storage coefficient.

Values of hydraulic diffusivity estimated by stream-aquifer interaction in the Arkansas River valley (1.6×10^6 feet squared per day) and the Little Arkansas River valley (2.2×10^6 feet squared per day) are within the range of those shown in table 18 but are larger than most. This could be because many of the wells on which pump tests were performed (Williams and Lohman, 1949) were deep, 200 feet or greater, and were screened at the bottom where deposits in the area are of Pleistocene and Late Pliocene age and are less permeable than the Holocene alluvium adjacent to the river (Lane and Miller, 1965a). If an average storage coefficient of 0.15 is assumed, the stream-aquifer transmissivity ranges from 240,000 feet squared per day in the Arkansas River valley to 330,000 feet squared per day in the Little Arkansas River valley. These values and the hydraulic diffusivity are reasonably close to the maximum values determined from data used in modeling ground-water flow (Spinazola and others, 1985).

SUMMARY AND CONCLUSIONS

The study area, which includes Sedgwick County and Wichita, has a large population and diverse economy. Most of the population and economic activity are centered in Wichita, the largest city in the State. Personal income is derived primarily from private, nonfarm activities that include manufacturing (fabricated metal, machinery, aircraft, food products, chemicals, and petroleum products), trade, and service industries. However, agricultural

Table 18. *Values of transmissivity (T), storage coefficient (S), and hydraulic diffusivity (T/S) for unconsolidated aquifers of the Arkansas and Little Arkansas Rivers in Reno, Harvey, and Sedgwick Counties, compiled from previous investigations*

Source of data	T, in feet squared per day		S, dimensionless		T/S, in feet squared per day	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Williams and Lohman, 1949[1]	6,100	44,000	0.08	0.38	1.6×10^4	5.5×10^5
Lane and Miller, 1965a[2]	3,300	33,000	.20	.20	1.6×10^4	1.6×10^5
Reed and Burnett, 1985[3]	4,900	34,000	.0004	.16	4.1×10^4	4.2×10^7
Spinazola and others, 1985[4]	500	200,000	.15	.15	2.5×10^3	1.3×10^6

[1] Values of transmissibility, an obsolete term, were converted to transmissivity, and values of specific yield were assumed to be virtually equal to the storage coefficient, as is the case in an unconfined aquifer. Values of transmissibility had been determined by pump tests, and specific yields were determined by laboratory analysis of core samples. Maximum hydraulic diffusivity was estimated by dividing maximum observed T by minimum observed S, and minimum hydraulic diffusivity was estimated by dividing minimum T by maximum S.

[2] Values of transmissibility were determined from a map in the report and converted to transmissivity. An average specific-yield value given in the report was assumed to be virtually equal to the storage coefficient. Maximum hydraulic diffusivity was estimated by dividing the maximum observed T by the average S, and minimum hydraulic diffusivity was estimated by dividing minimum observed T by the average S.

[3] These values represent results of pump tests used to determine T and S. In some cases, S values were estimated.

[4] Transmissivity was estimated from maps showing hydraulic conductivity and saturated thickness. The storage coefficient is equivalent to an average specific yield presented in the report. Maximum hydraulic diffusivity was estimated by dividing maximum T by average S, and minimum hydraulic diffusivity was estimated by dividing minimum T by average S.

activities are also important as the Sedgwick County ranked first in the State in number of farms, third in acres harvested, and 10th in crop value during 1984. During 1985, about 45,000 acres were irrigated. The large population and diverse economy of the study area need adequate water supplies.

During 1985, an estimated 134,200 acre-feet of water were used for public supplies (42 percent), irrigation (40 percent), self-supplied industrial use (14 percent), and self-supplied domestic use (4 percent). About 84 percent of the water used was ground water. The city of Wichita, which has annual water-rights appropriations of 40,000 acre-feet from a well field in the *Equus* beds aquifer, 17,900 acre-feet from a local well field, and 52,600 acre-feet from Cheney Reservoir, used 53,500 acre-feet of water during 1985. If the city could fully utilize these existing water rights, public supplies should meet demand until at least 2015.

