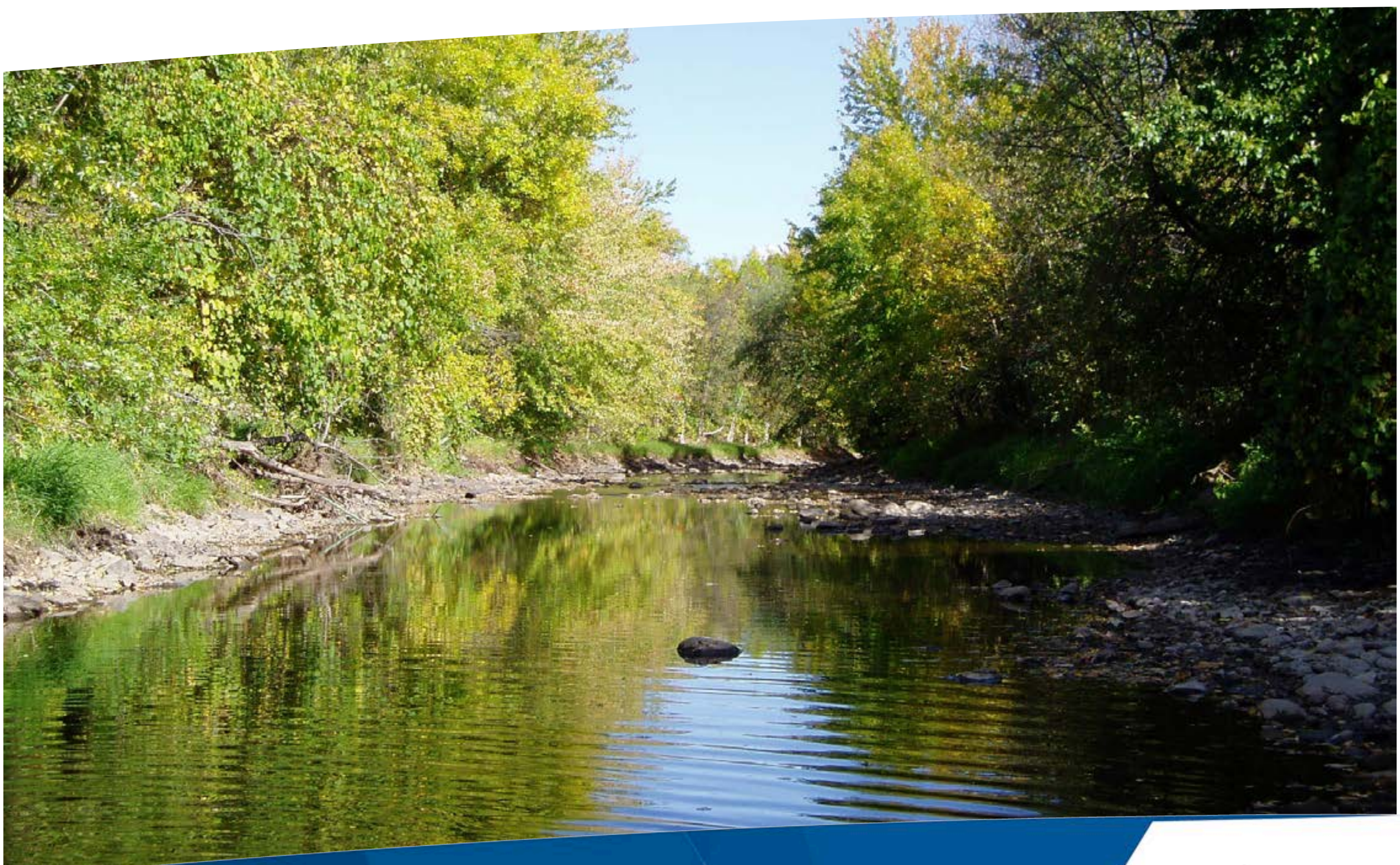
Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

SAND CREEK



METROPOLITAN COUNCIL

December 2014

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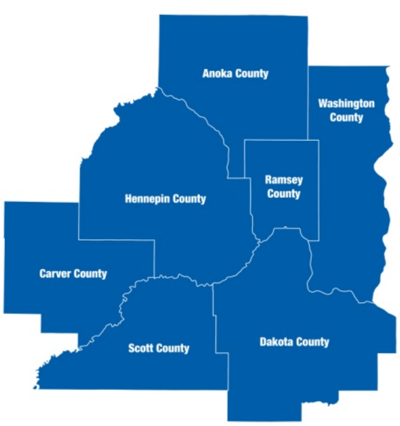

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide 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 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, *Sand Creek*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located in Le Sueur, Rice, and Scott counties, Sand Creek 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 Sand Creek.

Cover Photo

The photo on the cover of this section depicts Sand Creek downstream of the MCES monitoring site.

Recommended Citations

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

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Content

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Introduction

Sand Creek is located in the southern metropolitan area and is a tributary to the Minnesota River. It drains approximately 274 square miles of mixed agricultural land, open space, bluff land, and urban areas (cities of New Prague, Montgomery, and Jordan) through Le Sueur, Rice, and Scott counties.

Figure SA-1: Sand Creek at the Rice Lake Outlet

This report:

- documents those characteristics of Sand Creek 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 Sand Creek flow and water quality with other streams within the metropolitan area monitored by Metropolitan Council Environmental Services (MCES).
- makes general recommendations for future assessment activities, watershed management, partnerships, and other potential actions to remediate water quality or flow concerns.

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

Partnerships and Funding

MCES has performed water quality monitoring of Sand Creek since 1989 (when a partial year of data was collected) as part of its NPS (non-point source) monitoring program. MCES staff maintains the rating curve and operates the monitoring station. All staff and equipment costs are funded solely by MCES.

During 2006-2010, MCES staff partnered with the Scott County Natural Resources Department, with additional cooperation from the Minnesota Pollution Control Agency (MPCA), Scott Water Management Organization (WMO), Scott Soil and Water Conservation District (SWCD), Rice County, and Le Sueur County, to prepare the total maximum daily load (TDML) for the *Sand Creek Watershed TMDL and Impaired Waters Investigation Project* (Scott County, 2010). Scott WMO formulated a detailed set of recommendations based on the results of SWAT modeling, water resources data assessment, and watershed land practices assessment. Since 2010 Scott WMO has worked to implement the recommendations. The WMO, working in partnership with Professor Mae Davenport of the University of Minnesota, has made innovative use of social metrics to develop partnerships with agricultural producers within the watershed, allowing further implementation of agricultural best management practices.

In 1996 MCES provided a Twin Cities Water Quality Initiative (TCQI) grant to Scott SWCD to conduct a paired watershed study within the West Raven and County Ditch 10 subwatersheds of the Sand Creek watershed to assess nutrient reductions from implementing agricultural best management practices (Scott SWCD, 2001).

Monitoring Station Description

The MCES monitoring station is located on Sand Creek in Jordan, Minnesota, approximately 8.2 miles upstream from the creek's confluence with the Minnesota River. During 1989-1990, MCES also operated a second monitoring station at the outlet of Louisville Swamp, near the creek's confluence with the Minnesota River (Mile 1.6). This station was abandoned due to frequent inundation by Minnesota River flood waters. During 2004-2009, MCES and Scott SWCD also operated stations on the West Raven and Scott County Ditch 10 tributaries of Sand Creek (located in the west portion of the watershed) as part of the paired watershed study (Scott SWCD, 2001). Only the data collected at the Jordan station (Sand 8.2) is discussed in this report.

The station at Jordan has been in operation continuously since late 1989, with the exception of 2011, when the station was damaged by flood flows. This report uses data from 1990-2012, except for 2011.

The monitoring station includes continuous flow monitoring, event-based composite sample collection, and on-site conductivity and temperature probes. The Sand Creek station also includes an in-stream turbidity sensor (Forest Technology Systems DTS-12). There is no rain gauge at this station; however, precipitation data are available from the Minnesota Climatology Working Group, Jordan Station Number 214176. 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.

Stream and Watershed Description

Sand Creek drains portions of Scott, Le Sueur and Rice counties. The main branch of Sand Creek flows northerly through Le Sueur and Rice counties, the cities of Montgomery, New Prague and Jordan, and the Louisville Swamp (a floodplain wetland of the Minnesota River; Figure SA-2) before ultimately discharging to the Minnesota River in Scott County. The portion of Sand Creek in Scott County lies within the seven-county metropolitan area and the Metropolitan Council's jurisdiction (Council District 4.) A dam was constructed during the early 20th century in Sand Creek just upstream of Jordan, forming an approximately 8-foot drop which currently serves as a fish migration barrier (Figure SA-3).

Figure SA-2: Louisville Swamp at low water

Figure SA-3: Dam on Sand Creek immediately upstream of Jordan, Minnesota

The creek has a total channel length of approximately 230 miles and is fed by several tributaries. Porter Creek drains the east section of the watershed; Raven Creek (which is further divided into West Raven Creek and County Ditch 10) drains the west portion of the watershed; and Picha Creek drains a small section of the northeast watershed and enters Sand Creek downstream of the monitoring station.

While many of the watershed's wetlands have been ditched and drained, a number of small lakes and open water wetlands still exist in the portion of the watershed above the Minnesota River bluff line. Cedar and McMahon lakes (796 and 184 acres, respectively) are located near the confluence of Porter Creek and the Sand Creek main channel and are the focus of a TMDL study (Scott County, 2010). A number of large, shallow, highly eutrophic lakes are located near the city of Montgomery in the upper watershed, including Lake Pepin (459 acres), Cody Lake (287 acres), Rice Lake (366 acres), and Sanborn Lake (361 acres).

The Sand Creek watershed encompasses a total of 175,247 acres (274 mi^2), with 151,795 acres (86.6%; 237 mi^2) of the watershed upstream of the monitoring station (Figure SA-4; Table SA-1). The watershed is 51% agricultural land (52% within the monitored area), and only 9.6% developed urban land (9.2% within monitored), including the cities of Montgomery, Heidelberg, New Prague, and Jordan, and portions of Lonsdale, Elko New Market, Prior Lake, and Shakopee (based on 2008 Minnesota Land Cover Classification System (MLCCS) data). Of the agricultural land, 34% (35% within monitored) is planted in corn, 35% in soybeans (36% monitored), and 21% is pasture/hay (20% monitored). Of the agricultural land in the watershed, 23% (24% monitored) is potentially draintiled, based on soils and slope analysis by the University of Minnesota (D. Mulla, University of Minnesota, personal communication, 2012). Other primary land covers in the watershed are forest, grasses/herbaceous, and wetlands.

According to the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) STATSGO soils data, more than two-thirds (70%) of soils in the Sand Creek watershed are Type B, which are moderately well drained. The primary Type B soil association is Lester-Le Sueur-Cordova, covering the western portion of the watershed. Other Type B soils are Lester-Hamel, Muskego-Lester-Hayden, and Kilkenny-Caron. The majority of the rest of the soils are poorly drained Type C soils (Lerdal-Kilkenny-Hamel), which are located in the eastern part of the watershed. There is a small pocket of Type A soils in the unmonitored portion below the Minnesota River bluff, as well as Types B/D soils.

Table SA-1: Sand Creek Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	2,239	1.5%	675	2.9%	2,914	1.7%
11-25% Impervious	5,808	3.8%	884	3.8%	6,692	3.8%
26-50% Impervious	2,745	1.8%	695	3.0%	3,440	2.0%
51-75% Impervious	977	0.6%	420	1.8%	1,397	0.8%
76-100% Impervious	2,127	1.4%	272	1.2%	2,399	1.4%
Agricultural Land	78,640	51.8%	11,356	48.4%	89,996	51.4%
Forest (all types)	10,003	6.6%	3,165	13.5%	13,169	7.5%
Open Water	2,732	1.8%	655	2.8%	3,387	1.9%
Barren Land	2	<0.1%	83	0.4%	85	<0.1%
Shrubland	1,082	0.7%	20	0.1%	1,102	0.6%
Grasses/Herbaceous	24,612	16.2%	2,423	10.3%	27,035	15.4%
Wetlands (all types)	20,826	13.7%	2,806	12.0%	23,632	13.5%
Total	151,795	100.0%	23,452	100.0%	175,247	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.

Figure SA-4

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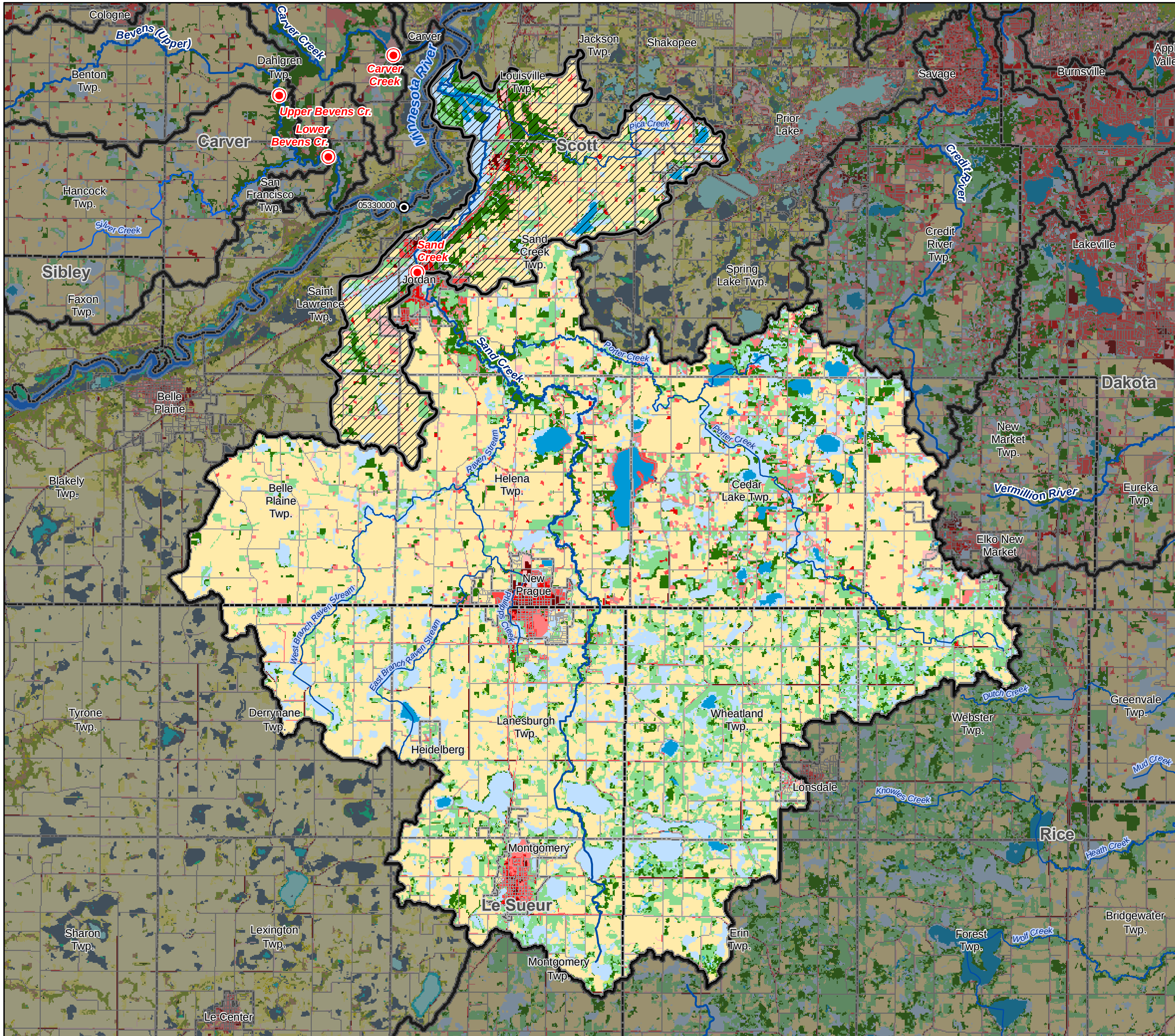
MLCCS-NLCD Hybrid Land Cover

Sand Creek



- 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						
Sand Creek						
	Monitored		Unmonitored		Total	
Land Cover Class	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	2,239	1.5%	675	2.9%	2,914	1.7%
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Total	**151,795**	**100.0%**	**23,452**	**100.0%**	**175,247**	**100.0%**

0 2 4 6

Miles

The watershed topography is fairly gradual until the Minnesota River bluff, where there is a steep drop in elevation (the geological knickpoint) to the Minnesota River floodplain (Figure SA-5). The maximum watershed elevation is 1200.4 MSL (mean sea level) and the minimum elevation is 453.2 MSL within the monitored area. Within the monitored area, 3.0% of the terrain slope is considered steep, and an additional 0.6% is considered very steep (MnDNR, 2011).

