SELECTED WATER-QUALITY CHARACTERISTICS IN THE UPPER MISSISSIPPI RIVER BASIN, ROYALTON TO HASTINGS, MINNESOTA

By M. R. Have

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply Inch-Pound Unit	By	To obtain Metric Unit
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
ton, short (T)	0.9072	megagram
feet per mile (ft/mi)	0.1894	meters per kilometer

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

MAP CREDITS

Maps for this report were prepared using Digital Line Graph maps unless otherwise noted. Hydrologic information is from the following 1:100,000 digital data maps: Anoka, 1985; Glencoe, 1986; Hastings, 1985; Lake Mille Lacs, 1985; Lake Minnewaska, 1986; Litchfield, 1986; Mora, 1985; St. Cloud, 1986; St. Paul, 1985; and Wilmar, 1986.

1:250,000 land use and land cover digital data (which includes land use and land cover units, political units, and hydrologic units) are from Brainerd, 1977; Duluth, 1980; New Ulm, 1979; St. Paul, 1979; and Stillwater, 1980.

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ABSTRACT

The upper Mississippi River basin from Royalton to Hastings, Minnesota, includes seven subbasins in east-central Minnesota that cover an area of 8,500 square miles. Results of a study, using data from the Minnesota Pollution Control Agency, Metropolitan Waste Control Commission, and the U.S. Geological Survey, indicate that selected water-quality characteristics differ significantly among subbasins. Results of the study also indicate that the quality of water leaving the basin at Hastings is affected primarily by inflow from the Minnesota River and by effluent from the Metropolitan sewage-treatment plant.

Subbasins in the western part of the study area are underlain by prairie soils and cultivation of row crops is a common land use. Streams draining these subbasins have a median dissolved-solids concentration of 389 mg/L (milligrams per Liter) and a median concentration of nitrite plus nitrate nitrogen of 0.59 mg/L. Subbasins in the northern and eastern parts of the study area are underlain by more acidic podzol soils. Land use in these subbasins is less devoted to cultivated crops; forested areas, pastures, and wetlands are common. Streams draining these subbasins have a median dissolved-solids concentration of 184 mg/L and a median concentration of nitrite plus nitrate nitrogen of 0.17 mg/L.

The quality of water changes dramatically in the most downstream subbasin, which includes the Twin Cities Metropolitan Area. On the basis of hourly data from automatic monitors, specific conductance increases from 345 μS/cm (microsiemens per centimeter) at 25° Celsius above the confluence with the Minnesota River to 467 μS/cm below it. Specific conductance increases to a median of 513 μS/cm where effluent from the Metropolitan sewage-treatment plant enters the Mississippi River.

Dissolved-oxygen concentrations in the Mississippi River begin to decline below the confluence with the Minnesota River. Concentrations of dissolved oxygen reach a minimum median value in summer of 6.3 mg/L at a point about 9 miles downstream from the Metropolitan sewage-treatment plant. In winter, minimum median concentration is downstream at Lock and Dam 2, which is approximately 20 miles below the plant.

Results of this study show that the quality of water in the Mississippi River as it leaves the accounting unit at Hastings is not representative of water quality in most of the accounting unit. Three water-quality regions have been identified, and sampling sites are needed in each region to assess the quality of streams throughout the study area adequately.

INTRODUCTION

In recent years, great emphasis has been placed on protection and conservation of water resources. In response to these needs, the U.S. Geological Survey established a monitoring network called NASQAN (National Stream Quality Accounting Network) in 1973. It was established to provide uniform and continuing measurements to document the quality of the Nation's rivers.

To fulfill the objectives of NASQAN, stations were established near the downstream ends of hydrologic-accounting units. These accounting units are further divided into subbasins called cataloging units that are bounded by drainage divides. This study was initiated mainly to review and analyze data for accounting unit 070102 in east central Minnesota and to determine whether data collected at the NASQAN station, Mississippi River at Nininger, Minnesota, is representative of the accounting unit in general. The study area is divided into seven subbasins (fig. 1). The numeric character in the site number represents the number of the subbasin. The alpha characters are used as sequence numbers. Site 6K, Mississippi River at Nininger, is the NASQAN station shown downstream from the Twin Cities (Minneapolis-St. Paul) in subbasin 6. Quality of water leaving the study area is monitored at this site.

Site 1A, Mississippi River near Royalton, is a NASQAN station located within the headwaters of the study area. Quality of water entering the study area is monitored at this site.

Purpose and Scope

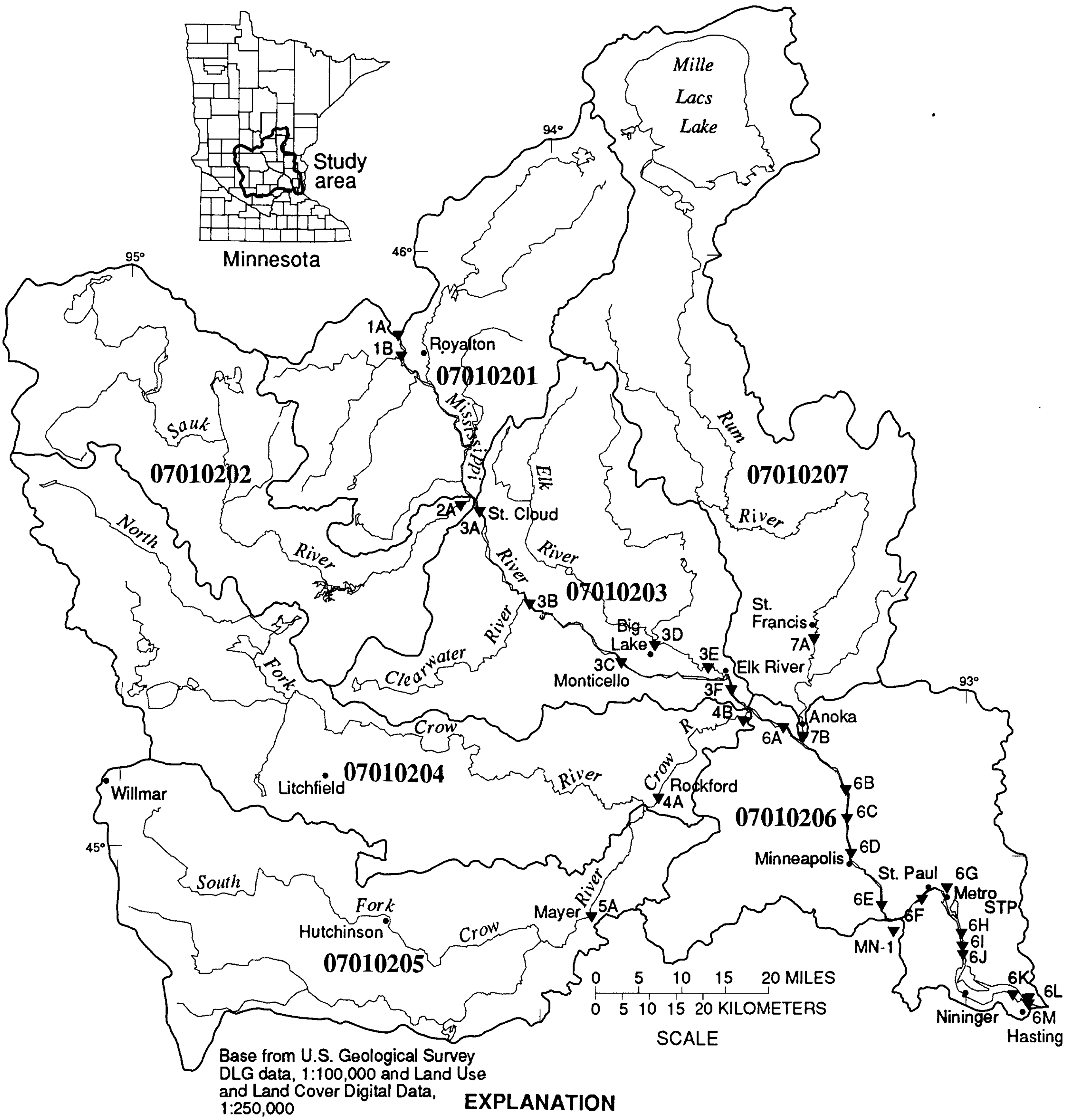
One of the objectives of NASQAN is to describe the areal variability in the quality of water in the nation's streams through analysis of data from this and other programs. With computerized statistical-analysis techniques available today, it is possible to analyze large quantities of data to aid in interpreting and in making decisions.

This report has the following primary objectives:

1. Describe, on both a spatial and temporal basis, the stream-water quality throughout the study area upstream from the NASQAN site, Mississippi River at Nininger, Minnesota.
2. Relate water-quality variability to general causes, such as selected basin characteristics, including land and water use.
3. Assess how well water-quality data collected at Nininger represent the quality of water throughout the study area.

The following secondary objectives are briefly addressed:

1. Describe the minimum data-collection program necessary to adequately assess the quality of water in the study area.
2. Assess the usefulness of daily values as compared to periodic water-quality data.



EXPLANATION

HYDROLOGIC UNIT CODE

Region — Accounting Unit

07010201

Subregion — Cataloging Unit (Subbasin)

——— Cataloging Unit boundary

▼7A Sampling site, number indicates Cataloging Unit

Figure 1. Location of primary sampling sites in Hydrologic Unit 070102.

In addressing the above objectives, this report first discusses the water quality in each subbasin, then examines the differences between subbasins, and then evaluates the representativeness of data collected at Nininger.

Study Area

The part of the Upper Mississippi River basin within the study area includes about 8,500 mi^2 (square miles) and 25 counties in Minnesota. The unit extends from approximately site 1A (milepoint 956) in the north to the mouth of the St. Croix River (milepoint 811).

There are six population centers in the study area with more than 5,000 people (table 1). The Twin Cities Metropolitan area, by far the largest of the six, includes 52 percent of the State's population. Statewide, between 1960 and 1970, there was about a 4-percent shift in population from rural to urban, but from 1970 to 1980, this general distribution remained relatively constant. The 1980 census showed that the population was 66.9 percent urban and 33.1 percent rural; within large metropolitan areas, however, redistribution of the population from urban to rural was occurring.

Water-use estimates for the study area, compiled from the Minnesota State Water-Use Data System maintained by the MDNR (Minnesota Department of Natural Resources), are shown in table 2. Surface-water use is larger than ground-water use because of surface-water requirements for power generation and because Minneapolis and St. Paul withdraw water from the Mississippi River for municipal use. Withdrawal for power generation is mainly for cooling; it does not include withdrawals for hydroelectric power.

The economy of the study area is based on agriculture and, in the metropolitan area, on electronics and medical-technology industries. Dairy farming is the main type of farming; dairy farmers generally grow most of their own feed crops such as corn, oats, and hay. The Mississippi River serves as a major transportation artery for shipment of grains south to other centers of population.

Topography and Geology

The watershed consists principally of level to rolling terrain. The present topography is derived mainly from drift left by glaciers of Pleistocene age that subsequently has been modified by erosion, plants and animals, and, more recently, man.

Three soil groups (fig. 2) within the study area roughly follow the distribution of the natural vegetation that existed before the arrival of settlers (Brown and others, 1969). The podzol soils in the northern part of the study area were developed under a mainly coniferous type forest. This type of soil is acidic and has a rather low natural productivity for cultivated crops. The gray-brown podzolic soils in the eastern part were developed under a mainly hardwood forest. These soils also tend to be acidic but are more productive than the podzol soils in the northern part. The prairie soils, covering the largest part of the watershed, are dark brown to nearly black because of a high organic content. The natural fertility of this group of soils is relatively high.

Table 1.--*Cities in Hydrologic Unit 070102 with populations greater than 5,000*

Source: U.S. Department of Commerce, 1982

City	Population 1960	Population 1980	Percentage increase	Subbasin
Hastings	8,965	12,827	43	6
Hutchinson	6,207	9,244	49	5
Litchfield	5,078	5,904	16	4
St. Cloud Metropolitan Area	37,853	48,359	28	3
Twin Cities Metropolitan Area	1,597,815	2,113,533	32	6
Willmar	10,417	15,895	53	5

Table 2.--*Water-use estimates for Hydrologic Unit 070102*

[Water use in millions of gallons per year]

Use type	Municipal	Private industrial	Irrigation	Power generation	Rural domestic	Rural livestock	Private commercial
Ground water	35,833.5	11,965.8	30,037.7	0	7,380.3	2,660.9	738.0
Percent of total ground water used	40	14	34	0	8	3	1
Surface water	61,367.4	18,952.1	3,803.1	145,781.3	0	469.0	0
Percent of total surface water used	27	8	2	63	0	0	0
Combined total	97,202.9	30,917.9	33,840.8	145,781.3	7,380.3	3,129.9	738.0
Percent of all use	30	10	11	46	2	1	0

From Minnesota water use data system, 1983.

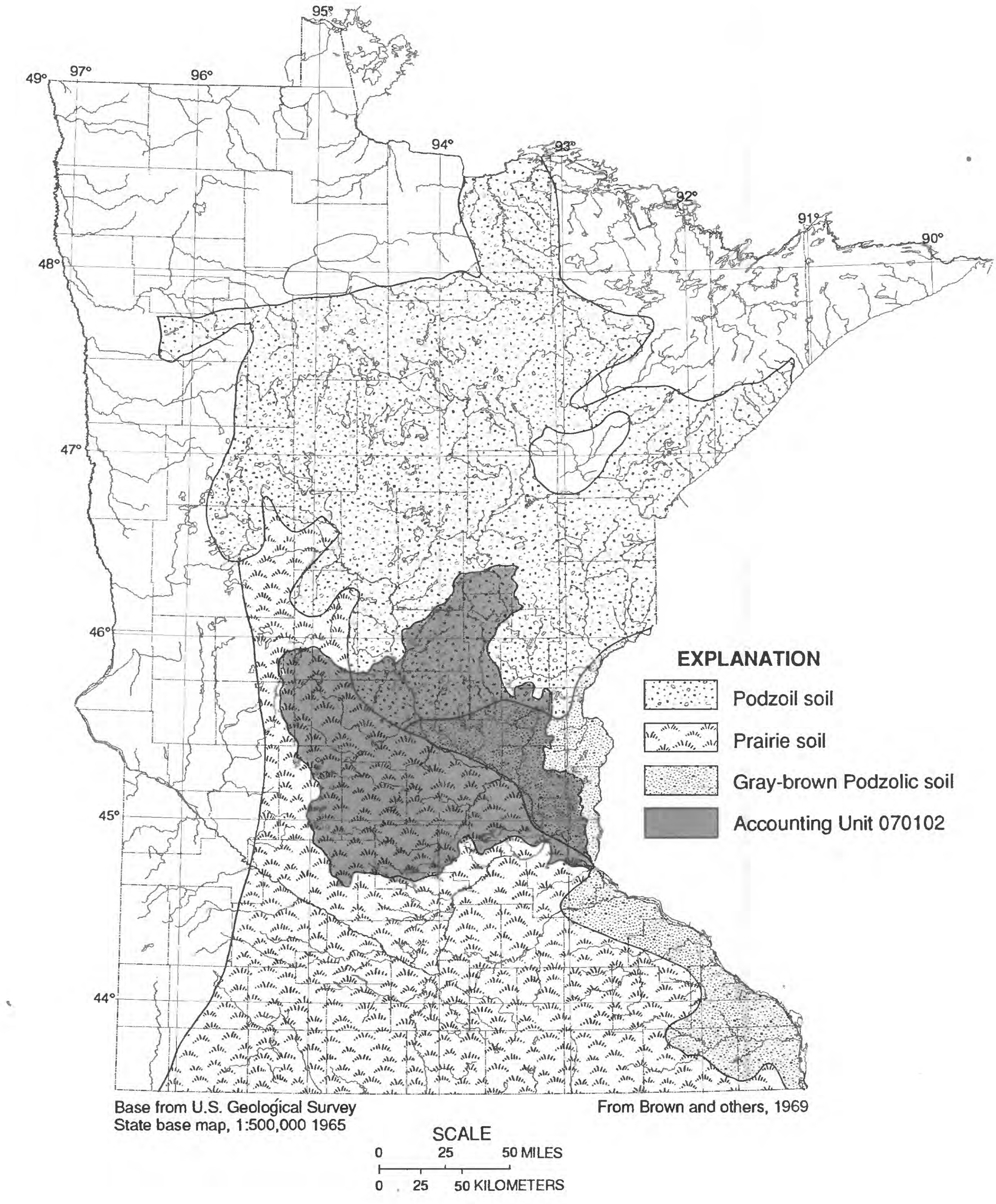


Figure 2. Soil groups in study area.

The watershed is underlain by Precambrian igneous and metamorphic rocks north of Big Lake. South of Big Lake, the watershed is underlain primarily by sandstone, dolomite, and limestone of Precambrian, Cambrian, and Ordovician age to the east and south and by shale of Cretaceous age to the southwest (Colingsworth and others, 1973).

Climate and Hydrology

The climate in Minnesota is a continental type, characterized by wide variations in temperature. The location of Minnesota makes it susceptible to frequent outbreaks of cold polar air from the north as well as warm moist air from the Gulf of Mexico. Lowest monthly average temperatures occur in January and the highest average temperatures occur in July. In general, there is a temperature decrease from south to north [fig. 3; (National Oceanic and Atmospheric Administration, 1984)].

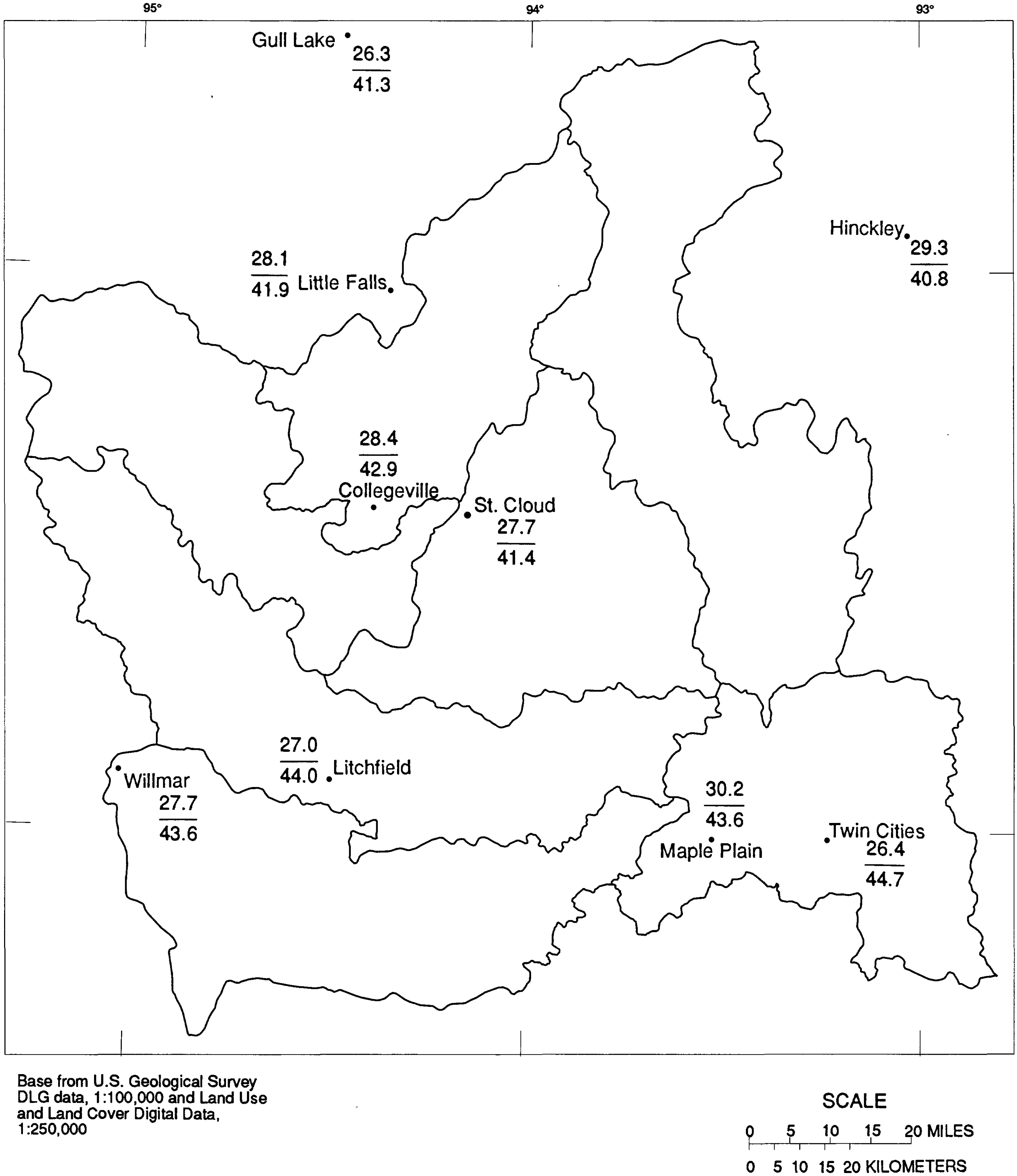
Average annual precipitation in the study area ranges from 26 to 30 in. (inches) with no discernible trend in any direction (fig. 3). Statewide, however, precipitation increases from northwest to southeast. June is the rainiest month followed by July and August. Precipitation in the winter months is mainly snow, with March being the snowiest month.

Evapotranspiration in the study area, based on the difference between precipitation and runoff, ranges from 20 in. in the north and west to more than 21 in. in the east (Baker and others, 1979). Runoff ranges from 5 to 6 in. in the north and west to 3 to 4 in. in the east and south.

SOURCES OF DATA AND LOCATION OF SAMPLING SITES

The two main sources of data were (1) STORET (Storage and Retrieval System) for data from the U.S. Geological Survey and MPCA (Minnesota Pollution Control Agency) and (2) a computer data base at the University of Minnesota for data from the MWCC (Metropolitan Waste Control Commission). WATSTORE (National Water Storage and Retrieval System) was the source of automatic-monitor data for the Twin Cities Metropolitan Area. Land-use data at a resolution of 40 acres were obtained from Minnesota Land Management Information Center.

Table 3 lists the primary water-quality sites. Sites 6C, 6E, 6G, 6I, 6J, and 6L, and MN-1 are also automatic-monitor sites where specific conductance, temperature, dissolved oxygen, and pH are automatically measured and recorded hourly. Mean daily values are calculated from the hourly readings. MN-1 is in Hydrologic Unit 070200 and is used, for the purposes of this report, as a point-source discharge to Hydrologic Unit 070102. There is a temperature recorder at site 6F. As with the automatic-monitor data, mean daily values are calculated from the temperature-recorder data. Secondary sites, where a limited amount of data from miscellaneous samplings was available, were used to help analyze areal variability within each subbasin.



EXPLANATION

27.0 Average annual precipitation in inches (1951-1980)

44.0 Average annual temperature in degrees Fahrenheit (1951-1980)

Figure 3. Average annual temperature and precipitation distribution in Hydrologic Unit 070102.

Table 3.--*Primary water-quality sites in Hydrologic Unit 070102*

[USGS, U.S. Geological Survey; MPCA, Minnesota Pollution Control Agency; MWCC, Metropolitan Waste Control Commission; mile point, miles upstream from the confluence of the Mississippi and Ohio Rivers; mile point for other rivers, miles upstream from mouth]

Site number	Name	Agency	Location	Drainage area (square miles)
1A	Mississippi River near Royalton	USGS	Mile point 956, 0.25 mile downstream from Minnesota Power Co. hydroelectric power plant	11,600
1B	Mississippi River west of Royalton	MPCA	Mile point 953, 3 miles downstream from Minnesota Power Co. hydroelectric power plant	11,650
2A	Sauk River at St. Cloud	MPCA	Mile point 2, 3 miles downstream from USGS gaging station 05270500, Sauk River near St. Cloud	930
3A	Mississippi River at Sauk Rapids	MPCA	Mile point 930, 3 miles downstream from Sauk River	13,400
3B	Mississippi River at Clearwater	MPCA	Mile point 914, 0.5 mile downstream from Clearwater River	13,700
3C	Mississippi River at Monticello	MPCA	Mile point 895	13,800
3D	Elk River near Big Lake	MPCA	Mile point 8, at USGS gaging station 05275000, Elk River near Big Lake	615
3E	Elk River at Elk River	MPCA	Mile point 1, above dam	650
3F	Mississippi River at Elk River	MPCA	Mile point 883, 2 miles downstream from Elk River	14,500

Table 3.--*Primary water-quality sites in Hydrologic Unit 070102*--Continued

Site number	Name	Agency	Location	Drainage area (square miles)
4A	Crow River at Rockford	USGS & MWCC	Mile point 17, 1 mile downstream from confluence of North and South Forks of the Crow River	2,520
4B	Crow River at Dayton	MPCA	Mile point 0.2, about 17 miles downstream from USGS gaging station 05280000, Crow River at Rockford	2,600
5A	South Fork Crow River near Mayer	USGS & MWCC	16 miles upstream from confluence with North Fork Crow River	1,170
6A	Mississippi River at Anoka	USGS & MWCC MPCA	Mile point 871.3, 0.3 mile upstream from Rum River	17,100
6B	Mississippi River near Anoka	USGS	Mile point 864.8, 6.2 miles downstream from Rum River at USGS gaging station 05288500, Mississippi River near Anoka	19,100
6C	Mississippi River at Fridley	USGS & MWCC	Mile point 862.8	19,110
6D	Mississippi River at Minneapolis Waterworks	MPCA	Mile point 859, 6 miles downstream from USGS gaging station 05288500, Mississippi River near Anoka	19,400
6E	Mississippi River at Ford Plant, St. Paul	USGS & MWCC	Mile point 847.6, 3 miles upstream from Minnesota River, above dam	19,700
6F	Mississippi River at St. Paul	USGS & MWCC MPCA	Mile point 839.3, 5.5 miles downstream from Minnesota River at USGS gaging station 05331000, Mississippi River at St. Paul. MPCA sampled 1,000 ft upstream	36,800

Table 3.--*Primary water-quality sites in Hydrologic Unit 070102*--Continued

Site number	Name	Agency	Location	Drainage area (square miles)
6G	Mississippi River at Industrial Molasses Plant, St. Paul	USGS & MWCC	Mile point 836.6, 0.5 mile upstream from Metropolitan sewage-treatment plant	36,840
6H	Mississippi River at Highway 494, Newport	USGS & MWCC	Mile point 832.5, 2.8 miles downstream from Metropolitan sewage-treatment plant	36,880
6I	Mississippi River at Fifth St., Newport	USGS & MWCC MPCA	Mile point 830.6. MPCA site is 1,500 ft downstream at the Inver Grove Heights bridge	36,900
6J	Mississippi River at Grey Cloud Island	USGS & MWCC	Mile point 826.2	37,000
6K	Mississippi River at Nininger	USGS & MWCC	Mile point 817.8	37,050
6L	Mississippi River at Lock and Dam 2	USGS & MWCC	Mile point 815.2 above Lock and Dam 2	37,080
6M	Mississippi River below Lock and Dam 2	USGS & MWCC MPCA	Mile point 814	37,100
7A	Rum River near St. Francis	USGS & MWCC	Mile point 15.8	1,360
7B	Rum River at Anoka	USGS & MWCC MPCA	Mile point 0.6, 450 ft downstream from dam	1,580
MN-1[a]	Minnesota River at Fort Snelling State Park, St. Paul	USGS & MWCC MPCA	Mile point 3	16,900

[a] MN-1 is in Hydrologic Unit 070200. It is used as a point-source discharge to Hydrologic Unit 070102.

METHODS OF EVALUATION

Except for data from automatic monitors, all water-quality data were stored on a computer at the University of Minnesota at Minneapolis. Missing streamflow data for sites on the Mississippi River between Royalton and Anoka were calculated using a log-transformed linear regression of site 6B against site 1A. Streamflows at site 7B were calculated using a linear regression of site 7A against site 7B. Streamflows for sites 6L and 6M were obtained from the U.S. Army Corps of Engineers. Missing streamflows for all other sites were calculated by using nearby gaging stations and adjusting for drainage area and travel time.

Values that were reported as "less than" were changed to values half the detection limit for purposes of statistical analysis. The data were evaluated by using the following guidelines:

1. maximum and minimum values for determining outlyers;
2. cation-anion balance within $\pm$ 5 percent;
3. ratio of specific conductance to sum of cations between 0.55 - 0.75;
4. ratio of specific conductance to sum of anions between 0.55 - 0.75;
5. ratio of dissolved solids to specific conductance between 0.55 - 0.75.

Statistical analysis of data on the university computer was done by using SPSS[1] (Statistical Package for the Social Sciences); (Nie and others, 1975). Monitor data were analyzed with the aid of SAS (Statistical Analysis System); (SAS Institute Inc., 1982)].

Trend analyses were done by using the nonparametric Spearman correlation test. Regressions of selected constituents with specific conductance were done by using a least-squares technique. The symbols, +, -, and 0 are used to denote trends, as follows: + is increasing trend; - is decreasing trend; ++ or -- are respectively, increasing or decreasing trends with the absolute value of the correlation coefficient greater than 0.75; and 0 is no apparent trend. No trend is indicated if the significance level is greater than 0.05 for a two-tailed test.

Five seasons are used for showing seasonal trends. They are: early spring, March and April; late spring, May and June; summer, July through September; fall, October and November; and winter, December through February.

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

SUBBASIN CHARACTERISTICS

Subbasin 1

Physical Characteristics

Subbasin 1 includes approximately 1,030 mi^2 and lies in the north-central part of the study area. It is mostly a rolling glacial-till plain ranging in elevation from about 1,260 to 990 feet above sea level. Most of the land is used for agriculture and dairying, but there is also a significant amount of forest (table 4). Urban areas are small and most communities have wastewater-treatment facilities.

Table 4.--Land use in subbasin 1

Use	Acres	Percentage of total
Cultivated	270,040	41.04
Extractive	120	.02
Forested	142,520	21.66
Marsh	12,440	1.89
Pasture and open	205,600	31.25
Transportation	80	.01
Urban nonresidential or mixed residential development	4,560	.69
Urban residential	8,440	1.28
Water	14,160	2.15

The Mississippi River flows 26 miles across subbasin 1 from NASQAN site 1A, river mile 956, to the mouth of the Sauk River, mile 930. The gradient is 1.5 feet per mile.

Site 1A, Mississippi River near Royalton, has been gaged since 1924, and mean-daily streamflow was computed on the basis of powerplant records provided by Minnesota Power Company. The average streamflow for the period of record through water year 1983 is 4,503 ft^3/s (U.S. Geological Survey, 1984, p. 56). A maximum daily discharge of 37,700 ft^3/s occurred April 16, 1965; a minimum of 254 ft^3/s occurred November 25, 1936. During the 1976-77 drought, a minimum streamflow of 412 ft^3/s occurred September 10, 1976 (U.S. Geological Survey, 1977, p. 241).

Water-Quality Characteristics

Two primary sites, 1A and 1B, and four secondary sites are used to describe the water quality. Site locations and land-use are shown in figure 4. The primary sites are on the Mississippi River and are approximately 3 miles apart. Inspection of data from the sites and results from the Mann-Whitney U-test suggest that the data sets can be combined. The Mann-Whitney U-test is a nonparametric test for differences between two sets of data.

The quality of water in the Mississippi River in this subbasin is considered to be the quality of the water entering the study area. Summary statistics for sites 1A and 1B are shown in table 5. The seasonal trend shows spring runoff beginning in early spring and the major part occurring in late spring. Peak daily flows, however, generally occur in April.

Concentrations of some constituents vary seasonally because of their relation with streamflow. Examples of this relation are shown in figure 5.

Specific conductance and concentrations of calcium and chloride are relatively large in early spring when the early part of spring runoff is mixed with base flow. As spring runoff increases, values of these constituents reach their minimum and then increase throughout the remainder of the year. There is a small increase in streamflow during the fall when evapotranspiration diminishes, but specific conductance and calcium and chloride concentrations continue to increase because streamflow during this period is increasingly composed of ground-water discharge. Ice formation in the winter increases concentrations to their maximum values as, for example, occurred with specific conductance and calcium concentration. Chloride concentration also increased at site 1A, however, when combined with site 1B, a slight decrease was noted, which can happen statistically when dealing with small concentrations. An increase in chloride concentration is expected to be similar to the increases in specific conductance and calcium concentration.

Concentrations of suspended solids and total phosphorus generally vary directly with streamflow (fig 5). Neither constituent is present in large concentrations, partly because of the large proportion of forested area above Royalton.

Examples of three constituents that are significantly influenced by factors other than streamflow are shown in figure 6. Dissolved oxygen is influenced mainly by water temperature. As temperatures decrease in the fall, dissolved-oxygen concentrations increase. Ice formation in the winter reduces reaeration, causing concentrations to decrease. Dissolved-oxygen concentrations increase again in early spring and then decrease to the lowest median concentrations in summer. Concentrations were below the 5.0 mg/L 1-day minimum for early life stages of warm-water fish populations (U.S. Environmental Protection Agency, 1986) during 3 of the 136 measurements. Dissolved-oxygen concentrations were 4.9 mg/L on February 7-8, 1977, and 4.6 mg/L on July 17, 1981.

Concentrations of fecal coliform bacteria increase with spring runoff, but the highest median concentrations occur during winter base flow. Although bacteria counts generally are not very high, it appears from the ratio of the medians for fecal coliform and fecal *Streptococci* in the winter (table 5) that the source of the bacteria is sewage effluent. Individual sample values, to which this ratio relation actually pertains, commonly have fecal coliform-to-fecal *Streptococci* ratios of four or greater in the winter. When the ratio is that large, it is evidence that the bacteria are derived from human wastes (Millipore, 1973).

Median concentrations of ammonia nitrogen did not vary seasonally; hence, the mean concentrations and ranges are plotted in figure 7. The mean-seasonal graph shows a trend in ammonia nitrogen that might be expected--an increase in winter during ice cover and lower concentrations during open water. There also is an inverse relation with streamflow, although the changes in concentration are slight. The range shows seasonal variations more dramatically. The higher concentrations in winter are further evidence of the influence of sewage effluent.

Regressions shown in table 6 were derived from the combined data for sites 1A and 1B, and are expected to be valid for the Mississippi River within subbasin 1. The equations that estimate concentrations of potassium, sulfate, and chloride are the least accurate and should be used with caution. The lower correlations for these three constituents reflect the low variance in concentrations of the ions themselves.

Trends for the period 1963-84 for sites 1A and 1B are shown in table 7. The 1976-77 drought probably had the most effect on the trends shown. Generally, water quality at sites 1A and 1B has not changed significantly during 1963-84. However, the increasing trends in sodium and chloride are possible evidence of road-salt usage. The high negative correlation coefficient for arsenic probably reflects refinements in the analytical method rather than a real trend. Older arsenic data reported by the State for concentrations below 10 were reported "less than 10". However, in late 1975, the State began reporting arsenic concentrations below 10 to whole numbers.

Data for the four secondary sites show many similarities but also some differences (table 8). Little Rock Creek has much higher nitrite plus nitrate nitrogen concentrations than any of the other streams. Both sites on Little Rock Creek are in an area where there is a relatively high percentage of cultivation compared to the other watersheds in the subbasin.

The Watab River has larger concentrations of dissolved solids than the other streams, reflecting effects of the higher population in its watershed on water quality. The Watab River is near the cites of St. Cloud and Sauk Rapids. Typically, the net effect of urbanization in a drainage area is an increase in dissolved solids concentration in runoff. Increased chloride concentrations, which contribute to dissolved solids, also result from urbanization, primarily from the use of road-deicing salts.

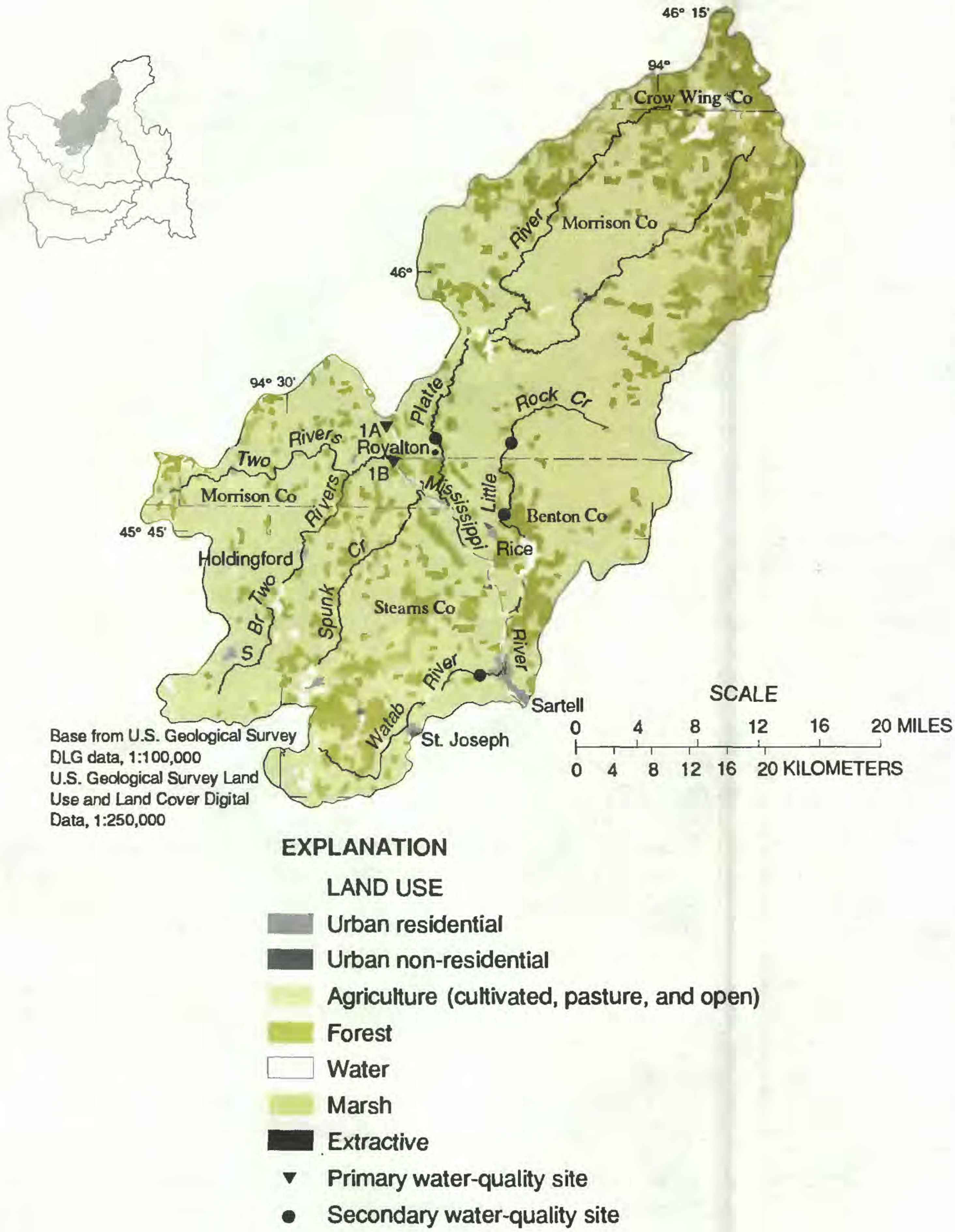


Figure 4. Land use and location of sampling sites in subbasin 1.

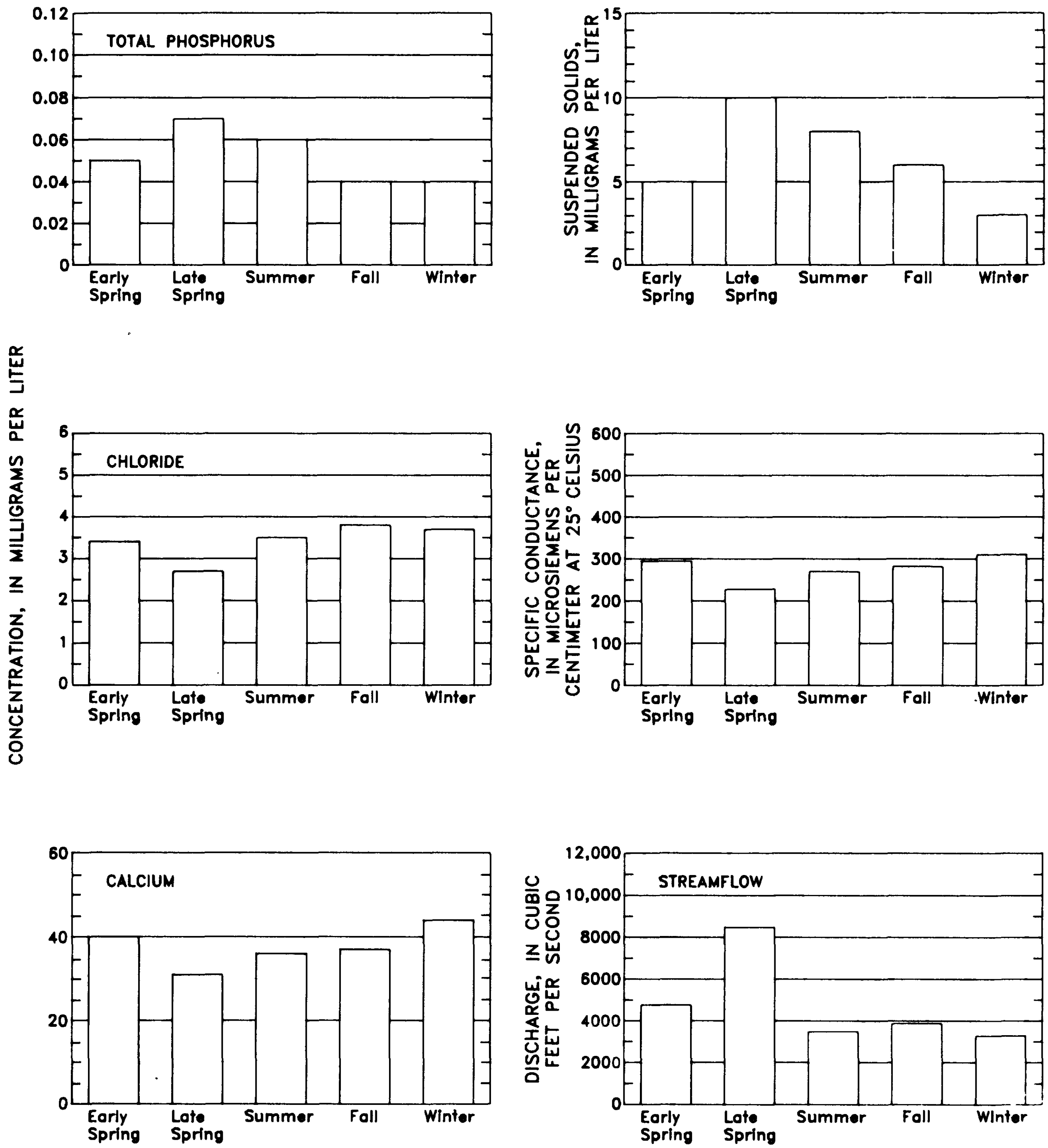


Figure 5.--Median seasonal variation in concentrations of selected constituents and in properties that change with streamflow in subbasin 1.

