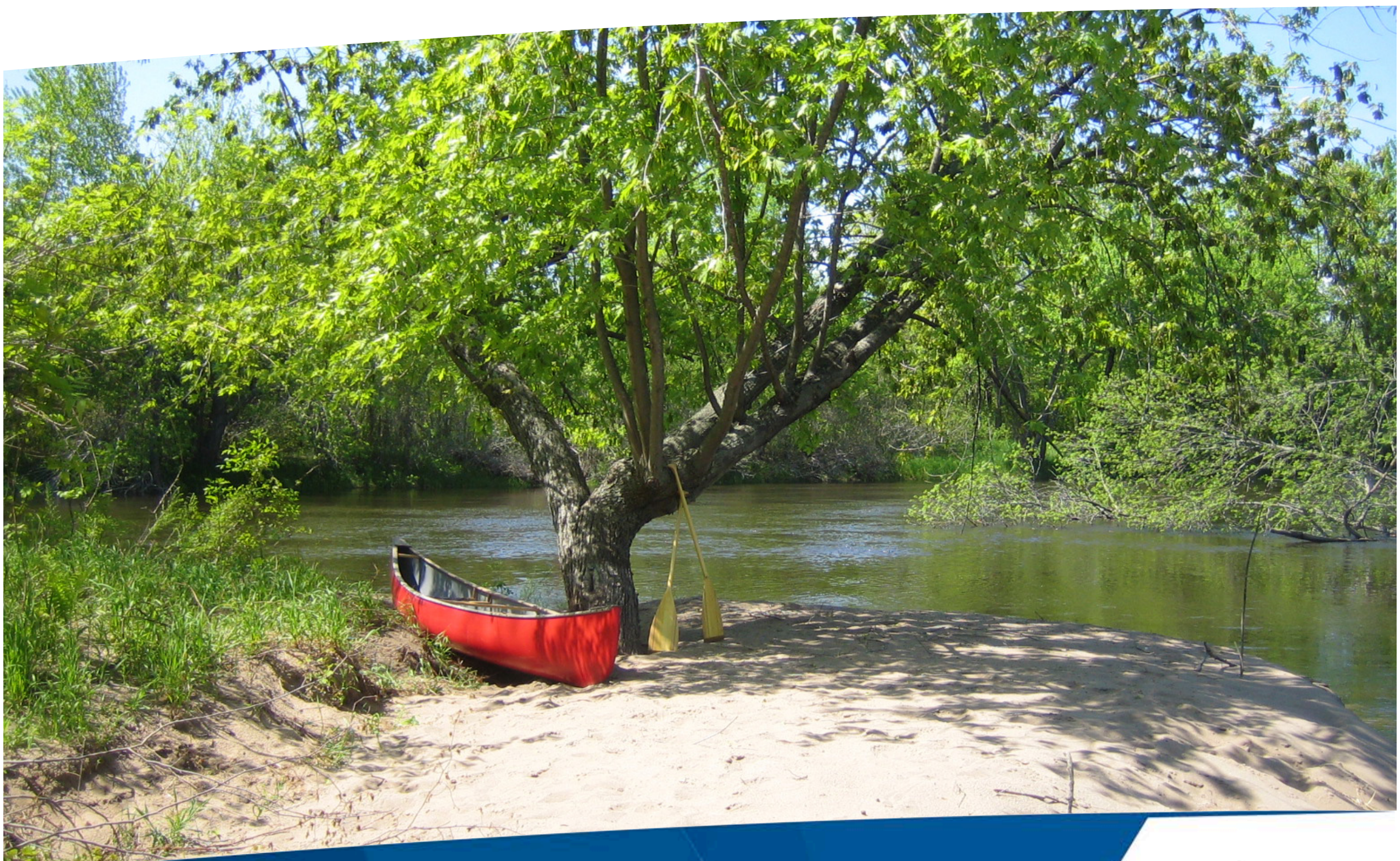
Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

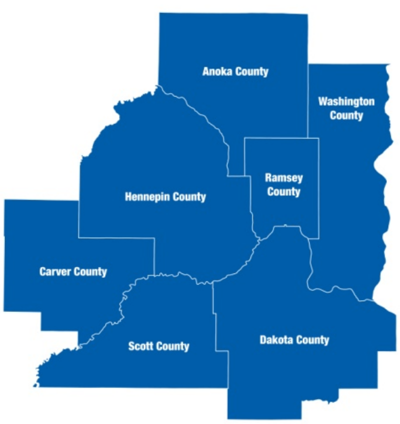
RUM RIVER



METROPOLITAN COUNCIL

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, *Rum River*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located in Crow Wing, Aitkin, Mille Lacs, Morrison, Kanabec, Benton, Isanti, Chisago, Sherburne, and Anoka counties, the Rum River is one of the eight Mississippi River tributaries examined in the report. This section discusses a wide range of factors that have affected the condition and water quality of the Rum River.

Cover Photo

The cover photo shows a paddling rest stop on the Rum River, a Minnesota State Water Trail and Wild and Scenic River (Photo Credit: MnDNR).

Recommended Citations

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Content

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Introduction

The Rum River is located in the northern portion of the metropolitan area and is a tributary to the Mississippi River. It drains approximately 1,584 square miles of wetland, forest, grasses, agricultural, and urban areas (cities of Onamia, Milaca, Princeton, Cambridge, Isanti, St. Francis, Bethel, Nowthen, Oak Grove, Andover, and Anoka) through portions of Crow Wing, Aitkin, Mille Lacs, Morrison, Kanabec, Benton, Isanti, Chisago, Sherburne, and Anoka counties.

This report:

- documents those characteristics of the Rum River and its watershed most likely to influence stream flow and water quality.
- presents the results from assessments of flow and water quality.
- presents statistical assessments of trends in stream chemistry concentrations.
- draws conclusions about possible effects of landscape features, climatological changes, and human activities on flow and water quality.
- compares the Rum 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 summary reports.

Partnerships and Funding

MCES has supported water quality monitoring of the Rum River since 1996. MCES partners with the Anoka Conservation District to operate the monitoring station. The city of Anoka operates the Rum River Anoka Dam sluice gate control structure, and when needed, adds flashboards during high water seasons.

In 2013, the MCES Streams Program decided to discontinue the grab and composite chemistry sampling above the Anoka Dam due to the proximity of the MCES Rivers Program grab sampling site below the dam (weekly sampling during open water, biweekly sampling during winter, ~40 sampler per year), only 0.1 miles downstream of the stream monitoring station.

Monitoring Station Description

The flow monitoring station is located immediately upstream of the Rum River Dam in Anoka, Minnesota, 0.7 miles upstream from the river confluence with the Mississippi River and immediately upstream of the Anoka Dam. The monitoring station was moved to this location in 2000 from the original site (0.5 miles upstream from the confluence, below the Anoka Dam), and began operation in April 2001. In 2013, the water chemistry monitoring site was moved downstream of the Rum River Dam in Anoka, 0.6 miles upstream from the confluence with the Mississippi River.

The flow monitoring station includes continuous stage monitoring (Design Analysis H350/H355 Bubbler) and continuous water temperature monitoring (Campbell Scientific Inc.). An automatic sampler (Hach Sigma Sampler) was used when composite samples were collected. The rating curve at this location is based on the empirical formulas for the Rum River Dam and sluice gate control structures. The final flow record is often compared to the flows recorded by the United States Geologic Survey (USGS) at their St. Francis, MN site (USGS 05826000) to ensure accuracy and consistency.

The precipitation data for this monitoring station were obtained from NWS COOP stations 21390 – Cedar, 212500- Elk River, 210190- Andover 1N, and 215838- New Hope. Supplemental winter precipitation data are obtained from the Minnesota Climatology Working Group, St. Francis Station Number 211390 and Coon Creek Station Number 211785.

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 represented (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

The Rum River flows through Mille Lacs, Sherburne, Isanti, and Anoka counties and has a drainage area of approximately 1,584 square miles. The Rum River headwaters originate from Lake Mille Lacs, in the northwest portion of Mille Lacs County, a premiere fishery and recreational lake. The river generally flows to the south for 148 miles where it discharges into the Mississippi River near the city of Anoka. The portion of the Rum River in Anoka County lies within the seven-county metropolitan area and the Metropolitan Council’s jurisdiction (Council District 9).

In 1978, the State of Minnesota included the Rum River in the Wild and Scenic Rivers Program. According to the Minnesota Department of Natural Resources (MnDNR), in order to qualify for this program, a river “must possess outstanding scenic, recreations, natural, historical, scientific, or similar values” (MnDNR, 2013a). Different sections of the Rum River were classified as Wild, Scenic, and Recreational (Table RUM-1). These designations increase the management activities to ensure the unique characteristics of the river are maintained.

Table RUM-1: Rum River Wild, Scenic, and Recreational River Segments[1]

River Classification	Segments
Wild	Ogechie Lake spillway to the confluence with Lake Onamia
Scenic	Mille Lacs CSAH 20 bridge to the Mille Lacs CSAH 9 bridge; Mille Lacs CSAH 13 bridge to the T 31 N – T 32 N line on the southern border of the Anoka County fairgrounds
Recreational	Hwy 27 bridge in Onamia to the Mille Lacs CSAH 20 bridge; the Mille Lacs CSAH 9 bridge to the Mille Lacs CSAH 13 bridge; T 31 N – T 32 N line on the southern border of the Anoka County fairgrounds to between Madison Street and Rice Street in the City of Anoka

[1] MnDNR, 2013a

In addition to the Rum River, there are many other open water bodies within the watershed. For example, Ogechie Lake (410 acres), Shakopee Lake (622 acres), Lake Onamia (1,040 acres), Green Lake (833 acres), Lake Francis (264 acres), and George Lake (488 acres) are lakes in the Rum River watershed. Additionally, 34 Rum River watershed water bodies have been identified and inventoried by the MnDNR as locations of wild rice stands, of which six are inside the metropolitan area (MPCA, 2014a). For more information about lakes in the watershed, please see the Lake Finder website from the MnDNR (MnDNR, 2014).

The Rum River watershed encompasses a total of 1,013,791 acres, with 1,010,164 acres (99.6%) of the watershed upstream of the monitoring station (Figure RUM-1). The watershed is 15.9% agricultural land (15.9% within the monitored area) and 7.7% developed urban land (7.5% within the monitored area). The urbanized land includes the cities of Garrison, Isle, Wahkon, Onamia, Bock, Milaca, Foreston, Pease, Princeton, Cambridge, Isanti, Bethel, St. Francis, and Oak Grove and portions of Braham, Elk River, East Bethel, Ham Lake, Ramsey, Andover, Coon Rapids, and Anoka. The primary land covers in the watershed are forest, open water (including Mille Lacs), grasses/herbaceous, and wetlands.

Based on the United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) 2009 Cropland Data Layer of agricultural land in the watershed, 20% is planted in corn and 19% in soybeans. According to a statewide estimate of potentially draintiled fields by University of Minnesota researchers, 4% of the agricultural land in the monitored and total watershed is potentially draintiled (D. Mulla, University of Minnesota, personal communication, 2012). Table RUM-2 shows the watershed area by land cover.

