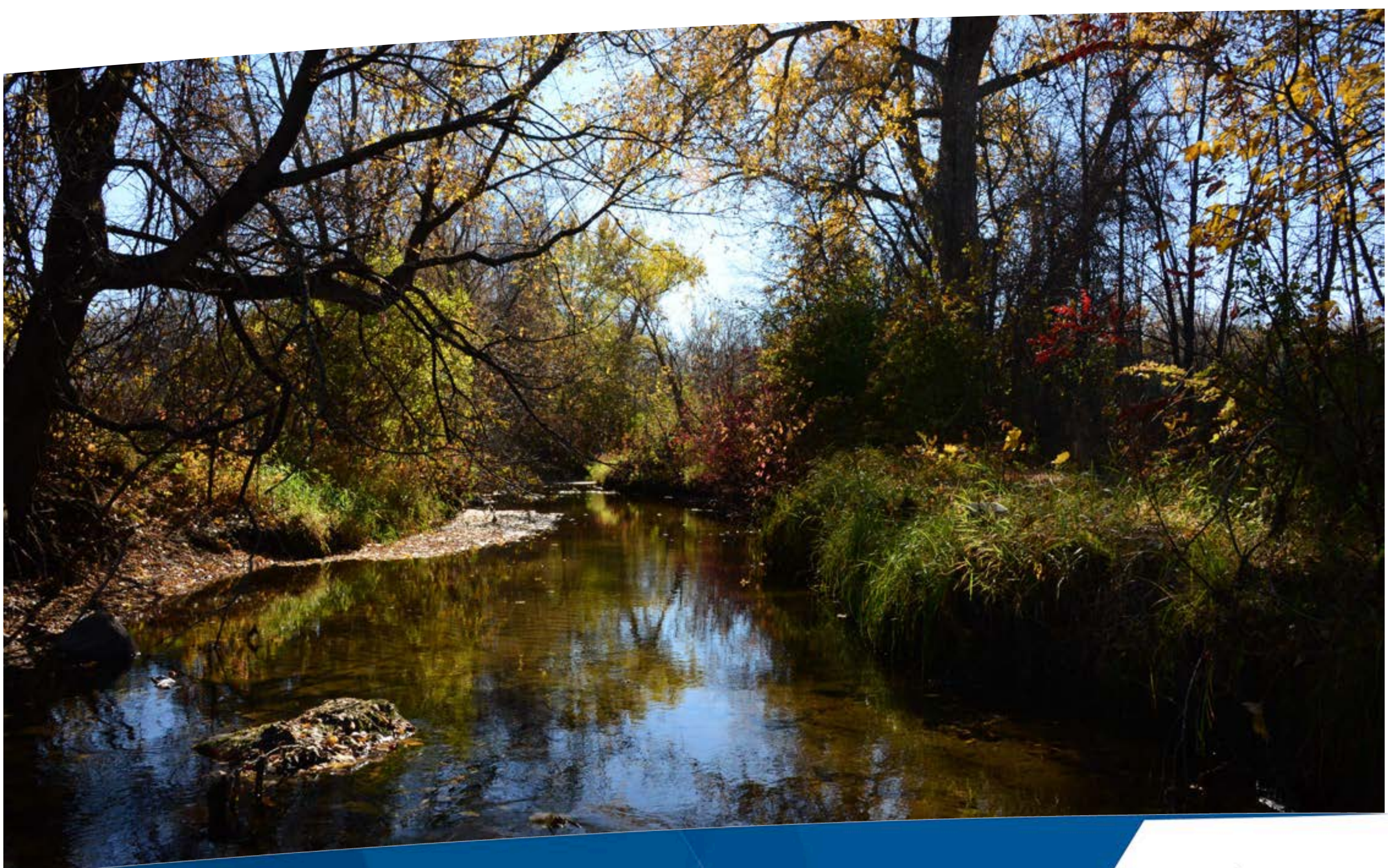
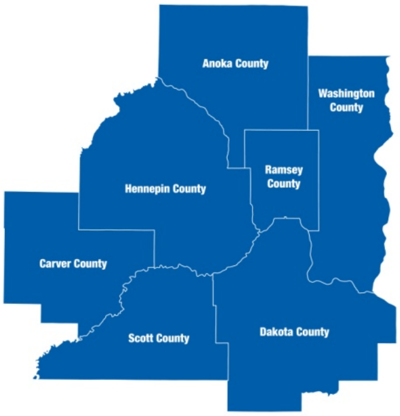
Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

CREDIT RIVER



December 2014

The Council's mission is to foster efficient and economic growth for a prosperous metropolitan region.



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 partners 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, *Credit River*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located in Scott and Dakota counties, the Credit River is one of the nine Minnesota River tributaries examined. This section discusses a wide range of factors that have affected the condition and water quality of the Credit River.

Cover Photo

The photo on the cover of this section depicts Credit River at the MCES monitoring site. It was taken by Metropolitan Council staff.

Recommended Citations

Please use the following to cite this section of the report:

Metropolitan Council. 2014. *Credit River*. In *Comprehensive water quality assessment of select metropolitan area streams*. St. Paul: Metropolitan Council.

Please use the following to cite the entire report:

Metropolitan Council. 2014. *Comprehensive water quality assessment of select metropolitan area streams*. St. Paul: Metropolitan Council.

Content

Figures

Tables

Introduction

Credit River is located in the south western metropolitan area and is a tributary to the Minnesota River. It drains approximately 47.2 square miles of undeveloped land, mixed agricultural, single family residential, parks and open space (especially Murphy-Hanrehan Regional Park), and urban areas (city of Savage) in Scott and Dakota County (Metropolitan Council District 4).

Figure CR-1: Credit River

This report:

- documents the characteristics of Credit River and its watershed most likely to influence stream flow and water quality.
- presents the results from assessments of flow, water quality, and biological data.
- presents statistical assessments of trends in stream chemistry concentrations.
- draws conclusions about possible effects of landscape features, climatological changes, and human activities on flow and water quality.
- compares Credit 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 has supported water quality monitoring of Credit River since 1989. MCES staff maintains the rating curve and operates the monitoring station. All staff and equipment costs are funded solely by MCES.

Monitoring Station Description

The MCES monitoring station is located on the Credit River in Savage, Minnesota, about 0.9 miles upstream from the river's confluence with the Minnesota River. Credit River starts in New Market Township and generally flows north through Credit River Township before ultimately discharging to the Minnesota River.

The monitoring station includes continuous flow monitoring, event-based composite sample collection, and on site conductivity and temperature probes. The Credit River station also includes an in-stream turbidity sensor (Forest Technology Systems DTS-12). There is a rain gauge at this station; however, it is not used due to infrequent site visits for calibration. Precipitation data are available from the Minnesota Climatology Working Group, MSP airport station number 215435. Daily precipitation totals from this station 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 represent the variability of rainfall within the watersheds (Minnesota Climatology Working Group, 2013). These data are generated from Minnesota's HIDEN (High Spatial Density Precipitation Network) dataset. The gridded data was aerially-weighted based on the watershed boundaries.

Due to site logistical problems the monitoring station was moved in 2000, from the former site at Credit River Mile 0.6 to the current location at river mile 0.9. Flow and pollutant load data were unavailable for 2002 due to monitoring equipment problems that persisted at the site for most of the 2002 monitoring year. 2002 water chemistry and biological monitoring data are available. No 2009 stage or flow data was available due to persistent equipment problems. Because of these problems, no pollutant load data for the years 2000, 2002, and 2009 are included in this report.

Stream and Watershed Description

The Credit River watershed encompasses a total of 30,236 acres, with 30,039 acres (99.3%) of the watershed upstream of the monitoring station. The monitored watershed land cover is a diverse mix of agricultural, forest, grasses/herbaceous, and urban. The watershed has 10,008 acres/33.1% (9,940 acres/33.1% within the monitored area) of developed urban land, including portions of the cities of Prior Lake, Lakeville, Burnsville, and Savage. The watershed is urbanizing from downstream to upstream, with the most heavily urbanized areas in the north. Of the 4,235 acres/14.0% (4,234 acres/14.1% within the monitored area) agricultural land, 33.9% is planted in corn, 23.5% in soybeans, and 29.7% is pasture/hay (for both the monitored and entire watershed). Of the agricultural land in the watershed 11.1% is potentially drain tiled (D. Mulla, University of Minnesota, personal communication, 2012). The watershed has 4,456 acres/14.7% (4,453 acres/14.8% within the monitored area) of forested land and 6,147 acres/20.3% (6,100 acres/20.3% within the monitored area) of grasses/herbaceous land cover, the majority of it in two regional parks, Murphy-Hanrehan Park Reserve and Cleary Lake Regional Park, both located near the middle of the watershed. The watershed also has 4,449 acres/14.7% (4,371 acres/14.6% within the monitored area) of wetlands. Figure CR-2 and Table CR-1 show the watershed area by land cover.

Table CR-1: Credit River Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	607	2.0%	0	0.1%	607	2.0%
11-25% Impervious	3,389	11.3%	0	0.2%	3,389	11.2%
26-50% Impervious	4,380	14.6%	12	6.2%	4,392	14.5%
51-75% Impervious	1,142	3.8%	0	0.0%	1,142	3.8%
76-100% Impervious	422	1.4%	55	27.9%	477	1.6%
Agricultural Land	4,234	14.1%	1	0.7%	4,235	14.0%
Forest (all types)	4,453	14.8%	2	1.2%	4,456	14.7%
Open Water	829	2.8%	0	0.0%	829	2.7%
Barren Land	0	0.0%	0	0.0%	0	0.0%
Shrubland	112	0.4%	0	0.0%	112	0.4%
Grasses/Herbaceous	6,100	20.3%	48	24.2%	6,147	20.3%
Wetlands (all types)	4,371	14.6%	78	39.5%	4,449	14.7%
Total	**30,039**	**100.0%**	**197**	**100.0%**	**30,236**	**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.

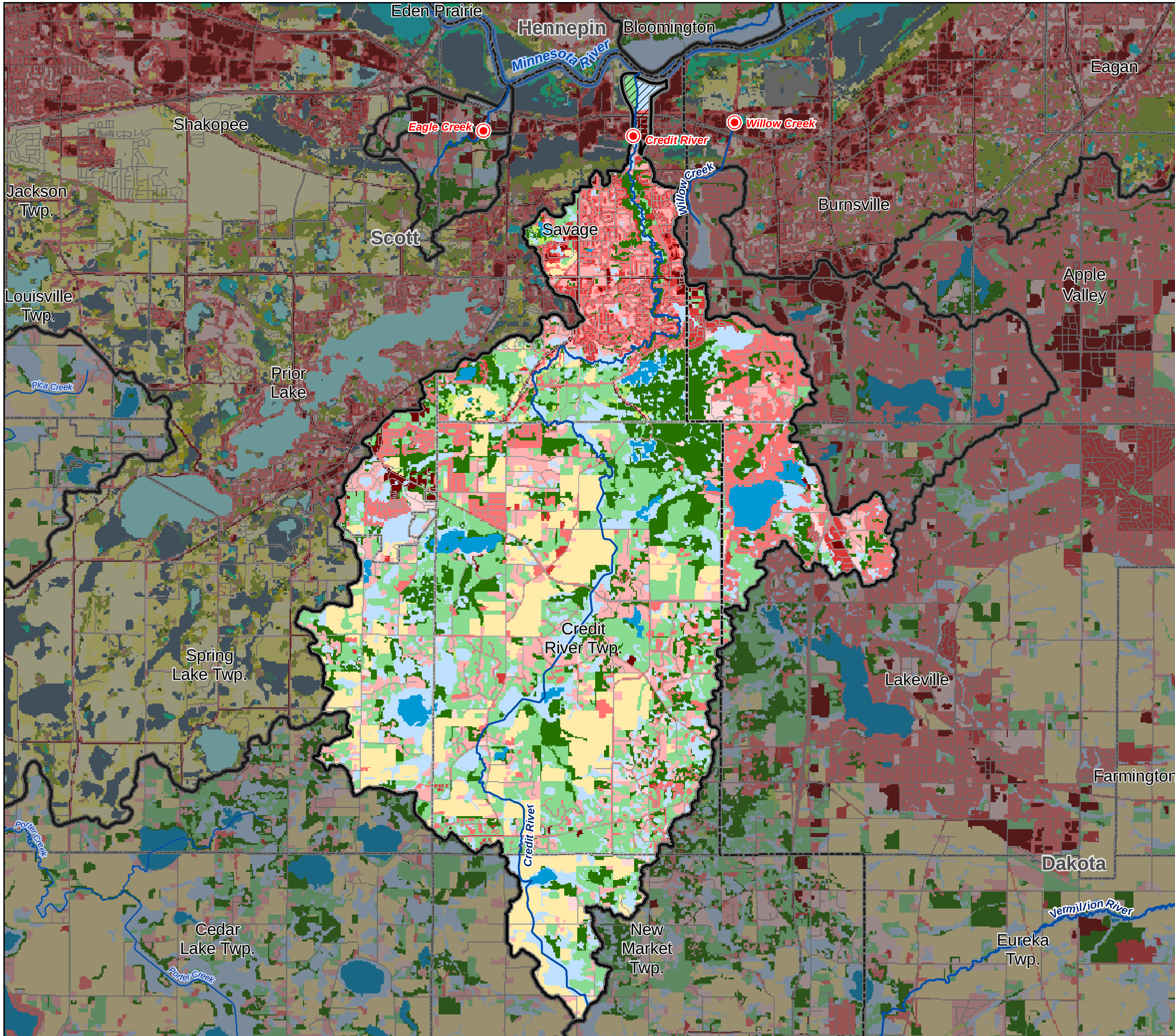
The upstream watershed topography is fairly steep on the east side of the watershed, while more gradual on the west side (Figure CR-3). At the downstream end Credit River enters the Minnesota River Valley through a deep ravine. The maximum watershed elevation is 1181.7 MSL and the minimum elevation is 726.8 MSL within the monitored area. Within the monitored area 5.2% of the slopes are considered steep, and an additional 1.6% are considered very steep (MnDNR, 2011).

One domestic wastewater treatment plant (Permit Number MN0066826), and two feedlots are located within the Credit River watershed (Figure CR-4). The wastewater treatment plant does not discharge to any surface water.