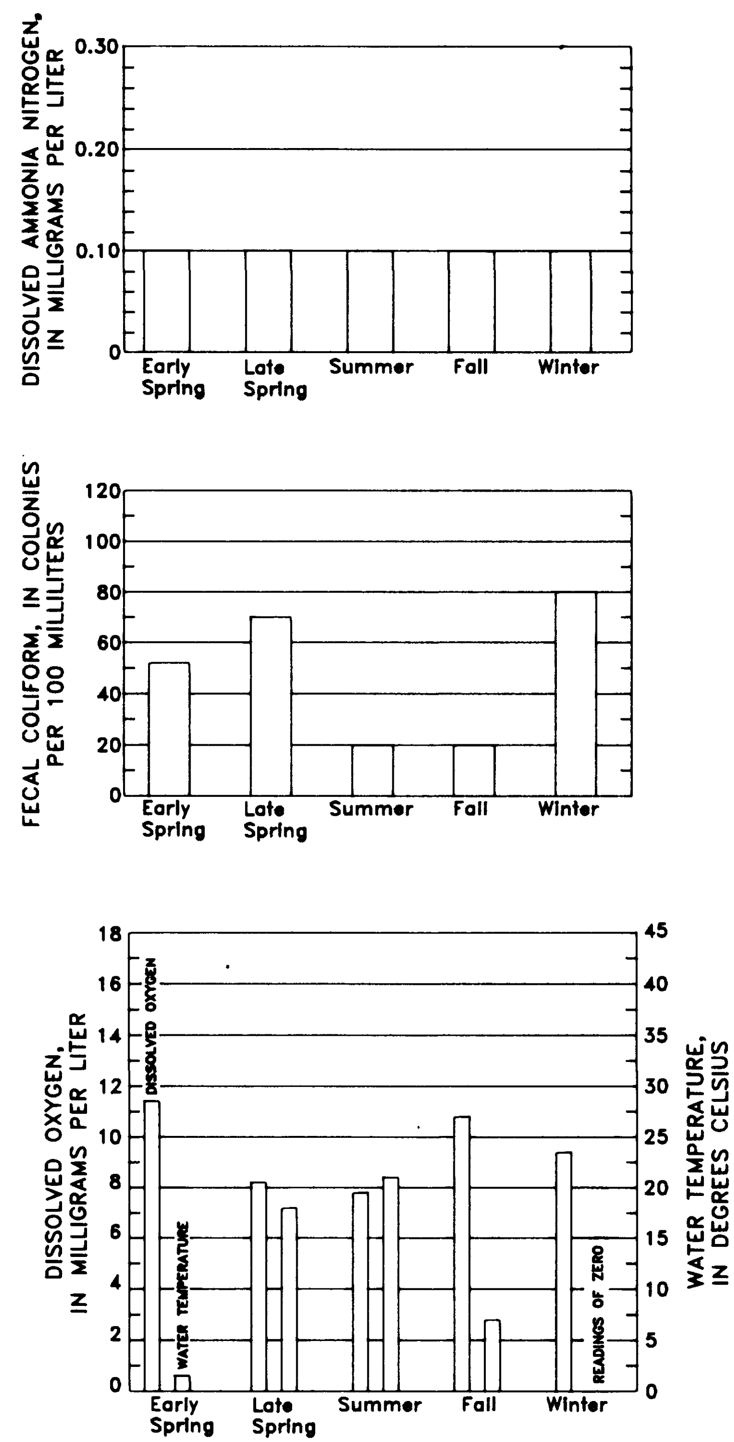


Figure 6.--Median seasonal variation in concentrations of selected constituents and in properties that are influenced by factors other than streamflow in subbasin 1.

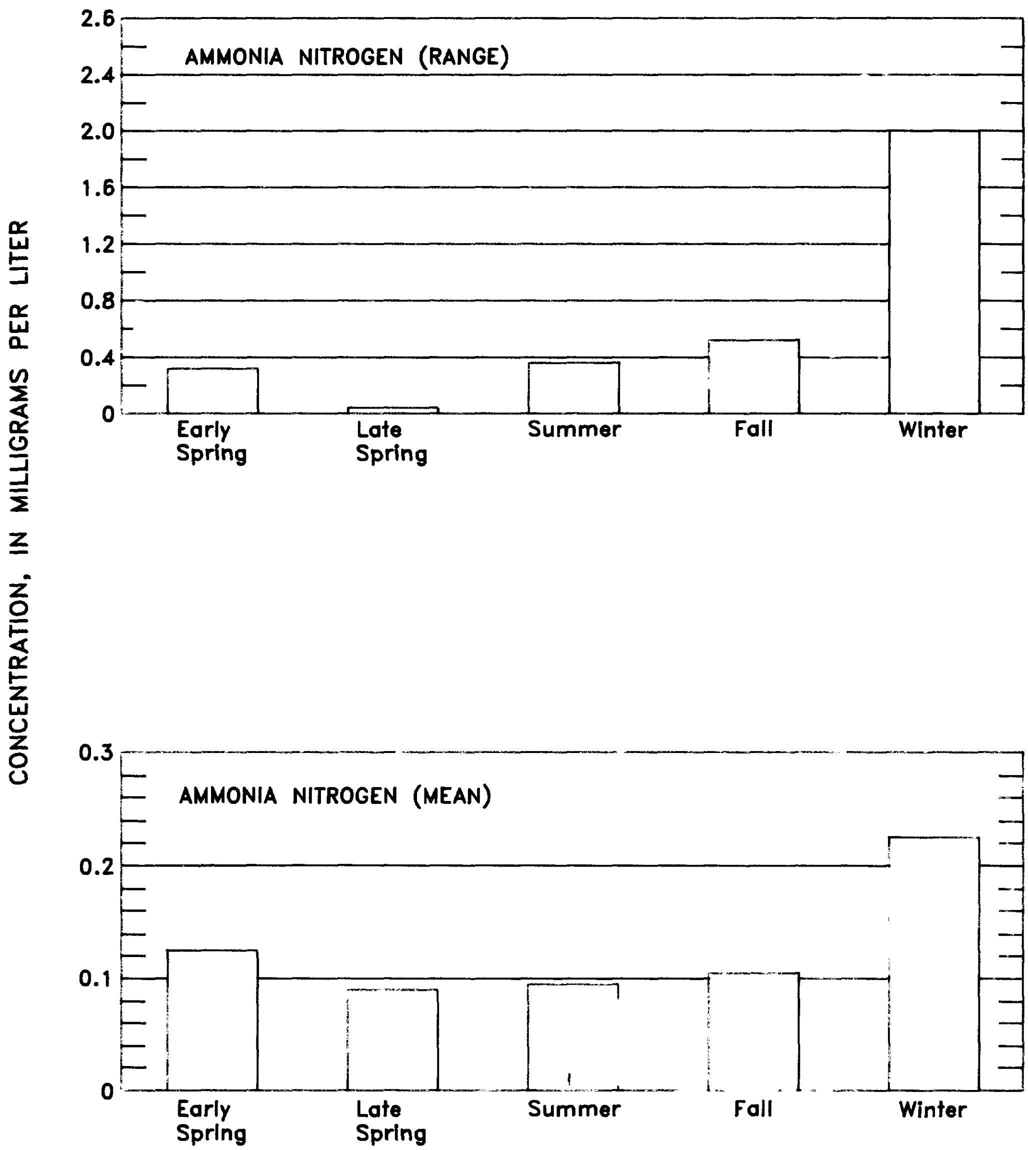


Figure 7.--Seasonal variation in the mean and range of ammonia-nitrogen concentrations in subbasin 1.

Table 5.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

	Period of record					
Constituent or property	Number of meas- urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	191	33,000	605	5,840	3,910	5,700
Specific conductance (μS/cm)............	187	580	150	280	280	61
pH (units)...........	183	8.9	6.8	7.8	7.9	0.4
Temperature (°Celsius).........	128	30.0	0.0	10.0	8.0	9.5
Oxygen, dissolved (mg/L).............	136	16.0	4.6	9.6	9.4	2.3
Fecal coliform (colonies/100mL)...	143	7,200	1	180	50	640
Fecal Streptococci (colonies/100mL)...	75	1,200	2	140	51	230
Calcium, dissolved (mg/L).............	165	60	17	38	38	7.5
Magnesium, dis- solved (mg/L)......	122	19	3.0	12	13	2.8
Sodium, dissolved (mg/L).............	166	11	1.2	5.4	5.2	1.9
Potassium, dis- solved (mg/L)......	165	5.0	.8	1.9	1.8	.7
Alkalinity, total (mg/L).............	145	220	74	140	140	26
Sulfate, dissolved (mg/L).............	148	23	2.5	9.3	8.8	3.6
Chloride, dissolved (mg/L).............	183	20	.6	3.7	3.4	2.0
Solids, dissolved (mg/L).............	0	--	--	--	--	--
Solids, suspended (mg/L).............	141	91	<1	12	8	13
Nitrite plus nitrate as nitrogen, dis- solved (mg/L)......	78	.57	.00	.16	.14	.12
Ammonia as nitrogen, dissolved (mg/L)...	116	2.1	.01	.13	.10	.20
Phosphorus, total (mg/L).............	149	.61	.02	.07	.06	.07
Phosphorus, dis- solved (mg/L)......	45	.15	.01	.03	.02	.02
Arsenic, total (μg/L).............	73	33	<1	4	5	3.9
Cadmium, total (μg/L).............	93	38	<1	6	5	5.9
Chromium, total (μg/L).............	30	30	<1	15	19	10
Lead, total (μg/L)...	75	29	<1	6	5	4.7
Manganese, total (μg/L).............	118	280	<1	84	80	54

at sites 1A and 1B, Mississippi River near Royalton, Minnesota, 1963-84

fall, October-November; winter, December-February; ft^3/s, cubic feet per second;
per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
4,710	--	8,600	--	3,440	--	3,980	--	3,350	--
293	--	230	--	272	--	280	--	312	--
7.8	--	8.0	--	8.0	--	8.2	--	7.7	--
1.5	--	18.0	--	21.5	--	7.0	--	.0	--
11.5	--	8.2	--	7.9	--	10.9	--	9.6	--
51	--	70	--	20	--	20	--	80	--
65	--	100	--	90	--	27	--	25	--
40	509	31	720	36	334	37	398	44	398
13	165	11	255	12	111	13	140	14	127
5.5	69.9	4.0	92.9	5.0	46.4	5.0	53.7	5.9	53.4
2.2	28.0	1.7	39.5	1.5	13.9	1.8	1.83	1.9	17.2
150	1,910	120	2,790	139	1,290	130	129	160	1,450
8.7	111	7.5	174	8.5	78.9	9.0	8.92	9.2	83.2
3.4	43.2	2.7	62.7	3.5	32.5	3.8	3.76	3.7	33.5
--	--	--	--	--	--	--	--	--	--
5	63.6	10	232	8	74.3	6	5.91	3	27.1
.24	3.05	.06	1.39	10	.93	.08	.11	.22	1.99
.10	1.27	.10	2.32	.10	.93	.10	.11	.10	.90
.05	.64	.07	1.62	.06	.56	.04	.43	.04	.36
.02	.25	.02	.46	.03	.28	.02	.21	.02	.18
4	.05	4	.09	5	.05	3	.03	2	.02
5	.06	5	.12	5	.05	5	.05	5	.04
25	.32	18	.42	10	.09	20	.21	10	.09
5	.06	5	.12	5	.05	5	.05	5	.04
80	1.02	100	2.32	95	.88	50	.54	70	.63

Table 6.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance in subbasin 1*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; <, less than]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Significance of r	Standard error of estimate
Streamflow (Q), ft^3/s.........	186	$Q = 535x10^7(SpC)^{-2.5}$	-0.66	<0.001	67 percent
Calcium (Ca), mg/L..........	158	Ca = 0.09(SpC) + 12	.74	<.001	5.1 mg/L
Magnesium (Mg), mg/L..........	113	Mg = 0.04(SpC) + 1.0	.84	<.001	1.4 mg/L
Sodium (Na), mg/L..........	159	Na = 0.02(SpC) + 0.4	.58	<.001	1.5 mg/L
Potassium (K), mg/L..........	151	K = 0.002(SpC) + 1.2	.24	.002	0.4 mg/L
Alkalinity (Alk) as $CaCO_3$, mg/L..........	145	Alk = 0.37(SpC) + 38	.84	<.001	14 mg/L
Sulfate (SO_4), mg/L..........	141	SO_4 = 0.2(SpC) + 3.3	.34	<.001	3.4 mg/L
Chloride (Cl), mg/L..........	173	Cl = 0.01(SpC) + 0.9	.36	<.001	1.4 mg/L

Table 7.--*Trends for selected constituents and properties at sites 1A and 1B near Royalton, Minnesota*

[+, increasing trend; -, decreasing trend; 0, no apparent trend]

Constituent or property	Number of observations	Trend for period of record
Streamflow	191	-
Specific conductance	187	+
pH	183	+
Temperature	128	0
Dissolved oxygen	136	0
Fecal coliform	143	-
Fecal *Streptococci*	75	0
Calcium	165	0
Magnesium	122	0
Sodium	166	+
Potassium	165	0
Alkalinity	145	0
Sulfate	148	0
Chloride	183	+
Suspended solids	141	0
Nitrite plus nitrate as nitrogen	78	0
Ammonia as nitrogen	116	-
Total phosphorus	149	-
Dissolved phosphorus	45	0
Arsenic	73	-
Cadmium	93	-
Chromium	30	+
Lead	75	0
Manganese	118	+

Table 8.--*Streamflow and water quality at secondary sites in subbasin 1*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; °C, °Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, value not determined; <, less than]

	Platte River at Royalton (05268000)				Little Rock Creek near Royalton (05268500)	Little Rock Creek at Rice (05268700)			Watab River near Sartell (05269800)
Constituent	Aug. 21, 1969	July 31, 1974	Sept. 29, 1976	Sept. 5, 1978	Sept. 6, 1978	Aug. 19, 1976	May 23, 1978	Sept. 6, 1978	Aug. 18, 1976
Streamflow (ft^3/s)...	49	48	3.9	76	3.3	7.7	19	16	5.3
Specific conductance (µS/cm)............	263	229	280	260	290	290	300	290	400
pH (units)...........	8.0	--	--	--	7.6	--	7.6	7.7	8.5
Temperature (°C).....	21.0	14.5	12.5	25.0	17.0	18.5	19.5	21.0	24.0
Calcium, dissolved (mg/L).............	34	28	38	36	43	40	48	43	47
Magnesium, dissolved (mg/L).............	11	9.5	13	11	10	10	11	10	21
Sodium, dissolved (mg/L).............	4.9	4.4	7.3	5.0	4.6	4.7	5.0	4.5	9.3
Potassium, dissolved (mg/L).............	1.0	.90	3.2	2.4	2.0	1.0	1.4	1.6	2.5
Alkalinity, total as $CaCO_3$ (mg/L).......	133	110	135	120	140	135	140	140	178
Sulfate, dissolved (mg/L).............	7.0	6.6	20	5.5	9.1	11	13	11	24
Chloride, dissolved (mg/L).............	2.6	3.5	4.7	5.1	3.5	3.0	4.7	3.9	12
Solids, dissolved (mg/L).............	162	128	172	183	189	166	199	188	227
Nitrite plus nitrate as nitrogen (mg/L).	--	<.10	.04	<.10	.99	1.4	.87	.53	.03
Phosphorus, total (mg/L).............	--	.05	.03	.05	.02	.05	.10	.04	.06
Manganese, total (µg/L).............	50	--	80	80	140	100	230	160	60

Subbasin 2

Physical Characteristics

Subbasin 2 has an area of approximately 1,000 mi^2 and is located in the northwestern part of the study area. It is mostly a rolling, glacial-till plain ranging in elevation from about 1,350 to 990 feet above sea level. Most of the land is used for agriculture and dairying and a significant amount is cultivated (table 9). The northwestern part of the St. Cloud area is within the lower end of the subbasin. All other urban areas are small, and most communities have waste-water-treatment facilities.

The Sauk River, which drains the entire subbasin, rises in Osakis Lake and flows southeast for 93 miles to join the Mississippi River near St. Cloud. The Sauk River falls about 340 feet in its length. Steepest slopes occur in the upper 12 miles where the fall is about 115 feet.

Table 9.--*Land use in subbasin 2*

Use	Acres	Percentage of total
Cultivated	366,200	54.80
Extractive	400	0.06
Forested	52,840	7.91
Marsh	11,240	1.68
Pasture and open	189,760	28.40
Transportation	800	.12
Urban nonresidential or mixed residential development	6,720	1.01
Urban residential	11,600	1.74
Water	28,680	4.29

U.S. Geological Survey gaging station 05270500 on the Sauk River near St. Cloud was operated for 51 years as follows: water years 1910-12, 1931, and 1935-81. The station was located 3 miles above site 2A. Average streamflow during the period of record was 276 ft^3/s, and the median of yearly mean streamflows was 237 ft^3/s (U.S. Geological Survey, 1982, p. 76). An instantaneous maximum flow of 9,100 ft^3/s occurred April 13, 1965; a minimum of 0.3 ft^3/s occurred November 25, 1936. During the 1976-77 drought, a minimum of 14 ft^3/s occurred October 28, 1976 (U.S. Geological Survey, 1978, p. 48).

Water-Quality Characteristics

Site 2A, sampled by MPCA from 1953-82, is the primary sampling site for subbasin 2. Data from this and seven secondary sites are used to describe water quality in subbasin 2 (fig. 8).

Table 10 shows summary statistics for site 2A. Trace-element concentrations, except for cadmium, meet ambient water-quality human-health criteria (U.S. Environmental Protection Agency, 1986). Cadmium exceeded the criterion in two samples collected on June 21, 1972, and July 29, 1974. Analytical methods were not as sensitive then as they are now (1984), which may explain the two high values. In fact, most of the arsenic, cadmium, and lead values were reported to be less than 10, which is why the medians tend to be near 5.0 μg/L.

Figure 9 shows selected constituents that usually exhibit a good direct or inverse relation to streamflow. At site 2A, however, water in the Sauk River does not show these typical relations because of the effect of lakes about 15 miles upstream.

Apparently, during spring runoff, the normal decrease in concentrations of dissolved solids (evidenced by specific conductance), chloride, and calcium and the normal increase in concentrations of suspended solids and total phosphorus occur. By summer, however, specific conductance and calcium values decrease more, total phosphorus increases, and suspended-solids concentrations remain relatively high. Summer concentrations at site 2A appear to reflect upstream release of impounded water. Most of the phosphorus probably is contained in algae. The suspended-solids concentration probably reflects the inorganic-material content of the stream in spring and organic-matter content in the summer. In fall and winter, streamflow is derived predominately from ground-water discharge; at this time, concentrations of chemical constituents return to levels more typical of most natural streams.

Examples of selected constituents whose concentrations depend on factors other than streamflow are shown in figure 10. Dissolved-oxygen concentrations show a good direct relation to temperature during the open-water period. In winter, during ice cover, dissolved-oxygen concentrations decline to a median of 9.7 mg/L. The minimum of 4.8 mg/L (table 10) was measured December 5, 1973. Ice cover in winter decreases reaeration, which reduces dissolved-oxygen concentration. In general, dissolved-oxygen concentrations are adequate to maintain healthy fish populations year round.

Median fecal-coliform counts vary directly with water temperature until winter. The unexpected increase during winter suggests that sewage effluent is entering the stream. The fecal coliform/fecal *Streptococci* ratio supports this suggestion, although there are not enough fecal *Streptococci* data to draw firm conclusions. Fecal-coliform counts greater than 1,000 colonies/100 mL of water were found in 16 of 124 samples. None of these high counts occurred concurrently with high flows, which is further evidence that the origin of the high fecal-coliform counts is sewage effluent rather than overland runoff.

Median ammonia-nitrogen concentrations increase under ice cover in winter and early spring. As spring runoff progresses, concentrations of ammonia nitrogen decrease rapidly and remain low until the following winter.

Seasonal means and ranges of ammonia-nitrogen concentrations are plotted, because they can show more information about seasonal variations (fig. 11). The plotted means for site 2A are similar to the medians shown in table 10. The ranges suggest that large concentrations occur in winter.

All correlation coefficients in table 11, except that for potassium, are statistically significant at the 95-percent confidence level. The regression equation for potassium is not usable.

The relatively low correlation coefficient for streamflow is from the effect of upstream lakes on specific conductance of water in the Sauk River. One should keep in mind that the standard error of estimate is 107 percent for this regression.

Trends from 1953-82 for site 2A are shown in table 12. In general, the quality of water has not changed. However, the increase in chloride, which has a Spearman correlation coefficient of 0.72 (probability level = 0.001) is evidence of road salts. Decreasing trends for trace-metal concentrations probably indicate refinement in analytical methods. The detection limits for many trace metals decreased in the 1970's and 80's. Concentrations for many trace metals are now reported to values below the original detection limits. As a result, the concentrations determined by improved analytical methods can show apparent decreases in metals concentrations over time.

Miscellaneous results in table 13 show variations in water quality in the subbasin. The effects of lakes can be seen in the miscellaneous analyses. Sauk River sites above the lakes near Cold Spring tend to have higher dissolved-solids concentrations, as evidenced by specific conductance, than sites downstream from the lakes. The August 17, 1976, sample collected near Farming is much different chemically from the sample collected August 18, 1976, at Cold Spring, even though the Cold Spring site is only about 15 miles downstream from the Farming site. The sample at Cold Spring shows streamflow to be much greater and concentrations of major ions and nitrite plus nitrate to be lower. The lower concentrations suggest that there is settling in the lakes and utilization of inorganic nitrogen. Total-phosphorus concentrations in the Sauk River are higher above the lakes, indicating nonpoint-source loading.

The two tributary streams, Adley Creek and Ashley Creek, seem to have lower dissolved-solids concentrations than the reach of the Sauk River above the lakes, but nitrite plus nitrate concentrations are similar.

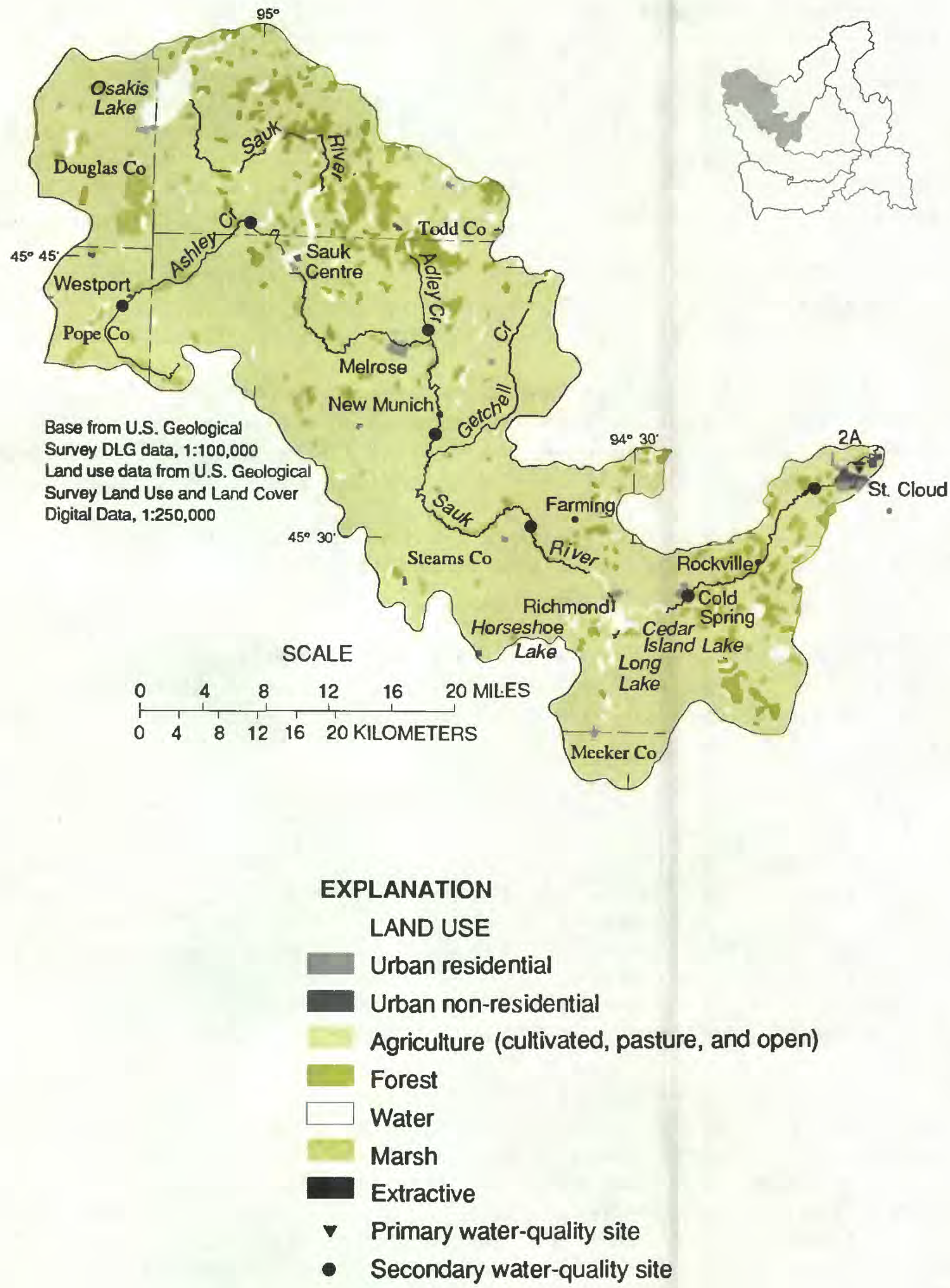


Figure 8. Land use and location of sampling sites in subbasin 2.

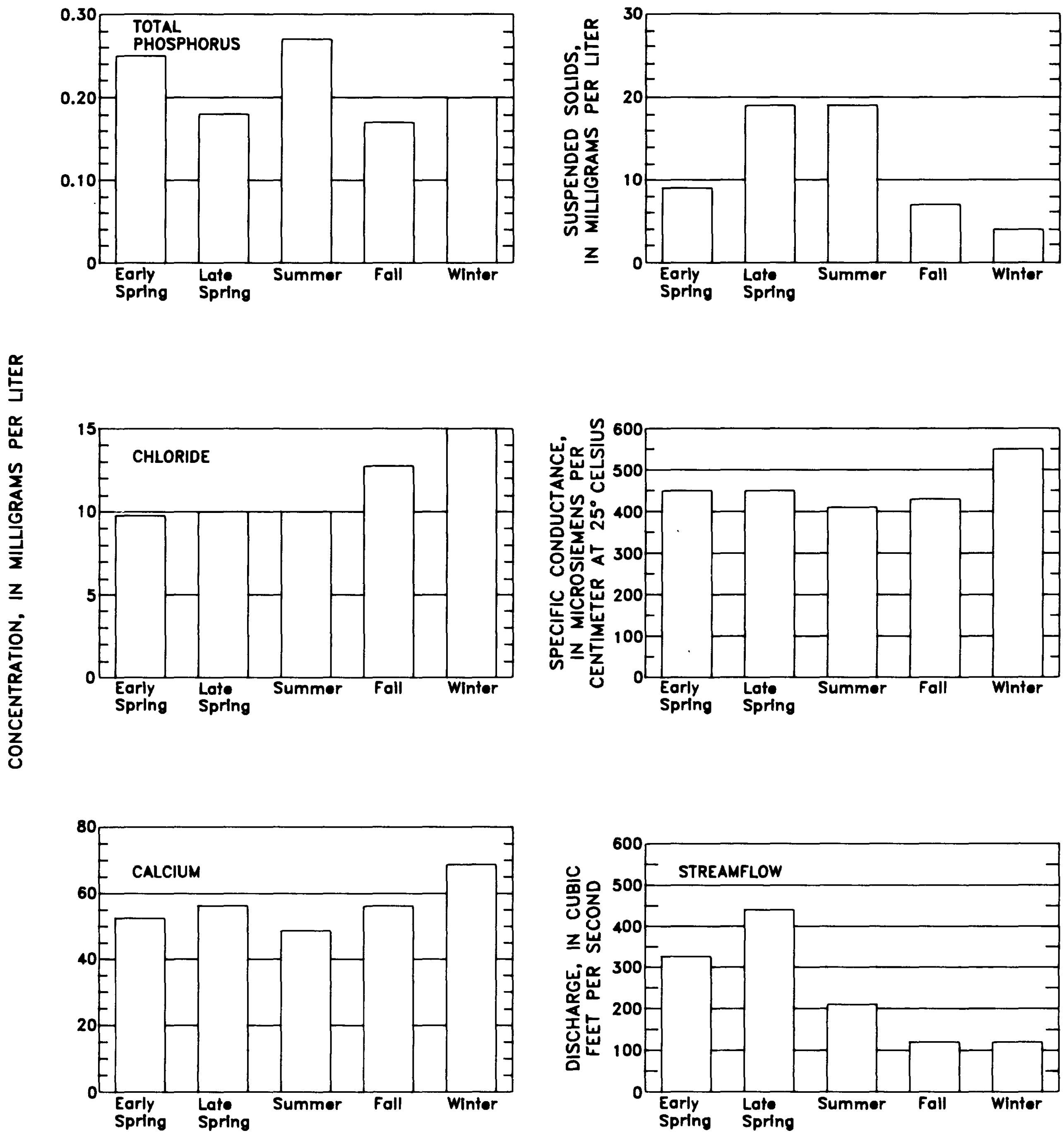


Figure 9.--Median seasonal variation in concentrations of selected constituents and in properties that change with streamflow at site 2A.

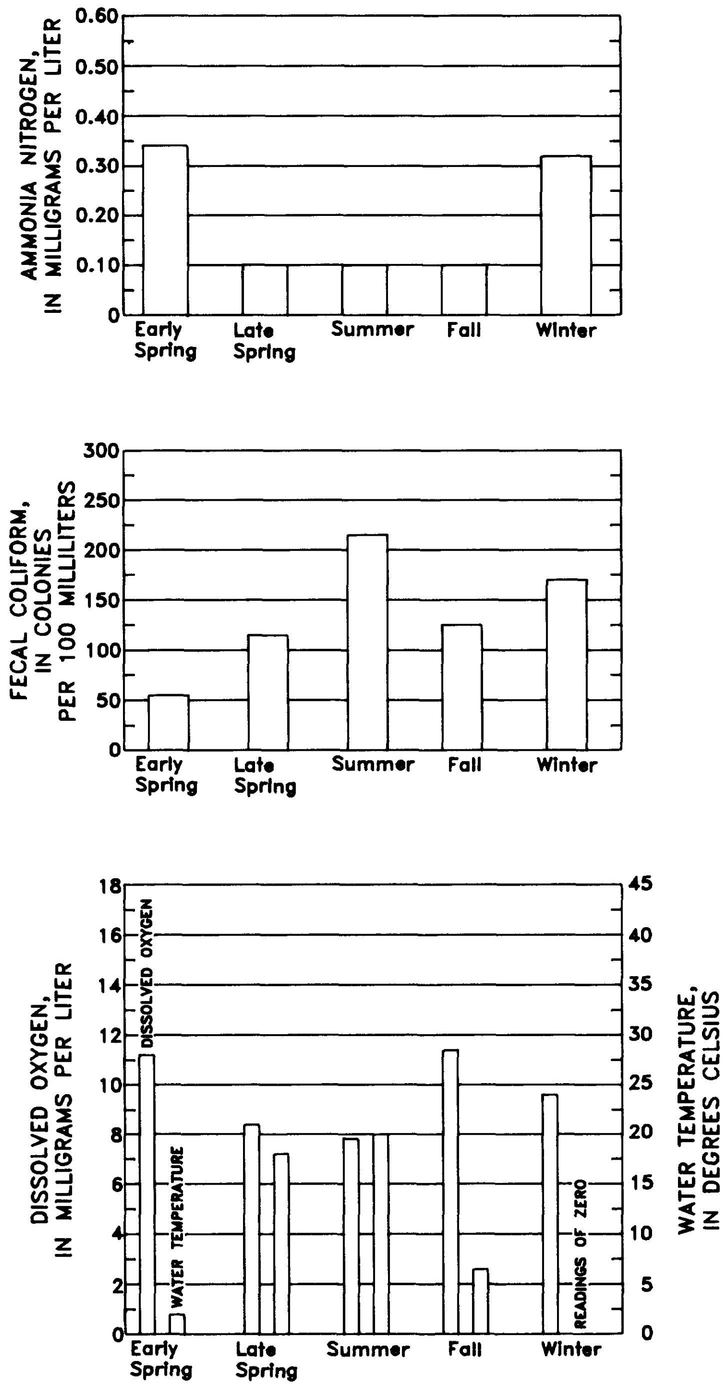


Figure 10.--Median seasonal variation in concentrations of selected constituents and in properties that are influenced by factors other than streamflow at site 2A.

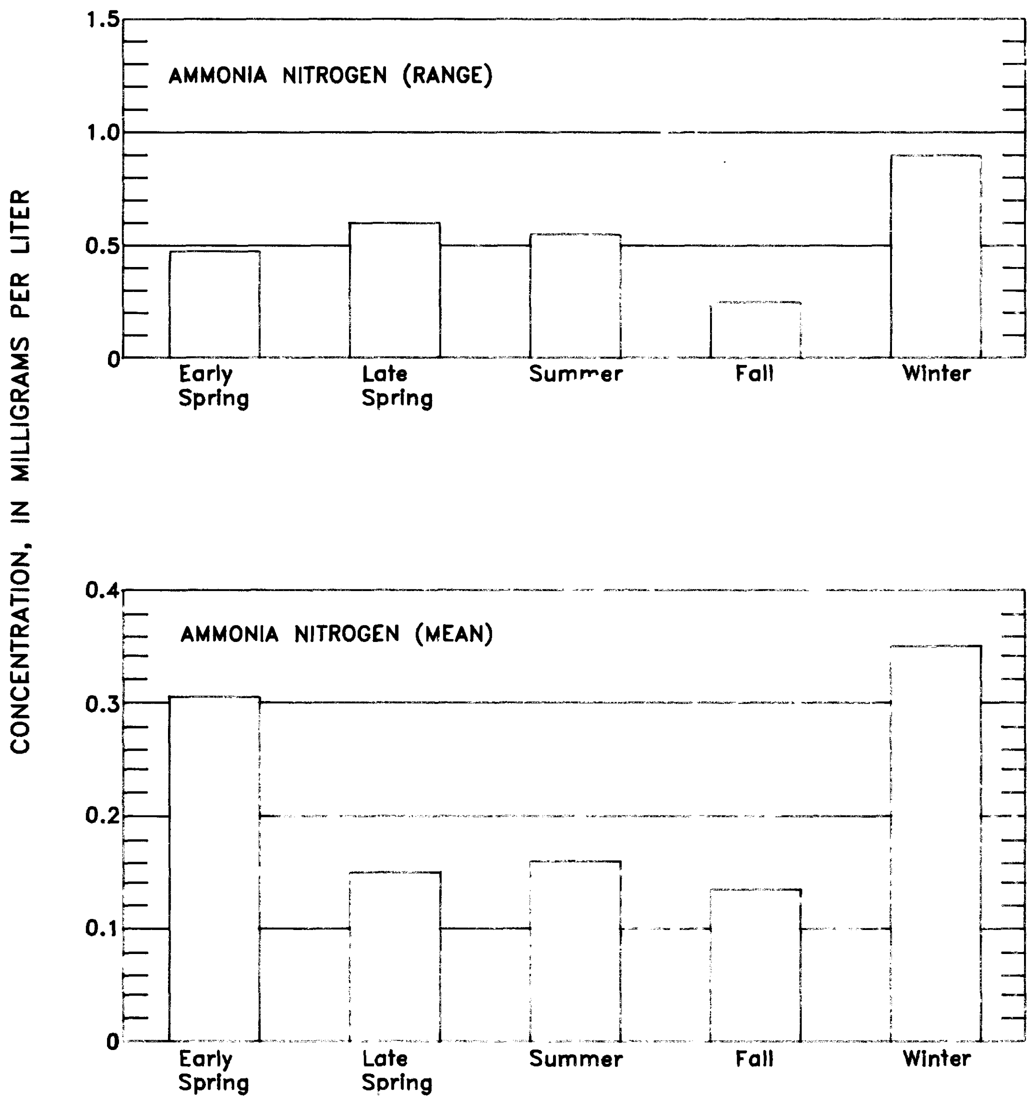


Figure 11.--Seasonal variation in the mean and range of ammonia-nitrogen concentrations at site 2A.