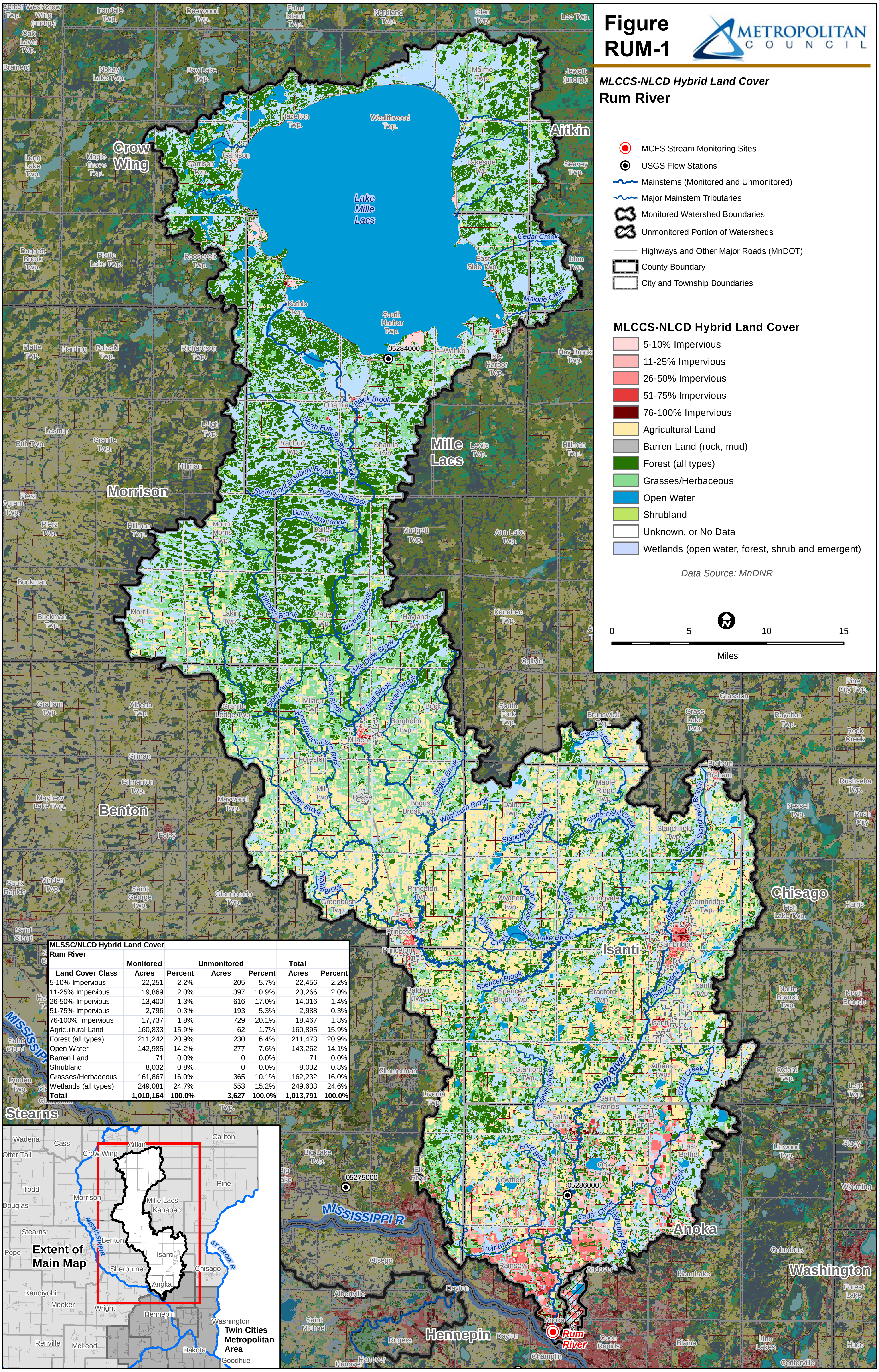
Table RUM-2: Rum River Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	22,251	2.2%	205	5.7%	22,456	2.2%
11-25% Impervious	19,869	2.0%	397	10.9%	20,266	2.0%
26-50% Impervious	13,400	1.3%	616	17.0%	14,016	1.4%
51-75% Impervious	2,796	0.3%	193	5.3%	2,988	0.3%
76-100% Impervious	17,737	1.8%	729	20.1%	18,467	1.8%
Agricultural Land	160,833	15.9%	62	1.7%	160,895	15.9%
Forest (all types)	211,242	20.9%	230	6.4%	211,473	20.9%
Open Water	142,985	14.2%	277	7.6%	143,262	14.1%
Barren Land	71	0.0%	0	0.0%	71	0.0%
Shrubland	8,032	0.8%	0	0.0%	8,032	0.8%
Grasses/Herbaceous	161,867	16.0%	365	10.1%	162,232	16.0%
Wetlands (all types)	249,081	24.7%	553	15.2%	249,633	24.6%
Total	**1,010,164**	**100.0%**	**3,627**	**100.0%**	**1,013,791**	**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 geologic history of a watershed dictates many soil and hydrologic properties and surface topography. The Rum River watershed was last glaciated during the Wisconsin Glaciation, which began approximately 75,000 years before present (Lusardi, 1997). Two separate lobes of the glacier advanced and retreated over the watershed, first forming the St. Croix moraine and then later forming the Mille Lacs-Highland moraine. As the glaciers retreated they exposed the limestone, dolomite, sandstone, and shale bedrock. Additionally, glacial till was deposited that created the moraines most notable in the north portion of the watershed.

According to the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) STATSGO soils data, the majority of soils in the southern Rum River watershed have low (Type A) to moderately low (Type B) runoff potentials. The soils in the central portion of the Rum River watershed, south of Mille Lacs and north of Princeton, are primarily Type C soils with slow infiltration rates. The soils surrounding Mille Lacs are a mix of Type A, B, and C soils.



MLSSC/NLCD Hybrid Land Cover						
Rum River						
	Monitored		Unmonitored		Total	
Land Cover Class	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	22,251	2.2%	205	5.7%	22,456	2.2%
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The watershed topography is generally fairly flat, except for the hilly end moraine areas around the west and south sides of Lake Mille Lacs, and in the southwest portion of the watershed encompassing the city of Nowthen (Figure RUM-2). The majority of the southern part of the watershed is in the Anoka Sand Plain. The maximum watershed elevation is 1454.6 MSL (mean sea level) and the minimum elevation is 840.2 MSL within the monitored area. Within the monitored area, 1% of the slopes are considered steep, and less than 1% is considered very steep. Steep slopes are those between 12-18%, and very steep slopes are those 18% or greater (MnDNR, 2011).

The Rum River watershed contains many point source dischargers, including 16 domestic wastewater treatment plants (WWTPs), one of which is a Class A facility - the Cambridge WWTP - with a design flow of 1.92 MGD (Table RUM-3). There are no WWTPs in the unmonitored part of the watershed. In 2014, MCES began operation of the East Bethel Wastewater Reclamation Facility (WWRF). The WWRF produces tertiary-treated, disinfected effluent that will be available for reuse (spray irrigation of golf course and agricultural fields, industrial cooling water, fountains, and toilet flushing). That effluent not reused will be infiltrated through two separate grass-covered subsurface disposal sites. There is no proposed discharge to surface water from the WWRF. The project Environmental Assessment Worksheet (EAW; Metropolitan Council, 2010a) states that the subsurface disposal sites drain to the unsaturated zone above shallow groundwater. The EAW states that the effluent applied to the subsurface disposal sites will migrate to surface waters and adjacent wetlands. Water from the north disposal site may migrate to Cedar Creek, a tributary to the Rum. The discharge to Cedar Creek is estimated to be 0.23 cfs and is estimated to not produce any significant increase in flow depth in Cedar Creek.

The watershed has two cooling, potable treatment and dewatering facilities, two industrial wastewater permit holders, and 31 industrial stormwater permit holders within the monitored part of the watershed. There are five additional industrial stormwater permit holders in the unmonitored portion. The Rum River watershed has 193 registered feedlots with a total of 24,224 animal units (AUs), all within the monitored part of the watershed. Seventy-eight of the feedlots in the monitored area have 100 AUs or more. The largest feedlot in the watershed is a dairy farm with 1,496 AUs.

Table RUM-3: Permitted Domestic Wastewater Treatment Facilities Discharging to the Rum River

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus Removal[3]	General Notes[3]
MN0020362	Cambridge WWTP	1.92	A	--	Median P = 8 mg/l. 2,122 kg/yr P limit in effect ASAP but before 5/31/2015.
MN0024147	Milaca WWTP	0.679	D	--	No significant reduction. 938 kg/yr limit included in 06/2012 permit.
MNG550008	Isanti WWTP	0.657	C	Commenced 09/2010.	No P limit in permit. Apparent reductions to <1 mg/l starting 09/2010.
MN0024538	Princeton WWTP	0.635	C	--	SDS permit only until 12/2009. New discharge started 10/2012. Mean P = 0.27 mg/l
MN0021407	St Francis WWTP	0.54	C	Projected P removal 2016	Facility seldom discharges to surface water.
MN0022870	Braham WWTP	0.2851	B	Commenced 12/2004	P permit limit in effect 2010. Facility had low P prior to permit limit.
MNG580050	Onamia WWTP	0.21	D	NA	--
MN0023809	Isle WWTP	0.2	--	NA	--
MN0042196	Castle Towers WWTP	0.12	B	NA	--
MNG580017	Foreston WWTP	0.0489	D	NA	--
MNG580167	Pease WWTP	0.039	D	NA	--
MN0058475	Bethel WWTP	0.0375	D	NA	--
MN0069795[4]	MCES – East Bethel Wastewater Reclamation Facility[4]	0.47	B	2014; included in new WWRF construction	WWRF went online in 2014; discharge is subsurface only
MN0052132	Village Green North Mobile Home Park	0.03	C	NA	--
MN0059480	ISD 15 - Cedar Creek Community	0.022	D	NA	--

Table RUM-3: Permitted Domestic Wastewater Treatment Facilities Discharging to the Rum River

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus Removal[3]	General Notes[3]
	School				
MN0054518	Isanti Estates LLC	0.02	C	NA	--
MN0033723	MnDNR Father Hennepin State Park	0.0086	D	NA	--

[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 WWTPs 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] MCES East Bethel Wastewater Reclamation Facility started operation in 2014. The WWRF (wastewater reclamation facility) discharges to subsurface only, with no surface discharge.

There are two watershed management organizations that help to manage the lower part of the Rum River watershed within the metropolitan area. The Upper Rum River Watershed Management Organization (URRWMO) boundaries begin where the Rum River watershed crosses into Anoka County and extend south to the city lines of Ramsey and Andover. The Lower Rum River Watershed Management Organization (LRRWMO) is also in Anoka County, and its boundaries begin south of the URRWMO and continue to where the Rum River converges with the Mississippi River.

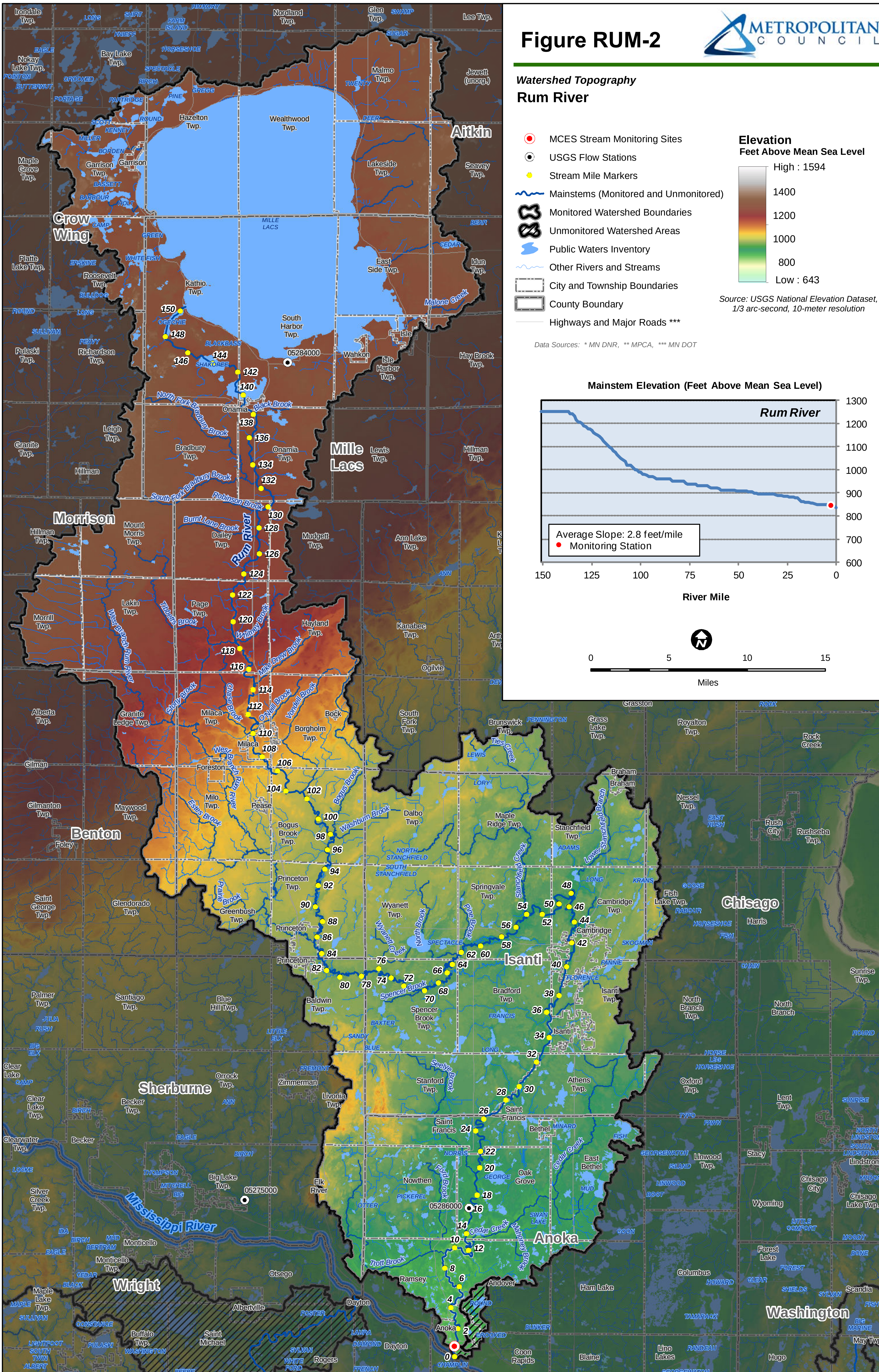
Figure RUM-2
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Watershed Topography
Rum River
MCES Stream Monitoring Sites
USGS Flow Stations
Stream Mile Markers
Mainstems (Monitored and Unmonitored)
Monitored Watershed Boundaries
Unmonitored Watershed Areas
Public Waters Inventory
Other Rivers and Streams
City and Township Boundaries
County Boundary
Highways and Major Roads ***
Data Sources: * MN DNR, ** MPCA, *** MN DOT
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)
Rum River
Average Slope: 2.8 feet/mile
Monitoring Station
1300
1200
1100
1000
900
800
700
600
150
125
100
75
50
25
0
River Mile
0
5
10
15
Miles
Aitkin
Crow Wing
Mille Lacs
Morrison
Benton
Sherburne
Wright
Isanti
Chisago
Anoka
Washington
Rum River
Mississippi River
05284000
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05275000

