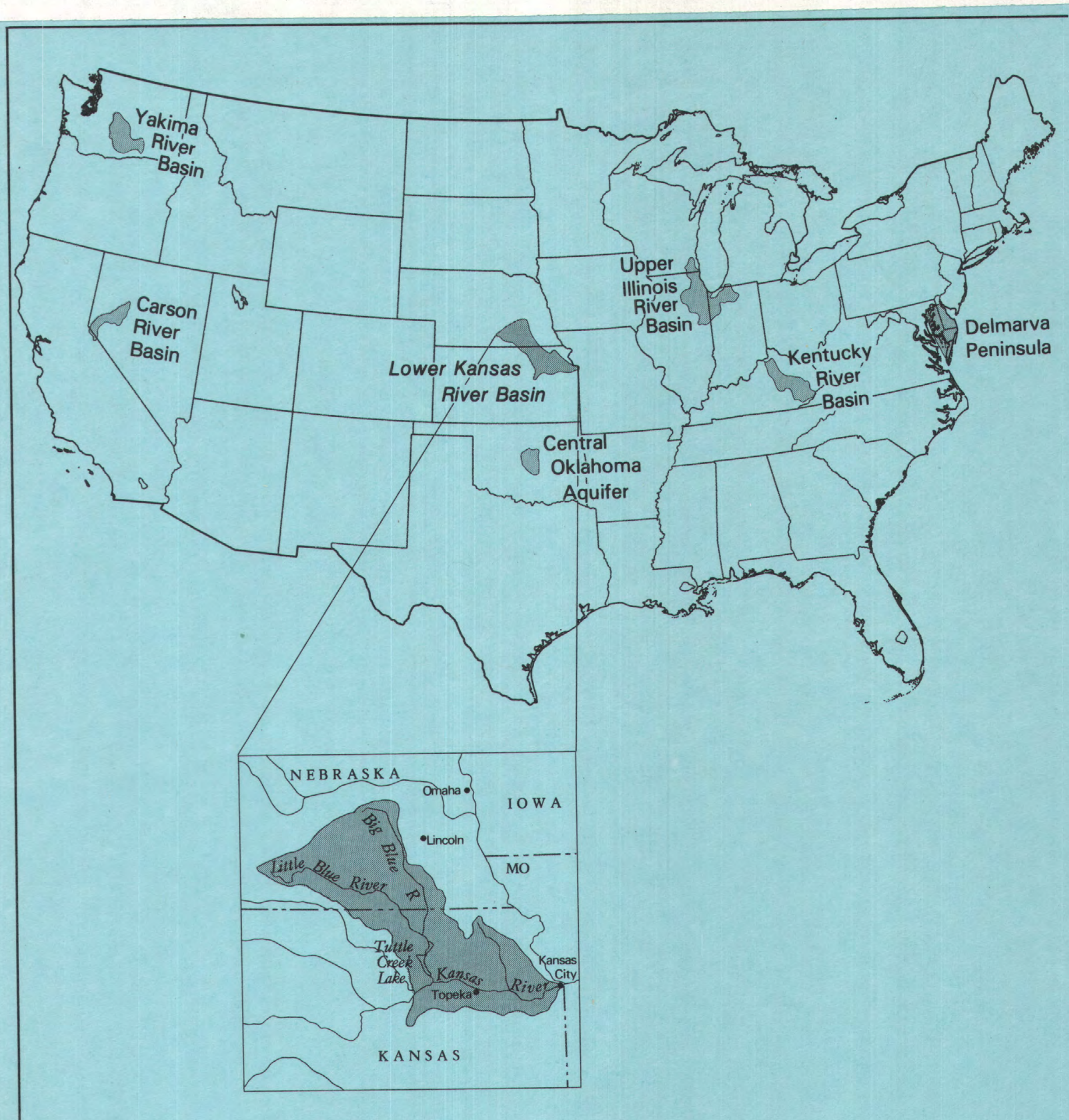
SURFACE WATER-QUALITY ASSESSMENT OF THE LOWER KANSAS RIVER BASIN, KANSAS AND NEBRASKA: ANALYSIS OF AVAILABLE DATA THROUGH 1986



U.S. GEOLOGICAL SURVEY
Open-File Report 91—75

NATIONAL WATER - QUALITY ASSESSMENT PROGRAM

CONVERSION FACTORS

Multiply	By	To obtain
inch	2.54	centimeter
foot	0.3048	meter
yard	0.9144	meter
mile	1.609	kilometer
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.0283	cubic meter per second
gallon per minute (gal/min)	0.06308	liter per second
acre-foot	1,233	cubic meter
pound	0.4535	kilogram
ton	0.9022	megagram
ton per square mile	0.3483	megagram per square kilometer
degree Fahrenheit (°F)	°C = (°F – 32)/1.8 °F = 1.8 (°C) + 32	degree Celsius (°C)

Additional Abbreviations

mL = milliliter
mg/L = milligram per liter
μg/L = microgram per liter
μg/g = microgram per gram
pCi/L = picocurie per liter

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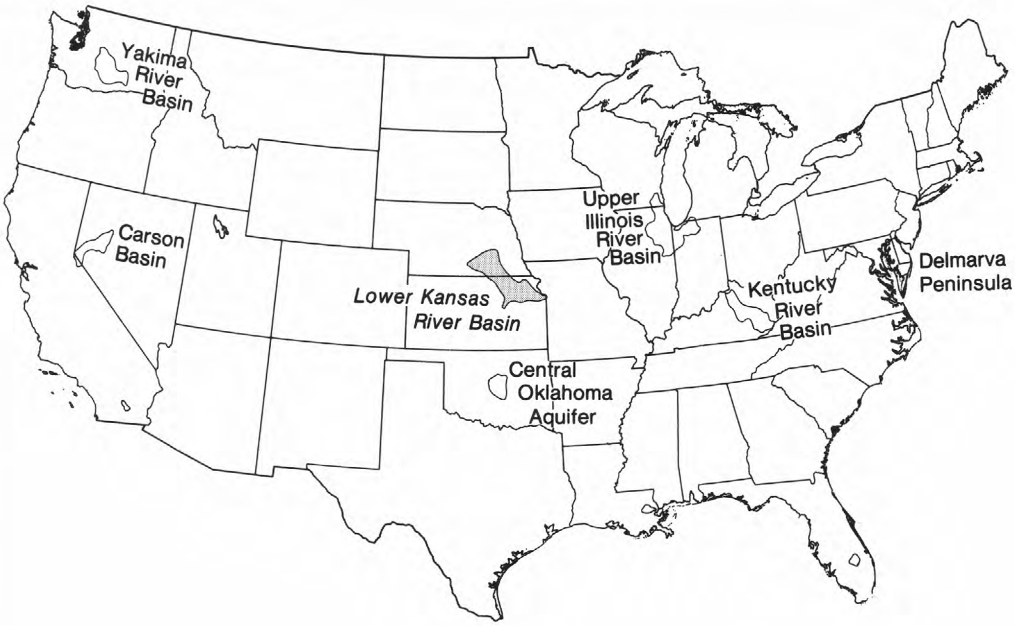
Edited by P.R. Jordan and J.K. Stamer



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Open-File Report 91—75

1991

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
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FOREWORD

One of the great challenges faced by water-resources scientists is providing reliable water-quality information to guide the management and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resources agencies and by academic institutions. Many of these organizations are collecting water-quality data for a host of purposes, including compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research to advance our understanding of water-quality processes. In fact, during the past two decades, tens of billions of dollars have been spent on water-quality data-collection programs. Unfortunately, the utility of these data for present and future regional and national assessments is limited by such factors as the areal extent of the sampling network, the frequency of sample collection, the varied collection and analytical procedures, and the types of water-quality characteristics determined.

To address this deficiency, the Congress appropriated funds for the U.S. Geological Survey, beginning in 1986, to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program that, if fully implemented, would:

1. Provide a nationally consistent description of water-quality conditions for a large part of the Nation's water resources;

2. Define long-term trends (or lack of trends) in water quality; and

3. Identify, describe, and explain, as possible, the major factors that affect observed water-quality conditions and trends.

As presently envisioned, a full-scale NAWQA Program would be accomplished through investigations of a large set of major river basins and aquifer systems that are distributed throughout the Nation and that account for a large percentage of the Nation's population and freshwater use. Each investigation would be conducted by a small team that is familiar with the river basin or aquifer system. Thus, the investigations would take full advantage of the region-specific knowledge of persons in the areas under study.

Four surface-water projects and three ground-water projects are being conducted as part of the pilot program to test and refine the assessment methods and to help determine the need for and the feasibility of a full-scale program. An initial activity of each pilot project is to compile, screen, and interpret available data to provide an initial description of water-quality conditions and trends in the study area. The results of this analysis of available data are presented in individual reports for each project.

The pilot studies depend heavily on cooperation and information from many Federal, State, interstate, and local agencies. The assistance and suggestions of all are gratefully acknowledged.

Philip Cohen
Chief Hydrologist

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SURFACE WATER-QUALITY ASSESSMENT OF THE LOWER KANSAS RIVER BASIN, KANSAS AND NEBRASKA: ANALYSIS OF AVAILABLE DATA THROUGH 1986

Edited by P.R. Jordan and J.K. Stamer

EXECUTIVE SUMMARY

Beginning in 1986, the U.S. Congress appropriated funds for the U.S. Geological Survey to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The long-term goals of the full-scale program are to: (1) provide a nationally consistent description of current water-quality conditions for a large part of the Nation's surface- and ground-water resources; (2) define long-term trends (or lack of trends) in water quality; and (3) identify, describe, and explain, insofar as possible, the major factors that affect current conditions and trends in water quality. This information, obtained on a continuing basis, will be made available to water managers, policy makers, and the public to provide an improved scientific basis for evaluating the effectiveness of water-quality-management programs and for predicting the likely effects of contemplated changes in land- and water-management practices. At present (1990), the assessment program is in a pilot phase in seven areas that represent diverse hydrologic environments and water-quality conditions.

This report completes one of the first activities undertaken as part of the lower Kansas River basin pilot study, which was to compile, screen, and interpret available water-quality data for the study unit through 1986. The report includes information on the sources and types of water-quality data available, the utility of available water-quality data for assessment purposes, and a description of current water-quality conditions and trends and their relation to natural and human factors.

The Lower Kansas River Basin

The lower Kansas River basin drains about 15,300 mi^2 (square miles) in southeast Nebraska and northeast Kansas. The study unit includes the Big Blue River basin in Nebraska and Kansas and other basins of smaller tributaries to the 170-mile reach of the Kansas River from Junction City to its confluence with the Missouri River at Kansas City, Kansas. The Kansas River is formed by the confluence of the Smoky Hill and Republican Rivers at Junction City, Kansas. Three large Federal reservoirs, Tuttle Creek Lake on the Big Blue River, Perry Lake on the Delaware River, and Clinton Lake on the Wakarusa River, lie within the Kansas part of the study unit. These reservoirs have a substantial effect on water quality of the Kansas River.

Mean annual precipitation for 1951-80 ranged from 24 inches in the northwest part of the basin to 36 inches in the southeast and produced mean annual runoff of 2 to 9 inches. During 1971-86, when most of the large reservoirs were in place, outflow from the basin was 8,600 ft^3/s (cubic feet per second), of which the Big Blue River contributed the largest fraction, 27 percent. Surface-water use in 1985 totalled 1.28 million acre-feet, which accounted for about 41 percent of the total water use.

About 85 percent of the study unit is agricultural land and is typical of the midwestern United States agricultural region. Principal row crops are corn, grain sorghum, wheat, and soybeans. Irrigation has increased severalfold in the past few decades in the upper Big Blue River basin in Nebraska. Population of the study unit was about 750,000 in 1980. Urban development represents a very small fraction of total basin land use. The major urban and industrial areas in the basin are the Kansas part of the Kansas City metropolitan area, Topeka, and Lawrence, Kansas.

Sources and Characteristics of Available Surface Water-Quality Data

Most of the data analyzed in the report were collected by the Nebraska Department of Environmental Control, the Kansas Department of Health and Environment (and its predecessor agencies), and the U.S. Geological Survey. Additional data were collected by the U.S. Army Corps of Engineers, the Nebraska Game and Park Commission, and the U.S. Environmental Protection Agency. Other data were collected by researchers at Kansas State University (Manhattan) and the University of Kansas (Lawrence). After initial compilation of data for many sites, available data from 29 sampling stations were determined suitable for the intended purposes. The quantity of data available for the 29 principal sampling stations varied among the groups of constituents examined. For example, more than 4,000 samples were analyzed for pH, alkalinity, major ions, and suspended sediment, and more than 2,500 samples were analyzed for nutrients, dissolved oxygen, and fecal-indicator bacteria, but only about 500 samples were analyzed for major metals in water. Data for dissolved-oxygen concentrations were not representative of the full range of concentrations that can occur during a 24-hour cycle period. Data for about 50 additional sampling stations were analyzed for some constituents or characteristics related to water, sediments, and fish tissue. Most of the available data that were used were in machine-readable format.

Current Water-Quality Conditions and Long-Term Trends

On the basis of existing or proposed Federal water-quality criteria, most streams in the lower Kansas River basin were suitable for uses such as public-water supply, irrigation, and maintenance of aquatic life. However, there were a number of findings of concern in the study unit, which included: (1) increasing trends of dissolved-solids and nitrate concentrations in the northwestern part of the study unit due to increased use of ground water for irrigation and to increased application of fertilizers; (2) large concentrations of dissolved solids, due to chloride, on the main stem of the Kansas River resulting from the inflow of water from the Smoky Hill River; (3) large sediment yields in northeast Kansas due to erodible soils, row-crop production, and large amounts of precipitation and runoff; (4) large concentrations of herbicides in water, particularly during June, July, and August in northeast Kansas, due to the extensive use of atrazine and other herbicides for corn and sorghum production; and (5) large densities of fecal indicator bacteria in the Big and Little Blue Rivers upstream of Tuttle Creek Lake.

Physical properties, inorganic and organic constituents, and biological data were analyzed to define current water-quality conditions, trends in water quality, and to relate, to the extent possible, these conditions and trends to human and natural factors. Summaries of station median values and trends for selected water-quality constituents and properties are presented in tables A and B, respectively.

pH and Major Inorganic Constituents

Streams in the lower Kansas River basin are generally well buffered and slightly alkaline. Station median pH values (table A) were within the range of natural water (6.5-8.5 standard units), and median concentrations of alkalinity met the chronic freshwater-aquatic criterion of not less than 20 mg/L (milligrams per liter) established by the U.S. Environmental Protection Agency. Acidic waters are not a problem in the basin.

The maximum station median concentrations of dissolved solids and major ions (table A) did not exceed Maximum Contaminant Levels (MCL's) or Secondary Maximum Contaminant Levels (SMCL's) established by the U.S. Environmental Protection Agency. However, about 25 percent of the samples collected from the Kansas River at DeSoto, Kansas, contained concentrations of dissolved solids that exceeded the SMCL of 500 mg/L for dissolved solids. In addition, the median station median of 29 mg/L of sodium (table A) exceeded the 20-mg/L recommendation established by the U.S. Environmental Protection Agency for persons on very restricted sodium diets. The Smoky Hill River contributed large concentrations of sodium and chloride ions to the Kansas River as a result of ground-water discharge from underlying aquifers that contain sodium chloride. Concentrations of dissolved solids and major ions decreased downstream along the Kansas River because of dilution by water from the Big Blue River and other tributaries.

Time trends in concentrations of major ions were significant and positive in the upper part of the Big Blue River basin, probably as a result of the increase in application of ground water for irrigation purposes since 1950. Seven of eleven stations had positive trends of flow-adjusted concentrations of dissolved solids with a median slope of 1.4 percent per year (table B).

Suspended Sediment

Suspended-sediment concentrations of predominantly silt and clay were large enough to give the water from the lower Kansas River basin a muddy appearance in many of the samples. From table A, the median station median concentration of suspended sediment was 280 mg/L. **The largest suspended-sediment yields (sediment transport divided by drainage area) occurred in the Dissected Till Plains physiographic sections because of the erodible glacial till, hilly topography, large quantities of precipitation to aid erosion, and large rates of runoff to transport the sediment.**

Time trends in flow-adjusted concentrations of suspended sediment were consistent among six sampling stations and were toward smaller concentrations. Because most of these downward trends occurred after construction of Tuttle Creek and Perry Lakes, it is probable that most of the decreasing trends were a consequence of the use of soil- and water-conservation measures, such as terraces, grassed waterways, and farm ponds. Implementation

Table A.—*Summary of station median values for selected water-quality constituents and properties in lower Kansas River basin, 1978-86 water years*

[Abbreviations: mg/L, milligrams per liter; μg/L, micrograms per liter; μS/cm, microsiemens per centimeter at 25 degrees Celsius; colonies/100 mL, colonies per 100 milliliters; <, less than]

Constituent or property	Number of stations	Concentration or other measure		
		Minimum station median	Median station median	Maximum station median
pH and alkalinity				
pH, in standard units	29	7.7	8.0	8.3
Alkalinity, in mg/L as calcium carbonate	18	145	190	270
Dissolved solids and major ions				
Dissolved solids, in mg/L	10	260	350	440
Specific conductance, in μS/cm	28	340	540	790
Hardness, in mg/L as calcium carbonate	21	120	220	310
Calcium, dissolved, in mg/L	15	38	60	88
Magnesium, dissolved, in mg/L	15	6.0	12	19
Sodium, dissolved, in mg/L	15	5.3	29	57
Potassium, dissolved, in mg/L	12	1.1	9.9	11
Sulfate, dissolved, in mg/L	18	34	60	98
Chloride, dissolved, in mg/L	21	2.0	17	82
Fluoride, dissolved, in mg/L	12	.3	.3	.4
Silica, dissolved, in mg/L	18	9.0	16	29
Suspended sediment				
Suspended sediment, in mg/L	12	17	280	580
Nutrients				
Nitrate, total, in mg/L as N (nitrite plus nitrate, total, in mg/L as N)	21	< .09	1.2	2.3
Nitrogen, ammonia, total, in mg/L as N	22	< .07	.12	.25
Nitrogen, total organic, in mg/L as N	13	.40	1.4	1.9
Nitrogen, total, in mg/L as N	12	2.0	3.2	4.2
Phosphorus, total, in mg/L as P	18	.02	.34	1.0
Phosphorus, dissolved, in mg/L as P	12	.02	.30	.53
Phosphorus, dissolved orthophosphate, in mg/L as P	9	.02	.14	.30
Major metals and trace elements				
Arsenic, total, in μg/L	7	4.0	7.0	10
Barium, total recoverable, in μg/L	5	150	200	300
Boron, total recoverable, in μg/L	9	100	120	160
Cadmium, total recoverable, in μg/L	9	< 1	1.0	1.5
Chromium, total recoverable, in μg/L	10	5.0	10	40
Copper, total recoverable, in μg/L	8	8.0	16	36
Iron, dissolved, in μg/L	16	< 10	30	200
Lead, total recoverable, in μg/L	8	5.0	12	33
Manganese, dissolved, in μg/L	16	2.0	49	260
Mercury, total recoverable, in μg/L	11	< .1	.1	< .5
Selenium, total recoverable, in μg/L	6	< .1	1.0	3.0
Silver, total recoverable, in μg/L	6	< 1	< 1	< 10
Zinc, total recoverable, in μg/L	7	30	70	150
Fecal-indicator bacteria				
Coliform, fecal, in colonies/100 mL	22	28	690	5,000

of additional conservation practices in the Dissected Till Plains, such as removing very erodible land from production, probably could further decrease sediment concentrations in the Kansas River.

Nutrients

Median station concentrations of total nitrate as nitrogen ranged from less than 0.09 to 2.3 mg/L, and median station concentrations of dissolved orthophosphate as phosphorus ranged from 0.02 to 0.30 mg/L (table A). No seasonality of concentrations of nitrate was detected upon analysis of water from several stations that drained predominantly cropland. **Concentrations of nitrogen and phosphorus species were generally larger in water from stations in the Big Blue River basin than from the remaining part of the study unit.** Dissolved forms of nitrate and phosphorus can be readily assimilated by plants, and nutrient enrichment of natural water can encourage blooms of nuisance algae. Sources of nutrients in the study unit include fertilizers, discharges from wastewater-treatment facilities, animal waste, and precipitation.

No measured concentrations of total nitrite plus nitrate as nitrogen in the study unit from 1978-86 exceeded the MCL of 10 mg/L for drinking water established by the U.S. Environmental Protection Agency. During this time period, however, exceedances of the acute ammonia criteria for freshwater-aquatic life occurred in about 2 percent of the samples, and exceedances of the chronic ammonia criteria for freshwater-aquatic life ranged from less than 1 to 7 percent of the samples. Exceedances of the acute and chronic ammonia criteria in water occurred only at stations in the Big Blue River basin.

Mean annual transport of total phosphorus in the Big Blue River near Manhattan, Kansas, was much smaller than the sum of the sources into Tuttle Creek Lake. Thus, the lake seems to be retaining much of the total phosphorus associated with suspended sediment that is trapped in the lake. **Transport of nutrients (nitrogen and phosphorus) in the lower Kansas River basin was affected much more by agricultural nonpoint sources than by point sources; point sources contributed generally less than 10 percent of the total transport of nitrogen and phosphorus.** About one-half of the phosphorus transported by streams was associated with suspended sediment. If soil-erosion control practices were to be implemented to a greater extent within the study unit, these practices might further decrease suspended-sediment and phosphorus discharge to streams and lakes and possibly increase lake productivity.

Flow-adjusted concentrations of total nitrate in water had increasing trends in the Big Blue River and its tributaries in Nebraska during 1968-86. No statistically significant trends were observed elsewhere in the basin. Increases in total nitrate ranged from 1.2 percent per year (1968-86) in water from the Big Blue River at Barneston, Nebraska, to 6.0 percent per year (1970-86) in water from Lincoln Creek near Seward, Nebraska. Trends in total nitrogen also increased and were significant in the Big Blue River basin. **These trends were consistent with the increased amount of nitrogen fertilizer applied in the northwestern part of the basin.** Time trends in concentrations of total ammonia were significant and downward in water from most stations in the study unit. Decreases in flow-adjusted concentrations of total ammonia ranged from 4.5 to 19 percent per year. The decrease in concentrations of ammonia can be attributed, in part, to improved farming practices and, in part, to an increase in the level of wastewater treatment that began with the passage of the Water Pollution Control Act Amendments of 1972 (Public Law 92-500). **Time trends in flow-adjusted concentrations of total phosphorus were downward in the northwestern part of the basin but increased or were not significant elsewhere. The general downward trends in total phosphorus in the northwestern part of the basin were consistent with decreasing time trends in flow-adjusted suspended-sediment concentrations (table B).**

Major Metals and Trace Elements

Analysis of available data on major metals and trace elements in streambed sediments within the lower Kansas River basin, compared with data from soils and surficial materials in the entire conterminous United States, showed that 10 elements had appreciably larger concentrations within the lower Kansas River basin. These elements were barium, cobalt, lanthanum, lead, magnesium, nickel, phosphorus, sodium, strontium, and uranium. The larger concentrations may indicate some human-induced enrichment or simply some differences in the regional surficial geology as compared to the rest of the conterminous United States. For example, large concentrations of barium showed a clustering in the northwestern part of the study unit that appears to be related to the loess deposits in that part of the basin.

The data for water showed no appreciable differences in the distribution of concentrations of major metals and trace elements, with the exception of total iron and total and dissolved manganese, which were larger in the northwestern part of the basin. The only meaningful comparison of median concentrations of the major metals and trace elements that could be made to published data for surface water throughout the United States was for concentrations of dissolved iron and manganese. Median concentrations of dissolved iron and manganese were 30 and 49 $\mu g/L$ (micrograms per liter), respectively, which were considerably larger than the typical dissolved-iron concentration of 10 $\mu g/L$ and the expected solubility for uncomplexed manganese in surface water of 5.5 $\mu g/L$. The larger median concentrations of dissolved iron and manganese measured at stations in the study unit may reflect colloidal iron and manganese that can pass through a 0.45-micrometer filter during sample processing.

For all major metals and trace elements, the acute freshwater-aquatic criteria were exceeded by 10 percent of the 1,032 water samples analyzed, the chronic freshwater-aquatic criteria were exceeded by 36 percent of 1,153 samples, and the drinking-water MCL's were exceeded by 3 percent of 693 samples.

Table B—*Summary of water-quality trends for selected constituents and properties in lower Kansas River basin*

[Trend slopes reported in percent per year except for flow-adjusted pH, which is reported in standard units per year. Trend slopes not significant at 0.1 probability level were not included in determination of median slopes. —, not applicable]

Constituent or property	Trends of unadjusted concentration or property					Trends of flow-adjusted concentration or property				
	Number of stations	Increasing trends		Decreasing trends		Number of stations	Increasing trends		Decreasing trends	
		Number	Median slope	Number	Median slope		Number	Median slope	Number	Median slope
<u>pH and alkalinity</u>										
pH, in standard units	22	14	0.23	3	-0.42	18	14	0.030	4	-0.034
Alkalinity, as calcium carbonate	15	6	10	4	-.67	15	7	.78	7	-1.2
<u>Dissolved solids and major ions</u>										
Dissolved solids	11	8	.92	3	-1.4	11	7	1.4	4	—
Specific conductance	23	15	.92	1	-1.0	23	18	1.2	0	—
Hardness, as calcium carbonate	20	13	.64	4	-.76	20	15	1.8	5	—
Calcium, dissolved	16	12	.55	1	—	16	15	2.1	1	—
Magnesium, dissolved	16	12	.89	1	—	16	14	2.0	2	—
Sodium, dissolved	16	12	.74	2	—	15	13	1.5	2	-3.4
Potassium, dissolved	13	9	1.1	4	-2.4	8	6	1.4	2	-2.0
Sulfate, dissolved	18	13	2.0	3	-2.0	18	15	1.7	3	—
Chloride, dissolved	19	8	2.4	10	-2.5	18	12	1.8	5	-2.9
Silica, dissolved	12	3	1.7	4	-.96	11	5	1.8	6	-1.1
<u>Suspended sediment</u>										
Suspended sediment	8	0	—	8	-7.4	8	0	—	6	-8.1
<u>Nutrients</u>										
Nitrate, total, as N (nitrite plus nitrate, total, as N)	14	13	4.5	1	—	10	9	3.2	1	—
Nitrogen, ammonia, total, as N	13	1	—	11	-8.4	8	0	—	8	-11
Nitrogen, total ammonia plus organic, as N	9	7	5.3	2	-3.2	7	1	—	6	-6.0
Nitrogen, total, as N	7	6	3.2	0	—	7	5	2.2	2	—
Phosphorus, total, as P	12	5	3.5	5	-6.8	10	3	6.1	7	-5.5
<u>Major metals and trace elements</u>										
Boron, total recoverable	6	1	3.1	4	-3.4	0	—	—	—	—
Boron, dissolved	11	1	—	4	-4.0	5	1	—	4	-2.6
Iron, dissolved	8	3	4.4	4	-12	5	3	4.4	2	—
Manganese, dissolved	8	0	—	6	-4.2	5	1	—	4	-6.5
<u>Fecal indicator bacteria</u>										
Coliform, fecal	13	6	8.9	5	-9.8	11	1	—	10	-12

Total-recoverable iron and mercury accounted for one-half of the chronic freshwater-aquatic exceedances. Of these, total-recoverable iron had the largest percentage of exceedances (81 percent) of any major metal or trace element. The occurrence of the iron exceedances was mostly in the Big Blue River basin and its tributaries, although a large percentage of occurrences were in water samples from the Kansas River at DeSoto, Kansas. Because the chronic freshwater-aquatic criterion for iron of 1,000 μg/L is not hardness dependent and because the criterion is for total-recoverable iron, a large number of exceedances is not unexpected in view of the fact that iron is an abundant element and most of the exceedances occurred during periods of high streamflow rates when suspended-sediment concentrations were large. To further illustrate this point, only 0.2 percent of the concentrations of dissolved iron exceeded the chronic freshwater-aquatic criterion.

Concentrations of total-recoverable copper and zinc accounted for about 89 of the 104 exceedances of the acute freshwater-aquatic criteria. All of the measured exceedances occurred in the Big Blue River and its tributaries. Similar to iron, the number of concentrations of dissolved copper and zinc that exceeded the acute freshwater-aquatic criteria were quite small compared to total-recoverable copper and zinc exceedances.

Drinking-water MCL's for major metals and trace elements had the smallest percentage of exceedances (3 percent). Total-recoverable barium and lead accounted for 21 of the 22 exceedances, with barium having the largest percentage of these exceedances, which occurred in water from the Big and Little Blue River basins. Exceedances by barium in this part of the study unit may be related to the clustering of large barium concentrations in the streambed sediments in the northwestern part of the basin. However, a comparison of dissolved concentrations of barium and lead to the drinking-water MCL's indicates that only 2 of the 147 samples analyzed exceeded the drinking-water MCL's, and the two exceedances were concentrations of dissolved lead in water from the Little Blue River near Hollenberg, Kansas.

Results of time-trend tests for concentrations of major metals and trace elements in water showed little consistency (table B). Unadjusted concentrations of boron showed decreasing trends, but flow-adjusted concentrations of dissolved iron showed increasing trends. Two of the three increasing trends in dissolved iron were in water from the Big and Little Blue River basins and may be associated with increasing use of ground water for irrigation.

Trend tests were done for 14 major metals and trace elements in water from the Kansas River at DeSoto, Kansas. Statistically significant trends were identified for dissolved iron, dissolved manganese, and total zinc, all of which showed decreasing trends. Point sources can account for only a small part of the total transport of these metals. In addition, major metals and trace elements at other stations showed statistically significant trends; however, insufficient information was available to determine the causes of these long-term trends.

Fish can accumulate in their tissue many metals and trace elements; thus, fish are good indicators of the presence of these elements that might otherwise be undetected in water or sediment. Fish that have been analyzed typically include bottom-feeding fish such as channel catfish and common carp. Median and 90th-percentile concentrations of cadmium, copper, and zinc in the lower Kansas River basin were larger than corresponding nationwide concentrations. No obvious relationship could be seen between concentrations of these elements in fish, in streambed-sediment samples, and in water samples from the study unit.

Pesticides and Other Synthetic-Organic Compounds

Large amounts of corn, grain sorghum, wheat, and soybeans are produced in the lower Kansas River basin, and large quantities of agricultural pesticides are applied to increase crop productivity. Of the 10 pesticides that were applied in the largest quantities in the basin in 1982, atrazine, alachlor, trifluralin, and 2,4-D accounted for 82 percent of the total.

Pesticides were detected in surface-water and streambed-sediment samples. **Triazine and other nitrogen-containing herbicides were the most frequently detected pesticides in water, and they occurred in the largest concentrations. They included atrazine (61 percent of 458 samples), metolachlor (44 percent of 313 samples), and alachlor (27 percent of 419 samples).** These compounds are frequently detected in water because they are used in large quantities, are generally water soluble, and are relatively persistent. Dieldrin was the most frequently detected organochlorine insecticide in water (3 percent of 732 samples). Diazinon was the most frequently detected organophosphorus insecticide in water (25 percent of 57 samples), and 2,4-D was the most frequently detected chlorophenoxy acid herbicide in water (14 percent of 369 samples).

Atrazine and alachlor most frequently exceeded the proposed drinking-water MCL's of 3.0 and 2.0 μg/L, respectively. The largest concentrations of atrazine, metolachlor, and alachlor in water occurred in June, July, and August.

Organochlorine insecticides and PCB's have been detected in streambed sediments, whereas organophosphorus insecticides and herbicides have not. One or more organochlorine insecticides were detected in 96 percent of the samples of fish tissue (52 of 54 samples). PCB's were detected in 88 percent of the fish-tissue samples (28 of 32 samples). Concentrations of organochlorine insecticides and PCB's in several fish-tissue samples exceeded the National Academy of Sciences and National Academy of Engineering guidelines for the protection of fish-eating birds and mammals. Most of the exceedances were due to chlordane, but PCB's also exceeded the guidelines in some samples.

Fecal-Indicator Bacteria

Many water samples analyzed for fecal-coliform bacteria exceeded the Kansas criterion of 2,000 colonies per 100 mL (milliliters) for secondary-contact recreational uses, such as fishing. Eighteen to 74 percent of the fecal-coliform densities in water samples from the Little Blue and Big Blue Rivers and their tributaries in Nebraska exceeded the Kansas recreational criterion. Median station densities ranged from 28 to 5,000 colonies per 100 mL (table A). Median bacterial densities along the Kansas River were variable and did not follow a consistent pattern. However, fecal-coliform densities tended to be largest downstream from wastewater-treatment plant effluents. In the Big Blue River near Manhattan, Kansas, which is downstream from Tuttle Creek Lake, 98 percent of the samples had fecal-coliform densities less than the criterion. Bacterial densities in water directly downstream from a lake commonly are less than those in streams feeding the lake due to several factors, such as long residence time in the lake, which allows for settling of sediment-transported colonies.

Time trends of flow-adjusted fecal-coliform densities in the study unit were toward smaller densities (table B). Decreases of fecal-coliform bacteria that were statistically significant ranged from 8.4 percent per year in the Kansas River at DeSoto, Kansas, to 15 percent per year in the Kansas River at Wamego, Kansas.

Aquatic Biological Community

Available information did not permit characterization of regional water quality and detection of alterations using phytoplankton and periphyton populations as indicators. However, short-duration studies and studies of localized problems in Tuttle Creek and Perry Lakes indicated that the productivity of these lower life forms in the aquatic food chain was less than in most North American reservoirs because of turbidity.

Studies of macroinvertebrates by the Kansas Department of Health and Environment indicated that water quality has not severely hindered the macroinvertebrate communities in the Kansas part of the study unit. Studies of macroinvertebrates by the Nebraska Department of Environmental Control indicated that the benthic communities in larger streams of the Big Blue River basin in the Nebraska part of the study unit were slightly healthier than those in larger streams of the Little Blue River basin; the health of benthic communities in smaller streams in both of these basins was very similar.

Surface-water impoundments destroy habitat for fish species adapted only to flowing water; however, impoundments provide new habitat for fish suited to more lentic conditions. **Overall, diversity of fish in the study unit may have increased as a result of reservoir development.** However, three fish species, the blue sucker, paddlefish, and sauger, are no longer found or are rare upstream of the dam that was constructed before 1900 on the Kansas River at Lawrence, Kansas.

INTRODUCTION

Background

Beginning in 1986, the Congress appropriated funds for the U.S. Geological Survey to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The NAWQA Program is designed to address a variety of water-quality issues that include chemical contamination, acidification, eutrophication, salinity, sedimentation, and sanitary quality. The long-term goals of the program are to:

1. Provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources;
2. Define long-term trends (or lack of trends) in water quality; and
3. Identify, describe, and explain, as possible, the major factors that affect current conditions and trends in water quality.

This information will provide water managers, policy makers, and the public with an improved scientific basis for evaluating the effectiveness of water-quality management programs and for predicting the likely effects of contemplated changes in land- and water-management practices.

The NAWQA Program is organized into study units on the basis of known hydrologic systems (Leahy and others, 1990). For ground water, the study units cover large parts of aquifers or aquifer systems, and for surface water, the study units are major river basins. The study units are large, ranging from a few thousand to several tens of thousands of square miles.

The pilot phase of the assessment program covers seven study units representing a diversity of hydrologic environments and water-quality conditions. The seven pilot study units include four that focus primarily on surface water and three that focus primarily on ground water. The subject of this report is the lower Kansas River basin, which consists of the Kansas River and its drainage area downstream from the confluence of the Republican and Smoky Hill Rivers to the confluence with the Missouri River as shown in figure 1. The other surface-water pilot study units are the Yakima River basin in Washington; the Upper Illinois River basin in Illinois, Indiana, and Wisconsin; and the Kentucky River basin in Kentucky. The ground-water pilot study units cover the Carson basin in Nevada and California; the Central Oklahoma aquifer in Oklahoma; and the Delmarva Peninsula in Delaware, Maryland, and Virginia.

Purpose and Scope

A large amount of water-quality data has been collected in the United States by a diverse group of organizations for a variety of purposes. One of the first activities to be undertaken in each pilot study was a compilation, screening, and interpretation of available water-quality data for the study unit. This preliminary analysis was used to help establish priorities and help formulate plans for the study's field activities.

This report presents the results of the analysis of available information for the lower Kansas River basin in Kansas and Nebraska. More specifically, the purposes of the report are to describe to the extent possible:

- Current water-quality conditions in the lower Kansas River basin,
- Long-term trends in water quality that have occurred over recent decades, and
- Relations of current conditions and trends in water quality to natural and human factors.

The scope of the report covers information describing the sources and types of water-quality data that are available, a preliminary assessment of water-quality conditions and trends, and a discussion of the utility of available water-quality data for assessment and implications for future data collection and analysis.

Acknowledgments

The authors and editors wish to thank the various Federal and State agencies and members of the lower Kansas River basin Liaison Committee for their cooperation in providing information and data that were used in preparing this report. Specifically, the authors and editors are grateful to Region VII of the U.S. Environmental Protection Agency, the Nebraska Department of Environmental Control, the Nebraska Game and Parks Commission, the Kansas Department of Health and Environment, the Kansas Department of Wildlife and Parks, the Division of Water Resources of the Kansas State Board of Agriculture, the Kansas Biological Survey, and Frank Cross, Professor, Department of Systematics and Ecology, University of Kansas, Lawrence, for their assistance during the preparation of this report. The assistance in interpretation of major metals and trace elements in streambed sediments provided by Robert Clark and Kenneth Watts of the U.S. Geological Survey is greatly appreciated.

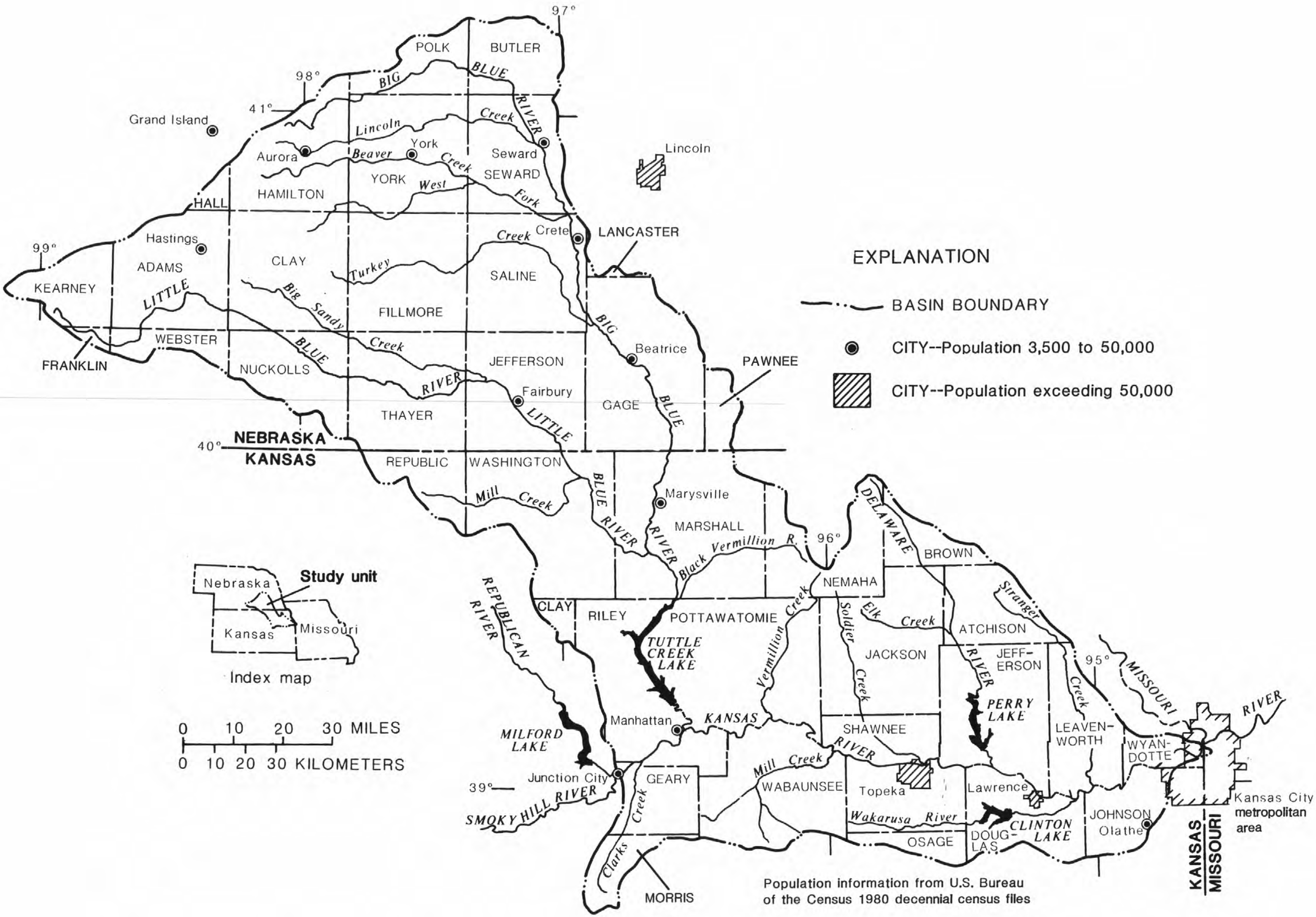

Figure 1.—Major streams, surface-water impoundments, cities, and other geographic features in and near lower Kansas River basin, Kansas and Nebraska.

DESCRIPTION OF LOWER KANSAS RIVER BASIN

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The lower Kansas River basin drains about 15,300 mi^2 and coincides with the area defined by the U.S. Water Resources Council as hydrologic subregion 1027 (Seaber and others, 1984). Although 7.5 mi^2 of the subregion lies within Missouri, drainage from this small area near the confluence of the Kansas and Missouri Rivers does not affect the quality of water used within the study unit and is not included in the study. The study unit does include the Big Blue River basin in Nebraska and Kansas, as well as basins of smaller tributaries to the 170-mile reach of the Kansas River from Junction City to Kansas City, Kans. (fig. 1).

The Kansas River is formed by the confluence of the Smoky Hill and Republican Rivers at Junction City, Kans. Three large Federal reservoirs, Tuttle Creek Lake on the Big Blue River, Perry Lake on the Delaware River, and Clinton Lake on the Wakarusa River, lie within the Kansas part of the study unit (fig. 1).

Physiography, Topography, and Soils

Land forms in the lower Kansas River basin are characterized by the four physiographic sections shown in figure 2 (Fenneman, 1946). The High Plains and Plains Border sections are parts of the Great Plains province. Smooth plains with little local relief dominate the High Plains section; fluvial and eolian deposits comprised of sand, gravel, silt, and clay underlie this part of the study unit. The generally flat topography of the High Plains provides gentle stream gradients that contribute to only limited stream dissection and rather broad, poorly defined valleys. The flat topography has contributed also to a lack of external drainage in some areas.

The Plains Border physiographic section is more dissected than the High Plains and thus has greater local relief. It is underlain by shale, sandstone, and limestone, and minor fluvial and eolian deposits. The drainage pattern in the Plains Border section is more defined than in the High Plains section. Stream channels are characteristically narrow, well established, and bounded by a perceptible series of terraces.

The Dissected Till Plains and Osage Plains sections are parts of the Central Lowland province. The Dissected Till Plains section is characterized by dissected deposits of glacial till comprised of silt, clay, sand, gravel, and boulders that overlie bedrock of primarily shale and limestone, with some sandstone. Maximum local relief is from 300 to 500 feet in the downstream part of the Big Blue River basin and generally less than 300 feet elsewhere. Drainage channels are well entrenched by tributaries flowing south to the Kansas River.

The Osage Plains are south of the limit of glaciation and are underlain primarily by shale and limestone, with some sandstone. The Osage Plains in Riley, Geary, and Wabaunsee Counties, Kans., are underlain principally by cherty limestone and are known locally as the Flint Hills. Local relief in the Osage Plains section is generally less than 300 feet but exceeds 300 feet in parts of the Flint Hills. Drainage patterns are well defined although dissection of the land is less than in the Dissected Till Plains.

In both the Osage Plains and the Dissected Till Plains physiographic sections, alluvial and terrace deposits comprised of sand, gravel, silt, and clay occur in major stream valleys. The Kansas River, from Junction City to Kansas City, generally separates the Osage Plains from the Dissected Till Plains in a broad, flat alluvial valley bounded by rolling hills.

Soil characteristics are important to an understanding of the overall hydrology of the study unit. From the principal hydrologic characteristics of permeability, slope, depth to the seasonally high water table, and thickness of the soil profile, the potential for such processes as overland runoff, infiltration, ground-water recharge, evapotranspiration, and irrigation can be assessed.

The soils of the uplands are slightly to moderately permeable, whereas those along the major drainage systems, both in flood plains and terraces, are more permeable. Only in isolated areas in the upper part of the Little Blue River drainage are very permeable sandy soils found. Soil slopes are an expression of the topography and directly affect overland-runoff potential and infiltration. In the High Plains section, the slopes are minimal, typically less than 3 percent. In the remainder of the study unit, the extensive dissection causes soil slopes to generally exceed 10 percent. Extensive areas of soil having seasonally high water tables (less than 6 feet from the surface) are found only along the flood plain of the Kansas River. Soils having shallow profiles over bedrock generally are along the Kansas-Nebraska border south and west of the Little Blue River.

Land Use

Land use in the lower Kansas River basin (fig. 3) is typical of the agricultural region of the midwestern United States. Types of agricultural uses are affected by the physiographic and topographic characteristics of the different parts of the study unit. Agriculture accounts for about 95 percent of the land use in the

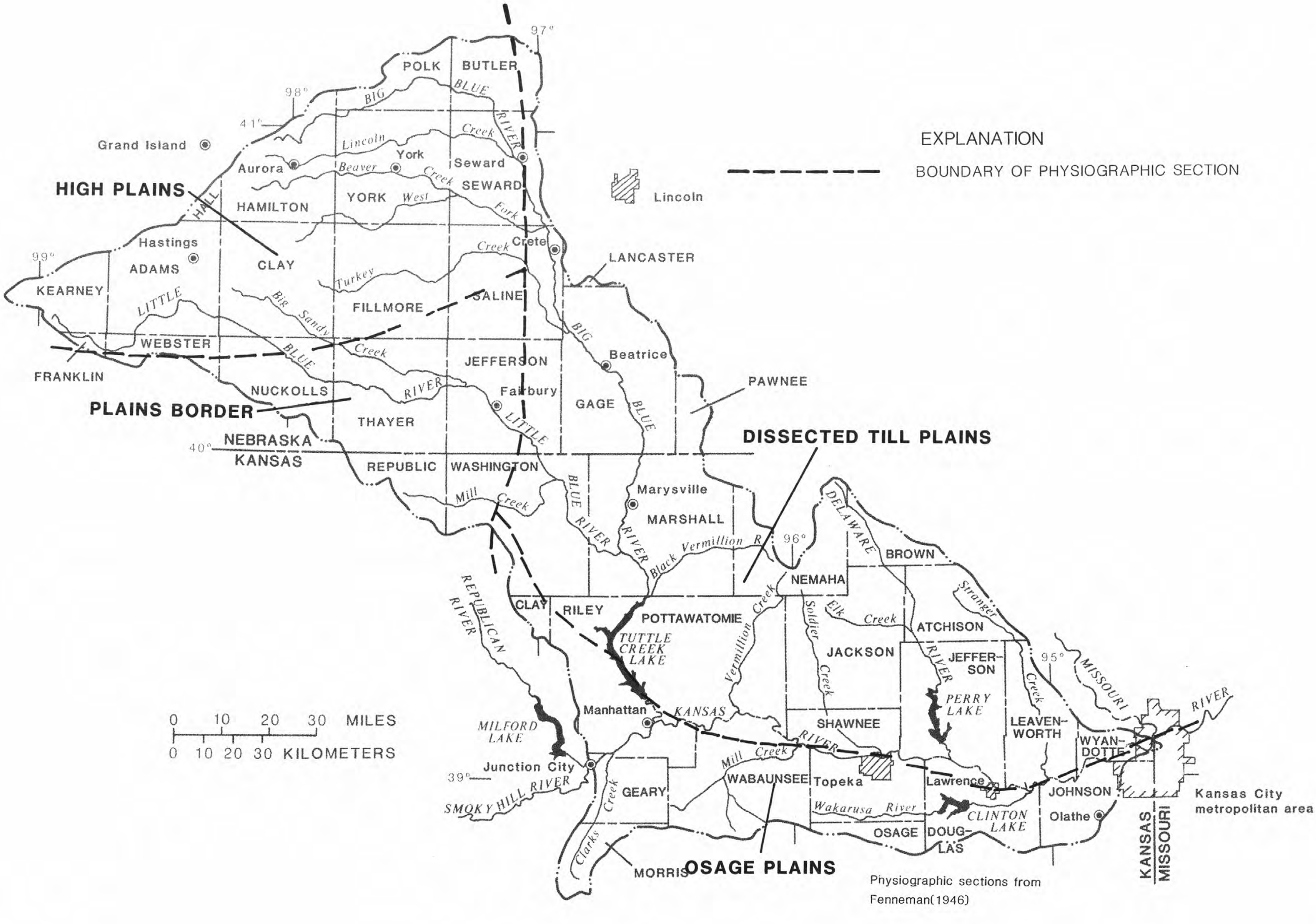

Figure 2.—Physiographic sections in lower Kansas River basin.

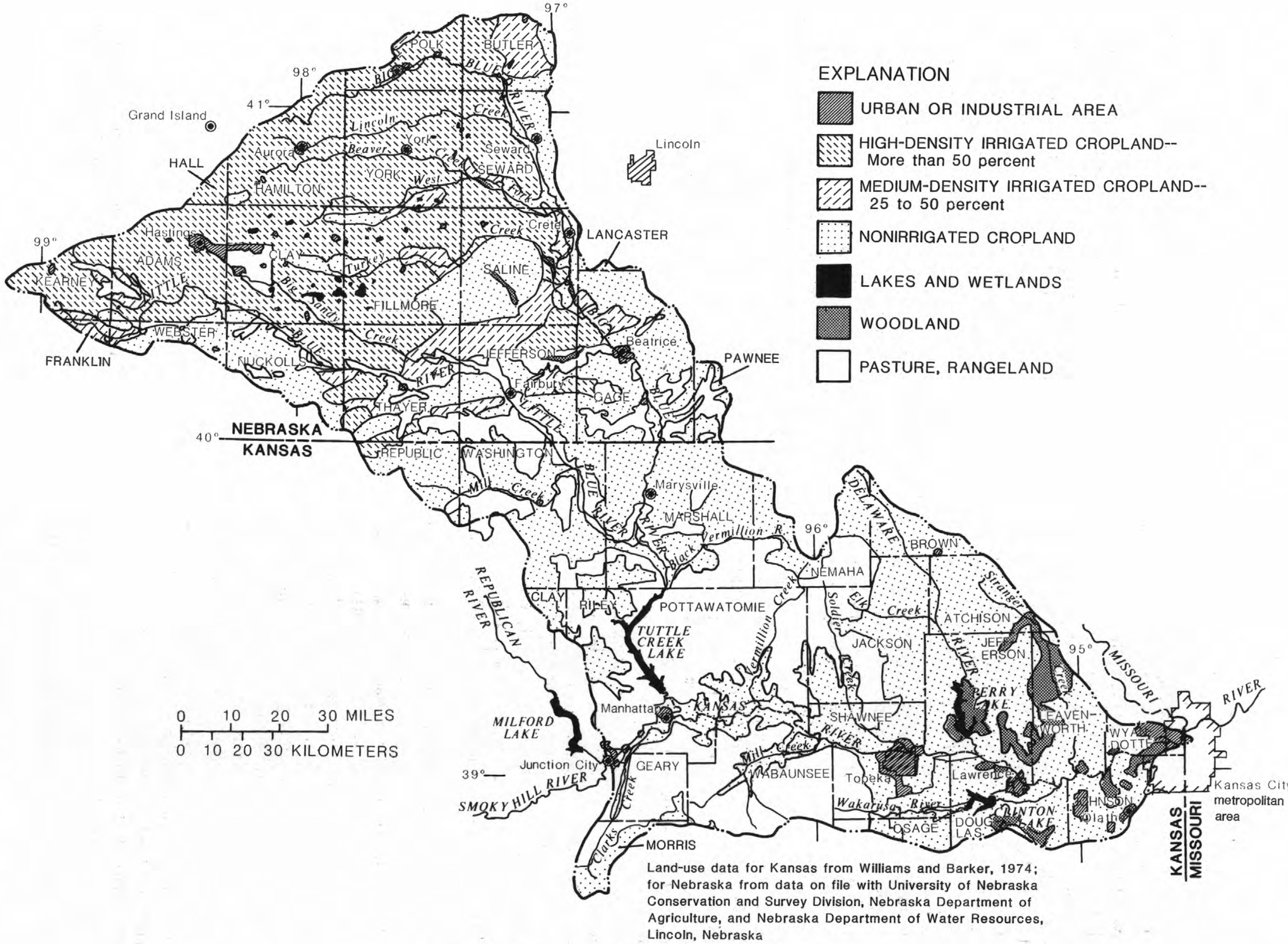

Figure 3.—Land use in lower Kansas River basin.

High Plains and Plains Border physiographic sections. More than 75 percent of the agricultural land in this part of the study unit is used for cultivated crops, and the balance is used principally as pasture. The principal crops in this part of the study unit, ordered by decreasing acreage, are corn, grain sorghum, wheat, and soybeans. The most intensely cultivated part of the study unit is in the High Plains section, in which about 85 percent of the agricultural land is cultivated. In this area, soil, topography, and ground-water availability are well suited for cultivated and irrigated crops. Although the area has long been used for cultivated crops, the amount of irrigation has increased severalfold since 1950, as shown in figure 4 for three representative counties. In the Plains Border section of the study unit, about 70 percent of the agricultural land is used for nonirrigated, cultivated crops, and the remainder is used for pasture.

Land use in the Dissected Till Plains and the Osage Plains also is predominantly agricultural. These sections are characterized by more topographic relief and less ground-water availability than the area of the basin that lies in the High Plains and Plains Border sections; thus, the area is less suited for cultivated and irrigated crops. The exception is the Kansas River flood plain and terrace area, which has low relief and good availability of ground water. Irrigation is practiced along much of the Kansas River, in areas too small to be shown in figure 3. Principal crops in the Dissected Till Plains and Osage Plains are grain sorghum, wheat, corn, soybeans, and hay. The Flint Hills area in Riley, Geary, and Wabaunsee Counties, Kansas, is mostly rangeland, and the remaining area in the Dissected Till Plains and Osage Plains is mixed cropland (30-60 percent) and pasture.

Wetlands, as defined by Cowardin and others (1979, p. 3), are capable of providing all or some of the life requirements for a myriad of wildlife. In the lower Kansas River basin, riverine wetlands are important nursery areas for larval fish. They also contain large numbers of species that have a preference for a particular habitat type, such as gar, carp, red shiner, and bluegill. Lacustrine wetlands are primarily in the deeper areas of oxbow lakes and in upstream reaches of Tuttle Creek, Perry, and Clinton Lakes. They support populations of centrarchid game fish, such as largemouth bass, crappie, and bluegill. Marshy areas of oxbow lakes provide spawning and nursery habitat for both forage and game fish where the lakes are connected to the Kansas River or its tributaries during wet seasons. The palustrine marshes (perched pothole wetlands) of the upper Big and Little Blue River basins are shallow and provide little if any fishery resource but are important for migratory waterfowl and other wildlife.

Urban development represents a very small fraction of the total basin land use. The major urban and industrial areas in the basin are the Kansas part of the Kansas City metropolitan area, Topeka, and Lawrence, Kans. The industrial area near Hastings, Nebr. (fig. 3) is larger than the city itself, but development in the area is very low density. Although the Kansas City metropolitan area is at the downstream end of the basin and has little effect on the Kansas River, some of its water supplies are affected by activities in the basin. Other land uses, such as forest, water, and mining, also occupy a very small part of the total area of the basin. The population of the study unit was about 750,000 in 1980 (U.S. Bureau of the Census 1980 decennial census files).

Climate

Climate in the lower Kansas River basin is characterized by hot, humid summers and cold winters with no particular dry season. July is normally the warmest month in the basin with a mean temperature of about 25 °C (degrees Celsius), and January is normally the coldest month with a mean temperature

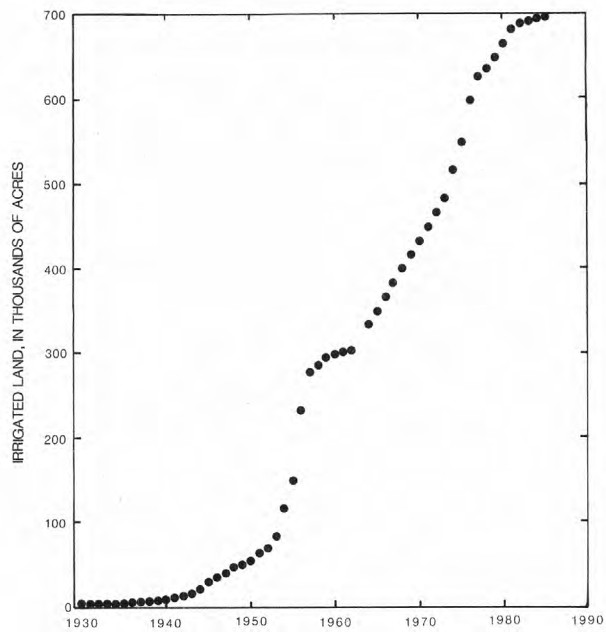

Figure 4.—Total irrigated acreage in Adams, Butler, and Hamilton Counties, Nebraska, 1930-85 (from data on file with the Nebraska Department of Water Resources, Lincoln).

of about -4 °C. Mean annual temperatures range from about 11 °C in the northwestern part of the basin to about 12 °C in the southeast. (Except as noted, climatic data are from the National Oceanic and Atmospheric Administration, 1951-80.)

Precipitation in the basin is the most significant climatic factor for agriculture and surface-water availability because of both temporal and spatial variability. The 1951-80 mean annual precipitation ranged from about 24 inches in the northwestern part of the basin to about 36 inches in the southeast (fig. 5). Extreme variability, however, characterizes annual precipitation patterns. For example, from 1951 to 1980, annual precipitation on large parts of the basin has ranged from less than 15 inches to more than 50 inches. The potential for drought, both short and long term, is always great within the basin. The potential for periodic flooding caused by excessive precipitation and runoff is equally great.

About 75 percent of the precipitation in the basin normally occurs during the warm season, April through September (see fig. 5), which coincides for the most part with the growing season. Precipitation during the growing season, however, is not always sufficient to provide optimal soil-moisture conditions for most crops grown in the study unit. Thus, where water supplies are plentiful, irrigation is a common practice.

Potential evapotranspiration, an indicator of energy available for consumptive water use, ranges from about 48 inches per year in the western part of the basin to about 42 inches per year in the northern part (Dugan and Peckenpaugh, 1985, based on Jensen-Haise technique). During the growing season, potential evapotranspiration normally exceeds precipitation, and during the nongrowing season, evapotranspiration is less than precipitation. Because of minimal evapotranspiration demands, the nongrowing season is, therefore, the most effective time for precipitation to replenish soil moisture and to recharge the ground-water system.

Surface-Water Hydrology

The Republican and Smoky Hill Rivers, which join to form the Kansas River at Junction City, Kans., both begin in the plains of eastern Colorado and flow about 500 miles eastward to their confluence (fig. 1). Thus, the Kansas River at its beginning receives streamflow from a drainage area of about 45,000 mi^2. The Republican River, although it drains more than one-half of the area, provides only about one-third of the mean flow (about 2,600 ft^3/s) entering the lower Kansas River study unit, and the Smoky Hill River provides the other two-thirds of the flow.

The largest tributary downstream from Junction City is the Big Blue River, which originates in Nebraska as does its principal tributary, the Little Blue River. The Big Blue River enters the Kansas River at Manhattan, Kans. Other principal tributaries that drain from the north to the Kansas River are Vermillion Creek, Soldier Creek, the Delaware River, and Stranger Creek. The drainage to the Kansas River from the south is much smaller than that from the north and includes Clarks and Mill Creeks and the Wakarusa River.

Although the basin contains many ponds and lakes, three large Federal reservoirs provide most of the surface-water storage. Tuttle Creek Lake on the Big Blue River has a sedimentation pool of 211,500 acre-feet, a conservation pool of 177,100 acre-feet, and a flood-control pool of 1,937,000 acre-feet. In 1986, Tuttle Creek Lake was used for flood control, low-flow augmentation, and recreation, but allocations for water supply were being studied. Perry Lake on the Delaware River has a conservation and sedimentation pool of 225,000 acre-feet and a flood-control pool of 517,500 acre-feet. Perry Lake is used for flood control, recreation, and public-water supply. Clinton Lake on the Wakarusa River has a conservation and sedimentation pool of 129,100 acre-feet and a flood-control pool of 268,400 acre-feet. Clinton Lake is used for flood control, recreation, and public-water supply.

Runoff in the study unit varies areally as determined by precipitation, vegetation, topography, soil, and geology, and seasonally in response to precipitation and evapotranspiration. The 50-percent increase in mean annual precipitation from about 24 inches in the northwest to about 36 inches in the southeast (fig. 5) is accompanied by a 350-percent increase in mean annual runoff from less than 2 inches in the northwestern part of the study unit to almost 9 inches in the southeast (fig. 6). Mean monthly runoff is largest in the spring and summer and smallest in the late fall and early winter (fig. 6).

The mean flow rate of the Kansas River at its confluence with the Missouri River during 1971-86 was about 8,600 ft^3/s, of which the Big Blue River contributed about 27 percent; the Smoky Hill River, 19 percent; the Republican River, 12 percent; the Delaware River, 9 percent; and smaller tributaries, the remaining 33 percent. Streamflow characteristics (table 1) were calculated from the entire period of record through 1986 for U.S. Geological Survey streamflow-gaging stations that measure unregulated flow, and from a period of record representing conditions of regulated flow at sites where flow is regulated by major reservoirs.

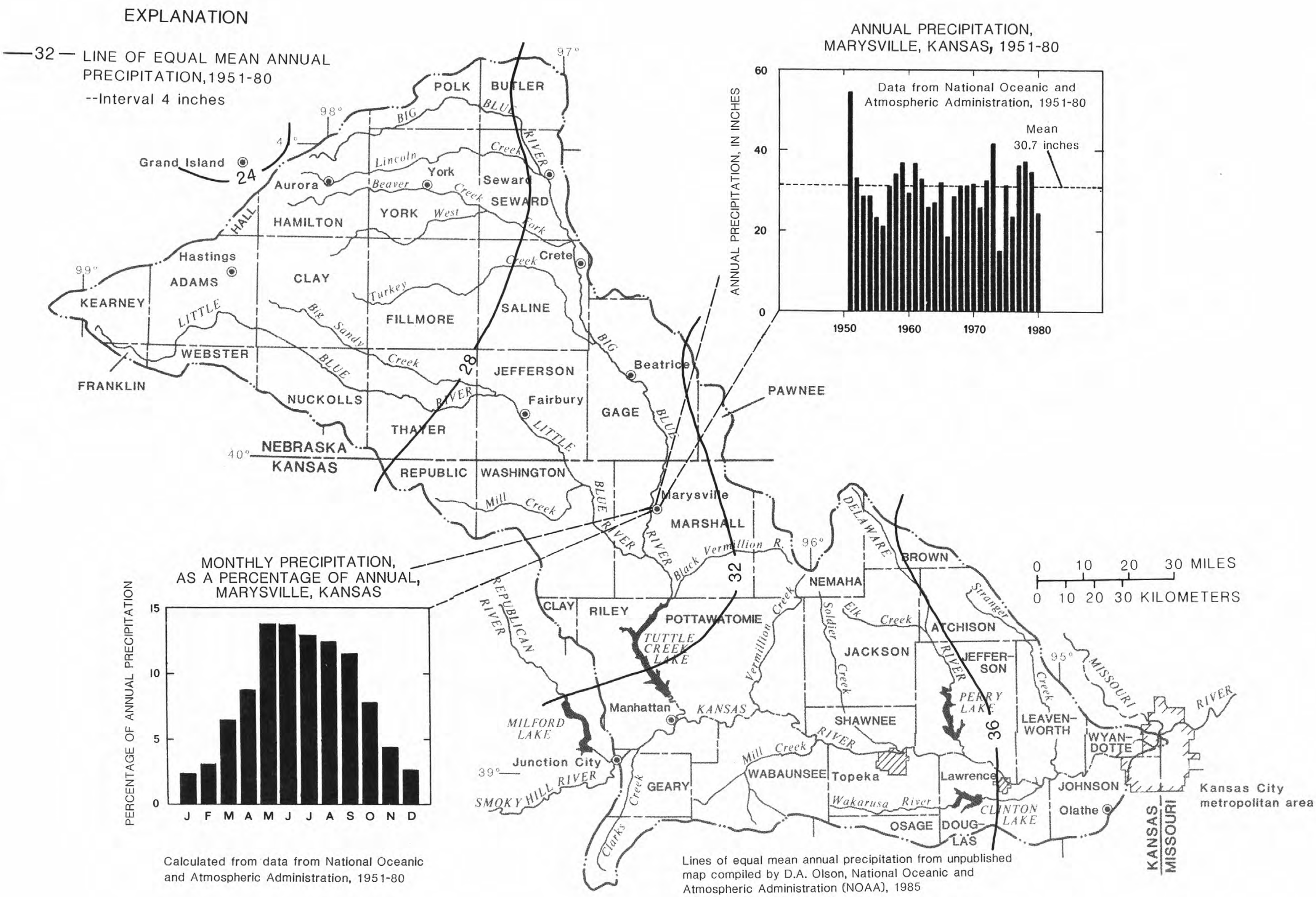

Figure 5.—Areal distribution of mean annual precipitation, 1951-80, and annual and monthly distribution of precipitation at Marysville, Kans.

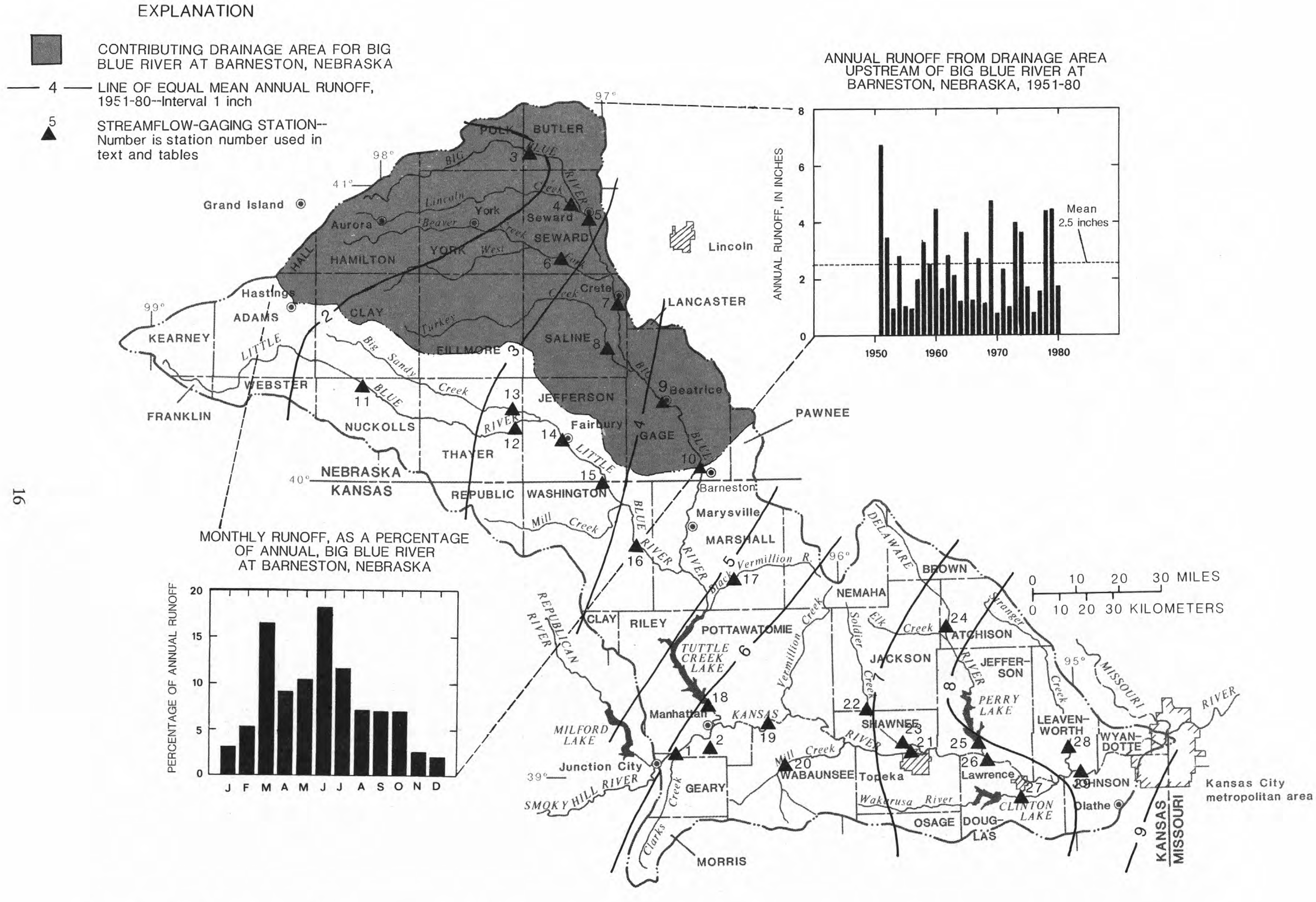

Figure 6.—Areal distribution of mean annual runoff, 1951-80, location of streamflow-gaging stations for which streamflow characteristics are shown in table 1, and annual and monthly distribution of runoff from drainage area upstream of Barneston, Nebraska.