Figure CR-2

MLCCS-NLCD Hybrid Land Cover

Credit River



MCES Stream Monitoring Sites
USGS Flow Stations
Mainstems (Monitored and Unmonitored)
Major Mainstem Tributaries
Monitored Watershed Boundaries
Unmonitored Portion of Watersheds
NCompass Street Centerlines, 2012
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

MLSSC/NLCD Hybrid Land Cover						
Credit River						
	Monitored		**Unmonitored**		**Total**	
Land Cover Class	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**
5-10% Impervious	607	2.0%	0	0.1%	607	2.0%
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Total	**30,039**	**100.0%**	**197**	**100.0%**	**30,236**	**100.0%**

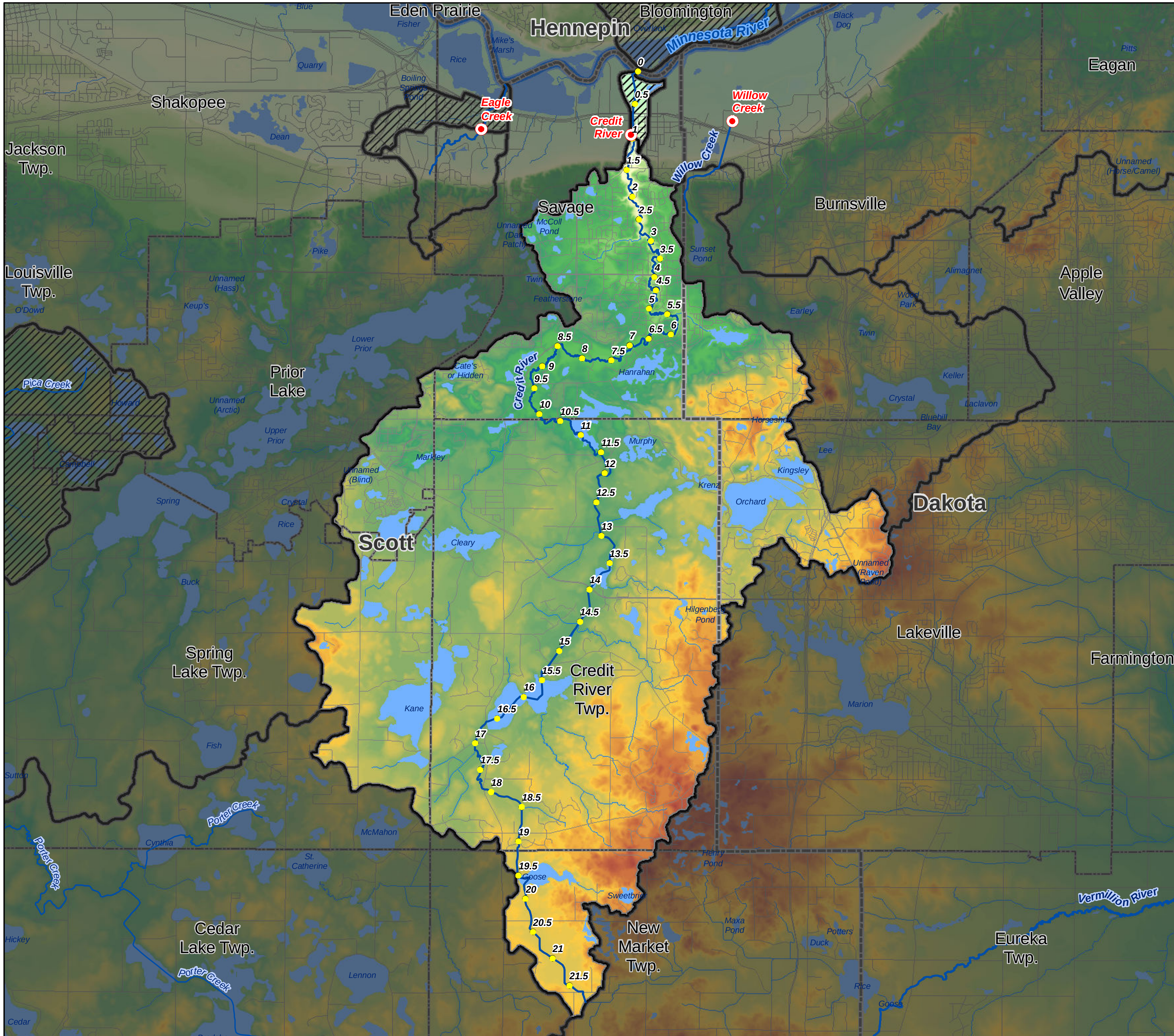
0 1 2 3 4
Miles

Figure CR-3

METROPOLITAN COUNCIL

Watershed Topography

Credit River



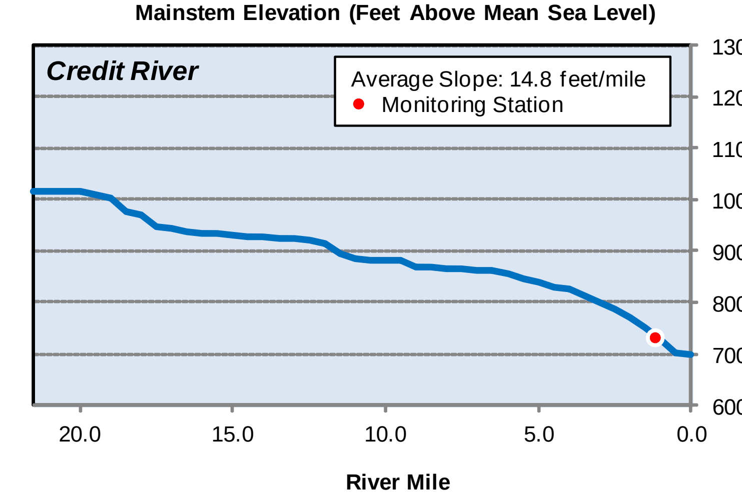
- MCES Stream Monitoring Sites
- USGS Flow Stations
- Stream Mile Markers
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- Public Waters Inventory
- Other Rivers and Streams
- City and Township Boundaries
- County Boundary
- NCompass Street Centerlines, 2010

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

Mainstem Elevation (Feet Above Mean Sea Level)



0 0.5 1 1.5 2 2.5 3 3.5 4
Miles

Water Quality Impairments

The Scott Watershed Management Organization (WMO), its member cities and townships, and the Scott Soil and Water Conservation District (SWCD) have made a concerted effort to improve and protect the water quality of Credit River and other waters in the county. These efforts include construction erosion control programs and stormwater management practices required for new development, education and cost share programs for small acreage and agricultural land owners, increased conservation tillage, wetland restoration, and park land management by Three Rivers Park District.

In the Credit River watershed, the city of Savage has implemented targeted ravine erosion stabilization projects in the lower part of the watershed over the last decade. Credit River was listed as impaired for turbidity in 2002; these projects, and the ravine stabilizations in particular, helped Credit River meet the water quality standard for turbidity, and be removed from the state impaired water list in 2011 (Table CR-2).

Table CR-2: Impaired Reaches of Credit River as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Water Quality Impairment[1]	Approved Plan[2]	Needs Plan
Credit River	Headwaters to Minnesota River	07020012-517	AQL	T (stream was delisted in 2011)	---

[1] AQL = aquatic life;[2] T = turbidity;

Three lakes in the Credit River watershed (Cleary, Murphy, and Orchard) are impaired for aquatic consumption based on mercury and are covered by the statewide mercury TMDL, and one lake (Cleary) is also impaired for aquatic recreation based on nutrient concentrations (Table CR-3).

Table CR-3: Impaired Lakes in the Credit River Watershed as Identified on the MPCA 2014 Impaired Waters List

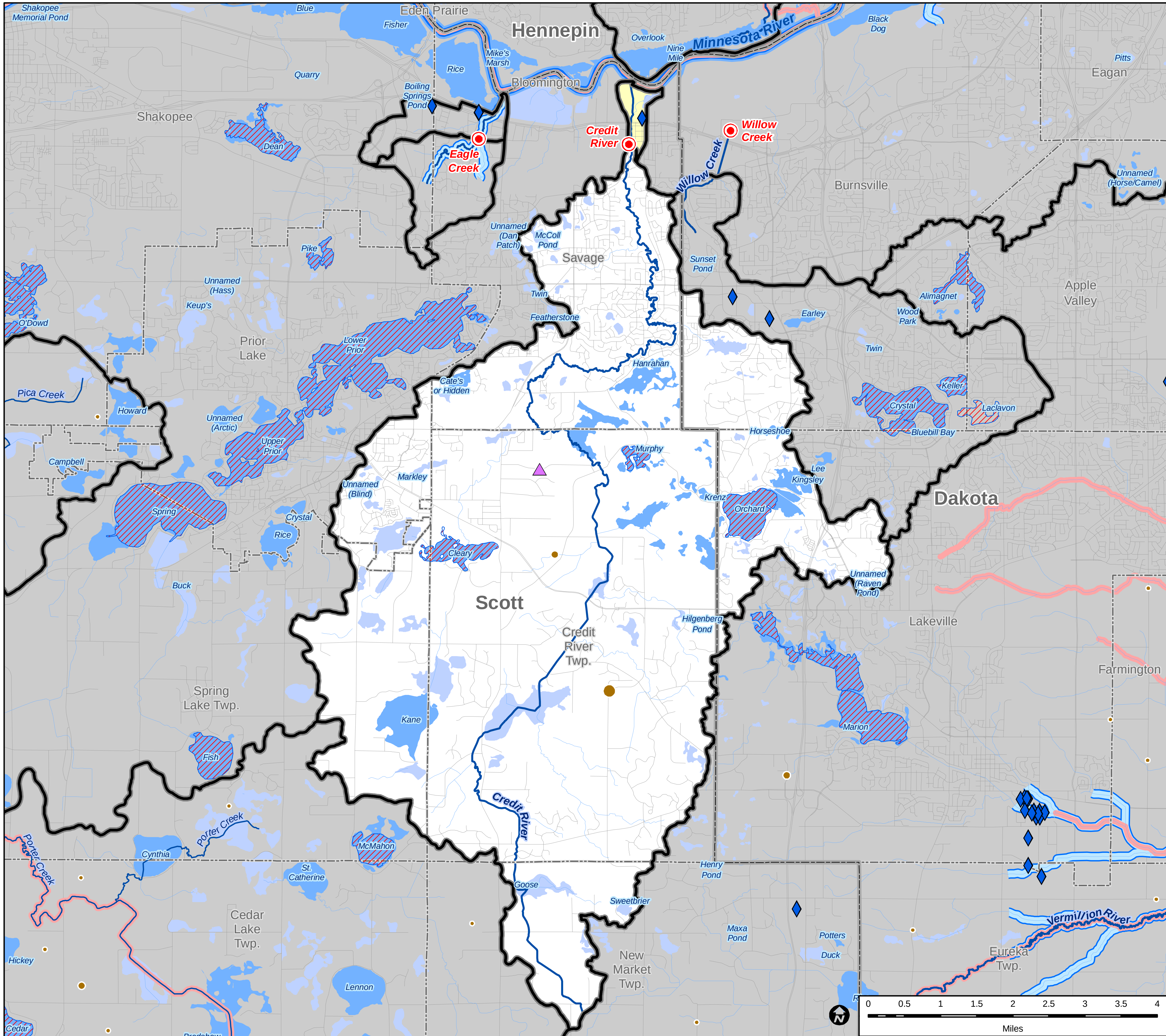
Lake Name	Lake ID	Water Quality Impairment[1]	Approved Plan[2]	Needs Plan[2]
Cleary	70-0022-00	AQC, AQR	HgF	Nutrients
Murphy	70-0010-00	AQC	HgF	---
Orchard	19-0031-00	AQC	HgF	---

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

Figure CR-4

Public and Impaired Waters and Potential Pollution Sources

Credit River



- 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

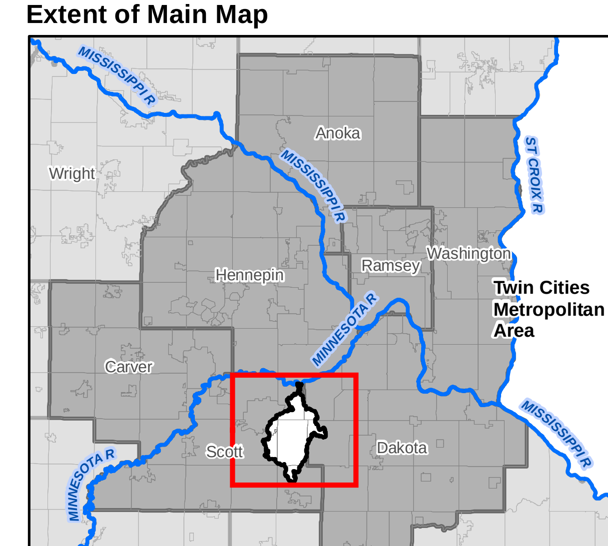
Feedlots with 100 or more animal units **

- 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 *
- NCompass Street Centerlines, 2013
- County Boundary
- City and Township Boundaries

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

Extent of Main Map



Hydrology

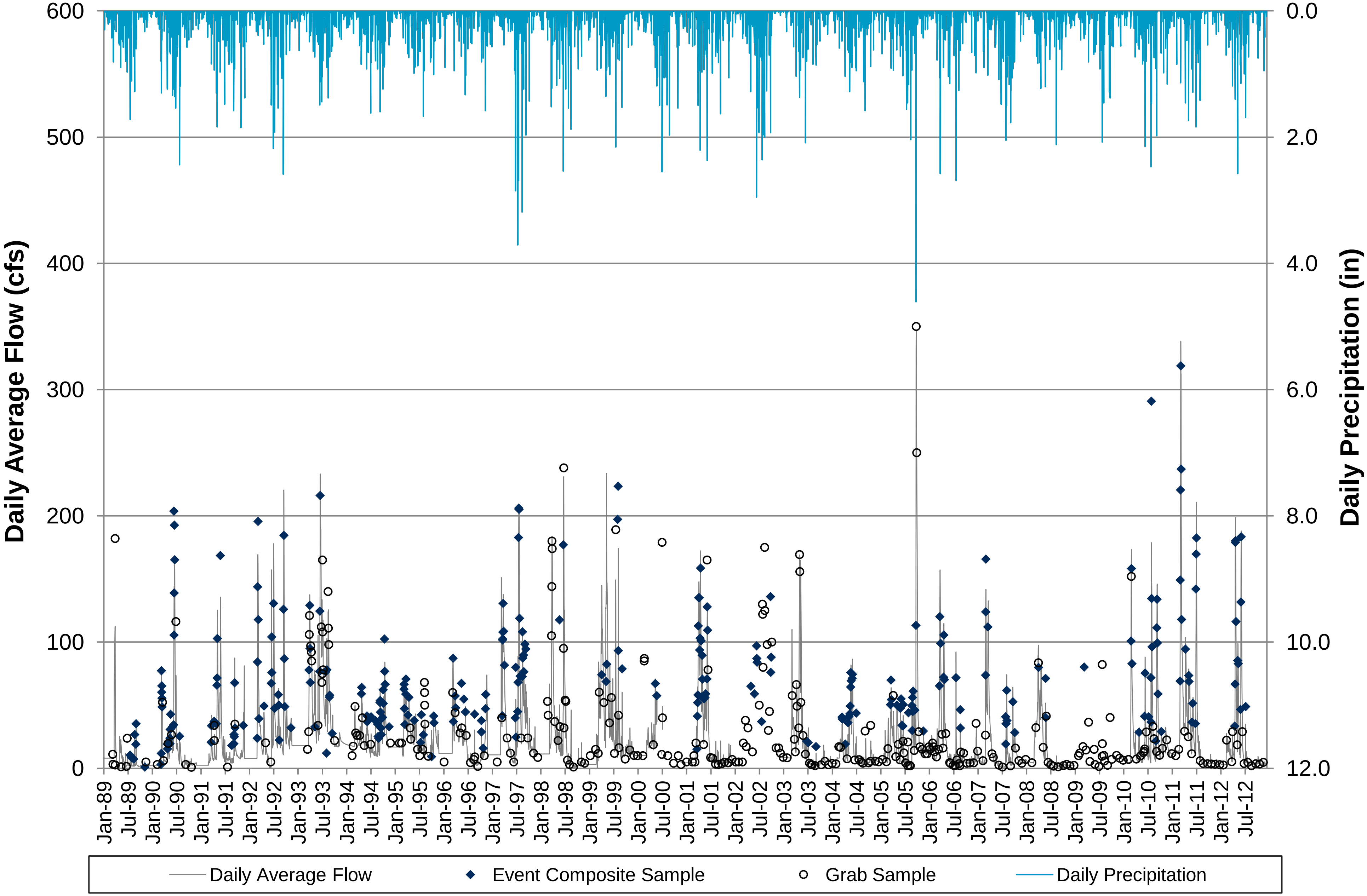
MCES has monitored Credit River flow at mile 0.6 since 1989 and at mile 0.9 since 2000. Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrograph of Credit River, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variation in flow rates from season to season and from year to year (Figure CR-5), 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.

