Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

CROW RIVER

Metropolitan Council

December 2014

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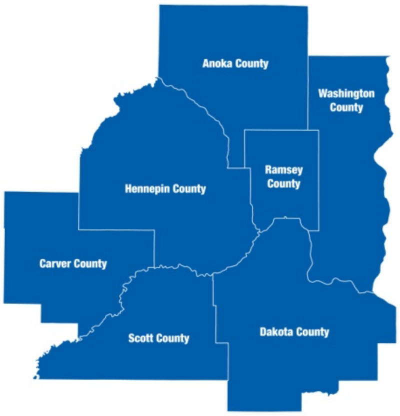

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide housing opportunities for low- and moderate-income individuals and families. The 17-member Council board is appointed by and serves at the pleasure of the governor.

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About the Study

The Twin Cities metropolitan area has a wealth of streams that traverse its landscape and ultimately flow into one of its three major rivers – the Mississippi, the Minnesota, and the St. Croix. These streams provide rich habitat for aquatic life and wildlife and enhance the recreational and aesthetic value of the metro area.

The Metropolitan Council is committed to the conscientious stewardship of the region's streams and works with its partners to maintain and improve their health and function. The foundation for these efforts is the collection and analysis of high-quality data about their condition over time.

The *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* is a major study conducted by the Metropolitan Council that examines the water quality of 21 streams or stream segments that discharge into the metropolitan area's major rivers. The study provides a base of technical information that can support sound decisions about water resources in the metro area − decisions by the Council, state agencies, watershed districts, conservation districts, and county and city governments.

All background information, methodologies, and data sources are summarized in *Introduction and Methodologies*, and a glossary and a list of acronyms are included in *Glossary and Acronyms*. Both of these, as well as individual sections for each of the 21 streams, are available for separate download from the report website. The staff of Metropolitan Council Environmental Services (MCES) and local cooperators conducted the stream monitoring work, while MCES staff performed the data analyses, compiled the results and prepared the report.

About This Section

This section of the report, *Crow River*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Stretching across much of south-central Minnesota, the Crow River is one of the eight Mississippi River tributaries examined. This section discusses a wide range of factors that have affected the condition and water quality of the Crow River.

CLEAN WATER LAND & LEGACY AMENDMENT

Cover Photo

The photo on the cover of this section depicts the Crow River near Hutchinson, MN. (photo credit Kevin Bare / Crow Organization of Water (CROW)).

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Introduction

The Crow River is a major tributary to the Mississippi River above the confluence with the Minnesota River, and is located primarily west of the metropolitan area. It drains approximately 2,755 square miles of mixed agricultural land, open space, forest land, and urban areas. The majority of the Crow River watershed is located outside the metro area, but portions of Hennepin and Carver County are within the watershed.

This report:

- documents the characteristics of the Crow River and its watershed most likely to influence stream flow and water quality.
- presents the results from assessments of flow and water quality.
- presents statistical assessments of trends in TSS (total suspended solids), TP (total phosphorus), and NO_3 (nitrate).
- draws conclusions about possible effects of landscape features, climatological changes, and human activities on flow and water quality.
- compares the Crow River flow and water quality with other streams within the metropolitan area monitored by Metropolitan Council Environmental Services (MCES).
- makes general recommendations for future monitoring and assessment activities, watershed management, and other potential actions to remediate any water quality or flow concerns.

MCES plans to update this report approximately every five to 10 years, in addition to issuing annual data and load summary reports.

Partnerships and Funding

MCES monitors two sites on the Crow River. MCES has supported water quality monitoring of the Crow River at Rockford, Minnesota since 1998 and on the South Fork of the Crow River near Mayer, Minnesota since 2001 as part of its Watershed Outlet Monitoring Program (WOMP). Partial funding for the Rockford site is provided by the Minnesota Legislature through a grant from the Minnesota Pollution Control Agency (MPCA) using Clean Water Land and Legacy Amendment funds.

The Crow River site at Rockford is operated in partnership with the Wright County Soil and Water Conservation District (WCSWCD) and the United States Geological Survey (USGS). WCSWCD maintains and operates the monitoring station and collects water quality samples (approximately 20-30 samples per year). The USGS has been monitoring flow at this location, station number 05280000, since 1906. The USGS also intermittently collected water quality samples at this station from 1952 to 1997.

MCES partners with the Minnesota Department of Natural Resources (MnDNR) to maintain the South Fork of the Crow River station's stage measurement equipment, rating curve, and rain gauge. This station (MnDNR Waters Station Number 19082001) is part of the MnDNR's statewide flood-forecasting network. Flow has been measured at this location since 1999.

MCES also partners with Carver County Environmental Services to operate and maintain the monitoring station and collect water samples.

Monitoring Station Description

Crow River at Rockford

The monitoring station is located on the main stem of the Crow River in Rockford, Minnesota, 23.1 miles upstream from the confluence with the Mississippi River. The monitoring site is one mile downstream of the confluence of the North and South Forks of the Crow River, and thus provides data on the combined flows and pollutant loads (Figure CW-1).

Figure CW-1: Crow River Station below Highway 55 near Rockford (CW 23.1)

The main stem monitoring station includes continuous stage monitoring, base flow grab sample collection, event-based composite sample collection, and *in situ* conductivity and temperature probes. The USGS and MCES both monitor this site but have different shelters. The USGS measures stage with a shaft encoder and a pressure transducer, and calibrate stage during site visits with a staff gauge in the stilling well. A continuous discharge record is obtained by relating stage to flow with a rating unique to the site. MCES relies on the current USGS rating curve which includes a flow value every 0.01 foot of stage, and fits an equation to those values. The USGS makes 6-12 measurements a year at the site and adjusts the rating curve when measurements fall significantly off the existing curve or when a change in the station cross-section is observed. MCES adjusts its rating accordingly after the USGS rating is adjusted.

MCES maintains its own rating curve and gas-purge bubbler stage sensor in order to trigger the autosampler for event-based composite sample collection, and in order to generate a continuous flow record for the calendar year. The USGS operates on an October to September water year; October to December flows for a given calendar year are not reviewed or approved by the USGS until the following winter. During data review the MCES and USGS flows are compared to ensure consistency.

A tipping bucket rain gauge is present at this location for measurement of precipitation. However, because there were some gaps in the precipitation record, daily precipitation totals from Minnesota Climatology Working Group stations 217020-Rockford and 211448-Chanhassen WSFO were used to create the hydrograph in the ***Hydrology*** section of this report. For the analysis of precipitation-weighted loads, MCES used the Minnesota Climatological Working Group's monthly 10-kilometer gridded precipitation data to ensure the variability of rainfall within the watersheds was represented (Minnesota Climatology Working Group, 2013). This data is generated from Minnesota's HIDEN (High Spatial Density Precipitation Network) dataset. The gridded data was aerially-weighted based on the watershed boundaries.

Water quality monitoring at the Crow River at Rockford station began in 1998, with the first full year of water quality sample collection beginning in 1999. This report uses flow data from 1998 to 2012, and water quality data from 1999 to 2012.

South Fork of the Crow River near Mayer

The monitoring station is located on the South Fork of the Crow River north of Mayer, Minnesota, on the north side of Hwy. 7, 20.3 miles upstream from the South Fork confluence with the North Fork of the Crow River in Rockford (Figure CW-2).

Figure CW-2: South Fork Crow River Station near Mayer (CWS 20.3)

The South Fork monitoring station includes continuous flow monitoring, event-based composite sample collection, and continuous *in situ* water temperature. The MnDNR and MCES both monitor this site but have different shelters. The MnDNR measures stage with a pressure transducer and calibrates stage on site visits with a staff gauge (MnDNR, 2009). A continuous discharge record is obtained by relating stage to flow with a rating unique to the site. The MnDNR makes several measurements a year at the site and adjusts the rating when measurements fall significantly from the existing curve or when a change in the station cross-section is observed. MCES does not generate a continuous flow record from its own data, but relies on the MnDNR flow record. MCES does have its own gas-purge bubbler stage sensor to trigger the autosampler for event-based composite sample collection, but the autosampler has not been in operation since 2010.

A tipping bucket rain gauge is present at this location for measurement of precipitation. However, because there were some gaps in the precipitation record, daily precipitation totals from Minnesota Climatology Working Group stations 219085-Winsted, 217020-Rockford, 211448-Chanhassen WSFO, and 214692-Lester Prairie 1E were used to create the hydrograph in the ***Hydrology*** section of this report. For the analysis of precipitation-weighted loads, MCES used the Minnesota Climatological Working Group's monthly 10-kilometer gridded precipitation data to ensure the variability of rainfall within the watersheds was represented (Minnesota Climatology Working Group, 2013). This data is generated from Minnesota's HIDEN (High Spatial Density Precipitation Network) dataset. The gridded data was aerially-weighted based on the watershed boundaries.

Water quality monitoring at the South Fork of the Crow River near Mayer station began in 2001, with the first full year of water quality sample collection beginning in 2002. This report uses flow data from 2001 to 2012, and water quality data from 2002 to 2012.

Stream and Watershed Description

The Crow River has two main branches - the North and South Forks - which join together near the city of Rockford. The North Fork headwaters originate at Grove Lake in eastern Pope County. The North Fork flows to the southeast for 157.4 miles through Stearns, Kandiyohi, Meeker, and Wright Counties before converging with the South Fork at the northwestern corner of Hennepin County at Rockford. The South Fork headwaters originate at Little Kandiyohi Lake in Kandiyohi County. The river flows to the east and northeast for 112.9 miles through Meeker, McLeod, Carver, and Wright Counties before converging with the North Fork. The main stem continues on from Rockford to the northeast for 25.7 miles until it discharges into the Mississippi River near the city of Dayton.

The North Fork of the Crow River has a number of smaller tributaries, among them the Middle Fork of the Crow River, Grove Creek, and Sucker Creek. The South Fork of the Crow River has one major tributary, Buffalo Creek, which drains the southern portion of the watershed, and a number of smaller tributaries. Most waterways in the western portion of the watershed are ditched, including South Fork Crow River and Buffalo Creek.

In 1976, the State of Minnesota included the North Fork of the Crow River in the Wild and Scenic Rivers Program. According to the Minnesota Department of Natural Resources (MnDNR), in order to qualify for this program, a river “must possess outstanding scenic, recreation, natural, historical, scientific, or similar values” (MnDNR, 2014a). The reach of the North Fork of the Crow River that starts at the spillway at the southern end of Lake Koronis to the Meeker-Wright County line was designated a Recreational River. This designation increases the management activities to ensure the unique characteristics of the river are maintained.

While many of the watershed’s wetlands have been ditched and drained, a number of lakes and open water wetlands still exist (for example, Koronis Lake (2,968 acres), Green Lake (5,561 acres), Lake Diamond (1,607 acres), Lake Wakanda (1,754 acres), Big Kandiyohi Lake (2,682 acres), Cedar Lake (1,860 acres), Lake Washington (2,434 acres), Howard Lake (745 acres), and Lake Buffalo (1,552 acres)). For more information about all of the lakes in the watershed, please see the Lake Finder website maintained by the MnDNR (MnDNR, 2014b).

The Crow River watershed is a total of 1,762,955 acres (extending to the confluence with the Mississippi River), with 1,687,041 acres (95.7%) upstream of the monitoring station at Rockford. The entire watershed encompasses all or parts of the counties of Carver, Hennepin, Kandiyohi, McLeod, Meeker, Pope, Renville, Sibley, Stearns, and Wright. The entire watershed has 1,028,560 acres/ 58.3% (1,004,178 acres/ 59.5% upstream of Rockford monitoring station) of agricultural land, and only 123,388 acres/ 7% (112,362 acres/ 6.7% upstream of Rockford monitoring station) developed urban land, including all or parts of the cities of Albertville, Atwater, Belgrade, Bird Island, Biscay, Brooten, Brownton, Buffalo, Buffalo Lake, Cedar Mills, Cokato, Corcoran, Cosmos, Darwin, Dassel, Dayton, Delano, Elrosa, Glencoe, Greenfield, Grove City, Hanover, Hector, Howard Lake, Hutchinson, Independence, Kandiyohi, Kingston, Lake Lillian, Lester Prairie, Litchfield, Loretto, Maple Lake, Maple Plain, Mayer, Medina, Minnetrista, Monticello, Montrose, New Germany, New Long, Norwood Young America, Otsego, Paynesville, Plato, Regal, Rockford, Rogers, Saint Michael, Sedan, Silver Lake, Spicer, Stewart, Watertown, Waverly, Willmar, and Winsted.

The North Fork of the Crow River watershed plus the South Fork Downstream watershed (that portion of the South Fork watershed between the Mayer and Rockford monitoring stations) comprises 49.3% of the total watershed area; the South Fork of the Crow River watershed upstream of the Mayer monitoring station comprises 46.4%, and the main stem of the Crow River watershed downstream of the Rockford monitoring station (Main Stem Crow Unmonitored watershed) comprises the remaining 4.3% of the total watershed area. The South Fork Crow watershed has the highest percentage of agricultural land (68.2%), followed by the North Fork Crow watershed (51.4%) and the Main Stem Crow Unmonitored watershed (32.1%). The Main Stem Crow Unmonitored watershed has the greatest percentage of urban areas (14.5%), followed by the South Fork Crow watershed (7.1%), and the North Fork Crow watershed (6.3%). Tables CW-1, CW-2, and CW-3, and Figure CW-3 show the land cover of subwatersheds.

Watershed management within the Crow River watershed is covered by a variety of government and joint powers organizations. Parts of the Crow River watershed are contained within the North Fork Crow River, Middle Fork Crow River, and Buffalo Creek Watershed Districts. That portion of the Crow River watershed contained within Carver County is part of the Carver County Watershed Management Organization. Parts of the Crow River watershed within Hennepin County are contained within the Pioneer-Sarah Creek Water Management Commission and the Elm Creek Watershed Management Commission. Technical support for both of these governmental joint powers organizations is provided by Hennepin County Department of Environmental Services. The entire watershed, whether located in a formal watershed management organization or not, is included under the auspices of the Crow River Organization of Water (CROW) Joint Powers Board, a joint powers organization of the ten counties with land in the Crow River watershed. The CROW was formed to deal with water quality and quantity issues through the entire Crow River watershed, but has no regulatory, permitting, or taxation authority. County soil and water conservation districts are also active in managing the Crow River watershed. The portion of the Crow River watershed inside the seven-county metropolitan area falls within Metropolitan Council Districts 1, 3, and 4.

Table CW-1: Crow River Land Cover Classes[1]

Land Cover Class	Area Draining to Rockford Monitoring Station (North Fork Crow, South Fork Crow, South Fork Crow Downstream Watersheds)		Main Stem Crow Unmonitored[2]		Total to Confluence with Mississippi River	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	34,009	2.0%	451	0.6%	34,460	2.0%
11-25% Impervious	13,696	0.8%	3,786	5.0%	17,482	1.0%
26-50% Impervious	28,158	1.7%	3,154	4.2%	31,312	1.8%
51-75% Impervious	6,282	0.4%	1,231	1.6%	7,512	0.4%
76-100% Impervious	30,218	1.8%	2,403	3.2%	32,621	1.9%
Agricultural Land	1,004,178	59.5%	24,382	32.1%	1,028,560	58.3%
Forest (all types)	72,950	4.3%	7,178	9.5%	80,128	4.5%
Open Water	67,887	4.0%	5,710	7.5%	73,598	4.2%
Barren Land	450	0.0%	11	0.0%	461	0.0%
Shrubland	13,241	0.8%	1,017	1.3%	14,258	0.8%
Grasses/Herbaceous	179,804	10.7%	15,931	21.0%	195,734	11.1%
Wetlands (all types)	236,168	14.0%	10,662	14.0%	246,830	14.0%
Total	**1,687,041**	**100.0%**	**75,915**	**100.0%**	**1,762,955**	**100.0%**

[1] Land cover spatial data file provided by MnDNR. The data is a composite of the 2008 MLCCS (Minnesota Land Cover Classification System), which covered primarily the 7-county metro area; and the 2001 NLCD (National Land Cover Data), which covered the outstate areas not included in the 2008 MLCCS.

[2] The Main Stem Crow Unmonitored watershed in Table CW-1 represent the drainage area of the main stem of the Crow River downstream of the MCES monitoring station at Rockford, Minnesota extending to the confluence with the Mississippi River. See Figure CW-3.

Table CW-2: North Fork of the Crow River Land Cover Classes[1]

Land Cover Class	North Fork Crow Watershed[2]	
	Acres	Percent
5-10% Impervious	16,361	1.9%
11-25% Impervious	8,627	1.0%
26-50% Impervious	11,931	1.4%
51-75% Impervious	2,442	0.3%
76-100% Impervious	15,142	1.7%
Agricultural Land	446,430	51.4%
Forest (all types)	44,500	5.1%
Open Water	43,407	5.0%
Barren Land	133	0.0%
Shrubland	10,537	1.2%
Grasses/Herbaceous	119,374	13.7%
Wetlands (all types)	150,063	17.3%
Total	**868,946**	**100.0%**

[1] Land cover spatial data file provided by MnDNR. The data is a composite of the 2008 MLCCS (Minnesota Land Cover Classification System), which covered primarily the 7-county metro area; and the 2001 NLCD (National Land Cover Data), which covered the outstate areas not included in the 2008 MLCCS.

[2] The North Fork Crow watershed in Table CW-2 represents the drainage area of the North Fork of the Crow River plus the small amount of drainage area between the North and South Fork confluence and the monitoring station at Rockford. See Figure CW-3.

Table CW-3: South Fork of the Crow River and South Fork Downstream Watershed Land Cover Classes[1]

Land Cover Class	South Fork Crow (that area draining to the monitoring station at Mayer)		South Fork Downstream[2]		Total South Fork	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	15,834	2.2%	1,814	2.2%	17,648	2.2%
11-25% Impervious	1,373	0.2%	3,696	4.5%	5,069	0.6%
26-50% Impervious	13,703	1.9%	2,524	3.1%	16,227	2.0%
51-75% Impervious	3,158	0.4%	681	0.8%	3,840	0.5%
76-100% Impervious	13,487	1.8%	1,589	1.9%	15,076	1.8%
Agricultural Land	525,792	71.4%	31,956	38.9%	557,748	68.2%
Forest (all types)	19,798	2.7%	8,652	10.5%	28,450	3.5%
Open Water	20,899	2.8%	3,581	4.4%	24,480	3.0%
Barren Land	251	0.0%	67	0.1%	318	0.0%
Shrubland	2,124	0.3%	580	0.7%	2,704	0.3%
Grasses/Herbaceous	48,281	6.6%	12,148	14.8%	60,430	7.4%
Wetlands (all types)	71,337	9.7%	14,769	18.0%	86,105	10.5%
Total	**736,038**	**100.0%**	**82,057**	**100.0%**	**818,095**	**100.0%**

[1] Land cover spatial data file provided by MnDNR. The data is a composite of the 2008 MLCCS (Minnesota Land Cover Classification System), which covered primarily the 7-county metro area; and the 2001 NLCD (National Land Cover Data), which covered the outstate areas not included in the 2008 MLCCS.

[2] The South Fork Downstream watershed in Table CW-3 represents the drainage area of the South Fork downstream of the MCES monitoring station at Mayer. See Figure CW-3.

Figure CW-3

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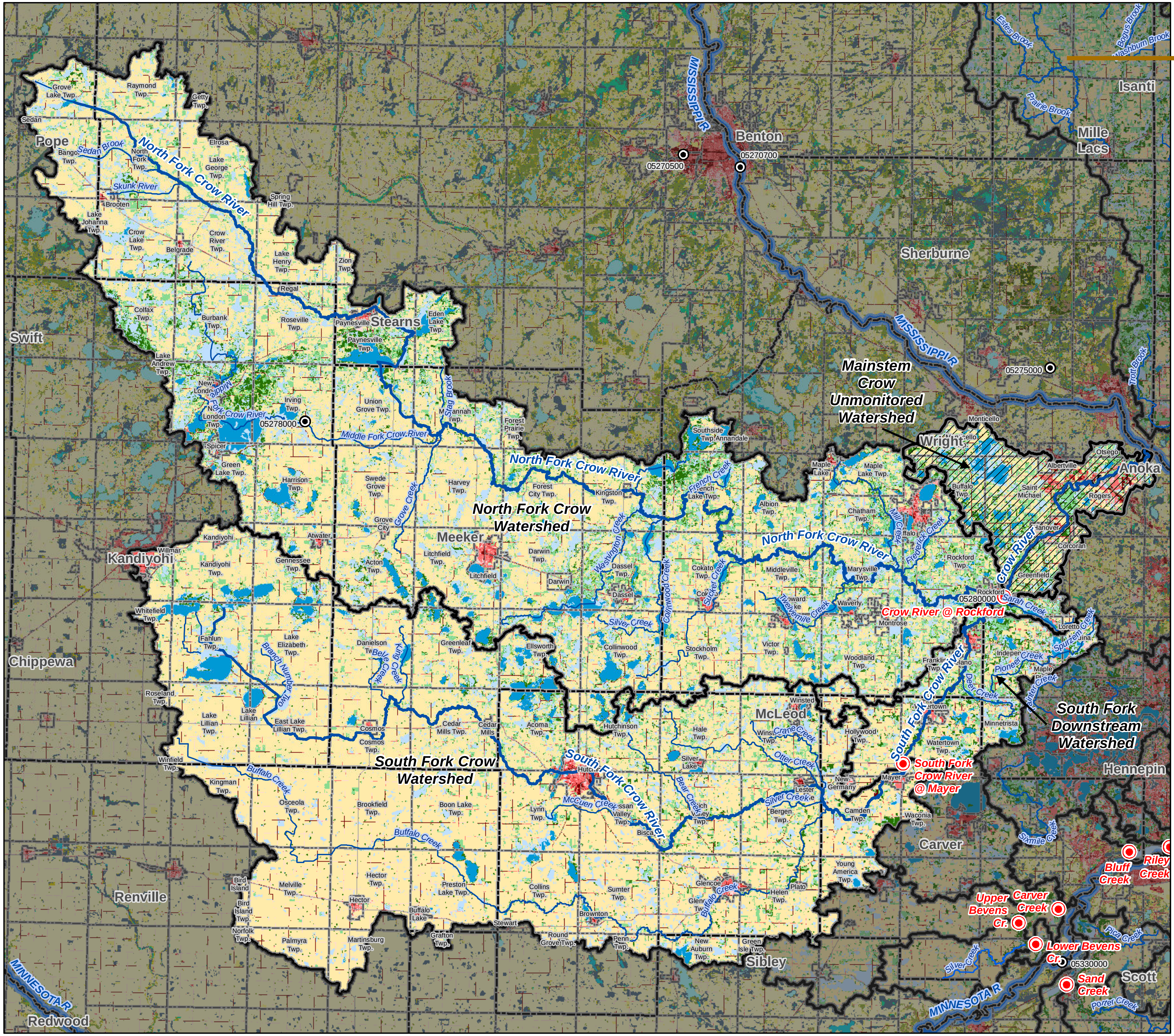
MLCCS-NLCD Hybrid Land Cover

Crow River (North and South Forks)



- MCES Stream Monitoring Sites
- USGS Flow Stations
- Mainstems (Monitored and Unmonitored)
- Major Mainstem Tributaries
- Monitored Watershed Boundaries
- Unmonitored Portion of Watersheds
- Highways and Other Major Roads (MnDOT)
- County Boundary
- City and Township Boundaries

MLCCS-NLCD Hybrid Land Cover

- 5-10% Impervious
- 11-25% Impervious
- 26-50% Impervious
- 51-75% Impervious
- 76-100% Impervious
- Agricultural Land
- Barren Land (rock, mud)
- Forest (all types)
- Grasses/Herbaceous
- Open Water
- Shrubland
- Unknown, or No Data
- Wetlands (open water, forest, shrub and emergent)

Data Source: MnDNR

Watershed land cover tabulated within report text.

0 5 10 15

Miles

Based on the United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) 2009 Cropland Data Layer, the agricultural land in the Crow River watershed is primarily planted in corn (38%) and soybeans (31%). The South Fork watershed has a greater percentage of agricultural areas planted in corn (42%) and soybeans (34%), while the North Fork watershed has a lower percentage planted in corn (33%) and soybeans (28%). Other prominent land covers in the watershed are grassland and wetlands. According to a statewide estimate of potentially drain tiled fields by University of Minnesota researchers (D. Mulla, University of Minnesota, personal communication, 2012), 34% of the agricultural land in the entire watershed is potentially drain tiled (46% of the South Fork watershed; 21% of the North Fork watershed).

The Crow River watershed was last glaciated during the Wisconsin Glaciation, which began approximately 75,000 years ago (Lusardi, 1997). Two separate lobes of the glacier advanced and retreated over the watershed. The Wadena Lobe deposited glacial till and created the moraines in the northwest portion of the watershed know as the Alexandria moraine. Later, the Des Moines Lobe advanced and retreated, depositing till from the Altamont moraine. As the glaciers retreated they exposed the limestone, dolomite, sandstone, and shale bedrock.

The South Fork watershed is generally quite flat and the surficial geology is mostly made up of glacial till with a high percentage of silt and clay (CROW, 2005). The maximum watershed elevation is 1297.0 MSL (above mean sea level) and the minimum elevation is 891.0 MSL (Figure CW-4). Less than 1% of the slopes are considered steep or very steep. Steep slopes are those between 12-18%, and very steep slopes are those 18% or greater (MnDNR, 2011).