The Arkansas, Little Arkansas, North Fork Ninnescah, South Fork Ninnescah, and Ninnescah Rivers are the principal streams in the county. Streamflow in the area is directly related to cumulative departure from average precipitation, except for the Ninnescah and North Fork Ninnescah Rivers which are regulated by Cheney Reservoir. In recent years (1975-85), precipitation and streamflow have been near average, except for the Arkansas River where streamflow has declined since 1980, possibly because of increased irrigation or other agricultural practices such as terracing. The streams are sustained by ground-water discharge during times of little or no surface runoff, except for the North Fork Ninnescah River upstream of Cheney Reservoir, which flows primarily in response to surface runoff, and the North Fork Ninnescah River downstream from Cheney Reservoir, which is controlled by the reservoir. Streamflow in the Ninnescah River has been decreased by Cheney Reservoir.

The Arkansas River is in approximate equilibrium with the ground water in the valley-fill deposits north of Wichita but becomes a gaining stream at Wichita. The Little Arkansas and Ninnescah Rivers are gaining streams through the county. However, effects of ground-water withdrawals for public and industrial supplies have decreased gains in localized reaches.

Water in the Arkansas River is a sodium chloride type, with a median dissolved-solids concentration of 1,700 mg/L at Hutchinson and 1,200 mg/L at Derby. The Little Arkansas River has a calcium bicarbonate type water, with a median dissolved-solids concentration of 480 mg/L. The North Fork Ninnescah, South Fork Ninnescah, and Ninnescah Rivers have a sodium chloride type water, with median dissolved-solids concentrations ranging from 590 mg/L for the North Fork Ninnescah River at Cheney Dam to 760 mg/L for the South Fork Ninnescah River near Murdock. The source of sodium and chloride in the Arkansas, North Fork Ninnescah, South Fork Ninnescah, and Ninnescah Rivers is ground water from Permian rocks west of Sedgwick County. Concentrations of principal dissolved constituents in the streams are inversely related to streamflow rates, whereas the concentration of suspended sediment is directly related to streamflow rate.

Chemical and physical erosion rates in major stream basins were estimated from annual loads of dissolved solids and suspended sediment. The Arkansas River basin upstream of Hutchinson has the smallest annual rate of chemical erosion (16.8 tons dissolved solids per square mile) and physical erosion (12.8 tons suspended sediment per square mile). The South Fork Ninnescah River has the largest annual rate of chemical erosion, 206 tons dissolved solids per square mile. The Little Arkansas River has the largest annual rate of physical erosion, 239 tons suspended sediment per square mile.

A low-flow seepage and water-quality survey of area streams was conducted in March 1985. The data indicate that the Arkansas River was losing water in its reaches between 4 miles east of Maize and 21st Street in Wichita and between Derby and Mulvane, possibly because of nearby ground-water withdrawals for industrial and public supplies. Water in the Arkansas River was a sodium chloride type, and concentrations of dissolved solids decreased through the county from 1,800 mg/L near Mount Hope to 1,000 mg/L at Mulvane. The Little Arkansas River gained water in the reach from the town of Sedgwick to its confluence with the Arkansas River in Wichita. Concentrations of dissolved solids increased slightly from 350 mg/L near Sedgwick to 400 mg/L at 37th Street in Wichita. The increase in dissolved solids was caused by sodium chloride water from the Arkansas River moving through the alluvium and into the Little Arkansas River in north Wichita. Water in the Little Arkansas River was a calcium bicarbonate type, except near its confluence with the Arkansas River where it was a mixed calcium sodium bicarbonate chloride type.

The Ninnescah River generally gained streamflow, and concentrations of dissolved solids decreased through the county (water was not being released from Cheney Reservoir), except between Kansas Highway 42 and Clearwater, where streamflow and concentrations of dissolved solids remained constant. Large withdrawals of ground water for industrial supplies west of Clearwater could have caused a local loss of streamflow. Water in the Ninnescah River is a sodium chloride type.

Small streams draining the area generally had water-quality characteristics that were related to the rock types that provided base flow. Streams draining the Wellington Formation, where it occurs at or near the surface east of the Arkansas River, commonly had calcium sulfate type water, with concentrations of dissolved solids greater than 1,000 mg/L. However, small tributary streams to the Little Arkansas River generally had calcium bicarbonate type water, with less than 500 mg/L dissolved solids. Streams draining the uplands between the Arkansas and Ninnescah Rivers, where the Ninnescah Shale and Wellington Formation are overlain by lower Pleistocene (undifferentiated pre-Illinoian age) deposits, and (or) loess and colluvium, generally had calcium bicarbonate type water, with less than 500 mg/L dissolved solids. In the vicinity of the Wichita-Valley Center floodway in west Wichita, water in small streams became a mixed type as sodium chloride type water from the Arkansas River alluvium was gained. Small streams draining the southwest corner of the county, where the Ninnescah Shale is overlain by colluvium, had mixed-ion type water, with less than 1,000 mg/L dissolved solids.

