

Water-Quality Parameters and Benthic Algal Communities at Selected Streams in Minnesota, August 2000—Study Design, Methods, and Data

By K.E. Lee

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CONVERSION FACTORS AND ABBREVIATIONS

<u>Multiply metric unit</u>	<u>By</u>	<u>To obtain inch-pound unit</u>
inches (in.)	2.54	centimeters
square mile (mi ²)	2.590	square kilometer
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second
degrees Fahrenheit (°F)	(Temp. °F - 32) / 1.8	degrees Celsius (°C)

Concentrations are given milligrams per milliliter (mg/L). A milligram is one thousandth of a gram. Electrical conductivity is measured as specific electrical conductance in units of microsiemens per centimeter (μS/cm) at 25 degrees Celsius.

Water-Quality Parameters and Benthic Algal Communities at Selected Streams in Minnesota, August 2000—Study Design, Methods, and Data

By Kathy E. Lee

ABSTRACT

Water-quality measurements and benthic algal samples were measured or collected from select Minnesota streams as part of a multiagency (Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, U.S. Environmental Protection Agency, and U.S. Geological Survey) study. The goal of the multiagency study was to identify quantifiable thresholds of water-quality impairment and establish quantifiable indicators of nutrient enrichment for medium to high-order streams.

This report describes the study design, sampling methods, and summarizes the physical, chemical, and benthic algal data for a component of the multiagency study that was designed to document diurnal water-quality measurements (specific conductance, pH, water temperature, and dissolved oxygen), benthic algal community

composition and chlorophyll-*a* content, and primary productivity at 12 stream sites on 6 streams in Minnesota during August 2000. Specific conductance, pH, water temperature, dissolved oxygen concentrations and percent dissolved oxygen saturation measurements were made with submersible data recorders at 30 minute intervals for a period of 3–6 days during August 2000. Benthic algae collected from wood and rock substrate were identified and enumerated. Biovolume (volume of algal cells per unit area), density (number of cells per unit area), and chlorophyll-*a* content from benthic algae were determined. These data can be used as part of the multiagency study to develop an understanding of the relations among nutrient concentrations, algal abundance, algal community composition, and primary production and respiration processes in rivers of differing ecoregions in Minnesota.

INTRODUCTION

The presence of contaminants, and physical or chemical degradation affects 36 percent of surveyed river miles in the United States (U.S. Environmental Protection Agency, 1998). Historically, water-resource management efforts focused on point sources of contaminants such as industrial and wastewater treatment discharges. The focus has shifted more recently to the influence of nonpoint source runoff on water quality (Boyd, 2000). Nonpoint source contaminants such as nutrients (nitrogen and phosphorus) enter streams through runoff from the land surface during snow-melt, spring and summer precipitation, from ground-water discharge, or from tile drains and storm sewers (Osborne and Wiley, 1988; Wiley and others, 1990).

Nutrients are essential for animal and plant growth; however, elevated nutrient concentrations are potentially toxic to humans and wildlife and can stimulate excessive algal and plant growth (Wetzel, 1983).

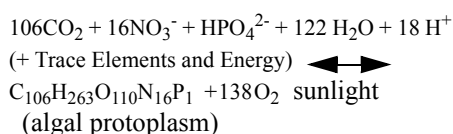
The U.S. Environmental Protection Agency (USEPA) total maximum daily load (TMDL) rules are part of the Clean Water Act section 303(d) requiring each state to identify streams that are not in compliance with multiple water quality standards including nutrient concentrations (U.S. Environmental Protection Agency, 1998). Both abiotic and biotic factors and interactions between them influence nutrient concentrations, and a greater understanding of these factors and interactions is

necessary to develop locally-relevant TMDLs.

Abiotic factors influencing water chemistry include climate, geology, land use and land cover, soil type, topography, and hydrologic characteristics. Biotic factors including instream plant and animal metabolism also influence water chemistry. The most influential biotic factor affecting nutrient concentrations and other constituents in streams is algal community uptake and metabolism (Stumm and Morgan, 1996). Algal communities in streams are comprised of phytoplankton (algae entrained in water column) and benthic algae that reside on submerged substrates including woody debris (epidendric), rock (epilithic), and macrophytes (epiphytic). Benthic algae include

attached forms and phytoplankton that have settled onto the bottom of streams in quiescent areas.

Benthic algal photosynthesis and respiration processes influence nutrient flux (Newbold and others, 1982; Stumm and Morgan, 1996) and other water-quality parameters such as specific conductance, pH, dissolved oxygen and carbon dioxide. During photosynthesis, algae utilize energy from sunlight, take in nutrients and carbon to produce carbohydrates (needed in algal cell growth), and produce oxygen as characterized by this stoichiometry (Stumm and Morgan, 1996):



Changes in pH, dissolved oxygen, and nutrient concentrations occur during this process. Dissolved oxygen and pH concentrations increase, and dissolved nutrient concentrations decrease as algae increase photosynthetic activity during the day. The uptake of carbon dioxide during daylight accompanied by the uptake of nitrate (NO_3^-) or phosphate (HPO_4^-) and H^+ ions results in a pH increase due to the remaining OH^- ions. Dissolved oxygen and pH decrease during the night as photosynthesis ceases and aquatic animals continue to consume oxygen and respire. The reduced dissolved oxygen concentrations and pH at night are also augmented by microbial bacterial decomposition of biota to NO_3^- . Biological oxygen demand (BOD) is a measurement of the amount of oxygen required to stabilize the demands for oxygen during the microbial decomposition of organic matter (Reid and Wood, 1976).

In addition to their roles in chemical modulation, algae provide a source of oxygen and carbon for primary and secondary consumers such as aquatic macroinvertebrates and

fish. Primary productivity (the rate of formation of organic material over some time period) is an indicator of the health of a stream (Wetzel, 1983) because oxygen and carbon sources form the base of the food chain in aquatic systems. Benthic algae are important primary producers in streams (Stevenson and others, 1996) and may be the primary source in mid-size streams (Vanote and others, 1980).

Establishment of water-quality standards for nutrients has not historically been based on the complex interactions of abiotic and biotic factors. The information generated in this and concurrent studies will provide an opportunity to develop statistical relations between chemical factors (nutrient concentrations) and biological factors (primary production processes or algal community composition) that can be used by managers in stream-water-quality-criteria development.

Purpose and Scope

The report describes the study design, methods, and provides selected water-quality parameters and benthic algal data for 12 sites located on six Minnesota streams sampled during August 2000. The purposes of the study were to document specific conductance, pH, water temperature, dissolved oxygen (DO), benthic algal abundance, community composition, and chlorophyll-*a* content, and to provide estimates of net primary productivity and respiration at each site. This study is one component of a multiagency (Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, U.S. Environmental Protection Agency, and U.S. Geological Survey) study designed to develop an understanding of the relations among nutrient concentrations, algal abundance, algal composition, and primary production and respiration processes in rivers of differing ecoregions in Minnesota. Ecoregions

were used as the major spatial strata because they are areas with common ecological settings that have relatively homogenous features including climate, geology, land use and land cover, soil type, and physiography (Fandrei and others, 1988; Omernik and Gallant, 1988). The goal of the multiagency study is to identify quantifiable thresholds of water-quality impairment and establish quantifiable indicators of nutrient enrichment for medium to high-order streams.

STUDY DESIGN AND METHODS

Site selection criteria included drainage area, ecoregion type, and presence of a streamflow gaging station. The 12 sites on six rivers selected for this study had drainage areas greater than 1,000 mi^2 . These sites were located within four different ecoregions at or near U.S. Geological Survey (USGS) or other streamflow gaging stations (fig. 1, table 1, at the back of the report). Rivers that were representative of each ecoregion were selected. Two sites were sampled on each river to allow upstream and downstream comparisons of nutrient flux in a concurrent study. Each site has a designated site identifier. The site identifier is comprised of two or three letters corresponding to the river name followed by numbers that correspond to the river mile near the site location. For example, the Crow Wing River near Nimrod, Minnesota (CWR-72.3) is located 72.3 miles upstream of the confluence of the Crow Wing and the Mississippi Rivers.

August was selected as the time frame for this study because the objective was to determine water quality and algal characteristics during low to medium flow and to minimize the likelihood of runoff. Precipitation generally is less frequent during late summer and rainfall events usually produce less runoff, because

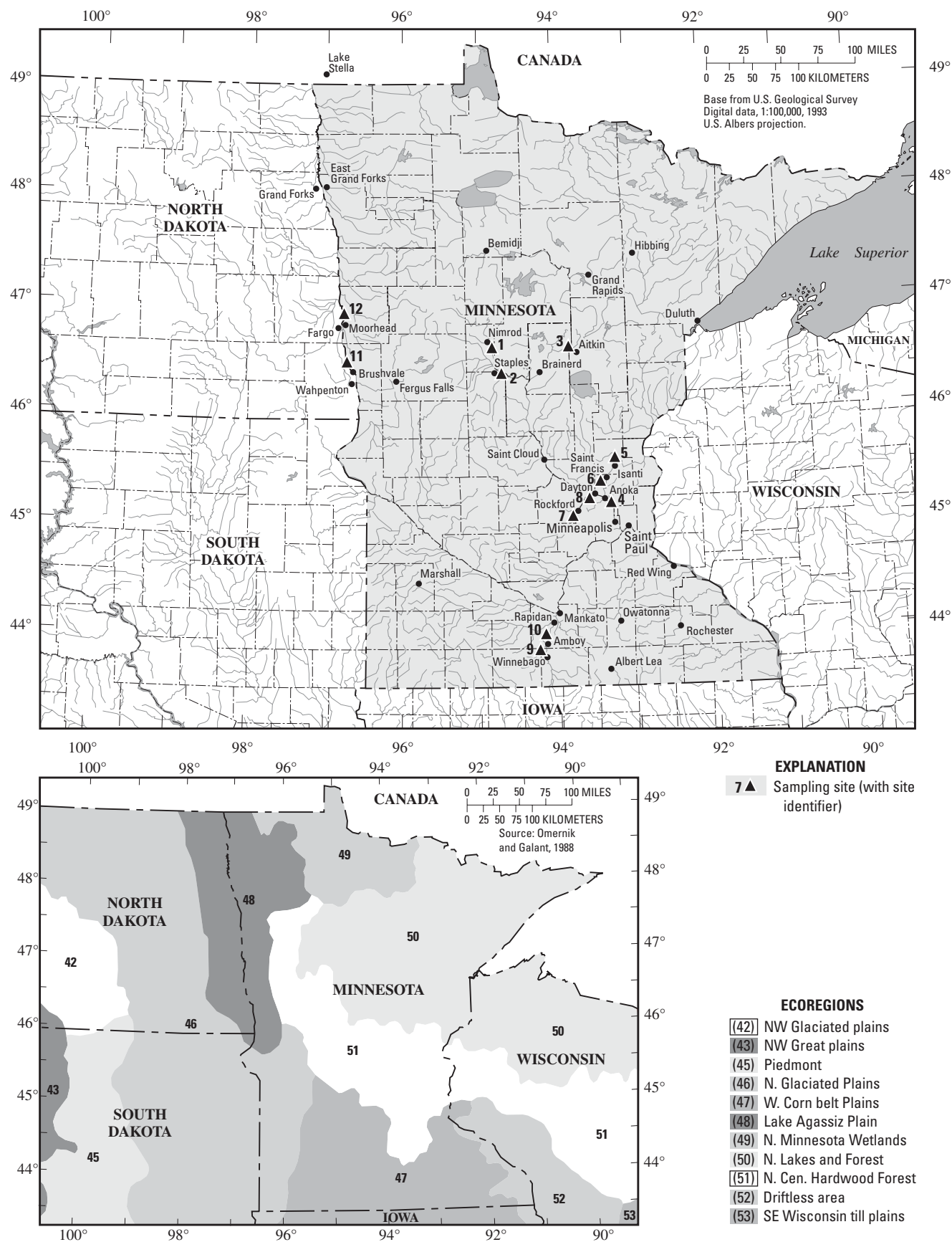


Figure 1. The location of sampling sites where diurnal water-quality measurements and benthic algae samples were collected during August 2000, and ecoregions in the study area.

of reduced soil-moisture and extensive vegetative cover on cropland areas. In an extensive study area, such as Minnesota, the amount of time required to adequately sample selected streams increases the probability that streamflow will be unsteady in some streams because of precipitation-induced runoff.

Precipitation Data

Daily precipitation data were obtained to provide an environmental context for diurnal water-quality measurements and benthic algal data. Daily precipitation amounts for August 2000 were obtained from the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>). Daily rainfall data were obtained for the weather station closest to the stream sampling site.

Hydrologic Data

Daily-mean streamflow (the mean discharge for a particular day) for June through August 2000 was obtained for USGS stream gages that were located near sampling sites (table 1). The daily-mean streamflow provides information about near-term conditions that may influence physical, chemical and biological characteristics. The long term mean-daily streamflow (mean for a particular day over the period of record) was also computed for each site and provides a benchmark to determine if streamflows during the study period were generally higher or lower than average conditions. These hydrologic data were obtained from the USGS National Water Information System's Automated Data Processing System.

Diurnal Water-Quality Measurements

Measurements of specific conductance, pH, water temperature, and DO were recorded at 30 minute inter-

vals over a period of 3-6 days using submersible data recorders (Hydrolab Data Sonde units). The probes were positioned in the euphotic zone in an area of streamflow of at least 1 ft³/s. The probes were calibrated according to manufacturers specifications before installation at a site and following retrieval. New batteries and DO sensor membranes were installed prior to each deployment.

Stream Productivity and Respiration Estimates

Stream productivity and respiration were estimated using DO concentrations over diurnal periods (table 2, at the back of the report). Chlorophyll-*a* content in benthic algae was also measured as an alternate measure of primary production. Net productivity and respiration estimates were quantified according to Sorrenson and others (1999). Briefly, productivity estimates were determined by calculating the slope of the DO concentrations between 10 am and 3 pm. This time period was used because the rapid rates of change in DO were linear. The estimates define the net rate of oxygen accrual in milligrams of oxygen per Liter per hour (mg O₂/L/hr), which is equivalent to grams of O₂ per cubic meter per hour (g O₂/m³/hr). Net community respiration was quantified by calculating the slope of the DO concentrations between midnight and 6 a.m. Estimates of productivity and respiration do not account for rates of oxygen diffusion that are a function of water temperature and the difference in oxygen saturation between water and air (Odum, 1956).

Benthic Algae Collection and Identification

Benthic algae were collected from each site during the period of diurnal water-quality measurements. Site conditions were characterized at the time

of benthic algae sample collection (table 2). Benthic algae were collected from both wood (epidendric) and rock (epilithic) substrate at each site and processed separately. Benthic algae samples were collected in accordance with the USGS National Water Quality-Assessment Program (NAWQA) algal sampling protocols (Porter and others, 1993).

Epidendric samples were collected from submerged woody debris that was in the euphotic zone of the stream. Epidendric samples were collected from 10 locations in each stream reach. Snags were gently removed from the water to minimize disturbance of the algal community; a 3–4 inch cylindrical section was cut from each snag with lopping shears; and the snag sections were retained in a plastic bag prior to processing. After algae were removed from the snag sections, the length and diameter of each section was measured, and the surface area of each snag segment was calculated.

Epilithic samples were collected from submerged rocks located in the euphotic zone. Approximately 10 different rocks, which were carefully removed and placed in a container with benthic algal growth facing up. After algae were removed from each rock a foil template was created to cover the section of the rock covered with algae. This foil template was retained and measured to determine surface area.

Samples were processed similarly as described below. Algae were removed from each snag section or rock using a stiff-bristled brush and de-ionized water from a rinse bottle. The algal suspension from each sample (epilithic and epidendric samples were processed separately) was washed into a small, plastic processing pan. Samples were processed until about 50 to 100 mL of water had accumulated in the processing pan. The combined algal-water suspension

was homogenized for approximately 30 seconds. The homogenate was split into subsamples for determinations of chlorophyll-*a* (5mL), and identification (60 mL). The homogenate from one sample (Mississippi River near Anoka, Minnesota) was split into three portions to determine variability in algal samples.

Chlorophyll-*a* samples were filtered through a 0.47 mm glass fiber filter with 5 pounds of pressure per square inch. The filter was placed in foil inside of a petri dish and placed on dry ice prior to analysis at the Minnesota Department of Health Laboratory. Taxonomic samples were placed in a glass bottle with 1 percent glutaraldehyde as a preservative and kept in a refrigerated low light environment prior to shipment to Phycotech in St. Joseph, Michigan for analyses. Identification of algal taxa were accomplished by Phycotech personnel using methods modified from Crumpton (1987). HPMa (2-hydroxypropyl methacrylate) was used in sample mounting which provides an optically clear background while permanently infiltrating and preserving the sample for archival purposes.

HYDROLOGIC CHARACTERIZATION

The hydrologic conditions during June and July 2000 prior to sampling were characterized by variable stream discharge in response to storm events. Daily-mean stream discharges during June and July 2000 were characterized by one or more storm events of varying magnitudes (fig.2).