Table 10.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter;

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	148	2,780	23	385	224	478
Specific conductance (μS/cm)............	125	700	250	460	450	86
pH (units)...........	155	8.7	7.4	8.1	8.1	0.3
Temperature (degree Celsius)...	75	28.0	.0	10.5	11.5	9.0
Oxygen, dissolved (mg/L).............	157	15.9	4.8	9.6	9.3	2.2
Fecal coliform (colonies/100mL)...	124	16,000	2	770	130	2,200
Fecal Streptococci (colonies/100mL)...	8	370	9	120	50	130
Calcium, dissolved (mg/L).............	68	88	29	57	56	12
Magnesium, dissolved (mg/L)......	25	34	11	24	24	5.5
Sodium, dissolved (mg/L).............	59	22	4.2	10	9.6	3.7
Potassium, dissolved (mg/L)......	58	9.0	1.0	4.4	4.0	1.6
Alkalinity, total (mg/L).............	85	300	140	212	206	34
Sulfate, dissolved (mg/L).............	43	48	10	30	30	8.3
Chloride, dissolved (mg/L).............	82	30	.5	12	12	6.2
Solids, dissolved (mg/L).............	2	300	280	290	290	14
Solids, suspended (mg/L).............	140	150	<1	16	12	18
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	68	3.0	.01	.66	.38	.63
Ammonia as nitrogen, dissolved (mg/L)...	126	.99	.03	.22	.12	.17
Phosphorus, total (mg/L).............	125	2.7	.01	.26	.22	.26
Arsenic, total (μg/L).............	52	23	2	5	5	3.4
Cadmium, total (μg/L).............	72	25	<1	5	5	3.4
Chromium, total (μg/L).............	9	10	<1	2	1	3.0
Lead, total (μg/L)...	63	25	<1	5	5	3.4
Manganese, total (μg/L).............	57	770	10	100	90	100

at site 2A, Sauk River at St. Cloud, Minnesota, 1953-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; µg/L, micrograms per liter; mL, milliliter; --, value not determined; <, less than]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
328	--	443	--	210	--	128	--	128	--
450	--	452	--	408	--	442	--	555	--
8.0	--	8.0	--	8.1	--	8.2	--	8.0	--
2.0	--	18.0	--	20.0	--	7.0	--	0.0	--
11.3	--	8.4	--	7.9	--	11.4	--	9.7	--
60	--	120	--	220	--	130	--	170	--
87	--	--	--	140	--	220	--	14	--
53	46.9	56	67.0	49	27.8	56	19.4	69	23.8
23	20.4	26	31.1	18	10.2	25	8.64	30	10.4
9.9	8.77	7.1	8.49	7.5	4.25	11	3.80	13	4.49
4.5	3.98	4.0	4.78	4.0	2.27	4.0	1.38	4.2	1.45
198	175	208	249	196	111	212	73.3	257	88.8
33	29.2	30	35.9	23	13.0	33	11.4	36	12.4
9.8	8.68	10	12.0	10	5.67	13	4.49	15	5.18
--	--	--	--	290	164	--	--	--	--
9	7.97	19	22.7	19	10.8	7	2.42	4	1.38
.99	.88	.16	.19	.34	.19	.32	.11	1.1	.38
.34	.30	.10	.12	.10	.06	.10	.03	.32	.11
.25	.22	.18	.22	.27	.15	.17	.06	.20	.07
5	.00	5	.00	5	.00	4	.00	5	.00
5	.00	5	.00	6	.00	5	.00	5	.00
--	--	1	.00	3	.00	1	.00	--	--
5	.00	5	.00	6	.00	5	.00	5	.00
62	.05	94	.11	110	.06	40	.01	85	.03

Table 11.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance at site 2A*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; <, less than; *, not significant at the 95-percent confidence level]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Significance of r	Standard error of estimate
Streamflow (Q), ft^3/s..........	116	$Q = 150x10^6(SpC)^{-2.2}$	-0.40	<0.001	107 percent
Calcium (Ca), mg/L..........	68	Ca = 0.11(SpC) + 9.6	.70	<.001	8.7 mg/L
Magnesium (Mg), mg/L..........	25	Mg = 0.05(SpC) - 0.1	.72	<.001	3.9 mg/L
Sodium (Na), mg/L..........	59	Na = 0.03(SpC) - 1.5	.57	<.001	3.0 mg/L
Potassium (K), mg/L..........	58	K = 0.002(SpC) + 3.6	.09	*.510	1.6 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	70	Alk = 0.28(SpC) + 88	.66	<.001	26 mg/L
Sulfate (SO_4), mg/L..........	43	SO_4 = 0.06(SpC) + 2.4	.64	<.001	6.5 mg/L
Chloride (Cl), mg/L..........	71	Cl = 0.03(SpC) - 0.5	.53	<.001	4.4 mg/L

Table 12.--*Trends for selected constituents and properties at site 2A at St. Cloud, Minnesota*

[+, increasing trend; -, decreasing trend; 0, no apparent trend]

Constituent or property	Number of observations	Trend for period of record
Streamflow	148	0
Specific conductance	125	+
pH	155	0
Temperature	75	0
Dissolved oxygen	157	0
Fecal coliform	124	0
Fecal *Streptococci*	8	0
Calcium	68	0
Magnesium	25	0
Sodium	59	0
Potassium	58	0
Alkalinity	85	0
Sulfate	43	0
Chloride	82	+
Suspended solids	140	0
Nitrite plus nitrate as nitrogen	68	0
Ammonia as nitrogen	126	+
Total phosphorus	125	0
Arsenic	52	-
Cadmium	72	-
Chromium	9	-
Lead	63	-
Manganese	57	0

Table 13.--*Streamflow and water-quality*

[-, value not determined; U.S. Geological Survey station

Sampling locations	Date	Streamflow, cubic feet per second	Specific conductance, microsiemens per centimeter	pH units	Temperature, degrees Celsius	Calcium, dissolved, milligrams per liter	Magnesium, dissolved, milligrams per liter	Sodium, dissolved, milligrams per liter
Ashley Creek at Westport (05270130)	6-09-70	10	375	8.1	28.0	42	19	4.1
	5-12-71	13	391	7.9	13.0	49	22	3.3
	11-13-72	22	433	7.3	.5	55	23	4.1
	11-02-73	13	403	8.1	5.0	46	22	4.3
Ashley Creek near Sauk Centre (05270150)	8-20-69	9.2	503	7.8	18.0	60	26	5.1
Adley Creek near Melrose (05270210)	8-20-69	4.8	378	8.1	24.0	43	21	4.9
Sauk River at New Munich (05270230)	8-20-69	33	488	8.0	24.0	52	25	13
	8-17-76	13	500	8.1	18.5	48	26	25
Sauk River near Farming (05270350)	8-21-69	44	481	7.3	23.0	57	26	11
	8-17-76	17	560	8.5	22.0	61	26	21
Sauk River at Cold Spring (05270440)	8-18-76	71	380	-	22.0	43	22	12
Sauk River near St. Cloud (05270500)	9-22-67	76	409	8.0	-	41	22	8.0
	8-29-68	39	428	7.5	19.0	43	24	8.3
	12-10-68	157	495	7.8	1.0	58	26	7.8
	6-23-69	267	456	7.6	16.0	56	25	7.2
	8-21-69	58	415	7.9	26.0	40	23	7.4
	4-06-71	1780	265	7.5	2.0	37	10	3.8
	11-30-71	817	480	7.8	.0	57	24	6.8
	8-20-76	72	420	8.0	24.5	51	23	12

at secondary sites in subbasin 2

number is in parenthesis after sampling location]

Potassium, dissolved, milligrams per liter	Alkalinity, total as $CaCO_3$, milligrams per liter	Sulfate, dissolved, milligrams per liter	Chloride, dissolved, milligrams per liter	Solids, dissolved, milligrams per liter	Nitrite plus nitrate, as nitrogen, milligrams per liter	Phosphorus, total, milligrams per liter	Phosphorus, dissolved, milligrams per liter	Manganese, total, micrograms per liter
2.5	180	11	2.8	208	0.33	0.07	-	-
2.8	198	12	3.2	220	.00	.10	-	-
2.3	217	16	4.7	256	.23	.03	-	-
2.3	200	12	4.3	227	.20	.01	-	-
-	243	29	3.6	306	.50	-	0.01	110
2.9	192	13	3.0	230	.30	-	.02	27
-	225	28	14	297	.30	-	.33	29
5.4	212	30	28	307	.51	1.6	-	150
3.9	230	26	13	307	.50	-	.30	34
4.6	239	31	26	326	.79	.96	-	180
4.1	172	25	16	247	.01	.45	-	100
4.8	180	28	7.5	241	-	-	-	10
4.4	182	27	8.8	253	-	-	-	-
3.9	219	39	8.7	295	-	-	.09	-
3.6	217	27	8.0	262	.30	-	.05	30
3.6	176	25	9.0	239	.80	-	.09	38
6.8	105	24	5.3	168	3.1	.28	-	-
2.9	206	38	8.4	320	1.1	.16	-	-
4.5	190	25	17	266	.25	.42	-	150

Subbasin 3

Physical Characteristics

Subbasin 3 includes approximately 1,120 mi^2 and lies in the central part of the study area. Glacial deposits overlie bedrock in virtually the entire area. Drift exceeds 300 feet in thickness in the southern part of the study area where the drift fills bedrock valleys (Lindholm, 1980). The northern half of the subbasin is relatively flat and is underlain by outwash. The southern half of the subbasin is underlain mainly by gray till. Three fourths of the subbasin is used for agriculture and dairying and about 17 percent is forested (table 14).

Table 14.--*Land use in subbasin 3*

Use	Acres	Percentage of total
Cultivated	299,080	41.82
Extractive	200	0.03
Forested	119,240	16.67
Marsh	13,920	1.95
Pasture and open	234,560	32.79
Transportation	80	.01
Urban nonresidential or mixes residential development	11,000	1.54
Urban residential	17,640	2.47
Water	19,520	2.73

The largest urban area is the twin cities of Sauk Rapids and St. Cloud, with a combined 1980 population of 48,359 (U.S. Department of Commerce, 1982). Most communities in subbasin 3 have waste-water-treatment facilities.

The Mississippi River flows southeasterward across subbasin 3, approximately 55 miles from the Sauk River to the Crow River. The gradient in this reach is 2.5 feet per mile. The U.S. Geological Survey gaging station, Mississippi River at Elk River, was operated from 1915-56. Average streamflow during that period was 5,324 ft^3/s (U.S. Geological Survey, 1964, p. 169). A maximum flow of 49,200 ft^3/s occurred April 12, 1952, and a minimum of 278 ft^3/s occurred November 15, 1933. After the station was discontinued, an estimated maximum flow of 62,000 ft^3/s occurred April 16, 1965 (Anderson and Burmeister, 1970, p. A121). The estimated maximum flow was based on a high-water mark at the location of the discontinued station.

The largest tributary of the Mississippi River in subbasin 3 is Elk River, which is 51 miles long with a drainage area of 650 mi^2; it's gradient is 3.9 ft/mi. Streamflow at site 3D, the U.S. Geological Survey gaging station Elk River near Big Lake, has averaged 260 ft^3/s during 55 years of record. A maximum flow of 7,360 ft^3/s occurred April 16, 1965, and a minimum of 3.6 ft^3/s occurred July 31, 1934. During the 1976-77 drought, a minimum flow of 18 ft^3/s occurred August 28, 1976.

Water-Quality Characteristics

Sites 3A, 3B, 3C, 3D, 3E, and 3F are used to describe water quality in subbasin 3 (fig. 12). All are on the Mississippi River, except D and E, which are on the Elk River. Data summaries for all sites are shown in tables 15-20. Inspection of the data shows little difference between sites, even though they have different periods of record. The MPCA collected samples on the Elk River at site 3E above the dam on Orono Lake from 1971-73 and sampling then was moved 7 miles upstream to site 3D. Even though site 3E represents lake conditions, the data are similar to data from site 3D.

For a better comparison between sites, figure 13 shows plots of medians of selected constituents for the period 1977-82. 3A, 3B, and 3C were the only sites that were sampled during that period. For each constituent in figure 14, site 3A had 42 observations and 3B and 3C had 54. These data also show water quality in subbasin 3 to be uniform. Where there appear to be minor differences, such as in the nitrite plus nitrate concentrations, the differences are not significant when one considers sampling error, analytical error, and the magnitude of the values in question.

Figure 14 shows median seasonal variations for some selected constituents. Because of the uniform water quality, data for the Mississippi River sites were combined. Specific conductance and concentrations of suspended solids, calcium, and chloride vary as expected with streamflow.

Suspended-solids concentrations are lowest in winter during ice cover. The highest median value is only 15 mg/L and occurs in late spring. The low range of suspended-solids concentrations is mainly attributable to the flatness of the terrain and the fact that half the land is forested or in pasture. These attributes help minimize sediment yields.

Table 15.--*Summary statistics for selected constituents and properties at site 3A, Mississippi River at Sauk Rapids, Minnesota, 1953-82*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

	Period of record					
Constituent or property	Number of meas- urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	160	34,300	699	5,700	3,850	5,620
Specific conductance (µS/cm)............	92	460	160	297	291	61
pH (units)...........	159	8.6	6.7	7.9	8.0	0.3
Temperature (°Celsius).........	63	27.0	.0	11.0	11.5	9.0
Oxygen, dissolved (mg/L).............	158	15.4	4.8	9.4	9.1	2.3
Fecal coliform (colonies/100mL)...	104	5,400	20	320	110	880
Fecal Streptococci (colonies/100mL)...	8	1,600	9	460	86	710
Calcium, dissolved (mg/L).............	50	60	26	39	39	7.7
Magnesium, dis- solved (mg/L)......	24	19	10	14	13	2.6
Sodium, dissolved (mg/L).............	42	12	3.0	6.7	6.0	2.5
Potassium, dis- solved (mg/L)......	42	7.5	1.0	2.1	1.9	1.1
Alkalinity, total (mg/L).............	66	200	79	143	149	23
Sulfate, dissolved (mg/L).............	42	26	6.5	14	12	4.5
Chloride, dissolved (mg/L).............	78	13	.5	4.4	4.0	2.6
Solids, dissolved (mg/L).............	1	--	--	--	--	--
Solids, suspended (mg/L).............	132	120	<1	13	9	14
Nitrite plus nitrate as nitrogen, dis- solved (mg/L)......	56	.61	.01	.16	.11	.15
Ammonia as nitrogen, dissolved (mg/L)...	115	.58	.03	.14	.10	.09
Phosphorus, total (mg/L).............	118	.76	.01	.11	.08	.09
Arsenic, total (µg/L).............	31	15	1	4	5	2.8
Cadmium, total (µg/L).............	54	61	<1	6	5	7.8
Chromium, total (µg/L).............	6	10	<1	2	1	3.7
Lead, total (µg/L)...	52	60	<1	7	5	8.6
Manganese, total (µg/L).............	41	450	10	110	110	89

at site 3A, Mississippi River at Sauk Rapids, Minnesota, 1953-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
4,160	--	7,220	--	3,960	--	3,490	--	3,450	--
285	--	285	--	281	--	280	--	332	--
8.0	--	8.0	--	8.0	--	8.0	--	7.9	--
2.0	--	18.5	--	21.0	--	6.0	--	.0	--
11.2	--	8.3	--	7.7	--	11.0	--	9.3	--
77	--	160	--	170	--	55	--	80	--
180	--	--	--	1,200	--	18	--	9	--
40	449	36	702	35	374	40	377	43	400
12	135	10	195	12	128	16	151	15	140
6.2	69.6	4.2	81.9	5.9	63.1	7.0	66.0	6.4	59.6
2.0	22.5	1.7	33.1	1.4	15.0	2.0	18.8	2.0	18.6
135	1,520	130	2,530	139	1,490	150	1,410	158	1,470
11	124	13	253	12	128	14	132	11	102
4.0	44.9	2.8	54.6	4.5	48.1	3.3	31.1	4.0	37.3
--	--	--	--	180	1,920	--	--	--	--
8	89.8	15	292	11	118	7	66.0	4	37.3
.31	3.48	.04	.78	.06	.64	.06	.56	.34	3.17
.20	2.25	.10	1.95	.10	1.07	.10	.94	.10	.93
.07	.79	.10	1.95	.09	.96	.07	.66	.05	.46
5	.06	5	.10	5	.05	1	.01	5	.05
5	.06	5	.10	5	.05	5	.05	8	.07
--	--	1	.02	2	.02	1	.01	--	--
6	.07	5	.10	5	.05	5	.05	5	.05
110	1.24	140	2.73	110	1.18	51	.48	90	8.38

Table 16.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μ/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	164	69,500	801	7,490	4,740	8,510
Specific conductance (μ/cm).............	162	510	150	299	299	67
pH (units)...........	164	8.6	7.0	7.8	7.9	0.3
Temperature (°Celsius).........	75	25.0	0.0	11.0	10.5	9.0
Oxygen, dissolved (mg/L).............	162	16.2	5.5	9.9	9.9	2.1
Fecal coliform (colonies/100mL)...	164	23,000	20	760	230	2,000
Fecal Streptococci (colonies/100mL)...	9	990	18	170	72	310
Calcium, dissolved (mg/L).............	69	68	16	40	40	9.1
Magnesium, dissolved (mg/L)......	27	22	4.9	15	14	3.8
Sodium, dissolved (mg/L).............	61	16	2.2	6.6	6.0	2.8
Potassium, dissolved (mg/L)......	60	6.0	1.0	2.6	2.1	1.3
Alkalinity, total (mg/L).............	109	320	88	150	150	29
Sulfate, dissolved (mg/L).............	46	30	6.0	13	12	4.5
Chloride, dissolved (mg/L).............	109	27	.7	5.5	4.9	3.2
Solids, dissolved (mg/L).............	2	190	174	182	182	11
Solids, suspended (mg/L).............	163	46	<1	10	8	8
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	68	.61	.01	.20	.16	.15
Ammonia as nitrogen, dissolved (mg/L)...	165	.99	.03	.15	.10	.14
Phosphorus, total (mg/L).............	163	.90	.00	.11	.09	.09
Arsenic, total (μg/L).............	61	5	1	4	5	1.4
Cadmium, total (μg/L).............	100	30	<1	5	5	3
Chromium, total (μg/L).............	9	10	1	4	2	3.8
Lead, total (μg/L)...	86	25	<1	6	5	4
Manganese, total (μg/L).............	84	610	10	100	80	97

at site 3B, Mississippi River at Clearwater, Minnesota, 1967-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second;
per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring Median	Early spring Tons per day	Late spring Median	Late spring Tons per day	Summer Median	Summer Tons per day	Fall Median	Fall Tons per day	Winter Median	Winter Tons per day
6,050	--	9,500	--	4,570	--	4,720	--	4,130	--
302	--	268	--	290	--	281	--	338	--
7.9	--	7.9	--	8.0	--	8.1	--	7.8	--
3.0	--	18.0	--	22.0	--	7.0	--	.0	--
11.6	--	8.6	--	7.9	--	10.9	--	11.3	--
140	--	230	--	490	--	320	--	220	--
76	--	--	--	120	--	54	--	36	--
44	719	32	821	37	456	40	3.7	48	535
14	229	13	333	13	160	15	1.4	19	212
7.1	116	4.0	103	5.3	65.4	6.0	.56	8.0	89.2
2.7	44.1	2.0	51.3	1.8	22.2	2.0	.19	3.0	33.4
159	2,600	131	3,360	144	1,780	148	14	170	1,900
14	229	9.9	254	9.7	120	12	1.1	15	167
5.0	81.7	4.6	118	.43	5.30	4.7	.44	5.0	55.8
--	--	--	--	182	2,240	--	--	--	--
7	114	15	385	11	136	<1	--	4	44.6
.34	5.55	.04	1.03	.12	1.48	.12	.01	.40	4.46
.13	2.12	.10	2.56	.10	1.23	.10	.01	.10	1.12
.09	1.47	.09	2.31	.11	1.36	.08	.01	.06	.67
5	.08	5	.13	5	.06	5	.00	5	.06
6	.10	5	.13	6	.07	5	.00	5	.06
--	--	1	.02	3	.04	1	.00	--	--
5	.08	5	.13	5	.06	5	.00	5	.06
89	14.5	120	3.08	97	1.20	51	.00	48	.54

Table 17.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	69	39,700	830	6,920	4,790	7,100
Specific conductance (μS/cm)............	69	480	200	321	328	54
pH (units)...........	69	8.7	6.9	8.0	8.1	0.3
Temperature (°Celsius).........	69	26.5	0.0	12.0	12.0	8.5
Oxygen, dissolved (mg/L).............	69	15.0	6.7	9.9	10.0	2.0
Fecal coliform (colonies/100mL)...	68	5,400	20	210	54	660
Fecal Streptococci (colonies/100mL)...	1	--	--	--	--	--
Calcium, dissolved (mg/L).............	24	56	33	43	41	6.7
Magnesium, dissolved (mg/L)......	24	19	11	14	14	2.3
Sodium, dissolved (mg/L).............	15	14	5.6	9.1	8.6	2.5
Potassium, dissolved (mg/L)......	15	6.7	1.6	2.5	2.2	1.2
Alkalinity, total (mg/L).............	24	200	120	154	150	20
Sulfate, dissolved (mg/L).............	16	26	12	21	22	4.2
Chloride, dissolved (mg/L).............	15	15	4.7	8.5	8.0	2.5
Solids, dissolved (mg/L).............	0	--	--	--	--	--
Solids, suspended (mg/L).............	69	36	<1	10	10	7
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	68	1.7	.01	.26	.18	.25
Ammonia as nitrogen, dissolved (mg/L)...	69	.75	.02	.16	.11	.13
Phosphorus, total (mg/L).............	69	.20	.00	.09	.08	.04
Arsenic, total (μg/L).............	9	4	1	2	1	.9
Cadmium, total (μg/L).............	9	5	<1	3	5	2.6
Chromium, total (μg/L).............	4	1	1	1	1	.0
Lead, total (μg/L)...	9	25	1	6	5	7.6
Manganese, total (μg/L).............	5	220	90	150	160	54

at site 3C, Mississippi River at Monticello, Minnesota, 1976-62

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
4,690	--	9,760	--	4,910	--	5,420	--	3,760	--
342	--	278	--	319	--	305	--	355	--
7.9	--	8.1	--	8.3	--	8.1	--	7.8	--
5.0	--	18.5	--	22.0	--	8.0	--	.5	--
11.7	--	8.4	--	7.8	--	10.3	--	11.9	--
35	--	53	--	170	--	65	--	45	--
--	--	--	--	--	--	--	--	--	--
47	595	39	1,030	39	517	43	629	52	528
14	177	12	316	13	172	15	220	18	183
8.9	113	7.1	187	7.7	102	10	146	13	132
2.3	29.1	2.0	52.7	1.8	23.9	2.2	32.2	2.8	28.4
155	1,960	135	3,560	144	1,910	152	2,220	185	1,880
24	304	22	580	19	252	22	322	25	254
6.7	84.8	7.8	206	7.7	102	8.6	126	9.6	97.4
--	--	--	--	--	--	--	--	--	--
6	76.0	15	395	13	172	7	102	3	30.4
.41	5.19	.06	1.58	.12	1.59	.14	2.05	.42	4.26
.14	1.77	.10	2.64	.10	1.32	.10	1.46	.22	2.23
.08	1.01	.09	2.37	.12	1.59	.06	.88	.05	.51
1	.01	1	.03	3	.04	1	.01	1	.01
5	.06	<1	<.03	5	.07	<1	<.01	5	.05
--	--	1	.03	--	--	1	.01	--	--
5	.06	1	.03	15	.20	1	.01	5	.05
190	2.40	--	--	190	2.52	110	1.61	90	.91

Table 18.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

	Period of record					
Constituent or property	Number of meas-urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	30	1,480	85	272	134	329
Specific conductance (μS/cm)	30	390	170	295	292	53
pH (units)	30	8.4	7.4	7.9	7.9	0.2
Temperature (°Celsius)	6	18.5	0.0	7.0	1.0	8.5
Oxygen, dissolved (mg/L)	30	13.8	3.0	8.4	8.2	2.4
Fecal coliform (colonies/100mL)	30	490	20	64	24	94
Fecal Streptococci (colonies/100mL)	6	150	9	74	22	70
Calcium, dissolved (mg/L)	29	56	17	43	44	8.7
Magnesium, dissolved (mg/L)	9	17	6.6	14	15	3.1
Sodium, dissolved (mg/L)	30	9.7	2.9	5.0	4.6	1.6
Potassium, dissolved (mg/L)	30	5.1	1.0	2.0	1.6	1.0
Alkalinity, total (mg/L)	30	190	66	153	153	25
Sulfate, dissolved (mg/L)	30	21	9.3	14	14	2.8
Chloride, dissolved (mg/L)	30	13	3.8	6.8	5.5	2.8
Solids, dissolved (mg/L)	2	183	135	159	159	34
Solids, suspended (mg/L)	30	75	<1	13	7	16
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	0	--	--	--	--	--
Ammonia as nitrogen, dissolved (mg/L)	30	.71	.10	.16	.11	.13
Phosphorus, total (mg/L)	30	.20	.03	.09	.08	.05
Arsenic, total (μg/L)	16	10	1	5	5	2.0
Cadmium, total (μg/L)	30	10	5	5	5	.9
Chromium, total (μg/L)	1	2	2	2	2	--
Lead, total (μg/L)	30	35	5	7	5	5.9
Manganese, total (μg/L)	30	300	10	120	120	85

at site 3D, Elk River near Big Lake, Minnesota, 1974-76

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
236	--	344	--	122	--	122	--	126	--
260	--	280	--	275	--	305	--	355	--
7.9	--	8.0	--	8.1	--	8.0	--	7.8	--
3.5	--	17.0	--	--	--	--	--	0.0	--
10.7	--	7.8	--	8.0	--	10.6	--	5.4	--
23	--	90	--	65	--	45	--	22	--
84	--	--	--	150	--	110	--	9	--
41	26.1	45	41.8	44	14.5	46	15.2	48	16.3
10	6.37	14	13.0	--	--	15	4.94	17	5.78
5.0	3.19	4.0	3.72	4.1	1.35	4.7	1.55	5.2	1.77
1.8	1.15	1.4	1.30	1.3	.43	1.6	.53	1.7	.58
148	94.3	145	135	145	47.8	157	51.7	172	58.5
13	8.28	13	12.1	13	4.28	16	5.27	15	5.10
5.9	3.76	5.9	5.48	5.3	1.75	4.7	1.55	5.5	1.87
--	--	--	--	159	52.4	--	--	--	--
3	1.91	16	14.9	16	5.27	2	.66	4	1.36
--	--	--	--	--	--	--	--	--	--
.12	.08	.10	.09	.16	.05	.12	.04	.12	.04
.11	.07	.12	.11	.12	.04	.05	.02	.04	.01
4	.00	8	.01	5	.00	3	.00	4	.00
5	.00	5	.00	6	.00	5	.00	5	.00
--	--	--	--	2	.00	--	--	--	--
6	.00	5	.00	6	.00	5	.00	7	.00
140	.09	100	.09	180	.06	30	.01	120	.04

Table 19.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	26	845	110	317	233	209
Specific conductance (μS/cm)............	26	580	220	303	285	70
pH (units)...........	25	8.7	7.1	7.9	7.9	0.4
Temperature (°Celsius).........	0	--	--	--	--	--
Oxygen, dissolved (mg/L).............	25	13.3	5.4	9.7	8.9	2.0
Fecal coliform (colonies/100mL)...	26	340	20	46	22	70
Fecal Streptococci (colonies/100mL)...	1	--	--	--	--	--
Calcium, dissolved (mg/L).............	24	72	22	46	44	12
Magnesium, dissolved (mg/L)......	2	19	2.4	11	11	12
Sodium, dissolved (mg/L).............	24	9.4	3.0	5.7	5.2	1.8
Potassium, dissolved (mg/L)......	22	6.0	1.0	2.6	2.2	1.6
Alkalinity, total (mg/L).............	25	200	97	153	159	23
Sulfate, dissolved (mg/L).............	7	24	9.5	15	13	5.3
Chloride, dissolved (mg/L).............	26	16	3.7	6.5	6.0	2.4
Solids, dissolved (mg/L).............	0	--	--	--	--	--
Solids, suspended (mg/L).............	26	32	2	13	13	10
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	0	--	--	--	--	--
Ammonia as nitrogen, dissolved (mg/L)...	26	.36	.10	.13	.10	.07
Phosphorus, total (mg/L).............	26	.30	.06	.14	.14	.07
Arsenic, total (μg/L).............	26	5	5	5	5	0.0
Cadmium, total (μg/L).............	25	5	5	5	5	0.0
Chromium, total (μg/L).............	2	10	8	9	9	1.2
Lead, total (μg/L)...	17	21	5	10	9	3.7
Manganese, total (μg/L).............	23	440	16	160	140	100

at site 3E, Elk River near Elk River, Minnesota, 1971-73

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
591	--	368	--	208	--	252	--	163	--
390	--	275	--	290	--	275	--	325	--
7.9	--	8.0	--	7.9	--	7.8	--	7.8	--
--	--	--	--	--	--	--	--	--	--
11.6	--	9.0	--	8.5	--	11.7	--	8.8	--
40	--	20	--	24	--	23	--	35	--
--	--	--	--	9	--	--	--	--	--
58	92.6	44	43.7	44	24.7	45	30.6	60	26.4
--	--	--	--	11	6.18	--	--	--	--
8.0	12.8	4.5	4.47	4.2	2.36	5.5	3.74	7.4	3.26
5.0	7.98	3.0	2.98	1.8	1.01	2.2	1.50	1.0	.44
120	191	157	156	150	84.2	155	105	180	79.2
--	--	--	--	12	6.74	17	11.6	24	10.6
5.8	9.26	6.2	6.16	4.9	2.75	7.1	4.83	7.0	3.08
--	--	--	--	--	--	--	--	--	--
3	4.79	14	13.9	22	12.4	4	2.72	2	.88
--	--	--	--	--	--	--	--	--	--
.23	.37	.12	.12	.10	.06	.10	.07	.15	.07
.16	.26	.08	.08	.18	.10	.08	.05	.08	.04
5	.01	5	.00	5	.00	5	.00	5	.00
5	.01	5	.00	5	.00	5	.00	5	.00
--	--	--	--	9	.00	--	--	--	--
10	.02	10	.01	9	.00	9	.01	9	.00
72	.11	160	.16	190	.11	95	.06	130	.06

Table 20.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	65	29,000	975	5,480	3,840	5,350
Specific conductance (μS/cm)	0	--	--	--	--	--
pH (units)	42	8.6	6.6	7.7	7.7	0.4
Temperature (°Celsius)	0	--	--	--	--	--
Oxygen, dissolved (mg/L)	43	15.0	5.0	8.8	8.1	2.2
Fecal coliform (colonies/100mL)	13	4,900	200	1,500	1,100	1,300
Fecal <u>Streptococci</u> (colonies/100mL)	0	--	--	--	--	--
Calcium, dissolved (mg/L)	0	--	--	--	--	--
Magnesium, dissolved (mg/L)	0	--	--	--	--	--
Sodium, dissolved (mg/L)	0	--	--	--	--	--
Potassium, dissolved (mg/L)	0	--	--	--	--	--
Alkalinity, total (mg/L)	0	--	--	--	--	--
Sulfate, dissolved (mg/L)	0	--	--	--	--	--
Chloride, dissolved (mg/L)	26	18	.5	4.2	3.4	4.0
Solids, dissolved (mg/L)	0	--	--	--	--	--
Solids, suspended (mg/L)	25	52	3	18	16	11
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	0	--	--	--	--	--
Ammonia as nitrogen, dissolved (mg/L)	25	.30	.10	.12	.10	.05
Phosphorus, total (mg/L)	27	1.5	.04	.21	.16	.27
Arsenic, total (μg/L)	0	--	--	--	--	--
Cadmium, total (μg/L)	0	--	--	--	--	--
Chromium, total (μg/L)	0	--	--	--	--	--
Lead, total (μg/L)	0	--	--	--	--	--
Manganese, total (μg/L)	0	--	--	--	--	--

at site 3F, Mississippi River at Elk River, Minnesota, 1957-65

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per dey
2,740	--	5,490	--	4,140	--	3,510	--	2,710	--
--	--	--	--	--	--	--	--	--	--
7.9	--	7.8	--	7.4	--	8.0	--	7.7	--
--	--	--	--	--	--	--	--	--	--
8.1	--	8.2	--	7.1	--	10.4	--	7.5	--
800	--	1,100	--	2,000	--	800	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
4.4	32.6	1.7	25.2	3.5	39.1	2.5	23.7	5.0	36.6
--	--	--	--	--	--	--	--	--	--
7	51.8	20	296	17	190	9	85.3	8	58.5
--	--	--	--	--	--	--	--	--	--
.24	1.78	.10	1.48	.11	1.23	.10	.95	.12	.88
.14	1.04	.17	2.52	.19	2.12	.10	.95	.09	.66
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--

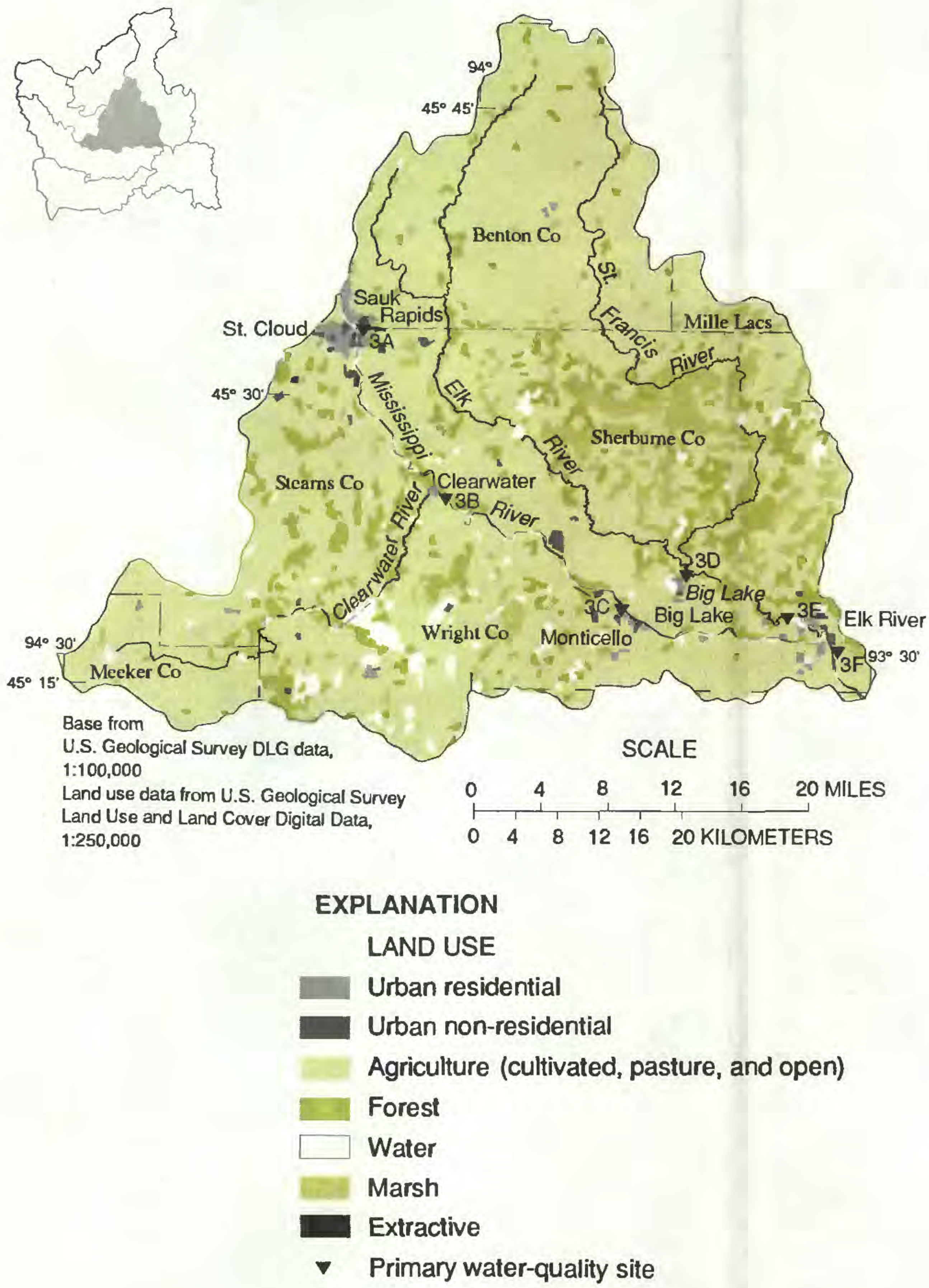


Figure 12. Land use and location of sampling sites in subbasin 3.

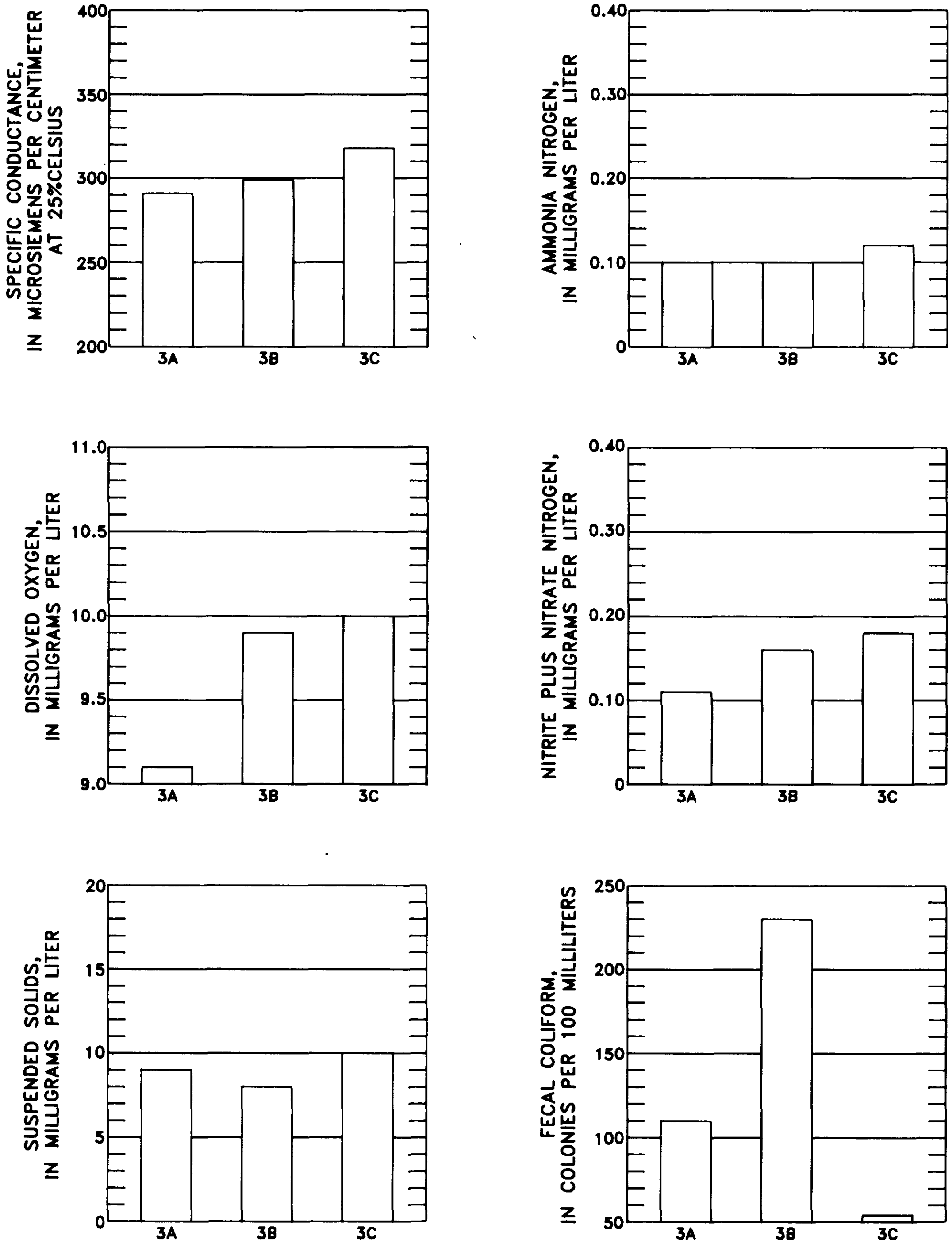


Figure 13.--Median concentrations of selected constituents and of selected properties at sites 3A, 3B, and 3C in subbasin 3, 1977-82.

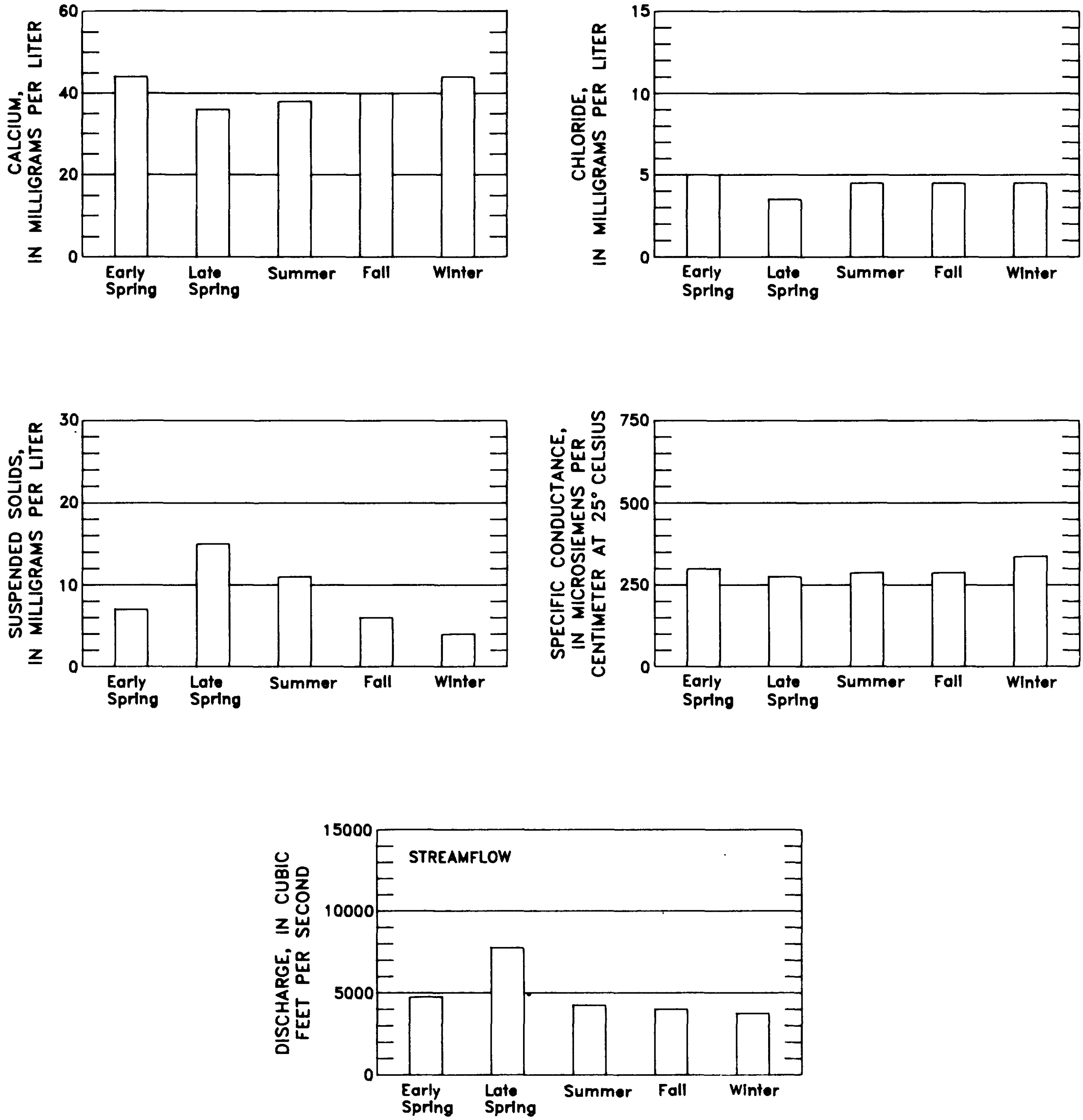
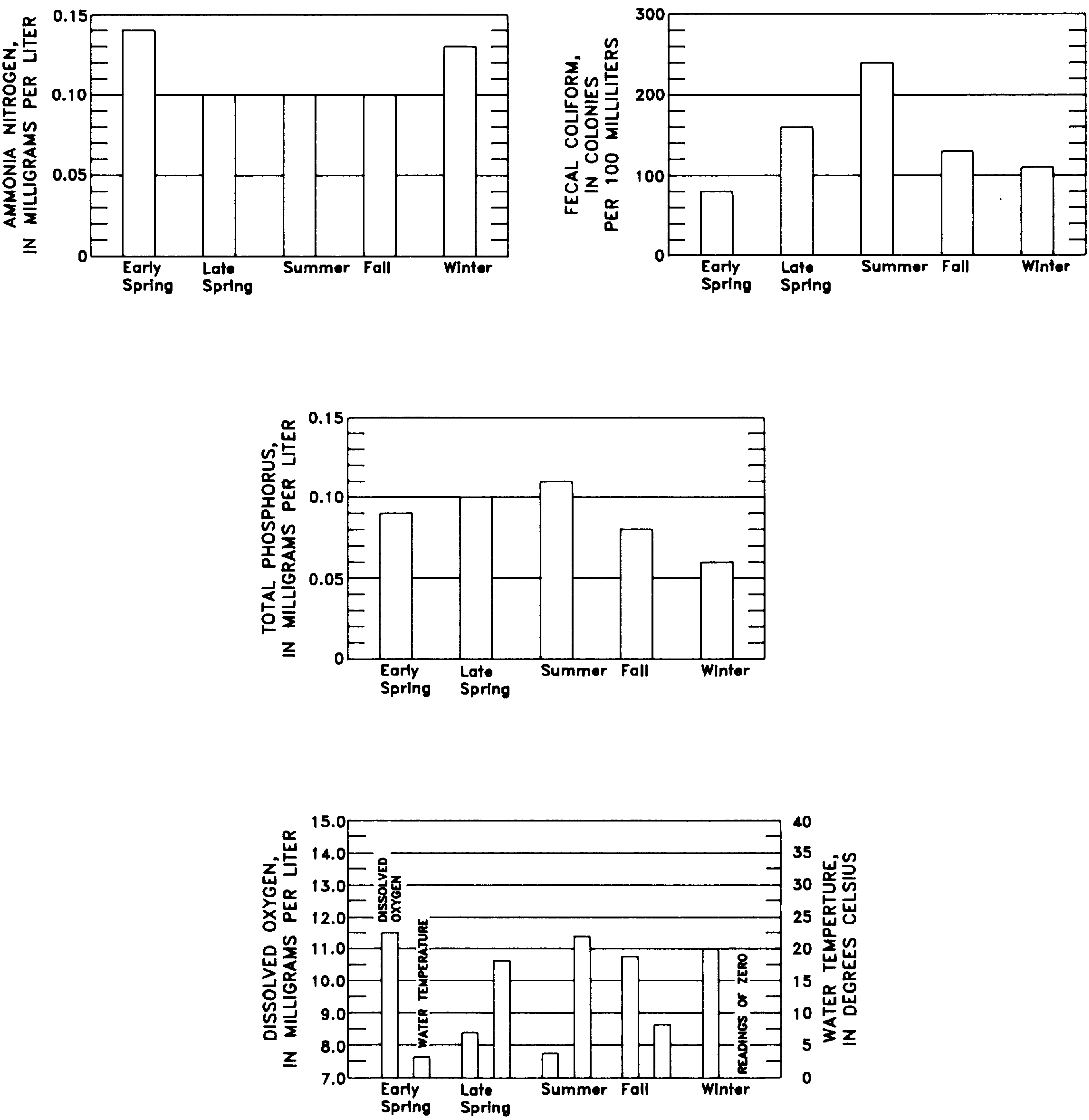


Figure 14.--Median seasonal variation in concentrations of selected



constituents and in properties at sites 3A, 3B, 3C, and 3F in subbasin 3.