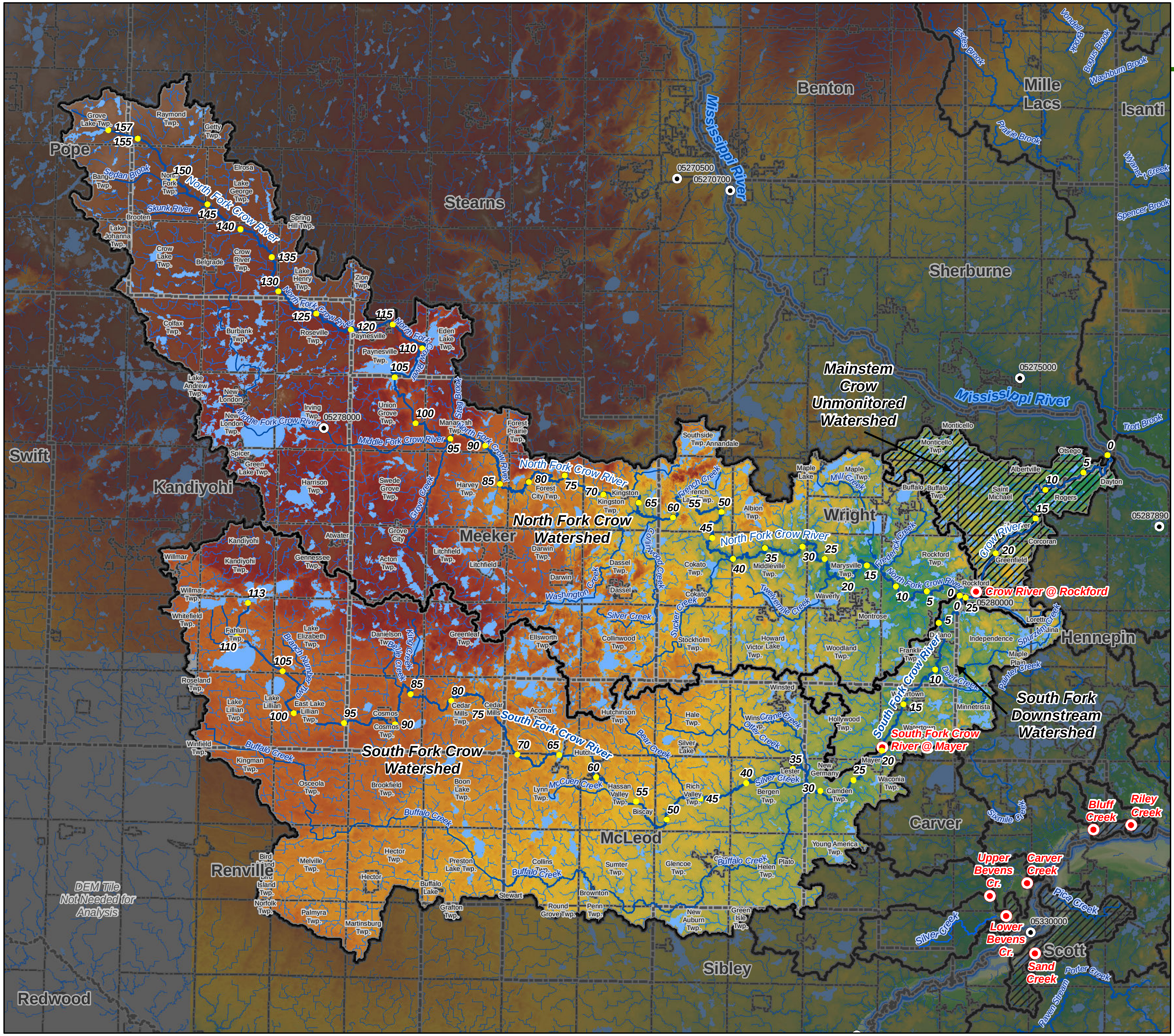
The North Fork watershed has more varied topography than the South Fork, with some areas of nearly flat to gently rolling hills, as well as a band of more steeply sloped lands through Kandiyohi and northwestern Meeker counties, with pockets of steep slopes in the northeastern part of the watershed. The surficial geology is some glacial till, but also outwash sands and gravels (CROW, 2005). The maximum watershed elevation is 1411.9 MSL at the northwest end of the North Fork watershed (Figure CW-4). The minimum elevation is 891.0 MSL in the eastern part of the watershed. 1% of the slopes in the North Fork watershed are considered steep, and less than 1% are considered very steep.

According to the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) STATSGO soils data, the majority (66%) of native soils in the entire Crow River watershed are B soils, which have moderately low runoff potential (USDA, 2009).. The remaining soils are primarily B/D soils (24%), which have high runoff potential if undrained, and moderately low runoff potential if drained, and C/D soils (8%), which have a high runoff potential if undrained, and a moderately high runoff potential if drained. Within the South Fork watershed, 40% of soils are categorized as B soils, 44% are categorized as B/D soils, and 15% are categorized as C/D soils. The B/D and C/D soils are primarily located in the western portion of the South Fork Crow River watershed. Within the North Fork watershed, 88% of soils are categorized as Type B, and 7% are categorized as Type B/D.

Figure CW-4

Watershed Topography

Crow River (North and South Forks)



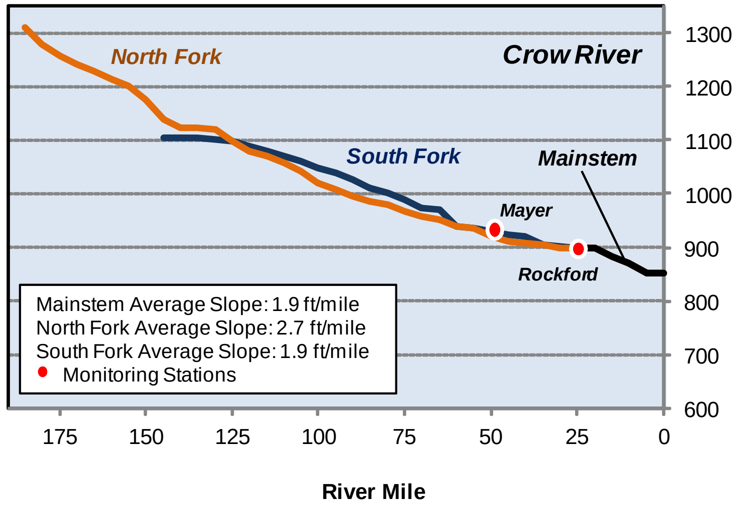
- MCES Stream Monitoring Sites
- USGS Flow Stations
- Mainstems (Monitored and Unmonitored)
- Stream Mile Markers
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- County Boundaries
- City and Township Boundaries
- Public Waters Inventory
- Other Rivers and Streams

Elevation
Feet Above Mean Sea Level

High : 1594
1400
1200
1000
800
Low : 643

Source: USGS National Elevation Dataset, 1/3 arc-second, 10-meter resolution

Elevation (Feet Above Mean Sea Level)



0 5 10 15 20
Miles

The South Fork watershed contains 20 domestic wastewater treatment plants (WWTPs), 16 of which are in the monitored part of the watershed (labeled “South Fork Crow Watershed” on Figure CW-5). The South Fork Crow Watershed includes five Class A facilities, with the three largest facilities - Glencoe, Willmar and Hutchinson WWTPs - having a combined design flow of approximately 13.1 MGD (20.2 cfs). The South Fork Downstream Watershed has an additional four domestic wastewater treatment facilities, including one Class A facility. Table CW-4 lists the domestic WWTPs, and includes design flows and known information about when phosphorus removal commenced. All of the Class A facilities had commenced phosphorus removal by the end of 2010 or were already discharging an acceptable level of phosphorus.

Table CW-4: Permitted Domestic Wastewater Treatment Plants (WWTPs) Discharging to South Fork Crow River and South Fork Downstream Watersheds

Permit #[1]	Permit Holder	Design Flow (mgd)	Class	Phosphorus removal[2]	General Notes[2]
MN0055832	Hutchinson WWTP	5.43	A	Commenced 07/2009	—
MN0025259	Willmar WWTP	5.04	A	Commenced 10/2010	—
MN0022233	Glencoe WWTP	2.6	A	P consistently > 4 mg/l	Reissued permit will require 2874 kg/yr P limit
MN0021571	Winsted WWTP	0.82	C	Commenced 07/2012	—
MN0025445	Hector WWTP	0.66	B	No P limit	09/2005 showed slight decrease in P concentration
MN0021202	Mayer WWTP	0.435	A	Commenced 11/2002	—
MN0023957	Lester Prairie WWTP	0.364	A	Commenced 05/2007	—
MN0022951	Brownton WWTP	0.196	B	P consistently > 3 mg/l	—
MN0050211	Buffalo Lake WWTP	0.165	C	NA	—
MNG580164	Silver Lake WWTP	0.139	D	NA	—
MNG580077	Stewart WWTP	0.114	D	NA	—
MN0023841	Kandiyohi WWTP	0.112	C	NA	—
MNG580056	Cosmos WWTP	0.09	D	NA	—
MN0021954	Lake Lillian WWTP	0.0535	D	NA	—

Table CW-4: Permitted Domestic Wastewater Treatment Plants (WWTPs) Discharging to South Fork Crow River and South Fork Downstream Watersheds

Permit #[1]	Permit Holder	Design Flow (mgd)	Class	Phosphorus removal[2]	General Notes[2]
MN0069388	Blomkest Svea Sewer Board WWTP	0.04	D	NA	—
MN0066605	Cedar Mills WWTP	0.00915	C	NA	—
MN0051250[4]	Delano WWTP	2.199	A	Commenced 08/2005	—
MN0020940[4]	Watertown WWTP	1.262	B	No significant P reduction	—
MN0023990[4]	Loretto WWTP	0.061	C	NA	—
MN0024295[4]	New Germany WWTP	0.052	D	NA	—

[1] Facilities with design flow > 1 mgd shown in gray

[2] In general, Class A and B WWTPs are mechanical systems with activated sludge which continuously discharge; Class D WWTPs are stabilization ponds with assumed acceptable discharge periods of March 1 – June 15 (spring discharge) and September 15 – December 31 (fall discharge). See Minn.Rule 9400.0500 Classification of Facilities for more information.

[3] Information provided by MPCA, April 2013. Information was not tabulated for smallest facilities and thus labeled NA.

[4] Facility located downstream of the Mayer monitoring station in the “South Fork Downstream Watershed”

The North Fork Watershed contains 16 domestic WWTPs, and the Main Stem Crow Unmonitored Watershed includes an additional 5 wastewater treatment facilities. The North Fork watershed includes two Class A WWTPs - Litchfield and Green Lake SSWD - which collectively have a design flow of 3.3 MGD. The Main Stem Crow Unmonitored Watershed includes one Class A facility. The five facilities in the Main Stem Crow Unmonitored Watershed have a combined design flow of approximately 6.4 MGD (9.9 cfs). Table CW-5 tabulates the domestic WWTPs discharging to the North Fork Crow and Main Stem Crow Unmonitored Watersheds, and includes the design flow where included in the permit, and known information about when phosphorus removal commenced.

Table CW-5: Permitted Domestic Wastewater Treatment Plants (WWTPs) Discharging to North Fork Crow River and Main Stem Crow Unmonitored Watersheds

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus removal[3]	General Notes[3]
MN0040649	Buffalo WWTP	3.6	B	Commenced 09/2009	—
MN0023973	Litchfield WWTP	2.37	A	Commenced	—

Table CW-5: Permitted Domestic Wastewater Treatment Plants (WWTPs) Discharging to North Fork Crow River and Main Stem Crow Unmonitored Watersheds

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus removal[3]	General Notes[3]
				04/2004	
MN0052752	Green Lake SSWD WWTP	0.889	A	No P removal	Reissued permit in 12/2013 likely will include P limit
MN0020168	Paynesville WWTP	0.887	C	Commenced 03/2010	—
MN0066966	Annandale/Maple Lake/Howard Lake WWTP	0.827	B	Commenced 09/2009	New facility in 2009 replacing old facilities for Annandale, Maple Lake, and Howard Lake
MN0024228	Montrose WWTP	0.781	B	Commenced 07/2004	—
MN0049204	Cokato WWTP	0.726	C	No P removal	Reissued permit in 2015 likely will include P limit
MN0024082	Maple Lake WWTP	0.461	B	Commenced 1995	Ceased operation in 11/2010. Connected to new Annandale/Maple Lake/Howard Lake WWTP
MN0051926	Howard Lake WWTP	0.369	B	Commenced 1995.	Ceased operation in 01/2010. Connected to new Annandale/Maple Lake/Howard Lake WWTP
MN0023574	Grove City WWTP	0.224	C	NA	—
MN0022659	Atwater WWTP	0.2	D	NA	—
MN0063762	Greenfield WWTP	0.2	B	NA	—
MN0054127	Dassel WWTP	0.188	B	NA	—
MN0051381	Belgrade WWTP	0.167	D	NA	—
MN0025909	Brooten WWTP	0.133	D	NA	—
MNG580150	Darwin WWTP	0.05	D	NA	—
MN0020222[4]	Saint Michael WWTP	2.445	B	Commenced 07/2002	—
MN0064190[4]	Otsego East WWTP	1.65	A	P<1 mg/l since 12/2000	—

Table CW-5: Permitted Domestic Wastewater Treatment Plants (WWTPs) Discharging to North Fork Crow River and Main Stem Crow Unmonitored Watersheds

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus removal[3]	General Notes[3]
MN0029629[4]	Rogers WWTP	1.602	B	Commenced 12/1996	—
MN0024627[4]	Rockford WWTP	0.651	B	Minor reductions from 6/6 mg/l before 10/2007 to 4.4 mg/l after 10/2007	New permit issues 12/2012 requires P limit of 899 kg/yr.
MN0066753[4]	Meadows of Whisper Creek WWTP	0.02	B	NA	—

[1] Facilities with design flow > 1 mgd shown in gray

[2] In general, Class A and B WWTPs use mechanical systems with activated sludge that continuously discharge; Class D WWTPs are stabilization ponds with assumed acceptable discharge periods of March 1 – June 15 (spring discharge) and September 15 – December 31 (fall discharge). See Minn.Rule 9400.0500 Classification of Facilities for more information.

[3] Information provided by MPCA, April 2013. Information was not tabulated for smallest facilities and thus labeled NA.

[4] Facility located downstream of the monitoring station at Rockford, in the Main Stem Crow Unmonitored Watershed

The South Fork Crow Watershed has two cooling, potable, treatment and dewatering facilities, seven facilities holding industrial wastewater permits, and 27 facilities holding industrial stormwater permits (Figure CW-5). The South Fork Downstream Watershed has one cooling, potable, treatment and dewatering facility, one facility holding an industrial wastewater permit, and seven facilities holding industrial stormwater permits.

The North Fork Crow Watershed has five facilities holding industrial wastewater permits and 28 facilities holding industrial stormwater permits (Figure CW-5). There are ten additional facilities holding industrial stormwater permits in the Main Stem Crow Unmonitored Watershed.

The South Fork Crow Watershed has 733 registered feedlots, with a total of 133,555 animal units, including 346 feedlots having 100 or more animal units. The South Fork Downstream Watershed has an additional 83 feedlots with 7,289 animal units, including 24 feedlots with 100 animal units or more. The largest feedlot in the South Fork watershed is a farm with 5,445 animal units.

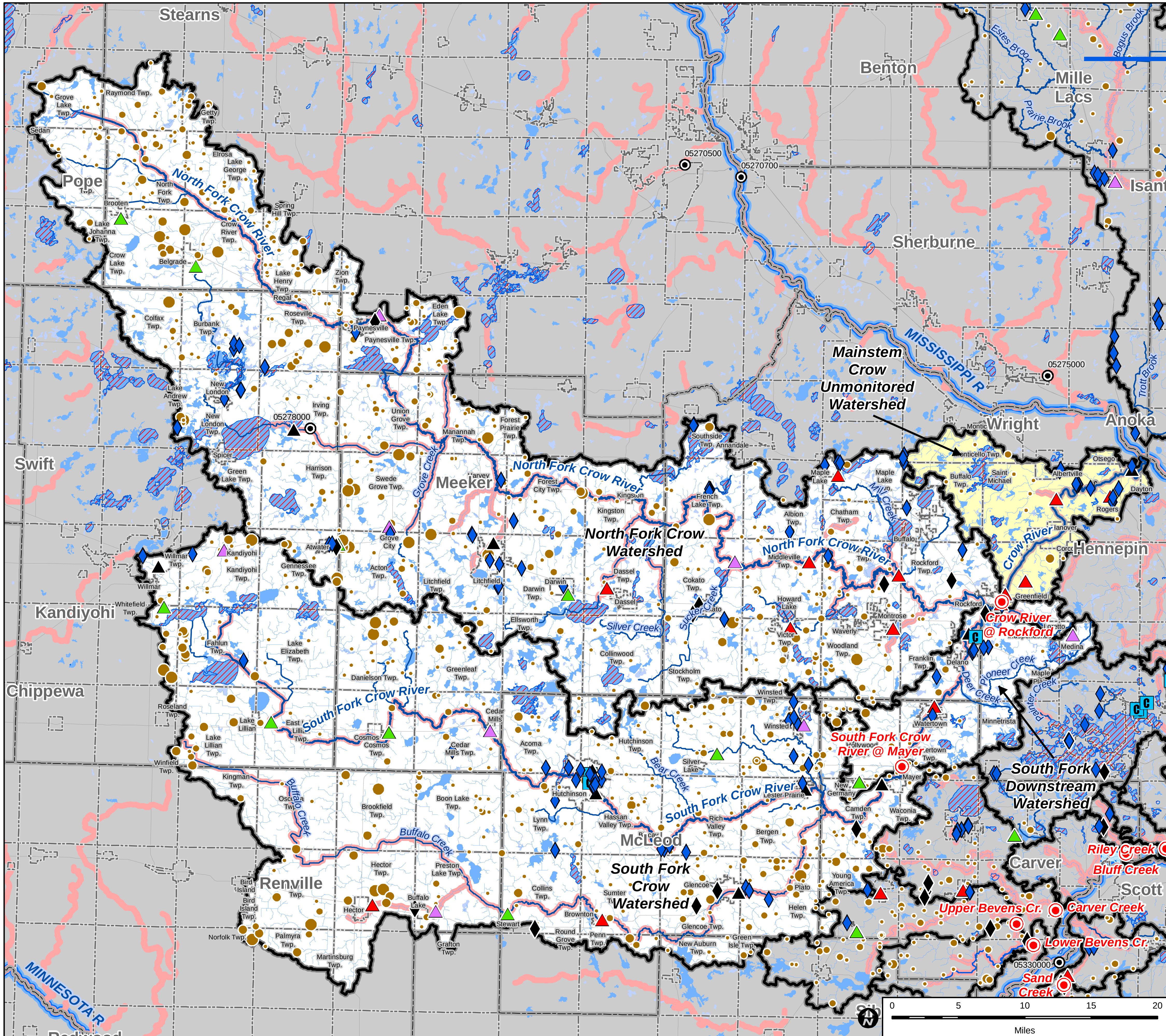
The North Fork Crow Watershed has 1,043 registered feedlots with a total of 171,784 animal units including 425 feedlots with 100 animal units or more. The Main Stem Crow Unmonitored Watershed has 51 feedlots with 4,004 animal units, including 11 feedlots with 100 animal units or more. The largest feedlot in the watershed is a turkey farm with 5,778 animal units.

Figure CW-5

METROPOLITAN COUNCIL

Public and Impaired Waters and Potential Pollution Sources

Crow River (North and South Forks)



MCES Stream Monitoring Sites
USGS Flow Stations
Mainstems (Monitored and Unmonitored)
Monitored Watershed Boundaries
Unmonitored Portion of Watersheds

Industrial Discharges **

Industrial Stormwater
Industrial & Individual Wastewater
Cooling, Potable Treatment & Dewatering

Domestic Wastewater Discharges **

Class A
Class B
Class C
Class D
Class Unknown

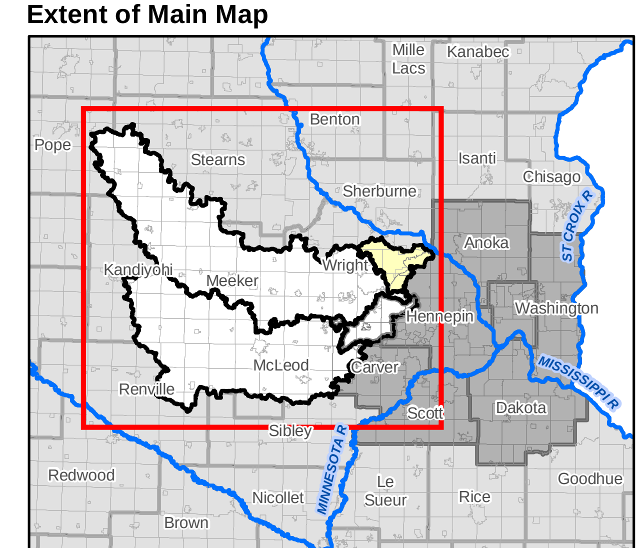
Feedlots with 100 or more animal units **

100 - 249
250 - 499
500 - 999
1000 or more

Impaired Lakes (2014 Draft MPCA 303(d) List) **
Impaired Streams (2014 Draft MPCA 303(d) List) **
Other Rivers and Streams *
Lakes and Other Open Water (PWI) *
Wetlands (PWI) *
Designated Trout Streams *
Highways and Major Roads ***
County Boundary
City and Township Boundaries

*Data Sources: * MN DNR, ** MPCA, *** MN DOT*

Extent of Main Map



Water Quality Impairments

The South Fork watershed contains eight stream reaches (all within the monitored part of the watershed) that are included on the MPCA 2014 303d list (Table CW-6, Figure CW-5). The entire length (five separate reaches) of the South Fork of the Crow River, from the headwaters at Little Kandiyohi Lake to the confluence with the North Fork, is impaired for aquatic consumption due to high levels of mercury, and is covered by the statewide mercury TMDL. Two reaches - from the Hutchinson Dam to Bear Creek and from Bear Creek to Otter Creek - are impaired for aquatic life due to high levels of turbidity. One reach - from the headwaters to the Hutchinson Dam - is impaired for aquatic life due to high levels of turbidity and stressors affecting the fish and macroinvertebrate communities. One reach - from Buffalo Creek to the confluence with the North Fork of the Crow River - is impaired for aquatic life based on high levels of turbidity and chloride and stressors affecting the fish community. The reach from Buffalo Creek to the confluence with the North Fork of the Crow River is also impaired for aquatic recreation based on levels of fecal coliform.

The other streams in the watershed with impairments are Buffalo Creek and Judicial Ditch 15. The entire length of Buffalo Creek (from headwaters to confluence with Crow River North Fork) is impaired for aquatic life based on stressors affecting the fish and macroinvertebrate communities and aquatic recreation based on levels of fecal coliform. Buffalo Creek has an approved TMDL for aquatic recreation based on fecal coliform levels. The reach of Buffalo Creek from Judicial Ditch 15 to the confluence with the South Fork of the Crow River is also impaired for aquatic life based on levels of dissolved oxygen. Judicial Ditch 15 is impaired from the west line of T115 R32W S32 to the confluence with Buffalo Creek as a limited value resource water for levels of *E. coli* (*Escherichia coli*). An aquatic life impairment for Buffalo Creek from JD 15 to the South Fork based on turbidity was removed in 2012 because new, more comprehensive data meets the standard.

Table CW-6: South Fork of the Crow River Impaired Stream Reaches as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Affected Use(s)[1]	Approved Plan	Needs Plan[2]
Buffalo Creek	Headwaters to JD 15	07010205-502	AQR, AQL	FC	M-IBI, FC, F-IBI
Buffalo Creek	JD 15 to S Fk Crow R	07010205-501	AQR, AQL	FC, T (delisted in 2012)	M-IBI, FC, F-IBI, DO
South Fork Crow River	Bear Cr to Otter Cr	07010205-511	AQC, AQL	HgF	T
South Fork Crow River	Buffalo Cr to N Fk Crow R	07010205-508	AQC, AQR, AQL	HgF	FC, F-IBI, T, Cl-
South Fork Crow River	Headwaters to Hutchinson Dam	07010205-540	AQC, AQL	HgF	M-IBI, F-IBI, T
South Fork Crow River	Hutchinson Dam to Bear Cr	07010205-510	AQC, AQL	HgF	T
South Fork Crow River	Otter Cr to Buffalo Cr	07010205-512	AQC	HgF	—
Judicial Ditch 15	T115 R32W S32, west line to Buffalo Cr	07010205-513	Class 7[3]	—	E.coli

[1] AQR = aquatic recreation; AQL = aquatic life; AQC = aquatic consumption

[2] FC = fecal coliform; T = turbidity; Cl = chloride; F-IBI = fisheries bioassessments; DO = dissolved oxygen; M-IBI = aquatic macroinvertebrates bioassessments; HgF: mercury in fish tissue

[3] Limited resource value water (Class 7): *E. coli* not to exceed 630 organisms/100 ml (May 1- Oct. 31); dissolved oxygen not less than 1 mg/l as daily average; 6.0<pH<9.0; toxic pollutants not allowed in such quantities or concentrations that will impair the specified uses (MPCA, 2014b)

The North Fork watershed contains 23 stream reaches that are included on the MPCA 2014 303d list (Table CW-7, Figure CW-5). The entire length (eight separate reaches) of the North Fork of the Crow River, from the headwaters at Grove Lake to the confluence with the South Fork, is included on the 2014 303d list, as is the Middle Fork of the Crow River and number of other tributaries. All eight reaches of the North Fork are impaired for aquatic consumption due to high levels of mercury, and are covered by the statewide mercury TMDL. Other common impairments for streams in the watershed are aquatic recreation due to *E. coli* (*Escherichia coli*) levels and aquatic life due to turbidity, stressors affecting the fish and macroinvertebrate communities, and dissolved oxygen levels. The last reach of the North Fork before the confluence with the South Fork has an approved TMDL for aquatic life due to turbidity. Grover Creek, Jewitts Creek, and Mill Creek have approved TMDLs for aquatic life based on dissolved oxygen levels. No other TMDL plans have been completed in the watershed. An aquatic life impairment for Jewitts Creek based on un-ionized ammonia levels was removed in 2012 because new data meets the standard. The delisting occurred after the wastewater treatment facility in Litchfield was upgraded.

The Main Stem Crow Unmonitored Watershed downstream of Rockford includes 2 stream reaches included on the MPCA 2014 303d list (Table CW-7, Figure CW-5). The main stem of the Crow River from the confluence of the North and South Forks at Rockford to the Mississippi River is impaired for aquatic life due to levels of turbidity, dissolved oxygen, and stressors affecting the fish and macroinvertebrete communities, as well as impaired for aquatic recreation based on levels of fecal coliform. The Crow River main stem has approved TMDLs for aquatic recreation based on fecal coliform levels and aquatic life based on turbidity levels. Regal Creek is impaired for aquatic life due to dissolved oxygen levels, and aquatic recreation based on levels of *E. coli*. Regal Creek has an approved TMDL for aquatic life based on dissolved oxygen levels.