Hydrologic conditions during the August sampling period were stable and streamflows were below the long-term mean flows at most sites except at the Red River of the North sampling locations where the flow was low and stable, but was greater than the long-term mean streamflow. Precipitation events of approximately 0.5 inches occurred during sampling col-

lection periods at the following sites: Crow Wing River near Nimrod and Staples (CWR-72.3 and 35.5, respectively); Mississippi River near Aitkin (UM-872); Crow River at Rockford (CR-23); Blue Earth River near Winnebago and Amboy (BE-73.2 and 54, respectively); and Red River near Brushvale and Moorhead (RED-536 and 452, respectively).

PARAMETERS WATER QUALITY

Table 3, at the back of the report, shows summary statistics for diurnal measurements of specific conductance, pH, water temperature, dissolved oxygen and percent oxygen saturation at each site. Figures 3-14 show specific conductance, pH, water temperature and dissolved oxygen for each site. The y-axis scale for a selected constituent may not be similar in figures 3-14 due to differences in data magnitude which would obscure the patterns of the water-quality parameters within each site.

In general, dissolved oxygen concentrations, dissolved oxygen percent saturation, pH and temperature values increased, and specific conductance values decreased during daylight hours. These trends were reversed during nighttime period. Dissolved oxygen concentrations went below the state standard of 5.0 mg/L at the Mississippi River at Anoka (fig. 6).

The pH values for the Crow Wing River near Staples (fig. 4) is missing due to probe malfunction. Specific conductance at the Red River near Brushvale (fig. 13) is problematic due to the non-gradual change in specific conductance after the rain storm on August 16th. An independent measure of the specific conductance on August 15th was similar to that recorded by the submersible data sonde and the post deployment-calibration check of the sonde was

acceptable. It is not possible to determine if the abrupt change in specific conductance was a result of runoff from precipitation or probe malfunction.

Primary Production and Respiration

Net community primary production and respiration estimates are shown in table 4, at the back of the report. Potential factors influencing rates of primary production and respiration include the density of benthic algae, aquatic macrophytes, abundance of phytoplankton, solar intensity/cloud cover, precipitation, water temperature, hydrologic characteristics, the density of aquatic insects that graze on algae, microbial community composition, and density of aquatic organisms utilizing dissolved oxygen. Net community primary production varied from 0.03 to 1.10 g/O₂/m³/hr among all streams. Net community respiration estimates varied from 0 to 1.09 g/O₂/m³/hr. Chlorophyll-*a* content varied from 2.1 to 150 mg/m² among all samples (table 5, at the back of the report). Net community primary production and respiration rates and chlorophyll-*a* contents observed for streams in this study were similar to those observed for 72 agricultural streams in the upper mid-west (Sorenson and others, 1999).

Benthic Algae

Community composition is represented by both biovolume (volume of algal cells per unit area) and density (number of cells per unit area) of taxa. Biovolume is closely linked with observed thickness of algae on a substrate. Biovolume provides an estimate of biomass and represents taxa shifts well when the size of algae are variable (Stevenson and others, 1996). Density estimates generally have less variability than biovolume, but taxa shifts may be obscured when cell sizes are variable. Table 6, at the back

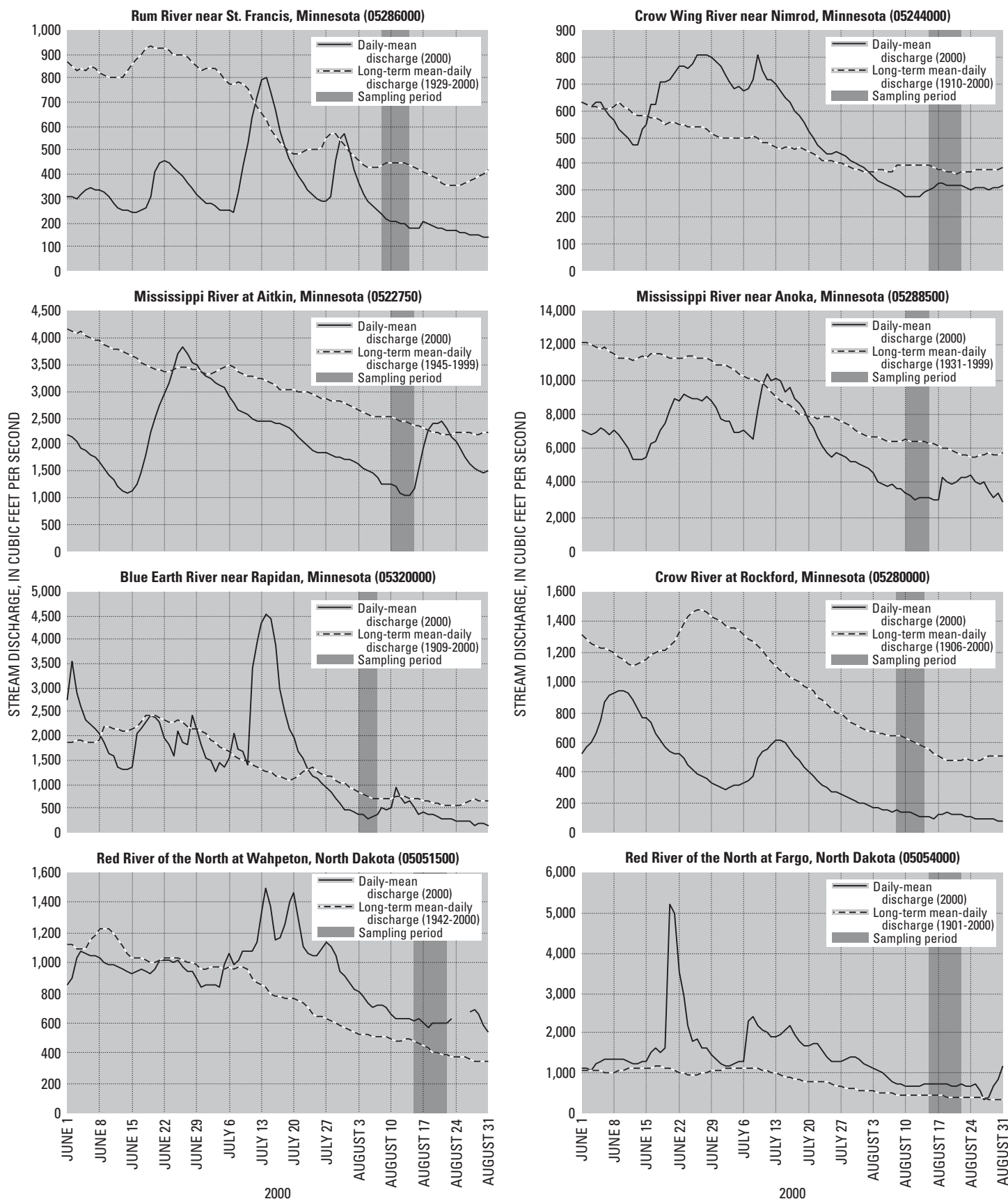


Figure 2. Daily-mean stream discharge during 2000, and long-term mean-daily stream discharge during June, July, and August at U.S. Geological Survey gaging stations near sampling sites. USGS stream gaging station names and numbers are shown on each figure. (See Table 2 for information that corresponds USGS gaging station to sampling site.)

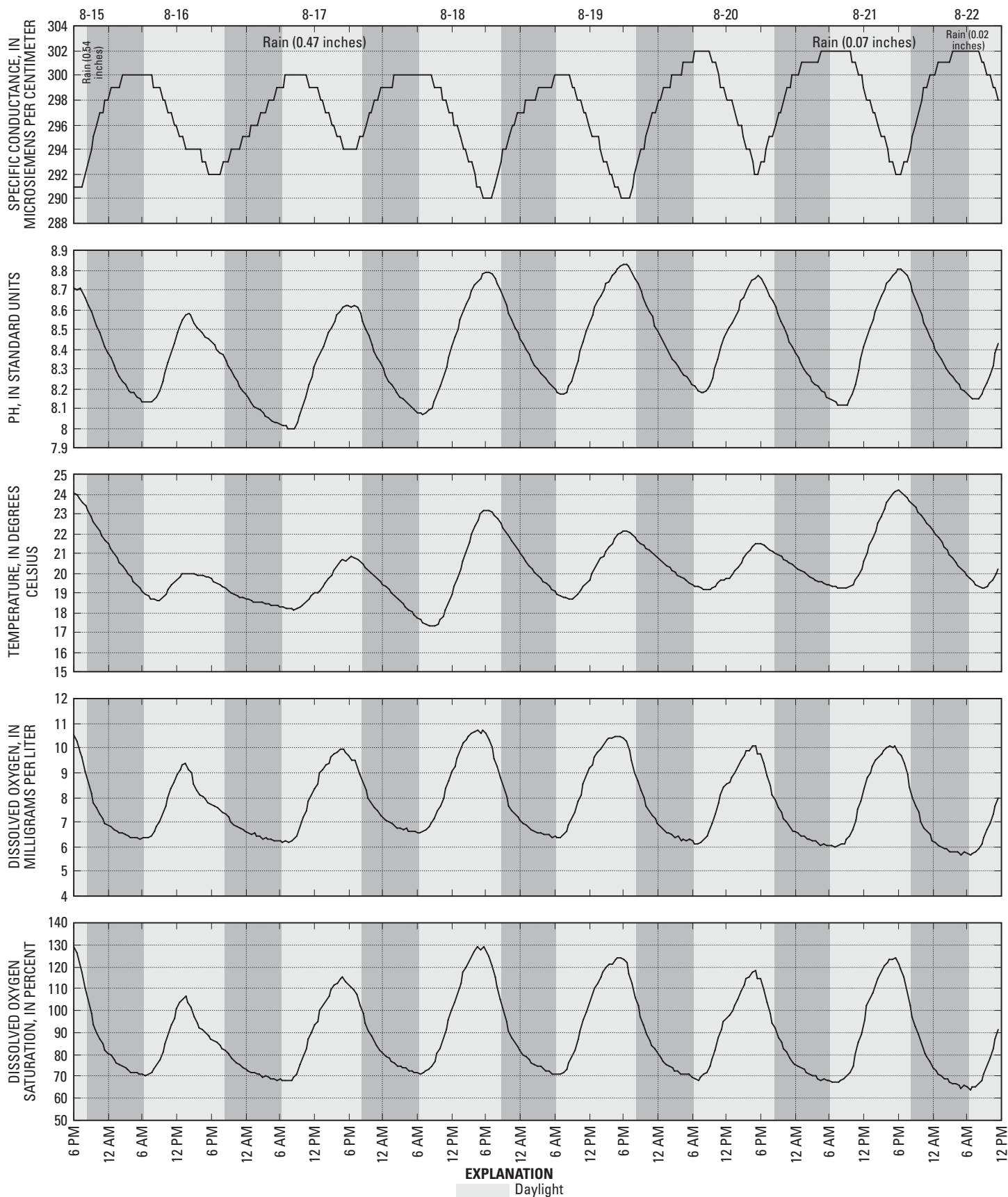


Figure 3. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow Wing River near Nimrod, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 15-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>).)

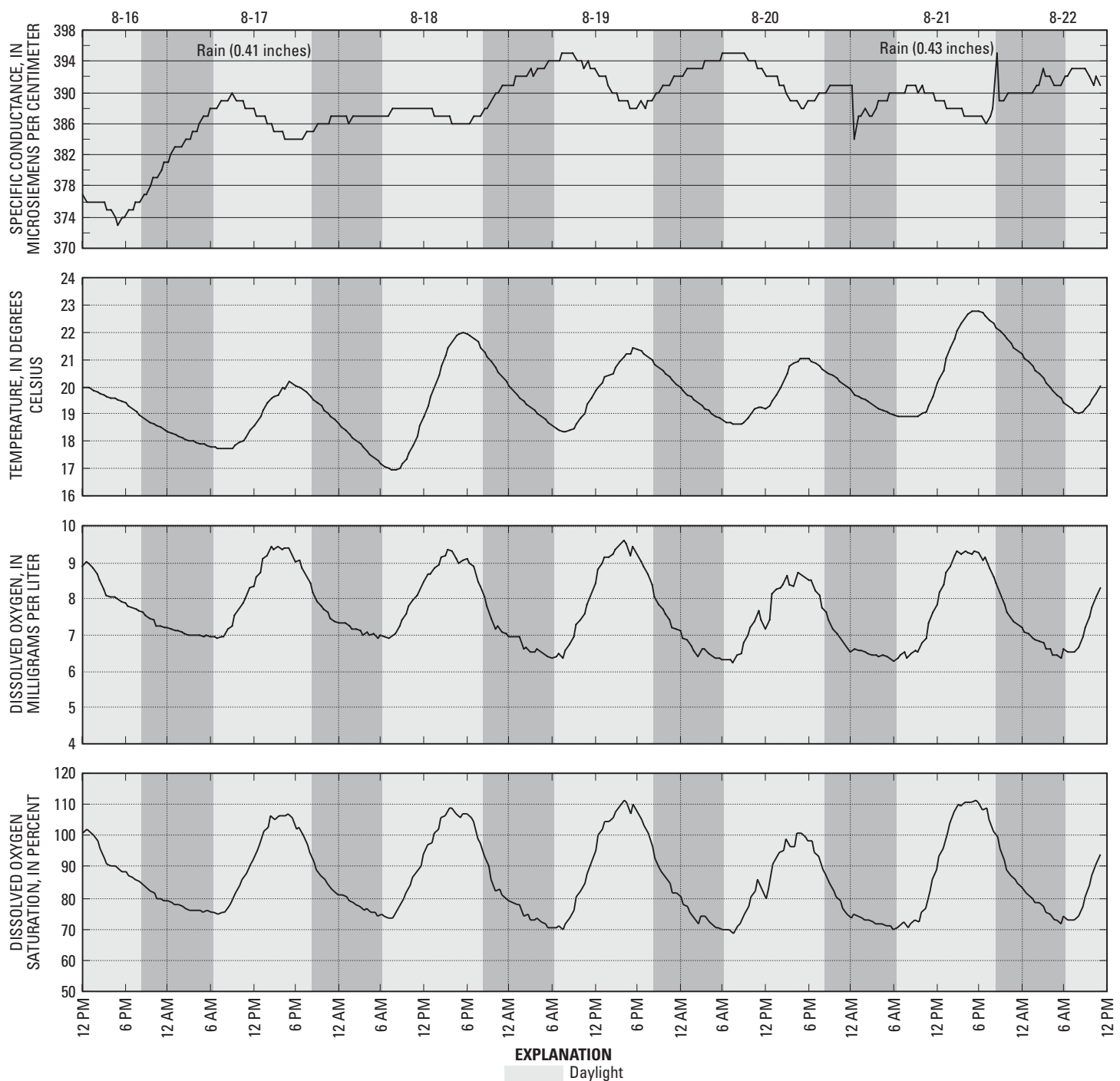


Figure 4. Specific conductance, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow Wing River near Staples, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 16-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>). pH values are missing due to equipment malfunction.)

of the report, shows the total biovolume and density for each site. Tables 7-10, at the back of the report, show the relative biovolume and density of

benthic algae on rock and wood substrates. There were five major divisions and 154 algal taxa found among all sites. The composition of the com-

munity varied between substrate types and among all sites. Biovolume and density varied among sites as well as the number and types of taxa.