Table 1.—*Streamflow characteristics for selected streamflow-gaging stations in lower Kansas River basin*

[Streamflow is in cubic feet per second. Exceedance frequency is percentage of time that indicated streamflow was equaled or exceeded. Index of variability, dimensionless, is the 10-percent minus the 90-percent exceedance-frequency streamflow divided by the median streamflow. —, not determined]

Station number (fig. 6)	U.S. Geological Survey number	Station name	Streamflow data used (water years)	Drainage area (square miles)	Mean streamflow	7-day, 10-year low flow	Streamflow for indicated exceedance frequency 90	50 (median)	10	Index of variability
1	06879100	Kansas River at Fort Riley, Kans.	1968-86	44,870	2,640	220	424	1,330	6,320	4.4
2	06879650	Kings Creek near Manhattan, Kans.	1980-86	4.09	2.76	—	0	.73	7.0	9.6
3	06879900	Big Blue River at Surprise, Nebr.	1965-86	345	28.9	0	0	.92	32.7	35.5
4	06880000	Lincoln Creek near Seward, Nebr.	1953-73, 1975-86	446	51.3	2.7	6.3	13.0	76.1	8.1
5	06880500	Big Blue River at Seward, Nebr.	1955-86	1,099	129	1.5	10.9	26.1	219	8.3
6	06880800	West Fork Big Blue River near Dorchester, Nebr.	1959-86	1,206	182	24	43.0	79.5	310	3.4
7	06881000	Big Blue River near Crete, Nebr.	1953-86	2,716	390	16	72.1	136	721	4.8
8	06881200	Turkey Creek near Wilber, Nebr.	1960-86	460	92.4	.2	4.0	16.6	129	7.5
9	06881500	Big Blue River at Beatrice, Nebr.	1911-15, 1975-86	3,900	745	33	100	244	1,690	6.5
10	06882000	Big Blue River at Barneston, Nebr.	1933-86	4,447	828	35	93.7	253	1,720	6.4
11	06883000	Little Blue River near Deweese, Nebr.	1954-72, 1975-86	979	144	10	43.1	70.5	200	2.2
12	06883570	Little Blue River near Alexandria, Nebr.	1960-72, 1975-86	1,557	245	—	57	107	390	3.1
13	06883940	Big Sandy Creek at Alexandria, Nebr.	1980-86	607	119	—	20	30.9	154	4.3
14	06884000	Little Blue River near Fairbury, Nebr.	1909-15, 1929-86	2,350	380	45	91.9	162	589	3.1
15	06884025	Little Blue River at Hollenberg, Kans.	1975-86	2,752	533	5.0	104	213	931	3.9
16	06884400	Little Blue River near Barnes, Kans.	1959-86	3,324	682	51	126	265	1,340	4.6
17	06885500	Black Vermillion River near Frankfort, Kans.	1954-86	410	158	.1	3.5	25.9	229	8.7
18	06887000	Big Blue River near Manhattan, Kans.	1965-86	9,640	2,350	—	166	948	6,480	6.7
19	06887500	Kansas River at Wamego, Kans.	1968-86	55,280	5,450	390	881	2,820	13,600	4.5
20	06888500	Mill Creek near Paxico, Kans.	1955-86	316	183	0	4.0	58.8	347	5.9
21	06889000	Kansas River at Topeka, Kans.	1968-86	56,720	6,230	540	1,040	3,170	15,800	4.7
22	06889200	Soldier Creek near Delia, Kans.	1959-86	157	100	.01	3.7	21.9	164	7.3
23	06889500	Soldier Creek near Topeka, Kans.	1930-32, 1936-86	290	144	0	1.6	29.7	247	8.3
24	06890100	Delaware River near Muscotah, Kans.	1970-86	431	296	.5	7.3	56.9	513	8.9
25	06890900	Delaware River below Perry Dam, Kans.	1971-86	1,117	746	—	22.4	102	2,250	21.8
26	06891000	Kansas River at Lecompton, Kans.	1971-86	58,460	7,600	750	1,150	3,740	19,500	4.9
27	06891500	Wakarusa River near Lawrence, Kans.	1981-86	425	300	—	14.9	60.0	1,080	17.8
28	06892000	Stranger Creek near Tonganoxie, Kans.	1930-86	406	238	0	2.1	40.0	437	10.9
29	06892350	Kansas River at Desoto, Kans.	1971-86	59,756	8,630	800	1,280	4,480	22,600	4.8

Flow in the Big and Little Blue Rivers generally is well sustained during dry weather by ground-water contributions (Ellis, 1981, p. 44). Thus, surface-water quality during low flow is affected by ground-water quality although the effect is not quantitatively known. Although wells completed in sandstone, which underlies parts of the Plains Border, western Dissected Till Plains, and western Osage Plains physiographic sections, yield as much as 100 gal/min (gallons per minute) (Bayne, 1975), little is known about the quantity of ground water contributed to streams in these areas. Ground water is scarce in the uplands of the central and eastern parts of the Dissected Till Plains and Osage Plains where bedrock is primarily shale with thin strata of limestone and sandstone. Wells in buried-valley aquifers north of the Kansas River yield as much as 500 gal/min (Bayne, 1975). The extent of hydraulic connection of these aquifers to streams varies considerably within the area, thus the effect of buried-valley aquifers on the quantity and quality of water in the streams ranges from negligible to significant.

Considerable interchange of water occurs between the Kansas River and its 1- to 2.5-mile wide alluvial aquifer. During periods of high river stage, the river provides recharge to the aquifer. During lengthy dry-weather periods, the alluvial aquifer contributes an estimated 1 to 4 ft^3/s of flow per river mile to the Kansas River (Fader, 1974). The exchange of water probably has a significant effect on quantity and quality of water in both the river and the aquifer; however, quantitative studies of those effects have not been conducted.

Water Use

Water use in the lower Kansas River basin in 1985 totaled about 2.6 million acre-feet (calculated from data on file with the U.S. Geological Survey, Lawrence, Kans., and Lincoln, Nebr.) The location of major municipal and industrial water withdrawals (greater than 1,000 acre-feet per year) and sources of supply in the study unit are shown in figure 7. Irrigation withdrawals account for about 1.2 million acre-feet of the total water use and are predominantly ground water from the High Plains aquifer and the alluvial aquifer along the Kansas River and partly surface water from the Big and Little Blue Rivers and the Kansas River. Irrigation accounts for about 90 percent (about 0.8 million acre-feet) of the consumptive use of water in the basin. Other major uses having significant (more than 25 percent) consumptive components are self-supplied industry and thermoelectric power generation (115,000 acre-feet), and public supply (142,000 acre-feet).

Surface-water use was about 1.3 million acre-feet per year, which accounts for about 50 percent of the total water use. Surface water is used instream, nonconsumptively, for hydroelectric power (1.0 million acre-feet per year) and offstream for self-supplied industry and thermoelectric power generation (91,000 acre-feet per year), irrigation (82,000 acre-feet per year), and public supplies (86,000 acre-feet per year). Surface-water withdrawals for offstream use are mainly from the Kansas River, and the water is used within counties adjoining the river.

Stream and Lake Classification and Associated Water-Quality Criteria

Water-quality regulatory agencies of Kansas and Nebraska have taken slightly different approaches to stream classification. Although both States in 1986 had classified streams or stream segments for noncontact or secondary contact recreational use, Kansas additionally designated points (defined as 200 yards long) for contact recreation, whereas Nebraska applied the criteria for contact recreation to the same stream segments (miles long) as for other uses. Kansas designated streams for drinking-water use if their quality was potentially suitable for such use after appropriate treatment, whether or not the stream was being used currently for that purpose. Nebraska designated stream segments for public drinking water only if that use was being made currently. In the following abbreviated summary, the only uses discussed will be recreation, aquatic life, and drinking-water supply. Other uses designated by the State classifications, such as livestock watering, will not be discussed here.

Kansas stream classifications and associated water-quality criteria are described in detail by the Kansas Department of Health and Environment (Fromm and Wilk, 1988). The quality criteria in general are based on the harmful effects of substances that originate from artificial sources, turbidity, nutrients, pH, temperature, dissolved oxygen, residual chlorine, toxic substances, and fecal-coliform bacteria. The entire lengths of the Kansas and Big Blue Rivers are designated for noncontact recreation, aquatic life, and drinking-water supply. Nine points on the Kansas River and one point on the Big Blue River are designated for contact recreation. On other streams in the lower Kansas River basin, 16 points are designated for contact recreation, and 37 streams are designated for noncontact recreation, aquatic life, and drinking-water supply.

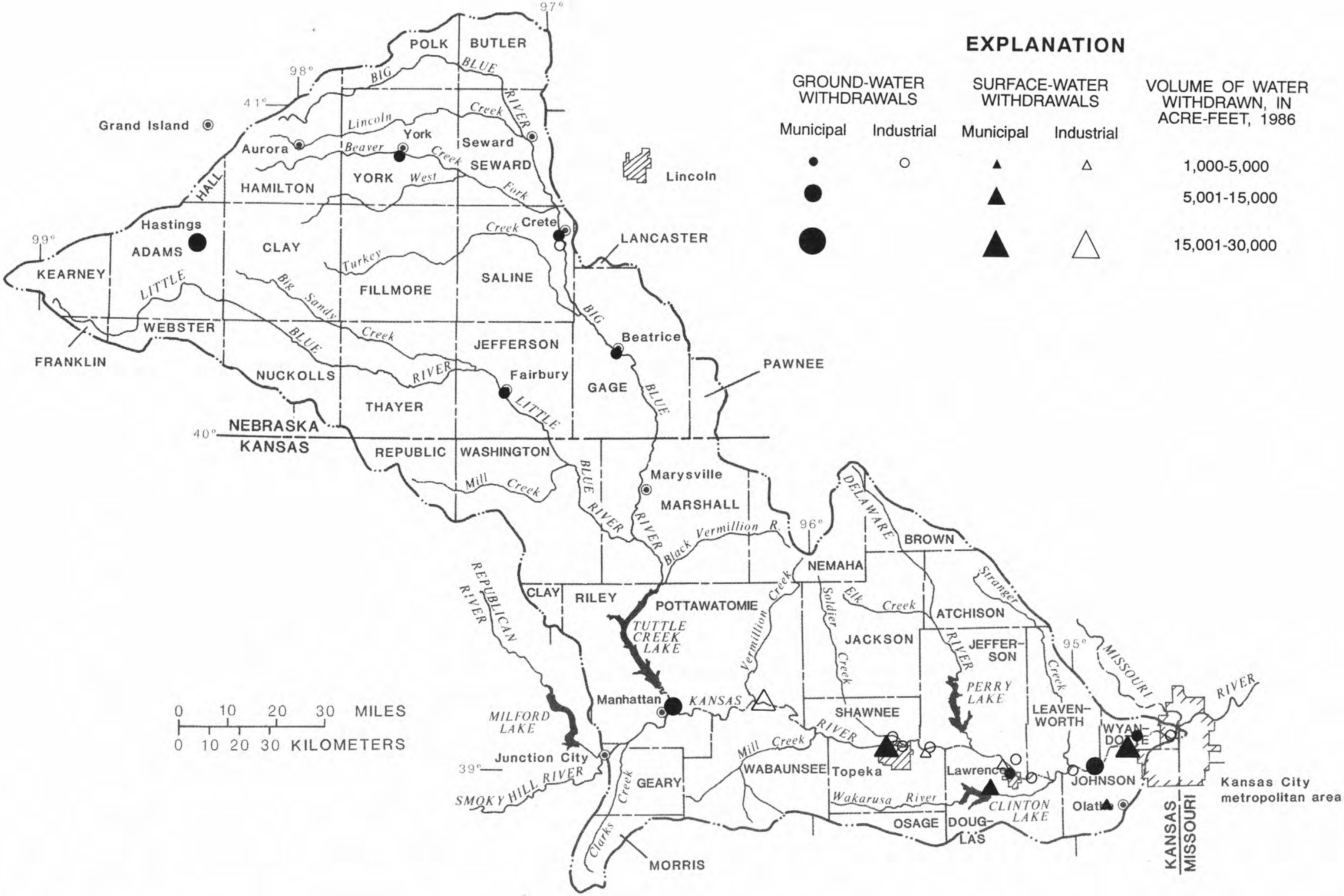

Figure 7.—Location of major municipal and industrial water withdrawals in lower Kansas River basin (water rights or estimated withdrawals of more than 1,000 acre-feet per year).

Nebraska stream classifications in effect in 1986 and associated water-quality criteria are described by the Nebraska Department of Environmental Control (1986, p. 12, 29-33, and 55-59). The criteria considered chemical information, fecal-indicator bacteria, toxic substances, suspended sediment, and biological information. Of the 415 stream miles in the lower Kansas River basin within Nebraska that had been classified, 272 miles were assigned the designation "Recreation Class B (secondary contact)," and none were assigned "Recreation Class A (primary contact)." In addition, 360 stream miles were assigned the aquatic-life designation "Warmwater Class A," 55 miles were assigned "Warmwater Class B," and none were assigned a "Coldwater" designation. No stream miles were designated for "Public Drinking Water Supply."

ASSESSMENT APPROACH

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U.S. Geological Survey

Selection of Constituents and Properties for Analysis

The National Water-Quality Assessment Program has a set of water-quality constituents and properties that comprise the target variables on which the Program focused (Hirsch and others, 1988). The inorganic constituents and properties that have been selected are shown in table 2. They were selected based primarily on their effects on human health, ecosystems, and agriculture, and on their relevance to water-quality issues (Hirsch and others, 1988). Many of the constituents are listed because of regulatory purposes, such as those developed under the Safe Drinking Water Act of 1987. Water temperature is not discussed in this report because preliminary analysis showed apparent site-to-site variability that resulted only from differences in the number of observations made during different seasons and times of day. Actual differences in temperature resulting from human factors could not be determined without extensive modeling.

Suitability of Water-Quality Data

Sample-collection methods are important for obtaining reliable data that can be interpreted with confidence. The U.S Geological Survey uses depth-integrated water samples from at least three verticals in the stream cross section to guard against nonrepresentative results due to lack of mixing of inflows and for constituents that are associated with suspended sediment. For constituents not associated with suspended sediment, data from other agencies were used if at least three verticals were used or if the flow was known to be well mixed within the distance downstream from possible point sources of constituents. For most streams in the study unit, the stream-channel and flow characteristics indicate good mixing due to narrowness or braiding of the channel during low-flow conditions and increased turbulence during high-flow conditions. For constituents associated with suspended sediment, samples were not used for this report unless they were known to be depth-integrated at three or more verticals in the cross section (Guy and Norman, 1970).

Laboratory analyses were considered reliable if they were performed by the U.S. Environmental Protection Agency or a laboratory certified by the U.S. Environmental Protection Agency, by the U.S. Geological Survey, or by a laboratory participating in the standard-reference-sample quality-control program of the U.S. Geological Survey.

A critical need, and one that often is more difficult to evaluate, is for accurate recording and transcribing of data into machine-readable formats. Two procedures were followed for evaluation of this factor. One was the examination of the description and longitude-latitude coordinates shown for each set of data. If the description and coordinates did not agree, the data set was not used. The other procedure was the examination of data by plotting and tabulating as described later in this section of the report.

Methods of Data Analysis

This section describes the methods of data analysis that were used in two or more sections of this report; any method used in only one section is described in that section. The methods were used to examine the available surface-water-quality data for suitability for analysis, for assessing current (1978-86) water-quality conditions, and for the analysis of long-term trends.

Analysis of Suitability

For the purpose of judging the suitability of available data for analysis, preliminary examinations of the available data were performed for the stations that had been sampled repeatedly. Examinations for each water-quality characteristic at each sampling station consisted of (1) tabulating the number of analyses by year, by month, and by decile of streamflow rate; and (2) plotting of analyses by year, by month, by streamflow rate, and by specific conductance.

As a result of these preliminary examinations, a few data values were identified as being erroneous and either were corrected or deleted. However, some erroneous values undoubtedly remain undetected. The examinations showed that, for most water-quality characteristics at most stations that were sampled repeatedly, the data were collected in all months, with fewer analyses in January and February. The data generally represented all deciles of streamflow rates and were not greatly concentrated in one or a few deciles. The number of analyses by year varied greatly for different constituents or properties.

Assessment of Current Water-Quality Conditions

Methods used for assessing current water-quality conditions included: (1) summarizing data, (2) comparing available data with water-quality criteria, and (3) calculating constituent transport. To summarize data and assess current conditions, a relatively short recent period of available data had to be chosen. All available data could not be used because long-term time trends may exist for many constituents at many stations. In addition, for many constituents present in very small concentrations, the detection levels and methods of reporting data have changed through time. Finally, large reservoirs, which affect streamflow and some constituents, have been completed at different times in and upstream from the study unit. After evaluating these considerations, the 1978-86 water years (Oct. 1–Sept. 30) were selected to represent current conditions. This selection provides the following advantages: (1) The 9-year period is short enough to exhibit little change for most constituents that may have long-term trends; (2) detection levels and methods of reporting data have been more consistent during 1978-86 than at prior times; and (3) the most recent large reservoir, either in or upstream from the study unit, that affects

Table 2.—*Selected inorganic constituents and properties, their principal environmental effects, and their association with the water-quality issues addressed by the National Water-Quality Assessment Program (NAWQA)*

[Modified from Hirsch and others (1988, table 3). −, no environmental effect or association with NAWQA water-quality issues; +, environmental effect or association with NAWQA water-quality issues]

Constituent or property	Principal effects			Water-quality issues				
	Human health	Ecosystems	Agri-culture	Toxic contamination	Nutrient enrichment	Acidification	Salinity	General suitability
pH, alkalinity, and acidity								
pH	−	+	−	−	−	+	−	−
Alkalinity	−	+	−	−	−	+	+	+
Acidity	−	+	−	−	−	+	−	−
Dissolved solids and major ions								
Dissolved solids	−	+	+	−	−	−	+	+
Calcium	−	+	+	−	−	+	+	+
Magnesium	−	+	+	−	−	+	+	+
Sodium	+	+	+	−	−	+	+	+
Sulfate	+	+	−	−	−	+	+	+
Chloride	−	+	+	−	−	+	+	+
Fluoride	+	−	−	+	−	−	−	−
Nutrients								
Nitrate	+	+	+	+	+	+	−	−
Nitrite	+	+	+	+	+	−	−	−
Ammonia	−	+	−	+	+	−	−	−
Total nitrogen	−	+	−	−	+	−	−	−
Total phosphorus	−	+	−	−	+	−	−	−
Orthophosphate	−	+	−	−	+	−	−	−
Dissolved oxygen								
Dissolved oxygen	−	+	−	−	−	−	−	+
Major metals and trace elements								
Aluminum	−	+	+	+	−	+	−	−
Antimony	+	+	−	+	−	−	−	−
Arsenic	+	+	+	+	−	−	+	−
Barium	+	−	−	+	−	−	−	−
Beryllium	+	−	−	+	−	−	−	−
Boron	−	−	+	−	−	−	+	−
Cadmium	+	+	−	+	−	+	−	−
Chromium	+	+	−	+	−	+	−	−
Copper	−	+	+	+	−	+	−	−
Iron	−	−	−	−	−	−	−	+
Lead	+	+	−	+	−	+	−	−
Manganese	−	−	−	−	−	−	−	+
Mercury	+	+	+	+	−	+	−	−
Molybdenum	+	−	+	+	−	−	+	−
Nickel	+	−	−	+	−	+	−	−
Selenium	+	+	+	+	−	−	+	−
Silver	−	+	−	+	−	−	−	−
Vanadium	+	−	−	+	−	−	−	−
Zinc	−	+	−	+	−	+	−	−
Radionuclides								
Gross alpha	+	−	−	+	−	−	−	−
Gross beta	+	−	−	+	−	−	−	−

streamflow and constituents in the study unit is Clinton Lake on the Wakarusa River, which began storage in November 1977.

Selected percentiles of the available data at each site are provided in the summary tables to indicate the central tendency and the typical variation of the data. The median was selected as the measure of central tendency of the data because it is insensitive to extreme values. The 25th and 75th percentiles span the central one-half of the analyses and thus provide information on both central tendency and variation. The 10th and 90th percentiles provide a good estimate of the typical variation of the data because they account for all but the most extreme 10 percent at each end of the distribution.

Because the purpose of summarizing data is to represent the conditions during a selected time period, the number of analyses summarized should be adequate to provide a valid estimate of the conditions during the period. For example, although the middle value in three analyses of concentration is the median for those analyses, it would not be expected that this value would be a good estimate of the median of all the concentrations that occurred during a 9-year period. For the purpose of this report, a liberal policy was adopted, and the 25th, 50th, and 75th percentiles were calculated for 10 or more analyses, and the 10th and 90th percentiles were calculated for 30 or more analyses. The summary tables presented later in this report show, in addition to the percentiles, the number of analyses to aid in judging the adequacy of the data. It should be kept in mind that, even if the analyses had been random, the minimum number of analyses (10 or 30) would not necessarily provide good estimates of the true percentiles for the 9 years (Conover, 1980, p. 105-117). In reality, the analyses were not random; in fact, special-purpose analyses may have been made during certain hydrologic conditions. Special-purpose analyses generally are not identified as such in the data bases, and where they are included, they may have injected bias into the percentile calculations. In a few instances, special-purpose analyses were recognized, and they were either excluded or their bias is noted in this report.

To compare the available data with water-quality criteria for either instream or offstream use, the "Water Quality Criteria Summary" chart included in a report by the U.S. Environmental Protection Agency (1987d) was used (the exceptions were for fecal-indicator bacteria and some synthetic-organic compounds, as noted in the appropriate sections of this report). Because the criteria are often for averages of analyses during specified times and the criteria for drinking water are for treated water rather than for raw water, the analyses of individual instantaneous samples of ambient water quality are not strictly comparable with the U.S. Environmental Protection Agency criteria.

State water-quality criteria of Kansas or Nebraska exist for some constituents or properties not covered by U.S. Environmental Protection Agency criteria. Some State criteria also differ from U.S. Environmental Protection Agency criteria in either the numerical value or in the method of averaging or in frequency of occurrence. In addition, State criteria of Kansas and Nebraska are not identical. Therefore, only the U.S. Environmental Protection Agency criteria are reported herein (with the exceptions previously noted).

Determining suitability of data for calculations of constituent transport was partly subjective and involved judgment of the effect of the absence of data during some of the 9-year period, the effect of extrapolating beyond the range of streamflow rates sampled, and the effect of nonuniform data coverage during the four seasons. Constituents for which transport values might have some meaning and which had at least 30 analyses during the 9 years were considered for calculations of transport. Calculations were made if no seasons were drastically underrepresented, if analyses were fairly well distributed throughout the range of streamflow, and if the largest decile of streamflow had more than two analyses.

For constituents that had adequate data for such calculations, transport was calculated for five key streamflow-gaging and sampling stations representing transport from major parts of the study unit, into and out of Tuttle Creek Lake, and out of the study unit. These stations, shown in figure 6, were:

- Big Blue River at Barneston, Nebr. (Big Blue River upstream from Little Blue River and part of inflow to Tuttle Creek Lake, station 10);
- Little Blue River at Hollenberg, Kans. (most of the Little Blue River and part of inflow to Tuttle Creek Lake, station 15);
- Big Blue River near Manhattan, Kans. (outflow from Tuttle Creek Lake, station 18);
- Kansas River at Wamego, Kans. (Kansas River downstream from Big Blue River, station 19); and
- Kansas River at DeSoto, Kans. (outflow from study unit, station 29).

Calculations for suspended sediment, nitrogen, and phosphorus were made for additional stations that had suitable data to provide improved areal definition of these constituents for which transport is of special interest.

Relations between instantaneously observed constituent-transport rate and streamflow rate and season were developed by least-squares regressions using the logarithm of transport rate, the logarithm of streamflow rate, and seasonal factors calculated as trigonometric functions of the date. Because this type of regression provided an estimate of the mean logarithm of transport for a given streamflow rate and season, it provided a biased estimate of the mean transport rate. This bias was removed by using Duan's estimator (Duan, 1983). The regression equation corrected for bias was used to estimate transport for each day of the 9-year period. The mean annual constituent transport rate in tons per year then was calculated.

A measure of the accuracy of estimate of mean annual transport rate was calculated by a method that accounted for the standard errors of the regression coefficients, the number of days involved in the estimated mean, and the serial correlation of daily values. The result was a root mean-square error value for each mean annual transport rate. These root mean-square errors do not account for biases that might result from extrapolation or other causes; the calculated root mean-square errors that were less than 4 percent were increased arbitrarily to 4 percent to avoid an unwarranted impression of great accuracy.

Analysis of Long-Term Trends

Long-term trends over time were tested using the seasonal Kendall test (Hirsch and others, 1982). The analysis of long-term trends used data from earlier years in addition to the 1978-86 water years chosen to represent current conditions. The objective was to be able to have some confidence in the results of the analysis; if only a few samples over a few years are analyzed for trends, the explainable variance is likely to be so small relative to the unexplained variance that the results would not be meaningful. Where data were adequate for the analysis, all available data on the constituent at each sampling station were used, with the exception of replicate samples on the same day and data extremely isolated in time from the main body of data (for example, a single sample in 1903 at one station).

The judgment regarding the adequacy of available data for analysis of long-term trends was partly subjective. Minimum requirements applied were: (1) at least 40 analyses; (2) at least 10 years from first year to last year of data used; and (3) a year would not be counted as the first or last of the 10 years if there were fewer than three analyses in that year. Another consideration was that sparse or absent data in middle years could be accepted because they would have little effect on the analysis. Equal spacing of the analyses in time was not required because the analysis accounts for the season of each sample; however, data sets having conspicuous absence of data in one or more seasons were not used. Uniform coverage of rates of flow was not required because flow adjustment could be used for constituents or properties showing relations to streamflow rate. However, data sets having conspicuous absence of analyses in a high or low range of streamflow rate were not used. Each analysis was assigned to one of four seasons, and the analysis of long-term trends compared only analyses from the same season (Hirsch and others, 1982). All possible pairs of analyses from each season were compared.

Analyses for long-term time trends were made on the numerical values of the constituents or properties from the data base; in addition, for constituents or properties that showed a relation to streamflow rate, the values were flow adjusted if the relation had a probability level of 0.20 or less. Flow adjustment meant that an analysis was performed on the residuals from a regression, with streamflow rate as the independent variable. Flow adjustment usually provides more sensitivity to the statistical analysis by decreasing the amount of unexplained variation in the data and by preventing incorrect conclusions where a trend existed in the streamflow rates associated with the samples. The analysis procedure also provided adjustment for the effects of serial correlation. Results of the analyses included the probability level and the average rate of trend in units per year and (or) percent. The standard for significance for trend at an individual station was established as a probability level of 0.10 or less; however, trends with probability levels larger than 0.10 may be meaningful if consistent with trends at other sampling stations.

The rate of trend was calculated for all analyses whether the result was statistically significant or not. For all flow-adjusted analyses, except pH, the rate was converted to percentage from the original logarithmic units. Percentage calculated this way means percentage of the previous year's value rather than percentage of the median; therefore, the percentage cannot be applied in a simple way to a series of years. The percentages were used appropriately to judge only whether a statistically significant trend had practical significance. For example, a trend might be statistically significant with a rate of 0.2 percent but may not have practical significance because of such a small trend rate. The rate calculated is only an average of rates that may have varied considerably during the time period of data used. Both the probability level and the rate apply only to the time period of the analysis and should not be used for projections beyond that period.

SOURCES AND CHARACTERISTICS OF AVAILABLE SURFACE WATER-QUALITY DATA

By P.R. Jordan
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Sources of Water-Quality Data

The bulk of the surface water-quality data available for streams and lakes in the lower Kansas River basin has been collected by the Nebraska Department of Environmental Control, the Kansas Department of Health and Environment (and its predecessor agencies), and the U.S. Geological Survey. Additional data have been collected by the U.S. Army Corps of Engineers (in relation to large Federal reservoirs), the Nebraska Game and Park Commission, and the U.S. Environmental Protection Agency. Data collected by the U.S. Environmental Protection Agency were collected either directly by that agency or by contractors, such as the National Sanitation Foundation for a study of a water-quality index (McClelland, 1974) and the University of Nevada (Reno). Other data have been collected by researchers at Kansas State University (Manhattan) and the University of Kansas (Lawrence), partly for studies by the Kansas Water Resources Research Institute. Data collected through 1986 generally were used for this study; in a few cases, some data for 1987 were readily available and were used.

For the purposes of this report, only water-quality data available in machine-readable form (with the exception of biological data and some data on pesticides and other synthetic-organic compounds) were analyzed. Because of the computerized systems established by the U.S. Environmental Protection Agency and the U.S. Geological Survey for the storage and retrieval of water-quality data, most of the available data are in machine-readable form. A system of routine transmittal of data provides that all the data in the U.S. Geological Survey computerized system are also in the U.S. Environmental Protection Agency's STORET system. For the lower Kansas River basin, STORET also includes data collected by other Federal and State agencies, principally the Kansas Department of Health and Environment and the Nebraska Department of Environmental Control.

The machine-readable data analyzed for this report were retrieved from the U.S. Geological Survey data base and from STORET and were stored in separate local data bases by sampling station for use in this study. Data on biological characteristics and some data on pesticides and other synthetic-organic compounds were obtained from published reports and agency files.

Characteristics of Water-Quality Data

Characteristics of ambient surface-water-quality determinations vary considerably among sampling stations and for different time periods at individual stations. The largest number of samples were analyzed for those constituents associated with water-quality issues of long-standing concern, such as acidification (pH and alkalinity), salinity (major cations and anions), sedimentation (suspended sediment), eutrophication (nutrients), and sanitary quality (dissolved oxygen and fecal-indicator bacteria). Fewer analyses were made for those constituents that are associated with the issue of toxic contamination (trace elements and synthetic-organic compounds). One reason for the smaller quantity of data for these constituents is the relatively large cost of analysis.

The number of samples analyzed for selected property and constituent groups at stations that had been sampled repeatedly is illustrated in figure 8. In this illustration, a sample is counted for a property and constituent group if a significant number of individual parts of the group were determined. For example, a sample was counted for pH and alkalinity

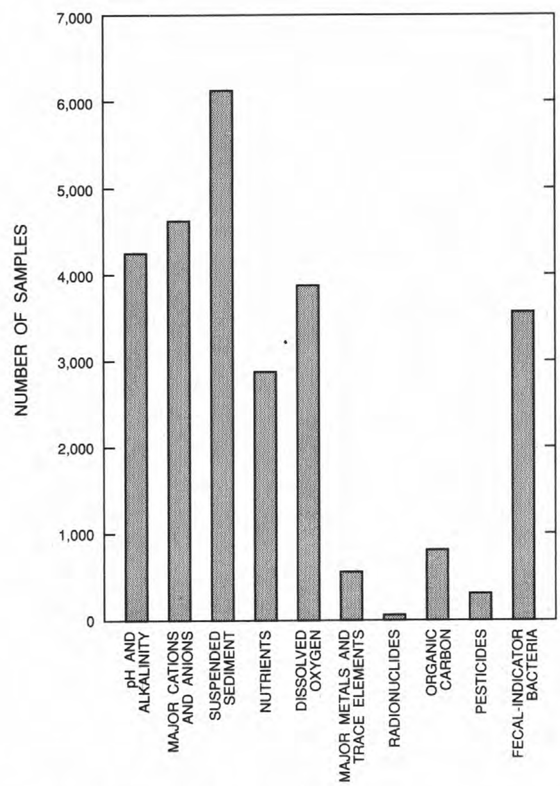

Figure 8.—Number of ambient surface-water samples analyzed for major property and constituent groups during 1978-86 water years at stations that were sampled repeatedly.

only if both determinations were made. Every suspended-sediment determination on a different day was counted (multiple samples on the same day at the same station were counted as one sample). A sample was counted for nutrients if determinations were made of at least three nutrients, including at least one form of nitrogen and one form of phosphorus, and a sample was counted for major metals and trace elements if at least six of the metals and elements were determined. A sample was counted for pesticides if at least three pesticides were determined. As figure 8 shows, the number of analyses for major metals and trace elements, radionuclides, organic carbon, and pesticides was relatively small. However, the number of samples alone does not indicate adequacy or inadequacy of the data for statistical analysis or interpretation. For example, because suspended-sediment concentration is usually the most variable of constituents and is a recognized problem in the lower Kansas River basin, a large number of samples well distributed seasonally and spatially is required for adequate assessment of that property; however, if constituents such as major metals and trace elements have small variability and concentrations consistently meet water-quality criteria, much smaller numbers of samples would be adequate.

Spatial Distribution of Sampling Stations

An examination of available data showed stations where data were available for several constituents over a long enough time to span the seasons and show the typical yearly variations in hydrologic conditions. Sampling stations 1 through 29 are the principal sites for which surface-water quality data are analyzed in this report (fig. 9). Figure 9 also shows stations where only data from fish-tissue analyses were used (stations 30 through 35). The availability of data at the sampling stations is far from equal. For example, pH data were available for all 29 principal stations (fig. 9, stations 1-29), whereas selenium data were available for only 8 of those stations. Other differences in data availability not shown in figure 9 are illustrated by the fact that station 29 on the Kansas River had a large number of analyses for a variety of constituents, whereas station 1 had analyses for only a few constituents. In some cases, two or more stations complemented each other in the types of data available; station 15 on the Little Blue River had many analyses for many constituents but few data on suspended sediment, whereas station 16 had a substantial amount of data on suspended sediment. Station 23 best represented the outflow from the Soldier Creek subbasin for the constituents having available data, whereas station 22 complemented station 23 with data for additional constituents. The spatial distribution of the sampling stations was adequate for representing the ambient surface-water quality for many constituents, for the different land uses and hydrologic conditions within the study unit, and for the outflow from the study unit. The major deficiency, not evident from figure 9, is that there were no analyses for most constituents at the upstream boundary of the study unit on the Kansas River (near station 1).

Temporal and Hydrologic Distribution of Analyses

To meet the objectives of the surface-water-quality assessment, analyses needed to be available for the commonly occurring range of hydrologic conditions at each sampling station, for all seasons, and for enough years to provide for time-trend analysis. The distributions of analyses were similar in many ways for most of the 29 principal sampling stations (stations 1-29, fig. 9). Two stations were selected to describe the distributions commonly found. The distribution of samples collected at the Big Blue River at Surprise, Nebr. (station 3, fig. 9), is representative of stations having a modest amount of data, sufficient for statistical summary and analysis. The distribution of samples at the Kansas River at DeSoto, Kans. (station 29, fig. 9), is representative of the few stations that have a large amount of data on a large number of constituents. In table 3, the streamflow rates of all the daily mean flows have been divided into 10 deciles, and the number of analyses obtained within each decile of streamflow is tabulated. For the Big Blue River at Surprise (station 3), the absence of analyses in the second decile of streamflow probably does not limit the utility of the data because a substantial number of analyses are available in the first and third deciles. The absence of suspended-sediment analyses in the first and second deciles of streamflow also is not a serious limitation because suspended-sediment concentrations are characteristically small during low-flow conditions. For the Kansas River at DeSoto (station 29), although the distribution of analyses by streamflow rate is not precisely uniform, each decile of streamflow is represented.

Typical monthly distribution of analyses is shown in table 4. All the months are represented although some months have a larger number of analyses than others. Although fewer analyses were available in winter months (December, January, and February), those months were adequately represented for a generalized assessment of water quality.

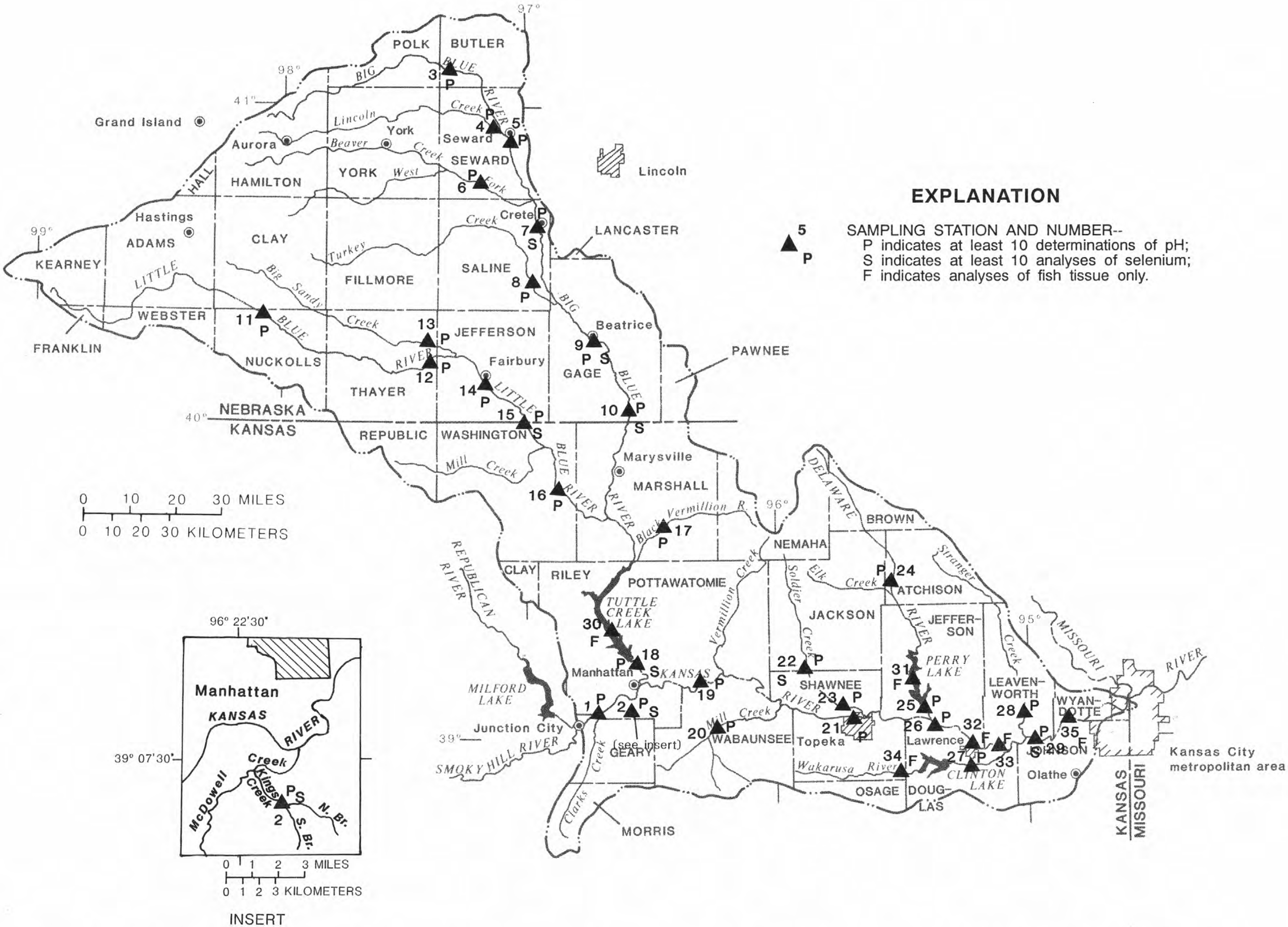

Figure 9.—Location of sampling stations for which available water-quality data are analyzed in this report and availability of pH, selenium, and fish-tissue analyses during 1978-86 water years.

The distribution of analyses by year at two stations (table 5) illustrates characteristics common to the data available at several stations. The annual distribution of analyses from the Big Blue River at Surprise (station 3, fig. 9) is similar to that of a few stations where data collection was discontinued before 1986. Discontinuance or initiation of data collection often occurred for different constituents independently, as indicated by the Big Blue River at Surprise where few data on suspended sediment were collected after 1970, and few data on dissolved oxygen were collected before 1970. For the Kansas River at DeSoto (station 29, fig. 9), few data were collected before 1973 because, until that year, the streamflow-gaging station was several miles downstream. Periods of more intensive data collection occurred at many stations. For example, the Kansas River at DeSoto was sampled intensively during 1974-81 to improve understanding of the patterns of short-term variation in concentrations of several constituents at the station (different analyses within 1 day are counted separately in tables 3, 4, and 5).

Other Relevant Data

Data on numerous other characteristics of the study unit were used to improve interpretation of the available data on surface-water quality. Land-use data were obtained from a map by Williams and Barker (1974) for Kansas and unpublished data from

Table 3.—*Distribution of analyses for selected constituents for 10 deciles of streamflow rates at two sampling stations within lower Kansas River basin*

Decile of streamflow rate	Number of analyses for indicated constituent					
	pH	Dissolved oxygen	Dissolved sulfate	Total nitrite plus nitrate	Dissolved arsenic	Suspended sediment
	Big Blue River at Surprise, Nebr. (station 3, fig. 9), 1965-80					
1	18	19	3	20	0	0
2	0	0	0	0	0	0
3	17	13	8	13	0	2
4	6	2	4	2	0	5
5	21	10	14	10	0	10
6	16	3	12	3	0	13
7	12	8	9	7	0	6
8	9	5	7	4	0	3
9	24	8	9	8	0	6
10	17	6	11	6	0	19
Total	130	74	77	73	0	64
	Kansas River at DeSoto, Kans. (station 29, fig. 9), 1967-80					
1	28	21	25	19	6	19
2	30	24	25	20	7	22
3	20	15	14	10	4	8
4	26	17	19	5	2	11
5	40	30	37	25	5	25
6	25	21	23	9	8	32
7	21	15	16	7	8	31
8	31	22	25	17	8	90
9	21	18	21	10	2	60
10	27	14	19	10	2	38
Total	[1]275	[1]197	[1]224	[1]132	[1]52	[1]336

[1]Total is less than in tables 4 and 5 because some analyses lacked associated data on streamflow rate.

Table 4.—*Monthly distribution of analyses for selected constituents at two sampling stations within lower Kansas River basin*

Month	pH	Dissolved oxygen	Dissolved sulfate	Total nitrite plus nitrate	Dissolved arsenic	Suspended sediment
	Number of analyses for indicated constituent					
	Big Blue River at Surprise, Nebr. (station 3, fig. 9), 1965-80					
January	9	6	4	6	0	3
February	9	5	5	5	0	5
March	8	5	4	5	0	3
April	9	7	6	7	0	6
May	8	4	4	4	0	3
June	16	10	12	10	0	9
July	14	6	9	4	0	11
August	16	7	11	7	0	7
September	13	7	6	7	0	4
October	10	7	7	7	0	4
November	10	6	5	6	0	5
December	8	4	4	5	0	4
Total	130	74	77	73	0	64
	Kansas River at DeSoto, Kans. (station 29, fig. 9), 1967-80					
January	19	17	19	10	3	29
February	14	13	13	7	5	29
March	28	23	22	12	5	155
April	26	19	20	11	4	263
May	24	20	19	12	7	192
June	24	20	18	13	2	213
July	25	20	21	12	2	181
August	26	18	21	12	8	149
September	24	43	20	12	2	131
October	23	19	19	11	5	118
November	27	17	16	10	5	107
December	20	19	19	12	4	54
Total	280	248	227	134	52	1,621

files of the U.S. Soil Conservation Service (Lincoln) for Nebraska. Water-use data were compiled by the U.S. Geological Survey from State agency and local sources. Climatological data were obtained from monthly and annual reports of the National Weather Service (National Oceanic and Atmospheric Administration, 1951-80). Data on use of pesticides and fertilizers were obtained from State and Federal agricultural agencies. Point-source pollutant-discharge data were compiled by Resources for the Future (Gianessi, 1986b) from data assembled by the U.S. Environmental Protection Agency from Kansas and Nebraska State agencies. Data on contaminants in fish tissue were obtained from the National Contaminant Bio-Monitoring Program of the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service, and from the Ambient Fish Tissue Monitoring Program of the U.S. Environmental Protection Agency, Region VII. Information on geology and soils was obtained from a variety of published and unpublished sources. Data on elemental composition of streambed sediments were obtained from the National Uranium Resource Evaluation Program of the U.S. Department of Energy.

Table 5.—*Annual distribution of analyses for selected constituents through 1986 at two sampling stations within lower Kansas River basin*

Year	Number of analyses for indicated constituent					
	pH	Dissolved oxygen	Dissolved sulfate	Total nitrite plus nitrate	Dissolved arsenic	Suspended sediment
			Big Blue River at Surprise, Nebr. (station 3, fig. 9)			
1965	7	0	7	0	0	6
1966	13	0	13	0	0	14
1967	9	0	9	0	0	10
1968	10	2	10	2	0	8
1969	12	0	12	0	0	14
1970	10	2	10	2	0	6
1971	2	2	2	2	0	0
1972	3	3	3	3	0	6
1973	3	3	3	2	0	0
1974	3	3	3	3	0	0
1975	5	5	5	5	0	0
1976	12	12	0	13	0	0
1977	8	8	0	8	0	0
1978	12	12	0	13	0	0
1979	10	12	0	12	0	0
1980	11	10	0	10	0	0
Total	130	74	77	73	0	64
			Kansas River at DeSoto, Kans. (station 29, fig. 9)			
1967	0	2	0	0	0	0
1968	0	8	0	0	0	0
1969	0	9	0	0	0	0
1970	0	7	0	0	0	0
1971	3	4	0	0	0	0
1972	0	0	0	0	0	0
1973	8	2	8	0	0	0
1974	25	14	25	3	3	0
1975	30	22	31	11	4	20
1976	23	23	24	12	6	154
1977	23	21	21	19	6	202
1978	24	22	22	22	4	319
1979	26	23	22	22	4	390
1980	32	47	24	23	4	256
1981	27	15	28	17	4	250
1982	13	5	6	0	4	5
1983	12	7	7	1	4	6
1984	14	6	6	1	3	7
1985	15	6	8	2	4	7
[1]1986	5	5	5	1	2	5
Total	280	248	227	145	52	1,621

[1]This tabulation includes data for only part of 1986.

CURRENT WATER-QUALITY CONDITIONS AND LONG-TERM TRENDS

Streamflow

By P.R. Jordan
U.S. Geological Survey

Variations in streamflow rate in most cases have large effects on surface-water quality; a naturally occurring example is the typical decrease in major-ion concentrations during a rainstorm when the predominant source of streamflow changes from ground-water seepage to overland runoff. Thus, if the streamflow conditions during the period selected to represent current conditions (1978-86) differed significantly from the long-term normal conditions because of variations in weather conditions, the water-quality conditions would have a natural component differing from the long-term normal.

Streamflow during 1978-86 tended to exceed streamflows typical of the longer records used in table 1. Typical of this tendency is flow of the Big Blue River at Barneston, Nebr. (fig. 10). For a given percentage of days, streamflow at Barneston during 1978-86 was consistently larger than for the same percentage of days during the period used in table 1, 1933-86. Part of the difference may stem from the fact that the longer period included two extreme multi-year droughts, in the 1930's and 1950's. A possibility also exists that streamflow in the study unit did have a long-term trend. A 15-year weighted moving average of streamflow of the Kansas River at DeSoto, Kans. (station 29, fig. 6), for 1917-84 (Jordan, 1986, fig. 2) seems to indicate an upward trend despite known increasing losses to evaporation from irrigated fields

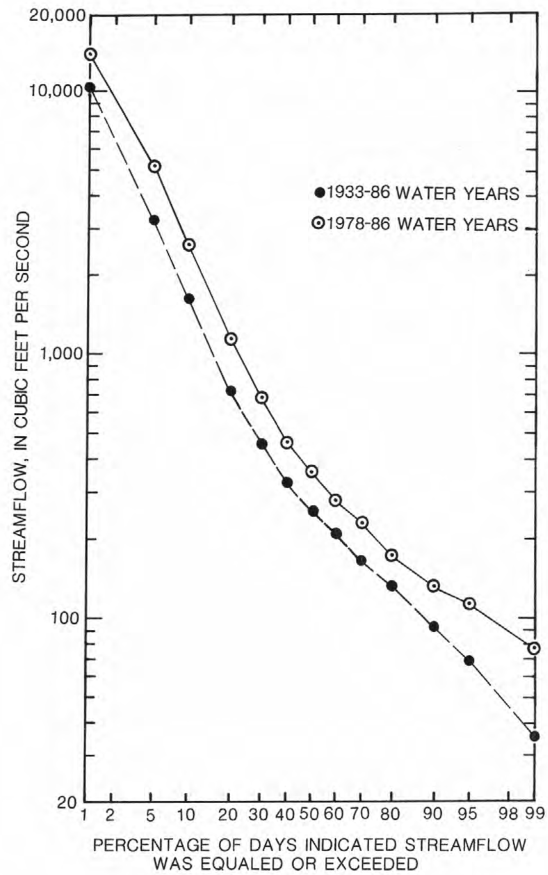

Figure 10.—Flow-duration curves of daily mean streamflow of Big Blue River at Barneston, Nebraska, 1933-86 and 1978-86 water years.

and reservoir surfaces. However, for stations on the Kansas River main stem and the Big Blue River near Manhattan, no recent period could represent long-term streamflow conditions because the conditions have been altered by the impoundments. The 1978-86 period serves the dual purpose of representing hydrologic conditions as affected by the reservoirs and providing comparability among the different stations for interpretation of differences in water quality.

Because water-quality constituents are transported by streamflow, differences in constituent transport among sampling stations are affected as much by differences in streamflow as by differences in concentration. Streamflow volumes and yields for 1978-86 are shown in table 6 for selected sampling stations that represent the variation among stations for which transport of constituents is calculated later in this report. The yields of streamflow per unit area varied considerably within the study unit and from the area that contributes to flow at the upstream boundary of the study unit.

The streamflow volume entering the study unit (measured at station 1 in table 6) was large enough to transport substantial quantities of constituents into the study unit even though the streamflow yield was small. On the Big and Little Blue Rivers, streamflow yields increased from west to east and north to south to provide streamflow volumes large enough to transport substantial quantities of constituents into Tuttle Creek Lake. The outflow from Tuttle Creek Lake (measured at station 18) continued the transport of constituents that had not been deposited in the lake. The streamflow volume in the Kansas River increased greatly at station 19 as compared to station 1 because of the large contribution from the Big Blue River (measured at station 18). Continuing downstream, streamflow volumes and yields of the Kansas River increased significantly even though the tributaries drain smaller areas (table 1) than does the Big Blue River. This occurs because of the much larger yields of those tributaries (station 28 is an example). These larger yields result mainly from a west-to-east increase in precipitation.

Table 6.—*Streamflow volumes and yields at selected sampling stations within lower Kansas River basin, 1978-86 water years*

Sampling-station number (fig. 9)	Station name	Mean annual streamflow (acre-feet per year)	Mean annual streamflow yield (acre-feet per square mile of drainage area per year)
1	Kansas River at Fort Riley, Kans.	1,750,000	39.0
7	Big Blue River near Crete, Nebr.	383,000	141
10	Big Blue River at Barneston, Nebr.	860,000	193
15	Little Blue River at Hollenberg, Kans.	414,000	150
17	Black Vermillion River near Frankfort, Kans.	161,000	393
18	Big Blue River near Manhattan, Kans.	2,170,000	225
19	Kansas River at Wamego, Kans.	4,090,000	74.0
24	Delaware River near Muscotah, Kans.	238,000	552
26	Kansas River at Lecompton, Kans.	5,730,000	98.0
28	Stranger Creek near Tonganoxie, Kans.	257,000	633
29	Kansas River at DeSoto, Kans.	6,550,000	110

pH, Alkalinity, and Acidity

By J.K. Stamer
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pH is defined as the negative base-10 logarithm of hydrogen-ion activity measured in moles per liter. The pH of pure water at 25 °C is 7.0 standard units. pH is an important factor affecting the chemical and biological quality of water in streams and lakes; however, the pH of water in a stream does not indicate its ability to neutralize an acid or base. This ability to neutralize a strong acid or base is characterized by the alkalinity or acidity of the water and defined as a "capacity" function (Hem, 1985). If the capacity is considerably large, then the water is considered to be a "buffered system" (Hem, 1985).

The principal source of alkalinity is atmospheric carbon dioxide. Other potential sources of alkalinity are the dissolution of rocks and minerals. Sedimentary rocks, which are abundant in the study unit, are probably the largest source of carbonate ions. In natural water, alkalinity generally results from dissolved-carbon-dioxide species, bicarbonate, and carbonate. Alkalinity is an important characteristic of water because it helps protect fish and other aquatic life from changes in pH due to photosynthesis or point-source discharges. Alkalinity is also an important characteristic of water for municipal, industrial, and irrigation uses.

The principal sources of acidity can include solution of volcanic gases, oxidation of sulfide-bearing minerals from mining operations, and acid rain. Natural rain has a pH of 5.6 standard units, which is acidic, but acid rain generally is defined as having a pH of less than 4.0 standard units. Acid rain is produced by the hydrolysis of nitrogen and sulfur oxides, which results, in part, from the burning of fossil fuel by thermoelectric powerplants, automobiles, and heating systems.

Current Conditions

The statistical summary of pH and alkalinity data collected during 1978-86 (table 7) shows that, for pH in water from 26 stations, the smallest 10th-percentile value was 7.0 standard units and the largest 90th-percentile value was 8.6 standard units. The variation of the median values was only 0.8 standard unit, from 7.5 to 8.3. These data show that overall the streams do not exhibit a large amount of variation in pH, that pH values in the lower Kansas River basin generally were neutral to slightly alkaline, and that pH values were within the range of natural water (6.5 to 8.5 standard units) as reported by Hem (1985). The lack of variation is in large part due to the buffering capacity of the surficial soils and rocks in the study unit. The total alkalinity concentrations in table 7 also show that the streams are well buffered and that the variability of alkalinity is not large. The range of median concentrations of alkalinity in the basin was approximately 120 mg/L. There is little difference in the median concentrations in water from the Big Blue River and its tributaries and the Kansas River and its tributaries.

The distribution of pH values measured in water for the 1978-86 water years at stations in the lower Kansas River basin is shown in figure 11. Median pH values in water from the Big Blue River basin (the Big Blue River and its tributaries, fig. 11B) are generally less than 8.0, whereas the median values in water from the Kansas River and its tributaries are mostly equal to or greater than 8.0 (fig. 11A). In addition, the variation of pH is larger in water from sampling stations in the Big Blue River basin than in the rest of the lower Kansas River basin. The smaller median pH values and the larger variation in water from stations in the Big Blue River basin may reflect the intensity of agricultural practices in this part of the lower Kansas River basin. Anhydrous ammonia is applied by the tens of pounds per acre to corn and grain sorghum. The oxidation of anhydrous ammonia to nitrate releases hydrogen ions that can, in effect, lower the pH of the water that reaches the streams (Snoeyink and Jenkins, 1980). In addition, the application of large amounts of ground water for irrigation in the northwestern part of the Big Blue River basin also may account for the smaller median pH values and larger variation in water from sampling stations in the Big Blue River basin. The pH of ground water in this part of the lower Kansas River basin is typically less than 8.0 as discussed in reports on Hamilton and Seward Counties in Nebraska, which represent areas underlain by the High Plains aquifer (Keech, 1962; 1978).

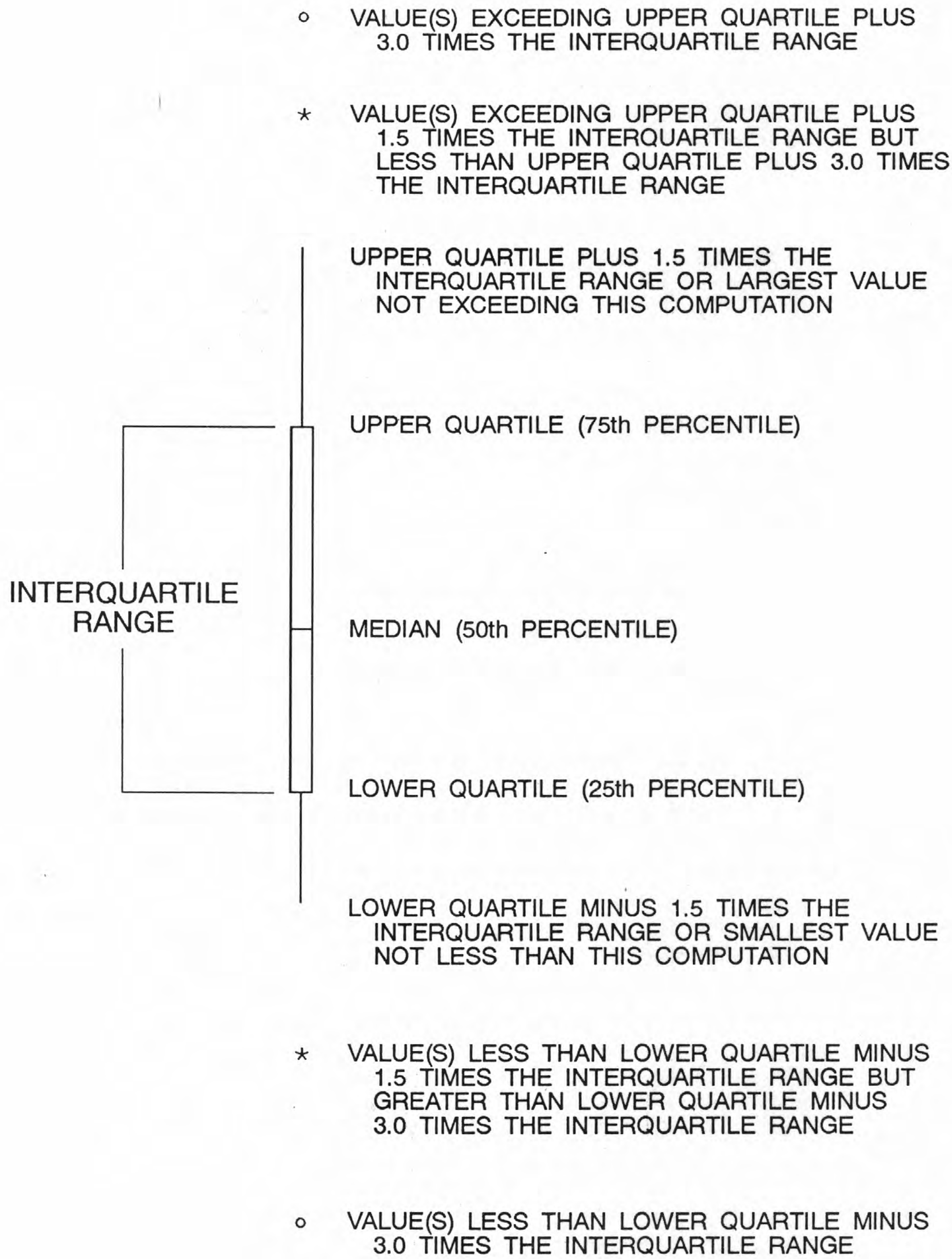
As shown in table 8, few determinations of pH and one determination of alkalinity did not meet the chronic freshwater-aquatic criteria established by the U.S. Environmental Protection Agency (1987d). There were no determinations of acidity that did not meet the acidity criterion, and therefore the criterion is not shown in table 8. Although the pH of precipitation collected near Manhattan, Kans., is mostly less than 6.0 (data from the National Atmospheric Deposition Program, Natural Resource Ecology Laboratory, Ft. Collins, Colo.), the surficial soil and rocks in the study unit have sufficient capacity to react with the hydrogen ions and keep the streams slightly basic.

Table 7.—*Statistical summary of data on pH and alkalinity in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[This table includes only those stations having 10 or more determinations; —, the 10- and 90-percentile values are not shown for stations having fewer than 30 determinations]

Sampling-station number (fig. 9)	Station name	Number of determinations	Value at indicated percentile				
			10	25	50 (median)	75	90
		pH, in standard units					
1	Kansas River at Fort Riley, Kans.	15	—	7.7	7.9	8.1	—
2	Kings Creek near Manhattan, Kans.	38	7.2	7.5	8.0	8.1	8.2
3	Big Blue River near Surprise, Nebr.	36	7.0	7.2	7.5	7.8	8.0
4	Lincoln Creek near Seward, Nebr.	119	7.2	7.5	7.8	8.0	8.2
5	Big Blue River at Seward, Nebr.	128	7.3	7.6	7.8	8.0	8.2
6	West Fork Big Blue River near Dorchester, Nebr.	158	7.3	7.5	7.8	8.0	8.2
7	Big Blue River near Crete, Nebr.	245	7.1	7.6	7.7	7.9	8.1
8	Turkey Creek near Wilber, Nebr.	118	7.3	7.4	7.7	8.0	8.1
9	Big Blue River at Beatrice, Nebr.	66	7.3	7.6	7.8	8.2	8.5
10	Big Blue River at Barneston, Nebr.	115	7.3	7.6	7.9	8.2	8.5
11	Little Blue River near Deweese, Nebr.	100	7.3	7.5	7.8	8.1	8.3
12	Little Blue River near Alexandria, Nebr.	56	7.5	7.7	8.0	8.2	8.4
13	Big Sandy Creek at Alexandria, Nebr.	36	7.2	7.4	7.7	8.0	8.3
14	Little Blue River near Fairbury, Nebr.	21	—	7.7	7.9	7.9	—
15	Little Blue River at Hollenberg, Kans.	126	7.3	7.5	7.9	8.2	8.4
16	Little Blue River near Barnes, Kans.	42	7.2	7.6	8.0	8.1	8.4
17	Black Vermillion River near Frankfort, Kans.	53	7.3	7.6	7.9	8.1	8.4
18	Big Blue River near Manhattan, Kans.	97	7.5	7.9	8.2	8.3	8.4
19	Kansas River at Wamego, Kans.	38	8.0	8.2	8.3	8.4	8.6
20	Mill Creek near Paxico, Kans.	61	7.8	8.0	8.0	8.1	8.2
21	Kansas River at Topeka, Kans.	91	7.7	7.9	8.2	8.4	8.6
22	Soldier Creek near Delia, Kans.	66	7.6	7.8	8.0	8.2	8.3
23	Soldier Creek near Topeka, Kans.	62	7.5	7.8	8.1	8.3	8.4
24	Delaware River near Muscotah, Kans.	48	7.3	7.6	8.0	8.2	8.3
25	Delaware River below Perry Dam, Kans.	16	—	7.8	8.2	8.4	—
26	Kansas River at Lecompton, Kans.	73	7.7	8.0	8.2	8.4	8.6
27	Wakarusa River near Lawrence, Kans.	44	7.2	7.6	8.0	8.1	8.3
28	Stranger Creek near Tonganoxie, Kans.	59	7.5	7.8	8.0	8.2	8.3
29	Kansas River at DeSoto, Kans.	125	7.8	8.0	8.2	8.5	8.6
		Total alkalinity as $CaCO_3$, in milligrams per liter					
2	Kings Creek near Manhattan, Kans.	31	230	250	266	280	289
4	Lincoln Creek near Seward, Nebr.	28	—	140	220	240	—
5	Big Blue River at Seward, Nebr.	24	—	100	240	280	—
6	West Fork Big Blue River near Dorchester, Nebr.	38	40	100	170	200	230
7	Big Blue River near Crete, Nebr.	25	—	100	200	240	—
8	Turkey Creek near Wilber, Nebr.	28	—	74	145	190	—
9	Big Blue River at Beatrice, Nebr.	21	—	120	200	230	—
10	Big Blue River at Barneston, Nebr.	23	—	90	190	230	—
11	Little Blue River near Deweese, Nebr.	36	61	140	180	190	200
15	Little Blue River at Hollenberg, Kans.	164	74	140	190	200	210
18	Big Blue River near Manhattan, Kans.	182	110	120	150	180	210
19	Kansas River at Wamego, Kans.	105	130	150	170	200	220
21	Kansas River at Topeka, Kans.	50	120	140	150	190	220
22	Soldier Creek near Delia, Kans.	117	160	220	250	280	290
23	Soldier Creek near Topeka, Kans.	92	150	200	230	260	300
24	Delaware River near Muscotah, Kans.	53	120	180	210	260	280
26	Kansas River at Lecompton, Kans.	114	120	140	160	200	230
29	Kansas River at DeSoto, Kans.	122	110	130	160	200	220

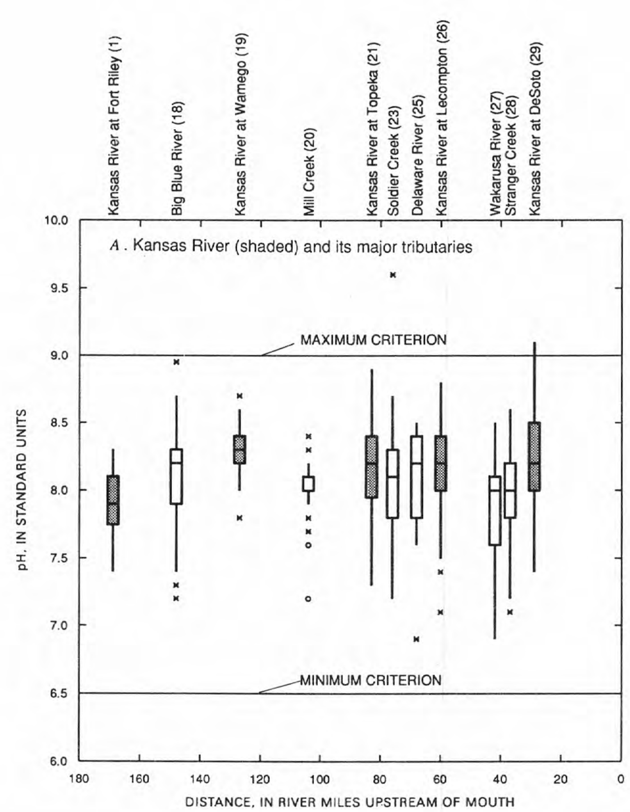
EXPLANATION

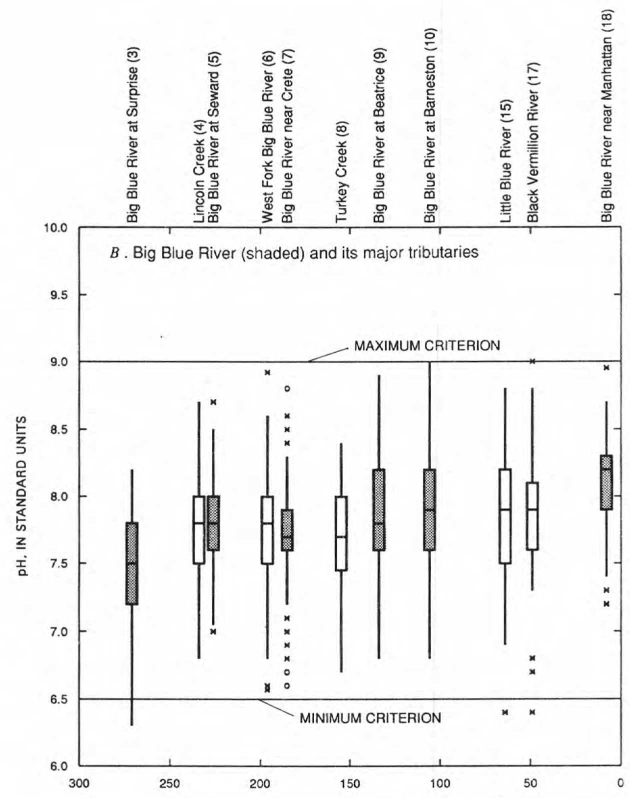


NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

WATER-QUALITY CRITERION ARE FOR FRESHWATER, CHRONIC (U.S. ENVIRONMENTAL PROTECTION AGENCY, 1987d)

Figure 11.—**Distribution of pH values measured in water from (*A*) Kansas and (*B*) Big Blue Rivers and**





their major tributaries and relation of values to chronic freshwater-aquatic criteria, 1978-86 water years.