Table CW-7: North Fork of the Crow River and Crow River Main Stem Impaired Stream Reaches as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Affected Uses[1]	Approved Plan	Needs Plan[2]
Collinwood Creek	Unnamed cr (Unnamed lk 47-0031-00 outlet) to Big Swan Lk	07010204-604	AQR	—	E.coli
Crow River, Middle Fork	Green Lk to N Fk Crow R	07010204-511	AQR	—	E.coli
Crow River, North Fork	Headwaters (Grove Lk 61-0023-00) to Rice Lk	07010204-685	AQC, AQL	HgF	F-IBI, DO
Crow River, North Fork	Jewitts Cr to Washington Cr	07010204-506	AQC, AQL	HgF	M-IBI, F-IBI
Crow River, North Fork	Lk Koronis to M Fk Crow R	07010204-504	AQC, AQL	HgF	M-IBI
Crow River, North Fork	M Fk Crow R to Jewitts Cr	07010204-507	AQC, AQR, AQL	HgF	E.coli, F-IBI
Crow River, North Fork	Meeker/Wright County line to Mill Cr	07010204-556	AQC, AQR, AQL	HgF	M-IBI, E.coli, F-IBI, DO, T
Crow River, North Fork	Mill Cr to S Fk Crow R	07010204-503	AQC, AQR, AQL	HgF, T	M-IBI, E.coli, F-IBI, DO
Crow River, North Fork	Rice Lk to Lk Koronis	07010204-687	AQC, AQL	HgF	M-IBI
Crow River, North Fork	Washington Cr to Meeker/Wright County line	07010204-555	AQC	HgF	—
Grove Creek	Unnamed cr to N Fk Crow R	07010204-514	AQR, AQL	DO	M-IBI, E.coli, F-IBI, T

Table CW-7: North Fork of the Crow River and Crow River Main Stem Impaired Stream Reaches as Identified on the MPCA 2014 Impaired Waters List

Jewitts Creek (County Ditch 19, 18, and 17)	Headwaters (Lk Ripley 47-0134-00) to N Fk Crow R	07010204-585	AQR, AQL	DO, Ammonia (un-ionized) (delisted in 2012)	M-IBI, Cl-, E.coli, F-IBI
Mill Creek	Buffalo Lk to N Fk Crow R	07010204-515	AQR, AQL	DO	E.coli, T
Sarah Creek	Lk Sarah to Crow R	07010204-628	AQR	—	E.coli
Stag Brook	Headwaters (Unnamed lk 73-0153-00) to N Fk Crow R	07010204-572	AQL	—	M-IBI, F-IBI
Sucker Creek	Cokato Lk to N Fk Crow R	07010204-682	AQL	—	M-IBI, T
Twelvemile Creek	Little Waverly Lk to N Fk Crow R	07010204-681	AQR, AQL	—	E.coli, DO
Unnamed creek	Headwaters to Unnamed cr	07010204-543	AQL	—	M-IBI
Unnamed creek	Unnamed cr to Woodland WMA wetland (86-0085-00)	07010204-668	AQR, AQL	—	E.coli, T
Unnamed creek	Woodland WMA wetland (86-0085-00) to N Fk Crow R	07010204-667	AQR, AQL	—	E.coli, DO
Unnamed creek (Battle Creek)	T120 R31W S32, south line to Jewitts Cr	07010204-552	AQL	—	M-IBI, F-IBI
Washington Creek (County Ditch 9)	Washington Lk to N Fk Crow R	07010204-518	AQR	—	E.coli
Crow River[3]	S Fk Crow R to Mississippi R	07010204-502	AQR, AQL	FC, T	M-IBI, F-IBI, DO
Unnamed creek (Regal Creek)[3]	Unnamed cr to Crow R	07010204-542	AQR, AQL	DO	E.coli

[1] AQR = aquatic recreation; AQL = aquatic life; AQC = aquatic consumption

[2] FC = fecal coliform; T = turbidity; Cl = chloride; F-IBI = fisheries bioassessments; DO = dissolved oxygen; M-IBI = aquatic macroinvertebrates bioassessments;

[3]All or part of the reach is located downstream of the Rockford monitoring station, in the Main Stem Crow Unmonitored Watershed

The South Fork watershed has 24 lakes (14 within the monitored part of the watershed) included on the MPCA 2014 303d list (Table CW-8, Figure CW-5). The lakes are primarily along the northern border of the watershed. Within the monitored part of the watershed, Big

Kandiyohi, Eagle, Elizabeth (Main Lake), Marion, Otter (Main Basin, North Arm and South Arm), Stahl's and Winsted Lakes are impaired for aquatic consumption based on mercury and are covered by the statewide mercury TMDL. Big Kandiyohi, Cedar, Eagle, Greenleaf, Kasota, Little Kandiyohi, Marion, Otter (Main Basin), and Wakanda (Main Basin) Lakes are impaired for aquatic recreation based on nutrient levels. Only Eagle Lake has a completed TMDL plan for the aquatic recreation impairment based on nutrient levels. Within the unmonitored part of the South Fork watershed, Half Moon, North Little Long, South Little Long, Independence, North Whaletail, Oak, Rebecca, South Whaletail, and Spurzem Lakes are impaired for aquatic consumption based on mercury and are covered by the statewide mercury TMDL. Independence, North Whaletail, Oak, Rebecca, South Whaletail, Spurzem, and Swede Lakes are impaired for aquatic recreation based on nutrient levels. Independence, Oak, and Swede Lakes have completed TMDL plans for aquatic recreation based on nutrient levels.

Table CW-8: South Fork of the Crow River Watershed Impaired Lakes as Identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Affected Use(s)[1]	Approved Plan[2]	Needs Plan[2]
Big Kandiyohi	34-0086-00	AQC, AQR	HgF	Nutrients
Cedar	43-0115-00	AQR	—	Nutrients
Eagle	10-0121-00	AQC, AQR	HgF, Nutrients	—
Elizabeth (Main Lake)	34-0022-02	AQC	HgF	—
Greenleaf	47-0062-00	AQR	—	Nutrients
Half Moon	27-0152-00	AQC	HgF	—
Independence	27-0176-00	AQC, AQR	HgF, Nutrients	—
Kasota	34-0105-00	AQR	—	Nutrients
Little Kandiyohi	34-0096-00	AQR	—	Nutrients
Marion	43-0084-00	AQC, AQR	HgF	Nutrients
North Little Long	27-0179-01	AQC	HgF	—
North Whaletail	27-0184-01	AQC, AQR	HgF	Nutrients
Oak	10-0093-00	AQC, AQR	HgF, Nutrients	—
Otter (Main Basin)	43-0085-01	AQC, AQR	HgF	Nutrients
Otter (North Arm/Campbell)	43-0085-03	AQC	HgF	—
Otter (South Arm)	43-0085-02	AQC	HgF	—
Rebecca	27-0192-00	AQC, AQR	HgF	Nutrients
South Little Long	27-0179-02	AQC	HgF	—
South Whaletail	27-0184-02	AQC, AQR	HgF	Nutrients

Spurzem	27-0149-00	AQC, AQR	HgF	Nutrients
Stahl's	43-0104-00	AQC	HgF	—
Swede	10-0095-00	AQR	Nutrients	—
Wakanda (Main Basin)	34-0169-03	AQR	—	Nutrients
Winsted	43-0012-00	AQC	HgF	—

[1] AQC = aquatic consumption; AQR = aquatic recreation
[2] HgF = mercury in fish tissue;

The North Fork watershed has 58 lakes included on the MPCA 2014 303d list (Table CW-9, Figure CW-5). 41 lakes are impaired for aquatic consumption based on mercury, and all but six are covered by the statewide mercury TMDL. 35 lakes are impaired for aquatic recreation based on nutrient levels. Ann, Diamond, East and West Sarah, Rice, and Emma Lakes are the only lakes that have completed TMDL plan for the aquatic recreation impairment based on nutrient levels.

The Main Stem Crow Unmonitored Watershed has an additional seven lakes included on the MPCA 2014 303d list (Table CW-9, Figure CW-5). Beebe, Hafften, Constance, Cowley, Foster, and Pelican are impaired for aquatic recreation based on nutrient levels. None of these lakes have an approved TMDL plan for the aquatic recreation impairment. Beebe, Charlotte, and Hafften are impaired for aquatic consumption based on mercury, and only Lake Beebe is covered by the statewide mercury TMDL.

Table CW-9: North Fork of the Crow River and Main Stem Crow Unmonitored Watershed Impaired Lakes as Identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Affected Uses[1]	Approved Plan[2]	Needs Plan
Albert	86-0127-00	AQR	—	Nutrients
Ann	86-0190-00	AQC, AQR	HgF, Nutrients	—
Arvilla	47-0023-00	AQC	HgF	—
Big Swan	47-0038-00	AQC, AQR	HgF	Nutrients
Brooks	86-0264-00	AQR	—	Nutrients
Buffalo	86-0090-00	AQC, AQR	HgF	Nutrients
Calhoun	34-0062-00	AQC	HgF	—
Camp	86-0221-00	AQR	—	Nutrients
Cokato	86-0263-00	AQR	—	Nutrients
Collinwood	86-0293-00	AQC, AQR	HgF	Nutrients
Crow River Mill Pond (East)	34-0158-03	AQC	—	HgF
Crow River Mill Pond	34-0158-04	AQC	—	HgF

Table CW-9: North Fork of the Crow River and Main Stem Crow Unmonitored Watershed Impaired Lakes as Identified on the MPCA 2014 Impaired Waters List

(Middle)				
Crow River Mill Pond (West)	34-0158-05	AQC	—	HgF
Dean	86-0041-00	AQR	—	Nutrients
Deer	86-0107-00	AQR	—	Nutrients
Diamond	34-0044-00	AQC, AQR	HgF, Nutrients	—
Dunns	47-0082-00	AQC, AQR	HgF	Nutrients
Dutch	86-0184-00	AQR	—	Nutrients
East Lake Sylvia	86-0289-00	AQC	HgF	—
East Sarah	27-0191-02	AQC, AQR	HgF, Nutrients	—
Emma	86-0188-00	AQR	Nutrients	—
Fountain	86-0086-00	AQR	—	Nutrients
Francis	47-0002-00	AQC	HgF	—
French	86-0273-00	AQC, AQR	HgF	Nutrients
George	34-0142-00	AQC	HgF	—
Granite	86-0217-00	AQC, AQR	HgF	Nutrients
Green	34-0079-00	AQC	—	HgF
Grove	61-0023-00	AQC	HgF	—
Hook	43-0073-00	AQC, AQR	HgF	Nutrients
Hope	47-0183-00	AQR	—	Nutrients
Howard	86-0199-00	AQC, AQR	HgF	Nutrients
Jennie	47-0015-00	AQC, AQR	HgF	Nutrients
John	86-0288-00	AQC	HgF	—
Koronis (main lake)	73-0200-02	AQC	HgF	—
Light Foot	86-0122-00	AQR	—	Nutrients
Little Waverly	86-0106-00	AQR	—	Nutrients
Long	47-0177-00	AQR	—	Nutrients
Long	34-0066-00	AQC	HgF	—
Long	47-0026-00	AQC	HgF	—
Malardi	86-0112-00	AQR	—	Nutrients

Table CW-9: North Fork of the Crow River and Main Stem Crow Unmonitored Watershed Impaired Lakes as Identified on the MPCA 2014 Impaired Waters List

Mary	86-0193-00	AQC	HgF	—
Minnie-Belle	47-0119-00	AQC	HgF	—
Monongalia (Main Basin)	34-0158-01	AQC	—	HgF
Monongalia (Middle Fork Crow River)	34-0158-02	AQC	—	HgF
Mud	73-0200-01	AQC	HgF	—
Nest	34-0154-00	AQC, AQR	HgF	Nutrients
Pulaski (Main Bay)	86-0053-02	AQC	HgF	—
Ramsey	86-0120-00	AQR	—	Nutrients
Rice	73-0196-00	AQC, AQR	HgF, Nutrients	—
Richardson	47-0088-00	AQC, AQR	HgF	Nutrients
Rock	86-0182-00	AQR	—	Nutrients
Smith	86-0250-00	AQR	—	Nutrients
Spring	47-0032-00	AQC, AQR	HgF	Nutrients
Upper Maple	86-0134-01	AQC	HgF	—
Washington	47-0046-00	AQC	HgF	—
Waverly	86-0114-00	AQC, AQR	HgF	Nutrients
West Lake Sylvia	86-0279-00	AQC	HgF	—
West Sarah	27-0191-01	AQC, AQR	HgF, Nutrients	—
Beebe[3]	86-0023-00	AQC, AQR	HgF	Nutrients
Charlotte[3]	86-0011-00	AQC	—	HgF
Constance[3]	86-0051-00	AQR	—	Nutrients
Cowley[3]	27-0169-00	AQR	—	Nutrients
Foster[3]	86-0001-00	AQR	—	Nutrients
Hafften[3]	27-0199-00	AQC, AQR	—	HgF, Nutrients
Pelican[3]	86-0031-00	AQR	—	Nutrients

[1] AQC = aquatic consumption; AQR = aquatic recreation

[2] HgF = mercury in fish tissue;

[3]Lake is located downstream of the Rockford monitoring station, in the Main Stem Crow Unmonitored Watershed

Hydrology

MCES has monitored water quality on the Crow River at Rockford since 1998 (first full year of sampling was 1999) and on the South Fork of the Crow River at Mayer since 2001 (first full year of sampling was 2002). Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrographs of the Crow River sites, which display daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicate the variation in flow rates from season to season and from year to year (Figures CW-6 and CW-7), and the effect of precipitation events on flow.

The MCES sampling program specifies collection of baseflow grab samples between events and event-based composites. The hydrograph indicates samples were collected during most events and that baseflow was also adequately sampled.

Both the Crow River at Rockford and the South Fork of the Crow River at Mayer have hydrographs characteristic of large order stream systems. Generally, the Crow River at Rockford storm event daily average flows were less than 7,000 cubic feet per second (cfs). Four spring rains or snowmelt-driven events exceeded this level in 2001, 2010, 2011, and 2012. Of those events, the highest recorded daily average flow in the Crow River at Rockford - 11,927 cfs - occurred in 2010. The mean average daily flow is much lower - 1,184 cfs - but is still higher than the median average daily flow of 486 cfs. The difference between the mean and median average flow indicates the high flow events have a great influence on the mean average value.

The South Fork of the Crow River at Mayer storm event daily average flows were generally less than 6,000 cfs. Three spring rains or snowmelt-driven events exceeded this level in 2001, 2010, and 2011. Of those events, the highest recorded daily average flow in the South Fork at Mayer - 8,800 cfs - occurred in 2010. The mean average daily flow is much lower - 589 cfs - but is still higher than the median average daily flow of 189 cfs. Similar to the Crow River at Rockford, the difference between these flow values highlights the influence of high flow events on the mean average value.

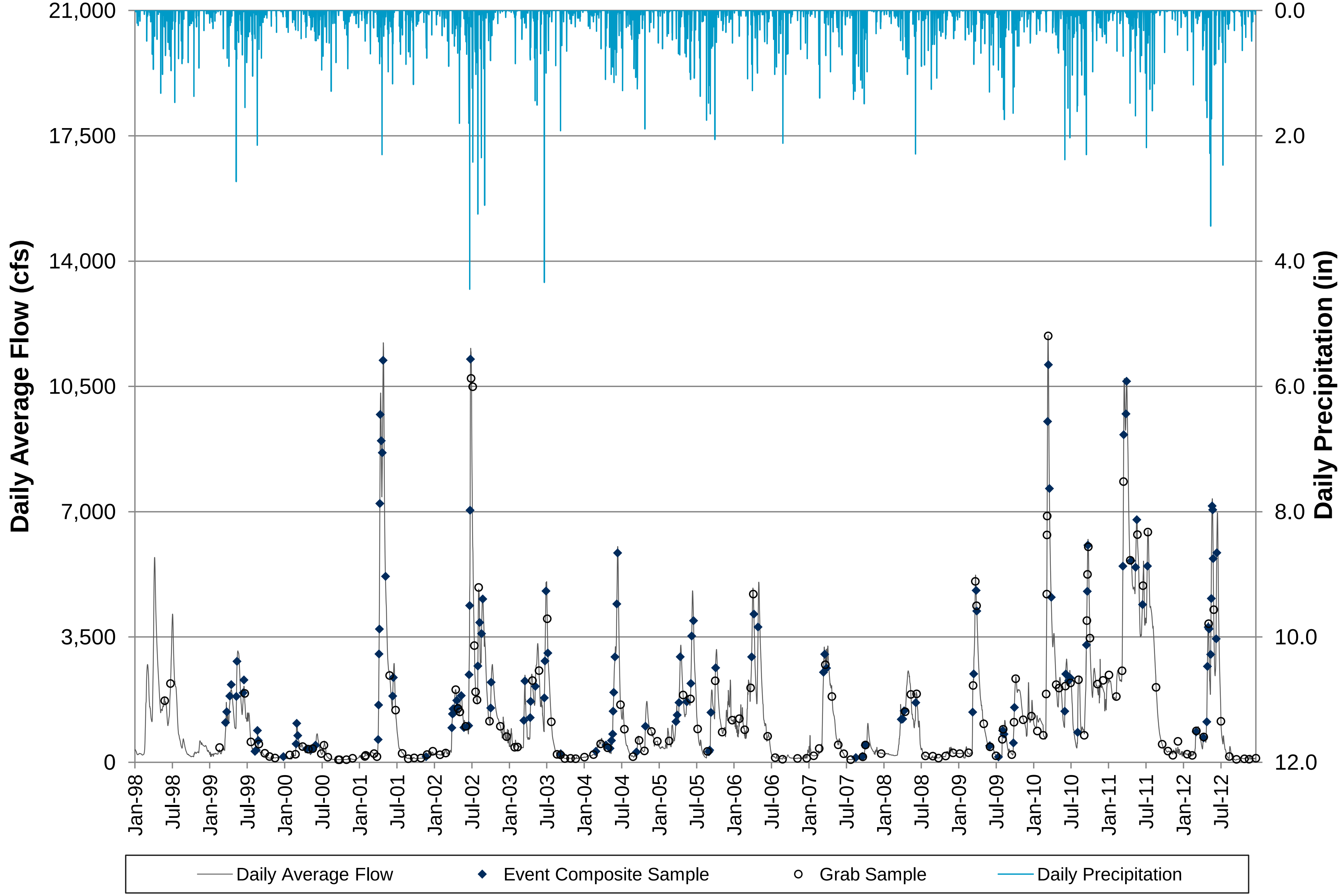
Neither the Crow River at Rockford nor the South Fork of the Crow at Mayer freeze solid during the winter months or run dry during prolonged periods with little precipitation. However seven percent of the daily average flows on the South Fork of the Crow at Mayer were very low (less than 10 cfs), and usually occurred at the end of summer.

Analysis of the duration of daily average flows indicates that the upper 10^{th} percentile flows for the Crow River main stem (1998-2012) ranged between approximately 2,913-11,927 cfs, while the lowest 10^{th} percentile flows ranged from 63-112 cfs. The upper 10^{th} percentile flows for the South Fork of the Crow River (2001-2012) ranged between approximately 1,666-8,800 cfs, while the lowest 10^{th} percentile flows ranged from 3-12 cfs (See Figures CW-20 and CW-21 in the ***Flow and Load Duration Curves*** section of this report).

The variations in flow are somewhat driven by annual precipitation amounts as well as by variation in frequency of intense storm events. However, nearly half of the precipitation most likely does not affect the stream as surface runoff or overland flows. The median runoff ratio at the Crow River at Rockford (1998-2012) and the South Fork of the Crow at Mayer (2001-2012) was approximately 20%, indicating an average of 80% of the precipitation infiltrated the soils, evaporated off of the surface, was evapotranspirated by vegetation, or was stored in watershed wetlands, lakes, and ponds.

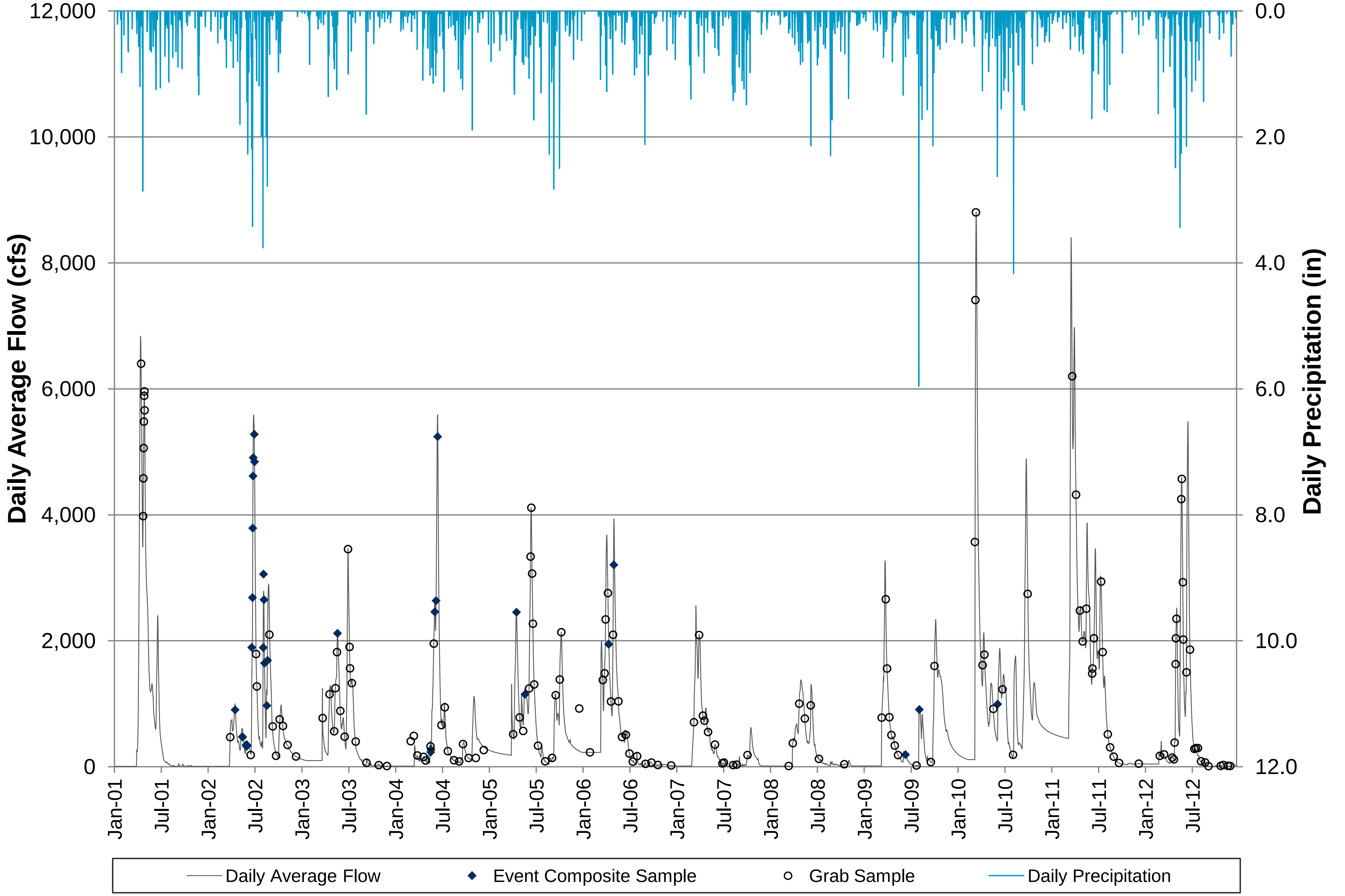
Additional annual flow and volume metrics are shown on Figures CW-8 through CW-15, along with the annual pollutant load parameters. The first graph on each sheet illustrates an annual flow metric consisting of 1) average annual flow (a measure of annual flow volume); 2) areal-weighted flow; and 3) fraction of annual precipitation converted to flow. Figures CW-8 and CW-9 indicate that the highest average annual flow, and thus the highest volume of flow, occurred during 2011 for both the Crow River at Rockford and the South Fork at Mayer (3,120 and 1,280 cfs average annual flow, respectively). The lowest average annual flow and lowest volume of Crow River at Rockford flows occurred in 2000 (239 cfs average annual flow) and occurred in 2008 for the South Fork of the Crow at Mayer (208 cfs average annual flow). Both the Crow River at Rockford and South Fork of the Crow at Mayer mean average annual flows (1,186 and 586 cfs, respectively) were higher than the median average annual flows (977 and 479 cfs, respectively), highlighting the influence of high flow events that skew the mean annual flow values. Both the South Crow at Mayer mean and median average annual flows make up about 49% of the Crow River at Rockford mean and median average annual flows respectively, while the monitored part of the South Fork watershed ("South Fork Crow Watershed") is 43.6% of the overall Crow River monitored watershed at Rockford.

Figure CW-6: Crow River Main Stem at Rockford
Daily Average Flow, Sample Flow, and Precipitation, 1998-2012*



*Precipitation record was acquired from NWS COOP stations: 217020-Rockford and 211448-Chanhassen WSFO

Figure CW-7: South Fork Crow River at Mayer Daily Average Flow, Sample Flow, and Precipitation, 2001-2012*



*Precipitation record was acquired from NWS COOP stations: 219085-Winsted, 217020-Rockford, 211448-Chanhassen WSFO, and 214692-Lester Prairie 1E

Vulnerability of Stream to Groundwater Withdrawals

Regional analysis (Metropolitan Council, 2010) of hydrogeologic conditions in the seven-county metropolitan area suggests that some surface water features are in direct connection with the underlying regional groundwater flow system and may be impacted by groundwater pumping. While regional in nature, this analysis serves as a screening tool to increase awareness about the risk that groundwater pumping may have for surface water protection and to direct local resources toward monitoring and managing the surface waters most likely to be impacted by groundwater pumping. Additional information, including assumptions and analytical methodologies, can be found in the 2010 report.

To assess the vulnerability of the Crow River watershed to groundwater withdrawals, MCES staff examined spatial datasets of vulnerable stream segments and basins created as part of the 2010 regional groundwater analysis. Results were available only for that portion of the watershed located within the seven-county metropolitan area boundary (that is, only that portion of the watershed in Carver and Hennepin counties).

Within Carver County, a 3.5 mile segment of the South Fork of the Crow River starting at the western border of Carver County and a 6.5 mile segment between Mayer and the northern Carver County border are shown to be potentially vulnerable, while the remainder of the South Fork of the Crow River within Carver County is not identified as being vulnerable. Several basins within the Carver County portion of the watershed were identified as vulnerable to groundwater withdrawals, primarily lakes and wetlands between the cities of Lester Prairie and New Germany, including Reich and Firemen’s Lakes.

Within Hennepin County the entire reach of the Crow River main stem starting at the confluence of the North and South Forks of the Crow River to the confluence with the Mississippi River is shown to be potentially vulnerable. Several basins within the Hennepin County portion of the watershed were identified as vulnerable to groundwater withdrawals, including Hafften, Rebecca, Sarah, Independence, Half Moon, Winterhalter, Peter, and Little Long Lakes.

MCES is continuing to evaluate the effects of groundwater withdrawal on surface waters, including updating analyses with the best available data and linking results to predictive groundwater modeling and the comprehensive planning process.

Pollutant Loads

The U.S. Army Corps of Engineers program Flux32 (Walker, 1999) was used to convert daily average flow, coupled with grab and event-composite sample concentrations, into annual and monthly loads and flow-weighted mean concentrations (FWM). Loads were estimated for total suspended solids (TSS), total phosphorus (TP), total dissolved phosphorus (TDP), nitrate (NO_3), ammonia (NH_3), and chloride (Cl) for each year of monitored data at the Crow River at Rockford (1999-2012) and the South Fork of the Crow River at Mayer (2002-2012). The Crow River main stem monitoring station at Rockford began in 1998, but loads were calculated beginning in 1999. The South Fork Crow River at Mayer monitoring station began in 2001, but loads were calculated beginning in 2002. Loads were calculated beginning with the first complete year of data collection for each site.

Figures CW-8 to CW-15 illustrate annual loads expressed as mass, as flow-weighted mean (FWM) concentration, as mass per unit of area (lb/ac), and as mass per unit of area per inch of precipitation (lb/ac/in), as well as three hydrological metrics (annual average flow rate, depth of flow (annual flow per unit area) coupled with precipitation depth, and runoff ratio). A later section in this report (***Comparison with Other Metro Area Streams***) offers graphical comparison of the Crow River stations' loads and FWM concentrations with the other MCES-monitored metropolitan area tributaries.

The flow metrics indicate year-to-year variations in annual flow rate that is likely driven by variation in annual precipitation amount as well as by variation in frequency of intense storm events, as expected from a surface-water fed stream. The runoff ratio is relatively stable for both monitoring sites through 2009; year-to-year variation is likely influenced by drought periods, by low soil moisture during antecedent dry periods, and by increase capacity in upland storage areas during drought periods. The 2010 and 2011 runoff and runoff coefficient values are significantly higher than previous years at both monitoring sites, but this is still likely due to year-to-year variations in rainfall timing and watershed conditions. The runoff ratio for 2012 returns to more historic levels at both sites.

The annual mass loads (Figures CW-8 and CW-9) for both monitoring sites for all parameters exhibited significant year-to-year variation, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream.

For both monitoring sites, the annual FWM concentrations (Figures CW-10 and CW-11) for all parameters also fluctuated from year-to-year and were likely influenced by annual precipitation and flow. For the main stem at Rockford, TSS, TP, and NH_3 concentrations have decreased fairly steadily from 1999 to 2012. TDP concentration has also decreased since 1999, though there was a marked increase in 2009. NO_3 concentration increased from 1999 to 2006, but has decreased since. Cl concentration has stayed relatively stable, with a slight peak in concentration in 2007 and 2008.

For the South Fork station at Mayer, TSS concentration increased from 2002 through 2008, before decreasing sharply in 2009 and remaining fairly stable since. TP and TDP concentrations were stable from 2002-2004, decreased slightly from 2004-2005, and have remained relatively stable since. NO_3 concentration peaked in 2006 and has steadily decreased since. NH_3 concentration was stable until 2009, when there was a sudden jump in concentration. Concentrations were high from 2009-2011, before returning to historic levels in 20012. Cl concentration increased from 2002 through 2008 before decreasing from 2008-2012.