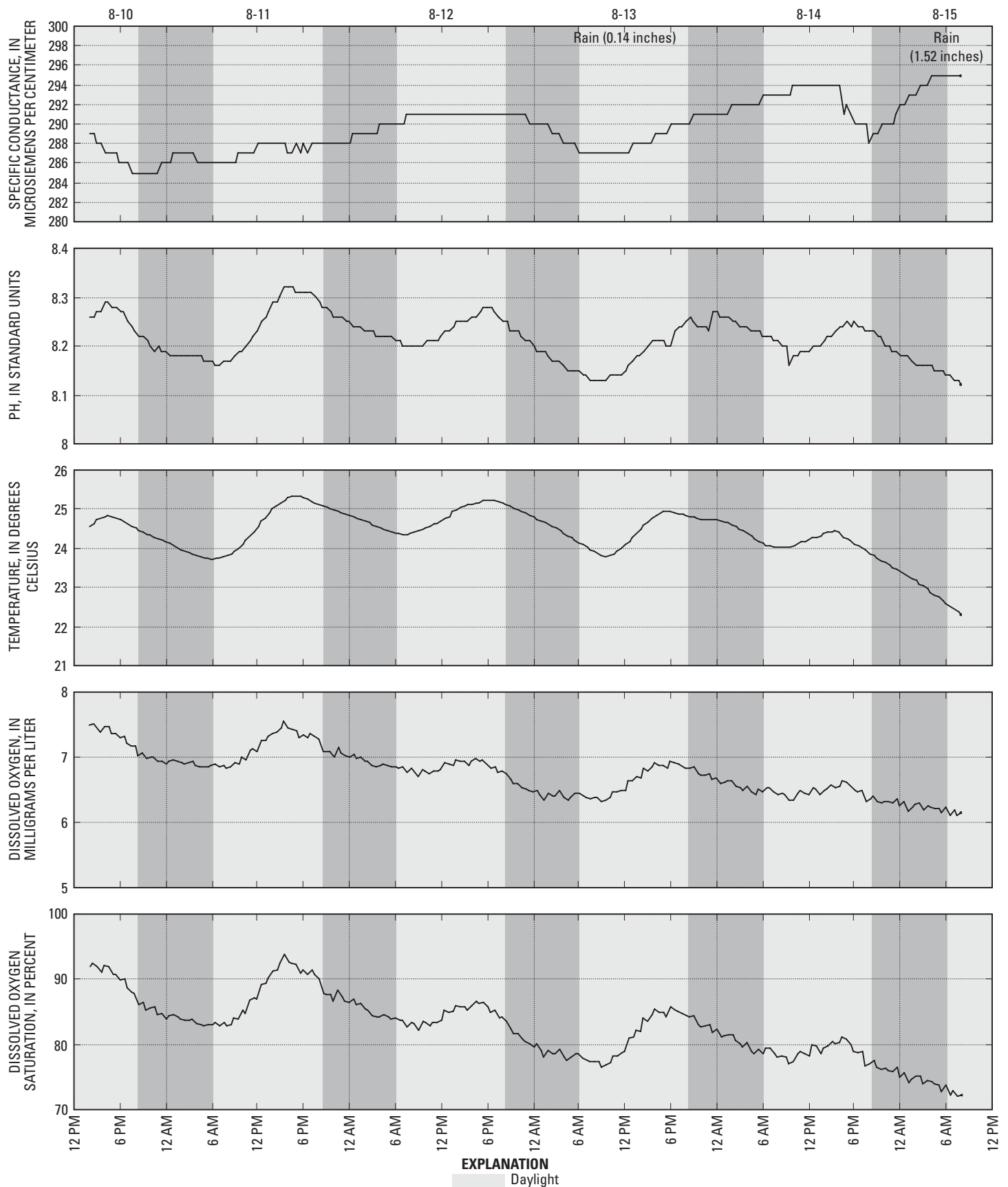


Figure 5. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Mississippi River near Aitkin, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 10-15, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu/>.)

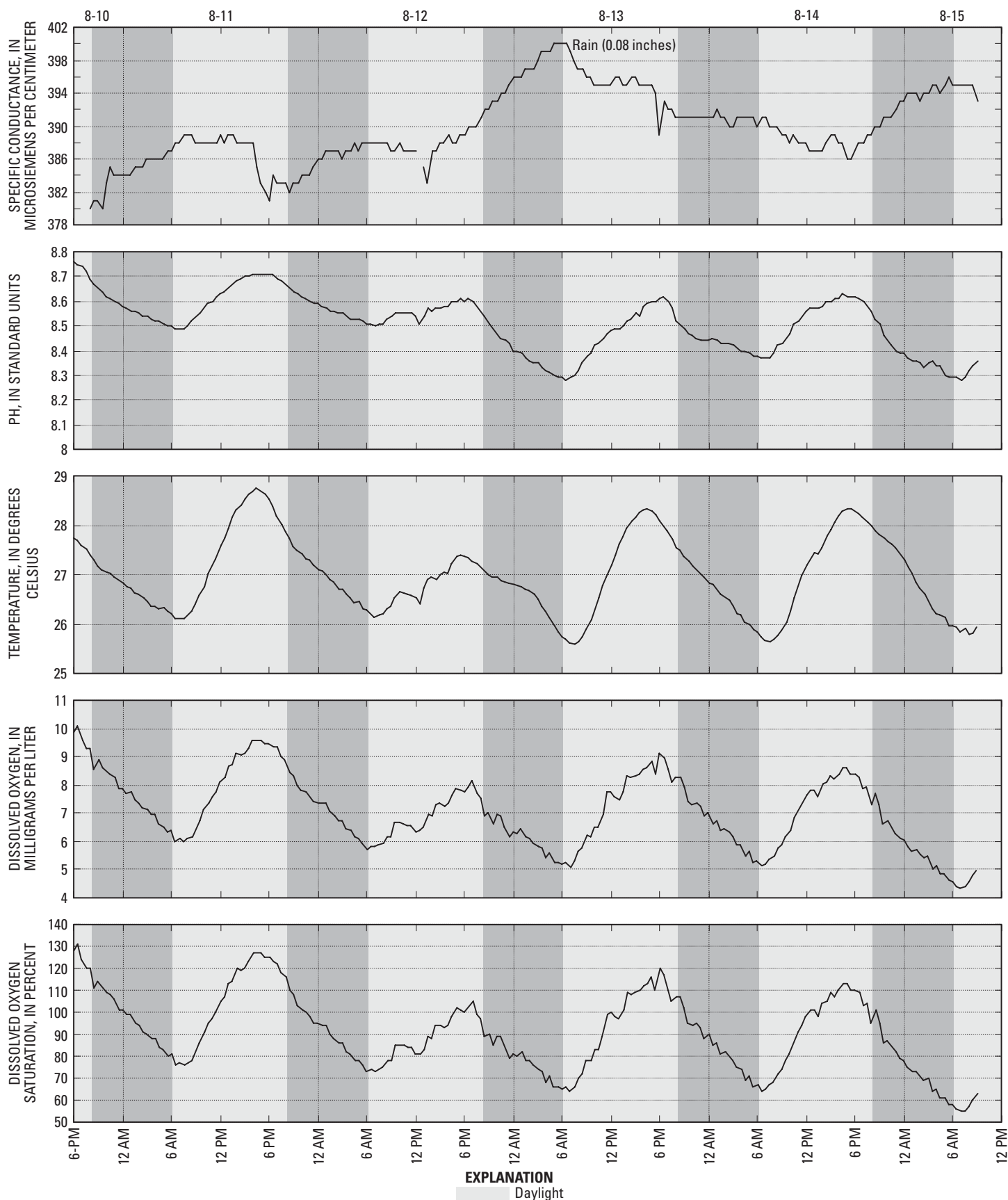


Figure 6. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Mississippi River near Anoka, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 10-15, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu/>).)

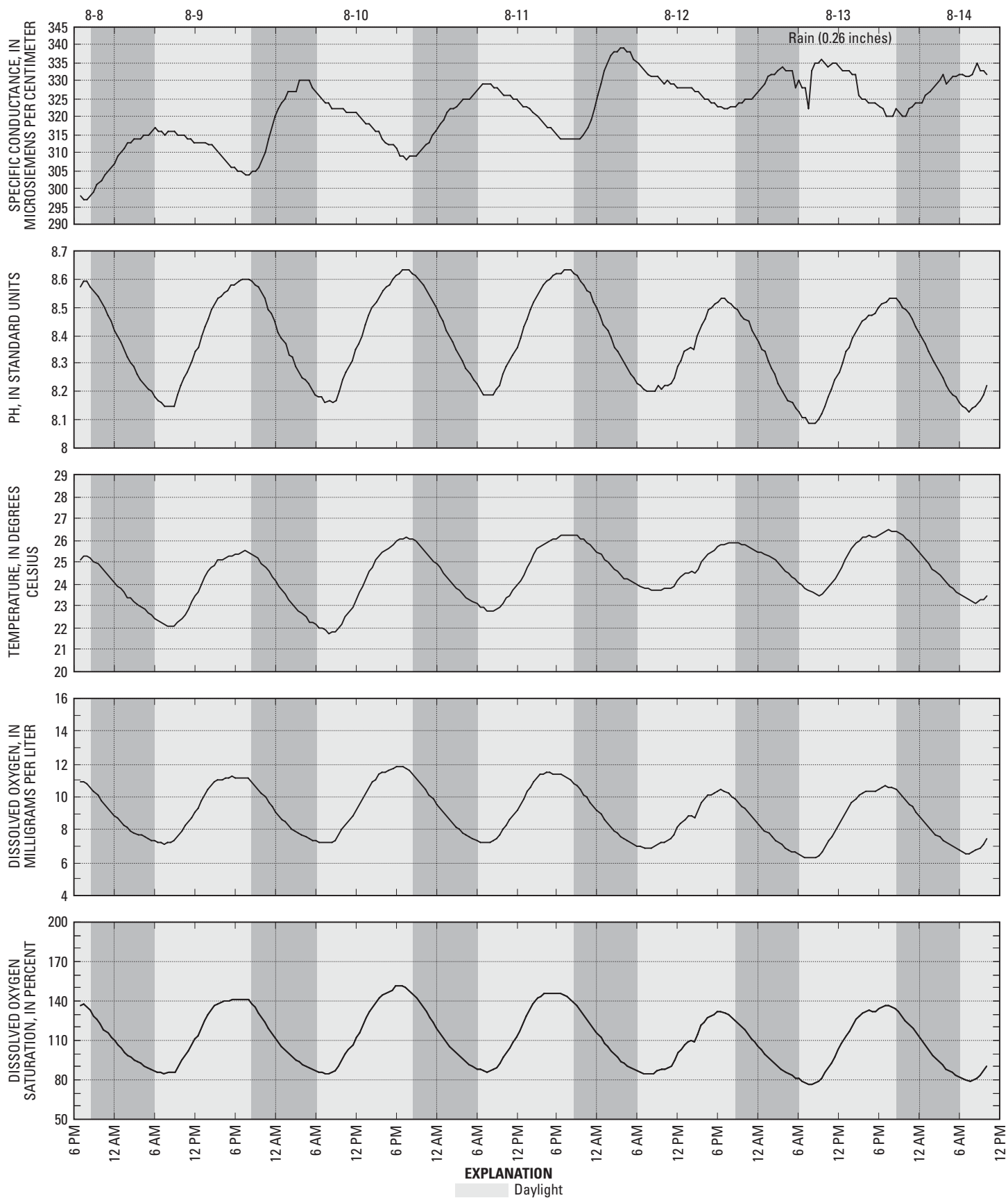


Figure 7. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Rum River near Isanti, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 8-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>).)

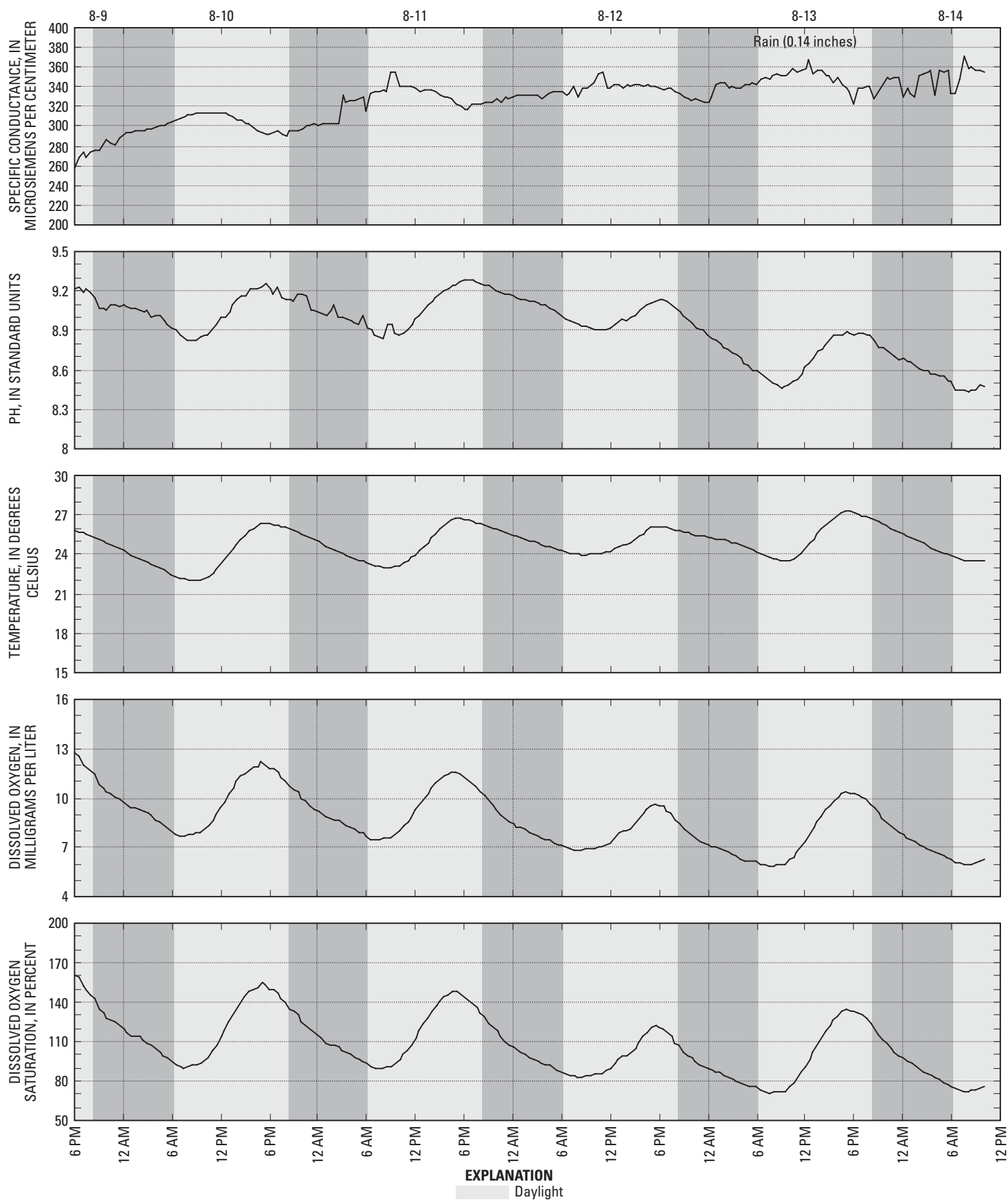


Figure 8. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Rum River near St. Francis, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 9-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>.)

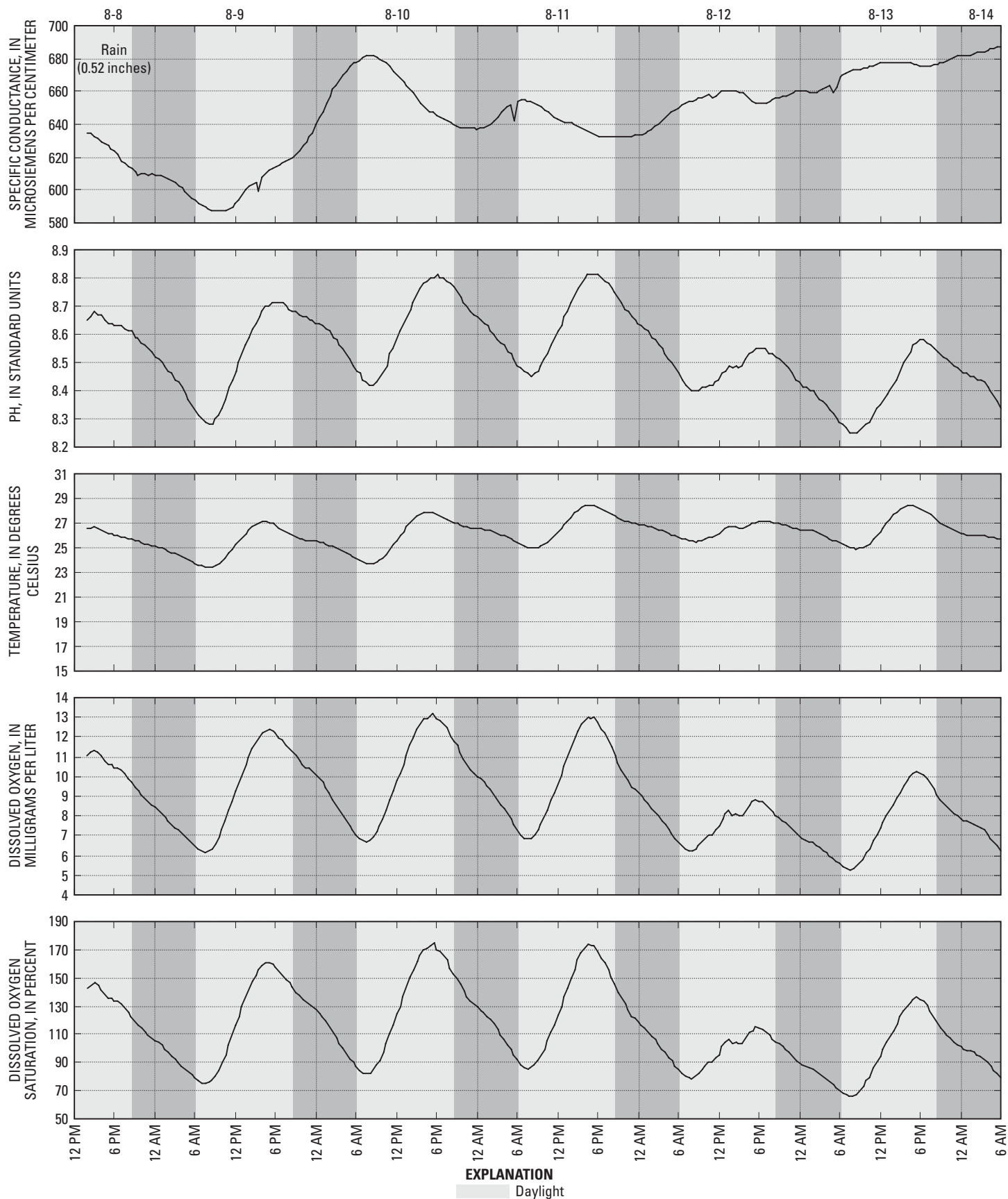


Figure 9. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow River near Rockford, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 8-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu/>.)