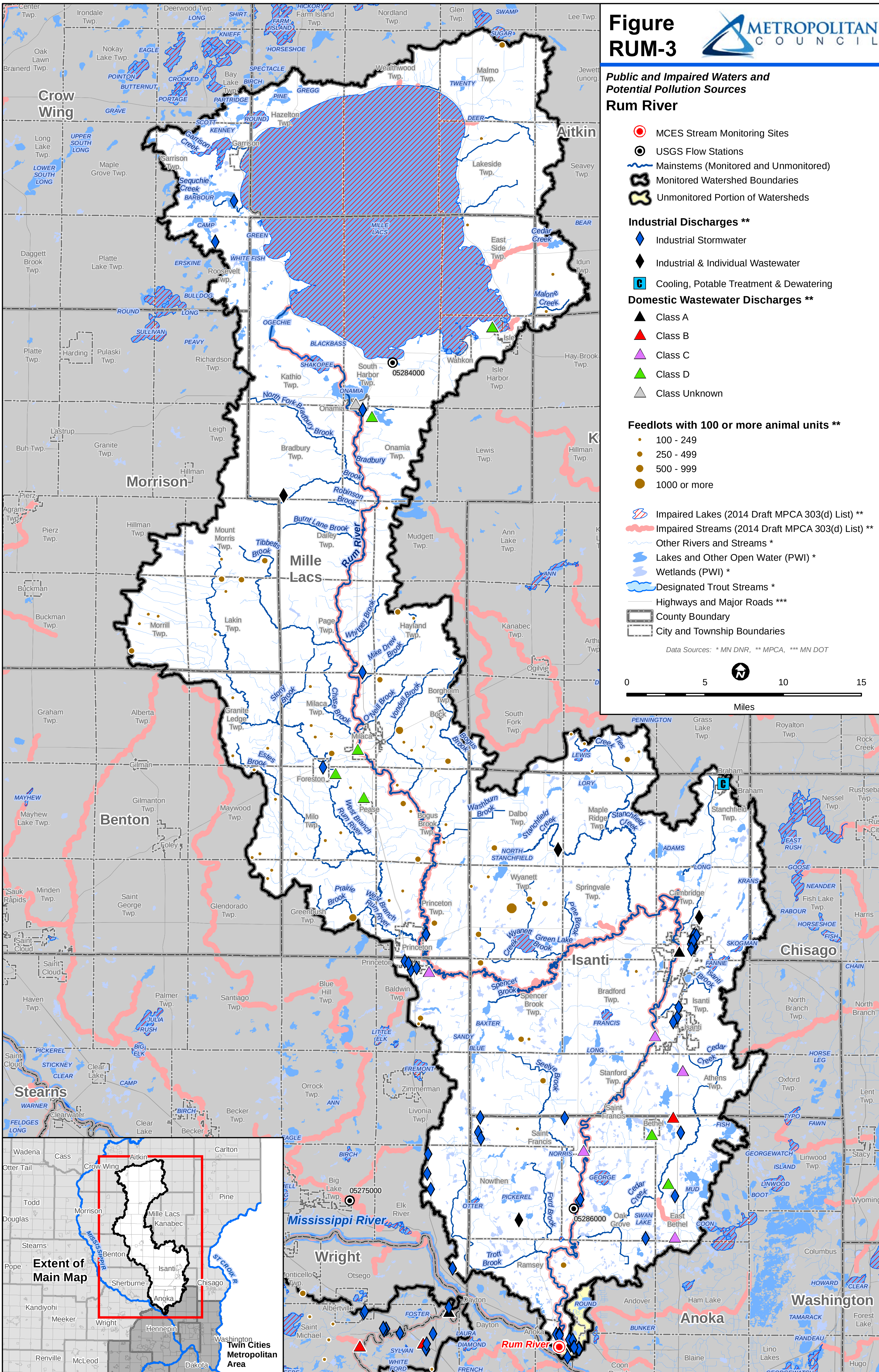


Figure RUM-3
METROPOLITAN COUNCIL
Public and Impaired Waters and Potential Pollution Sources
Rum River
MCES Stream Monitoring Sites
USGS Flow Stations
Mainstems (Monitored and Unmonitored)
Monitored Watershed Boundaries
Unmonitored Portion of Watersheds
Industrial Discharges **
Industrial Stormwater
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 *
Highways and Major Roads ***
County Boundary
City and Township Boundaries
Data Sources: * MN DNR, ** MPCA, *** MN DOT
0 5 10 15
Miles
Crow Wing
Aitkin
Morrison
Mille Lacs
Benton
Isanti
Chisago
Stearns
Wright
Anoka
Washington
Rum River
Mississippi River
05284000
05275000
05286000
Extent of Main Map
Twin Cities Metropolitan Area

Water Quality Impairments

The Rum River watershed contains 19 stream reaches that are included on the MPCA 2014 303d list (Figure RUM-3, Table RUM-4). This includes 14 reaches of the Rum River from Ogechie Lake to the confluence with the Mississippi River; 5 reaches of smaller streams that drain into Mille Lacs, and one tributary to Cedar Creek. All of the Rum River impairments are for aquatic consumption based on mercury in fish tissue, and the other smaller tributary stream impairments are for aquatic life based on dissolved oxygen levels. All the reaches impaired for aquatic consumption have approved TMDL plans.

Table RUM-4: Impaired Reaches of the Rum River Watershed as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Affected Uses[1]	Approved Plan[2]	Needs Plan[2]
Borden Creek	Deer Lk to Lk Mille Lacs	07010207-554	AQL	--	DO
Cedar Creek (Little River)	Cedar Lk to Lk Mille Lacs	07010207-546	AQL	--	DO
Crooked Brook	CD 28 to Cedar Cr	07010207-575	AQL	--	DO
Malone Creek (Thains Creek)	Anderson Lk to Lk Mille Lacs	07010207-547	AQL	--	DO
Reddy Creek (Marmon Creek)	Unnamed cr to Lk Mille Lacs	07010207-544	AQL	--	DO
Rum River	Lk Onamia to Tibbetts Bk	07010207-509	AQC	HgF	--
Rum River	Madison/Rice St in Anoka to Mississippi R	07010207-556	AQC	HgF	--
Rum River	Seelye Bk to Cedar Cr	07010207-503	AQC	HgF	--
Rum River	Cedar Cr to Trott Bk	07010207-502	AQC	HgF	--
Rum River	Headwaters (Lk Mille Lacs 48-0002-00) to Ogechie Lk	07010207-506	AQC	HgF	--
Rum River	W Br Rum R to Stanchfield Cr	07010207-512	AQC	HgF	--
Rum River	Trott Bk to Madison/Rice St in Anoka	07010207-555	AQC	HgF	--
Rum River	Shakopee Lk to Lk Onamia	07010207-585	AQC	HgF	--
Rum River	Ogechie Lk to Shakopee Lk	07010207-583	AQC	HgF	--
Rum River	Stanchfield Cr to Seelye Bk	07010207-504	AQC	HgF	--
Rum River	Bogus Bk to W Br Rum R	07010207-511	AQC	HgF	--
Rum River	Tibbetts Bk to Bogus Bk	07010207-510	AQC	HgF	--
Rum River	Trott Bk to Anoka Dam	07010207-666	AQC	HgF	--
Rum River	Anoka Dam to Madison/Rice St in Anoka	07010207-665	AQC	HgF	--

Rum River	Anoka Dam to Madison/Rice St in Anoka	07010207-665	AQC	HgF	--
Unnamed creek (Seastade Creek)	Unnamed cr to Lk Mille Lacs	07010207-558	AQL	--	DO

[1] AQL = Aquatic Life; AQC = Aquatic Consumption; [2] DO = Dissolved Oxygen; HgF = Mercury in Fish Tissue;

The Rum River watershed contains 12 lakes that are included on the MPCA 2014 303d list (Figure RUM-3, Table RUM-5). Most of the lakes impaired for aquatic consumption have approved TMDL plans, with the exception of Lewis and Green Lakes. All of the lakes that are impaired for aquatic recreation are located in the southern portion of the watershed and need TMDL plans. Of these lakes, all five are impaired for nutrient concentrations.

Table RUM-5: Impaired Lakes of the Rum River Watershed as Identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Affected Uses[1]	Approved Plan[2]	Needs Plan[2]
Borden	18-0020-00	AQC	HgF	--
East Twin	02-0133-00	AQC	HgF	--
Fannie	30-0043-00	AQR	--	Nutrients
Francis	30-0080-00	AQR	--	Nutrients
George	02-0091-00	AQC	HgF	--
Green	30-0136-00	AQC, AQR	HgF	Nutrients, PCBF
Lewis	33-0032-00	AQC	--	HgF
Mille Lacs	48-0002-00	AQC	HgF	--
Rogers	02-0104-00	AQR	--	Nutrients
Round	01-0204-00	AQC	HgF	--
Shakopee	48-0012-00	AQC	HgF	--
Skogman	30-0022-00	AQR	--	Nutrients

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

[2] HgF = mercury in fish tissue; PCBF = polychlorinated biphenyl in fish tissue;

The Anoka Conservation District is working to develop a WRAPS (Watershed Restoration and Protection Strategy) for the Rum River watershed, with a goal to maintain or improve the water quality of the watershed, through a Clean Water Fund Watershed Restoration and Protection Project (Legislative Coordinating Commission, 2014).

Hydrology

MCES has monitored flow on the Rum River at Anoka, Minnesota since 1996. Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrograph of the Rum River, 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 (Figure RUM-4), and the effect of precipitation events on flow.

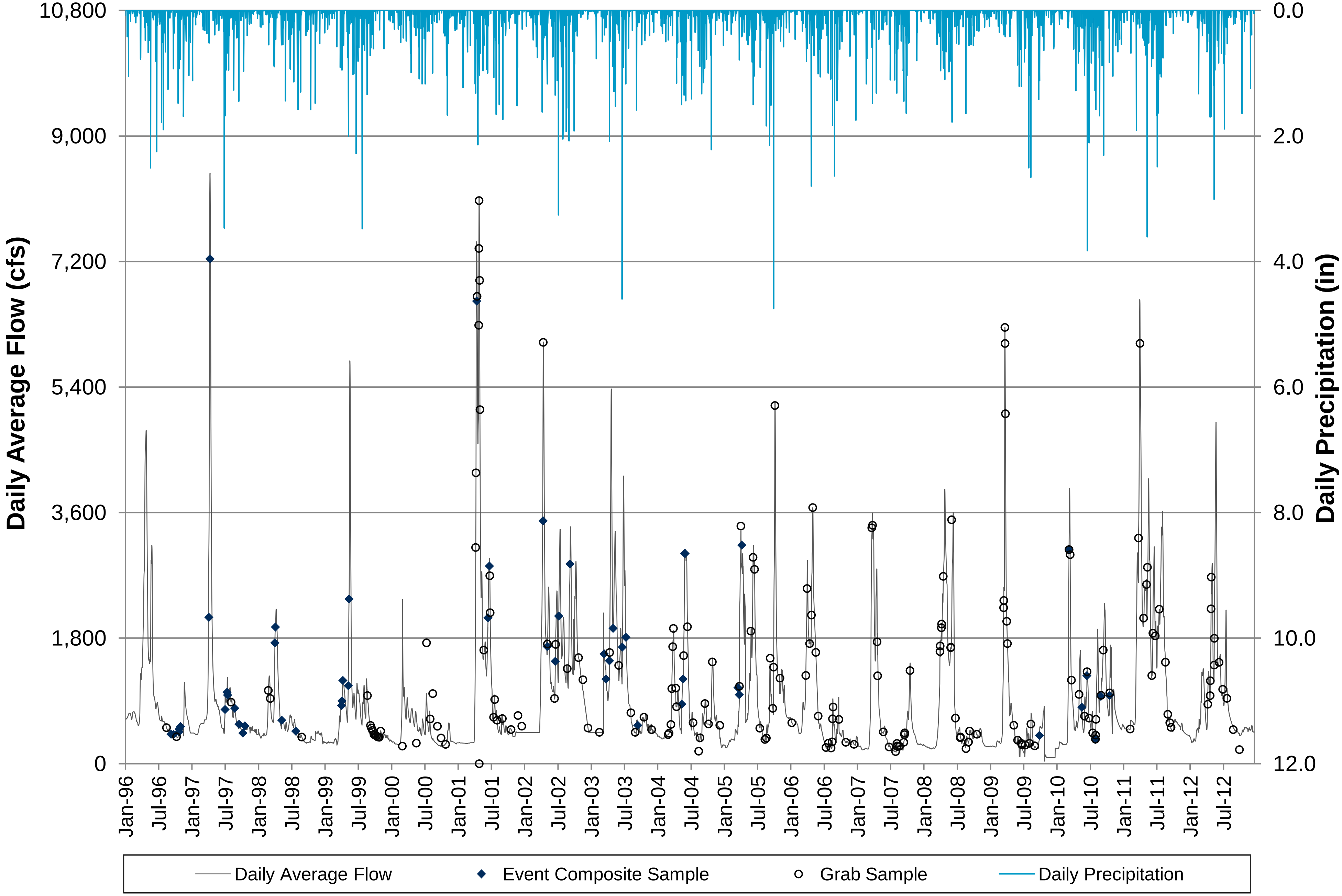
The MCES sampling program specifies collection of baseflow grab samples between events and event-based composites. The hydrograph indicates samples were collected during most events and that baseflow was also adequately sampled.

The Rum River hydrograph is characteristic of a large, fifth order river system (Figure RUM-5). Generally, the storm event daily average flows were less than 5,400 cfs (cubic feet per second). High flows caused by six spring rains or snowmelt driven events exceeded this level in 1997, 1999, 2001, 2002, 2009, and 2011. Of those events, the highest recorded daily average flow in the Rum River, approximated 8,469 cfs, occurred in 1997. The mean average daily flow is 881 cfs, which is larger than the median average daily flow of 535 cfs, indicating the influence of large events on the average flow value. Due to its size, the Rum River maintains a baseflow during the winter months or during prolonged periods with little precipitation. The lowest recorded average daily flow was 36.4 cfs.

Analysis of the duration of daily average flows indicates that the upper 10th percentile flows for the period 1996-2012 ranged between approximately 1,986-8,469 cfs, while the lowest 10th percentile flows ranged from 36.4-280 cfs (See Figure RUM-11 in the ***Flow and Load Duration Curves*** section of this report).