Figures CW-12 through CW-15 present the Crow River main stem at Rockford and South Fork at Mayer areal- and precipitation-weighted loads. These graphics are presented to assist local partners and watershed managers, and will generally not be discussed here.

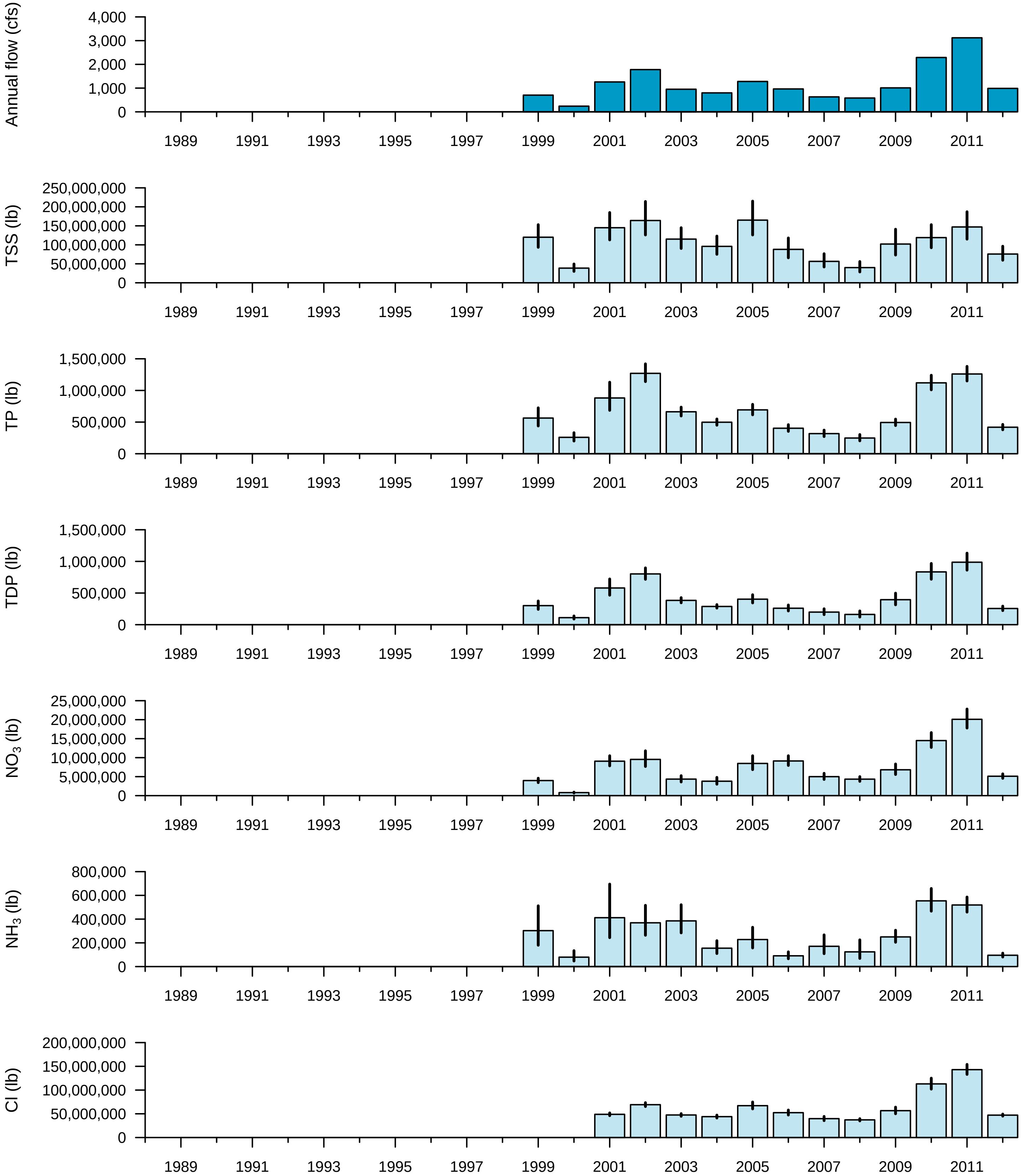
The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of time-based patterns in the loads in the Crow River (Figures CW-16 and CW-18 for the Crow River main stem at Rockford, Figures CW-17 and CW-19 for the South Fork Crow River at Mayer). The results for each month were expressed in two ways: the monthly results for the most recent year of data (2012 for the Crow River main stem at Rockford and South Fork at Mayer) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month). Because there have been very few samples collected at the South Fork Crow River site during the winter period (0 samples in January, 1 sample in February, 3 samples in November, 6 samples in December), loads and concentrations calculated during these months may have greater error.

For the constituents in the Crow River main stem at Rockford and South Fork at Mayer, the mass load closely followed with monthly flow. The monthly load was low in January and February and then began increasing in March, likely due to effects of snow melt and spring rains. The load plateaued in March through June, which was likely due to drain tile runoff and lack of evapotranspiration. Beginning in July the flow and load began to decrease as crops were fully established, although there was a slight bump in load in October likely due to fall precipitation and vegetation die-off. Loads fell off in November and December as snowpack began to build. The only pollutant load that did not really follow this pattern is NH_3, which for both monitoring stations peaked in March, ahead of the other pollutants.

The FWM concentration showed less month-to-month variability than the loads for both the Crow River main stem at Rockford and South Fork at Mayer. For the main stem at Rockford, TSS followed closely with flow in the spring, but remained high through September. TP concentration was very stable through the year. TDP and NH_3 concentrations were higher in January to March before dropping to be relatively stable for the remainder of the year. The elevated TDP and NH_3 concentrations may be due to limited algal assimilation due to low temperatures (Lee *et al.*, 2012). NO_3 concentration followed flow fairly closely. Cl concentrations were fairly stable but were lowest in the spring and early summer, likely reflecting some impact of road de-icers, but a greater impact of water softeners from wastewater treatment plants rather than road de-icers.

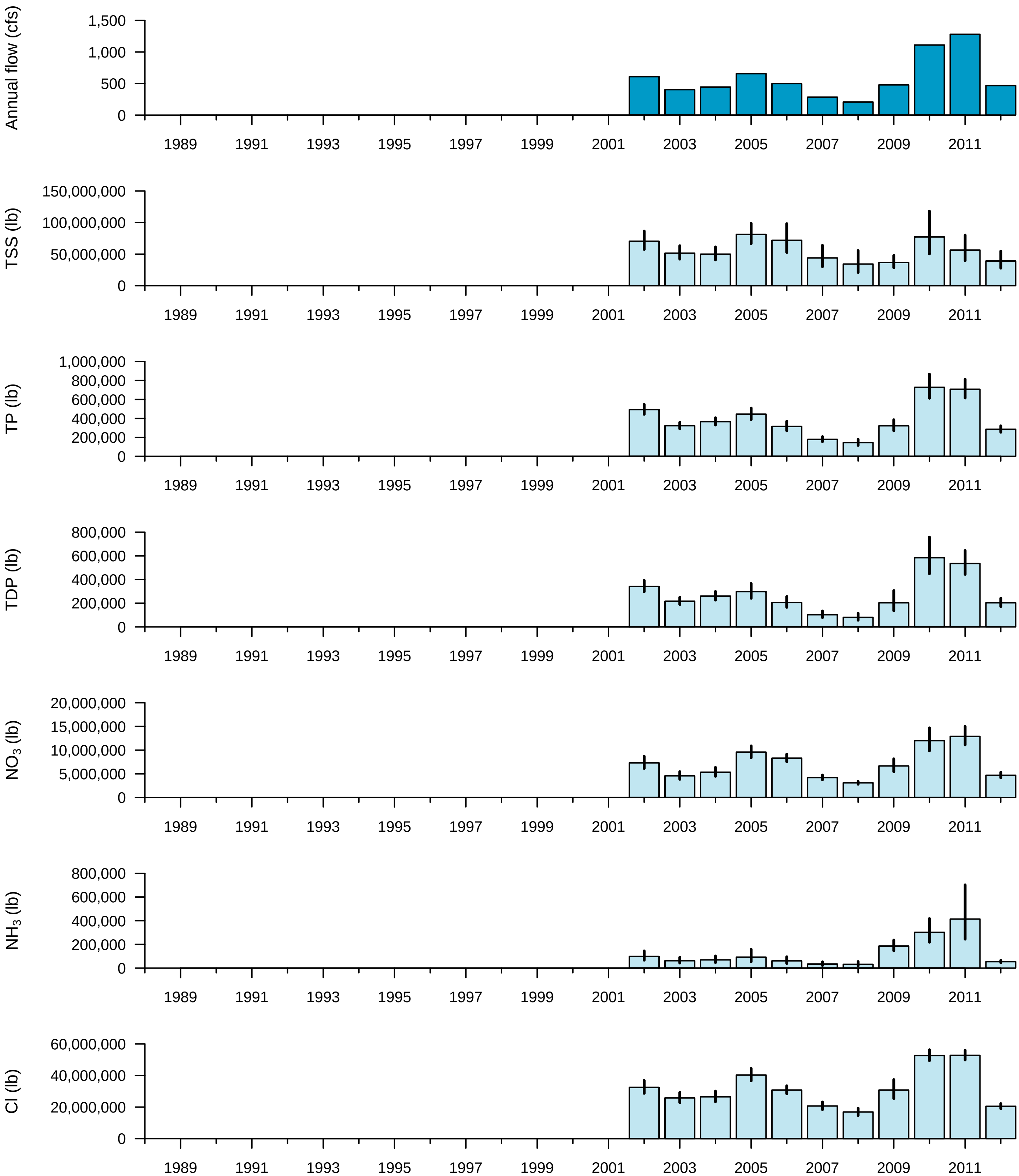
For the South Fork of the Crow River at Mayer, TSS FWM concentration was very stable through the year. TP and TDP concentrations were fairly stable, but lowest in the spring and summer months. NO_3 concentration followed flow fairly closely. NH_3 concentration was elevated in January to March, before dropping off quickly, which may have been caused by lower rates of nitrification and limited algal assimilation due to low temperatures (Lee *et al.*, 2012). As with the main stem at Rockford, Cl concentrations were fairly stable but were lowest in the spring and early summer, likely reflecting some impact of road de-icers, but a greater impact of water softeners from wastewater treatment plants rather than road de-icers. For most of the parameters there is great variability in concentration values over the 2003-2012 period for November to February. This reflects the error in concentration estimates because of the low number of samples during this period.

Figure CW−8: Crow River Main Stem at Rockford*
Annual Mass Load



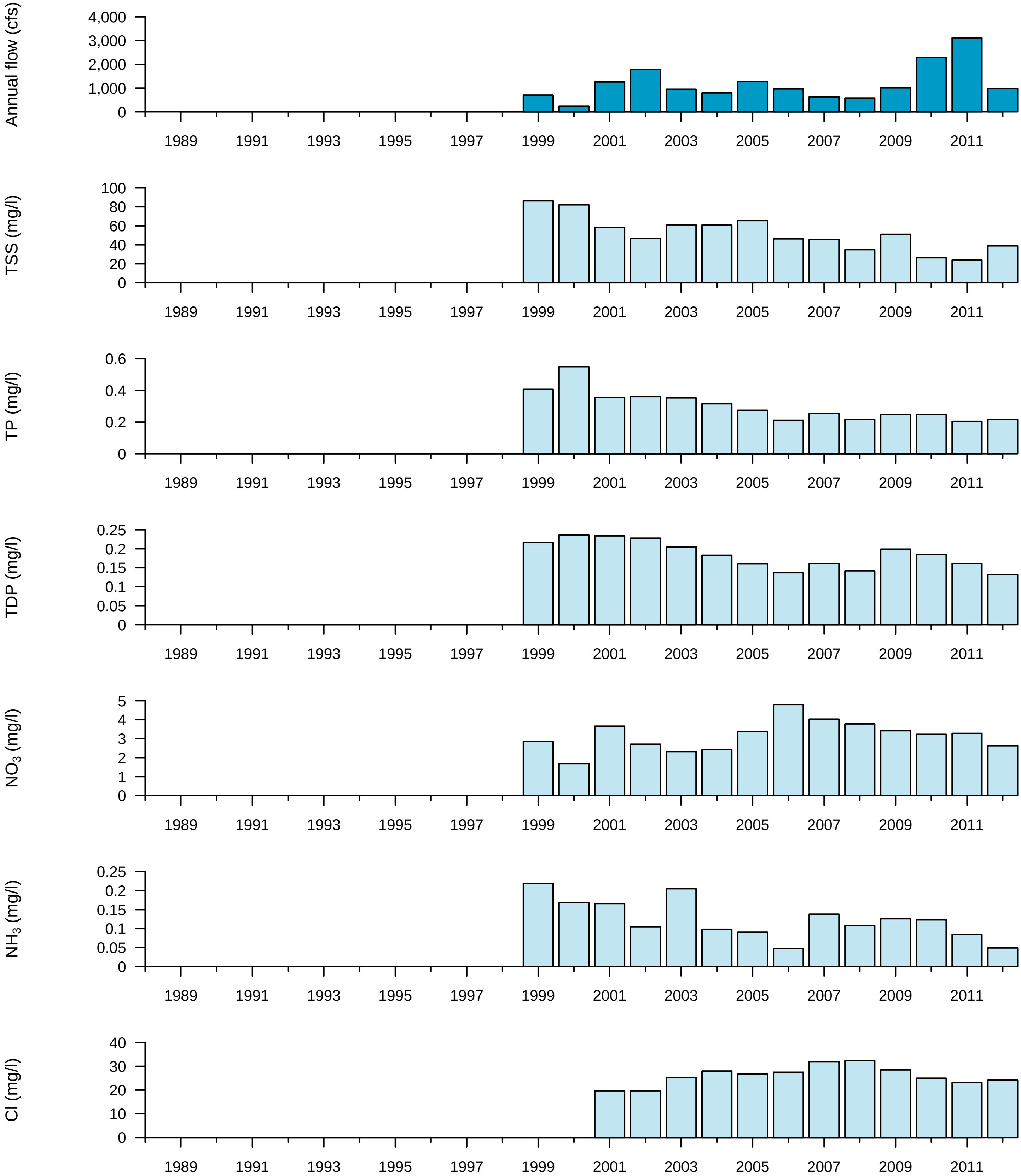
*First full year of sampling for TSS, TP, TDP, NO3, and NH3 began in 1999, Cl began in 2001.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure CW−9: South Fork Crow River at Mayer*
Annual Mass Load



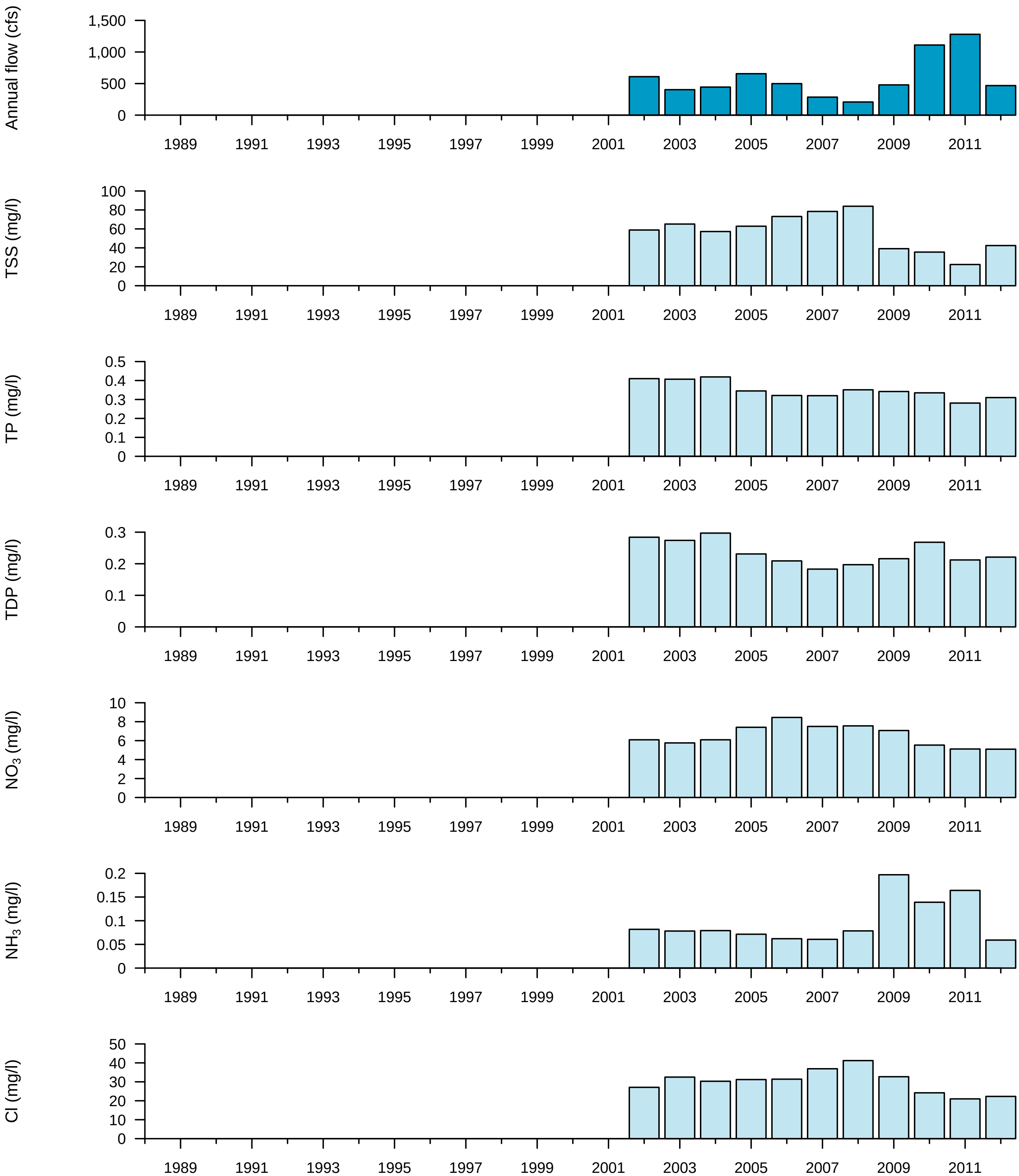
*First full year of sampling began in 2002.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure CW−10: Crow River Main Stem at Rockford* Annual Flow−Weighted Mean Concentration



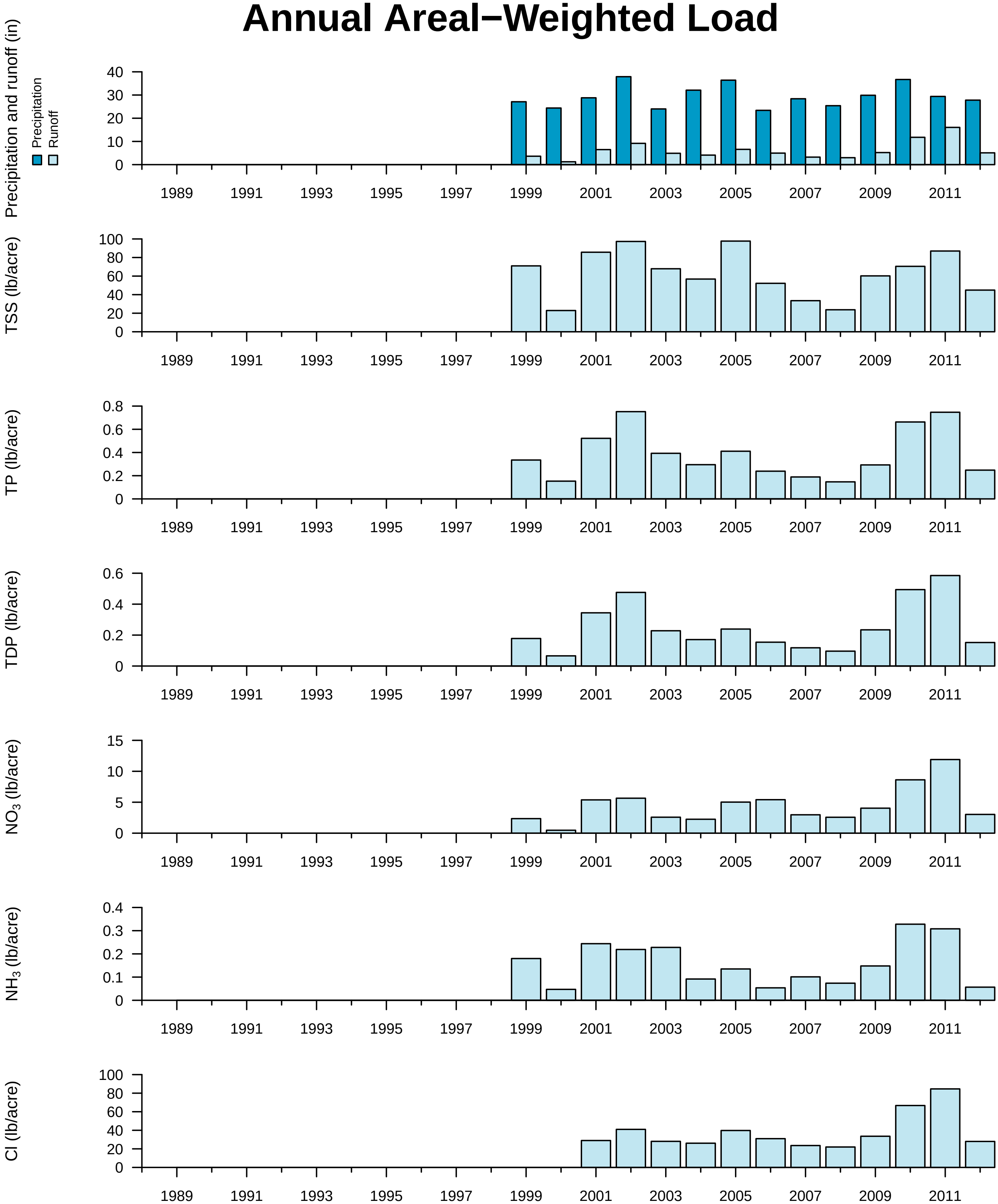
*First full year of sampling for TSS, TP, TDP, NO3, and NH3 began in 1999, Cl began in 2001.

Figure CW−11: South Fork Crow River at Mayer*
Annual Flow−Weighted Mean Concentration



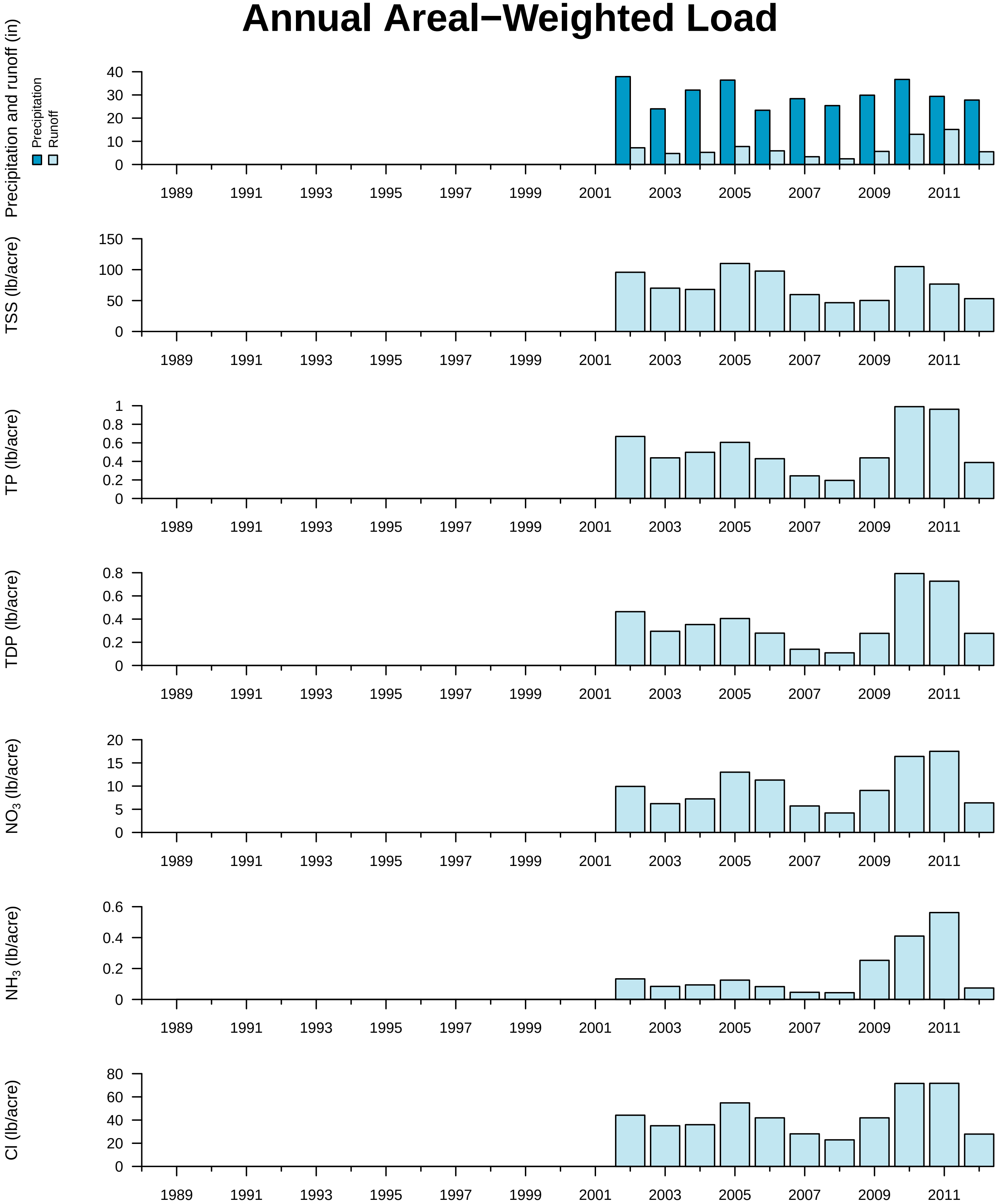
*First full year of sampling began in 2002.