Table 8.—*Number of pH or alkalinity determinations not meeting chronic freshwater-aquatic criteria in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[Determinations counted in this table as not meeting criteria do not necessarily represent violations of the criteria but may indicate need for further study. Criteria listed are the numerical values from the summary chart of U.S. Environmental Protection Agency (1987d). In addition to the numerical values, full criteria also consider duration and frequency of concentrations. Statistical summaries of pH and alkalinity are listed in table 7]

Sampling-station number (fig. 9)	Station name	Number of determinations	Number of determinations not meeting the criterion for freshwater-aquatic life, chronic
	pH: Chronic, not less than 6.5, not to exceed 9.0 standard units		
3	Big Blue River at Surprise, Nebr.	36	1
15	Little Blue River at Hollenberg, Kans.	126	1
16	Little Blue River near Barnes, Kans.	42	1
17	Black Vermillion River near Frankfort, Kans.	52	1
23	Soldier Creek near Topeka, Kans.	61	1
29	Kansas River at DeSoto, Kans.	123	1
	Total alkalinity: Chronic, not less than 20 milligrams per liter		
4	Lincoln Creek near Seward, Nebr.	29	1

Trends

Time-trend tests were applied to pH and alkalinity values for periods of record of 10 years or more. The results of the trend tests are shown in tables 9 and 10. Trends that were determined to be significant were equal to or less than the 0.1 probability level and are underlined in the tables. The time-trend tests were applied to unadjusted pH values and also to flow-adjusted pH values if a relation between pH and streamflow rates existed. In instances in which the unadjusted and flow-adjusted values did not agree, the flow-adjusted result was used for interpretation. For example, as shown in table 9, the time trend was not significant for unadjusted values but was significant for flow-adjusted values for the Big Blue River at Seward, Nebr. (station 5). The flow-adjusted values were used for interpretation. Similar results are shown for time trends in alkalinity.

For pH, there were adequate data to perform the time-trend tests for 22 of the 29 principal sampling stations, and trends were significant at 15 of the 22. Of the 15 trends that were significant, 13 stations had positive trends. The significant trends that were positive indicate a change in pH ranging from 0.009 to 0.030 standard unit per year. For example, for the Big Blue River at Barneston (station 10, fig. 9), the trend was +0.01 standard unit per year. This means that in 10 years, the pH increased by 0.1 standard unit.

For alkalinity, data were adequate to perform the time-trend tests for 15 of the 29 stations, and trends were significant at 4 of them (table 10). Alkalinity increased in the water at two stations and decreased at two stations where trends were significant. The flow-adjusted trends, which are expressed as percent per year, are small. The general lack of significant trends in alkalinity for stations in the basin suggests that human or natural factors have not significantly affected alkalinity concentrations for the time periods used in the analysis.

Figure 12 shows the spatial distribution of results of time-trend tests for pH and alkalinity in water from the basin. At two stations, the Big Blue River at Barneston, Nebr. (station 10), and at Manhattan, Kans. (station 18), trends in pH and alkalinity were both positive and significant, whereas at other stations trends in pH were positive, but trends in alkalinity were generally not significant. These data suggest that land use may have had some effect on the pH but not on alkalinity. In terms of future data needs relative to pH and alkalinity, such data should continue to be collected to determine if existing trends or lack of trends continue and to determine trends at stations for which data through 1986 were insufficient.

Table 9.—*Trend-test results for pH in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level; Probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: pH: Probability level	pH: Average rate of change: pH units per year	pH: Average rate of change: Percent of median per year	Flow-adjusted pH: Probability level	Flow-adjusted pH: Average rate of change (pH units per year)
3	Big Blue River at Surprise, Nebr.	1965-80	16	1.00	0	0	0.49	-0.001
4	Lincoln Creek near Seward, Nebr.	1963-86	24	.62	0	0	.06	+ .009
5	Big Blue River at Seward, Nebr.	1970-86	17	.31	0	0	.01	+ .015
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	.01	+ .012	+ .16	0	+ .011
7	Big Blue River near Crete, Nebr.	1961-83	23	0	+ .036	+ .46	0	+ .030
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.54	0	0	.60	+ .003
9	Big Blue River at Beatrice, Nebr.	1968-83	16	.01	+ .043	+ .55	.12	+ .022
10	Big Blue River at Barneston, Nebr.	1961-86	26	.20	+ .006	+ .08	.02	+ .010
11	Little Blue River near Deweese, Nebr.	1956-86	31	.01	+ .011	+ .14	.01	+ .010
12	Little Blue River near Alexandria, Nebr.	1968-80	13	.18	- .010	- .12	.56	- .013
15	Little Blue River at Hollenberg, Kans.	1972-86	15	.01	+ .033	+ .43	0	+ .028
16	Little Blue River near Barnes, Kans.	1962-86	25	.96	0	0	.08	+ .009
18	Big Blue River near Manhattan, Kans.	1955-86 1963-86	32 24	0 0	+ .015 + .020	+ .19 + .25	— —	— —
19	Kansas River at Wamego, Kans.	1956-85	30	0	+ .020	+ .28	.01	+ .019
21	Kansas River at Topeka, Kans.	1953-86	34	.04	+ .015	+ .19	—	—
22	Soldier Creek near Delia, Kans.	1965-86	22	0	+ .017	+ .21	.01	+ .018
23	Soldier Creek near Topeka, Kans.	1972-86	15	.15	- .042	- .51	.04	- .041
24	Delaware River near Muscotah, Kans.	1969-86	18	.61	+ .012	+ .15	.56	+ .013
26	Kansas River at Lecompton, Kans.	1957-86	30	0	+ .028	+ .35	—	—
27	Wakarusa River near Lawrence, Kans.	1964-86	23	.22	+ .006	+ .07	—	—
28	Stranger Creek near Tonganoxie, Kans.	1970-86	17	.06	- .033	- .42	.06	- .026
29	Kansas River at DeSoto, Kans.	1973-86	14	.19	+ .025	+ .31	.13	+ .029

Table 10. — *Trend-test results for alkalinity concentrations in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Alkalinity concentration: Probability level	Alkalinity concentration: Average rate of change: Milligrams per liter per year	Alkalinity concentration: Average rate of change: Percent of median per year	Flow adjusted alkalinity concentration: Probability level	Flow adjusted alkalinity concentration: Average rate of change (percent per year)
3	Big Blue River at Surprise, Nebr.	1965-75	11	0.04	+ 13	+ 10	1.00	0
6	West Fork Big Blue River near Dorchester, Nebr.	1965-86	22	.79	- .29	- .15	.52	- .46
7	Big Blue River near Crete, Nebr.	1971-83	13	.27	- 2.2	- 1.1	.74	- .23
8	Turkey Creek near Wilber, Nebr.	1965-84	20	.02	- 2.0	- 1.1	.01	- 1.8
10	Big Blue River at Barneston, Nebr.	1961-86	26	0	- .23	- 5.8	.03	+ 1.0
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.54	+ .33	+ .18	.23	+ .91
16	Little Blue River near Barnes, Kans.	1962-78	17	.11	+ 1.6	+ .87	.18	+ 1.1
18	Big Blue River near Manhattan, Kans.	1955-86	32	.78	+ .10	+ .06	.11	+ .39
		1963-86	24	.34	+ .41	+ .26	.08	+ .56
19	Kansas River at Wamego, Kans.	1956-85	30	.74	- .16	- .09	.76	+ .05
21	Kansas River at Topeka, Kans.	1953-81	29	.97	0	0	.86	- .04
22	Soldier Creek near Delia, Kans.	1965-86	22	.01	- 1.9	- .73	.69	- .22
23	Soldier Creek near Topeka, Kans.	1975-86	12	.89	+ .33	+ .15	.31	+ .93
24	Delaware River near Muscotah, Kans.	1969-86	18	.13	- 2.7	- 1.2	.37	- 1.2
26	Kansas River at Lecompton, Kans.	1961-86	26	.01	- 1.2	- .67	.03	- .70
29	Kansas River at DeSoto, Kans.	1973-86	14	.62	+ .50	+ .29	.78	+ .43

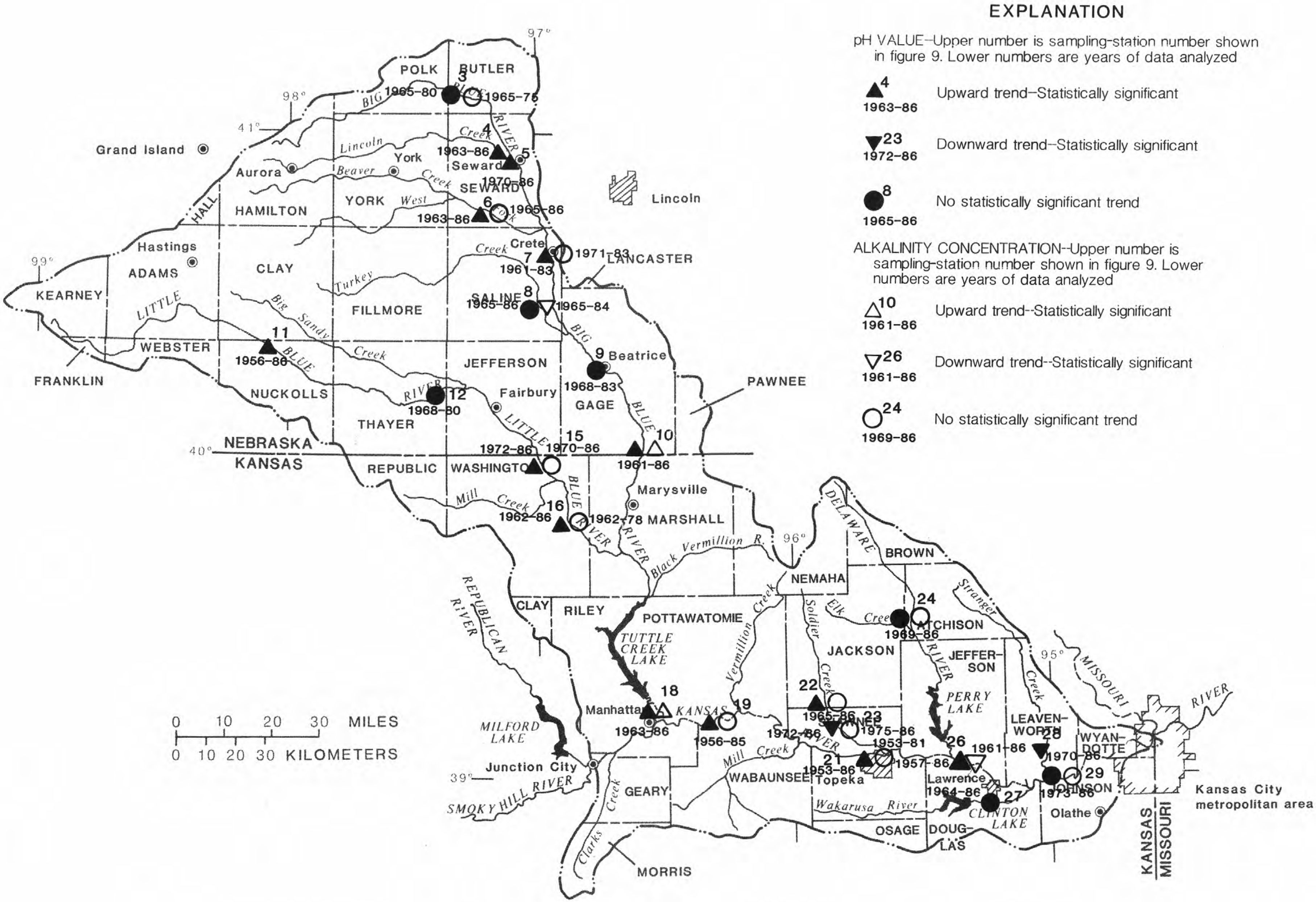


Figure 12.—Results of time-trend tests for pH values and total alkalinity concentrations in water from lower Kansas River basin.

Dissolved Solids and Major Ions

By P.R. Jordan
U.S. Geological Survey

The dissolved-solids content of natural surface water is made up principally of the cations calcium, magnesium, sodium, and potassium, and the anions bicarbonate, sulfate, and chloride. The elements forming these ions are abundant in the rocks and soil common to the study unit. A few other constituents, such as fluoride, carbon dioxide, and silica, are included with the summary of data on major ions because they do not fit in any other defined category used for this report. Although not an individual ion, hardness is a property closely related to some of the major ions, principally calcium and magnesium.

Current Conditions

Concentrations

A large number of analyses of major cations and anions are available for most of the 29 principal sampling stations in the lower Kansas River basin during the 1978-86 water years, the period selected to represent current conditions. Fewer analyses are available for dissolved solids (residue on evaporation at 180 °C) during 1978-86; however, large numbers of analyses are available at most of the stations for specific conductance, which is very highly correlated with dissolved solids (correlation coefficient of +0.997 for the Kansas River at DeSoto, Kans., station 29 in fig. 9). Data on dissolved solids and major ions are summarized in table 11. Dissolved-solids concentrations begin to be of concern when they exceed 500 mg/L for public-water supplies and for irrigation of sensitive crops. Concentrations (measured, or estimated from specific-conductance data) reached that level only in the Kansas River in approximately one-fourth to one-third of the samples.

Calcium and magnesium concentrations typically were large enough to produce median hardness concentrations in the ranges classified as "hard" and "very hard" by Durfor and Becker (1964, p. 27). Sodium in drinking water has not been shown to adversely affect the general population; however, a limit of 20 mg/L has been recommended for persons on very restricted sodium diets and a limit of 270 mg/L for persons on moderately restricted sodium diets (U.S. Environmental Protection Agency, 1978, p. 205-206). Median sodium concentrations exceeded 20 mg/L at most stations, but the 90th-percentile concentration did not exceed 270 mg/L at any station (table 11). In the absence of added sodium from water softening, sodium in the water would be of concern only for persons on very restricted diets. Fluoride was present in a narrow range of concentrations at all stations where it was analyzed. Tenth- and 90th-percentile concentrations ranged from 0.2 to 0.4 mg/L, well within the typical range for natural water as reported by Hem (1985, p. 122).

Comparison of data in table 11 for the two largest streams in the study unit shows the Kansas River to be consistently more mineralized than the Big Blue River. In both streams, the five ions having the largest concentrations were bicarbonate, calcium, sulfate, chloride, and sodium. At all percentiles in table 11, the concentrations of these five ions were larger in the Kansas River at Wamego, Kans. (station 19) than in the Big Blue River near Manhattan, Kans. (station 18), except for the 90th-percentile concentration of bicarbonate, for which they were equal. For the Big Blue River near Manhattan, the five ions in their order of abundance were: bicarbonate, calcium, sulfate, sodium, and chloride. For the Kansas River at Wamego, the order at the 10th percentile was bicarbonate, sulfate, calcium, chloride, and sodium, whereas at the 90th percentile, chloride concentrations had increased to second in abundance and calcium concentrations had decreased to fifth in abundance; so the order was bicarbonate, chloride, sulfate, sodium, and calcium. These 90th-percentile concentrations reflect the effect of the Smoky Hill River, which at times brings large concentrations of chloride into the study unit as a result of ground-water discharge of chloride from underlying formations that contain sodium chloride (see Gillespie and Hargadine, 1981).

Diagrams showing distributions of specific-conductance values in water from the Kansas and Big Blue Rivers and their major tributaries are shown in figure 13. (Dissolved-solids concentrations in milligrams per liter can be estimated as 0.6 times the specific conductance.) The Kansas River at Fort Riley (station 1, fig. 9) has the largest specific-conductance values because of inflow of large concentrations of chloride, sulfate, and associated ions from the Smoky Hill River (see Gillespie and Hargadine, 1981). Specific conductance is smaller in water from the Big Blue River and its tributaries, and dilution by flow from the Big Blue into the Kansas River causes the specific conductance of water in the Kansas River to decrease, as seen in data for the Kansas River at Wamego (station 19, fig. 9) in table 11 and figure 13. The specific conductance of water in the Kansas River generally shows a small decrease in the downstream direction as a result of inflow from tributaries (the apparent small increase from Wamego to Topeka probably reflects slight bias in the summary at Topeka because of special-purpose samples in relation to Topeka's water supply during times of increased concentrations of dissolved solids).

Table 11.—*Statistical summary of data on dissolved solids and major ions in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[This table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Dissolved solids, residue at 180 degrees Celsius, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	—	300	310	330	—
4	Lincoln Creek near Seward, Nebr.	29	—	270	330	360	—
5	Big Blue River at Seward, Nebr.	24	—	320	390	470	—
6	West Fork Big Blue River near Dorchester, Nebr.	31	150	250	340	360	410
7	Big Blue River near Crete, Nebr.	30	180	310	360	420	460
8	Turkey Creek near Wilber, Nebr.	32	120	250	340	490	770
9	Big Blue River at Beatrice, Nebr.	20	—	300	410	480	—
15	Little Blue River at Hollenberg, Kans.	22	—	330	370	380	—
18	Big Blue River near Manhattan, Kans.	76	190	230	260	310	360
29	Kansas River at DeSoto, Kans.	75	250	310	440	540	620
	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius						
1	Kansas River at Fort Riley, Kans.	496	400	560	790	1,140	1,490
2	Kings Creek near Manhattan, Kans.	40	430	490	530	560	600
3	Big Blue River at Surprise, Nebr.	70	180	270	450	600	740
4	Lincoln Creek near Seward, Nebr.	119	240	430	540	580	610
5	Big Blue River at Seward, Nebr.	131	240	520	640	720	800
6	West Fork Big Blue River near Dorchester, Nebr.	162	230	370	510	580	620
7	Big Blue River near Crete, Nebr.	230	170	350	510	610	650
8	Turkey Creek near Wilber, Nebr.	118	180	360	530	670	770
9	Big Blue River at Beatrice, Nebr.	66	210	380	600	720	790
10	Big Blue River at Barneston, Nebr.	121	250	440	600	700	780
11	Little Blue River near Deweese, Nebr.	115	200	400	450	470	500
12	Little Blue River near Alexandria, Nebr.	35	240	350	440	490	520
13	Big Sandy Creek at Alexandria, Nebr.	38	220	320	340	370	380
15	Little Blue River at Hollenberg, Kans.	197	220	390	540	600	640
16	Little Blue River near Barnes, Kans.	89	250	410	580	670	730
17	Black Vermillion River near Frankfort, Kans.	604	320	450	550	630	660
18	Big Blue River near Manhattan, Kans.	250	320	350	420	470	570
19	Kansas River at Wamego, Kans.	367	440	520	690	900	1,050
20	Mill Creek near Paxico, Kans.	59	460	540	620	690	760
21	Kansas River at Topeka, Kans.	138	410	540	720	940	1,100
22	Soldier Creek near Delia, Kans.	200	320	530	630	700	750
23	Soldier Creek near Topeka, Kans.	158	270	460	570	630	710
24	Delaware River near Muscotah, Kans.	205	270	400	500	580	640
25	Delaware River below Perry Dam, Kans.	15	—	330	350	360	—
26	Kansas River at Lecompton, Kans.	503	400	490	650	870	1,040
27	Wakarusa River near Lawrence, Kans.	41	300	340	360	400	460
28	Stranger Creek near Tonganoxie, Kans.	78	270	370	450	530	580
29	Kansas River at DeSoto, Kans.	594	400	480	620	890	980
	Hardness, total, as $CaCO_3$, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	—	270	290	300	—
3	Big Blue River at Surprise, Nebr.	35	56	100	200	290	340
4	Lincoln Creek near Seward, Nebr.	91	76	170	230	250	270
5	Big Blue River at Seward, Nebr.	106	93	210	280	310	340
6	West Fork Big Blue River near Dorchester, Nebr.	125	76	140	200	230	240
7	Big Blue River near Crete, Nebr.	210	51	140	250	310	410
8	Turkey Creek near Wilber, Nebr.	93	51	98	160	220	240
9	Big Blue River at Beatrice, Nebr.	51	57	100	190	230	270
10	Big Blue River at Barneston, Nebr.	114	88	150	210	250	300
11	Little Blue River near Deweese, Nebr.	99	64	160	190	210	220

Table 11.—*Statistical summary of data on dissolved solids and major ions in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[This table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile 10	25	50 (median)	75	90
	Hardness, total, as $CaCO_3$, in milligrams per liter–Continued						
12	Little Blue River near Alexandria, Nebr.	32	100	160	200	220	280
13	Big Sandy Creek at Alexandria, Nebr.	33	60	110	120	130	210
15	Little Blue River at Hollenberg, Kans.	188	76	130	190	210	230
18	Big Blue River near Manhattan, Kans.	188	120	150	170	210	250
19	Kansas River at Wamego, Kans.	111	160	190	240	280	330
21	Kansas River at Topeka, Kans.	49	140	180	220	280	320
22	Soldier Creek near Delia, Kans.	133	190	270	310	340	360
23	Soldier Creek near Topeka, Kans.	95	170	240	270	310	350
24	Delaware River near Muscotah, Kans.	60	150	220	260	310	340
26	Kansas River at Lecompton, Kans.	107	150	190	240	270	320
29	Kansas River at DeSoto, Kans.	124	160	180	220	270	310
	Noncarbonate hardness, as $CaCO_3$, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	—	17	26	31	—
4	Lincoln Creek near Seward, Nebr.	91	0	0	0	0	.8
5	Big Blue River at Seward, Nebr.	87	0	0	0	0	16
6	West Fork Big Blue River near Dorchester, Nebr.	93	0	0	0	0	8.6
7	Big Blue River near Crete, Nebr.	210	0	0	0	0	0
8	Turkey Creek near Wilber, Nebr.	93	0	0	0	0	12
9	Big Blue River at Beatrice, Nebr.	51	0	0	0	11	18
10	Big Blue River at Barneston, Nebr.	79	0	0	0	0	13
11	Little Blue River near Deweese, Nebr.	99	0	0	0	4	15
13	Big Sandy Creek at Alexandria, Nebr.	33	0	0	0	0	0
15	Little Blue River at Hollenberg, Kans.	187	0	0	9	16	23
18	Big Blue River near Manhattan, Kans.	185	12	18	27	36	46
19	Kansas River at Wamego, Kans.	110	34	51	66	92	120
21	Kansas River at Topeka, Kans.	49	30	43	71	92	110
22	Soldier Creek near Delia, Kans.	133	26	46	56	66	76
23	Soldier Creek near Topeka, Kans.	95	24	33	44	56	64
24	Delaware River near Muscotah, Kans.	59	17	30	45	54	75
26	Kansas River at Lecompton, Kans.	105	32	46	60	84	100
29	Kansas River at DeSoto, Kans.	122	28	41	60	78	94
	Calcium, total, in milligrams per liter						
15	Little Blue River at Hollenberg, Kans.	58	37	50	64	69	75
18	Big Blue River near Manhattan, Kans.	99	37	44	53	62	76
19	Kansas River at Wamego, Kans.	99	50	60	68	82	96
21	Kansas River at Topeka, Kans.	48	43	52	64	80	94
22	Soldier Creek near Delia, Kans.	117	59	77	86	96	100
23	Soldier Creek near Topeka, Kans.	92	52	68	80	91	100
24	Delaware River near Muscotah, Kans.	53	44	61	76	90	100
26	Kansas River at Lecompton, Kans.	114	46	55	66	78	95
29	Kansas River at DeSoto, Kans.	48	45	53	64	74	93
	Calcium, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	—	83	88	92	—
3	Big Blue River at Surprise, Nebr.	35	13	23	55	78	120
4	Lincoln Creek near Seward, Nebr.	90	21	51	70	74	83
5	Big Blue River at Seward, Nebr.	106	27	60	80	89	96
6	West Fork Big Blue River near Dorchester, Nebr.	125	22	42	60	72	76
7	Big Blue River near Crete, Nebr.	210	14	39	73	100	140
8	Turkey Creek near Wilber, Nebr.	92	16	29	48	66	73
9	Big Blue River at Beatrice, Nebr.	50	21	35	56	70	81

Table 11.—*Statistical summary of data on dissolved solids and major ions in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[This table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Calcium, dissolved, in milligrams per liter–Continued						
10	Big Blue River at Barneston, Nebr.	114	25	42	63	75	88
11	Little Blue River near Deweese, Nebr.	98	19	50	60	65	69
12	Little Blue River near Alexandria, Nebr.	33	31	49	64	73	99
13	Big Sandy Creek at Alexandria, Nebr.	33	14	32	38	40	76
15	Little Blue River at Hollenberg, Kans.	120	21	40	60	67	74
18	Big Blue River near Manhattan, Kans.	81	33	42	50	60	72
29	Kansas River at DeSoto, Kans.	73	45	50	65	78	89
	Magnesium, total, in milligrams per liter						
15	Little Blue River at Hollenberg, Kans.	58	5.4	7.9	9.5	10	11
18	Big Blue River near Manhattan, Kans.	99	8.0	9.1	11	14	17
19	Kansas River at Wamego, Kans.	99	10	12	16	20	23
21	Kansas River at Topeka, Kans.	48	8.0	11	15	20	23
22	Soldier Creek near Delia, Kans.	117	12	18	22	24	25
23	Soldier Creek near Topeka, Kans.	92	10	15	18	21	23
24	Delaware River near Muscotah, Kans.	53	8.5	14	18	20	22
26	Kansas River at Lecompton, Kans.	112	8.9	12	15	19	22
29	Kansas River at DeSoto, Kans.	48	8.0	11	14	18	20
	Magnesium, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	–	16	17	18	–
3	Big Blue River at Surprise, Nebr.	35	4.6	8.0	13	16	24
4	Lincoln Creek near Seward, Nebr.	91	5.4	11	14	15	16
5	Big Blue River at Seward, Nebr.	106	6.6	14	19	22	24
6	West Fork Big Blue River near Dorchester, Nebr.	125	4.9	8.2	12	13	14
7	Big Blue River near Crete, Nebr.	210	4.0	9.0	12	15	16
8	Turkey Creek near Wilber, Nebr.	92	3.8	6.8	11	14	15
9	Big Blue River at Beatrice, Nebr.	50	4.4	8.1	12	15	17
10	Big Blue River at Barneston, Nebr.	114	6.1	10	15	16	20
11	Little Blue River near Deweese, Nebr.	98	4.2	9.2	10	11	11
12	Little Blue River near Alexandria, Nebr.	32	6.0	7.0	9.0	10	10
13	Big Sandy Creek at Alexandria, Nebr.	33	4.0	5.0	6.0	7.0	8.0
15	Little Blue River at Hollenberg, Kans.	119	3.7	7.3	9.7	11	11
18	Big Blue River near Manhattan, Kans.	81	7.5	9.4	12	15	17
29	Kansas River at DeSoto, Kans.	73	10	12	16	19	21
	Sodium, total, in milligrams per liter						
15	Little Blue River at Hollenberg, Kans.	57	15	30	40	44	49
18	Big Blue River near Manhattan, Kans.	97	12	15	19	24	29
19	Kansas River at Wamego, Kans.	98	24	36	58	92	120
21	Kansas River at Topeka, Kans.	48	18	26	62	92	100
22	Soldier Creek near Delia, Kans.	117	12	17	20	23	26
23	Soldier Creek near Topeka, Kans.	92	12	17	21	23	27
24	Delaware River near Muscotah, Kans.	53	13	16	22	24	27
26	Kansas River at Lecompton, Kans.	114	18	26	47	84	100
29	Kansas River at DeSoto, Kans.	49	16	25	50	80	110
	Sodium, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	–	5.1	5.3	5.6	–
3	Big Blue River at Surprise, Nebr.	38	6.0	12	29	40	53
4	Lincoln Creek near Seward, Nebr.	62	7.4	21	27	29	31
5	Big Blue River at Seward, Nebr.	77	8.5	27	35	40	44
6	West Fork Big Blue River near Dorchester, Nebr.	94	9.6	20	29	36	39

Table 11.—*Statistical summary of data on dissolved solids and major ions in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[This table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Sodium, dissolved, in milligrams per liter–Continued						
7	Big Blue River near Crete, Nebr.	184	4.0	19	28	39	42
8	Turkey Creek near Wilber, Nebr.	58	9.3	17	37	48	67
9	Big Blue River at Beatrice, Nebr.	24	–	15	46	62	–
10	Big Blue River at Barneston, Nebr.	98	11	25	42	55	65
11	Little Blue River near Deweese, Nebr.	66	6.7	16	17	19	19
12	Little Blue River near Alexandria, Nebr.	33	7.8	16	20	23	25
13	Big Sandy Creek at Alexandria, Nebr.	36	11	21	28	29	30
15	Little Blue River at Hollenberg, Kans.	112	8.0	18	34	41	46
18	Big Blue River near Manhattan, Kans.	74	12	14	18	25	30
29	Kansas River at DeSoto, Kans.	73	20	32	57	80	110
	Potassium, total, in milligrams per liter						
15	Little Blue River at Hollenberg, Kans.	57	6.1	7.0	8.7	11	12
18	Big Blue River near Manhattan, Kans.	97	6.8	7.4	8.1	8.6	9.1
19	Kansas River at Wamego, Kans.	98	7.1	7.8	8.4	9.1	9.8
21	Kansas River at Topeka, Kans.	48	6.1	7.2	8.0	8.9	9.9
22	Soldier Creek near Delia, Kans.	117	2.4	2.7	3.1	3.6	4.5
23	Soldier Creek near Topeka, Kans.	92	2.0	2.6	2.8	3.6	4.0
24	Delaware River near Muscotah, Kans.	53	2.6	3.2	3.7	4.4	5.4
26	Kansas River at Lecompton, Kans.	114	5.6	6.6	7.6	8.5	9.3
29	Kansas River at DeSoto, Kans.	49	5.9	6.8	7.5	8.3	8.9
	Potassium, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	–	1.0	1.1	1.3	–
4	Lincoln Creek near Seward, Nebr.	28	–	7.4	9.8	12	–
5	Big Blue River at Seward, Nebr.	24	–	9.5	11	14	–
6	West Fork Big Blue River near Dorchester, Nebr.	28	–	8.2	10	12	–
7	Big Blue River near Crete, Nebr.	25	–	9.2	11	13	–
8	Turkey Creek near Wilber, Nebr.	27	–	8.8	11	12	–
9	Big Blue River at Beatrice, Nebr.	24	–	8.4	10	12	–
10	Big Blue River at Barneston, Nebr.	17	–	9.0	10	11	–
11	Little Blue River near Deweese, Nebr.	36	7.0	7.9	9.0	11	14
15	Little Blue River at Hollenberg, Kans.	99	6.1	6.7	8.6	10	12
18	Big Blue River near Manhattan, Kans.	74	7.0	7.5	8.1	8.5	9.3
29	Kansas River at DeSoto, Kans.	72	5.5	6.3	7.2	8.3	9.0
	Bicarbonate, as HCO_3, in milligrams per liter						
15	Little Blue River at Hollenberg, Kans.	54	72	140	220	240	250
18	Big Blue River near Manhattan, Kans.	87	120	150	180	210	270
19	Kansas River at Wamego, Kans.	53	150	170	200	220	270
21	Kansas River at Topeka, Kans.	45	140	160	190	230	280
22	Soldier Creek near Delia, Kans.	81	220	270	310	340	360
23	Soldier Creek near Topeka, Kans.	39	200	240	290	320	390
26	Kansas River at Lecompton, Kans.	59	150	170	180	230	250
29	Kansas River at DeSoto, Kans.	72	140	170	200	240	280
	Carbonate, in milligrams per liter						
15	Little Blue River at Hollenberg, Kans.	54	0	0	0	0	0
18	Big Blue River near Manhattan, Kans.	81	0	0	0	0	0
19	Kansas River at Wamego, Kans.	53	0	0	0	0	0
21	Kansas River at Topeka, Kans.	44	0	0	0	0	0
22	Soldier Creek near Delia, Kans.	81	0	0	0	0	0
23	Soldier Creek near Topeka, Kans.	38	0	0	0	0	0
26	Kansas River at Lecompton, Kans.	58	0	0	0	0	0
29	Kansas River at DeSoto, Kans.	70	0	0	0	0	3.6

Table 11.—*Statistical summary of data on dissolved solids and major ions in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[This table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile: 10	25	50 (median)	75	90
	Carbon dioxide, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	31	3.2	4.1	6.3	11	23
4	Lincoln Creek near Seward, Nebr.	117	0	0	0	.2	9.3
5	Big Blue River at Seward, Nebr.	104	0	0	0	0	8.6
6	West Fork Big Blue River near Dorchester, Nebr.	127	0	0	0	2.4	6.9
7	Big Blue River near Crete, Nebr.	245	0	0	0	0	1.3
8	Turkey Creek near Wilber, Nebr.	118	0	0	0	0	8.6
9	Big Blue River at Beatrice, Nebr.	66	0	0	0	2.4	6.5
10	Big Blue River at Barneston, Nebr.	84	0	0	0	1.3	3.4
11	Little Blue River near Deweese, Nebr.	100	0	0	0	3.3	6.4
13	Big Sandy Creek at Alexandria, Nebr.	36	0	0	0	0	0
15	Little Blue River at Hollenberg, Kans.	126	0	1.1	2.6	5.2	11
18	Big Blue River near Manhattan, Kans.	81	1.0	1.3	2.0	2.9	6.0
26	Kansas River at Lecompton, Kans.	18	—	1.4	2.2	3.0	—
29	Kansas River at DeSoto, Kans.	78	.7	1.1	2.1	3.5	7.2
	Sulfate, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	—	30	34	40	—
4	Lincoln Creek near Seward, Nebr.	90	17	33	43	51	60
5	Big Blue River at Seward, Nebr.	88	30	51	74	96	120
6	West Fork Big Blue River near Dorchester, Nebr.	93	17	36	51	58	64
7	Big Blue River near Crete, Nebr.	51	13	45	63	72	83
8	Turkey Creek near Wilber, Nebr.	92	10	28	52	63	71
9	Big Blue River at Beatrice, Nebr.	50	18	38	58	76	85
10	Big Blue River at Barneston, Nebr.	78	27	43	66	79	89
11	Little Blue River near Deweese, Nebr.	98	13	30	36	39	44
15	Little Blue River at Hollenberg, Kans.	176	17	33	43	49	57
18	Big Blue River near Manhattan, Kans.	180	32	39	48	60	69
19	Kansas River at Wamego, Kans.	106	58	76	92	120	150
21	Kansas River at Topeka, Kans.	48	48	68	90	120	140
22	Soldier Creek near Delia, Kans.	117	43	62	77	86	96
23	Soldier Creek near Topeka, Kans.	92	36	55	64	73	86
24	Delaware River near Muscotah, Kans.	53	31	46	57	72	92
26	Kansas River at Lecompton, Kans.	114	44	58	90	130	150
29	Kansas River at DeSoto, Kans.	120	49	65	98	130	150
	Chloride, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	—	1.7	2.0	2.4	—
3	Big Blue River at Surprise, Nebr.	38	6.4	12	15	21	32
4	Lincoln Creek near Seward, Nebr.	116	5.3	6.7	8.0	9.7	13
5	Big Blue River at Seward, Nebr.	129	5.5	7.6	9.6	12	14
6	West Fork Big Blue River near Dorchester, Nebr.	153	8.4	13	17	22	26
7	Big Blue River near Crete, Nebr.	234	7.0	11	16	22	25
8	Turkey Creek near Wilber, Nebr.	117	8.0	14	29	62	89
9	Big Blue River at Beatrice, Nebr.	65	9.0	17	41	55	67
10	Big Blue River at Barneston, Nebr.	117	8.6	17	32	45	56
11	Little Blue River near Deweese, Nebr.	98	6.5	9.5	11	12	14
12	Little Blue River near Alexandria, Nebr.	35	8.4	12	14	16	18
13	Big Sandy Creek at Alexandria, Nebr.	38	13	18	23	25	26
15	Little Blue River at Hollenberg, Kans.	184	10	22	36	43	54
18	Big Blue River near Manhattan, Kans.	179	9.8	12	16	20	25
19	Kansas River at Wamego, Kans.	106	26	45	72	110	160

Table 11.—*Statistical summary of data on dissolved solids and major ions in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[This table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile: 10	25	50 (median)	75	90
	Chloride, dissolved, in milligrams per liter–Continued						
21	Kansas River at Topeka, Kans.	48	21	34	82	120	130
22	Soldier Creek near Delia, Kans.	117	8.1	12	17	22	28
23	Soldier Creek near Topeka, Kans.	92	7.4	10	14	17	22
24	Delaware River near Muscotah, Kans.	53	6.9	10	12	16	19
26	Kansas River at Lecompton, Kans.	114	19	27	55	100	130
29	Kansas River at DeSoto, Kans.	120	20	30	63	96	130
	Fluoride, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans.	28	–	.4	.4	.5	–
4	Lincoln Creek near Seward, Nebr.	29	–	.3	.3	.4	–
5	Big Blue River at Seward, Nebr.	24	–	.3	.3	.3	–
6	West Fork Big Blue River near Dorchester, Nebr.	28	–	.3	.3	.4	–
7	Big Blue River near Crete, Nebr.	25	–	.2	.3	.4	–
8	Turkey Creek near Wilber, Nebr.	28	–	.2	.3	.4	–
9	Big Blue River at Beatrice, Nebr.	25	–	.2	.3	.3	–
10	Big Blue River at Barneston, Nebr.	18	–	.3	.4	.4	–
11	Little Blue River near Deweese, Nebr.	38	.2	.3	.3	.4	.4
15	Little Blue River at Hollenberg, Kans.	102	.2	.3	.3	.3	.4
18	Big Blue River near Manhattan, Kans.	76	.3	.3	.3	.3	.4
29	Kansas River at DeSoto, Kans.	75	.2	.3	.3	.4	.4
	Silica, dissolved, in milligrams per liter						
2	Kings Creek near Manhattan, Kans	28	–	12	13	14	–
4	Lincoln Creek near Seward, Nebr.	29	–	16	29	34	–
5	Big Blue River at Seward, Nebr.	25	–	13	22	26	–
6	West Fork Big Blue River near Dorchester, Nebr.	28	–	17	24	29	–
7	Big Blue River near Crete, Nebr.	25	–	12	22	27	–
8	Turkey Creek near Wilber, Nebr.	28	–	15	19	23	–
9	Big Blue River at Beatrice, Nebr.	24	–	11	22	25	–
10	Big Blue River at Barneston, Nebr.	17	–	14	21	24	–
11	Little Blue River near Deweese, Nebr.	36	15	21	28	32	33
15	Little Blue River at Hollenberg, Kans.	166	12	17	22	25	29
18	Big Blue River near Manhattan, Kans.	180	3.8	10	12	15	19
19	Kansas River at Wamego, Kans.	102	5.2	9.6	12	14	18
21	Kansas River at Topeka, Kans.	49	3.0	5.0	9.5	12	14
22	Soldier Creek near Delia, Kans.	133	4.0	7.0	9.0	12	14
23	Soldier Creek near Topeka, Kans.	95	5.6	9.0	11	13	15
24	Delaware River near Muscotah, Kans.	60	5.1	9.6	14	17	27
26	Kansas River at Lecompton, Kans.	108	4.0	8.0	11	14	17
29	Kansas River at DeSoto, Kans.	123	1.5	5.1	9.0	11	13

Concentrations of major ions generally followed the same pattern as specific conductance in their variation among sampling stations. Of special interest is chloride because of its maximum desirable concentration of 250 mg/L in drinking water (National Academy of Sciences, 1972, p. 61), and its approach to and occasional exceedance of that level along the Kansas River (fig. 14). Figure 14 illustrates the distribution of chloride concentrations in water from the Kansas and Big Blue Rivers and their major tributaries. Concentrations were fairly similar along the Kansas River from Wamego to DeSoto. Concentrations increased along the Big Blue River from Seward to Beatrice, then decreased to Manhattan.

Some effects of ground water on major ions in surface water can be inferred from graphs of concentration or specific conductance versus streamflow rate at stations where the effects were not obscured by such human-induced factors as reservoir releases or irrigation return flows. For example, the Delaware

River near Muscotah (station 24, fig. 9) showed close relations of specific conductance, hardness, sodium, sulfate, and chloride to streamflow rate. The increase of concentration or specific conductance between high and low streamflow rates ranged from threefold for sodium to eightfold for sulfate, indicating much larger concentrations at times when ground water was the source of the streamflow. In contrast, for the Kansas River, the effects of ground water were obscured by releases from the many reservoirs and varying contributions of water from major tributaries having differing qualities of water. At the Topeka station (station 21, fig. 9), relations between concentrations and streamflow rate were barely discernible amid much scatter of data points. For most sites on streams in the study unit, determination of the specific effects of ground water on surface-water quality would require a large quantity of ground-water data and modeling of the flow system.

Transport

Transport rates of dissolved solids and major ions are shown in table 12 for five selected sampling stations and for constituents that had adequate data for the calculations. Transport of all the major ions shows the same type of pattern as does chloride in figure 15; for example, major-ion transport of Big Blue River at Barneston (station 10, fig. 9) as a percentage of the transport of Kansas River at DeSoto (station 29) was about 8 percent for dissolved calcium, 9 percent for magnesium, 10 percent for sodium, 8 percent for sulfate, and 6 percent for chloride. The largest contributions of major ions were from the Smoky Hill and Republican Rivers and were estimated to be about 77 percent of the chloride transported past DeSoto (station 29) and 47 percent of the calcium, despite the fact that these rivers contributed only 27 percent of the streamflow reaching DeSoto. These estimates were based on transport and streamflow values for the Kansas River at Wamego (station 19) and the Big Blue River near Manhattan (station 18).

Precipitation probably contributed less than 25 percent of the dissolved solids and major ions transported by the streams. Twenty-five percent is the proportion that sulfate from precipitation would be if all the sulfate load from precipitation on the drainage area of the Big Blue River at Barneston, Nebr. (estimated from fig. 3b of Rinella and Miller, 1988) was transported unchanged to the Barneston streamflow-gaging station. Whether or not all sulfate from precipitation was transported to Barneston is unknown.

Trends

Results of trend analyses for specific conductance, dissolved solids, and selected major ions in water from sampling stations that had adequate data are shown in tables 13 and 14. Seven of the eight sampling stations in the upper Big Blue River basin (upstream of the Little Blue River, stations 3-10) showed significant positive trends in specific conductance, and no stations showed negative trends (fig. 16). Calcium and sodium showed significant increasing trends at four and five of the eight stations, respectively (table 14). Increasing trends were found for sulfate (fig. 17) at six stations and chloride at four stations of the seven that had adequate data for the trend tests (table 14). As noted earlier, irrigated acreage has increased severalfold in the upper Big Blue River basin since 1950 (see fig. 4). The trends in specific conductance and major ions probably are related to increased irrigation drainage.

The mechanism of increasing concentrations was explained by L.R. Petri (U.S. Geological Survey, written commun., 1968):

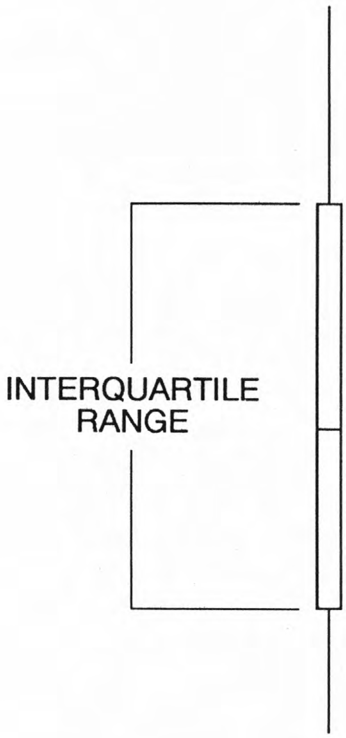
> "Most of the water that is applied in irrigation returns to the atmosphere by evaporation and transpiration. However, most of the dissolved solids that are applied with the water remain in the soil until they are removed through drainage. Because the volume of the drainage water commonly is only a small fraction of the volume of the applied water, concentrations of dissolved solids in the drainage tend to be higher than the concentrations in the applied water . . . Drainage from irrigation commonly contains a higher percentage of sodium, chloride, and sulfate ions than does the applied water. . . . Calcium and bicarbonate, however, are only slightly soluble and tend to precipitate as evapotranspiration reduces the volume of irrigation water after it has been applied. The result is formation of inert, solid calcium carbonate in the soil. Sodium, chloride, and sulfate, by contrast, are highly soluble and are readily removed by drainage water. Thus, drainage water is likely to be significantly higher in these soluble ions than the applied water was."

Petri (U.S. Geological Survey, written commun., 1968) noted that enrichment of dissolved constituents had been observed by 1968 in Nebraska streams that had been affected by irrigation for a long time. Concentrations of the constituents were still relatively

EXPLANATION

o VALUE(S) EXCEEDING UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

* VALUE(S) EXCEEDING UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE BUT LESS THAN UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE



UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE OR LARGEST VALUE NOT EXCEEDING THIS COMPUTATION

UPPER QUARTILE (75th PERCENTILE)

MEDIAN (50th PERCENTILE)

LOWER QUARTILE (25th PERCENTILE)

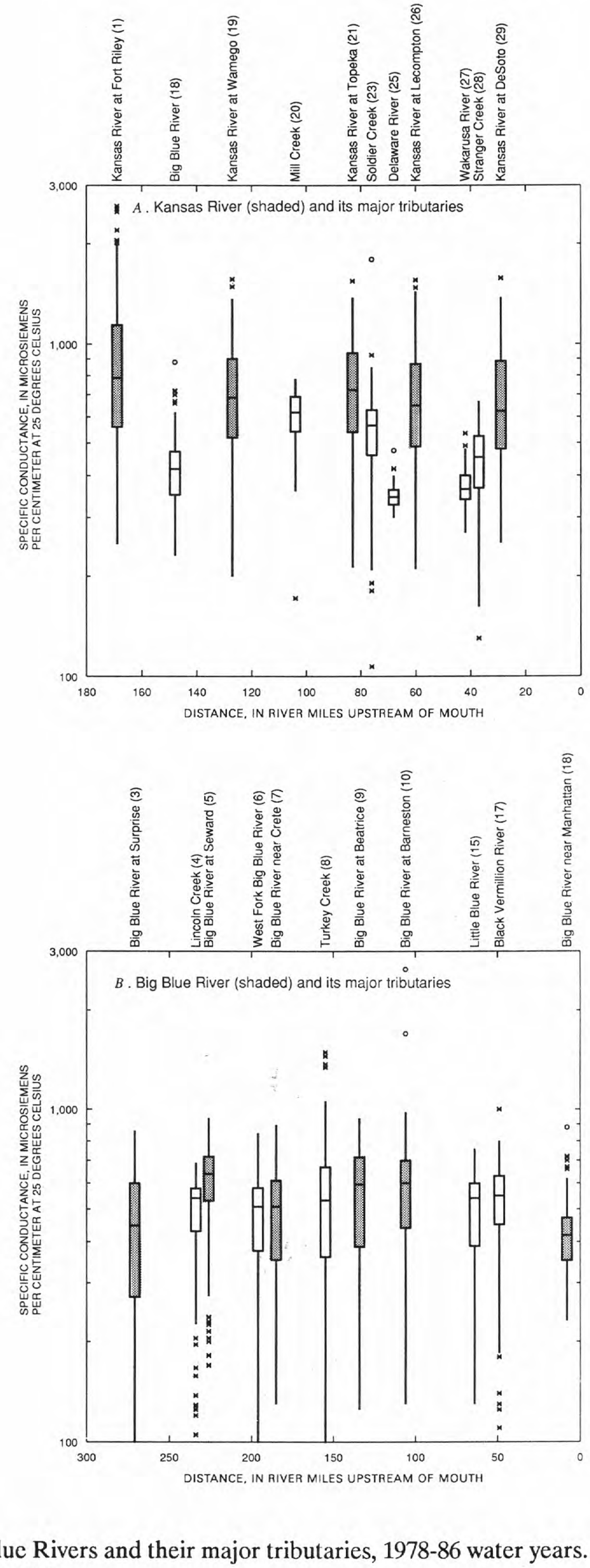
LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE OR SMALLEST VALUE NOT LESS THAN THIS COMPUTATION

* VALUE(S) LESS THAN LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE BUT GREATER THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

o VALUE(S) LESS THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

Figure 13.—Distribution of specific-conductance values analyzed in water from
Specific-conductance scale is logarithmic; minimum

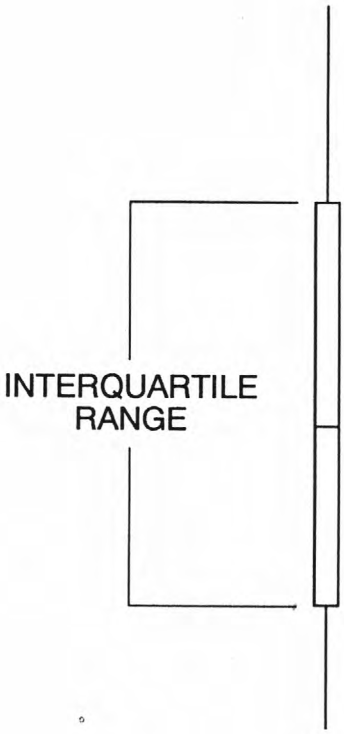


(*A*) Kansas and (*B*) Big Blue Rivers and their major tributaries, 1978-86 water years.
scale value arbitrarily set at 100.

EXPLANATION

o CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

* CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE BUT LESS THAN UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE



UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE OR LARGEST CONCENTRATION NOT EXCEEDING THIS COMPUTATION

UPPER QUARTILE (75th PERCENTILE)

MEDIAN (50th PERCENTILE)

LOWER QUARTILE (25th PERCENTILE)

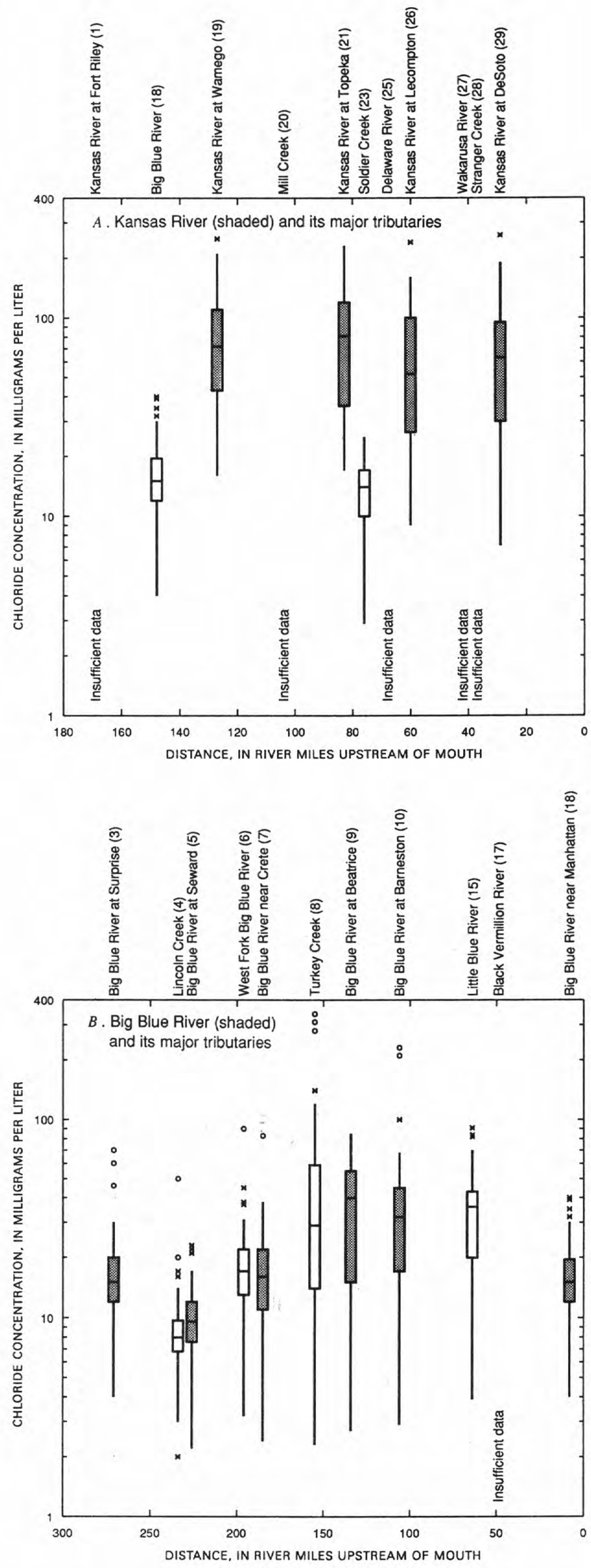
LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE OR SMALLEST CONCENTRATION NOT LESS THAN THIS COMPUTATION

* CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE BUT GREATER THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

o CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

Figure 14.—Distribution of dissolved-chloride concentrations analyzed in water from
Chloride-concentration scale is logarithmic;



(*A*) Kansas and (*B*) Big Blue Rivers and their major tributaries, 1978-86 water years. minimum scale value arbitrarily set at 1.

Table 12.—*Transport of dissolved solids and major ions in water at selected sampling stations within lower Kansas River basin, 1978-86 water years*

[—, data inadequate for computation]

Sampling-station number (fig. 9)	Station name	Mean annual transport (tons per year)	Root mean-square error of mean annual transport (percent)[1]	Mean annual yield, (tons per square mile of drainage area per year)
		Dissolved solids		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	—	—	—
18	Big Blue River near Manhattan, Kans.	660,000	4	68
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	2,700,000	4	45
		Dissolved calcium		
10	Big Blue River at Barneston, Nebr.	39,000	4	8.8
15	Little Blue River at Hollenberg, Kans.	20,000	4	7.3
18	Big Blue River near Manhattan, Kans.	130,000	5	13
19	Kansas River at Wamego, Kans.[2]	350,000	4	6.3
29	Kansas River at DeSoto, Kans.	470,000	4	7.9
		Dissolved magnesium		
10	Big Blue River at Barneston, Nebr.	9,400	4	2.1
15	Little Blue River at Hollenberg, Kans.	3,300	4	1.2
18	Big Blue River near Manhattan, Kans.	29,000	6	3.0
19	Kansas River at Wamego, Kans.[3]	76,000	4	1.4
29	Kansas River at DeSoto, Kans.	100,000	4	1.7
		Dissolved sodium		
10	Big Blue River at Barneston, Nebr.	26,000	6	5.8
15	Little Blue River at Hollenberg, Kans.	9,500	4	3.5
18	Big Blue River near Manhattan, Kans.	42,000	6	4.4
19	Kansas River at Wamego, Kans.[4]	230,000	4	4.2
29	Kansas River at DeSoto, Kans.	270,000	4	4.5
		Dissolved potassium		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	5,600	4	2.0
18	Big Blue River near Manhattan, Kans.	26,000	4	2.7
19	Kansas River at Wamego, Kans.[5]	48,000	4	.87
29	Kansas River at DeSoto, Kans.	62,000	4	1.0
		Total bicarbonate, whole water		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	—	—	—
18	Big Blue River near Manhattan, Kans.	460,000	4	48
19	Kansas River at Wamego, Kans.	980,000	4	18
29	Kansas River at DeSoto, Kans.	1,500,000	4	25
		Dissolved sulfate		
10	Big Blue River at Barneston, Nebr.	43,000	6	9.7
15	Little Blue River at Hollenberg, Kans.	15,000	4	5.4
18	Big Blue River near Manhattan, Kans.	130,000	4	13
19	Kansas River at Wamego, Kans.	440,000	4	8.0
29	Kansas River at DeSoto, Kans.	570,000	4	9.5
		Dissolved chloride		
10	Big Blue River at Barneston, Nebr.	19,000	6	4.3
15	Little Blue River at Hollenberg, Kans.	10,000	4	3.6
18	Big Blue River near Manhattan, Kans.	39,000	4	4.0
19	Kansas River at Wamego, Kans.	270,000	4	4.9
29	Kansas River at DeSoto, Kans.	300,000	4	5.0

Table 12. — *Transport of dissolved solids and major ions in water at selected sampling stations within lower Kansas River basin, 1978-86 water years* — Continued

[—, data inadequate for computation]

Sampling-station number (fig. 9)	Station name	Mean annual transport (tons per year)	Root mean-square error of mean annual transport (percent)[1]	Mean annual yield, (tons per square mile of drainage area per year)
		Dissolved fluoride		
10	Big Blue River at Barneston, Nebr	—	—	—
15	Little Blue River at Hollenberg, Kans	180	4	0.065
18	Big Blue River near Manhattan, Kans.	860	4	.089
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	2,600	4	.044
		Dissolved silica		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	10,000	4	3.6
18	Big Blue River near Manhattan, Kans.	46,000	12	4.8
19	Kansas River at Wamego, Kans.	83,000	9	1.5
29	Kansas River at DeSoto, Kans.	120,000	15	2.0

[1]Where root mean-square error was calculated as less than 4 percent, a value of 4 percent is shown to account for unknown biases.

[2]Total calcium used in absence of adequate data on dissolved calcium.

[3]Total magnesium used in absence of adequate data on dissolved magnesium.

[4]Total sodium used in absence of adequate data on dissolved sodium.

[5]Total potassium used in absence of adequate data on dissolved potassium.

small because the constituents were present in relatively small quantities in the applied irrigation water. Similarly in the Big Blue River basin, concentrations by 1986 were not yet large enough to be harmful. Simple projection of the past trends would not provide reliable estimates of future concentrations; mathematical modeling of the physical processes would be feasible and could provide reliable estimates of future concentrations that result from different management practices and structures such as reuse pits.

The Little Blue River basin (represented by stations 11-16) is not as extensively irrigated as the upper Big Blue River basin (stations 3-10), but it does have a substantial quantity of irrigated land. Trends in specific conductance in water from the Little Blue River basin were not evident as consistently as they were in the upper Big Blue River basin; an increasing trend was found at one of the four stations that had adequate data. However, trends were consistent for those major ions expected to be affected by irrigation; increasing trends were found in eight of the 11 tests for sodium, sulfate, and chloride concentrations (table 14).

The trends on the upper Big Blue River and the Little Blue River basins were of large enough magnitude to have effects on concentrations downstream, even though little land is irrigated downstream from station 10 on the Big Blue River and station 16 on the Little Blue River. The Big Blue River near Manhattan (station 18) showed increasing trends in specific conductance, sodium, and sulfate despite whatever effect Tuttle Creek Lake might have had by mixing waters from large and small rates of inflow. No significant trend was found for chloride, however. Further downstream, consistent significant trends were found only in sulfate, which had increasing trends at stations 19 and 21. Because data were inadequate for the Kansas River at station 1, no opportunity was available for studying the effects of water originating upstream from the Big Blue River on masking or contributing to trends in constituents of interest.

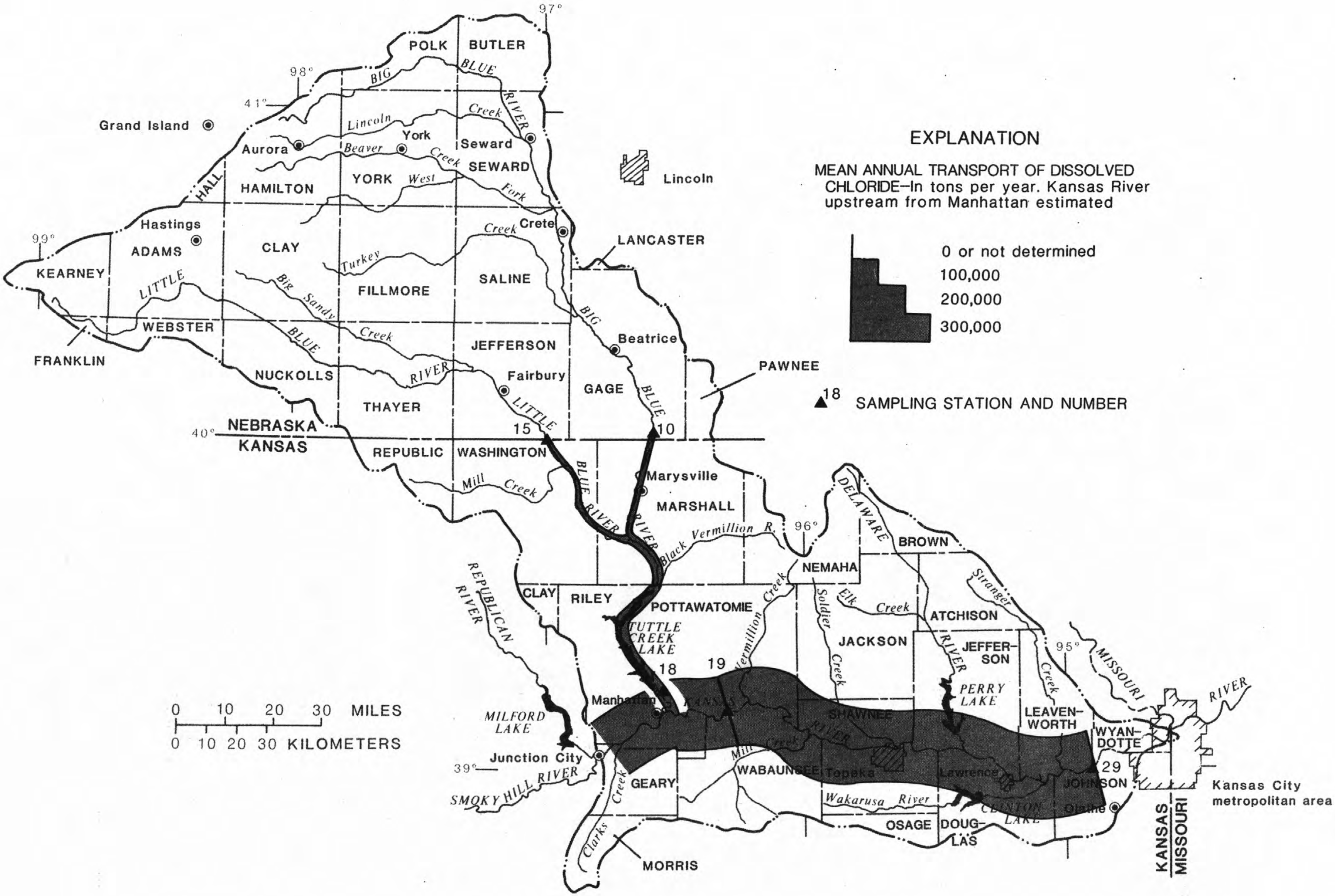


Figure 15.—Distribution of mean annual transport of dissolved chloride in lower Kansas River basin, 1978-86 water years.