The variations in flow are likely driven by annual precipitation amounts as well as by frequency of intense storm events. However, well over half of the precipitation most likely does not affect the stream as surface runoff. During the years 2001-2012, the average runoff ratio was 0.26, indicating an average of 74% of the precipitation either infiltrated the soils, evaporated off of the surface, was stored in lakes or wetlands, or was evaportranspirated by vegetation. As mentioned in the stream and watershed description, the lower part of the Rum River watershed has soil types (Type A and B) that facilitate high or moderately high infiltration. Given this characteristic, the infiltrated precipitation recharges the groundwater aquifers that eventually discharge into the Mississippi River.

Figure RUM-4: Rum River Daily Average Flow, Sample Flow, and Precipitation, 1996-2012*



*Precipitation record was acquired from NWS COOP stations: 211390-Cedar, 212500-Elk River, 210190-Andover 1N, and 215838-New Hope

Vulnerability of Stream to Groundwater Withdrawals

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

To assess the vulnerability of the Rum River 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 Rum River watershed located within the seven-county metropolitan area boundary, which is only the small southern part of the watershed included in Anoka County. Within Anoka County, the majority of waterbodies are located at or below the water table, indicating a groundwater connection. The entire length of Rum River within Anoka County as well as a significant number of wetlands, are identified as being susceptible to groundwater pumping.

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 the Rum River (2001-2011). Figures RUM-5 – RUM-8 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 the Rum River loads and FWM concentrations with the other MCES-monitored metropolitan area tributaries.

The first charts in Figures RUM-5 and RUM-6 plot the annual flows from 2001-2012. The highest average annual flow, and thus the highest volume of flow, occurred during 2011 (approximately 1,485 cfs average annual flow); the lowest average annual flow, and lowest volume of flow, occurred in 2009 (approximately 535 cfs average annual flow). For the full data record the mean average annual flow was 947 cfs, which is higher than the median average annual flow of 877 cfs, suggesting the large annual flows bias the mean annual flow. The flow metrics indicate a gradual decrease in flows from 2002 to 2009. The flows increase in 2010 and 2011, but decrease in 2012.

The annual mass load of the pollutants exhibit slight year-to-year variation, but generally mirror the pattern in annual flows (Figure RUM-5). However, all but Cl show the highest load in the year 2002, matching the second highest annual flow (1,410 cfs). Almost every graph shows the lowest loads occurred in 2009, with the exception of NO_3, which was in 2007. This strongly suggests that loads in the Rum River are driven by changes in water flow conditions.

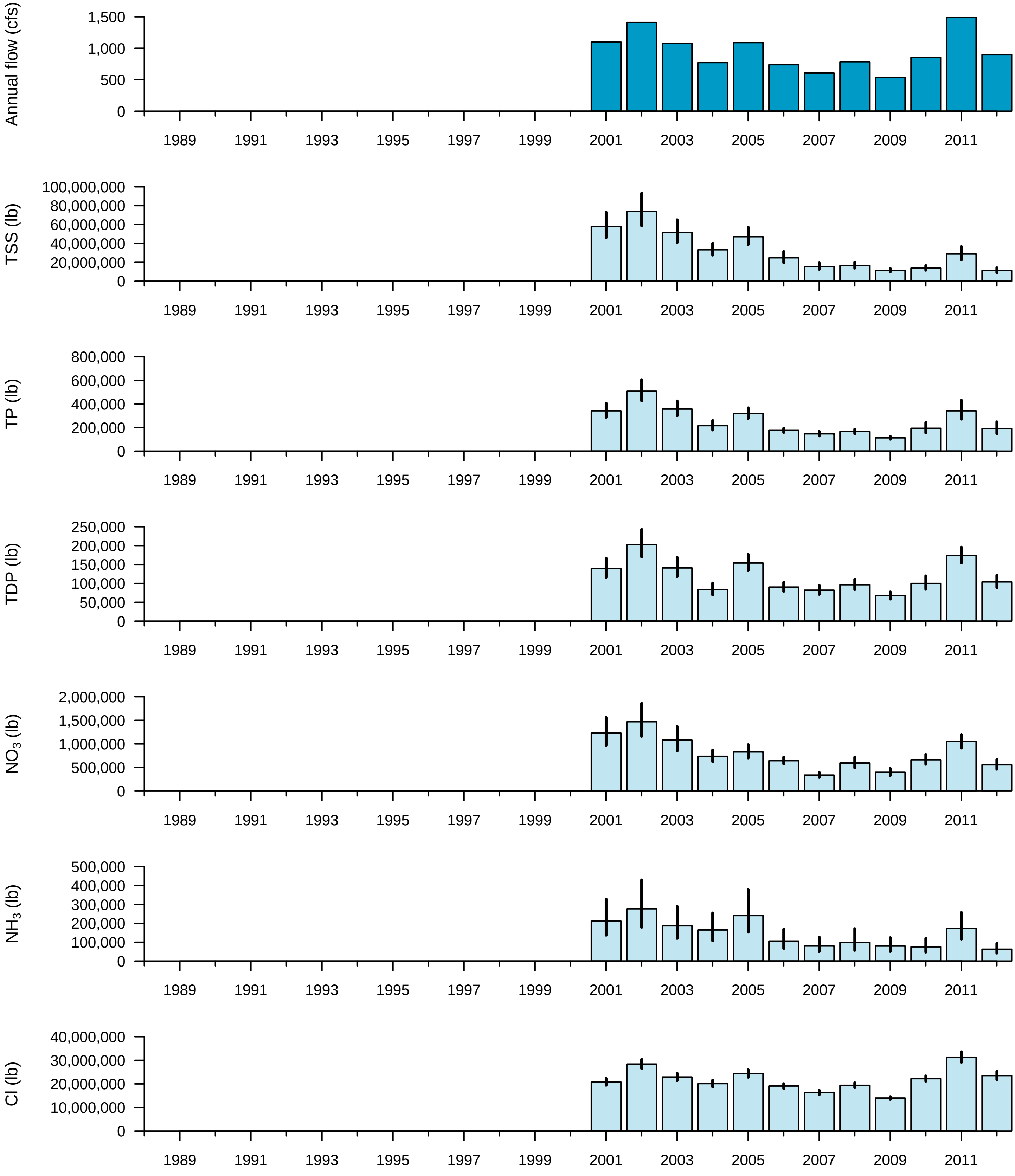
The annual FWM concentrations provide a greater insight to the loading dynamics in the Rum River (Figure RUM-6). The TSS and NH_3 FWM concentrations show a clear decrease over this time period. The other monitored pollutants exhibit some variation, but in general are relatively steady. The steady nature of the chemical composition is to be expected in a river of this size which is highly influenced by lake water quality.

Figures RUM-7 and RUM-8 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 the Rum River (Figure RUM-9 and RUM-10). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for the Rum River) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month).

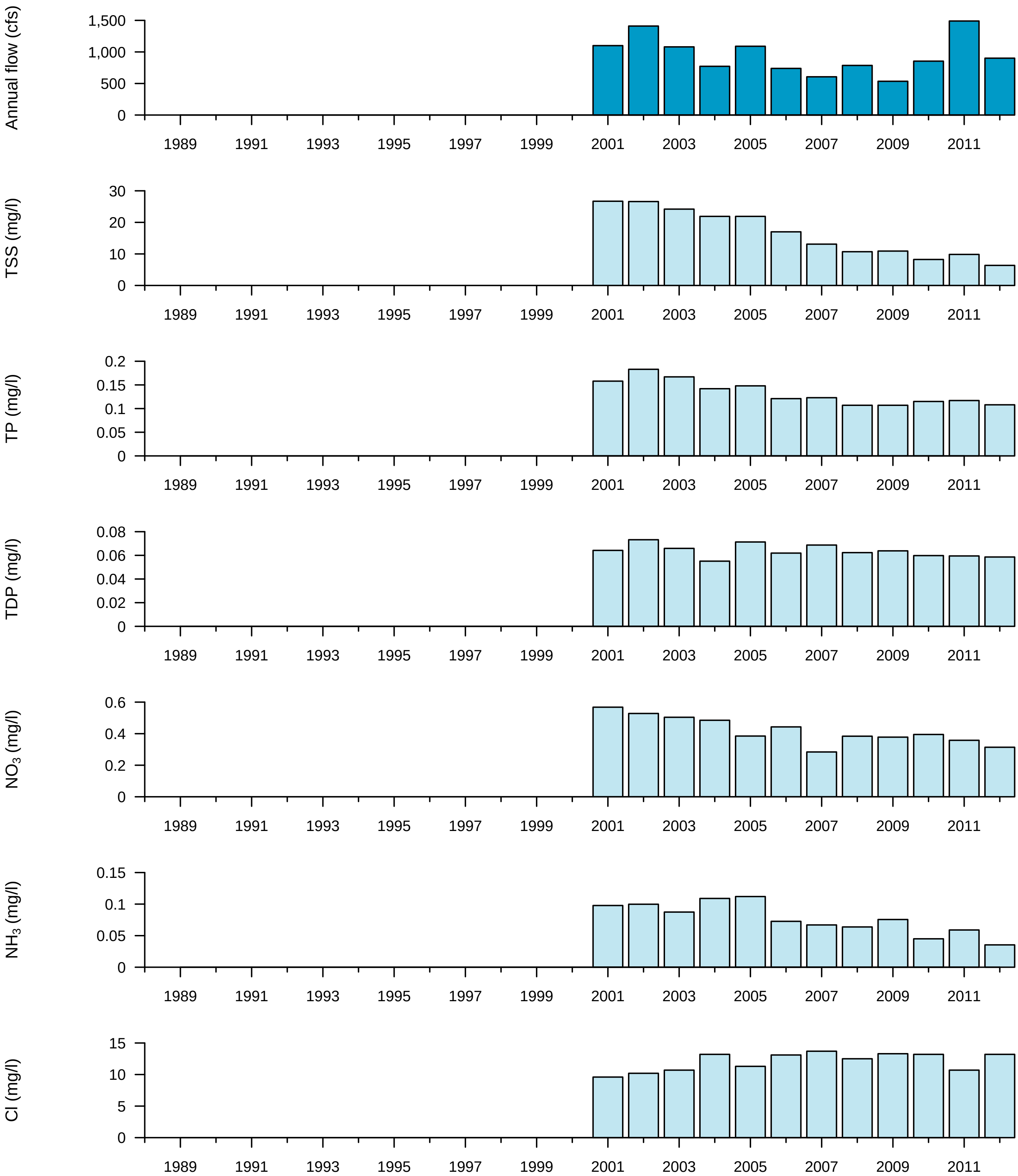
It is apparent that the highest mass loads in the Rum River occur in April each year, likely due to effects of snow melt. Afterwards, the loads generally decrease throughout the remainder of the year. The FWM concentration show less month-to-month variability than the loads. All of the monitored pollutant concentrations, with the exception of Cl, are slightly elevated in spring, corresponding to high flow periods. Cl decreases during this period, showing a dilution of the pollutant as more water flows in the Rum River. In the summer and fall it rebounds to nearly the same concentration as the pre-snowmelt period.

Figure RUM−5: Rum River*
Annual Mass Load



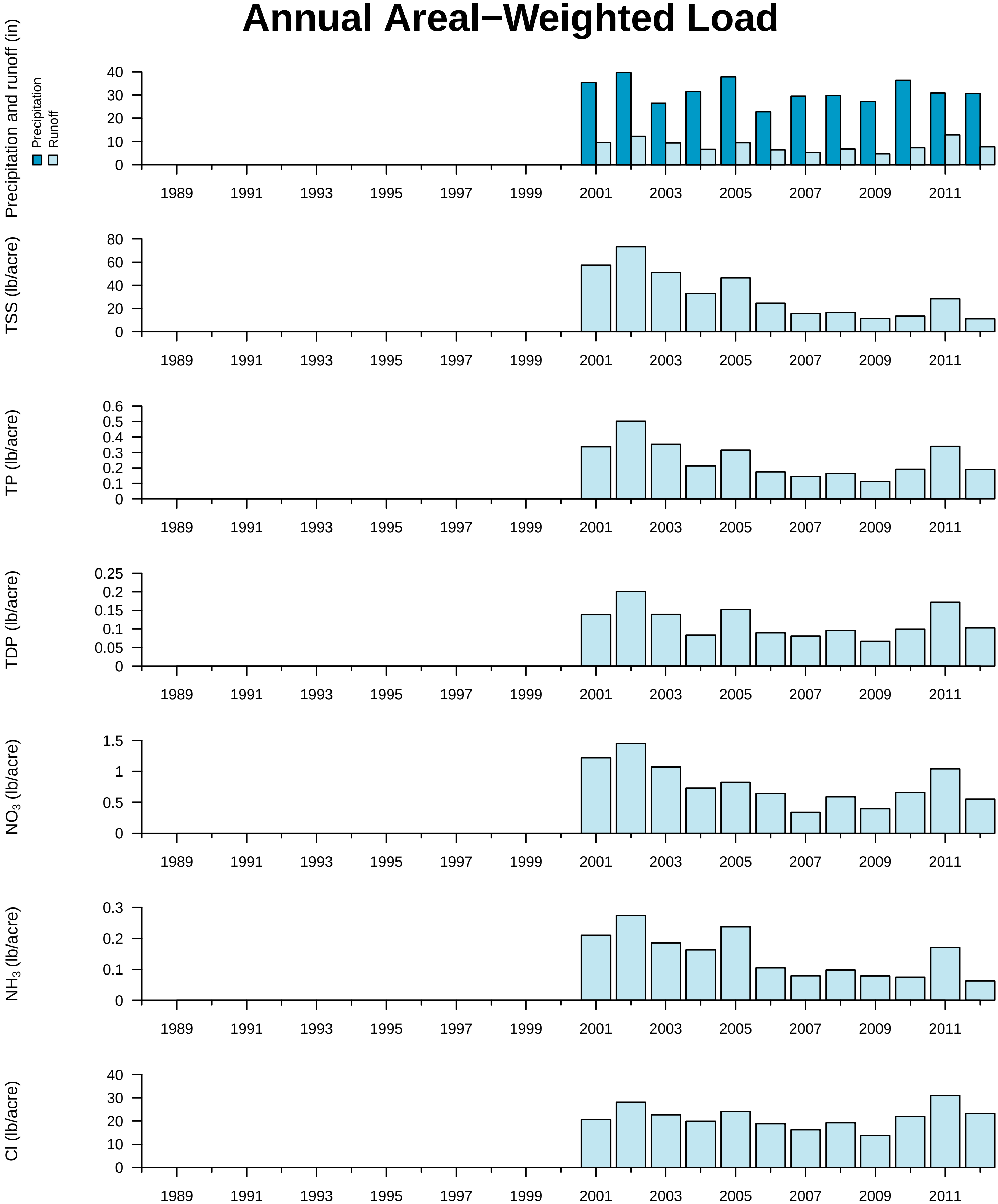
*First full year of sampling began in 2001.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure RUM−6: Rum River*
Annual Flow−Weighted Mean Concentration