Specific conductance varies little until winter, when it reaches a median of 340 μS/cm because of the higher proportion of ground water in streamflow during the winter. The influence of ground water also is shown by the steady increase in calcium concentration as streamflow decreases. Rocks composed of calcium carbonate are common, and ground water, therefore, generally contains higher concentrations of calcium compared to overland runoff. Chloride in ground water, on the other hand, does not increase substantially compared to runoff.

Total-phosphorus concentrations show only slight variations throughout the year. Even during spring runoff, there is not a substantial increase in phosphorus concentration. The land-use factors controlling suspended solids indirectly control phosphorus concentrations, because phosphorus easily adsorbs to suspended solids.

Dissolved-oxygen concentrations vary inversely with temperature. Lowest median concentrations of dissolved oxygen (7.7 mg/L) occur in summer and are high enough to support a variety of aquatic life. A minimum observed concentration of 4.8 mg/L of dissolved oxygen in the Mississippi River occurred July 28, 1976, at site 3A.

Fecal-coliform concentrations tend to be higher in summer. Of the individual counts greater than 1,000 colonies/100 mL, approximately half occurred in summer. A maximum of 23,000 colonies/100 mL of water occurred at site 3B on September 14, 1971. Records from NOAA (September 1971) show no reported rain for 4 days prior to the sampling, which suggest sources for fecal coliform other than overland runoff.

Ammonia-nitrogen concentrations increase slightly in winter, persist into early spring, and then decrease and remain fairly constant throughout the open-water period.

Regressions shown for the Mississippi River in table 21 were derived by combining data from all the Mississippi River sites. Specific conductance can be used for estimating streamflow and concentrations of the constituents shown for the Mississippi River within subbasin 3. Regressions for potassium and chloride give the poorest estimates but can be used with caution.

Regressions shown for the Elk River in table 21 were derived from the combined data for sites 3D and 3E. Correlation coefficients for potassium and chloride are not significant at the 95-percent-confidence level, and the corresponding regression equations are not usable. The correlation coefficient for sodium is relatively low, but this regression can be used with caution.

Trends from 1953-82 are shown in table 22 for the four Mississippi River sites. Even though some trends are shown, none except the ones for sodium, chloride, and specific conductance are considered to be significant. Sodium chloride, widely used as a road deicer in winter, may have increased the concentrations of these ions, which, in turn, have increased the specific conductance. Decreasing trends for trace elements probably indicate refinement in analytical methods.

Table 21.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance in subbasin 3*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; <, less than; *, not significant at the 95-percent confidence level]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Significance of r	Standard error of estimate
		Results for Mississippi River			
Streamflow (Q), ft^3/s.........	231	$Q = 264x10^7(SpC)^{-2.3}$	-0.59	<0.001	74 percent
Calcium (Ca), mg/L..........	92	Ca = 0.09(SpC) + 14	.75	<.001	5.8 mg/L
Magnesium (Mg), mg/L..........	50	Mg = 0.04(SpC) + 0.2	.72	<.001	2.3 mg/L
Sodium (Na), mg/L..........	75	Na = 0.02(SpC) - 0.4	.67	<.001	2.2 mg/L
Potassium (K), mg/L..........	74	K = 0.01(SpC) + 0.7	.38	<.001	1.2 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	132	Alk = 0.23(SpC) + 80	.69	<.001	17 mg/L
Sulfate (SO_4), mg/L..........	61	SO_4 = 0.05(SpC) - 1.0	.68	<.001	4.4 mg/L
Chloride (Cl), mg/L..........	123	Cl = 0.02(SpC) + 0.2	.42	<.001	3.0 mg/L
		Results for Elk River			
Streamflow (Q), ft^3/s.........	56	$Q = 171x10^5(SpC)^{-2.0}$	-.55	<0.001	62 percent
Calcium (Ca), mg/L..........	53	Ca - 0.09(SpC) + 18	.53	<.001	8.8 mg/L
Magnesium (Mg), mg/L..........	11	Mg - 0.06(SpC) - 6.3	.77	.005	3.3 mg/L
Sodium (Na), mg/L..........	54	Na - 0.01(SpC) + 2.2	.38	.005	1.6 mg/L
Potassium (K), mg/L..........	52	K = 0.002(SpC) + 1.6	.10	*.496	1.3 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	55	Alk = 0.21(SpC) + 91	.54	<.001	20 mg/L
Sulfate (SO_4), mg/L..........	37	SO_4 = 0.03(SpC) + 6.6	.40	.015	3.1 mg/L
Chloride (Cl), mg/L..........	56	Cl = -0.002(SpC) + 7.3	-.05	*.727	2.6 mg/L

Table 22.--*Trends for selected constituents and properties at Mississippi River sites 3A, 3B, 3C, and 3F in subbasin 3*

[+, increasing trend; -, decreasing trend; --, decreasing trend with absolute value of correlation coefficient greater than 0.75; 0, no apparent trend]

Constituent or property	Number of observations	Trend for period of record
Streamflow	460	0
Specific conductance	323	+
pH	434	+
Temperature	207	0
Dissolved oxygen	432	0
Fecal coliform	349	-
Fecal *Streptococci*	18	0
Calcium	143	0
Magnesium	75	-
Sodium	118	+
Potassium	117	0
Alkalinity	199	0
Sulfate	104	+
Chloride	228	+
Suspended solids	389	-
Nitrite plus nitrate as nitrogen	192	0
Ammonia as nitrogen	374	0
Total phosphorus	377	-
Arsenic	101	--
Cadmium	163	-
Chromium	19	--
Lead	147	-
Manganese	130	+

Subbasin 4

Physical Characteristics

Subbasin 4 includes approximately 1,500 mi^2 and lies in the west-central part of the study area (fig. 15). It is an area of low hills (moraines) interspersed with till plains. Gray to brownish-gray soils derived from limey clayey till predominate except for areas of dark-colored, well-drained sandy loams that underlie parts of the central and northwest areas of the subbasin.

The largest town in subbasin 4 is Litchfield, with a 1980 population of 5,904 (U.S. Department of Commerce, 1982). Most of the communities are sewered. Subbasin 4 is the second-most-cultivated subbasin in the accounting unit with 61.7 percent (table 23).

Table 23.--*Land use in subbasin 4*

Use	Acres	Percentage of total
Cultivated	582,360	61.70
Extractive	400	.04
Forested	61,000	6.46
Marsh	28,560	3.03
Pasture and open	187,240	19.84
Transportation	80	.01
Urban nonresidential or mixed residential development	9,880	1.05
Urban residential	17,080	1.81
Water	57,200	6.06

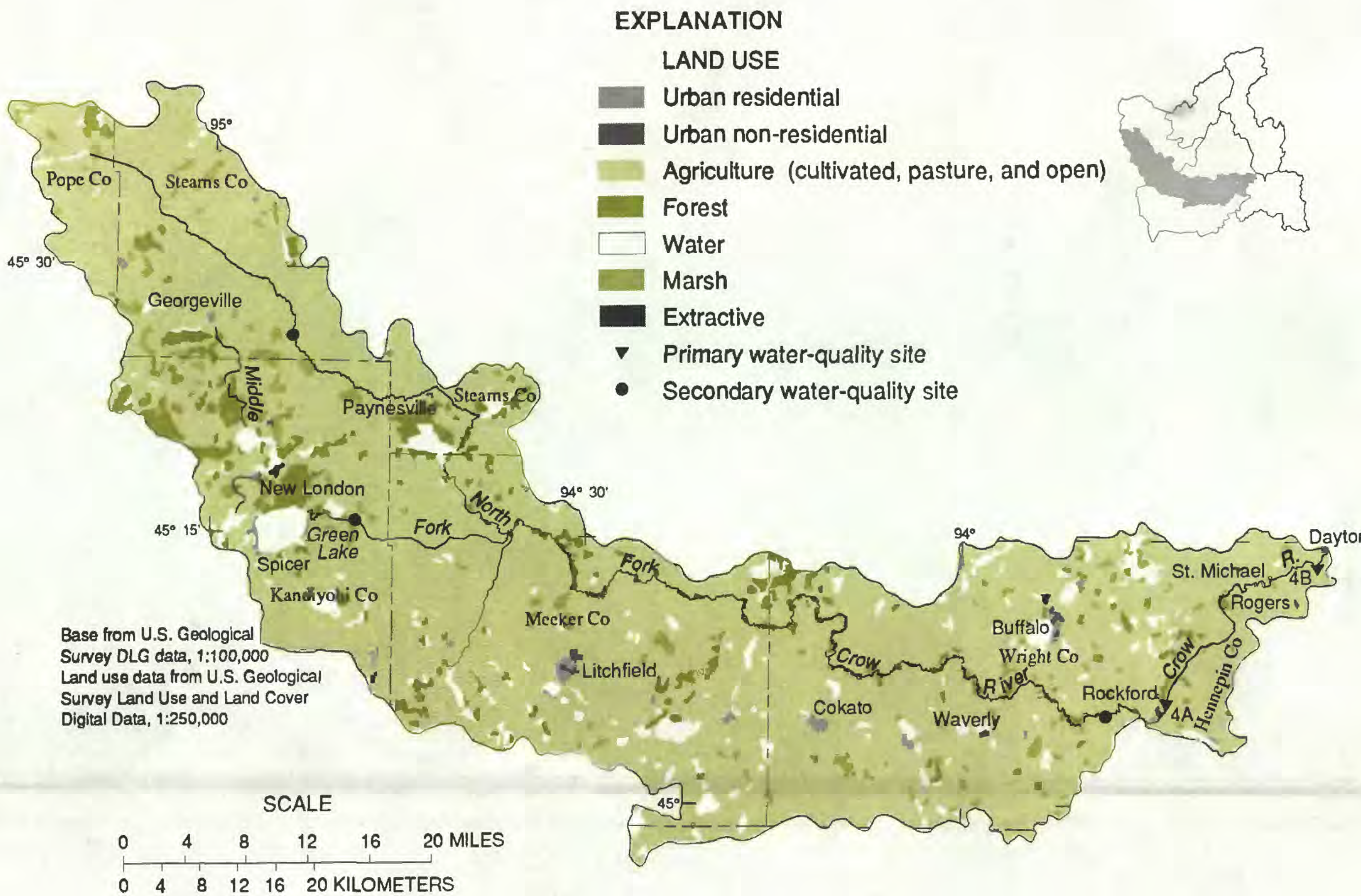


Figure 15. Land use and location of sampling sites in subbasin 4.

The principal streams in subbasin 4 are the North Fork Crow River, which flows southeasterly for about 175 miles to its junction with the South Fork Crow River at the southeast edge of the subbasin, and the main stem of the Crow River, which continues northeasterly about 24 miles to join the Mississippi River at Dayton. The South Fork is in subbasin 5. The slope of the North Fork channel averages 2.9 ft/mi in the upper 100 miles and 1.6 ft/mi in the lower 75 miles. Slope of the main stem is about 2.1 ft/mi. The Middle Fork Crow River, which is the main tributary of the North Fork, has a total length of 30 miles and a drainage area of 280 mi^2.

The U.S. Geological Survey operates continuous-record gaging stations on the Middle Fork Crow River near Spicer (Number 05278000) and on the Crow River at Rockford (site 4A, Number 05280000). A high-flow partial-record station, North Fork Crow River at Paynesville (Number 05276200) also is operated.

Middle Fork Crow River near Spicer has had an average flow of 55.5 ft^3/s and a median of yearly mean flows of 42 ft^3/s for 34 years of record. During the sampling period, a maximum flow of 408 ft^3/s occurred June 29, 1953; no flow has occurred several times in winter and early spring when the stream literally has been frozen to its bed (U.S. Geological Survey, 1983, p. 66). A new maximum flow of 509 ft^3/s occurred June 22, 1983, after the sampling period. During the 1976-77 drought, a minimum of 0.16 ft^3/s occurred April 6, 1977 (U.S. Geological Survey, 1978, p. 51).

Flow of the Crow River at Rockford, site 4A, has averaged 664 ft^3/s and the median of yearly mean flows has been 514 ft^3/s for 58 years of record. A maximum flow of 22,400 ft^3/s occurred April 16, 1965; a minimum flow of 1.8 ft^3/s occurred November 15, 1936 (U.S. Geological Survey, 1984, p. 65). During the 1976-77 drought, a minimum daily flow of 18 ft^3/s occurred September 12 and 13, 1976 (U.S. Geological Survey, 1977, p. 266).

North Fork Crow River at Paynesville has a peak-flow record beginning in 1973. The maximum flow thus far (1985) has been 2,300 ft^3/s on June 21, 1983 (U.S. Geological Survey, 1984, p. 262) and June 12, 1984 (U.S. Geological Survey, 1985, p. 252).

Water-Quality Characteristics

Two primary sampling sites, 4A and 4B, and three secondary sites are used to describe the quality of water in subbasin 4. Site locations and land-use descriptions are shown in figure 15. Data for site 4A are from a MWCC and U.S. Geological Survey cooperative monitoring program. Data for site 4B were collected by MPCA (tables 24 and 25).

Concentrations of dissolved nitrite plus nitrate nitrogen and of total arsenic, cadmium, chromium, and lead, are within the primary drinking-water standards except for one analysis of cadmium, which determined a concentration of 20 $\mu g/L$ at site 4B on October 14, 1969.

Table 24.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record: Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	76	4,710	22	616	246	803
Specific conductance (μS/cm)	72	1,100	280	652	645	142
pH (units)	61	8.7	7.0	7.9	8.0	0.4
Temperature (°Celsius)	69	27.5	0.0	10.0	9.0	9.5
Oxygen, dissolved (mg/L)	49	13.9	3.5	8.7	8.5	2.7
Fecal coliform (colonies/100mL)	34	5,000	<1	340	120	860
Fecal Streptococci (colonies/100mL)	26	2,200	<1	260	62	540
Calcium, dissolved (mg/L)	61	110	25	72	71	14
Magnesium, dissolved (mg/L)	61	44	11	32	32	6.1
Sodium, dissolved (mg/L)	61	53	5.2	20	19	10
Potassium, dissolved (mg/L)	61	11	3.8	5.7	5.3	1.2
Alkalinity, total (mg/L)	56	442	144	265	261	54
Sulfate, dissolved (mg/L)	61	73	3.0	24	21	12
Chloride, dissolved (mg/L)	61	110	23	57	55	15
Solids, dissolved (mg/L)	0	--	--	--	--	--
Solids, suspended (mg/L)	49	391	<1	41	27	60
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	37	3.8	.01	.89	.48	1.1
Ammonia as nitrogen, dissolved (mg/L)	45	1.4	.01	.31	.12	.34
Phosphorus, total (mg/L)	4	.38	.08	.24	.22	.13
Phosphorus, dissolved (mg/L)	52	.38	.03	.20	.20	.09
Arsenic, total (μg/L)	4	6	4	5	5	1
Cadmium, total (μg/L)	6	20	<1	13	15	10
Chromium, total (μg/L)	4	20	<1	5	3	10
Lead, total (μg/L)	2	50	2	26	26	34
Manganese, total (μg/L)	13	750	<1	240	150	230

at site 4A, Crow River at Rockford, Minnesota, 1952-76

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
955	--	1,120	--	238	--	112	--	120	--
593	--	567	--	630	--	686	--	708	--
7.8	--	8.0	--	8.2	--	8.2	--	7.6	--
2.5	--	19.5	--	22.0	--	5.0	--	0.0	--
9.2	--	8.7	--	8.1	--	10.7	--	5.9	--
140	--	140	--	180	--	90	--	40	--
54	--	34	--	160	--	62	--	6	--
64	165	63	190	67	43.0	76	23.0	84	27.2
25	64.5	30	0.7	32	20.6	33	9.98	38	12.3
13	33.5	12	6.3	22	14.1	21	6.35	22	7.13
5.8	15.0	4.8	4.5	5.1	3.28	5.2	1.57	6.0	1.94
202	521	239	723	261	168	269	81.3	306	99.1
50	129	68	206	50	32.1	51	15.4	58	18.8
19	49.0	17	1.4	22	14.1	18	5.44	24	7.78
--	--	--	--	--	--	--	--	--	--
24	61.9	77	233	67	43.0	20	6.05	4	1.30
2.4	6.19	1.0	.02	.08	.05	.14	.04	.60	.19
.65	1.68	.04	.12	.06	.04	.11	.03	.58	.19
.28	.72	.31	.94	.08	.05	--	--	--	--
.28	.72	.10	.30	.15	.10	.22	.07	.23	.07
--	--	--	--	6	.00	4	.00	--	--
--	--	<1	.00	20	.01	15	.00	--	--
--	--	--	--	10	.01	<1	.00	--	--
--	--	--	--	--	--	26	.01	--	--
350	.90	125	.38	90	.06	150	.04	--	--

Table 25.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	200	15,300	26	838	328	1,490
Specific conductance (μS/cm)	130	1,200	210	572	570	153
pH (units)	195	8.7	6.8	7.9	8.0	0.4
Temperature (°Celsius)	45	24.5	0.0	11.0	11.0	9.5
Oxygen, dissolved (mg/L)	200	17.7	4.2	9.8	9.7	2.3
Fecal coliform (colonies/100mL)	146	13,000	20	600	200	1,600
Fecal Streptococci (colonies/100mL)	8	770	9	150	76	250
Calcium, dissolved (mg/L)	60	112	27	68	68	16
Magnesium, dissolved (mg/L)	19	54	18	33	32	6.9
Sodium, dissolved (mg/L)	61	150	5.0	22	16	22
Potassium, dissolved (mg/L)	59	18	1.0	5.8	5.2	2.5
Alkalinity, total (mg/L)	113	360	120	257	252	51
Sulfate, dissolved (mg/L)	44	130	11	56	49	24
Chloride, dissolved (mg/L)	149	400	1.5	24	18	36
Solids, dissolved (mg/L)	2	410	379	394	394	22
Solids, suspended (mg/L)	171	110	<1	32	31	25
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	38	8.1	.01	1.5	.91	1.8
Ammonia as nitrogen, dissolved (mg/L)	161	1.7	.08	.26	.10	.29
Phosphorus, total (mg/L)	154	1.1	.07	.29	.28	.14
Arsenic, total (μg/L)	59	15	<1	7	5	3.2
Cadmium, total (μg/L)	123	20	5	5	5	1.4
Chromium, total (μg/L)	7	5	1	3	4	1.9
Lead, total (μg/L)	84	30	4	6	5	3.9
Manganese, total (μg/L)	83	1,100	10	170	160	140

at site 4B, Crow River at Dayton, Minnesota, 1953-79

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
844	--	1,090	--	330	--	156	--	114	--
506	--	550	--	550	--	630	--	685	--
7.9	--	8.1	--	8.0	--	8.1	--	7.8	--
2.0	--	20.0	--	21.0	--	2.0	--	0.0	--
11.1	--	8.2	--	8.3	--	11.3	--	10.0	--
170	--	200	--	170	--	200	--	330	--
81	--	--	--	140	--	53	--	9	--
61	139	73	215	61	54.4	73	30.7	77	23.7
27	61.5	32	94.2	34	30.3	33	13.9	35	10.8
12	27.3	10	29.4	16	14.2	18	7.58	20	6.16
5.9	13.4	5.4	15.9	5.2	4.63	5.0	2.11	5.0	1.54
216	492	236	694	242	216	288	121	302	93.0
52	118	70	206	49	43.6	56	23.6	44	13.5
16	36.5	18	53.0	17	15.1	22	9.27	21	6.46
--	--	--	--	394	351	--	--	--	--
25	57.0	42	124	46	41.0	14	5.90	4	1.23
2.0	4.56	1.1	3.24	.15	.13	.84	.35	.91	.28
.39	.89	.10	.29	.10	.09	.10	.04	.54	.17
.28	.64	.28	.82	.30	.27	.21	.09	.25	.08
5	.01	8	.02	9	.01	5	.00	6	.00
5	.01	5	.01	5	.00	5	.00	5	.00
--	--	--	--	5	.00	--	--	--	--
6	.01	5	.01	5	.00	5	.00	5	.00
160	.36	130	.38	200	.18	82	.03	120	.04

Most of the concentrations at site 4A tend to be higher than at site 4B. Site 4B is only 0.2 mile above the mouth; slow velocities and backwater from the Mississippi River probably decrease the concentrations by dilution, settling, and uptake of various nutrients by algae.

Nitrite plus nitrate nitrogen concentrations are higher in subbasin 4 than in subbasins 1, 2, and 3; higher concentrations may occur naturally because of runoff from the fertile Prairie soils. However, there undoubtedly is a large amount of commercial fertilizer used in subbasin 4, that may contribute additional nitrogen. The lowest median nitrite plus nitrate nitrogen concentrations at both primary sites occur during the summer growing season.

A sample collected at site 4B on September 11, 1970, was unusual; it contrained the maximum concentrations determined for specific conductance, magnesium, sodium, and chloride in any sample collected. The source of these high concentrations may be the South Fork Crow River. Evidence of high concentrations of various constituents in the South Fork is presented in the discussion of subbasin 5.

Figure 16 shows median seasonal variations for sites 4A and 4B. Seasonal responses for many of the constituents differ between the two sites. For example, specific conductance and concentrations of calcium and chloride decrease with increased streamflow in late spring at site 4A but increase at site 4B. The decrease at site 4A is attributed to dilution from spring runoff. Backwater effects from the Mississippi River may cause seasonal responses at site 4B to be different from those at 4A. Samples at site 4B probably represent a mixture of water from the Mississippi and Crow Rivers during periods of medium and low flow; this would tend to lower concentrations (fig. 16). At high flow, the water in the Crow River would be dominant and increase concentrations of dissolved constituents. This is shown in the graph of specific conductance (fig. 16), where the plots of late spring values for sites 4A and 4B approach one another.

Seasonal ammonia-nitrogen concentrations are similar at sites 4A and 4B, with the highest concentrations occurring in winter and early spring. Peak median concentrations of ammonia nitrogen are higher in subbasin 4 than in subbasin 1, 2, and 3.

Total-phosphorus concentrations at site 4A, which were determined only during the first three seasons of the year, vary in a manner similar to concentrations of suspended solids. At site 4B, phosphorus concentrations generally follow the suspended-solids pattern throughout the year. The increase of suspended-solids and total-phosphorus concentrations in summer at site 4B may be caused by algae. The relatively slack water near the mouth of the Crow River at site 4B probably allows algal growth.

Median dissolved-oxygen concentrations are adequate throughout the year for maintenance of healthy fish populations. Generally, concentrations decrease in winter during ice cover when reaeration is minimized. A minimum concentration of 3.5 mg/L at site 4A was observed on February 11, 1975. The median concentration of dissolved oxygen in winter is approximately 4 mg/L lower at site 4A than at 4B. The difference in medians is based on 13 observations at site 4A and 44 at site 4B. Comparison of winter dissolved-oxygen concentrations based on the 13 concurrent observations shows means of 7.8 and 10.1 mg/L at 4A and 4B, respectively. Because of the relatively large standard deviation at site 4A, a t-test does not show its mean to be significantly different from the mean at 4B.

Fecal-coliform counts for the two sites are relatively similar until fall when counts begin to decrease at site 4A and increase at 4B. However, because of the fewer observations at 4A and the imprecision inherent in the bacteria determination, this is not considered to be significant.

Regressions in table 26 were derived from data at site 4A; backwater effects prohibited the derivation of reliable regressions at site 4B. Correlation coefficients for potassium and sulfate were not significant at the 95-percent-confidence level, and their regression equations are not usable. The equations for streamflow and chloride can be used with caution.

There are no significant trends in subbasin 4 for the period 1952-79 except for chloride (table 27). Both primary sites show a positive trend for chloride, the major anion in road salt. In 1978, Hennepin and Wright Counties were reported to rank first and third in Minnesota counties in use of road salt (Minnesota Pollution Control Agency, 1978, p. 55). The Crow River is the border between the two counties.

Sodium, the main cation in road salt, is not as mobile as chloride because it commonly enters into cation-exchange reactions in soil. Therefore, a positive trend for sodium is not as great as it is for chloride.

Analyses at three secondary sites show areal variations in water quality (table 28). Each site was sampled in September 1971, which allows comparisons of water quality between sites during similar flow conditions.

The data for the secondary sites indicate that the North Fork Crow River near Georgeville, which is in the headwaters area of subbasin 4, has slightly higher concentrations of calcium and bicarbonate than do the other two secondary sites. The quality of water in the Middle Fork is strongly influenced by the lakes around Spicer, in that the lakes have lower dissolved solids and concentrations of inorganic nitrogen. Generally speaking, the quality of water from the upper to the lower parts of the subbasin is about the same, with some local variation between.

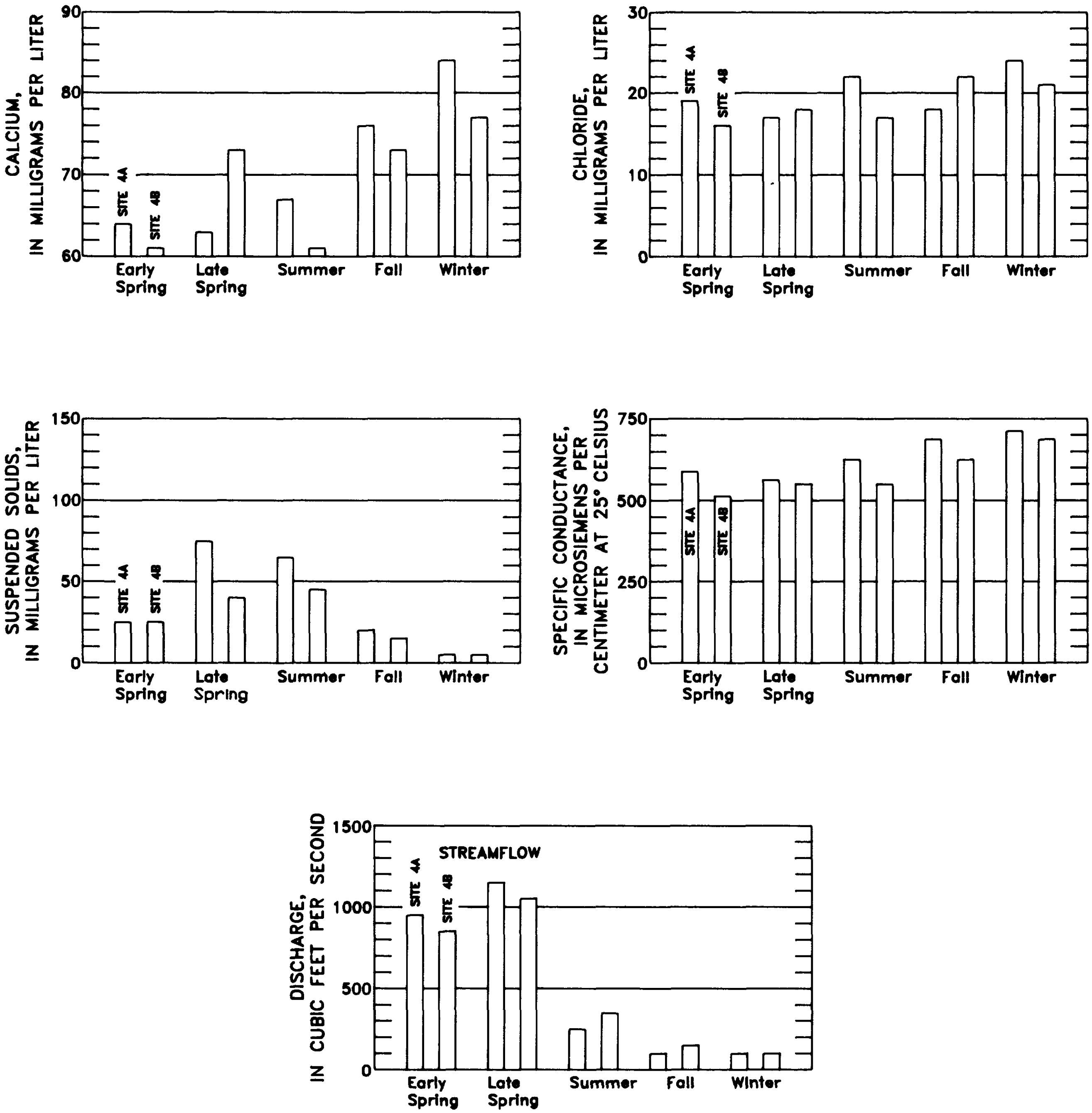
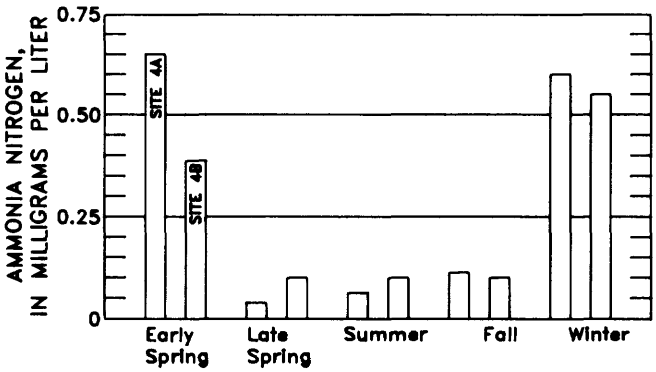
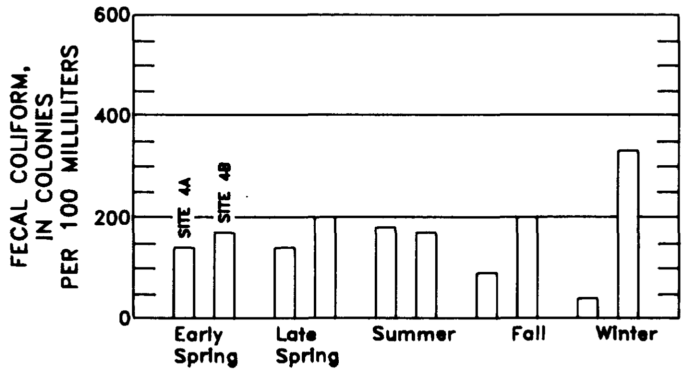
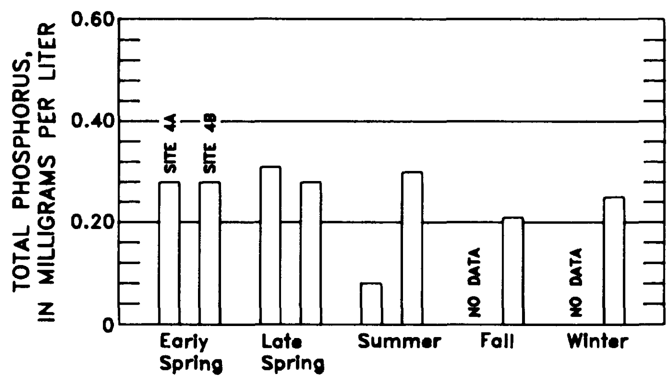
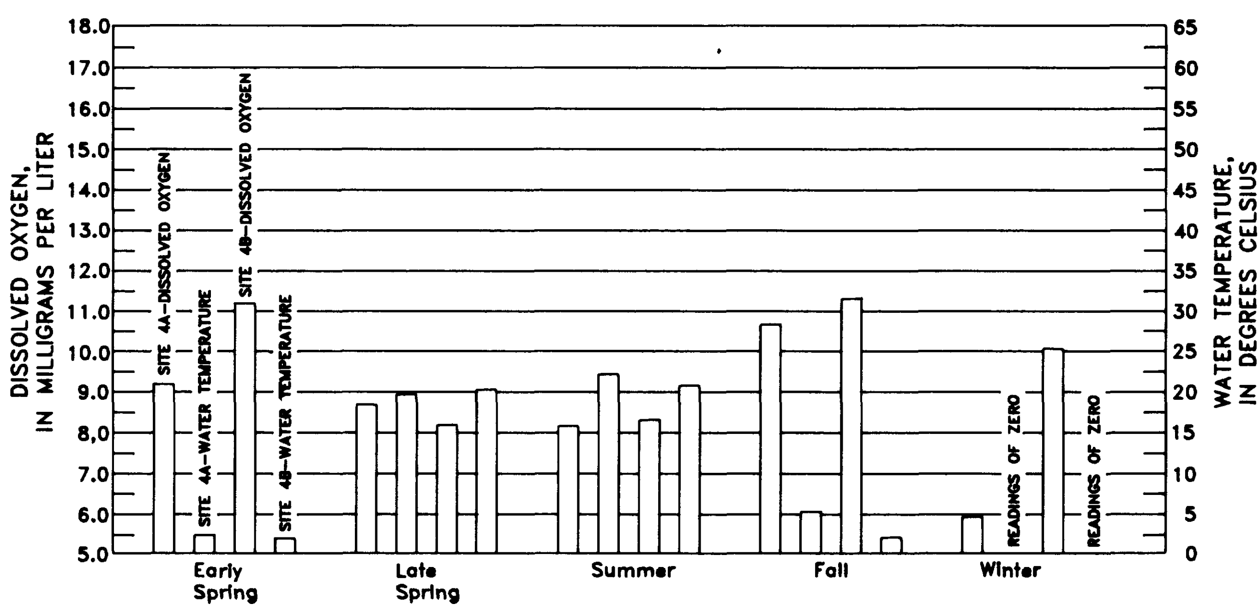


Figure 16.--Median seasonal variation in concentrations of selected









constituents and in properties sampled in subbasin 4.

Table 26.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance at site 4A*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; <, less than; *, not significant at the 95-percent confidence level]

Constituent or property	Number of observations	Regression equation	Correlation coefficient	Significance of (r)	Standard error of estimate
Streamflow (Q), ft^3/s.........	72	$Q = 720x10^9(SpC)^{-3.4}$	-0.58	<0.001	130 percent
Calcium (Ca), mg/L..........	61	Ca = .07(SpC) + 27	.67	<.001	10 mg/L
Magnesium (Mg), mg/L..........	61	Mg = .03(SpC) + 11	.69	<.001	4.5 mg/L
Sodium (Na), mg/L..........	61	Na = .05(SpC) - 12	.65	<.001	8.0 mg/L
Potassium (K), mg/L..........	61	K = .001(SpC) + 5.1	.10	*.430	1.2 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	56	Alk = .30(SpC) + 72	.70	<.001	39 mg/L
Sulfate (SO_4), mg/L..........	61	SO_4 = .01(SpC) + 50	.08	*.518	15 mg/L
Chloride (Cl), mg/L..........	61	Cl = .05(SpC) - 9.5	.56	<.001	10 mg/L

Table 27.--*Trends for selected constituents and properties at sites 4A and 4B*

[+, increasing trend; -, decreasing trend; 0, no apparent trend]

Constituent or property	Site 4A: Number of observations	Site 4A: Trend for period of record	Site 4B: Number of observations	Site 4B: Trend for period of record
Streamflow	76	0	201	0
Specific conductance	72	0	130	0
pH	61	+	195	0
Temperature	52	0	45	0
Dissolved oxygen	49	0	200	0
Fecal coliform	31	0	146	0
Fecal *Streptococci*	23	0	8	0
Calcium	61	0	60	0
Magnesium	61	0	19	0
Sodium	61	+	61	0
Potassium	61	0	59	0
Alkalinity	56	0	113	0
Sulfate	61	0	44	0
Chloride	61	+	149	+
Suspended solids	42	0	171	0
Nitrite plus nitrate as nitrogen	37	-	38	+
Ammonia as nitrogen	45	0	161	+
Total phosphorus	4	0	154	0
Arsenic	4	0	59	0
Cadmium	4	0	123	0
Chromium	1	0	7	-
Lead	2	0	84	0
Manganese	11	0	83	+

Table 28.--*Streamflow and water quality at secondary sites in subbasin 4*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; °C, degrees Celsius; mg/L, milligrams per liter; U.S. Geological Survey station number is in parenthesis]

Constituent or property	North Fork Crow River near Georgeville (05275970)				Middle Fork Crow River near Spicer (05278000)	North Fork Crow River near Delano (05278340)
	May 12, 1971	September 20, 1971	November 13, 1972	November 2, 1973	September 20, 1971	September 21, 1971
Streamflow (ft^3/s)...	44	7.0	75	18	39	146
Specific conductance (µS/cm)............	539	544	594	568	361	505
pH (units)...........	7.9	8.0	7.7	8.2	8.3	8.1
Temperature (°C).....	13.0	11.0	.0	3.5	11.0	13.0
Calcium, dissolved (mg/L).............	69	73	82	77	28	57
Magnesium, dissolved (mg/L).............	25	28	29	27	29	29
Sodium, dissolved (mg/L).............	5.5	6.3	5.5	6.3	5.2	9.4
Potassium, dissolved (mg/L).............	4.3	3.2	3.8	3.1	3.6	4.5
Alkalinity, total as $CaCO_3$ (mg/L).......	263	268	294	285	175	237
Sulfate, dissolved (mg/L).............	30	39	35	25	23	39
Chloride, dissolved (mg/L).............	5.1	4.9	7.3	6.3	4.6	7.9
Solids, dissolved (mg/L).............	310	358	372	351	230	320
Nitrite plus nitrate as nitrogen (mg/L).	0.10	0.54	.43	0.30	0.05	0.31
Phosphorus, total (mg/L).............	.10	.06	.06	.05	.04	.14

Subbasin 5

Physical Characteristics

Subbasin 5 is an undulating, clayey till plain roughly 65 miles long and 20 miles wide; it includes an area of about 1,400 mi^2. The fertile Prairie soil is the principal natural resource in the subbasin. Nearly 80 percent of the area is cultivated (table 29). The western part of the subbasin is covered

Table 29.--*Land use in subbasin 5*

Use	Acres	Percentage of total
Cultivated	582,360	79.86
Extractive	400	.04
Forested	20,880	2.58
Marsh	28,560	1.91
Pasture and open	187,240	9.85
Transportation	200	.02
Urban nonresidential or mixed residential development	9,880	1.41
Urban residential	17,080	.61
Water	57,200	3.71

by dark-colored, medium- to fine-textured calcareous soils. The rest of the area consists of gray to brownish-gray soils derived from limey clayey till.