Analysis of the duration of daily average flows indicates that the upper 10th percentile flows for the period 1989-2012 ranged between approximately 47 - 346 cubic feet per second (cfs), while the lowest 10th percentile flows ranged from 0.2-2.8 cfs. (See Figure CR-12 in the ***Flow and Load Duration Curves*** section of this report.)

Additional annual flow/volume metrics are shown on Figures CR-6 to CR-9, 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) the fraction of annual precipitation ending up as flow.

Figure CR-5: Credit River Daily Average Flow, Sample Flow, and Precipitation, 1989-2012*



*Flows could not be determined for parts of 2000 and all of 2002 and 2009 due to equipment problems; precipitation record was acquired from NWS COOP station 215435-Minneapolis/St. Paul AP

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 Credit River to groundwater withdrawals, MCES staff examined spatial datasets of vulnerable stream segments and basins created as part of the 2010 regional groundwater analysis. Within the Credit River watershed, nearly the entire stream was identified as potentially vulnerable to groundwater withdrawals. Numerous basins within the watershed, including Markey Lake, Murphy Lake, Hanrehan Lake, and Orchard Lake, plus a number of unnamed wetlands along the stream, were also identified as potentially vulnerable to groundwater withdrawals.

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. 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 in Credit River (1989-2012). Note the Credit River monitoring station was out of commission in 2000, 2002, and 2009; therefore results are not presented for those years.

Figures CR-6 to CR-9 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 area-per inch of precipitation (lb/ac/in), as well as two hydrological metrics (annual average flow rate and fraction of annual precipitation as flow). A later section in this report (***Comparison with Other Metro Area Streams***) offers graphical comparison of the Credit River loads and FWM concentrations with the other MCES-monitored metropolitan area tributaries.

The flow metrics indicate year-to-year variation 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. The fraction of annual precipitation delivered as flow also varies between years; year-to-year variation is likely influenced by drought periods, timing of rainfall events, low soil moisture caused by dry periods, increased capacity in upland storage areas during drought periods, and other factors.

The annual mass loads for all parameters exhibit significant year-to-year variation, generally mirroring the annual variations in flow and indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream. The annual FWM concentrations for all parameters also fluctuate year-to-year and are likely influenced by annual precipitation and flow.

Figures CR-8 and CR-9 present the areal and precipitation-weighted loads, respectively. These graphics are presented to assist local partners and watershed managers, and will not be discussed here.

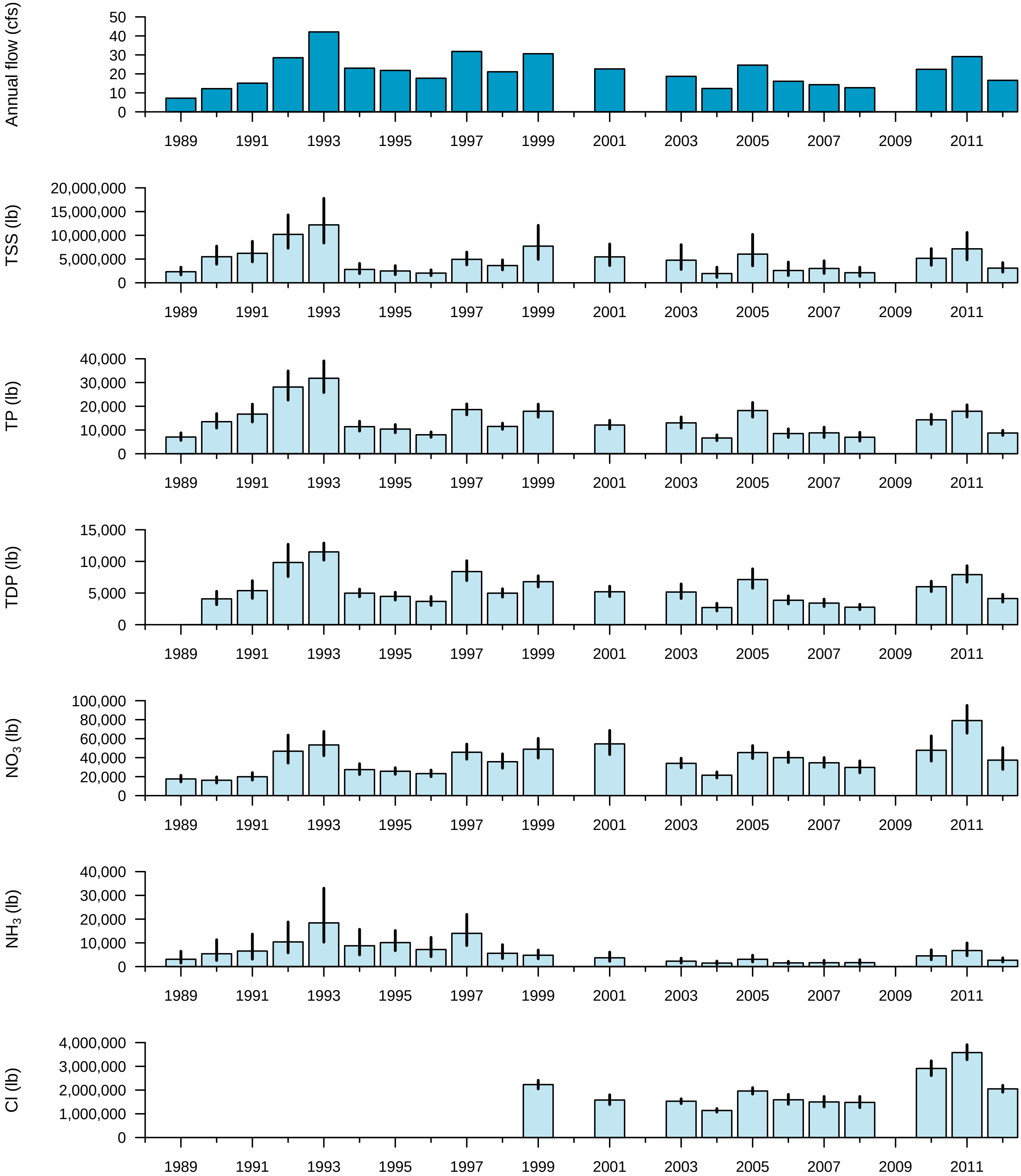
The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of time based patterns in the loads in Credit River (Figures CR-10 and CR-11). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for Credit River) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month).

Over the 2003-2012 period highest average flows, and in turn mass loads, generally occur in the spring of each year (typically March or May), likely due to effects of snow melt and spring rains. Flows then generally decrease each subsequent month until fall, when a secondary flow/load pulse may occur. In 2012, the highest loads of all parameters occurred in May, as did the highest monthly flow. There were no secondary load pulses in the late summer or fall of 2012, due to low precipitation (and in turn flows) during this period.

From Figure CR-10, it is apparent that the highest mass loads of all constituents in Credit River generally occurred in spring each year, likely due to high flows caused by snow melt and spring rains. Over the 2003-2012 period, a secondary load pulse often occurred in late summer or fall, likely due to precipitation. Average monthly loads showed a large range, especially for the spring flow peak, and the secondary flow peak in late summer or fall.

The FWM concentrations generally show less month-to-month variability than the loads. Average TSS concentrations were highest in late summer and fall. These likely corresponded to high flow periods driven by thunderstorms when agricultural row crops had been, or were being, harvested. Monthly mean FWM concentrations for dissolved pollutants, including TDP, NO_3, and Cl, generally show less month to month variation than the loads. Cl concentrations in particular showed little variation throughout the year, with the highest loads in March, April, and May. The two most prevalent sources of chloride to streams are thought to be road surfaces (from chloride application as a de-icer) and WWTP effluent (from domestic water softeners). The source of the consistently high monthly Cl concentrations in the watershed should be investigated further.

Figure CR−6: Credit River*
Annual Mass Load

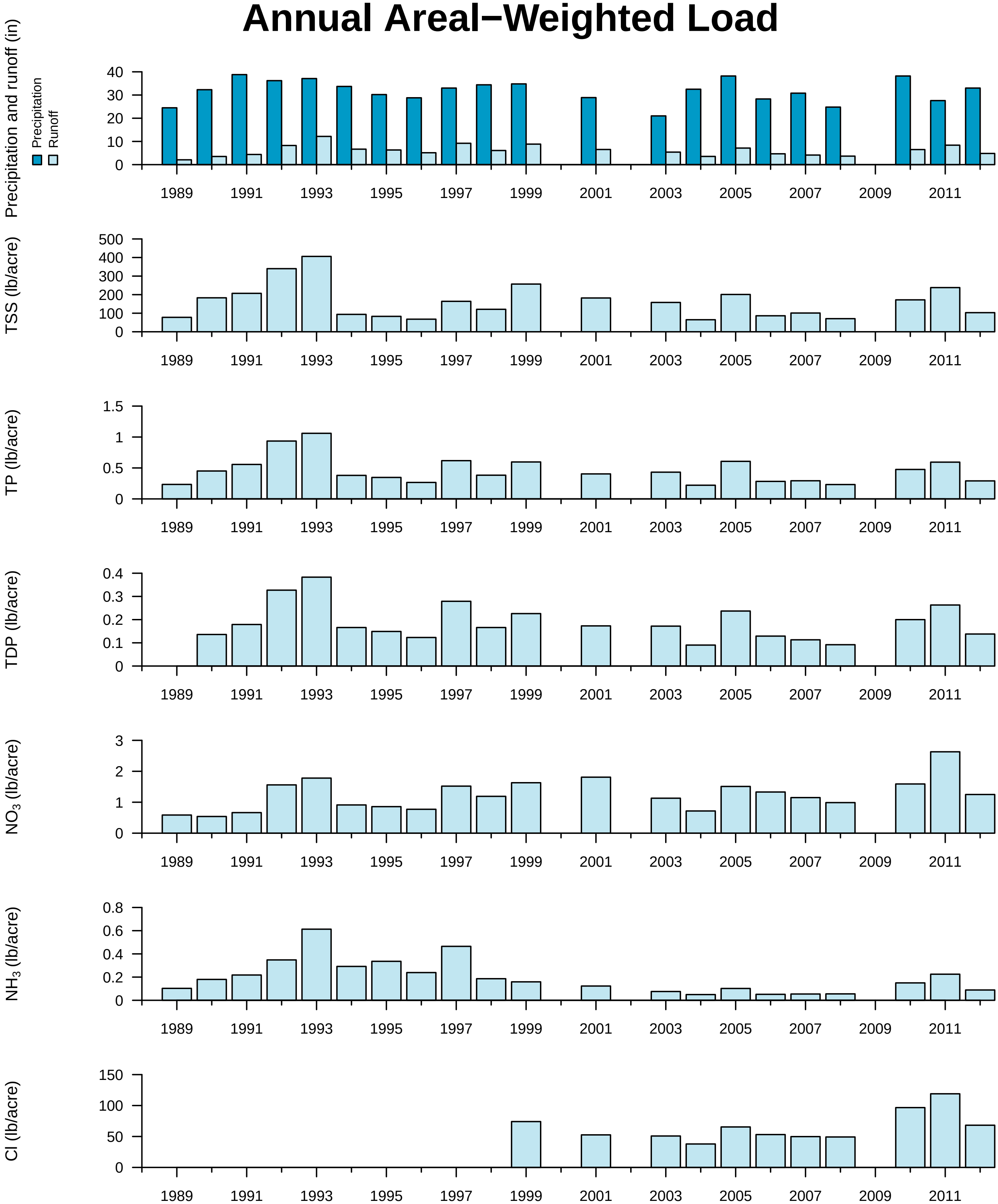


*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2000, 2002 and 2009 so no loads could be calculated.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure CR−7: Credit River*
Annual Flow−Weighted Mean Concentration

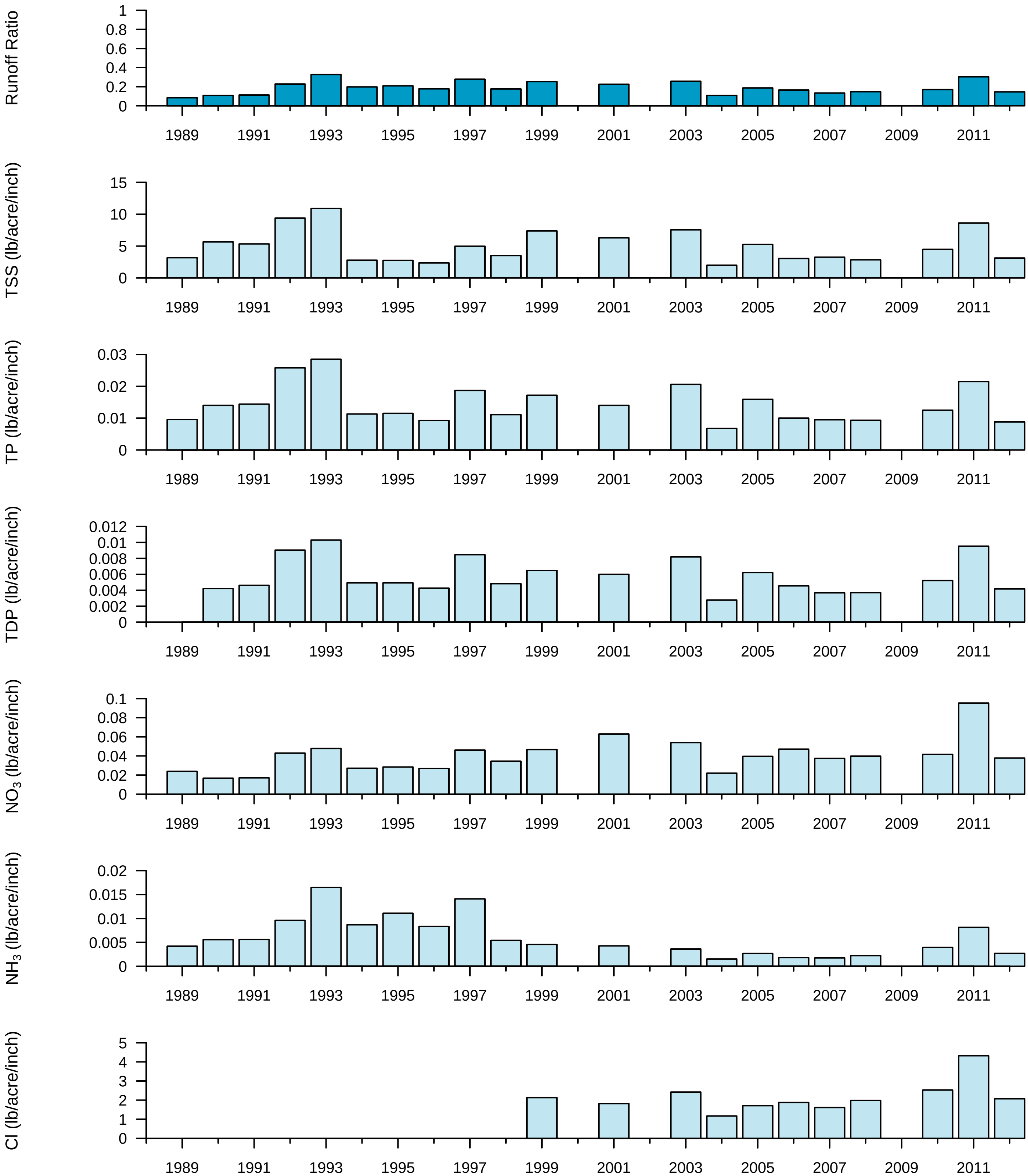
*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2000, 2002 and 2009 so no loads could be calculated.