The gradient of the creek channel averages 8.7 feet/mile. The Minnesota River watershed is the remnant of the glacial River Warren. Since the glacial river receded, its channel has been filling with sediment as tributary streams to the Minnesota River transport sediment from the upward migration of the knickpoint located near the present Minnesota River bluff line (Jennings, 2010). The knickpoint migration makes the Minnesota River tributaries susceptible to increased streambank erosion and transport and discharge of high loads and concentrations of TSS.

The monitored Sand Creek watershed contains three domestic wastewater treatment plants (WWTPs): New Prague, Montgomery, and Riverbend Mobile Home Park (Figure SA-6). The Jordan WWTP is located in the unmonitored portion of the watershed downstream of the monitoring station. Because of its rural makeup, there are few industrial permits in the watershed: one industrial wastewater permit holder, four industrial stormwater permit holders and two cooling, potable, treatment and dewatering facilities. There are two additional industrial stormwater permit holders in the unmonitored portion.

The Sand Creek watershed has 272 registered feedlots in its monitored area with a total of 23,745 animal units (AUs), and an additional 26 feedlots in the unmonitored area with 2,835 AUs. Seventy-eight of the feedlots in the monitored area have over 100 AUs, and 11 feedlots in the unmonitored area have over 100 AUs. The largest feedlot in the watershed is a pig farm with 999 AUs.

Table SA-2: Permitted Domestic Wastewater Treatment Facilities Discharging to Sand Creek

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus removal[3]	General Notes[3]
MN0020150	New Prague WWTP	2.5	A	Commenced 07/2005	None
MNG550016	Montgomery WWTP	0.968	B	Commenced 06/2004	None
MN0042251	Riverbend Mobile Home Park WWTP	0.06	C	NA	None
MN0020869[4]	Jordan WWTP	1.289	B	Commenced 05/2003	None

[1] Facilities with design flow > 1 mgd shaded in gray.

[2] In general, Class A and B WWTPs use mechanical systems with activated sludge that continuously discharge. Class D are stabilization ponds that are allowed to discharge 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.

Figure SA-5

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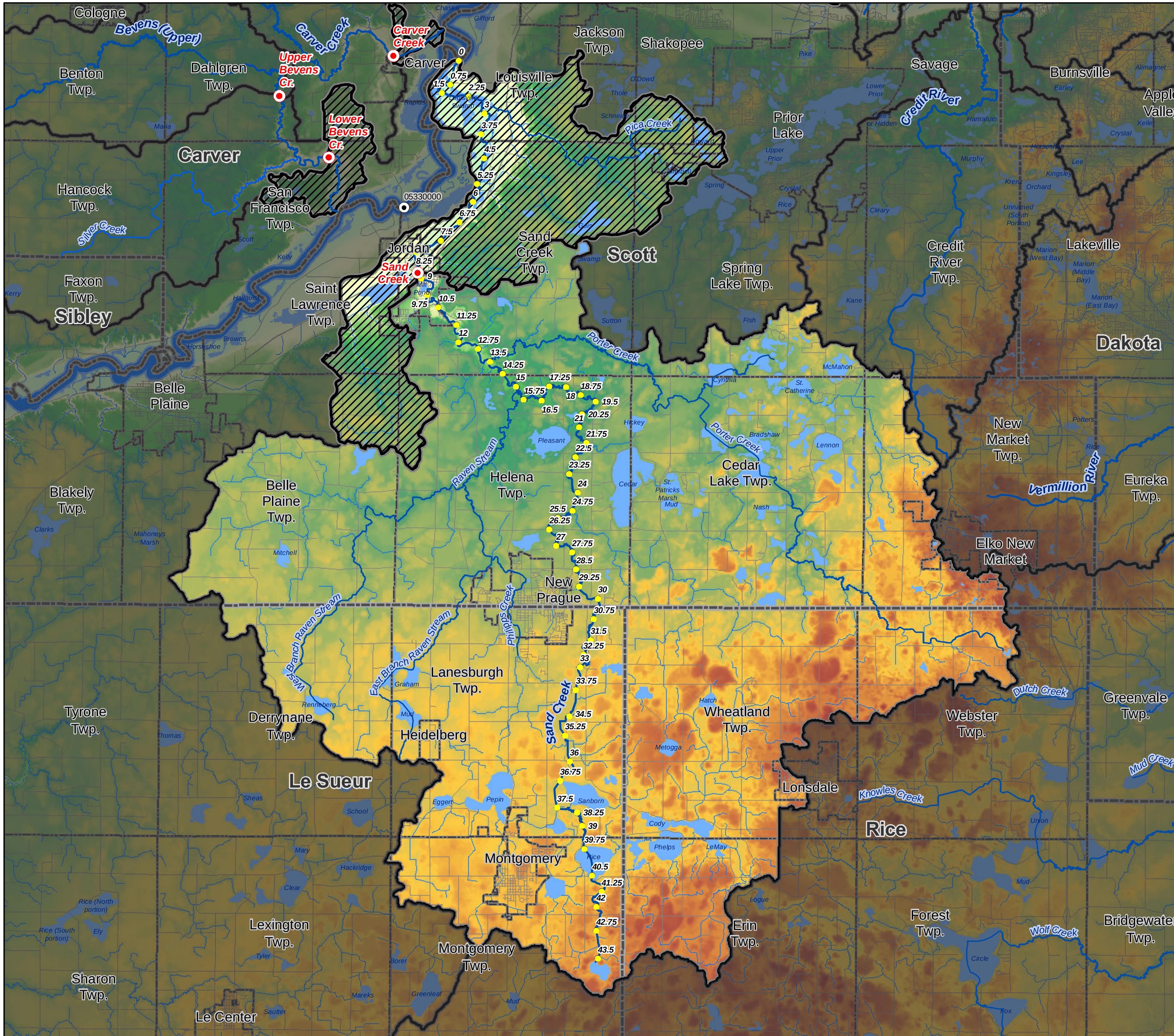
Watershed Topography

Sand Creek



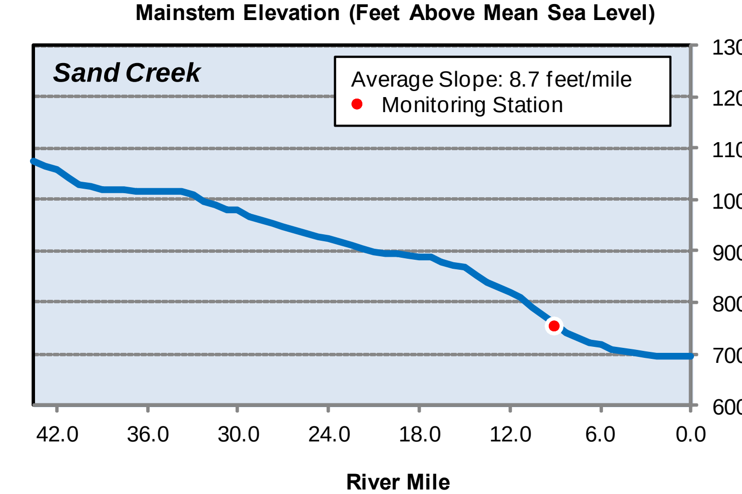
- MCES Stream Monitoring Sites
- USGS Flow Stations
- Stream Mile Markers
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- Public Waters Inventory
- Other Rivers and Streams
- City and Township Boundaries
- County Boundaries
- NCompass Street Centerlines, 2012

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 1 2 3 4 5 6
Miles

Figure SA-6

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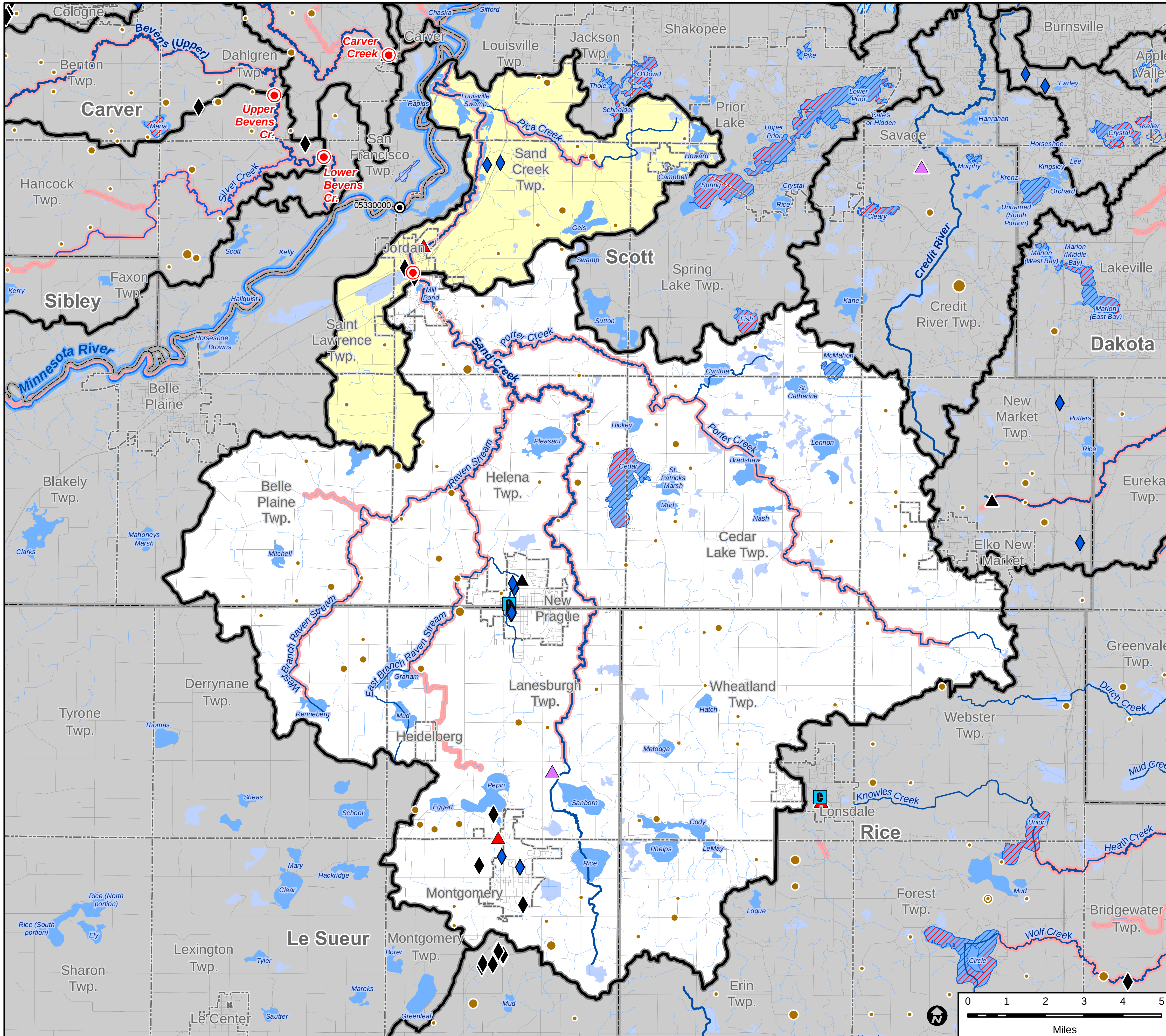
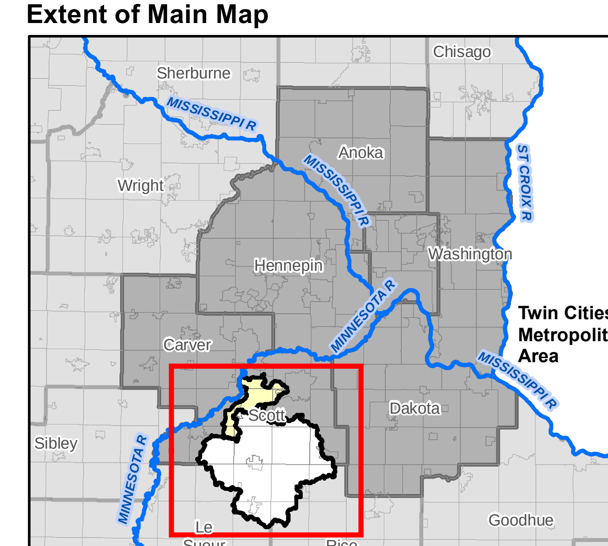
Public and Impaired Waters and Potential Pollution Sources

Sand Creek





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

Imparied 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

Water Quality Impairments

The Sand Creek watershed contains nine stream reaches and two lakes that are included on the MPCA's 2014 impaired waters list (Figure SA-6, Table SA-3 and SA-4). Three reaches of Sand Creek are all impaired for aquatic life due to high levels of turbidity: from T112 R23W S23, south line, to Raven Stream, from Raven Stream to Porter Creek, and from Porter Creek to the Minnesota River. Also impaired are the reach from T112 R23W S23, south line, to Raven Stream due to high levels of chloride, and the reach from Porter Creek to the Minnesota River due to stressors affecting the fish community.

Two reaches of Raven Stream − Raven Stream East Branch from its headwaters to Raven Stream, and from East Branch Raven Stream to Sand Creek − are impaired for aquatic life based on levels of chloride. West Branch Raven Stream from the headwaters to East Branch Raven Stream is impaired for aquatic recreation based on levels of fecal coliform bacteria. County Ditch 10 from County Ditch 3 to Raven Stream is also impaired for aquatic recreation based on levels of fecal coliform. Porter Creek for its entire length is impaired for aquatic life based on levels of turbidity. One stream outside of the monitored area, Picha Creek, is impaired for aquatic life due to stressors affecting the fish community.

Cedar Lake in the north center of the watershed is impaired for aquatic consumption based on mercury and is covered by the statewide TMDL for mercury. Cedar and McMahon Lakes are impaired for aquatic recreation based on nutrient levels.