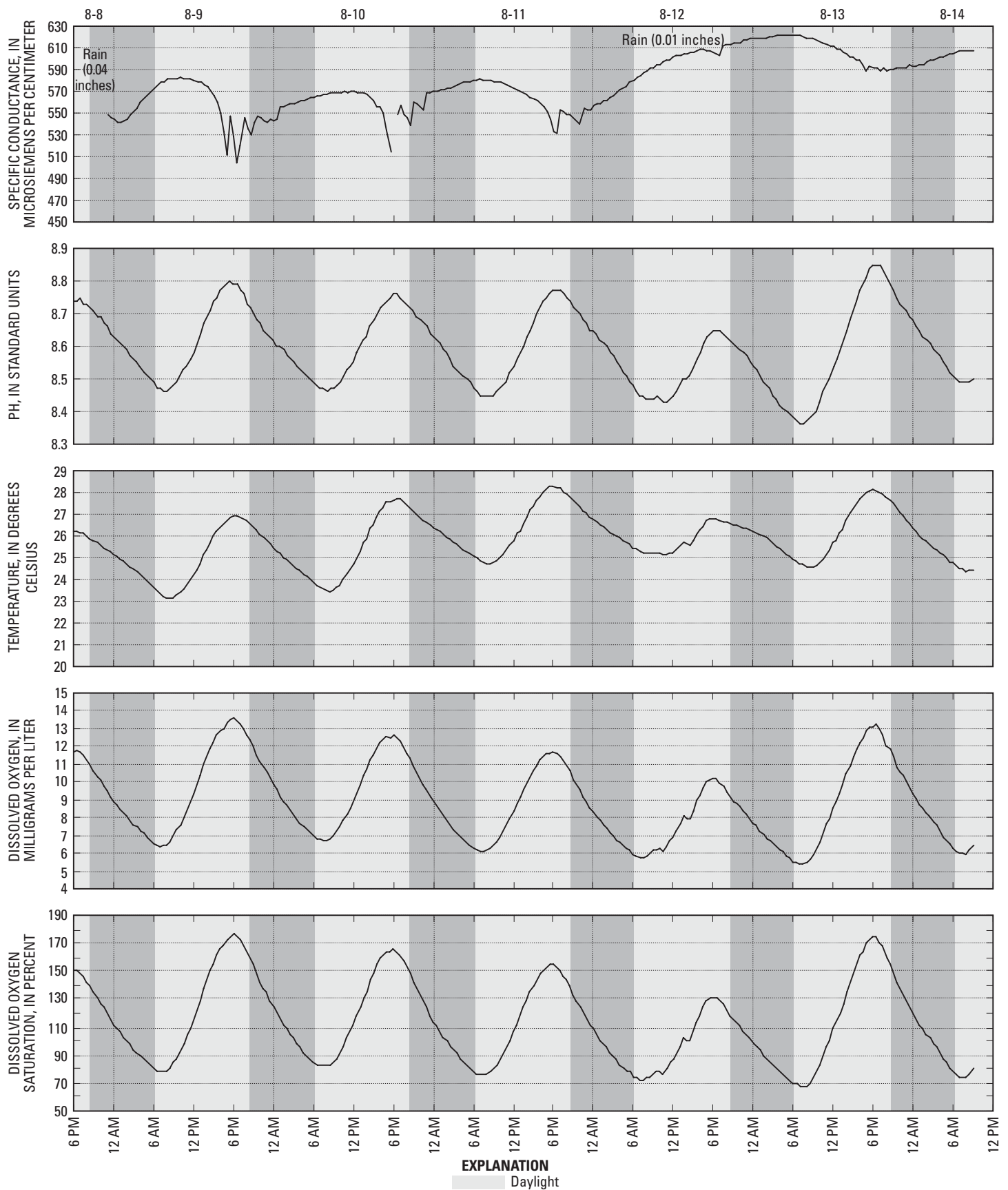


Figure 10. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow River near Dayton, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 8-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>.)

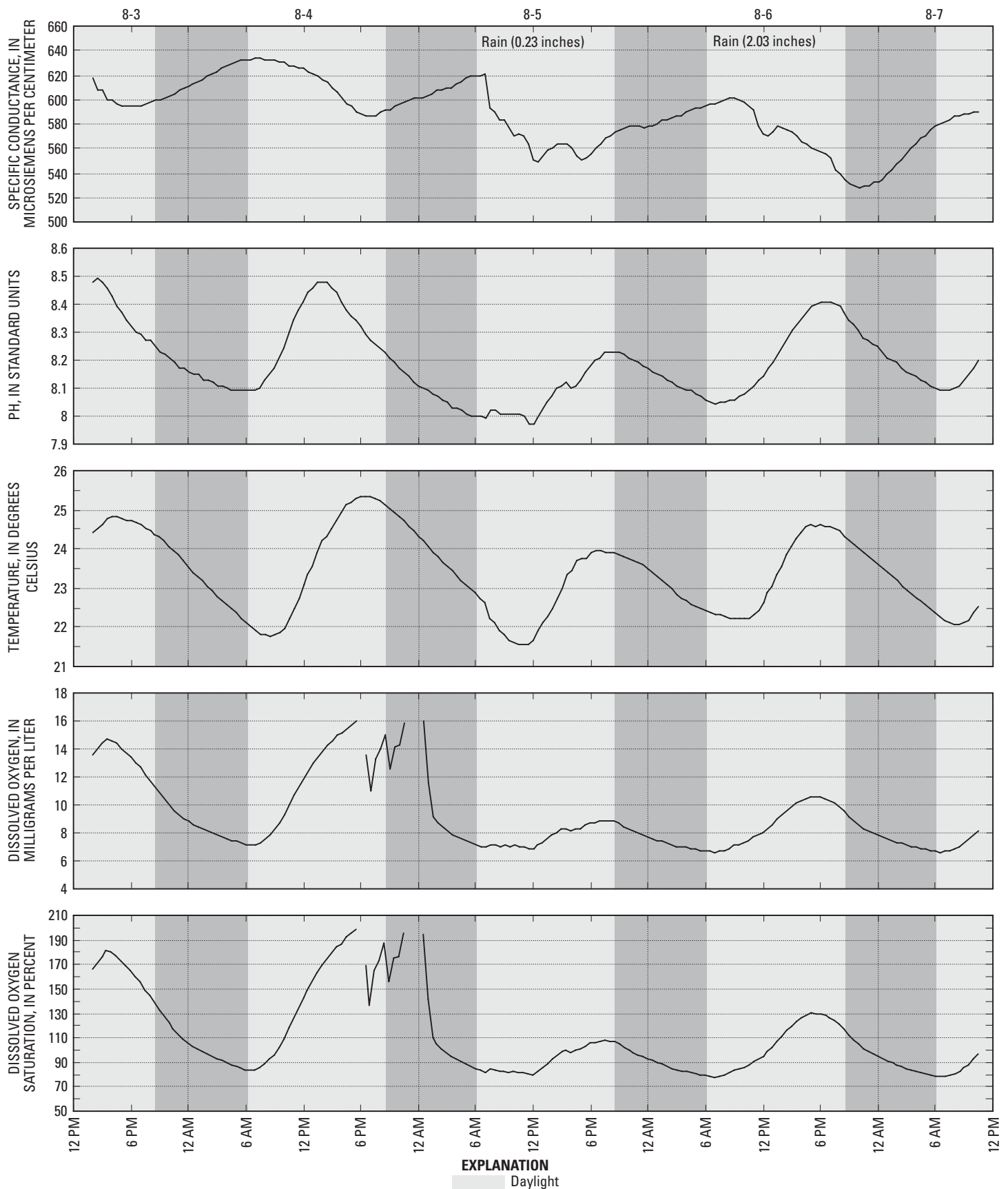


Figure 11. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Blue Earth River near Winnebago, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 3-7, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>).)

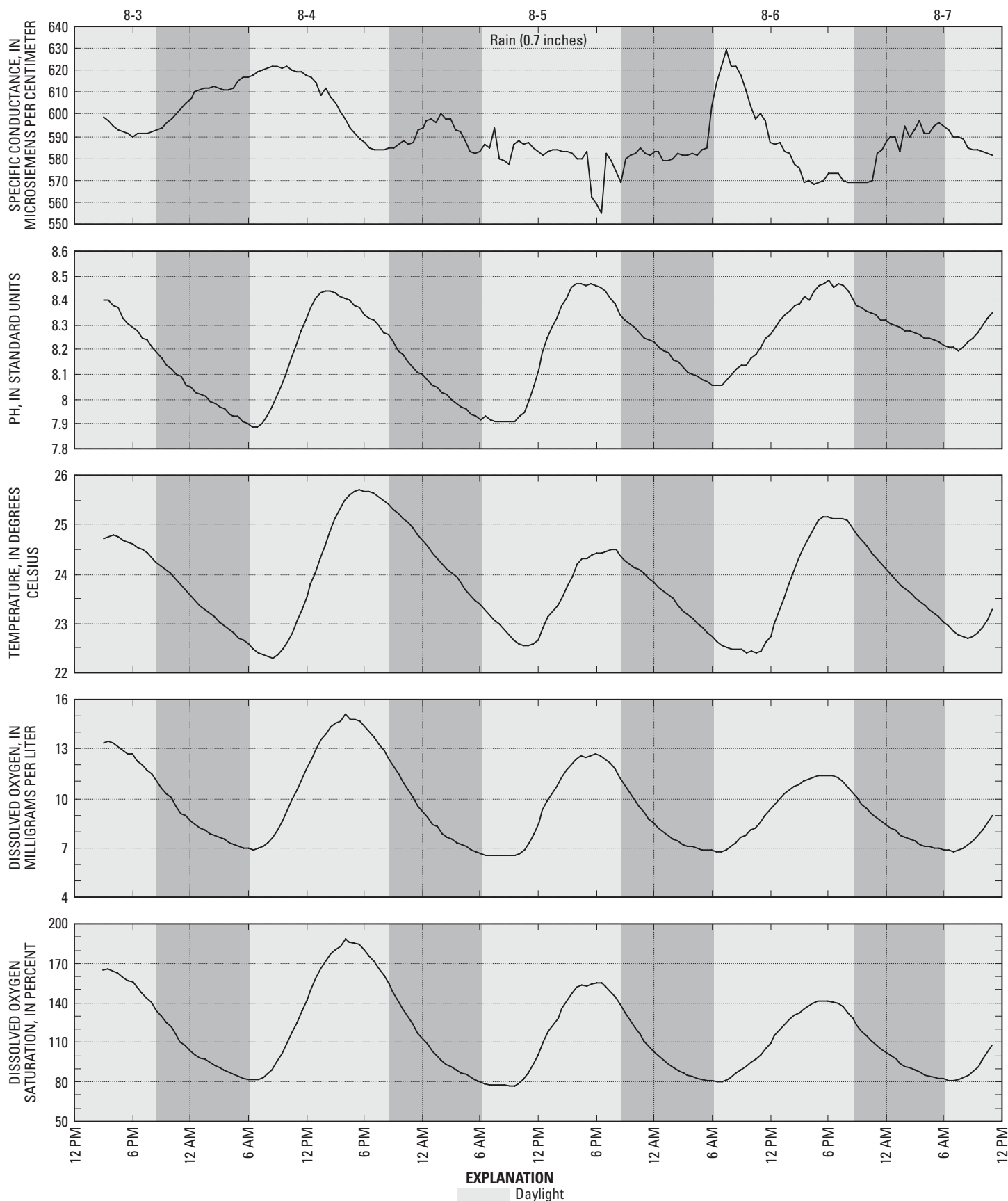


Figure 12. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Blue Earth River near Amboy, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 3-7, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>).)

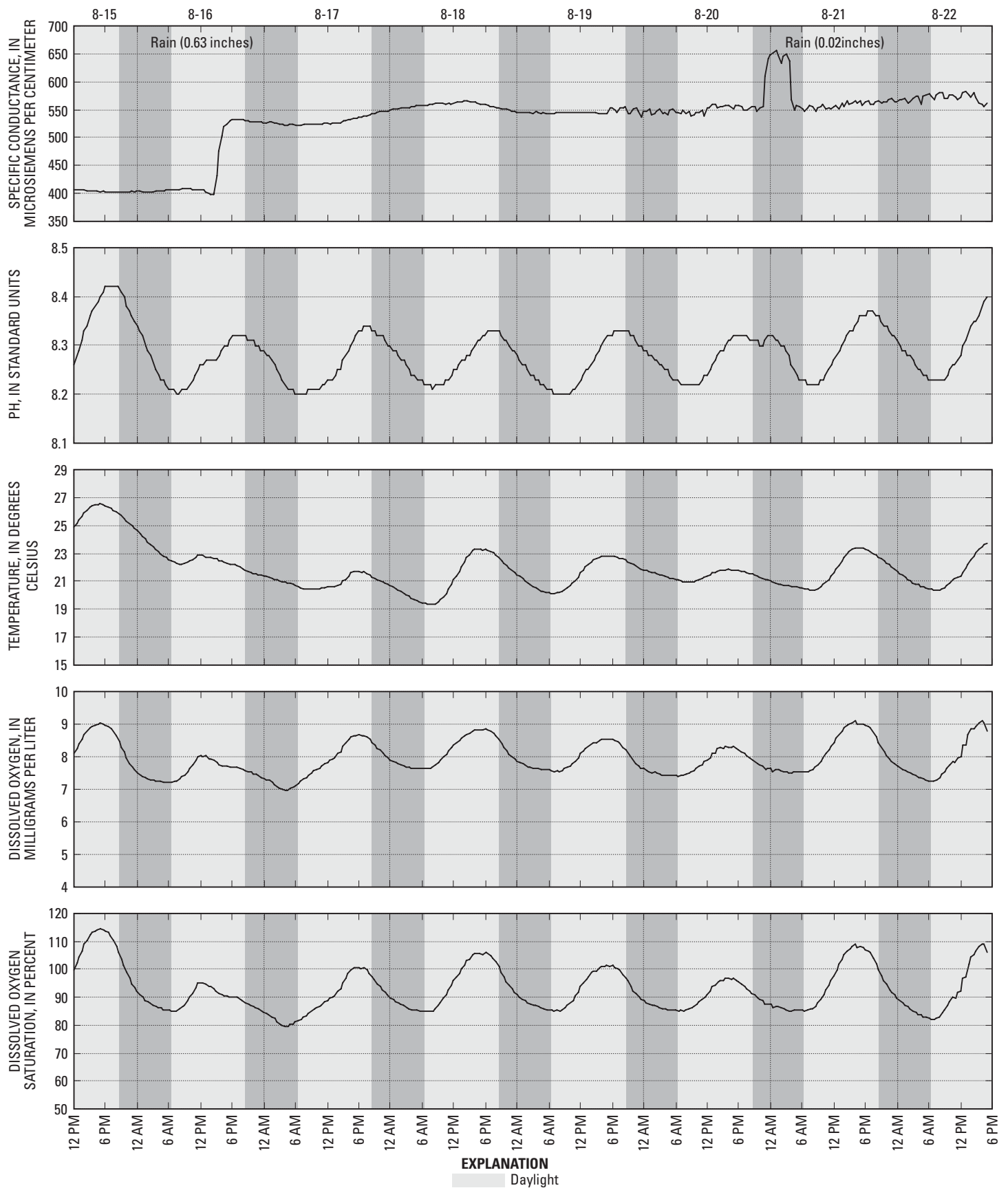


Figure 13. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Red River near Brushvale, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 15-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>).)