Figure CW−12: Crow River Main Stem at Rockford*
Annual Areal−Weighted Load



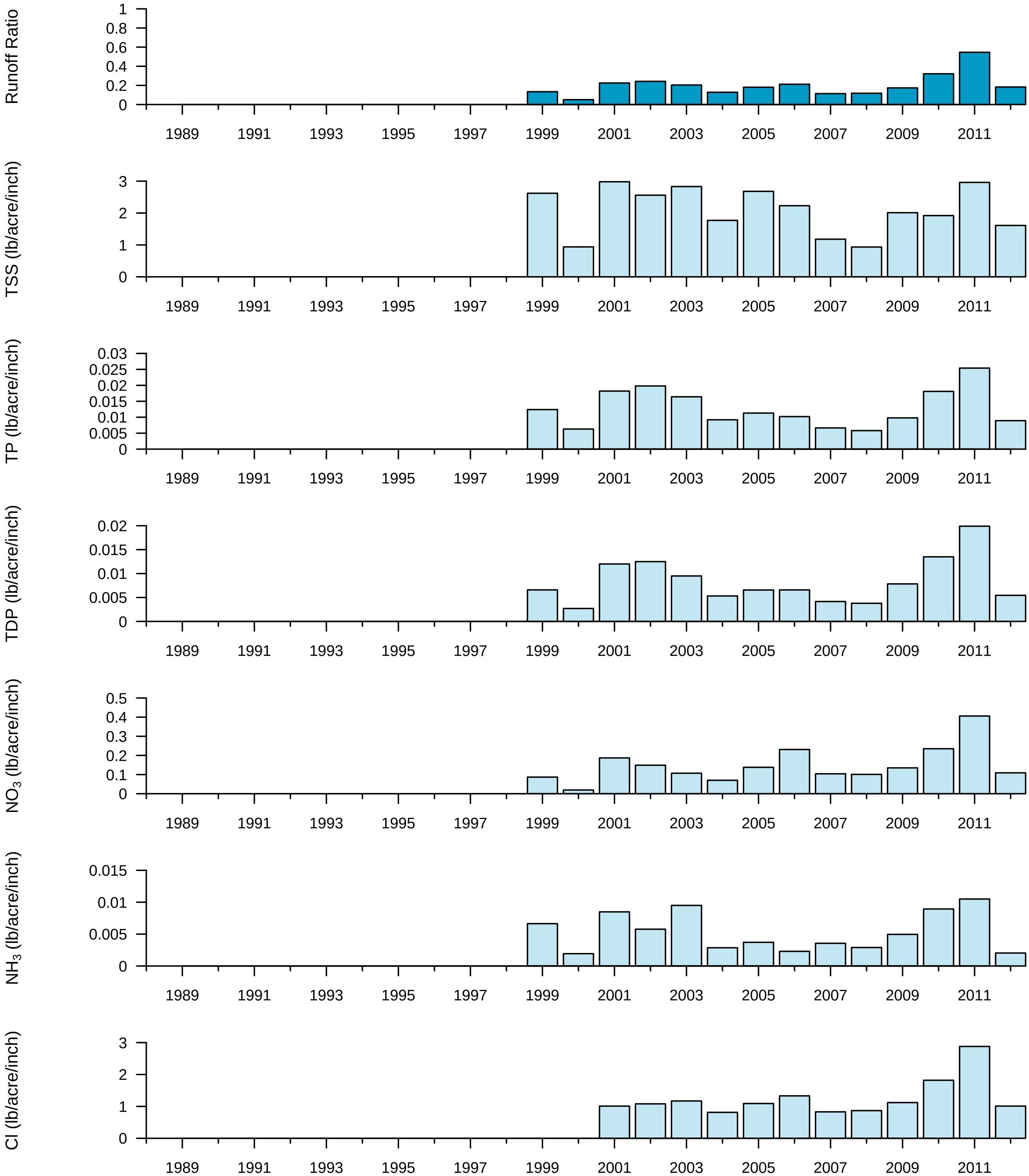
*First full year of sampling for TSS, TP, TDP, NO3, and NH3 began in 1999, Cl began in 2001.

Figure CW−13: South Fork Crow River at Mayer*
Annual Areal−Weighted Load



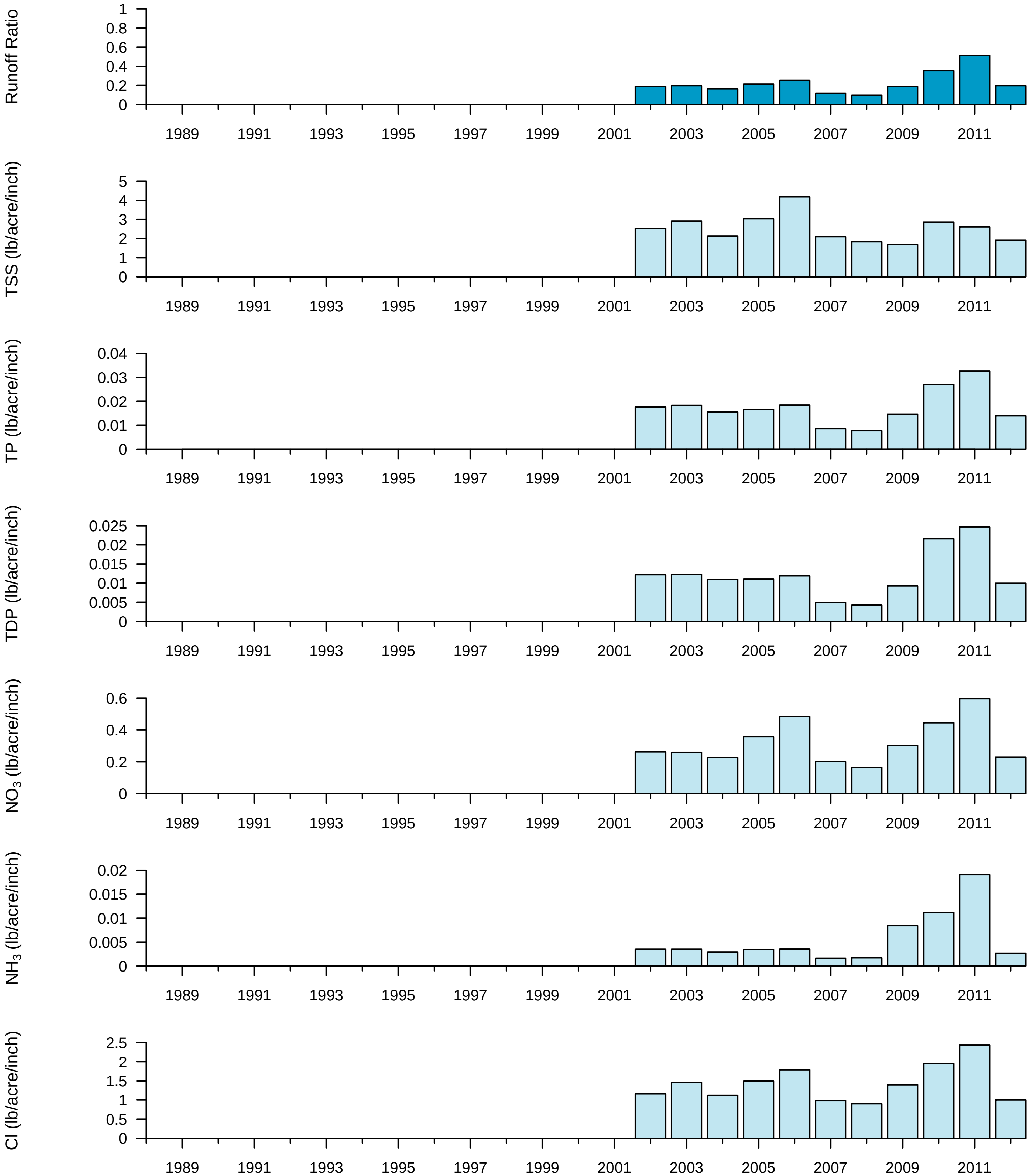
*First full year of sampling began in 2002.

Figure CW−14: Crow River Main Stem at Rockford*
Annual Precipitation−Weighted Areal Load



*First full year of sampling for TSS, TP, TDP, NO3, and NH3 began in 1999, Cl began in 2001.

Figure CW−15: South Fork Crow River at Mayer*
Annual Precipitation−Weighted Areal Load



*First full year of sampling began in 2002.

Figure CW−16: Crow River Main Stem at Rockford Mass Load by Month

Most Recent Year (2012) of Data Compared to 2003−2012 Average

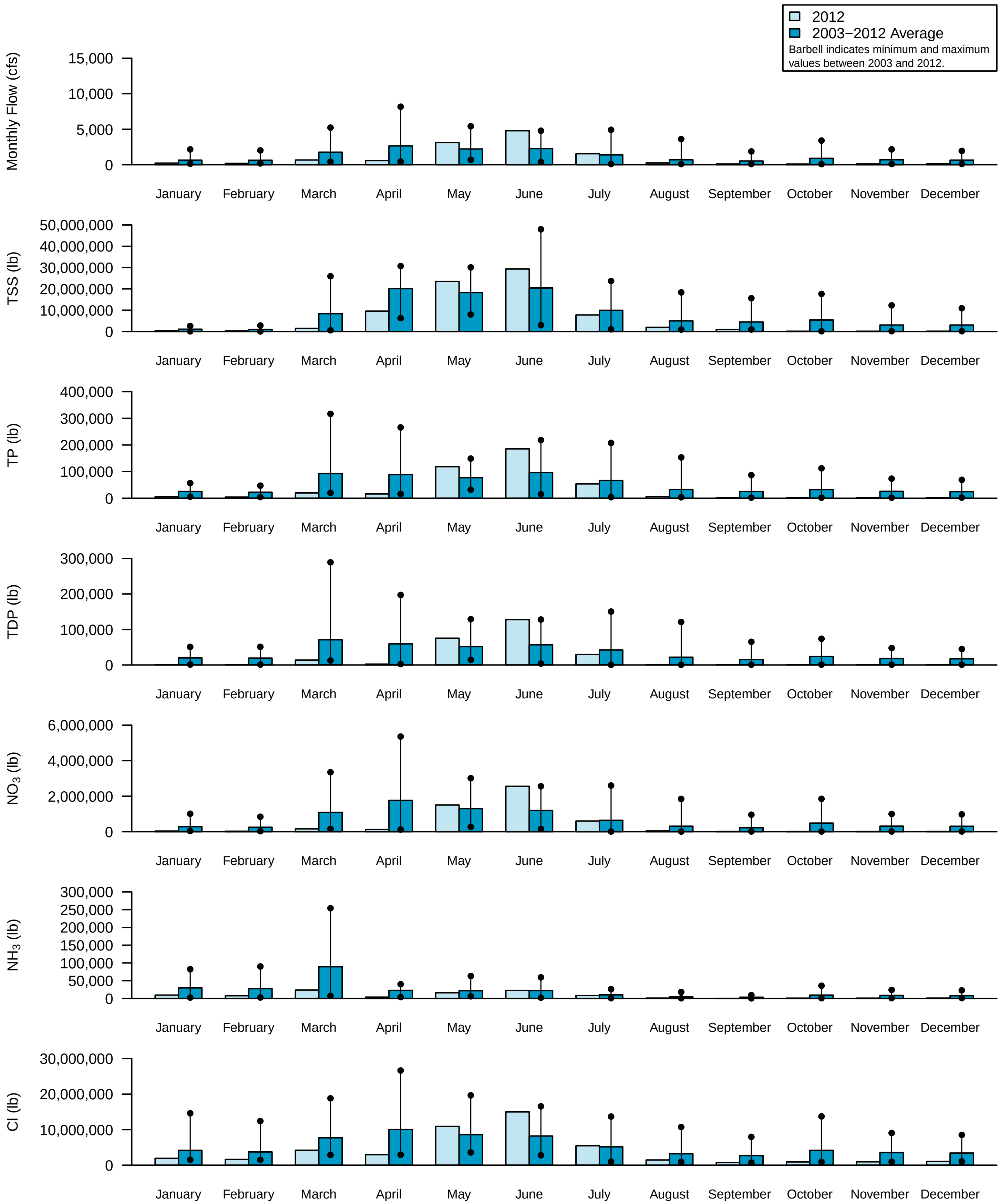


Figure CW−17: South Fork Crow River at Mayer Mass Load by Month

Most Recent Year (2012) of Data Compared to 2003−2012 Average

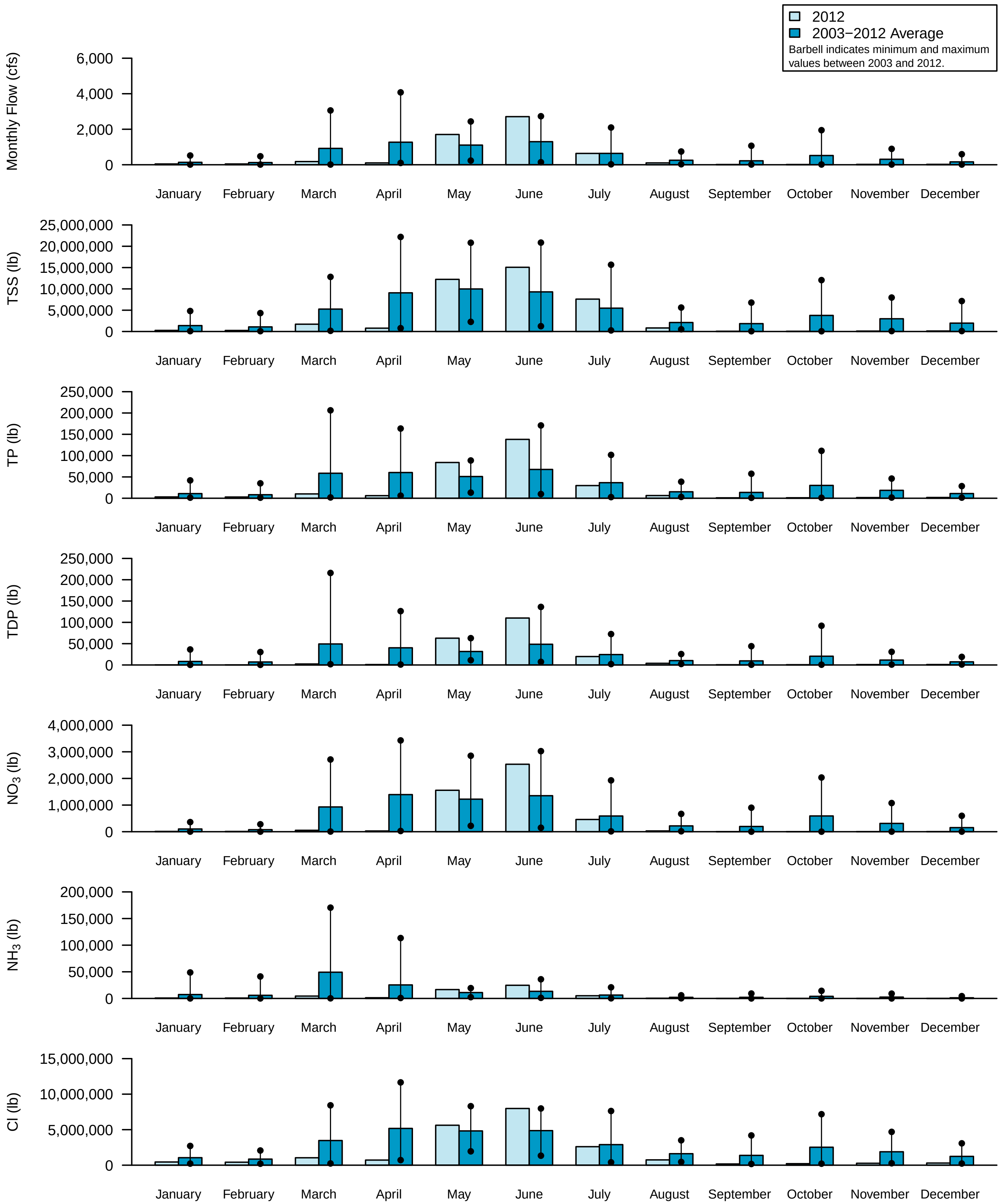


Figure CW−18: Crow River Main Stem at Rockford Flow−Weighted Mean Concentation by Month

Most Recent Year (2012) of Data Compared to 2003−2012 Average

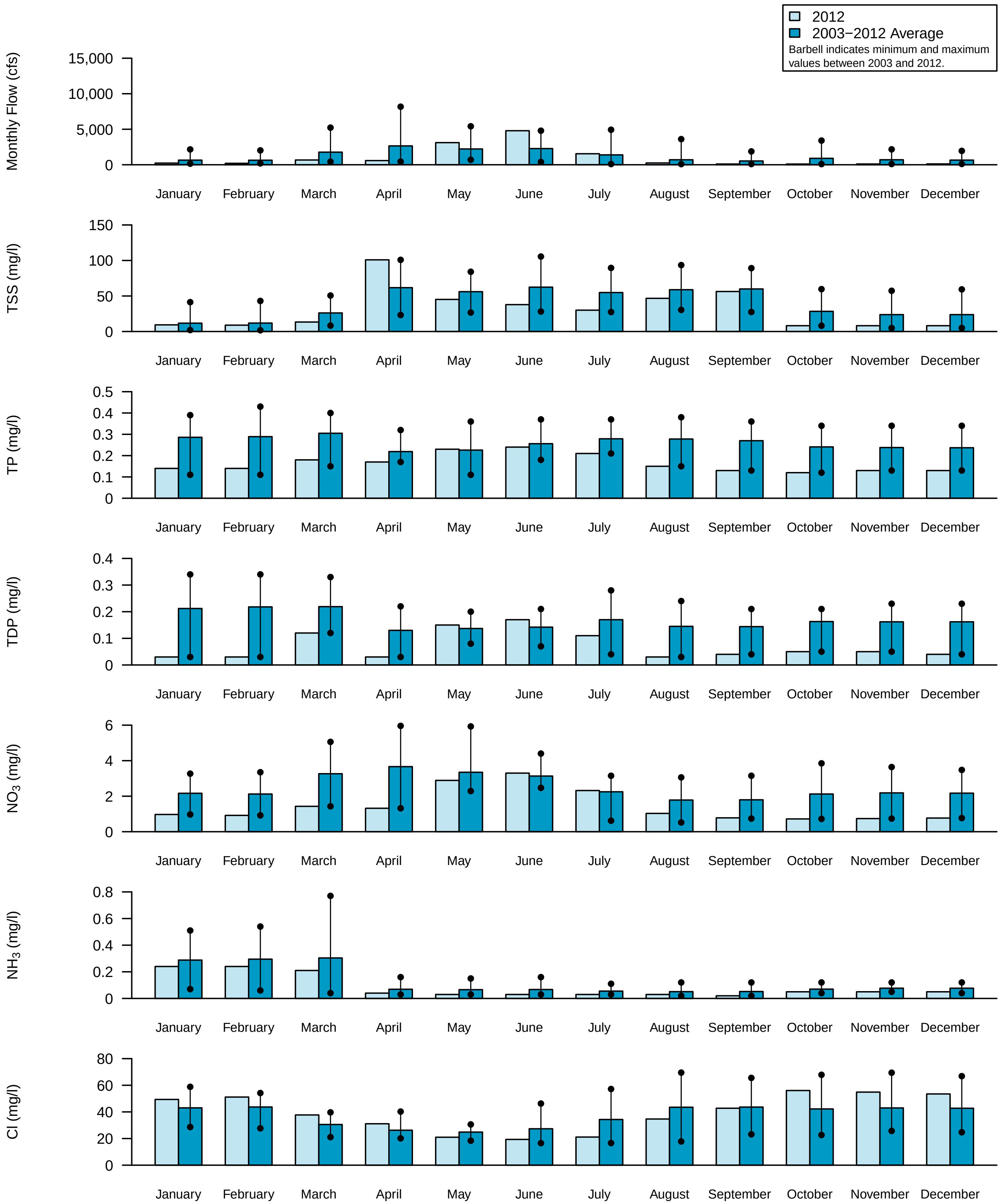
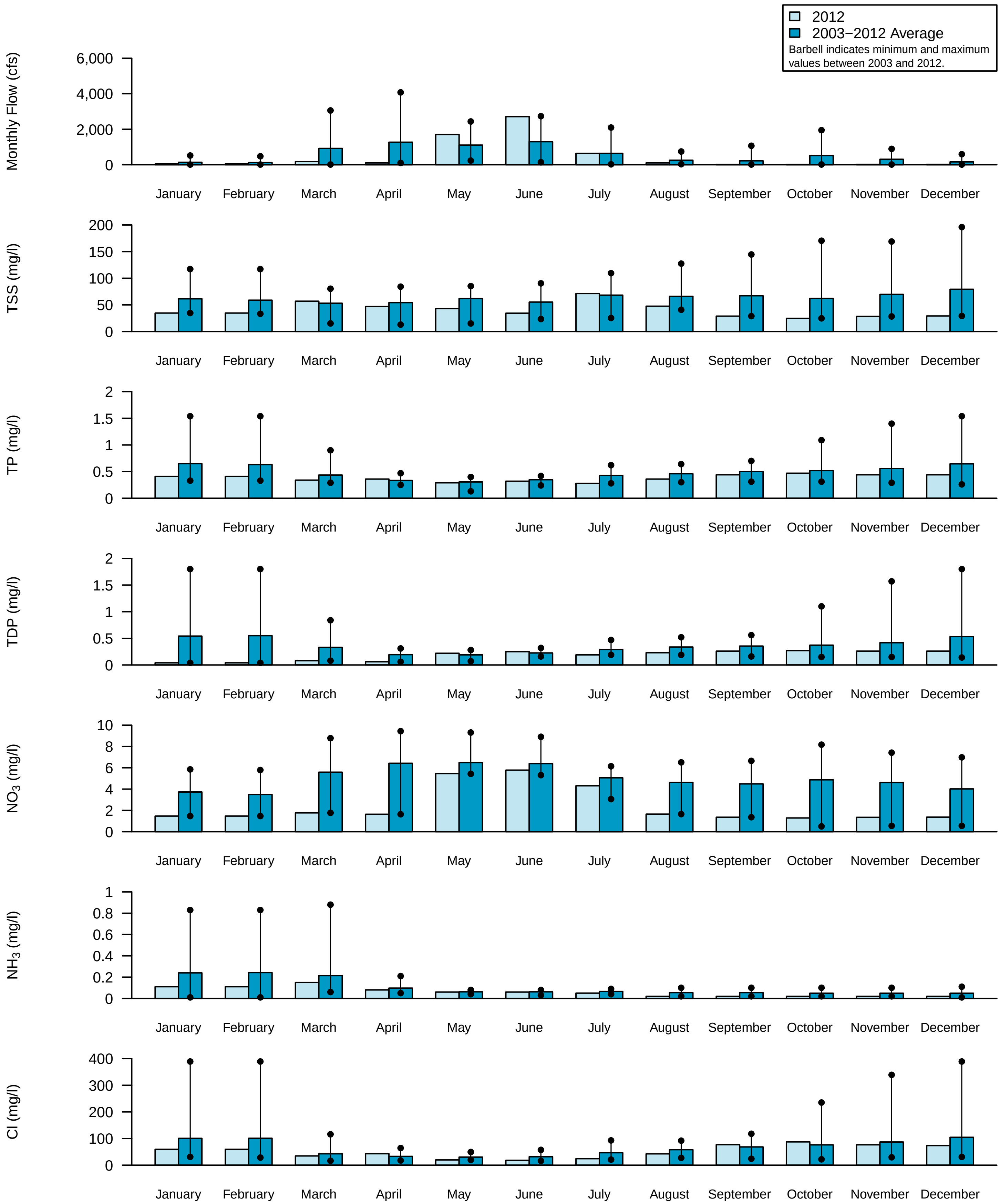


Figure CW−19: South Fork Crow River at Mayer
Flow−Weighted Mean Concentation by Month

Most Recent Year (2012) of Data Compared to 2003−2012 Average



Comparison between Crow River Main Stem at Rockford and Crow River South Fork at Mayer

The water quality monitoring stations at South Fork at Mayer and Crow River main stem at Rockford were originally sited in coordination with existing flow gauging stations operated by the MnDNR and USGS, respectively. This coordinated effort provided MCES with quality flow data without additional cost; however the station locations do not allow ready estimation of separate load contributions from the North Fork and the South Fork to the combined load estimated at the Rockford station, located downstream of the confluence. MCES has no direct measurements from the North Fork, and the South Fork at Mayer is located approximately 20 miles upstream from the confluence of the two Forks. Figure CW-5 shows watershed delineations for the North Fork of the Crow, the South Fork of the Crow at Mayer, and the South Fork Downstream watershed (that portion of the South Fork downstream of Mayer but upstream of the confluence at Rockford).

MCES compiled the following information to allow indirect comparison of the North Fork and the South Fork contributions to the water quality measured at the Rockford station below the confluence. Readers are reminded that the South Fork is measured at Mayer and that the Rockford station includes contributions from the North Fork, the South Fork, and the South Fork Downstream watersheds (Figure CW-5). The Crow River Downstream watershed includes inflow from Deer Creek and Pioneer Creek. Sarah Creek enters the system below the confluence but above the Rockford station.

The median annual runoff ratio is virtually the same for the Crow River main stem at Rockford and the South Fork of the Crow River at Mayer (0.18 vs. 0.2, respectively), which indicates the North and South Fork watersheds have similar percentages of precipitation runoff (versus evapotranspirate or infiltrate) averaged over the course of a year (Table CW-10). The runoff ratios in the Crow main stem and Crow South are probably most highly influenced by watershed drain tile, soil types, and available storage in lakes and wetlands.

The median annual FWM concentration for TSS in the South Fork Crow River at Mayer is higher than the FWM concentration for the Crow River main stem at Rockford (60 mg/l vs. 46 mg/l), which indicates the South Fork may have a higher median concentration than the North Fork. The median TSS load from the South Fork watershed draining to Mayer (50,800,000 lbs) is 51% of the Crow River main stem load (99,950,000 lbs), which includes contributions of the North Fork, South Fork, and South Fork Downstream (which includes Deer and Pioneer Creeks) watersheds.

As with TSS, the FWM TP concentration in the South Fork of the Crow River at Mayer is higher than the Crow River main stem at Rockford (0.34 mg/l vs. 0.25 mg/l), and thus may contribute a higher concentration of TP to the main stem of the Crow than the North Fork. The median TP load from the South Fork watershed draining to Mayer (322,500 lbs) is 65% of the Crow River main stem load at Rockford (496,000 lbs).

NO_3 FWM concentration in South Fork Crow River at Mayer is again higher than the Crow River main stem at Rockford (6.6 mg/l vs. 3.3 mg/l). Thus, the South Fork Crow River may contribute the majority of the annual load to the main stem of the Crow River.

Similar to the other pollutants, the Cl FWM concentration in South Fork Crow River at Mayer is higher than the Crow River main stem at Rockford (31.3 mg/l vs. 27.1 mg/l). The median Cl load from the South Fork watershed draining to Mayer (28,650,000 lbs) is 57% of the Crow River main stem load at Rockford (49,950,000 lbs).

Table CW-10: Crow River South Fork at Mayer and Crow River Main Stem at Rockford Annual Median Runoff Ratios, Concentrations, Loads and Pollutant Yields, 2003-2012

Pollutant Measure	Crow River South Fork at Mayer	Crow River Main Stem at Rockford
Median Runoff Ratio[1]	0.2	0.18
TSS Median Annual FWM Conc[2] (mg/l)	60	46
TSS Median Annual Load[3] (lb/yr)	50,800,000	98,950,000
TSS Median Annual Yield[4] (lb/ac/yr)	69	59
TP Median Annual FWM Conc[2] (mg/l)	0.339	0.248
TP Median Annual Load[3] (lb/yr)	322,500	496,000
TP Median Annual Yield[4] (lb/ac/yr)	0.438	0.294
NO_3 Median Annual FWM Conc[2] (mg/l)	6.58	3.33
NO_3 Median Annual Load[3] (lb/yr)	5,995,000	5,960,000
NO_3 Median Annual Yield[4] (lb/ac/yr)	8.2	3.5
Cl Median Annual FWM Conc[2] (mg/l)	31	27
Cl Median Annual Load[3] (lb/yr)	28,650,000	49,950,000
Cl Median Annual Yield[4] (lb/ac/yr)	39	29.6

[1] Runoff ratio = annual flow volume at monitoring station / annual area-weighted precipitation. Area-weighted precipitation for each watershed provided by Minnesota Climatological Working Group (2013)

[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

[3] Load = annual pollutant load mass estimated using Flux32 (Walker, 1999).