The South Fork Crow River drains the entire subbasin. The river begins southeast of Willmar and flows eastward for about 104 miles to its junction with the North Fork. Buffalo Creek, the major tributary, drains an area of 394 mi^2 in the southern part of the watershed.

Two continuous-record gaging stations operated during the sample-collection period--Buffalo Creek near Glencoe (Number 05278930) and site 5A, South Fork Crow River near Mayer (Number 05279000).

Records for Buffalo Creek were collected from October 1972 through September 1980. Average flow at the station was 88.1 ft^3/s. A maximum flow of 2,590 ft^3/s occurred on April 9, 1979, and minimum daily flows of 0.01 ft^3/s occurred on August 28, 29, and September 8, 1976 (U.S. Geological Survey, 1981, p. 66).

Site 5A was a continuous-record station from April 1934 through September 1979; it was converted to a partial-record high-flow station in the 1980 water year. Average flow at the station for 45 years was 259 ft^3/s. The median of the yearly mean streamflows is 185 ft^3/s. A maximum of 16,100 ft^3/s occurred on April 13, 1965. No flow has occurred during some years (U.S. Geological Survey, 1980, p. 62).

Water-Quality Characteristics

One primary site and three secondary sites are used to describe water quality in subbasin 5. Site locations and land use are shown in figure 17. The period of record at site 5A is 1961-76, but only four samples were collected through 1971 (table 30). Most samples for water-quality analyses were collected from October 1972 to December 1976 as part of a cooperative monitoring program between the U.S. Geological Survey and the Metropolitan Waste Control Commission.

The last two samples, collected on November 16, and December 14, 1976, set a new maximum for specific conductance and new maximum concentrations for calcium, magnesium, sodium, potassium, alkalinity, chloride, sulfate, and dissolved solids. There were, however, other times when concentrations of these constituents were high. For example, potassium concentrations were equal to or greater than 10 mg/L in 11 different samples. Generally, potassium concentrations in ordinary surface and ground waters are less than 10 mg/L (Hem, 1985, p. 105). The high values occurred in the summer, fall, and winter.

Maximum counts of fecal coliform and fecal *Streptococci* bacteria occurred on April 18, 1975, during the early stages of spring runoff. The mean daily streamflows for the day before sampling, the day of sampling, and the day after, were 600, 872, and 1,100 ft^3/s, respectively (U.S. Geological Survey 1976, p. 137). The fecal coliform/fecal *Streptococci* ratio is 2.2, which indicates the bacteria are from a mixed population (Millipore, 1973).

Median seasonal variations in concentration of selected constituents and properties are shown in figure 18. The major part of spring runoff occurs in early spring followed by a rapid decline in streamflow until summer. Streamflow then is sustained mainly by ground water for the rest of the year.

Concentrations of specific conductance, calcium, chloride, and dissolved phosphorus at site 5A have a general upward trend throughout the year. Chloride, like potassium, does not appear to be coming from the drift. Chloride

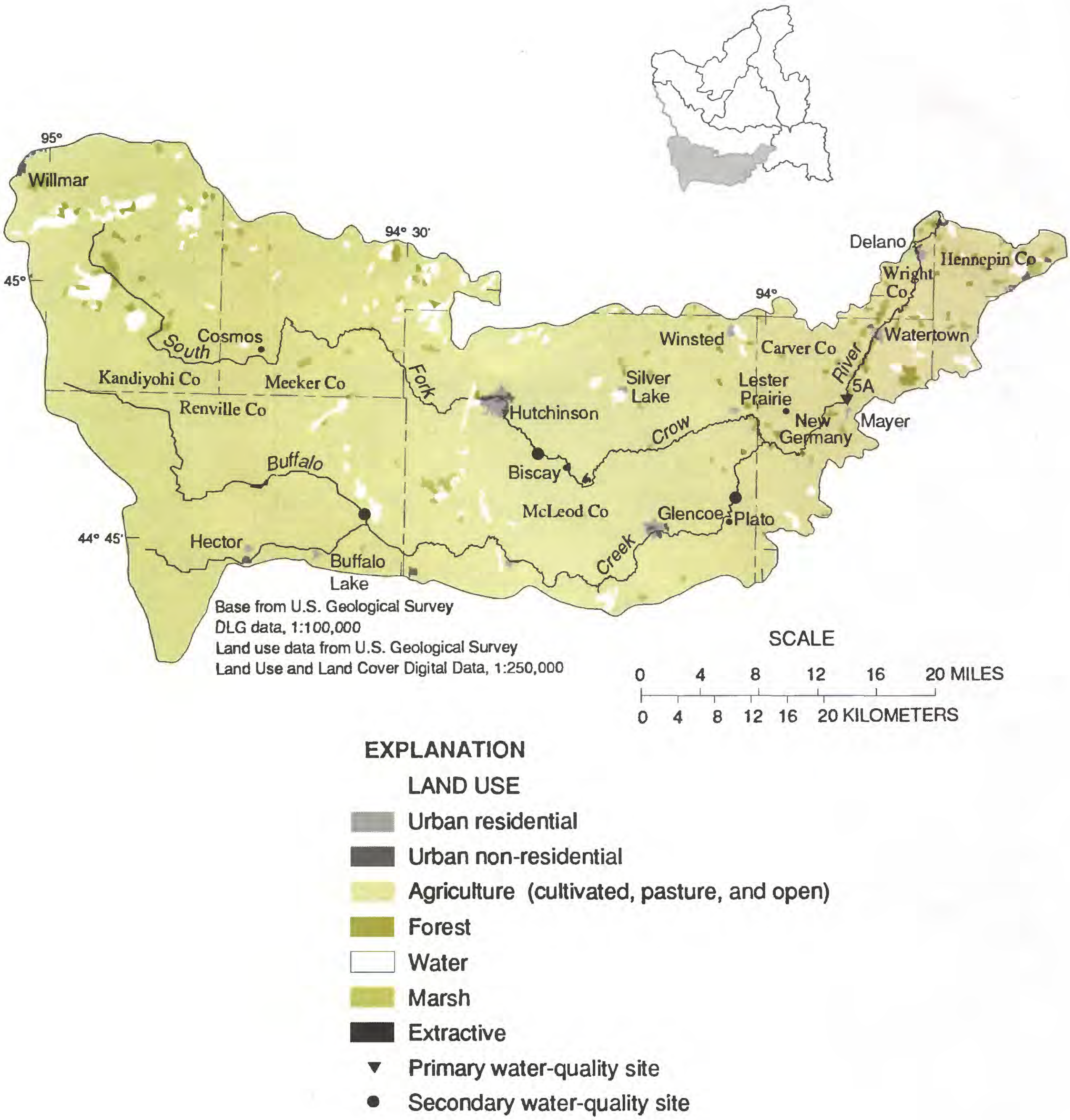


Figure 17. Land use and location of sampling sites in subbasin 5.

Table 30.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record: Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	54	2,870	0.1	269	67	547
Specific conductance (µS/cm)	54	4,110	327	1,060	928	566
pH (units)	54	8.9	7.2	8.0	8.1	0.4
Temperature (°Celsius)	52	26.0	0.0	9.0	5.0	9.0
Oxygen, dissolved (mg/L)	50	15.0	.6	8.0	8.0	3.5
Fecal coliform (colonies/100mL)	33	10,000	1	1,300	490	2,400
Fecal Streptococci (colonies/100mL)	26	4,500	<1	490	210	870
Calcium, dissolved (mg/L)	54	170	38	95	92	24
Magnesium, dissolved (mg/L)	54	95	13	44	44	14
Sodium, dissolved (mg/L)	54	590	4.2	67	40	90
Potassium, dissolved (mg/L)	54	170	4.9	12	8.1	22
Alkalinity, total (mg/L)	52	671	93	306	290	101
Sulfate, dissolved (mg/L)	54	220	42	130	130	37
Chloride, dissolved (mg/L)	54	950	9.0	96	60	140
Solids, dissolved (mg/L)	54	2,330	243	692	634	319
Solids, suspended (mg/L)	50	444	<1	51	29	71
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	38	8.8	.01	1.7	.76	2.3
Ammonia as nitrogen, dissolved (mg/L)	49	4.9	.01	.74	.14	1.2
Phosphorus, total (mg/L)	1	--	--	--	--	--
Phosphorus, dissolved (mg/L)	50	2.1	.03	.62	.39	.57
Arsenic, total (µg/L)	1	--	--	--	--	--
Cadmium, total (µg/L)	3	20	<1	7	5	12
Chromium, total (µg/L)	1	--	--	--	--	--
Lead, total (µg/L)	2	50	2	26	26	34
Manganese, total (µg/L)	5	4,900	<1	1,200	360	2,100

at site 5A, South Fork Crow River near Mayer, Minnesota, 1961-76

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
554	--	315	--	29	--	29	--	10	--
750	--	872	--	925	--	946	--	1,300	--
7.8	--	8.2	--	8.5	--	8.2	--	7.5	--
4.0	--	16.5	--	20.0	--	2.5	--	0.0	--
9.8	--	9.3	--	7.4	--	11.4	--	4.0	--
800	--	1,000	--	360	--	410	--	1,200	--
240	--	310	--	150	--	250	--	200	--
73	109	88	74.8	87	6.81	92	7.20	120	3.24
35	52.4	44	37.4	42	3.29	44	3.44	53	1.43
18	26.9	20	17.0	50	3.92	66	5.17	96	2.59
6.0	8.97	5.2	4.42	8.0	.63	8.2	.64	9.8	.26
214	320	265	225	276	21.6	314	24.6	394	10.6
88	132	138	117	114	8.93	112	8.77	160	4.32
27	40.4	31	26.4	64	5.01	95	7.44	120	3.24
512	766	599	509	595	46.6	641	50.2	854	23.0
59	88.2	68	57.8	40	3.13	22	1.72	8	.22
3.5	5.24	3.0	2.55	.04	.00	.10	.01	.93	.02
.24	.36	.04	.03	.09	.01	.10	.01	1.7	.04
--	--	--	--	.37	.03	--	--	--	--
.28	.42	.17	.14	.38	.03	.32	.02	.73	.02
--	--	--	--	--	--	3	.00	--	--
--	--	<1	.00	--	--	10	.00	--	--
--	--	--	--	--	--	<1	.00	--	--
--	--	--	--	--	--	26	.00	--	--
4,900	7.33	360	.31	<1	.00	280	.02	--	--

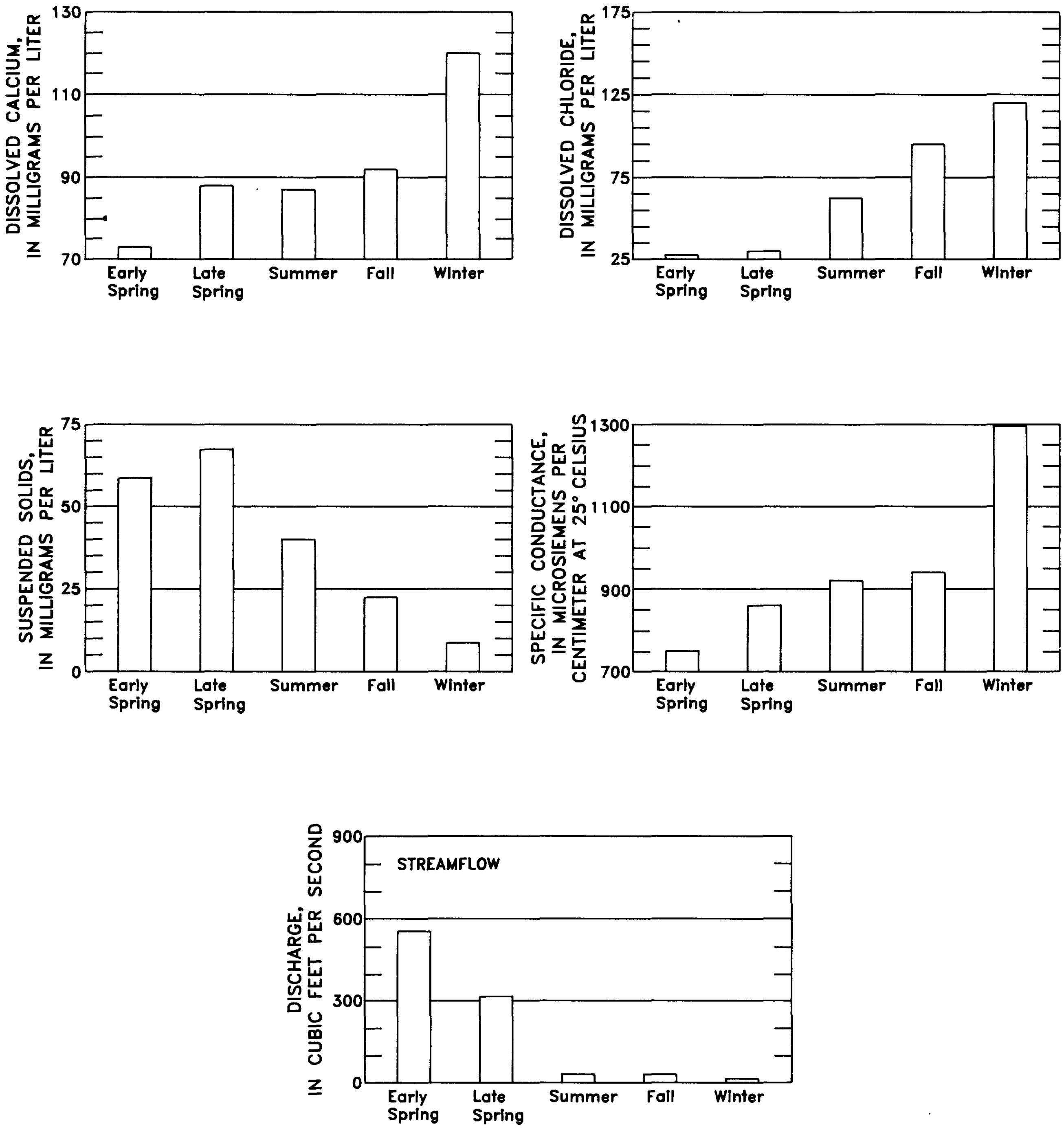
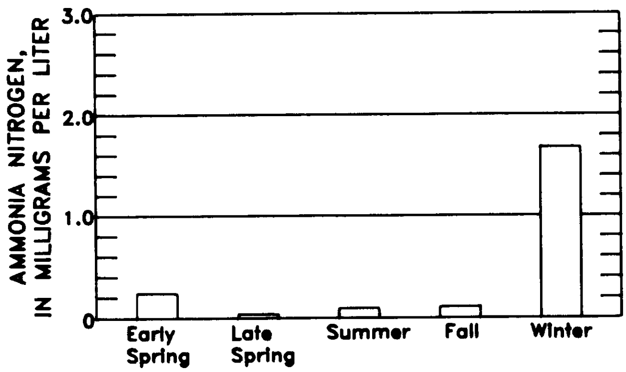
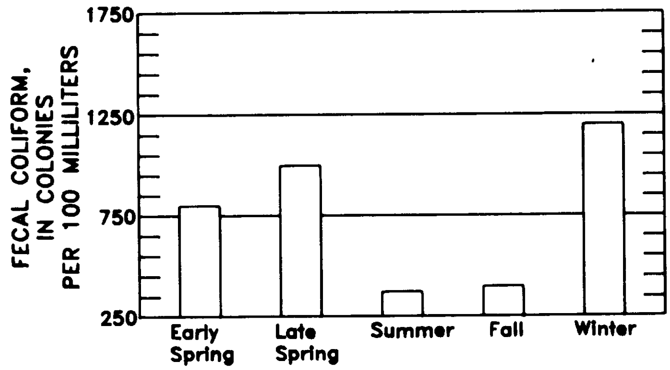
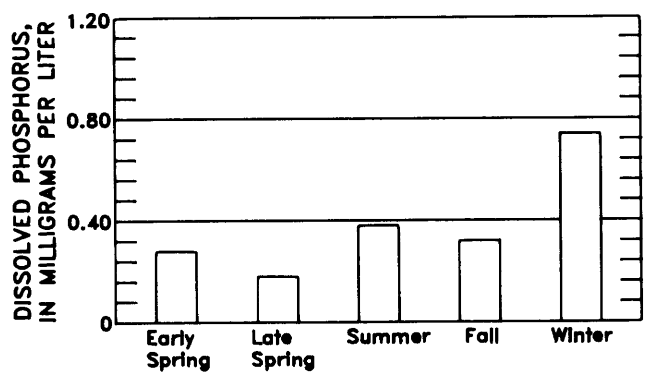
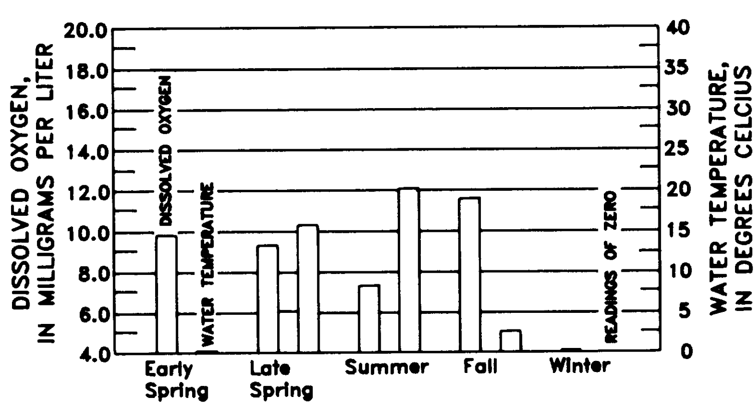


Figure 18.--Median seasonal variation in concentrations of









selected constituents and in properties sampled at site 5A.

concentrations in water from three drift wells at Watertown range from 2.3 to 4 mg/L (Minnesota Department of Health, 1983). One should not rule out the possibility, however, that these wells might not be located in an area where concentrations of chloride in ground water are high.

Probable causes of high chloride concentrations are point sources. Chloride concentrations are inversely related to streamflow (fig. 18). This relation suggests that chloride input to the stream is relatively high and that concentrations vary seasonally because of a varying degree of dilution brought about by seasonal variations in flow. If the source were strictly road salt entering via storm sewers, a rising concentration curve during the summer and fall would not be expected. More likely, there are one or more point sources upstream of site 5A that contribute elevated concentrations of salts to the river.

Dissolved oxygen, fecal coliform, and ammonia nitrogen concentrations in winter show evidence of point-source contamination; nonpoint-source contamination should be expected to be at a minimum during this time of year. The mean fecal coliform to fecal *Streptococci* ratio for the six winter samples is 3.1, which suggests that the origin of the bacteria is a mixed population with predominantly human waste. The winter rise in ammonia concentration and the decline in dissolved-oxygen concentration is further evidence, if considered with the bacteria concentrations, of biodegradable wastes entering the river.

Regressions between various constituents or properties and specific conductance shown in table 31 are from site 5A data. The regressions apply to the reach of the South Fork Crow River from site 5A to the mouth.

Trends for the period of record are shown in table 32. As indicated earlier, most of the samples were collected between 1972-76; therefore, the effective period of record is short. The trends are not significant; they reflect short-term changes that were affected by the 1976-77 drought.

Miscellaneous analyses in table 33 include results for samples collected in September 1971. Dissolved-solids concentrations of September 1971 show Buffalo Creek to have higher concentrations than the South Fork of the Crow River. Dissolved-solids concentrations appear to increase downstream in Buffalo Creek, although some constituents decreased in concentration downstream in September 1971. There is a large increase in sodium and chloride concentrations between the two Buffalo Creek sampling sites. Elevated dissolved-solids concentrations can occur at Buffalo Creek near Plato, as evidenced by the September 1969 sample. These high concentrations most likely result from a point-source discharge to Buffalo Creek.

An analysis of load data helps locate point sources of high concentrations of some chemical constituents found at site 5A. An analysis of sodium, potassium, and chloride data, for example, shows that the total load, in tons per day, at Biscay and Plato to approximately equal that found at Mayer (site 5A). The increase in load from Buffalo Lake to Plato suggests point-source contamination and possibly more than one source. It also suggests that the locations of the point sources are at or upstream of Biscay, near Plato.

Table 31.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance at site 5A*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; <, less than]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Siginicence of r	Standard error of estimate
Streamflow (Q), ft^3/s.........	54	$Q = 117x10^{10}(SpC)^{-3.5}$	0-0.65	<0.001	249 percent
Calcium (Ca), mg/L..........	54	Ca = 0.02(SpC) + 77	.41	.002	23 mg/L
Magnesium (Mg), mg/L..........	54	Mg = 0.02(SpC) + 23	.83	<.001	8.0 mg/L
Sodium (Na), mg/L..........	54	Na = 0.15(SpC) - 94	.96	<.001	25 mg/L
Potassium (K), mg/L..........	54	K = 0.03(SpC) - 23	.84	<.001	12 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	52	Alk = 0.15(SpC) + 149	.84	<.001	56 mg/L
Sulfate (SO_4), mg/L..........	54	SO_4 = 0.03(SpC) + 98	.45	<.001	34 mg/L
Chloride (Cl), mg/L..........	54	Cl = 0.24(SpC) - 152	.95	<.001	42 mg/L

Table 32.--*Trends for selected constituents and properties at site 5A*

[+, increasing trend; -, decreasing trend; 0, no apparent trend]

Constituent or property	Number of observations	Trend for period of record
Streamflow	54	-
Specific conductance	54	+
pH	54	+
Temperature	35	0
Dissolved oxygen	50	0
Fecal coliform	33	-
Fecal *Streptococci*	25	0
Calcium	54	0
Magnesium	54	0
Sodium	54	+
Potassium	54	0
Alkalinity	52	0
Sulfate	54	0
Chloride	54	+
Dissolved solids	54	0
Suspended solids	47	0
Nitrite plus nitrate as nitrogen	38	-
Ammonia as nitrogen	49	0
Dissolved phosphorus	50	0

Table 33.--*Streamflow and water quality at secondary sites in subbasin 5*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; °C, degrees Celsius; mg/L, milligrams per liter; U.S. Geological Survey station number is in parenthesis]

Constituent or property	South Fork Crow River at Biscay (05278590)	Buffalo Creek near Buffalo Lake (05278830)	Buffalo Creek near Plato (05278950)		South Fork Crow River near Mayer[1] (05279000)
	Sept. 21, 1971	Sept. 21, 1971	Sept. 10, 1969	Sept. 21, 1971	Sept. 22, 1971
Streamflow (ft^3/s)...	27	1.6	1.5	7.2	43
Specific conductance (µS/cm)...........	853	1,000	5,950	1,190	860
pH (units)..........	7.9	8.0	7.7	8.3	8.3
Temperature (°C).....	15.0	16.0	15.0	14.0	13.0
Calcium, dissolved					
(mg/L)............	82	110	120	120	91
(tons/day).........	6.0	.48	.49	2.3	10
Magnesium, dissolved					
(mg/L)............	42	66	70	54	42
(tons/day).........	3.1	.28	.28	1.0	4.9
Sodium, dissolved					
(mg/L)............	39	18	1,200	58	31
(tons/day).........	2.8	.08	4.9	1.1	3.6
Potassium, dissolved					
(mg/L)............	8.9	5.5	78	6.6	7.3
(tons/day).........	.65	.02	.32	.13	.85
Alkalinity, total as					
$CaCO_3$ (mg/L).......	273	213	587	309	282
(tons/day).........	20	.92	2.4	6.0	33
Sulfate, dissolved					
(mg/L)............	130	330	28	250	140
(tons/day).........	9.5	1.4	.11	4.9	16
Chloride, dissolved					
(mg/L)............	45	17	1,800	68	40
(tons/day).........	3.3	.07	7.3	1.3	4.6
Solids, dissolved					
(mg/L)............	564	760	3,610	816	580
(tons/day).........	41	3.3	15	16	67
Nitrite plus nitrate					
as nitrogen (mg/L).	1.1	1.0	[2]8.6	3.7	--
(tons/day).........	.80	.004	.12	.07	--
Phosphorus, total					
(mg/L)............	.58	.05	[3]7.4	--	.78
(tons/day).........	.04	.0002	.15	--	.09

[1] Site 5A.
[2] Dissolved nitrate without nitrite.
[3] Dissolved phosphorus. Orthophosphorus also was analyzed and was 5.5 mg/L.

Subbasin 6

Physical Characteristics

Subbasin 6 covers an area of approximately 1,030 mi^2 including most of the Twin Cities Metropolitan area; it encompasses the reach of the Mississippi River between the mouth of the Crow River and the mouth of the St. Croix River. Major streams that enter the subbasin are the Rum and Minnesota Rivers. The central part of the subbasin is largely a rolling till plain bounded on the east and west by hilly glacial moraines.

The 1980 population of the Twin Cities Metropolitan area was 2,113,533, an increase of 32 percent since 1960 (U.S. Department of Commerce, 1982) (table 1). Land use in subbasin 6 is approximately 37 percent urban (table 34),

Table 34.--*Land use in subbasin 6*

Use	Acres	Percent of total
Cultivated	148,960	22.52
Extractive	1,440	0.22
Forested	61,760	9.33
Marsh	25,600	3.87
Pasture and open	130,320	19.70
Transportation	2,840	.43
Urban nonresidential or mixed residential development	124,120	18.76
Urban residential	122,960	18.59
Water	43,600	6.59

the highest of all the subbasins. Truck and dairy farming are the two major types of agriculture.

A 9-foot channel in the Mississippi River is maintained by the U.S. Army Corps of Engineers to mile point 857.6 at Minneapolis. Within the study area, both upper and lower St. Anthony Falls pools, pool 1, pool 2, and upper pool 3 are maintained for navigation by locks and dams (fig. 19). The pools are limited by law to the amount of allowable drawdown. During most of the year, the Mississippi River in subbasin 6 is not a free-flowing stream. In the

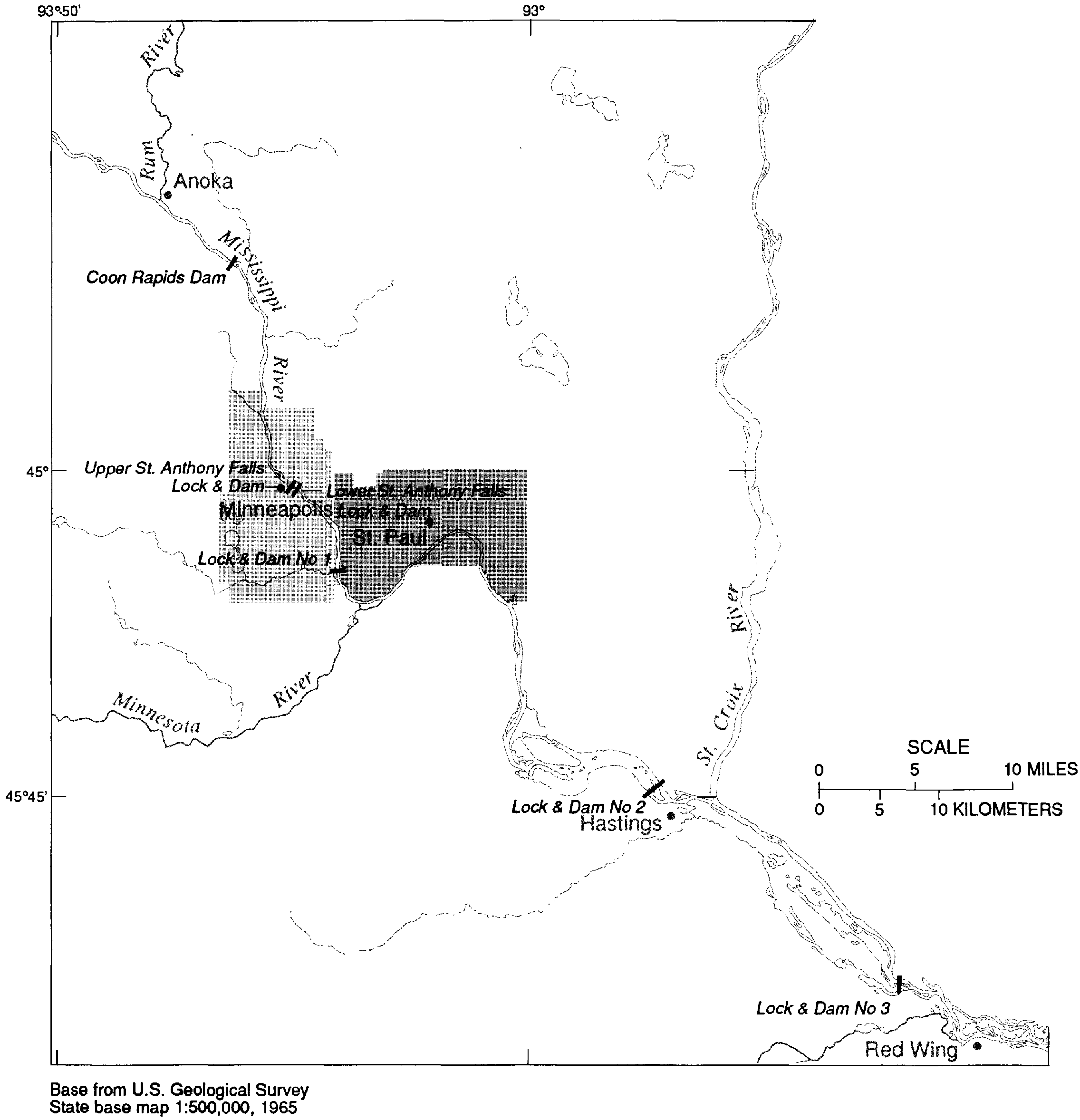


Figure 19. Location of locks and dams in and near the Twin Cities area.

spring, however, control gates and locks sometimes are opened during peak runoff periods and the river flows freely (Great River Environmental Action Team, March 1978).

The U.S. Geological Survey operates two gaging stations, sites 6B and 6F, in the subbasin. Average flow at site 6B, Mississippi River near Anoka, was 7,655 ft^3/s for 52 years of record (U.S. Geological Survey, 1984, p. 69). A maximum flow of 91,000 ft^3/s occurred April 17, 1965, and a minimum flow of 529 ft^3/s occurred on August 29, 1976.

Average flow at site 6F, Mississippi River at St. Paul, was 10,780 ft^3/s; the median of yearly mean flows was 10,130 ft^3/s (U.S. Geological Survey, 1984, p. 174). A maximum flow of 171,000 ft^3/s occurred on April 16, 1965, and a minimum flow of 632 ft^3/s occurred on August 26, 1934. During the 1976-77 drought, a minimum flow of 723 ft^3/s occurred on August 30, 1976 (U.S. Geological Survey, 1977, p. 394.

Water-Quality Characteristics

Thirteen primary sites, 6A to 6M, are used to describe the quality of water in subbasin 6 (fig. 20). Site MN-1 is on the Minnesota River and is used, for purposes of analysis, as a point-source discharge to the Mississippi River.

Most of the data for subbasin 6 were collected as part of a cooperative monitoring program between the U.S. Geological Survey and the Metropolitan Waste Control Commission. The Minnesota Pollution Control Agency also collected samples at six of the sites that were part of the USGS/MWCC monitoring program (table 3). The sampling periods were not always concurrent, but inspection shows that the different sets of data are comparable. Data collected by the three agencies at sites 6A, 6F, 6J, 6M, and MN-1 were combined in order to have a larger data base at each site. The MPCA and USGS/MWCC data at site 6I were left separate because the USGS/MWCC data consist only of specific conductance, pH, dissolved oxygen, and temperature from an automatic monitor, whereas the MPCA data are from samples collected manually and analyzed in the laboratory.

Figure 21 shows the location of seven automatic-monitor sites and the thermograph at site 6F. The monitors were installed in the mid-1970's. They have variable periods of record because of different installation dates and different amounts of downtime for maintenance. Because much of the data are not normally distributed, quartiles are used for comparisons between sites (table 35). Site MN-1 is on the Minnesota River near the mouth, which is between sites 6E and 6F.

Water from the Minnesota River increases the specific conductance of water in the Mississippi River as shown at site 6G, 7.5 miles downstream from the confluence. Specific conductance increases again at site 6I, below the metropolitan sewage-treatment plant, where about 80 percent of the sewage from the Twin Cities is treated.

During the colder months, water temperature tends to be higher below the treatment plant, as evidenced by the relatively higher 25-percent-quartile

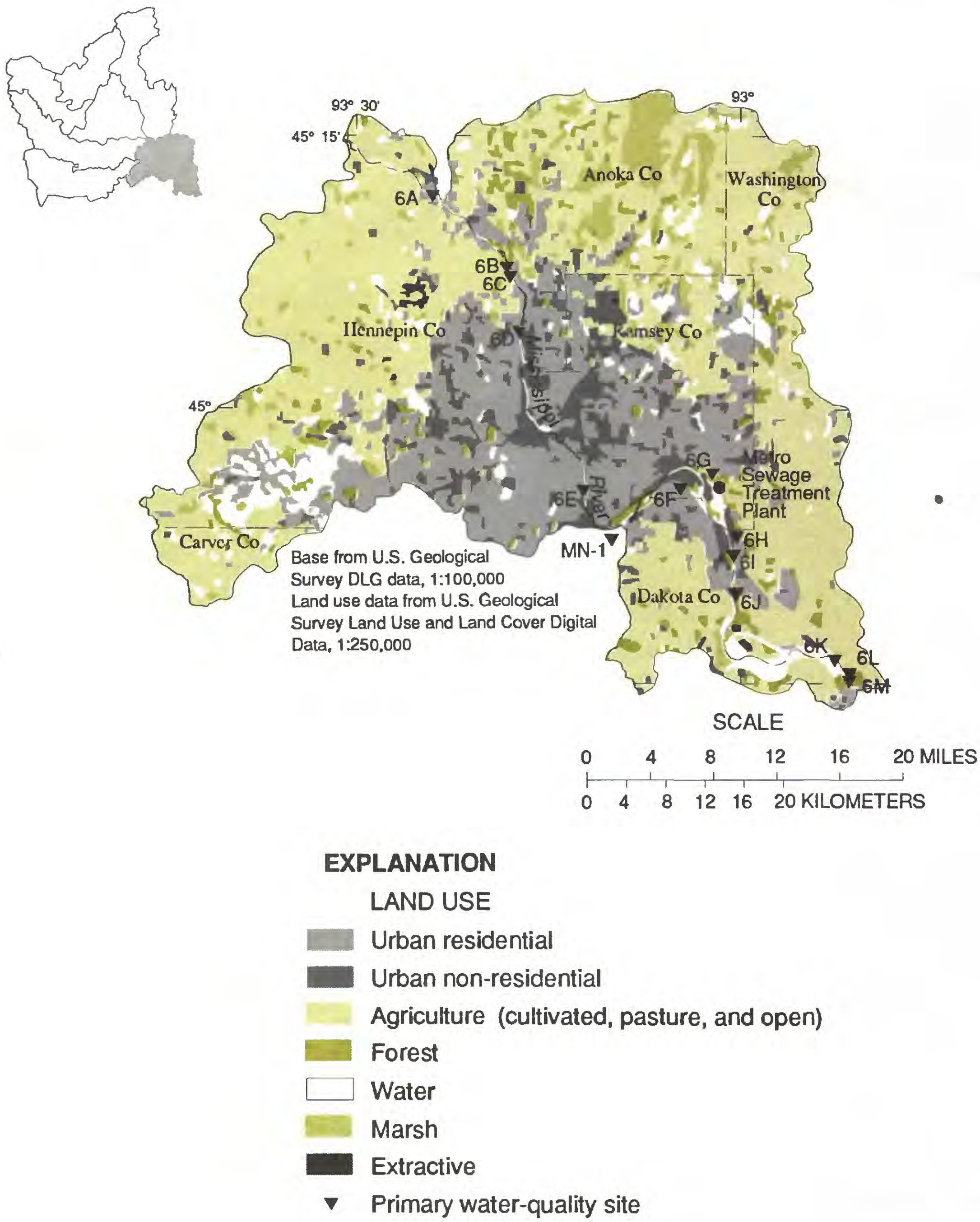


Figure 20. Land use and location of sampling sites in subbasin 6.

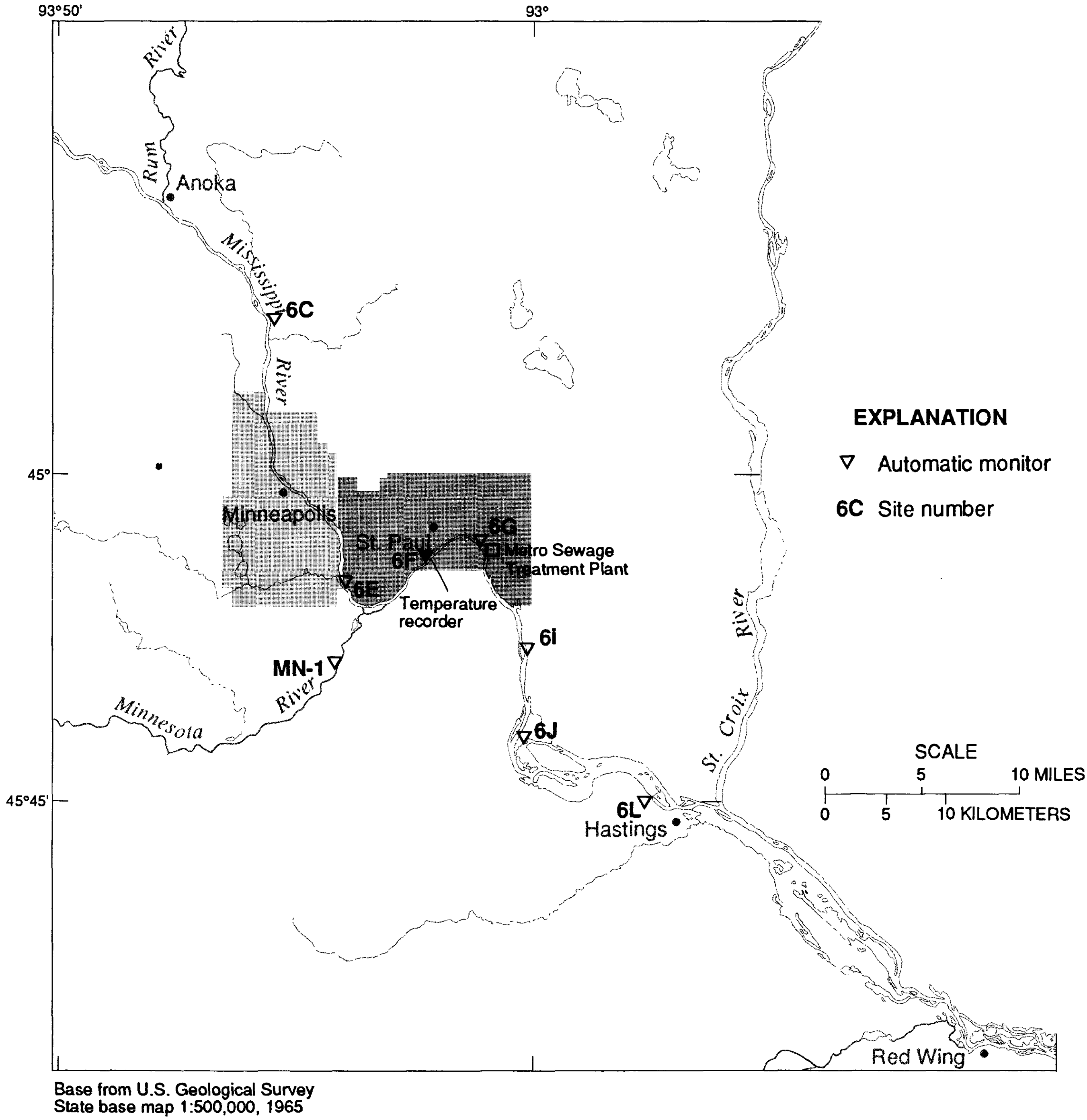


Figure 21. Location of automatic monitors in subbasin 6.

Table 35.--*Summary of daily data from automatic monitors in subbasin 6*

[Site 6F has temperature only. Number of measurements very from 721 to 2,084. --, no data]

Site	Temperature (degrees Celsius)			Specific conductance (miscrosiemens per centimeter)			Dissolved oxygen (milligrams per liter)			pH		
	75 percent quartile	median	25 percent quartile	75 percent quartile	median	25 percent quartile	75 percent quartile	median	25 percent quartile	75 percent quartile	median	25 percent quartile
6C	19.4	6.9	0.9	341	317	292	12.7	11.6	9.0	8.2	8.0	7.8
6E	20.5	11.5	2.4	374	345	313	12.9	11.2	8.5	8.3	8.1	7.9
MN-1	19.9	8.5	1.2	1,020	887	817	11.3	9.6	7.5	8.1	8.0	7.8
6F	20.6	10.5	1.4	--	--	--	--	--	--	--	--	--
6G	22.0	11.4	1.7	540	467	409	12.3	10.5	7.4	8.1	7.9	7.8
6I	22.2	16.0	4.0	557	513	476	11.2	8.9	6.6	8.1	8.0	7.8
6J	20.7	14.0	3.5	538	476	438	11.1	9.1	6.8	8.1	7.9	7.8
6L	22.3	14.4	1.2	539	482	435	11.4	9.5	7.3	8.1	7.9	7.8

temperatures at sites 6I and 6J. The temperature shows recovery at site 6L, which is 20 miles downstream of the treatment plant. Although site 6F is about 1 mile below a power plant that has a gross capacity of 347 megawatts per hour (Ed Loye, Northern States Power Company, oral commun., 1986), water temperature at 6F is not affected.