Figure CR−8: Credit River*
Annual Areal−Weighted Load



*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2000, 2002 and 2009 so no loads could be calculated.

Figure CR−9: Credit River*
Annual Precipitation−Weighted Areal Load



*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2000, 2002 and 2009 so no loads could be calculated.

Figure CR−10: Credit River Mass Load by Month

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

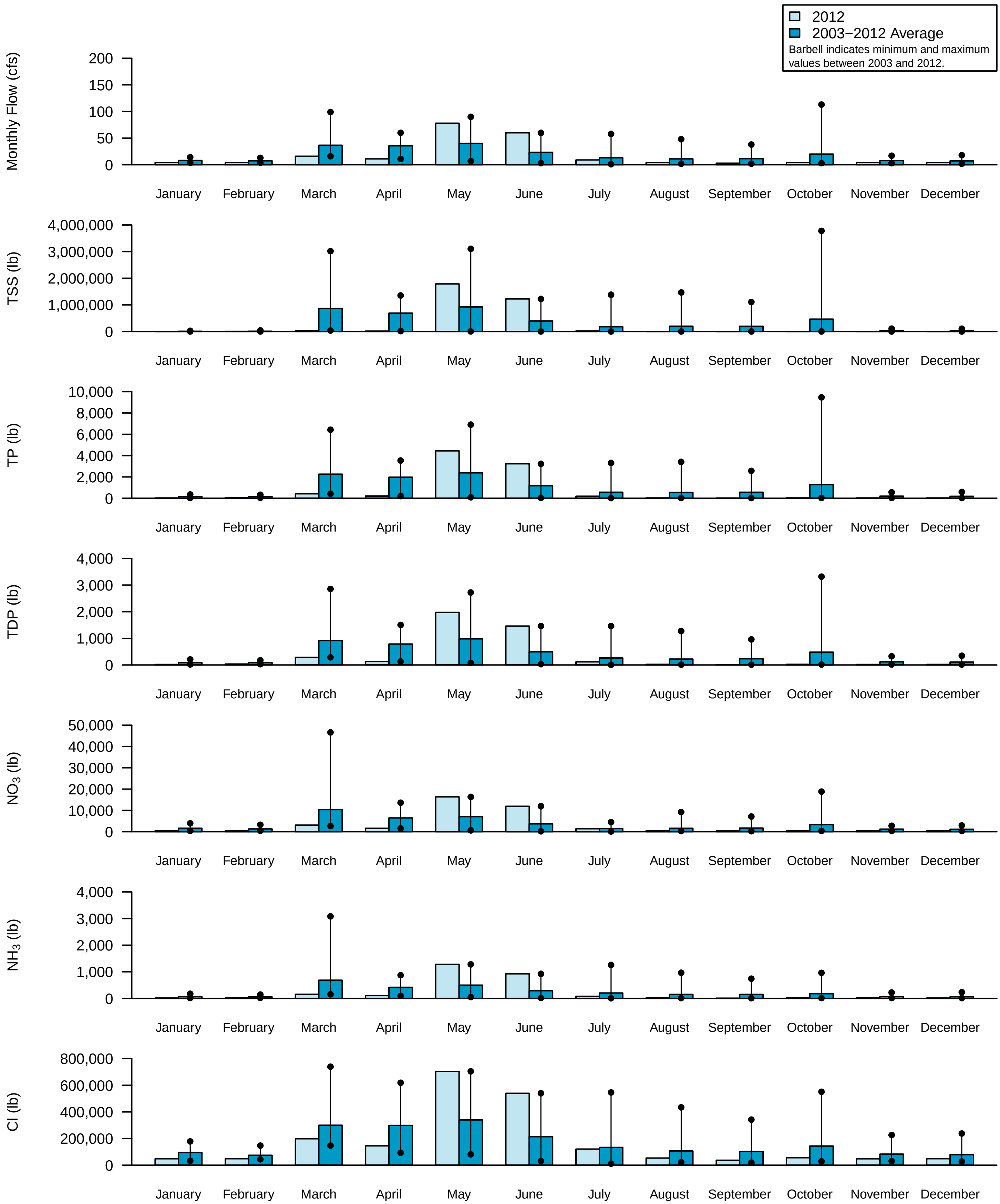
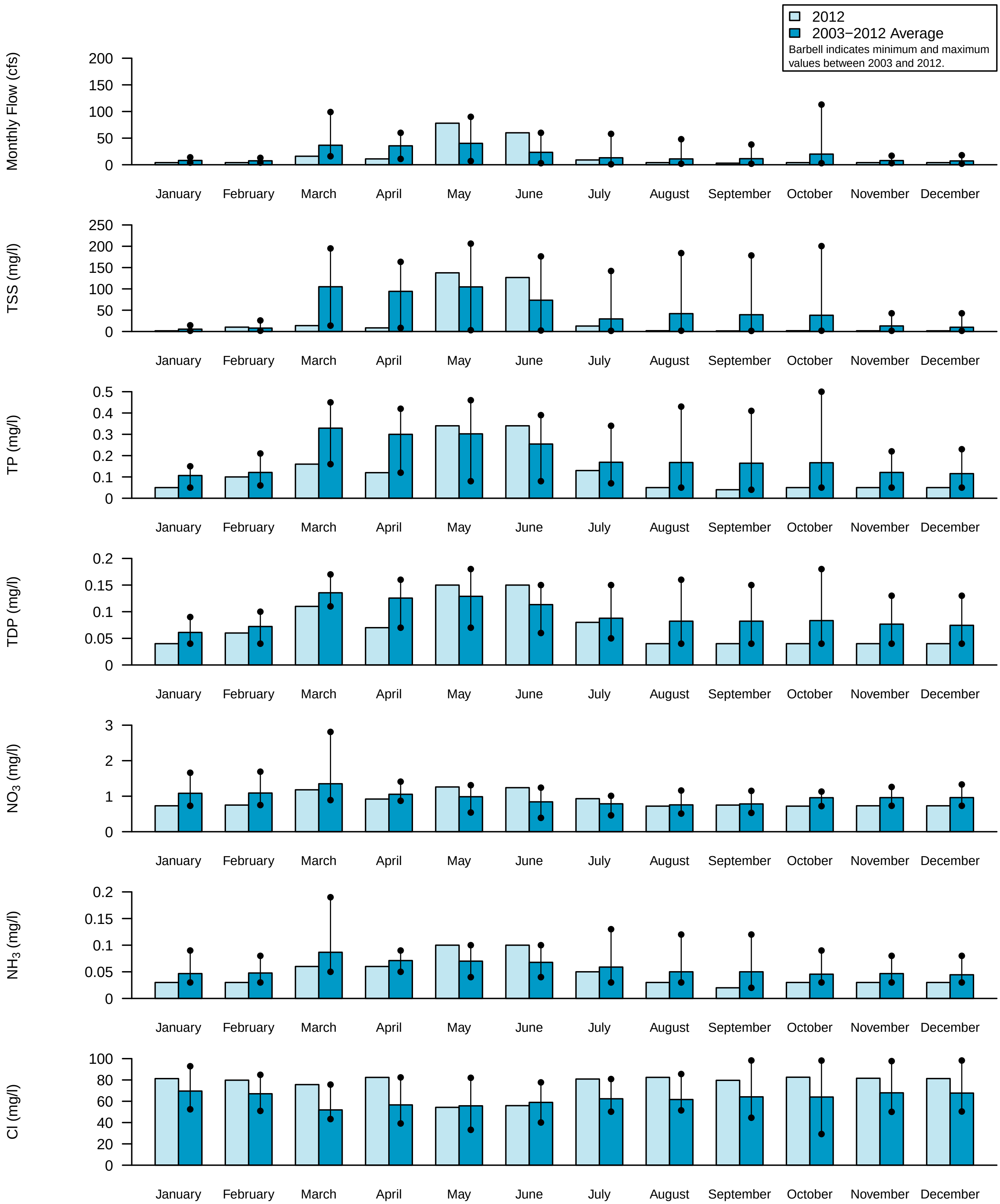


Figure CR−11: Credit River
Flow−Weighted Mean Concentation by Month

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



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 locations using recommendations of the U. S. Environmental Protection Agency, 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 chloride. Each of the parameters was plotted using Credit River monitoring station daily average flows and sample data, along with the most appropriate Minnesota Pollution Control Agency (MPCA) draft numerical standard as listed in Table CR-4. 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 criteria, 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 1989–2012 flow duration curve and load duration curves for TSS, TP, NO_3, and Cl for the Credit River monitoring station (mile 0.9, in the city of Savage) are shown in Figure CR-12. TSS concentrations have remained below the draft standard at low flow, and there were a few exceedances during dry conditions and mid-range flows. During moist conditions and high flow many samples collected exceed the draft standard. This response is consistent with other streams in the Minnesota River watershed, where high flows lead to streambank, bluff, and ravine erosion.

Total phosphorus concentrations exceed the draft nutrient criteria concentration consistently at high flow and moist conditions. The draft standard is also often exceeded at mid-range flows and dry conditions, but rarely at low flows. Thus the total phosphorus concentrations also appear to be driven by precipitation and related high flows.

All NO_3 concentrations at all flow regimes met the drinking water standard of 10 mg/l. The final river nutrient standard for NO_3 will likely be lower than this and may be exceeded at the higher flow regimes.

There appears to be one exceedance of the draft chloride standard in the mid-range flow regime. All other chloride concentrations in Credit River were below the draft chloride criteria at all flow regimes. As mentioned above, the sources of high chloride concentrations in Credit River should be investigated further.

Table CR-4: Credit 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	Chloride Draft Stnd[3] (mg/l)	TSS Draft Stnd[4] (mg/l)	TP Draft Criteria[5] (ug/l)	Nitrate DW Stnd[6] (mg/l)
Credit River near 126th St. in Savage (CR0.9)	2B	Central	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430

[2] MPCA, 2010.

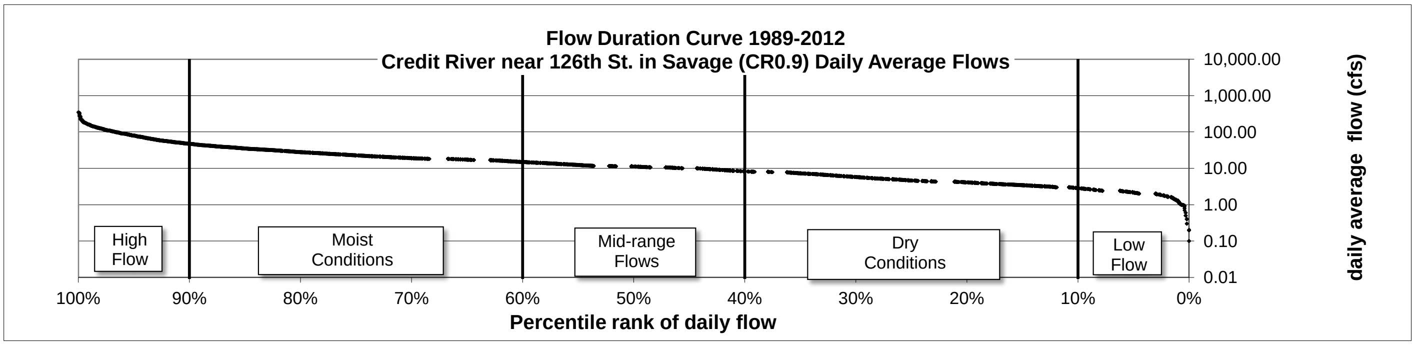
[3] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft chloride standard pending results of EPA toxicity tests.

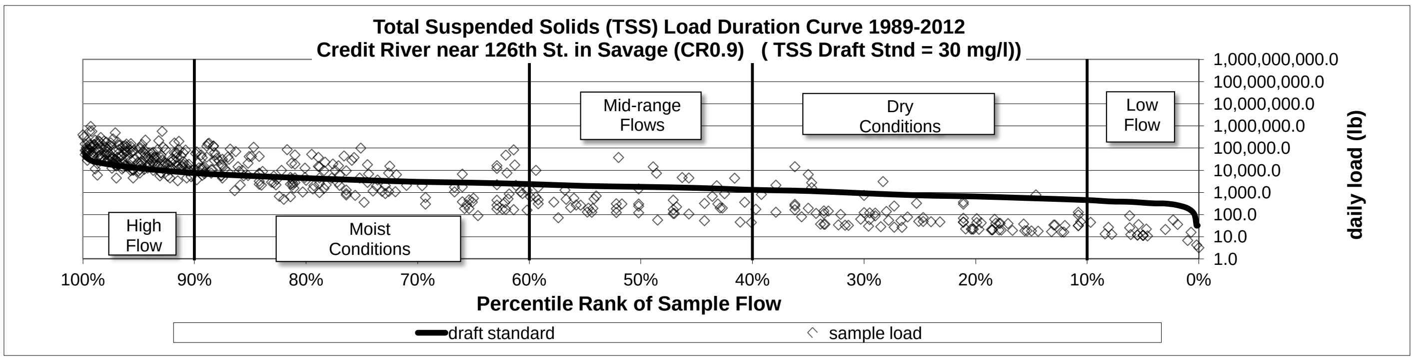
[4] MPCA, 2011. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

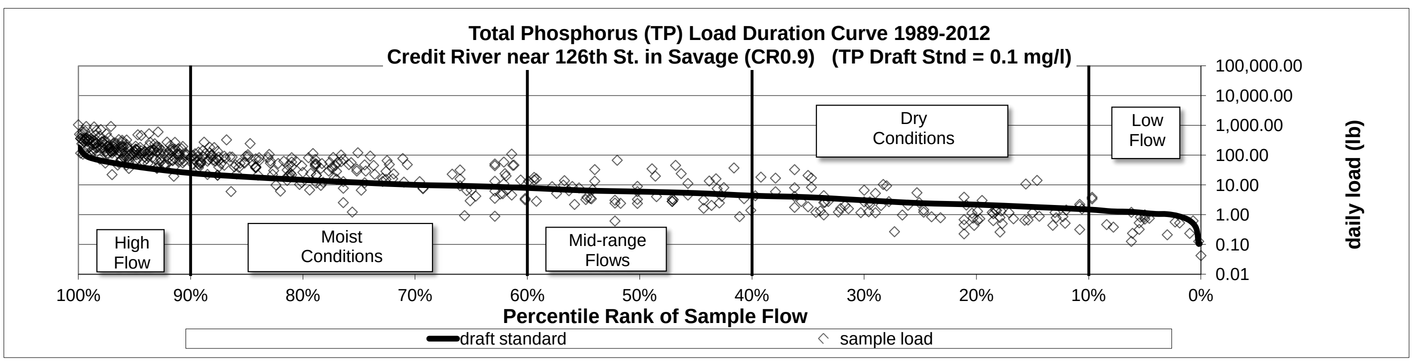
[5] MPCA, 2013a.