Table 13. —*Trend-test results for specific conductance in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Specific conductance: Probability level	Specific conductance: Average rate of change: Microseimens per centimeter per year	Specific conductance: Average rate of change: Percent of median per year	Flow adjusted specific conductance: Probability level	Flow adjusted specific conductance: Average rate of change (percent per year)
1	Kansas River at Fort Riley, Kans.	1972-86	14	0.48	+ 14	+ 1.4	0.25	+ 2.4
3	Big Blue River at Surprise, Nebr.	1965-81	17	.59	+ 2.6	+ .69	.86	+ .21
4	Lincoln Creek near Seward, Nebr.	1963-86	24	0	+ 3.1	+ .59	0	+ 1.6
5	Big Blue River at Seward, Nebr.	1970-86	17	.04	+ 7.0	+ 1.2	0	+ 3.8
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	0	+ 3.3	+ .65	.04	+ .61
7	Big Blue River near Crete, Nebr.	1961-83	23	0	+ 8.2	+ 1.6	.02	+ .90
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.27	+ 2.8	+ .53	.02	+ 1.2
9	Big Blue River at Beatrice, Nebr.	1968-83	16	.17	+ 6.9	+ 1.1	.02	+ 1.7
10	Big Blue River at Barneston, Nebr.	1962-86	25	0	+ 8.1	+ 1.5	0	+ 2.0
11	Little Blue River near Deweese, Nebr.	1956-86	31	0	+ 1.9	+ .44	.19	+ .18
12	Little Blue River near Alexandria, Nebr.	1968-80	13	.66	- 1.0	- .25	.31	- .93
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.17	+ 2.5	+ .48	.42	+ .50
16	Little Blue River near Barnes, Kans.	1962-86	25	.57	+ 1.2	+ .22	.01	+ 1.2
17	Black Vermillion River near Frankfort, Kans.	1977-86	10	.10	+ 12	+ 2.4	.60	+ 1.9
18	Big Blue River near Manhattan, Kans.	1955-86	32	.79	+ .36	+ .08	.17	+ .45
		1963-86	24	.24	+ 2.2	+ .51	.06	+ .66
19	Kansas River at Wamego, Kans.	1956-85	30	.95	0	0	.21	+ .52
21	Kansas River at Topeka, Kans.	1953-86	34	.18	- 4.3	- .58	.17	+ .50
22	Soldier Creek near Delia, Kans	1965-86	22	0	- 7.0	- 1.0	.42	- .37
23	Soldier Creek near Topeka, Kans.	1972-86	15	.15	- 5.8	- 1.0	.26	+ 1.4
24	Delaware River near Muscotah, Kans.	1969-86	18	.60	- 4.1	- .79	1.00	0
26	Kansas River at Lecompton, Kans.	1957-86	30	.30	- 4.4	- .63	1.00	0
28	Stranger Creek near Tonganoxie, Kans.	1970-86	17	.32	+ 6.2	+ 1.5	.14	+ 1.1
29	Kansas River at DeSoto, Kans.	1973-86	14	.29	- 7.6	- 1.0	.67	- .48

Table 14. — *Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend — Concentration: Probability level	Concentration: Average rate of change — Milligrams per liter per year	Concentration: Average rate of change — Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
				Dissolved solids				
4	Lincoln Creek near Seward, Nebr.	1963-80	18	0.07	+ 1.8	+0.55	0.40	+0.19
6	West Fork Big Blue River near Dorchester, Nebr.	1963-80	18	.02	+ 3.0	+ .92	.43	- .27
7	Big Blue River near Crete, Nebr.	1961-80	20	0	+ 6.3	+ 1.8	.32	+ .50
8	Turkey Creek near Wilber, Nebr.	1965-80	16	.04	+ 5.6	+ 1.7	.38	+ .65
11	Little Blue River near Deweese, Nebr.	1956-69	14	.02	+ 1.0	+ .37	.28	+ .32
16	Little Blue River near Barnes, Kans.	1962-75	14	.03	+ 5.9	+ 1.6	.03	+ 2.1
18	Big Blue River near Manhattan, Kans.	1955-86	32	.39	+ .68	+ .25	.09	+ .50
		1963-86	24	.09	+ 1.8	+ .66	.04	+ .74
19	Kansas River at Wamego, Kans.	1956-75	20	.27	+ 3.5	+ .85	.12	+ 1.6
22	Soldier Creek near Delia, Kans.	1965-75	11	.01	- 6.2	- 1.4	.74	- .30
26	Kansas River at Lecompton, Kans.	1957-78	22	.69	- 1.5	- .33	.83	- .14
29	Kansas River at DeSoto, Kans.	1973-86	14	.40	- 3.0	- .66	.46	- .77
				Hardness, total				
3	Big Blue River at Surprise, Nebr.	1965-80	16	.50	+ 1.6	+ 1.2	.04	+ 2.5
4	Lincoln Creek near Seward, Nebr.	1963-86	24	.01	+ .83	+ .38	0	+ 1.9
5	Big Blue River at Seward, Nebr.	1970-86	17	.09	+ 3.3	+ 1.4	0	+ 4.0
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	.10	+ 1.0	+ .50	.14	+ .45
7	Big Blue River near Crete, Nebr.	1961-83	23	0	+ 3.1	+ 1.5	.13	+ .84
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.94	0	0	.50	+ .41
9	Big Blue River at Beatrice, Nebr.	1974-83	10	.13	+ 1.9	+ 1.0	.09	+ 1.8
10	Big Blue River at Barneston, Nebr.	1961-86	26	.19	+ 1.0	+ .48	.01	+ 1.4
11	Little Blue River near Deweese, Nebr.	1956-86	31	.02	+ .45	+ .25	.30	+ .16
12	Little Blue River near Alexandria, Nebr.	1968-80	13	.81	0	0	.87	- .38
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.30	+ .69	+ .37	.27	+ .80

Table 14. – *Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin* – Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
			Hardness, total – Continued					
16	Little Blue River near Barnes, Kans.	1962-78	17	0.12	+ 2.9	+ 1.4	0.09	+ 1.8
18	Big Blue River near Manhattan, Kans.	1955-86	32	.10	+ .83	+ .46	.01	+ .72
		1963-86	24	.04	+ 1.4	+ .79	.02	+ .90
19	Kansas River at Wamego, Kans.	1956-85	30	.42	+ .62	+ .26	.22	+ .40
21	Kansas River at Topeka, Kans.	1953-81	29	.88	0	0	.76	+ .09
22	Soldier Creek near Delia, Kans.	1965-86	22	0	- 2.5	- .76	.55	- .31
23	Soldier Creek near Topeka, Kans.	1975-86	12	.51	+ 1.7	+ .62	.20	+ 1.2
24	Delaware River near Muscotah, Kans.	1969-86	18	.11	- 2.6	- .94	.60	- .26
26	Kansas River at Lecompton, Kans.	1957-86	30	.24	- 1.1	- .46	.67	- .15
29	Kansas River at DeSoto, Kans.	1973-86	14	.27	- 2.0	- .82	1.00	- .04
			Calcium, dissolved					
3	Big Blue River at Surprise, Nebr.	1965-80	16	.16	+ 1.0	+ 3.1	.07	+ 2.4
4	Lincoln Creek near Seward, Nebr.	1963-86	24	0	+ .35	+ .54	.01	+ 2.1
5	Big Blue River at Seward, Nebr.	1971-86	16	.33	+ .54	+ .74	.01	+ 3.7
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	.08	+ .33	+ .55	.19	+ .46
7	Big Blue River near Crete, Nebr.	1961-83	23	.01	+ .75	+ 1.2	.53	+ .30
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.94	0	0	.25	+ .89
9	Big Blue River at Beatrice, Nebr.	1974-83	10	.44	+ .53	+ .89	.14	+ 2.0
10	Big Blue River at Barneston, Nebr.	1966-86	22	.44	+ .36	+ .61	0	+ 2.1
11	Little Blue River near Deweese, Nebr.	1956-86	31	.02	+ .14	+ .25	.39	+ .14
12	Little Blue River near Alexandria, Nebr.	1971-80	10	1.00	0	0	.94	+ .26
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.15	+ .75	+ 1.3	.11	+ 2.3
16	Little Blue River near Barnes, Kans.	1962-78	17	.05	+ 1.0	+ 1.5	.04	+ 2.0
18	Big Blue River near Manhattan, Kans.	1955-86	32	.32	+ .15	+ .29	.06	+ .48
		1963-86	24	.17	+ .29	+ .56	.09	+ .53

Table 14. — *Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin* — Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
				Calcium, dissolved — Continued				
19	Kansas River at Wamego, Kans.	1956-78	23	0.41	+ 0.22	+ 0.33	0.11	+ 1.1
26	Kansas River at Lecompton, Kans.	1957-75	19	.50	+ .31	+ .42	.19	+ 1.0
29	Kansas River at DeSoto, Kans.	1973-86	14	.52	- .50	- .70	.51	- .67
				Magnesium, dissolved				
3	Big Blue River at Surprise, Nebr.	1965-80	16	.54	+ .15	+ 1.3	.85	+ .33
4	Lincoln Creek near Seward, Nebr.	1963-86	24	.01	+ .062	+ .48	0	+ 2.0
5	Big Blue River at Seward, Nebr.	1971-86	16	.15	+ .28	+ 1.6	.02	+ 3.4
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	.04	+ .059	+ .53	.12	+ .53
7	Big Blue River near Crete, Nebr.	1961-83	23	.04	+ .21	+ 1.6	.11	+ 1.3
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.09	+ .057	+ .52	.08	+ 1.1
9	Big Blue River at Beatrice, Nebr.	1974-83	10	.81	0	0	.10	+ 2.6
10	Big Blue River at Barneston, Nebr.	1966-86	21	.15	+ .12	+ .88	.02	+ 2.1
11	Little Blue River near Deweese, Nebr.	1956-86	31	0	+ .081	+ .89	0	+ .70
12	Little Blue River near Alexandria, Nebr.	1971-80	10	.20	- .40	- 4.5	.13	- 4.6
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.10	+ .10	+ 1.1	.18	+ 1.7
16	Little Blue River near Barnes, Kans.	1962-78	17	.78	+ .01	+ .13	.18	+ 1.8
18	Big Blue River near Manhattan, Kans.	1955-86	32	.05	+ .09	+ .75	.01	+ 1.2
		1963-86	24	.02	+ .14	+ 1.2	.01	+ 1.6
19	Kansas River at Wamego, Kans.	1956-78	23	.11	+ .19	+ 1.2	.02	+ 2.3
26	Kansas River at Lecompton, Kans.	1957-75	19	.81	0	0	.31	+ 1.3
29	Kansas River at DeSoto, Kans.	1973-86	14	.82	0	0	.97	- .08
				Sodium, dissolved				
3	Big Blue River at Surprise, Nebr.	1965-80	16	.14	+ .60	+ 3.1	.27	+ 2.7
4	Lincoln Creek near Seward, Nebr.	1963-86	24	0	+ .17	+ .64	0	+ 2.0
5	Big Blue River at Seward, Nebr.	1971-86	16	.83	0	0	.05	+ 3.3

Table 14. — *Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin* — Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
				Sodium, dissolved — Continued				
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	0.17	+ 0.21	+ 0.73	0.16	+ 0.38
7	Big Blue River near Crete, Nebr.	1961-83	23	.04	+ .45	+ 1.7	.09	+ 1.3
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.54	+ .18	+ .50	—	—
9	Big Blue River at Beatrice, Nebr.	1974-83	10	.88	+ .17	+ .36	.06	+ 2.2
10	Big Blue River at Barneston, Nebr.	1966-86	21	.95	- .042	- .099	0	+ 1.6
11	Little Blue River near Deweese, Nebr.	1956-86	31	0	+ .11	+ .74	.01	+ .45
12	Little Blue River near Alexandria, Nebr.	1968-80	13	.84	0	0	.01	- 3.4
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.68	+ .17	+ .52	.06	+ 1.5
16	Little Blue River near Barnes, Kans.	1962-75	14	.76	+ .08	+ .25	.01	+ 1.3
18	Big Blue River near Manhattan, Kans.	1955-86	32	.98	0	0	.37	+ .42
		1963-86	24	.24	+ .16	+ .87	.08	+ .98
19	Kansas River at Wamego, Kans.	1956-75	20	.39	+ .68	+ 1.1	.13	+ 2.0
26	Kansas River at Lecompton, Kans.	1957-75	19	.23	+ 1.1	+ 1.9	.18	+ 2.3
29	Kansas River at DeSoto, Kans.	1973-86	14	.67	- .33	- .55	.49	- 1.1
				Potassium, dissolved				
3	Big Blue River at Surprise, Nebr.	1965-75	11	.28	+ .25	+ 1.5	—	—
4	Lincoln Creek near Seward, Nebr.	1963-84	22	.08	+ .036	+ .37	.15	+ .57
6	West Fork Big Blue River near Dorchester, Nebr.	1963-84	22	0	+ .10	+ 1.1	0	+ 1.4
7	Big Blue River near Crete, Nebr.	1961-83	23	.59	+ .020	+ .20	.34	+ .41
8	Turkey Creek near Wilber, Nebr.	1965-84	20	0	+ .20	+ 2.2	0	+ 2.3
9	Big Blue River at Beatrice, Nebr.	1968-83	16	.35	+ .09	+ .91	—	—
10	Big Blue River at Barneston, Nebr.	1966-84	19	.65	+ .012	+ .12	.67	+ .27
11	Little Blue River near Deweese, Nebr.	1956-84	29	0	+ .10	+ 1.4	0	+ 1.4
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.06	+ .094	+ 1.1	—	—

Table 14. — *Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin* — Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
				Potassium, dissolved — Continued				
16	Little Blue River near Barnes, Kans.	1962-75	14	0.41	- 0.035	- 0.43	—	—
18	Big Blue River	1955-86	32	.34	+ .014	+ .18	—	—
	near Manhattan, Kans.	1963-86	24	.46	- .011	- .14	—	—
19	Kansas River at Wamego, Kans.	1956-75	20	.17	- .064	- .72	0.14	- 0.87
26	Kansas River at Lecompton, Kans.	1957-75	19	0	- .20	- 2.4	0	- 2.0
				Bicarbonate				
6	West Fork Big Blue River near Dorchester, Nebr.	1963-78	16	.20	+ 1.1	+ .46	.18	- 1.2
8	Turkey Creek near Wilber, Nebr.	1965-78	14	.15	- 1.8	- .85	.10	- 1.2
11	Little Blue River near Deweese, Nebr.	1956-84	29	.02	+ .61	+ .28	.29	- .17
15	Little Blue River at Hollenberg, Kans.	1970-82	13	.70	0	0	.94	- .19
16	Little Blue River near Barnes, Kans.	1962-78	17	.11	+ 2.3	+ 1.0	.11	+ 1.3
18	Big Blue River	1955-86	32	.71	0	0	.21	+ .31
	near Manhattan, Kans.	1963-86	24	.19	+ .77	+ .40	.06	+ .53
19	Kansas River at Wamego, Kans.	1956-82	27	.69	0	0	.85	- .06
21	Kansas River at Topeka, Kans.	1953-81	29	.41	- .48	- .25	.52	- .07
22	Soldier Creek near Delia, Kans.	1965-81	17	.14	- 2.0	- .61	.85	- .20
26	Kansas River at Lecompton, Kans.	1957-81	25	.03	- 1.6	- .72	.02	- .89
29	Kansas River at DeSoto, Kans.	1973-86	14	.89	0	0	.45	- 1.4
				Carbon dioxide, dissolved				
3	Big Blue River at Surprise, Nebr.	1965-80	16	.74	- .12	- 2.0	—	—
4	Lincoln Creek near Seward, Nebr.	1963-86	24	0	- .29	- 13	—	—
5	Big Blue River at Seward, Nebr.	1970-86	17	0	- .26	—	—	—
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	0	- .36	- 56	.02	- 2.1
7	Big Blue River near Crete, Nebr.	1961-83	23	0	- .58	- 25	0	- 4.7
8	Turkey Creek near Wilber, Nebr.	1965-84	20	0	- .20	—	—	—
9	Big Blue River at Beatrice, Nebr.	1968-83	16	0	- .48	- 37	.71	- 1.8

Table 14.—*Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin*—Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
				Carbon dioxide, dissolved—Continued				
10	Big Blue River at Barneston, Nebr.	1961-86	26	0	- 0.23	- 5.8	0.07	- 2.2
11	Little Blue River near Deweese, Nebr.	1956-84	29	0	- .29	- 5.3	0	- 12
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.01	+ .17	+ 9.3	—	—
16	Little Blue River near Barnes, Kans.	1962-75	14	.03	+ .27	+ 3.2	—	—
18	Big Blue River near Manhattan, Kans.	1955-86	32	0	- .14	- 3.2	—	—
		1963-86	24	0	- .16	- 3.8	—	—
19	Kansas River at Wamego, Kans.	1956-75	20	.76	- .040	- .60	.75	+ .56
22	Soldier Creek near Delia, Kans.	1965-86	22	.44	- .14	- 1.7	.44	- 1.8
26	Kansas River at Lecompton, Kans.	1957-78	22	.01	- .29	- 4.2	—	—
				Sulfate, dissolved				
3	Big Blue River at Surprise, Nebr.	1965-75	11	.70	+ .33	+ 2.1	.34	+ 1.8
4	Lincoln Creek near Seward, Nebr.	1963-86	24	0	+ 1.1	+ 3.7	0	+ 4.0
5	Big Blue River at Seward, Nebr.	1971-86	16	.04	+ 1.8	+ 2.5	0	+ 1.7
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	0	+ .82	+ 1.8	0	+ 1.7
7	Big Blue River near Crete, Nebr.	1961-83	23	0	+ 1.5	+ 2.9	.01	+ 2.3
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.04	+ .56	+ 1.2	.09	+ 1.1
10	Big Blue River at Barneston, Nebr.	1966-86	21	.04	+ 1.0	+ 1.7	.06	+ 1.0
11	Little Blue River near Deweese, Nebr.	1956-86	31	.01	+ .21	+ .69	.01	+ .53
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.01	+ .54	+ 1.4	.06	+ 2.2
16	Little Blue River near Barnes, Kans.	1962-78	17	.01	+ 3.0	+ 5.2	.01	+ 5.6
18	Big Blue River near Manhattan, Kans.	1955-86	32	0	+ .66	+ 1.5	0	+ 1.9
		1963-86	24	0	+ .96	+ 2.1	0	+ 2.3
19	Kansas River at Wamego, Kans.	1956-85	30	.16	+ .71	+ .78	.03	+ 1.5
21	Kansas River at Topeka, Kans.	1953-81	29	.27	+ .62	+ .65	.06	+ 1.4
22	Soldier Creek near Delia, Kans.	1965-86	22	0	- 1.0	- 1.3	.15	- .55

Table 14. — *Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin* — Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
				Sulfate, dissolved — Continued				
23	Soldier Creek near Topeka, Kans.	1975-86	12	0.03	- 1.3	- 2.0	0.88	- 0.25
24	Delaware River near Muscotah, Kans.	1969-86	18	.06	- 1.4	- 2.3	.46	+ .16
26	Kansas River at Lecompton, Kans.	1957-86	30	.88	0	0	.11	+ 1.1
29	Kansas River at DeSoto, Kans.	1973-86	14	.42	- 1.4	- 1.3	.66	- .56
				Chloride, dissolved				
3	Big Blue River at Surprise, Nebr.	1965-80	16	.08	+ .45	+ 2.9	.34	+ 1.8
4	Lincoln Creek near Seward, Nebr.	1963-86	24	0	+ .20	+ 3.0	0	+ 3.3
5	Big Blue River at Seward, Nebr.	1971-86	16	.82	+ .014	+ .15	.11	+ 2.1
6	West Fork Big Blue River near Dorchester, Nebr.	1963-86	24	.16	+ .12	+ .74	.03	+ .62
7	Big Blue River near Crete, Nebr.	1961-83	23	.08	+ .33	+ 2.0	0	+ 2.2
8	Turkey Creek near Wilber, Nebr.	1965-86	22	.45	+ .29	+ 1.1	0	+ 2.8
10	Big Blue River at Barneston, Nebr.	1965-86	22	.97	0	0	—	—
11	Little Blue River near Deweese, Nebr.	1956-86	31	0	+ .12	+ 1.3	0	+ 1.4
12	Little Blue River near Alexandria, Nebr.	1971-80	10	.16	+ .15	+ 1.2	.77	+ .37
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.13	- .32	- .90	.17	- .70
16	Little Blue River near Barnes, Kans.	1962-78	17	.67	- .15	- .42	.01	+ 1.5
18	Big Blue River near Manhattan, Kans.	1955-86	32	.28	- .11	- .65	.61	- .28
		1963-86	24	.52	- .071	- .42	.99	0
19	Kansas River at Wamego, Kans.	1956-85	30	.60	- .26	- .34	.63	+ .31
21	Kansas River at Topeka, Kans.	1953-81	29	.27	- .80	- .94	.86	+ .05
22	Soldier Creek near Delia, Kans.	1965-86	22	0	- .48	-2.6	.12	- .91
23	Soldier Creek near Topeka, Kans.	1972-86	15	.02	- .67	- 4.4	.03	- 2.9
24	Delaware River near Muscotah, Kans.	1969-86	18	.06	- .36	- 2.5	.47	- .93
26	Kansas River at Lecompton, Kans.	1957-86	30	.35	- .59	- .88	.87	+ .16

Table 14. — *Trend-test results for dissolved-solids and major-ion concentrations in water from selected sampling stations within lower Kansas River basin* — Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow-adjusted concentration: Probability level	Flow-adjusted concentration: Average rate of change (percent per year)
			Chloride, dissolved — Continued					
29	Kansas River at DeSoto, Kans.	1973-86	14	0.23	- 2.0	- 2.9	0.13	- 2.8
			Fluoride, dissolved					
6	West Fork Big Blue River near Dorchester, Nebr.	1963-84	22	—	—	—	.07	- .59
7	Big Blue River near Crete, Nebr.	1961-83	23	.21	0	0	.07	- .66
8	Turkey Creek near Wilber, Nebr.	1965-84	20	—	—	—	0	- 1.6
11	Little Blue River near Deweese, Nebr.	1956-84	29	.24	0	0	—	—
16	Little Blue River near Barnes, Kans.	1962-75	14	.70	0	0	—	—
22	Soldier Creek near Delia, Kans.	1965-75	11	.53	0	0	.65	+ .69
26	Kansas River at Lecompton, Kans.	1957-75	19	.66	0	0	—	—
			Silica, dissolved					
6	West Fork Big Blue River near Dorchester, Nebr.	1963-84	22	.12	- .13	- .56	.03	- 1.1
7	Big Blue River near Crete, Nebr.	1961-83	23	.43	+ .12	+ .57	.19	- .75
8	Turkey Creek near Wilber, Nebr.	1965-84	20	.10	- .19	- .96	.03	- 1.6
11	Little Blue River near Deweese, Nebr.	1956-84	29	.40	- .045	- .15	.01	- .64
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.77	0	0	.40	+ .47
16	Little Blue River near Barnes, Kans.	1962-75	14	.67	0	0	.86	+ .20
18	Big Blue River	1955-86	32	.73	0	0	.55	- .37
	near Manhattan, Kans.	1963-86	24	.01	+ .20	+ 1.7	.03	+ 1.8
19	Kansas River at Wamego, Kans.	1956-86	31	.33	- .038	- .31	—	—
22	Soldier Creek near Delia, Kans.	1965-86	22	.83	0	0	.40	- .60
23	Soldier Creek near Topeka, Kans.	1975-86	12	1.00	0	0	.73	+ .42
24	Delaware River near Muscotah, Kans.	1969-86	18	.90	+ .044	+ .38	.84	+ .44
26	Kansas River at Lecompton, Kans.	1957-86	30	.60	0	0	.28	- .69

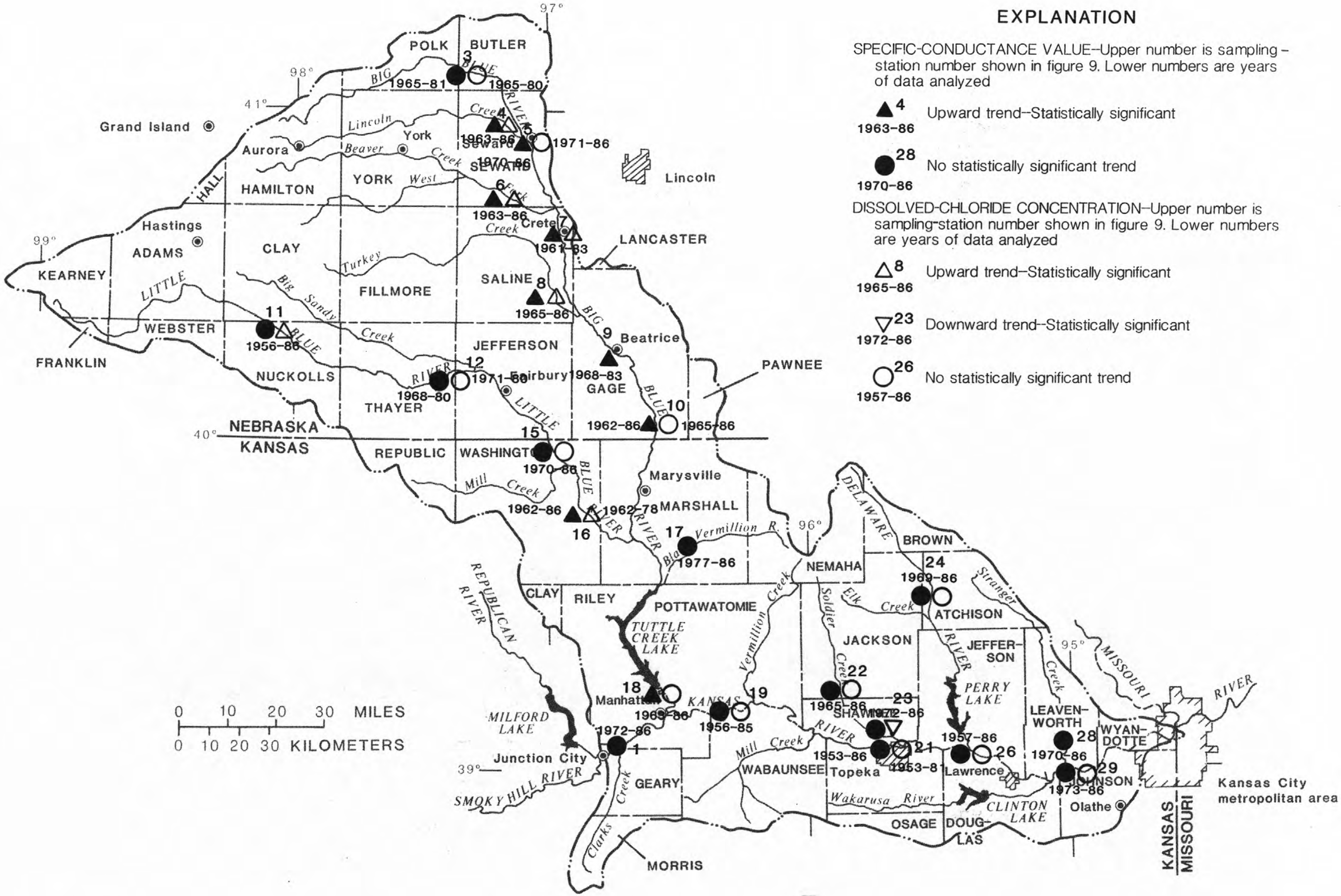


Figure 16.—Results of time-trend tests for specific-conductance values and dissolved-chloride concentrations in water from lower Kansas River basin.

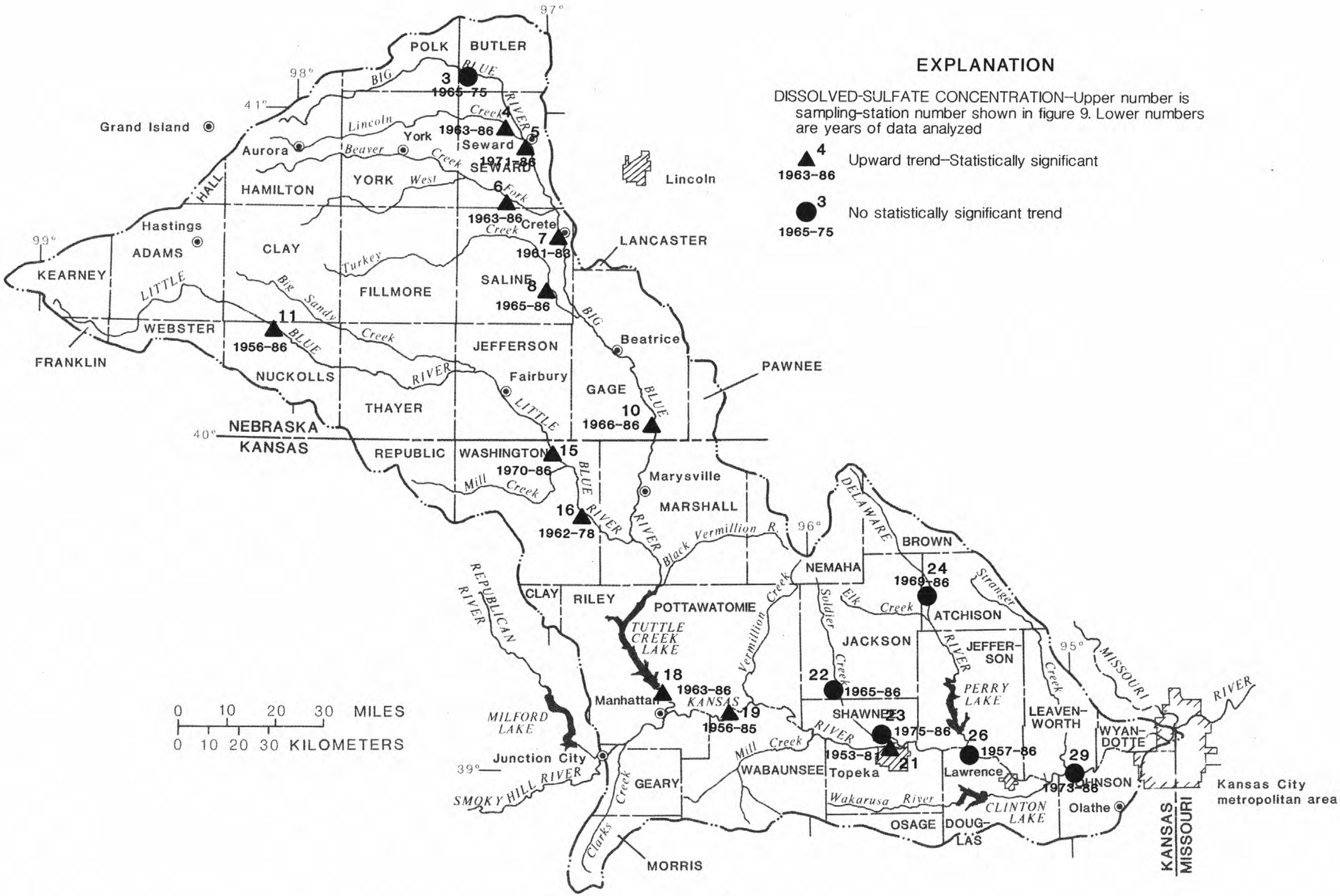


Figure 17.—Results of time-trend tests for dissolved-sulfate concentrations in water from lower Kansas River basin.

Data needs

The principal need for additional data on dissolved solids and major ions is for the Kansas River upstream from the Big Blue River (station 1, fig. 9). Because the concentrations of dissolved solids and major ions, particularly chloride, at the confluence of the Republican and Smoky Hill Rivers are affected by the concentrations in water from the two rivers and their relative flows, data collection at the downstream sampling stations on the two rivers and at Fort Riley (station 1, fig. 9) should be coordinated. Constituent concentrations in water from the Kansas River at Fort Riley (station 1) probably are not as well correlated with streamflow rates as at most other sampling stations. For example during a drought period, the concentration of chloride in Kansas River water at Fort Riley may be large because of large concentrations in water from the Smoky Hill River, but if surplus water is available for release from Milford Lake, the concentration in the Kansas River at Fort Riley may be reduced by dilution. Additional data on dissolved solids are needed at some other stations for calculation of transport rates and mass balance, as mentioned earlier. Data collection should be continued periodically for sulfate, sodium, and chloride to analyze for time trends downstream from areas of intensive irrigation. In addition, modeling could be used to investigate the possible magnitude of increases in concentrations of major ions as a result of irrigation.

Suspended Sediment

By P.R. Jordan
U.S. Geological Survey

Suspended sediment affects water use both as an inert substance and as a carrier of active chemical constituents although the mechanism of many of the effects is poorly understood (Angino and O'Brien, 1967). Suspended sediment limits the penetration of light through the water to the detriment of some species of fish and other aquatic life. However, in nutrient-rich lakes that potentially could support a large algal population and resultant seasonal deficiencies of oxygen, limitation of light penetration by suspended sediment can prevent those oxygen deficiencies by limiting algal proliferation (Hammer and Hergenrader, 1971). Suspended sediment, particularly sediment composed of fine material (silt and clay), gives streams a muddy appearance and thus reduces esthetic and recreational appeal. Suspended sediment provides opportunity for transport of chemical compounds that have very slight solubility but that attach themselves to sediment particles. Substantial expense is required for removal of suspended sediment from water supplies.

When suspended sediment becomes deposited in large quantities in a stream channel or an inlet of a lake or reservoir, it can raise the water levels of floods. Sediment deposited in streams sometimes interferes with water-supply intakes. Deposits of sediment in surface-water impoundments reduce the storage capacity for water supply or flood control. Such deposits in impoundments or streams also can impair propagation of fish and other aquatic life, and if harmful chemical constituents are sorbed on the deposited sediment, it can be dangerous to bottom-feeding fish, some waterfowl, and bottom-dwelling fauna.

Current Conditions

Concentrations

Suspended-sediment concentrations in streams of the lower Kansas River basin during 1978-86 (table 15) tended to be larger than 200 mg/L much of the time; this fact, together with the predominance of silt and clay (finer than 0.062 millimeter, table 15), gives the streams a muddy appearance. Variations in suspended-sediment concentration in the downstream direction along the Kansas and Big Blue Rivers, with data from selected tributary stations, are shown in figure 18. Because the same set of tributary stations was used for all similar illustrations in this report, suspended-sediment data for Little Blue River near Barnes, Soldier Creek near Delia, and Delaware River near Muscotah are not shown in figure 18, but these data are included in table 15.

The smallest median suspended-sediment concentrations were in water from Kings Creek (station 2), draining an unplowed area well covered with tall grasses and having no loess or glacial till, and the Big Blue River near Manhattan (station 18), a short distance downstream from Tuttle Creek Lake which has removed most of the sediment. Although the largest median concentration shown is for water from the Kansas River at Fort Riley (station 1), this value may have been biased by special-purpose samples. With this exception, the largest concentrations at the 50th and 90th percentiles were observed in water from the Delaware River near Muscotah, Kans. (station 24), which drains an area in the Dissected Till Plains where much of the land is under cultivation. The possibility also exists that some overgrazing of pastures may have contributed to the large suspended-sediment concentrations. The sediment in the Delaware River is trapped in Perry Lake before reaching the Kansas River, thus the concentrations in the Kansas River at Lecompton (station 26) are generally smaller than in the Delaware River upstream from Perry Lake. The Dissected Till Plains section is represented also by the Black Vermillion River near Frankfort, Kans. (station 17), Soldier Creek near Delia, Kans. (station 22), and Stranger Creek near Tonganoxie, Kans. (station 28).

The Little Blue River is represented in table 15 by the station near Barnes, Kans. (station 16). The median suspended-sediment concentration in water from near Barnes indicates that the Little Blue River typically may have smaller suspended-sediment concentrations than most of the other streams in the study unit, such as the Kansas River stations.

Transport

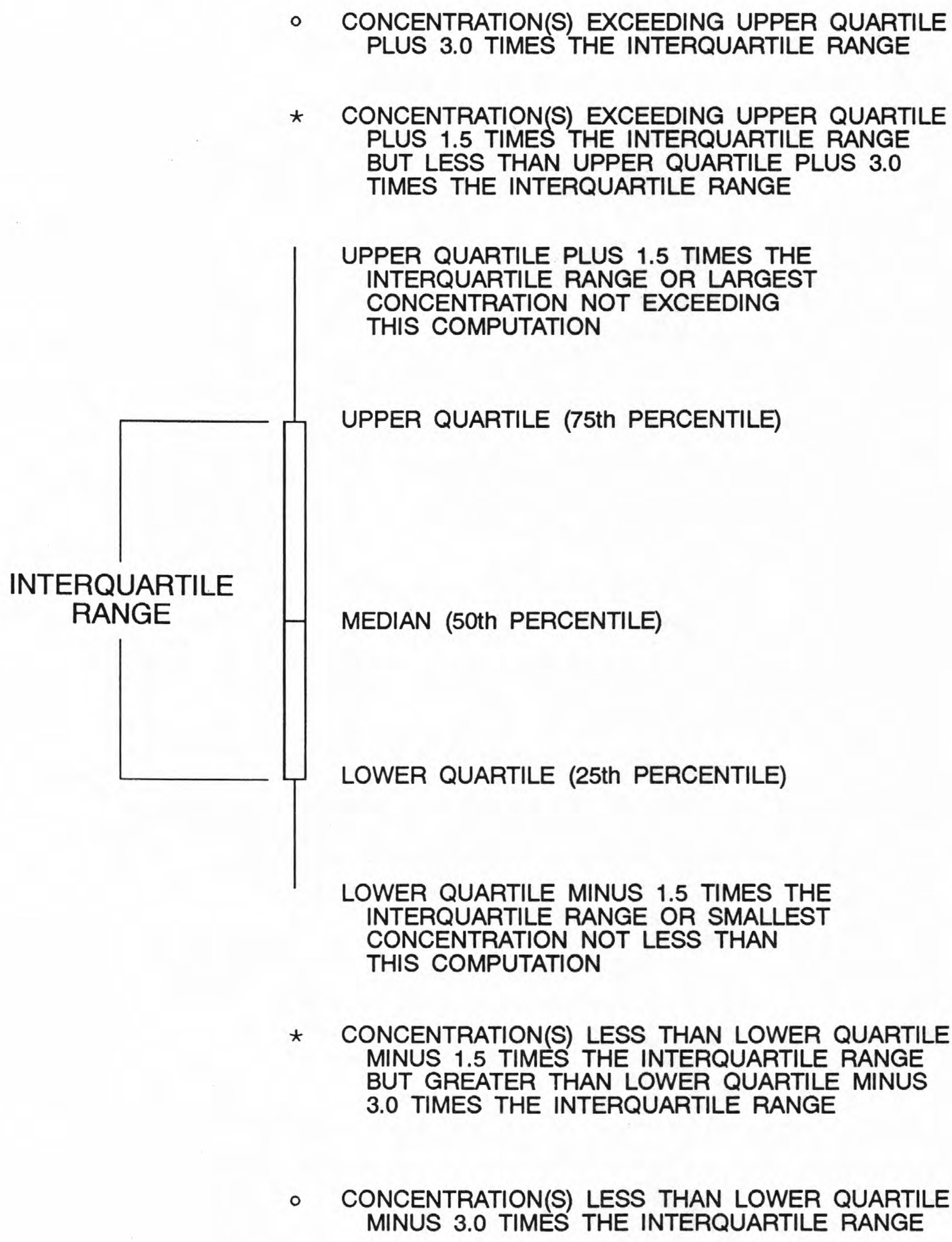
Nine stations had adequate data for calculation of suspended-sediment transport during 1978-86 (table 16). Comparison of suspended-sediment yields at Lecompton (station 26) and DeSoto (station 29) shows the increased yield at DeSoto that results from large sediment yields of tributaries (despite the trapping of sediment from the Delaware and Wakarusa Rivers in Perry and Clinton Lakes) and erosion of the Kansas River channel. The relative magnitudes and spatial relations of suspended-sediment transport values from table 16 are illustrated in figure 19. Of the nearly 10 million tons per year of suspended sediment transported by the Kansas River at Wamego (station 19), only about 50 percent was accounted for by the Kansas River at Fort Riley (station 1) and the Big

Table 15. —*Statistical summary of data on suspended sediment in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[This table includes only those stations having 10 or more analyses; —, the 10- and 90-percentile values are not shown for sampling stations having fewer than 30 analyses]

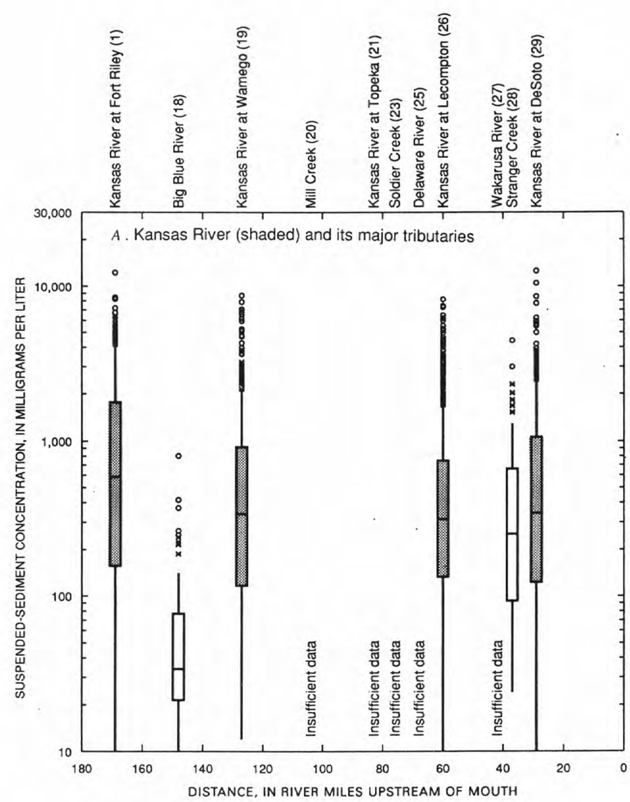
Sampling station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Suspended-sediment concentration, in milligrams per liter						
1	Kansas River at Fort Riley, Kans.	559	61	150	580	1,800	3,300
2	Kings Creek near Manhattan, Kans.	28	—	9.0	17	28	—
6	West Fork Big Blue River near Dorchester, Nebr.	26	—	36	240	500	—
16	Little Blue River near Barnes, Kans.	80	49	110	220	1,000	3,000
17	Black Vermillion River near Frankfort, Kans.	998	48	83	220	590	1,700
18	Big Blue River near Manhattan, Kans.	83	10	21	34	80	220
19	Kansas River at Wamego, Kans.	504	59	120	340	920	2,000
22	Soldier Creek near Delia, Kans.	16	—	53	350	3,000	—
24	Delaware River near Muscotah, Kans.	269	45	100	420	2,100	4,000
26	Kansas River at Lecompton, Kans.	987	63	130	310	750	1,600
28	Stranger Creek near Tonganoxie, Kans.	53	58	90	250	700	1,800
29	Kansas River at DeSoto, Kans.	1,312	51	120	340	1,100	2,100
	Suspended-sediment particle size, percent finer than 0.004 millimeter						
16	Little Blue River near Barnes, Kans.	19	—	50	59	73	—
17	Black Vermillion River near Frankfort, Kans.	43	35	45	54	64	68
24	Delaware River near Muscotah, Kans.	16	—	36	42	45	—
26	Kansas River at Lecompton, Kans.	17	—	53	61	64	—
29	Kansas River at DeSoto, Kans.	126	35	43	52	58	73
	Suspended-sediment particle size, percent finer than 0.062 millimeter						
1	Kansas River at Fort Riley, Kans.	465	78	89	95	98	99
2	Kings Creek near Manhattan, Kans.	11	—	31	51	83	—
6	West Fork Big Blue River near Dorchester, Nebr.	26	—	79	98	99	—
16	Little Blue River near Barnes, Kans.	29	—	93	95	98	—
17	Black Vermillion River near Frankfort, Kans.	49	86	96	98	99	100
18	Big Blue River near Manhattan, Kans.	35	66	85	95	98	99
19	Kansas River at Wamego, Kans.	315	30	54	77	90	97
24	Delaware River near Muscotah, Kans.	16	—	94	96	98	—
26	Kansas River at Lecompton, Kans.	642	69	81	92	97	99
29	Kansas River at DeSoto, Kans.	1,142	96	83	92	96	98

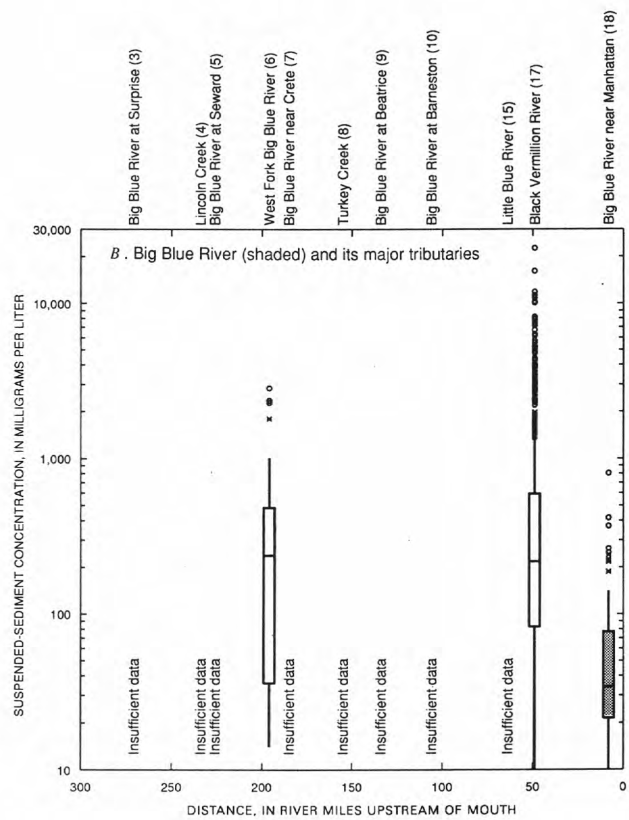
EXPLANATION



NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

Figure 18. – Distribution of suspended-sediment concentrations analyzed in water from Suspended-sediment concentration scalé is logarithmic;





(*A*) Kansas and (*B*) Big Blue Rivers and their major tributaries, 1978-86 water years. minimum scale value is arbitrarily set at 10.

Table 16.—*Transport of suspended sediment in water at selected sampling stations within lower Kansas River basin, 1978-86 water years*

[–, data inadequate for computation]

Sampling-station number (fig. 9)	Station name	Mean annual transport (tons per year)	Root mean-square error of mean annual transport (percent)	Mean annual yield, (tons per square mile of drainage area per year)
1	Kansas River at Fort Riley, Kans.	5,000,000	11	110
10	Big Blue River at Barneston, Nebr.	–	–	–
15	Little Blue River at Hollenberg, Kans.	–	–	–
16	Little Blue River near Barnes, Kans.	2,000,000	22	600
17	Black Vermillion River near Frankfort, Kans.	980,000	9	2,400
18	Big Blue River near Manhattan, Kans.	430,000	21	–
19	Kansas River at Wamego, Kans.	9,700,000	7	180
24	Delaware River near Muscotah, Kans.	2,200,000	16	5,100
26	Kansas River at Lecompton, Kans.	11,000,000	6	190
28	Stranger Creek near Tonganoxie, Kans.	650,000	31	1,600
29	Kansas River at DeSoto, Kans.	16,000,000	9	270

Blue River near Manhattan (station 18). The increase in drainage area from stations 1 and 18 to station 19 is small, suggesting that most of the increase in sediment transport originated from the channel of the Kansas River and the few miles of Big Blue River channel downstream from station 18. This hypothesis, however, would need to be tested by thorough study of channel erosion.

Differences in physiography and climate may account for differences in suspended-sediment yields for four of the stations in table 16. The suspended-sediment yield at station 16 is principally representative of the High Plains and Plains Border physiographic sections and to a lesser extent the Dissected Till Plains section (fig. 2). Suspended-sediment yields at stations 17, 24, and 28 represent the Dissected Till Plains physiographic section and greatly exceed the yields of the other physiographic sections because of the erodible glacial till, hilly topography, larger quantities of precipitation (fig. 5) to aid erosion, and larger rates of runoff (fig. 6) to transport the sediment. This implies that use of soil-conservation measures will have the greatest effect on sediment transport in the Kansas River if focused in areas of the Dissected Till Plains.

Trends

Results of time-trend analyses for suspended-sediment concentrations are shown in table 17 and figure 20. The results of flow-adjusted time-trend tests consistently showed that suspended-sediment concentrations have decreased in the lower Kansas River basin during the periods of record available. The Kansas River at Wamego (station 19) is the only station where the decreasing trend during the period analyzed could have resulted from new large reservoirs in the area draining to the station. For the Kansas River at DeSoto (station 29), the only change in large reservoirs during the period analyzed (1975-86) was the beginning of storage in Clinton Lake in 1977, which trapped the sediment from a small percentage of the upstream drainage area and is unlikely to have had a significant effect by itself. In the absence of detailed cause-and-effect studies, these results may indicate improved conditions resulting from soil- and water-conservation practices, such as terraces, grassed waterways, and farm ponds.

Data needs

Collection and analysis of additional suspended-sediment data at a few sites would provide an improved assessment of suspended sediment in the lower Kansas River basin. Data for the Big Blue River at Seward (station 5, fig. 9) and Barneston (station 10, fig. 9), Nebr., would enhance the assessment for that river. Additional data at the Hollenberg station (station 15) on the Little Blue River are needed to provide additional information on concentration and transport. In addition, new data at the Deweese station (station 11) could be used with data collected in 1957-61 (Mundorff and Waddell, 1966) to analyze time trends on the upper Little Blue River. Additional samples from station 23 near the confluence of Soldier Creek with the Kansas River would provide additional information on that stream's contribution to the Kansas River.

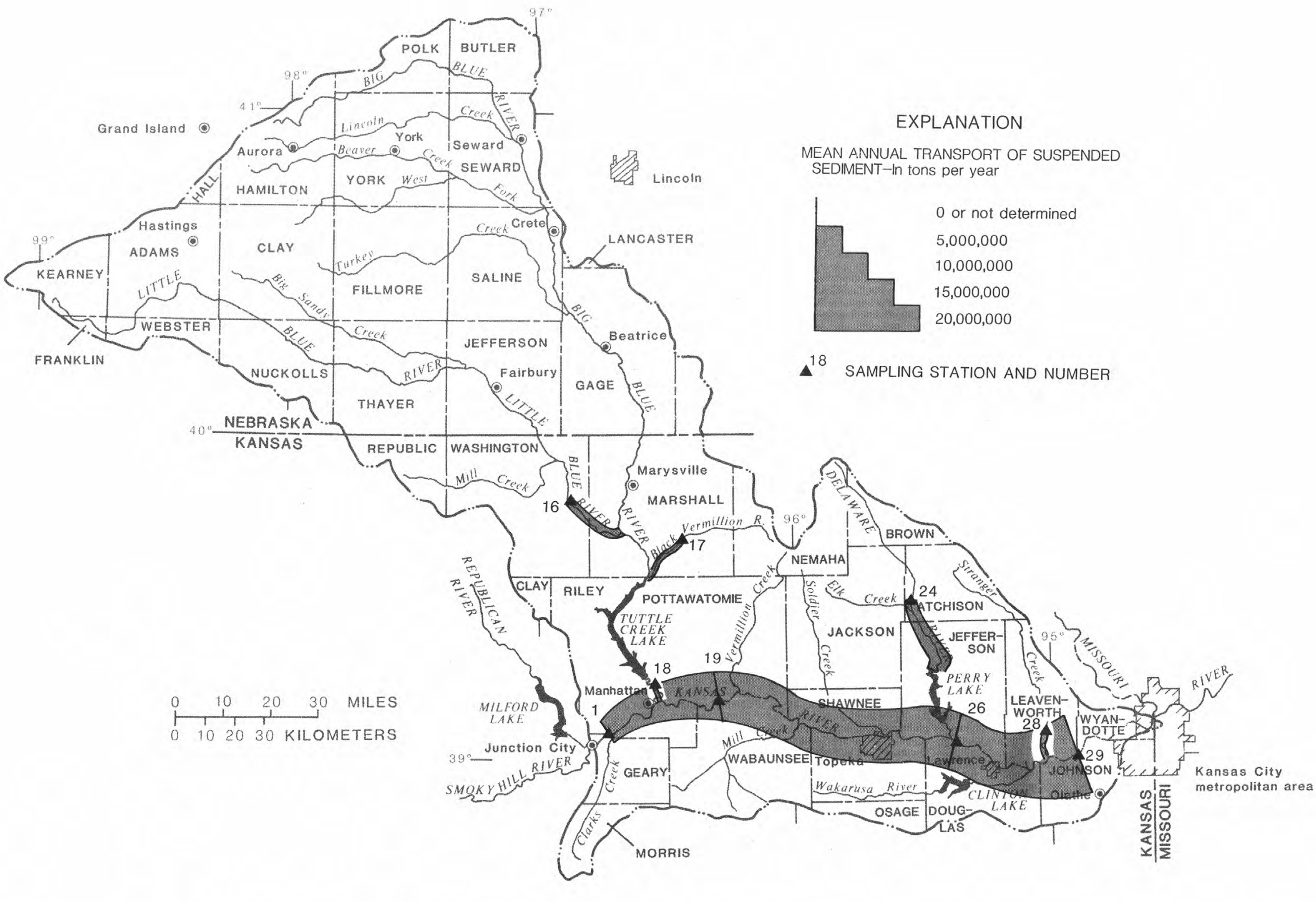


Figure 19.—Distribution of mean annual transport of suspended sediment in lower Kansas River basin, 1978-86 water years.

Table 17. — *Trend-test results for suspended-sediment concentrations in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Suspended-sediment concentration: Probability level	Suspended-sediment concentration: Average rate of change: Milligrams per liter per year	Suspended-sediment concentration: Average rate of change: Percent of median per year	Flow-adjusted suspended-sediment concentration: Probability level	Flow-adjusted suspended-sediment concentration: Average rate of change (percent per year)
6	West Fork Big Blue River near Dorchester, Nebr.	1963-82	20	0.52	- 2.7	- 1.0	1.00	0
16	Little Blue River near Barnes, Kans.	1976-86	11	.48	- 28	- 6.0	.02	- 8.1
17	Black Vermillion River near Frankfort, Kans.	1977-86	10	.55	- 6.7	- 3.7	1.00	0
18	Big Blue River near Manhattan, Kans.	1975-86	12	.75	- .45	- 1.2	.80	- 1.8
19	Kansas River at Wamego, Kans.	1957-85	29	0	- 38	- 7.4	0	- 3.8
22	Soldier Creek near Delia, Kans.	1967-80	14	.55	- 8.3	- 2.6	.12	- 6.9
28	Stranger Creek near Tonganoxie, Kans.	1957-85	29	.97	- .12	- .03	.34	- .93
29	Kansas River at DeSoto, Kans.	1975-86	12	.11	- 7.5	- 4.1	.05	- 9.0

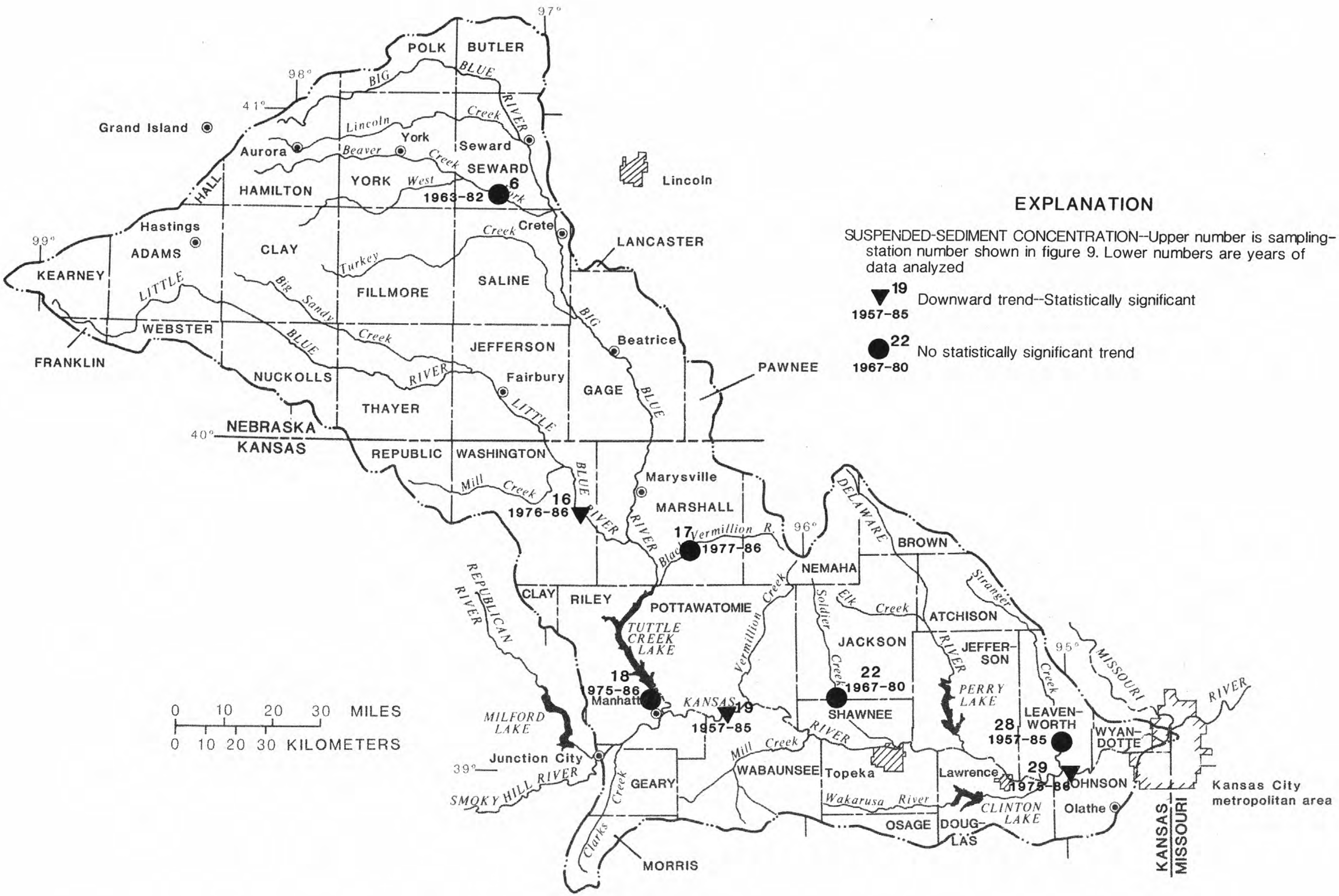


Figure 20.—Results of time-trend tests for suspended-sediment concentrations in water from lower Kansas River basin.

Nutrients

By J.K. Stamer and P.R. Jordan
U.S. Geological Survey

In this report, nutrients are defined as nitrogen and phosphorus species. Forms of nitrogen in water include organic nitrogen, ammonia, nitrite, and nitrate. Of these forms, nitrate is usually the dominant species and most readily available for plant growth. Forms of phosphorus in water include simple ionic orthophosphate and bound phosphate in solution and (or) as particulate matter, the latter of which may be released by bacterial action.

Dissolved forms of nitrate and phosphate can be rapidly assimilated by plants; consequently, their concentrations in natural water are usually small. Nutrient enrichment of natural water can encourage blooms of nuisance algae. Such blooms are more likely to occur in lakes than in streams because (1) the velocity of water in lakes is much slower than in streams, which permits more opportunity for assimilation of nutrients by algal populations than do streams; (2) water temperatures in lakes tend to be warmer than in streams, which promotes faster algal growth; and (3) turbidity in lakes is often less than in streams, which allows for more light penetration and plant growth. The effects of nutrient enrichment from agricultural practices and wastewater seem to be decreased by increased stream and lake turbidity as a result of erosion or effluent discharges.

Sources of nitrogen in surface water include: (1) The use of synthetic fertilizers, such as anhydrous ammonia; (2) precipitation containing nitrogen oxides, which result from the combustion of fossil fuel; (3) discharges from wastewater-treatment facilities; (4) animal waste; and (5) nitrogen-fixing algae (Hem, 1985). Concentrations of nitrate are important when assessing the quality of drinking water. Large concentrations of nitrate in drinking water are associated with methemoglobinemia in infants (blue babies). Because nitrate can have an adverse health effect, the U.S. Environmental Protection Agency has established a Maximum Contaminant Level (MCL) for nitrate as nitrogen in public-drinking water supplies of 10 mg/L (U.S. Environmental Protection Agency, 1986a). It should be noted that nitrate is the end product of the oxidation of reduced forms of nitrogen, such as ammonia, organic nitrogen, and nitrite. Concentrations of ammonia in its gaseous form also can have an adverse effect on aquatic life.

Sources of phosphorus in the aquatic environment can include: (1) The use of phosphate fertilizer, (2) discharges from wastewater-treatment facilities, (3) animal waste, and (4) erosion of sediments to which phosphorus is bound in surface water (Hem, 1985). Unlike nitrate, the U.S. Environmental Protection Agency has not established any MCL's for phosphorus species in public-drinking water supplies.

Current Conditions

Concentrations

A statistical summary of concentrations of the various forms of total and dissolved nitrogen and phosphorus species from selected sampling stations within the lower Kansas River basin is given in table 18. Where available, the data were summarized for a particular nutrient species if both total and dissolved analyses were in the data base. In the case of nitrite plus nitrate as nitrogen (hereafter reported as nitrate as nitrogen) and ammonia nitrogen, differences in the summary may exist for a particular station. Differences may be attributed to the fact that the total- and dissolved-nitrate determinations may have been performed at different times by different agencies. On those occasions when an agency performed both total and dissolved determinations for nitrate and ammonia on a sample collected at the same time, the dissolved values are probably more accurate for assessment purposes. The analytical procedures for determining nitrate and ammonia do not differentiate between total and dissolved forms. It is preferable to use a filtered sample for analysis because the filter removes suspended sediment from the water and can remove bacteria that act upon the nutrient species. Nitrate is very soluble in water, and although ammonia may occur in solution to some extent, the ammonium ion often is bound to sediment. The analytical procedure for ammonia only determines what is in solution and is not designed to remove the bound ammonium ion from the sediment.

Nitrate accounted for about 50 percent of the total nitrogen measured in water from the lower Kansas River basin, and organic nitrogen accounted for most of the remaining nitrogen (table 18). Ammonia was but a small component of the total nitrogen measured in the study unit. The median of the sampling-station median concentrations for dissolved nitrate as nitrogen was 1.6 mg/L; the median for total organic nitrogen as nitrogen was 1.4 mg/L; and the median for ammonia as nitrogen was 0.12 mg/L (calculated from table 18). Much of the nitrate probably is the oxidized end product of nitrogenous fertilizer and human and animal wastes, and most of the organic nitrogen probably is derived from degraded plant and animal materials. The small concentrations of ammonia reflect the fact that the principal point-source discharges of wastewater are not significant contributors of ammonia to the total nitrogen in the study unit and that ammonia is biochemically unstable; it can be assimilated by plants, oxidized to nitrate, or under

Table 18.—*Statistical summary of data on nutrients in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[Concentrations in milligrams per liter; this table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Total nitrate as nitrogen (nitrite plus nitrate, total, as N)						
2	Kings Creek near Manhattan, Kans.	12	—	<0.09	<0.09	0.11	—
3	Big Blue River at Surprise, Nebr.	38	0.02	.04	.80	1.8	2.3
4	Lincoln Creek near Seward, Nebr.	117	1.2	1.6	2.3	3.0	3.6
5	Big Blue River at Seward, Nebr.	129	.40	1.2	1.9	2.4	2.9
6	West Fork Big Blue River near Dorchester, Nebr.	153	.73	1.6	2.0	2.5	2.9
7	Big Blue River near Crete, Nebr.	234	.70	1.4	2.0	2.3	2.5
8	Turkey Creek near Wilber, Nebr.	118	.22	.53	1.1	1.5	2.3
9	Big Blue River at Beatrice, Nebr.	65	.66	1.8	2.1	2.6	3.2
10	Big Blue River at Barneston, Nebr.	117	.88	1.7	2.1	2.5	2.9
11	Little Blue River near Deweese, Nebr.	78	.62	.89	1.1	1.3	1.5
12	Little Blue River near Alexandria, Nebr.	35	.04	.34	1.2	1.4	1.6
13	Big Sandy Creek at Alexandria, Nebr.	38	1.0	1.2	1.4	1.5	1.9
15	Little Blue River at Hollenberg, Kans.	188	.30	.85	1.3	1.7	2.1
18	Big Blue River near Manhattan, Kans.	150	.80	1.2	1.5	1.8	1.9
19	Kansas River at Wamego, Kans.	103	.30	.80	1.1	1.4	1.6
21	Kansas River at Topeka, Kans.	50	< .01	.37	1.0	1.5	1.9
22	Soldier Creek near Delia, Kans.	133	.10	.38	.80	1.3	1.8
23	Soldier Creek near Topeka, Kans.	96	.10	.24	.89	1.3	1.8
24	Delaware River near Muscotah, Kans.	60	.15	.63	1.7	2.2	2.9
26	Kansas River at Lecompton, Kans.	121	.10	.72	1.1	1.4	1.7
29	Kansas River at DeSoto, Kans.	95	.02	.39	1.0	1.4	1.7
	Dissolved nitrate as nitrogen (nitrite plus nitrate, dissolved, as N)						
2	Kings Creek near Manhattan, Kans.	30	.04	< .1	< .1	.11	.30
4	Lincoln Creek near Seward, Nebr.	22	—	1.3	1.8	2.7	—
5	Big Blue River at Seward, Nebr.	23	—	1.3	1.7	2.4	—
6	West Fork Big Blue River near Dorchester, Nebr.	24	—	1.3	2.0	2.5	—
7	Big Blue River near Crete, Nebr.	19	—	1.4	2.0	2.6	—
8	Turkey Creek near Wilber, Nebr.	22	—	.53	1.3	1.5	—
9	Big Blue River at Beatrice, Nebr.	23	—	1.4	2.4	2.9	—
10	Big Blue River at Barneston, Nebr.	21	—	1.8	2.2	2.6	—
11	Little Blue River near Deweese, Nebr.	38	.19	.58	.96	1.2	1.7
15	Little Blue River at Hollenberg, Kans.	98	.38	.90	1.4	1.7	2.2
18	Big Blue River near Manhattan, Kans.	52	.40	.95	1.4	1.4	1.8
29	Kansas River at DeSoto, Kans.	52	.01	.17	1.0	1.3	1.4
	Nitrogen, ammonia, total, as N						
2	Kings Creek near Manhattan, Kans.	17	—	< .07	< .07	< .07	—
3	Big Blue River at Surprise, Nebr.	38	.05	.10	.25	.80	1.3
4	Lincoln Creek at Seward, Nebr.	117	< .06	< .06	.12	.23	.71
5	Big Blue River at Seward, Nebr.	129	.04	.08	.16	.34	.86
6	West Fork Big Blue River near Dorchester, Nebr.	152	.03	.08	.19	.50	1.0
7	Big Blue River near Crete, Nebr.	234	.04	.10	.20	.70	1.0
8	Turkey Creek near Wilber, Nebr.	118	.03	.06	.11	.33	.81
9	Big Blue River at Beatrice, Nebr.	66	< .06	.07	.19	.70	.94
10	Big Blue River at Barneston, Nebr.	120	.04	.07	.14	.46	.77
11	Little Blue River near Deweese, Nebr.	78	.03	.04	.06	.17	.40
12	Little Blue River near Alexandria, Nebr.	61	.02	.05	.10	.18	.30
13	Big Sandy Creek at Alexandria, Nebr.	38	< .03	< .03	.10	.10	.58
14	Little Blue River near Fairbury, Nebr.	25	—	.08	.12	.29	—
15	Little Blue River at Hollenberg, Kans.	188	.03	.06	.13	.28	.55
18	Big Blue River near Manhattan, Kans.	152	.01	.02	.07	.18	.43
19	Kansas River at Wamego, Kans.	100	< .01	.03	.08	.15	.30
21	Kansas River at Topeka, Kans.	48	.02	.05	.14	.26	.38
22	Soldier Creek near Delia, Kans.	130	.01	.02	.07	.15	.23

Table 18.—*Statistical summary of data on nutrients in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[Concentrations in milligrams per liter; this table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile: 10	25	50 (median)	75	90
	Nitrogen, ammonia, total, as N–Continued						
23	Soldier Creek near Topeka, Kans.	92	< 0.01	< 0.01	0.03	0.11	0.20
24	Delaware River near Muscotah, Kans.	60	< .01	.02	.04	.10	.14
26	Kansas River at Lecompton, Kans.	118	< .01	.04	.13	.27	.42
29	Kansas River at DeSoto, Kans.	97	.02	.05	.15	.26	.46
	Nitrogen, ammonia, dissolved, as N						
2	Kings Creek near Manhattan, Kans.	27	–	< .07	< .07	< .07	–
15	Little Blue River at Hollenberg, Kans.	17	–	.07	.31	.55	–
18	Big Blue River near Manhattan, Kans.	51	.01	.03	.06	.12	.23
29	Kansas River at DeSoto, Kans.	51	.01	.03	.06	.18	.41
	Nitrogen, total organic, as N						
2	Kings Creek near Manhattan, Kans.	11	–	.26	.40	.46	–
4	Lincoln Creek at Seward, Nebr.	112	.50	.83	1.4	2.6	5.9
5	Big Blue River at Seward, Nebr.	102	.70	1.1	1.7	2.5	5.4
6	West Fork Big Blue River near Dorchester, Nebr.	115	.40	.76	1.5	2.4	5.0
7	Big Blue River near Crete, Nebr.	231	.50	1.2	1.9	3.7	5.3
8	Turkey Creek near Wilber, Nebr.	117	.40	.79	1.4	2.2	3.9
9	Big Blue River at Beatrice, Nebr.	61	.90	1.1	1.8	2.8	8.0
10	Big Blue River at Barneston, Nebr.	96	.95	1.1	1.6	2.4	4.1
11	Little Blue River near Deweese, Nebr.	71	.31	.42	.77	1.6	2.7
15	Little Blue River at Hollenberg, Kans.	120	.35	.66	1.3	2.5	6.0
18	Big Blue River near Manhattan, Kans.	47	.41	.60	.74	.93	1.3
26	Kansas River at Lecompton, Kans.	12	–	.65	1.0	1.3	–
29	Kansas River at DeSoto, Kans.	46	.50	.91	1.5	1.9	2.7
	Nitrogen, dissolved organic, as N						
15	Little Blue River at Hollenberg, Kans.	14	–	1.2	1.4	1.7	–
18	Big Blue River near Manhattan, Kans.	21	–	.60	.69	.92	–
29	Kansas River at DeSoto, Kans.	22	–	.64	.90	1.2	–
	Nitrogen, total ammonia plus organic, as N						
2	Kings Creek near Manhattan, Kans.	27	–	.20	.40	.55	–
4	Lincoln Creek at Seward, Nebr.	115	.50	.90	1.5	3.0	6.0
5	Big Blue River at Seward, Nebr.	103	.80	1.2	1.8	2.7	5.6
6	West Fork Big Blue River near Dorchester, Nebr.	119	.60	1.1	1.7	3.0	6.5
7	Big Blue River near Crete, Nebr.	232	1.1	1.4	2.0	4.1	5.9
8	Turkey Creek near Wilber, Nebr.	118	.50	.89	1.6	2.7	5.5
9	Big Blue River at Beatrice, Nebr.	63	1.1	1.6	2.1	3.1	8.4
10	Big Blue River at Barneston, Nebr.	104	1.1	1.3	1.9	2.7	4.2
11	Little Blue River near Deweese, Nebr.	78	.35	.50	.90	1.6	3.4
15	Little Blue River at Hollenberg, Kans.	123	.50	.76	1.4	2.6	6.2
18	Big Blue River near Manhattan, Kans.	71	.60	.74	1.0	1.3	1.8
26	Kansas River at Lecompton, Kans.	12	–	.91	1.1	1.4	–
29	Kansas River at DeSoto, Kans.	68	.90	1.2	1.5	2.0	2.7
	Nitrogen, dissolved ammonia plus organic as N						
15	Little Blue River at Hollenberg, Kans.	14	–	1.2	1.8	2.3	–
18	Big Blue River near Manhattan, Kans.	44	.48	.60	.73	1.1	1.6
29	Kansas River at DeSoto, Kans.	44	.50	.70	1.0	1.3	2.2
	Nitrogen, total, as N						
4	Lincoln Creek at Seward, Nebr.	113	2.2	3.0	4.2	5.7	8.3
5	Big Blue River at Seward, Nebr.	102	2.0	2.9	3.9	5.2	7.8
6	West Fork Big Blue River near Dorchester, Nebr.	116	2.3	3.0	3.8	5.2	8.4
7	Big Blue River near Crete, Nebr.	214	2.8	3.5	4.0	6.8	8.2

Table 18.—*Statistical summary of data on nutrients in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[Concentrations in milligrams per liter; this table includes only those stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Nitrogen, total, as N–Continued						
8	Turkey Creek near Wilber, Nebr.	116	1.1	1.7	2.6	4.2	7.9
9	Big Blue River at Beatrice, Nebr.	62	2.9	3.6	4.2	5.3	11
10	Big Blue River at Barneston, Nebr.	97	2.9	3.3	4.1	4.9	6.5
11	Little Blue River near Deweese, Nebr.	78	1.2	1.5	2.0	2.7	5.1
15	Little Blue River at Hollenberg, Kans.	120	1.4	1.9	2.6	4.5	8.4
18	Big Blue River near Manhattan, Kans.	42	1.6	1.9	2.2	2.6	3.7
26	Kansas River at Lecompton, Kans.	12	–	1.7	2.2	3.0	–
29	Kansas River at DeSoto, Kans.	41	1.4	1.8	2.3	3.2	3.9
	Phosphorus, total, as P						
2	Kings Creek near Manhattan, Kans.	30	< .01	< .01	.02	.03	.05
4	Lincoln Creek at Seward, Nebr.	115	.30	.36	.52	.79	1.3
5	Big Blue River at Seward, Nebr.	127	.16	.31	.46	.68	1.1
6	West Fork Big Blue River near Dorchester, Nebr.	125	.50	.64	.82	1.1	1.6
7	Big Blue River near Crete, Nebr.	212	.60	.70	1.0	1.6	2.0
8	Turkey Creek near Wilber, Nebr.	117	.26	.39	.55	.71	1.1
9	Big Blue River at Beatrice, Nebr.	66	.52	.65	.79	.95	1.6
10	Big Blue River at Barneston, Nebr.	102	.32	.55	.67	.85	1.4
11	Little Blue River near Deweese, Nebr.	82	.20	.25	.34	.54	.93
15	Little Blue River at Hollenberg, Kans.	187	.26	.33	.46	.73	1.4
18	Big Blue River near Manhattan, Kans.	180	.11	.16	.20	.26	.35
19	Kansas River at Wamego, Kans.	104	.14	.19	.26	.41	.58
21	Kansas River at Topeka, Kans.	49	.16	.20	.24	.42	1.1
22	Soldier Creek near Delia, Kans.	129	.05	.08	.12	.23	.48
23	Soldier Creek near Topeka, Kans.	93	.04	.06	.11	.25	.75
24	Delaware River near Muscotah, Kans.	60	.09	.14	.21	.40	.77
26	Kansas River at Lecompton, Kans.	119	.17	.25	.33	.48	.76
29	Kansas River at DeSoto, Kans.	118	.21	.26	.32	.43	.65
	Phosphorus, dissolved, as P						
2	Kings Creek near Manhattan, Kans.	26	–	.01	.02	.03	–
4	Lincoln Creek at Seward, Nebr.	28	–	.28	.32	.45	–
5	Big Blue River at Seward, Nebr.	23	–	.24	.29	.37	–
6	West Fork Big Blue River near Dorchester, Nebr.	28	–	.45	.53	.65	–
7	Big Blue River near Crete, Nebr.	25	–	.41	.50	.59	–
8	Turkey Creek near Wilber, Nebr.	28	–	.30	.37	.45	–
9	Big Blue River at Beatrice, Nebr.	25	–	.27	.45	.65	–
10	Big Blue River at Barneston, Nebr.	20	–	.37	.46	.56	–
11	Little Blue River near Deweese, Nebr.	37	.17	.24	.26	.34	.44
15	Little Blue River at Hollenberg, Kans.	96	.17	.21	.27	.33	.40
18	Big Blue River near Manhattan, Kans.	74	.07	.11	.15	.21	.23
29	Kansas River at DeSoto, Kans.	74	.04	.10	.13	.19	.28
	Phosphorus, dissolved orthophosphate, as P						
2	Kings Creek near Manhattan, Kans.	16	–	.01	.02	.03	–
3	Big Blue River at Surprise, Nebr.	29	–	.03	.20	.20	–
6	West Fork Big Blue River near Dorchester, Nebr.	29	–	.20	.20	.30	–
7	Big Blue River near Crete, Nebr.	144	.20	.20	.30	.40	.40
10	Big Blue River at Barneston, Nebr.	34	.10	.20	.20	.30	.40
12	Little Blue River near Alexandria, Nebr.	27	–	.10	.10	.20	–
13	Big Sandy Creek at Alexandria, Nebr.	29	–	.07	.10	.20	–
18	Big Blue River near Manhattan, Kans.	29	–	.10	.14	.17	–
29	Kansas River at DeSoto, Kans.	26	–	.07	.11	.17	–

extreme conditions, volatilized. This is possible particularly if sampling stations are some distance downstream from point-source wastewater discharges.