Table 35 shows pH to be relatively uniform, but the concentration of dissolved oxygen varies. About 5 miles below the treatment plant at site 6I, dissolved-oxygen concentrations are about 1 mg/L less than concentrations above the plant at site 6G; median concentrations are 8.9 and 10.5 mg/L, respectively. A gradual recovery trend in dissolved-oxygen concentrations occurs downstream from the treatment plant where median concentrations of 9.1 and 9.5 mg/L are shown at sites 6J and 6L, respectively.

Figure 22 shows seasonal dissolved-oxygen-concentration curves prepared from a balanced data set; medians for each site are calculated from the same days for each season. There is a decrease in concentration below the mouth of the Minnesota River. Then there is a further decline below the sewage-treatment plant. The lowest median dissolved-oxygen concentrations occur at site 6J, except in winter. The dissolved-oxygen "sag" shifts downstream in winter because of the slower degradation rate of the sewage effluent and the lower phytoplankton activity.

In late spring and fall, dissolved oxygen recovers to concentrations that are even greater than the concentrations shown at site 6C. Presumably, the increase in dissolved-oxygen concentration at site 6L is assisted by phytoplankton activity. A University of Minnesota study done in August 1976 reported an increase in chlorophyll concentrations below the metropolitan sewage-treatment plant (Megard and others, 1978). The study concluded, however, that the increase did not occur because nutrients from the treatment plant stimulated photosynthesis, but because the thickness of the mixed layer in this reach of the river was less than at other localities. The report stated that algae apparently are saturated with phosphorus at all localities in the metropolitan reach of the river.

During high flow, as in early and late spring, effluent from the sewage-treatment plant is aerated by pumping it to a higher elevation and then allowing the effluent to cascade downward over a series of weirs toward the river. Even though the river has a much larger volume of water than the effluent channel, higher dissolved-oxygen concentrations occur at 6I. Site 6I is on the same side of the river as the effluent channel, and there is incomplete mixing at that point.

Tables 36 to 47 show summary statistics for each of the sites that were sampled by hand in subbasin 6. Most constituent concentrations increase in the Mississippi River below the Minnesota River and below the sewage-treatment plant. Table 48 shows the summary statistics for site MN-1.

Figure 23 shows median seasonal variations in concentration of selected constituents and properties in water samples collected manually. Because of the areal variability within subbasin 6, sites were put into one of three groups - those above the Minnesota River, those between the Minnesota River and the sewage-treatment plant, and those below the treatment plant.

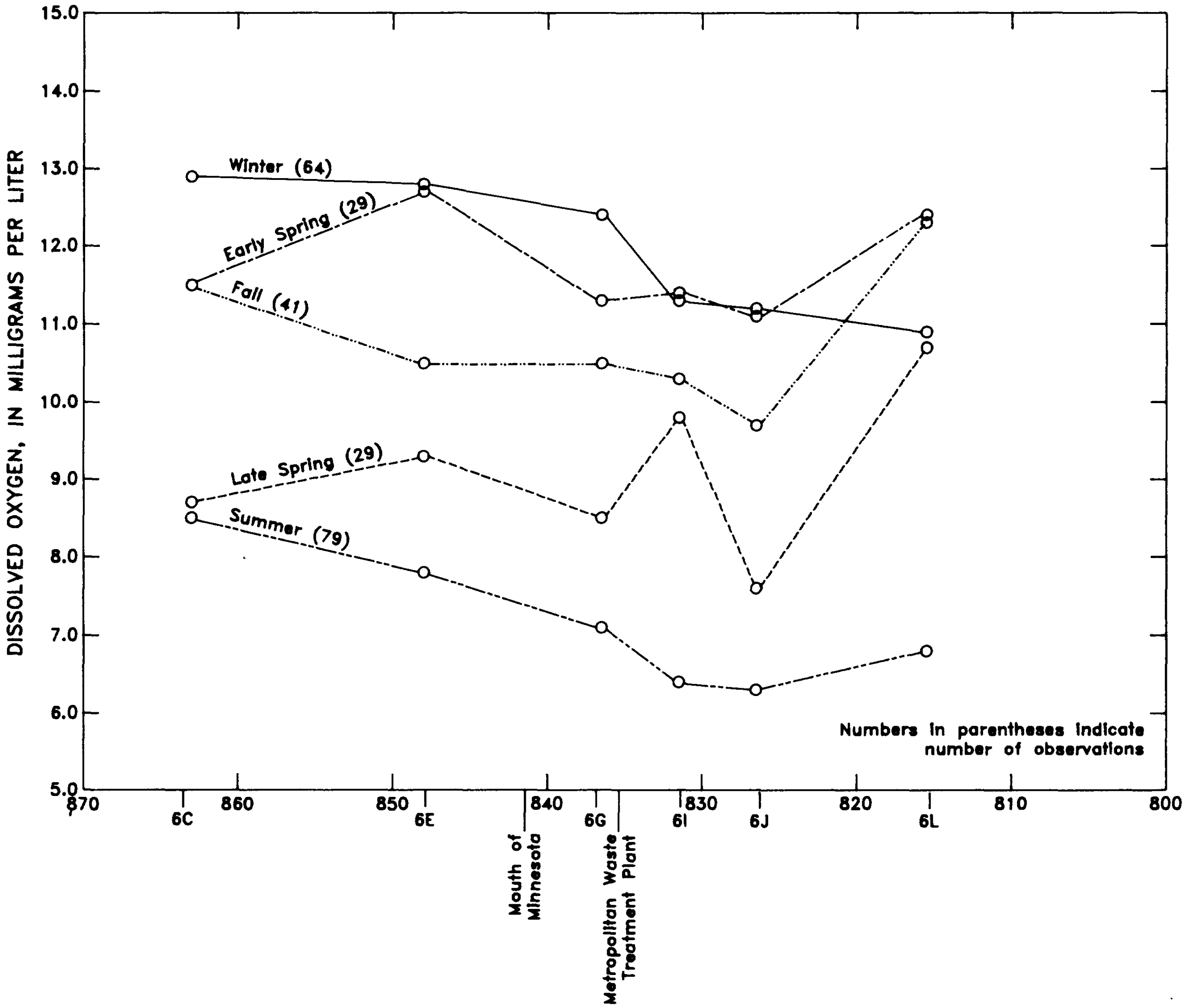


Figure 22.--Seasonal dissolved-oxygen concentrations in subbasin 6 using median values from balanced automatic-monitor data.

Table 36.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	434	44,300	963	7,380	5,150	6,760
Specific conductance (µS/cm)...........	228	560	223	357	350	60.4
pH (units)..........	411	8.9	6.5	8.0	8.0	0.4
Temperature (°Celsius).........	338	28	.0	10.5	10.0	.50
Oxygen, dissolved (mg/L)............	410	15.6	5.2	10.3	10.1	2.51
Fecal coliform (colonies/100mL)...	331	3,400	0	165	68	330
Fecal Streptococci (colonies/100mL)...	80	3,900	0	364	92	748
Calcium, dissolved (mg/L)............	104	64	31	46	45	6.2
Magnesium, dissolved (mg/L)......	107	32	8.9	16.4	16	3.3
Sodium, dissolved (mg/L)............	102	22.5	3.8	8.1	7.2	3.78
Potassium, dissolved (mg/L)......	104	6.9	.8	2.58	2.4	.837
Alkalinity, total (mg/L)............	121	240	95	164	164	26.9
Sulfate, dissolved (mg/L)............	105	50	8.6	20.9	19	9.2
Chloride, dissolved (mg/L)............	137	24	.5	6.96	6.7	3.46
Solids, dissolved (mg/L)............	163	856	163	246	240	64.01
Solids, suspended (mg/L)............	308	224	.4	20.5	17	21.1
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	247	5	.02	.528	.36	.612
Ammonia as nitrogen, dissolved (mg/L)...	352	3	.01	.197	.100	.249
Phosphorus, total (mg/L)............	252	.91	.02	.121	.100	.099
Phosphorus, dissolved (mg/L)......	118	.88	.01	.07	.05	.102
Arsenic, total (µg/L)............	40	7	<1	2	2	1.4
Cadmium, total (µg/L)............	41	20	<1	3	1	4.8
Chromium, total (µg/L)............	40	20	<1	7	5	5.5
Lead, total (µg/L)...	32	120	<1	18	4	28
Manganese, total (µg/L)............	42	390	1	123	110	87

at site 6A, Mississippi River at Anoka, Minnesota, 1953-81

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
6,500	--	8,320	--	5,310	--	5,410	--	4,140	--
350	--	350	--	350	--	335	--	370	--
8.0	--	8.0	--	8.2	--	8.1	--	7.9	--
4.0	--	19.0	--	22.5	--	6.5	--	.0	--
12	--	8.4	--	7.7	--	11.2	--	12.8	--
42	--	90	--	100	--	36	--	45	--
166	--	172	--	105	--	130	--	12	--
45	790	44	988	42	602	44	643	49	548
16	281	16	359	16	229	16	234	18	201
7.4	130	6.6	148	6.7	96.0	6.0	87.6	8.2	91.6
3.2	56.2	2.6	58.4	2.0	28.7	2.2	32.1	2.4	26.8
168	2,950	160	3,590	154	2,210	159	2,320	183	2,040
19	333	23	517	19	272	17	248	18	201
7.2	126	6.8	153	6.6	94.6	6.0	87.6	6.9	77.1
236	4,140	241	5,410	230	3,300	222	3,240	247	2,760
22	386	28	629	23	330	10	146	6	67.1
.60	10.5	.22	4.94	.22	3.15	.20	2.92	.50	5.59
.25	4.39	.10	2.25	.10	1.43	.10	1.46	.20	2.24
.12	2.11	.13	2.92	.13	1.86	.06	.88	.08	.89
.06	1.05	.05	1.12	.06	.86	.05	.73	.05	.56
2	.03	2	.05	2	.03	2	.03	1	.01
1	.02	1	.02	<1	<.01	<1	<.01	<1	<.01
5	.09	10	.22	10	.14	4	.06	5	.06
14	.24	5	.11	1	.01	4	.06	4	.05
125	2.19	155	3.48	132	1.89	75	1.10	50	.56

Table 37.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	119	72,100	1,230	9,280	5,950	10,800
Specific conductance (μS/cm)	118	468	185	330	233	52
pH (units)	118	8.3	6.9	7.5	7.5	0.3
Temperature (°Celsius)	45	25.0	.0	8.5	7.0	8.5
Oxygen, dissolved (mg/L)	0	--	--	--	--	--
Fecal coliform (colonies/100mL)	0	--	--	--	--	--
Fecal Streptococci (colonies/100mL)	0	--	--	--	--	--
Calcium, dissolved (mg/L)	118	58	22	43	43	6.3
Magnesium, dissolved (mg/L)	118	22	2.8	14	15	3.2
Sodium, dissolved (mg/L)	118	9.1	2.6	5.8	5.8	1.5
Potassium, dissolved (mg/L)	118	5.2	1.4	2.3	2.1	.7
Alkalinity, total (mg/L)	48	213	82	157	159	29
Sulfate, dissolved (mg/L)	118	39	7.8	16	14	5.3
Chloride, dissolved (mg/L)	118	9.6	<1	3.3	3.6	1.8
Solids, dissolved (mg/L)	118	291	124	207	203	27
Solids, suspended (mg/L)	0	--	--	--	--	--
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	0	--	--	--	--	--
Ammonia as nitrogen, dissolved (mg/L)	0	--	--	--	--	--
Phosphorus, total (mg/L)	0	--	--	--	--	--
Phosphorus, dissolved (mg/L)	8	.23	.02	.08	.08	.06
Arsenic, total (μg/L)	0	--	--	--	--	--
Cadmium, total (μg/L)	0	--	--	--	--	--
Chromium, total (μg/L)	4	<1	<1	<1	<1	<1
Lead, total (μg/L)	0	--	--	--	--	--
Manganese, total (μg/L)	55	284	0	48	40	51

at site 6B, Mississippi River near Anoka, Minnesota, 1960-80

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
9,980	--	12,700	--	5,950	--	3,460	--	2,900	--
290	--	294	--	322	--	347	--	394	--
7.6	--	7.4	--	7.4	--	7.4	--	7.5	--
5.0	--	11.5	--	22.0	--	6.0	--	.0	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
37	997	40	1,370	42	675	44	411	50	392
13	350	11	377	14	225	15	140	17	133
4.9	132	4.5	154	5.6	90.0	6.3	58.8	7.2	56.4
3.0	80.8	2.1	72.0	1.8	28.9	2.2	20.6	2.1	16.4
122	3,290	149	5,110	159	2,550	163	1,520	193	1,510
14	377	16	549	14	225	13	121	14	110
3.8	102	2.2	75.4	3.0	48.2	3.8	35.5	3.9	30.5
184	4,960	191	6,550	200	3,210	209	2.950	236	1,850
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
.08	2.16	.03	1.03	.08	1.28	--	--	.08	.63
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	<1	.00	--	--	<1	.00	--	--
--	--	--	--	--	--	--	--	--	--
55	1.48	45	1.54	15	.24	3	.03	60	.47

Table 38.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record: Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	177	48,500	2,100	9,080	6,160	8,000
Specific conductance (μS/cm)	72	420	180	316	316	46
pH (units)	177	9.1	6.8	7.9	8.0	0.4
Temperature (°Celsius)	176	27.0	.0	10.0	9.0	9.0
Oxygen, dissolved (mg/L)	176	16.6	6.2	11.4	11.4	2.4
Fecal coliform (colonies/100mL)	176	2,000	4	98	48	190
Fecal Streptococci (colonies/100mL)	15	2,000	1	750	260	860
Calcium, dissolved (mg/L)	0	--	--	--	--	--
Magnesium, dissolved (mg/L)	0	--	--	--	--	--
Sodium, dissolved (mg/L)	0	--	--	--	--	--
Potassium, dissolved (mg/L)	0	--	--	--	--	--
Alkalinity, total (mg/L)	0	--	--	--	--	--
Sulfate, dissolved (mg/L)	0	--	--	--	--	--
Chloride, dissolved (mg/L)	0	--	--	--	--	--
Solids, dissolved (mg/L)	0	--	--	--	--	--
Solids, suspended (mg/L)	100	111	1	16	12	15
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	99	2.8	.05	.44	.30	.42
Ammonia as nitrogen, dissolved (mg/L)	176	1.4	.02	.19	.12	.18
Phosphorus, total (mg/L)	101	.63	.02	.10	.08	.08
Phosphorus, dissolved (mg/L)	27	.13	.01	.04	.03	.03
Arsenic, total (μg/L)	0	--	--	--	--	--
Cadmium, total (μg/L)	0	--	--	--	--	--
Chromium, total (μg/L)	0	--	--	--	--	--
Lead, total (μg/L)	0	--	--	--	--	--
Manganese, total (μg/L)	0	--	--	--	--	--

at site 6C, Mississippi River at Fridley, Minnesota, 1977-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; μg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
6,310	--	13,000	--	6,500	--	7,330	--	4,510	--
300	--	300	--	340	--	310	--	340	--
7.8	--	7.9	--	8.3	--	8.0	--	7.8	--
3.5	--	18.5	--	23.0	--	7.0	--	.5	--
13.4	--	9.4	--	8.3	--	12.3	--	14.0	--
29	--	82	--	140	--	50	--	21	--
964	--	550	--	1,900	--	36	--	40	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
19	324	25	878	22	386	8	158	4	48.7
.72	12.3	.20	7.02	.15	2.63	.25	4.95	.50	6.09
.30	5.11	.10	3.51	.06	1.05	.10	1.98	.22	2.68
.14	2.38	.10	3.51	.10	1.76	.06	1.19	.05	.61
.04	.68	.02	.70	.06	1.05	.02	.40	.04	.49
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--

Table 39.--*Summary statistics for selected constituents*
Minneapolis Waterworks at

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

	Period of record					
Constituent or property	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	178	64,000	934	8,410	6,660	8,360
Specific conductance (μS/cm)	142	690	160	330	348	69
pH (units)	177	8.9	7.0	7.9	8.0	0.3
Temperature (°Celsius)	79	27.0	.0	12.5	12.0	9.0
Oxygen, dissolved (mg/L)	176	15.3	5.8	10.2	10.4	2.2
Fecal coliform (colonies/100mL)	144	13,000	20	370	80	1,200
Fecal Streptococci (colonies/100mL)	9	1,500	27	220	72	480
Calcium, dissolved (mg/L)	49	56	17	43	44	6.5
Magnesium, dissolved (mg/L)	28	19	12	15	14	1.9
Sodium, dissolved (mg/L)	39	15	3.3	7.4	6.6	2.7
Potassium, dissolved (mg/L)	40	4.6	1.0	2.3	2.2	.7
Alkalinity, total (mg/L)	102	320	71	156	158	31
Sulfate, dissolved (mg/L)	39	36	5.0	16	14	6.1
Chloride, dissolved (mg/L)	96	28	.5	8.6	7.5	4.9
Solids, dissolved (mg/L)	2	200	190	195	195	7
Solids, suspended (mg/L)	158	120	<1	16	14	15
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	70	2.2	.01	.33	.28	.34
Ammonia as nitrogen, dissolved (mg/L)	145	1.2	.01	.15	.11	.14
Phosphorus, total (mg/L)	143	.48	.03	.12	.10	.06
Arsenic, total (μg/L)	39	60	1	5	1	9.2
Cadmium, total (μg/L)	88	60	<1	5	<1	6.8
Chromium, total (μg/L)	16	5	<1	1	1	1.1
Lead, total (μg/L)	87	240	<1	9	2	26
Manganese, total (μg/L)	66	1,200	10	130	100	160

and properties at site 6D, Mississippi River at Minneapolis, Minnesota, 1953-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
10,900	--	11,000	--	5,640	--	5,000	--	4,700	--
320	--	305	--	322	--	312	--	362	--
8.0	--	8.0	--	8.2	--	8.0	--	7.9	--
6.0	--	20.5	--	22.0	--	9.0	--	.0	--
11.3	--	8.6	--	8.4	--	11.2	--	12.5	--
51	--	83	--	220	--	51	--	170	--
54	--	--	--	130	--	46	--	49	--
42	1,240	45	1,340	44	670	44	594	48	609
15	441	16	475	14	213	15	202	17	216
6.1	180	8.6	255	6.5	99.0	6.7	90.49	6.8	86.3
2.5	73.6	2.5	74.2	2.0	30.4	2.1	28.43	2.2	27.9
148	4,360	148	4,400	151	2,300	158	2,130	175	2,220
15	441	16	475	13	198	12	162	14	178
7.2	212	6.7	199	7.5	114	8.5	115	8.5	108
--	--	--	--	195	2,970	--	--	--	--
15	441	22	653	20	304	9	122	3	38.1
.40	11.8	.13	3.86	.12	1.83	.26	3.51	.60	7.61
.14	4.12	.10	2.97	.10	1.52	.10	1.35	.18	2.28
.13	3.82	.14	4.16	.15	2.28	.10	1.35	.08	1.02
5	.15	5	.15	5	.08	1	.01	4	.05
5	.15	5	.15	5	.08	5	.07	5	.06
1	.03	1	.03	2	.03	1	.01	1	.01
5	.15	5	.15	5	.08	5	.07	5	.06
140	4.12	140	4.16	120	1.83	83	1.12	54	.68

Table 40.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record: Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	741	49,800	723	7,580	5,330	6,580
Specific conductance (µS/cm)...........	185	550	215	359	350	62.8
pH (units)...........	824	8.9	7.0	8.0	8.0	0.3
Temperature (°Celsius).........	838	29	.0	10.5	9.0	9.44
Oxygen, dissolved (mg/L)............	837	16	.0	9.8	9.9	3.23
Fecal coliform (colonies/100mL)...	294	42,000	11	1,900	330	5,870
Fecal Streptococci (colonies/100mL)...	52	71,000	1	3,510	333	11,200
Calcium, dissolved (mg/L)............	20	58	30	45	46	6.6
Magnesium, dissolved (mg/L)......	21	28	12	16.7	16	3.8
Sodium, dissolved (mg/L)............	17	25	4	10.3	8.1	6.1
Potassium, dissolved (mg/L)......	17	7.8	1.9	2.97	2.1	1.68
Alkalinity, total (mg/L)............	20	209	116	158	152	22.9
Sulfate, dissolved (mg/L)............	19	32	8	19.1	19.0	5.5
Chloride, dissolved (mg/L)............	18	12	4.9	8.5	8.3	2.0
Solids, dissolved (mg/L)............	52	307	195	241	236	28.7
Solids, suspended (mg/L)............	223	90	1	18.8	16.6	14.8
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	225	3.9	.02	.448	.356	.513
Ammonia as nitrogen, dissolved (mg/L)...	305	.85	.02	.184	.120	.146
Phosphorus, total (mg/L)............	255	.36	.02	.096	.090	.050
Phosphorus, dissolved (mg/L)......	69	.31	.01	.07	.05	.05
Arsenic, total (µg/L)............	6	1.5	<1	1	1	.4
Cadmium, total (µg/L)............	6	.3	<1	<1	<1	.1
Chromium, total (µg/L)............	6	8.5	2	5	3	3.1
Lead, total (µg/L)...	6	29.7	1	7	3	11
Manganese, total (µg/L)............	6	140	35	96	98	45

at site 6E, Mississippi River at Ford Plant, St. Paul, Minnesota, 1926-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
7,220	--	10,300	--	5,210	--	5,220	--	4,020	--
331	--	345	--	356	--	330	--	386	--
7.9	--	8.1	--	8.2	--	8.2	--	7.8	--
3.5	--	19.0	--	23.0	--	8.0	--	.0	--
12	--	8.5	--	7.7	--	11.5	--	12.4	--
112	--	480	--	449	--	325	--	375	--
108	--	506	--	330	--	281	--	322	--
40	780	40	1,110	43	605	46	848	47	510
14	273	15	417	16	225	16	226	16	174
10	195	4.8	133	8.1	114	7.0	98.6	8.9	96.6
5.0	97.5	2.6	72.3	2.4	33.8	2.6	36.6	2.1	22.8
126	2,460	153	4,250	151	2,120	152	2,140	174	1,890
15	292	18	500	19	267	17	240	20	217
7.6	148	6.6	184	10	141	12	169	8.4	91.2
234	4,560	216	6,010	238	3,350	235	3,310	264	2,860
24	468	27	751	23	324	12	169	5	54.3
.55	10.7	.20	5.56	.16	2.25	.20	2.82	.45	4.88
.20	3.90	.10	2.78	.10	1.41	.10	1.41	.20	2.17
.10	1.95	.10	2.78	.10	1.41	.08	1.13	.07	.76
.06	1.17	.05	1.39	.06	.84	.04	.56	.04	.43
1	.02	1	.03	2	.03	1	.01	1	.01
<1	<.02	<1	<.03	<1	<.01	<1	<.01	<1	<.01
6	.11	8	.22	2	.03	8	.11	2	.02
30	.58	4	.11	2	.03	6	.08	2	.02
140	2.73	140	3.89	120	1.69	90	1.27	42	.46

Table 41.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of meas-urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	972	77,400	723	11,600	7,220	11,100
Specific conductance (µS/cm)............	439	780	240	479	470	97.9
pH (units)...........	963	8.8	6.7	8.0	8.0	0.3
Temperature (°Celsius).........	951	29	.0	11.5	10.5	9.33
Oxygen, dissolved (mg/L).............	956	15.7	1.4	10.0	10.1	2.5
Fecal coliform (colonies/100mL)...	527	79,000	1	2,350	520	7,510
Fecal Streptococci (colonies/100mL)...	224	85,000	<1	2,580	370	8,460
Calcium, dissolved (mg/L).............	165	80	35	54	52	9.1
Magnesium, dis-solved (mg/L)......	113	47	11	21	20	5.3
Sodium, dissolved (mg/L).............	140	43	4.7	13.6	12.0	6.4
Potassium, dis-solved (mg/L)......	142	8.4	1.6	3.4	3.1	1.19
Alkalinity, total (mg/L).............	156	289	100	180	180	30.7
Sulfate, dissolved (mg/L).............	142	96	18	45	40	18.4
Chloride, dissolved (mg/L).............	168	51	6.0	16.7	15	7
Solids, dissolved (mg/L).............	128	443	186	307	304	59
Solids, suspended (mg/L).............	475	564	<	44.9	29	57
Nitrite plus nitrate as nitrogen, dis-solved (mg/L)......	423	9.6	.01	1.5	.85	1.6
Ammonia as nitrogen, dissolved (mg/L)...	541	1.7	.01	.332	.26	.258
Phosphorus, total (mg/L).............	475	1.9	.01	.178	.15	.121
Phosphorus, dis-solved (mg/L)......	125	.22	.01	.10	.09	.05
Arsenic, total (µg/L).............	97	8	<1	3	2	1.7
Cadmium, total (µg/L).............	220	21	<1	4	5	4.2
Chromium, total (µg/L).............	206	42	<1	5	2	6.8
Lead, total (µg/L)...	205	200	<1	14	5	25
Manganese, total (µg/L).............	214	1,100	<1	156	140	106

at site 6F, Mississippi River at St. Paul, Minnesota, 1938-81

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; μg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
11,800	--	16,700	--	7,390	--	6,670	--	5,040	--
440	--	495	--	460	--	450	--	500	--
7.9	--	8.1	--	8.1	--	8.2	--	7.8	--
4.5	--	20.0	--	23.0	--	8.5	--	.0	--
12	--	8.2	--	7.3	--	11.2	--	12.3	--
290	--	420	--	920	--	690	--	600	--
310	--	620	--	560	--	300	--	160	--
52	1,660	56	2,520	48	958	50	900	57	70.6
19	605	23	1,040	19	379	19	342	21	34.6
11	350	10	451	11	219	11	198	14	27.6
3.7	118	3.2	144	2.7	53.9	2.7	48.6	3.2	16.8
164	5,220	180	8,120	170	3,390	176	3,170	201	215
48	1,530	64	2,880	34	678	32	576	38	51.6
16	510	15	676	15	299	14	252	16	29.6
298	9,490	312	14,100	284	5,670	288	5,190	326	340
46	1,460	49	2,210	37	738	2	468	7	20.6
1.2	38.2	1.5	67.6	.75	15.0	.45	8.10	.75	14.4
.40	12.7	.17	7.66	.18	3.59	.21	3.78	.40	14.0
.18	5.73	.18	8.12	.19	3.79	.14	2.52	.12	13.7
.10	3.19	.09	4.06	.10	2.00	.09	1.62	.09	13.7
2	.06	4	.16	4	71.8	2	.04	1	13.6
5	.16	5	.22	5	.10	5	.09	5	13.6
3	.10	3	.12	2	.04	2	.03	2	13.6
5	.16	5	.22	5	.10	5	.09	5	13.6
130	4.14	182	8.21	186	3.71	110	1.98	90	13.7

Table 42.--*Summary statistics for selected constituents and properties at*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of meas-urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	309	79,800	941	11,600	7,350	11,400
Specific conductance (µS/cm)............	196	880	260	530	525	104
pH (units)...........	305	8.8	6.4	7.8	7.9	0.3
Temperature (°Celsius).........	309	27.5	0.0	11.0	9.5	9.0
Oxygen, dissolved (mg/L).............	309	14.5	.1	9.6	10.1	3.1
Fecal coliform (colonies/100mL)...	302	98,000	1	1,800	330	6,600
Fecal <u>Streptococci</u> (colonies/100mL)...	54	8,300	1	860	390	1,600
Calcium, dissolved (mg/L).............	14	69	46	57	58	5.9
Magnesium, dis-solved (mg/L)......	16	40	15	22	20	6.1
Sodium, dissolved (mg/L)............	12	46	9.9	20	17	9.9
Potassium, dis-solved (mg/L)......	14	8.0	2.2	3.9	3.6	1.6
Alkalinity, total (mg/L).............	15	260	101	186	181	40
Sulfate, dissolved (mg/L).............	13	91	40	60	52	18
Chloride, dissolved (mg/L).............	14	36	15	23	21	6.2
Solids, dissolved (mg/L).............	46	470	286	354	350	42
Solids, suspended (mg/L).............	238	223	1	37	26	38
Nitrite plus nitrate as nitrogen, dis-solved (mg/L)......	236	7.1	.04	1.4	.85	1.4
Ammonia as nitrogen, dissolved (mg/L)...	305	5.7	.10	1.2	.90	1.0
Phosphorus, total (mg/L).............	239	.85	.02	.30	.25	.16
Phosphorus, dis-solved (mg/L)......	93	.70	.02	.14	.12	.09
Arsenic, total (µg/L).............	37	6	<1	2	2	1.5
Cadmium, total (µg/L).............	37	20	<1	4	1	4.7
Chromium, total (µg/L).............	37	30	.5	10	10	6.9
Lead, total (µg/L)...	32	120	.5	20	6.1	32
Manganese, total (µg/L).............	37	840	65	160	130	130

site 6H, Mississippi River at Highway 494 at Newport, Minnesota, 1977-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
8,890	--	14,200	--	8,280	--	8,460	--	5,420	--
430	--	510	--	542	--	550	--	559	--
7.9	--	7.9	--	7.9	--	8.0	--	7.7	--
5.0	--	19.5	--	24.0	--	9.5	--	.5	--
11.7	--	8.0	--	6.8	--	10.6	--	12.2	--
110	--	550	--	680	--	260	--	52	--
420	--	440	--	210	--	500	--	52	--
48	1,150	54	2,070	60	1,340	60	1,370	56	820
16	384	20	777	21	469	23	525	21	307
30	720	15	575	18	402	16	365	17	249
3.5	84.0	3.8	146	3.6	80.5	3.8	86.8	3.2	46.8
139	3,340	179	6,860	193	4,310	170	3.880	216	3,160
45	1,080	50	1,920	54	1,210	48	1,100	58	849
21	504	18	690	28	626	25	571	22	322
312	7,490	336	12,900	356	7,960	332	7,580	382	5,590
32	768	51	1,960	40	894	25	571	8	117
.82	31.2	1.6	61.3	1.2	26.8	.70	16.0	.76	11.1
.90	22.8	.50	19.2	.60	13.4	.75	17.1	1.4	20.5
.26	5.52	.24	9.20	.28	6.26	.20	4.57	.24	3.51
.13	2.88	.06	2.30	.15	3.35	.10	2.28	.14	2.05
2	.05	3	.12	4	.09	2	.05	1	.01
1	.02	1	.04	1	.02	1	.02	1	.01
10	.26	8	.31	12	.27	5	.11	6	.09
24	.58	7	.27	4	.09	7	.16	5	.07
140	3.12	200	7.67	190	4.25	120	2.74	91	1.33

Table 43.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record: Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	46	76,200	2,810	15,500	8,560	14,700
Specific conductance (µS/cm)	45	640	280	442	437	96
pH (units)	46	8.4	7.4	7.8	7.9	0.3
Temperature (°Celsius)	0	--	--	--	--	--
Oxygen, dissolved (mg/L)	46	13.1	3.5	8.8	8.7	2.3
Fecal coliform (colonies/100mL)	46	330,000	20	28,000	1,700	67,000
Fecal <u>Streptococci</u> (colonies/100mL)	2	390	45	220	220	240
Calcium, dissolved (mg/L)	38	80	36	55	53	11
Magnesium, dissolved (mg/L)	2	24	19	22	22	3.4
Sodium, dissolved (mg/L)	38	38	5.7	16	16	7.2
Potassium, dissolved (mg/L)	36	8.0	1.5	4.5	4.0	1.7
Alkalinity, total (mg/L)	46	220	120	175	180	27
Sulfate, dissolved (mg/L)	22	67	25	40	36	13
Chloride, dissolved (mg/L)	46	61	8.0	18	17	8.7
Solids, dissolved (mg/L)	1	--	--	--	--	--
Solids, suspended (mg/L)	45	97	<1	35	30	28
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	0	--	--	--	--	--
Ammonia as nitrogen, dissolved (mg/L)	46	2.0	1.0	.72	.72	.53
Phosphorus, total (mg/L)	46	.99	.20	.40	.39	.15
Arsenic, total (µg/L)	34	10	5	5	5	.9
Cadmium, total (µg/L)	39	32	5	6	5	4.4
Chromium, total (µg/L)	5	13	3	9	10	3.7
Lead, total (µg/L)	31	150	5	12	5	26
Manganese, total (µg/L)	37	320	10	140	120	72

at site 6I, Mississippi River south of St. Paul, Minnesota, 1967-75

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
11,500	--	30,000	--	7,790	--	7,670	--	6,460	--
455	--	395	--	385	--	355	--	508	--
8.0	--	7.9	--	7.9	--	7.8	--	7.7	--
--	--	--	--	--	--	--	--	--	--
11.3	--	8.7	--	6.8	--	9.2	--	10.5	--
3,600	--	360	--	1,700	--	830	--	2,300	--
--	--	--	--	390	--	--	--	45	--
66	2,050	48	3,890	49	1,030	54	1,120	60	1,050
--	--	--	--	22	463	--	--	--	--
10	310	8.4	680	14	294	14	290	22	384
5.2	161	3.5	284	3.1	65.2	3.1	64.2	5.0	87.2
165	5,120	158	12,800	163	3,430	175	3,620	200	3,490
44	1,370	63	5,100	35	736	30	621	29	506
13	404	11	891	17	358	13	269	24	419
--	--	--	--	280	5,890	--	--	--	--
35	1,090	69	5,590	31	652	24	497	9	157
--	--	--	--	--	--	--	--	--	--
.40	12.4	.12	9.72	.72	15.1	.34	7.04	1.1	19.2
.40	12.4	.26	21.1	.39	8.20	.41	8.49	.40	6.98
5	.16	6	.49	5	.10	5	.10	5	.09
5	.16	5	.40	6	.13	5	.10	5	.09
--	--	--	--	8	.17	--	--	11	.19
6	.19	29	2.35	10	.21	7	.14	6	.10
110	3.42	120	9.72	140	2.94	92	1.90	130	2.27

Table 44.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	473	73,400	1,090	11,600	7,240	11,200
Specific conductance (µS/cm)............	357	870	200	518	510	107
pH (units)...........	467	8.6	6.7	7.8	7.9	0.3
Temperature (°Celsius).........	471	26.5	.0	11.0	11.0	9.0
Oxygen, dissolved (mg/L).............	470	14.2	.8	9.1	9.4	3.1
Fecal coliform (colonies/100mL)...	463	130,000	1	2,290	320	9,580
Fecal Streptococci (colonies/100mL)...	191	27,000	1	986	230	2,610
Calcium, dissolved (mg/L).............	86	80	33	54	55	8.6
Magnesium, dissolved (mg/L)......	51	49	14	22	21	6.3
Sodium, dissolved (mg/L).............	57	69	3.5	20.4	17.8	11.8
Potassium, dissolved (mg/L)......	61	13	2.2	4.2	3.6	1.7
Alkalinity, total (mg/L)............	74	265	120	186	180	30
Sulfate, dissolved (mg/L).............	62	94	9.2	49	45	20
Chloride, dissolved (mg/L).............	87	100	10.5	28	24	16
Solids, dissolved (mg/L).............	53	468	266	351	347	44
Solids, suspended (mg/L).............	395	315	.5	33.9	23.9	38.2
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	393	11.1	.01	1.5	.9	1.6
Ammonia as nitrogen, dissolved (mg/L)...	467	5.8	.1	1.06	.8	.88
Phosphorus, total (mg/L).............	397	1.2	.02	.31	.26	.16
Phosphorus, dissolved (mg/L)......	70	.66	.01	.17	.16	.10
Arsenic, total (µg/L).............	73	62	<1	3	2	7.1
Cadmium, total (µg/L).............	182	25	<1	3	5	3.2
Chromium, total (µg/L).............	184	70	<1	8	5	8.3
Lead, total (µg/L)...	178	100	<1	12	5	17
Manganese, total (µg/L).............	170	560	10	148	140	63

at site 6J, Mississippi River at Grey Cloud Island, Minnesota, 1975-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second;
per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
9,440	--	14,600	--	7,000	--	7,780	--	5,300	--
461	--	505	--	526	--	496	--	551	--
7.9	--	7.9	--	7.9	--	7.9	--	7.8	--
5.0	--	19.5	--	23.0	--	8.5	--	.0	--
11.3	--	7.6	--	6.7	--	10	--	12.0	--
200	--	600	--	470	--	170	--	60	--
499	--	361	--	230	--	300	--	56	--
48	1,220	56	2,210	52	983	52	1,090	60	859
19	484	23	907	21	397	22	462	24	343
12	306	14	552	18	340	18	378	21	300
4.3	110	3.6	142	3.7	69.9	3.5	73.5	3.5	50.1
161	4,100	180	7,100	180	3,400	180	3,780	211	3,020
41	1,040	55	2,170	38	718	35	735	57	816
22	561	20	788	25	472	23	483	25	358
300	7,650	332	13,100	360	6,800	343	7,200	364	5,210
31	790	39	1,540	32	605	21	441	5	71.6
1.2	30.6	1.6	63.1	.84	15.9	.70	14.7	.75	10.7
.92	23.4	.52	20.50	.60	11.3	.69	14.5	1.2	17.2
.28	7.14	.26	10.25	.28	5.29	.23	4.83	.24	3.43
.16	4.08	.10	3.94	.16	3.02	.16	3.36	.16	2.29
3	.08	3	.12	4	.08	2	.04	1	.01
5	.13	4	.16	5	.09	5	.10	2	.03
5	.13	5	.20	4	.08	7	.15	6	.08
5	.13	5	.20	5	.09	5	.10	5	.07
140	3.57	180	7.10	160	3.02	120	2.52	110	1.57

Table 45.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

	Period of record					
Constituent or property	Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	263	76,800	1,470	12,900	8,600	11,800
Specific conductance (µS/cm)............	201	860	310	514	505	92
pH (units)...........	244	8.9	6.8	7.9	7.9	0.3
Temperature (°Celsius).........	247	27.0	.0	10.5	9.0	9.5
Oxygen, dissolved (mg/L).............	243	15.8	2.3	9.9	10.2	2.6
Fecal coliform (colonies/100mL)...	235	34,700	1	539	92	2,370
Fecal Streptococci (colonies/100mL)...	70	5,400	1	452	100	970
Calcium, dissolved (mg/L).............	42	80	39	58	57	8.6
Magnesium, dissolved (mg/L)......	43	30	15	22	22	3.2
Sodium, dissolved (mg/L).............	40	35	8.3	18	16	6.1
Potassium, dissolved (mg/L)......	40	4.8	.6	3.4	3.3	.71
Alkalinity, total (mg/L).............	28	230	130	186	190	30.6
Sulfate, dissolved (mg/L).............	38	91	25	48	42	14.3
Chloride, dissolved (mg/L).............	39	42	12	22	23	7.2
Solids, dissolved (mg/L).............	51	460	227	335	324	56
Solids, suspended (mg/L).............	189	126	2	30	27	23
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	177	7.2	.05	1.6	1.2	1.3
Ammonia as nitrogen, dissolved (mg/L)...	211	4.8	.04	.85	.7	.67
Phosphorus, total (mg/L).............	187	.72	.07	.23	.21	.10
Phosphorus, dissolved (mg/L)......	85	.37	.00	.13	.12	.06
Arsenic, total (µg/L).............	35	6	1	2	2	1.2
Cadmium, total (µg/L).............	34	12	<1	3	2	3
Chromium, total (µg/L).............	35	40	5	15	10	9.8
Lead, total (µg/L)...	28	130	<1	22	7	34.6
Manganese, total (µg/L).............	36	250	60	145	142	47

at site 6K, Mississippi River at Nininger, Minnesota, 1977-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
8,840	--	16,100	--	12,400	--	9,100	--	5,260	--
442	--	505	--	520	--	490	--	530	--
7.9	--	8.0	--	8.0	--	8.1	--	7.7	--
5.5	--	20.0	--	23.0	--	8.0	--	.0	--
11.4	--	8.2	--	7.0	--	11.2	--	11.9	--
38	--	112	--	133	--	390	--	8	--
101	--	80	--	72	--	174	--	142	--
54	1,290	54	2,350	56	1,870	50	,2301	65	923
20	477	22	956	22	737	19	467	23	327
20	477	14	608	12	402	14	344	20	284
4.1	98	3.2	139	3.1	104	3.0	73.7	3.3	46.9
140	3,340	165	7,170	190	6,360	165	,0504	210	2,980
44	1,050	54	2,350	42	1,410	40	983	43	611
25	597	19	826	16	536	19	467	25	355
327	7,600	322	14,000	318	10,600	308	,5707	352	5,000
27	644	43	1,870	37	1,240	23	565	5	71.0
1.4	33.4	2.0	86.9	1.4	46.9	1.0	24.6	.96	13.6
.70	16.7	.50	21.7	.48	16.1	.60	14.7	1.2	17.0
.24	5.73	.21	9.13	.24	8.04	.18	4.42	.19	2.70
.14	3.34	.10	4.35	.14	4.69	.11	2.70	.16	2.27
2	.05	3	.13	4	.13	2	.05	1	.01
1	.02	4	.17	2	.07	2	.05	2	.03
19	.45	13	.56	10	.33	10	.24	18	.26
8	.19	7	.30	7	.23	7	.17	5	.07
130	3.10	192	8.35	175	5.8	135	3.32	115	1.63