Table SA-3: Impaired Reaches of Sand Creek as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Affected Use[1]	Approved Plan	Needs Plan[2]
County Ditch 10	CD 3 to Raven Str	07020012-628	AQR	—	FC
Porter Creek	Headwaters to Sand Cr	07020012-540	AQL	—	T
Raven Stream	E Br Raven Str to Sand Cr	07020012-716	AQL	—	Cl
Raven Stream, East Branch	Headwaters (Lk Pepin 40-0028-00) to Raven Str	07020012-543	AQL	—	Cl
Raven Stream, West Branch	Headwaters (Rennenberg Lk 40-0088-00) to E Br Raven Str	07020012-715	AQR	—	FC
Sand Creek	Porter Cr to Minnesota R	07020012-513	AQL	—	Cl, F-IBI, T
Sand Creek	Raven Str to Porter Cr	07020012-538	AQL	—	T
Sand Creek	T112 R23W S23, south line to Raven Str	07020012-662	AQL	—	Cl, T
Unnamed creek (Picha Creek)	Unnamed cr to Unnamed cr	07020012-579	AQL	—	F-IBI

[1] AQR = Aquatic Recreation; AQL = Aquatic Life;

[2] FC = Fecal Coliform; T = Turbidity; Cl = Chloride; F-IBI = Fisheries Bioassessments;

Table SA-4: Impaired Lakes in the Sand Creek Watershed as Identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Affected Use[1]	Approved Plan[2]	Needs Plan
Cedar	70-0091-00	AQC, AQR	Hg, Nutrients	—
McMahon	70-0050-00	AQC, AQR	Hg, Nutrients	—

[1] AQC = Aquatic Consumption; AQR = Aquatic Recreation.

[2] Hg = Mercury in Fish Tissue.

Hydrology

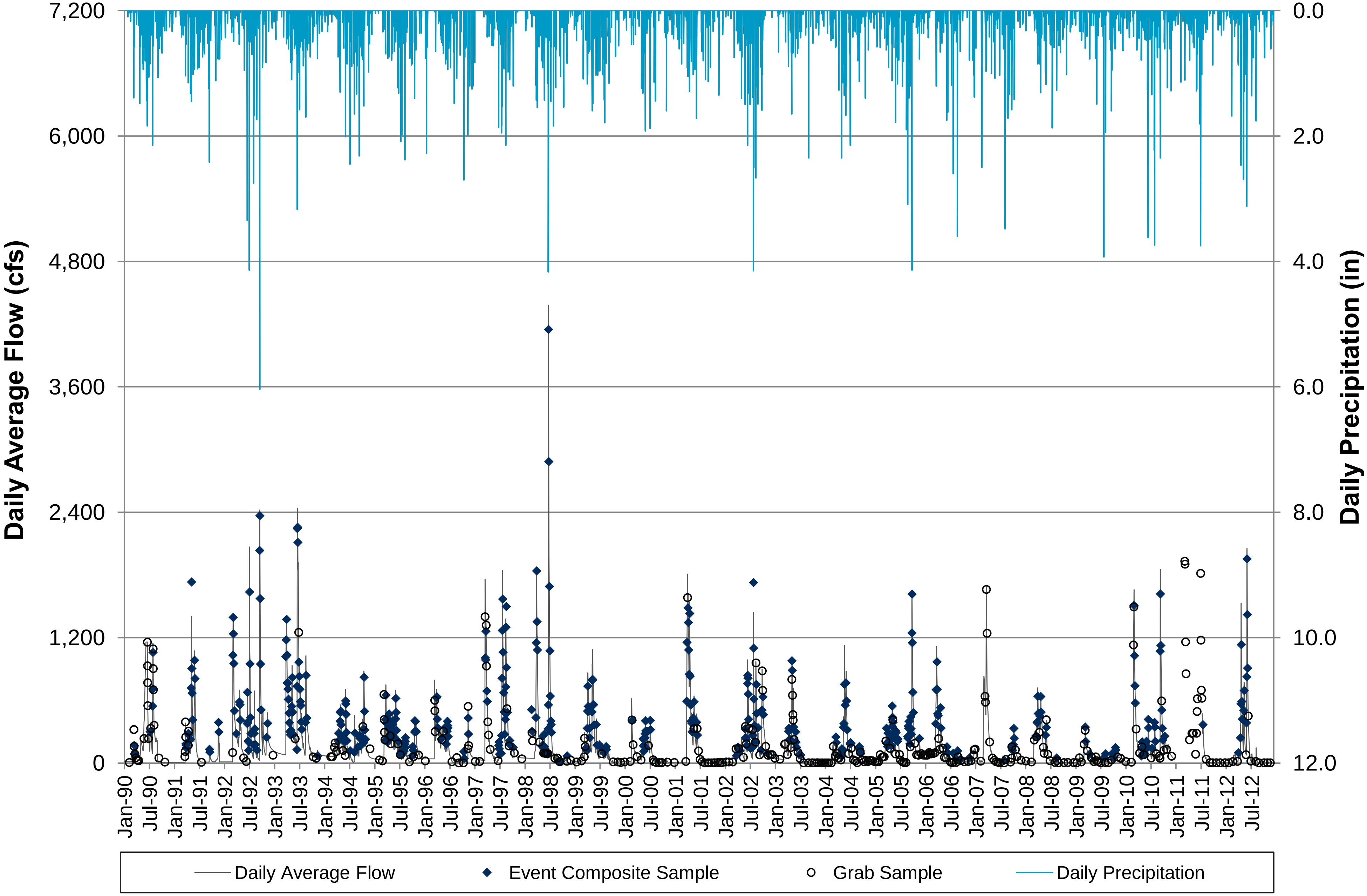
MCES has monitored flow on Sand Creek at Jordan, Minnesota, since 1990. Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrograph of Sand Creek, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variations in flow rates from season to season and from year to year, and the effect of precipitation events on flow (Figure SA-7).

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

Analysis of the duration of daily average flows indicates that the upper 10th percentile flows for the period 1990-2010 ranged between approximately 700-1,700 cubic feet per second (cfs), while the lowest 10th percentile flows ranged from 0.8-7.0 cfs. (See Figure SA-14 in the ***Flow and Load Duration Curves*** section of this report.)

Additional annual flow/volume metrics are shown on Figures SA-8 to SA-11, 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 SA-8 indicates that the highest average annual flow (and thus the highest volume of flow during 1990-2012 occurred during 1993 (approximately 290 cfs average annual flow); the lowest occurred in 2009 (approximately 42 cfs average annual flow).

Figure SA-7: Sand Creek Daily Average Flow, Sample Flow, and Precipitation, 1990-2012*



*2011 flows are not suitable for use due to equipment problems; precipitation record was acquired from NWS COOP stations: 214176-Jordan 1 S, 211468-Chaska 2NW, and 211448-Chanhassen WSFO

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 Sand Creek 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 Sand Creek watershed located within the seven-county metropolitan area boundary (that is, including Scott County, with no data available for Rice or Le Sueur counties).

Within Scott County, two streams segments were identified as potentially vulnerable: a short segment of the Sand Creek main stem immediately upstream of the confluence with Porter Creek, and a second longer segment of the Sand Creek main stem starting near the Minnesota River bluff line and extending to the Minnesota River proper. Several basins within the watershed were identified as vulnerable to groundwater withdrawals, including Louisville Swamp, Mill Pond, McMahon Lake, St. Catherine Lake, and Bradshaw Lake, plus a number of surrounding smaller unnamed wetlands.

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 involving local communities.

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 Sand Creek (1990-2012). (The Jordan monitoring station was out of commission in 2011 due to flood damage; therefore, results are not presented for that year.)

Figures SA-8 through SA-11 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) and precipitation depth coupled with runoff ratio). A later section in this report, ***Comparison with Other Metro Area Streams***, offers graphical comparison of the Sand Creek 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 is relatively stable between years; year-to-year variation is likely influenced by drought periods, by low soil moisture caused by dry periods, by 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, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream (Figure SA-8). Notable is the apparent decrease in NH_3 load from the early 1990s to 2012. This decrease may be due to changes in agricultural practices or the implementation of nitrogen reduction at the WWTPs discharging to Sand Creek.

The annual FWM concentrations for all parameters also fluctuate year-to-year and are likely influenced by annual precipitation and flow (Figure SA-9). The NH_3 concentrations follow the same trend exhibited by the annual loads, with an obvious decrease from the early 1990s to 2012. The statistical trend for NH_3 is not assessed in this report; it is recommended that this parameter be added to future trend assessments.

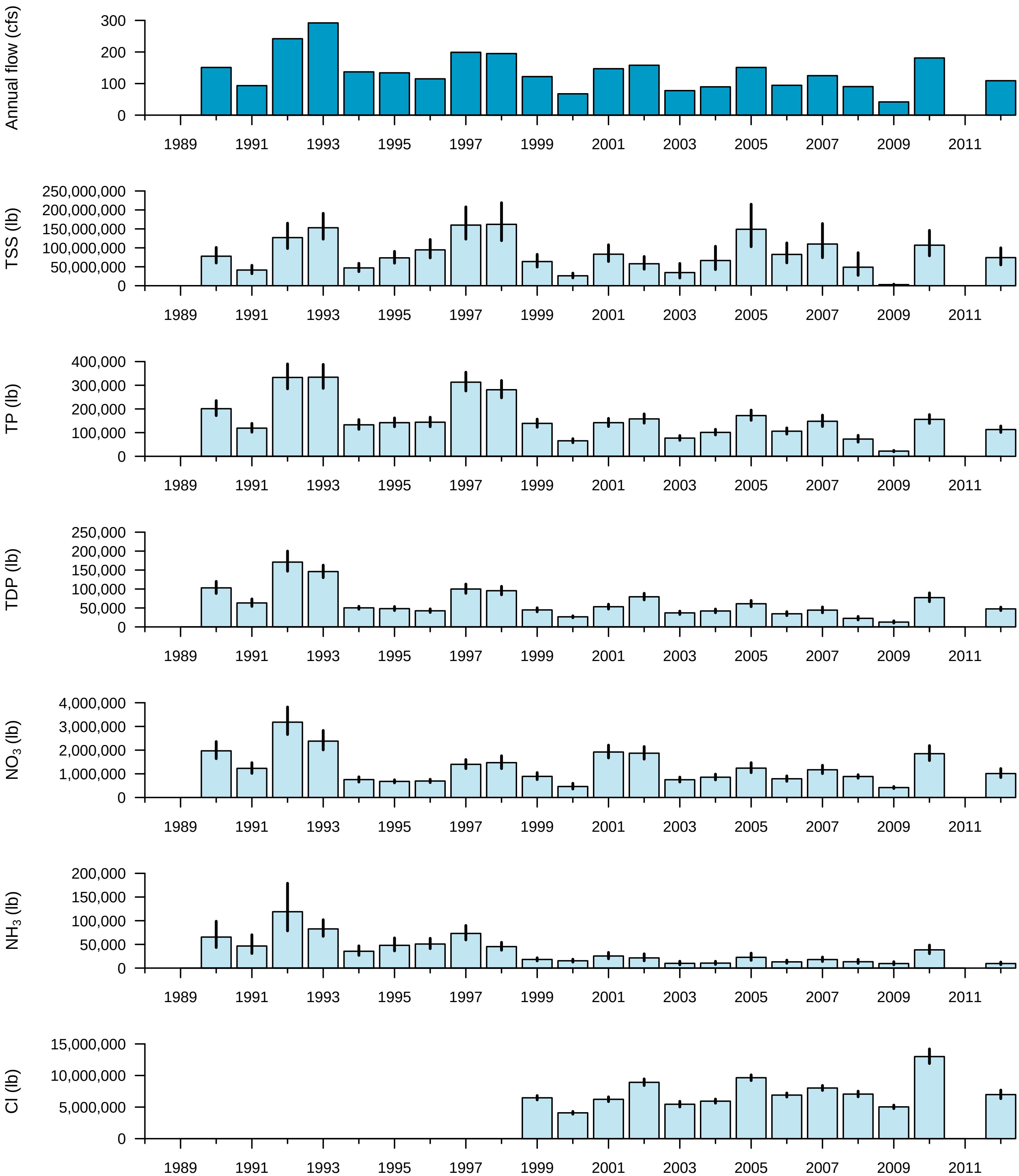
Figures SA-10 and SA-11 present the areal and precipitation-weighted loads, respectively. These graphics are presented to assist local partners and watershed managers, and will not be discussed here.

The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of time-based patterns in the loads in Sand Creek (Figure SA-12 and Figure SA-13). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for Sand Creek) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month).

It is apparent that the highest mass loads in Sand Creek occur in March and/or April each year, likely due to effects of snow melt and spring rains. Secondary load pulses occur in September and October and are likely due to fall precipitation occurring after tree leaf fall and vegetation die-off.

The FWM concentrations show less month-to-month variability than the loads. TSS concentrations are highest in spring and fall, corresponding to high flow periods. The TP and TDP monthly concentrations remain fairly stable and are likely influenced, even during low flow periods, by WWTP effluent discharge. Chloride concentrations are highest in January and February, likely reflecting the impact of road de-icers during winter months.

Figure SA−8: Sand Creek*
Annual Mass Load

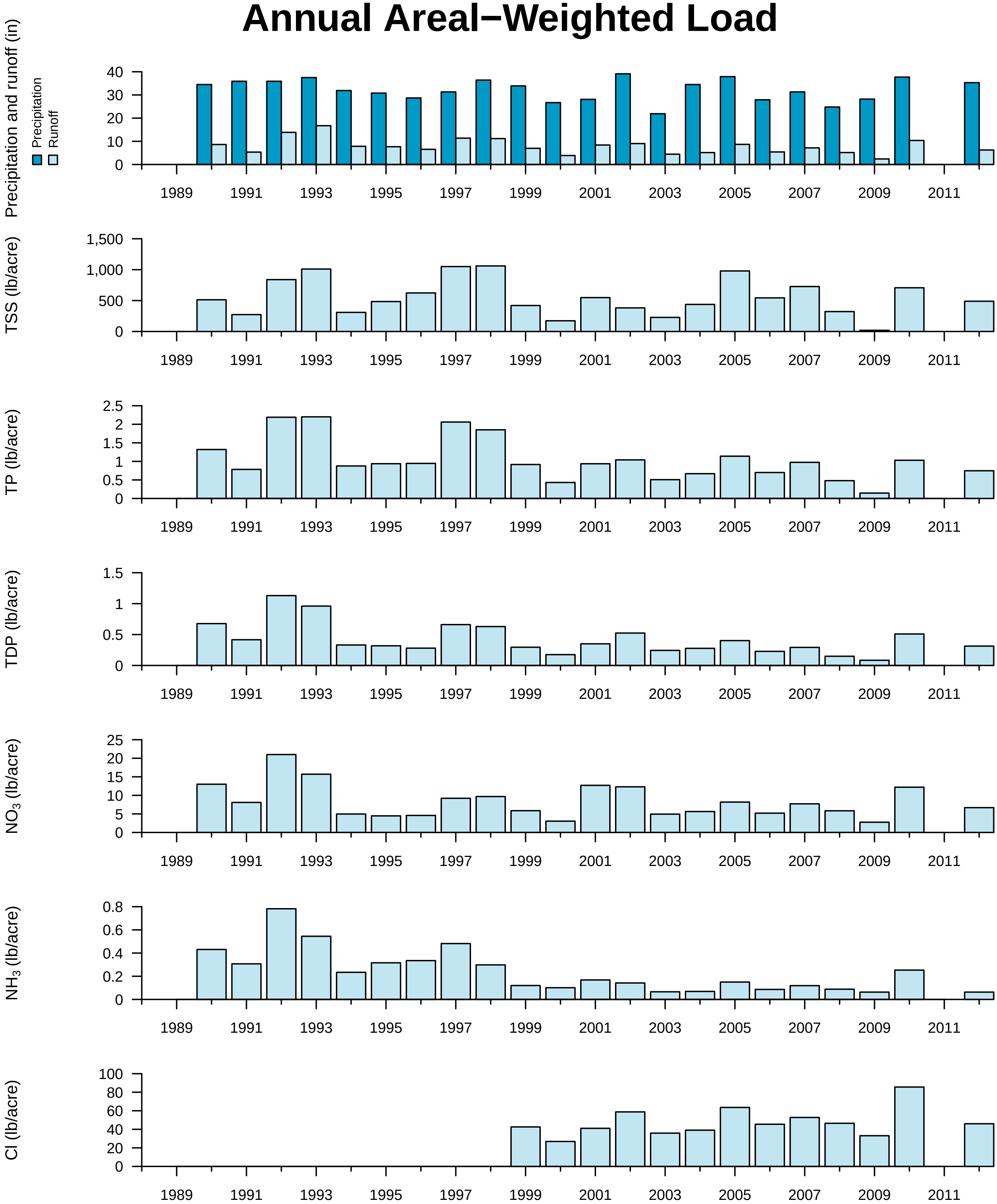


*TSS, TP, TDP, NO3, and NH3 sampling began in 1990, Cl began in 1999. The station was down in 2011 so no loads could be calculated.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure SA−9: Sand Creek*
Annual Flow−Weighted Mean Concentration