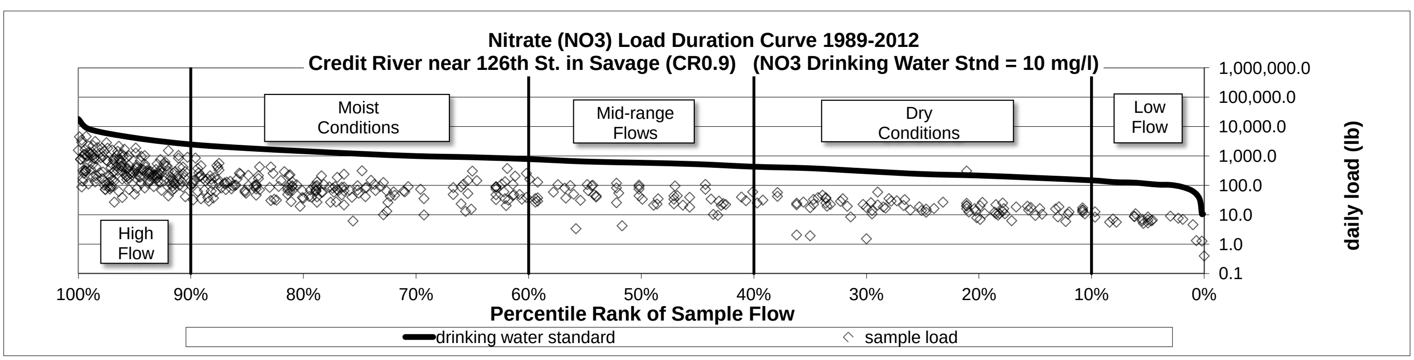
[6] MCES used the NO_3 drinking water standard of 10 mg/l pending results of EPA toxicity tests and establishment of a draft NO_3 standard for rivers and streams.

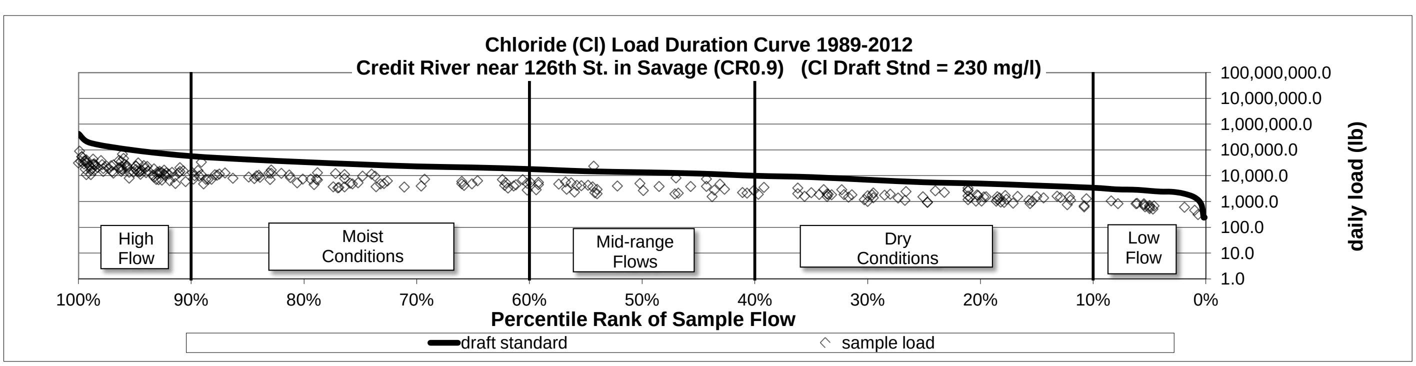
Figure CR-12: Credit River Flow and Load Duration Curves, 1989-2012











Aquatic Life Assessment Based on 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.

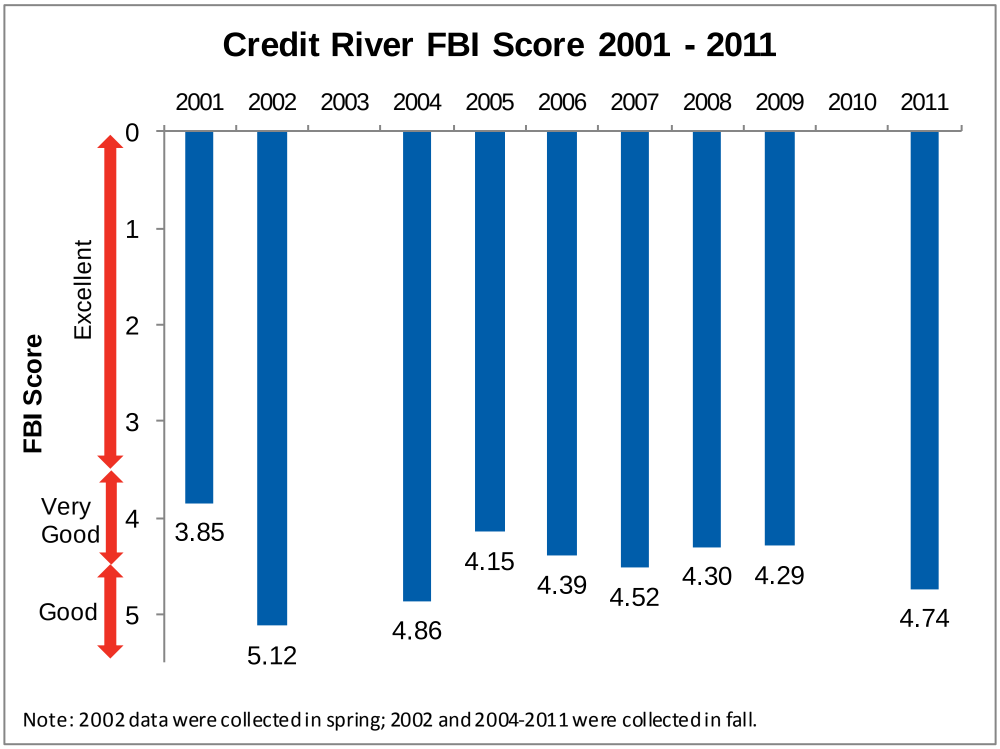
Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. Multi-metric analysis integrates the individual metrics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

MCES has been sampling for macroinvertebrates in the Credit River since 2001. The entire dataset was analyzed with three metrics: Family Biotic Index (FBI), Percent Intolerant Taxa, and Percent POET Taxa. A subset of data, 2004-2009 and 2011, was analyzed using the multi-metric, Minnesota-specific, MPCA 2014 Macroinvertebrate Index of Biological Integrity (M-IBI).

Family Biotic Index (FBI)

FBI is a commonly used water quality assessment. Each family is assigned a tolerance value that describes its ability to tolerate organic pollution. The values range from 0 to 10; zero is intolerant to pollution; 10 is quite tolerant of pollution. The tolerance values are used to calculate a weighted average tolerance value for the sample, allowing for year to year comparisons. Credit River FBI scores show very good water quality (for years 2001, 2005, 2006, 2008, and 2009), to good water quality (2002, 2004, 2007, and 2011), indicating slight organic (high oxygen demand) pollution (Figure CR-13).

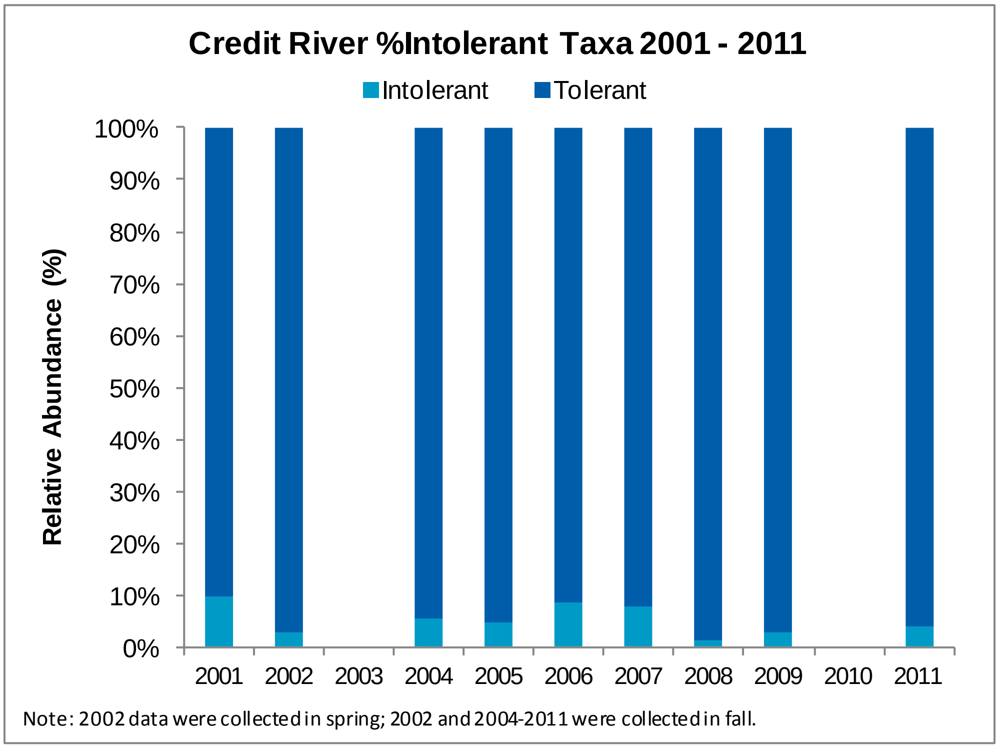
Figure CR-13: Credit River Annual Family Biotic Index (FBI) Scores, 2001-2011



Percent Intolerant Taxa

The Percent Intolerant Taxa is another assessment to evaluate the degree of pollution at the monitoring reach. This metric identifies the percent of taxa with a tolerance value of two or less (Figure CR-14). The presence of moderate numbers of intolerant taxa is an indicator of good aquatic health (Chirhart 2003). Intolerant taxa were greater than 10% of the sample in 2001 and 2003. The highest percent Intolerant taxa, 14%, occurred in 2003. Intolerant taxa were present in every year's samples.

Figure CR-14: Credit River Annual Percent Abundance of Pollution Intolerant Taxa, 2001-2011

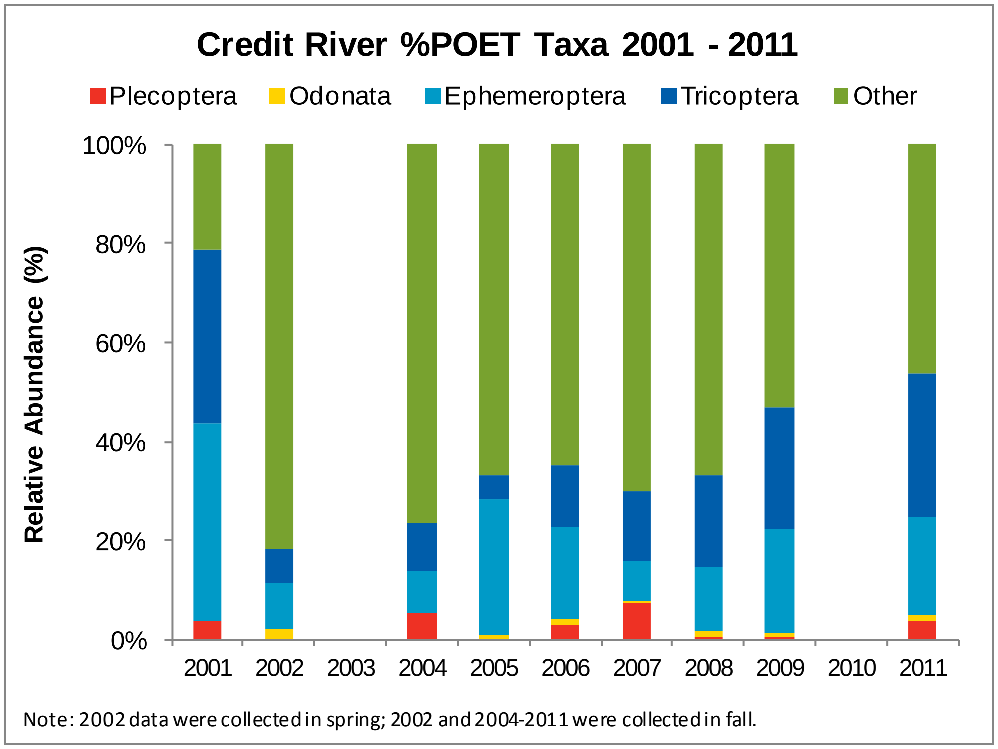


Percent POET Taxa

The taxonomic richness metric, Percent POET Taxa (Figure CR-15), is the percent of individuals in the sample that belong to the orders **P**lecoptera (stoneflies), **O**donata (dragonflies and damselflies), **E**phemeroptera (mayflies), and **T**richoptera (caddisflies). Individuals in these orders vary in sensitivity to organic pollution and sedimentation. High percent POET values indicate high community diversity due to good water quality. The percent POET taxa value was highest in 2001 at 79%, then fell dramatically in 2002 to 18%, and has been increasing fairly steadily since.

All three single metrics indicate that 2002 was a particularly bad year for the ecosystem health of this Credit River reach, and the stream appears to be slowly recovering from a disturbance.