Table 46.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of meas- urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)	306	71,000	900	12,300	8,200	11,800
Specific conductance (µS/cm)	193	860	330	527	510	110
pH (units)	294	9.1	6.9	7.9	8.0	0.3
Temperature (°Celsius)	295	27.5	.0	11.0	10.0	9.5
Oxygen, dissolved (mg/L)	295	18.2	2.3	9.9	10.2	2.8
Fecal coliform (colonies/100mL)	292	5,600	1	240	28	560
Fecal <u>Streptococci</u> (colonies/100mL)	51	8,800	1	440	80	1,300
Calcium, dissolved (mg/L)	62	78	42	57	57	7.6
Magnesium, dissolved (mg/L)	66	40	14	22	22	4.9
Sodium, dissolved (mg/L)	62	82	6.7	24	18	15
Potassium, dissolved (mg/L)	64	9.0	.9	4.0	3.5	1.4
Alkalinity, total (mg/L)	65	293	107	183	180	34
Sulfate, dissolved (mg/L)	63	134	30	60	54	23
Chloride, dissolved (mg/L)	64	93	9.5	26	21	15
Solids, dissolved (mg/L)	96	520	246	348	349	53
Solids, suspended (mg/L)	227	200	1	33	32	26
Nitrite plus nitrate as nitrogen, dissolved (mg/L)	224	7.2	.04	1.5	1.0	1.3
Ammonia as nitrogen, dissolved (mg/L)	294	6.5	.07	1.0	.70	1.1
Phosphorus, total (mg/L)	228	.85	.10	.27	.22	.14
Phosphorus, dissolved (mg/L)	89	.24	.01	.11	.10	.05
Arsenic, total (µg/L)	32	5	<1	2	2	1.1
Cadmium, total (µg/L)	32	13	<1	3	1	4.0
Chromium, total (µg/L)	32	30	<1	10	10	7.4
Lead, total (µg/L)	27	83	<1	20	5	27
Manganese, total (µg/L)	31	600	50	160	140	91

at site 6L, Mississippi River at Lock and Dam 2 at Hasting, Minnesota, 1977-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second;
per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
10,200	--	13,600	--	8,760	--	8,000	--	5,060	--
450	--	500	--	540	--	525	--	541	--
7.9	--	8.1	--	8.0	--	8.0	--	7.8	--
4.0	--	19.5	--	23.5	--	8.0	--	.0	--
11.4	--	8.6	--	7.2	--	10.8	--	12.0	--
26	--	74	--	38	--	53	--	6	--
35	--	74	--	54	--	150	--	31	--
50	1,380	61	2,240	55	1,300	52	1,120	62	847
18	496	23	844	22	522	21	454	22	300
20	551	16	588	14	332	16	346	26	355
4.2	116	3.6	132	3.5	83.0	3.2	69.1	3.5	47.8
157	4,320	170	6,240	178	4,220	178	3,840	210	2,870
50	1,380	70	2,570	52	1,230	44	950	57	779
14	386	18	661	21	498	20	432	25	342
315	8,680	344	12,600	346	8,200	332	7,170	380	5,190
31	854	42	1,540	35	830	28	605	6	82.0
.86	23.7	1.5	55.1	1.3	30.8	1.1	23.8	.80	10.9
.90	24.8	.42	15.4	.55	13.0	.64	13.8	1.3	17.8
.24	6.61	.20	7.34	.24	5.69	.19	4.10	.26	3.55
.12	3.30	.06	2.20	.14	3.32	.10	2.16	.10	1.37
2	.06	2	.07	3	.07	2	.04	1	.01
5	.14	2	.07	2	.05	<1	<.02	1	.01
5	.14	10	.37	10	.24	9	.19	5	.07
27	.74	5	.18	5	.12	4	.09	3	.04
120	3.30	170	6.24	160	3.79	150	3.24	120	1.64

Table 47.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of meas- urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	690	77,500	270	11,600	7,600	10,300
Specific conductance (μS/cm)...........	246	865	270	499	500	108
pH (units)...........	747	8.9	6.5	7.9	7.9	0.3
Temperature (°Celsius).........	658	28	.0	11.5	12.0	9.5
Oxygen, dissolved (mg/L)............	753	14.7	.0	8.0	8.0	2.9
Fecal coliform (colonies/100mL)...	284	33,000	<1	810	70	3,000
Fecal Streptococci (colonies/100mL)...	75	4,700	<1	280	40	690
Calcium, dissolved (mg/L)............	97	80	37	55	55	9.4
Magnesium, dis- solved (mg/L)......	54	28	15	20	20	3.3
Sodium, dissolved (mg/L)............	95	52	5.8	17.4	16	8.4
Potassium, dis- solved (mg/L)......	93	9	1.2	3.8	3.4	1.2
Alkalinity, total (mg/L)............	104	260	67	178	180	29
Sulfate, dissolved (mg/L)............	82	130	24	43	40	17.5
Chloride, dissolved (mg/L)............	144	67	3.2	20.5	18	12
Solids, dissolved (mg/L)............	50	435	238	314	302	51
Solids, suspended (mg/L)............	301	140	.5	36	35	26.3
Nitrite plus nitrate as nitrogen, dis- solved (mg/L)......	186	9.8	.05	1.4	.85	1.4
Ammonia as nitrogen, dissolved (mg/L)...	328	6.8	.08	.98	.70	1.05
Phosphorus, total (mg/L)............	266	1.1	.01	.34	.30	.18
Phosphorus, dis- solved (mg/L)......	74	.68	.01	.19	.16	.11
Arsenic, total (μg/L)............	43	7	1	5	5	1.0
Cadmium, total (μg/L)............	65	38	<1	6	5	4.8
Chromium, total (μg/L)............	18	20	<1	7	6	5.6
Lead, total (μg/L)...	57	50	3	8	5	8
Manganese, total (μg/L)............	59	590	14	160	130	98

at site 6M, Mississippi River below Lock and Dam 2, Minnesota, 1936-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
12,900	--	17,400	--	7,600	--	6,600	--	4,910	--
441	--	491	--	500	--	452	--	520	--
7.9	--	8.0	--	8.0	--	8.0	--	7.7	--
3.0	--	19.0	--	24.0	--	8.0	--	.0	--
10.4	--	7.8	--	6.7	--	9.8	--	7.4	--
120	--	160	--	52	--	120	--	21	--
100	--	48	--	30	--	152	--	8	--
56	1,950	56	2,630	48	985	52	927	60	795
19	662	22	1,030	18	369	19	338	21	278
14	488	11	517	15	308	17	303	20	265
4.1	143	3.4	160	3.0	61.6	3.2	57.0	3.4	45.1
160	5,570	160	7,520	170	3,490	180	3,210	200	2,650
42	1,460	51	2,400	32	657	33	588	39	517
16	557	12	564	17	349	18	321	23	305
300	10,400	318	14,900	278	5,700	266	4,740	321	4,260
28	975	46	2,160	42	862	29	517	6	79.5
.80	27.9	1.2	56.4	1.3	26.7	.65	11.6	.66	8.75
.85	29.6	.42	19.7	.52	10.7	.84	15.0	1.2	15.9
.29	10.1	.25	11.7	.28	5.74	.27	4.81	.40	5.30
.14	4.88	.11	5.17	.16	3.28	.17	3.03	.29	3.84
5	.17	5	.23	5	.10	5	.09	5	.07
6	.21	5	.23	5	.10	5	.09	5	.07
13	.45	8	.38	4	.08	3	.05	9	.12
5	.17	5	.23	5	.10	6	.11	5	.07
140	4.88	130	6.11	150	3.08	150	2.67	120	1.59

Table 48.--*Summary statistics for selected constituents at Fort Snelling State Park,*

[Early spring, March-April; late spring, May-June; summer, July-September; μ/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record					
	Number of meas-urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	347	21,500	215	3,200	1,460	3,920
Specific conductance (μ/cm)............	235	1,400	240	848	845	164
pH (units)...........	345	8.8	6.7	7.9	7.9	0.3
Temperature (°Celsius).........	346	29.5	.0	11.5	10.25	9.5
Oxygen, dissolved (mg/L)............	339	19.3	.2	9.1	8.7	2.9
Fecal coliform (colonies/100mL)...	326	14,400	0	507	60	1,600
Fecal Streptococci (colonies/100mL)...	107	6,800	0	458	108	1,020
Calcium, dissolved (mg/L)............	106	150	45	92	90	19.4
Magnesium, dis-solved (mg/L)......	108	65	14	39	38	8.8
Sodium, dissolved (mg/L)............	97	9.5	7.7	34	33	16.1
Potassium, dis-solved (mg/L)......	98	10	3.4	5.6	5.7	1.3
Alkalinity, total (mg/L)............	109	446	115	262	260	61
Sulfate, dissolved (mg/L)............	98	265	30	137	130	48
Chloride, dissolved (mg/L)............	100	86	14	40	38	16
Solids, dissolved (mg/L)............	92	911	281	597	590	110
Solids, suspended (mg/L)............	297	1,303	1	121	68	179
Nitrite plus nitrate as nitrogen, dis-solved (mg/L)......	257	15	.04	3.4	2	3.3
Ammonia as nitrogen, dissolved (mg/L)...	335	3.9	.05	.83	.58	.75
Phosphorus, total (mg/L)............	247	1.3	.03	.38	.34	.19
Phosphorus, dis-solved (mg/L)......	131	.94	<.01	.25	.23	.16
Arsenic, total (μ/L).............	31	6	1	3	3	1.4
Cadmium, total (μ/L).............	33	20	<1	3	1	4.2
Chromium, total (μ/L).............	31	20	<1	8	5	6.6
Lead, total (μ/L)....	28	130	<1	17	4	32.5
Manganese, total (μ/L).............	31	1,200	12	244	210	206

and properties at Station MN-1, Minnesota River St. Paul, Minnesota, 1967-82

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µ/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
3,700	--	4,580	--	1,770	--	1,130	--	650	--
701	--	775	--	800	--	880	--	1,000	--
7.9	--	8.0	--	7.9	--	8.1	--	7.7	--
5.0	--	19.5	--	24.0	--	9.0	--	.5	--
10.8	--	8.0	--	6.4	--	11.2	--	10.0	--
24	--	102	--	176	--	77	--	5.5	--
256	--	312	--	137	--	88	--	7.0	--
82	819	90	1,110	80	382	90	274	110	193
31	310	37	453	36	172	39	119	45	79.0
22	220	19	235	32	153	36	110	40	70.2
5.9	58.9	4.9	60.6	5.2	24.3	5.6	17.1	5.9	10.4
220	2,200	212	2,620	240	1,150	270	824	337	591
130	1,300	131	1,620	110	526	120	366	141	247
23	230	26	322	38	182	51	156	45	79.0
507	5,060	557	6,890	544	2,600	602	1,840	703	1,230
120	1,200	140	1,730	77	368	80	244	9	15.8
1.9	19.0	3.4	42.0	2.8	18.4	2.8	8.54	1.4	2.46
.58	5.79	.26	3.22	.40	1.91	.50	1.52	1.3	2.28
.34	3.40	.29	3.59	.34	1.62	.32	.98	.35	.61
.24	2.40	.14	1.73	.20	.96	.24	.73	.32	.56
3	.08	4	.05	5	.02	3	.01	2	.00
2	.02	1	.01	1	.00	<1	<.01	2	.00
8	.08	5	.06	5	.02	1	.00	5	.01
21	.21	7	.09	4	.02	3	.01	4	.00
200	2.00	295	3.65	285	1.36	123	.38	190	.33

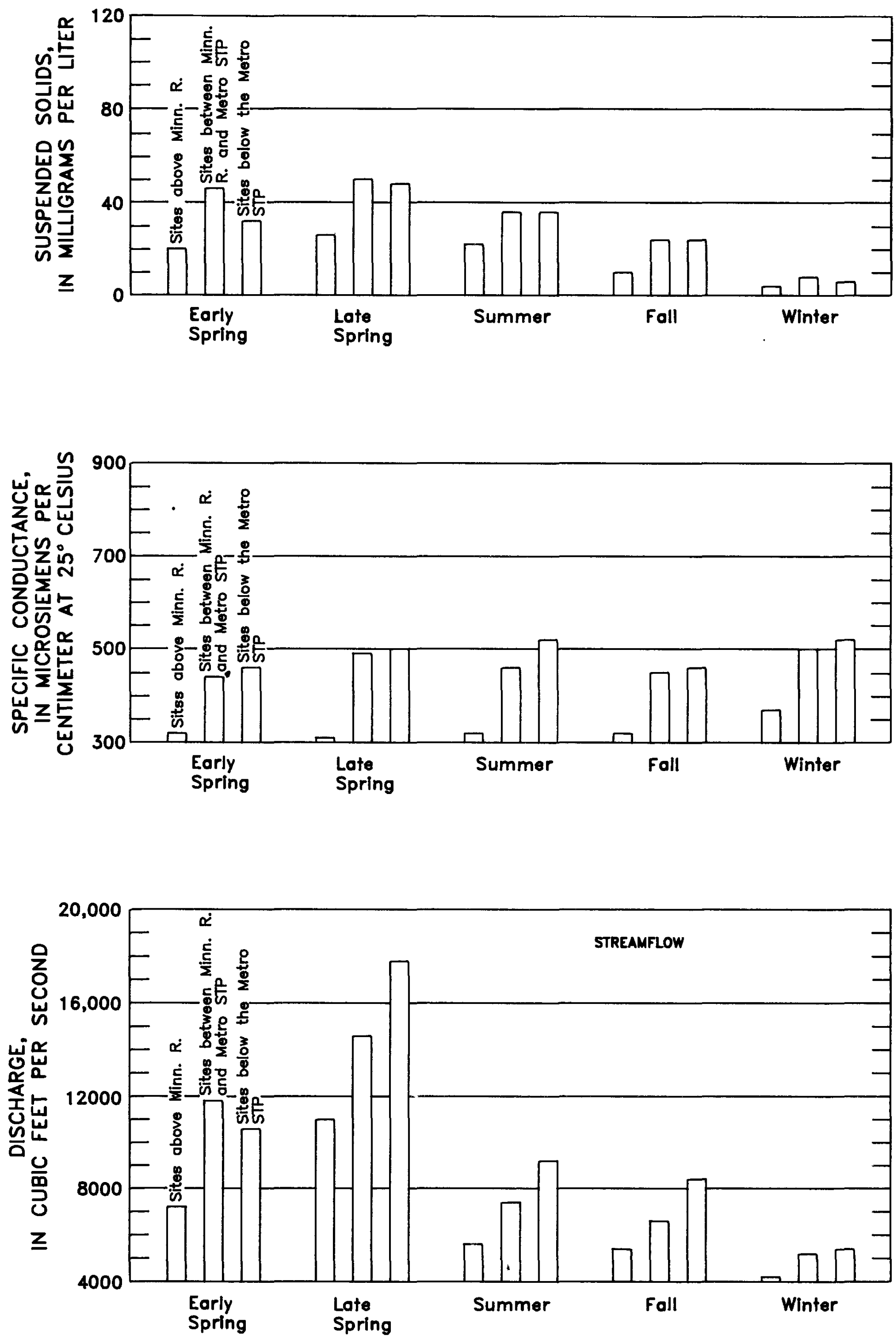
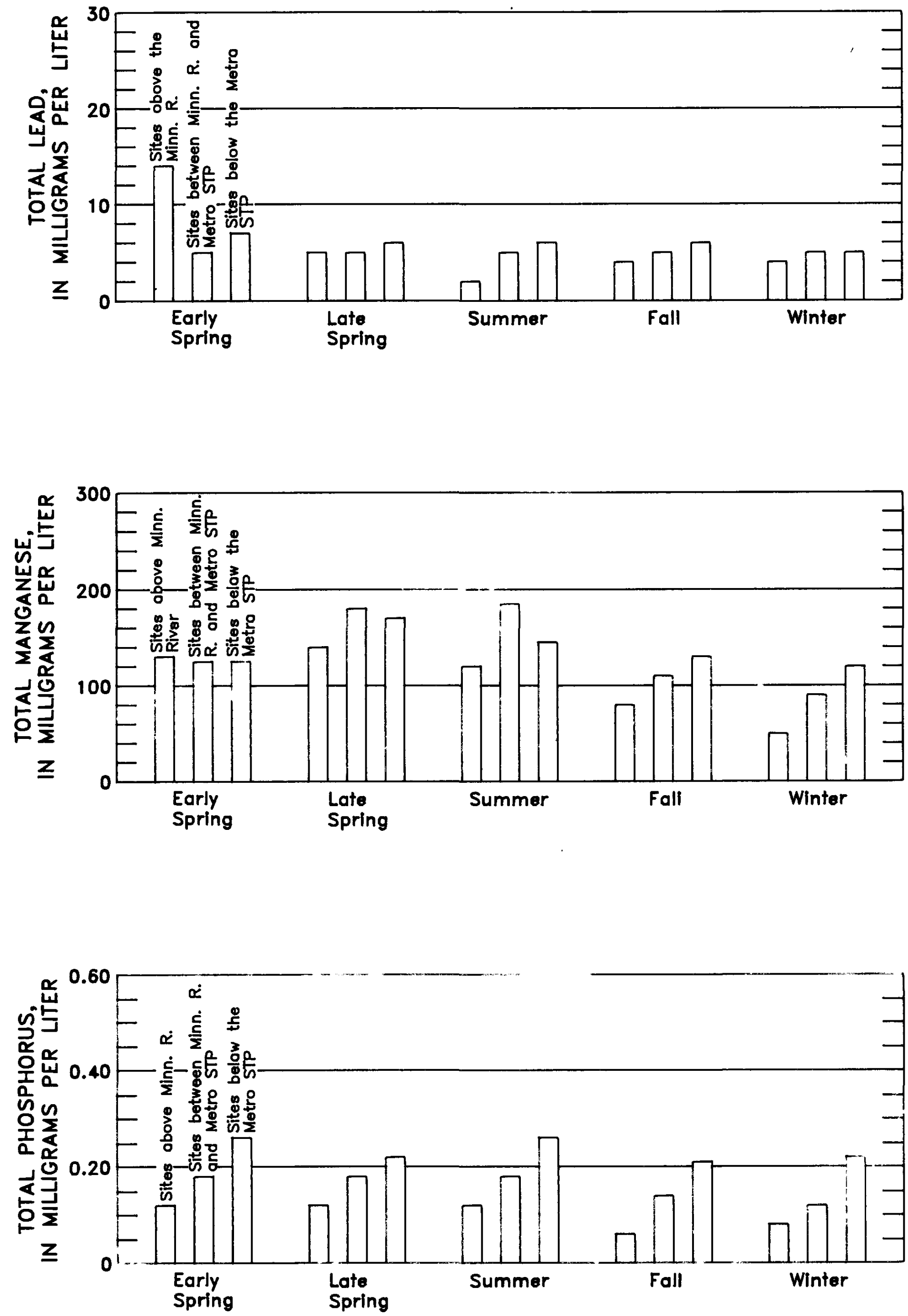


Figure 23.--Median seasonal variation in concentrations of selected constituents



and in properties in water samples collected manually in subbasin 6.

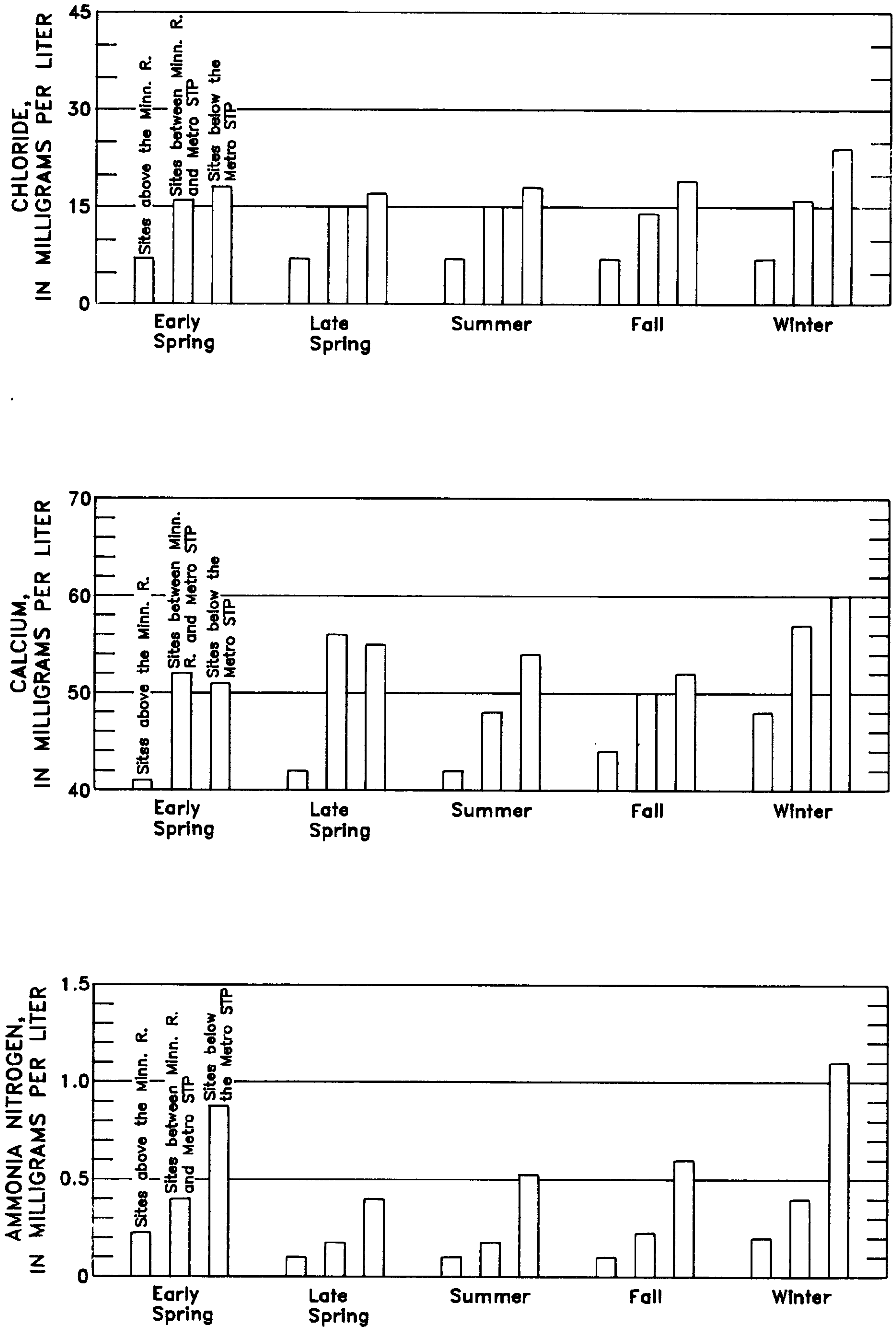
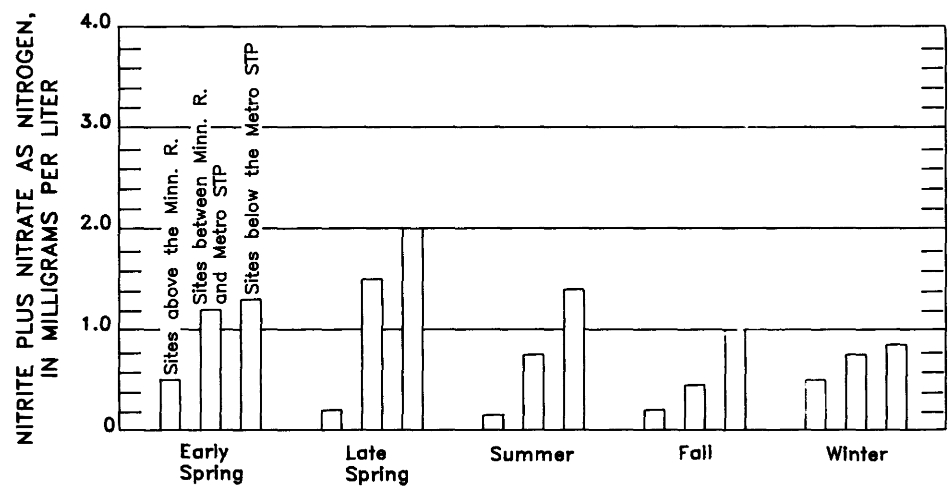
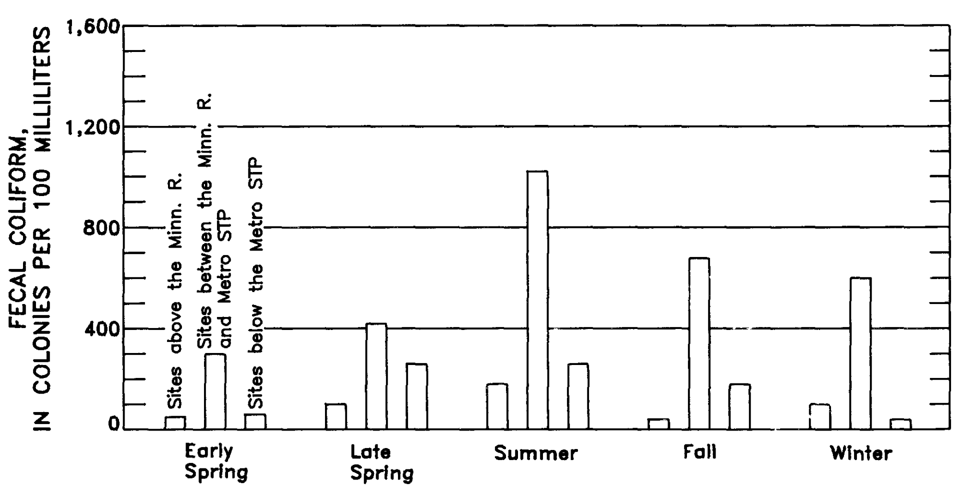


Figure 23.--Median seasonal variation in concentrations of selected constituents





and in properties in water samples collected manually in subbasin 6--Continued.

Two things are apparent from figure 23; concentrations generally increase by group in a downstream direction, and many constituents do not behave normally with streamflow. The causes of these phenomena are two important point sources--the Minnesota River and the sewage-treatment plant.

The specific-conductance curve for stations above the Minnesota River behaves in a normal inverse fashion with streamflow. However, curves for stations below the Minnesota River show an increase in specific conductance, even during high flow, because of the higher concentration of dissolved solids contributed by the Minnesota River. As seen with the automatic-monitor data (table 35), specific conductance of the Minnesota River is more than twice that of the Mississippi River above the confluence. As streamflow subsides in summer, specific conductance decreases at site 6F (fig. 23) -- the only site representing the group between the Minnesota River and the treatment plant. The decrease in specific conductance indicates a reduced percentage of Minnesota River water in the total streamflow in summer at 6F. The same trend is seen with calcium, chloride, and nitrite plus nitrate nitrogen.

Generally, the highest constituent concentrations occur below the treatment plant. Water from the Minnesota River increases the concentrations in the Mississippi River, and the treatment-plant effluent further increases the concentrations.

The ammonia-nitrogen curve (fig. 23) for stations below the treatment plant shows median seasonal values ranging from 0.41 to 1.2 mg/L. These values are two to three times higher than those for upstream stations. Ammonia nitrogen consists of free ammonia (NH_3) and ammonium ion (NH_4^+). Ammonia nitrogen is of concern because of the toxicity of NH_3. The relative abundance of this form of ammonia nitrogen is dependent on pH and temperature. Using the median seasonal values for NH_4^+, pH, and temperature, none of the calculated NH_3 values exceeded the 0.04 mg/L limit set by the Minnesota Pollution Control Agency (1988, p. 23) for class B fisheries. However, NH_3, in some individual samples at each site below the treatment plant (sites 6H-6M) and at site MN-1 did exceed the limit. Excessive concentrations were not observed at site 6F or at any sites above the confluence with the Minnesota River, indicating that dilution and/or NH_4^+ uptake by algae keep NH_3 within standards at site 6F.

Trace elements are represented by median lead and manganese concentrations in figure 23. Total lead concentrations in the Mississippi River tend to increase below the Minnesota River and further increase below the sewage-treatment plant, although all lead concentrations meet the Federal ambient water quality human-health criterion. The relatively high lead concentration in early spring at sites above the Minnesota River is not significant when one considers the ambient human-health criterion for lead of 50 μg/L (U.S. Environmental Protection Agency, 1986).

Total manganese concentrations are highest at site 6F in late spring and summer because of elevated manganese concentrations in the Minnesota River. Later in the year, when the Minnesota River has less influence on quality of the Mississippi, manganese concentrations are highest below the treatment plant.

Tables 49 through 51 show correlation coefficients and regressions for streamflow, major ions, and alkalinity for three groups of sites--those above the Minnesota River, sites between the Minnesota River and the sewage-treatment plant, and sites below the sewage-treatment plant. The only correlation coefficient that is not significant at the 95-percent confidence level is for potassium (table 49). The corresponding regression equation is not usable.

The regressions are valid only for those reaches of the Mississippi River described in each table. Regressions in table 49 are for sites above the confluence with the Minnesota River, regressions in table 50 are for sites between the Minnesota River and the sewage-treatment plant, and regressions in table 51 are for sites below the sewage-treatment plant.

Trends based on analyses of manually collected samples for the three groups of sites in subbasin 6 are shown in table 52. Constituents or properties that show positive trends in all three groups are streamflow, dissolved oxygen, sodium, sulfate, chloride, and nitrite plus nitrate nitrogen. Sodium and chloride increases probably reflect the long-term use of road salts. Environmental efforts in recent years to improve the water quality may have improved conditions for dissolved oxygen. Increases in streamflow may result, in part, from continuing urban development in the Twin Cities Metropolitan area, and a long-term increase in precipitation. Subbasin 6 is the only subbasin in the study area that shows a positive trend for streamflow. The increase in nitrite plus nitrate nitrogen also may be associated with increased urbanization in the metropolitan area. Expansion of urban areas increases runoff which can be enriched with nitrogen from lawn fertilizers. Use of commercial fertilizers also has increased in the rural areas. Decreases in concentrations of heavy metals may result from more sensitive analytical methods and regulation of point sources.

Trends for temperature, specific conductance, pH, and dissolved oxygen shown by interpretation of automatic-monitor data are shown in table 53. Instead of using the Spearman method, the Seasonal Kendall Tau method is used to interpret these data. There are eight statistically significant trends shown at the 0.05 significance level for a two-tailed test. These include one temperature trend, four specific-conductance trends, and three pH trends. Only one, specific conductance at site 6G, is considered to be significant, because of the increasing streamflow in the Minnesota River in recent years. Site 6G is between the Minnesota River and the metropolitan sewage-treatment plant.

The statistically significant decreasing trend for temperature at site 6I demonstrates how misleading trend analyses can be. A negative trend using monitor data is shown at 6I, but a positive trend is shown in table 52 for stations below the treatment plant that were sampled manually.

This difference in trends may be caused when trend analyses are performed on data sets having different periods of record and different measuring frequencies. Data from a daily monitor site can result in fallacious conclusions if there are periods of missing record. Missing record generally shifts the balance of data from one season to another, which can raise havoc with yearly trend analyses.

Table 49.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance for sites upstream from the Minnesota River in subbasin 6*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; *, not sigificant at the 95-percent confidence level]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Significence of r	Standard error of estimate
Streamflow (Q), ft^3/s.........	413	$Q = 135 \times 10^9 (SpC)^{-2.9}$	-0.58	<0.001	75 percent
Calcium (Ca), mg/L..........	96	Ca = 0.08(SpC) + 16	.79	<.001	3.3 mg/L
Magnesium (Mg), mg/L..........	98	Mg = 0.04(SpC) + 3.6	.76	<.001	1.9 mg/L
Sodium (Na), mg/L..........	89	Na = 0.03(SpC) - 3.4	.49	<.001	3.3 mg/L
Potassium (K), mg/L..........	90	K = 0.003(SpC) + 1.6	.20	*.062	.9 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	94	Alk = 0.29(SpC) + 59	.75	<.001	16 mg/L
Sulfate (SO_4), mg/L..........	92	SO_4 = 0.07(SpC) - 6.8	.55	<.001	7.1 mg/L
Chloride (Cl), mg/L..........	92	Cl = 0.03(SpC) - 1.8	.64	<.001	2.0 mg/L

Table 50.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance for sites downstream from the Minnesota River and upstream from the Metropolitan sewage-treatment plant in subbasin 6*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Significence of r	Standard error of estimate
Streamflow (Q), ft^3/s.........	438	$Q = 385x10^5(SpC)^{-1.4}$	-0.31	<0.001	97 percent
Calcium (Ca), mg/L..........	155	Ca = 0.07(SpC) + 23	.67	<.001	6.6 mg/L
Magnesium (Mg), mg/L..........	101	Mg = 0.04(SpC) - 0.6	.77	<.001	3.3 mg/L
Sodium (Na), mg/L..........	129	Na = 0.04(SpC) - 4.5	.59	<.001	5.1 mg/L
Potassium (K), mg/L..........	127	K = 0.004(SpC) + 1.5	.36	<.001	1.0 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	140	Alk = 0.22(SpC) + 77	.66	<.001	22 mg/L
Sulfate (SO_4), mg/L..........	132	SO_4 = 0.12(SpC) - 7.4	.59	<.001	14 mg/L
Chloride (Cl), mg/L..........	156	Cl = 0.05(SpC) - 5.1	.66	<.001	5.0 mg/L

Table 51.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents in specific conductance for sites downstream from the Metropolitan sewage-treatment plant in subbasin 6*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Significence of r	Standard error of estimate
Streamflow (Q), ft^3/s.........	802	$Q = 601x10^7(SpC)^{-2.2}$	-0.48	<0.001	89 percent
Calcium (Ca), mg/L..........	216	Ca = 0.06(SpC) + 29	.60	<.001	7.1 mg/L
Magnesium (Mg), mg/L..........	139	Mg = 0.03(SpC) + 4.6	.64	<.001	3.5 mg/L
Sodium (Na), mg/L..........	183	Na = 0.06(SpC) - 11	.67	<.001	6.3 mg/L
Potassium (K), mg/L..........	180	K = 0.004(SpC) + 1.9	.34	<.001	1.1 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	194	Alk = 0.20(SpC) + 87	.70	<.001	20 mg/L
Sulfate (SO_4), mg/L..........	170	SO_4 = 0.08(SpC) - 4.1	.53	<.001	14 mg/L
Chloride (Cl), mg/L..........	228	Cl = 0.09(SpC) - 20	.72	<.001	9.2 mg/L

Table 52.--*Trends for selected constituents and properties in subbasin 6*

[++ indicates increasing trend with correlation coefficient greater than 0.75; + indicates increasing trend; - indicates decreasing trend; 0 indicates no apparent trend]

	Sites above Minnesota River		Sites between Minnesota River and Metropolitan sewage-treatment plant		Sites below Metropolitan sewage-treatment plant	
Constituent or property	Number of measurements	Trend for period of record	Number of measurements	Trend for period of record	Number of measurements	Trend for period of record
Streamflow, mean daily	1,175	+	972	+	1,426	+
Specific conductance	413	0	439	+	804	+
pH	1,235	+	963	0	1,458	0
Temperature	1,176	0	951	0	1,376	+
Oxygen, dissolved	1,247	+	956	+	1,466	+
Fecal coliform	625	-	527	0	982	-
Fecal Streptococci	132	+	224	+	336	0
Calcium, dissolved	218	++	259	-	373	0
Magnesium, dissolved	222	++	261	0	375	+
Sodium, dissolved	119	+	140	+	192	+
Potassium, dissolved	121	0	142	+	194	0
Alkalinity, total	141	0	156	0	206	0
Sulfate, dissolved	124	+	142	+	182	+
Chloride, dissolved	155	+	168	+	270	+
Solids, suspended	692	-	575	-	1,046	-
Nitrite plus nitrate as nitrogen, dissolved	472	+	423	+	756	+
Ammonia as nitrogen, dissolved	657	-	541	0	1,006	-
Phosphorus, total	507	0	475	0	850	-
Arsenic, total	46	0	97	-	151	-
Cadmium, total	47	-	220	-	281	-
Chromium, total	46	0	206	0	237	0
Lead, total	38	0	205	-	263	-
Manganese, total	48	-	214	0	265	0

Table 53.--*Trends indicated by automatic-monitor data*

[N, number of measurements; °C/yr, degrees Celsius per year; (µS/cm)/yr, microsiemens per centimeter per year; (mg/L)/yr, milligrams per liter per year; --, value not determined; <, less than]

		Temperature			Specific conductance			pH			Dissolved oxygen		
Site	Period of record (water year)	N	Trend (°C/yr)	Significance level	N	Trend (µS/cm)/yr)	Significance level	N	Trend (units/yr)	Significance level	N	Trend (mg/L)/yr)	Significance level
6C	1975-82	2,084	-0.05	0.330	1,786	4.6	0.049	2,031	-0.03	0.008	1,909	-0.05	0.063
6E	1974-82	1,805	-.02	.648	1,370	5.6	.011	1,935	-.04	.000	1,750	-.05	.131
MN-1	1979-82	1,074	.20	.096	1,042	8.5	.623	1,060	-.03	.233	1,083	.22	.117
6F	1978-82	1,791	.15	.177	--	--	--	--	--	--	--	--	--
6G	1976-82	1,549	-.20	.125	1,438	22.2	.002	1,536	<.01	.724	1,443	.09	.103
6I	1979-82	784	-.88	.037	721	2.5	1.000	766	.08	.421	721	-.09	.875
6J	1977-82	1,052	.02	.659	1,017	14.5	.081	972	.03	.287	989	.41	.100
6L	1974-82	1,838	-.10	.093	1,744	8.8	.008	1,871	-.02	.049	1,673	-.04	.565

Subbasin 7

Physical Characteristics

Subbasin 7 covers an area of approximately 1,580 mi^2 and contains the second largest lake, Mille Lacs Lake, in Minnesota. This lake is the source of the Rum River, which drains the entire subbasin (fig. 24). The Rum River is about 140 miles long and empties into the Mississippi River at Anoka. Topographic relief from north to south is about 400 feet, and the average gradient of the Rum River is 2.9 ft/mi.

The northern half of subbasin 7 consists of an undulating glacial-till plain containing numerous marshes; it is crossed by several morainal ridges. Mille Lacs Lake was formed by the damming action of a prominent morainal ridge that extends along the southern end of the lake basin (Minnesota Department of Conservation, 1968, p. 284). The southern half of the watershed consists of hills that rise above a glacial-outwash plain known as the Anoka Sand Plain.

Slate of Precambrian age forms the bedrock as far south as the lower end of Mille Lacs Lake. From there to Princeton the bedrock consists of granitic and metamorphic rocks of Precambrian age that crop out at the surface along the Rum River and its tributaries. Bedrock in the area between Princeton and Anoka is Precambrian and Cambrian sandstone and shale. Most of the bedrock throughout the subbasin is covered by glacial deposits about 100 feet thick.

Forest (mostly hardwood) is the largest land use in the subbasin (table 54). Most of the forested area is in the upper part of the subbasin

Table 54.--*Land use in subbasin 7*

Use	Acres	Percent of total
Cultivated	209,640	20.78
Extractive	80	0.01
Forested	316,080	31.32
Marsh	44,760	4.44
Pasture and open	268,440	26.60
Urban nonresidential or mixed residential development	10,440	1.03
Urban residential	17,680	1.75
Water	141,920	14.06

between Mille Lacs Lake and Milaca. Dairy farming is the principal farming activity.

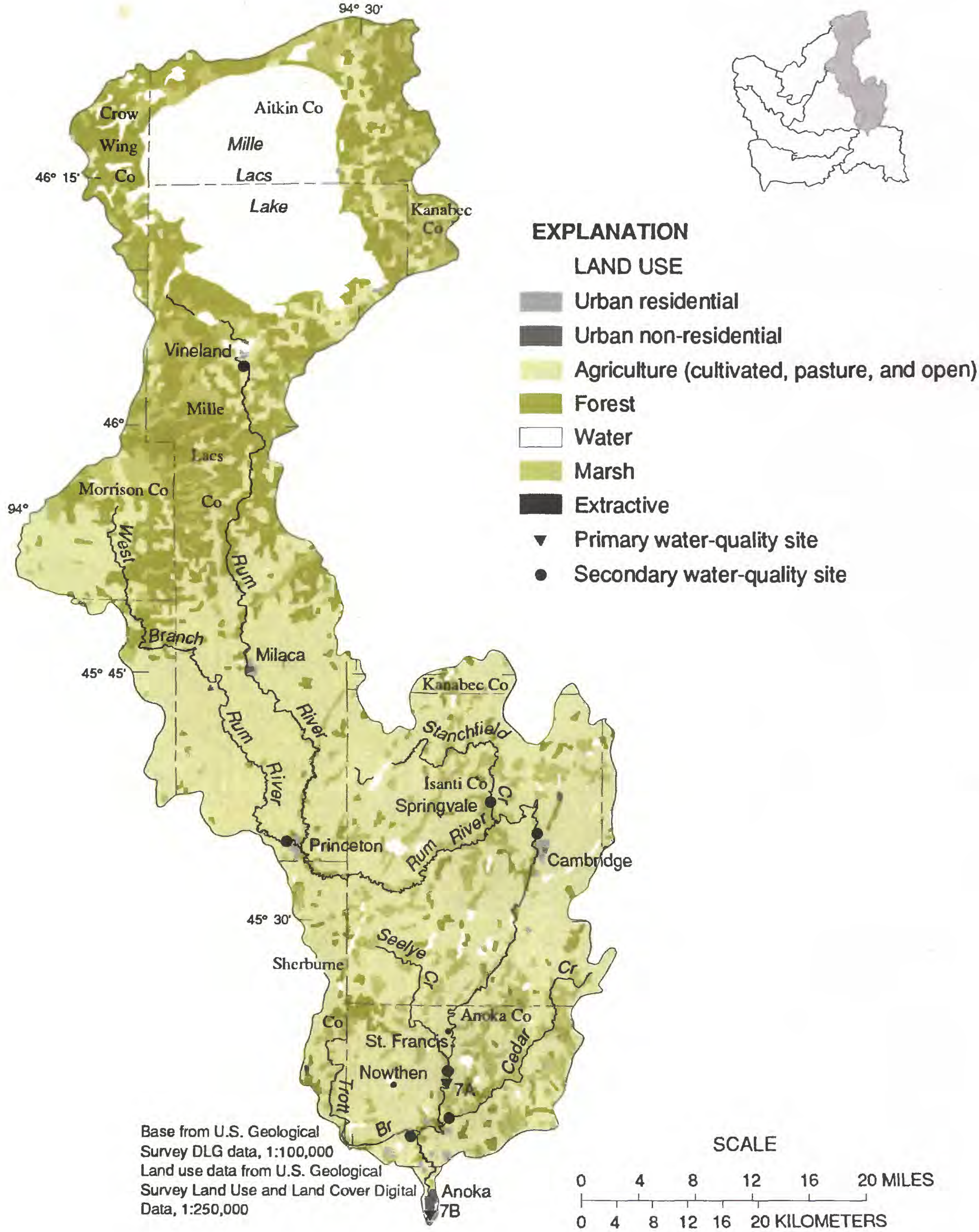


Figure 24. Land use and location of sampling sites in subbasin 7.