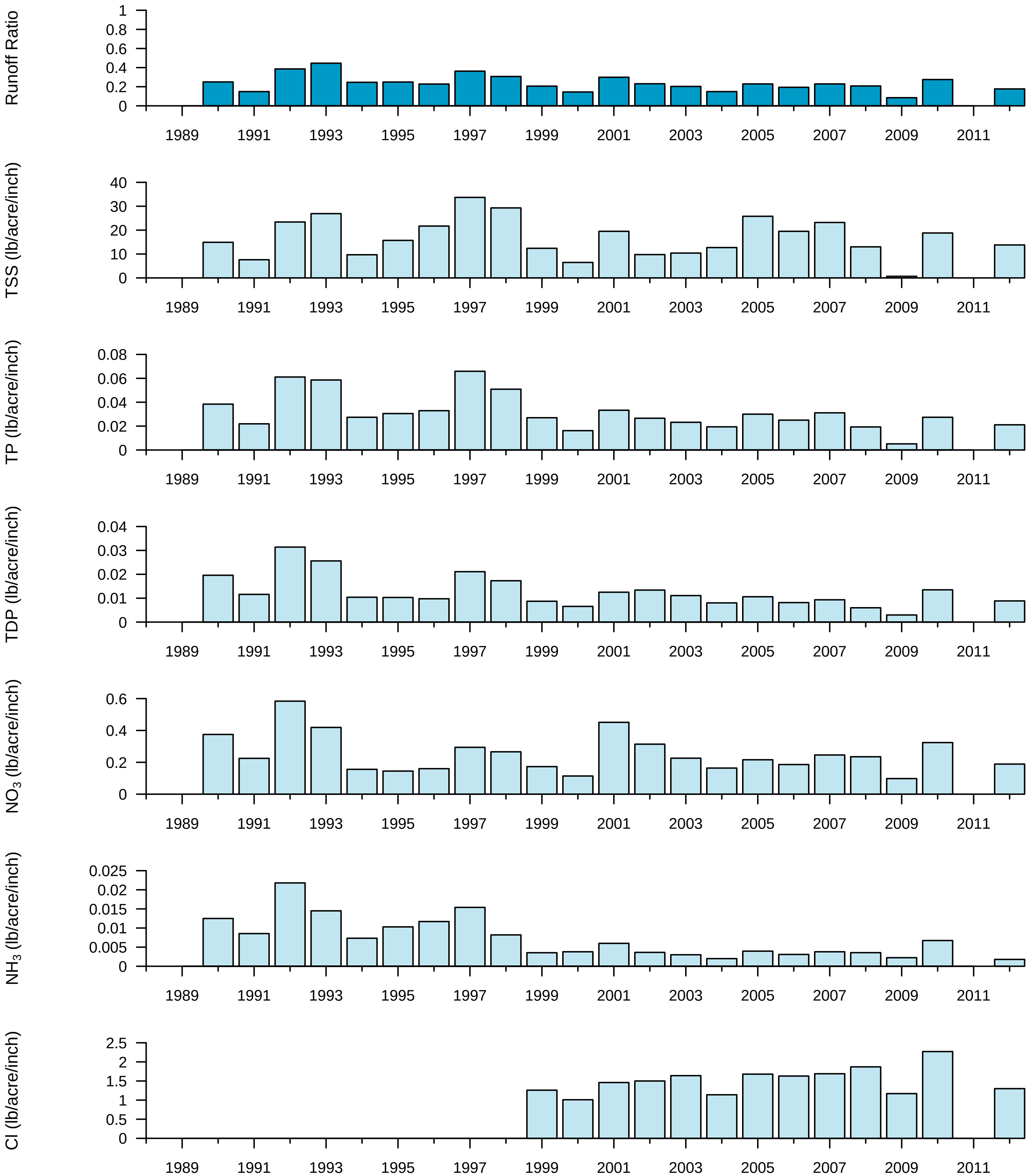
*TSS, TP, TDP, NO3, and NH3 sampling began in 1990, Cl began in 1999. The station was down in 2011 so no loads could be calculated.

Figure SA−10: Sand Creek*
Annual Areal−Weighted Load



*TSS, TP, TDP, NO3, and NH3 sampling began in 1990, Cl began in 1999. The station was down in 2011 so no loads could be calculated.

Figure SA−11: Sand Creek*
Annual Precipitation−Weighted Areal Load



*TSS, TP, TDP, NO3, and NH3 sampling began in 1990, Cl began in 1999. The station was down in 2011 so no loads could be calculated.

Figure SA−12: Sand Creek
Mass Load by Month

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

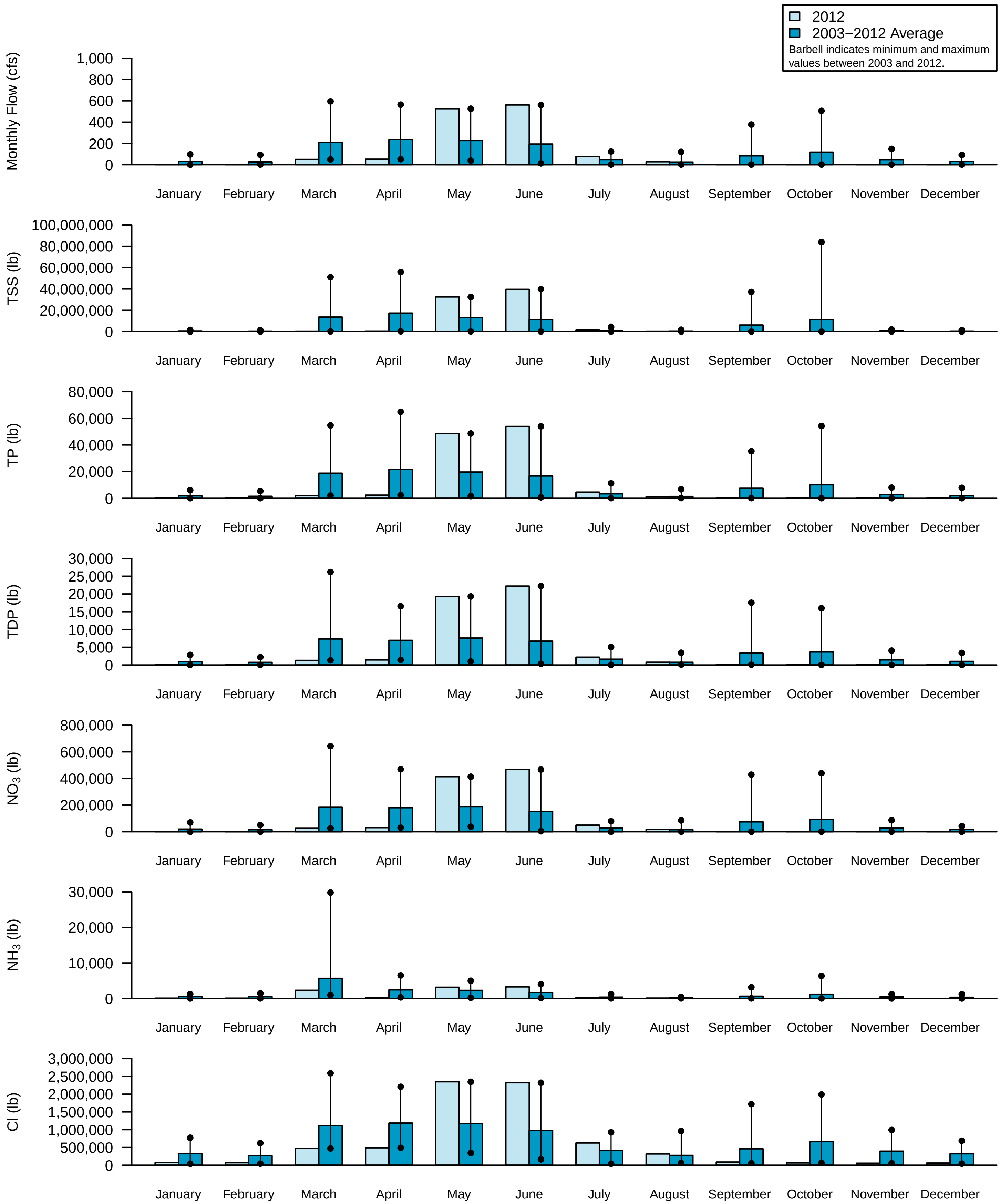
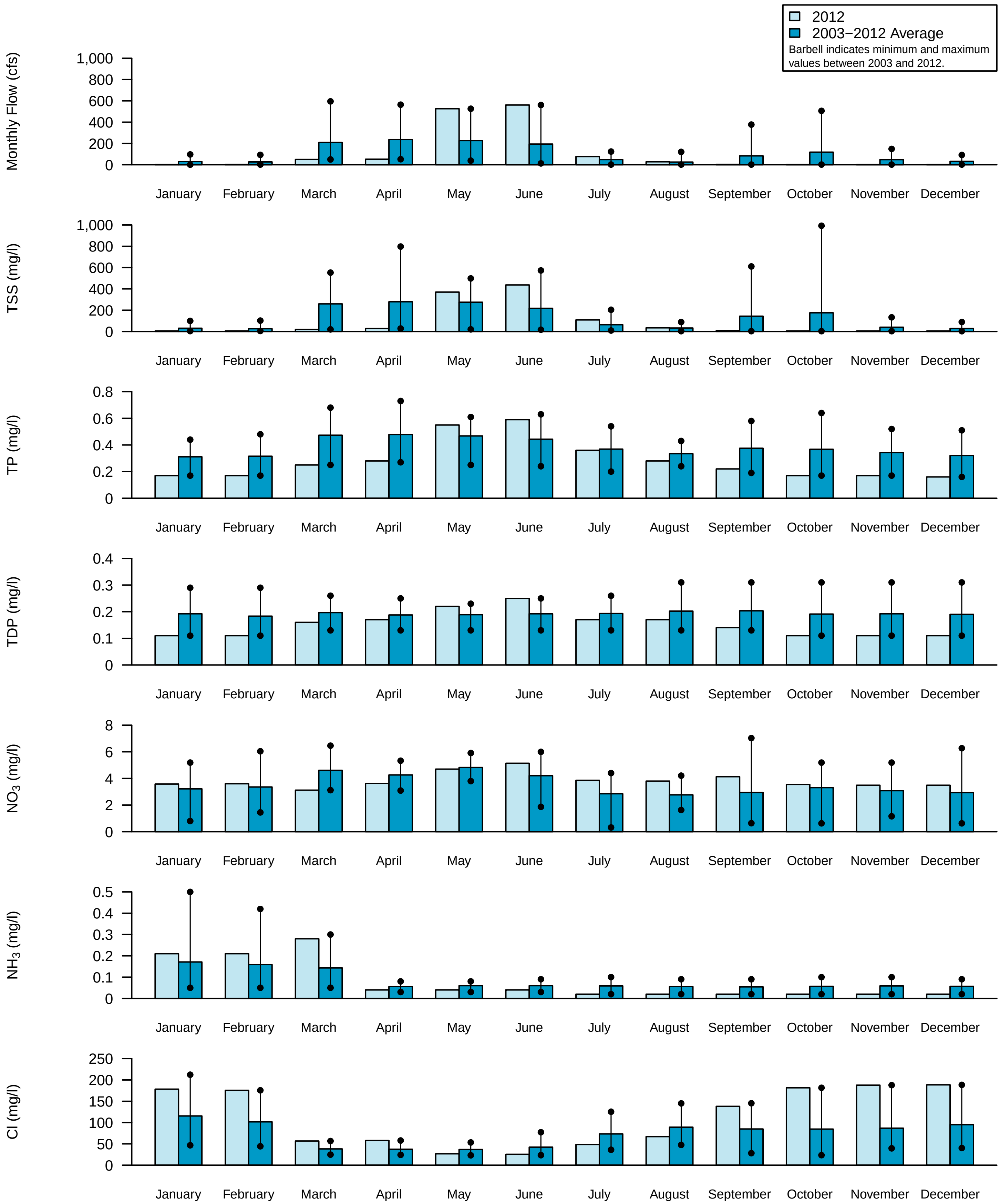


Figure SA−13: Sand Creek
Flow−Weighted Mean Concentation by Month

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 location 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 Cl. Each of the parameters was plotted using Sand Creek monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table SA-5. 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 1990–2012 flow duration curve and load duration curves for TSS, TP, NO_3, and Cl for the Sand Creek monitoring station (mile 8.2, above Louisville Swamp) are shown in Figure SA-14. TSS concentrations have remained below the draft standard at low flow and dry conditions. During moist conditions and high flow, most samples collected exceed the draft standard. This response is consistent with other streams in the Minnesota River watershed, where high flows lead to stream bank, bluff, and ravine erosion.

Total phosphorus concentration exceeds the draft nutrient criteria concentration consistently at all flows. The two domestic WWTPs upstream of the monitoring station started reducing effluent phosphorus in 2004 and 2005. Since the stream sediments downstream of the WWTPs have likely been enriched by years of high phosphorus effluent, 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 five to 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. The final river nutrient standard for nitrate will likely be much less than that and will likely be exceeded at the higher flow regimes.

Cl concentrations in Sand Creek are below the draft chloride criteria at all flow regimes. Concentrations are highest at the lowest flows, indicating either groundwater contribution of chloride at base flow conditions, or very early spring snowmelt carrying dissolved road salt.

Table SA-5: Sand Creek 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[3] (mg/l)	TSS Draft Stnd[4] (mg/l)	TP Draft Criteria[5] (ug/l)	Nitrate DW Stnd[6] (mg/l)
Sand Creek upstream of Louisville Swamp (SA8.2)	2B	Central	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430.

[2] MPCA, 2010.