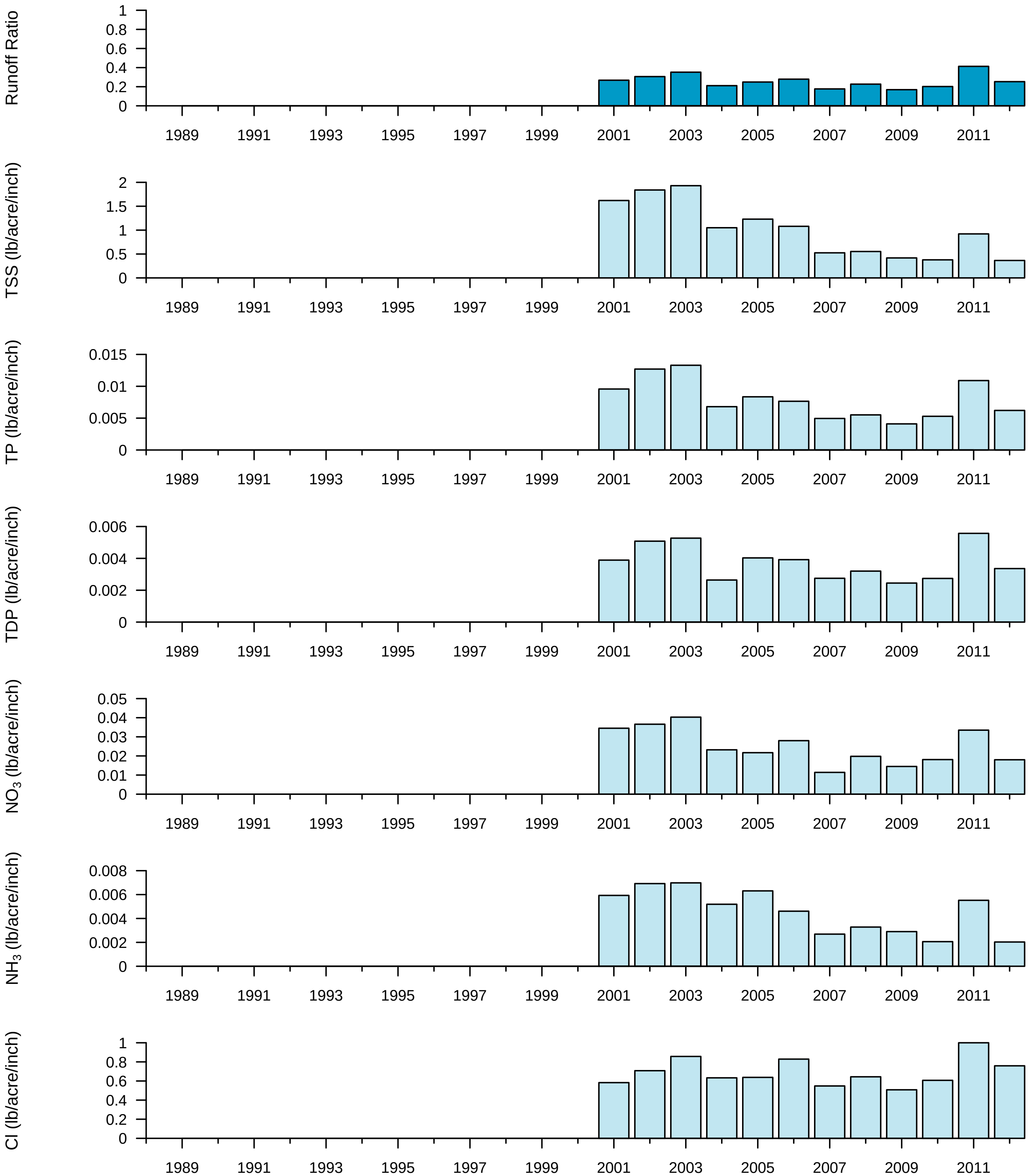
*First full year of sampling began in 2001.

Figure RUM−7: Rum River*
Annual Areal−Weighted Load



*First full year of sampling began in 2001.

Figure RUM−8: Rum River*
Annual Precipitation−Weighted Areal Load



*First full year of sampling began in 2001.

Figure RUM−9: Rum River Mass Load by Month

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

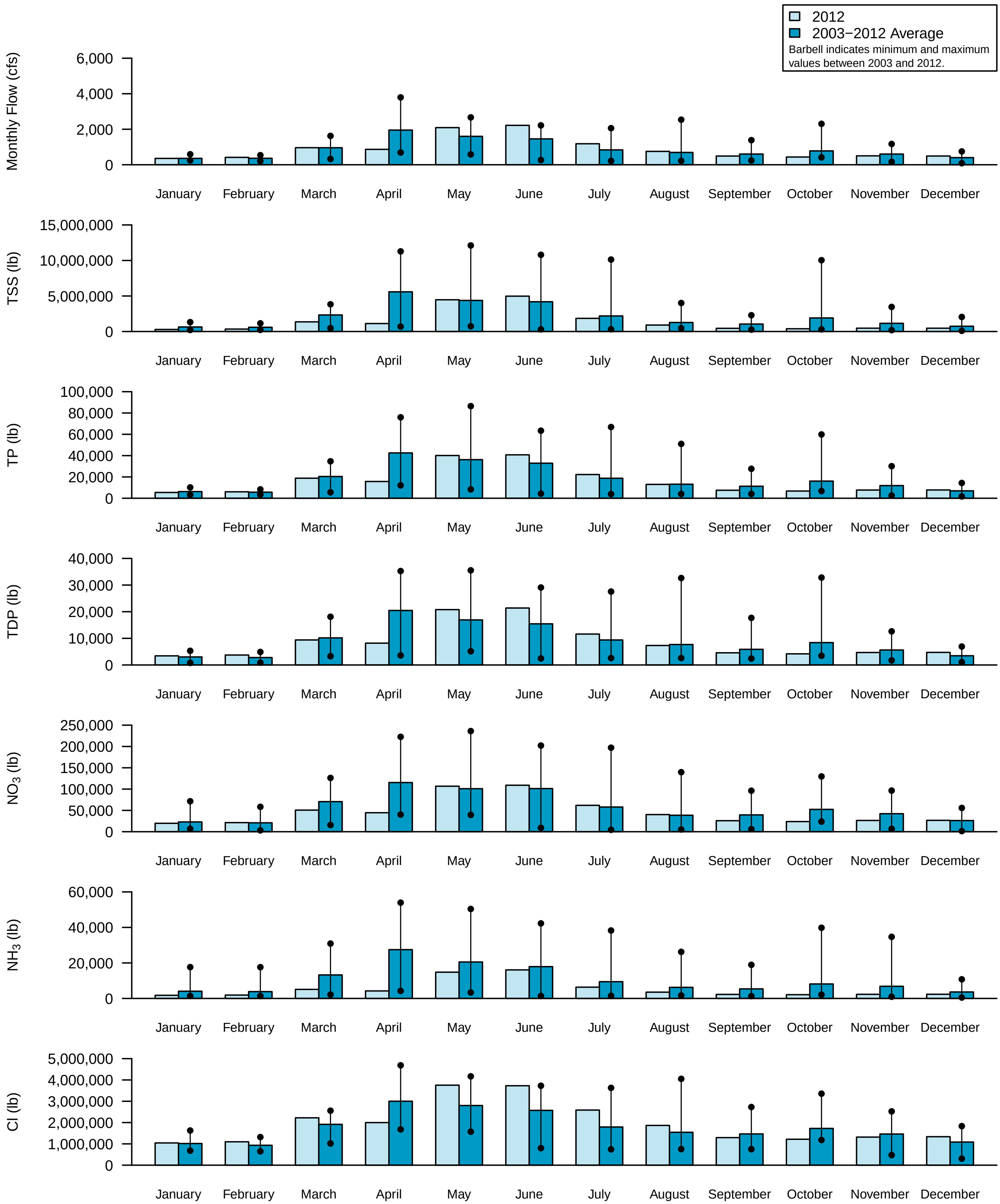
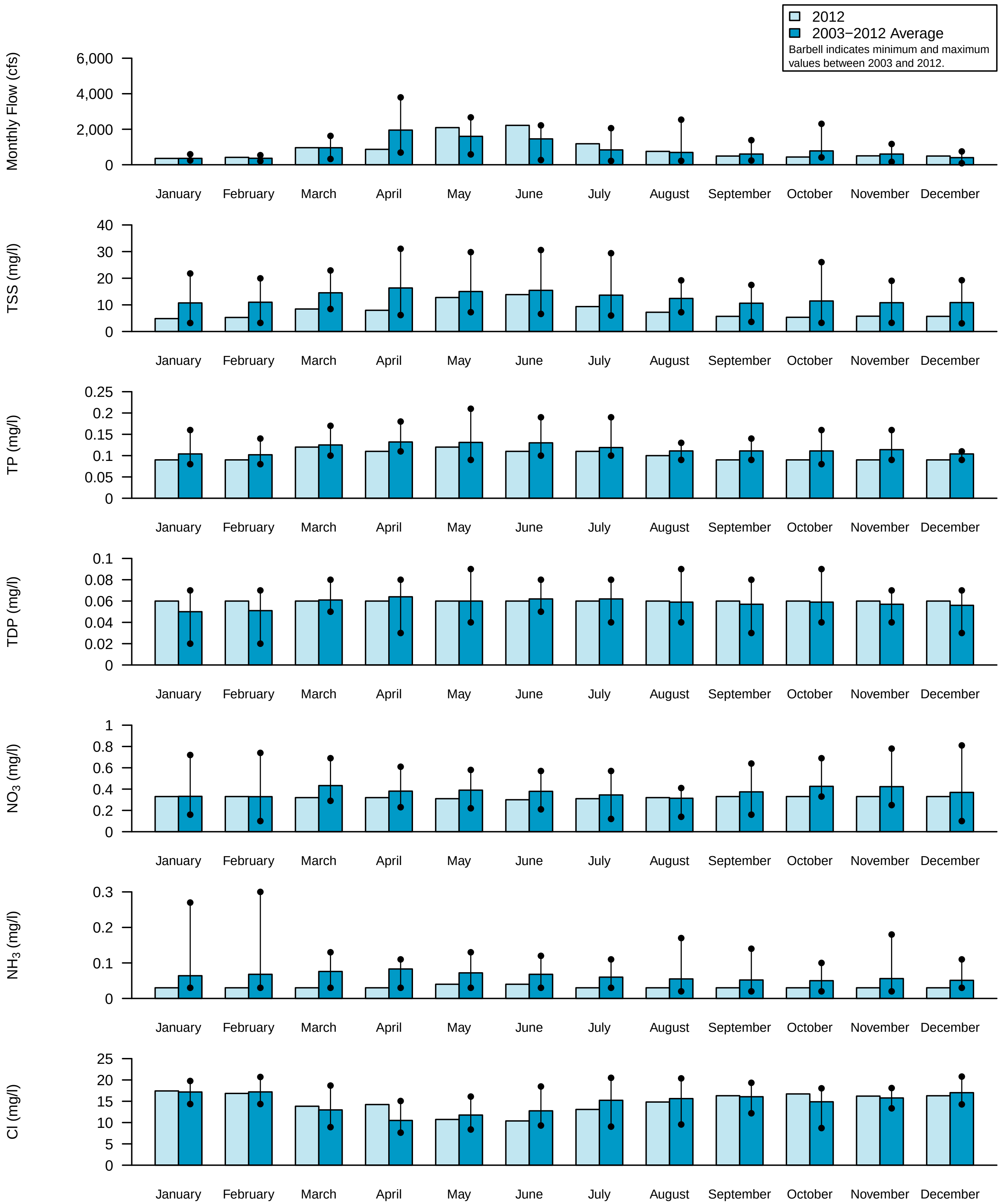


Figure RUM−10: Rum River
Flow−Weighted Mean Concentation by Month

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 location using U.S. Environmental Protection Agency (USEPA) recommendations, 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 5th, 25th, 50th, 75th, and 95th 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 the Rum River monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table RUM-6. 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 standards that are difficult to show on the load duration curves. For example, for a water body to violate the draft TP river standard, the water body must exceed the causative variable (TP concentration), as well as one or more response variables: sestonic (suspended) chlorophyll, biochemical oxygen demand (BOD_5), dissolved oxygen (DO) flux, and/or pH (MPCA, 2013a). Thus for this report, the load duration curves are used as a general guide to identify flow regimes at which water quality violations may occur. The MPCA is responsible for identifying and listing those waters not meeting water quality standards; the results of this report in no way supersede MPCA’s authority or process.