Figure CR-15: Credit River Annual Percent Abundance of POET Taxa, 2001-2011



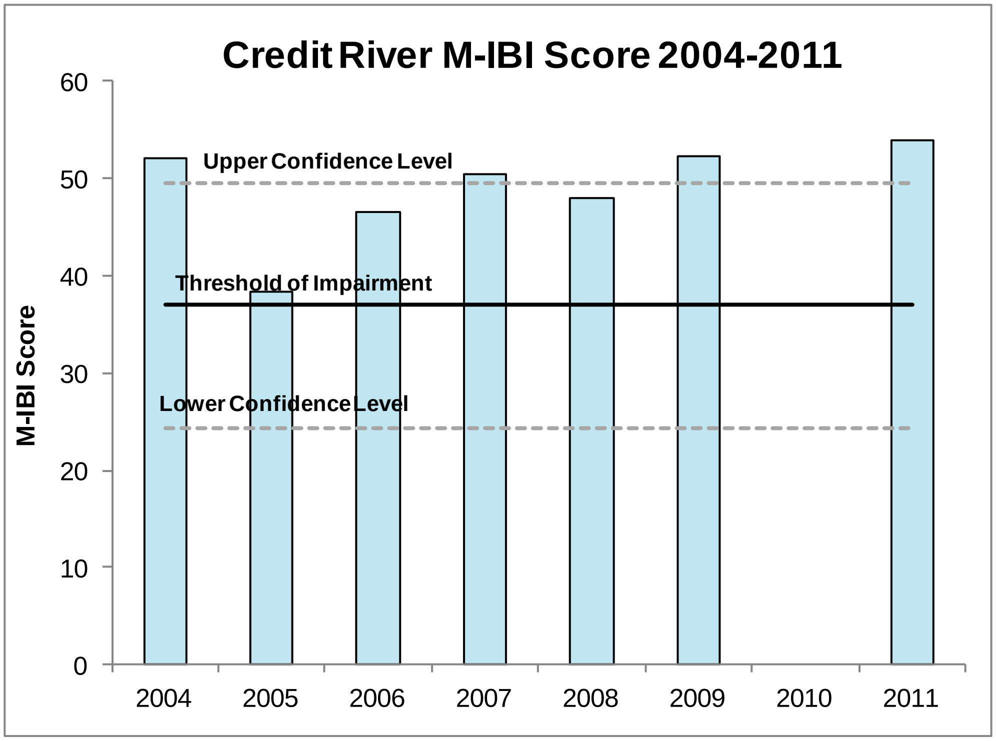
Macroinvertebrate Index of Biotic Integrity (M-IBI)

The M-IBI score integrates community richness and composition, pollution tolerance, life histories, trophic interactions, and physical and other parameters that all are components of the biological integrity of the stream. These composite scores are usually shown in context with a threshold value and confidence levels to aid in the assessment of the water quality (MPCA, 2014b). If the value for a given year is above the threshold of impairment and the upper confidence level, it can confidently be said the site is not impaired. Conversely, if the value is below the threshold of impairment and below the lower confidence level, it can be said the site is likely to be impaired.

All of the Credit River M-IBI data points fell above impairment threshold, and four of the seven values were above the upper confidence level (Figure CR-16). The M-IBI scores suggest the stream experienced a disturbance in 2005 and steadily recovered during the subsequent year. The most recent data (2009, 2011) indicate the stream can likely sustain the needs for aquatic life.

August of 2005 was dry with average daily flows in Credit River generally below 5 cfs. On the day the macroinvertebrate sampling occurred (9-1-2005), the average daily flow was 2 cfs. These low flows may be the reason the M-IBI score for 2005 was so low. MCES is planning additional future analysis to fully investigate our biological monitoring data.

Figure CR-16: Credit River Annual Macroinvertebrate Index of Biological Integrity (M-IBI) Scores, 2004-2011



Trend Analysis

Trend analysis was completed for the historical record of TP, NO_3, and TSS using the U. S. Geological Survey (USGS) program QWTREND (Vecchia, 2003). QWTREND removes the variability of annual flow and seasonality from the statistical analysis; thus 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 variations 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 a period of 10 to 90 years, finding that peak flow due to snowmelt was the only stream flow 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 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 have also likely 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 natural storage. MCES staff plan to repeat the following trend analyses in five to 10 years. At that time, we anticipate sufficient data will have been collected to assess changes in flow rate, as well as to update the pollutant trends discussed below.

MCES staff assessed trends for the period of 1989-2012 on Credit River for TSS, TP, and NO_3, (no data was available for 2000, 2002, and 2009). The results are presented below and in Figure CR-17.

Total Suspended Solids (TSS)

A downward trend was identified for TSS flow-adjusted concentrations in Credit River from 1989 to 2012 (Figure CR-17, top panel). Based on analysis using QWTREND without precedent 5-year flow, the trend identified was statistically significant ($p=6.6x10^{-8}$). The average flow-adjusted concentration decreased from 15.5 mg/l to 5.7 mg/l (-63%) at a rate of -0.41 mg/l/yr from 1989 to 2012.

The five year trend in TSS concentration in Credit River (2008-2012) was calculated to compare with other MCES-monitored streams in the report section ***Comparison with Other Metro Area Streams***. TSS flow-adjusted concentration decreased from 6.5 mg/l to 5.7 mg/l (12% reduction) at a rate of -0.16 mg/l/yr. Based on the QWTREND results, the water quality in Credit River in terms of TSS improved during 2008-2012.

Total Phosphorus (TP)

Based on QWTREND run without precedent 5-year flow, TP flow-adjusted concentration shows one downward trend from 1989 to 2012 (Figure CR-17, middle panel). The trend identified was statistically significant (p=0.001). Average total phosphorus flow-adjusted concentration decreased from 0.12 mg/l to 0.09 mg/l (-27%) at a rate of -0.0013 mg/l/yr from 1989 to 2012.

The five year trend in TP flow-adjusted concentration in Credit River (2008-2012) was calculated to compare with other MCES-monitored streams in the report section ***Comparison with Other Metro Area Streams***. Average TP concentration decreased slightly from 0.10 mg/l to 0.09 mg/l (-4%) at a rate of -0.0008 mg/l/yr. Based on the QWTREND results, the water quality in Credit River in terms of TP improved during 2008-2012.

Nitrate (NO_3)

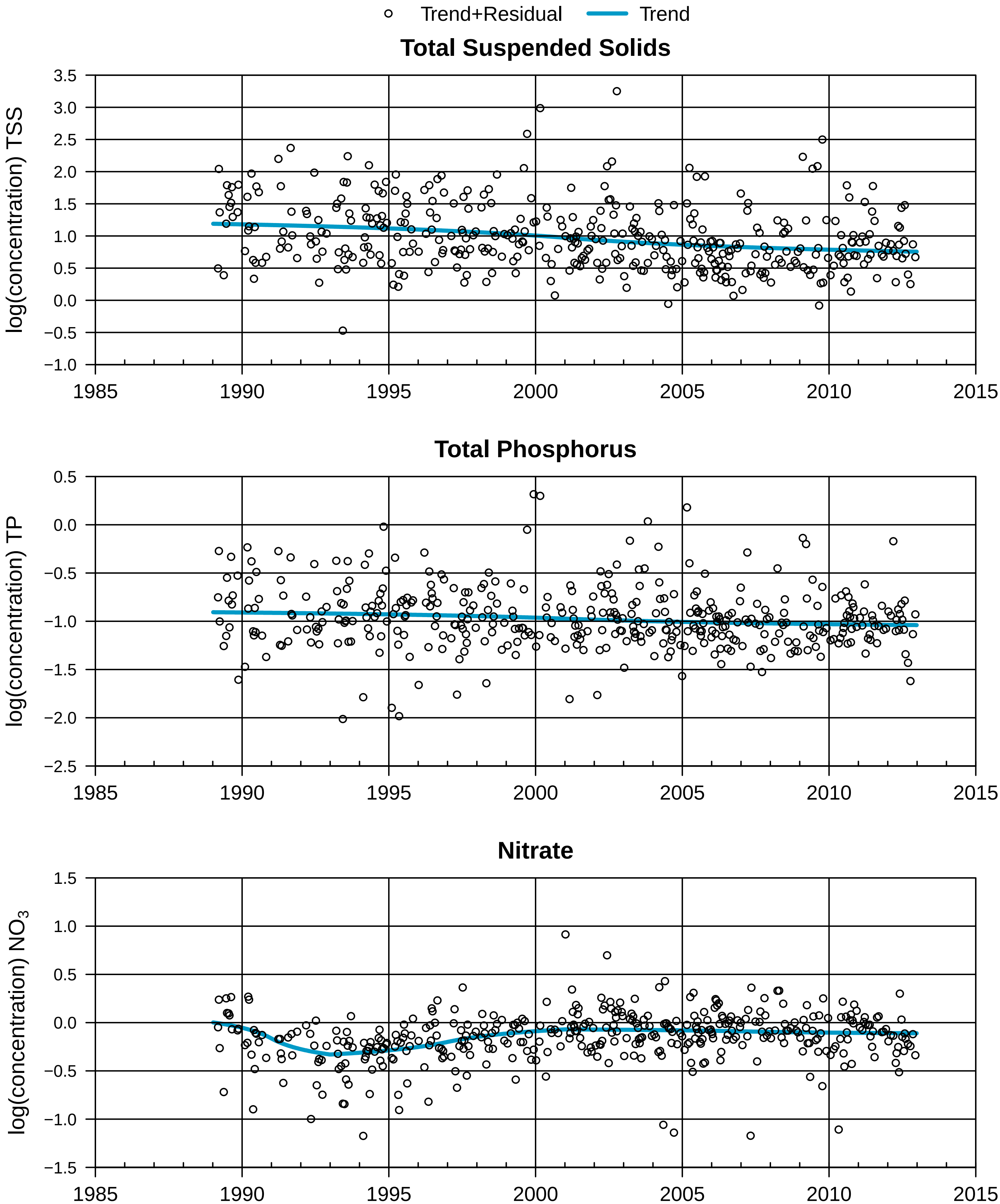
Three trends were identified for NO_3 flow-adjusted concentration in Credit River from 1989 to 2012 (Figure CR-17, bottom panel). Based on QWTREND run without precedent 5-year flow, the trends identified were statistically significant ($p=1.1x10^{-7}$).

- Trend 1: 1989-1992, average NO_3 flow-adjusted concentration decreased from 1.00 mg/l to 0.47 mg/l (-53%) at a rate of -0.13 mg/l/yr.
- Trend 2: 1993-2000, NO_3 increased from 0.47 mg/l to 0.85 mg/l (82%) at a rate of 0.048 mg/l/yr.
- Trend 3: 2001-2012, NO_3 slowly decreased again from 0.86 mg/l to 0.78 mg/l (-9%) at a rate of -0.026 mg/l/yr.

The five year trend in NO_3 flow-adjusted concentration in Credit River (2008-2012) was calculated to compare with other MCES-monitored streams in the report section ***Comparison***

with Other Metro Area Streams. NO_3 flow-adjusted concentration decreased slightly from 0.80 mg/l to 0.78 mg/l (-3%) at a rate of -0.0051 mg/l/yr. Based on these QWTREND results, the water quality in Credit River in terms of NO_3 improved during 2008-2012.

Figure CR−17: Credit River Trends for TSS, TP and NO_3



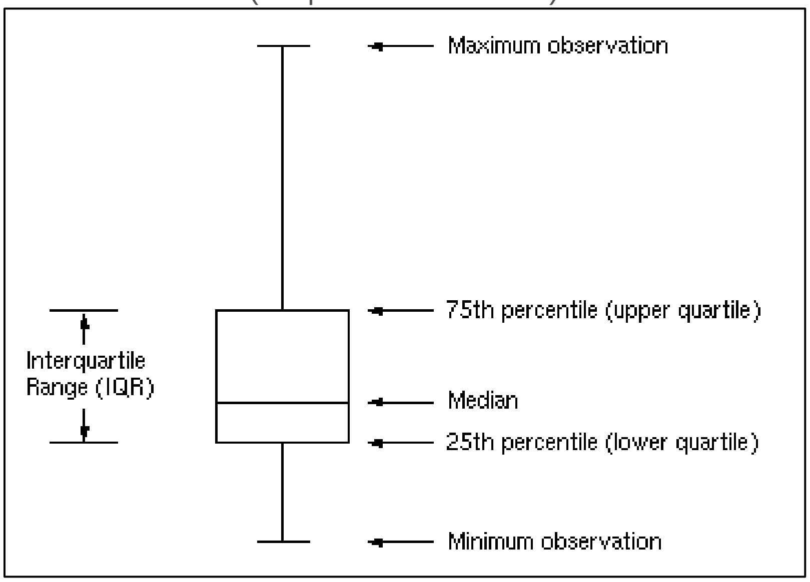
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots are used to summarize the comparison of the historical flow, TSS, TP, NO3, and Cl data for the Credit River with those of the other metropolitan area streams monitored by MCES, and with the major receiving water (in this case the Minnesota River). These comparisons are shown in Figures CR-19 through CR-22.

Figure CR-18 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 extents of the whiskers designate the maximum and minimum values.

Figure CR-18: General Schematic of a Box-and-Whisker Plot
(adapted from *sas.com*)



Comparisons for each chemical parameter for the 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 are 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 median annual FWM TSS concentration in Credit River was lower than that of the Minnesota River for 2003-2012, (107 mg/l vs. 142 mg/l) indicating that Credit River discharge was serving to dilute the river’s TSS concentration (Table CR-5; Figure CR-19).

Credit River’s median annual TSS load was lower than that of Sand, Bevens, and Carver Creeks, the more agricultural Minnesota River tributaries monitored by MCES, but greater than those of Eagle, Willow, Riley, Nine Mile, and Bluff Creeks, the more urban Minnesota River tributaries. In contrast, Credit River’s median annual TSS yield (103 lbs/acre) for 2003-2012 was greater than that of Willow and Nine Mile Creeks, but less than those of all other monitored Minnesota River streams.

Total Phosphorus. Median annual FWM TP concentration in Credit River (Figure CR-20) was higher than that of the Minnesota River for 2003-2012, (0.304 mg/l compared to 0.24 mg/l) indicating that Credit River discharge was increasing the river's TP concentration. Similar to TSS, Credit River's median annual TP load was lower than those of Sand, Bevens, and Carver Creeks, and greater than those of Eagle, Willow, Riley, Nine Mile, and Bluff Creeks, while the median annual TP yield (lbs/acre) for 2003-2012 was greater than those of Willow and Nine Mile Creeks, but less than those of all other monitored Minnesota River streams.

Nitrate. The median annual Credit River NO_3 FWM concentration for 2003-2012 (Figure CR-21) was much less than that of the Minnesota River (1.4 mg/l compared to 6.8 mg/l). It was also less than that of Bevens, Carver, and Sand Creeks. The Credit River median annual NO_3 load was greater than that of Willow, Eagle, Bluff, Riley, and Nine Mile Creeks, but less than that of Carver, Bevens, and Sand Creeks. The Credit River median annual NO_3 yield pattern was similar to that of the NO_3 loads except that it was also less than that of Eagle Creek.

Chloride. Median annual FWM Cl concentration in Credit River was greater than that of the Minnesota River, and also greater than that of Eagle, Bevens, Sand, and Carver Creeks (Figure CR-22). It was less than that of the other more urbanized Minnesota River tributaries: Riley, Bluff, Nine Mile, and Willow Creeks.

The Credit River median annual Cl load was higher than that of Eagle, Riley, Bluff, and Willow Creeks and lower than that of Carver, Bevens, Nine Mile, and Sand Creek. Conversely, the Credit River median annual Cl yield was greater than those of Bevens, Sand and Carver Creeks, but less than those of Eagle, Bluff, Nine Mile, Willow, and Riley Creeks.

Macroinvertebrates

The historic biomonitoring data, summarized as M-IBI scores, are also shown as box-and-whisker plots. However, the streams were divided by stream type because the MPCA impairment thresholds are type-specific and this attribute does not correlate with major river basins.