[4] Yield = watershed pollutant yield calculated from annual pollutant load mass estimated using Flux32 (Walker, 1999) divided by area of watershed upstream of MCES monitoring station

In 2009, the MPCA and MnDNR installed new flow and water quality stations on the North Fork at Farmington Avenue in Rockford and on the South Fork at Bridge Avenue in Delano, upstream of the confluence. Load and volume estimates reported by the MPCA indicate similar annual volumes delivered by the two forks during 2009-2012 (Table CW-11), with an average of contribution of 48% North Fork and 52% South Fork . Similarly, the average contribution of TSS was 36% and 64%; for TP was 34% and 66%; and for NO_3 + NO_2 was 16% and 84%, for North Fork and South Fork, respectively.

To avoid duplication of the information provided by the new South Fork station installed by the MPCA, MCES discontinued its South Fork at Mayer station in 2013. MCES will continue to operate the Crow River main stem at Rockford, both to provide comparative loads to those measured by the MPCA, and to continue the historical data collection necessary to estimate water quality trends with QWTREND and other statistical tools.

Table CW-11: Percent Contribution of North Fork and South Fork of Crow River above Confluence at Rockford based on MPCA Load Estimates, 2009-2012

Year	Volume[1]		TSS[1]		TP[1]		$NO_3 + NO_2$[1]	
	North Fork	South Fork	North Fork	South Fork	North Fork	South Fork	North Fork	South Fork
2009	49%	51%	46%	54%	31%	69%	19%	81%
2010	41%	59%	35%	65%	28%	72%	15%	85%
2011	53%	47%	24%	76%	43%	57%	15%	85%
2012	50%	50%	38%	62%	NA	NA	16%	84%
Average	48%	52%	36%	64%	34%	66%	16%	84%

[1] Percent contributions based on loads and volumes estimated by the MPCA from data collected at their stations at North Fork Crow River at Farmington Avenue near Rockford (HydstraID H18088001; EquisID S001-256)) and South Fork Crow River at Bridge Avenue at Delano (HydstraID H19001001; EquisID S001-255).

(wq-cm4-05.xlsx downloaded from http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/streams-and-rivers/watershed-pollutant-load-monitoring-network.html#products-data by MCES on 04/01/2015).

Flow and Load Duration Curves

Load duration curves are frequently used to assess water quality concentrations occurring at different flow regimes within a stream or river (high flow, moist conditions, mid-range, dry conditions, and low flow). The curves can also be used to provide a visual display of the frequency, magnitude, and flow regime of water quality standard exceedances if standard concentrations are added to the plots (USEPA, 2007).

MCES developed flow and load duration curves for each stream location using recommendations of the U.S. Environmental Protection Agency (USEPA), including:

- Develop flow duration curves using average daily flow values for the entire period of record plotted against percent of time that flow is exceeded during the period of record.
- Divide the flow data into five zones: high flows (0-10% exceedance frequency); moist conditions (10-40%); mid-range flows (40-60%); dry conditions (60-90%); and low flows (90-100%). Midpoints of each zone represent the 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles, respectively.
- Multiply concentration and flow for each sampling event for period of record, to result in approximate daily mass loads included on the curve as points.
- Multiply water quality standard concentration and monitored flow to form a line indicating allowable load. Sample load points falling below the line meet the standard; those falling above the line exceed the standard.

The final load duration curves provide a visual tool to assess if standard exceedances are occurring, and if so, at which flow regimes.

MCES selected four parameters to assess using load duration curves: TSS, TP, NO_3, and Cl. Each of the parameters was plotted using Crow River main stem at Rockford and South Fork Crow River at Mayer monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table CW-12. No draft standard has been set for NO_3, so MCES used the drinking water standard of 10 mg/l.

Most of the draft standards proposed by MPCA have accompanying criteria that are difficult to show on the load duration curves. For example, for a water body to violate the draft TP river standard, the water body must exceed the causative variable (TP concentration), as well as one or more response variables: sestonic (suspended) chlorophyll, biochemical oxygen demand (BOD_5), dissolved oxygen (DO) flux, and/or pH (MPCA, 2013a). Thus for this report, the load duration curves are used as a general guide to identify flow regimes at which water quality violations may occur. The MPCA is responsible for identifying and listing those waters not meeting water quality standards; the results of this report in no way supersede MPCA's authority or process.

The 1998–2012 flow duration curve and load duration curves for TSS, TP, NO_3, and Cl for the Crow River main stem monitoring station (below Hwy 55 in Rockford, MN) is shown in Figure CW-20. The 2001–2012 flow duration curve and load duration curves for the South Fork Crow River monitoring station (near Mayer, MN) is shown in Figure CW-21. The load duration curve shows that the South Fork of the Crow River has been undersampled. Out of 167 samples, only 4 (2.4%) are in the lowest 20% of flows. Any statements made below about samples exceeding the standard is based on this biased sampling.

At all flow conditions, the Crow River main stem at Rockford TSS sample loads were both above and below the draft standard. This response is consistent with other agricultural streams in the metropolitan area, where high flows lead to streambank, bluff, and ravine erosion. This pattern is similar in the data shown from the South Fork of the Crow River at Mayer, except at lower flows. This exception could be due to the biased sampling.

The Crow River main stem at Rockford and the South Fork of the Crow River at Mayer TP concentrations exceed the draft nutrient standard concentration consistently at all flows. The South Fork station near Mayer is downstream of 16 domestic WWTPs. The Crow River main stem station near Rockford is downstream of the South Fork station and an additional 20 WWTPs. Thirteen of the total contributing WWTPs have started phosphorus reductions during the period of record. Since the stream sediments downstream of the WWTPs have likely been enriched by years of high phosphorus effluent discharge, it will take some time for a new water-sediment phosphorus equilibrium to form. Until then, the sediments may continue to release phosphorus to the stream flow. MCES plans to repeat this assessment in 5 -10 years and will specifically investigate if low flow phosphorus concentrations have decreased.

All NO_3 concentrations at all flow regimes met the drinking water standard of 10 mg/l in both the Crow River main stem and the South Fork of the Crow River. The final river nutrient standard for NO_3 will likely be much less than that and likely will be exceeded at the higher flow regimes.

Cl concentrations in the Crow River main stem are below the draft Cl standard at all flow regimes, and the South Fork of the Crow River has two exceedances of the draft Cl standard in dry and low flow conditions. Generally, for both stations, the Cl concentrations are highest at the lowest flows, indicating a WWTP source, groundwater contribution of Cl at baseflow conditions, or very early spring snowmelt carrying dissolved road salt.

Table CW-12: Crow River Beneficial Use and River Nutrient Region (RNR) Classifications and Pollutant Draft Standards

Monitoring Station	Use Classification[1] for Domestic Consumption (Class 1) and Aquatic Life and Recreation (Class 2)	River Nutrient Region (RNR)[2] of Monitoring Station	Cl Draft Stnd[4] (mg/l)	TSS Draft Stnd[5] (mg/l)	TP Draft Stnd[6] (ug/l)	NO_3 DW Stnd[7] (mg/l)
Crow River below Hwy 55 at Rockford (CW23.1)	2B	Central[3]	230	30	100	10
South Fork Crow River near Mayer (CWS20.3)	2B	South[3]	230	65	150	10

[1] MN Rules 7050.0470 and 7050.0430

[2] MPCA, 2010.

[3] Watershed includes more than one River Nutrient Region (RNR). Listed RNR is for watershed at monitoring station or as designated by MPCA, 2010.

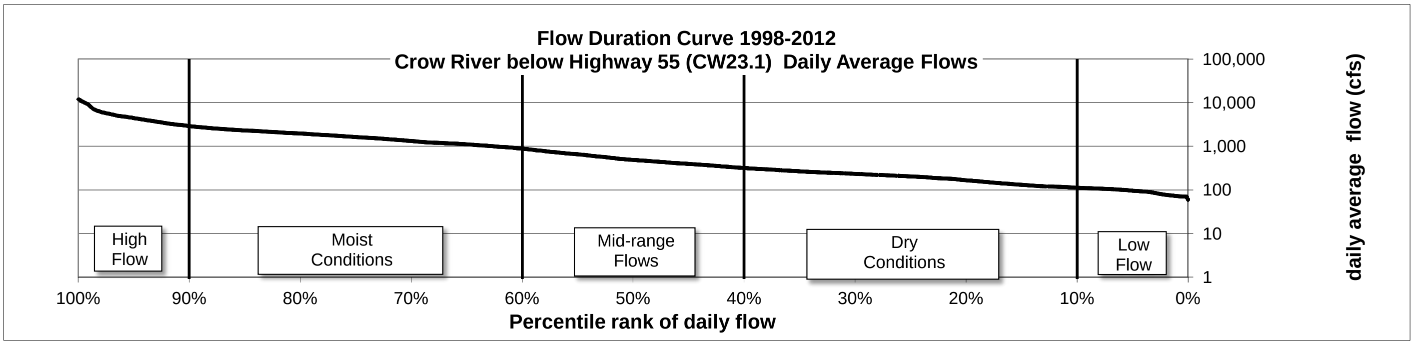
[4] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft chloride standard pending results of USEPA toxicity tests.

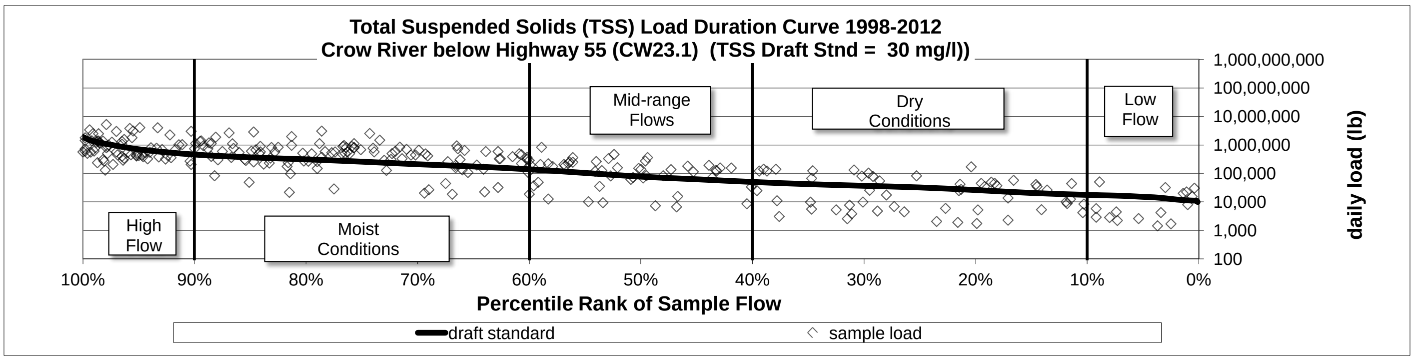
[5] MPCA, 2011a. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

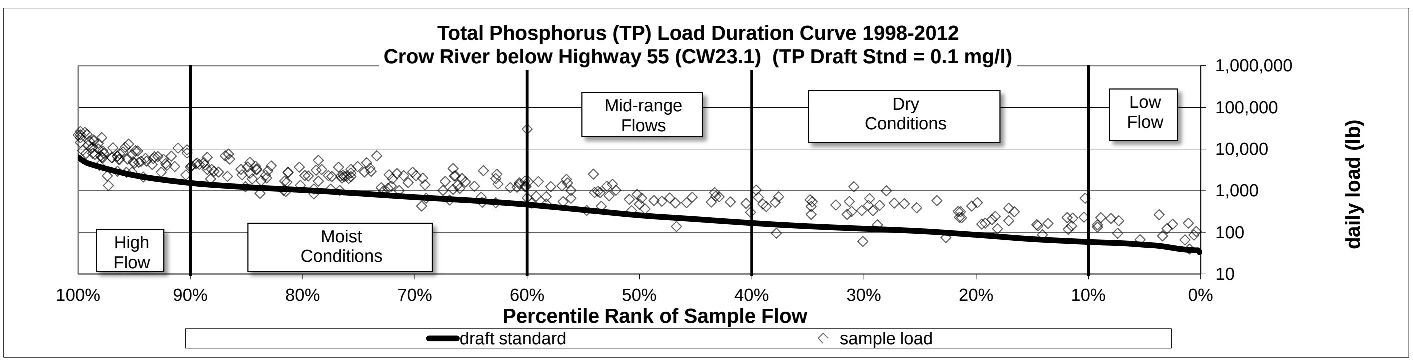
[6] MPCA, 2013a. To violate the standard, concentration of causative variable (TP) must be exceeded, as well as one or more response variables: sestonic chlorophyll, BOD_5, DO flux, and/or pH.

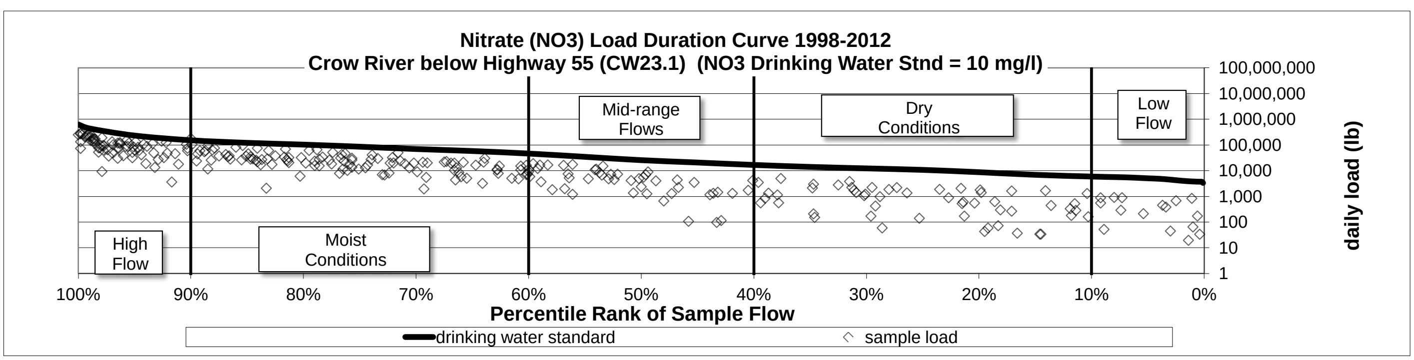
[7] MCES used the nitrate drinking water standard of 10 mg/l pending results of USEPA toxicity tests and establishment of a draft nitrate standard for rivers and streams.

Figure CW-20: Crow River Main Stem at Rockford Flow and Load Duration Curves, 1998-2012









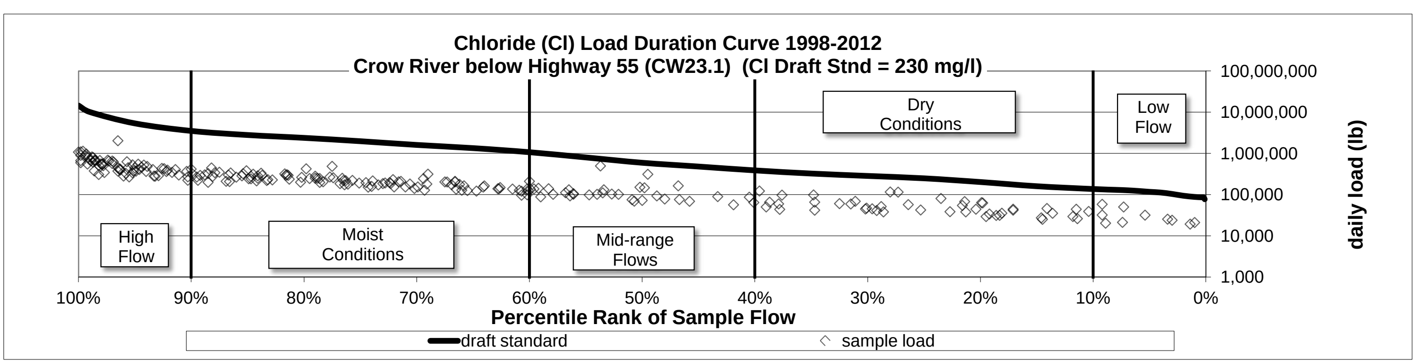
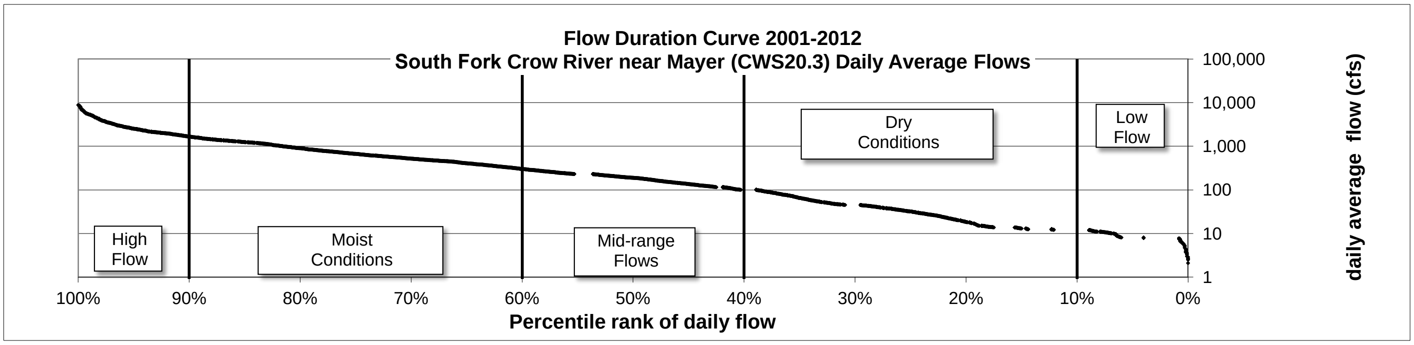
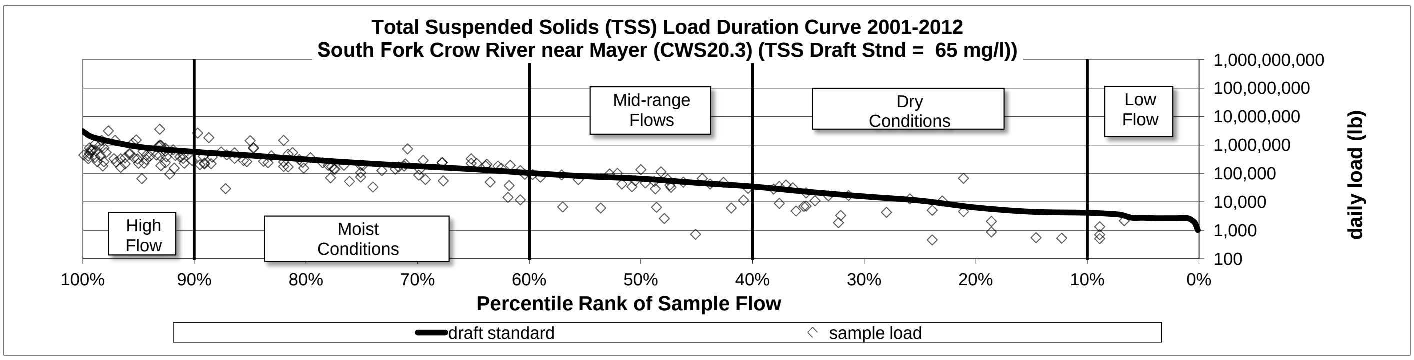
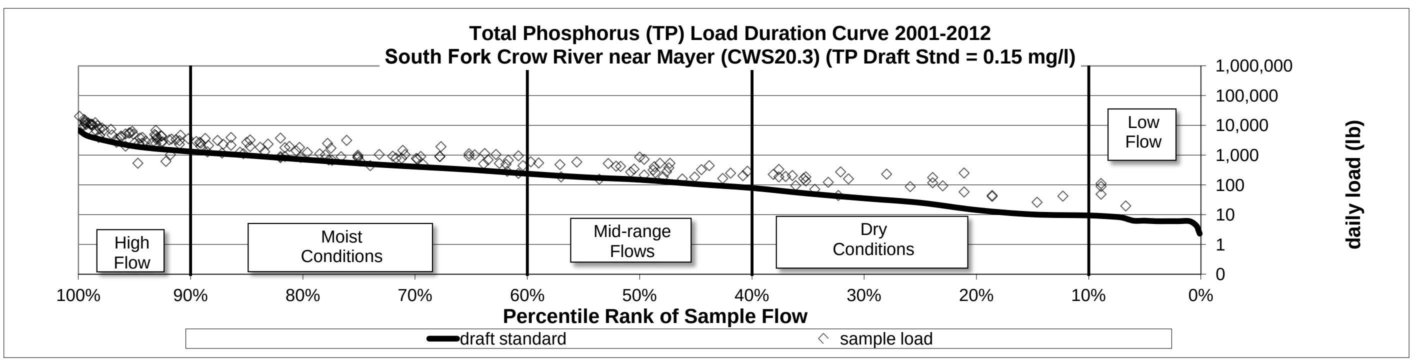
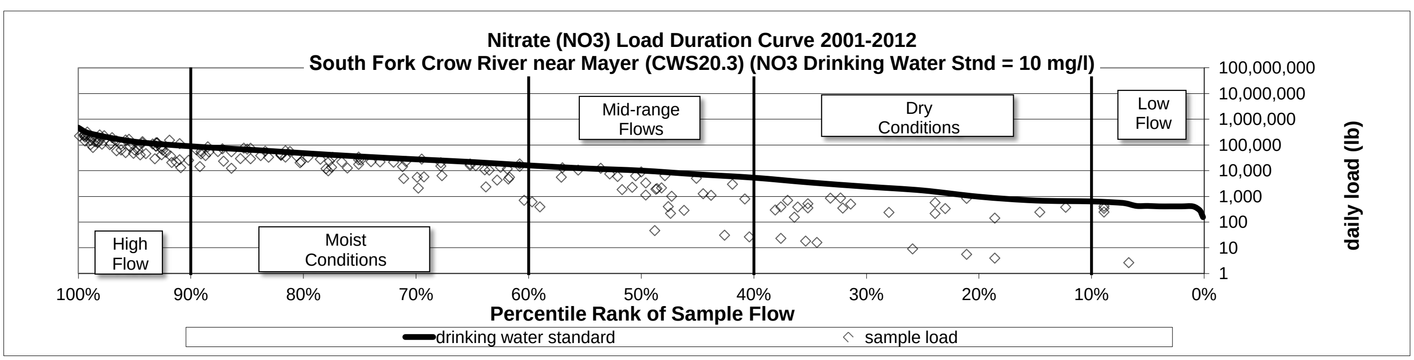


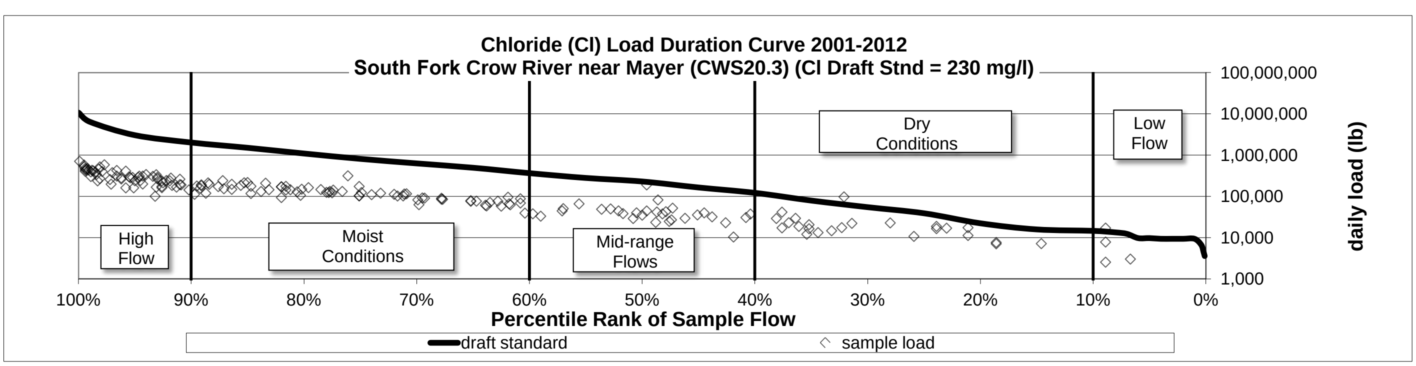
Figure CW-21: South Fork Crow River at Mayer Flow and Load Duration Curves, 2001-2012











Aquatic Life Assessment via Macroinvertebrates

Macroinvertebrates, including aquatic insects, worms, snails, crustaceans, and bivalves, are important indicators of water quality. Different types of macroinvertebrates have differing sensitivities to changes in pollution levels, habitat, flows, energy, and biotic interactions. As these environmental attributes change over time, they shape the composition of the macroinvertebrate community. Metrics have been developed that relate these community shifts with human-caused stresses.

Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. However, integrating the individual metrics into a multi-metric analysis provides a holistic assessment of the stream system.

The Crow River has not been monitored by MCES at either of the monitoring stations. As a part of the MPCA Watershed Monitoring and Assessment Reporting, the macroinvertebrate communities in various streams within the North Fork Crow River watershed were monitored in 2007-2010 (MPCA, 2011c) and in the South Fork Crow River watershed in 2012-2013 (MPCA, 2014b). Future adjustments to the MCES sampling program should consider cooperating with watershed organizations on macroinvertebrate sample collection and analysis.

Trend Analysis

Trend analysis was completed for the historical record of TP, NO_3, TSS and Chl a using the U.S. Geological Survey (USGS) program QWTREND (Vecchia, 2003). QWTREND removes the variability of annual flow and seasonality from the statistical analysis, so any trend identified should be independent of flow or seasonal variation.

Due to relatively short flow record for the monitored streams, MCES did not attempt to assess increases or decreases in flow. However, other researchers have performed regional assessments of alterations in flow rate; their results can be used to form general assumptions about changes in flows in the metropolitan area streams. Novotny and Stefan (2007) assessed flows from 36 USGS monitoring stations across Minnesota over periods of 10 to 90 years, finding that peak flow due to snowmelt was the only streamflow statistic that has not changed at a significant rate.

Peak flows due to rainfall events in summer were found to be increasing, along with the number of days exhibiting higher flows. Both summer and winter baseflows were found to be increasing, as well. Novotny and Stefan (2007) hypothesized that increases in annual precipitation, larger number of intense precipitation events, and more days with precipitation are driving the increased flows.

Alterations in land use and land management likely have also contributed to increasing flow rates. For example, Schottler et al. (2013) found that agricultural watersheds with large land use changes have exhibited increases in seasonal and annual water yields, with most of the increase in flow rate due to changes in artificial drainage and loss of depressional storage. MCES staff plan to repeat the following trend analyses in 5 to10 years. At that time, we anticipate sufficient data will have been collected for us to assess changes in flow rate, as well as to update the pollutant trends discussed below.

MCES staff assessed trends for the period of 1998-2012 for TP, NO_3, Chl a and TSS on the Crow River main stem at Rockford and for the period of 2001-2012 for TP, NO_3, and TSS on the South Fork of the Crow River at Mayer, using daily average flow, baseflow grab sample, and event composite sample data. The results are presented below.

Total Suspended Solids

One trend was identified for TSS flow-adjusted concentrations in the Crow River main stem at Rockford during the assessment period from 1998 to 2012 (Figure CW-22, top panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=2.06x10^{-7}$):

- Trend 1: 1998 to 2012, TSS flow-adjusted concentration decreased from 18.9 mg/l to 16.0 mg/l (-49%) at a rate of -1.0 mg/l/yr.

One trend was identified for TSS flow-adjusted concentrations in the South Fork of the Crow River at Mayer during the assessment period from 2001 to 2012 (Figure CW-23, top panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=0.029$):

- Trend 1: 2001 to 2012, TSS flow-adjusted concentration decreased from 24.7 mg/l to 16.3 mg/l (-34%) at a rate of -0.7 mg/l/yr.