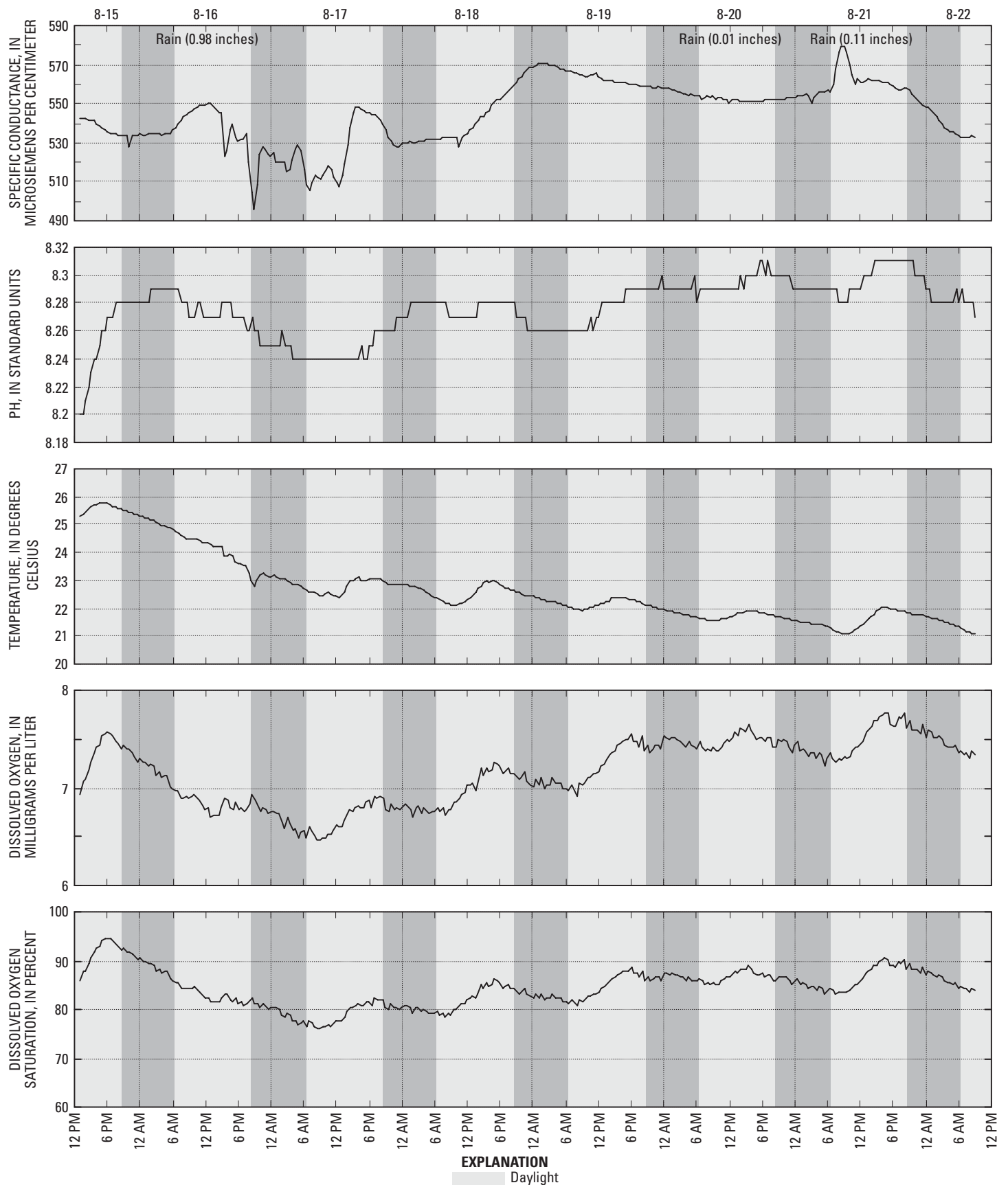


Figure 14. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Red River near Moorhead, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 15-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (<http://www.climate.umn.edu>).)

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SUPPLEMENTAL INFORMATION

Table 1. Drainage area, latitude and longitude, land use, ecoregion for 12 sites located on six streams in Minnesota where diurnal water-quality measurements and benthic algae samples were collected during August 2000
[LAP = Lake Agassiz Plain; NLF= Northern Lakes and Forests, NCHF= North Central Hardwoods Forests, WCBP= Western Corn Belt Plains, NGP = Northern Glaciated Plains.]

Site number (shown on fig. 1)	Site Name	U.S.			Latitude	Longitude	Major Basin Land Use	Ecoregion
		Drainage Area (mi ²)	Site identifier	Geological Survey Gaging Station Identifier ²				
1	Crow Wing River near Nimrod, MN	1030	CWR-72.3	05244000	46°38'24"	94°52'46"	Forest	NLF
2	Crow Wing River near Staples, MN	2130	CWR-35.5	05244000	46°21'40"	94°43'22"	Forest	NLF/NCHF
3	Mississippi River near Aitkin, MN	6140	UM-1055.9	05227500	46°32'26"	93°42'26"	Forest	NLF
4	Mississippi River near Anoka, MN	19,100	UM-872	05288500	45°11'30"	93°23'42"	Mixed	NCHF
5	Rum River near Isanti, MN	1232	RU-34	05286000	45°29'36"	93°16'01"	Forest	NCHF
6	Rum River near St. Francis, MN	1360	RU-18	05286000	45°23'13"	93°21'27"	Forest	NCHF
7	Crow River near Rockford, MN	2640	CR-23	05280000	45°05'06"	93°44'08"	Agriculture	NCHF
8	Crow River near Dayton, MN	2761	CR-0.2	05280000	45°14'41"	93°31'24"	Agriculture	NCHF
9	Blue Earth River West of Winnebago, MN	1000	BE-73.2	05320000	43°46'10"	94°11'42"	Agriculture	WCP
10	Blue Earth River near Amboy, MN	1055	BE-54	05320000	43°53'41"	94°11'57"	Agriculture	WCP
11	Red River near Brushvale, MN	4050	RED-536	05054000	46°22'06"	96°39'21"	Agriculture	LAP/NGP
12	Red River near Moorhead, MN	6800	RED-452	05054000	46°52'26"	96°46'35"	Agriculture	LAP/NGP

¹ The code for the site number is comprised of two or three letters corresponding to the river followed by numbers that correspond to the river mile near the site location. For example the Crow Wing River near Nimrod, Minnesota (CWR-72.3) is located 72.3 miles upstream of the confluence of the Crow Wing and the Mississippi Rivers.

² Refers to the nearest U.S. Geological Survey stream gaging station. USGS stream gages were not collocated with all sites.

Table 2. Site conditions at time of benthic algae collection and dates for diurnal water-quality measurements for 12 sites located on six Minnesota streams sampled during August 2000.

Site identifier	Start date for diurnal monitoring	End date for diurnal monitoring	Collection date for benthic algae (time)	Average Velocity (cubic feet per second)	Secchi disc depth (inches)	Water color-clarity
CWR-72.3	8/15/00	8/22/00	8/15/00	1.3	> 36	Clear-stained
CWR-35.5	8/16/00	8/22/00	8/16/00	1.5	> 36	Clear-stained
UM-1055.9	8/10/00	8/15/00	8/16/00	0.8	24	Brown-turbid
UM-872	8/10/00	8/15/00	8/9/00	0.6	24	Clear stained
RU-34	8/8/00	8/14/00	8/9/00	1.3	> 36	Clear-stained
RU-18	8/9/00	8/14/00	8/9/00	0.9	> 36	Clear-stained
CR-23	8/8/00	8/14/00	8/8/00	0.76	8	Brown-turbid
CR-0.2	8/8/00	8/14/00	8/8/00	0.6	10	Brown-turbid
BE-73.2	8/3/00	8/7/00	8/7/00	1.4	12	Green-turbid
BE-54	8/3/00	8/7/00	8/7/00	2.0	12	Green-turbid
RED-536	8/15/00	8/22/00	8/15/00	1.5	12	Brown-turbid
RED-452	8/15/00	8/22/00	8/15/00	0.9	6	Brown-turbid

Table 3. Median specific conductance, pH, water temperature, dissolved oxygen, and percent dissolved oxygen saturation for 12 sites located on six streams in Minnesota during August 2000.

[uS/cm, microsiemens per centimeter at 25 degrees Celsius, s.u., standard units, °C, degrees Celsius, mg/L, milligrams per liter; na, not available]

Site identifier	Specific Conductance, median (uS/cm)	pH, median (s.u.)	Water Temperature, median (°C)	Dissolved oxygen, median (mg/L)	Dissolved oxygen saturation, median (percent)
CWR-72.3	298	8.38	19.92	7.31	82.5
CWR-35.5	389	na	19.52	7.43	83.2
UM-1055.9	290	8.21	24.43	6.79	83
UM-872	389	8.53	26.9	6.99	89.6
RU-34	323	8.37	24.53	8.78	108.4
RU-18	332	8.97	24.84	8.45	103.3
CR-23	651	8.53	26.15	8.49	109
CR-0.2	575	8.59	25.79	8.59	108.5
BE-73.2	590	8.16	23.36	8.24	98.4
BE-54	588	8.23	23.73	8.91	107.7
RED-536	547	8.28	21.60	7.8	90.3
RED-452	548	8.28	22.33	7.22	84.5

Table 4. Estimates of net community primary production and respiration for 12 sites located on six Minnesota streams sampled during August 2000.
[gO₂/m³/hr, grams of oxygen per cubic meter per hour]

Site identifier	Estimates of net community primary production, maximum (gO ₂ /m ³ /hr)							Estimates of net community respiration, maximum (gO ₂ /m ³ /hr)						
	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7
CWR-72.3	0.24	0.49	0.58	0.50	0.43	0.63	--	0.09	0.06	0.09	0.10	0.12	0.09	0.08
CWR-35.5	0.36	0.37	0.29	0.42	0.28	0.53	--	0.04	0.07	0.11	0.11	0.04	0.13	--
UM-1055.9	0.10	0.04	0.09	0.03	--	--	--	0.01	0.03	0.00	0.04	0.00	--	--
UM-872	0.43	0.15	0.36	0.33	--	--	--	0.27	0.28	0.22	0.28	0.24	--	--
RU-34	0.61	0.63	0.66	0.41	0.65	--	--	0.26	0.30	0.36	0.35	0.31	0.35	--
RU-18	0.72	0.65	0.31	0.69	--	--	--	0.28	0.23	0.22	0.18	0.25	--	--
CR-23	0.90	0.91	0.88	0.28	0.62	--	--	0.34	0.53	0.47	0.42	0.23	0.27	--
CR-0.2	0.96	0.82	0.76	0.47	0.94	--	--	0.39	0.48	0.44	0.40	0.35	0.51	--
BE-73.2	1.06	0.26	0.51	--	--	-	--	0.27	1.09	0.17	0.20	--	--	--
BE-54	1.10	1.07	0.61	--	--	--	--	0.28	0.40	0.27	0.25	--	--	--
RED-536	0.29	0.03	0.13	0.15	0.15	0.14	0.22	0.04	0.05	0.04	0.04	0.03	0.02	0.08
RED-452	0.04	0.06	0.05	0.06	0.05	0.08	--	0.05	0.04	0.01	0.00	0.02	0.03	0.03

Stream productivity and stream respiration estimates were quantified according to Sorrenson and others (1999). Briefly, Productivity estimates were determined by calculating the slope of the dissolved oxygen concentrations between 10 am and 3 pm. The estimates define the net rate of oxygen accrual in grams of oxygen per hour (mg O₂/L/hr), which is equivalent to grams of oxygen per cubic meter per hour (g O₂/m³/hr). Stream respiration was calculated in the same manner for oxygen concentrations between 12 am and 6 am.

Table 5. Chlorophyll-*a* content of benthic algae collected from rock and wood substrate from 12 sites located on six streams in Minnesota during August 2000.
[mg/m², milligram per square meter]

Site identifier	Chlorophyll- <i>a</i> content (mg/m ²)	
	Wood substrate	Rock substrate
CWR-72.3	16.4	17.4
CWR-35.5	26.6	23.6
UM-1055.9	16.8	2.1
UM-872	117	150
RU-18	15.6	47.7
RU-34	40.5	68.5
CR-23	7.94	19
CR-0.2	8.22	19.5
BE-54	13.4	34.2
BE-73.2	3.98	17
RE-536	48.9	14.3
RE-452	7.53	57.9

Table 6. Total biovolume and density of benthic algae collected from rock and wood substrate from 12 sites located on six streams in Minnesota during August 2000

[$\mu\text{m}^3/\text{cm}$, cubic micrometer per square centimeter; cm^2 , square centimeter; --, not collected]

Site identifier	Total biovolume ($\mu\text{m}^3/\text{cm}^2$)		Total density (number of cells/ cm^2)	
	Rock substrate	Wood substrate	Rock substrate	Wood substrate
CWR-72.3	113,923,900	58,355,787,392	1,291,601	581,917
CWR-35.5	541,846,200	529,357,200	1,082,148	1,799,878
UM-1055.9	90,862,517	146,236,416	246,234	203,397
UM-872	129,906,614	541,859,656	736,078	2,472,874
UM-872 (Replicate)	227,948,884	--	1,567,368	--
UM-872 (Replicate)	216,515,943	--	1,188,846	--
RU-34	484,437,457	2,871,319,970	1,618,846	656,460
RU-18	971,845,124	167,582,762	1,507,407	632,221
CR-23	224,446,205	22,257,629	1,260,949	112,129
CR-0.2	163,319,073	90,778,998	765,937	401,998
BE-73.2	205,407,100	36,778,565	1,790,662	188,540
BE-54	896,036,700	86,408,799	2,639,934	945,037
RED-536	99,078,874	618,333,300	622,254	1,554,338
RED-452	755,708,700	43,400,898	1,873,043	505,499

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 [site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
Chlorophyta (Green Algae)														
<i>Ankistrodesmus convolutus</i> Corda	0.07													
<i>Ankistrodesmus falcatus</i> (Corda) Ralfs	0.04	0.10	0.06	0.04	0.09									
<i>Chlamydomonas platystigma</i> (Korshikoff) Pascher														
<i>Chlorococcum</i> sp. Meneghini	39.02	1.62	3.45	11.77	1.94	3.65	3.20	9.00	3.02	4.23	9.14	0.62		
<i>Cladophora</i> sp. Kützing	53.21													
<i>Closterium moniliferum</i> (Bory) Ehrenberg					0.89									
<i>Coelastrum astroideum</i> De Not.			0.49	0.13										
<i>Coelastrum microporum</i> Nägeli									0.12		0.20			
<i>Crucigenia crucifera</i> (Wolle) Collins														
<i>Crucigenia quadrata</i> Morren				0.15										
<i>Dictyosphaerium pulchellum</i> Wood			0.12		0.01	0.17								
<i>Didymogenes anomala</i> (G.M. Smith) Hinkak						0.06								
<i>Monoraphidium capricornutum</i> (Printz) Nygaard				0.02							0.02			
<i>Mougeotia</i> sp. Agardh			1.38											
<i>Nephroselmis</i> sp. Stein					0.13									
Non-motile Chlorococcales (spherical, >10µm)				6.30										
<i>Oedogonium</i> sp. Link		0.77						10.64						2.60
<i>Oocystis parva</i> West & West				0.24	0.12	0.01	0.07	0.23						

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Pediastrum duplex</i> Meyen								5.28	0.28					
<i>Pediastrum tetras</i> (Ehrenberg) Ralfs									0.43					
<i>Phacotus</i> sp. Perty														
<i>Protoderma viride</i> Kützing						1.94								
<i>Pyramichlamys</i> sp. Ettl							1.40							
<i>Scenedesmus abundans</i> (Kirchner) Chodat		0.03			0.06		0.03	0.08	0.48	0.71				
<i>Scenedesmus acuminatus</i> (Lagerheim) Chodat														
<i>Scenedesmus bijuga</i> (Turpin) Lagerheim				0.07			0.09	0.12					0.72	
<i>Scenedesmus dimorphus</i> (Turpin) Kützing								0.03		0.23				
<i>Scenedesmus opoliensis</i> v. <i>carinatus</i> Lemmermann				0.73	0.31		0.41	0.47				0.22		
<i>Scenedesmus quadricauda</i> (Turpin) de Brébisson							0.89	0.04	0.10	0.09		0.31		
<i>Scenedesmus serratus</i> (Corda) Bohlin							0.10	0.11						
<i>Selenastrum gracile</i> Reinsch														
<i>Sphaerocystis Schroeteri</i> Chodat				0.63							0.23			
<i>Spirogyra</i> sp. Link														
<i>Stigeoclonium</i> sp. Kützing					0.81		12.05							
<i>Tetraedron caudatum</i> (Conda) Hansgirg								0.06						
<i>Tetraedron minimum</i> (Braun) Hansgirg									0.04					
<i>Tetraedron regulare</i> var. <i>incus</i> Telling														

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Tetrastrum staurogeniaeforme</i> (Schroeder) Lemmermann														
						0.07			0.15					
Chrysophyta														
Cyst (Chrysophyte)						0.15	0.44	0.05						
Cryptophyta (Cryptomonads)														
<i>Cryptomonas erosa</i> Ehrenberg									0.22					
<i>Cryptomonas ovata</i> Ehrenberg														0.20
Cyanophyta (Blue-Greens)														
<i>Anabaena circinalis</i> Rabenhorst														
<i>Aphanocapsa delicatissima</i> West & West														
<i>Aphanocapsa elachista</i> West & West	0.60		0.13											
<i>Aphanocapsa koordersi</i> Strom														
<i>Aphanothecae saxicola</i> Nägeli														
<i>Calothrix</i> sp. Agardh	0.29	0.16	0.06	0.06	0.06	0.06		0.06						0.39
<i>Chroococcus minimus</i> (Keissler) Lemmermann				0.15	0.05	0.07			0.07	0.03				
<i>Chroococcus minutus</i> (Kützinger) Nägeli			0.32		0.34									
<i>Lyngbya digueti</i> Gomont	0.15		0.54	1.96	0.40	0.37	0.44	0.25	0.19					
<i>Lyngbya</i> sp. 1 (small) Agardh	27.09													
<i>Lyngbya</i> sp. 3 Agardh			2.88			0.37								
<i>Lyngbya</i> sp. 4 Agardh						0.58								
<i>Lyngbya subtilis</i> West	1.64	0.45	2.65	1.97	1.18	0.16	0.15		0.14		0.25		0.97	