The M-IBI scores for the Credit River were above the MPCA 2014 impairment threshold (Figure CR-23). This includes the median, which suggests that this stream reach habitat and water quality typically were able to sustain the needs for aquatic life. These results are unlike the other similar warm water, developing Minnesota River tributary watershed, Bluff Creek, whose scores were lower and intersected the threshold. Additionally, the Credit River median M-IBI score was more similar to that of the Vermillion River, a larger, agricultural watershed. This highlights the importance of drivers other than land use and watershed area on M-IBI scores of the streams in the metropolitan area.

Figure CR−19: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

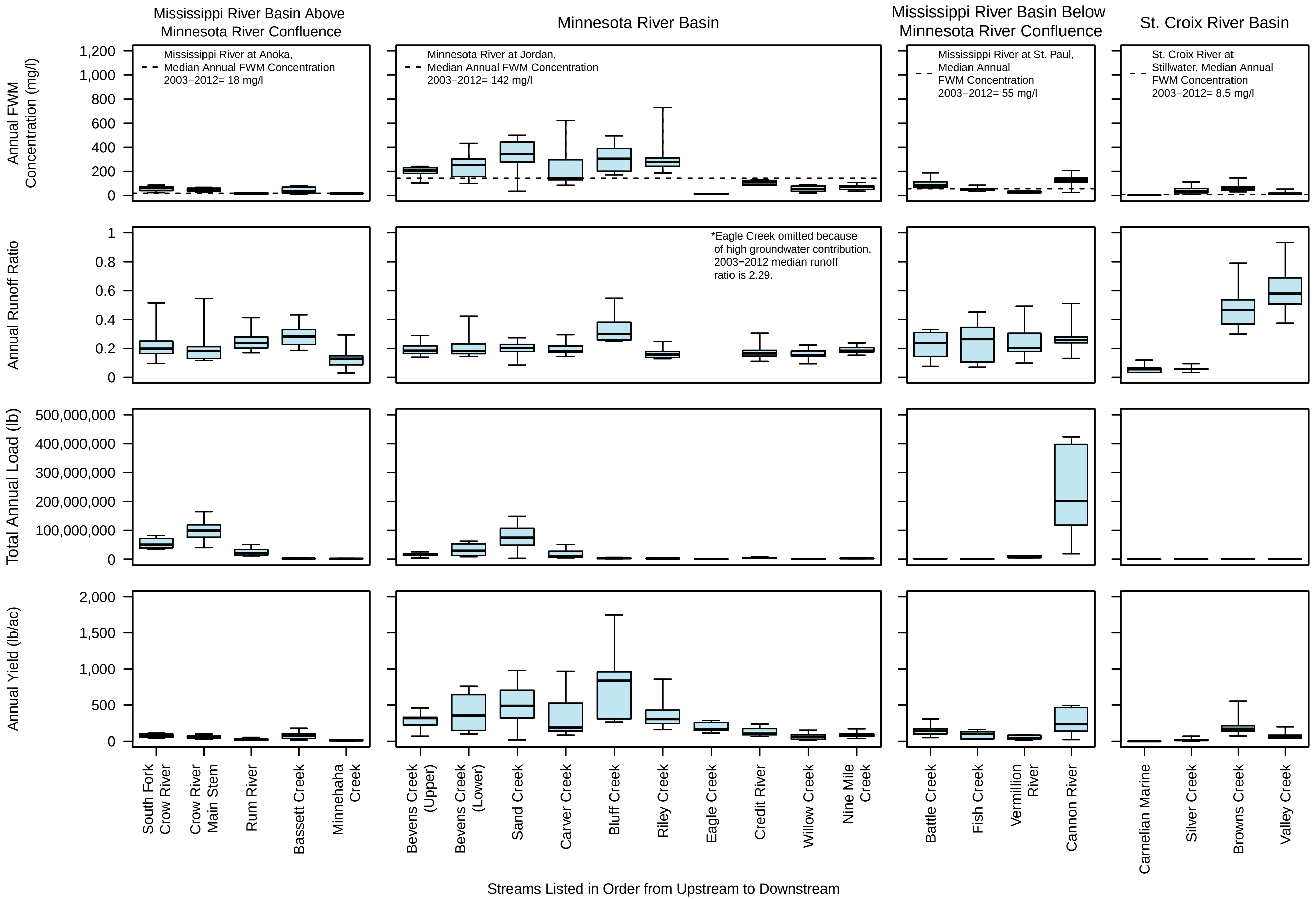


Figure CR−20: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

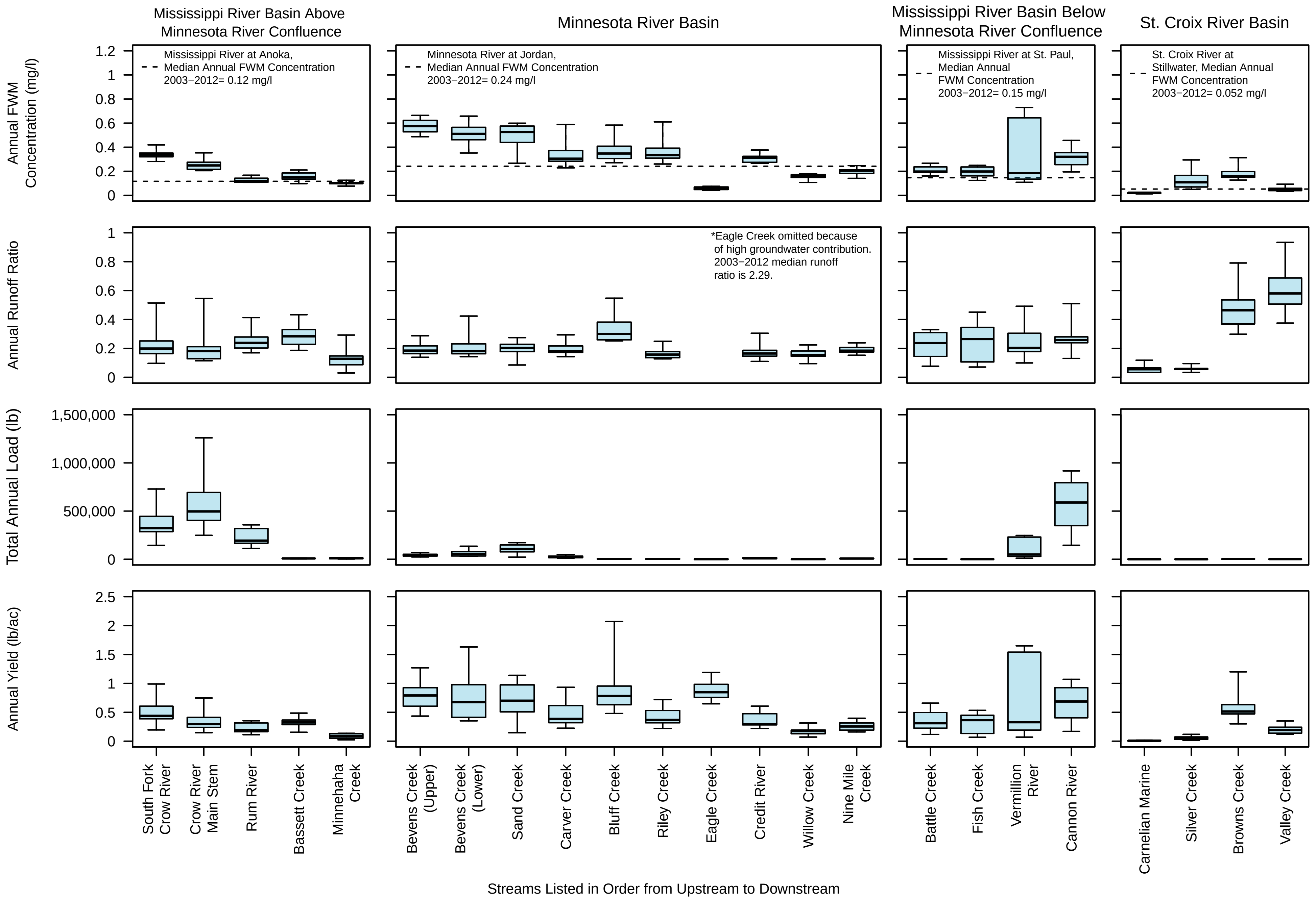


Figure CR−21: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

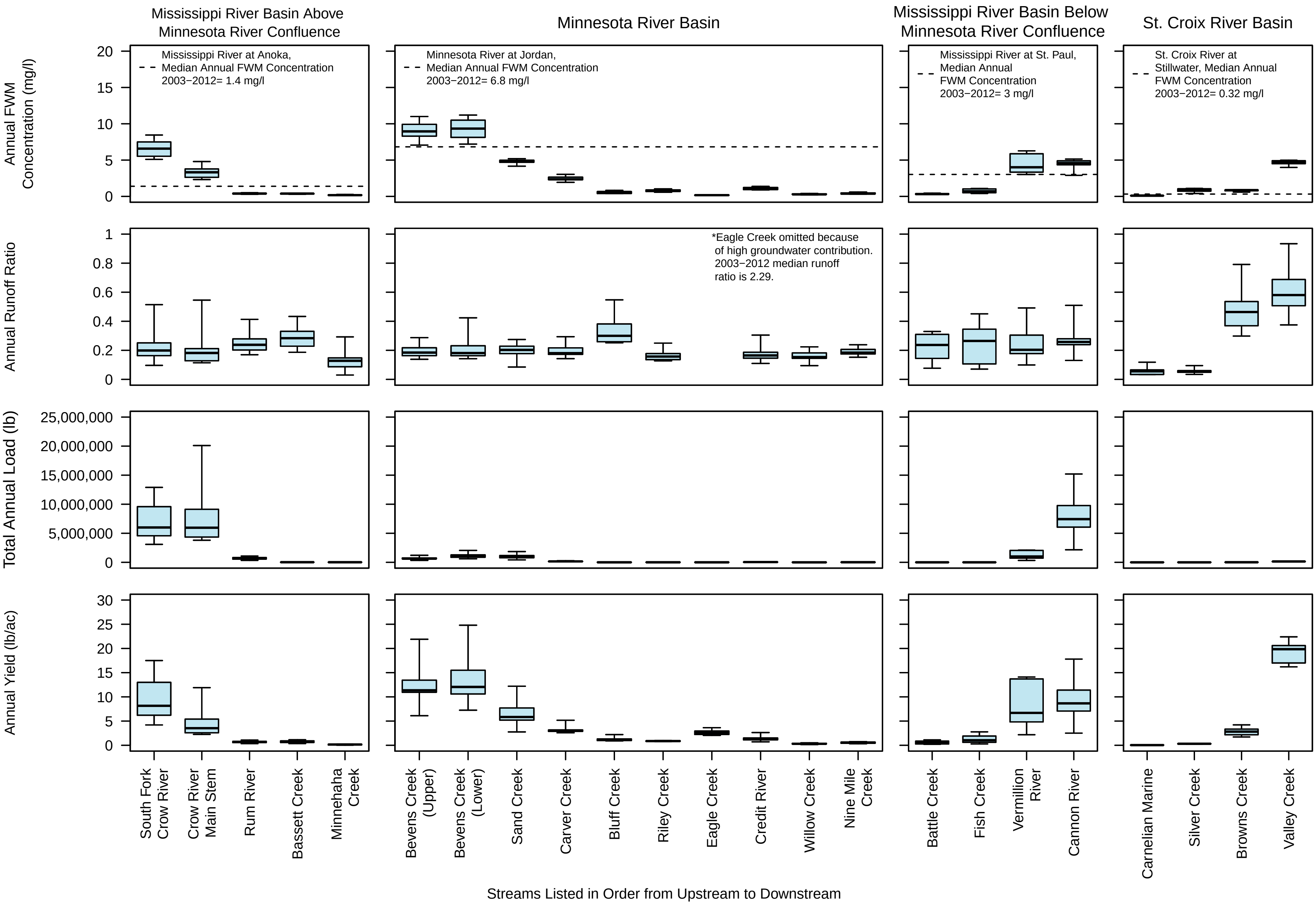


Figure CR−22: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

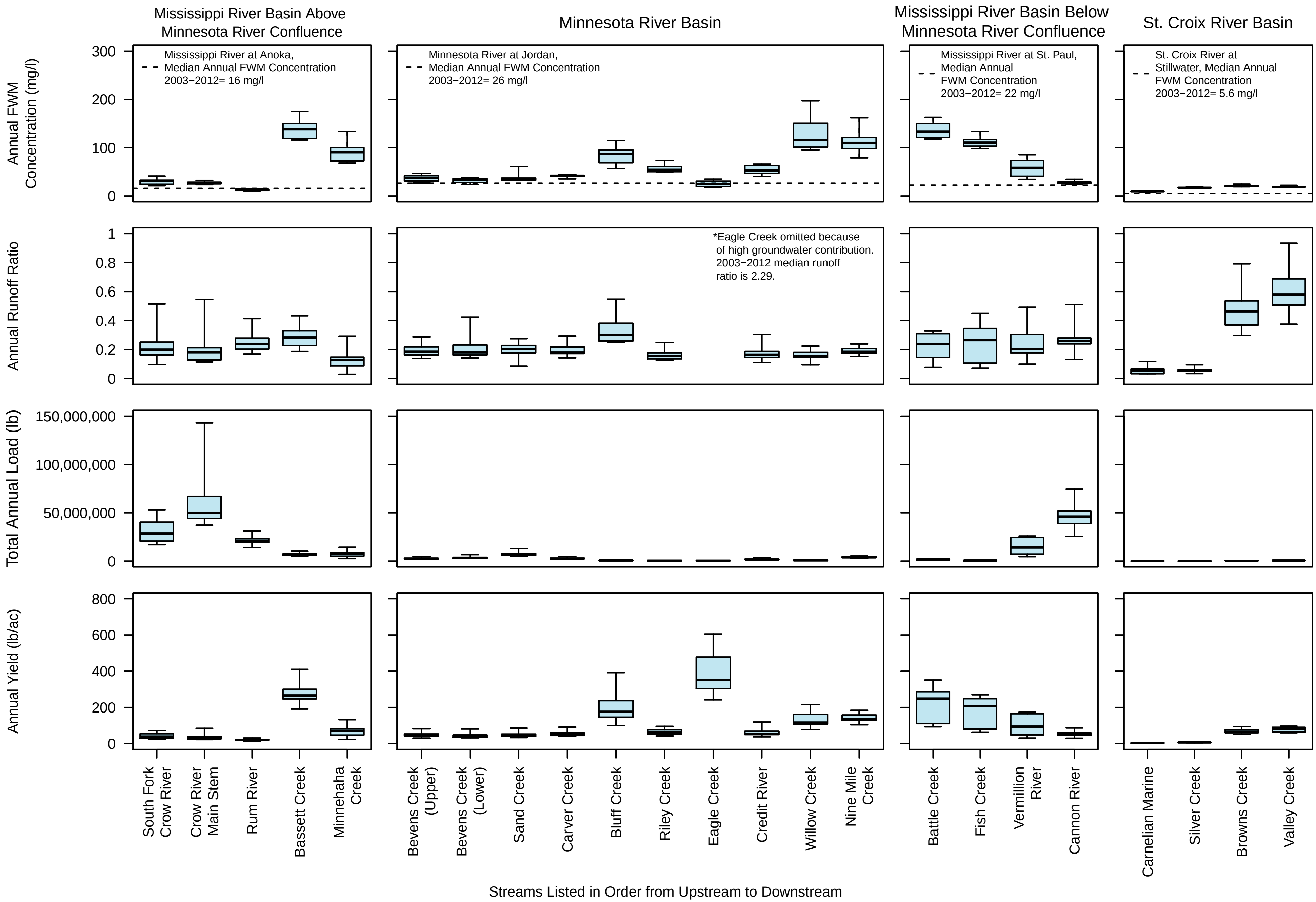


Table CR-5: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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)