Further evidence of the effect of agricultural land use on nitrogen concentrations is seen by looking at the total nitrogen concentrations in table 18. Median concentrations of total nitrogen that occurred in water from station 15 on the Little Blue River and stations 4, 5, 7, 9, and 10 on the Big Blue River upstream of Tuttle Creek Lake were almost twice those concentrations from other stations. The stations with large median concentrations of total nitrogen drain large areas of irrigated and intensively cultivated cropland.

Examination of the phosphorus data in table 18 indicates that about one-half of the total phosphorus in water from the basin was composed of dissolved phosphorus and that most of the dissolved phosphorus was in the form of orthophosphate, which is the most readily available species for growth of phytoplankton and periphyton. The median of the sampling-station median concentrations for total phosphorus as phosphorus was 0.34 mg/L; the median for dissolved phosphorus as phosphorus was 0.30 mg/L; and the median for dissolved orthophosphate as phosphorus was 0.14 mg/L (calculated from table 18). The effect of intensively cultivated cropland in the northern part of the lower Kansas River basin (fig. 3) is shown by comparing concentrations of phosphorus in water from stations on the Little Blue River and Big Blue River upstream of Tuttle Creek Lake to those stations on the Kansas River and its tributaries. Although there are some point sources of nutrients in the northern part of the study unit, median concentrations of total phosphorus, dissolved phosphorus, and dissolved orthophosphate in this part of the study unit were generally twice those in the southern part. Because about one-half of the phosphorus is associated with suspended sediment, one hypothesis is that if soil-erosion practices were implemented to a large extent within the study unit, these practices might decrease suspended-sediment discharge into the streams and lakes. Whether the decrease in sediment discharge would decrease levels of turbidity in the lakes and thereby increase lake productivity would depend on the particle-size distribution of the suspended sediment. Available data, however, preclude speculation that erosion-control measures would result in increased lake productivity.

An additional effect of land use on the concentrations of nitrogen and phosphorus is demonstrated by comparing the concentrations in water from Kings Creek near Manhattan, Kans. (station 2, fig. 9), to concentrations in water from other stations in table 18. Land cover in the Kings Creek watershed is native prairie grass, which reflects the natural and unaltered land use that once prevailed in the study unit. At least 30 analyses for Kings Creek were required to have some confidence in such a comparison because Kings Creek is not a perennial stream, and samples have not been collected throughout the expected range of streamflow rates as compared to other streams in the study unit. The median concentration of dissolved nitrate as nitrogen was less than 0.1 mg/L from Kings Creek near Manhattan, Kans., as compared to a median concentration of 1.8 mg/L from five other stations that are located on unregulated streams (stations 4, 6, 8, 10, and 15, fig. 9). In addition, the 90th percentile of the concentration of dissolved nitrate as nitrogen from Kings Creek was much less than the 10th percentile of dissolved nitrate as nitrogen from stations 4, 6, 8, 10, and 15 shown in table 18. The 90th-percentile concentration of dissolved nitrate as nitrogen was 0.30 mg/L from Kings Creek as compared to the 10th-percentile concentration of 0.38 mg/L from the Little Blue River at Hollenberg, Kans. (station 15, fig. 9), which was the smallest concentration from the five other stations.

The median concentration of total phosphorus was 0.03 mg/L in water from Kings Creek as compared to a median concentration of 0.52 mg/L from seven other stations that are located on unregulated streams (stations 4, 6, 8, 10, 15, 23, and 24, fig. 9). The 90th-percentile concentration of total phosphorus as phosphorus from Kings Creek was 0.05 mg/L as compared to the 10th-percentile concentration of 0.04 mg/L from Soldier Creek near Topeka, Kans. (station 23, fig. 9), which was the smallest concentration from the other seven stations. The small median and 90th-percentile concentrations of these constituents in the Kings Creek watershed as compared to the median and 10th-percentile concentrations from other stations in the study unit occur because land in the watershed is relatively unaffected by human activity.

Areal distributions of total nitrate as nitrogen and total phosphorus as phosphorus concentrations in water from the lower Kansas River basin are shown in figures 21 and 22. A comparison of the median concentrations of total nitrate in water from the Big Blue River and its tributaries (fig. 21B) with median concentrations in water from the Kansas River and its tributaries (fig. 21A) shows that median concentrations in the Big Blue River and its tributaries were about twice those in the Kansas River and its tributaries. A comparison of the two distributions of total nitrate also indicates that concentrations in the Kansas River and its tributaries (fig. 21A) were less variable than for the Big Blue River and its tributaries (fig. 21B).

The large variability of concentrations depicted in figure 21B could be attributed to the seasonal application of fertilizers. The aspect of seasonality of nitrate concentrations was examined at several stations that drain predominantly cropland in the basin. At Turkey Creek near Wilber, Nebr. (station 8), which drains a large amount of irrigated cropland, the largest concentrations of nitrate occurred from June through September. In contrast, concentrations in water from the Delaware River near Muscotah, Kans. (station 25), which drains unirrigated cropland, were generally the smallest in July. Concentrations of nitrate in water from Lincoln Creek near Seward, Nebr. (station 4), which drains irrigated cropland, seemed to have the smallest concentrations occurring in April and September as compared to other months, but otherwise there was no pattern. Concentrations of nitrate in Kings Creek tend to be largest in the fall and winter months when the prairie grass is no longer growing and assimilating nutrients.

For ammonia nitrogen, as un-ionized ammonia (that is, ammonia in gaseous form), the acute and chronic criteria for freshwater aquatic life are dependent on ammonia concentration, pH, and water temperature (see U.S. Environmental Protection Agency, 1987d). Exceedances of these ammonia criteria (table 19) occurred only in water from stations in the Big Blue River basin in Nebraska and Kansas. Exceedance of the acute ammonia criterion occurred in about 2 percent of the samples (1 of 55 samples) in water from the Big Blue River near Manhattan, Kans. (station 18). Exceedances of the chronic ammonia criterion ranged from less than 1 to 7 percent (2 of 29 samples at Big Blue River at Surprise, Nebr.) of the samples analyzed. The exceedances occurred during the months of January through September and had no relation to season, streamflow rate, pH, or water temperature. There is, however, one interesting observation that emerges from examination of all of the exceedance data. All the exceedances that are listed in table 19 occurred from February 1978 to April 1984, with most exceedances occurring from February 1978 to May 1981. A possible explanation is the downturn in the agricultural economy (John Bender, Nebraska Department of Environmental Control, oral commun., 1990), which began about 1981, and the subsequent decrease in the use of fertilizer, as discussed later in the section on "Trends."

The areal distribution of total phosphorus concentrations shown in figure 22 has two interesting patterns. First, median and interquartile ranges of total phosphorus in water from stations on the main stem of the Kansas River (fig. 22A) did not vary greatly although the effect of wastewater discharges from the Topeka, Kans., area may be seen in increased concentrations in water from the stations at Lecompton (station 26) and DeSoto (station 29). Second, median concentrations of total phosphorus in water from stations on the Big Blue River increased from Seward (station 5) to Crete (station 7) and decreased downstream at Beatrice (station 9), Barneston (station 10), and near Manhattan (station 18). Increased phosphorus concentrations in water from the West Fork Big Blue River near Dorchester, Nebr. (station 6), and discharges from wastewater-treatment plants upstream of the Crete station may have contributed to the large median concentration that occurred in water from the Big Blue River near Crete (station 7). On the basis of an estimate of the city of Crete's wastewater discharge of total phosphorus from Gianessi (1986b), a mass-balance calculation of phosphorus transport indicates that treatment-plant discharges could have increased the median total phosphorus-as-phosphorus concentration in the Big Blue River near Crete, Nebr. (station 7), by about 0.1 mg/L.

Transport

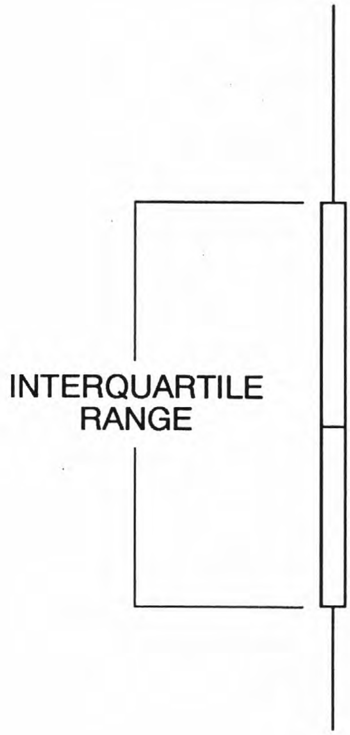
Mean annual constituent transport and mean annual yield for the 1978-86 water years were calculated at selected stations in the lower Kansas River basin for total nitrate, total ammonia, total ammonia plus organic nitrogen, and total and dissolved phosphorus (table 20). Transport also was calculated at additional sampling stations for total ammonia plus organic nitrogen and total phosphorus, for which point-source data were available; these calculations will be discussed later in this section. Interpretation of data in table 20 is limited by the fact that constituent transport could not be calculated for many stations, particularly stations such as Black Vermillion River near Frankfort, Kans. (station 17, fig. 9), which would have helped to understand the effects of Tuttle Creek Lake on transport, and stations on unregulated tributaries to the Kansas River. These additional calculations would have allowed for comparison of transport and yields in these streams to those in the Big Blue River basin. Nevertheless, some observations about the data in table 20 are made in the following paragraphs.

Precipitation contributed about 5,400 tons of both nitrate and ammonia as nitrogen to the land upstream of Big Blue River near Barneston, Nebr., station (estimated from figs. 3c and 3d of Rinella and Miller, 1988), and fertilizer contributed about 88,000 tons of nitrogen as nitrogen (based on data from Alexander and Smith, 1990). The sum of these two inputs is

EXPLANATION

o CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

* CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE BUT LESS THAN UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE



UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE OR LARGEST CONCENTRATION NOT EXCEEDING THIS COMPUTATION

UPPER QUARTILE (75th PERCENTILE)

MEDIAN (50th PERCENTILE)

LOWER QUARTILE (25th PERCENTILE)

LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE OR SMALLEST CONCENTRATION NOT LESS THAN THIS COMPUTATION

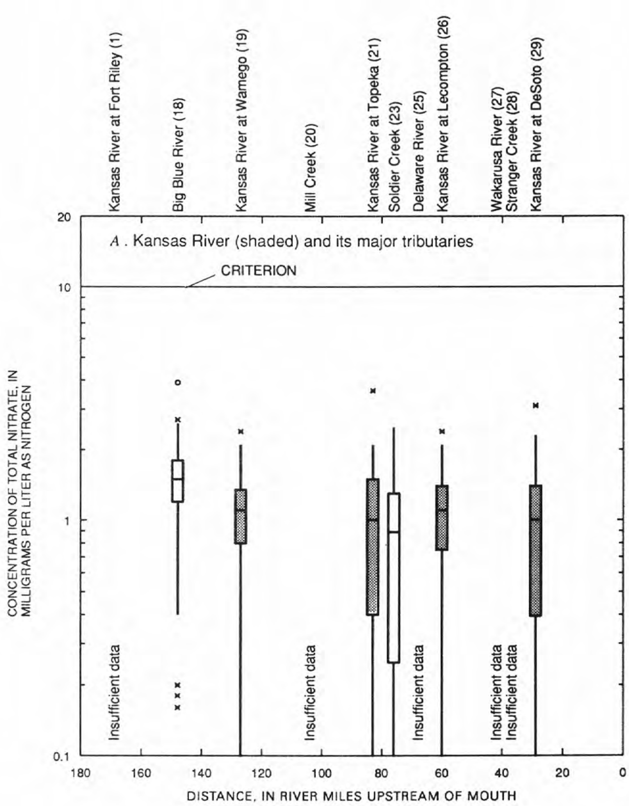
* CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE BUT GREATER THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

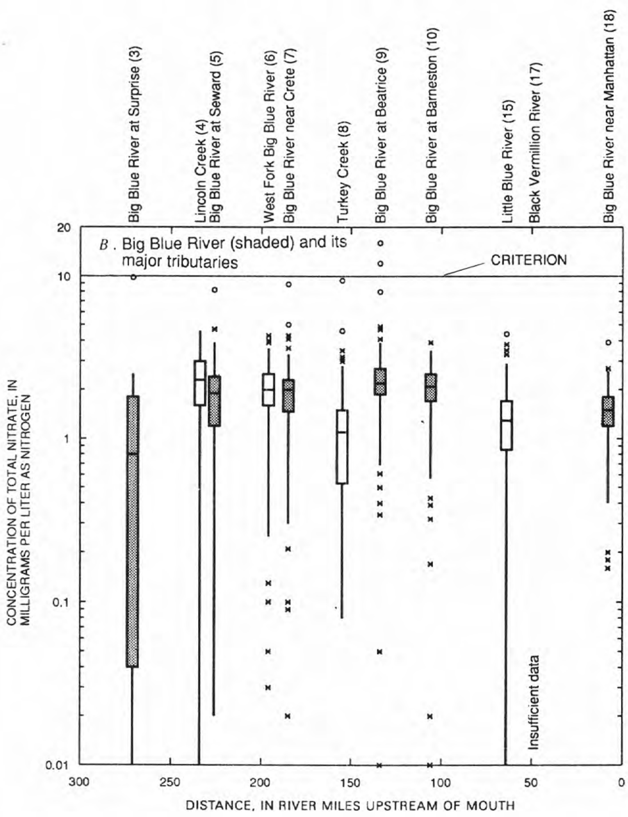
o CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

WATER-QUALITY CRITERION IS DRINKING-WATER STANDARD (U.S. ENVIRONMENTAL PROTECTION AGENCY, 1987d)

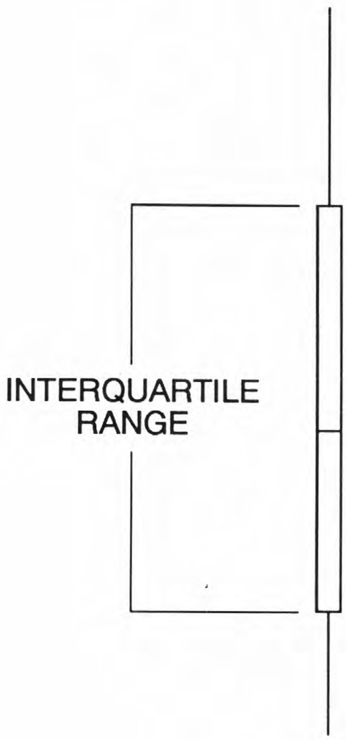
Figure 21. – Distribution of concentrations of total nitrate as nitrogen in water from (*A*) Kansas and criterion, 1978-86 water years. Total nitrate-as-nitrogen concentration





(*B*) Big Blue Rivers and their major tributaries and relation of concentrations to water-quality scale is logarithmic; minimum scale value arbitrarily set at 0.1 or 0.01.

EXPLANATION



o CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

* CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE BUT LESS THAN UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE OR LARGEST CONCENTRATION NOT EXCEEDING THIS COMPUTATION

UPPER QUARTILE (75th PERCENTILE)

MEDIAN (50th PERCENTILE)

LOWER QUARTILE (25th PERCENTILE)

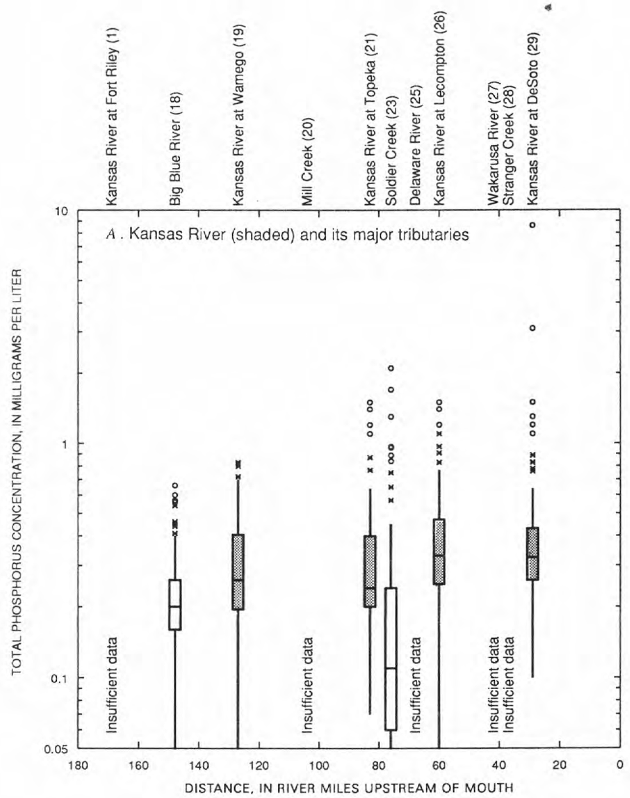
LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE OR SMALLEST CONCENTRATION NOT LESS THAN THIS COMPUTATION

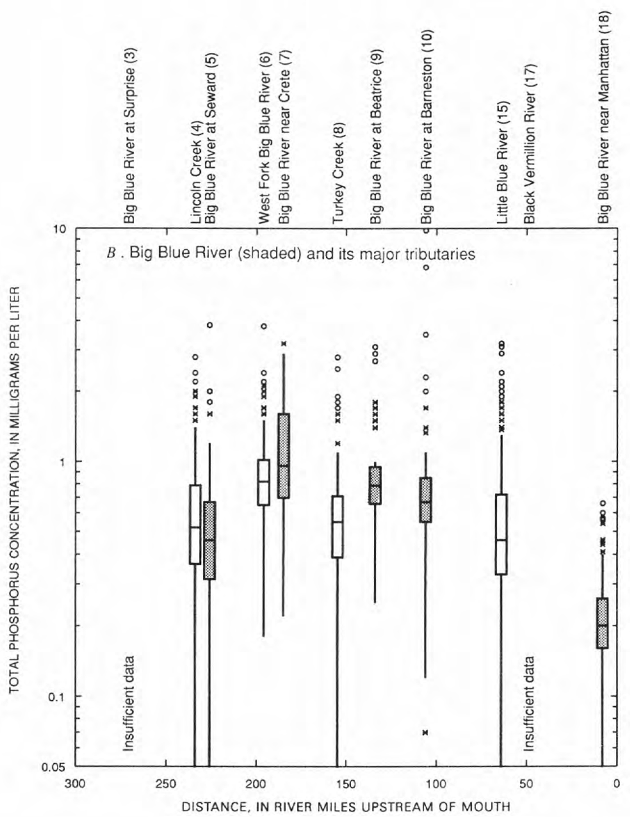
* CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE BUT GREATER THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

o CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

Figure 22. – Distribution of total phosphorus concentrations in water from (*A*) Kansas and Total phosphorus concentration scale is logarithmic;





(*B*) Big Blue Rivers and their major tributaries, 1978-86 water years. minimum scale value arbitrarily set at 0.05.

Table 19.—*Number of ammonia analyses not meeting water-quality criteria in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[Samples counted in this table as not meeting criteria do not necessarily represent violations but may indicate need for further study. Criteria listed are the numerical values of concentrations from the summary chart of U.S. Environmental Protection Agency (1987d). In addition to concentrations, water-quality criteria also consider, for aquatic life, the duration and frequency of concentrations. For drinking water, criteria in most cases apply to treated water rather than raw water. Statistical summaries of constitutent concentrations are listed in table 18. —, not applicable]

Sampling-station number (fig. 9)	Station name	Number of analyses	Number of analyses not meeting criteria: Freshwater aquatic life		Human health (drinking water)
			Acute	Chronic	
	Total un-ionized ammonia: Acute and chronic criteria are pH and temperature dependent				
3	Big Blue River at Surprise, Nebr.	29	0	2	—
4	Lincoln Creek near Seward, Nebr.	116	0	1	—
5	Big Blue River at Seward, Nebr.	123	0	2	—
6	West Fork Big Blue River near Dorchester, Nebr.	142	0	5	—
7	Big Blue River near Crete, Nebr.	75	0	2	—
8	Turkey Creek near Wilber, Nebr.	117	0	3	—
10	Big Blue River at Barneston, Nebr.	109	0	6	—
14	Little Blue River near Fairbury, Nebr.	21	0	1	—
15	Little Blue River at Hollenberg, Kans.	120	0	3	—
18	Big Blue River near Manhattan, Kans.	55	1	3	—

about 93,000 tons for 1983. (The precipitation and fertilizer data are for 1983, which is considered typical for the 1978-86 water years.) Two points about these data and the total nitrogen load calculated for Big Blue River near Barneston, Nebr. (station 10, table 20) can be made. First, nitrogen from precipitation accounted for less than 6 percent of the total contribution of nitrogen from precipitation and fertilizer. Second, the mean annual load of nitrogen as nitrogen that was transported past the Big Blue River near Barneston station was about 11 percent of the total amount of nitrogen contributed to the land by precipitation and fertilizer.

The mean annual transport of total ammonia was much smaller in the outflow from Tuttle Creek Lake at the Big Blue River near Manhattan, Kans. (station 18), than the sum for the Big Blue River at Barneston, Nebr. (station 10), and the Little Blue River at Hollenberg, Kans. (station 15). The loss of ammonia may be attributed to conversion of ammonia to nitrate, uptake by plants, conversion to the gaseous form, or to possible settling of sediment onto which ammonia transported into the lake is sorbed. The decrease in ammonia and the lack of decrease in the mean annual transport of total nitrate at the Big Blue River near Manhattan, Kans., seem to provide additional support for processes that are occurring within Tuttle Creek Lake. This is consistent with the distribution of total nitrate concentrations shown in figure 21B. Mean annual yields of total nitrate as nitrogen in the Big Blue River at Barneston, Nebr., and the Little Blue River at Hollenberg, Kans., were within 30 percent of each other although the yield in the Big Blue was larger (compare 0.65 to 0.51 ton per square mile of drainage area per year). Finally, the mean annual transport of nitrogen in the Kansas River at DeSoto, Kans. (station 29), was composed of 50-percent total nitrate, and the remainder was total ammonia and organic nitrogen; of the latter, approximately 11 percent was ammonia.

Mean annual transport of total phosphorus in the Big Blue River near Manhattan, Kans. (station 18), was much smaller than the sum of the sources into Tuttle Creek Lake. Thus, the lake appears to have trapped much of the total phosphorus associated with suspended sediment. This is consistent with the distribution of total phosphorus concentrations shown in figure 22B. The phosphorus transported by the Big Blue River near Manhattan was mostly in the form of dissolved phosphorus. Of the total phosphorus transported past the Manhattan station, 68 percent was dissolved (see table 20). In contrast, dissolved phosphorus was 17 percent of the total phosphorus at the Little Blue River at Hollenberg,

Table 20. — *Transport of nutrients in water at selected sampling stations within lower Kansas River basin, 1978-86 water years*

[—, data inadequate for computation]

Sampling-station number (fig. 9)	Station name	Mean annual transport (tons per year)	Root mean-square error of mean annual transport (percent)	Mean annual yield, (tons per square mile of drainage area per year)
	Total nitrate as nitrogen (nitrite plus nitrate as N)			
10	Big Blue River at Barneston, Nebr.	2,900	15	0.65
15	Little Blue River at Hollenberg, Kans.	1,400	13	.51
18	Big Blue River near Manhattan, Kans.	5,200	6	.54
19	Kansas River at Wamego, Kans.	8,500	10	.15
29	Kansas River at DeSoto, Kans.	18.000	27	.30
	Total ammonia as N			
10	Big Blue River at Barneston, Nebr.	830	21	.19
15	Little Blue River at Hollenberg, Kans.	320	13	.12
18	Big Blue River near Manhattan, Kans.	620	22	.064
19	Kansas River at Wamego, Kans.	980	20	.018
29	Kansas River at DeSoto, Kans.	2,000	19	.033
	Total ammonia plus organic nitrogen as N			
4	Lincoln Creek near Seward, Nebr.	670	15	1.5
5	Big Blue River at Seward, Nebr.	1,100	12	1.0
6	West Fork Big Blue River near Dorchester, Nebr.	1,200	11	1.0
7	Big Blue River near Crete, Nebr.	2,500	8	.92
8	Turkey Creek near Wilber, Nebr.	660	15	1.4
9	Big Blue River at Beatrice, Nebr.	5,700	12	1.5
10	Big Blue River at Barneston, Nebr.	7,100	8	1.6
11	Little Blue River near Deweese, Nebr.	920	14	.94
15	Little Blue River at Hollenberg, Kans.	3,800	9	1.4
18	Big Blue River near Manhattan, Kans.	4,300	10	.45
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	18,000	9	.30
	Total phosphorus as P			
6	West Fork Big Blue River near Dorchester, Nebr.	290	6	.24
7	Big Blue River near Crete, Nebr.	900	6	.33
8	Turkey Creek near Wilber, Nebr.	160	9	.35
9	Big Blue River at Beatrice, Nebr.	1,200	8	.31
10	Big Blue River at Barneston, Nebr.	2,300	10	.52
15	Little Blue River at Hollenberg, Kans.	1,000	5	.36
18	Big Blue River near Manhattan, Kans.	920	5	.095
19	Kansas River at Wamego, Kans.	2,200	7.	.040
21	Kansas River at Topeka, Kans.	4,300	12	.076
26	Kansas River at Lecompton, Kans.	4,400	7	.075
29	Kansas River at DeSoto, Kans.	5,700	9	.095
	Dissolved phosphorus as P			
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	170	6	.062
18	Big Blue River near Manhattan, Kans.	630	11	.065
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	2,700	17	.045

Kans. (station 16), which is upstream of Tuttle Creek Lake. Finally, of the mean annual transport of total phosphorus in the Kansas River past DeSoto, Kans. (station 29), 47 percent was dissolved, and the remainder was associated with suspended particulate matter. From a management point of view, even if no sediment were transported past the DeSoto station, about one-half of the phosphorus is in solution and potentially available to plants. Thus, if turbidity caused by the suspended sediment is an important factor affecting algal growth, undesirable algal blooms could be produced in the Kansas River when streamflow rates are small and water temperatures are warm.

Mean annual transport rates of two representative nutrients, total nitrate and total phosphorus, are shown in figures 23 and 24. Mean transport rates in table 20 were used as the basis for these two figures. Transport of nitrate was about the same for the Little Blue and Big Blue Rivers upstream of Tuttle Creek Lake. Downstream from the confluence of the Big Blue River with the Kansas River, the nitrate transport increased steadily (fig. 23). As previously noted, constituent transport is dominated largely by streamflow rates, and this explains, in large part, the geographic distribution. The distribution of transport of total phosphorus is similar to that of nitrate, but the transport of total phosphorus for the Big Blue River at Barneston, Nebr. (station 10), was somewhat larger than for the Little Blue River at Hollenberg, Kans. (station 15). The mean annual transport of total nitrate at Kansas River at DeSoto, Kans. (station 29), was about three times as large as the mean annual transport of total phosphorus (table 20). A ratio of constituent loads of nitrate to total phosphorus greater than 2:1 has been observed in streams elsewhere (Stamer and others, 1979).

Data on municipal and industrial point-source loads of total ammonia plus organic nitrogen and total phosphorus were available from files of the U.S. Environmental Protection Agency, Region VII (Kansas City, Kans.). These data were used to calculate the loads of these two constituents for subbasins within the northwestern part of the study unit (figs. 25 and 26). To qualitatively determine the relative magnitude of point and nonpoint sources of these constituents, the calculation assumed that the constituents were conservative (that is, the loads were calculated as if the constituents did not change in species nor the load change with distance). Because total ammonia plus organic nitrogen and total phosphorus are essentially trapped within the three major reservoirs in the study unit and because data were not available to calculate transport of these constituents at the upstream boundary of the study unit at Kansas River at Fort Riley, Kans., no calculations are shown downstream from the reservoirs or on the main stem of the Kansas River.

Transport rates and the part of the total contributed by point sources are shown in figure 25 for total ammonia plus organic nitrogen. Point sources contributed no more than 5 percent of the transport of total ammonia plus organic nitrogen in the Big Blue River at Barneston, Nebr. (station 10, fig. 25), and the Little Blue River at Hollenberg, Kans. (station 15). Even in the smaller West Fork Big Blue River near Dorchester (station 6), which receives treated wastewater from two of the larger cities in the Big Blue River basin (Hastings and York), the contribution from point sources was less than 10 percent.

Transport rates and comparisons of the relative contributions of point sources to the transport rates from table 20 for total phosphorus are shown in figure 26. Point sources contributed less than 4 percent of the total transport at the two largest stream stations, the Big Blue River at Barneston, Nebr. (station 10, fig. 26), and the Little Blue River at Hollenberg, Kans. (station 15). On the West Fork Big Blue River near Dorchester, Nebr. (station 6), the percentage from point sources (mostly Hastings and York) was larger than for ammonia plus organic nitrogen but at 17 percent remained a minor part of the total transport. These observations on nitrogen and phosphorus support the conclusion that transport of nutrients in the lower Kansas River basin is dominated by nonpoint sources.

Trends

Time-trend tests for the longest periods of data available were performed on the nutrient data (table 21). Of the 29 stations selected for analysis of available data, there were sufficient data to perform the time-trend tests for nitrogen at 2 to 14 stations, depending on species, and for phosphorus at 3 to 12 stations, depending on species. For nitrogen species, trend tests indicate that concentrations of total nitrate increased in water from the Big Blue River and its tributaries in Nebraska from about 1968-86; no statistically significant trends were observed elsewhere in the basin. Increases in total nitrate as nitrogen ranged from 1.2 percent per year (1968-86) in water from the Big Blue River at Barneston, Nebr. (station 10, fig. 9), to 6.0 percent per year (1970-86) in water from Lincoln Creek near Seward, Nebr. (station 5, fig. 9). Trends in dissolved nitrate also increased in water from the Big Blue River near Crete, Nebr. (station 7, fig. 9) and the Little Blue River at Hollenberg, Kans.

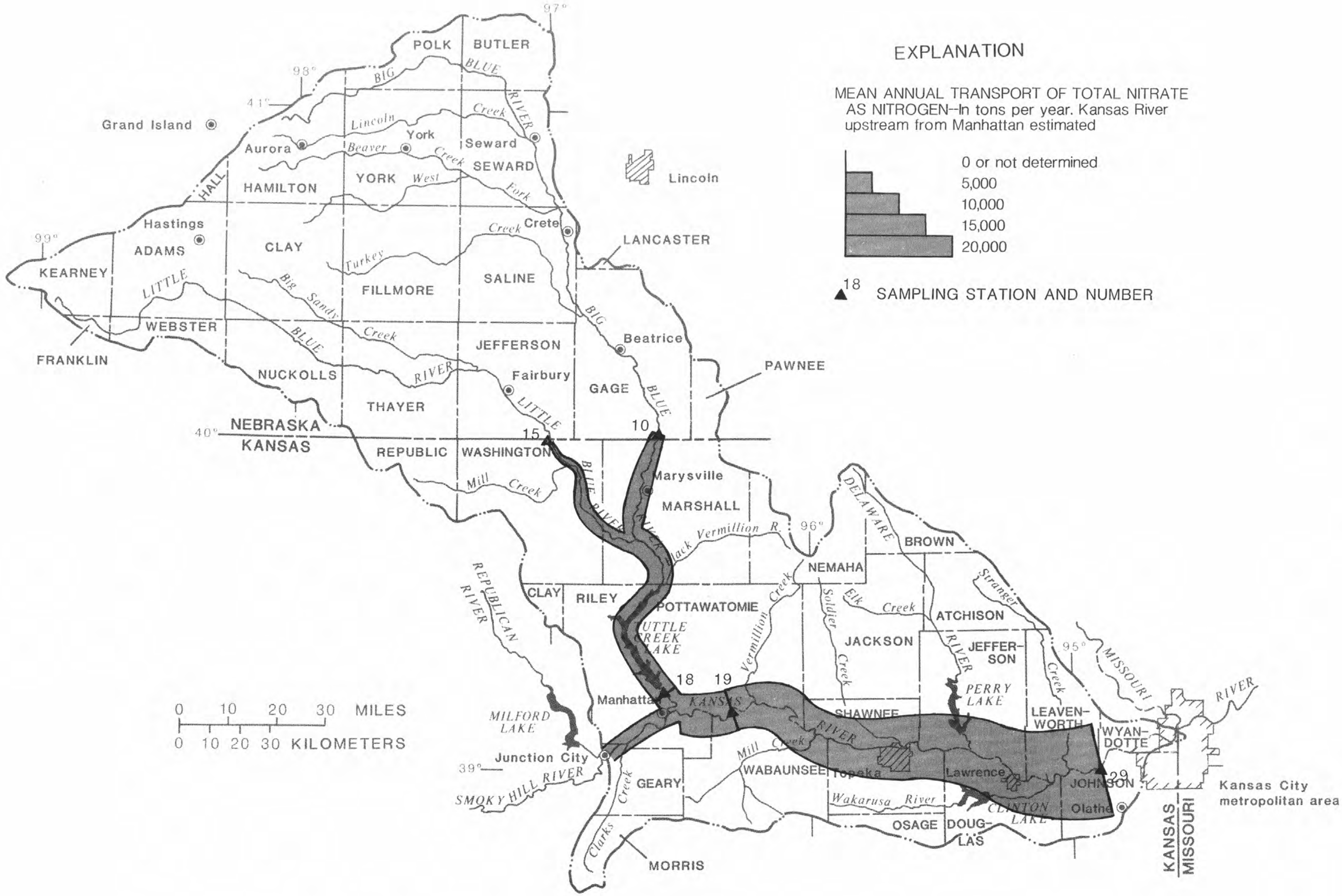


Figure 23.—Distribution of mean annual transport of total nitrate as nitrogen in lower Kansas River basin, 1978-86 water years.

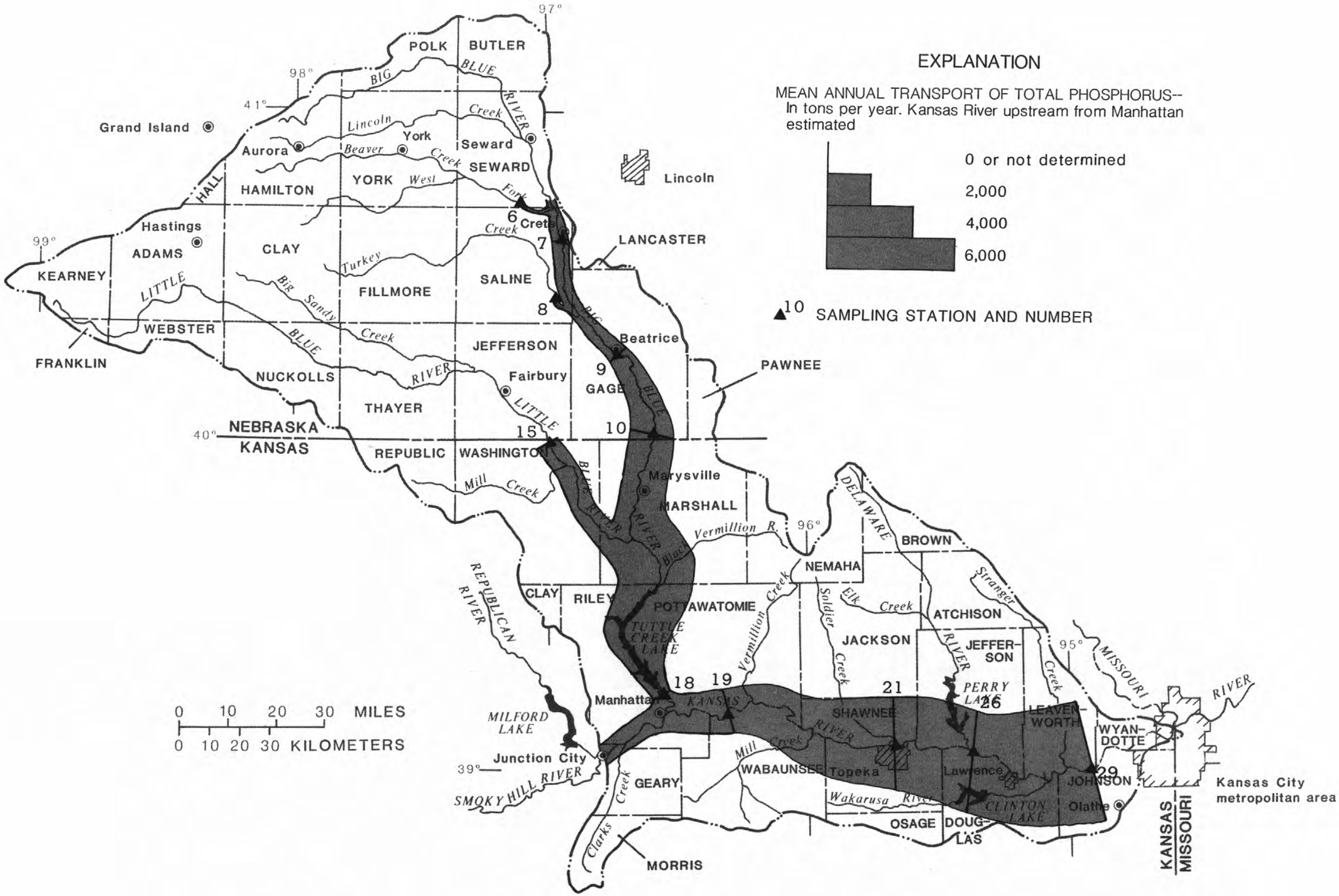


Figure 24.—Distribution of mean annual transport of total phosphorus in lower Kansas River basin, 1978-86 water years.

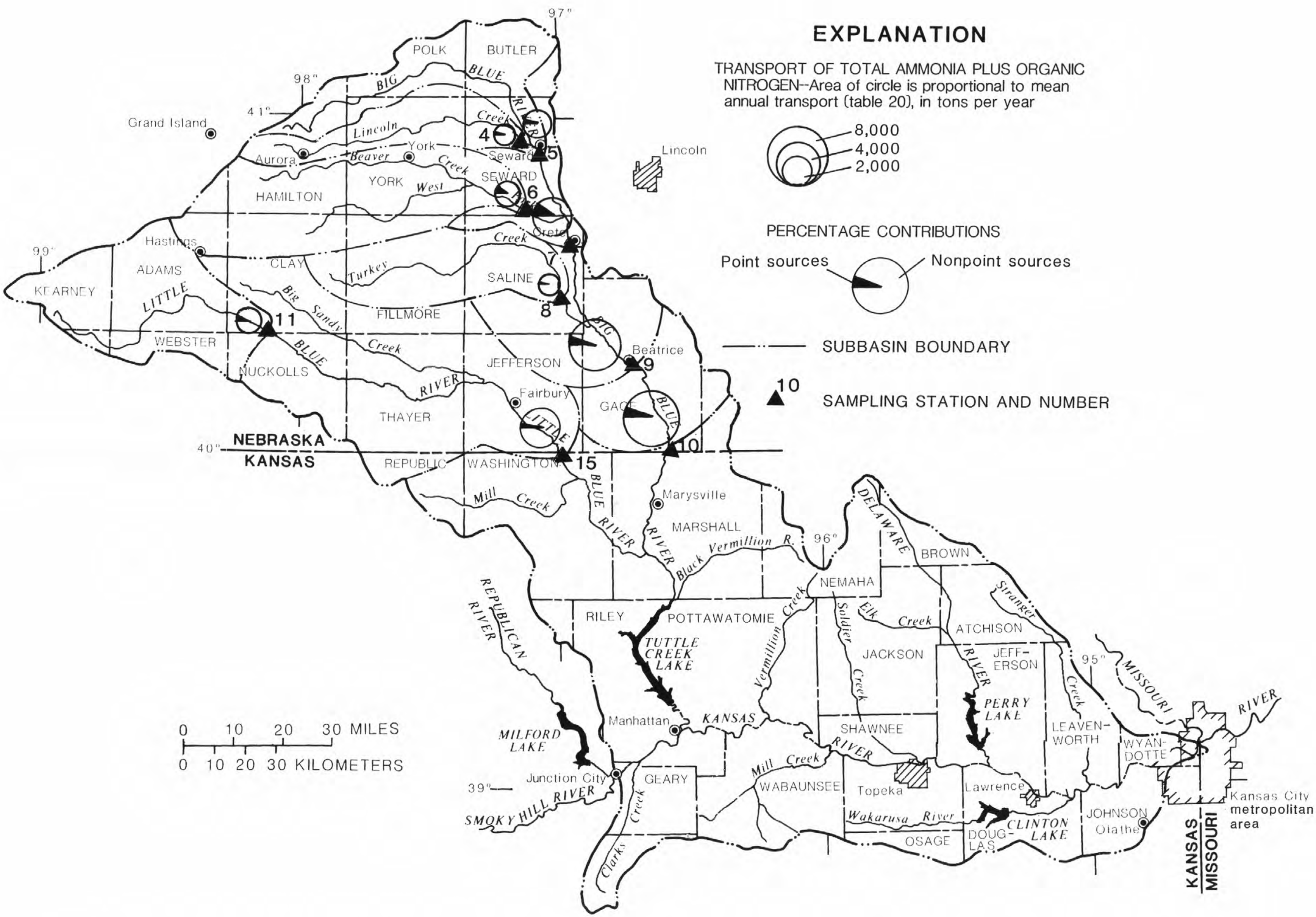


Figure 25.—Relative transport rates and percentage contributions from point and nonpoint sources of total ammonia plus organic nitrogen in northwestern part of lower Kansas River basin, 1978-86 water years.

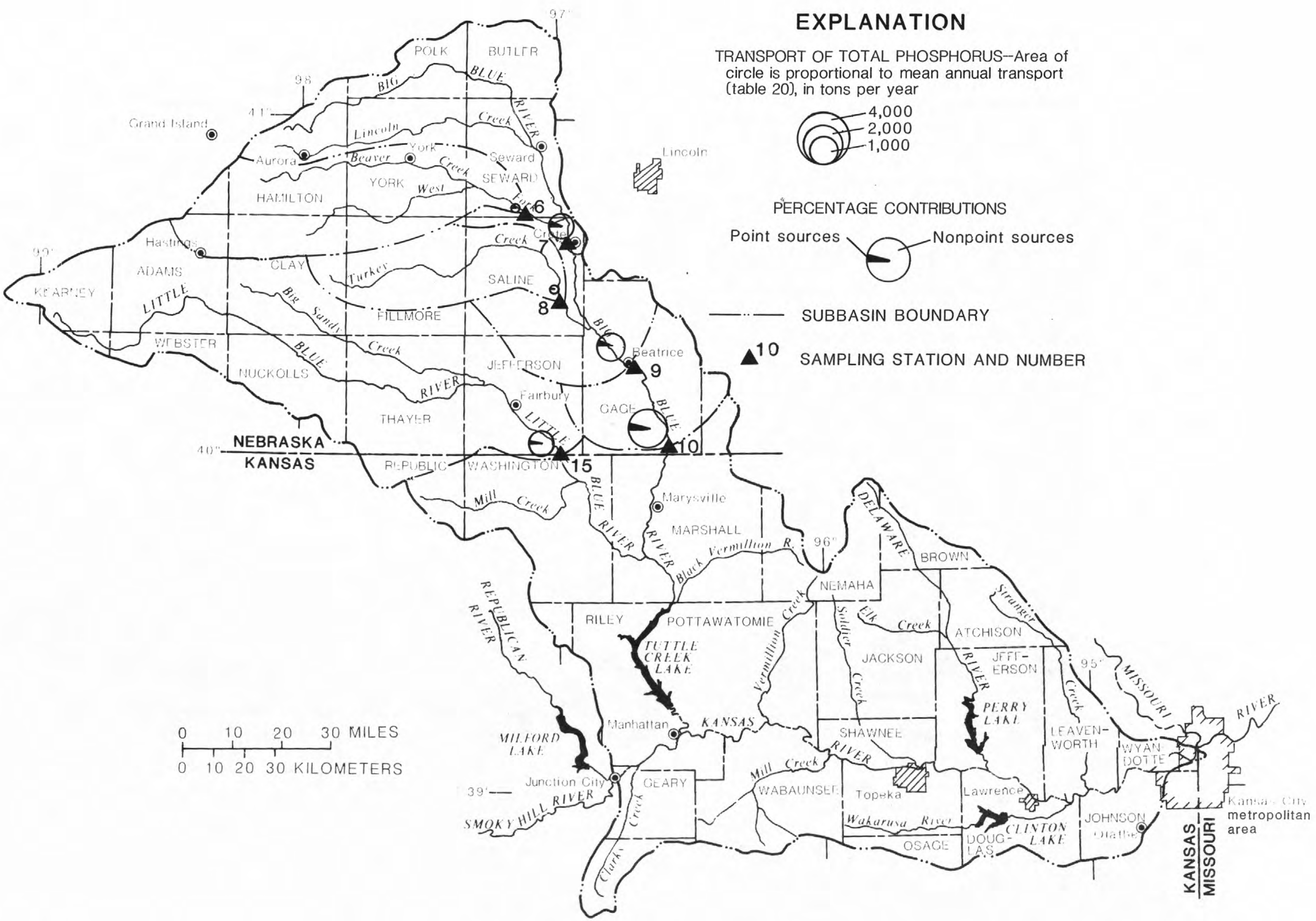


Figure 26.—Relative transport rates and percentage contributions from point and nonpoint sources of total phosphorus in northwestern part of lower Kansas River basin, 1978-86 water years.

Table 21. — *Trend-test results for nutrient concentrations in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend				
				Concentration			Flow adjusted concentration	
					Average rate of change			
				Probability level	Milligrams per liter per year	Percent of median per year	Probability level	Average rate of change (percent per year)
	Total nitrate as nitrogen (Nitrite plus nitrate, total, as N)							
4	Lincoln Creek near Seward, Nebr.	1970-86	17	0	+0.14	+ 8.8	0.01	+ 6.0
5	Big Blue River at Seward, Nebr.	1970-86	17	.01	+ .10	+ 6.2	.04	+ 5.0
6	West Fork Big Blue River near Dorchester, Nebr.	1970-86	17	.01	+ .050	+ 2.6	.02	+ 2.1
7	Big Blue River near Crete, Nebr.	1970-83	14	.25	+ .025	+ 1.4	.07	+ 3.2
8	Turkey Creek near Wilber, Nebr.	1970-86	17	.78	+ .003	+ .29	–	–
9	Big Blue River at Beatrice, Nebr.	1968-83	16	.60	- .020	- .95	–	–
10	Big Blue River at Barneston, Nebr.	1968-86	19	.04	+ .029	+ 1.5	.05	+ 1.2
12	Little Blue River near Alexandria, Nebr.	1968-80	13	.22	+ .019	+ 4.2	.74	+ 1.4
15	Little Blue River at Hollenberg, Kans.	1974-86	13	.27	+ .012	+ .96	.52	- .67
18	Big Blue River near Manhattan, Kans.	1972-86	15	.01	+ .050	+ 3.6	.16	+ 3.1
19	Kansas River at Wamego, Kans.	1972-86	15	.15	+ .016	+ 1.6	–	–
23	Soldier Creek near Topeka, Kans.	1972-86	15	.63	+ .012	+ 1.7	.16	+ 6.0
26	Kansas River at Lecompton, Kans.	1972-86	15	.01	+ .050	+ 5.4	.17	+ 5.7
29	Kansas River at DeSoto, Kans.	1974-86	13	.34	+ .026	+ 2.8	–	–
	Dissolved nitrate as nitrogen Nitrite plus nitrate, dissolved, as N)							
7	Big Blue River near Crete, Nebr.	1973-83	11	.09	+ .053	+ 2.8	.04	+ 2.7
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.28	+ .014	+ 1.0	.07	+ 1.7
	Nitrogen, ammonia, total, as N							
4	Lincoln Creek near Seward, Nebr.	1973-86	14	.82	0	0	–	–
5	Big Blue River at Seward, Nebr.	1973-86	14	.27	- .005	- 3.6	.02	- 11
6	West Fork Big Blue River near Dorchester, Nebr.	1973-87	15	.74	+ .002	+ .72	.40	- 2.0
7	Big Blue River near Crete, Nebr.	1973-83	11	.33	- .018	- 6.1	.37	- 3.2
8	Turkey Creek near Wilber, Nebr.	1973-86	14	.28	- .005	- 4.2	.12	- 5.7

Table 21. — *Trend-test results for nutrient concentrations in water from selected sampling stations within lower Kansas River basin* — Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow adjusted concentration: Probability level	Flow adjusted concentration: Average rate of change (percent per year)
				Nitrogen, ammonia, total, as N–Continued				
10	Big Blue River at Barneston, Nebr.	1973-86	15	0.03	-0.014	-9.0	0.01	-11
15	Little Blue River at Hollenberg, Kans.	1967-86	20	0	-.010	-5.4	—	—
18	Big Blue River near Manhattan, Kans.	1972-86	15	0	-.015	-16	0	-15
19	Kansas River at Wamego, Kans.	1971-86	16	0	-.018	-18	—	—
21	Kansas River at Topeka, Kans.	1967-81	15	0	-.011	-5.7	.06	-4.5
23	Soldier Creek near Topeka, Kans.	1972-86	15	0	-.016	-25	.01	-19
26	Kansas River at Lecompton, Kans.	1971-86	16	0	-.012	-7.8	—	—
29	Kansas River at DeSoto, Kans.	1967-86	20	0	-.014	-5.6	—	—
				Nitrogen, total organic, as N				
4	Lincoln Creek near Seward, Nebr.	1973-86	14	0	+.078	+5.8	.86	-.69
6	West Fork Big Blue River near Dorchester, Nebr.	1973-86	14	.07	+.050	+3.8	.72	+.71
7	Big Blue River near Crete, Nebr.	1973-83	11	.05	+.055	+3.5	.88	+.21
10	Big Blue River at Barneston, Nebr.	1973-86	14	.46	-.073	-3.8	.02	-5.3
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.06	+.042	+3.3	.82	+.66
				Nitrogen, total, ammonia plus organic, as N				
4	Lincoln Creek near Seward, Nebr.	1973-86	14	.01	+.080	+5.3	.73	-1.2
5	Big Blue River at Seward, Nebr.	1973-86	14	.39	+.039	+2.3	.02	-6.3
6	West Fork Big Blue River near Dorchester, Nebr.	1973-86	14	.29	+.039	+2.6	.99	-.05
7	Big Blue River near Crete, Nebr.	1973-83	11	.20	+.025	+1.2	—	—
8	Turkey Creek near Wilber, Nebr.	1973-86	14	.17	+.032	+2.1	.98	-.07
10	Big Blue River at Barneston, Nebr.	1973-86	14	.73	-.042	-2.1	.07	-5.6
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.27	+.021	+1.5	.81	-.49
18	Big Blue River near Manhattan, Kans.	1974-86	13	.22	+.028	+3.1	.19	+3.7
29	Kansas River at DeSoto, Kans.	1974-86	13	.09	-.050	-3.2	—	—

Table 21. — *Trend-test results for nutrient concentrations in water from selected sampling stations within lower Kansas River basin* — Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow adjusted concentration: Probability level	Flow adjusted concentration: Average rate of change (percent per year)
				Nitrogen, total, as N				
4	Lincoln Creek near Seward, Nebr.	1974-86	13	0	+ 0.26	+ 7.2	0.09	+ 2.4
5	Big Blue River at Seward, Nebr.	1973-86	14	.03	+ .24	+ 6.4	.37	- 1.1
6	West Fork Big Blue River near Dorchester, Nebr.	1974-86	13	.01	+ .10	+ 2.9	.12	+ 1.5
7	Big Blue River near Crete, Nebr.	1968-83	16	.03	+ .12	+ 3.2	.09	+ 2.1
8	Turkey Creek near Wilber, Nebr.	1974-86	13	.06	+ .05	+ 1.8	.85	+ .48
10	Big Blue River at Barneston, Nebr.	1968-86	19	1.00	0	0	.14	- 1.6
15	Little Blue River at Hollenberg, Kans.	1974-86	13	.12	+ .055	+ 2.3	.55	+ .85
				Phosphorus, total				
5	Big Blue River at Seward, Nebr.	1973-86	14	.71	+ .004	+.85	.18	- 4.0
6	West Fork Big Blue River near Dorchester, Nebr.	1973-86	14	.80	- .002	- .25	.13	- 1.3
7	Big Blue River near Crete, Nebr.	1973-83	11	.97	0	0	.76	- .52
8	Turkey Creek near Wilber, Nebr.	1973-86	14	.68	- .002	- .35	.10	- 1.7
10	Big Blue River at Barneston, Nebr.	1973-86	15	.05	- .041	- 5.9	0	- 9.3
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.33	- .005	- 1.1	.23	- 1.5
18	Big Blue River near Manhattan, Kans.	1971-86	16	.10	+ .005	+ 2.8	.10	+ 2.6
19	Kansas River at Wamego, Kans.	1971-86	16	.11	+ .005	+ 2.0	—	—
22	Soldier Creek near Delia, Kans.	1971-86	16	.01	+ .005	+ 4.5	.03	+ 7.4
23	Soldier Creek near Topeka, Kans.	1972-86	15	.08	- .010	- 7.7	.29	- 7.6
26	Kansas River at Lecompton, Kans.	1971-86	16	.04	+ .011	+ 3.5	.02	+ 6.1
29	Kansas River at DeSoto, Kans.	1973-86	14	.97	0	0	—	—
				Phosphorus, dissolved				
7	Big Blue River near Crete, Nebr.	1973-83	11	.49	- .002	- .41	.85	- .17
8	Turkey Creek near Wilber, Nebr.	1969-84	16	.42	- .003	- .84	—	—
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.48	- .002	- .90	—	—

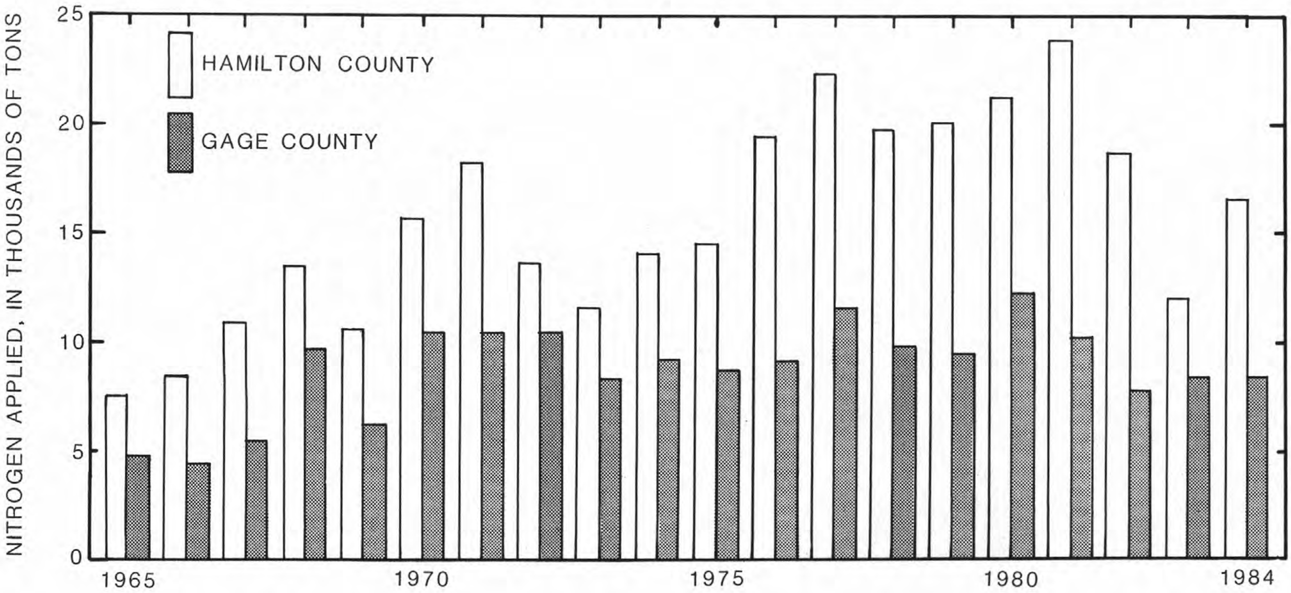


Figure 27.—Nitrogen applied in Hamilton and Gage Counties, Nebraska, 1965-84 (data from Nebraska Department of Agriculture and U.S. Department of Agriculture, 1965-84).

(station 15, fig. 9). These observations are consistent with the increasing trend in the amount of nitrogen applied as fertilizer in Hamilton and Gage Counties during 1965-84 (fig. 27). These two counties are representative of the agricultural land use in the northwestern part of the basin. The data shown generally correspond to the time period used for the time-trend tests. The amount of nitrogen applied in Hamilton and Gage Counties increased from less than 10,000 tons in 1965-66 to about 20,000 tons from 1976-81 and then decreased to about 17,000 tons in 1984 (Nebraska Department of Agriculture and U.S. Department of Agriculture, 1965-84). The decrease in the amount of nitrogen applied beginning in 1981 may be related to the downward turn in the agricultural economy and may have contributed to the fact that all ammonia analyses after 1981 met the acute and chronic criteria for freshwater aquatic life, as described in a previous section.

Time trends in concentrations of total ammonia decreased consistently in the basin and were statistically significant at 9 of the 13 stations. Decreases in flow-adjusted concentrations ranged from 4.5 to 19 percent per year, whereas decreases in unadjusted concentrations ranged from 5.4 to 18 percent of the median per year. The decrease in concentrations of ammonia may be attributed, in part, to improved farming practices and, in part, to an increase in the level of wastewater treatment that began with the passage of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500). When anhydrous ammonia is applied to the land, the ammonia is converted to the ammonium ion, which tends to sorb onto soil particles. The decrease in ammonia may be directly related to a general downward trend in sediment concentrations. Trends in concentrations of total ammonia plus organic nitrogen generally decreased in water from the Big Blue River basin. The trends were statistically significant in water from two stations in the Big Blue River basin and in water from the Kansas River at DeSoto, Kans. (table 21).

Trends in total phosphorus concentrations decreased in the northwestern part of the basin but increased or were not significant elsewhere (fig. 28). For example, flow-adjusted total phosphorus concentrations decreased in water from the Barneston sampling station at a rate of 9.3 percent per year from 1973-86 (table 21). Because phosphorus is closely associated with sediment, the downward trends in the northwestern part of the basin are consistent with downward trends in suspended-sedimentconcentrations.

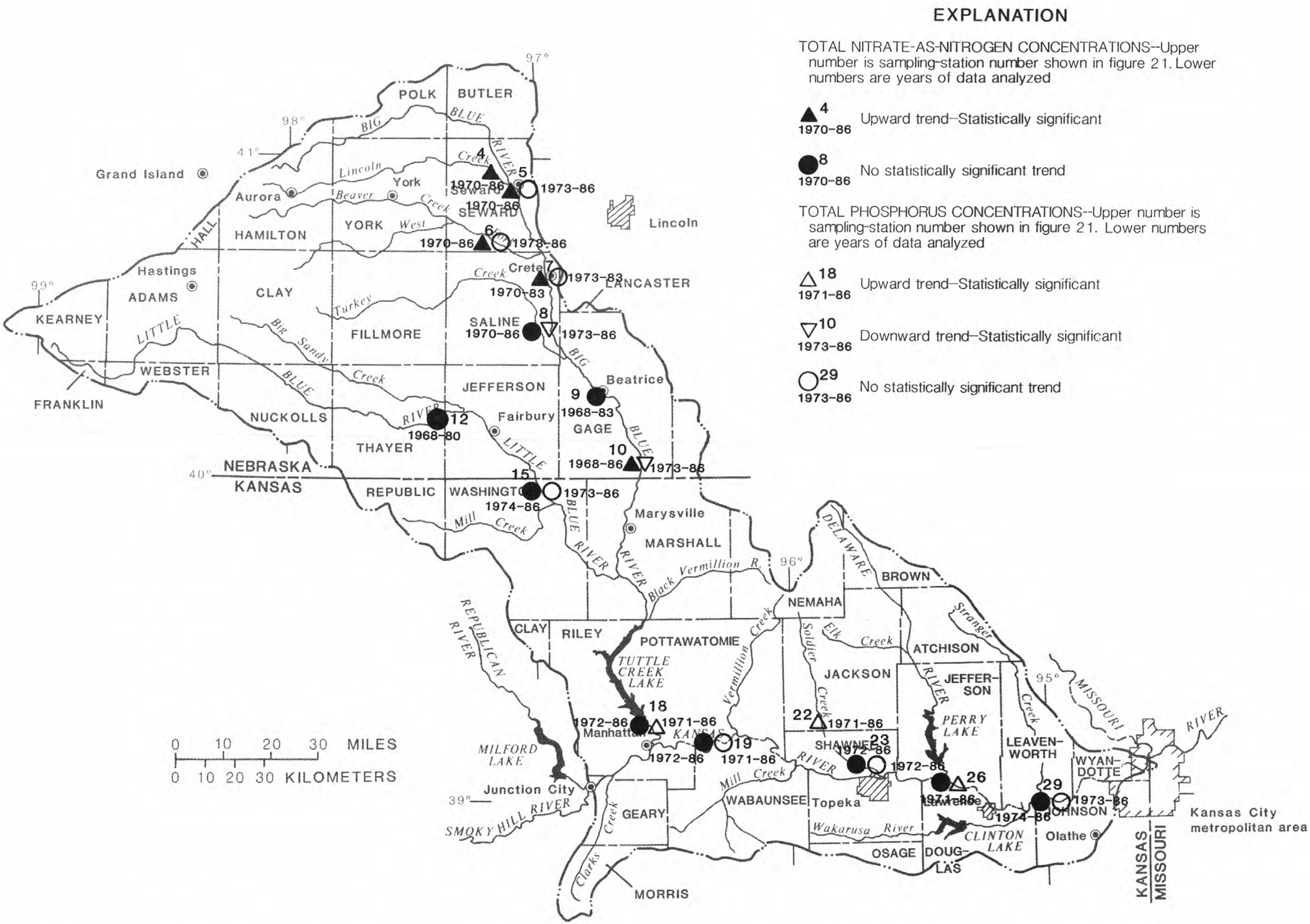


Figure 28.—Results of time-trend tests for total nitrate-as-nitrogen and total phosphorus concentrations in water from lower Kansas River basin.

Data needs

Although there is a large amount of available nutrient data, these data should continue to be collected to determine if observed trends continue and to define trends at stations where data through 1986 are insufficient. Future data collection should be consistent in analyzing the appropriate forms of nutrients that are important. For example, the trend in total nitrate concentrations was not found to be significant in water from the Hollenberg sampling station (station 15, table 21), but the trend in dissolved nitrate was significant and consistent with the application of nitrogen fertilizers in the northwestern part of the study unit. There were not sufficient data to perform time-trend tests for dissolved phosphorus, which is composed mostly of orthophosphate, and is the species of phosphorus that is available for growth of phytoplankton and periphyton. As progress is made to decrease suspended-sediment concentrations in the basin, stream and lake productivity may increase because productivity is limited greatly by turbid waters. Thus, the concentrations and trends in dissolved orthophosphate may become very important. Similarly, there were insufficient data to compute transport and time trends for dissolved nitrate, which is the more appropriate species of nitrate to analyze because of the analytical procedures that are used. Although nitrate as nitrogen does not seem to be a problem relative to drinking-water standards, data on concentrations and trends of dissolved nitrate are important because it is also available for growth of phytoplankton and periphyton. Finally, data should be collected for dissolved ammonia to determine if the apparent frequency of exceedances of the ammonia water-quality criteria in streams is real or an artifact of the analytical method.

In addition to performing nutrient determinations in a manner that is more environmentally relevant, there is a need to improve the ancillary data that include fertilizer usage, crop cover, amount of land in irrigated and nonirrigated crops, amount of land that is placed in the U.S. Department of Agriculture's Conservation Reserve Program, and more refined data on point-source discharges. There is also a need to collect the types and amounts of nonnutrient data that can help to improve the interpretation of nutrient data. These nonnutrient data include streamflow rates, suspended-sediment concentrations and associated particle-size distributions, and precipitation quality.

Dissolved Oxygen and Biochemical Oxygen Demand

By J.K. Stamer
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Dissolved oxygen (DO) in surface water is necessary for the survival and propagation of many forms of aquatic life. Concentrations of DO are affected by processes that deoxygenate and reoxygenate the water. Processes that deoxygenate water include: (1) microbial decomposition of carbonaceous organic matter, which in this report is defined as 5-day BOD (biochemical oxygen demand); (2) microbial oxidation of reduced forms of nitrogen, which is referred to as nitrification; (3) sediment oxygen demand, which is the oxygen demand exerted by benthic sediments and organisms; and (4) plant respiration. Processes that reoxygenate surface water include: (1) atmospheric reaeration (2) and plant photosynthesis. Where plants exist in the aquatic system, DO will tend to increase during daylight hours and decrease during nighttime hours because of photosynthesis and respiration, respectively.

Current Conditions

Statistical summaries of the DO and 5-day BOD data are listed in table 22. Data were sufficient to define the median and expected variability of DO and 5-day BOD concentrations in water from 20 and 14 sampling stations, respectively. For the most part, measurements of DO and BOD concentrations were collected during daylight hours on a monthly or quarterly basis, with supplemental DO measurements made when streamflow measurements were made. Thus, although the data were distributed evenly throughout the months of each year and throughout the years, the data were not representative of the full range of concentrations that can occur during a 24-hour cycle.