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Merismopedia tenuissima</i> Lemmermann						0.01								
<i>Non-motile blue-greens (>1 µm)</i>	12.34	1.77	2.11	6.54	6.37	6.00	2.07	1.11	4.49	4.35	9.91	3.63	7.48	1.82
<i>Nostoc sp. Vaucher</i>														
<i>Oscillatoria amphibia</i> Agardh							0.08							
<i>Oscillatoria chlorina</i> Kützing ex Gomont		5.99	0.06	3.03		0.36		0.13				10.18		
<i>Oscillatoria hamelii</i> Frémy													3.90	16.24
<i>Oscillatoria limnetica</i> Lemmermann							0.06							
<i>Oscillatoria sp. 4 Vaucher</i>					1.84									
<i>Oscillatoria tenuis</i> Agardh				2.20	1.63	0.73	1.38		0.39			4.26		
<i>Phormidium fragile</i> (Meneghini) Gomont														
<i>Phormidium jadinianum</i> Gomont														
<i>Pseudanabaena galeata</i> Bocher			0.03	0.02										
<i>Synechococcus elongatus</i> Nägeli			0.10		0.43			0.06	0.49	0.22	0.16		0.10	0.06
<i>Xenococcus sp. Thuret</i>								0.13						
Bacillariophyceae (Diatoms)														
<i>Achnanthes exigua</i> Grunow														
<i>Achnanthes lanceolata ssp. dubia</i> (Grunow) Lange-Bertalot							0.52							
<i>Achnanthes lanceolata ssp. frequentissima</i> Lange-Bertalot				0.32			0.33							
<i>Achnanthes lanceolata v. frequentissima</i> Lange-Bertalot							0.33							
<i>Achnanthes minutissima</i> Kützing	0.18	0.05		0.19	0.14	0.24	0.00	0.02			0.16	0.09	0.04	

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Amphora montana</i> Krasske	3.88													
<i>Amphora pediculus</i> (Kützing) Grunow	1.08	0.69	0.06	14.91	12.16	28.52	6.95	0.85	0.13	0.08	1.86	0.18	0.91	
<i>Amphora veneta</i> Kützing														
<i>Cocconeis pediculus</i> Ehrenberg	12.14			21.22		2.57								15.16
<i>Cocconeis placentula</i> v. <i>lineata</i> (Ehrenberg) Van Heurck	24.33	14.09	1.83	1.70	1.77	2.31	0.74	8.10	11.03				9.70	3.64
<i>Cocconeis placentula</i> v. <i>pseudolineata</i> Geitler	0.30													
<i>Cyclotephanos invisitatus</i> (Hohn & Hel.) Ther., Stoerm. & Håkansson														
<i>Cyclotella bodanica</i> Grunow	3.92													
<i>Cyclotella meneghiniana</i> Kützing				1.02	0.77	4.44	21.82	0.88	14.98	55.45	2.57	55.14		1.29
<i>Cyclotella</i> sp. <i>I</i> (Kützing) de Brébisson						0.08			0.47	0.09		0.16		0.63
<i>Cymbella affinis</i> Kützing	7.92													
<i>Cymbella minuta</i> Hilse	1.27				1.93	2.11							3.81	
<i>Cymbella silestaca</i> Bleisch	1.52													
<i>Cymbella sinuata</i> Gregory						2.56	0.96							
<i>Cymbellonitzschia</i> sp. Hustedt	0.55													
<i>Diatoma vulgaris</i> Bory	3.05													
<i>Diploneis finnica</i> (Ehrenberg) Cleve	0.13													
<i>Epithemia sorex</i> Kützing								0.11						
<i>Epithemia sorex</i> v. <i>sorex</i> Kützing	1.81													
<i>Epithemia turgida</i> v. <i>westernianii</i> (Ehrenberg) Grunow	41.02													

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
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Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Fragilaria capucina</i> Desmazières	0.48													
<i>Fragilaria capucina</i> v. <i>vaucheriae</i> (Kützing) Lange-Bertalot														
<i>Fragilaria construens</i> (Ehrenberg) Grunow	0.43													
<i>Fragilaria construens</i> f. <i>venter</i> (Ehrenberg) Hustedt	3.68	0.77		0.59	0.46	0.38		0.31					0.41	
<i>Fragilaria leptostauron</i> v. <i>dubia</i> (Grunow) Hustedt	1.77	0.64					3.86							
<i>Fragilaria pinnata</i> v. <i>pinnata</i> Ehrenberg														
<i>Gomphonema augur</i> Ehrenberg	5.38													
<i>Gomphonema gracile</i> Ehrenberg														
<i>Gomphonema olivaceum</i> (Hornemann) de Brébisson		3.33	9.27	5.84	2.32	1.04								
<i>Gomphonema parvulum</i> (Kützing) Kützing	0.45	2.82	0.36	1.86	0.14	0.08	0.44	1.09	0.61					
<i>Gomphonema pumilum</i> (Grunow) Reichardt & Lange-Bertalot	0.15 0.22 1.05													
<i>Gyrosigma scalpoides</i> (Radenhorst) Cleve														
<i>Gyrosigma</i> sp. Hassall														
<i>Gyrosigma spencerii</i> (W. Smith) Cleve	4.05								13.34	20.79				
<i>Melosira</i> cf. <i>distans</i> Agardh	1.10													
<i>Melosira granulata</i> (Ehrenberg) Ralfs							20.19	2.76	1.60					
<i>Melosira varians</i> Agardh	43.74						0.23	8.47						
<i>Navicula absoluta</i> Hustedt	0.31													

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
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Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Navicula capitata</i> Ehrenberg	0.55													
<i>Navicula cf gregaria</i> Donkin	0.48 0.77													
<i>Navicula cf. lacunolaciniata</i> Lange-Bertalot & Bonik	0.10 0.33 0.23 0.11													
<i>Navicula cryptocephala</i> Kützing	0.91 0.80 2.57 1.04 1.74 0.86 1.50 3.43 1.52													
<i>Navicula cryptotenella</i> Lange-Bertalot	0.10 0.21													
<i>Navicula cuspidata</i> (Kützing) Kützing	2.90													
<i>Navicula decussis v. decussis</i> Østrup	2.94 5.02													
<i>Navicula erifuga</i> Lange-Bertalot	2.49													
<i>Navicula goeppertiana v. goeppertiana</i> (Bleisch) H.L. Smith														
<i>Navicula menisculus v. grunowii</i> Lange-Bertalot	0.48	0.63	4.53	2.92	0.60	1.04	0.85	0.12	0.82					
<i>Navicula pupula</i> Kützing	2.61 0.77													
<i>Navicula rhynchocephala</i> Kützing														
<i>Navicula salinarum</i> Grunow	8.34 2.56 4.63 2.32													
<i>Navicula sp. Bory</i>	0.15													
<i>Navicula subminuscula</i> Manguin	0.09 0.30													
<i>Navicula viridula v. germainii</i> (Walc) Lange-Bertalot	2.57	2.92	8.11	19.64	5.74	7.42	2.90	2.66	9.58					
<i>Nitzschia acicularis</i> (Kützing) W. Smith	0.77 7.67 2.12 0.76													
<i>Nitzschia constricta</i> (Kützing) Ralfs														

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Nitzschia dissipata</i> (Kützing) Grunow	4.39													
<i>Nitzschia fonticola</i> Grunow		0.16		3.46	1.99	1.45	3.55	0.60	0.13	4.65	4.08	3.66		
<i>Nitzschia fonticola</i> v. <i>pelagica</i> Hustedt	0.04													
<i>Nitzschia gracilis</i> Hantzsch							0.66	0.09	2.41	1.88	32.24	0.59	2.29	12.16
<i>Nitzschia inconspicua</i> Grunow			0.05	0.02	0.04					0.10			0.03	
<i>Nitzschia intermedia</i> Hantzsch									2.30					
<i>Nitzschia palea</i> (Kützing) W. Smith					0.44	2.21		0.25	0.38	13.96	1.33	1.37	0.95	
<i>Nitzschia perminuta</i> (Grunow) Peragallo	0.10													
<i>Nitzschia pumila</i> Hustedt					0.68									
<i>Nitzschia reversa</i> W. Smith										3.49	6.41		3.05	
<i>Nitzschia sigmoides</i> (Nitzsch) W. Smith								6.14						
<i>Nitzschia</i> sp. Hassall														
<i>Pinnularia microstauron</i> (Ehrenberg) Cleve					11.74									
<i>Rhoicosphenia curvata</i> (Kützing) Grunow	0.13	38.96	2.16	2.72	2.48	4.17	3.17	3.95				3.02	14.19	
<i>Stephanodiscus hantzschii</i> (8-11µm) Grunow									0.41					
<i>Stephanodiscus medius</i> Håkansson											3.81			
<i>Stephanodiscus niagarae</i> Ehrenberg														
<i>Surirella</i> sp. Turpin													3.81	
<i>Surirella visurgis</i> Hustedt										9.31				

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
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Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	UM- 872 ₁	UM- 872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon														
<i>Synedra tenera</i> W. Smith														
						0.14								
<i>Synedra ulna</i> v. <i>ulna</i> (Nitzsch) Lange-Bertalot														
						0.24	0.15	2.63						
Pyrrhophyta (Dinoflagellates)														
<i>Gymnodinium</i> sp. 3 Stein														
							0.04							
Euglenophyta														
<i>Euglena</i> sp. Ehrenberg														
											14.69			
<i>Trachelomonas volvocina</i> Ehrenberg														
Miscellaneous														
<i>Barrachospermum vagum</i> (Roth) Agardh														
												31.19		

¹Quality assurance sample

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000.
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Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon	Chlorophyta (Green Algae)											
<i>Ankistrodesmus convolutus</i> Corda			0.02			0.01		0.04				
<i>Ankistrodesmus falcatus</i> (Corda) Ralfs							0.43	0.98				0.60
<i>Chlamydomonas platystigma</i> (Korshikoff) Pascher					0.01							
<i>Chlorococcum</i> sp. Meneghini	0.02	1.36		4.16	0.01	3.39		2.21	6.13		2.72	4.41
<i>Cladophora</i> sp. Kützing	99.73				6.36							
<i>Closterium moniliferum</i> (Bory) Ehrenberg									0.13			
<i>Coelastrum asteroideum</i> De Not.								0.13				
<i>Coelastrum microporum</i> Nägeli												
<i>Crucigenia crucifera</i> (Wolle) Collins						0.15						
<i>Crucigenia quadrata</i> Morren												
<i>Dictyosphaerium pulchellum</i> Wood												
<i>Didymogenes anomala</i> (G.M. Smith) Hinkak												
<i>Monoraphidium capricornutum</i> (Printz) Nygaard												
<i>Mougeotia</i> sp. Agardh												
<i>Nephroselmis</i> sp. Stein												
Non-motile Chlorococcales (spherical, >10µm)												
<i>Oedogonium</i> sp. Link			44.13									
<i>Oocystis parva</i> West & West							0.24	0.79				
<i>Pediastrum duplex</i> Meyen												
<i>Pediastrum tetras</i> (Ehrenberg) Ralfs		0.71										
<i>Phacotus</i> sp. Perty											0.39	
<i>Protoderma viride</i> Kützing												

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
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Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon												
<i>Pyramichlanys</i> sp. Ettl												
<i>Scenedesmus abundans</i> (Kirchner) Chodat					0.02		0.09		0.35			
<i>Scenedesmus acuminatus</i> (Lagerheim) Chodat							0.34					
<i>Scenedesmus bijuga</i> (Turpin) Lagerheim												
<i>Scenedesmus dimorphus</i> (Turpin) Kützing	0.00											
<i>Scenedesmus opoliensis</i> v. <i>carinatus</i> Lemmermann				0.21	0.02		2.72		0.94			
<i>Scenedesmus quadricauda</i> (Turpin) de Brébisson						0.10	0.26		0.16	1.12	0.30	
<i>Scenedesmus serratus</i> (Corda) Bohlin	0.00	0.08			0.26							
<i>Selenastrum gracile</i> Reinsch							0.76					
<i>Sphaerocystis Schroeteri</i> Chodat	0.00	0.29										
<i>Spirogyra</i> sp. Link					86.86							
<i>Stigeoclonium</i> sp. Kützing												
<i>Tetraedron caudatum</i> (Conda) Hansgirg												
<i>Tetraedron minimum</i> (Braun) Hansgirg												
<i>Tetraedron regulare</i> var. <i>incus</i> Teiling							0.08					
<i>Tetrastrum staurogeniaeforme</i> (Schroeder) Lemmermann						0.16	0.13					
Chrysophyta												
Cyst (Chrysophyte)	0.01					0.32					0.27	
Cryptophyta (Cryptomonads)												
<i>Cryptomonas erosa</i> Ehrenberg												
<i>Cryptomonas ovata</i> Ehrenberg					0.02							
Cyanophyta (Blue-Greens)												
<i>Anabaena circinalis</i> Rabenhorst						0.03						

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Taxon												
<i>Aphanocapsa delicatissima</i> West & West	0.00											
<i>Aphanocapsa elachista</i> West & West	0.01											
<i>Aphanocapsa koordevsi</i> Strom	0.90											
<i>Aphanothece saxicola</i> Nägeli	1.06											
<i>Calothrix</i> sp. Agardh	0.38											
<i>Chroococcus minimus</i> (Keissler) Lemmermann	0.07											
<i>Chroococcus minutus</i> (Kützinger) Nägeli	0.06											
<i>Lyngbya digueti</i> Gomont	5.43											
<i>Lyngbya</i> sp. 1 (small) Agardh	0.95											
<i>Lyngbya</i> sp. 3 Agardh												
<i>Lyngbya</i> sp. 4 Agardh												
<i>Lyngbya subtilis</i> West	0.30											
<i>Merismopedia tenuissima</i> Lemmermann												
Non-motile blue-greens (>1 µm)	0.01	2.30	1.40	3.37	0.27	3.64	6.26	4.59	6.53	17.51	2.55	11.15
<i>Nostoc</i> sp. Vaucher	0.33											
<i>Oscillatoria amphibia</i> Agardh	0.42											
<i>Oscillatoria chlorina</i> Kützinger ex Gomont	0.63											
<i>Oscillatoria hamelii</i> Frémy	61.07											
<i>Oscillatoria limnetica</i> Lemmermann												
<i>Oscillatoria</i> sp. 4 Vaucher												
<i>Oscillatoria tenuis</i> Agardh	2.15											
<i>Phormidium fragile</i> (Meneghini) Gomont	0.17											
<i>Phormidium jadinianum</i> Gomont	0.00											
<i>Pseudanabaena galeata</i> Bocher	0.03											

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
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Taxon												
<i>Synechococcus elongatus</i> Nägeli		0.06	0.09	0.59	0.00	0.01	0.33	0.17	0.02	0.07		1.27
<i>Xenococcus</i> sp. Thuret									0.12			
Bacillariophyceae (Diatoms)												
<i>Achnanthes exigua</i> Grunow		0.43										
<i>Achnanthes lanceolata</i> ssp. <i>dubia</i> (Grunow) Lange-Bertalot				0.36							0.20	
<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> Lange-Bertalot						0.09						
<i>Achnanthes lanceolata</i> v. <i>frequentissima</i> Lange-Bertalot												
<i>Achnanthes minutissima</i> Kützing	0.00			0.05	0.00	0.15	0.05					
<i>Amphora montana</i> Krasske				24.05	0.42	6.21	1.32				1.27	
<i>Amphora pediculus</i> (Kützing) Grunow	0.00	0.67		6.52	0.28	4.13		0.67			0.48	0.60
<i>Amphora veneta</i> Kützing	0.00							3.37				
<i>Cocconeis pediculus</i> Ehrenberg	0.01			10.94				5.46				7.97
<i>Cocconeis placentula</i> v. <i>lineata</i> (Ehrenberg) Van Heurck	0.07	38.18	10.87	5.99	0.60	4.27	8.99	1.43			0.27	
<i>Cocconeis placentula</i> v. <i>pseudolineata</i> Geitler												
<i>Cyclotephantos invisitatus</i> (Hohn & Hel.) Ther., Stoerm. & Håkansson										2.79		
<i>Cyclotella bodanica</i> Grunow												
<i>Cyclotella meneghiniana</i> Kützing				2.57	0.18	0.55	3.12	17.15	3.92	31.58	1.33	
<i>Cyclotella</i> sp. <i>I</i> (Kützing) de Brébisson					0.00	0.14					0.04	
<i>Cymbella affinis</i> Kützing												
<i>Cymbella minuta</i> Hilse	0.00			4.95								
<i>Cymbella silesiaca</i> Bleisch	0.01											
<i>Cymbella sinuata</i> Gregory	0.00				0.02	0.08						
<i>Cymbellonitzschia</i> sp. Hustedt												