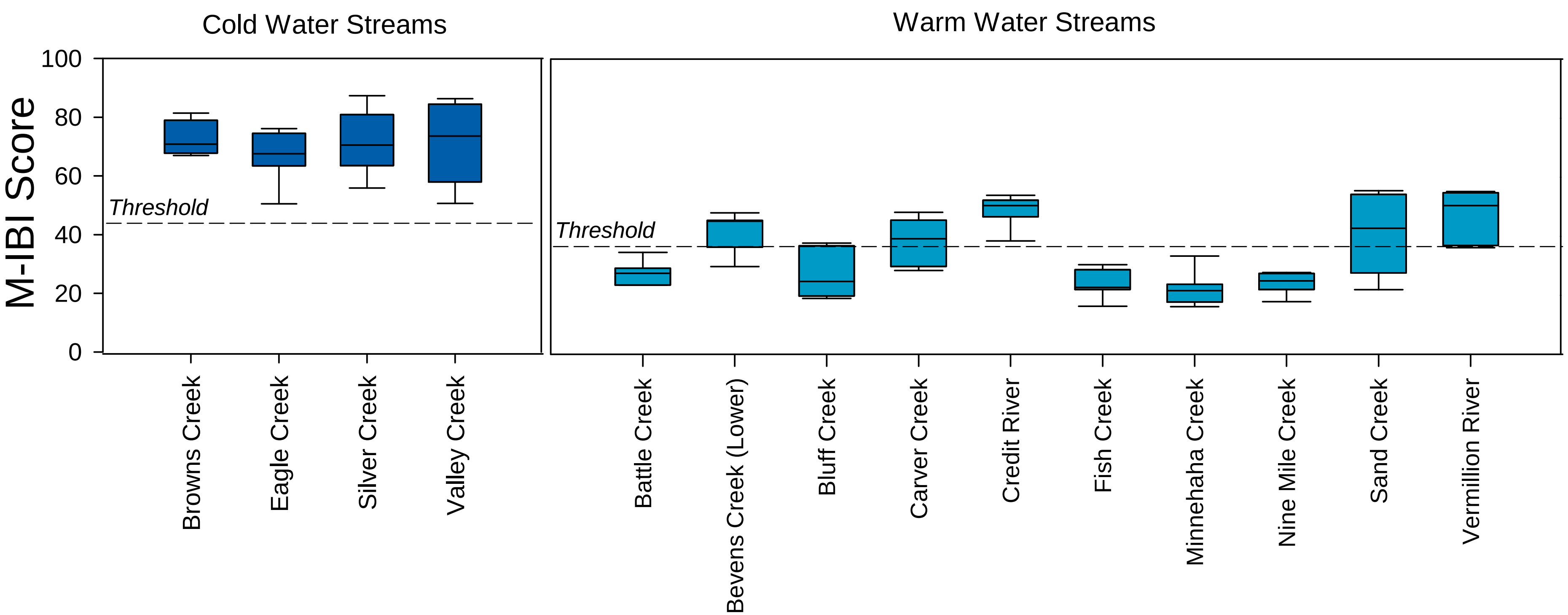
[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

[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

Figure CR-23: M-IBI Results for MCES-Monitored Streams, 2004-2011

Organized by Stream Type



Higher M-IBI scores are indicative of a better water quality.
Each stream type has system-specific impairment thresholds set by the MPCA (2014b).
If a portion of the box plot is below the threshold, the stream may not have supported the needs of aquatic life during the study period.

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.

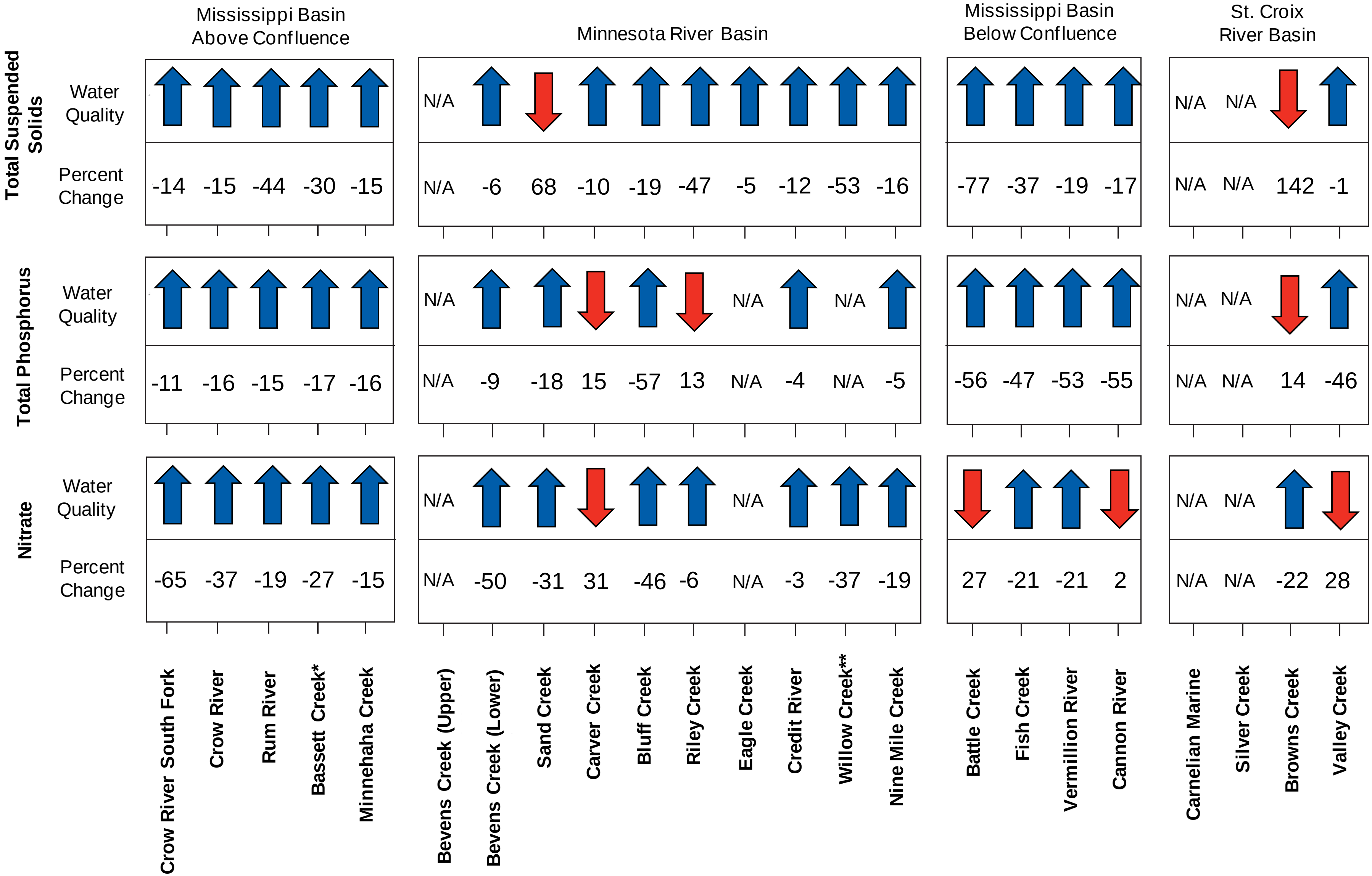
Estimated changes for TSS, TP, and NO_3 in MCES-monitored streams are presented below in two ways. First, tabulated results with directional arrows indicating improving (blue upward arrow) and declining (red downward arrow) water quality paired with percent change in flow-adjusted concentration estimated for 2008-2012 (Figure CR-24). 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 CR-25). 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 (including Credit River) exhibited improving water quality (and thus decreasing flow-adjusted 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 Minnesota River and its tributaries typically have had higher TSS concentrations than the Mississippi or St. Croix Rivers and associated tributaries. The trend analysis results indicate decreasing TSS flow-adjusted concentrations in all Minnesota River tributaries with the exception of Sand Creek. In addition to decreasing TSS concentrations, the Credit River also had decreasing TP and NO_3 concentrations over the last five years.

Figure CR-24: Regional Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO_3, 2008-2012

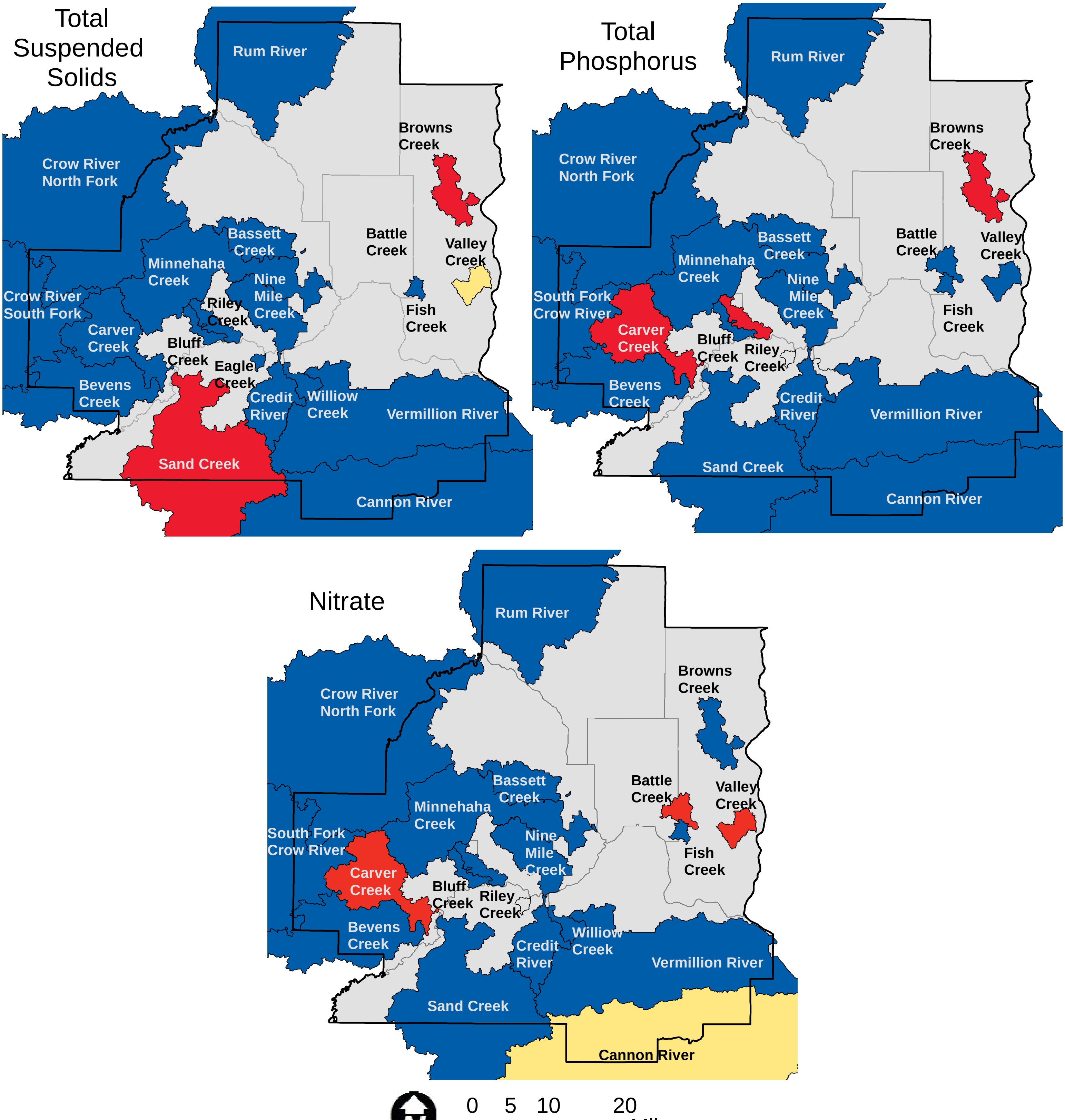
(Grouped by Major River Basin; As estimated by QWTrend)



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 CR-25: Regional Maps of Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO3, 2008-2012

(As estimated by QWTrend)



Less than -3% Change (Indicates Increasing Water Quality)

-3% to 3% Change

Greater than 3% Change (Indicates Decreasing Water Quality)

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Conclusions

Credit River is a tributary to the Minnesota River in the southwestern metropolitan area. The creek drains portions of Scott and Dakota Counties, and receives runoff from the city of Savage. The watershed is in a mixture of agricultural, forest, open space, wetland, and developed land cover. There is one domestic WWTP and two permitted feedlots in the Credit River watershed. The elevation is highest at the southeastern part of the watershed, and the land generally slopes to the north. The steepest drop occurs from the top of the Minnesota River bluff to CSAH 13. The MCES monitoring station is located on Credit River just south of Highway 13 in Savage, Minnesota, about 0.9 miles upstream from the creek confluence with the Minnesota River.

Credit River was designated as impaired for turbidity but has been de-listed. Concentrations and loads for monitored constituents generally rank near the middle of the MCES-monitored Minnesota River tributaries. Trend analysis shows that flow-adjusted concentrations of TSS, TP and NO_3 have all decreased over the most recent five year period (2008-2012), resulting in improving water quality for those pollutants.

Macroinvertebrate M-IBI scores for Credit River indicate that habitat and water quality in the stream reach near the MCES monitoring station are generally able to sustain the needs of warm water aquatic life.

Recommendations

This section presents recommendations for monitoring and assessment of Credit River, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like Scott WMO, 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 years, to assess potential changes in water quality.

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 continue monitoring of Credit River and should partner with Scott WMO to investigate possible sources of pollutants in the creek.
- MCES and partners (especially Scott WMO) 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.
- MCES should partner with Scott WMO to further investigate sources of high Cl concentrations observed in Credit River in the summer and fall months.
- MCES should continue macroinvertebrate monitoring in Credit River and further investigate the lack of intolerant species. MCES should continue to analyze and evaluate the biomonitoring program. Potential additions should include a Stream Habitat

Assessment similar to the habitat surveys performed by the MPCA or the addition of fish population and algal community data.

- MCES should continue 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.
- Local surface water management plans should acknowledge the heightened potential for surface waters to be impacted by groundwater changes in this area.
- The trend analysis should be repeated in 5 years, expanding the list of assessed parameters to include NH3, bacteria, and chlorophyll. Sufficient data should exist at that time to also assess trends in Cl and flow.

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