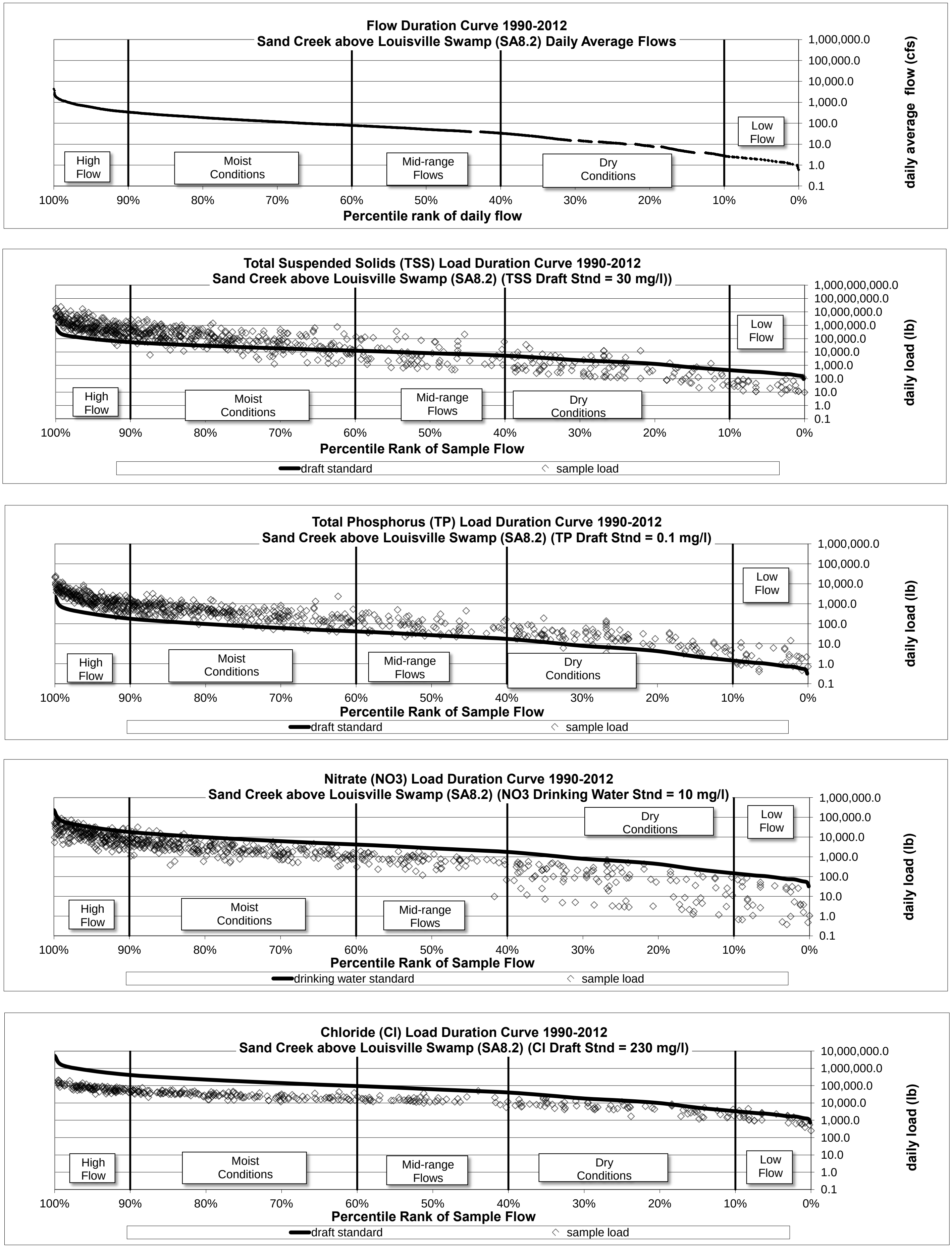
[3] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft chloride standard pending results of EPA toxicity tests.

[4] MPCA, 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.

[5] MPCA, 2013a. To violate criteria, concentration of causative variable (TP) must be exceeded, as well as one or more response variables: sestonic chlorophyll, BOD5, DO flux, and/or pH.

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

Figure SA-14: Sand Creek Flow and Load Duration Curves, 1990-2012



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.

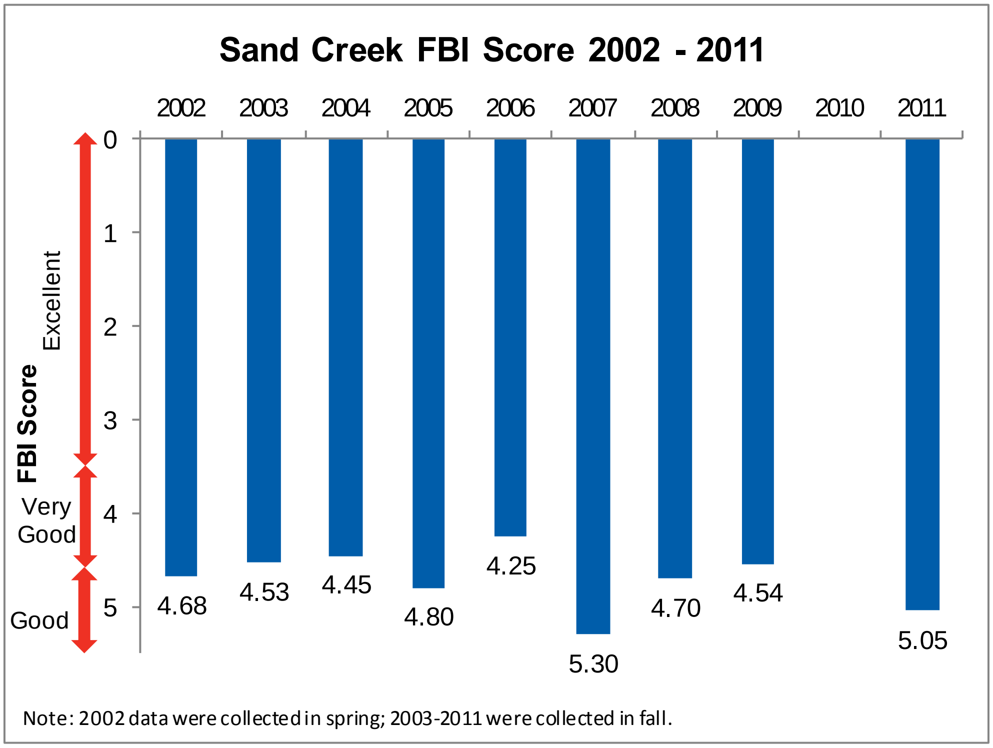
Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. However, integrating the individual metrics into a multi-metric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

MCES has been sampling for macroinvertebrates in Sand Creek since 2002. 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 comparisons from year to year. The Sand Creek FBI scores show very good water quality (for years 2004, 2006) to good water quality (2002, 2003, 2005, 2007-2011), indicating the possible presence of organic pollution (Figure SA-15).

Figure SA-15: Annual Family Biotic Index (FBI) Scores for Sand Creek Macroinvertebrates, 2002-2011

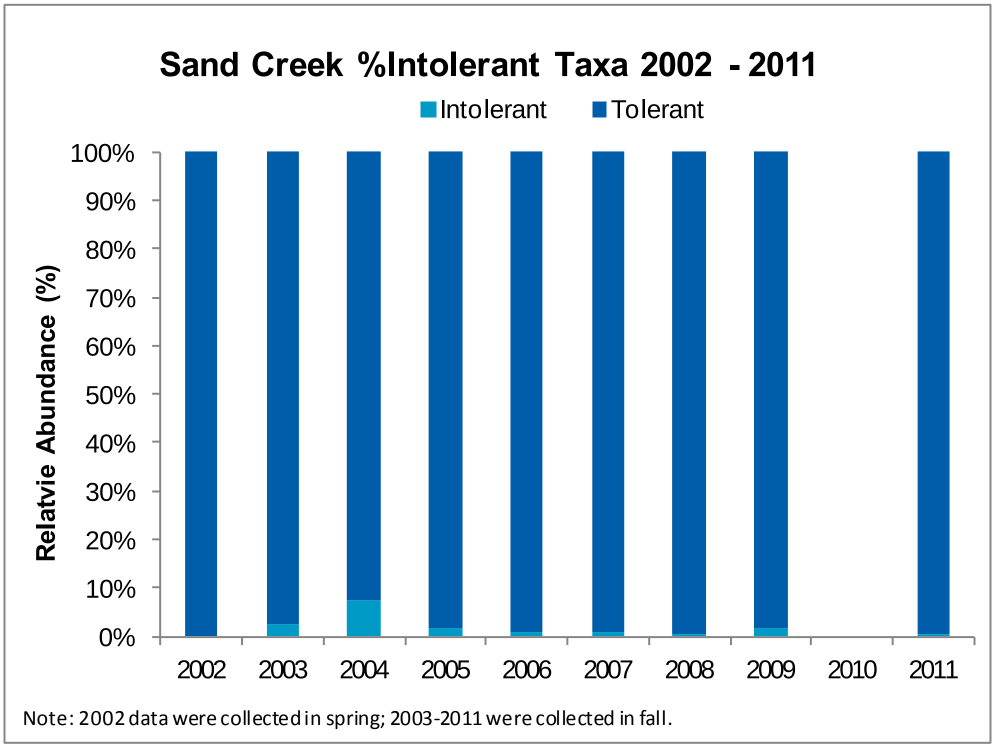


Percent Intolerant Taxa

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 SA-16). The presence of moderate numbers of intolerant taxa is an indicator of good aquatic health (Chirhart, 2003). Intolerant taxa were present in all samples except 2002 and 2011. The highest Percent Intolerant Taxa value was 7% in 2004.

The flooding event in 2011 may have greatly affected the abundance of the pollution intolerant macroinvertebrates.

Figure SA-16: Percent Abundance of Pollution Intolerant and Tolerant Macroinvertebrates, 2002-2011

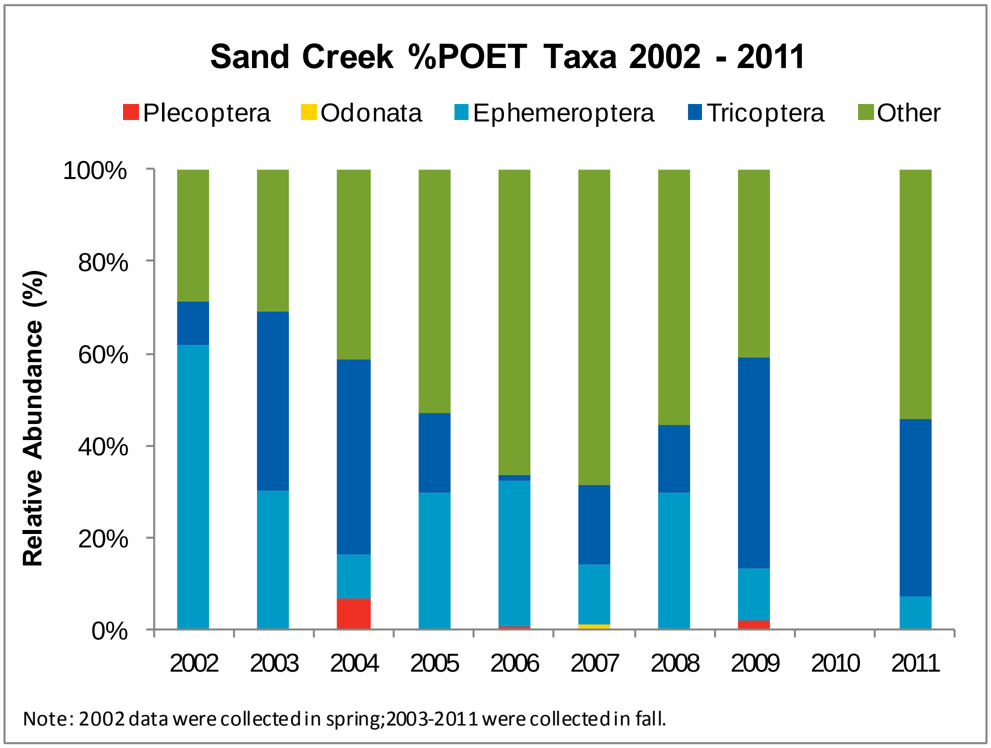


Percent POET Taxa

The taxonomic richness metric, Percent POET Taxa (Figure SA-17), 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 had the greatest value in 2002 at 71%, and lowest in 2007 at 31%.

These patterns in Percent POET Taxa values are inversely related to TSS mass load in Figure SA-8. The Odonata taxa tend to be more dominant in slow moving water, which explains the lack of representation in Sand Creek.

Figure SA-17: Percent Abundance of POET Macroinvertebrates, 2002-2011



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.

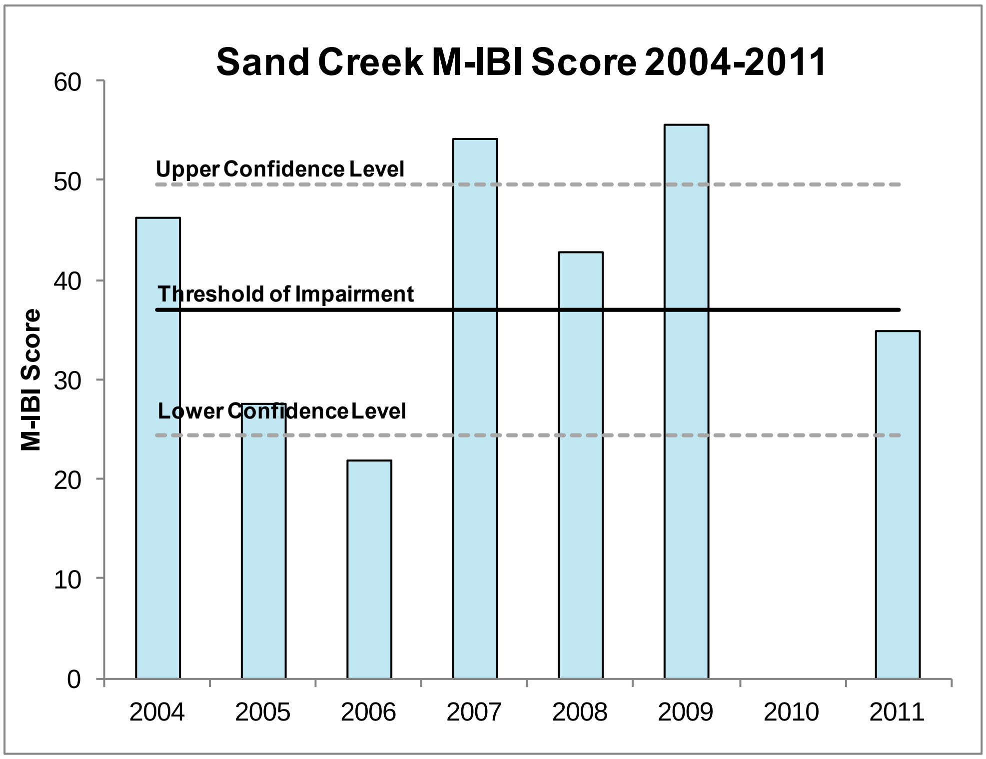
Four of the seven years of monitoring resulted in M-IBI scores above the impairment threshold (Figure SA-18). Two scores, 2007 and 2009, exceeded the upper confidence level. This indicates that in those years the water quality at this stream reach was adequate to sustain the needs of aquatic life. The 2006 score was below the lower confidence interval, suggesting the water quality in that year may not have been able to sustain the needs of aquatic life. The 2011 score suggests there are stressors negatively affecting the macroinvertebrate community.

Four M-IBI scores (2004, 2005, 2008, and 2011) fell between the upper and lower confidence levels. When the score falls between the confidence levels, it is difficult to confidently assess the water quality by biological assessment alone. It is necessary to incorporate other monitoring information, such as hydrology, water chemistry, and land use change into the final assessment (MPCA, 2014b).

Understanding physical and chemical influences on M-IBI scores leads to a more complete assessment of water quality. When plausible physical or chemical explanations exist for M-IBI scores between the confidence levels, these scores may be assigned more or less weight in the final evaluation.

In 2005, there was a large fall storm event (6 October 2005, 1576 cfs) and high annual pollutant loads (Figures SA-7 and SA-8). The large storm event could have flushed the macroinvertebrate community and deposited excess sediment. This disturbance may have depressed the 2006 M-IBI score below the lower confidence level. The subsequent M-IBI score suggests the stream recovered in 2007. Since there was a quick recovery from the disturbance, the 2006 M-IBI score has less weight in the overall evaluation. MCES is planning additional future analysis to fully investigate our biological monitoring data.