Although measurements of DO and 5-day BOD concentrations have been made on a routine basis and most often during the daytime, some general interpretations about the data listed in table 22 are useful. Concentrations of DO in streams generally ranged from about 6 to 8 mg/L for the 10th percentile and from about 13 to 15 mg/L for the 90th percentile, with median concentrations generally ranging from about 9 to 11 mg/L. In general, these data suggest little difference in DO concentrations between streams in the southern part of the basin (stations 2 and 18-29), where population centers are concentrated along the main stem of the Kansas River and land is mostly nonirrigated cropland and pasture, and streams in the northwestern part of the basin (stations 3-15), where no large population centers exist and land is mostly in irrigated cropland. The large median concentrations of DO are indicative of the fact that these measurements were made during the daytime and that the DO concentrations in the streams were somewhat supersaturated because of a positive net photosynthetic DO production.

Table 22.—*Statistical summary of data on dissolved-oxygen concentrations and 5-day biochemical oxygen demand in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[Concentrations in milligrams per liter; this table includes only those stations having 10 or more analyses; the 10- and 90-percentile concentrations are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Dissolved oxygen						
2	Kings Creek near Manhattan, Kans.	26	—	9.2	10.4	11	—
3	Big Blue River at Surprise, Nebr.	37	2.3	2.8	3.8	6.0	8.6
4	Lincoln Creek at Seward, Nebr.	116	6.4	7.3	9.5	12	14
5	Big Blue River at Seward, Nebr.	130	5.8	7.2	8.8	12	14
6	West Fork Big Blue River near Dorchester, Nebr.	161	6.7	8.0	9.6	11	13
7	Big Blue River near Crete, Nebr.	250	6.8	7.9	9.8	12	13
8	Turkey Creek near Wilber, Nebr.	114	6.2	7.5	9.6	12	14
9	Big Blue River at Beatrice, Nebr.	66	6.0	7.6	10	12	15
10	Big Blue River at Barneston, Nebr.	120	7.6	8.6	10	13	15
11	Little Blue River near Deweese, Nebr.	80	7.6	8.6	9.8	11	13
12	Little Blue River near Alexandria, Nebr.	38	8.2	8.8	9.7	11	12
13	Big Sandy Creek at Alexandria, Nebr.	38	8.0	8.9	10	11	13
15	Little Blue River at Hollenberg, Kans.	195	6.9	8.3	11	12	14
18	Big Blue River near Manhattan, Kans.	228	7.5	8.0	9.6	12	14
19	Kansas River at Wamego, Kans.	111	7.5	8.2	11	13	14
21	Kansas River at Topeka, Kans.	48	6.6	7.3	8.4	11	13
22	Soldier Creek near Delia, Kans.	122	6.0	7.1	8.8	11	13
23	Soldier Creek near Topeka, Kans.	89	7.8	8.9	11	13	15
24	Delaware River near Muscotah, Kans.	60	6.9	8.0	9.6	12	13
26	Kansas River at Lecompton, Kans.	119	7.1	7.8	9.2	12	13
29	Kansas River at DeSoto, Kans.	142	7.4	8.6	10	12	14
	5-day biochemical oxygen demand						
3	Big Blue River at Surprise, Nebr.	33	3.9	5.6	7.7	12	15
6	West Fork Big Blue River near Dorchester, Nebr.	31	1.1	2.6	4.4	7.1	9.6
10	Big Blue River at Barneston, Nebr.	32	1.8	2.8	4.8	7.5	9.2
12	Little Blue River near Alexandria, Nebr.	34	1.1	2.3	2.7	5.0	8.2
13	Big Sandy Creek at Alexandria, Nebr.	34	.2	1.0	1.6	2.5	4.1
15	Little Blue River at Hollenberg, Kans.	69	1.2	2.1	3.9	5.8	9.0
18	Big Blue River near Manhattan, Kans.	109	.6	1.2	1.8	2.7	4.3
19	Kansas River at Wamego, Kans.	109	.9	1.8	2.4	3.9	5.1
21	Kansas River at Topeka, Kans.	49	1.2	2.0	3.6	6.2	8.4
22	Soldier Creek near Delia, Kans.	86	1.1	1.5	2.1	3.0	4.5
23	Soldier Creek near Topeka, Kans.	84	.9	1.2	2.1	3.0	4.8
24	Delaware River near Muscotah, Kans.	60	.6	1.2	1.8	3.3	4.8
26	Kansas River at Lecompton, Kans.	108	.9	1.8	3.0	4.8	6.9
29	Kansas River at DeSoto, Kans.	48	1.8	2.2	4.0	6.5	8.8

Concentrations of 5-day BOD (table 22) in streams generally ranged from less than 1 to about 2 mg/L at the 10th percentile and from about 4 to 10 mg/L at the 90th percentile, with the median values ranging from about 2 to 5 mg/L. The large median 5-day BOD concentration of 7.7 mg/L in water from the Big Blue River at Surprise, Nebr. (station 3), agrees with the small median concentration of 3.8 mg/L of DO at this station, but the explanation as to the cause of these concentrations is not known. Examination of the inventory of point sources of wastewater (data from Industrial Discharge data base, U.S. Environmental Protection Agency) indicates that there are four very small municipal wastewater discharges and no confined-feedlot discharges upstream of the station at Surprise. However, during times when streamflow rates were small, the wastewater discharges had an adverse effect on DO concentrations even during the daytime because median streamflow at Surprise was less than 1 ft^3/s. Thus, there have been numerous occasions when streamflow did not allow for sufficient assimilation of the wastes.

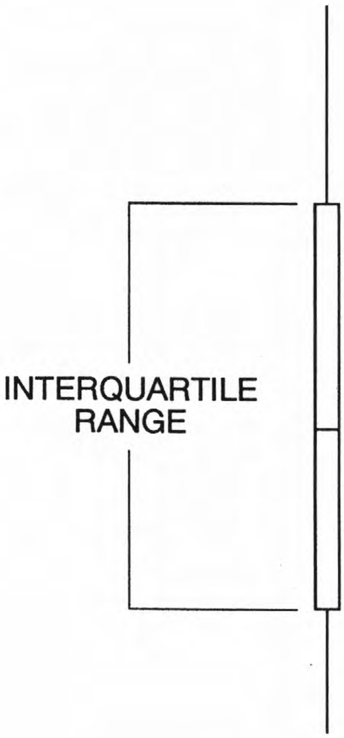
The distribution of DO concentrations in water from sampling stations in the lower Kansas River basin during the 1978-86 water years is shown in figure 29. The distribution of DO concentrations in water from the Kansas River and its tributaries (fig. 29A) shows that median values were substantially larger than the criterion of 3.0 mg/L established by the U.S. Environmental Protection Agency (1987d). Distributions of median concentrations and the interquartile ranges of DO concentrations in water from the Big Blue River and its tributaries (fig. 29B) were relatively consistent, with the exception of water from the Big Blue River at Surprise, Nebr. (station 3). At this station, more than 25 percent of the DO concentrations were less than the 3.0-mg/L criterion (table 23) for warmwater-aquatic life other than early-life stages (U.S. Environmental Protection Agency, 1987d). This criterion was established as a guideline to protect maturing and mature aquatic life from an inadequate supply of dissolved oxygen.

The distribution of 5-day BOD concentrations in water from sampling stations in the lower Kansas River basin during the 1978-86 water years is shown in figure 30. A general comparison of the 5-day BOD concentrations in water from the Kansas River and its tributaries (fig. 30A) to those in water from the Big Blue River and its tributaries (fig. 30B) indicates that smaller median concentrations occurred in water from the Kansas River and its tributaries than in water from the Big Blue River and its tributaries. The smaller median concentrations in water from the main stem of the Kansas River (fig. 30A) indicate that discharges from the wastewater-treatment facilities on the Kansas River seemed to have been adequately assimilated by the Kansas River, based on available DO data. The generally larger median 5-day BOD concentrations in water from the Big Blue River and its tributaries (fig. 30B) may be indicative of the fact that streams in this part of the study unit have not assimilated the wastes as well as in the Kansas River and its tributaries.

EXPLANATION

o CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

* CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE BUT LESS THAN UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE



UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE OR LARGEST CONCENTRATION NOT EXCEEDING THIS COMPUTATION

UPPER QUARTILE (75th PERCENTILE)

MEDIAN (50th PERCENTILE)

LOWER QUARTILE (25th PERCENTILE)

LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE OR SMALLEST CONCENTRATION NOT LESS THAN THIS COMPUTATION

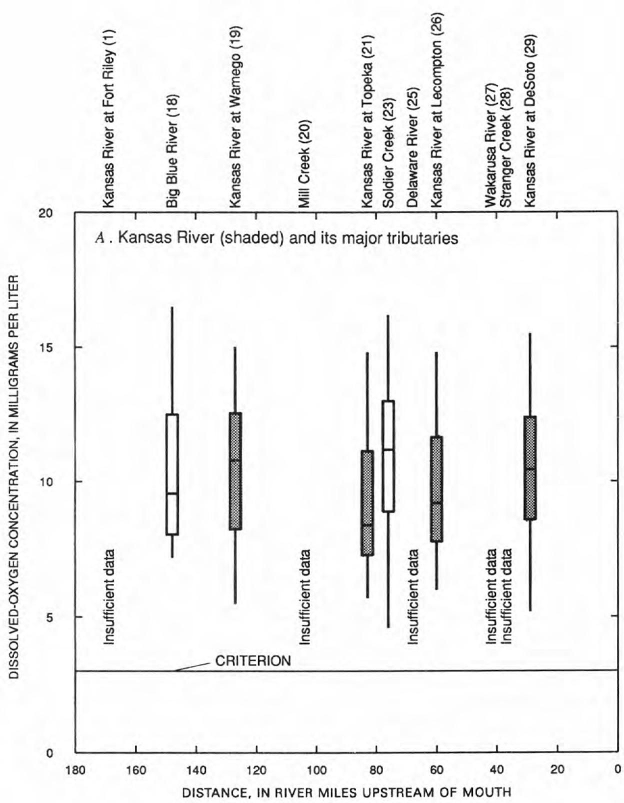
* CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE BUT GREATER THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

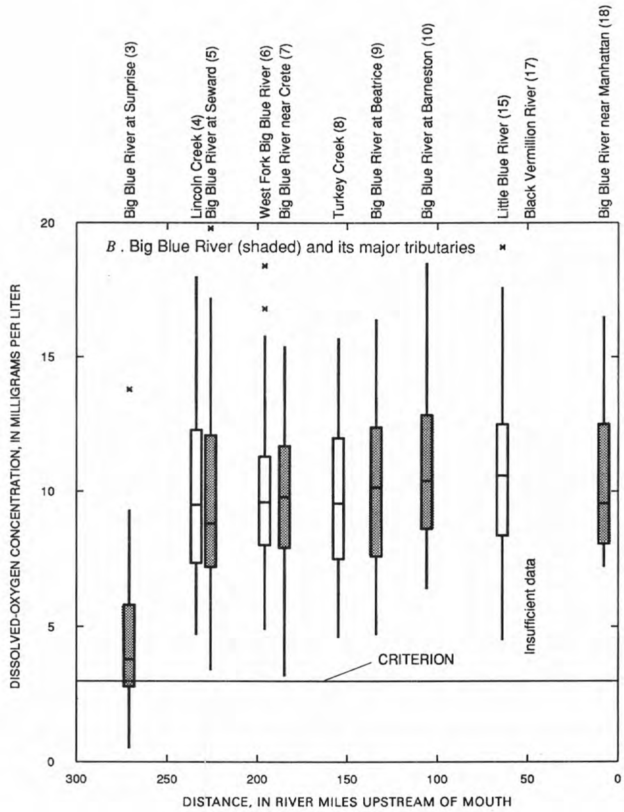
o CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

WATER-QUALITY CRITERION IS MINIMUM FOR FRESH, WARMWATER-AQUATIC LIFE OTHER THAN EARLY LIFE STAGES (U.S. ENVIRONMENTAL PROTECTION AGENCY, 1987d)

Figure 29.—Distribution of dissolved-oxygen concentrations in water from (*A*) Kansas warmwater-aquatic criterion,





and (*B*) Big Blue Rivers and their major tributaries and relation of concentrations to 1978-86 water years.

Table 23.—*Number of dissolved-oxygen analyses not meeting warmwater-aquatic criterion in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[Analyses counted in this table as not meeting the criterion do not necessarily represent violations of the criterion but may indicate the need for further study. Analyses were counted as not meeting the criterion if the concentration was less than 3.0 milligrams per liter, the criterion for warmwater-aquatic life other than early-life stages (U.S. Environmental Protection Agency, 1987d). Statistical summaries of dissolved-oxygen concentrations for selected sampling stations are listed in table 22]

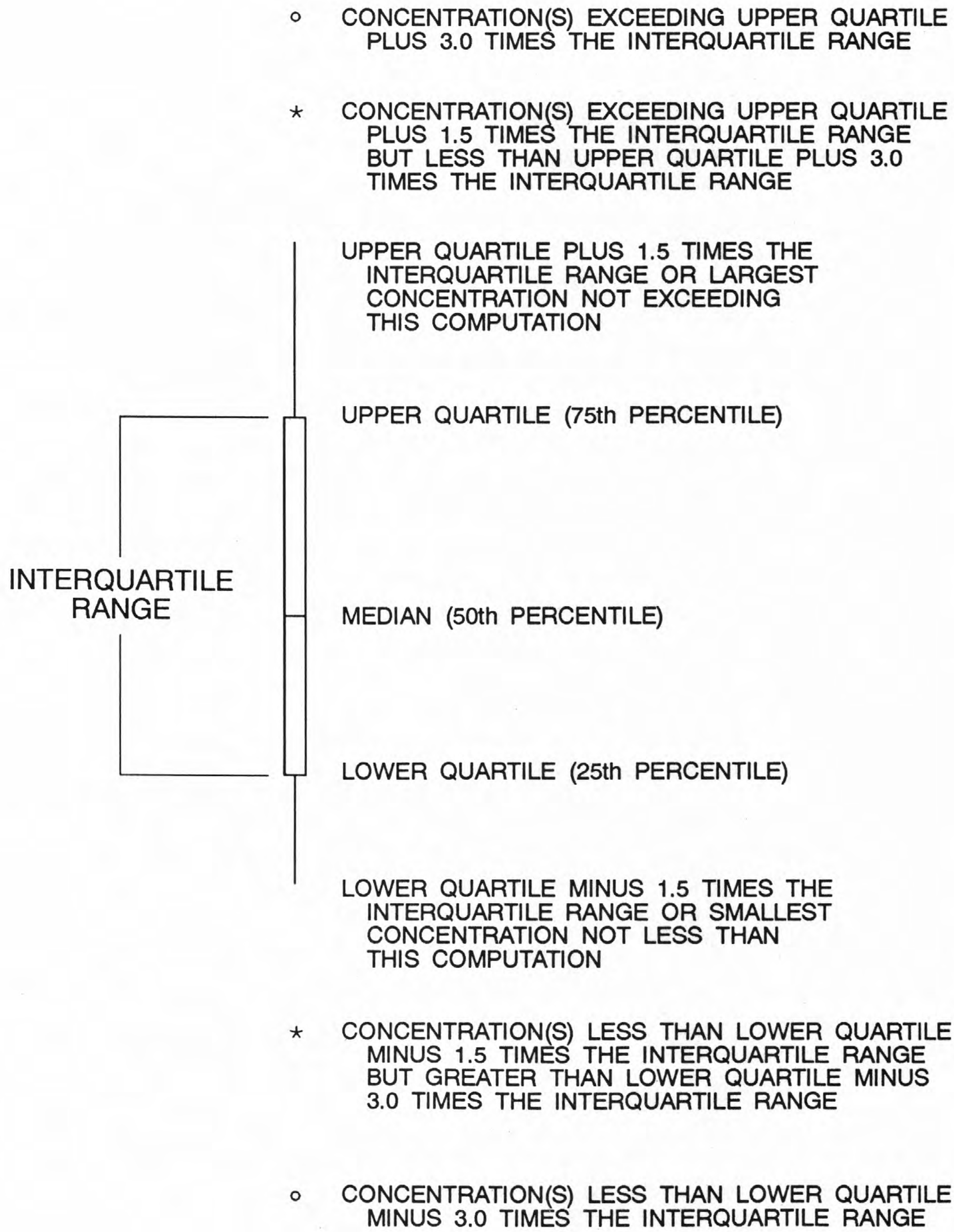
Sampling-station number (fig. 9)	Station name	Number of analyses	Number of analyses not meeting the criterion for warmwater-aquatic life other than early-life stages, 1-day minimum
3	Big Blue River at Surprise, Nebr.	37	11
22	Soldier Creek near Delia, Kans.	122	1

The available DO and BOD data indicate that small DO concentrations in water do not appear to be a regional problem. However, DO data were collected during the daytime when the aquatic system was least stressed. To confirm that small DO concentrations are not a problem, a synoptic DO study at many locations should be done during a warm low-flow period. During the synoptic study, measurements of DO and support variables should be collected before dawn when the effect of algal photosynthesis is minimal.

Trends

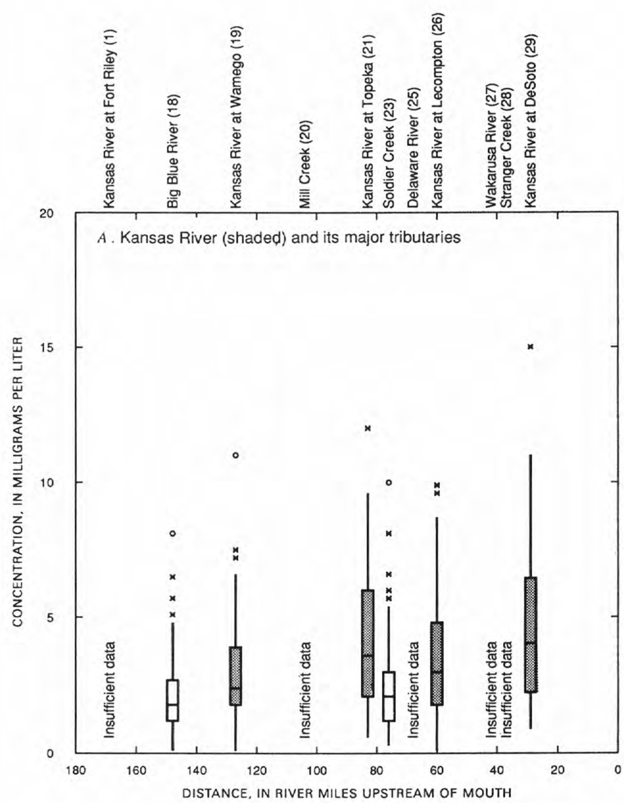
Time-trend tests were applied to DO data for the period of record (starting as early as 1961 for one station) using the seasonal Kendall method. Of the 29 stations that were selected for analysis of available data, there were adequate data to perform the time-trend tests for 15 stations as shown in table 24 and figure 31. Of the 15 stations for which trend tests were performed, six had significant trends, and all six trends were positive. The positive trends in DO in water from these six stations may reflect improved wastewater treatment although for the most part the stations are miles from any large wastewater-treatment plant that might have a direct effect on water quality. Although the trend-test results were not significant for the other nine stations, the trends in concentrations of DO, nevertheless, were positive. The increases in DO concentrations are consistent with the general decreases in densities of fecal-coliform bacteria (see section of this report on "Fecal-Indicator Bacteria").

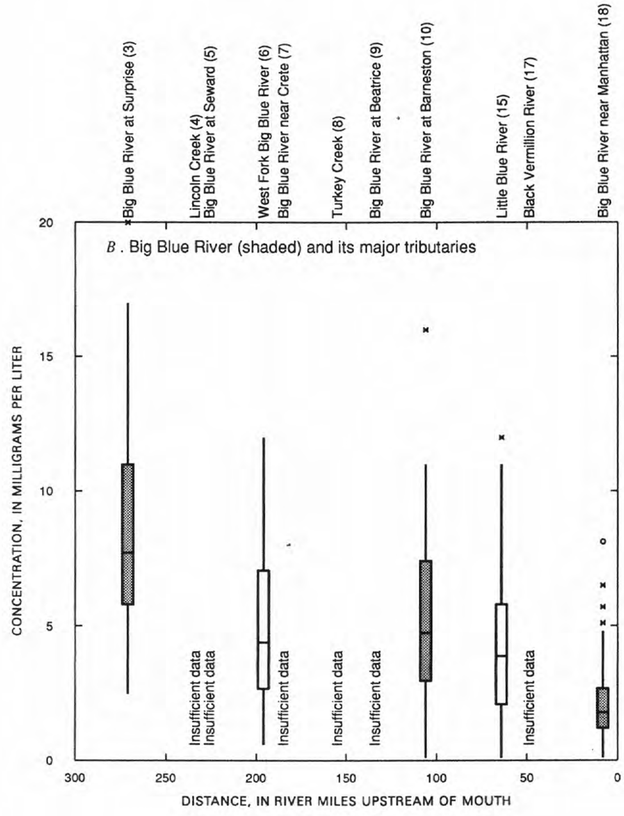
EXPLANATION



NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

Figure 30.—Distribution of 5-day biochemical oxygen demand concentrations in water





from (*A*) Kansas and (*B*) Big Blue Rivers and their major tributaries, 1978-86 water years.

Table 24. – *Trend-test results for dissolved-oxygen concentrations in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Milligrams per liter per year	Concentration: Average rate of change: Percent of median per year	Flow adjusted concentration: Probability level	Flow adjusted concentration: Average rate of change (percent per year)
4	Lincoln Creek near Seward, Nebr.	1970-86	17	0.09	+0.073	+0.78	0.04	+ 1.0
5	Big Blue River at Seward, Nebr.	1970-86	17	.26	+ .050	+ .57	–	–
6	West Fork Big Blue River near Dorchester, Nebr.	1968-86	19	.73	+ .011	+ .11	.18	+ .32
7	Big Blue River near Crete, Nebr.	1970-80	11	.07	+ .079	+ .85	.11	+ 1.1
8	Turkey Creek near Wilber, Nebr.	1970-86	17	.03	+ .093	+1.0	–	–
9	Big Blue River at Beatrice, Nebr.	1968-83	16	.08	+ .10	+1.0	1.00	0
10	Big Blue River at Barneston, Nebr.	1961-86	26	.06	+ .044	+ .44	.11	+ .48
12	Little Blue River near Alexandria, Nebr.	1968-80	13	.35	+ .054	+ .55	.05	+ 1.2
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.01	+ .067	+ .65	.09	+ .70
18	Big Blue River near Manhattan, Kans.	1971-86	16	.32	+ .026	+ .25	–	–
19	Kansas River at Wamego, Kans.	1971-86	16	.59	+ .028	+ .25	–	–
21	Kansas River at Topeka, Kans.	1967-81	15	.30	+ .033	+ .38	–	–
23	Soldier Creek near Topeka, Kans.	1972-86	15	.06	+ .18	+1.8	–	–
26	Kansas River at Lecompton, Kans.	1971-86	16	.36	+ .029	+ .31	–	–
29	Kansas River at DeSoto, Kans.	1970-86	17	.01	+ .077	+ .76	.06	+ .98

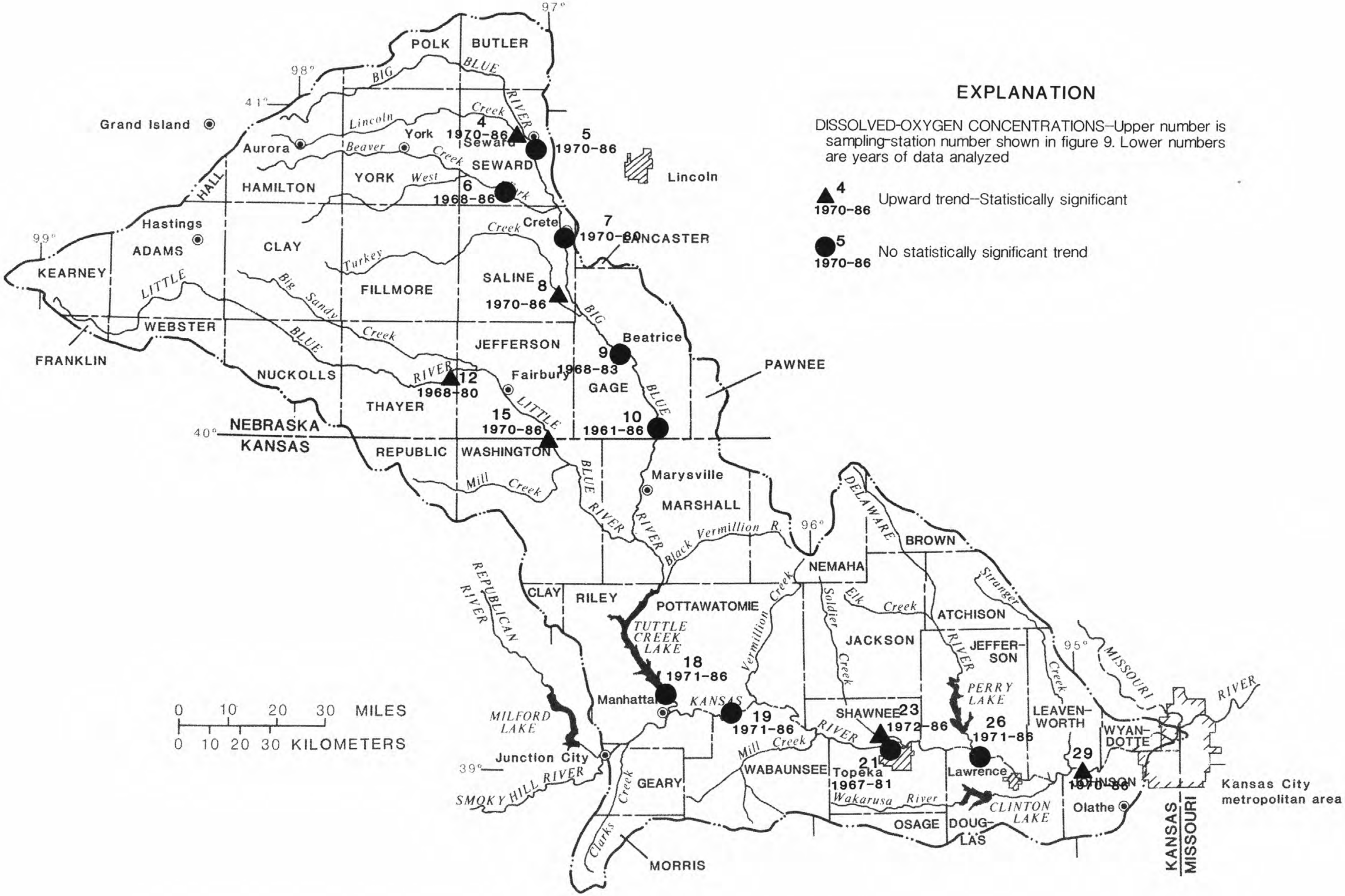


Figure 31.—Results of time-trend tests for dissolved-oxygen concentrations in water from lower Kansas River basin.

Major Metals and Trace Elements

By J.K. Stamer, R.F. Sanzolone, and J.L. Ryder
U.S. Geological Survey

Some major metals and most trace elements are essential to animal and plant nutrition, but they can be toxic in large quantities. Metals and trace elements in the aquatic environment can result from rocks and minerals in the drainage basin, but often the source is from human activities such as the burning of fossil fuel, automobile emissions, and various industries. Some trace elements, such as arsenic and mercury, were at one time components of some pesticides.

Streambed-Sediment Samples

Streambed sediments are useful for describing the occurrence and distribution of metals and trace elements because elemental concentrations in streambed sediments can be orders of magnitude larger than those in water. Elements in streambed sediments originate from either geologic or human sources. In the lower Kansas River basin, geologic sources of metals and trace elements consist chiefly of Quaternary glacial, alluvial, and eolian deposits, with some Permian and Cretaceous shale, carbonate rock, and sandstone, whereas human sources are primarily diversified agricultural and industrial activities.

A search was conducted to identify sources of geochemical information about elemental concentrations in streambed sediments in the lower Kansas River basin. Published literature, the computer files of the U.S. Geological Survey, and the files of the Kansas Geological Survey and the Nebraska Conservation and Survey Division were searched for pertinent information. The most extensive reconnaissance of streambed sediments in the study unit was conducted by the U.S. Department of Energy for the National Uranium Resource Evaluation (NURE) Program. Geochemical information for streambed sediments from other identified sources is very limited. The NURE Program was established in 1973 to assess uranium resources and to identify feasible areas for uranium exploration throughout the United States. The streambed-sediment data, which are contained in computer files of the U.S. Geological Survey, were obtained from the Hydrogeochemical and Stream Sediment Reconnaissance part of the NURE Program. The data also are available in reports compiled and published by the Union Carbide Corporation, Nuclear Division (1979b; 1979c; 1980; 1981a; 1981b). Data are available for 77 percent of the study unit or five of the seven U.S. Geological Survey 1- × 2-degree topographic quadrangles (1:250,000 scale) that lie west of the 96th meridian. Quadrangles for which data are available are Lincoln, Grand Island, and Fremont in Nebraska, and Hutchinson and Manhattan in Kansas. Quadrangles for which no data are available are Lawrence and Kansas City in Kansas and Missouri. The area where no data were collected is that part of the study unit east of the confluence of Mill Creek (Wabaunsee County) and the Kansas River and includes the cities of Topeka, Lawrence, and Kansas City, Kans.

Streambed-sediment samples were collected in the fall of 1978 for the NURE Program by Environmental Systems, Inc., in the Hutchinson and Manhattan quadrangles. Samples were collected in the fall of 1979 for the NURE Program by BCI Geonetics in the Fremont, Grand Island, and Lincoln quadrangles. A total of 1,066 streambed-sediment samples were collected in the lower Kansas River basin. Streambed-sediment samples were collected from drainage basins that ranged in area from 2.0 to 21.1 mi^2. This resulted in an average sample density of about one sample per 10 mi^2. Information regarding NURE procedures for sample collection, preparation, analysis, and quality control and assurance can be obtained from "Procedures Manual For Stream Sediment Reconnaissance Samples" (Union Carbide Corporation, Nuclear Division, 1978) and "Hydrogeochemical and Stream Sediment Reconnaissance Procedures of the Uranium Resource Evaluation Project" (Union Carbide Corporation, Nuclear Division, 1979a).

A statistical summary of concentrations of the 34 elements in the samples collected for the NURE Program is listed in table 25. Analyses of the elements listed in table 25 were performed on samples from each of the five quadrangles, except for hafnium, lanthanum, and lead, which were analyzed only for samples from the Fremont, Grand Island, and Lincoln quadrangles. The most abundant elements in the streambed sediments in descending order based on median concentrations were aluminum, iron, potassium, sodium, calcium, and magnesium. Expected variation in concentrations of constituents is shown by the range from the 10th to the 90th percentile. In general, the concentrations of each element did not vary greatly. The range from the 10th to the 90th percentile frequently was equal to or less than twice the 10th-percentile value.

A comparison of the median concentrations of 34 elements in table 25 was made to the geometric means of corresponding elemental concentrations in soils

Table 25.—*Statistical summary of elemental composition of streambed sediments in lower Kansas River basin, 1978-79*

[g/kg, grams per kilogram. Arsenic and selenium determined by atomic absorption; uranium-FL by fluorometry; uranium-NT by neutron activation, and remaining elements by plasma-source emission spectrometry; <, less than]

Element	Number of measurable concentrations	Number of concentrations less than detection level	Concentration, in micrograms per gram unless otherwise stated					
			Lower level of detection	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile
Aluminum, total as Al	1,066	0	500	36,000	41,000	47,000	52,000	56,000
Arsenic, total as As	1,065	1	.1	1.6	2.1	2.8	3.6	4.6
Barium, total as Ba	1,066	0	2	470	540	780	860	900
Beryllium, total as Be	1,064	2	1	1	1	1	2	2
Boron, total as B	1,007	59	10	11	15	21	25	28
Calcium, total as Ca, in g/kg	1,065	1	.5	5.7	6.3	7.4	14	37
Cerium, total as Ce	1,064	2	10	42	53	64	74	84
Chromium, total as Cr	1,066	0	1	28	31	35	38	42
Cobalt, total as Co	1,055	11	4	5	7	9	12	16
Copper, total as Cu	1,066	0	2	11	13	15	17	20
Hafnium, total as Hf	[1]168	[1]472	[2]3	< 3	< 15	< 15	< 15	42
Iron, total as Fe	1,066	0	500	15,000	17,000	19,000	21,000	23,000
Lanthanum, total as La	[1]640	[1]0	2	69	74	80	86	93
Lead, total as Pb	[1]467	[1]117	10	< 10	12	20	27	37
Lithium, total as Li	1,066	0	1	17	19	21	25	30
Magnesium, total as Mg, in g/kg	1,066	0	.5	3.5	4.2	4.9	5.9	7.7
Manganese, total as Mn	1,066	0	4	320	380	480	660	880
Molybdenum, total as Mo	133	933	4	< 4	< 4	< 4	< 4	4
Nickel, total as Ni	1,066	0	2	12	14	17	22	26
Niobium, total as Nb	1,055	11	4	5	6	8	13	15
Phosphorus, total as P	1,066	0	5	330	400	480	580	680
Potassium, total as K, in g/kg	1,066	0	.5	12	14	15	16	17
Scandium, total as Sc	1,066	0	1	4	5	6	6	7
Selenium, total as Se	810	256	.1	< .1	.1	.3	.6	.8
Silver, total as Ag	41	1,025	2	< 2	< 2	< 2	< 2	< 2
Sodium, total as Na, in g/kg	1,066	0	.5	5.3	6.6	8.2	9.4	10
Strontium, total as Sr	1,066	0	1	130	150	170	180	200
Thorium, total as Th	1,017	49	2	3	6	8	10	12
Titanium, total as Ti, in g/kg	1,066	0	.01	2.1	2.2	2.4	2.5	2.7
Vanadium, total as V	1,066	0	2	51	57	64	70	77
Uranium-FL, acid-soluble as U	1,065	0	.25	1.7	2.0	2.3	2.6	3.0
Uranium-NT, total as U	1,055	0	.02	2.9	3.1	3.3	3.5	3.8
Yttrium, total as Y	1,066	0	1	13	14	15	16	18
Zinc, total as Zn	1,066	0	2	39	45	53	62	72
Zirconium, total as Zr	1,066	0	2	77	82	88	93	100

[1]Values reported only for the Fremont, Grand Island, and Lincoln quadrangles.

[2]In the Fremont quadrangle, the lower level of detection for total hafnium was 15 micrograms per gram.

and other surficial materials from 1,318 samples in the conterminous United States (Shacklette and Boerngen, 1984). Concentrations of hafnium and silver are not described in Shacklette and Boerngen (1984). Although the median value and the geometric mean of a distribution of data are not calculated in the same manner, each is a good measure of the central tendency of the distribution of data. A comparison of the median values of the NURE data to the geometric means of soils and surficial-materials data indicates that 15 median concentrations of NURE data were larger than the corresponding geometric means of elements in the soils and surficial-materials data; of these 15 values, 10 were 25 percent or greater than their corresponding geometric means. These elements included barium, cobalt, lanthanum, lead, magnesium, nickel, phosphorus, sodium, strontium, and uranium. Six of the median values from the NURE data were the same as their corresponding geometric means, and 10 were smaller.

The median concentrations of the 10 elements in the NURE data that were appreciably larger than the concentrations of corresponding elements in soils and surficial materials may indicate some enrichment of the streambed sediments or simply some differences in the regional surficial geology as compared to the rest of the conterminous United States. For example, three of the alkali and alkaline-earth metals, which include barium, sodium, and strontium, in the lower Kansas River basin had median concentrations appreciably larger than the corresponding values for soils and surficial materials in the rest of the United States.

Areal distributions of streambed-sediment samples for barium and chromium from the NURE data are shown in figures 32 and 33. These two elements were selected for two reasons. First, the median concentration of barium from the NURE data in the lower Kansas River basin (780 μg/g (micrograms per gram)) was appreciably larger than the geometric mean for the conterminous United States (440 μg/g) reported by Shacklette and Boerngen (1984). Second, the median concentration of chromium from the NURE data is 35 μg/g, which compares favorably with the geometric-mean concentration for chromium of 37 μg/g reported by Shacklette and Boerngen (1984). An analysis of the areal distribution of the concentrations of barium equal to or greater than the 90th percentile (900 μg/g) in figure 32 shows a clustering, which appears to be related to the loess deposits in the northwestern part of the study unit, whereas the areal distribution of concentrations of chromium equal to or greater than the 90th percentile (42 μg/g) in figure 33 shows no clustering.

Water Samples

Concentrations

A statistical summary of concentrations of major metals and trace elements in water from selected sampling stations in the lower Kansas River basin for the 1978-86 water years is presented in table 26. More data are available for major metals, such as iron and manganese, than for trace elements, such as arsenic, beryllium, cobalt, and lead. The data show no appreciable differences in the distribution of concentrations of major metals and trace elements with the exception of total iron and total and dissolved manganese, which are larger in the northwestern part of the basin.

Because of the lack of adequate available data, the only meaningful comparison of median concentrations of the major metals and trace elements listed in table 26 that could be made to published data in surface water throughout the United States (see Hem, 1985) was for concentrations of dissolved iron and manganese. Median concentrations of dissolved iron and manganese from all the stations in table 26 were 30 and 49 μg/L (median pH value was 8.0 standard units), respectively, which are considerably larger than the typical dissolved concentration of iron of 10 μg/L and the expected solubility of uncomplexed manganese of 5.5 μg/L reported by Hem (1985) in surface water. The larger than expected median concentrations of dissolved iron and manganese measured at stations in the study unit may reflect the possible presence of colloidal forms of iron and manganese that can pass through a 0.45-micrometer filter during sample processing as noted by Hem (1985).

A comparison of concentrations of total arsenic and mercury, and total-recoverable barium, copper, chromium, iron, manganese, and zinc to streamflow in the lower Kansas River basin indicated a general increase in constituent concentrations with increasing streamflow. Increasing element concentrations tend to be associated with increasing amounts of suspended sediment. Unexpectedly, concentrations of total-recoverable lead were not related to streamflow, and concentrations of total-recoverable boron tended to decrease with increasing streamflow.

The number of analyses of major metals and trace elements by sampling station that did not meet various applicable freshwater-aquatic criteria and drinking-water MCL's (Maximum Contaminant Levels) as reported by the U.S. Environmental Protection Agency (1986a, 1987d) are listed in table 27. Several aspects of these data should be noted.

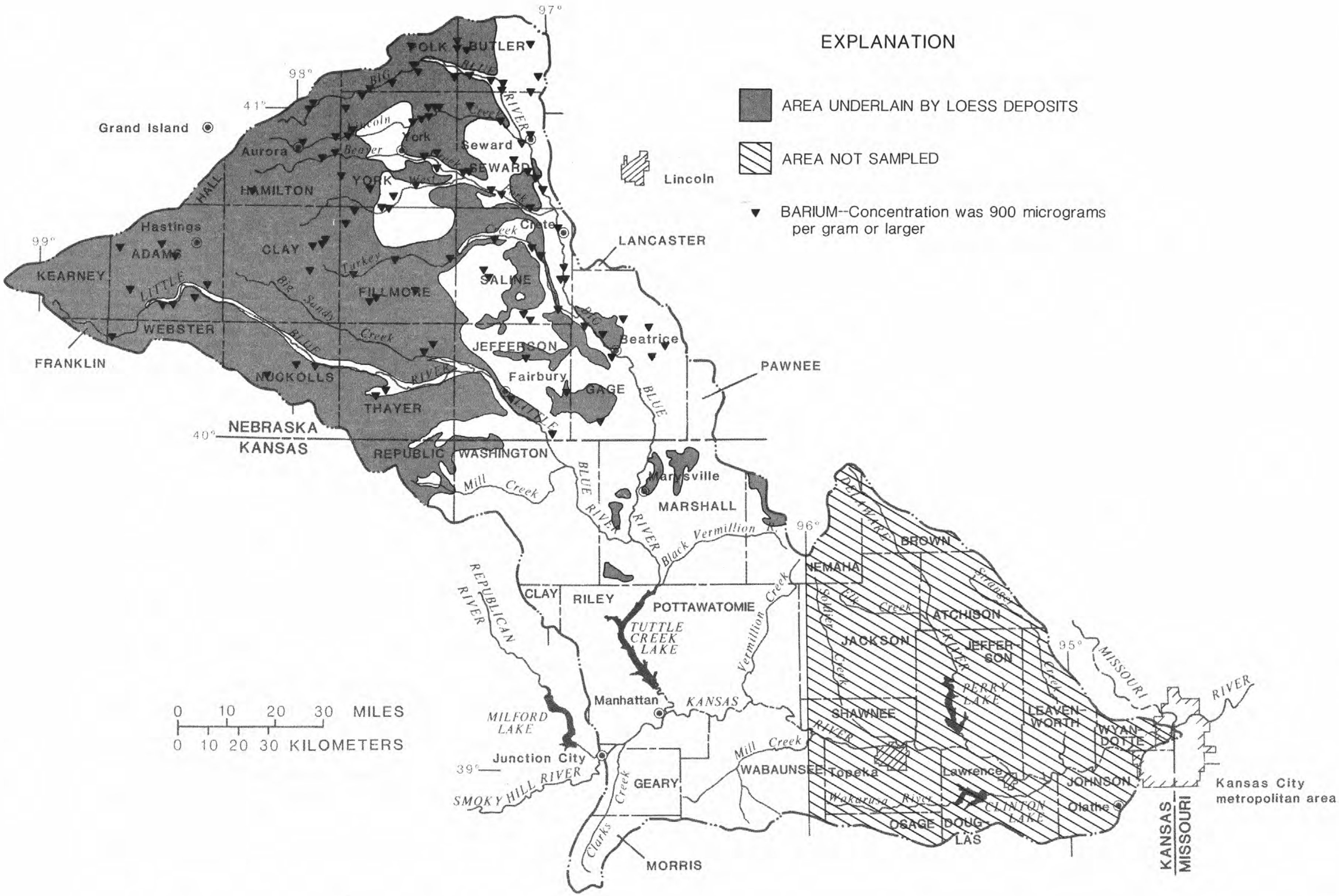


Figure 32.—Areal distribution of concentrations of barium equal to or larger than 90th percentile (900 micrograms per gram) in streambed-sediment samples relative to loess deposits in lower Kansas River basin, 1978-79.

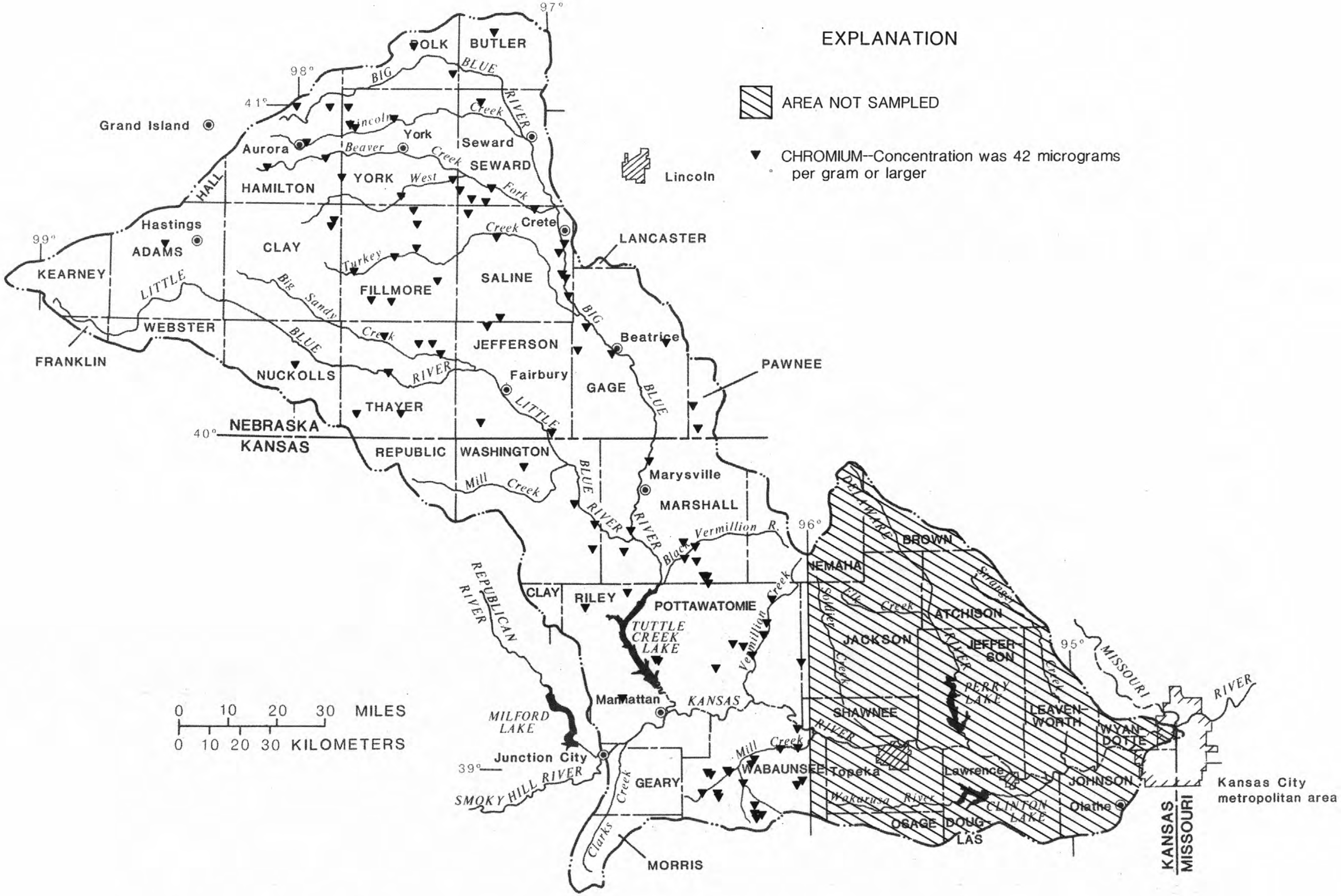


Figure 33.—Areal distribution of concentrations of chromium equal to or larger than 90th percentile (42 micrograms per gram) in streambed-sediment samples in lower Kansas River basin, 1978-79.

Table 26.—*Statistical summary of data on major metals and trace elements in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[Concentrations in micrograms per liter; this table includes only those sampling stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
		Aluminum, dissolved					
2	Kings Creek near Manhattan, Kans.	10	—	10	10	12	—
18	Big Blue River near Manhattan, Kans.	15	—	10	20	30	—
29	Kansas River at DeSoto, Kans.	13	—	10	20	35	—
		Arsenic, total					
9	Big Blue River at Beatrice, Nebr.	11	—	7.0	10	20	—
10	Big Blue River at Barneston, Nebr.	20	—	6.0	7.0	9.0	—
15	Little Blue River at Hollenberg, Kans.	32	4.0	6.0	8.0	18	26
18	Big Blue River near Manhattan, Kans.	27	—	3.0	4.0	4.0	—
22	Soldier Creek near Delia, Kans.	10	—	<1	6.5	10	—
26	Kansas River at Lecompton, Kans.	10	—	3.0	9.5	10	—
29	Kansas River at DeSoto, Kans.	26	—	2.0	4.0	5.2	—
		Arsenic, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	<1	<1	<1	—
9	Big Blue River at Beatrice, Nebr.	12	—	2.5	4.5	5.0	—
15	Little Blue River at Hollenberg, Kans.	26	—	2.7	3.5	6.0	—
18	Big Blue River near Manhattan, Kans.	37	1.8	2.0	3.0	4.0	4.2
29	Kansas River at DeSoto, Kans.	35	1.0	2.0	3.0	3.0	4.0
		Barium, total recoverable					
10	Big Blue River at Barneston, Nebr.	12	—	100	200	550	—
15	Little Blue River at Hollenberg, Kans.	17	—	100	200	350	—
18	Big Blue River near Manhattan, Kans.	28	—	100	150	200	—
22	Soldier Creek near Delia, Kans.	10	—	300	300	420	—
29	Kansas River at DeSoto, Kans.	25	—	200	200	250	—
		Barium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	100	110	120	—
18	Big Blue River near Manhattan, Kans.	35	<100	100	130	180	200
29	Kansas River at DeSoto, Kans.	32	100	110	130	190	280
		Beryllium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	.50	1.0	1.0	—
18	Big Blue River near Manhattan, Kans.	15	—	.50	.50	.50	—
29	Kansas River at DeSoto, Kans.	14	—	.50	.50	.50	—
		Boron, total recoverable					
15	Little Blue River at Hollenberg, Kans.	57	56	110	160	210	330
18	Big Blue River near Manhattan, Kans.	97	40	65	110	160	230
19	Kansas River at Wamego, Kans.	96	50	90	140	180	220
21	Kansas River at Topeka, Kans.	45	60	110	150	180	260
22	Soldier Creek near Delia, Kans.	126	30	70	110	160	190
23	Soldier Creek near Topeka, Kans.	90	30	50	100	160	210
24	Delaware River near Muscotah, Kans.	58	<10	57	120	170	220
26	Kansas River at Lecompton, Kans.	101	32	75	120	160	200
29	Kansas River at DeSoto, Kans.	44	60	100	140	180	240
		Boron, dissolved					
4	Lincoln Creek at Seward, Nebr.	29	—	40	50	70	—
5	Big Blue River at Seward, Nebr.	24	—	50	50	70	—
6	West Fork Big Blue River near Dorchester, Nebr.	28	—	50	60	78	—
7	Big Blue River near Crete, Nebr.	25	—	50	70	80	—
8	Turkey Creek near Wilber, Nebr.	28	—	42	60	80	—
9	Big Blue River at Beatrice, Nebr.	25	—	65	70	90	—
10	Big Blue River at Barneston, Nebr.	16	—	40	55	70	—
11	Little Blue River near Deweese, Nebr.	36	20	30	40	67	110

Table 26.—*Statistical summary of data on major metals and trace elements in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[Concentrations in micrograms per liter; this table includes only those sampling stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
		Cadmium, total recoverable					
5	Big Blue River at Seward, Nebr.	22	—	1.0	1.5	4.2	—
7	Big Blue River near Crete, Nebr.	50	<1	<1	<1	<1	<1
9	Big Blue River at Beatrice, Nebr.	11	—	<1	<1	<1	—
10	Big Blue River at Barneston, Nebr.	21	—	<1	<1	<15	—
15	Little Blue River at Hollenberg, Kans.	28	—	<1	<1	<2	—
18	Big Blue River near Manhattan, Kans.	27	—	<1	1.0	2.0	—
22	Soldier Creek near Delia, Kans.	10	—	<1	1.0	2.0	—
26	Kansas River at Lecompton, Kans.	10	—	1.0	1.5	2.2	—
29	Kansas River at DeSoto, Kans.	25	—	<1	1.0	2.0	—
		Cadmium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	<1	<1	1.8	—
9	Big Blue River at Beatrice, Nebr.	10	—	<1	<1	2.0	—
15	Little Blue River at Hollenberg, Kans.	26	—	<1	<1	2.0	—
18	Big Blue River near Manhattan, Kans.	37	<2	<2	<2	<2	2.0
29	Kansas River at DeSoto, Kans.	34	<1	<1	<1	<1	3.0
		Chromium, total recoverable					
5	Big Blue River at Seward, Nebr.	22	—	<10	<10	12	—
9	Big Blue River at Beatrice, Nebr.	11	—	20	40	70	—
10	Big Blue River at Barneston, Nebr.	21	—	<10	<10	19	—
15	Little Blue River at Hollenberg, Kans.	40	<10	<10	18	40	80
18	Big Blue River near Manhattan, Kans.	30	<10	<10	<20	<20	20
19	Kansas River at Wamego, Kans.	10	—	<20	<20	<20	—
22	Soldier Creek near Delia, Kans.	13	—	<10	10	10	—
23	Soldier Creek near Topeka, Kans.	13	—	<10	<10	15	—
26	Kansas River at Lecompton, Kans.	12	—	<10	5.0	10	—
29	Kansas River at DeSoto, Kans.	27	—	<10	10	20	—
		Chromium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	<1	<1	<1	—
9	Big Blue River at Beatrice, Nebr.	12	—	<20	<20	<20	—
15	Little Blue River at Hollenberg, Kans.	23	—	<20	<20	<20	—
18	Big Blue River near Manhattan, Kans.	35	<1	<1	1.0	1.0	10
29	Kansas River at DeSoto, Kans.	32	<1	<1	1.0	4.0	17
		Cobalt, total recoverable					
15	Little Blue River at Hollenberg, Kans.	13	—	10	20	30	—
18	Big Blue River near Manhattan, Kans.	20	—	<2	<2	2.0	—
29	Kansas River at DeSoto, Kans.	18	—	<2	2.0	3.2	—
		Cobalt, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	<3	<3	<3	—
15	Little Blue River at Hollenberg, Kans.	13	—	<2	<2	<2	—
18	Big Blue River near Manhattan, Kans.	35	<3	<3	<3	<3	3.0
29	Kansas River at DeSoto, Kans.	32	<3	<3	<3	<3	3.0
		Copper, total recoverable					
5	Big Blue River at Seward, Nebr.	22	—	7.0	9.0	16	—
9	Big Blue River at Beatrice, Nebr.	11	—	20	36	120	—
10	Big Blue River at Barneston, Nebr.	21	—	8.0	13	21	—
15	Little Blue River at Hollenberg, Kans.	41	<10	<10	20	63	90
18	Big Blue River near Manhattan, Kans.	28	—	5.0	8.0	12	—
22	Soldier Creek near Delia, Kans.	10	—	20	35	62	—
26	Kansas River at Lecompton, Kans.	10	—	10	18	22	—
29	Kansas River at DeSoto, Kans.	25	—	4.5	14	20	—

Table 26.—*Statistical summary of data on major metals and trace elements in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[Concentrations in micrograms per liter; this table includes only those sampling stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile 10	25	50 (median)	75	90
		Copper, dissolved					
2	Kings Creek near Manhattan, Kans.	16	–	<10	<10	<10	–
9	Big Blue River at Beatrice, Nebr.	12	–	4.0	6.5	16	–
15	Little Blue River at Hollenberg, Kans.	26	–	4.7	8.5	20	–
18	Big Blue River near Manhattan, Kans.	37	<2	<2	4.0	6.0	10
29	Kansas River at DeSoto, Kans.	34	2	3.0	5.0	6.2	10
		Iron, total recoverable					
9	Big Blue River at Beatrice, Nebr.	11	–	3,500	35,000	70,000	–
10	Big Blue River at Barneston, Nebr.	12	–	1,000	2,800	38,000	–
15	Little Blue River at Hollenberg, Kans.	23	–	3,300	27,000	59,000	–
18	Big Blue River near Manhattan, Kans.	20	–	610	1,000	2,500	–
29	Kansas River at DeSoto, Kans.	19	–	1,200	1,700	9,600	–
		Iron, dissolved					
2	Kings Creek near Manhattan, Kans	16	–	<10	<10	<10	–
4	Lincoln Creek at Seward, Nebr.	29	–	18	24	130	–
5	Big Blue River at Seward, Nebr.	25	–	11	30	79	–
6	West Fork Big Blue River near Dorchester, Nebr.	28	–	15	30	77	–
7	Big Blue River near Crete, Nebr.	25	–	20	30	120	–
8	Turkey Creek near Wilber, Nebr.	28	–	30	74	330	–
9	Big Blue River at Beatrice, Nebr.	25	–	20	50	205	–
10	Big Blue River at Barneston, Nebr.	17	–	10	24	140	–
11	Little Blue River near Deweese, Nebr.	37	<10	<10	20	110	330
15	Little Blue River at Hollenberg, Kans.	109	<10	<10	30	105	280
18	Big Blue River near Manhattan, Kans.	45	<10	<10	30	120	360
19	Kansas River at Wamego, Kans.	10	–	75	200	1,200	–
22	Soldier Creek near Delia, Kans.	13	–	20	50	2,100	–
23	Soldier Creek near Topeka, Kans.	13	–	90	130	730	–
26	Kansas River at Lecompton, Kans.	10	–	55	130	570	–
29	Kansas River at DeSoto, Kans.	40	<10	<10	20	50	150
		Lead, total recoverable					
5	Big Blue River at Seward, Nebr	22	–	6.7	18	23	–
9	Big Blue River at Beatrice, Nebr.	11	–	10	33	81	–
10	Big Blue River at Barneston, Nebr.	21	–	4.0	10	20	–
15	Little Blue River at Hollenberg, Kans.	40	<20	<20	20	57	100
18	Big Blue River near Manhattan, Kans.	27	–	2.0	6.0	12	–
22	Soldier Creek near Delia, Kans.	10	–	<1	10	44	–
26	Kansas River at Lecompton, Kans.	10	–	<1	5.0	12	–
29	Kansas River at DeSoto, Kans.	26	–	5.0	14	20	–
		Lead, dissolved					
2	Kings Creek near Manhattan, Kans.	16	–	<10	<10	<10	–
9	Big Blue River at Beatrice, Nebr.	11	–	1.0	3.0	5.0	–
15	Little Blue River at Hollenberg, Kans.	25	–	<2	2.0	18	–
18	Big Blue River near Manhattan, Kans.	37	<1	<1	1.0	3.0	22
29	Kansas River at DeSoto, Kans.	34	<1	<1	1.0	3.2	9.0
		Lithium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	–	12	14	18	–
18	Big Blue River near Manhattan, Kans.	15	–	11	15	18	–
29	Kansas River at DeSoto, Kans.	14	–	17	22	32	–
		Manganese, total recoverable					
9	Big Blue River at Beatrice, Nebr.	11	–	410	900	1,900	–
10	Big Blue River at Barneston, Nebr.	12	–	130	300	770	–

Table 26.—*Statistical summary of data on major metals and trace elements in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[Concentrations in micrograms per liter; this table includes only those sampling stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
	Manganese, total recoverable—Continued						
15	Little Blue River at Hollenberg, Kans.	24	—	280	780	1,800	—
18	Big Blue River near Manhattan, Kans.	20	—	42	75	120	—
29	Kansas River at DeSoto, Kans.	19	—	80	180	300	—
	Manganese, dissolved						
2	Kings Creek near Manhattan, Kans.	16	—	1.0	2.0	3.0	—
4	Lincoln Creek at Seward, Nebr.	28	—	42	140	260	—
5	Big Blue River at Seward, Nebr.	24	—	62	260	330	—
6	West Fork Big Blue River near Dorchester, Nebr.	28	—	25	80	200	—
7	Big Blue River near Crete, Nebr.	25	—	20	110	220	—
8	Turkey Creek near Wilber, Nebr.	28	—	54	100	170	—
9	Big Blue River at Beatrice, Nebr.	25	—	12	60	195	—
10	Big Blue River at Barneston, Nebr.	17	—	19	58	190	—
11	Little Blue River near Deweese, Nebr.	37	6	20	30	46	60
15	Little Blue River at Hollenberg, Kans.	109	<10	<10	20	40	70
18	Big Blue River near Manhattan, Kans.	45	<3	4.0	10	30	60
19	Kansas River at Wamego, Kans.	10	—	7.5	15	170	—
22	Soldier Creek near Delia, Kans.	13	—	10	40	220	—
23	Soldier Creek near Topeka, Kans.	13	—	40	140	210	—
26	Kansas River at Lecompton, Kans.	10	—	7.5	10	130	—
29	Kansas River at DeSoto, Kans.	41	<10	<10	10	20	90
	Mercury, total recoverable						
4	Lincoln Creek at Seward, Nebr.	12	—	< .1	< .1	< .1	—
5	Big Blue River at Seward, Nebr.	26	—	< .1	< .1	< .1	—
6	West Fork Big Blue River near Dorchester, Nebr.	11	—	.10	.10	.20	—
7	Big Blue River near Crete, Nebr.	19	—	.10	.10	.20	—
8	Turkey Creek near Wilber, Nebr.	11	—	.10	.10	.10	—
9	Big Blue River at Beatrice, Nebr.	14	—	.10	.20	.32	—
10	Big Blue River at Barneston, Nebr.	20	—	.10	.10	.20	—
15	Little Blue River at Hollenberg, Kans.	44	< .1	< .1	.10	.20	.60
18	Big Blue River near Manhattan, Kans.	28	—	< .1	.10	.30	—
26	Kansas River at Lecompton, Kans.	11	—	< .5	< .5	< .5	—
29	Kansas River at DeSoto, Kans.	25	—	.10	.20	.50	—
	Mercury, dissolved						
2	Kings Creek near Manhattan, Kans.	14	—	< .1	< .1	< .1	—
7	Big Blue River near Crete, Nebr.	46	< .1	< .1	< .1	< .1	.20
9	Big Blue River at Beatrice, Nebr.	12	—	.10	.20	.27	—
15	Little Blue River at Hollenberg, Kans.	24	—	< .1	.10	.10	—
18	Big Blue River near Manhattan, Kans.	34	< .1	< .1	.10	.10	.40
29	Kansas River at DeSoto, Kans.	31	< .1	< .1	< .1	< .1	.20
	Molybdenum, dissolved						
2	Kings Creek near Manhattan, Kans.	16	—	<10	<10	<10	—
18	Big Blue River near Manhattan, Kans.	15	—	<10	<10	<10	—
29	Kansas River at DeSoto, Kans.	14	—	10	10	10	—
	Nickel, total recoverable						
18	Big Blue River near Manhattan, Kans.	12	—	3.5	6.0	7.8	—
29	Kansas River at DeSoto, Kans.	12	—	4.0	11	17	—
	Nickel, dissolved						
2	Kings Creek near Manhattan, Kans.	10	—	1.8	2.0	2.8	—
18	Big Blue River near Manhattan, Kans.	27	—	2.0	3.0	5.0	—
29	Kansas River at DeSoto, Kans.	26	—	1.0	2.5	4.0	—

Table 26.—*Statistical summary of data on major metals and trace elements in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[Concentrations in micrograms per liter; this table includes only those sampling stations having 10 or more analyses; the 10- and 90-percentile values are not shown for stations having fewer than 30 analyses; <, less than]

Sampling-station number (fig. 9)	Station name	Number of analyses	Value at indicated percentile				
			10	25	50 (median)	75	90
		Selenium, total					
9	Big Blue River at Beatrice, Nebr.	11	—	1.7	2.0	3.0	—
10	Big Blue River at Barneston, Nebr.	19	—	2.0	2.0	3.0	—
15	Little Blue River at Hollenberg, Kans.	35	<1	<1	1.0	2.0	3.4
18	Big Blue River near Manhattan, Kans.	27	—	1.0	1.0	1.0	—
22	Soldier Creek near Delia, Kans.	10	—	<1	<1	1.0	—
29	Kansas River at DeSoto, Kans.	25	—	1.0	1.0	1.0	—
		Selenium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	<1	<1	<1	—
7	Big Blue River near Crete, Nebr.	10	—	1.0	3.0	4.2	—
9	Big Blue River at Beatrice, Nebr.	12	—	1.0	2.5	3.0	—
15	Little Blue River at Hollenberg, Kans.	21	—	1.0	1.0	1.0	—
18	Big Blue River near Manhattan, Kans.	35	<1	<1	1.0	1.0	2.0
29	Kansas River at DeSoto, Kans.	31	<1	<1	1.0	1.0	2.0
		Silver, total recoverable					
10	Big Blue River at Barneston, Nebr.	21	—	<1	<1	<1	—
10	Big Blue River at Barneston, Nebr.	21	—	<1	<1	<1	—
15	Little Blue River at Hollenberg, Kans.	27	—	<1	<1	<1	—
18	Big Blue River near Manhattan, Kans.	30	<1	<1	<1	1.0	9.0
22	Soldier Creek near Delia, Kans.	10	—	<10	<10	10	—
29	Kansas River at DeSoto, Kans.	27	—	<1	<1	<1	—
		Silver, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	<1	<1	<1	—
9	Big Blue River at Beatrice, Nebr.	12	—	<1	<1	<1	—
15	Little Blue River at Hollenberg, Kans.	23	—	<1	<1	<1	—
18	Big Blue River near Manhattan, Kans.	37	<1	<1	<1	1.0	1.0
29	Kansas River at DeSoto, Kans.	34	<1	<1	<1	<1	1.0
		Strontium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	890	940	980	—
18	Big Blue River near Manhattan, Kans.	15	—	360	420	510	—
29	Kansas River at DeSoto, Kans.	14	—	510	580	800	—
		Vanadium, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	6.0	6.0	6.0	—
18	Big Blue River near Manhattan, Kans.	15	—	<6	<6	8.0	—
29	Kansas River at DeSoto, Kans.	14	—	6.0	6.0	6.0	—
		Zinc, total recoverable					
5	Big Blue River at Seward, Nebr.	22	—	47	90	200	—
9	Big Blue River at Beatrice, Nebr.	11	—	60	150	300	—
10	Big Blue River at Barneston, Nebr.	21	—	30	40	70	—
15	Little Blue River at Hollenberg, Kans.	40	20	30	70	250	330
18	Big Blue River near Manhattan, Kans.	28	—	20	30	38	—
22	Soldier Creek near Delia, Kans.	10	—	37	95	130	—
29	Kansas River at DeSoto, Kans.	25	—	20	40	55	—
		Zinc, dissolved					
2	Kings Creek near Manhattan, Kans.	16	—	4.2	10	13	—
9	Big Blue River at Beatrice, Nebr.	12	—	8.5	20	20	—
15	Little Blue River at Hollenberg, Kans.	26	—	10	20	20	—
18	Big Blue River near Manhattan, Kans.	37	<3	5.0	10	20	40
29	Kansas River at DeSoto, Kans.	34	4	7.5	12	20	24

Table 27.—*Number of major-metal and trace-element analyses by sampling station not meeting freshwater-aquatic criteria and drinking-water Maximum Contaminant Levels within lower Kansas River basin, 1978-86 water years*

[Analyses counted as not meeting criteria do not necessarily represent violations but may indicate need for further study. Criteria listed are the numerical values of concentrations from U.S. Environmental Protection Agency (1986a) and from the summary chart in U.S. Environmental Protection Agency (1987d). In addition to concentrations, criteria for aquatic life also consider duration and frequency of concentrations. Number of analyses exceeding drinking-water Maximum Contaminant Levels (MCL's) are overestimated because the levels are for treated water rather than the untreated water analyzed. Statistical summaries of constitutent concentrations for sampling stations that have 10 or more analyses are listed in table 26. —, indicates no criterion]

Sampling-station number (fig. 9)	Station name	Number of analyses	Number of analyses not meeting criterion or MCL		
			Freshwater-aquatic life		Human health, drinking-water MCL
			Acute	Chronic	
Total-recoverable barium: Drinking-water MCL, 1.0 milligram per liter.					
4	Lincoln Creek near Seward, Nebr.	6	—	—	1
5	Big Blue River at Seward, Nebr.	6	—	—	1
9	Big Blue River at Beatrice, Nebr.	5	—	—	2
Total-recoverable cadmium: Acute and chronic, hardness-dependent criteria[1]. Number of analyses not meeting a criterion may be underestimated because of detection level exceeding criterion. Drinking-water MCL, 0.010 milligram per liter.					
2	Kings Creek near Manhattan, Kans.	6	0	1	0
5	Big Blue River at Seward, Nebr.	22	0	1	0
6	West Fork Big Blue River near Dorchester, Nebr.	6	0	1	0
7	Big Blue River near Crete, Nebr.	5	0	2	0
8	Turkey Creek near Wilber, Nebr.	6	0	1	0
15	Little Blue River at Hollenberg, Kans.	34	1	4	0
18	Big Blue River near Manhattan, Kans.	24	0	2	0
29	Kansas River at DeSoto, Kans.	25	0	4	0
Total-recoverable copper: Acute and chronic, hardness-dependent criteria[1].					
4	Lincoln Creek near Seward, Nebr.	6	2	2	—
5	Big Blue River at Seward, Nebr.	22	2	3	—
6	West Fork Big Blue River near Dorchester, Nebr.	6	3	4	—
7	Big Blue River near Crete, Nebr.	5	3	3	—
8	Turkey Creek near Wilber, Nebr.	7	4	4	—
9	Big Blue River at Beatrice, Nebr.	11	9	9	—
10	Big Blue River at Barneston, Nebr.	21	6	6	—
11	Little Blue River near Deweese, Nebr.	7	3	3	—
15	Little Blue River at Hollenberg, Kans.	41	18	21	—
18	Big Blue River near Manhattan, Kans.	28	1	2	—
29	Kansas River at DeSoto, Kans.	25	0	1	—
Total-recoverable iron: Chronic, 1,000 micrograms per liter.					
4	Lincoln Creek near Seward, Nebr.	6	—	6	—
5	Big Blue River at Seward, Nebr.	6	—	5	—
6	West Fork Big Blue River near Dorchester, Nebr.	6	—	5	—
7	Big Blue River near Crete, Nebr.	5	—	5	—
8	Turkey Creek near Wilber, Nebr.	6	—	6	—
9	Big Blue River at Beatrice, Nebr.	11	—	10	—
10	Big Blue River at Barneston, Nebr.	12	—	10	—

Table 27.—*Number of major-metal and trace-element analyses by sampling station not meeting freshwater-aquatic criteria and drinking-water Maximum Contaminant Levels within lower Kansas River basin, 1978-86 water years*—Continued

[Analyses counted as not meeting criteria do not necessarily represent violations but may indicate need for further study. Criteria listed are the numerical values of concentrations from U.S. Environmental Protection Agency (1986a) and from the summary chart in U.S. Environmental Protection Agency (1987d). In addition to concentrations, criteria for aquatic life also consider duration and frequency of concentrations. Number of analyses exceeding drinking-water Maximum Contaminant Levels (MCL's) are overestimated because the levels are for treated water rather than the untreated water analyzed. Statistical summaries of constitutent concentrations for sampling stations that have 10 or more analyses are listed in table 26. —, indicates no criterion]

Sampling-station number (fig. 9)	Station name	Number of analyses	Number of analyses not meeting criterion or MCL: Freshwater-aquatic life, Acute	Freshwater-aquatic life, Chronic	Human health, drinking-water MCL
Total-recoverable iron—Continued:					
11	Little Blue River near Deweese, Nebr.	7	—	5	—
15	Little Blue River at Hollenberg, Kans.	23	—	22	—
18	Big Blue River near Manhattan, Kans.	20	—	9	—
29	Kansas River at DeSoto, Kans.	19	—	15	—
Total-recoverable lead:	Acute and chronic, hardness-dependent criteria[1]. Number of analyses not meeting a criterion may be underestimated because of detection level exceeding criterion. Drinking-water MCL, 0.05 milligram per liter.				
2	Kings Creek near Manhattan, Kans.	6	0	1	0
4	Lincoln Creek near Seward, Nebr.	6	1	2	1
5	Big Blue River at Seward, Nebr.	22	1	2	1
6	West Fork Big Blue River near Dorchester, Nebr.	6	0	5	0
7	Big Blue River near Crete, Nebr.	5	0	3	0
8	Turkey Creek near Wilber, Nebr.	6	0	5	0
9	Big Blue River at Beatrice, Nebr.	11	3	9	5
10	Big Blue River at Barneston, Nebr.	21	0	9	0
11	Little Blue River near Deweese, Nebr.	7	2	2	1
15	Little Blue River at Hollenberg, Kans.	40	6	18	8
18	Big Blue River near Manhattan, Kans.	27	0	10	1
29	Kansas River at DeSoto, Kans.	26	0	11	0
Total-recoverable mercury:	Acute, 2.4 micrograms per liter. Chronic, 0.012 microgram per liter. Number of analyses not meeting the criterion may be underestimated because of detection level exceeding criterion. Drinking-water MCL, 0.002 milligram per liter.				
2	Kings Creek near Manhattan, Kans.	6	0	3	0
4	Lincoln Creek near Seward, Nebr.	12	0	6	0
5	Big Blue River at Seward, Nebr.	26	0	7	0
6	West Fork Big Blue River near Dorchester, Nebr.	11	1	7	1
7	Big Blue River near Crete, Nebr.	19	0	6	0
8	Turkey Creek near Wilber, Nebr.	11	0	6	0
9	Big Blue River at Beatrice, Nebr.	14	0	11	
10	Big Blue River at Barneston, Nebr.	20	0	11	0
11	Little Blue River near Deweese, Nebr.	7	0	7	0

Table 27.—*Number of major-metal and trace-element analyses by sampling station not meeting freshwater-aquatic criteria and drinking-water Maximum Contaminant Levels within lower Kansas River basin, 1978-86 water years*—Continued

[Analyses counted as not meeting criteria do not necessarily represent violations but may indicate need for further study. Criteria listed are the numerical values of concentrations from U.S. Environmental Protection Agency (1986a) and from the summary chart in U.S. Environmental Protection Agency (1987d). In addition to concentrations, criteria for aquatic life also consider duration and frequency of concentrations. Number of analyses exceeding drinking-water Maximum Contaminant Levels (MCL's) are overestimated because the levels are for treated water rather than the untreated water analyzed. Statistical summaries of constituent concentrations for sampling stations that have 10 or more analyses are listed in table 26. —, indicates no criterion]

Sampling-station number (fig. 9)	Station name	Number of analyses	Number of analyses not meeting criterion or MCL: Freshwater-aquatic life, Acute	Freshwater-aquatic life, Chronic	Human health, drinking-water MCL
Total-recoverable mercury—Continued:					
15	Little Blue River at Hollenberg, Kans.	44	0	25	0
18	Big Blue River near Manhattan, Kans.	28	0	13	0
29	Kansas River at DeSoto, Kans.	25	0	12	0
Total-recoverable silver:	Acute, hardness-dependent criterion[1]. Chronic, 0.12 microgram per liter. Number of analyses not meeting acute or chronic criterion may be underestimated because of detection level exceeding criterion. Drinking-water MCL, 0.05 milligram per liter.				
2	Kings Creek near Manhattan, Kans.	6	0	2	0
4	Lincoln Creek near Seward, Nebr.	6	1	1	0
5	Big Blue River at Seward, Nebr.	6	0	1	0
6	West Fork Big Blue River near Dorchester, Nebr.	6	0	1	0
8	Turkey Creek near Wilber, Nebr.	6	1	2	0
10	Big Blue River at Barneston, Nebr.	21	0	1	0
11	Little Blue River near Deweese, Nebr.	7	0	1	0
15	Little Blue River at Hollenberg, Kans.	27	0	3	0
18	Big Blue River near Manhattan, Kans.	30	0	2	0
29	Kansas River at DeSoto, Kans.	27	0	1	0
Total-recoverable zinc:	Acute and chronic, hardness-dependent criteria[1].				
4	Lincoln Creek near Seward, Nebr.	6	2	2	—
5	Big Blue River at Seward, Nebr.	22	2	2	—
6	West Fork Big Blue River near Dorchester, Nebr.	6	3	3	—
7	Big Blue River near Crete, Nebr.	5	3	3	—
8	Turkey Creek near Wilber, Nebr.	6	2	2	—
9	Big Blue River at Beatrice, Nebr.	11	6	7	—
10	Big Blue River at Barneston, Nebr.	21	3	3	—
11	Little Blue River near Deweese, Nebr.	7	2	2	—
15	Little Blue River at Hollenberg, Kans.	40	14	14	—
18	Big Blue River near Manhattan, Kans.	28	1	1	—
29	Kansas River at DeSoto, Kans.	25	0	1	—

[1]Hardness-dependent criteria were calculated from equations in U.S. Environmental Protection Agency (1987d).