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Taxon												
Diatoma vulgaris Bory												
Diploneis finnica (Ehrenberg) Cleve	0.00											
Epithemia sorex Kützing												
Epithemia sorex v. sorex Kützing	15.90											
Epithemia turgida v. westermanni (Ehrenberg) Grunow	13.32											
Fragilaria capucina Desmazières	0.00											
Fragilaria capucina v. vaucheriae (Kützing) Lange-Bertalot	0.25 0.29											
Fragilaria construens (Ehrenberg) Grunow	0.09 0.58											
Fragilaria construens f. venter (Ehrenberg) Hustedt	0.15 3.71											
Fragilaria leptostauron v. dubia (Grunow) Hustedt	0.66 0.14											
Fragilaria pinnata v. pinnata Ehrenberg	0.00											
Gomphonema augur Ehrenberg	4.09											
Gomphonema gracile Ehrenberg	1.09											
Gomphonema olivaceum (Hornemann) de Brébisson	4.22 1.55											
Gomphonema parvulum (Kützing) Kützing	0.01 1.52 0.67 0.08 0.08 2.51 1.22 1.70 1.12 0.99											
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot	0.02 0.80 0.19											
Gyrosigma scalproides (Radenhorst) Cleve	7.97											
Gyrosigma sp. Hassall	0.01											
Gyrosigma spencerii (W. Smith) Cleve	3.82											
Melosira cf. distans Agardh												
Melosira granulata (Ehrenberg) Ralfs	11.51 21.27 3.50 8.26 13.53											
Melosira varians Agardh	18.10 5.00 0.07											
Navicula absoluta Hustedt												

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
[site identifiers are defined in Table 1]; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon												
<i>Navicula capitata</i> Ehrenberg												
<i>Navicula cf gregaria</i> Donkin							0.84					4.47
<i>Navicula cf. lacunolaciniata</i> Lange-Bertalot & Bomk				0.02	0.01	0.62	0.07	0.06	0.12		0.07	0.40
<i>Navicula cryptocephala</i> Kützing	0.00	2.08	0.24	1.32	0.05	0.78			5.32		4.05	26.80
<i>Navicula cryptotenella</i> Lange-Bertalot				0.77		0.47						
<i>Navicula cuspidata</i> (Kützing) Kützing						8.28					4.00	
<i>Navicula decussis</i> v. <i>decussis</i> Østrup					0.62	0.46						
<i>Navicula erifuga</i> Lange-Bertalot							1.90	0.56				
<i>Navicula goeppertiana</i> v. <i>goeppertiana</i> (Bleisch) H.L. Smith	0.00											
<i>Navicula meniscus</i> v. <i>grunowii</i> Lange-Bertalot	0.00	13.14			0.09	2.24		0.88	0.12		0.20	2.78
<i>Navicula pupula</i> Kützing						2.68	1.88					
<i>Navicula rhynchocephala</i> Kützing						1.81						
<i>Navicula salinarum</i> Grunow	0.03		0.38	2.81	0.11	3.98	0.71	3.51				
<i>Navicula</i> sp. Bory	0.00			0.26					0.04			
<i>Navicula subminuscula</i> Manguin							0.15			0.24		
<i>Navicula viridula</i> v. <i>germainii</i> (Wallace) Lange-Bertalot	0.01	4.12	1.43	3.30	0.84	7.25	32.38	15.05	16.56	15.57		4.01
<i>Nitzschia acicularis</i> (Kützing) W. Smith	0.00							1.50	4.34			
<i>Nitzschia constricta</i> (Kützing) Ralfs				4.12					2.96			
<i>Nitzschia dissipata</i> (Kützing) Grunow				0.29								
<i>Nitzschia fonticola</i> Grunow				0.37	0.10	2.52	6.71	0.37	9.94	2.43	0.94	
<i>Nitzschia fonticola</i> v. <i>pelagica</i> Hustedt												
<i>Nitzschia gracilis</i> Hantzsch					0.06	0.23		1.06	8.20			5.95
<i>Nitzschia inconspicua</i> Grunow												

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
[site identifiers are defined in Table 1]; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR- 72.3	CWR- 35.5	UM- 1055.9	UM- 872	RU-34	RU-18	CR-23	CR-0.2	BE- 73.2	BE-54	RED- 536	RED- 452
Taxon												
<i>Nitzschia intermedia</i> Hantzsch					0.20	1.00		5.99		15.76		
<i>Nitzschia palea</i> (Kützing) W. Smith				0.13	0.01	0.44	0.06		2.26	2.34	2.92	4.32
<i>Nitzschia perminuta</i> (Grunow) Peragallo												
<i>Nitzschia pumila</i> Hustedt						0.27						
<i>Nitzschia reversa</i> W. Smith												
<i>Nitzschia sigmoidea</i> (Nitzsch) W. Smith											3.15	4.51
<i>Nitzschia</i> sp. Hassall	0.02	17.37	3.98									
<i>Pinnularia microstauron</i> (Ehrenberg) Cleve												
<i>Rhoicosphenia curvata</i> (Kützing) Grunow	0.02	9.04	9.20	6.34	1.38	15.98	5.99	0.60				6.09
<i>Stephanodiscus hantzschii</i> (8–11 µm) Grunow										1.28		
<i>Stephanodiscus medius</i> Håkansson												
<i>Stephanodiscus niagarae</i> Ehrenberg									24.38			
<i>Surirella</i> sp. Turpin												
<i>Surirella visurgis</i> Hustedt												
<i>Synedra tenera</i> W. Smith				0.16		0.28					0.81	
<i>Synedra ulna</i> v. <i>ulna</i> (Nitzsch) Lange-Bertalot				4.41								
Pyrrhophyta (Dinoflagellates)												
<i>Gymnodinium</i> sp. 3 Stein						0.10						
<i>Euglena</i> sp. Ehrenberg												
<i>Trachelomonas volvocina</i> Ehrenberg						0.04						
Miscellaneous												
<i>Batrachospermum vagum</i> (Roth) Agardh						0.96						

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872 ₁	UM-872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon	Chlorophyta (Green Algae)													
<i>Ankistrodesmus convolutus</i> Corda	0.8													
<i>Ankistrodesmus falcatus</i> (Corda) Ralfs			0.3	0.4	0.2	0.3	0.7							
<i>Chlamydomonas platystigma</i> (Korshikoff) Pascher														
<i>Chlorococcum</i> sp. Meneghini	35.3	18.3	14.6	14.4	7.9	12.6	23.7	18.4	7.4	3.2	9.7	5.6		
<i>Cladophora</i> sp. Kützing							0.2							
<i>Closterium moniliferum</i> (Bory) Ehrenberg					0.4									
<i>Coelastrum astroideum</i> De Not.			0.2			0.3								
<i>Coelastrum microporum</i> Nägeli											0.5			
<i>Crucigenia crucifera</i> (Wolle) Collins									0.2					
<i>Crucigenia quadrata</i> Morren					0.2									
<i>Dictyosphaerium pulchellum</i> Wood			0.3				0.2		0.2					
<i>Didymogenes anomala</i> (G.M. Smith) Hinkak									0.2					
<i>Monoraphidium capricornutum</i> (Printz) Nygaard					0.4						0.5			
<i>Mougeotia</i> sp. Agardh			0.2											
<i>Nephroselmis</i> sp. Stein							0.2							
Non-motile Chlorococcales (spherical, >10µm)			0.6											
<i>Oedogonium</i> sp. Link		0.3						0.4				1.4		
<i>Oocystis parva</i> West & West				0.4		0.3	0.2	0.4	0.2					
<i>Pediastrum duplex</i> Meyen							0.2	0.4						
<i>Pediastrum tetras</i> (Ehrenberg) Ralfs								0.4						
<i>Phacotus</i> sp. Perty														
<i>Protoderma viride</i> Kützing			0.4											
<i>Pyramichlamys</i> sp. Ettl										0.2				

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
<i>Scenedesmus abundans</i> (Kirchner) Chodat	0.3				0.2	0.3	0.5	1.1	1.5				
<i>Scenedesmus acuminatus</i> (Lagerheim) Chodat													
<i>Scenedesmus bijuga</i> (Turpin) Lagerheim	0.3					0.3	0.5					0.9	
<i>Scenedesmus dimorphus</i> (Turpin) Kützing							0.2		0.2				
<i>Scenedesmus opoliensis</i> v. <i>carinatus</i> Lemmermann	0.3			0.1		0.5	0.7				0.5		
<i>Scenedesmus quadricauda</i> (Turpin) de Brébisson						0.8	0.5	0.4	0.2		0.9		
<i>Scenedesmus serratus</i> (Corda) Bohlin						0.3	0.5						
<i>Selenastrum gracile</i> Reinsch													
<i>Sphaerocystis Schroeteri</i> Chodat	0.6									0.8			
<i>Spirogyra</i> sp. Link													
<i>Stigeoclonium</i> sp. Kützing					0.2	0.5							
<i>Tetradron caudatum</i> (Conda) Hansg.							0.2						
<i>Tetradron minimum</i> (Braun) Hansg.								0.4					
<i>Tetradron regulare</i> var. <i>incus</i> Teiling													
<i>Tetrasium staurogeniaeforme</i> (Schroeder) Lemmermann					0.2			0.4					
Chrysophyta													
Cyst (Chrysophyte)					0.2	0.5	0.2						
Cryptophyta (Cryptomonads)													
<i>Cryptomonas erosa</i> Ehrenberg								0.4					
<i>Cryptomonas ovata</i> Ehrenberg												1.4	
Cyanophyta (Blue-Greens)													
<i>Anabaena circinalis</i> Rabenhorst													

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
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<i>Aphanocapsa elachista</i> West & West	0.6	0.3												
Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872 ₁	UM-872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
<i>Aphanocapsa koordersi</i> Strom														
<i>Aphanothece saxicola</i> Nägeli														
<i>Calothrix</i> sp. Agardh	0.3	0.5		0.2				0.1						1.4
<i>Chroococcus minimus</i> (Keissler) Lemmermann				0.4	0.2				0.4	0.2				
<i>Chroococcus minutus</i> (Kützing) Nägeli			0.3		0.2									
<i>Lyngbya digueti</i> Gomont	1.2		0.6	1.0	0.4	0.5	1.1	0.4	0.2					
<i>Lyngbya</i> sp. 1 (small) Agardh	0.3													
<i>Lyngbya</i> sp. 3 Agardh				0.2			0.2							
<i>Lyngbya</i> sp. 4 Agardh						0.3								
<i>Lyngbya subtilis</i> West	6.7	3.5	4.3	2.4	3.5	0.8	1.4	0.2	0.2	0.5	2.2			
<i>Merismopedia tenuissima</i> Lemmermann					0.2									
Non-motile blue-greens (>1 µm)	57.9	47.2	41.5	61.4	49.3	58.1	33.0	38.0	42.5	49.4	60.5	65.5	63.4	39.0
<i>Nostoc</i> sp. Vaucher														
<i>Oscillatoria amphibia</i> Agardh						0.3								
<i>Oscillatoria chlorina</i> Kützing ex Gomont	6.4	0.3	0.3		0.4	0.2				0.3				
<i>Oscillatoria hamelii</i> Frémy											1.3	2.8		
<i>Oscillatoria limnetica</i> Lemmermann						0.3								
<i>Oscillatoria</i> sp. 4 Vaucher				0.2										
<i>Oscillatoria tenuis</i> Agardh			2.3	0.6	0.5	0.1		0.2	0.5					
<i>Phormidium fragile</i> (Meneghini) Gomont														
<i>Phormidium jadinianum</i> Gomont														
<i>Pseudanabaena galeata</i> Bocher		0.3	0.3											
<i>Synechococcus elongatus</i> Nägeli		8.1		13.2			8.1	18.4	9.9	1.6	3.5	5.6		
<i>Xenococcus</i> sp. Thuret							0.2							
Bacillariophyceae (Diatoms)														

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<i>Achnanthes exigua</i> Grunow													
Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872 ₁	UM-872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536 RED-452
<i>Achnanthes lanceolata</i> ssp. <i>dubia</i> (Grunow) Lange-Bertalot							0.5						
<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> Lange-Bertalot			0.3										
<i>Achnanthes lanceolata</i> v. <i>frequentissima</i> Lange-Bertalot							0.5						
<i>Achnanthes minutissima</i> Kützing	0.6	0.9	2.0	1.2	1.6	0.5	0.0	0.5	0.8	1.4	0.4		
<i>Amphora montana</i> Krasske			0.2			0.2							
<i>Amphora pediculus</i> (Kützing) Grunow	0.6	2.6	0.3	14.8	7.2	14.3	7.9	2.7	0.4	0.2	0.9	2.2	
<i>Amphora veneta</i> Kützing													
<i>Cocconeis pediculus</i> Ehrenberg	0.6		0.9		0.1								1.4
<i>Cocconeis placentula</i> v. <i>lineata</i> (Ehrenberg) Van Heurek	2.5	8.7	1.1	0.3	0.4	0.5	0.3	3.2	2.1		2.6	1.4	
<i>Cocconeis placentula</i> v. <i>pseudolineata</i> Geitler								0.2					
<i>Cyclostephanos invisitatus</i> (Hohn & Hel.) Ther., Stoerm. & Håkansson													
<i>Cyclotella bodanica</i> Grunow												0.5	
<i>Cyclotella meneghiniana</i> Kützing			0.3	0.6	0.9	0.7	7.9	0.7	5.0	23.7	0.8	11.4	2.8
<i>Cyclotella</i> sp. 1 (Kützing) de Brébisson				0.2		1.1	0.2		1.1	0.2	2.3		5.6
<i>Cymbella affinis</i> Kützing			0.2			0.1							
<i>Cymbella minuta</i> Hilse	0.3			0.1	0.2							0.4	
<i>Cymbella silesiaca</i> Bleisch			0.2										
<i>Cymbella sinuata</i> Gregory				0.4		0.5							
<i>Cymbellonitzschia</i> sp. Hustedt	0.3												
<i>Diatoma vulgare</i> Bory												0.1	
<i>Diploneis finnica</i> (Ehrenberg) Cleve						0.4							
<i>Epithemia sorex</i> Kützing							0.1						
<i>Epithemia sorex</i> v. <i>sorex</i> Kützing							0.3						
<i>Epithemia turgida</i> v. <i>westermanni</i> (Ehrenberg) Grunow			0.3										

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Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872 ₁	UM-872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
<i>Fragilaria capucina</i> Desmazières	0.4													
<i>Fragilaria capucina</i> v. <i>vaucheriae</i> (Kützinger) Lange-Bertalot														
<i>Fragilaria construens</i> (Ehrenberg) Grunow	0.5													
<i>Fragilaria construens</i> f. <i>venter</i> (Ehrenberg) Hustedt	0.8	1.2		0.9	0.2	0.2		1.8					0.4	
<i>Fragilaria leptostauron</i> v. <i>dubia</i> (Grunow) Hustedt	0.3	0.3					0.3							
<i>Fragilaria pinnata</i> v. <i>pinnata</i> Ehrenberg														
<i>Gomphonema augur</i> Ehrenberg	0.3													
<i>Gomphonema gracile</i> Ehrenberg														
<i>Gomphonema olivaceum</i> (Hornemann) de Brébisson	0.3 0.6 0.5 0.5 0.5													
<i>Gomphonema parvulum</i> (Kützinger) Kützinger	1.4	4.3	0.3	0.4	1.1	0.3	0.2	0.4	0.8	0.9				
<i>Gomphonema pumilum</i> (Grunow) Reichardt & Lange-Bertalot	0.5 0.4 2.4													
<i>Gyrosigma scalproides</i> (Radenhorst) Cleve														
<i>Gyrosigma</i> sp. Hassall														
<i>Gyrosigma spencerii</i> (W. Smith) Cleve	0.3												0.4	0.7
<i>Melosira</i> cf. <i>distans</i> Agardh	0.2													
<i>Melosira granulata</i> (Ehrenberg) Ralfs	1.1 1.0 0.9													
<i>Melosira varians</i> Agardh	0.1 0.5													
<i>Navicula absoluta</i> Hustedt	0.5													
<i>Navicula capitata</i> Ehrenberg	0.2													
<i>Navicula</i> cf. <i>gregaria</i> Donkin	0.2 0.5													
<i>Navicula</i> cf. <i>lacunolacinata</i> Lange-Bertalot & Bonik	1.1 2.6 1.6													4.2
<i>Navicula cryptocephala</i> Kützinger	0.5 0.3 0.6 1.0 0.2 0.9 0.9 2.8													