Figure SA-18: Annual Macroinvertebrate Index of Biological Integrity (M-IBI) Scores for Sand Creek



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 base flows 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 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 1990-2012 on Sand Creek for TP, NO_3, and TSS, using daily average flow, baseflow grab sample, and event composite sample data. The results are presented below. Readers should note that while QWTREND allows identification of changes of pollutant concentration with time, it does not identify causation. MCES staff have not attempted to identify changes in watershed management, climactic changes, or any other actions which may affected concentration in the stream. A recommendation of this report is for MCES staff to work with local partners to identify causative actions which will aid in interpretation when MCES repeats the trend analysis in five years.

Total Suspended Solids (TSS)

Sand Creek was identified to have multiple trends for TSS flow-adjusted concentration during 1990-2012 (Figure SA-19). Five trend periods were identified ($p=0.0001$):

- Trend 1: 1990 – 1995, TSS flow-adjusted concentration increased from 18.0 mg/l to 32.0 mg/l (78%) at a rate of 2.3 mg/l/yr.
- Trend 2: 1996 – 2001, TSS flow-adjusted concentration decreased from 32.0 mg/l to 17.7 mg/l (-44%) at a rate of -2.4 mg/l/yr.
- Trend 3: 2002 – 2005, TSS flow-adjusted concentration increased from 17.7 mg/l to 30.5 mg/l (73%) at a rate of 3.2 mg/l/yr.

- Trend 4: 2006 – 2009, TSS flow-adjusted concentration decreased from 30.5 mg/l to 10.7 mg/l (-65%) at a rate of -4.9 mg/l/yr.
- Trend 3: 2010 – 2012, TSS flow-adjusted concentration increased from 10.7 mg/l to 30.6 mg/l (186%) at a rate of 6.6 mg/l/yr.

The five-year trend in TSS flow-adjusted concentration in Sand Creek (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. TSS flow-adjusted concentration increased from 18.2 mg/l to 30.6 mg/l (68%) at an average rate of 2.5 mg/l/yr. Based on the QWTREND results, the water quality in Sand Creek in terms of TSS declined during 2008-2012.

Paul Nelson of Scott WMO has suggested that the apparent rise in the TSS trend (and thus declining water quality) was caused by a number of unusual, short intense summer storms during 2011 and 2012. Reassessment of the TSS trend in a few years may indicate that the TSS flow-adjusted concentration increase identified for 2010-2012 was temporary.

Total Phosphorus (TP)

Two downward trends were identified for TP flow-adjusted concentration in Sand Creek during 1990-2012 (Figure SA-19; $p=7.7 \times 10^{-4}$). The accelerated rate of TP flow-adjusted concentration decrease starting in 2004 may correspond to implementation of phosphorus removal at the Montgomery and New Prague WWTPs (Table SA-6):

- Trend 1: 1990-2003, TP flow-adjusted concentration decreased from 0.36 mg/l to 0.31 mg/l (-13%) at a rate of -0.0034 mg/l/yr.
- Trend 2: 2004-2012, the TP flow-adjusted concentration decreased from 0.31 mg/l to 0.22 mg/l (-28%) at a rate of -0.0096 mg/l/yr.

The five-year trend in TP flow-adjusted concentration in Sand Creek (2008-2012) was calculated to compare with other MCES-monitored streams in the report section ***Comparison with Other Metro Area Streams***. TP flow-adjusted concentration decreased from 0.27 mg/l to 0.22 mg/l (-18%) at an average rate of -0.0098 mg/l/yr. Based on the QWTREND results, the water quality in Sand Creek in terms of TP improved during 2008-2012.

Nitrate (NO_3)

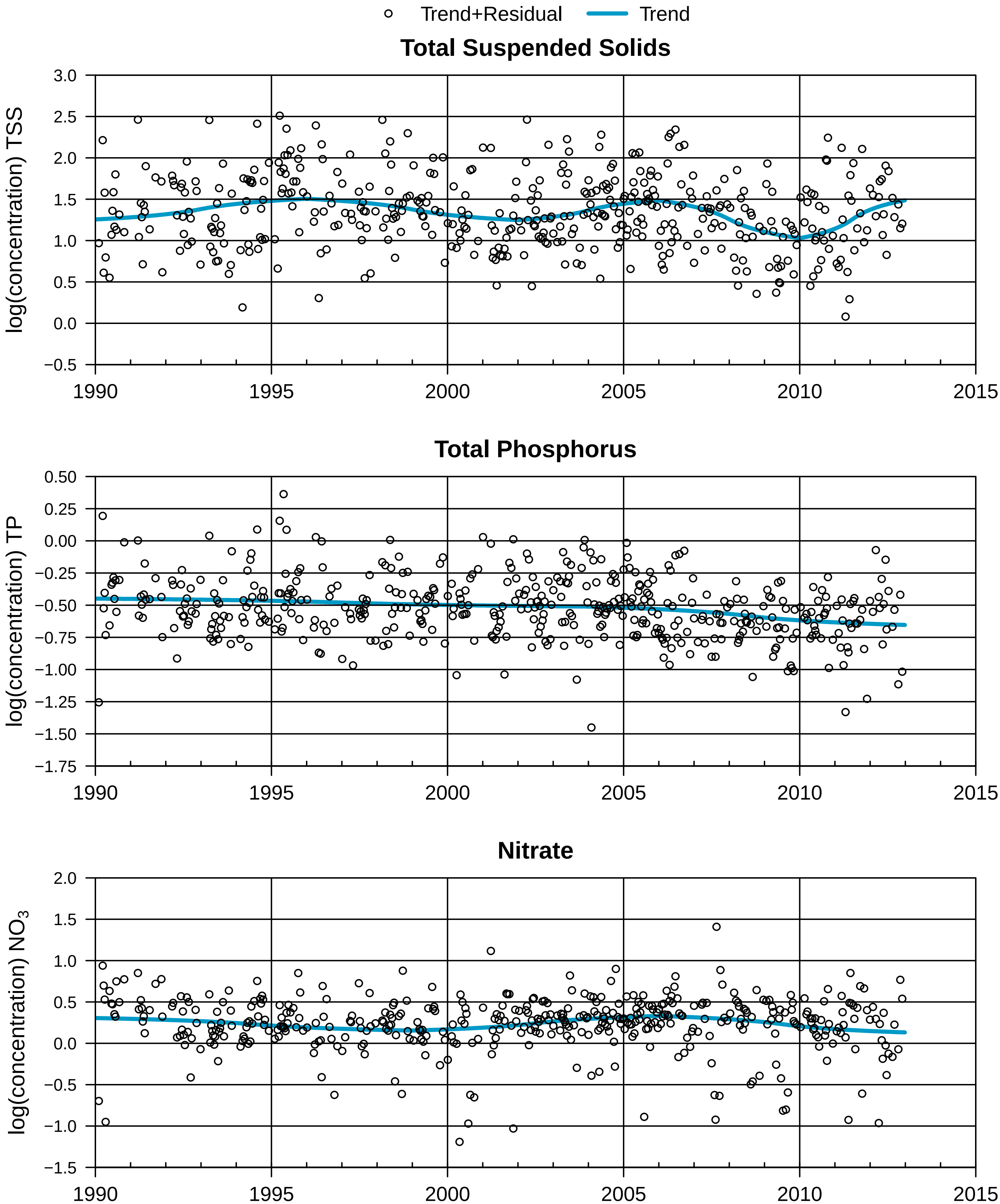
Both upward and downward trends were identified for NO_3 in Sand Creek during 1990-2012 (Figure SA-19; $p=0.012$).

- Trend 1: 1990-1998, NO_3 flow-adjusted concentration decreased from 2.0 mg/l to 1.4 mg/l (-29%) at a rate of -0.066 mg/l/yr.
- Trend 2: 1999-2005, NO_3 flow-adjusted concentration increased from 1.4 mg/l to 2.1 mg/l (50%) at a rate of 0.10 mg/l/yr.
- Trend 3: 2006-2012, NO_3 flow-adjusted concentration decreased from 2.1 mg/l to 1.4 mg/l (-37%) at a rate of -0.11 mg/l/yr.

The five-year trend in NO_3 flow-adjusted concentration in Sand Creek (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 from 2.0 mg/l to 1.4 mg/l (-31%) at a rate of -0.12 mg/l/yr. Based on the QWTREND results, the water quality in Sand Creek in terms of NO_3 improved during 2008-2012.

Figure SA−19: Sand Creek Trends for TSS, TP and NO_3



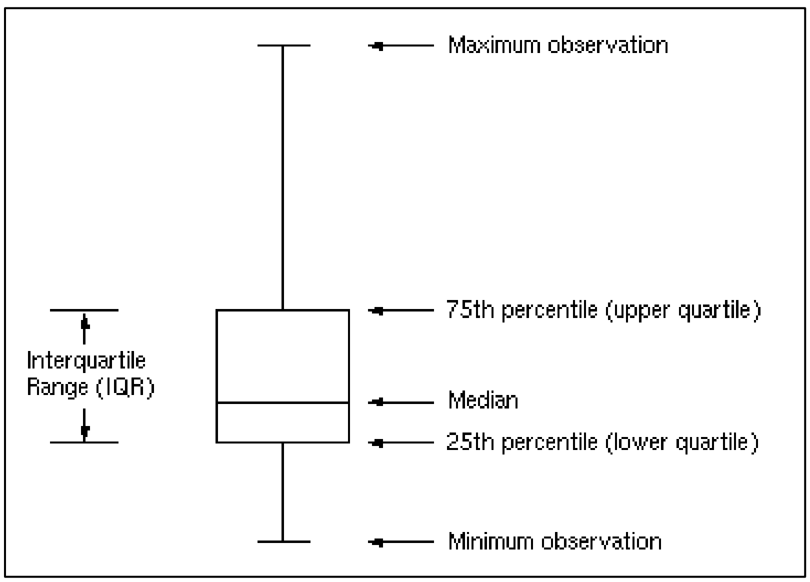
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots are used to summarize the comparison of the historical flow, TSS, TP, and NO_3, and Cl data for Sand Creek with those of the other metropolitan area streams monitored by MCES and with the major receiving water (in this case the Minnesota River). The comparisons are show in Figure SA-21 to Figure SA-24 and Table SA-6.

Figure SA-20 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 SA-20: 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. While the median annual FWM concentration for TSS in Sand Creek is similar to that of other Minnesota River tributaries like Riley Creek and Bluff Creek, it is higher than for tributaries closer to the convergence of the Minnesota River and the Mississippi River (that is, Eagle, Credit, Willow, and Nine Mile) (Figure SA-21). The FWM concentration in Sand Creek is also higher than that in the Minnesota River (as measured at Jordan Minnesota; ~300 mg/l vs. 142 mg/l, respectively, Table SA-6), indicating that Sand Creek is at times serving to increase the TSS concentration in the Minnesota. It is apparent that those tributaries entering the Minnesota River nearest Jordan have significantly higher FWM TSS concentrations and annual yields (expressed in lb/acre) than the other tributaries to the Minnesota or any of the tributaries entering the Mississippi or St. Croix Rivers monitored by MCES. This reflects the relatively unstable landform within the Minnesota River watershed, where the tributaries' channels and associated gullies and ravines are still down-cutting towards geographic equilibrium (Jennings, 2010).

Median annual runoff ratio for Sand Creek is similar to those of all metropolitan area streams. If Sand Creek flow were highly influenced by wetlands, lakes, or other impoundments on the stream channel, one would expect a relatively lower runoff ratio (for example, like those of Minnehaha Creek or Carnelian-Marine). If the flow were highly influenced by shallow groundwater inflow, one would expect a relatively higher runoff ratio (for example, like those of Eagle Creek or Valley Creek).

Total Phosphorus. As with TSS, the FWM TP concentration in Sand Creek is higher than that of the Minnesota River and thus serves to increase the TP concentration in the river (Figure SA-22). Sand Creek and the other metro area tributaries of the upper Minnesota River also have higher FWM concentrations than most of the other MCES-monitored streams, with the exception of the Vermillion River. The Sand Creek annual yield is similar to the other metro area tributaries of the upper Minnesota (for example, Bevens, Carver, Bluff) and is higher than for the Mississippi and St. Croix tributaries, with the exception of the Vermillion River. The TP concentration and load in Sand Creek is likely affected by a combination of land use management, especially in the highly agricultural sections of the watershed, and by the domestic effluent from the WWTPs in New Prague and Montgomery.

Nitrate. NO_3 FWM concentration in Sand Creek is lower than in the Minnesota River, and thus serves to dilute the river concentration (Figure SA-23). The areal load in Sand Creek is moderately less than for most other MCES-monitored tributaries, although it is similar to the other streams with primarily agricultural watersheds, including the Crow River, the Cannon River, and Bevens Creek.

Chloride. Chloride FWM concentration and load in Sand Creek is similar to that in the Minnesota River and is lower than the concentration observed in the most urbanized watersheds monitored by MCES (for example Willow, Bluff, Bassett, Minnehaha, Battle, and Fish) (Figure SA-24). The two most prevalent sources of chloride to streams are road surfaces (from chloride application as a de-icer) and WWTP effluent (from domestic water softeners).