The 1990–2012 flow duration and load duration curves for TSS, TP, NO_3, and Cl for the Rum River monitoring station (mile 0.7, above the Anoka Dam) are shown in Figure RUM-11. The range of flows and the flow duration curve shape describe the flow regime of the stream system. Flow duration analysis of daily average flows indicates the upper 10th percentile flows for period 1996-2012 ranged between approximately 2,017 – 8,469 cfs, while the lowest 10th percentile flows ranged from 36 - 276 cfs. The slight curve in the extreme left of the High Flow category indicates that high flows do not occur frequently and last for short periods of time, and may be attributed to rain-induced floods. Similarly, the slight drop at the extreme right of the Low Flow category indicates that the Rum River rarely has flows below 200 cfs and has baseflow throughout the year.

Table RUM-6: Rum River Beneficial Use and River Nutrient Region (RNR) Classifications and Pollutant Draft Standards

Monitoring Station	Use Classification[1] for Domestic Consumption (Class 1) and Aquatic Life and Recreation (Class 2)	River Nutrient Region (RNR)[2] of Monitoring Station	Cl Draft Stnd[4] (mg/l)	TSS Draft Stnd[5] (mg/l)	TP Draft Stnd[6] (ug/l)	NO_3 DW Stnd[7] (mg/l)
Rum River at Anoka Dam (RUM0.7)	2B	Central[3]	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430

[2] MPCA, 2010.

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

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

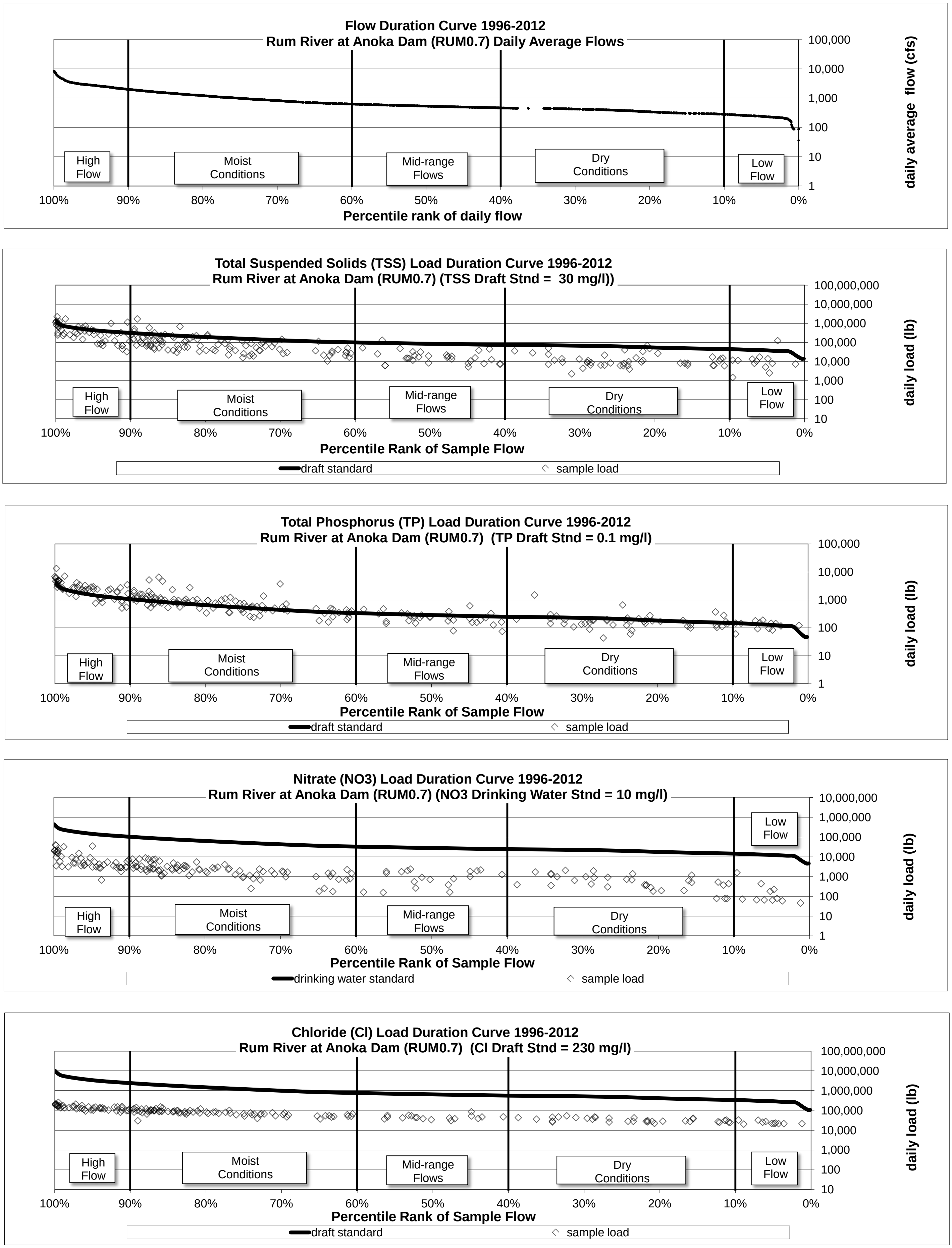
[5] MPCA, 2011. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

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

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

The load duration curves provide insight as to how flow conditions affect the stream load and the river's compliance with state standards. At all flow conditions, the Rum River loads were below the loads dictated by the draft standards for Cl and the drinking water standard for NO_3. The low flow TSS had one instance in which the load was higher than the standard, and the low flow TP loads were both above and below the standard. As the flows increase, the TSS loads generally were in compliance with the level set by the standard. The TP daily loads fell both above and below the dark line designating the standard, and mainly fell above the line at high flow, exceeding the draft standard.

Figure RUM-11: Rum River Flow and Load Duration Curves, 1996-2012



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 does not collect aquatic macroinvertebrates at this site. However, the URRWMO collaborates with the Anoka Conservation District and the students from St. Francis High School to collect macroinvertebrates for biomonitoring near Highway 24. For more information, please see the Anoka Conservation District's database website.

Trend Analysis

Trend analysis was completed for the historical record of TP, NO_3, and TSS using the 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 streamflow statistic that has not changed at a significant rate. Peak flows due to rainfall events in summer were found to be increasing, along with the number of days exhibiting higher flows. Both summer and winter baseflows were found to be increasing, as well. Novotny and Stefan 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 to10 years. At that time, we anticipate sufficient data will have been collected for us to assess changes in flow rate, as well as to update the pollutant trends discussed below.

MCES staff assessed trends for the period of 1996-2012 in the Rum River for TSS, TP, and NO_3. The results are presented below.

Total Suspended Solids (TSS)

The Rum River was identified to have multiple, statistically significant trends for TSS flow-adjusted concentration during 1996-2012 (Figure RUM-12, top panel). Two trend periods were identified ($p=7.6x10^{-4}$):

- Trend 1: 1996-2001, TSS flow-adjusted concentration increased from 7.9 mg/l to 11.9 mg/l (50%) at a rate of 0.66 mg/l/yr.
- Trend 2: 2002-2012, TSS flow-adjusted concentrations decreased quickly from 11.9 mg/l to 3.0 mg/l (-74%) at a rate of -0.80 mg/l/yr.

These trend periods coincide with the relocation of the water quality monitoring site. The first monitoring site (1996-2001) was below the outfall of the Anoka Dam, which may have resuspended particles in the water column. MCES moved the stream monitoring site to a side channel location above the Anoka Dam (2002-2012). At this point, the river has considerably less turbulent energy and is less likely to resuspend sediments.

The five-year trend in TSS flow-adjusted concentration in the Rum River (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 decreased from 5.4 mg/l to 3.0 mg/l (-44%) at a rate of -0.47 mg/l/yr.

Total Phosphorus (TP)

The Rum River was identified to have multiple, statistically significant trends for TP concentration during 1996-2012 (Figure RUM-12, middle panel). Two trend periods were identified ($p=1.2x10^{-4}$):

- Trend 1: 1996-2002, TP flow-adjusted concentrations increased slightly from 0.08 mg/l to 0.09 mg/l (19%) from 1996 to 2002 at a rate of 0.002 mg/l/yr.
- Trend 2: 2003-2012, TP flow-adjusted concentrations decreased from 0.09 mg/l to 0.07 mg/l (-27%) at a rate of -0.0026 mg/l/yr.

The five-year trend in TP flow-adjusted concentration in the Rum River (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section, ***Comparison with Other Metro Area Streams***. TP flow-adjusted concentrations decreased from 0.08 mg/l to 0.07 mg/l (-15%) at a rate of -0.0024 mg/l/yr.

Nitrate (NO_3)

One statistically significant (p value = $4.0x10^{-4}$), downward trend was identified for NO_3 flow-adjusted concentration from 2001 to 2012 (Figure Rum-12, lower panel). Average NO_3 flow-adjusted concentration decreased from 0.47 mg/l to 0.26 mg/l (-44%) at a rate of -0.017 mg/l/yr over the monitoring period.

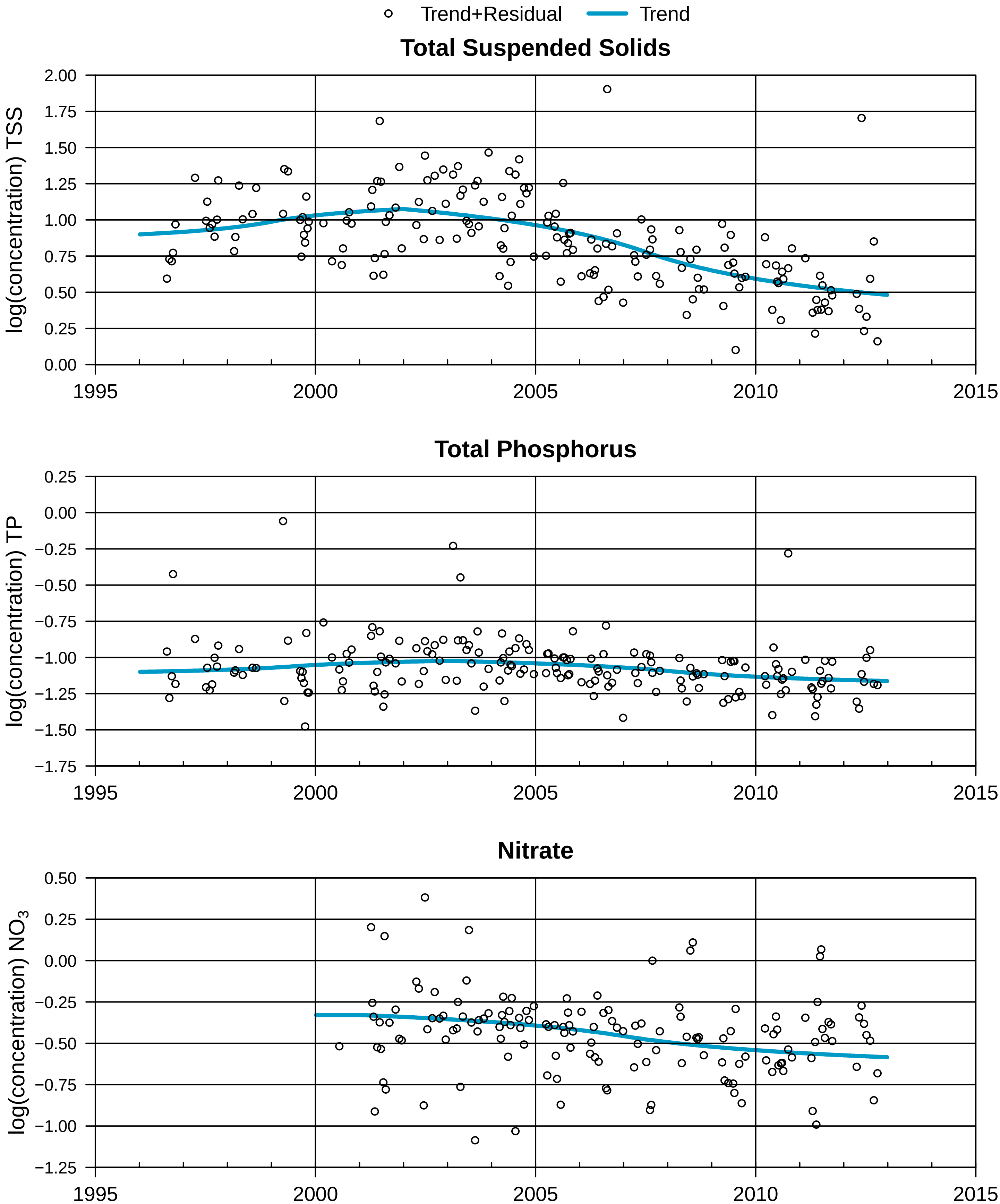
The five-year trend in NO_3 concentration in the Rum River (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section, ***Comparison with Other Metro Area Streams***. NO_3 flow-adjusted concentration decreased from 0.32 mg/l to 0.26 mg/l (-19%) at a rate of -0.0123 mg/l/yr.

While MCES staff have assessed monitoring data and trend analysis statistics, more work is needed to assign causative actions to the trend analysis results. TSS and TP chemistry, delivery, transport and remediation are complicated, although fairly well-understood. Identifying contributing events, implementation practices, and other causative actions is expected to be somewhat straightforward for these two parameters.

NO_3 chemistry and transport dynamics within the natural environmental are significantly more complicated. The NO_3 trends for most of 21 streams assessed in this study showed periods of both rising and falling flow-adjusted concentrations. NO_3 concentrations may be affected by periods of saturated and unsaturated soil conditions related to precipitation patterns, by agricultural crop rotations, by changing levels of fertilizer applications, or other unidentified causative variables, rather than true long-term improvement in concentrations based on intentional implementation of best management practices.