Sewage-treatment plant effluent resulted in increased concentrations of ammonia as nitrogen in the Arkansas River at Derby (1.70 mg/L) and Mulvane (1.5 mg/L), in the Little Arkansas River near Sedgwick (0.62 mg/L), in Cowskin Creek near Maize (0.74 mg/L) and at the Sumner County line (1.20 mg/L), and in West Fork Chisholm Creek near Park City (0.39 mg/L). Evidence of contamination by oilfield brine was detected in the Wichita-Valley Center floodway near Haysville, Prairie Creek 4 miles southeast of Furley, and Whitewater Creek at the Butler County line.

Water-quality data were collected from 14 selected impoundments during October 1985. About two weeks prior to sampling, a large storm had produced considerable runoff, and the impoundments were relatively full. Those in upland areas were turbid and generally had calcium bicarbonate type water, with very small concentrations of dissolved solids, generally less than 100 mg/L. However, agricultural pesticides (atrazine, cyanazine, propazine, and a degradation product, heptachlor epoxide) were detected in 8 of the 14 impoundments. Three sandpit impoundments near the Arkansas River were relatively clear because they receive little runoff and contain primarily ground water. However, they contained sodium chloride type water, with concentrations of dissolved solids ranging from 630 to 1,300 mg/L.

Water-quality characteristics of hypothetical impoundments on the Little Arkansas River at Valley Center and the South Fork Ninnescah River near Murdock were estimated from stream data. An impoundment on the Little Arkansas River would have water with a mean dissolved-solids concentration of about 220 mg/L and would lose about 160 to 310 acre-feet of storage per year to sedimentation. An impoundment on the South Fork Ninnescah River would have water with a mean dissolved-solids concentration of about 560 mg/L and would lose about 59 to 110 acre-feet of storage per year to sedimentation.

Cheney Reservoir contains water that is a sodium chloride type and has a mean dissolved-solids concentration of about 500 mg/L. The reservoir has lost approximately 290 to 530 acre-feet of storage due to sedimentation during 1964 through 1986. During 1985, the city of Wichita withdrew 18,300 acre-feet of water from Cheney Reservoir for public supplies. From 1966 through 1985, Wichita has withdrawn a total of 322,610 acre-feet of water from Cheney Reservoir.

Ground water occurs throughout the study area. The principal aquifer is unconsolidated deposits in the Arkansas River valley that are locally more than 200 feet thick and can yield as much as 2,000 gallons per minute to wells. Unconsolidated deposits in the Ninnescah River valley are thinner, less permeable, and yield less than 500 gallons per minute. Wells in the undifferentiated pre-Illinoian deposits on uplands north of the Ninnescah River yield as much as 50 gallons per minute. Wells in the Ninnescah Shale generally yield less than 10 gallons per minute, as do wells in the Wellington Formation, except when gypsum or anhydrite solution channels are encountered and yields of as much as 350 gallons per minute can be obtained.

Ground water in the county generally moves from upland areas towards streams. In the Arkansas River valley north of Wichita, the ground water moves in the same direction and with the same gradient as the Arkansas River. South of Wichita, ground water moves toward the Arkansas River, as it does in the Little Arkansas River and Ninnescah River valleys. In several areas of the county, particularly in the vicinity of the Wichita well field, ground-water withdrawals have caused cones of depression to form. Upstream from its confluence with the Arkansas River, a low-head dam on the Little Arkansas River has caused the formation of a ground-water mound. With the exception of the Wichita well field, effects of ground-water withdrawals on water levels are minor and localized. Ground-water levels are closely related to cumulative departure from average precipitation.