Figure SA−21: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

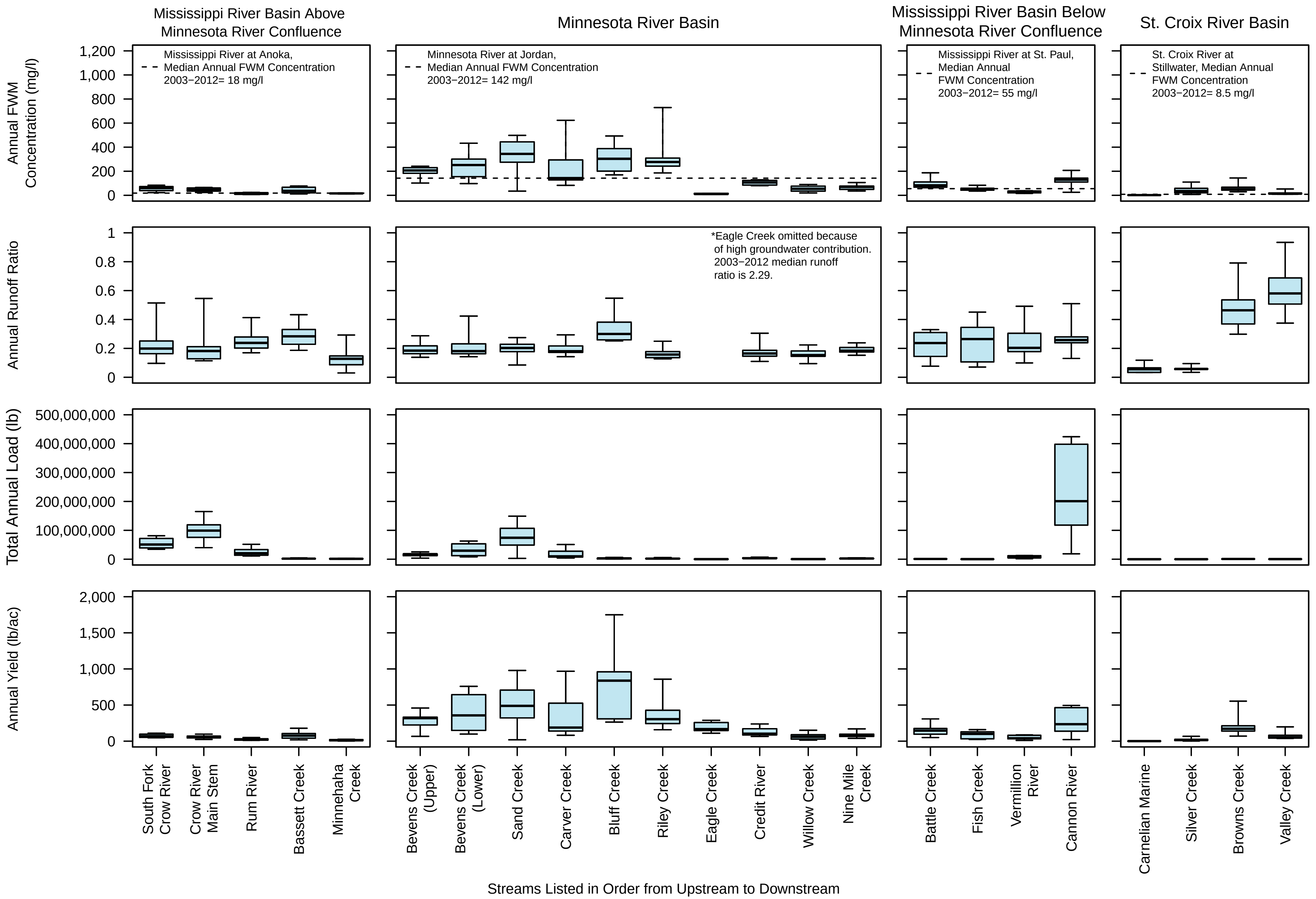


Figure SA−22: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

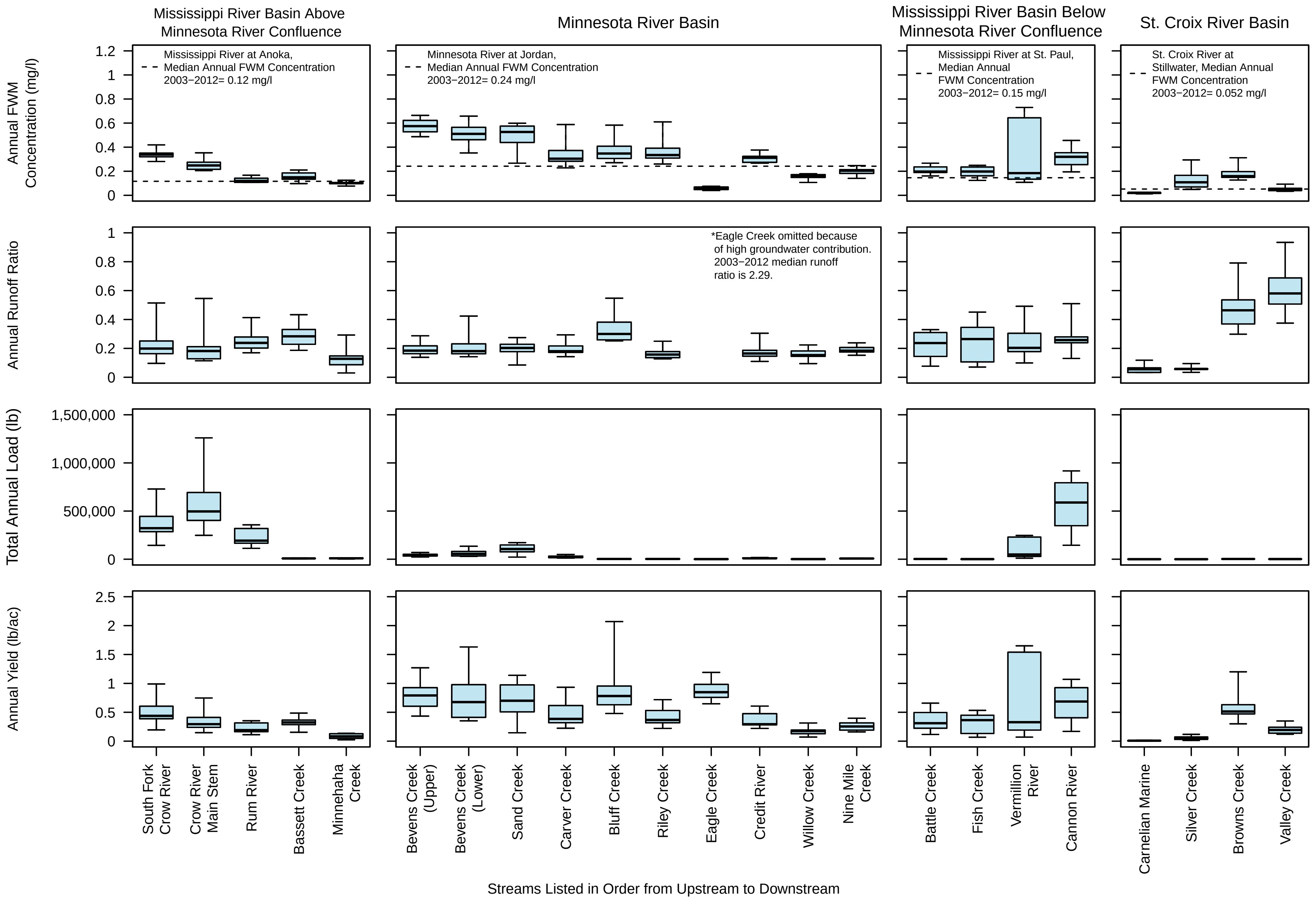


Figure SA−23: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

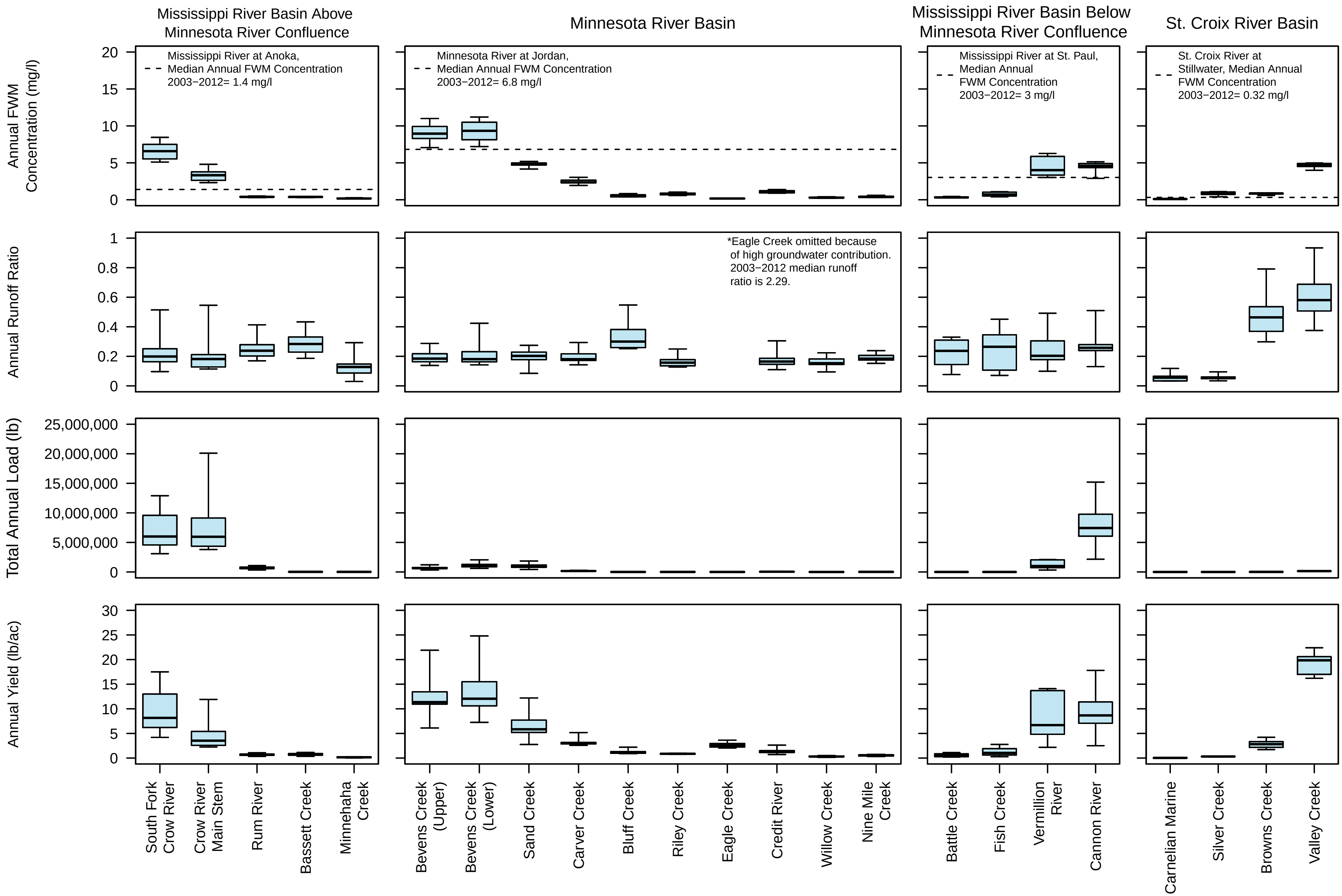


Figure SA−24: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

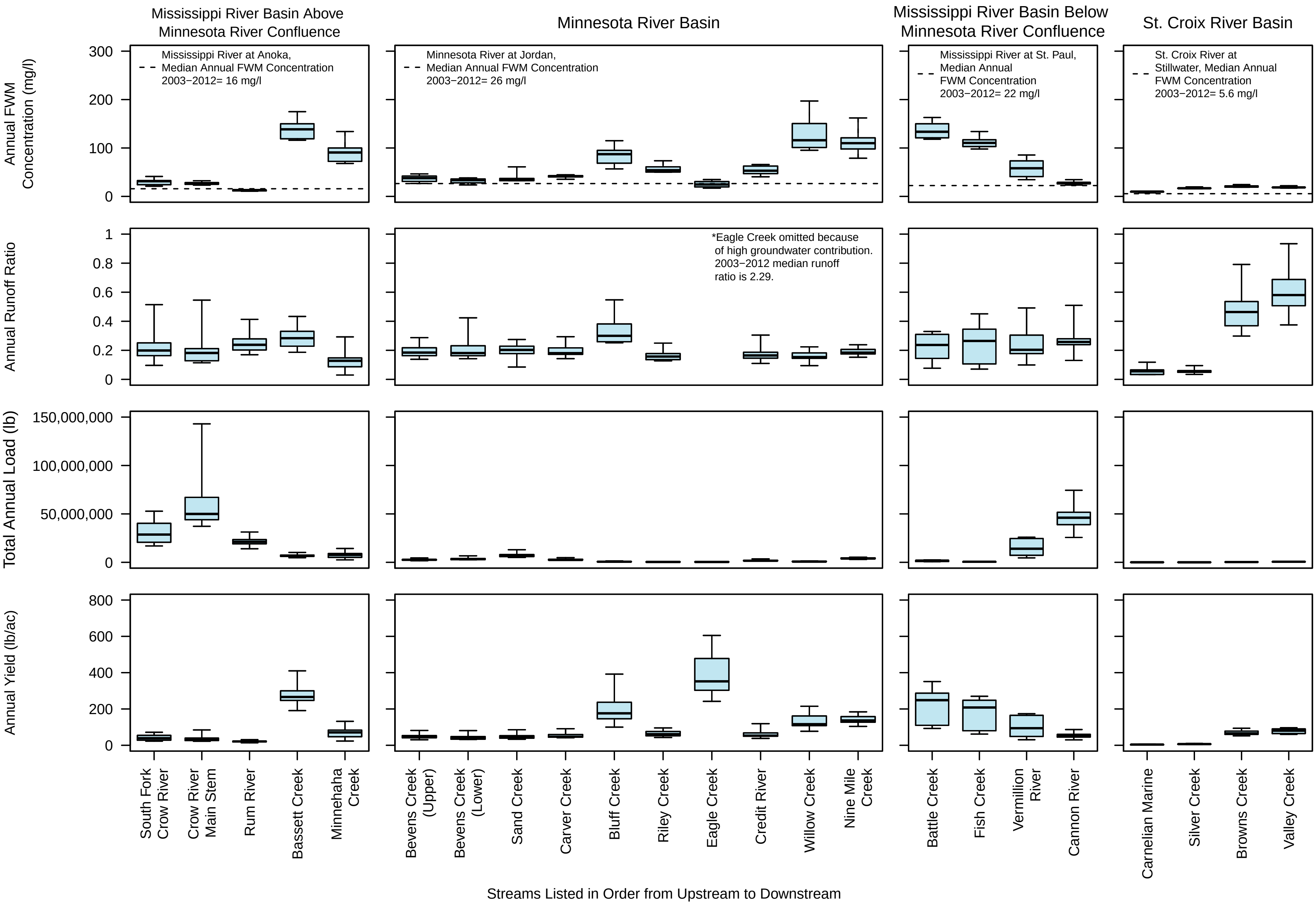


Table SA-6: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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

The historic biomonitoring data, summarized as the M-IBI metric 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 Sand Creek intersect the MPCA impairment threshold (Figure SA-25). This shows that over the period of study the monitored stream reach scored a range of values both above and below the threshold of impairment. The median was above the threshold, which suggests that this stream reach habitat and water quality typically were more able to sustain the needs for aquatic life.

These results are similar to other agricultural watersheds in both the Minnesota and Mississippi River basins, and higher than the urban watersheds. This suggests the agricultural macroinvertebrate communities are less stressed than the urban macroinvertebrates in the metropolitan area.

Metropolitan Area Trend 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.

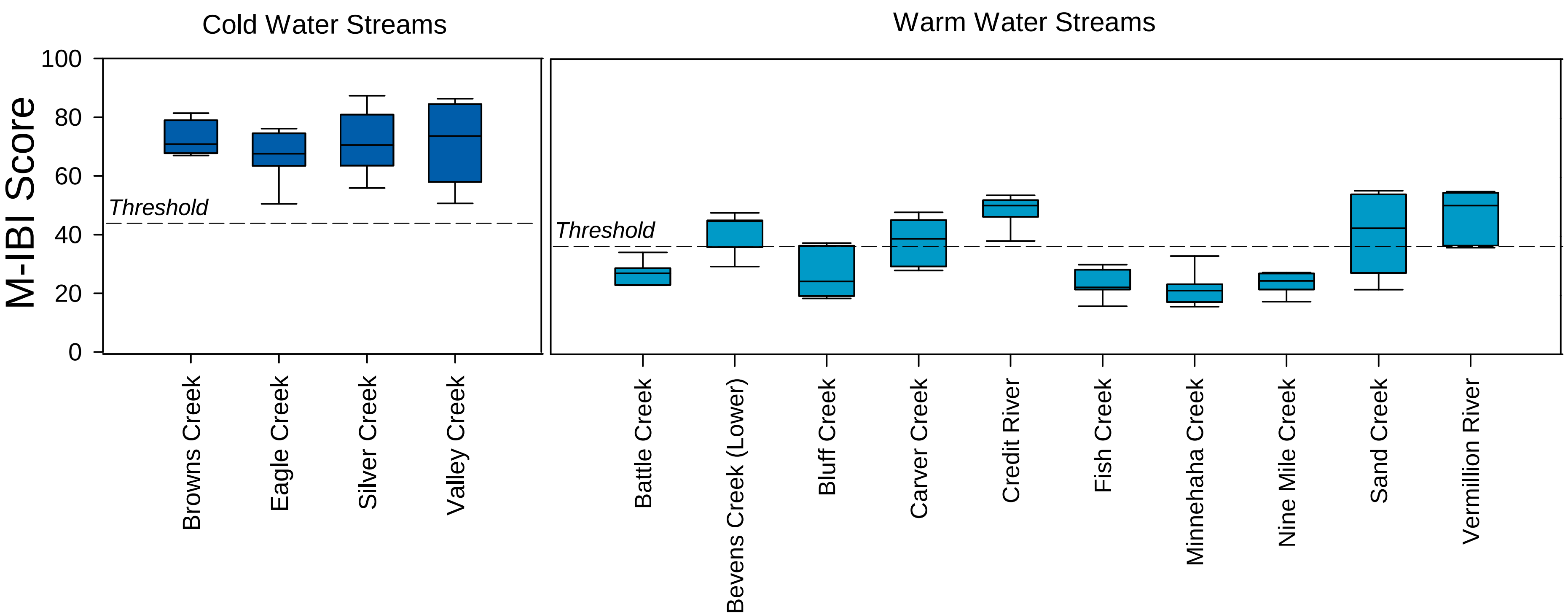
Estimated changes for TSS, TP, and NO3 in MCES-monitored streams are presented below in two ways. First, tabulated results with directional arrows indicate improving (blue upward arrow) and declining (red downward arrow) water quality, paired with percent change in flow-adjusted concentration estimated for 2008-2012 (Figure SA-26). Second, changes are shown by three seven-county metropolitan area maps (one each for TSS, TP, and NO3 trends), with stream watersheds colored to represent improving and declining water quality (Figure SA-27). 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 flow-adjusted concentration) for TSS, TP, and NO3. 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 NO3 flow-adjusted 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 does the Mississippi or St. Croix rivers and associated tributaries. The trend analysis results indicate decreasing TSS flow-adjusted concentrations in all Minnesota River tributaries, except for Sand Creek. Although the TSS flow-adjusted concentration in Sand Creek increased during the last five years, both TP and NO3 decreased.