MCES staff will repeat the trend analysis in 5 years, and the meantime will continue to investigate the $NO_{3,}$ TSS, and TP dynamics in streams entering the metropolitan area with local partners and state agency staff.

Figure RUM−12: Rum River Trends for TSS, TP and NO_3



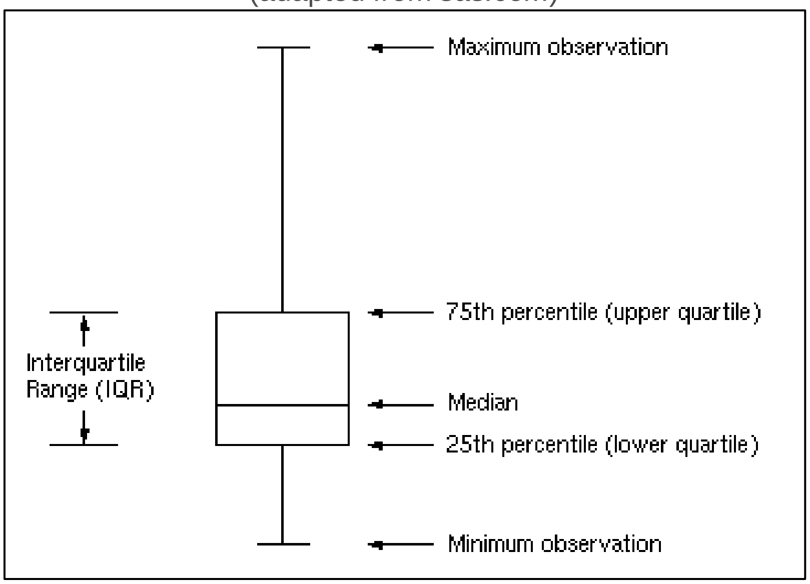
Comparison with Other Metro Area Streams

Chemistry

To compare the historical flow, TSS, TP, and NO_3, and Cl data for the Rum River with the other metropolitan area streams monitored by MCES and with the major receiving water (in this case the Mississippi River), the data were summarized on box-and-whisker plots.

The legend for the format of box-and-whisker plots used in this report is shown in Figure RUM-13. 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 RUM-13: 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 concentration for TSS in the Rum River was lower than the other Mississippi River tributaries entering the river above the confluence with the Minnesota River (Crow River, Crow River South, Bassett Creek, Minnehaha Creek), and was lower than all of the other metropolitan area tributaries except Eagle Creek and Carnelian Marine (Figure RUM-14, Table RUM-7). The FWM concentration in the Rum River was also lower than that in the Mississippi River at Anoka (12 mg/l vs. 18 mg/l, respectively), indicating that the Rum River diluted the TSS concentration in the Mississippi River.

Median annual runoff ratio for the Rum River was similar to the other Mississippi River tributaries. Since the Rum River flow is influenced by wetlands, lakes, and other impoundments on the stream channel, the runoff ratio is relatively low. If the flow was highly influenced by shallow groundwater inflow, one would expect a relatively higher runoff ratio (i.e. Eagle Creek or Valley Creek).

Despite the size of its large watershed, the Rum River did not generate as large a TSS load as other MCES-monitored streams. Adjusting for area, the Rum River's annual yield of TSS is only greater than Minnehaha Creek, Carnelian Marine, and Silver Creek. This could be attributed to the active management of the river as part of the MnDNR's Wild and Scenic River Program, which provides protective rules on the amount of development allowed along the river, which likely reduces and controls sediment delivery along the river.

Total Phosphorus. The FWM TP concentration in the Rum River, 0.12 mg/l, was the same as the Mississippi River and thus did not affect the TP concentration in the river (Figure RUM-15, Table RUM-7). The Rum River has similar median FWM concentrations as the other non-agricultural Mississippi River tributaries. They were generally lower than the agriculturally dominated tributaries to the Minnesota River, and similar to those of the FWM TP concentrations in the St. Croix River tributaries.

Although the TP concentrations were lower than several metropolitan area tributaries, the annual TP load from the Rum River was higher than most of the other MCES-monitored streams. The Crow River, the Crow River South, Sand Creek, and the Cannon River had the same magnitude of loads as the Rum River, most likely due to their larger watershed sizes. The annual yield, which normalizes the load by drainage area, was lower than most of the other MCES-monitored sites (only the St. Croix streams, Minnehaha Creek, and Willow Creek annual yields were smaller). The TP concentration and load in the Rum River 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 upstream of the MCES monitoring station.

Nitrate. NO_3 FWM concentration in the Rum River was lower than the Mississippi River (0.4 mg/l vs. 1.4 mg/l), and generally diluted the Mississippi River concentration (Figure RUM-16 Table RUM-7). This low concentration resulted in a low NO_3 load as well. The Rum River land cover (primarily forest, grassland, open water, and wetlands) is significantly different than that of the other larger (and primarily agricultural) watersheds – the Crow, Crow South, and Cannon Rivers - which produce the bulk of the NO_3 load from MCES-monitored streams.

Chloride. Cl FWM concentration in the Rum River was less than that in the Mississippi River (12.8 mg/l vs. 16 mg/l) and the other tributaries above the confluence with the Minnesota River (Figure RUM-17 Table RUM-7). The Rum River Cl concentration was significantly lower than the concentrations observed in the most urbanized watersheds monitored by MCES (Willow, Bluff, Bassett, Minnehaha, Battle, and Fish). However, because of the large watershed size, the Rum River is still one of the highest contributors of Cl load of the other MCES-monitored streams. The two most prevalent sources of Cl to streams are road surfaces (from Cl application as a de-icer) and WWTP effluent (from domestic water softeners).

Macroinvertebrates

In other chapters of this report, MCES created figures for area-wide comparisons of the macroinvertebrate M-IBI scores and the trends in water quality. However, since the Rum River was not included in biomonitoring it cannot be compared to the other metropolitan area streams. Please see the other sections in this report for further information.