Site 7A, Rum River near St. Francis, has been a U.S. Geological Survey gaging station since 1929 (U.S. Geological Survey, 1984, p. 67). Average streamflow through water year 1983 was 602 ft^3/s. A maximum flow of 10,100 ft^3/s occurred on April 20, 1965; minimum flow was 29 ft^3/s on August 18, 1934. During the 1976-77 drought, a minimum flow of 78 ft^3/s occurred on August 25, 1977 (U.S. Geological Survey, 1977, p. 272).

Water-Quality Characteristics

Records from two primary sites and seven secondary sites have been used to describe the quality of water in subbasin 7 (fig. 24). Most of the data at site 7A (table 55) were collected from 1973-77 as part of a cooperative monitoring program between the U.S. Geological Survey and the Metropolitan Waste Control Commission. Data at site 7B (table 56) were collected by the Minnesota Pollution Control Agency as well as the USGS and MWCC.

Based on median values, the concentrations of heavy metals at site 7A, except for cadmium, generally meet ambient human-health criteria (U.S. Environmental Protection Agency, 1986). Cadmium values at site 7A probably are higher than actual values because of a contamination problem that occurred in the middle 1970's. Some samples were inadvertently contaminated by lead and cadmium from a painted ring on vials of nitric acid used for preserving samples for analysis of metals. The lead values at site 7A, also, probably are higher than they should be, but they still are below the Federal human-health criterion of 50 µg/L for lead.

Figure 25 shows the seasonal median concentrations of selected constituents and properties at sites 7A and 7B. The highest streamflow occurs in the latter part of early spring and the early part of late spring. Median specific-conductance values are similar to those at sites 1A and 1B in subbasin 1. Median concentrations of suspended solids are highest in late spring after most of the protective snow cover has disappeared and erosion from runoff is greatest.

Nitrite plus nitrate nitrogen, chloride, calcium, ammonia nitrogen, and fecal-coliform concentrations generally are higher at site 7B because of backwater effects from the Mississippi River and a greater population density. The distance from site 7B to the mouth is about 0.6 mile and the fall is only 4 feet.

Many ammonia-nitrogen values at site 7B were reported as less than 0.20 mg/L. Setting these values to 0.10 mg/L, or halfway between 0 and the 0.20 mg/L detection limit, caused the first four seasonal medians to equal 0.10 mg/L. Ammonia nitrogen at both sites increased significantly in the winter, however, indicating decomposition of organic matter with less loss of ammonia to the atmosphere because of ice cover and less utilization by plants.

Dissolved-oxygen concentrations decrease in winter for much the same reason that ammonia concentrations increase. The dissolved oxygen that is taken up by decomposer microorganisms in winter is not readily replenished during ice cover. Concentrations of dissolved oxygen in winter are much higher at site 7B than at site 7A. A dam about 200 feet upstream of site 7B near Anoka provides a mechanism for aerating the water and reducing ice cover above and around site 7B as compared to 7A.

Table 55.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

	Period of record					
Constituent or property	Number of meas- urements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	56	5,390	85	750	500	880
Specific conductance (μS/cm)............	56	415	140	290	290	58
pH (units)...........	56	8.8	6.7	7.8	7.8	0.4
Temperature (°Celsius).........	53	25.5	.0	9.0	4.0	9.0
Oxygen, dissolved (mg/L).............	48	14.0	3.5	9.0	9.0	2.5
Fecal coliform (colonies/100mL)...	34	250	<1	49	20	71
Fecal <u>Streptococci</u> (colonies/100mL)...	26	520	<1	89	38	120
Calcium, dissolved (mg/L).............	56	55	14	37	38	8.5
Magnesium, dis- solved (mg/L)......	56	18	4.6	12	12	2.6
Sodium, dissolved (mg/L).............	56	8.9	1.8	4.8	4.8	1.3
Potassium, dis- solved (mg/L)......	56	4.6	1.3	2.0	1.9	.6
Alkalinity, total (mg/L).............	55	197	51	137	140	28
Sulfate, dissolved (mg/L).............	56	17	5.0	8.9	8.8	1.9
Chloride, dissolved (mg/L).............	56	12	3.0	5.0	4.3	1.9
Solids, dissolved (mg/L).............	0	--	--	--	--	--
Solids, suspended (mg/L).............	49	72	<1	16	12	16
Nitrite plus nitrate as nitrogen, dis- solved (mg/L)......	37	.98	.01	.26	.21	.22
Ammonia as nitrogen, dissolved (mg/L)...	49	.36	.01	.10	.09	.09
Phosphorus, total (mg/L).............	0	--	--	--	--	--
Phosphorus, dis- solved (mg/L)......	52	.63	.01	.07	.04	.10
Arsenic, total (μg/L).............	4	3	1	2	2	1
Cadmium, total (μg/L).............	6	20	0	14	20	10
Chromium, total (μg/L).............	3	<1	<1	<1	<1	<1
Lead, total (μg/L)...	2	50	2	26	26	34
Manganese, total (μg/L).............	10	210	30	100	95	56

at site 7A Rum River near St. Francis, Minnesota, 1963-76

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
1,160	--	1,020	--	400	--	376	--	396	--
218	--	240	--	282	--	282	--	326	--
7.6	--	8.2	--	8.2	--	8.0	--	7.4	--
1.0	--	16.0	--	21.0	--	3.0	--	.0	--
9.6	--	9.0	--	8.7	--	11.8	--	5.8	--
22	--	28	--	30	--	11	--	17	--
6	--	110	--	84	--	24	--	20	--
30	94.0	32	88.1	36	38.9	38	41.0	42	44.9
9.4	29.4	10	27.5	11	11.9	12	13.0	14	15.0
3.8	11.9	4.4	12.1	4.8	5.18	5.0	5.40	5.0	5.35
2.6	8.14	1.7	4.68	1.6	1.73	1.9	2.05	2.1	2.24
110	344	121	333	125	135	140	151	154	165
8.4	26.3	7.0	19.3	7.8	8.42	9.0	9.72	9.6	10.3
3.8	11.9	4.0	11.0	4.0	4.32	4.8	5.18	4.8	5.13
--	--	--	--	--	--	--	--	--	--
8	25.0	28	77.1	15	16.2	10	10.8	4	4.28
.42	1.32	.04	.11	.10	.11	.21	.23	.44	.47
.13	.41	.04	.11	.02	.02	.05	.05	.17	.18
--	--	--	--	--	--	--	--	--	--
.04	.12	.03	.08	.02	.02	.06	.06	.04	.04
--	--	--	--	2	.00	2	.00	--	--
--	--	<1	.00	20	.02	16	.02	--	--
--	--	--	--	<1	.00	<1	.00	--	--
--	--	--	--	--	--	26	.03	--	--
--	--	90	.25	65	.07	120	.13	60	.06

Table 56.--*Summary statistics for selected constituents and properties*

[Early spring, March-April; late spring, May-June; summer, July-September; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams

Constituent or property	Period of record: Number of measurements	Maximum	Minimum	Mean	Median	Standard deviation
Streamflow, mean daily (ft^3/s)......	161	10,300	128	832	521	1,100
Specific conductance (µS/cm)............	100	470	120	281	282	64
pH (units)...........	157	8.8	7.0	7.9	7.9	0.3
Temperature (°Celsius).........	15	25.0	.0	8.0	1.0	10.0
Oxygen, dissolved (mg/L).............	160	15.7	2.3	9.0	8.9	2.4
Fecal coliform (colonies/100mL)...	115	13,000	20	350	110	1,300
Fecal <u>Streptococci</u> (colonies/100mL)...	9	550	9	140	110	170
Calcium, dissolved (mg/L).............	59	56	13	38	40	8.7
Magnesium, dissolved (mg/L)......	15	19	4.8	13	13	3.3
Sodium, dissolved (mg/L).............	58	13	2.0	6.1	6.0	2.1
Potassium, dissolved (mg/L)......	57	6.9	1.0	2.3	2.0	1.1
Alkalinity, total (mg/L)............	110	310	48	141	140	33
Sulfate, dissolved (mg/L)............	42	23	5.0	12	11	3.4
Chloride, dissolved (mg/L)............	134	20	.5	6	6	3.2
Solids, dissolved (mg/L)............	2	157	150	153	153	4.9
Solids, suspended (mg/L)............	143	94	<1	16	14	14
Nitrite plus nitrate as nitrogen, dissolved (mg/L)......	8	1.5	.01	.5	.36	.52
Ammonia as nitrogen, dissolved (mg/L)...	130	.65	.10	.16	.10	.12
Phosphorus, total (mg/L)............	119	.54	.01	.16	.14	.09
Arsenic, total (µg/L)............	56	5	1	5	5	1.1
Cadmium, total (µg/L)............	90	20	5	7	5	2.7
Chromium, total (µg/L)............	5	16	3	7	5	5.2
Lead, total (µg/L)...	79	52	5	8	5	6.9
Manganese, total (µg/L)............	82	1,000	10	160	130	150

at site 7B, Rum River at Anoka, Minnesota, 1953-77

fall, October-November; winter, December-February; ft^3/s, cubic feet per second; per liter; µg/L, micrograms per liter; mL, milliliter; --, no data]

Early spring		Late spring		Summer		Fall		Winter	
Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day	Median	Tons per day
1,160	--	952	--	453	--	410	--	344	--
288	--	246	--	263	--	274	--	332	--
7.9	--	7.9	--	8.0	--	8.0	--	7.7	--
1.0	--	18.5	--	24.0	--	2.5	--	.0	--
9.8	--	8.6	--	8.0	--	10.9	--	9.8	--
32	--	85	--	170	--	85	--	90	--
78	--	--	--	160	--	280	--	14	--
36	113	38	97.7	35	42.8	40	44.3	44	40.9
11	34.4	13	33.4	12	14.7	12	13.3	15	13.9
4.4	13.8	4.8	12.3	5.0	6.12	6.7	7.42	6.5	6.04
2.6	8.14	2.1	5.40	1.9	2.32	2.0	2.21	2.2	2.04
123	385	130	334	132	161	144	159	165	153
11	34.4	10	25.7	10	12.2	12	13.3	12	11.1
6.1	19.1	4.7	12.1	6.0	7.34	6.2	6.86	7.2	6.69
--	--	--	--	154	188	--	--	--	--
8	25.0	24	61.7	23	28.1	8	8.86	3	2.79
1.5	4.70	--	--	.01	.01	.18	.20	.70	.65
.10	.31	.10	.26	.10	.12	.10	.11	.20	.18
.14	.44	.18	.46	.18	.22	.13	.14	.10	.09
5	.02	5	.01	5	.01	5	.00	5	.00
5	.02	6	.02	6	.01	6	.01	6	.00
--	--	--	--	5	.01	5	.00	--	--
6	.02	6	.02	5	.01	5	.00	6	.00
150	.47	140	.36	140	.17	76	.08	120	.11

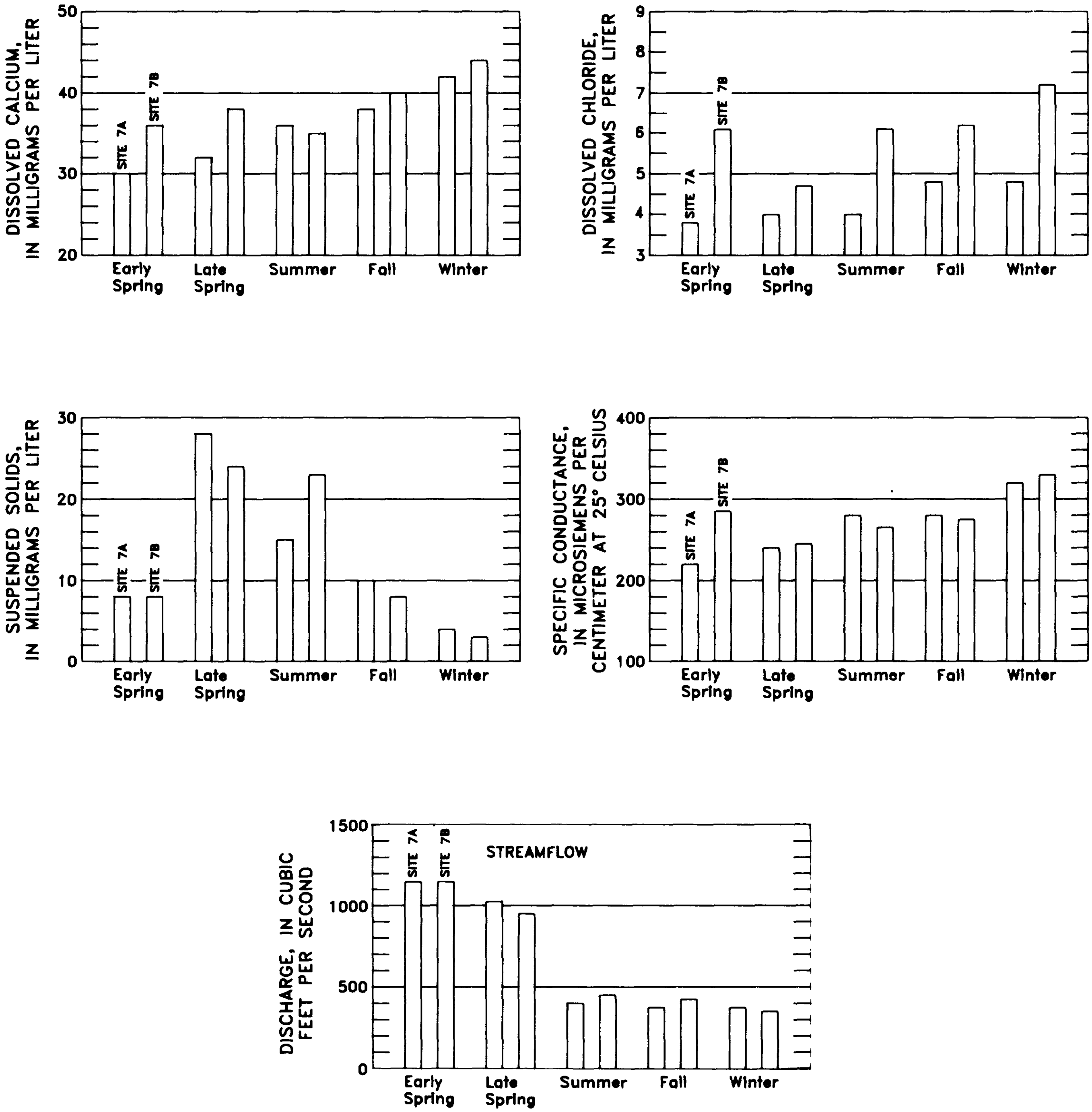
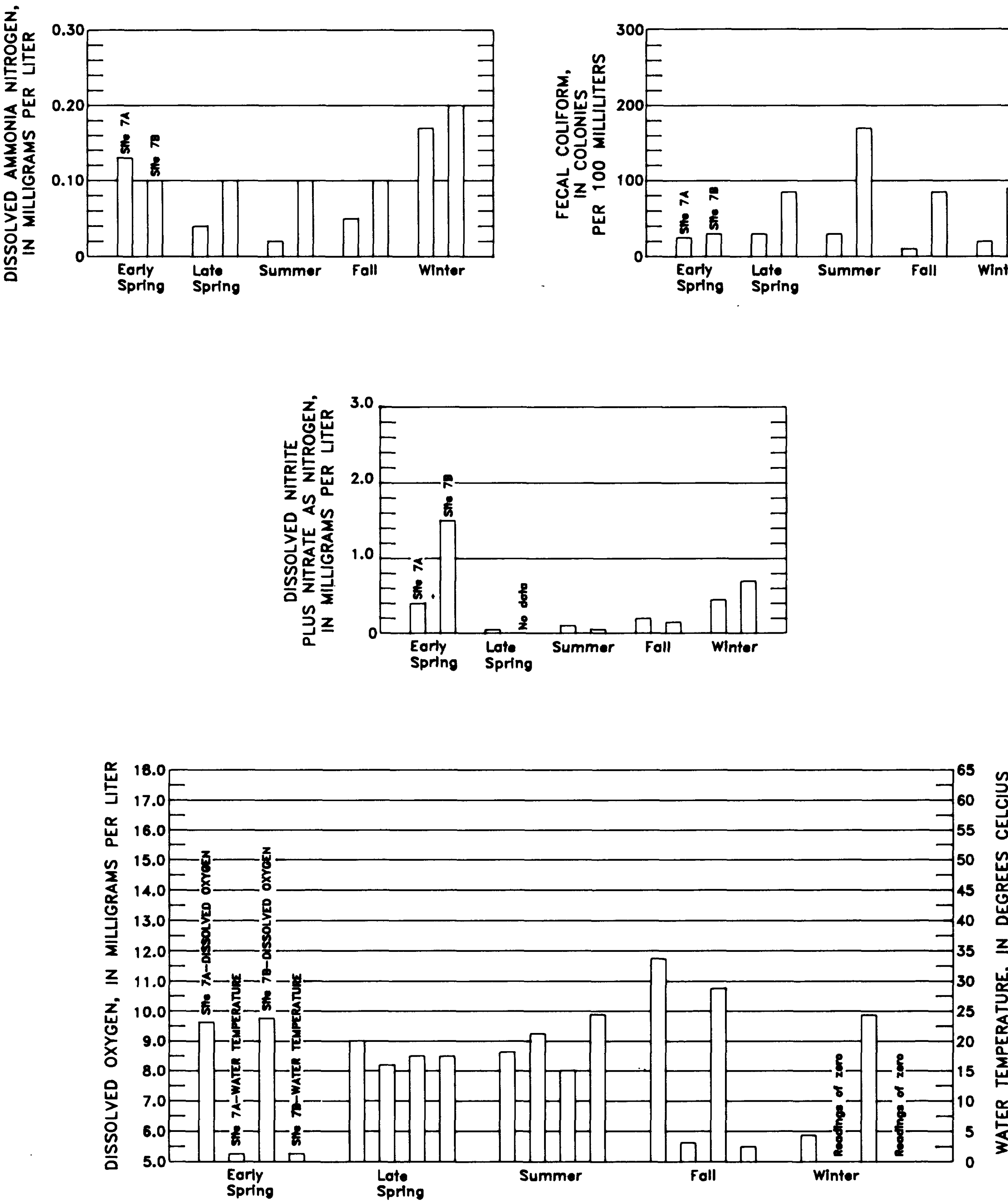


Figure 25.--Median seasonal variation in concentrations of selected



constituents and in properties sampled in subbasin 7.

Correlation coefficients and regression equations in table 57 were derived from data at site 7A. Data from site 7B were not used because of backwater effects, which, at times, resulted in the mixing of water from the Rum River with water from the Mississippi River. The correlation coefficient for potassium is not significant at the 95-percent confidence level, and its regression equation should not be used. The rest of the regressions can be used for the Rum River between St. Francis and the dam near Anoka. When using any of the regression equations, one should be aware of the standard error of estimate.

Trends from 1963-76 for site 7A and from 1953-77 for site 7B are shown in table 58. Chloride, the only constituent that showed a positive trend at both sites, reached its maximum during the 1976-77 drought, which occurred near the end of the sampling period. Chloride concentrations may have returned to predrought levels in subsequent years.

Table 59 shows areal variations in water quality in subbasin 7 in August 1969. Water discharging from Mille Lacs Lake is represented by data for the Rum River at Vineland. Streams tributary to the Rum River probably were being fed by ground water when sampled, as indicated by the larger dissolved-solids concentrations. Differences in major-ion concentrations between the tributary sites reflect differences in the drift material through which ground water discharging to the streams flows. The only evidence of the affect of human activities on water quality is the relatively large concentrations of dissolved phosphorus in water from Stanchfield Creek.

DIFFERENCES IN WATER QUALITY AMONG SUBBASINS

The study area covers an area of about 8,500 mi^2 and the quality of water differs from among subbasins. Data for selected indicator constituents collected in each subbasin are shown in table 60. Subbasins 1, 3, and 6 represent parts of the mainstem of the Mississippi River. Subbasin 3 also includes the Elk River (fig. 26). Subbasins 2, 4, and 5 drain the western part of the study area, where cultivation of crops is common, and subbasin 7 drains the eastern part where forests and wetlands are common.

Land use, especially cultivation, can have a significant effect on water quality. Intensive cultivation usually occurs in areas of more productive soils like those in the western part of the study area. In these areas, relatively larger amounts of many chemical constituents occur naturally in the productive soils, but some tillage practices and chemicals commonly used on cultivated land tend to increase concentrations of nutrients and other agricultural chemicals. Urban land use affects water quality, as does industrial and municipal water uses. In the Twin Cities area, the Metropolitan sewage-treatment plant is a well-known cause of water-quality changes.

The concentrations in subbasin 1 are the lowest for all constituents except fecal coliform, which is second smallest. Cultivated land comprises 41.04 percent of the total land use in subbasin 1 (table 61). This percentage is a little less than average for the study area. The percentage of urban land use is the lowest in the study area.

Table 57.--*Results of regression analyses relating streamflow and concentrations of selected chemical constituents to specific conductance at site 7A*

[SpC, specific conductance in microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; <, less than; *, not significant at the 95-percent confidence level]

Constituent or property	Number of observations	Regression equation	Correlation coefficient (r)	Significence of r	Standard error of estimate
Streamflow (Q), ft^3/s.........	56	$Q = 248x10^8(SpC)^{-3.1}$	-0.80	<0.001	56 percent
Calcium (Ca), mg/L..........	56	Ca = 0.13(SpC) - 0.6	.89	<.001	3.9 mg/L
Magnesium (Mg), mg/L..........	56	Mg = 0.04(SpC) + 0.2	.90	<.001	1.1 mg/L
Sodium (Na), mg/L..........	56	Na = 0.02(SpC) - 0.5	.84	<.001	.7 mg/L
Potassium (K), mg/L..........	54	K = -0.001(SpC) + 2.2	-.11	*.413	.5 mg/L
Alkalinity as $CaCO_3$ (Alk), mg/L..........	55	Alk = 0.47(SpC) + 0.4	.93	<.001	10 mg/L
Sulfate (SO_4), mg/L..........	52	SO_4 = 0.02(SpC) + 3.3	.55	<.001	1.4 mg/L
Chloride (Cl), mg/L..........	56	Cl = 0.02(SpC) - 1.5	.68	<.001	1.4 mg/L

Table 58.--*Trends for selected constituents collected at sites 7A and 7B on the Rum River*

[++ indicates increasing trend with correlation coefficient greater than 0.75; + indicates increasing trend; - indicates decreasing trend; 0 indicates no apparent trend; ND, not determined]

Constituent or property	Number of observations		Trend for period of record	
	7A	7B	7A	7B
Streamflow	56	161	0	0
Specific conductance	56	100	+	0
pH	56	157	+	0
Temperature	37	15	0	0
Dissolved oxygen	48	160	0	0
Fecal coliform	31	115	0	-
Fecal *Streptococci*	24	9	0	0
Calcium	56	59	+	0
Magnesium	56	15	0	0
Sodium	56	58	+	0
Potassium	56	57	0	0
Alkalinity	55	110	0	0
Sulfate	56	42	0	0
Chloride	56	134	+	+
Suspended solids	46	143	0	-
Nitrite plus nitrate as nitrogen	37	8	0	++
Ammonia as nitrogen	49	130	0	+
Total phosphorus	0	119	ND	-
Arsenic	4	56	0	-
Cadmium	5	90	0	-
Chromium	0	5	ND	0
Lead	0	79	ND	0
Manganese	10	82	++	0

Table 59.--*Streamflow and water quality at secondary sites in subbasin 7*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; <, less than; U.S. Geological Survey station number is in parenthesis]

Constituent or property	Rum River at Vineland (05284001) August 20, 1969	West Branch Rum River at Princeton (05284710) August 20, 1969	Stanchfield Creek at Springvale (05284950) August 22, 1969	Rum River at Cambridge (05285000) August 22, 1969	Seelye Brook near St. Francis (05285800) August 21, 1969	Cedar Creek near Anoka (05286300) August 21, 1969	Trott Brook near Nowthen (05286800) August 21, 1969
Streamflow (ft^3/s)...	121	7.8	1.8	202	2.4	2.4	5.1
Specific conductance (µS/cm)............	204	312	452	247	358	340	437
pH (units)...........	7.6	7.6	7.8	7.5	7.6	7.8	7.6
Temperature (°C).....	20.0	21.0	19.0	22.0	16.0	20.0	17.0
Calcium, dissolved (mg/L).............	25	39	53	29	47	48	57
Magnesium, dissolved (mg/L).............	8.4	13	23	11	15	12	21
Sodium, dissolved (mg/L).............	3.5	5.2	12	5.2	5.2	4.5	5.4
Potassium, dissolved (mg/L).............	3.2	2.5	3.4	2.0	1.5	2.3	2.5
Alkalinity, total as $CaCO_3$ (mg/L).......	99	144	240	120	170	167	233
Sulfate, dissolved (mg/L).............	7.0	12	5.3	6.3	15	11	8.2
Chloride, dissolved (mg/L).............	3.0	5.8	7.4	3.6	6.2	3.6	2.4
Solids, dissolved (mg/L).............	148	202	276	164	227	215	277
Nitrate, dissolved as nitrogen (mg/L)....	<0.1	0.4	<0.1	<0.1	0.2	<0.1	0.3
Phosphorus, dissolved (mg/L).............	<.01	.02	.14	.03	.03	.02	<.01

Table 60.--*Median concentration of selected constituents using data from primary sites*

[Fecal-coliform concentrations are in colonies per 100 milliliters. All other concentrations are in milligrams per liter.]

Subbasin	Dissolved solids[a]	Sulfate	Ammonia nitrogen	Nitrite plus nitrate nitrogen	Total phosphorus	Dissolved chloride	Fecal coliform
1	182	8.8	0.10	0.14	0.06	3.4	50
2	292	30	.12	.38	.22	12	130
3	195	13	.10	.15	.09	5.0	110
4	389	54	.11	.59	.28	20	170
5	603	130	.14	.77	.37	60	490
[b]6	223	15	.12	.33	.10	6.4	100
[c]6	320	43	.55	.94	.22	18	230
7	186	9.3	.10	.21	.12	5.0	38
[d]6K	328	42	.70	1.2	.21	23	92

[a] Dissolved solids = specific conductance x 0.65.

[b] Sites above the Minnesota River.

[c] Sites below the Minnesota River.

[d] NASQAN site 6K, Mississippi River at Nininger, Minn.

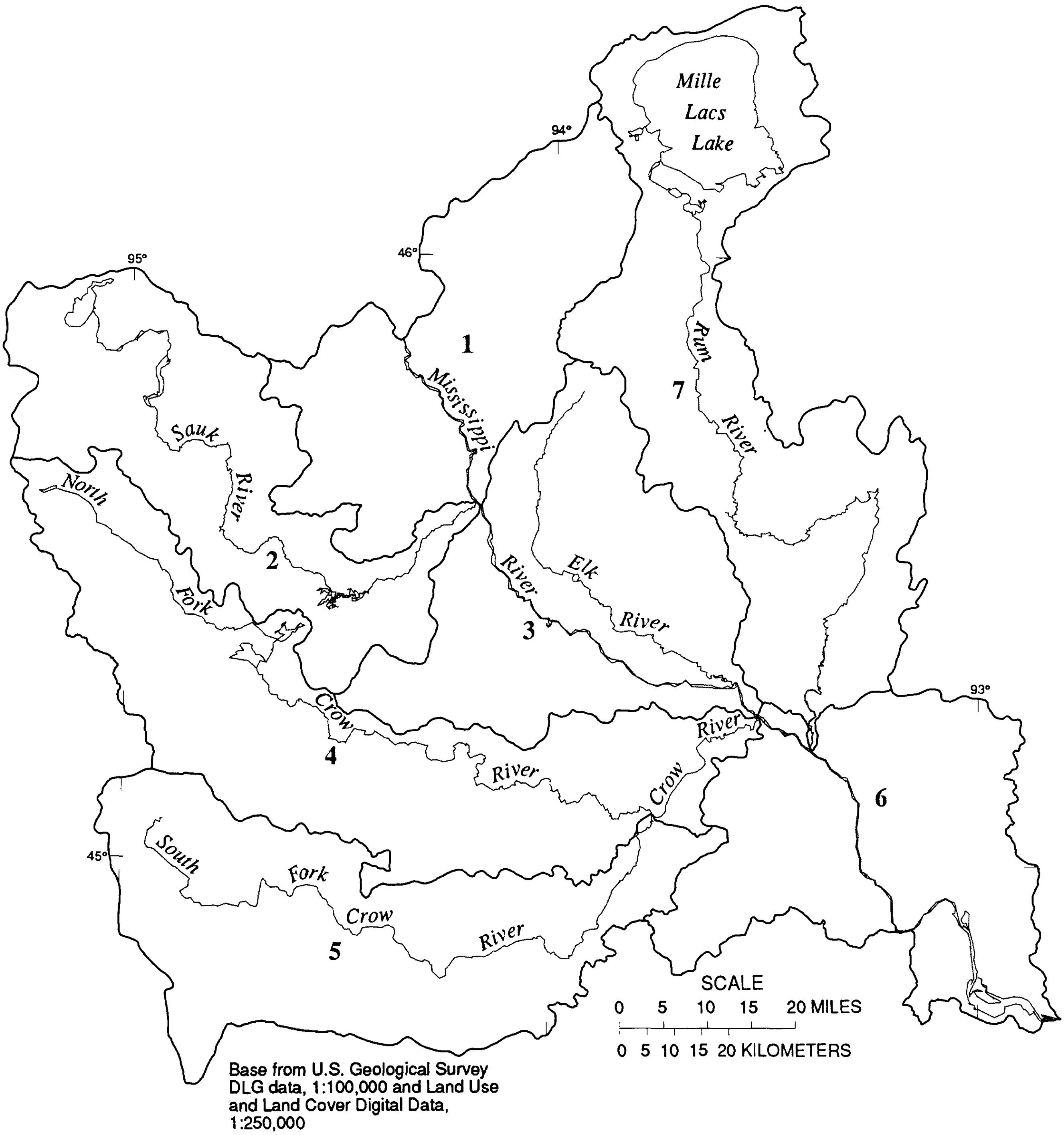


Figure 26. Principal waterways and subbasins in Hydrologic Unit 070102.

Table 61.--*Cultivated and urban land use in each subbasin within Accounting Unit 070102*

Subbasin	Percent cultivated	Percent urban
1	41.04	1.97
2	54.80	2.75
3	41.82	4.01
4	61.70	2.86
5	79.86	2.02
6	22.52	37.6
7	20.78	2.78

Subbasin 2 includes the Sauk River, which is the first tributary to the Mississippi entering from the west side of the study area. Constituent concentrations are much larger in the Sauk River than in the recipient Mississippi River. The larger concentrations result from cultivation of the land surface and from the natural chemical content of prairie soils compared to podzol soils, which occur in subbasin 1. Average flow of the Sauk River is approximately 6 percent of that in the Mississippi. The larger concentrations carried by the Sauk River are, therefore, quickly diluted. The result is a slight increase in concentrations in the Mississippi River.

Concentrations of chemical constituents in the Mississippi River subbasin 3 generally are larger than in subbasin 1. Concentrations in subbasin 3 are influenced by the Sauk River and by the larger percentage of urbanized land. The metropolitan area of St. Cloud and Sauk Rapids has a population of 48,359 (1980) and is the major urban area in subbasin 3.

Subbasin 4 is drained by the North Fork Crow River and the Crow River. It has the second highest percentage of cultivated land, and constituent concentrations are relatively large (table 60). As with drainage from subbasin 2, drainage from the Crow River generally increases the concentrations of constituents in the Mississippi River as evidenced by data for the upper part of subbasin 6 (table 6). Average flow of the Crow River is about 12 percent of the flow of the Mississippi. Therefore, there is a significant amount of dilution that dampens the effects from the Crow River.

Subbasin 5, drained by the South Fork Crow River, in many ways is significantly different from the rest of the subbasins. Subbasin 5 is nearly 80 percent cultivated, and many constituents have much larger median concentrations than are present in any of the other subbasins (table 60). Large concentrations of various constituents in samples collected in subbasin 5 have not been present in samples from other subbasins. It appears that the quality of water in subbasin 5 is affected by the large amount of cultivation and by point sources of contamination.

The Mississippi River in subbasin 6 is divided into upper and lower parts for purposes of discussion. The dividing line is at the confluence of the Minnesota and Mississippi Rivers. The drainage area of the Minnesota River is only 15 percent smaller than that of the Mississippi at the confluence. The Minnesota River drains intensively cultivated farmland that extends beyond the western border of the State, and discharge from the Minnesota has a very significant effect on the quality of water in the Mississippi River.

The median concentrations of indicator constituents gradually increase in the Mississippi River as each tributary enters from the west. For example, concentrations in the upper part of subbasin 6 are 20 to 136 percent larger than in subbasin 1 (table 62). The largest increase is in nitrite plus nitrate nitrogen, which increased from 0.14 to 0.33 mg/L.

The quality of water in subbasin 6 changes dramatically at the confluence of the Minnesota and Mississippi Rivers. Concentrations of indicator constituents in water from the Mississippi River increase from 43 to 358 percent from upper subbasin 6 to lower subbasin 6. These increases are attributed mainly to the inflow of water of lower quality from the Minnesota River. As mentioned earlier, constituent concentrations generally increase again below the

Table 62.--*Percent increase in median concentrations from subbasin 1 to upper subbasin 6 and from upper subbasin 6 to lower subbasin 6*

Constituent or property	Subbasin 1	Subbasin 6[a]	Subbasin 6[b]
Mile point at subbasin midpoint........	943	858	829
Miles between succeeding subbasins.....	---	85	29
[c]Dissolved solids, percent increase....	---	22	43
Sulfate, percent increase..............	---	70	187
Ammonia nitrogen, percent increase.....	---	20	358
Nitrite plus nitrate nitrogen, percent increase....................	---	136	185
Total phosphorus, percent increase.....	---	67	120
Dissolved chloride, percent increase...	---	88	181
Fecal coliform, percent increase.......	---	100	130

[a] Upper subbasin 6 (sites 6A-6E above the Minnesota River).

[b] Lower subbasin 6 (sites 6F-6M below the Minnesota River).

[c] Dissolved solids = specific conductance x 0.65.

metropolitan sewage-treatment plant. For example, the median concentration of ammonia nitrogen at site 6F -- the sampling site below the Minnesota River but above the treatment plant -- is 0.26 mg/L. Ammonia-nitrogen concentrations at sites below the treatment plant range from 0.70 to 0.90 mg/L.

Subbasin 7, drained by the Rum River, has the smallest percentage of cultivated land and has water-quality characteristics that are similar to those of subbasin 1. This similarity is a result of the similar geology and, more specifically, soil types (fig. 2). Unlike drainage from the western subbasins, drainage from subbasin 7 does not appear to increase constituent concentrations in the Mississippi River.

COMPARISON OF WATER QUALITY AT SITE 6K, MISSISSIPPI RIVER AT NININGER, AND UPSTREAM SUBBASINS

The third objective of this report is to assess the representativeness of data collected at site 6K, Mississippi River at Nininger, as it pertains to the quality of water in the study area. The data in table 60 indicate how the quality of water at site 6K represents that of the accounting unit as a whole.

Table 60 shows that water in each subbasin has its own unique quality. Water in subbasin 1 has the best quality in most respects. Streamflow at site 1A is about 45 percent of what it is at Nininger, which is one reason why the quality of water at Nininger does not represent the quality of water in most of the study area. Water in subbasin 7 is also good quality, second only to the water in subbasin 1. Water in the western subbasins, 2, 4, and 5, contain the highest concentrations of dissolved solids and chemical constituents commonly associated with row-crop farming. Water in the Mississippi River gradually worsens as it intercepts water from each of the western subbasins; this effect is shown in subbasins 3 and the upper part of subbasin 6 that is upstream from the Minnesota River. Downstream from the Minnesota River is the only part of the study area where the quality of water in the study area is represented by the data for Nininger.

From the discussions of each subbasin, three major water-quality regions can be identified in the study area. Subbasins 2, 4, and 5 could be considered as one region, subbasins 1, 3, 7, and upper 6 could be considered a second region, and the lower part of subbasin 6 could be considered the third region. By use of this scheme, it is apparent that the quality of water at site 6K does not represent water quality in a large part of the study area. Although the data at site 6K represent the total integration of the quality of water leaving the study area, the data do not represent the quality of water in most of the area.

Three sites would be needed in the study area to determine areal variations in water quality. Sites 4A, 7A, and 6K, which are the Crow River at Rockford, Rum River near St. Francis, and the present NASQAN site, Mississippi River at Nininger, respectively, would be appropriate sites. Sites 4A and 7A are continuous-record stream-gaging stations. Streamflow at site 6K is determined from site 6F, a continuous-record site.

Site 1A, Mississippi River near Royalton, needs to be retained as a NASQAN station. Although it is located within the study area, data collected at site 1A describe the quality of water in the accounting unit upstream from the study area.

Sampling frequencies for monitoring programs need to be based on a combination of hydrologic-event sampling and periodic sampling. A combination is important for obtaining as complete coverage as possible and so as to obtain the best hydrologic assessment of the accounting unit. Sampling throughout the range of streamflows in each month is important because a given quantity of streamflow does not necessarily carry the same concentrations of constituents in one month as it does in another month.

In determining periodicity, many things other than data also need to be considered, such as availability of personnel, laboratory capabilities, workload, and funding. A minimum of monthly sampling might be done at each of the suggested sites to adequately assess temporal and spatial water-quality changes in the study area over the long term.

SUMMARY AND CONCLUSIONS

The study area includes seven subbasins in east-central Minnesota that cover an area of 8,500 mi^2. Data from the MPCA, MWCC, and U.S. Geological Survey, indicate that selected water-quality characteristics differ significantly between subbasins, mainly because of differences in land use. Analysis of the data also indicate that the quality of water leaving the study area at Hastings is affected primarily by inflow from the Minnesota River and effluent from the Metropolitan sewage-treatment plant.

Subbasins 2, 4, and 5 in the western part of the study area, are underlain by fertile prairie soils and have the largest percentage of cultivation. Streams draining these subbasins have relatively large dissolved-solids and nutrient concentrations. The largest concentration of dissolved solids in streams are found in subbasin 5 where point-sources may add to the existing concentrations. For example, potassium concentration was equal to or greater than 10 mg/L in 11 different samples. A sample collected in 1976 at site 5A had the largest potassium concentration, 170 mg/L. Two areas in subbasin 5 where point sources of constituents appear to exist are Buffalo Creek near Plato and South Fork Crow River at or upstream of Biscay.

Streams in subbasins 1, 3, 7, and the part of subbasin 6 upstream from the confluence with the Minnesota River have the smallest concentrations of dissolved constituents. The concentration of most constituents in the Mississippi River increases downstream as a result of tributary inflow from the west. The greatest water-quality change in the Mississippi River occurs in the Twin Cities area below the confluence with the Minnesota River. There is further deterioration in the quality of water downstream from the Metropolitan sewage-treatment plant.

Trends over time show that concentrations of chloride, and usually sodium, are increasing in all seven subbasins. Road salt applied in winter may be a major cause of this increase. Chloride in streamflow in subbasin 7, however, reached a maximum during the 1976-77 drought, which occurred near the end of the sampling period. Chloride concentrations have virtually returned to predrought levels since then.

Ammonia nitrogen generally reaches its maximum yearly concentration in winter during ice cover. Sewage effluent probably is the cause of increases in ammonia nitrogen concentrations concurrent with increases in fecal-coliform bacteria and decreases in dissolved oxygen.

The quality of water in subbasin 6 changes dramatically at the confluence of the Minnesota and Mississippi Rivers. Most chemical concentrations increase by a large percentage below the mouth of the Minnesota River as a result of the inflow of water from the Minnesota River. Chemical concentrations also increase as a result of the discharge of effluent from the Metropolitan sewage-treatment plant. The median ammonia-nitrogen concentration at site 6F, which is upstream from the Metropolitan sewage-treatment plant, is 0.26 mg/L; at sites downstream from the plant, median concentrations ranged from 0.70 mg/L to 0.90 mg/L.

The data show that the quality of water in the Mississippi River as it leaves the study area at Hastings is not representative of the quality in most of the study area. Three water-quality regions have been identified, and sampling sites are needed in each region to assess adequately the quality of water in streams throughout the study area.

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