The five-year trend in TSS flow-adjusted concentrations in the Crow River main stem at Rockford and the South Fork of the Crow River at Mayer (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. The Crow River main stem TSS flow-adjusted concentration decreased 18.9 mg/l to 16.0 mg/l (-15%), at a rate of -0.59 mg/l/yr. The South Fork of the Crow River TSS flow-adjusted concentration decreased 18.9 mg/l to 16.3 mg/l (-14%), at a rate of -0.51 mg/l/yr.

Total Phosphorus

One trend was identified for TP flow-adjusted concentrations in the Crow River main stem during the assessment period from 1998 to 2012 (Figure CW-22, second panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=1.9x10^{-12}$):

- Trend 1: 1998 to 2012, TP flow-adjusted concentration decreased from 0.37 mg/l to 0.18 mg/l (-52%) at a rate of -0.013 mg/l/yr.

One trend was identified for TP flow-adjusted concentrations in the South Fork of the Crow River during the assessment period from 2001 to 2012 (Figure CW-23, middle panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=0.0039$):

- Trend 1: 2001 to 2012, TP flow-adjusted concentration decreased from 0.41 mg/l to 0.30 mg/l (-28%) at a rate of -0.010 mg/l/yr.

The five-year trend in TP flow-adjusted concentrations in the Crow River main stem and the South Fork of the Crow River (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. The Crow River main stem TP flow-adjusted concentration decreased 0.22 mg/l to 0.18 mg/l (-16%), at a rate of -0.0071 mg/l/yr. The South Fork of the Crow River TP flow-adjusted concentration decreased 0.34 mg/l to 0.30 mg/l (-11%), at a rate of -0.0075 mg/l/yr.

Chlorophyll a (Corrected)

Two trends were identified for chlorophyll a flow-adjusted concentration (Corrected) in the Crow River main stem during the assessment period from 2003 to 2012 (Figure CW-22, third panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=0.00062$):

- Trend 1: 2003 to 2010, chlorophyll a flow-adjusted concentration decreased from 0.038 mg/l to 0.022 mg/l (-43%) at a rate of -0.0021 mg/l/yr.
- Trend 2: 2011 to 2012, chlorophyll a flow-adjusted concentration increased sharply from 0.022 mg/l to 0.053 mg/l (143%) at a rate of 0.016 mg/l/yr.

Unfortunately, the chlorophyll a (Corrected) five year trend could not be calculated for the other MCES-monitored streams due to a lack of data, and is not included in the ***Comparison with Other Metro Area Streams***. The Crow River main stem five year trend for period 2008-2012 was calculated to have a complete statistical description of the data. The chlorophyll a (Corrected) flow-adjusted concentration increased from 0.026 mg/l to 0.053 mg/l (105%) at a rate of 0.0054 mg/l/yr.

Nitrate

Two trends were identified for NO_3 flow-adjusted concentrations in the Crow River main stem during the assessment period from 1998 to 2012 (Figure CW-22, bottom panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=3.7\times10^{-6}$):

- Trend 1: 1998 to 2005, NO_3 flow-adjusted concentration increased from 0.97 mg/l to 1.54 mg/l (59%) at a rate of 0.071 mg/l/yr.
- Trend 2: 2006 to 2012, NO_3 flow-adjusted concentration decreased from 1.54 mg/l to 0.86 mg/l (-44%) at a rate of -0.096 mg/l/yr.

Two trends were identified for NO_3 flow-adjusted concentrations in the South Fork of the Crow River during the assessment period from 2001 to 2012 (Figure CW-23, bottom panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=3.6\times10^{-9}$):

- Trend 1: 2001 to 2006, NO_3 flow-adjusted concentration increased from 1.8 mg/l to 3.2 mg/l (82%) at a rate of 0.24 mg/l/yr.
- Trend 2: 2007 to 2012, NO_3 flow-adjusted concentration decreased from 3.2 mg/l to 1.0 mg/l (-69%) at a rate of -0.44 mg/l/yr.

The five-year trend in NO_3 flow-adjusted concentrations in the Crow River main stem and the South Fork of the Crow River (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. The Crow River main stem NO_3 flow-adjusted concentration decreased 1.36 mg/l to 0.86 mg/l (-37%), at a rate of -0.10 mg/l/yr. The South Fork of the Crow River NO_3 flow-adjusted concentration decreased 2.9 mg/l to 1.0 mg/l (-65%), at a rate of -0.37 mg/l/yr.

Figure CW−22: Crow River Main Stem at Rockford Trends for TSS, TP, Chl-*a* and NO_3

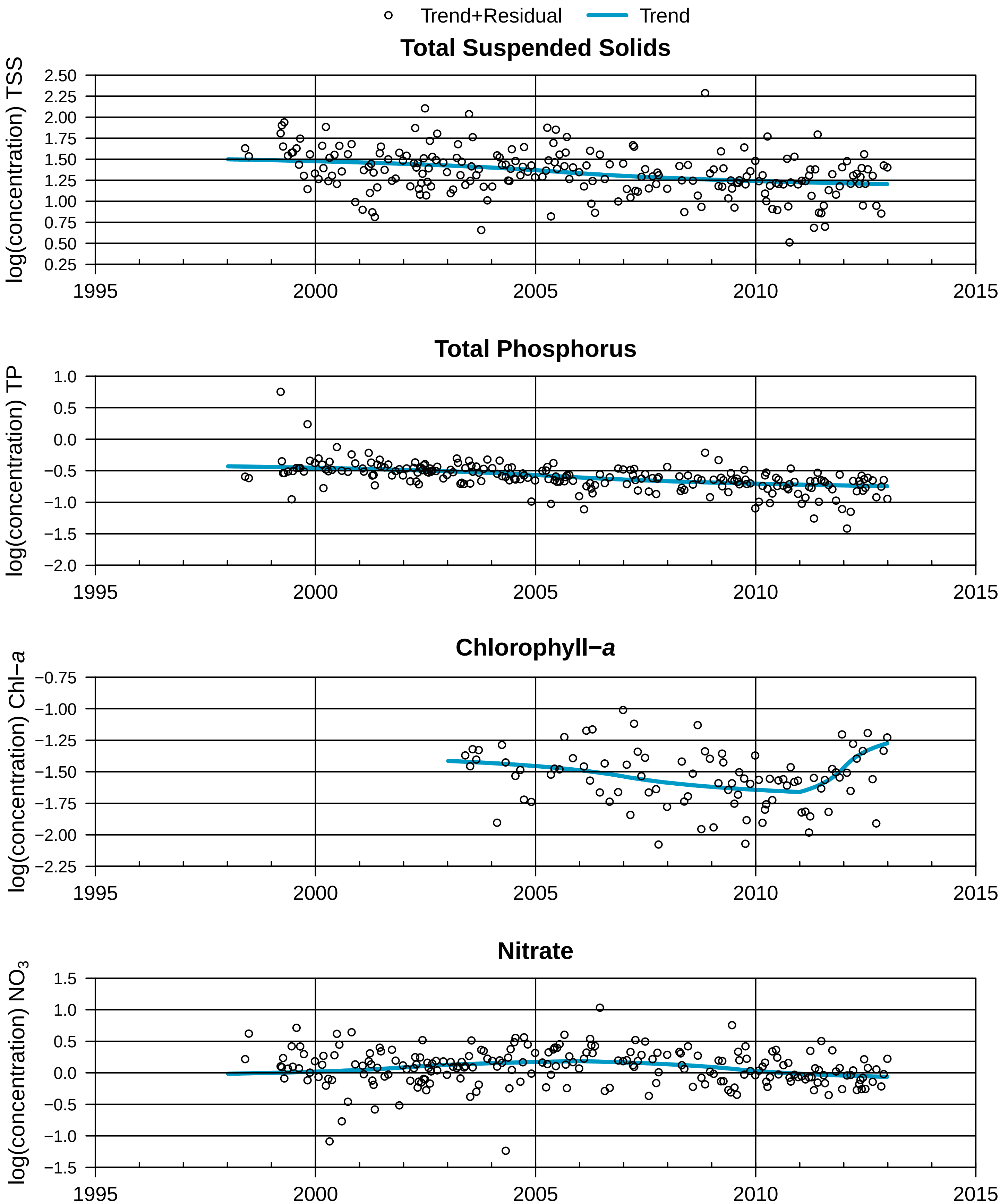
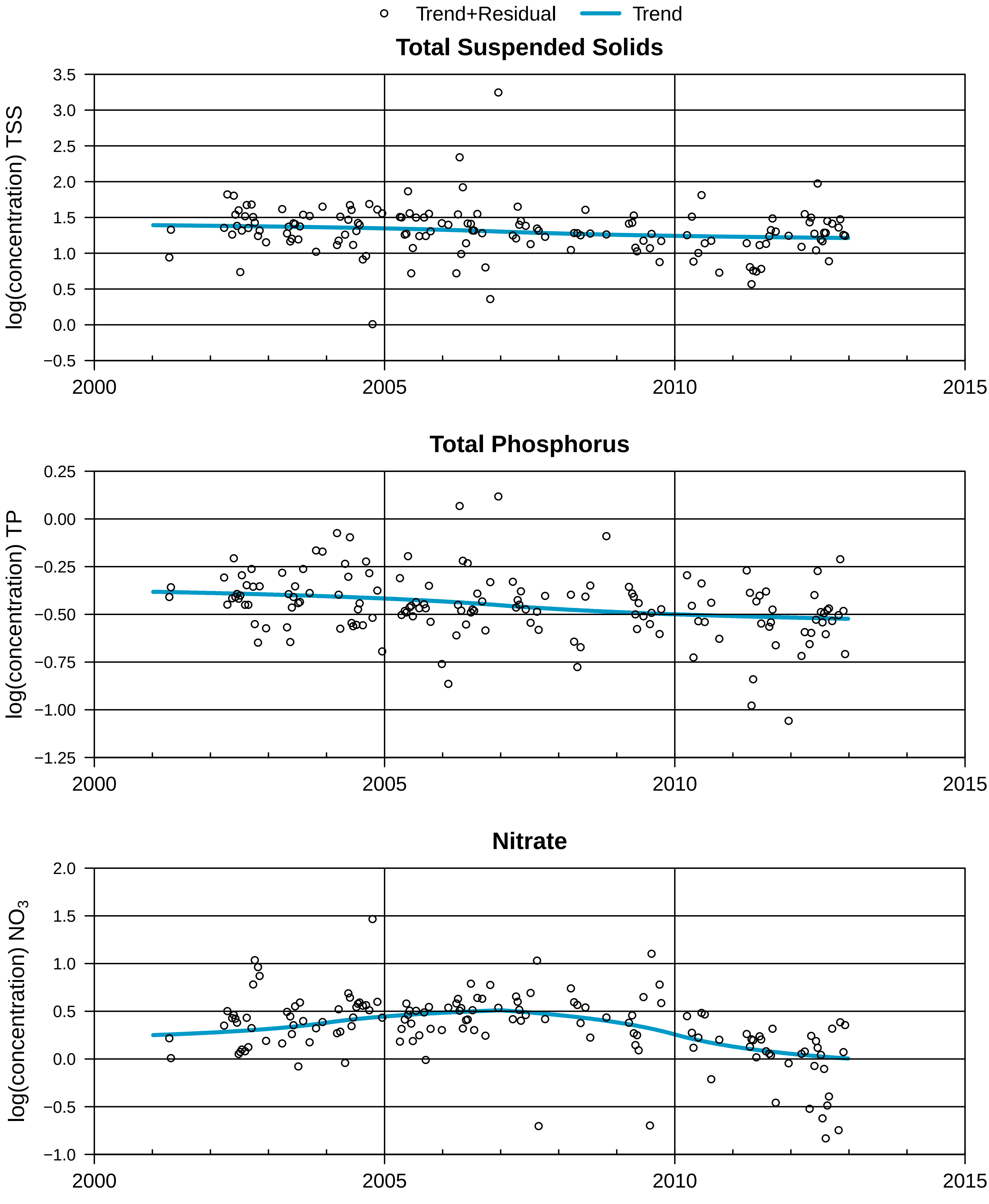


Figure CW–23: South Fork Crow River at Mayer Trends for TSS, TP and NO_3



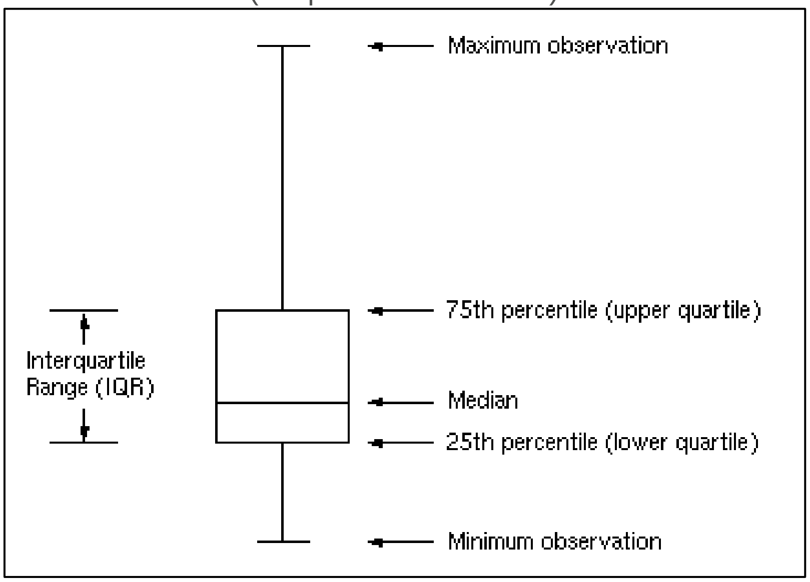
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots are used to summarize the comparison of the historical flow, TSS, TP, NO_3, and Cl data for the Crow River main stem at Rockford and South Fork of the Crow River at Mayer with those of the other metropolitan area streams monitored by MCES and with the major receiving water (in this case the Mississippi River above the confluence with the Mississippi River). The comparisons are show in Figure CW-25 to Figure CW-28 and Table CW-13.

Figure CW-24 shows the formatted legend of the box-and-whisker plots used in this report. Note that 50% of data points fall within the box (also known as the interquartile range), with the centroid delineated by the median line. The outer extent of the whiskers designate the maximum and minimum values.

Figure CW-24: General Schematic of a Box-and-Whisker Plot
(adapted from *sas.com*)



Comparisons for each chemical parameter for period 2003-2012 are shown using box-and-whisker plots of four metrics (annual flow-weighted mean (FWM) concentration, annual runoff ratio (volume/precipitation, which should be identical on each of the four parameter pages), total annual load, and annual areal yield), grouped on one page, with streams grouped by major receiving river and listed in order of upstream-to-downstream. In addition, the plot of FWM concentration includes the 2003-2012 FWM concentration for the three receiving rivers (Mississippi, St. Croix, and Minnesota), shown as a dashed line.

Total Suspended Solids. The South Fork Crow River and the Crow River main stem have higher FWM concentrations than the Mississippi River (as measured at Anoka; 60 mg/l and 46 mg/l vs. 18 mg/l, respectively), indicating that the entire Crow River is increasing the TSS concentration in the Mississippi, and the South Fork has a greater impact than the North Fork (Figure CW-25). The Crow River FWM TSS concentrations at both sites are greater than the Vermillion River and smaller than the Cannon River concentrations and much lower than the agriculturally dominated streams in the Minnesota River watershed (Bevens, Sand, and Carver).

Partially because of the large size of the watershed, the Crow River generates large TSS loads compared to other MCES-monitored streams. The Crow River main stem median TSS load is second largest only to the Cannon River watershed. The South Fork load is the fourth largest after the Cannon, Crow main stem, and Sand Creek. However, the Crow River main stem and Crow River South annual TSS yields are smaller than a number of Minnesota River tributaries.

Total Phosphorus. As with TSS, the South Fork Crow River and the Crow River main stem have higher FWM concentrations than the Mississippi River (0.34 mg/l and 0.25 mg/l vs. 0.12 mg/l, respectively), indicating that the entire Crow River increases the TP concentration in the Mississippi, and the South Fork has a greater impact than the North Fork (Figure CW-26). The Crow River stations have similar TP concentrations as the Vermillion and Cannon Rivers, but are generally lower than the more agriculturally intensive Minnesota River streams (both Bevens monitoring sites and Sand Creek). Even so, the loads from the Crow River watersheds are second and third in size of the MCES-monitored watersheds, ranking only after the Cannon River. The TP concentrations and load in Crow River stations are likely affected by a combination of land use management, especially in the highly agricultural sections of the watersheds, and by the domestic effluent from the WWTPs.

Nitrate. The South Fork Crow River and the Crow River main stem have higher FWM concentrations than the Mississippi River (6.6 mg/l and 3.3 mg/l vs. 1.4 mg/l, respectively), indicating that the entire Crow River is increasing the NO_3 concentration in the Mississippi, and the South Fork has a greater impact than the North Fork (Figure CW-27). The South Fork of the Crow River and the Cannon River contribute the majority of the NO_3 load to the major rivers of all MCES-monitored watersheds. The areal loads from the Crow River and the South Fork Crow River watersheds are comparable to the other agriculturally dominated watersheds including the Vermillion, Cannon, Bevens, and Sand Creeks. The NO_3 concentrations and load in Crow River stations are likely affected by a combination of land use management, especially in the highly agricultural sections of the watersheds with a large amount of draintile, and by effluent from the WWTPs.

Chloride. Similar to the other pollutants, the South Fork Crow River and the Crow River main stem have higher FWM concentrations than the Mississippi River (31.3 mg/l and 27.1 mg/l vs. 16 mg/l), which indicates that the entire Crow River watershed Cl concentration increases the Mississippi River concentration, and the South Fork has a greater impact than the North Fork (Figure CW-28). The Crow River stations' Cl concentrations fall within the range of concentrations from the other highly agriculturally dominated watersheds. They are significantly lower than the urbanized Mississippi River tributaries (Bassett, Minnehaha, Battle, and Fish). The two most prevalent sources of Cl to streams are road surfaces (from Cl application as a de-icer) and WWTP effluent (from domestic water softeners).

Even though concentrations of Cl in the Crow River main stem and Crow River South Fork are not particularly high, the Crow River still contributes one of the highest Cl loads of the MCES-monitored streams, because of the large watershed size. The largest Cl load contributors are the South Fork of the Crow River, the Crow River, the Vermillion River, and the Cannon River. However, only the Vermillion has an elevated Cl concentration.