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Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872 ₁	UM-872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
<i>Navicula cryptotenella</i> Lange-Bertalot		0.3		0.3										
<i>Navicula cuspidata</i> (Kützing) Kützing								0.2						
<i>Navicula decussis</i> v. <i>decussis</i> Østrup							0.5	1.4						
<i>Navicula erifuga</i> Lange-Bertalot							0.5							
<i>Navicula goeppertiana</i> v. <i>goeppertiana</i> (Bleisch) H.L. Smith														
<i>Navicula menisculus</i> v. <i>grunowii</i> Lange-Bertalot	0.1	2.0		2.3	0.6	0.4	1.6	1.6	0.4					2.6
<i>Navicula pupula</i> Kützing						0.4	0.3							
<i>Navicula rhynchocephala</i> Kützing														
<i>Navicula salinarum</i> Grunow				0.9		0.4	1.0	0.7						
<i>Navicula</i> sp. Bory					0.2									
<i>Navicula subminuscula</i> Manguin						0.2	0.5							
<i>Navicula viridula</i> v. <i>germainii</i> (Wallace) Lange-Bertalot	0.1		0.3	0.9	1.0	0.5	0.8	0.7	0.3	0.5				
<i>Nitzschia acicularis</i> (Kützing) W. Smith									0.7	1.2	2.7			2.8
<i>Nitzschia constricta</i> (Kützing) Ralfs														
<i>Nitzschia dissipata</i> (Kützing) Grunow							3.4							
<i>Nitzschia fonticola</i> Grunow			0.3	2.6	1.4	1.1	6.0	2.0	0.2	1.6	3.2	1.8		
<i>Nitzschia fonticola</i> v. <i>pelagica</i> Hustedt		0.3												
<i>Nitzschia gracilis</i> Hantzsch							0.8	0.2	0.7	5.6	0.5	2.6	5.6	
<i>Nitzschia inconspicua</i> Grunow				0.6	0.2	0.5			0.8			0.4		
<i>Nitzschia intermedia</i> Hantzsch									0.2					
<i>Nitzschia palea</i> (Kützing) W. Smith						0.5	6.5		0.4	0.2	12.9	3.6	1.8	7.0
<i>Nitzschia perminuta</i> (Grunow) Peragallo		0.3												
<i>Nitzschia pumila</i> Hustedt						0.4								
<i>Nitzschia reversa</i> W. Smith									0.8	2.3			1.4	
<i>Nitzschia sigmoidea</i> (Nitzsch) W. Smith									0.4					

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Nitzschia sp. Hassall													
Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872 ₁	UM-872 ₁	RU-34	RU-18	CR-23	CR-0.2	BE-54	RED-536	RED-452
Pinnularia microstauron (Ehrenberg) Cleve	0.2												
Rhoicosphenia curvata (Kützing) Grunow	0.3	23.3	0.9	1.0	0.7	2.1	3.2	1.4			0.9		7.0
Stephanodiscus hantzschii (8-11 µm) Grunow	0.2												
Stephanodiscus medius Håkansson	0.5												
Stephanodiscus niagarae Ehrenberg													
Surirella sp. Turpin	0.4												
Surirella visurgis Hustedt	0.8												
Synedra tenera W. Smith	0.5												
Synedra ulna v. ulna (Nitzsch) Lange-Bertalot	0.1	0.1	0.1	0.1	0.4								
Pyrrhophyta (Dinoflagellates)													
Gymnodinium sp. 3 Stein	0.2												
Euglenophyta													
Euglena sp. Ehrenberg	0.8												
Trachelomonas volvocina Ehrenberg													
Miscellaneous													
Batrachospermum vagum (Roth) Agardh	0.4												

¹Quality assurance sample

Table 10. Relative density (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Chlorophyta (Green Algae)												
<i>Ankistrodesmus convolutus</i> Corda			0.5		0.2		0.4					
<i>Ankistrodesmus falcatus</i> (Corda) Ralfs						0.4	1.5					0.8
<i>Chlamydomonas platystigma</i> (Korshikoff) Pascher				0.2								
<i>Chlorococcum</i> sp. Meneghini	15.7	9.0	10.5	1.1	7.6		5.7	7.9	7.2			8.5
<i>Cladophora</i> sp. Kützing	0.2			0.2								
<i>Closterium moniliferum</i> (Bory) Ehrenberg								0.2				
<i>Coelastrum astroideum</i> De Not.							0.4					
<i>Coelastrum microporum</i> Nägeli												
<i>Crucigenia crucifera</i> (Wolle) Collins					0.2							
<i>Crucigenia quadrata</i> Morren												
<i>Dictyosphaerium pulchellum</i> Wood												
<i>Didymogenes anomala</i> (G.M. Smith) Hinkak												
<i>Monoraphidium capricornutum</i> (Printz) Nygaard												
<i>Mougeotia</i> sp. Agardh												
<i>Nephroselmis</i> sp. Stein												
Non-motile Chlorococcales (spherical, >10µm)												
<i>Oedogonium</i> sp. Link		1.0										
<i>Oocystis parva</i> West & West						0.4	1.1					
<i>Pediastrum duplex</i> Meyen												
<i>Pediastrum tetras</i> (Ehrenberg) Ralfs		0.2										
<i>Phacotus</i> sp. Perty								0.2				
<i>Protoderma viride</i> Kützing												
<i>Pyramichlanys</i> sp. Ettl												
<i>Scenedesmus abundans</i> (Kirchner) Chodat				0.7			0.4		0.6			
<i>Scenedesmus acuminatus</i> (Lagerheim) Chodat							0.4					
<i>Scenedesmus bijuga</i> (Turpin) Lagerheim												

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<i>Scenedesmus dimorphus</i> (Turpin) Kützing	0.2											
<i>Scenedesmus opoliensis</i> v. <i>carinatus</i> Lemmermann			0.5	0.2				0.8		0.6		
<i>Scenedesmus quadricauda</i> (Turpin) de Brébisson					0.2			0.4	0.2	1.9	0.7	
<i>Scenedesmus serratus</i> (Corda) Bohlin	0.2	0.1			0.4							
<i>Selenastrum gracile</i> Reinsch								0.4				
<i>Sphaerocystis Schroeteri</i> Chodat	0.6	0.4										
<i>Spirogyra</i> sp. Link					0.4							
<i>Stigeoclonium</i> sp. Kützing												
<i>Tetradron caudatum</i> (Conda) Hansgird												
<i>Tetradron minimum</i> (Braun) Hansgird												
<i>Tetradron regulare</i> var. <i>incus</i> Teiling								0.4				
<i>Tetrasstrum staurogeniaeforme</i> (Schroeder) Lemmermann						0.4		0.4				
Chrysophyta												
Cyst (Chrysophyte)	0.2					0.4					0.7	
Cryptophyta (Cryptomonads)												
<i>Cryptomonas erosa</i> Ehrenberg												
<i>Cryptomonas ovata</i> Ehrenberg		0.2										
Cyanophyta (Blue-Greens)												
<i>Anabaena circinalis</i> Rabenhorst		0.4										
<i>Aphanocapsa delicatissima</i> West & West			0.3									
<i>Aphanocapsa elachista</i> West & West			0.3									
<i>Aphanocapsa koordersi</i> Strom						0.4				0.7		
<i>Aphanolthece saxicola</i> Nägeli											0.7	
<i>Calothrix</i> sp. Agardh						0.2						
<i>Chroococcus minimus</i> (Keissler) Lemmermann			0.3			0.2						
<i>Chroococcus minutus</i> (Kützing) Nägeli		0.3				0.2					0.2	

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<i>Lyngbya digueti</i> Gomont	8.4		0.3			0.2	0.4					
<i>Lyngbya</i> sp. 1 (small) Agardh	0.2											
<i>Lyngbya</i> sp. 3 Agardh												
<i>Lyngbya</i> sp. 4 Agardh												
<i>Lyngbya subtilis</i> West			2.8	1.3	0.2	2.0	3.0	8.0	0.2		2.2	
<i>Merismopedia tenuissima</i> Lemmermann												
Non-motile blue-greens (>1 µm)	59.3	36.0	53.6	39.3	61.7	51.3	66.1	55.2	67.8	85.2	54.0	51.0
<i>Nostoc</i> sp. Vaucher									0.2			
<i>Oscillatoria amphibia</i> Agardh									0.6			
<i>Oscillatoria chlorina</i> Kützing ex Gomont	2.0	2.4	0.7			0.6						
<i>Oscillatoria hamelii</i> Frény										8.6		
<i>Oscillatoria limnetica</i> Lemmermann												
<i>Oscillatoria</i> sp. 4 Vaucher												
<i>Oscillatoria tenuis</i> Agardh			1.3		0.2	0.4			0.2			
<i>Phormidium fragile</i> (Meneghini) Gomont												0.8
<i>Phormidium jadinianum</i> Gomont	0.2											
<i>Pseudanabaena galeata</i> Bocher	0.2	0.2										
<i>Synechococcus elongatus</i> Nägeli	1.7	14.5	27.5	0.9	0.6	0.6	14.0	8.0	0.6	1.3		23.2
<i>Xenococcus</i> sp. Thuret									0.2			
Bacillariophyceae (Diatoms)												
<i>Achnanthes exigua</i> Grunow	1.3											
<i>Achnanthes lanceolata</i> ssp. <i>dubia</i> (Grunow) Lange-Bertalot			0.3								0.7	
<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> Lange-Bertalot						0.4						
<i>Achnanthes lanceolata</i> v. <i>frequentissima</i> Lange-Bertalot												
<i>Achnanthes minutissima</i> Kützing	1.6		0.5	0.4	1.8		0.4					
<i>Amphora montana</i> Krasske			0.3	0.2	0.2	0.2	0.4				0.2	
<i>Amphora pediculus</i> (Kützing) Grunow	0.4	1.9	6.0	9.1	6.6			1.1			2.9	0.8

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<i>Anphora veneta</i> Kützing	0.1							0.4				
<i>Coroneis pediculus</i> Ehrenberg	0.4		1.0					0.4				0.2
<i>Cocconeis placentula</i> v. <i>lineata</i> (Ehrenberg) Van Heurck	8.6	15.4	7.6	1.6	2.2	1.2	2.1	0.4			0.2	
<i>Cocconeis placentula</i> v. <i>pseudolineata</i> Geitler												
<i>Cyclostephanos invisitatus</i> (Hohn & Hel.) Ther., Stoerm. & Håkansson										3.2		
<i>Cyclotella bodanica</i> Grunow												
<i>Cyclotella meneghiniana</i> Kützing			0.8		1.8	0.4	1.7	4.6	2.1	2.6	1.4	
<i>Cyclotella</i> sp. 1 (Kützing) de Brébisson					0.2	0.8					0.7	
<i>Cymbella affinis</i> Kützing												
<i>Cymbella minuta</i> Hilse	0.2		0.3									
<i>Cymbella silesiaca</i> Bleisch	0.2											
<i>Cymbella sinuata</i> Gregory	0.2				0.2	0.2						
<i>Cymbellonitzschia</i> sp. Hustedt												
<i>Diatoma vulgaris</i> Bory												
<i>Diploneis finnica</i> (Ehrenberg) Cleve					0.2							
<i>Epithemia sores</i> Kützing												
<i>Epithemia sores</i> v. <i>sores</i> Kützing						0.8						
<i>Epithemia turgida</i> v. <i>westermanni</i> (Ehrenberg) Grunow							0.2					
<i>Fragilaria capucina</i> Desmazières	0.2											
<i>Fragilaria capucina</i> v. <i>vaucheriae</i> (Kützing) Lange-Bertalot			0.3	0.3								
<i>Fragilaria construens</i> (Ehrenberg) Grunow						0.9	0.6					
<i>Fragilaria construens</i> f. <i>venter</i> (Ehrenberg) Hustedt			0.7		0.7	2.8						
<i>Fragilaria leptostauron</i> v. <i>dubia</i> (Grunow) Hustedt	0.4		0.3		0.2							
<i>Fragilaria pinnata</i> v. <i>pinnata</i> Ehrenberg	0.4											
<i>Gomphonema augur</i> Ehrenberg								0.4				
<i>Gomphonema gracile</i> Ehrenberg											0.5	

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<i>Gomphonema olivaceum</i> (Hornemann) de Brébisson			0.5		0.2						0.7	
<i>Gomphonema parvulum</i> (Kützing) Kützing	2.0	1.7	1.4	0.1	0.9	0.4	0.8		0.4		0.7	0.8
<i>Gomphonema punilum</i> (Grunow) Reichardt & Lange-Bertalot					0.4	1.6		0.4				
<i>Gyrosigma scalprooides</i> (Radenhorst) Cleve		1.4										
<i>Gyrosigma</i> sp. Hassall	0.1											
<i>Gyrosigma spencerii</i> (W. Smith) Cleve											0.2	
<i>Melosira cf. distans</i> Agardh												
<i>Melosira granulata</i> (Ehrenberg) Ralfs				1.3			1.3	1.5	0.4	1.3		0.8
<i>Melosira varians</i> Agardh		0.3	0.3	0.2								
<i>Navicula absoluta</i> Hustedt												
<i>Navicula capitata</i> Ehrenberg												
<i>Navicula cf. gregaria</i> Donkin				0.4							0.8	
<i>Navicula cf. lacunolacinata</i> Lange-Bertalot & Bonik			0.3	0.7	4.4	0.8	0.8	0.4	0.6	0.7	3.1	
<i>Navicula cryptocephala</i> Kützing	0.8	1.1	0.3	0.8	0.4	0.4			0.6	2.2	3.1	
<i>Navicula cryptotenella</i> Lange-Bertalot			1.0	0.2								
<i>Navicula cuspidata</i> (Kützing) Kützing				0.2						0.7		
<i>Navicula decussis</i> v. <i>decussis</i> Østrup			0.7	0.2								
<i>Navicula erifuga</i> Lange-Bertalot				0.2		0.4						
<i>Navicula goeppertiana</i> v. <i>goeppertiana</i> (Bleisch) H.L. Smith	0.2											
<i>Navicula meniscus</i> v. <i>grunowii</i> Lange-Bertalot	0.4	14.8		1.1	2.0	1.1	0.2				1.5	
<i>Navicula pupula</i> Kützing				0.6		0.4						
<i>Navicula rhynchocephala</i> Kützing				0.2								
<i>Navicula salinarum</i> Grunow	2.4		0.3	0.3	0.7	0.8	0.4	0.4				
<i>Navicula</i> sp. Bory	0.4		0.5						0.2			
<i>Navicula subminuscular</i> Manguin								0.4		1.4		
<i>Navicula viridula</i> v. <i>germainii</i> (Wallace) Lange-Bertalot	0.2	0.4	0.3	0.3	1.3	0.8	2.5	1.9	0.8	0.6	0.7	0.2

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<i>Nitzschia acicularis</i> (Kützing) W. Smith	0.2							0.4	4.2			
<i>Nitzschia constricta</i> (Kützing) Ralfs			0.3						0.2			
<i>Nitzschia dissipata</i> (Kützing) Grunow			0.3									
<i>Nitzschia fonticola</i> Grunow			0.5		2.4	2.8	1.3	0.4	5.0	0.6	0.7	
<i>Nitzschia fonticola</i> v. <i>pelagica</i> Hustedt												
<i>Nitzschia gracilis</i> Hantzsch					0.4	0.2		0.8	2.7			0.8
<i>Nitzschia inconspicua</i> Grunow												
<i>Nitzschia intermedia</i> Hantzsch					0.2	0.1		0.4		0.6		
<i>Nitzschia palea</i> (Kützing) W. Smith			0.3		0.2	0.8	0.4		3.6	0.6	9.4	3.1
<i>Nitzschia perminuta</i> (Grunow) Peragallo												
<i>Nitzschia pumila</i> Hustedt						0.4						
<i>Nitzschia reversa</i> W. Smith												
<i>Nitzschia sigmoidea</i> (Nitzsch) W. Smith											0.7	0.2
<i>Nitzschia</i> sp. Hassall	0.2	0.4	0.7									
<i>Pinnularia microstauron</i> (Ehrenberg) Cleve												
<i>Rhoicosphenia curvata</i> (Kützing) Grunow	2.0	4.3	12.8	1.3	7.1	3.4	1.3	0.4				0.6
<i>Stephanodiscus hantzschii</i> (8-11µm) Grunow										0.6		
<i>Stephanodiscus medius</i> Håkansson												
<i>Stephanodiscus niagarae</i> Ehrenberg									0.2			
<i>Surirella</i> sp. Turpin												
<i>Surirella visurgis</i> Hustedt												
<i>Synedra tenera</i> W. Smith			0.3			0.2					0.2	
<i>Synedra ulna</i> v. <i>ulna</i> (Nitzsch) Lange-Bertalot			0.3									
Pyrrhophyta (Dinoflagellates)												
<i>Gymnodinium</i> sp. 3 Stein									0.2			
Euglenophyta												
<i>Euglena</i> sp. Ehrenberg												
<i>Trachelomonas volvocina</i> Ehrenberg												0.2

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Miscellaneous												
<i>Batrachospermum vagum</i> (Roth) Agardh	0.1											