Figure SA-25: M-IBI Results for MCES-Monitored Streams, 2004-2011

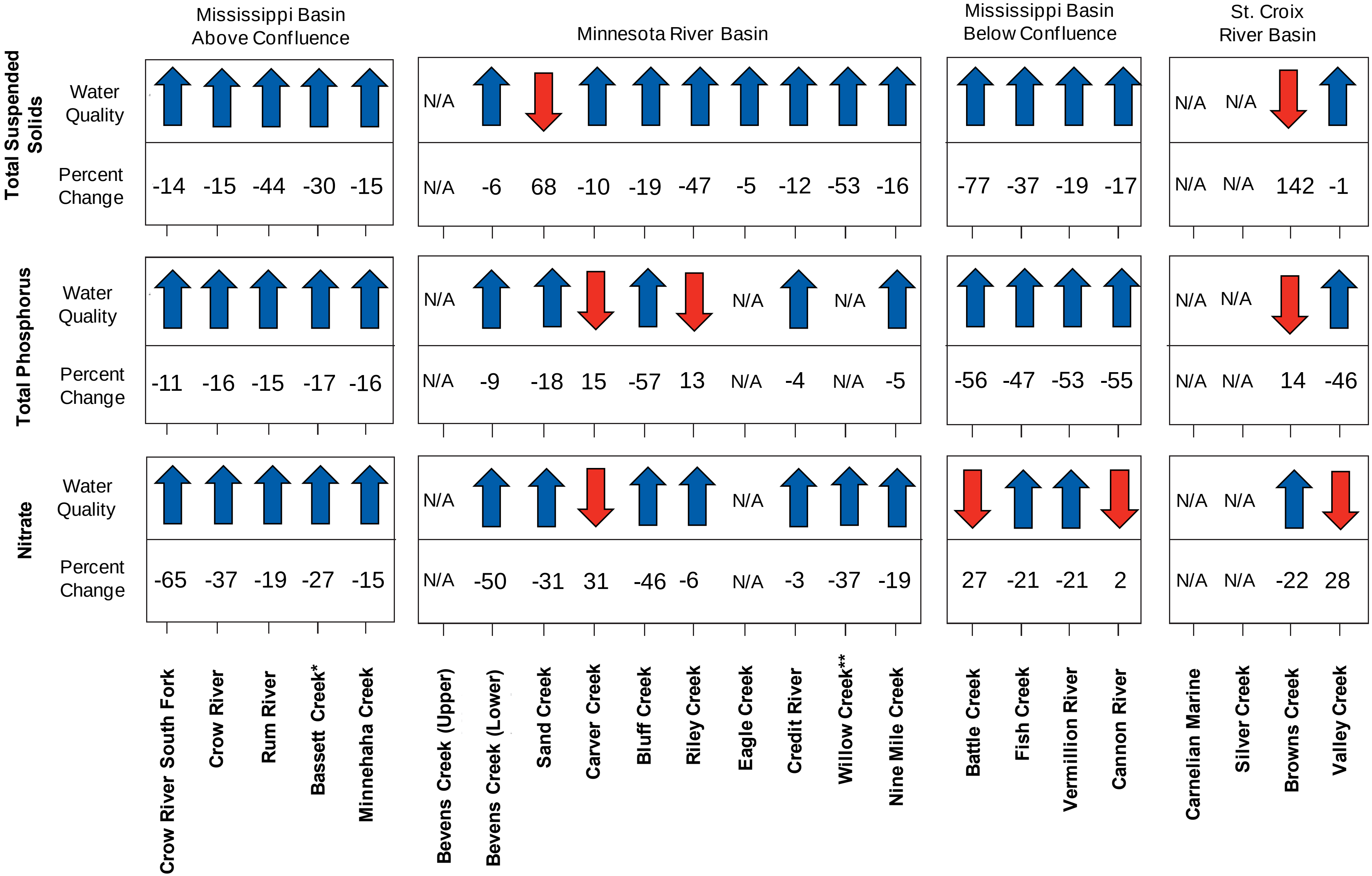
Organized by Stream Type



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.

Figure SA-26: 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)



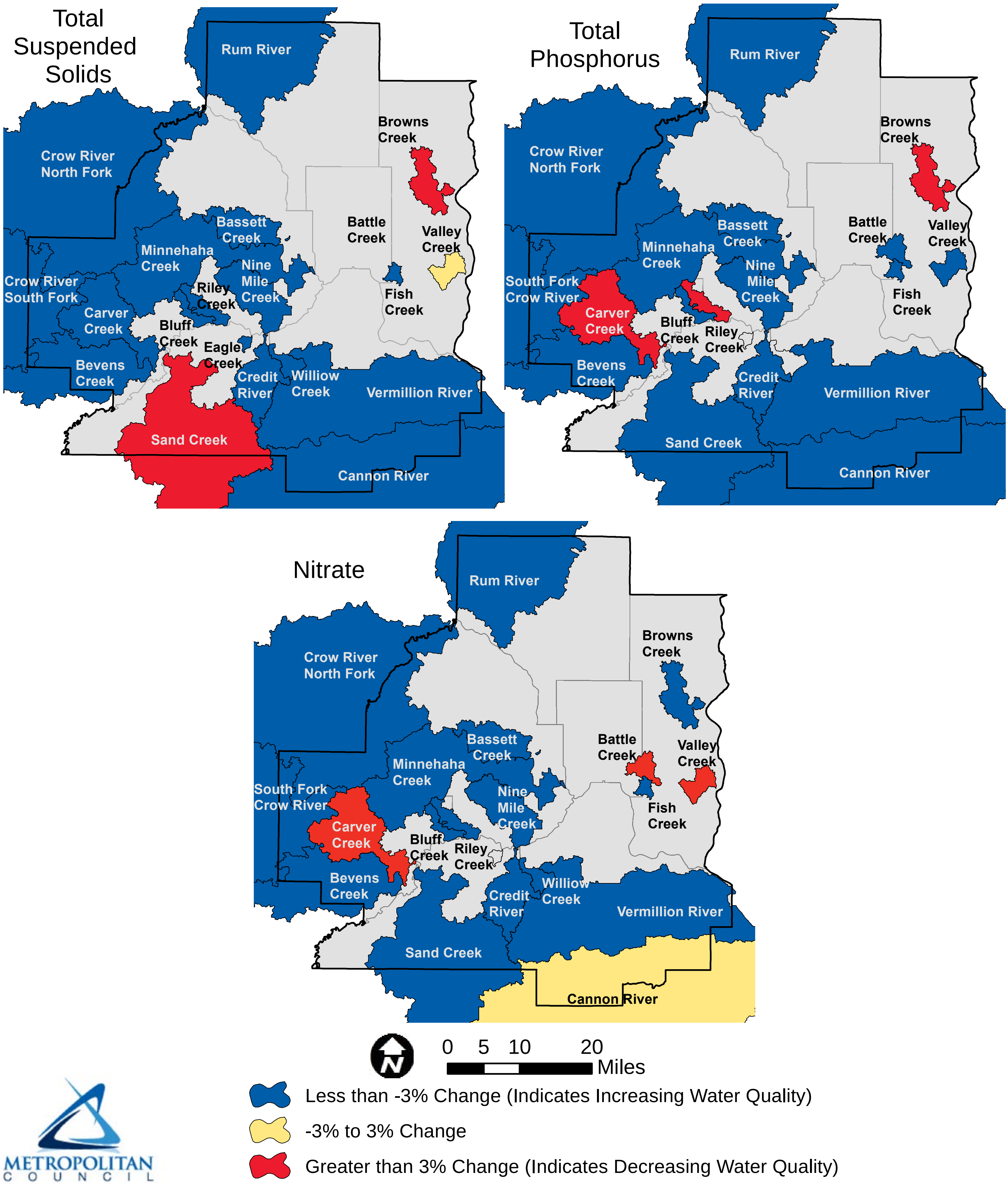
Blue arrows indicate improved water quality; Red arrows indicate declining water quality.

“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 SA-27: 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

Sand Creek is a tributary to the Minnesota River and drains portions of Scott, Rice, and Le Sueur Counties, and contains runoff from the cities of Montgomery, New Prague, and Jordan. The watershed is primarily agricultural, with small pockets of urbanized areas.

The east portion of the watershed is gradually converting to hobby farms and large-lot residential development. The west portion of the watershed is high quality production agricultural land. Three major WWTPs discharge to Sand Creek: New Prague, Montgomery, and Jordan. The upper watershed is relatively flat, while the topography steepens at the transition from the Minnesota River bluff to the river floodplain. The monitoring station is located near Jordan, Minnesota. Downstream of the monitoring station, the creek receives effluent from the Jordan WWTP and then flows through the Louisville Swamp (a Minnesota floodplain wetland). Consequently, the monitoring data presented in this report do not reflect the potential increases or decreases in water quality that may occur downstream of the monitoring station.

The water quality in Sand Creek is affected by several factors: agricultural activity; WWTP effluent, loss of wetlands and upland storage, and the instability of the area geology. TSS in the stream (both FWM concentration and load) was high, both in comparison to the Minnesota River and the other MCES-monitored metro area tributaries. Previous studies (Scott County, 2010) indicate that TSS is dominated by knickpoint migration at the Minnesota River bluff (location of the formation glacial River Warren channel) (Jennings, 2010). Increase in stream flow, whether from increased density of agricultural drain tiles, loss of upland storage, or from increased precipitation due to climate change, likely exacerbated the knickpoint migration through streambank, gully, and ravine erosion and led to heightened TSS loads and concentrations.

The NO_3 loads and concentrations are likely driven by agricultural activity in the watershed. The concentration and loads in Sand Creek are lower than those in the Minnesota River (which carries runoff from the intensely farmed area of western Minnesota), but are higher than most of the other MCES-monitored metro area tributaries. Trend analysis indicates periods of increasing and decreasing flow-adjusted concentration in the creek, although the most recent trend appears to be decreasing (and thus indicating improving water quality).

Sand Creek TP loads and concentrations are likely affected by agricultural activity and effluent discharge from the Montgomery and New Prague WWTPs. The concentration in Sand Creek is higher than that in Minnesota River, and is generally higher than the MCES-monitored tributaries in the Mississippi and St. Croix river basins. Trend analysis indicates a decrease in TP flow-adjusted concentration since 1990 (thus indicating improving water quality), with an accelerated decrease since about 2005. Changes in TP are likely due to increased implementation of agricultural practices and implementation of phosphorus removal at the New Prague and Montgomery WWTPs.

The chloride loads and concentrations in Sand Creek were lower than in the highly urbanized watersheds monitored by MCES, reflecting the low level of development and road density in the watershed and thus the relatively low input of chloride as road de-icer.

Trend analysis indicated both upward and downward trends in TSS flow-adjusted concentration since 1990; the most recent trend is of increasing TSS flow-adjusted concentration and thus declining water quality. This increase may have been caused by a series of unusual, short, and intense storms that occurred in 2011 and 2012. Both TP and NO3 flow-adjusted concentration trends were decreasing, thus indicating increasing water quality. This improvement may reflect the level of management practices, including conservation tillage, agricultural buffer strips, field terracing, and other practices implemented by local farmers with support from Scott WMO, Rice County, LeSueuer County and others, and phosphorus removal at the watersheds municipal WWTPs.

Analysis of macroinvertebrate samples indicated complicated F-IBI, POET, and M-IBI levels in Sand Creek. High-flow events appear to have decreased the number and diversity of macroinvertebrates some years; however, the median value of M-IBI is above the MPCA threshold, which suggests that habitat in this stream reach and water quality were typically more able to sustain the needs for aquatic life.

Recommendations

This section presents recommendations for monitoring and assessment of Sand Creek, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like Scott WMO and Rice and Le Sueur counties, 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 five 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:

- Louisville Swamp, located on Sand Creek downstream of the Jordan monitoring station, is a Minnesota River floodplain wetland within the jurisdiction of the Minnesota Valley State Recreation Area (DNR) and the Minnesota Valley National Wildlife Refuge (U.S. Fish and Wildlife Service). At high flows, the Minnesota River inundates Louisville Swamp. At low flows, Sand Creek flows through the swamp, over a low weir and into the Minnesota River. MCES located the original monitoring station (installed in 1989) at the weir outlet to capture effective load entering the Minnesota River. Frequent inundation by the Minnesota River forced MCES to move the station to mile 8.2 in Jordan. MCES currently does not adjust the Sand Creek annual loads for potential effects (settlement of sediment, resuspension of sediment and nutrients by carp activity, etc) introduced by Louisville Swamp. MCES should add a footnote to the annual load database informing users that potential effects from Louisville Swamp are not included in the load estimates.

- The MPCA compiles effluent flow and concentration data for the Jordan WWTP. MCES should add the Jordan WWTP effluent NO3, TP, and TSS loads (which are discharged to Sand Creek downstream of the monitoring station) to the annual and monthly estimates of Sand Creek loads to provide a more accurate estimate of load discharging to the Minnesota River from Sand Creek.

- Scott WMO occasionally collects flow and water quality data at several locations in the upper Sand Creek watershed as part of its regular monitoring program. MCES staff should meet with Scott WMO staff to implement data sharing to aid in interpretation of the Jordan station data.

- MCES and partners (especially Scott WMO and Scott, Rice, and Le Sueur Counties) 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, and would add evidence to the measurable benefits related to implementation of best management practices.

- MCES staff routinely attend meetings of the Scott WMO Technical Advisory Committee meetings. This partnership should continue.

- Scott County and Scott WMO (Scott County, 2010), in partnership with MCES and others, completed a TMDL and impaired waters investigation report of the Sand Creek watershed in 2010. This study resulted in the formation of a comprehensive management implementation plan for the entire watershed, including recommendations for agricultural best management practices, restoration of upland wetlands, conversion of large lot residential lands to prairie grass, implementation of stream buffers, restoration and stabilization of eroding streambanks, and many others. The WMO is actively implementing the recommended practices. MCES should offer technical assistance, as resources allow, to help Scott WMO achieve its goals.
- As resources allow, MCES should provide Scott WMO and other local water managers with information about the heightened potential for surface waters to be impacted by groundwater changes in the Sand Creek watershed. This information should be included in watershed and local surface water management plan updates.

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