First, concentrations of major metals and trace elements that apply to both the freshwater-aquatic criteria and drinking-water MCL's published by the U.S. Environmental Protection Agency (1986a) are for total-recoverable concentrations and not "acid-soluble," which the U.S. Environmental Protection Agency notes do not distinguish between individual oxidation states and may be overly protective. To put this into perspective with analyses performed on dissolved samples, the concentrations of major metals and trace elements in surface water in descending order of magnitude by analysis would be total-recoverable, acid-soluble, and dissolved. Second, for freshwater-aquatic criteria, most of the criteria are water-hardness dependent. As hardness increases, the concentration of a particular element that will meet a criterion also increases based on algorithms for each element. For example, for water-hardness concentrations of 100 and 200 mg/L, the respective chronic freshwater-aquatic criteria for total-recoverable cadmium are 1.1 and 2.0 μg/L, and for total-recoverable copper, the respective chronic criteria are 12 and 21 μg/L. Third, acute and chronic freshwater-aquatic criteria include the length and frequency of exposure to specific concentrations as additional factors. Acute criteria are specified as a 1-hour average concentration not to be exceeded more than once every 3 years on the average, and chronic criteria are specified as a 4-day average concentration not to be exceeded more than once every 3 years on the average. In contrast, drinking-water MCL's are concentrations that are not to be exceeded at any time. The data in table 27 simply enumerate the number of analyses of total-recoverable major metals and trace elements collected between October 1, 1977, and September 30, 1986, that did not meet specified freshwater-aquatic criteria or drinking-water MCL's.

Examination of the data in table 27 indicates that, overall, the acute freshwater-aquatic criterion was exceeded by 10 percent of the samples analyzed (104 of 1,032 samples); the chronic freshwater-aquatic criterion was exceeded by 36 percent of the samples analyzed (416 of 1,153 samples); and the drinking-water MCL's were exceeded by 3 percent of the samples analyzed (22 of 693 samples). Total-recoverable iron and mercury accounted for more than 50 percent of the chronic freshwater-aquatic exceedances (212 samples). Of these, total-recoverable iron had the largest percentage of exceedances (81 percent) of any major metal or trace element (98 of 121 samples). The occurrence of the iron exceedances was mostly in samples from the Big Blue River basin and its tributaries although a large percentage did occur in samples from the Kansas River at DeSoto, Kans. Because the chronic freshwater-aquatic criterion for iron is not hardness dependent and because the criterion is for total-recoverable iron, it is not unexpected that there would be a large number of exceedances in view of the fact that iron is an abundant element and most of the exceedances occurred during periods of high streamflow when suspended-sediment concentrations were large. To further illustrate this point, a comparison of dissolved-iron concentrations to the chronic freshwater-aquatic criterion for iron indicates that 0.2 percent of the samples (1 of 417 samples) exceeded this criterion. The data for concentrations of dissolved iron are some of the same data as for total-recoverable iron but are not the same set of analyses. Many more analyses for dissolved iron were performed than for total-recoverable iron for the 1978-86 water years.

Although the acute freshwater-aquatic criterion was exceeded by 10 percent of the sample analyses, concentrations of total-recoverable copper and zinc accounted for 89 of the 104 exceedances. All of the measured exceedances occurred in samples from the Big Blue River and its tributaries. Similar to iron, the number of analyses of dissolved copper and zinc that exceeded the acute freshwater-aquatic criterion was quite small as compared to total-recoverable copper and zinc. Only 16 of 307 samples or 5 percent of dissolved-copper and zinc concentrations exceeded the acute freshwater-aquatic criterion. The data for concentrations of dissolved copper and zinc are some of the same data as for total-recoverable iron but are not the same set of analyses.

Drinking-water MCL's had the smallest percentage of exceedances (3 percent). Total-recoverable barium and lead accounted for 21 of the 22 exceedances. Twenty-four percent of the 17 samples analyzed for total-recoverable barium and 9 percent of the 183 samples analyzed for total-recoverable lead exceeded the MCL's. The exceedances for barium occurred in samples from stations on the Big Blue and Little Blue Rivers or Lincoln Creek near Seward, Nebr. (station 4, fig. 9). Exceedances in this part of the basin by barium may be related to the clustering of large barium concentrations in the streambed sediments in the northwestern part of the basin (see fig. 32). However, a comparison of dissolved concentrations of barium and lead to the drinking-water MCL's indicates that only 1.4 percent of the 147 sample analyses exceeded the drinking-water MCL's, and the exceedances were concentrations of dissolved lead in two samples from the Little Blue River near Hollenberg, Kans.

Transport

Transport rates of metals and trace elements in water for the 1978-86 water years were calculated at five sampling stations for constituents for which adequate data were available. Results of the calculations are given in table 28 for the nine metals and trace elements that had adequate data for one or more stations. Given the lack of areal resolution, constituent transport does not have much utility for defining sources of major metals and trace elements. Additional data are needed to assess transport and sources of major metals and trace elements in the lower Kansas River basin.

Table 28.—*Transport of major metals and trace elements in water at selected sampling stations within lower Kansas River basin, 1978-86 water years*

[–, data inadequate for computation]

Sampling-station number (fig. 9)	Station name	Mean annual transport (tons per year)	Root mean-square error of mean annual transport (percent)	Mean annual yield, (tons per square mile per year)
		Total arsenic		
10	Big Blue River at Barneston, Nebr.	–	–	–
15	Little Blue River at Hollenberg, Kans.	7.4	12	0.0027
18	Big Blue River near Manhattan, Kans.	–	–	–
19	Kansas River at Wamego, Kans.	–	–	–
29	Kansas River at DeSoto, Kans.	–	–	–
		Total-recoverable boron		
10	Big Blue River at Barneston, Nebr.	–	–	–
15	Little Blue River at Hollenberg, Kans.	81	11	.029
18	Big Blue River near Manhattan, Kans.	320	11	.033
19	Kansas River at Wamego, Kans.	660	9	.012
29	Kansas River at DeSoto, Kans.	1,100	13	.018
		Total-recoverable copper		
10	Big Blue River at Barneston, Nebr.	–	–	–
15	Little Blue River at Hollenberg, Kans.	34	13	.012
18	Big Blue River near Manhattan, Kans.	–	–	–
19	Kansas River at Wamego, Kans.	–	–	–
29	Kansas River at DeSoto, Kans.	–	–	–
		Dissolved iron		
10	Big Blue River at Barneston, Nebr.	–	–	–
15	Little Blue River at Hollenberg, Kans.	220	16	.080
18	Big Blue River near Manhattan, Kans.	540	63	.056
19	Kansas River at Wamego, Kans.	–	–	–
29	Kansas River at DeSoto, Kans.	3,900	43	.065

Table 28.—*Transport of major metals and trace elements in water at selected sampling stations within lower Kansas River basin, 1978-86 water years*—Continued

[—, data inadequate for computation]

Sampling-station number (fig. 9)	Station name	Mean annual transport (tons per year)	Root mean-square error of mean annual transport (percent)	Mean annual yield, (tons per square mile per year)
		Total-recoverable lead		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	42	40	0.015
18	Big Blue River near Manhattan, Kans.	—	—	—
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	—	—	—
		Dissolved manganese		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	24	15	.0087
18	Big Blue River near Manhattan, Kans.	71	39	.0074
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	150	27	.0025
		Total-recoverable mercury		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	.2	12	.00007
18	Big Blue River near Manhattan, Kans.	—	—	—
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	—	—	—
		Total selenium		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	1.4	14	.00051
18	Big Blue River near Manhattan, Kans.	—	—	—
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	—	—	—
		Total-recoverable zinc		
10	Big Blue River at Barneston, Nebr.	—	—	—
15	Little Blue River at Hollenberg, Kans.	100	12	.036
18	Big Blue River near Manhattan, Kans.	—	—	—
19	Kansas River at Wamego, Kans.	—	—	—
29	Kansas River at DeSoto, Kans.	—	—	—

Trends

Results of tests for long-term trends of major metals and trace elements in water (table 29) showed little consistency. Boron showed decreasing trends in water from stations where trends were statistically significant, except at Hollenberg (station 15). Dissolved iron showed increasing trends in water from three stations and a decreasing trend at one station. Two of the three increasing trends in dissolved iron occurred in water from the Big and Little Blue River basins and may be associated with increasing use of ground water for irrigation.

Trend tests were done for 14 constituents at the Kansas River at DeSoto sampling station (station 29, fig. 9). Statistically significant trends were identified for dissolved iron, dissolved manganese, and total zinc, all of which showed decreasing trends. Point sources can account for only a small part of the total transport of these metals. In addition, several constituents at several stations showed statistically significant trends; however, insufficient information was available to determine the causes of these long-term trends.

Table 29.—*Trend-test results for major metals and trace elements in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Micrograms per liter per year	Concentration: Average rate of change: Percent of median per year	Flow adjusted concentration: Probability level	Flow adjusted concentration: Average rate of change (percent per year)
				Arsenic, dissolved				
18	Big Blue River near Manhattan, Kans.	1975-86	12	0.20	0	0	0.74	+ 0.57
29	Kansas River at DeSoto, Kans.	1974-86	13	.74	0	0	–	–
				Boron, total				
15	Little Blue River at Hollenberg, Kans.	1967-83	17	.06	+ 4.0	+ 3.1	–	–
18	Big Blue River near Manhattan, Kans.	1961-86	26	.06	- 1.7	- 1.4	–	–
		1963-86	24	.06	- 3.8	- 3.1	–	–
19	Kansas River at Wamego, Kans.	1962-86	25	.02	- 5.0	- 3.6	–	–
23	Soldier Creek near Topeka, Kans.	1975-86	12	.03	- 6.2	- 5.4	–	–
26	Kansas River at Lecompton, Kans.	1961-86	26	.02	- 2.9	- 2.1	–	–
29	Kansas River at DeSoto, Kans.	1974-86	13	.81	0	0	–	–
				Boron, dissolved				
4	Lincoln Creek near Seward, Nebr.	1963-84	22	.52	0	0	–	–
6	West Fork Big Blue River near Dorchester, Nebr.	1963-84	22	.71	0	0	.94	+ .09
7	Big Blue River near Crete, Nebr.	1961-83	23	.88	0	0	.88	- .07
8	Turkey Creek near Wilber, Nebr.	1965-84	20	.45	0	0	.26	- 1.0
11	Little Blue River near Deweese, Nebr.	1956-84	29	1.00	0	0	–	–
15	Little Blue River at Hollenberg, Kans.	1973-86	14	.01	- 2.0	- 4.0	–	–

Table 29.—*Trend-test results for major metals and trace elements in water from selected sampling stations within lower Kansas River basin*—Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Micrograms per liter per year	Concentration: Average rate of change: Percent of median per year	Flow adjusted concentration: Probability level	Flow adjusted concentration: Average rate of change (percent per year)
				Boron, dissolved—Continued				
16	Little Blue River near Barnes, Kans.	1962-75	14	0.36	- 1.0	-0.87	0.51	-0.59
18	Big Blue River	1955-75	21	.69	0	0	.49	+ .98
	near Manhattan, Kans.	1963-75	13	.04	- 2.5	- 2.5	.02	- 2.6
19	Kansas River at Wamego, Kans.	1956-75	20	.40	+ .83	+ .60	—	—
22	Soldier Creek near Delia, Kans.	1965-75	11	.01	- 5.6	- 4.6	—	—
26	Kansas River at Lecompton, Kans.	1957-75	19	.87	0	0	—	—
				Cadmium, dissolved				
29	Kansas River at DeSoto, Kans.	1974-86	13	.56	0	0	—	—
				Chromium, total				
29	Kansas River at DeSoto, Kans.	1974-86	13	.65	0	0	—	—
				Chromium, dissolved				
29	Kansas River at DeSoto, Kans.	1974-86	13	.23	0	0	—	—
				Copper, total				
15	Little Blue River at Hollenberg, Kans.	1974-86	13	0	7.2	- 26	.01	8.9
29	Kansas River at DeSoto, Kans.	1974-86	13	.18	- 1.0	- 5.0	—	—
				Copper, dissolved				
18	Big Blue River near Manhattan, Kans.	1974-86	13	.16	- .20	- 5.0	—	—
29	Kansas River at DeSoto, Kans.	1974-86	13	.67	0	0	—	—
				Iron, dissolved				
4	Lincoln Creek near Seward, Nebr.	1963-84	22	.17	- .89	- 2.7	.36	- 2.4
6	West Fork Big Blue River near Dorchester, Nebr.	1963-84	22	.88	0	0	.76	+ .27
7	Big Blue River near Crete, Nebr.	1961-83	23	.25	- .71	- 1.5	.93	- .14
8	Turkey Creek near Wilber, Nebr.	1965-84	20	.05	+ 1.7	+ 2.8	.06	+ 4.8
11	Little Blue River near Deweese, Nebr.	1956-84	29	.46	+ .21	+ .99	.02	+ 4.0
18	Big Blue River	1961-86	26	.95	0	0	—	—
	near Manhattan, Kans.	1963-86	24	.16	- 1.3	- 3.2	—	—
19	Kansas River at Wamego, Kans.	1956-86	31	.01	+ 5.3	+ 5.9	—	—
29	Kansas River at DeSoto, Kans.	1974-86	13	.02	- 3.5	- 12	—	—

Table 29.—*Trend-test results for major metals and trace elements in water from selected sampling stations within lower Kansas River basin*—Continued

[Underlined, significant at 0.1 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 9)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Concentration: Probability level	Concentration: Average rate of change: Micrograms per liter per year	Concentration: Average rate of change: Percent of median per year	Flow adjusted concentration: Probability level	Flow adjusted concentration: Average rate of change (percent per year)
				Lead, dissolved				
29	Kansas River at DeSoto, Kans.	1974-86	13	0.76	0	0	0.13	-8.5
				Manganese, dissolved				
4	Lincoln Creek near Seward, Nebr.	1963-84	22	.21	- 3.3	- 2.1	.22	- 2.0
6	West Fork Big Blue River near Dorchester, Nebr.	1963-84	22	.16	- 1.8	- 2.0	.13	- 2.2
7	Big Blue River near Crete, Nebr.	1961-83	23	.89	0	0	.52	- .86
8	Turkey Creek near Wilber, Nebr.	1965-84	20	.56	- .29	- .29	.80	+ .71
11	Little Blue River near Deweese, Nebr.	1956-84	29	.15	- .94	- 2.9	—	—
15	Little Blue River at Hollenberg, Kans.	1973-86	14	<u>.10</u>	- <u>.71</u>	- <u>3.0</u>	<u>.03</u>	- <u>6.5</u>
19	Kansas River at Wamego, Kans.	1961-86	26	<u>0</u>	+ <u>.83</u>	—	—	—
29	Kansas River at DeSoto, Kans.	1974-86	13	<u>.10</u>	- <u>.53</u>	- <u>5.3</u>	—	—
				Mercury, dissolved				
18	Big Blue River near Manhattan, Kans.	1974-86	13	.16	- .019	- 19	—	—
				Selenium, total				
29	Kansas River at DeSoto, Kans.	1974-86	13	.82	0	0	—	—
				Selenium, dissolved				
18	Big Blue River near Manhattan, Kans.	1975-86	12	.33	0	0	—	—
29	Kansas River at DeSoto, Kans.	1974-86	13	.58	0	0	—	—
				Zinc, total				
29	Kansas River at DeSoto, Kans.	1974-86	12	.52	- .71	- 1.8	<u>.05</u>	- <u>7.9</u>
				Zinc, dissolved				
29	Kansas River at DeSoto, Kans.	1974-86	13	.88	0	0	—	—

Fish Samples

Fish can accumulate in their tissues many metals and trace elements; thus, fish are good indicators of the presence of these elements that might otherwise be undetected in water or sediment. Typically, the kinds of fish that have been analyzed include bottom-feeding fish such as channel catfish and common carp. For such analyses, the entire fish is ground into a homogeneous mixture, and samples of the ground fish are analyzed. Data were available in the lower Kansas River basin for 1979-86. Because only a few samples from each station were analyzed, the analyses for all 14 stations are summarized in table 30 for the seven elements for which nationwide data are available for comparison.

The U.S. Fish and Wildlife Service operates a National Contaminant Biomonitoring Program at 112 surface-water stations in the United States including Alaska and Hawaii. This program, which began in 1967, analyzes samples of fish for seven elements: arsenic, cadmium, copper, lead, mercury, selenium, and zinc (Lowe and others, 1985). Because of the extensive network of stations operated by the U.S. Fish and Wildlife Service, median and 90th-percentile concentrations could be calculated to represent the central tendency and large values of concentrations of metals and trace elements in fish nationwide (table 30). Median and 90th-percentile concentrations of cadmium, copper, and zinc in the lower Kansas River basin were larger than the corresponding nationwide concentrations. No obvious relationship could be seen between concentrations of these elements in fish, in streambed-sediment samples, and in water samples from the study unit.

Table 30.—*Summary of data on metals and trace elements in composite samples of whole fish from 14 sampling stations within lower Kansas River basin, 1979-86, and from all National Contaminant Biomonitoring Program (NCBP) stations in the United States, 1978-81*

[Concentrations are in micrograms per kilogram; —, 90th percentile not calculated for fewer than 30 samples. Lower Kansas River samples were from stations 2, 4-6, 10, 11, 14, 15, and 30-35 (fig. 9). Source of data for lower Kansas River basin is from the U.S. Environmental Protection Agency STORET system (13 stations) and Lowe and others (1985, p. 385) (1 station); median and 90th-percentile concentrations for all NCBP samples were calculated from data in Lowe and others (1985)]

Element	Number of samples, lower Kansas River basin	Median concentration, lower Kansas River basin	Median concentration, all NCBP samples	90th-percentile concentration, lower Kansas River basin	90th-percentile concentration, all NCBP samples
Arsenic	42	60	110	180	370
Cadmium	45	70	20	290	100
Copper	41	980	700	1,600	1,300
Lead	[1]12	150	100	—	420
Mercury	44	50	90	95	230
Selenium	39	520	420	890	950
Zinc	41	52,000	20,000	78,000	67,000

[1]Excludes samples whose analyses had a lower level of detection of 500 micrograms per kilogram.

Radionuclides

By J.K. Stamer
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A large number of radionuclides in the environment are produced by the process of nuclear fission, which is the same process used by nuclear powerplants to produce energy. Other fission products, such as strontium-90, have been introduced into the environment from atmospheric nuclear tests. Other radionuclides occur naturally; these include uranium-238 and radon-226. Radionuclides emit energy through structural changes in the atoms. As nuclides emit energy, they decay into other elements. The rate of decay often is expressed as a half-life, which is the amount of time required for one-half of the original quantity to decay. Nuclides often are classified by the form of energy they emit, which can be particles or electromagnetic waves. The three principal forms or classes of radionuclides that are important in the aquatic environment are: (1) alpha emitters, in which the energy consists of positively charged helium nuclei; (2) beta emitters, in which the energy consists of electrons or positrons; and (3) gamma emitters, in which the energy consists of electromagnetic wave-type energy (similar to X-rays).

In natural water, alpha-emitting radionuclides are mainly isotopes of radium and radon, which are products of the decay of uranium and thorium series (Hem, 1985). The isotopes of radium and radon also can emit beta and gamma radiation, which is also characteristic of potassium-40 and rubidium-87. Potassium-40 activity is calculated as a function of the concentration of potassium in water. The conversion is 0.825 picocurie per milligram of potassium.

The importance of the occurrence of radionuclides in water is addressed by the National Interim Primary Drinking-Water Regulations (U.S. Environmental Protection Agency, 1986a). The regulations include gross alpha (15 pCi/L (picocuries per liter)) and beta (4 millirems per year) activity in general and more specifically the combined activity of radium-226 and -228 (5 pCi/L). Available potassium-40 data from STORET are expressed in picocuries per liter. From STORET, 41 measurements of dissolved potassium-40 in water from 12 sampling stations (4 in Kansas and 8 in Nebraska) were retrieved. Because each of the stations had fewer than 10 analyses, the data have been aggregated. Concentrations of potassium-40, which is a beta and gamma emitter, ranged from 4.1 pCi/L at the 10th percentile to 7.4 pCi/L at the 90th percentile. The median concentration was 5.6 pCi/L. Drinking-water regulations do not include potassium-40 as a contaminant because it is not synthetic nor does society alter its abundance in nature. The concentration of 7.4 pCi/L, when converted into millirems per year, based on a metabolic calculation for potassium, is less than 1 millirem per year (Neal Nelson, U.S. Environmental Protection Agency, oral commun., 1990). Due to lack of adequate data in machine-readable format, no other analyses of the radionuclide data are reported here.

The available data suggest that radionuclides do not seem to occur at levels that are of concern in the study unit. However, to be sure that this is the case, it would seem that a small amount of sampling conducted on a seasonal basis at a number of stations spatially distributed in the study unit would be appropriate to define the areal and temporal distribution of gross beta and alpha activities.

Organic Carbon

By J.K. Stamer
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Organic carbon in surface water generally consists of degraded plant and animal materials and humic substances that fall into or are washed into the streams and lakes. Additional sources of organic carbon are municipal and industrial wastewater discharges. The significance of organic carbon lies in its ability to: (1) deplete the amount of dissolved oxygen in water if the organic carbon is readily decomposable by aerobic bacteria; (2) form complexes with metals; (3) serve as a basic source of energy in the aquatic food chain; (4) cause taste, odor, or color problems in water; and (5) serve as a precursor to the formation of trihalomethane compounds, which result from chlorination in conventional water-treatment processes.

Current Conditions

Three forms of organic carbon have been included in the statistical summary in table 31. Total organic carbon (TOC) can be determined directly from a sample of a water-sediment mixture, or as the sum of independent measures of dissolved organic carbon (DOC) and suspended organic carbon (SOC). According to Thurman (1985), DOC is chemically more reactive than SOC because it is a measure of the organic matter that is in solution, whereas SOC may be composed of discrete plant or animal matter and organic coatings on silt and clay. Thus, DOC is more readily available to deplete dissolved oxygen, form complexes with metals, and serve as a precursor for trihalomethane formation during conventional water-treatment processes.

Most of the organic-carbon data in table 31 are for TOC. The distribution of TOC concentrations was calculated for 13 of the possible 29 stations. The expected range of TOC concentrations (10th to 90th percentile) was from as small as 1.9 mg/L to as large as 70 mg/L. According to Thurman (1985), TOC concentrations in natural streams that have a discharge of less than 3,550 ft^3/s would be expected to vary from about 1.1 to 4.4 mg/L. These expected concentrations are considerably smaller than the median concentrations listed in table 31, which vary from 5.0 to 21 mg/L. The median TOC concentrations in table 31 generally indicate substantial organic enrichment of the water.

The largest median and 90th-percentile TOC concentrations typically occurred in water from stations on the Big and Little Blue Rivers. These concentrations probably reflect the relatively large amount of cropland in these two river basins. Thus, based on the land use, the organic carbon probably is derived more from plant matter than from animal matter, such as treated wastewater. Additional examination of the TOC data indicates that the largest concentrations occurred in the spring and summer, and the smallest in the fall and winter. The seasonality of the concentrations probably is related also to land use and natural rainfall-runoff patterns.

An examination of the data in table 31 for the Big Blue River near Manhattan, Kans. (station 18, fig. 9), and Kansas River at DeSoto, Kans. (station 29, fig. 9), provides two examples of distinguishing between the forms of organic carbon. At the Big Blue River near Manhattan, Kans., which is downstream from Tuttle Creek Lake, the median DOC concentration of 15 samples was 6.2 mg/L, and the median TOC concentration of 39 samples was 6.5 mg/L. The DOC fraction accounts for 95 percent of the TOC in water from the Big Blue River near Manhattan station. In contrast, at the Kansas River at DeSoto, Kans., the median DOC concentration of 13 samples was 5.7 mg/L, and the median TOC concentration of 31 samples was 11 mg/L. The DOC fraction accounts for 52 percent of the TOC in water from the Kansas River at DeSoto. This smaller percentage accounted for by DOC can be attributed to the larger concentrations of suspended sediment (see table 15 in section on "Suspended Sediment") and associated organic carbon in water from the DeSoto station as compared to the Manhattan station.

The distribution of TOC concentrations in water from sampling stations on the Big Blue River and its tributaries for the 1978-86 water years is shown in figure 34. Data for the two stations on the Kansas River are listed in table 31. Median concentrations of TOC (fig. 34) increased in the main stem of the Big Blue River from Seward (station 5) to Beatrice, Nebr. (station 9), and then decreased from Beatrice to near Manhattan, Kans. (station 18). The increased median concentrations in water from the Big Blue River near Crete (station 7) and Beatrice, Nebr. (station 9), probably are due to municipal-wastewater discharge upstream of the Crete station and an industrial discharge upstream of the Beatrice station.

Trends

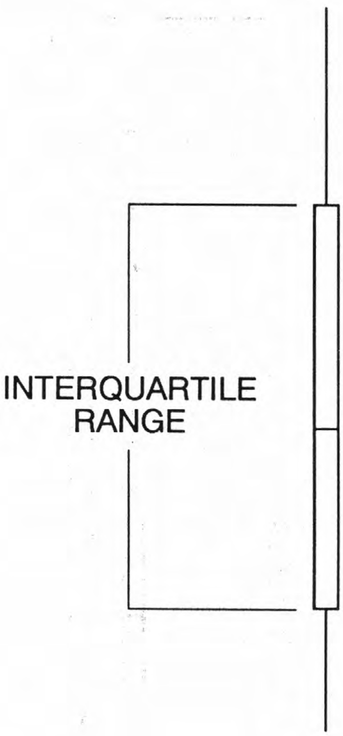
Time-trend tests were not performed on organic-carbon concentrations because the length of record was less than 10 years at any sampling station.

Table 31. —*Statistical summary of data on organic carbon in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[Concentrations in milligrams per liter; this table includes only those stations having 10 or more analyses; the 10- and 90-percentile concentrations are not shown for stations having fewer than 30 analyses]

Sampling-station number (fig. 9)	Station name	Number of analyses	Concentration at indicated percentile				
			10	25	50 (median)	75	90
	Carbon, organic, total						
4	Lincoln Creek near Seward, Nebr.	79	3.3	4.8	9.2	15	39
5	Big Blue River at Seward, Nebr.	91	3.6	6.0	9.5	15	27
6	West Fork Big Blue River near Dorchester, Nebr.	80	2.8	5.6	9.0	18	31
7	Big Blue River near Crete, Nebr.	38	5.0	7.3	14	19	46
8	Turkey Creek near Wilber, Nebr.	80	3.7	7.4	12	18	41
9	Big Blue River at Beatrice, Nebr.	44	4.8	8.1	18	36	70
10	Big Blue River at Barneston, Nebr.	78	5.2	6.7	9.4	15	35
11	Little Blue River near Deweese, Nebr.	76	1.9	2.4	5.0	11	30
15	Little Blue River at Hollenberg, Kans.	89	2.7	3.9	9.4	18	56
16	Little Blue River near Barnes, Kans.	15	—	6.6	21	42	—
17	Black Vermillion River near Frankfort, Kans.	16	—	6.2	9.7	51	—
18	Big Blue River near Manhattan, Kans.	39	4.3	5.2	6.5	9.5	13
29	Kansas River at DeSoto, Kans.	31	5.1	8.9	11	20	41
	Carbon, organic, dissolved						
18	Big Blue River near Manhattan, Kans.	15	—	4.9	6.2	10	—
29	Kansas River at DeSoto, Kans.	13	—	4.8	5.7	9.6	—
	Carbon, organic, suspended						
18	Big Blue River near Manhattan, Kans.	15	—	.40	.80	1.2	—

EXPLANATION



o CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

* CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE BUT LESS THAN UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE

UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE OR LARGEST CONCENTRATION NOT EXCEEDING THIS COMPUTATION

UPPER QUARTILE (75th PERCENTILE)

MEDIAN (50th PERCENTILE)

LOWER QUARTILE (25th PERCENTILE)

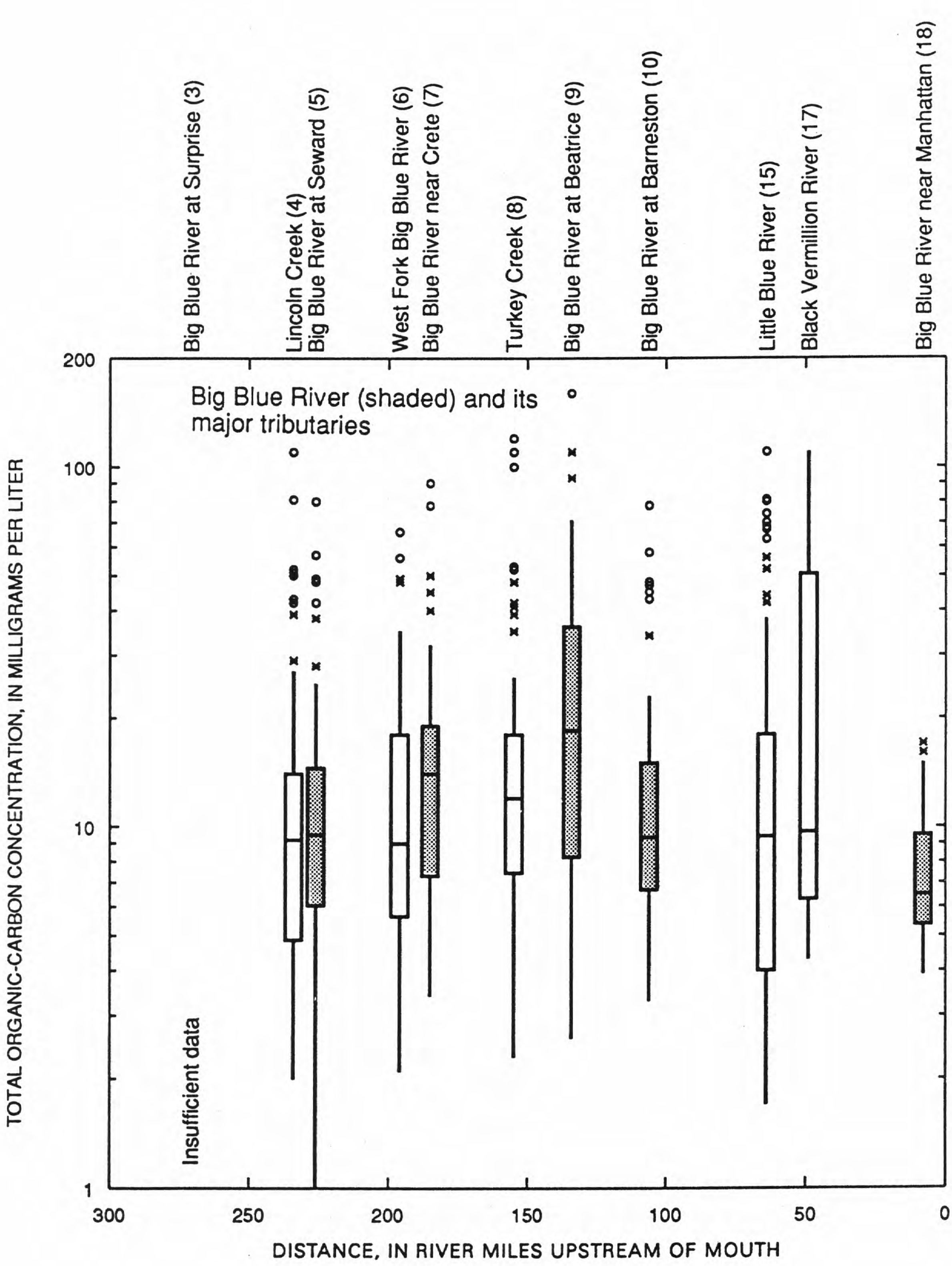
LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE OR SMALLEST CONCENTRATION NOT LESS THAN THIS COMPUTATION

* CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE BUT GREATER THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

o CONCENTRATION(S) LESS THAN LOWER QUARTILE MINUS 3.0 TIMES THE INTERQUARTILE RANGE

NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

Figure 34.—Distribution of total organic-carbon concentrations in water
Organic-carbon concentration scale is logarithmic;



from Big Blue River and its major tributaries, 1978-86 water years.
minimum scale value arbitrarily set at 1.

Pesticides and Other Synthetic-Organic Compounds

By H.E. Bevans
U.S. Geological Survey

Synthetic-organic compounds are used extensively as pesticides, solvents, plasticizers, aerosol propellants, lubricants, and refrigerants. Because of a significant increase in the use of synthetic-organic compounds, these compounds have become increasingly important in evaluating the quality of water resources. Some of these compounds, which are relatively soluble in water, are not removed by conventional water-treatment processes. Even in small concentrations many synthetic-organic compounds are either probable or possible carcinogens or can cause other adverse human- and wildlife-health effects.

The occurrence of synthetic-organic compounds in surface water depends primarily on the extent of usage and chemical characteristics of solubility and persistence (resistance to degradation). The characteristics of solubility and persistence are very important in determining the frequency with which a given compound will occur in surface water. The characteristics of solubility and persistence generally are inversely related; that is, the more-soluble compounds are not as persistent as the less-soluble ones. Less-soluble compounds commonly are associated with sediments and, due to their persistence, can have a major effect on the quality of surface-water resources. Organic compounds may enter surface water sorbed to particulate matter, such as soil, or compounds in water may sorb to stream sediment. Resuspension of bed sediments containing sorbed organic compounds may reintroduce such compounds into water.

Large amounts of corn, wheat, soybeans, and sorghum are produced in the lower Kansas River basin, and large quantities of agricultural pesticides are applied to increase crop production. Few large-scale industrial developments are present in the basin and, as a result, the synthetic-organic compounds of greatest importance in the basin are agricultural pesticides. The 10 pesticides that were applied in the largest quantities in the basin in 1982 are listed in table 32. Of the 10 pesticides listed, 6 are herbicides, and 4 are insecticides. The four pesticides used in the largest quantities are all herbicides and account for 82 percent of the total for the 10 pesticides listed in table 32. Atrazine, alachlor, and trifluralin are in the class referred to as the triazine and other nitrogen-containing herbicides, and 2,4-D is a chlorophenoxy acid herbicide.

Available Data

Most of the data for synthetic-organic compounds available for the lower Kansas River basin are pesticide analyses, which are available for 77 of the 78 stations shown in figure 35. More data are available for chlorinated insecticides (aldrin, chlordane, DDT, dieldrin, endrin, lindane) and PCB's than for any other class of synthetic-organic compounds. Data are available for chlorinated insecticides and PCB's from as early as the 1970's for several stations. The class of compounds for which the next largest amount of data are available are herbicides (alachlor, atrazine, dacthal, metolachlor, metribuzin, propachlor, silvex, 2,4-D, and 2,4,5-T), followed by organophosphorus insecticides (Diazinon, ethion, and parathion). All of these compounds have been detected in surface-water samples from the lower Kansas River basin.

Table 32.—*Ten pesticides applied in largest quantities within lower Kansas River basin, 1982*

[Pounds applied are active ingredients, and their use has been estimated based on application by county, crop cover, and location of crop cover within each county. Because these values are estimates, quantities applied have been rounded to two significant figures. Sources of data are Gianessi (1986a) for pesticide usage and crop coverage and the U.S. Geological Survey (1986) land-use and land-cover digital data base. Metribuzin, which may have been applied in larger quantities than carbaryl (H.E. Bevans, U.S. Geological Survey, written commun., 1990), was not included in Gianessi's (1986a) estimates]

Pesticide	Quantity applied, in pounds	Type of pesticide
Atrazine	2,200,000	Herbicide
Alachlor	1,400,000	Herbicide
Trifluralin	450,000	Herbicide
2,4-D	430,000	Herbicide
Carbofuran	260,000	Insecticide
Cyanazine	250,000	Herbicide
Metolachlor	160,000	Herbicide
Parathion	140,000	Insecticide
Phorate	97,000	Insecticide
Carbaryl	50,000	Insecticide

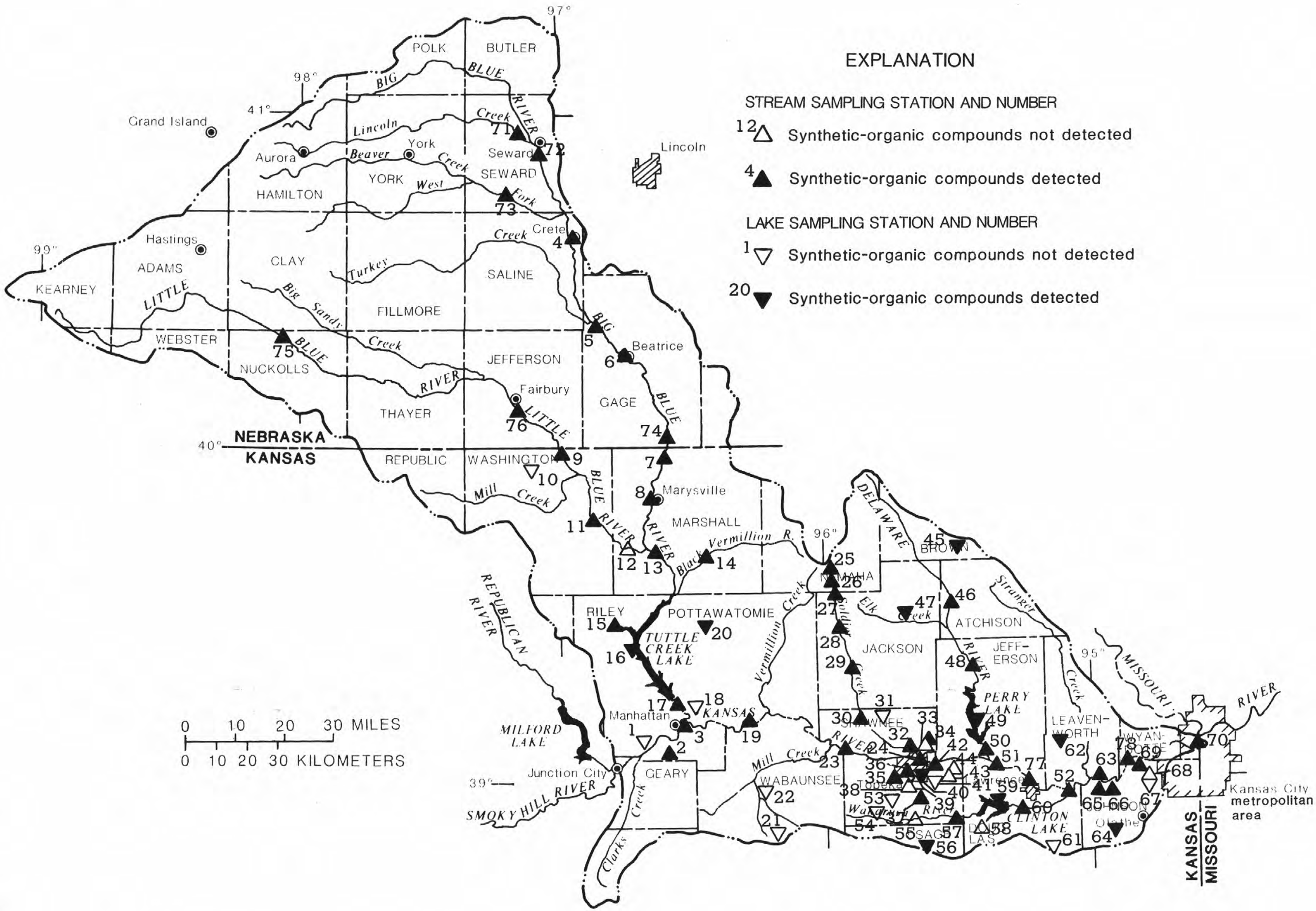


Figure 35.—Surface-water stations where synthetic-organic compounds have been sampled in lower Kansas River basin, 1964-86.

Table 33. —*Synthetic-organic compounds detected in surface water and streambed sediments within lower Kansas River basin, 1964-86*

[Lower levels of detection, maximum concentrations, and water-quality criteria are in micrograms per liter. —, not applicable. Data not shown for fewer than 10 samples]

Synthetic-organic compound	Water			Streambed sediments		Water-quality criteria	
	Number of detections (number of samples)	Lower level of detection	Maximum concentration detected	Number of detections (number of samples)	Lower level of detection	Drinking water	Freshwater-aquatic life, acute[1]
			Chlorinated insecticides and PCB's				
Aldrin	3 (740)	0.01	0.02	—	—	—	3.0
Alpha BHC	2 (62)	.01	.05	—	—	—	—
Chlordane	2 (733)	.1	.2	1 (28)	1.0	[2]2	2.4
DDD	1 (148)	.01	.84	4 (28)	.1	—	—
DDE	4 (158)	.01	.17	4 (28)	.1	—	1,050
DDT	3 (740)	.01	.90	5 (28)	.1	—	1.1
Dieldrin	22 (732)	.01	.04	3 (26)	.05	—	2.5
Endrin	2 (734)	.01	.13	—	—	[3].2	.18
Lindane	7 (740)	.01	.19	1 (28)	.1	[2]4	2.0
PCB's	2 (497)	.1	.1	2 (23)	1	[2].5	2.0
			Organophosphorus insecticides				
Diazinon	14 (57)	.01	1.9	—	—	[4].6	—
Ethion	1 (41)	.01	.20	—	—	—	—
Parathion	4 (54)	.01	.03	—	—	—	.065
			Herbicides				
Alachlor	112 (419)	.25	10	—	—	[2]2	—
Atrazine	282 (458)	1.2	51	—	—	[2]3	—
Dacthal	12 (416)	.05	.51	—	—	—	—
Metolachlor	137 (313)	.25	22	—	—	[4]100	—
Metribuzin	55 (390)	.1	5.6	—	—	[4]200	—
Propachlor	20 (392)	.25	10	—	—	[4]90	—
Silvex	2 (368)	.01	.20	—	—	[2]10	—
2,4-D	53 (369)	.01	7.0	—	—	[2]100	—
2,4,5-T	29 (355)	.01	1.4	—	—	[4]70	—

[1]U.S. Environmental Protection Agency (1987d).

[2]Established or proposed Maximum Contaminant Level (U.S. Environmental Protection Agency, 1990).

[3]Maximum Contaminent Level (U.S. Environmental Protection Agency, 1987d).

[4]Lifetime Health Advisory Level (U.S. Environmental Protection Agency, 1989).

Sources of data on synthetic-organic compounds in surface-water samples include the Kansas Department of Health and Environment (60 stations), the U.S. Geological Survey (16 stations), the U.S. Army Corps of Engineers (13 stations), the Nebraska Department of Environmental Control (7 stations), and the U.S. Environmental Protection Agency (3 stations). The data for stations 1-70 in figure 35 are available in the STORET data base (maintained by U.S. Environmental Protection Agency). Only fish-tissue data were available for stations 71-78 and were obtained from files of the U.S. Environmental Protection Agency (Region VII, Kansas City, Kans.).

A summary of detections of synthetic-organic compounds in surface water and selected water-quality criteria are presented in table 33. Cumulative and synergistic effects on human health and freshwater-aquatic life are not considered by the criteria presented in table 33. However, it is probable that cumulative and synergistic effects do exist and, when documented, may result in application of more rigorous water-quality criteria for certain combinations of synthetic-organic compounds. It must be emphasized that there are no data for many synthetic-organic compounds used in the lower Kansas River basin. For example, trifluralin and carbofuran, 2 of the 10 pesticides used in the largest quantities in the basin in 1982 (table 32), are not routinely analyzed in surface water. Carbofuran is not persistent in water, and trifluralin tends to sorb on sediments; thus, it is improbable that either compound would be detected in water.

Chlorinated Insecticides and PCB's

Chlorinated insecticides and PCB's are relatively insoluble in water. Solubility ranges from 3.1 μg/L for DDT to 7,870 μg/L for lindane. Chlorinated insecticides and PCB's are very persistent in soil; the time required for 75 percent of a compound to degrade ranges from about 100 weeks for aldrin to more than 420 weeks for PCB's. These compounds generally are transported into and occur in surface water sorbed to organic matter and sediment. They also tend to accumulate in biota, particularly in fatty tissues, and in sediments (Smith and others, 1988). Chlorinated insecticides and PCB's are probable or possible carcinogens, and the use of many of them has been restricted, suspended, or canceled by the U.S. Environmental Protection Agency (1985).

Data on chlorinated insecticides and PCB's are shown in table 34 for selected stations that had recurrent sampling. Chlorinated insecticides and PCB's were detected infrequently in water samples (tables 33 and 34). The maximum concentrations of these compounds that were detected in water generally were smaller than the Maximum Contaminant Levels (MCL's) for drinking water and did not exceed freshwater aquatic-life criteria. However, the freshwater aquatic-life criteria are established at concentrations that should never be exceeded (see U.S. Environmental Protection Agency, 1986a and 1986b, for a complete definition). These compounds were detected relatively frequently in streambed sediments that serve as a substrate for some aquatic organisms and tend to accumulate in biota.

Table 34.—*Summary of data on chlorinated insecticides and PCB's from selected surface-water stations within lower Kansas River basin, 1964-86*

[Concentrations in streambed sediments and fish are reported in micrograms per kilogram; dissolved and total concentrations are in micrograms of constituent per liter of water sample]

Sampling-station number (fig. 35)	Station name	Synthetic-organic compound	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
			Streambed sediments				
2	Kings Creek near Manhattan, Kans.	Chlorinated insecticides	1980, 1982	2	DDD	1	0.4
					DDE	1	.3
					DDT	1	2.1
		PCB's	1980	2	PCB's	0	–
6	Big Blue River at Beatrice, Nebr.	Chlorinated insecticides	1978-81	7	Chlordane	1	1.0
					DDD	3	0.1–0.2
					DDE	3	.2
					DDT	4	0.1–0.6
					Dieldrin	2	0.1–0.2
					Lindane	1	.2
		PCB's	1978-81	7	PCB's	1	1.0
9	Little Blue River at Hollenberg, Kans.	Chlorinated insecticides	1973, 1978-82	7	Dieldrin	1	.1
		PCB's	1973, 1978-82	8	none	0	–
63	Kansas River at DeSoto, Kans.	Chlorinated insecticides	1975-82, 1985	11	none	0	–
		PCB's	1977-80, 1982-85	6	PCB 1254	1	.5
			Dissolved in water				
4	Big Blue River near Crete, Nebr.	Chlorinated insecticides	1973-78	12	Dieldrin	4	.01
					Lindane	1	.1
		PCB's	1973-78	12	none	0	–
			Total in whole-water sample				
2	Kings Creek near Manhattan, Kans.	Chlorinated insecticides	1980, 1982	2	none	0	–
		PCB's	1980	1	none	0	–
3	Kansas River at Manhattan, Kans.	Chlorinated insecticides	1973-83, 1985-86	40	none	0	–

Table 34.—*Summary of data on chlorinated insecticides and PCB's from selected surface-water stations within lower Kansas River basin, 1964-86*—Continued

[Concentrations in streambed sediments and fish are reported in micrograms per kilogram; dissolved and total concentrations are in micrograms of constituent per liter of water sample]

Sampling-station number (fig. 35)	Station name	Synthetic-organic compound	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
			Total in whole-water sample—Continued				
		PCB's	1979-83, 1985-86	9	none	0	—
6	Big Blue River at Beatrice, Nebr.	Chlorinated insecticides	1978-81	7	Dieldrin	3	.01
		PCB's	1978-81	7	none	0	—
9	Little Blue River at Hollenberg, Kans.	Chlorinated insecticides	1973-83	34	Chlordane DDT Dieldrin	1 1 2	.2 .01 .01
		PCB's	1973, 1979-83	15	none	0	—
11	Little Blue River near Barnes, Kans.	Chlorinated insecticides	1986	15	DDE DDT Dieldrin	3 1 8	0.01—0.02 .04 0.02—0.04
		PCB's	1986	15	none	0	—
14	Black Vermillion River near Frankfort, Kans.	Chlorinated insecticides	1984-86	25	none	0	—
		PCB's	1984-86	19	none	0	—
16	Tuttle Creek Lake, Kans.	Chlorinated insecticides	1976, 1979, 1984-86	19	none	0	—
		PCB's	1979, 1984-86	18	none	0	—
17	Big Blue River near Manhattan, Kans.	Chlorinated insecticides	1976-86	25	DDE	1	.5
		PCB's	1979-86	21	none	0	—
19	Kansas River at Wamego, Kans.	Chlorinated insecticides	1976-77, 1979-86	21	DDE	1	.22
		PCB's	1979-86	11	none	0	—
24	Kansas River at Topeka, Kans.	Chlorinated insecticides	1969, 1976-80, 1983-86	14	Alpha BHC Hexachloro-benzene	1 1	.02 .03
30	Soldier Creek near Delia, Kans.	Chlorinated insecticides	1978-79, 1982-83, 1985	9	none	0	—
		PCB's	1979, 1982-83, 1985	6	none	0	—
32	Soldier Creek near Topeka, Kans.	Chlorinated insecticides	1976-78, 1980, 1982-84, 1986	13	none	0	—
		PCB's	1978, 1980, 1982-84, 1986	7	none	0	—
42	Shunganunga Creek near Topeka, Kans.	Chlorinated insecticides	1976-82, 1984, 1986	17	Alpha BHC	1	.05
		PCB's	1978-82, 1984, 1986	10	none	0	—
46	Delaware River near Muscotah, Kans.	Chlorinated insecticides	1981-82, 1984, 1986	5	none	0	—
		PCB's	1981-82, 1984, 1986	5	none	0	—
49	Perry Lake, Kans.	Chlorinated insecticides	1977, 1980, 1982, 1984-85	8	none	0	—
		PCB's	1980-82 1984-1985	5	none	0	—
50	Delaware River below Perry Dam, Kans.	Chlorinated insecticides	1976-86	17	none	0	—

Table 34. —*Summary of data on chlorinated insecticides and PCB's from selected surface-water stations within lower Kansas River basin, 1964-86* —Continued

[Concentrations in streambed sediments and fish are reported in micrograms per kilogram; dissolved and total concentrations are in micrograms of constituent per liter of water sample]

Sampling-station number (fig. 35)	Station name	Synthetic-organic compound	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
		Total in whole-water sample—Continued					
		PCB's	1978-86	12	none	0	–
51	Kansas River at Lecompton, Kans.	Chlorinated insecticides	1973-81, 1983-86	34	none	0	–
		PCB's	1978-81, 1983-86	12	none	0	–
59	Clinton Lake, Kans.	Chlorinated insecticides	1979, 1981, 1984	3	none	0	–
		PCB's	1979, 1981, 1984	1	none	0	–
60	Wakarusa River below Clinton Lake, Kans.	Chlorinated insecticides	1976-80, 1982-83, 1985-86	17	none	0	–
		PCB's	1978-80, 1982-83, 1985-86	11	none	0	–
63	Kansas River at DeSoto, Kans.	Chlorinated insecticides	1964-67, 1975-86	42	DDD	1	.84
					DDE	1	.17
					DDT	1	.90
					Dieldrin	4	0.003–0.04
					Endrin	2	0.005–0.13
		PCB's	1977-86	19	PCB 1254	1	.1
		Composite samples of whole fish					
2	Kings Creek near Manhattan, Kans.	Chlorinated insecticides	1984-85	2	p,p'DDE	2	4–5
16	Tuttle Creek Lake, Kans.	Chlorinated insecticides	1984-85	2	alpha BHC	1	6
					Aldrin	1	9
					Chlordane	2	130–200
					p,p'DDD	1	7
					p,p'DDE	2	22–41
					Dieldrin	2	71–76
					Heptachlor epoxide	2	11–16
49	Perry Lake, Kans.	Chlorinated insecticides	1984-85	2	alpha BHC	2	2–3
					Chlordane	2	150–180
					p,p'DDE	2	25–45
					Dieldrin	2	62–110
					Heptachlor	1	5
					Heptachlor epoxide	1	20
					Oxychlordane	1	9
71	Lincoln Creek near Seward, Nebr.	Chlorinated insecticides	1984-85	2	Chlordane	2	50–120
					cis Chlordane	1	5
					trans Chlordane	1	4
					cis Nonachlor	1	2
					trans Nonachlor	1	5
					Oxychlordane	1	9
					p,p'DDE	1	14
					Dieldrin	2	26–120
					Heptachlor epoxide	2	4–30
72	Big Blue River at Seward, Nebr.	Chlorinated insecticides	1984-85	2	alpha BHC	1	3
					Chlordane	2	210–5,600
					cis Chlordane	1	210
					trans Chlordane	1	1,300
					p,p'DDE	1	71
					Dieldrin	2	96–130

Table 34.—*Summary of data on chlorinated insecticides and PCB's from selected surface-water stations within lower Kansas River basin, 1964-86*—Continued

[Concentrations in streambed sediments and fish are reported in micrograms per kilogram; dissolved and total concentrations are in micrograms of constituent per liter of water sample]

Sampling-station number (fig. 35)	Station name	Synthetic-organic compound	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
		Composite samples of whole fish—Continued					
					Heptachlor epoxide	2	24–89
					cis Nonachlor	1	24
					trans Nonachlor	1	66
					Oxychlordane	1	120
74	Big Blue River at Barneston, Nebr.	Chlorinated insecticides	1980-83	4	alpha BHC	1	4
					cis Chlordane	1	31
					Chlordane	1	410
					trans Chlordane	1	57
					p,p'DDD	1	13
					p,p'DDE	3	29–50
					Dieldrin	2	24–44
					Heptachlor	1	4
					Heptachlor epoxide	1	13
					cis Nonachlor	1	9
					trans Nonachlor	1	42
75	Little Blue River near Deweese, Nebr.	Chlorinated insecticides	1984-85	2	Chlordane	2	50–220
					cis Chlordane	1	4
					trans Chlordane	1	4
					p,p'DDD	1	24
					p,p'DDE	2	32–120
					Dieldrin	1	17
					Heptachlor epoxide	1	3
					cis Nonachlor	1	3
					trans Nonachlor	1	6
					Oxychlordane	1	6
76	Little Blue River near Fairbury, Nebr.	Chlorinated insecticides	1980, 1982-83	3	alpha BHC	1	9
					Chlordane	2	120–180
					cis Chlordane	1	26
					trans Chlordane	1	26
					p,p'DDD	2	12–25
					p,p'DDE	2	32–66
					Dieldrin	3	25–32
					Heptachlor epoxide	2	6–8
					trans Nonachlor	1	22
77	Kansas River near Lawrence, Kans.	Chlorinated insecticides	1983, 1985	2	Chlordane	2	980–990
					p,p'DDE	2	68–69
					delta BHC	1	15
78	Kansas River near Bonner Springs, Kans.	Chlorinated insecticides	1970-74, 1977, 1979, 1981	33	alpha BHC	9	10–100
					gamma BHC	1	10
					cis Chlordane	10	40–710
					trans Chlordane	10	20–280
					p,p'DDD	32	20–850
					p,p'DDE	30	30–590
					p,p'DDT	20	20–950
					Dieldrin	31	20–5,010
					Endrin	7	10–30
					Heptachlor	12	10–120
					Hexachlor	1	10
					cis Nonachlor	8	20–130
					trans Nonachlor	8	40–300
					Oxychlordane	5	20–40
					Toxaphene	8	300–800
		PCB's	1970-74, 1977, 1979, 1981	32	PCB 1242	1	600
					PCB 1248	4	100–300
					PCB 1254	28	100–160
					PCB 1260	11	100–600

Table 35.—*Summary of data on organophosphorus insecticides from selected surface-water stations within lower Kansas River basin, 1973-86*

[Years and number of samples for some individual compounds in a group may be less than the years and number of samples shown for the group. Dissolved and total concentrations are in micrograms of constituent per liter of water sample; concentrations in fish are reported in micrograms per kilogram]

Sampling-station number (fig. 35)	Station name	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
		Dissolved in water				
4	Big Blue River near Crete,Nebr.	1973-78	12	Diazinon	7	0.01–0.10
				Parathion	1	.01
		Total in whole-water sample				
2	Kings Creek near Manhattan, Kans.	1980	1	none	0	–
6	Big Blue River at Beatrice, Nebr.	1978-81	7	Diazinon	4	0.01–0.07
9	Little Blue River at Hollenberg, Kans.	1978-82	8	Parathion	2	0.01–0.03
24	Kansas River at Topeka, Kans.	1976-80, 1983-86	1	Diazinon	1	.39
42	Shunganunga Creek near Topeka, Kans.	1980, 1982	2	Diazinon	2	1.3–1.9
63	Kansas River at DeSoto, Kans.	1975-82, 1985	25	Ethion	1	.20
		Composite sample of whole fish				
72	Big Blue River at Seward, Nebr.	1984	1	Chlorpyrifos	1	55

Concentrations of chlorinated insecticides and PCB's in several fish-tissue samples (common carp) exceeded the National Academy of Sciences and National Academy of Engineering guidelines for the protection of fish-eating birds and mammals (100 μg/kg for cyclodiene insecticides, either singly or in combination, and PCB's) (National Academy of Sciences and National Academy of Engineering, 1973). Most of the exceedences were due to chlordane (table 34), but PCB's also exceeded the guideline in some samples.

Organophosphorus Insecticides

Organophosphorus insecticides (Diazinon, ethion, and parathion) are much more soluble than chlorinated insecticides and PCB's, with solubility ranging from about 2,000 μg/L for ethion to 40,000 μg/L for Diazinon. These compounds are also much less persistent in soil, with persistence ranging from about 1 week for parathion to about 13 weeks for Diazinon. These compounds generally are transported into and occur in surface water in solution. They typically do not accumulate in aquatic biota or sediment (Smith and others, 1988).

Data for organophosphorus insecticides are shown in table 35 for selected stations that had recurrent sampling from 1973-86. Diazinon, ethion, and parathion were detected infrequently in samples of water (tables 33 and 35). Diazinon was detected at larger concentrations and more frequently than the other organophosphate compounds because Diazinon is the most soluble and persistent of these compounds. The maximum detected concentration of Diazinon exceeded the Lifetime Health Advisory Level for drinking water (table 33).

Herbicides

Herbicides generally were detected at larger concentrations and more frequently in water than were other synthetic-organic compounds (table 33 for all sampled stations and table 36 for stations that had recurrent sampling). They are the most soluble synthetic-organic compounds detected in the lower Kansas River basin and were applied in the largest quantities in 1982 (see table 32). These compounds occur generally in the hydrologic environment in solution and are not known to accumulate in biota or sediment. Human-health criteria were exceeded by maximum detected concentrations of alachlor and atrazine (table 33). Because of their frequent detection in water and their potential adverse effects on human health, these herbicides are of concern, and their environmental significance needs to be assessed further.