Figure CW−25: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

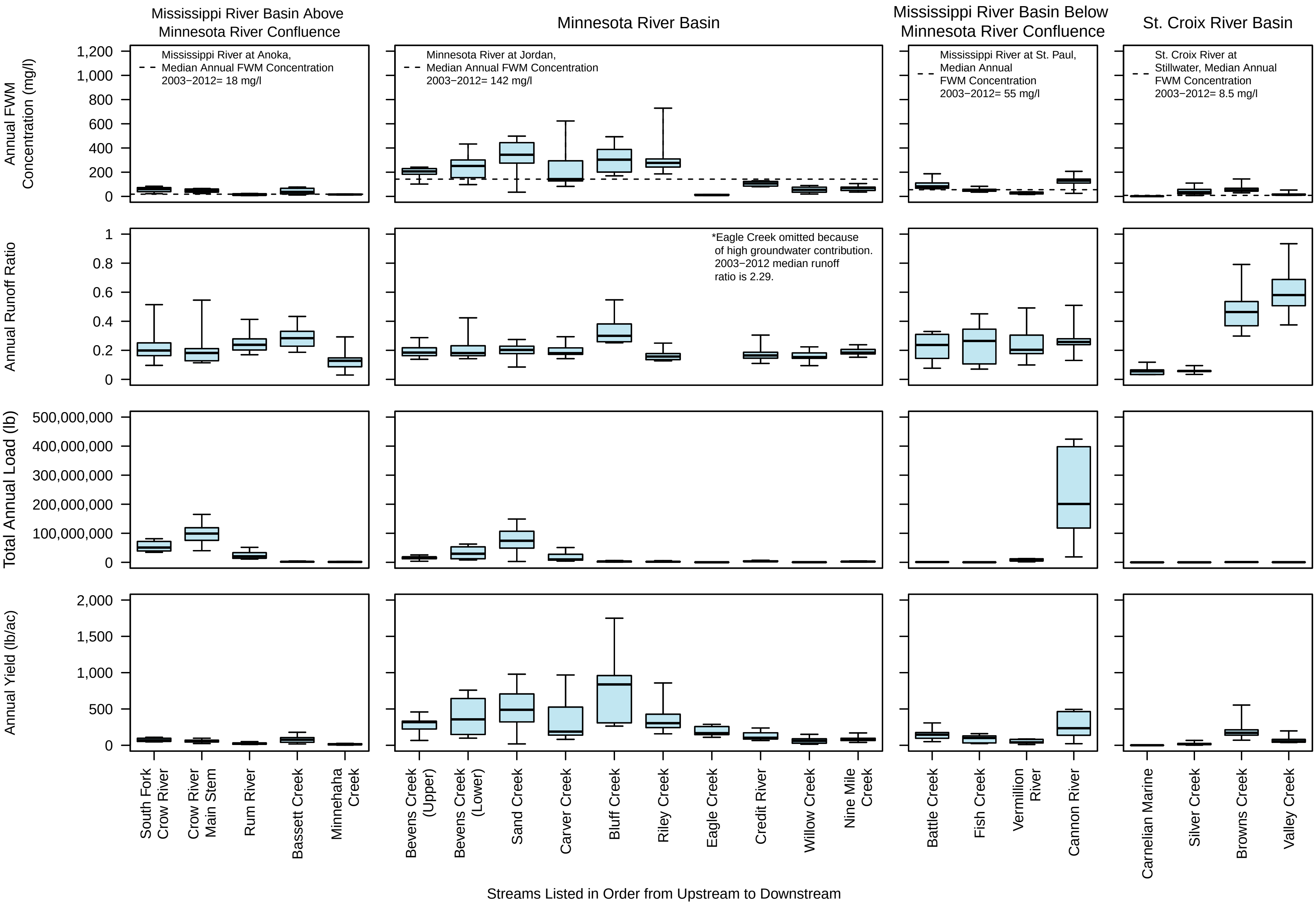


Figure CW−26: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

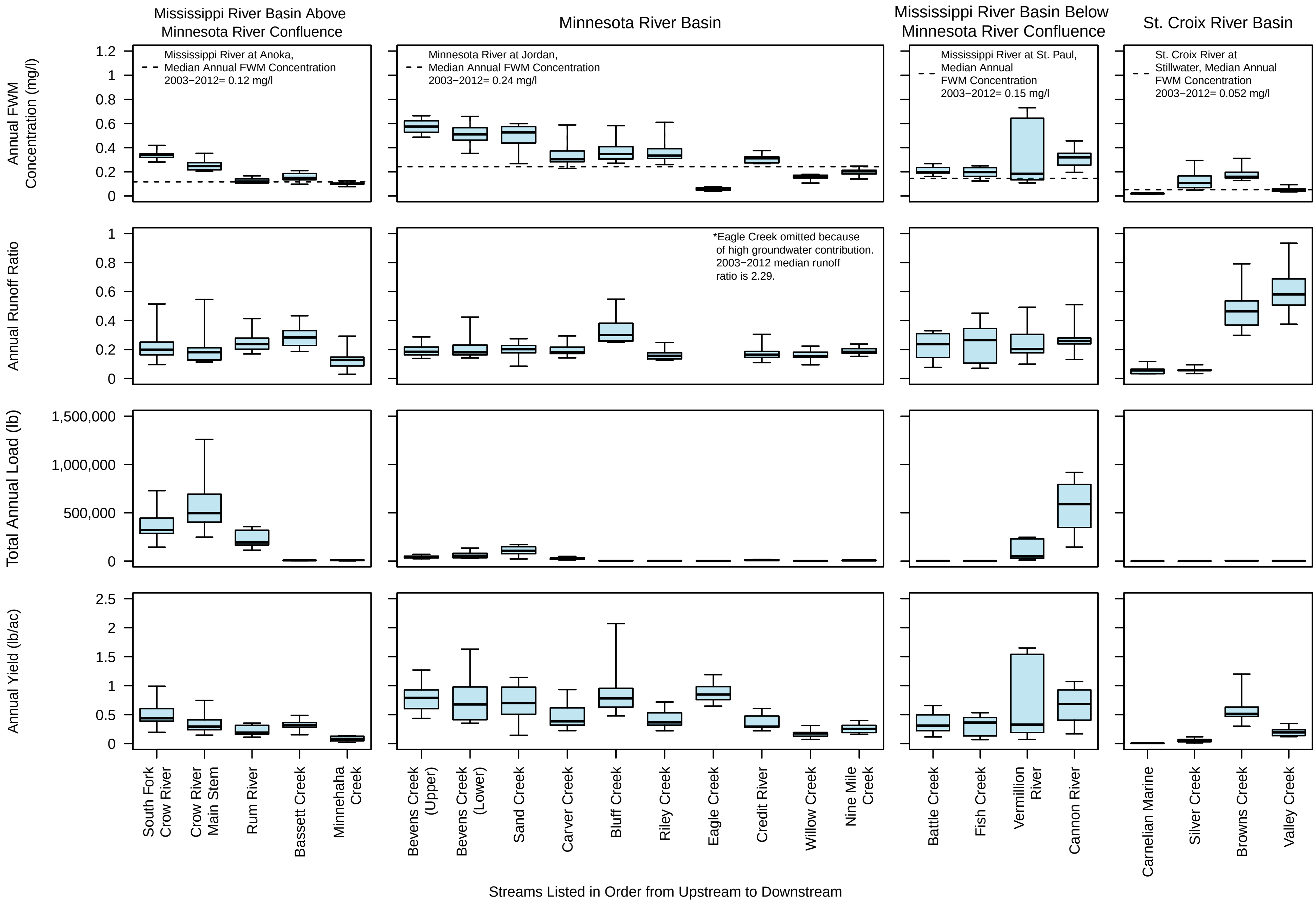


Figure CW−27: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

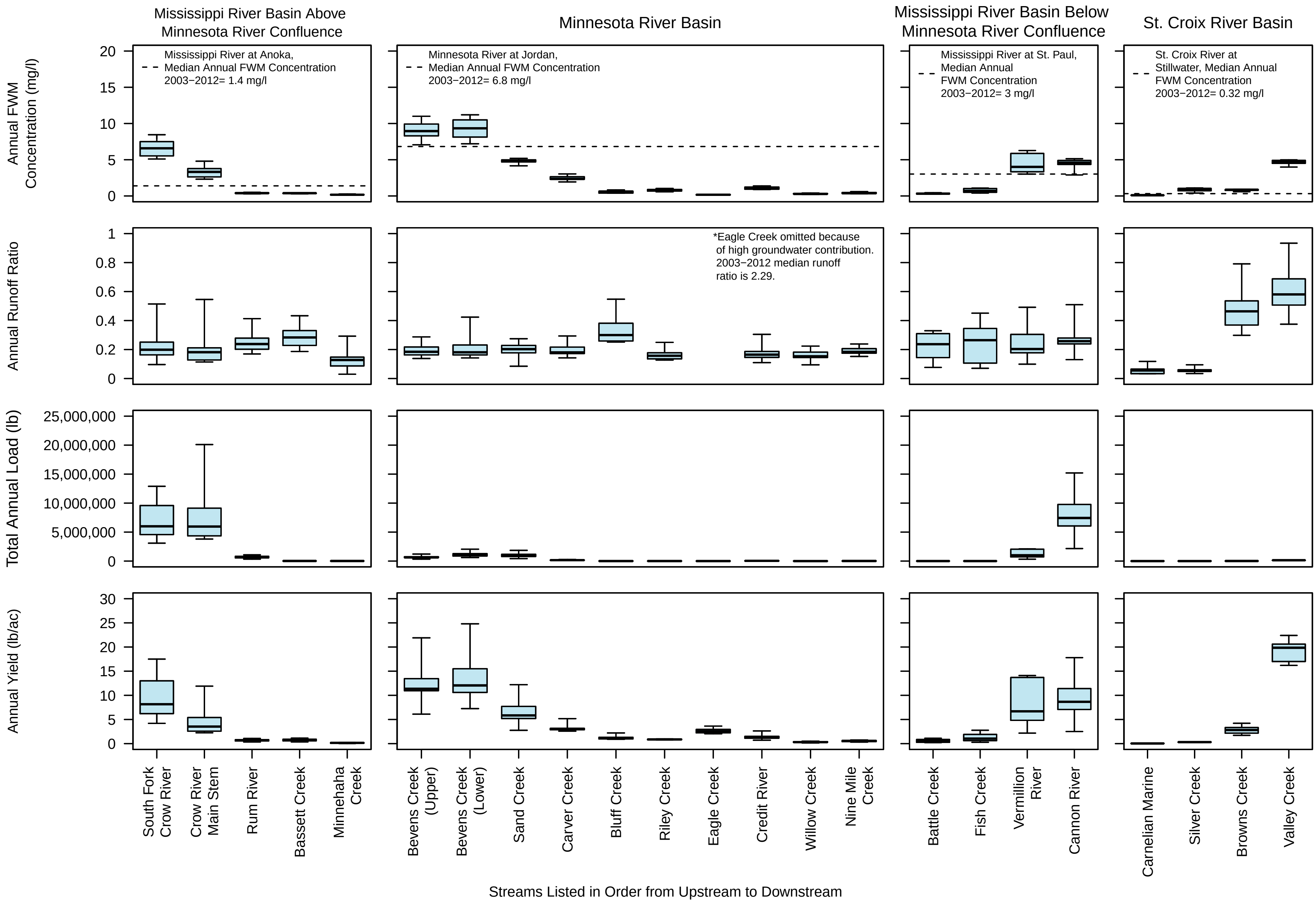


Figure CW−28: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

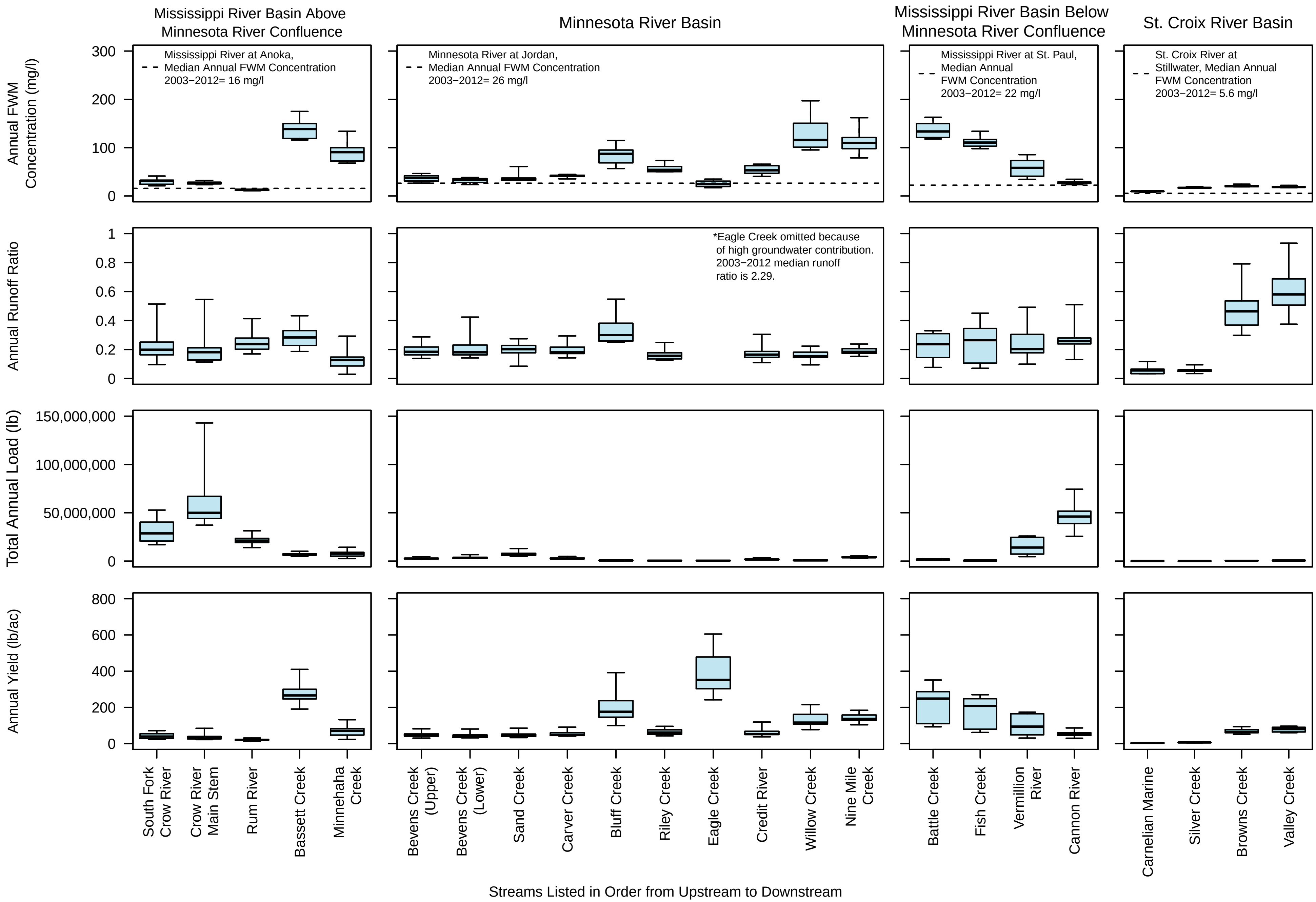


Table CW-13: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

Station	Stream Name	Major Watershed	Median Runoff Ratio[1]	TSS Median Annual FWM Conc[2] (mg/l)	TSS Median Annual Load[3] (lb/yr)	TSS Median Annual Yield[4] (lb/ac/yr)	TP Median Annual FWM Conc[2] (mg/l)l	TP Median Annual Load[3] (lb/yr)	TP Median Annual Yield[4] (lb/ac/yr)	NO_3 Median Annual FWM Conc[2] (mg/l)	NO_3 Median Annual Load[3] (lb/yr)	NO_3 Median Annual Yield[4] (lb/ac/yr)	Cl Median Annual FWM Conc[2] (mg/l)	Cl Median Annual Load[3] (lb/yr)	Cl Median Annual Yield[4] (lb/ac/yr)
BE5.0	Bevens Creek (Upper)	Minnesota	0.18	207	17,600,000	319	0.575	43,650	0.791	8.95	628,000	11.4	38	2,600,000	47.2
BE2.0	Bevens Creek (Lower)	Minnesota	0.18	252	29,550,000	357	0.511	55,950	0.677	9.34	996,500	12.1	34	3,395,000	41.1
SA8.2	Sand Creek	Minnesota	0.20	344	74,200,000	489	0.526	106,000	0.700	4.85	886,000	5.8	36	6,980,000	46.0
CA1.7	Carver Creek	Minnesota	0.18	143	9,870,000	188	0.304	20,200	0.385	2.35	157,000	3.0	41	2,500,000	47.5
BL3.5	Bluff Creek	Minnesota	0.30	304	3,025,000	838	0.348	2,820	0.782	0.61	4,405	1.2	87	635,500	176.0
RI1.3	Riley Creek	Minnesota	0.16	277	2,025,000	305	0.335	2,440	0.367	0.79	5,840	0.9	54	407,000	61.3
EA0.8	Eagle Creek	Minnesota	2.29	11	181,000	167	0.055	918	0.848	0.17	2,760	2.6	25	381,000	352.0
CR0.9	Credit River	Minnesota	0.16	107	3,090,000	103	0.312	8,800	0.293	1.15	37,400	1.3	53	1,590,000	53.1
WI1.0	Willow Creek	Minnesota	0.15	54	391,000	61	0.161	1,130	0.175	0.28	1,980	0.3	116	750,000	116.0
NM1.8	Nine Mile Creek	Minnesota	0.18	70	2,520,000	88	0.205	7,335	0.255	0.38	15,750	0.5	110	3,930,000	136.5
CWS20.3	Crow River (South)	Mississippi	0.20	60	50,800,000	69	0.339	322,500	0.438	6.58	5,995,000	8.2	31	28,650,000	39.0
CW23.1	Crow River (Main)	Mississippi	0.18	46	98,950,000	59	0.248	496,000	0.294	3.33	5,960,000	3.5	27	49,950,000	29.6
RUM0.7	Rum River	Mississippi	0.24	12	20,700,000	21	0.119	193,000	0.191	0.38	654,000	0.6	13	21,150,000	21.0
BS1.9	Bassett Creek	Mississippi	0.28	37	1,905,000	77	0.150	8,090	0.325	0.38	19,350	0.8	139	6,620,000	266.0
MH1.7	Minnehaha Creek	Mississippi	0.13	16	1,415,000	13	0.102	9,095	0.084	0.17	16,400	0.2	91	7,700,000	71.0
BA2.2	Battle Creek	Mississippi	0.24	83	1,043,000	146	0.197	2,220	0.311	0.32	3,945	0.6	134	1,775,000	248.5
FC0.2	Fish Creek	Mississippi	0.26	55	296,500	101	0.198	1,066	0.364	0.71	3,035	1.0	111	610,000	208.0
VR2.0	Vermillion River	Mississippi	0.20	29	6,025,000	40	0.185	49,000	0.328	4.02	1,001,500	6.7	58	14,050,000	94.1
CN11.9	Cannon River	Mississippi	0.26	130	201,000,000	235	0.320	589,000	0.687	4.59	7,435,000	8.7	28	46,050,000	53.8
CM3.0	Carnelian-Marine Outlet	St. Croix	0.06	2	7,570	0.4	0.022	156	0.009	0.10	701	0.04	10	69,500	3.9
SI0.1	Silver Creek	St. Croix	0.06	35	80,700	15	0.108	235	0.042	0.83	1,765	0.3	17	37,100	6.7
BR0.3	Browns Creek	St. Croix	0.46	51	785,500	172	0.160	2,355	0.514	0.86	12,900	2.8	20	300,000	65.6
VA1.0	Valley Creek	St. Croix	0.58	14	392,500	54	0.047	1,415	0.193	4.74	145,500	19.9	19	589,500	80.4

[1] Runoff ratio = annual flow volume at monitoring station / annual area-weighted precipitation. Area-weighted precipitation for each watershed provided by Minnesota Climatological Working Group (2013)

[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

[3] Load = annual pollutant load mass estimated using Flux32 (Walker, 1999).

[4] Yield = watershed pollutant yield calculated from annual pollutant load mass estimated using Flux32 (Walker, 1999) divided by area of watershed upstream of MCES monitoring station

Macroinvertebrates

In other chapters of this report, MCES created figures for area-wide comparisons of the macroinvertebrate M-IBI scores and the trends in water quality. However, since neither of the Crow River stations were included in biomonitoring they cannot be compared to the other metropolitan area streams. Please see the other sections in this report for further information.

Metropolitan Area Trends Analysis

Statistical trend analysis for each MCES stream monitoring station was performed using QWTREND (Vecchia, 2003). Trend estimates were calculated for 2008-2012 (the last five years of available data) to allow comparison of changes in water quality between streams. A similar approach was used in the 2013 MPCA nitrogen study (MPCA, 2013b) to compare QWTREND assessments in statewide streams and rivers.

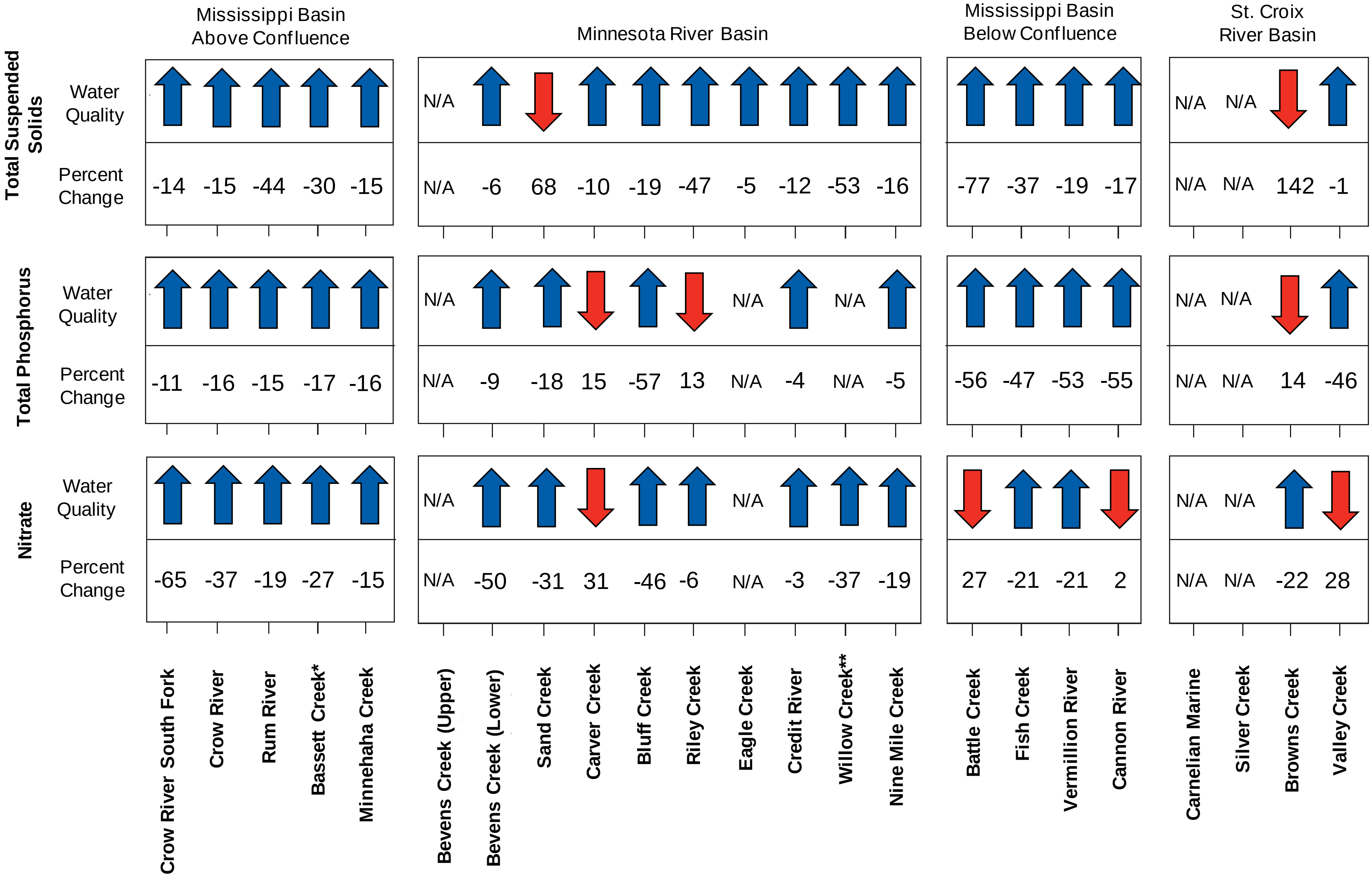
Estimated changes for TSS, TP, and NO_3 in MCES-monitored streams are presented below in two ways: First, tabulated results with directional arrows indicate increasing (blue upward arrow) and decreasing (red downward arrow) water quality paired with percent change in concentration estimated for 2008-2012 (Figure CW-29). Second, changes are shown by three seven-county metropolitan area maps (one each for TSS, TP, and NO_3 trends), with stream watersheds colored to represent improving and declining water quality (Figure CW-30). In both figures no trend was reported for those QWTREND analyses with poor quality of statistical metrics (for example, $p>0.05$).

In general, of the 20 monitoring stations assessed, most exhibited improving water quality (and thus decreasing concentration) for TSS, TP, and NO_3. There does not appear to be a spatial pattern for those few stations with declining water quality. There is no station with declining water quality for all three parameters, although both TP and NO_3 concentrations increased in Carver Creek (a Minnesota River tributary) and TSS and TP increased in Browns Creek (a St. Croix River tributary).

The Crow River stations are two of 11 MCES stations that have decreasing TSS, TP, and NO_3 concentrations since 2008, suggesting an improvement in water quality. The Mississippi River and its tributaries above the confluence with the Minnesota River typically had lower TSS concentrations than the Minnesota River and associated tributaries, but higher pollutant concentrations than the waters in the St. Croix River Basin. All of the Mississippi River tributaries above the Minnesota River had declining trends in TSS, TP, and NO_3 from 2008-2012.

Figure CW-29: Regional Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO_3, 2008-2012

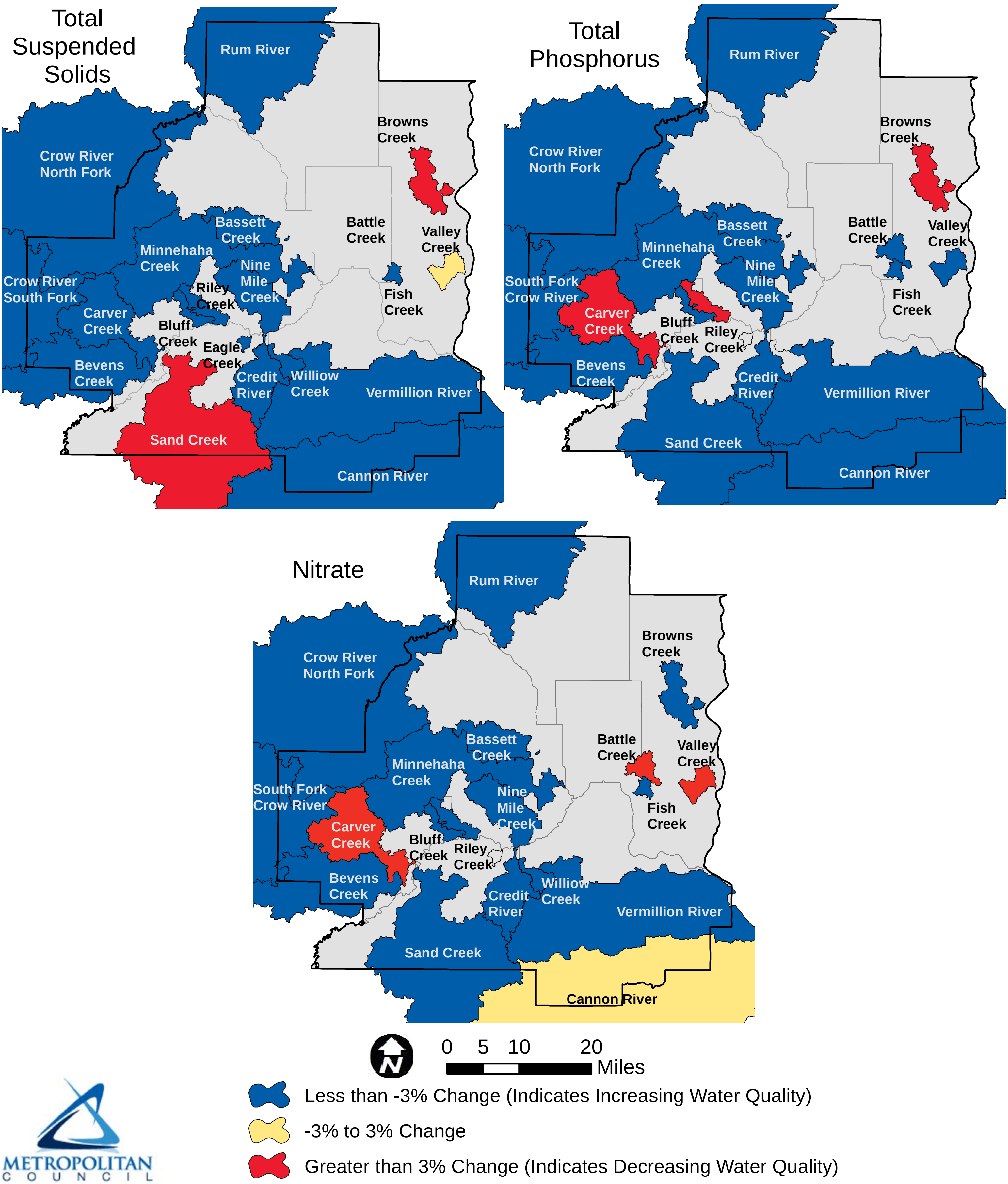
(Grouped by Major River Basin; As estimated by QWTrend)



Blue arrows indicate improved water quality; Red arrows indicate declining water quality.
"N/A" indicates analysis was not performed as data were not appropriate for analysis by QWTrend.
* Bassett Creek TSS Trends were assessed over 2009-2013. **Monitoring at Willow Creek was suspended in 2009.

Figure CW-30: Regional Maps of Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO3, 2008-2012

(As estimated by QWTrend)



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Conclusions

The Crow River discharges to the Mississippi north of the Twin Cities metropolitan area. The Crow River drains all or part of the counties of Carver, Hennepin, Kandiyohi, McLeod, Meeker, Pope, Renville, Sibley, Stearns, and Wright. The watershed is primarily agricultural, but includes pockets of forested and grass land, as well as some developed area, especially in the downstream part of the watershed in Carver and Hennepin Counties. 41 domestic WWTPs, including nine major Class A facilities, discharge to the Crow River. The overall watershed is flat, especially the South Fork watershed. The watershed does get steeper near the confluence with the Mississippi River.

MCES monitors two stations on the Crow River, one on the main stem of the river at mile 23.1 in Rockford, the other on the South Fork of the Crow River at mile 20.3 at Mayer. The station on the South Fork was discontinued in 2013. There are almost 76,000 acres in the unmonitored area (called the “Crow Main Stem Unmonitored Watershed” in this report) downstream of the Crow main stem monitoring station at Rockford. This area includes 5 domestic WWTPs and 159 feedlots. The monitoring data presented in this report does not reflect the potential changes in water quality that may occur downstream of the monitoring station.

The water quality in the Crow River watershed is affected by several factors: land cover, agricultural activity; WWTP effluent discharge; loss of wetlands and upland storage; and streambank and ravine erosion. TSS and TP concentrations at both monitoring stations are high, both in comparison to the Mississippi River near Anoka and to many other MCES monitored watersheds, especially the primarily urban watersheds. For both TSS and TP, the South Fork at Mayer concentrations are higher than the Crow River main stem at Rockford concentrations. However, highly agriculturally dominated watersheds in the Minnesota River basin, like Bevens and Sand Creeks, have TSS and TP concentrations higher than either the Crow main stem or Crow South watersheds. High TSS concentrations are likely due to erosion along streambanks, especially due to increased flows from drain tile, or from field sources. High TP concentrations may also be related to sediments eroded from streambanks, but also may be related to the large number of wastewater treatment facilities in the watershed and agricultural land use practices. The majority of major WWTPs in the watershed have implemented phosphorus removal and additional WWTPs will add phosphorus removal as their permits are renewed in the next few years.

NO_3 concentrations at both Crow River monitoring stations are higher than the Mississippi River above the confluence with the Minnesota, and also higher than most other MCES-monitored metropolitan area tributaries, other than Bevens, Sand, Cannon, Vermillion and Valley Creeks. The NO_3 concentration in the South Fork at Mayer is significantly higher than the concentration in the Crow River main stem at Rockford. NO_3 concentrations are likely driven by agricultural activity in the watershed and wastewater treatment facilities.

Cl concentrations in the Crow River main stem at Rockford and South Fork at Mayer are lower than the streams with urbanized watersheds and associated high road densities. Cl concentrations in the rivers are probably driven by a combination of road salt runoff, WWTP effluent (due to home water softening), and agricultural chemicals.

The Crow River has the second highest median pollutant load of all the MCES-monitored watersheds, after the Cannon River, for TSS, TP, and NO_3, and has the highest median pollutant load for Cl. For each of these loads the Crow River South Fork at Mayer load is at least 50% of the Crow River main stem at Rockford load. The high loads are driven both by fairly high concentrations of all pollutants and by high flows draining the watershed area, which is the largest of the MCES-monitored streams.

Trend analysis indicates decreasing trends in TSS and TP concentrations for both the Crow main stem and South Fork for the period of record. Trends analysis was completed for Chl-a only at the Crow main stem, and shows a decreasing concentration trend through 2010, followed by an increasing concentration trend through 2012. The NO_3 concentration trends at both the Crow main stem and South Fork were increasing early in the record (until 2006/2007), and more recently, are showing decreasing concentration trends. All trends will be investigated again in 5 years. At that time, sufficient data will have been collected for Cl trends to also be investigated.

No biological monitoring has occurred at either Crow River station by MCES.

Due to installation of new monitoring stations on the North Fork and the South Fork just upstream of the confluence at Rockford by the MPCA, MCES discontinued monitoring the South Fork at Mayer station in 2013. MCES will continue operating the Crow River main stem at Rockford station.

Recommendations

This section presents recommendations for monitoring and assessment of both Crow River stations, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like the CROW Joint Powers Board, the North Fork and Middle Fork Crow River Watershed Districts, and the Buffalo Creek Watershed District, are ideally suited to target and implement volume reduction, pollutant removal, and stream restoration projects within the watershed. It is beyond the scope of this document to suggest locations for implementation projects. Instead, MCES encourages the local water management organizations to use the results of this report to leverage funding and partnerships to target, prioritize, and implement improvement projects. MCES will repeat its analysis of water quality trends in 5 – 10 years, to assess potential changes in water quality in the Crow River main stem at Rockford.

The following recommendations have been drafted from the results of this report and are intended to assist MCES and its partners in directing future assessment work:

- MCES should work with our partners to identify all of the water quality and flow monitoring that is occurring regularly on the Crow River and its tributaries, to avoid duplicating efforts.

- MCES and MPCA should regularly compare MCES loads below confluence at Rockford and MPCA loads from the North Fork at Farmington Avenue in Rockford and the South Fork at Bridge Avenue at Delano. If necessary, a memo should be drafted explaining any major discrepancies between measured volumes and loads.

- As staff time and budget allow, MCES should work with our partners to analyze the load data from the monitoring stations upstream of the Rockford station, to fully understand relative contributions of pollutants from the different tributaries of the Crow River.

- MCES and partners should consider partnering to monitor and assess the water entering the Crow River downstream of the Rockford monitoring station. This would allow a more accurate estimate of the Crow River actually reaching the Mississippi River. In the meantime, MCES should add a footnote to the annual load database informing users that runoff volume and pollutant loads entering the Crow River downstream of the Rockford monitoring station are not included in the MCES load estimates.
- As resources allow, MCES should provide local partners with information about the heightened potential for surface waters to be impacted by groundwater withdrawals in the Crow River watershed. This information should be included in watershed and local surface water management plan updates.
- MCES and partners should add annual macroinvertebrate sampling at the Crow River station at Rockford. MCES and partners should also consider adding a Stream Habitat Assessment similar to the habitat surveys performed by the MPCA.
- MCES and partners should create a timeline of past projects and management activities that may have improved or altered stream flow and/or water quality. This information would allow more accurate assessment and interpretation of trends.
- In 2014, the North Fork of the Crow watershed was selected by the Minnesota Board of Water and Soil Resources (BWSR) for a “One Water, One Plan” pilot study. As time and budget allows, MCES staff will attend study technical advisory meetings. MCES will also provide data and analyses results as requested by BWSR.

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