Ground-water recharge in the area primarily occurs from precipitation and is estimated to average from 0.1 to 8.8 inches per year, depending on local conditions. Approximately 2.88 million acre-feet of water with less than 1,000 mg/L dissolved solids are stored in unconsolidated deposits of the Arkansas, Little Arkansas, and Ninnescah River valleys in Sedgwick County. Ground-water discharge occurs principally through gaining streams (the Arkansas River south of Wichita, the Little Arkansas River, and the Ninnescah River) and is estimated to be about 148,000 acre-feet per year. Ground-water discharge caused by well withdrawals was estimated to be about 112,700 acre-feet during 1985. The maximum rate of ground-water loss through evapotranspiration is estimated to be 3.5 inches per year. However, evapotranspiration from the saturated zone generally occurs only when the depth to water is less than 10 feet.

Analyses of water-quality data collected from 101 wells in Sedgwick County demonstrate the close relationship between geology and water-quality characteristics and indicate some of the potential sources of contamination in the area.

Water from wells in the Wellington Formation commonly is a calcium sulfate type, with more than 1,000 mg/L dissolved solids. The calcium and sulfate are derived primarily from the dissolution of gypsum and anhydrite. Hardness as calcium carbonate commonly approaches or exceeds 1,000 mg/L (primarily as noncarbonate hardness). Water from wells in the Ninnescah Shale is less mineralized and generally has less than 1,000 mg/L dissolved solids because the shale contains less soluble minerals. Dissolved-solids concentrations in water from wells completed in bedrock generally increase with depth because duration of contact between the water and minerals increases. Unconsolidated deposits generally yield calcium bicarbonate water, with less than 500 mg/L dissolved solids, except alluvium adjacent to the Arkansas River north of Wichita where sodium chloride water with more than 1,000 mg/L dissolved solids occurs. Unconsolidated deposits are erosional remnants with few soluble minerals. However, they are more susceptible to contamination from surface sources, such as infiltration of saline water from the Arkansas River north of Wichita.

Ground-water contamination by oilfield brine was indicated in water from 16 wells sampled in the county. These wells generally are in areas of past or present oilfield activities, such as the Gladys oilfield in southern Wichita. Concentrations of nitrite plus nitrate as nitrogen were greater than 10 mg/L in ground water from about 10 percent of the wells sampled. These wells are scattered randomly throughout the county, and the large concentrations probably result from local contamination (surface runoff or infiltration of nitrogen fertilizer, septic fields, or animal wastes). Iron concentrations exceeding 300 µg/L were detected in water from 18 wells. Most of the large concentrations of iron probably can be attributed to corroded steel or galvanized well casings. Manganese concentrations exceeding 50 µg/L were detected in water from 31 wells. All but one of the wells are completed in alluvium or terrace deposits, indicating that the source of manganese probably is organic material in the soil. Herbicides (atrazine, metolachlor, propazine, and simazine) were detected in water from 5 of the 19 wells from which water samples were collected for herbicide analysis. Although none of the herbicides exceeded available U.S. Environmental Protection Agency health advisory levels, the occurrence of several herbicides in water from any well may cause synergistic effects. Volatile organic compounds were analyzed in water samples from only 10 wells. Trichloroethylene was detected in water from one well, but the concentration did not exceed the water-quality criterion. Several other areas in the county have local ground-water contamination caused by volatile organic compounds.

The city of Wichita withdrew about 35,200 acre-feet of water from the Wichita well field during 1985. Since 1940, the city has withdrawn a total of 1,268,400 acre-feet of water from the well field. Earlier investigations estimated a perennial yield of 40,000 acre-feet from the well field, based on an average recharge by precipitation of about 6 inches per year. A recent ground-water modeling investigation indicates that average recharge by precipitation may be only about 3.25 inches, which would decrease the perennial yield to less than 30,000 acre-feet. Recent investigations using ground-water flow and solute-transport models predict that withdrawals at the 1971-79 rate (about 30,000 acre-feet per year) during 1980-2020 would have little effect on ground-water quality in the well field, but water levels would decline about 15 feet. Withdrawals at twice the 1971-79 rate during 1980-2020 would lower water levels an additional 40 feet and significantly increase chloride concentrations in the southern part of the well field. These models indicate that the continuous line source of sodium chloride water in the Arkansas River is a greater threat to the well field than brine contamination from the Burrton oilfield.

Analysis of base-flow recession curves was used to develop estimates of hydraulic diffusivity in the Arkansas River valley (1.6×10^6 feet squared per day) and the Little Arkansas River valley (2.2×10^6 feet squared per day). These hydraulic-diffusivity values are within the range of values determined by aquifer tests during previous investigations.

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