Table 36.—*Summary of data on herbicides from selected surface-water stations within lower Kansas River basin, 1969-86*

[Years and number of samples for some individual compounds in a group may be less than the years and number of samples shown for the group. Dissolved and total concentrations are in micrograms of constituent per liter of water sample; concentrations in fish are reported in micrograms per kilogram]

Sampling-station number (fig. 35)	Station name	Herbicide	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
			Dissolved in water				
4	Big Blue River near Crete, Nebr.	Chlorophenoxy acid herbicides	1973-78	12	2,4-D 2,4,5-T	11 12	0.03–0.48 0.01–0.11
			Total in whole-water sample				
2	Kings Creek near Manhattan, Kans.	Chlorophenoxy acid herbicides	1980, 1987	2	none	0	–
3	Kansas River at Manhattan, Kans.	Dacthal	1979-83, 1985-86	16	none	0	–
		Chlorophenoxy acid herbicides	1979-83, 1985-86	16	none	0	–
		Triazine and other nitrogen-containing herbicides	1979-83, 1985-86	16	Alachlor Atrazine Metolachlor	1 6 1	.32 1.5–6.2 .52
6	Big Blue River at Beatrice, Nebr.	Chlorophenoxy acid herbicides	1978-81	7	2,4-D 2,4,5-T	5 4	0.02–0.64 0.01–0.04
15	Little Blue River at Hollenberg, Kans.	Dacthal	1980-83	4	none	0	–
		Chlorophenoxy acid herbicides	1973, 1978-83	4	2,4-D 2,4,5-T	9 3	0.01–0.31 0.01–0.02
		Triazine and other nitrogen-containing herbicides	1970, 1980-83	5	Atrazine	4	1.3–3.8
11	Little Blue River near Barnes, Kans.	Dacthal	1986	15	none	0	–
		Triazine and other nitrogen-containing herbicides	1986	15	Alachlor Atrazine Metolachlor Metribuzin	5 9 7 5	0.35–1.6 1.5–17 .44–6.3 0.13–0.99
14	Black Vermillion River near Frankfort, Kans.	Dacthal	1986	25	none	0	–
		Chlorophenoxy acid herbicides	1985	25	none	0	–
		Triazine and other nitrogen-containing herbicides	1985-86	25	Alachlor Atrazine Metolachlor Metribuzin Propachlor	10 20 15 8 6	0.13–8.1 1.2–23 0.32–8.8 0.13–2.2 0.58–10
16	Tuttle Creek Lake, Kans.	Dacthal	1979, 1984-86	11	none	0	–
		Chlorophenoxy acid herbicides	1979, 1984-85	11	none	0	–
		Triazine and other nitrogen-containing herbicides	1979, 1984-86	62	Alachlor Atrazine Metolachlor Propachlor	32 51 37 1	0.09–3.1 1.5–22 0.29–3.2 .25
17	Big Blue River near Manhattan, Kans.	Dacthal	1979-86	10	none	0	–
		Chlorophenoxy acid herbicides	1979-86	10	none	0	–
		Triazine and other nitrogen-containing herbicides	1978-86	29	Alachlor Atrazine Metolachlor Metribuzin Propachlor	16 26 17 4 1	0.15–2.4 1.6–14 0.30–1.6 0.11–0.22 .25
19	Kansas River at Wamego, Kans.	Dacthal	1979-86	17	none	0	–

Table 36.—*Summary of data on herbicides from selected surface-water stations within lower Kansas River basin, 1969-86*—Continued

[Years and number of samples for some individual compounds in a group may be less than the years and number of samples shown for the group. Dissolved and total concentrations are in micrograms of constituent per liter of water sample; concentrations in fish are reported in micrograms per kilogram]

Sampling-station number (fig. 35)	Station name	Herbicide	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
		Total in whole-water sample—Continued					
		Chlorophenoxy acid herbicides	1979-86	17	none	0	—
		Triazine and other nitrogen-containing herbicides	1979-86	16	Alachlor Atrazine Metolachlor	2 14 7	0.26—0.28 1.3—8.8 0.25—0.88
24	Kansas River at Topeka, Kans.	Dacthal	1978-80, 1983-86	6	none	0	—
		Chlorophenoxy acid herbicides	1969, 1978-80, 1983-86	8	Silvex 2,4-D 2,4,5-T	1 1 1	.01 2.2 .02
		Triazine and other nitrogen-containing herbicides	1978-80, 1983-86	7	Alachlor Atrazine Metolachlor Metribuzin Propachlor	2 4 1 1 1	0.65—1.10 1.3—9.1 1.00 .12 .45
30	Soldier Creek near Delia, Kans.	Dacthal	1979, 1982-83, 1985	5	none	0	—
		Chlorophenoxy acid herbicides	1978-79, 1982-83, 1985	6	none	0	—
		Triazine and other nitrogen-containing herbicides	1979, 1982-83, 1985	8	Alachlor Atrazine Metolachlor Metribuzin Propachlor	1 2 1 1 1	4.4 1.2—1.8 .72 .78 1.30
32	Soldier Creek near Topeka, Kans.	Dacthal	1980, 1982-84, 1986	6	none	0	—
		Chlorophenoxy acid herbicides	1978, 80, 1982-84, 1986	7	none	0	—
		Triazine and other nitrogen-containing herbicides	1978, 80, 1982-84, 1986	8	Atrazine Metolachlor Metribuzin	3 1 1	1.2—3.6 .51 .10
42	Shunganunga Creek near Topeka, Kans.	Dacthal	1977, 1979-82, 1984, 86	11	Dacthal	6	0.11—0.51
		Chlorophenoxy acid herbicides	1978-82, 1984, 86	11	2,4-D 2,4,5-T	6 2	0.66—7.0 0.26—1.4
		Triazine and other nitrogen-containing herbicides	1978-82, 1984, 1986	11	Alachlor Atrazine Propachlor	1 5 1	2.7 1.1–6.4 .42
46	Delaware River near Muscotah, Kans.	Dacthal	1981-82, 1984, 86	5	none	0	—
		Chlorophenoxy acid herbicides	1981-82, 1984, 86	4	2,4-D	1	.46
		Triazine and other nitrogen-containing herbicides	1981-82, 1984, 86	4	Atrazine	1	1.8
49	Perry Lake, Kans.	Dacthal	1980, 82, 1984-85	9	none	0	—
		Chlorophenoxy acid herbicides	1980, 82, 1984-85	9	none	0	—
		Triazine and other nitrogen-containing herbicides	1977, 80, 1982, 1984-85	12	Alachlor Atrazine Metolachlor Metribuzin Propachlor	8 10 4 1 1	0.13—1.3 1.4—9.1 0.57—1.3 .24 .83

Table 36.—*Summary of data on herbicides from selected surface-water stations within lower Kansas River basin, 1969-86*—Continued

[Years and number of samples for some individual compounds in a group may be less than the years and number of samples shown for the group. Dissolved and total concentrations are in micrograms of constituent per liter of water sample; concentrations in fish are reported in micrograms per kilogram]

Sampling-station number (fig. 35)	Station name	Herbicide	Years	Number of samples	Compound detected	Number of detections	Range of detected concen-trations
		Total in whole-water sample—Continued					
50	Delaware River below Perry Dam, Kans.	Dacthal	1979-86	12	none	0	—
		Chlorophenoxy acid herbicides	1978-86	12	none	0	—
		Triazine and other nitrogen-containing herbicides	1978-86	12	Alachlor	2	0.34—0.57
					Atrazine	10	1.2—9.4
					Metolachlor	3	0.40—1.2
51	Kansas River at Lecompton, Kans.	Dacthal	1979-81, 1983-86	11	none	0	—
		Chlorophenoxy acid herbicides	1978-81, 1983-86	12	none	0	—
		Triazine and other nitrogen-containing herbicides	1978-81, 1983-86	13	Alachlor	1	.33
					Atrazine	9	1.2—6.9
					Metolachlor	2	0.43—0.61
59	Clinton Lake, Kans.	Dacthal	1979, 1981	1	none	0	—
		Chlorophenoxy acid herbicides	1979, 1981	1	none	0	—
		Triazine and other nitrogen-containing herbicides	1979, 1981	2	Atrazine	2	1.4—1.5
60	Wakarusa River below Clinton Lake, Kans.	Dacthal	1979-80, 1982-83, 1985-86	10	none	0	—
		Chlorophenoxy acid herbicides	1978-80, 1982-83, 1985-86	11	2,4-D	2	1.3—1.6
		Triazine and other nitrogen-containing herbicides	1977-80, 1982-83, 1985-86	13	Alachlor	2	0.26—3.2
					Atrazine	6	1.6—8.7
					Metolachlor	1	.27
					Metribuzin	1	.21
					Propachlor	1	2.0
63	Kansas River at DeSoto, Kans.	Dacthal	1980-81, 1983-86	6	none	0	—
		Chlophenoxy acid herbicides	1975-86	20	2,4-D	3	0.07—0.91
		Triazine and other nitrogen-containing herbicides	1975-81, 1983-86	18	Alachlor	2	0.85—1.5
					Atrazine	15	0.46—6.3
					Metolachlor	2	0.53—0.76
		Composite samples of whole fish					
78	Kansas River near Bonner Springs, Kans.	Dacthal	1979, 1981	5	Dacthal	3	10

Seasonal Variation in Herbicide Concentrations

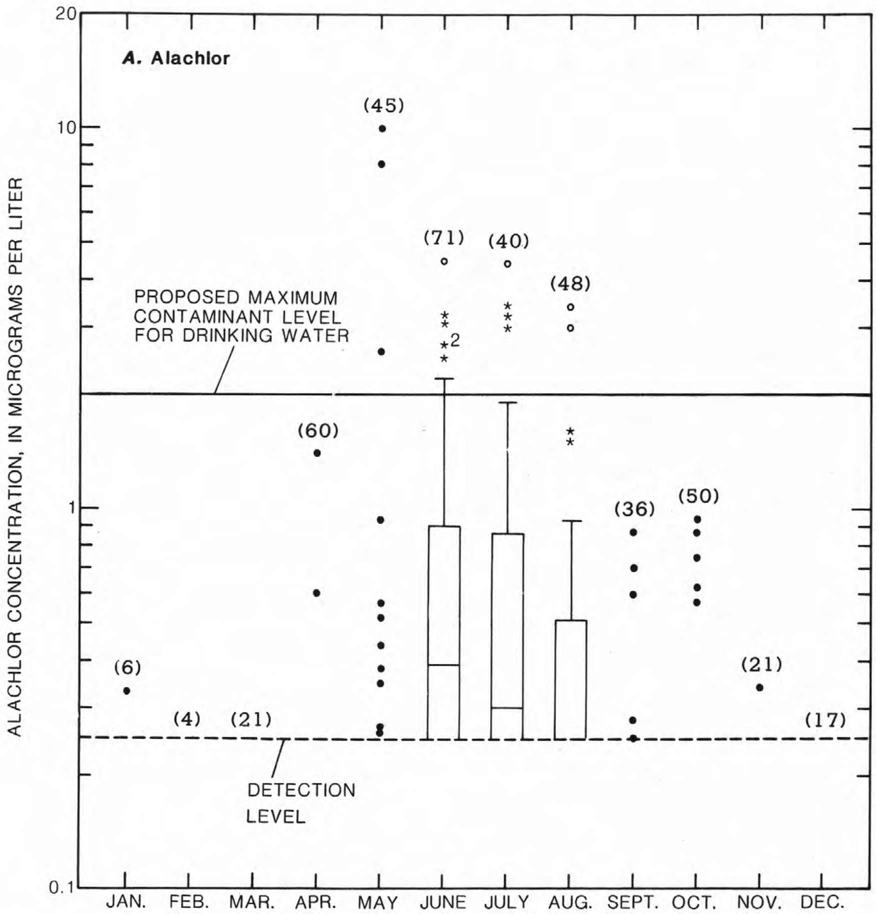
Agricultural herbicides usually are applied during the spring for preplant, pre-emergent, or early postemergent control of weeds and grasses. Because herbicides have relatively large solubilities, the largest concentrations in surface water would be expected to occur during the spring and early summer months. Monthly distributions of concentrations of alachlor, atrazine, and metolachlor detected in surface water are shown in figure 36. These distributions were computed from all available data for surface-water stations within the lower Kansas River basin for 1973-86 (see figure 35). Also shown are the number of monthly samples, the detection levels, and drinking-water criteria (see table 33). Data before 1973 were not used in figure 36 because of inconsistent detection levels.

Atrazine (fig. 36B) has been detected in surface water in the basin during every month of the year (detection level of 1.2 μg/L). More than 75 percent of the samples collected in May had detectable concentrations of atrazine. The largest concentrations occurred in June when between 50 and 75 percent of the samples had atrazine concentrations that exceeded the proposed MCL (3.0 μg/L). During July and August, median concentrations of atrazine still exceeded that level, and concentrations slowly and steadily decreased through late summer, fall, and winter.

The same seasonal patterns are evident for concentrations of alachlor (fig. 36A) and metolachlor (fig. 36C), except that they generally were not detected during winter months. Because alachlor is considered a greater health threat than metolachlor, the drinking-water criterion (table 33) for alachlor is 2 μg/L compared to 100 μg/L for metolachlor.

Other Groups of Synthetic-Organic Compounds

Other groups of synthetic-organic compounds as defined by Smith and others (1988) are: (1) phenols, including phenol and pentachlorophenol (PCP); (2) halogenated aliphatic and monocyclic aromatic hydrocarbons, including benzene, chloroform, and toluene; (3) phthalate esters, including dimethyl phthalate; (4) polychlorinated dibenzo-p-dioxins (PCDD's), including tetra-chlorodibenzo-p-dioxin; and (5) polycyclic aromatic hydrocarbons (PAH's), including anthracene and naphthalene. Very few data are available for these compounds in surface water in the lower Kansas River basin, and summaries of the available data are not included in this report. Synthetic-organic compounds in these groups that have been sampled for but not detected include phenols, bis(2-ethyl-hexyl)phthalate, and di-n-butyl phthalate. Data are needed to determine the effect of this group of compounds on surface-water quality, particularly at stations downstream of urban and industrial areas.



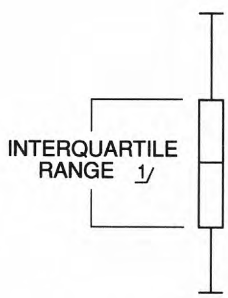
EXPLANATION

(24) NUMBER IN PARENTHESES IS NUMBER OF SAMPLES ANALYZED DURING EACH MONTH

○ 2 CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE. NUMBER IS NUMBER OF DETECTIONS

⋆ 2 CONCENTRATION(S) EXCEEDING UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE BUT LESS THAN UPPER QUARTILE PLUS 3.0 TIMES THE INTERQUARTILE RANGE. NUMBER IS NUMBER OF DETECTIONS

● ALL CONCENTRATIONS EXCEEDING DETECTION LEVEL FOR MONTHS IN WHICH MORE THAN 75 PERCENT OF CONCENTRATIONS WERE LESS THAN DETECTION LEVEL



UPPER QUARTILE PLUS 1.5 TIMES THE INTERQUARTILE RANGE OR LARGEST CONCENTRATION NOT EXCEEDING THIS COMPUTATION

UPPER QUARTILE (75th PERCENTILE)

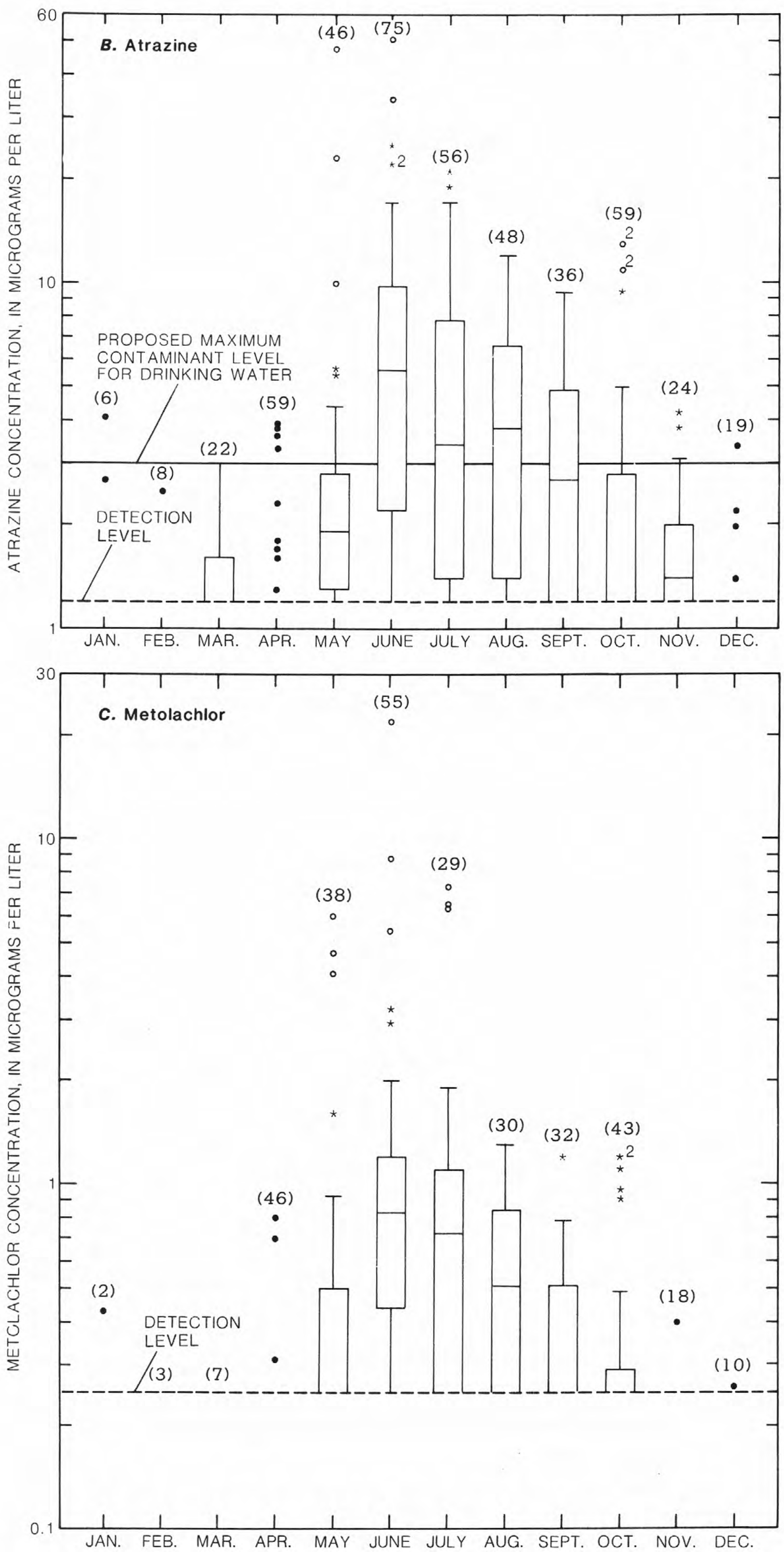
MEDIAN (50th PERCENTILE)

LOWER QUARTILE (25th PERCENTILE)

LOWER QUARTILE MINUS 1.5 TIMES THE INTERQUARTILE RANGE OR SMALLEST CONCENTRATION NOT LESS THAN THIS COMPUTATION

1/ ON DIAGRAMS WHERE THE 25th PERCENTILE WAS LESS THAN THE DETECTION LEVEL, THE INTERQUARTILE RANGE WAS CALCULATED BY USING ZERO AS THE 25th PERCENTILE VALUE

Figure 36.—Monthly distribution of (*A*) alachlor, (*B*) atrazine, stations sampled in lower Kansas River basin,



and (*C*) metolachlor concentrations in samples for all surface-water and relevant drinking-water criteria, 1973-86.

Fecal-Indicator Bacteria

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The role of fecal-indicator bacteria in water-quality assessment was described by Hirsch and others (1988, p. 19):

> "Water contaminated by fecal matter has served as a medium for the spread of a large number of diseases, including cholera, typhoid fever, and bacillary and amoebic dysentery. Thus, knowledge of the sanitary quality of water can be very important in assessing its suitability for public supply and recreational uses. Relatively elaborate procedures are required for the detection of most pathogens in natural waters. The most widely accepted procedures to indicate the presence of fecal matter in water rely on the detection of nonpathogenic bacteria, which are native to the intestines of humans and other warm-blooded animals. *** Until recently, *** [specialists] *** preferred to use fecal coliform bacteria (Dufour, 1977, p. 57)."

Presently, the use of *E. coli* bacteria is the preferred indicator of fecal contamination in freshwater (U.S. Environmental Protection Agency, 1986c).

The Kansas Department of Health and Environment has enumerated fecal-coliform and fecal-streptococci bacteria at selected locations within Kansas since 1967. As of 1986, this agency has collected bacteriological data from 24 of the stations in the study unit that are part of Kansas' statewide Surface-Water-Quality Sampling Network (fig. 37). The Nebraska Department of Environmental Control has collected bacteriological data since the early 1970's from seven sampling stations located within the study unit (fig. 37). These seven stations were part of Nebraska's Ambient Water-Quality Network. All stations in both states were sampled monthly.

Current Conditions

Summaries of bacteriological data collected during 1978-86 from selected sampling stations within the lower Kansas River basin are presented in table 37. The value of 2,000 col/100 mL (coliform colonies per 100 milliliters) of water has been established by the Kansas Department of Health and Environment as the water-quality criterion (Kansas Administrative Regulations 28-16-28e) for those streams available for all beneficial uses other than primary (full-body) contact recreation (Fromm and Wilk, 1988). The variation of fecal-coliform densities in water from the Kansas and Big Blue Rivers is illustrated in figure 38.

In general, median fecal-coliform densities in the Big Blue River basin upstream from the Little Blue River were fairly uniform; median densities varied only from 500 to 1,200 col/100 mL for stations 3-6 and 8-10. Fecal-coliform densities in the Big Blue River near Crete, Nebr. (station 7), a short distance downstream from the Crete wastewater-treatment plant, were significantly larger (5,000 col/100 mL). The 90th-percentile density was 30,000 col/100 mL at the Crete station and ranged from 8,700 to 35,000 col/100 mL at the other stations, indicating either that sources other than wastewater-treatment plants produced densities larger than 5,000 col/100 mL at times, or that fecal-coliform bacteria survived long distances of travel from upstream treatment plants. Seventy-four percent of the samples exceeded 2,000 col/100 mL at the Crete station, and 21 to 38 percent exceeded 2,000 col/100 mL at the other stations.

Median fecal-coliform densities in the Little Blue River basin were 1,200 col/100 mL or less (stations 11, 12, 13, and 15) except in the Little Blue River near Fairbury, Nebr. (station 14), where the median was 4,300 col/100 mL. Station 14 is a short distance downstream from the Fairbury wastewater-treatment plant. Seventy-nine percent of the samples exceeded 2,000 col/100 mL at the Fairbury station, and 18 to 47 percent exceeded 2,000 col/100 mL at the other stations.

At station 18, on the Big Blue River downstream from Tuttle Creek Lake, fecal-coliform densities in 98 percent of the samples were less than the criterion of 2,000 col/100 mL. Bacteria densities in water directly downstream from a lake often are less than those in streams feeding the lake due to several factors, such as long residence time in the lake, which allows for settling of sediment-transported colonies.

At the Fort Riley station (station 1, fig. 37), located on the Kansas River a few miles downstream from Junction City's wastewater-treatment facility, available data on bacteria were obtained before the 1978 water year and are not shown in table 37 or figure 38. Eighty-three percent of the samples exceeded the criterion value. Median bacterial densities at sampling stations on the Kansas River (stations 19, 21, 26, and 29) were variable and did not follow a consistent pattern. The variations in coliform densities at these locations probably reflect their relative proximity to wastewater effluent from Manhattan, Topeka, and Lawrence. Except for samples collected from Kings Creek (station 2) and the Big Blue River near

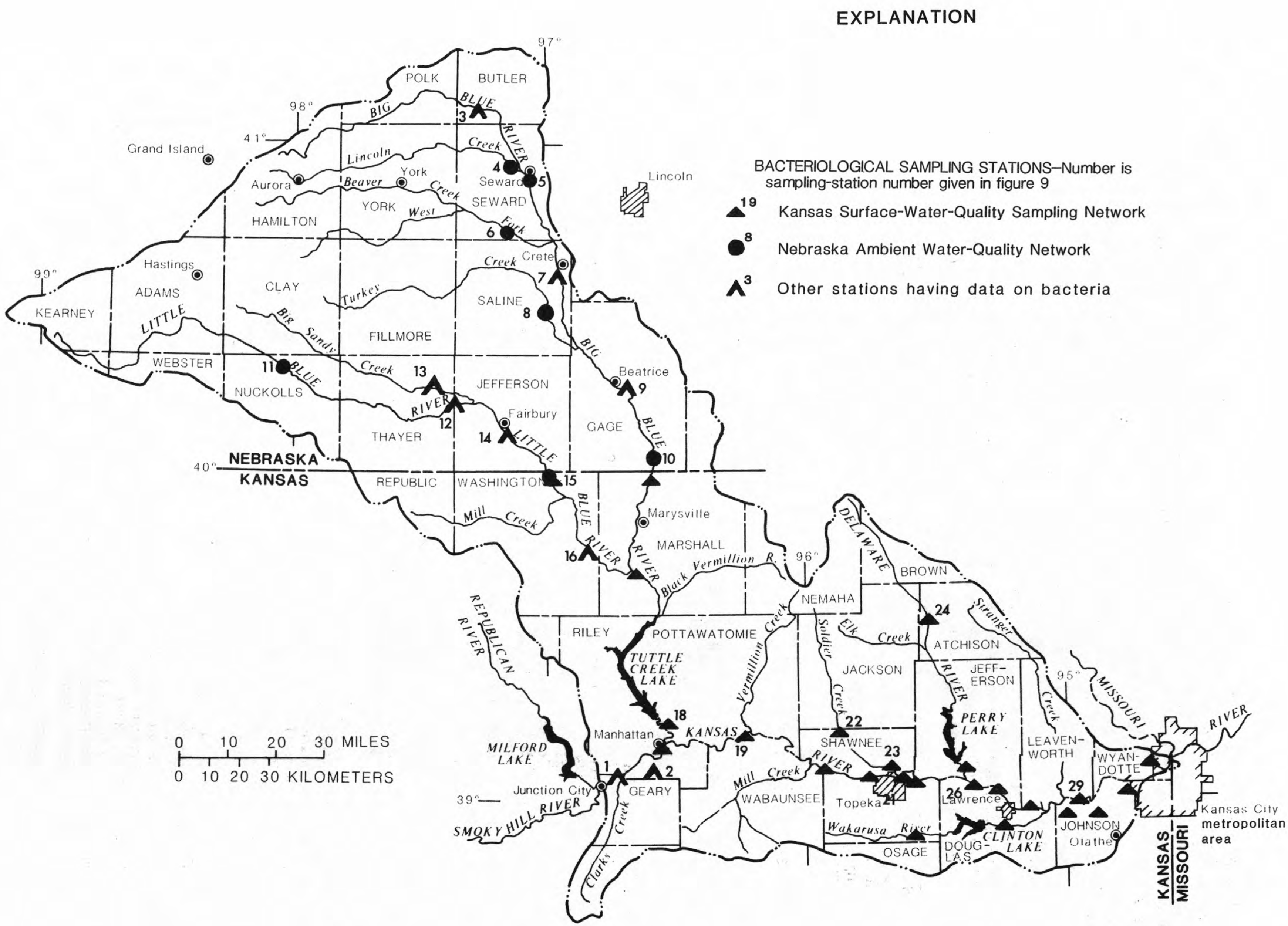


Figure 37.—Location of bacteriological sampling stations in lower Kansas River basin.

Manhattan (station 18, downstream from Tuttle Creek Lake), a large percentage of the samples from the Kansas River and its tributaries in Kansas had fecal-coliform densities that exceeded the criterion of 2,000 col/100 mL during 1978-86. The number of analyses exceeding the criterion ranged from 13 percent for Soldier Creek near Delia, Kans. (station 22), to 51 percent for the Kansas River at Lecompton, Kans. (station 26).

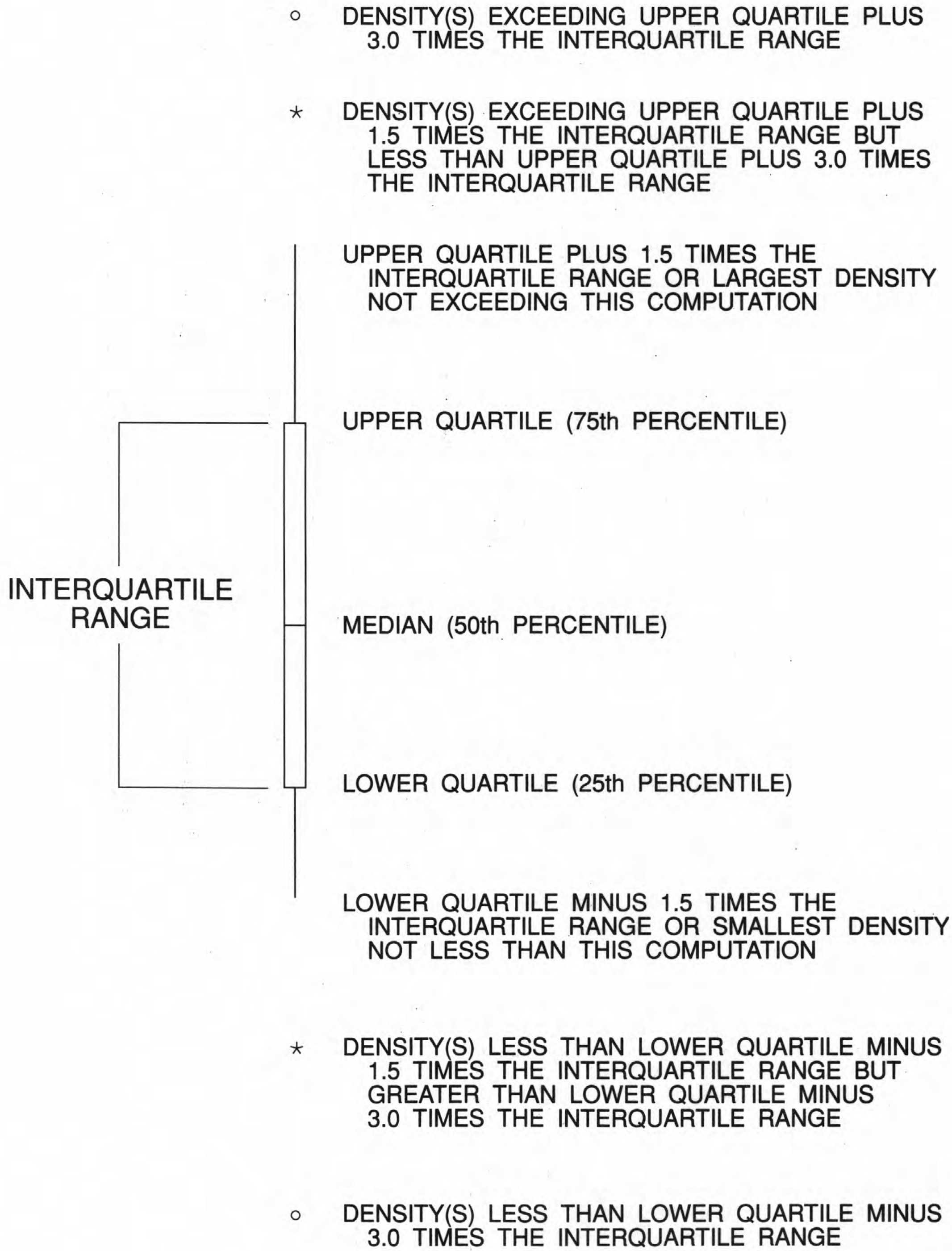
No criteria exist for densities of fecal streptococci even though these bacteria may be pathogenic. No consistent relation was observed between the median fecal-coliform densities and median fecal-streptococci densities shown in table 37. At a few stations, however, both streptococci and coliform densities were small (for example, station 2, Kings Creek near Manhattan, Kans.) or large (for example, station 9, Big Blue River at Beatrice, Nebr.).

Table 37.—*Statistical summary of fecal-coliform data and median fecal-streptococci densities in water from selected sampling stations within lower Kansas River basin, 1978-86 water years*

[All values are for fecal coliform except those in parentheses which are for fecal streptococci; bacterial densities in colonies per 100 milliliters; this table includes only those sampling stations with 10 or more analyses; the 10- and 90-percentile values are not shown for sampling stations having fewer than 30 analyses]

Sampling-station number (fig. 37)	Station name	Number of analyses	Value at indicated percentile: 10	50 (median)	90	Percentage exceeding 2,000 colonies per 100 milliliters
2	Kings Creek near Manhattan, Kans.	20	—	28 (29)	—	0
3	Big Blue River at Surprise, Nebr.	38	10	500	18,000	21
4	Lincoln Creek near Seward, Nebr.	116	27	930 (3,400)	8,700	29
5	Big Blue River at Seward, Nebr.	128	28	560 (1,800)	11,000	25
6	West Fork Big Blue River near Dorchester, Nebr.	151	100	1,000 (4,500)	35,000	35
7	Big Blue River near Crete, Nebr.	226	600	5,000 (3,000)	30,000	74
8	Turkey Creek near Wilber, Nebr.	118	36	700 (2,200)	14,000	29
9	Big Blue River at Beatrice, Nebr.	65	87	1,200 (2,800)	26,000	38
10	Big Blue River at Barneston, Nebr.	119	50	680 (1,000)	18,000	36
11	Little Blue River near Deweese, Nebr.	95	23	410 (530)	26,000	24
12	Little Blue River near Alexandria, Nebr.	61	100	1,200 (2,800)	26,000	47
13	Big Sandy Creek at Alexandria, Nebr.	38	10	245	6,300	18
14	Little Blue River near Fairbury, Nebr.	24	—	4,300 (3,500)	—	79
15	Little Blue River at Hollenberg, Kans.	195	100	1,000 (1,550)	18,000	40
18	Big Blue River near Manhattan, Kans.	178	10	44 (100)	290	2
19	Kansas River at Wamego, Kans.	106	100	400 (300)	2,900	15
21	Kansas River at Topeka, Kans.	50	100	200 (550)	9,700	18
22	Soldier Creek near Delia, Kans.	130	100	200 (700)	3,200	13
23	Soldier Creek near Topeka, Kans.	92	13	150 (400)	5,500	14
24	Delaware River near Muscotah, Kans.	56	97	450 (1,550)	20,000	30
26	Kansas River at Lecompton, Kans.	111	300	2,400 (1,000)	13,000	51
29	Kansas River at DeSoto, Kans.	123	100	880 (480)	4,000	28

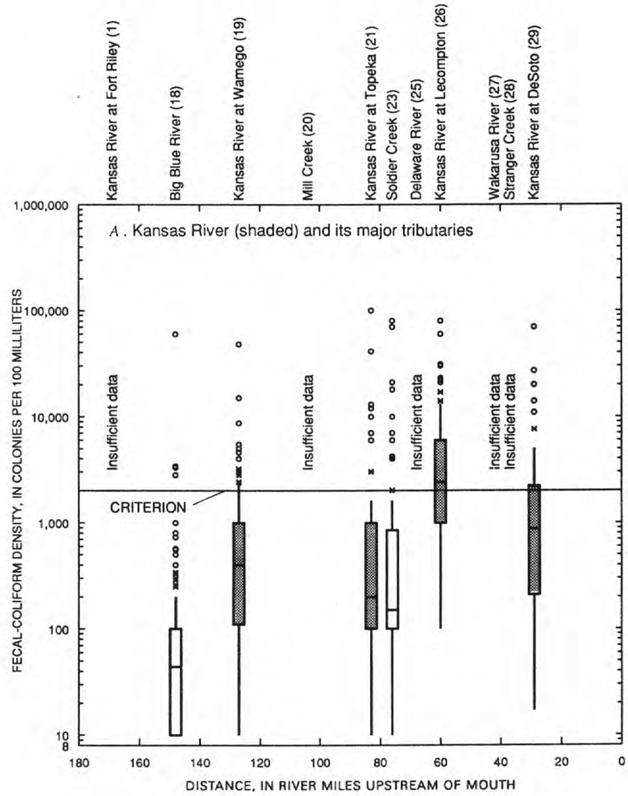
EXPLANATION

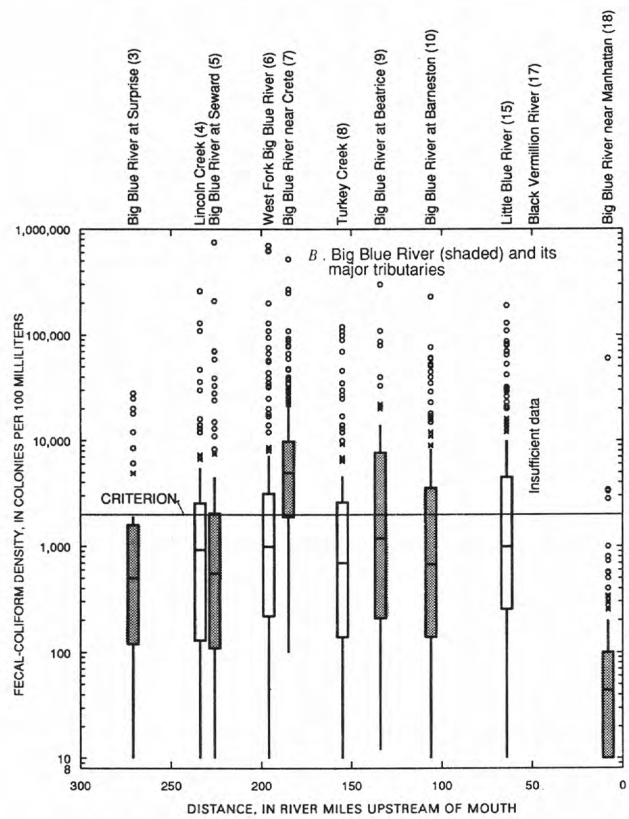


NUMBER IN PARENTHESES IS SAMPLING-STATION NUMBER (figure 9)

WATER-QUALITY CRITERION IS FOR NONCONTACT RECREATION, KANSAS (FROMM AND WILK, 1988, p.8)

Figure 38.—Distribution of densities of fecal-coliform bacteria in water from (*A*) Kansas Fecal-coliform-density scale is logarithmic;





and (*B*) Big Blue Rivers and their major tributaries, 1978-86 water years.
minimum scale value arbitrarily set at 8.

As early as the beginning of the 20th century, reports appeared suggesting that the use of data on streptococci might assist in differentiating between bacterial contamination originating from humans and that originating from other warm-blooded animals (Winslow and Palmer, 1910, p. 1). Geldreich and Kenner (1969, p. R337) reviewed numerous studies dealing with fecal-streptococci and fecal-coliform bacteria. They observed that fecal-streptococci densities were larger than fecal-coliform densities in feces from "farm animals, dogs, cats, and various wild animals," whereas fecal coliform were present at four times the levels of fecal streptococci in feces of humans. This species difference may explain the moderate coliform and larger streptococci densities in water from sampling stations downstream from small human populations but large populations of other animals (for example, station 4, Lincoln Creek near Seward, Nebr.), and larger coliform but moderate streptococci densities in water from sampling stations downstream from large municipal effluents (for example, station 26, Kansas River at Lecompton, Kans., downstream from the Topeka municipal effluent).

Trends

Trend-test results for bacterial densities at selected stations within the lower Kansas River basin are presented in table 38 and figure 39. Data as early as 1974 were used at all stations shown, and the earliest data used at any station were from 1967. Ten of the 13 stations showed decreasing trends in flow-adjusted fecal-coliform densities (table 38) although only two of the probabilities were at levels judged statistically significant for individual stations. The fact that so many of the stations had trends in the same direction probably is meaningful even though most did not show significance individually. The decreasing trends in fecal-coliform densities probably are related to the decreasing trends in suspended-sediment concentration discussed in another part of this report. Similarity of trends in bacteria and suspended sediment is consistent with the fact that bacteria commonly are transported on suspended sediment and with the inference that much of the fecal coliform and suspended sediment originated from nonpoint sources. Although the group of stations analyzed for suspended sediment was not identical to the group analyzed for fecal coliform, the two stations having statistically significant decreasing trends in fecal coliform also had statistically significant decreasing trends in suspended sediment.

Trend-test results for fecal-streptococci densities at five stations (table 38) were variable and did not follow a consistent areal pattern. Although three of the stations had statistically significant trends, the trends were not in the same direction, and variations in the years of data available made direct comparison impractical.

Table 38. – *Trend-test results for bacterial densities in water from selected sampling stations within lower Kansas River basin*

[Underlined, significant at 0.10 probability level; probability shown as 0 is less than 0.005]

Sampling-station number (fig. 37)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend: Bacterial density: Probability level	Bacterial density: Average rate of change: Colonies per 100 milliliters per year	Bacterial density: Average rate of change: Percent of median per year	Flow-adjusted density: Probability level	Flow-adjusted density: Average rate of change (percent per year)
				Coliform, fecal				
4	Lincoln Creek near Seward, Nebr.	1973-86	14	0.15	+11	+1.7	–	–
5	Big Blue River at Seward, Nebr.	1974-86	13	<u>0</u>	+<u>55</u>	+<u>8.9</u>	0.37	-6.2
6	West Fork Big Blue River near Dorchester, Nebr.	1973-87	15	.51	+10	+1.0	.46	-2.1
7	Big Blue River near Crete, Nebr.	1971-83	13	.65	-170	-3.2	.40	-3.9
8	Turkey Creek near Wilber, Nebr.	1973-86	14	.35	+8.2	+1.1	.50	-1.6
10	Big Blue River at Barneston, Nebr.	1968-86	19	.53	+10	+2.1	.40	-2.5
15	Little Blue River at Hollenberg, Kans.	1970-86	17	.32	-33	-2.4	.51	-2.0
18	Big Blue River near Manhattan, Kans.	1971-86	16	.17	0	0	.59	-1.4
19	Kansas River at Wamego, Kans.	1971-86	16	<u>.05</u>	-<u>50</u>	-<u>10</u>	<u>.01</u>	-<u>15</u>
21	Kansas River at Topeka, Kans.	1967-81	15	.64	- .28	- .11	.23	+6.1
23	Soldier Creek near Topeka, Kans.	1972-86	15	.78	0	0	.65	-7.9
26	Kansas River at Lecompton, Kans.	1971-86	16	.96	+12	+ .46	–	–
29	Kansas River at DeSoto, Kans.	1967-81	15	<u>.01</u>	-<u>200</u>	-<u>9.5</u>	<u>.02</u>	- <u>8.4</u>
				Streptococci, fecal				
18	Big Blue River near Manhattan, Kans.	1971-86	16	.19	+3.6	+3.6	.50	+4.4
21	Kansas River at Topeka, Kans.	1967-81	15	.77	+2.3	+ .45	<u>.05</u>	+<u>8.9</u>
23	Soldier Creek near Topeka, Kans.	1972-86	15	.98	0	0	.87	-3.3
26	Kansas River at Lecompton, Kans.	1971-86	16	.34	+29	+2.6	<u>.04</u>	+<u>16</u>
29	Kansas River at DeSoto, Kans.	1967-86	20	<u>.01</u>	-<u>75</u>	-<u>9.2</u>	<u>.01</u>	-<u>10</u>

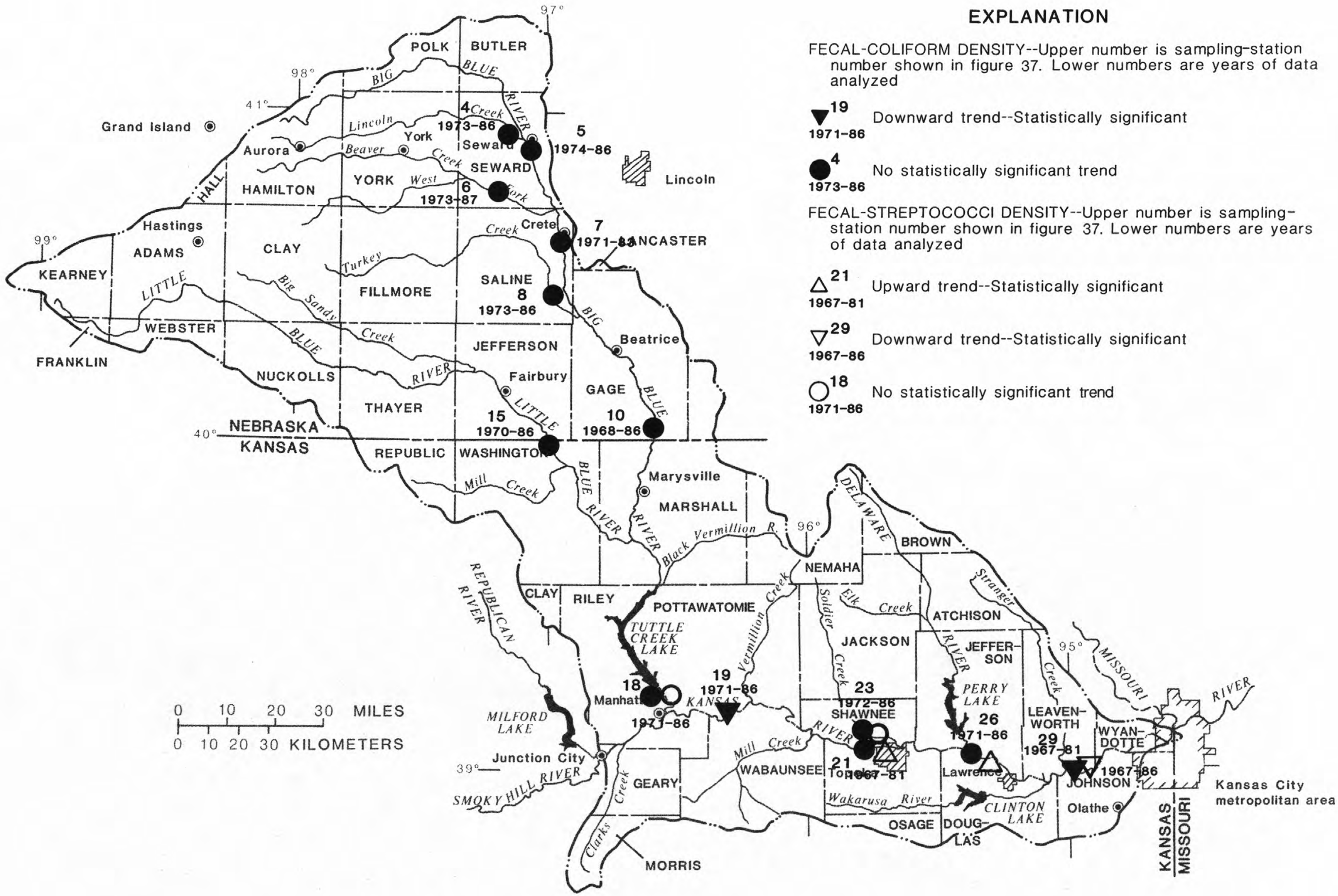


Figure 39.—Results of time-trend tests for fecal-indicator bacteria in water from lower Kansas River basin.

Aquatic Biological Community

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Periodic assessment of the aquatic biological community is an important part of any organized water-quality monitoring program. Changes in the composition of the biological community can serve as an index to changes and trends affecting human use of the resource. This section summarizes the biological water-quality data available within the lower Kansas River basin.

Phytoplankton and Periphyton

Phytoplankton (plants that are suspended or floating in the water) and periphyton (plants that are attached to various substrates) are primarily responsible for converting nutrients to organic, living substances and storing energy derived from light through the process of photosynthesis in the aquatic environment. They represent a major part of the aquatic food chain and, therefore, are important in characterizing the quality of surface water.

Phytoplankton and periphyton are present in lotic (flowing) environments, including the main stem Kansas River and its tributaries. In both lotic and lentic (stillwater) environments, turbidity can limit phytoplankton and periphyton growth by decreasing light penetration and absorption. Phytoplankton occur in small perennial tributaries and larger downstream waterways. Periphyton occur in shallow areas and slow-moving backwaters of both large and small waterways where sunlight can penetrate to the substrate.

Information on phytoplankton and periphyton in the lower Kansas River basin is limited to short-duration studies and studies of localized problems, and is of little value for characterizing regional water quality and detecting alterations. The main stem of the Kansas River was studied by Taylor (1976), Cross and deNoyelles (1982), and Howick and Huggins (1987). Data indicate that under optimum conditions in the Kansas River, total phytoplankton and periphyton photosynthetic production is only "intermediate" according to Taylor (1976). Little information regarding phytoplankton and periphyton was available for tributaries of the Kansas River, and no information was available for the Big Blue and Little Blue River basins in Nebraska. Data for phytoplankton in lentic environments have been collected from Perry Lake (Engelken, 1974; O'Brien, 1975; U.S. Environmental Protection Agency, 1977a), Tuttle Creek Lake (Marzolf and Osborne, 1971; Osborne and Marzolf, 1972; U.S. Environmental Protection Agency, 1977b), and Clinton Lake (U.S. Army Corps of Engineers, written commun., 1987; C. Fromm, Kansas Department of Health and Environment, written commun., 1987). Marzolf and Osborne (1971), Osborne and Marzolf (1972), and O'Brien (1975) concluded that primary productivity in Tuttle Creek and Perry Lakes was smaller than in most North American reservoirs because of turbidity.

Macroinvertebrates

Benthic macroinvertebrates are organisms growing on or principally associated with the bottom of waterways and include species of insects, clams, snails, and crayfish. The benthic macroinvertebrate community is a stationary water-quality monitor. Organisms in this community are constantly exposed to quality changes in the over-passing water. Because of minimal organism motility, detrimental water-quality changes may result in alterations in the macroinvertebrate community that persist for extended periods, even after the cause has been eliminated.

Three specific orders of insects, *Trichoptera* (caddisflies), *Plecoptera* (stoneflies), and *Ephemeroptera* (mayflies), are considered to be very sensitive to pollution, whereas other organisms are considered quite tolerant. A conspicuous absence of caddisflies, stoneflies, and mayflies or a large percentage of tolerant organisms (leeches, sludgeworms, sewage flies) can be an indication of poor water quality. Only time and a resurgence of adequate water quality will allow a "healthy" benthic community to become reestablished through drift and reproduction.

Macroinvertebrates have been studied in the lower Kansas River basin as part of several short-term studies and as part of a few long-term water-quality monitoring studies performed by State health and environmental agencies (fig. 40). Individual studies have been completed in Tuttle Creek Lake (Klaassen and Marzolf, 1971), Kings Creek (Petersen, 1979; Gurtz and others, 1982), Soldier Creek (Cringan and Haslouer, 1984), and in the Kansas River main stem (Marzolf, 1979; Cross and deNoyelles, 1982). A macroinvertebrate data base is being developed by the Kansas Biological Survey (Lawrence), and a seasonal water-quality model is under study using benthic macroinvertebrates as a monitoring element (Howick and Huggins, 1987).

Macroinvertebrates were collected from both the Big and Little Blue River basins in Nebraska (fig. 40) by the Nebraska Department of Environmental Control in 1985 and 1986. Most of the sites sampled were selected to represent the best stream conditions and biological fauna for the different-sized streams and substrate types in the two basins.

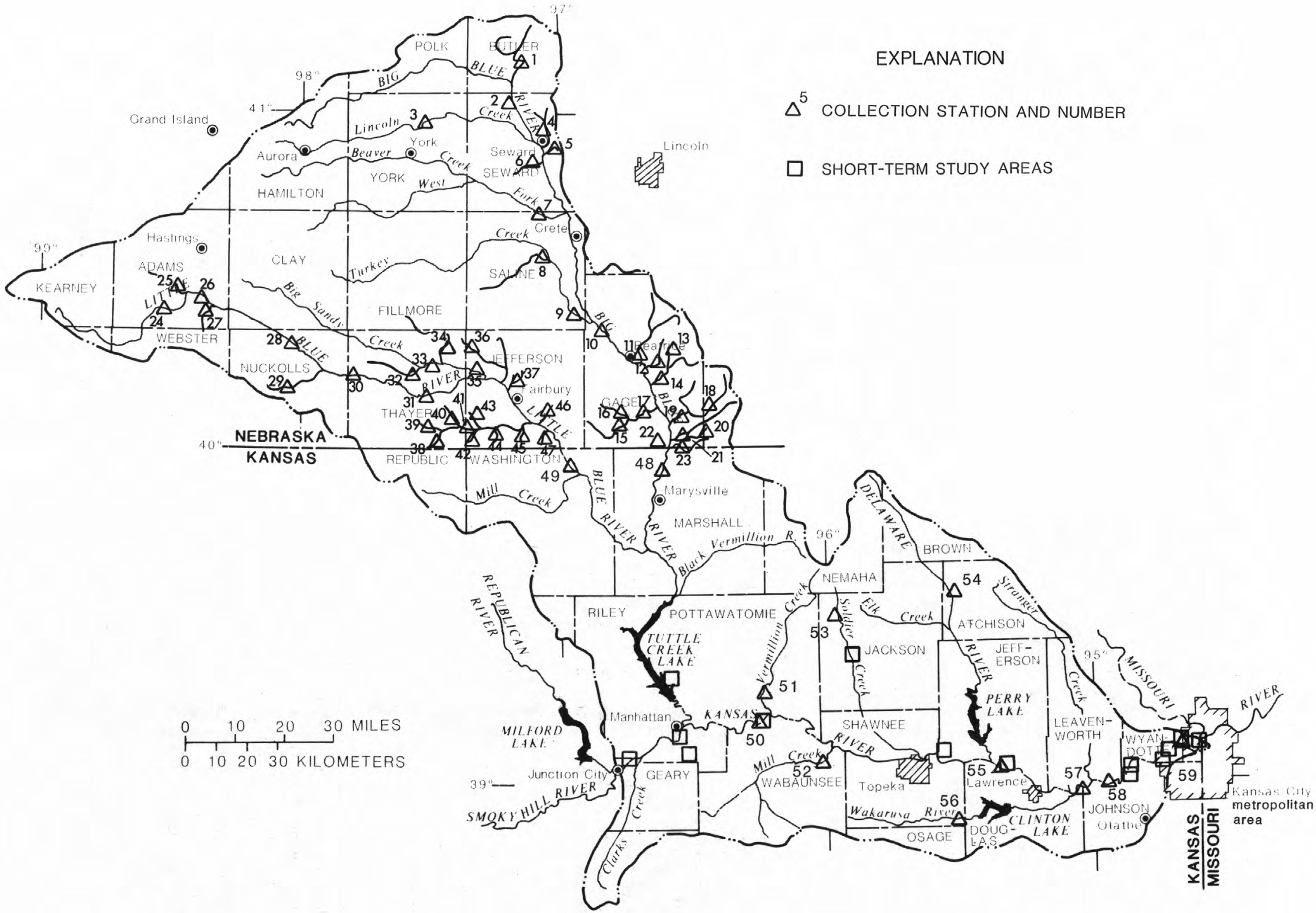

Figure 40.—Location of macroinvertebrate-collection stations and short-term study areas in lower Kansas River basin.

Table 39.—*Summary of macroinvertebrate data from selected collection stations in Big and Little Blue River basins in Nebraska, 1985-86*

[Summarized from data provided by Nebraska Department of Environmental Control (Lincoln). TPE, *Trichoptera*, *Plecoptera*, and *Ephemeroptera*]

Streams	Number of stations	Collection-station number (fig. 40)	Median number of species	Median of total TPE
Big Blue River main stem and West Fork Big Blue River	3	2,7,10	18	9
Big Blue River basin—smaller streams	20	1,3,4,5,6,8,9, 11,12,13,14,15, 16,17,18,19,20, 21,22,23	24	6.5
Little Blue River main-stem stations excluding smallest two; and Big Sandy Creek near its mouth	4	28,30,31,35	13	4
Little Blue River basin—smaller streams	20	24,25,26,27,29, 32,33,34,36,37, 38,39,40,41,42, 43,44,45,46,47	23.5	6

The total number of species sampled that belong to the orders *Trichoptera, Plecoptera, or Ephemeroptera* (TPE) provides an indication of the diversity in the benthic fauna at each location (table 39). These are the species that decrease in abundance with poor water-quality conditions. It appears that the larger streams in the Big Blue River basin possessed a slightly healthier benthic community (median number of species = 18; median of total TPE = 9) as compared to the larger streams in the Little Blue River basin (median number of species = 13; median of total TPE = 4). However, the smaller streams in the two basins had very similar median values.

The Kansas Department of Health and Environment has sampled macroinvertebrate communities as part of its biological monitoring since 1972 (stations 48-59, fig. 40). Macroinvertebrate data are assessed as a macroinvertebrate biotic index (MBI) based on identification to the family or generic level (Kansas Department of Health and Environment, 1986a, p. 8). The Kansas Department of Health and Environment determines the degree of support of aquatic life from the MBI and other biological and chemical data. The MBI combines the organic-pollution tolerance of benthic organisms with estimates of community structure and is applied to stream data to determine the general relation of these benthic communities to water quality (Kansas Department of Health and Environment, 1986a, p. 9).

Data presented in table 40 are a summary of data collected during 1978-86, the period selected to represent current conditions. According to the Kansas Department of Health and Environment (1986a, p. 14), an MBI of 5.4 or greater indicates nonsupport of aquatic life; an MBI greater than 4.5 but less than 5.4 indicates partial support; and an MBI of 4.5 or less indicates full support for the designated use. In general, water quality does not appear to have severely hindered the macroinvertebrate communities existing in the Kansas part of the lower Kansas River basin.

Fish Populations

Fish occupy the top part of the aquatic food chain and are dependent upon lower life forms in the chain. Nutrient concentrations, water temperature, turbidity, and many other factors determine the abundance of lower life forms upon which fish directly or indirectly depend. Other water-quality characteristics have direct effects on fish survival. These characteristics include dissolved-oxygen concentrations, sulfide concentrations, pH, and un-ionized ammonia levels. Although other elements combine to form suitable fish habitat, water quality and its generating factors are of utmost importance to a life form whose entire existence is within this single medium.

Table 40.—*Summary of data on number of taxa collected and macroinvertebrate biotic index for selected collection stations in Kansas, 1978-86*

[From data on file with the Kansas Department of Health and Environment, Topeka]

Collection-station number (fig. 40)	Location	Number of collections	Years	Median number of taxa collected	Macroinvertebrate biotic index[1] (rounded) Median	Range
48	Big Blue River near Oketo, Kans.	9	1978-86	26	4.3	3.5–5.2
49	Little Blue River near Hollenberg, Kans.	9	1978-86	35	4.5	3.9–5.0
50	Kansas River near Wamego, Kans.	9	1978-86	30	4.3	3.8–4.5
51	Vermillion Creek near Louisville, Kans.	3	1982-84	37	4.7	4.6–4.8
52	Mill Creek near Maple Hill, Kans.	3	1982-84	52	4.7	4.6–4.8
53	Soldier Creek near Circleville, Kans.	2	1985-86	39	4.5	4.2–4.8
54	Delaware River near Muscotah, Kans.	3	1982-84	36	4.5	4.4–4.6
55	Kansas River near Lecompton, Kans.	9	1978-86	32	4.3	3.6–5.1
56	Wakarusa River near Richland, Kans.	5	1982-86	46	5.3	4.6–5.5
57	Kansas River near Eudora, Kans.	4	1978-81	25.5	4.0	3.6–4.2
58	Kansas River near DeSoto, Kans.	9	1978-86	31	4.2	4.0–5.2
59	Kansas River near Kansas City, Kans.	9	1978-86	21	3.6	2.6–5.6

[1]Macroinvertebrate biotic index combines the organic-pollution tolerance of benthic organisms with estimates of community structure (Kansas Department of Health and Environment, 1986a, p. 8).

Fish in the lower Kansas River basin have been sampled on several occasions, mainly as part of short-term studies. Kansas and Nebraska fish and wildlife agencies have conducted comprehensive sampling studies in the study unit. The Nebraska Game and Parks Commission prepared two publications that dealt with species distributions in the Big and Little Blue River basins (Bliss and Schainost, 1973 a,b), and the Kansas Department of Wildlife and Parks prepared two stream-survey documents on the Big Blue and Kansas River basins (Hartmann, 1980a,b). An additional study was conducted on the lower Kansas River by Cross and deNoyelles (1982) for the U.S. Army Corps of Engineers. A compilation of information in these five documents, along with information taken from a stream- and river-evaluation map for Kansas (Moss and Brunson, 1981), has resulted in a list of fish species observed in the waterways of the study unit (table 41). Ponds in the lower Kansas River basin are dominated by populations of bluegill, bullhead, channel catfish, and largemouth bass.

As of 1986, there were no Federally listed endangered or threatened fish species within the lower Kansas River basin. Likewise, the State of Nebraska did not document any endangered or threatened fish as occurring within the Nebraska part of the study unit. However, the State of Kansas listed the pallid sturgeon and sicklefin chub as endangered species and the chestnut lamprey as a threatened species wherever they occur within the basin (Kansas Administrative Regulation 23-17-1). Additionally, Kansas Administrative Regulation 23-17-3 declared the following fish species in the study unit to be in need of additional conservation: blackside darter, blue sucker, brassy minnow, plains minnow, river shiner, tadpole madtom, and Topeka shiner.

Impoundments on streams have had more drastic effects on the fish fauna of the lower Kansas River basin than any other human factor, with the exception of agricultural development (both crop and livestock production). According to R.J. Higgins and P. Smith (U.S. Soil Conservation Service, oral commun., 1987), approximately 16,500 lakes and ponds have been built

Table 41.—*Fish species observed in waterways of lower Kansas River basin*

[Occurrence:

1, Kansas River	4, Delaware River	7, Vermillion Creek
2, Stranger Creek	5, Soldier Creek	8, Big Blue River
3, Wakarusa River	6, Mill Creek	8A, Little Blue River

N, fish species in need of conservation (Kansas Administrative Regulation 23-17-3);
T, threatened fish species (Kansas Administrative Regulation 23-17-1);
E, endangered fish species (Kansas Administrative Regulation 23-17-1)]

[Sources of information: Bliss and Schainost, 1973a,b; Hartmann, 1980a,b; Moss and Brunson, 1981; Cross and deNoyelles, 1982]

Species	Latin names	Occurrence								
		1	2	3	4	5	6	7	8	8A
American eel	*Anguilla rostrata*	x								
bigmouth buffalo	*Ictiobus cyprinellus*	x			x				x	
bigmouth shiner	*Notropis dorsalis*	x						x	x	
black bullhead	*Ictalurus melas*	x	x	x	x	x	x		x	x
black crappie	*Pomoxis nigromaculatus*	x		x					x	
blacknose shiner	*Notropis heterolepis*								x	x
blackside darter (N)	*Percina maculata*						x			
bluegill	*Lepomis macrochirus*	x	x	x	x	x	x	x	x	x
blue sucker (N)	*Cycleptus elongatus*	x								
bluntnose minnow	*Pimephales notatus*	x	x	x	x	x	x	x	x	x
brassy minnow (N)	*Hybognathus hankinsoni*							x		
bullhead minnow	*Pimephales vigilax*	x				x				
central stoneroller	*Campostoma anomalum*	x	x	x	x	x	x	x	x	x
channel catfish	*Ictalurus punctatus*	x	x	x	x	x	x	x	x	x
chestnut lamprey (T)	*Ichthyomyzon castaneus*	x								
common carp	*Cyprinus carpio*	x	x	x	x		x	x	x	x
common shiner	*Notropis cornutus*	x		x			x		x	x
creek chub	*Semotilus atromaculatus*	x	x	x	x		x	x	x	x
emerald shiner	*Notropis atherinoides*	x							x	x
fathead minnow	*Pimephales promelas*	x		x	x		x	x	x	x
flathead catfish	*Pylodictis olivaris*	x	x	x	x	x	x	x	x	x
freshwater drum	*Aplodinotus grunniens*	x	x	x	x	x	x	x	x	x
gizzard shad	*Dorosoma cepedianum*	x	x		x		x		x	x
golden shiner	*Notemigonus crysoleucas*	x	x	x	x		x		x	
goldeye	*Hiodon alosoides*	x							x	
green sunfish	*Lepomis cyanellus*	x	x	x	x	x	x	x	x	x
johnny darter	*Ethestoma nigrum*			x			x	x	x	
largemouth bass	*Micropterus salmoicles*	x	x	x	x		x	x	x	x
logperch	*Percina caprodes*	x		x			x			
longear sunfish	*Lepomis megulotis*	x	x		x		x			
longnose gar	*Lepisosteus osseus*	x					x	x	x	
mosquitofish	*Gambusia affinis*			x						
orange spotted sunfish	*Lepomis humilis*	x	x	x	x		x		x	x
orangethroat darter	*Ethestoma spectabile*	x	x	x	x	x	x		x	x
paddlefish	*Polyodon spathula*	x								
pallid sturgeon (E)	*Scaphir hynchus albus*	x								
plains killifish	*Fundulus kansae*									x
plains minnow (N)	*Hybognathus placitus*	x			x					
quillback	*Carpiodes cyprinus*	x							x	x
red shiner	*Notropis lutrensis*	x	x	x	x	x	x	x	x	x
redfin shiner	*Notropis umbratilis*	x		x			x			
river carpsucker	*Carpiodes carpio*	x	x	x	x	x	x	x	x	x
river shiner (N)	*Notropis blennius*	x								
rosyface shiner	*Notropis rubellus*					x				
sand shiner	*Notropis stramineus*	x	x	x	x	x	x	x	x	x
sauger	*Stizostedion canadense*	x								
shorthead redhorse	*Moxostoma macrolepidotum*	x		x	x	x	x	x	x	x
shortnose gar	*Lepisosteus platostomus*	x							x	
shovelnose sturgeon	*Scaphirhynchus platorynchus*	x								
sicklefin chub (E)	*Hybopsis meeki*	x								
silver chub	*Hybopsis storeriana*	x								
skipjack herring	*Alosa chrysochloris*	x								

Table 41.—*Fish species observed in waterways of lower Kansas River basin*—Continued

[Occurrence:
1, Kansas River; 2, Stranger Creek; 3, Wakarusa River; 4, Delaware River; 5, Soldier Creek; 6, Mill Creek; 7, Vermillion Creek; 8, Big Blue River; 8A, Little Blue River

N, fish species in need of conservation (Kansas Administrative Regulation 23-17-3);
T, threatened fish species (Kansas Administrative Regulation 23-17-1);
E, endangered fish species (Kansas Administrative Regulation 23-17-1)]

[Sources of information: Bliss and Schainost, 1973a,b; Hartmann, 1980a,b; Moss and Brunson, 1981; Cross and deNoyelles, 1982]

Species	Latin names	Occurrence								
		1	2	3	4	5	6	7	8	8A
slender madtom	*Noturus exilis*	x	x	x	x	x	x		x	
smallmouth buffalo	*Ictiobus bubalus*	x							x	x
southern redbelly dace	*Phoxinus erythrogaster*						x			
speckled chub	*Hybopsis aestivalis*	x								
spotted bass	*Micropterus punctulatus*			x						
stonecat	*Noturus flavus*	x	x	x	x	x	x		x	x
sturgeon chub	*Hybopsis gelida*	x								
suckermouth minnow	*Phenacobius mirabilis*	x	x	x	x	x	x	x	x	x
tadpole madtom (N)	*Noturus gyrinus*								x	
Topeka shiner (N)	*Notropis topeka*	x			x		x	x		
walleye	*Stizostedion vitreum*	x			x					
western silvery minnow	*Hybognathus argyritis*	x								
white bass	*Morone chrysops*	x							x	
white crappie	*Pomoxis annularis*	x		x	x		x		x	x
white sucker	*Catostomus commersoni*	x	x	x	x		x			
yellow bullhead	*Ictalurus natalis*	x	x	x		x		x	x	

in the study unit since 1945 for the storage of water and regulation of flows downstream. Impoundments decrease peak flows that occur during wet seasons and allow for increased flows during dry seasons. Regulated streams tend to decrease aquatic habitat diversity by decreasing the meandering nature of streams and leveling the stream bottom. These processes result in a decrease in pool-riffle-run complexes and decrease habitat diversity for fish.

Impoundments destroy habitat for fish species adapted only to flowing water; however, reservoirs provide new habitats for fish well suited to more lentic conditions. Area reservoir development has provided food chains, water types, and cover for adaptable native fish species as well as some fish not native to the basin. Increased abundance of predator species has decreased the abundance of some small stream fish. Overall, however, diversity of fish species in the lower Kansas River basin may have increased as a result of reservoir development.

According to Willis (1986, p. 110), water-level management for the benefit of fish in Kansas reservoirs consists of four basic steps. These steps are: (1) a spring rise and hold to flood terrestrial vegetation; (2) a summer drawdown of about 4 feet to allow regrowth of vegetation and concentrate predators and their prey; (3) an autumn rise of about 2 feet to flood some terrestrial vegetation and attract waterfowl; and (4) a winter drawdown to once again concentrate predators and prey and protect remaining vegetation from water damage. These steps usually are not fully realized because they often conflict with and are given lower priority than other water-management objectives.

The Kansas water-level management plan works well in achieving its objectives (Willis, 1986). Water transparency increased, and three of four targeted fish species benefited from these management efforts. Walleye, white crappie, and white bass had larger population densities as a result of these efforts, whereas largemouth bass appeared to be negatively affected and had smaller population densities.

A dam that has had significant effects on fish populations in the lower Kansas River basin is the Bowersock Mills and Power Company dam, constructed before 1900 on the Kansas River at Lawrence, Kans. This dam is a barrier to upstream fish migration. The dam's greatest effect is on those fish species that inhabit the lower part of the Kansas River and would otherwise migrate upstream to spawn. Most of the affected species, such as the channel catfish, flathead catfish, walleye, and white bass, are still able to spawn at sites upstream of the dam or are present in the river because they are stocked in tributary lakes. However, three species, the blue sucker, paddlefish, and sauger, are no longer found or are rare upstream of the dam.

A large number of commercial sand-and-gravel dredging operations occur on the Kansas River downstream from Lawrence, Kans. These operations have affected the fish community, as observed by Cross and deNoyelles (1982, p. 268-273):

> "In its natural state, the lower Kansas River has limited habitat diversity, consisting primarily of shallow flows over a nearly flat, sandy bed ***. The fish community is dominated by a few species well adapted to occupy shallow water over sandy substrates and feed on microorganisms or detritus ***.
>
> " *** changes in habitat conditions for fishes [near aging dredge sites in the lower Kansas River] resulted in 1) further decline in the abundance of species dominant in the undredged river, 2) loss of species adapted to gravelly riffles, and 3) further increase in the abundance of species adapted to large pools and silt substrate."

Sediment affects fish populations in several ways. Suspended sediment decreases light penetration and, thus, primary production of phytoplankton and plant growth. It also acts abrasively on fish gills and decreases the ability of predatory fish to find prey. Settling sediment fills pools, levels the stream bottom, covers benthos and spawning areas, and generally decreases habitat diversity for fish. Most of the fish species indigenous to the Kansas River in presettlement times were "*** morphologically adapted for life in shallow, sandy, turbid rivers" (Cross, 1967, p. 12).

Sediment accumulating in the three Federal reservoirs in the basin (as well as several such reservoirs in the basins of the two rivers forming the Kansas River) is not being transported downstream in the Kansas River (Simons, Li, and Associates, Inc., 1984, p. 4.33). Similarly, the numerous ponds and watershed lakes built in the area in about the last 50 years have acted to trap sediment originating from cultivated fields. The result is decreased turbidity and, as noted by Cross and deNoyelles (1982, p. 160), a change in the relative abundance of different fish species. Almost all of the fish species that have decreased in abundance are small-eyed and possess dense tactile and chemosensory systems, which are characteristic of fish inhabiting turbid water. Fish species that have increased in abundance are large-eyed and lack an abundance of tactile and chemosensory systems, which makes them more adapted to clearer water.

Fish samples have been analyzed for selected contaminants as part of the National Pesticide Monitoring Program [known as the National Contaminant Biomonitoring Program (NCBP) since 1984] and the U.S. Environmental Protection Agency's Regional Ambient Fish Tissue Monitoring Program (RAFTMP). Pertinent results from these programs are summarized in the sections of this report entitled "Major Metals and Trace Elements" and "Pesticides and Other Synthetic-Organic Compounds."

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