Figure RUM−14: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

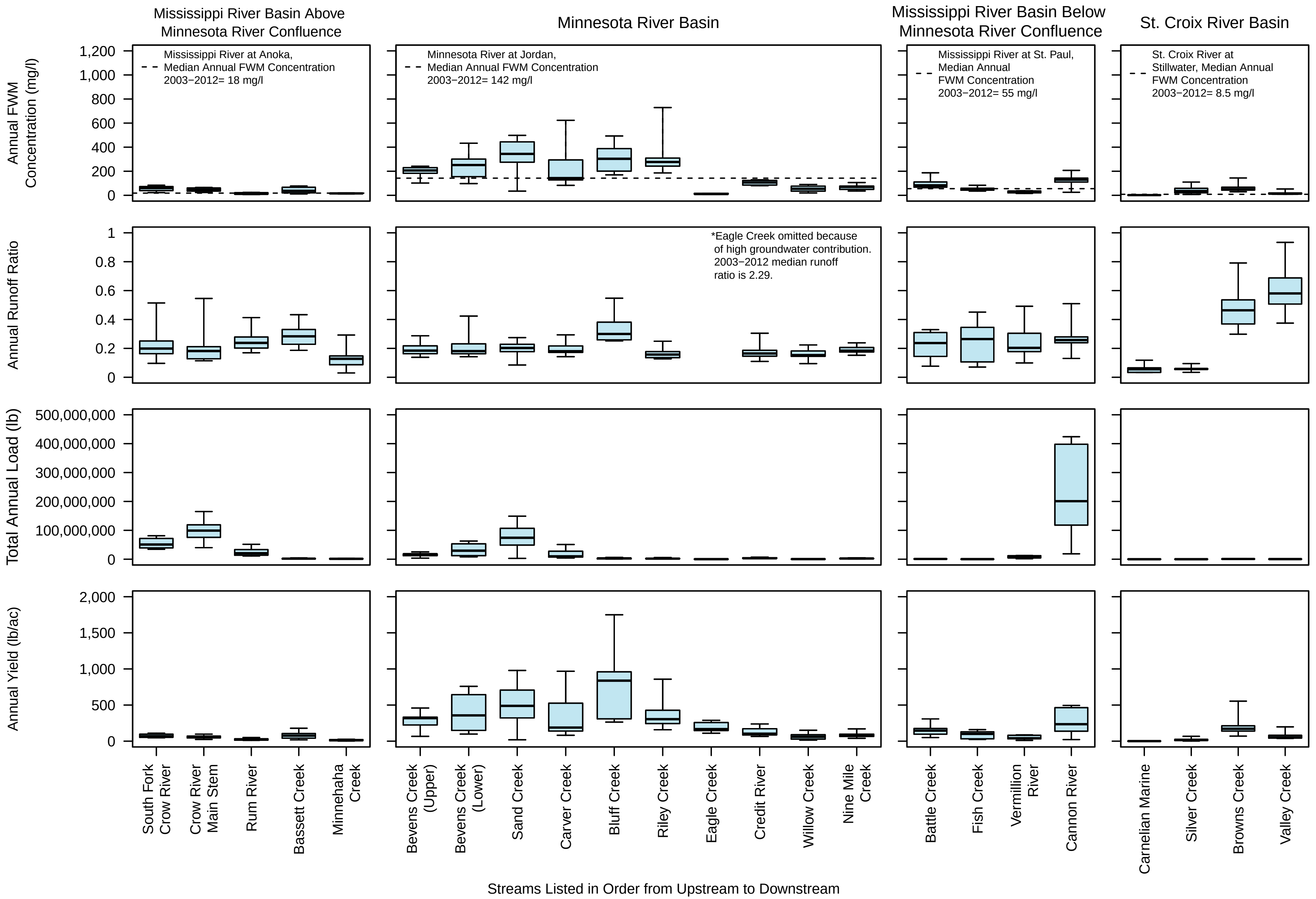


Figure RUM−15: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

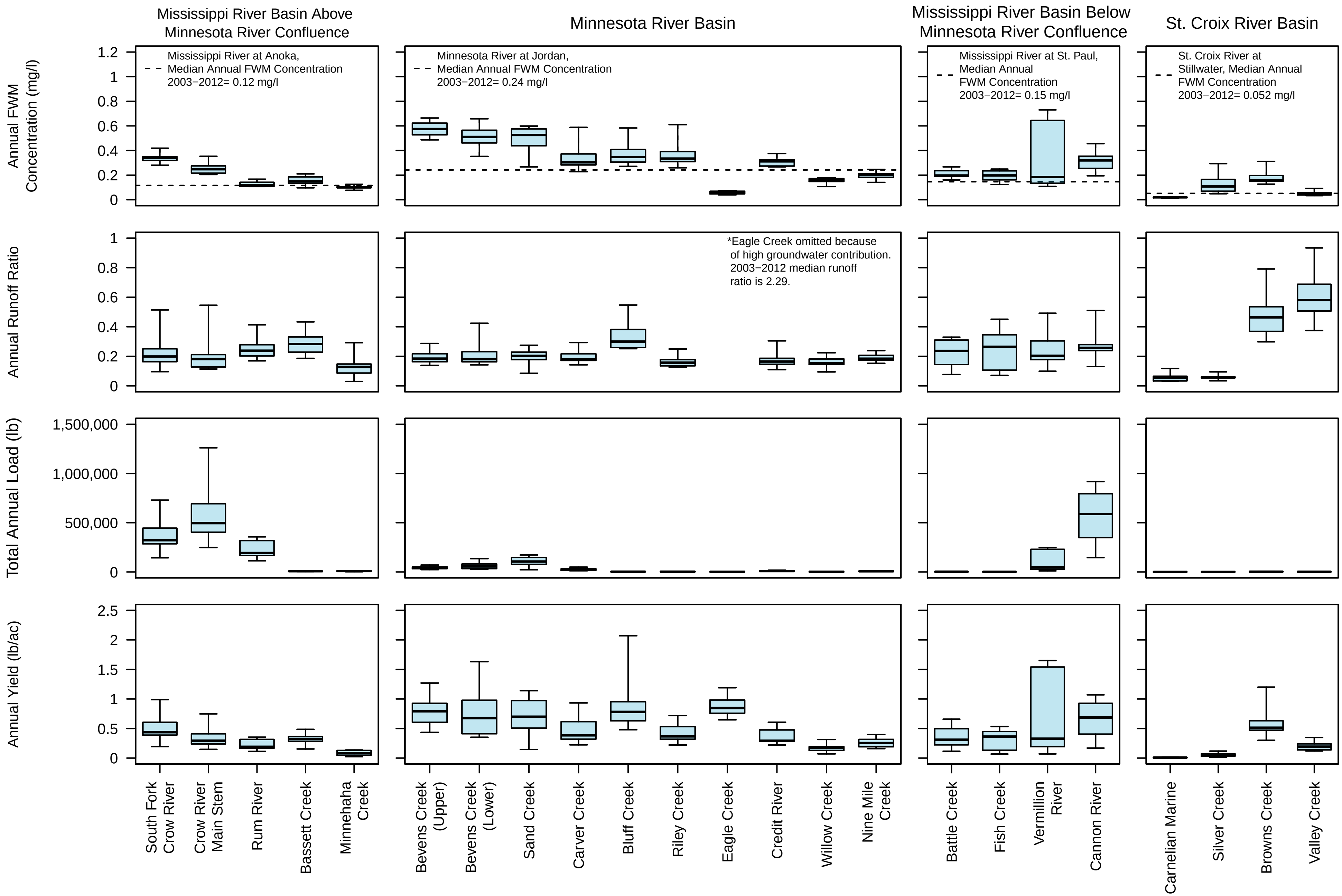


Figure RUM−16: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

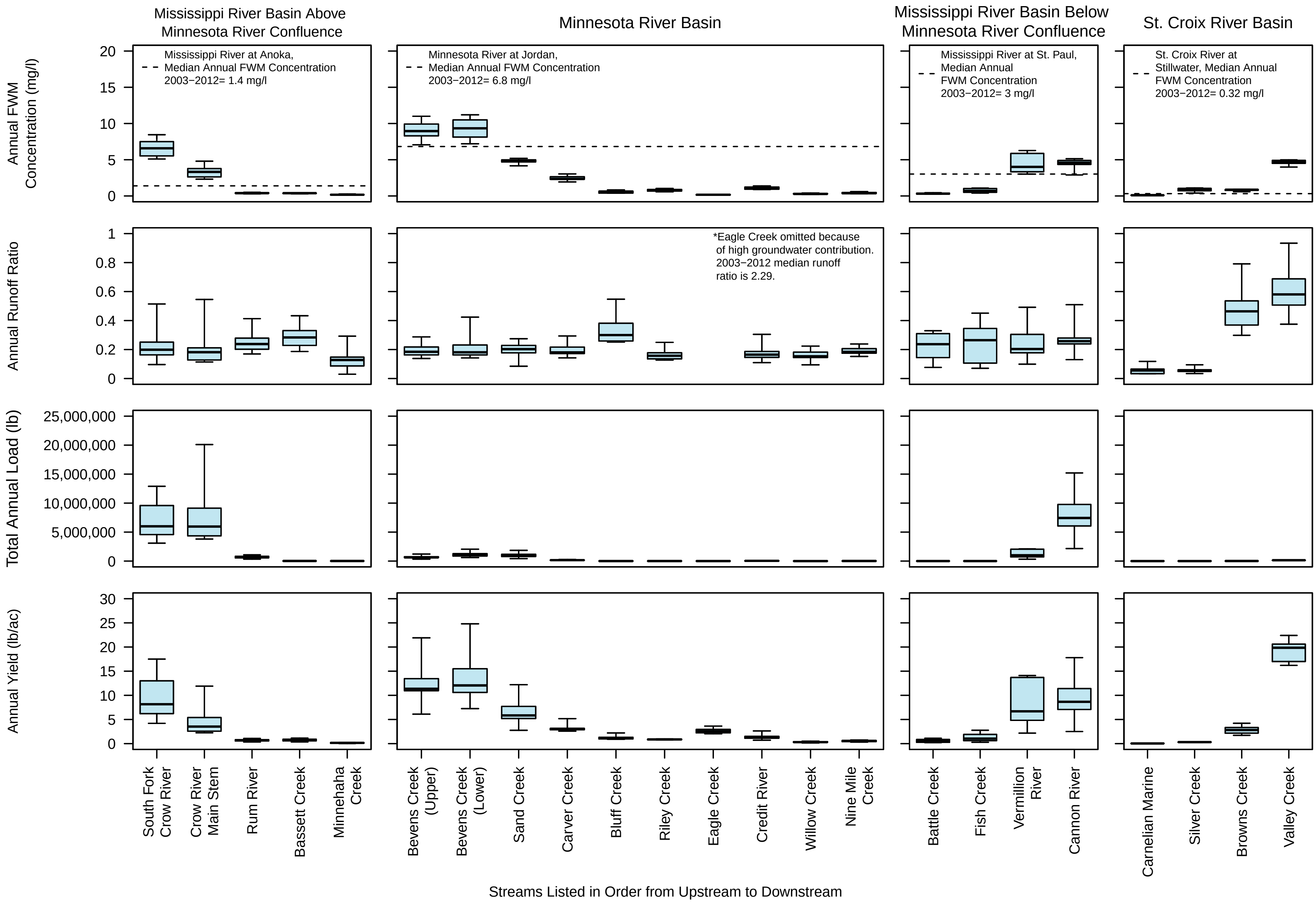


Figure RUM−17: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

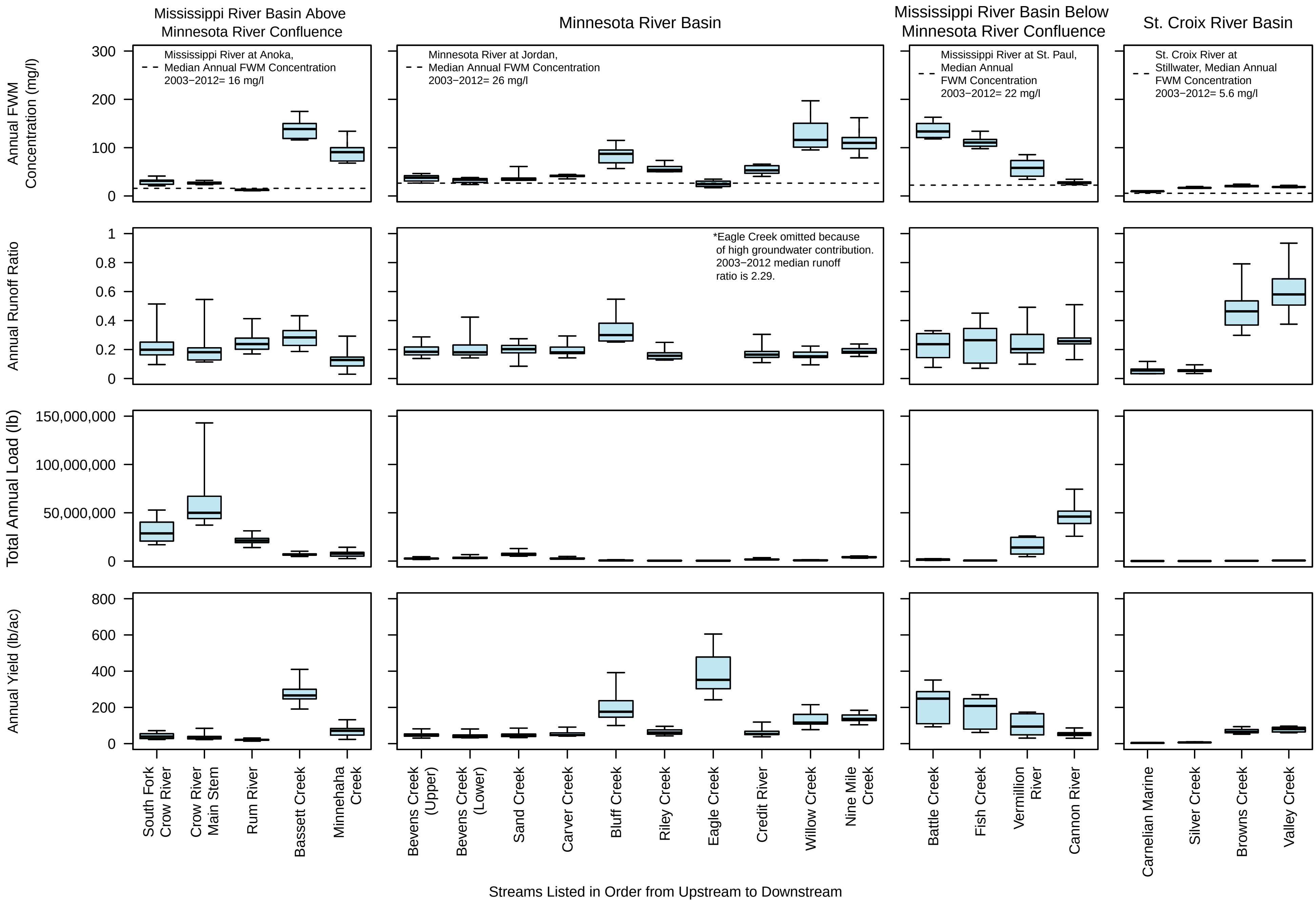


Table RUM-7: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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

Metropolitan Area Trends Analysis

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

Estimated changes for TSS, TP, and NO_3 in MCES-monitored streams are presented below in two ways. First, tabulated results with directional arrows indicate improving (blue upward arrow) and declining (red downward arrow) water quality paired with percent change in flow-adjusted concentration estimated for 2008-2012 (Figure RUM-18). 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 RUM-19). In both figures no trend was reported for those QWTREND analyses with poor quality of statistical metrics (for example, $p>0.05$).

In general, of the 20 monitoring stations assessed, most exhibited improving water quality (and thus decreasing concentration) for TSS, TP, and NO_3. There does not appear to be a spatial pattern for those few stations with declining water quality. There is no station with declining water quality for all three parameters, although both TP and NO_3 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 Mississippi River and its tributaries above the confluence with the Minnesota River typically had lower TSS concentrations than the Minnesota River and associated tributaries, but higher pollutant concentrations than the waters in the St. Croix River Basin. The trend analysis results indicate decreasing TSS flow-adjusted concentrations in all Mississippi River tributaries above the confluence with the Minnesota River with the exception of Bassett Creek. All of the Mississippi River tributaries above the Minnesota River had decreasing trends in both TP and NO_3 from 2008-2012.

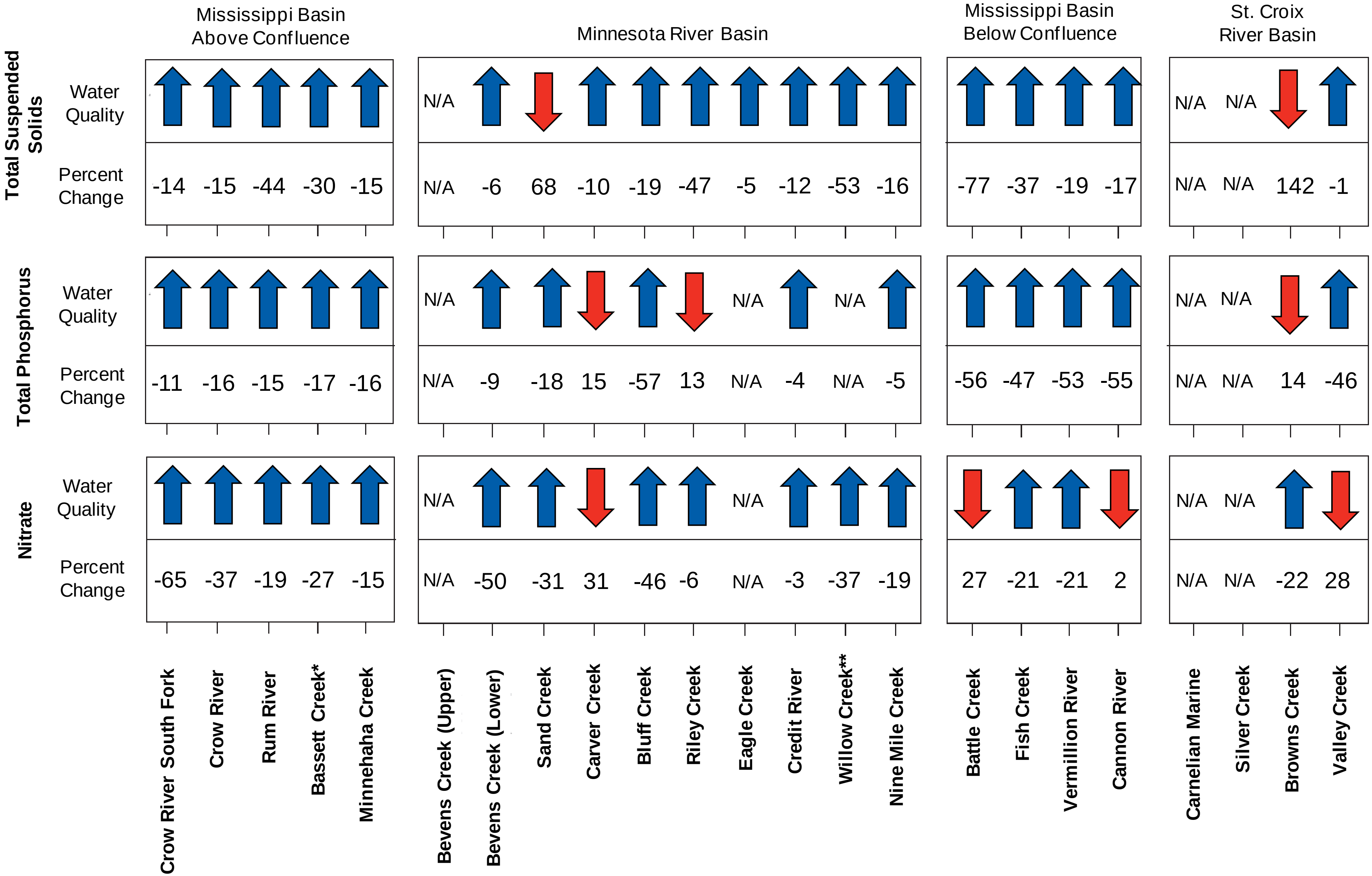
While MCES staff have assessed monitoring data and trend analysis statistics, more work is needed to assign causative actions to the trend analysis results. TSS and TP chemistry, delivery, transport and remediation are complicated although fairly well-understood. Identifying contributing events, implementation practices, and other causative actions is expected to be somewhat straightforward for these two parameters.

NO_3 chemistry and transport dynamics within the natural environmental are significantly more complicated. The NO_3 trends for most of 21 streams assessed in this study showed periods of both rising and falling flow-adjusted concentrations. NO_3 concentrations may be affected by periods of saturated and unsaturated soil conditions related to precipitation patterns, by agricultural crop rotations, by changing levels of fertilizer applications, or other unidentified causative variables, rather than true long-term improvement in concentrations based on intentional implementation of best management practices.

MCES staff will repeat the trend analysis in 5 -10 years, and in the meantime will continue to investigate the $NO_{3,}$ TSS, and TP dynamics in streams entering the metropolitan area with local partners and state agency staff.

Figure RUM-18: 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)



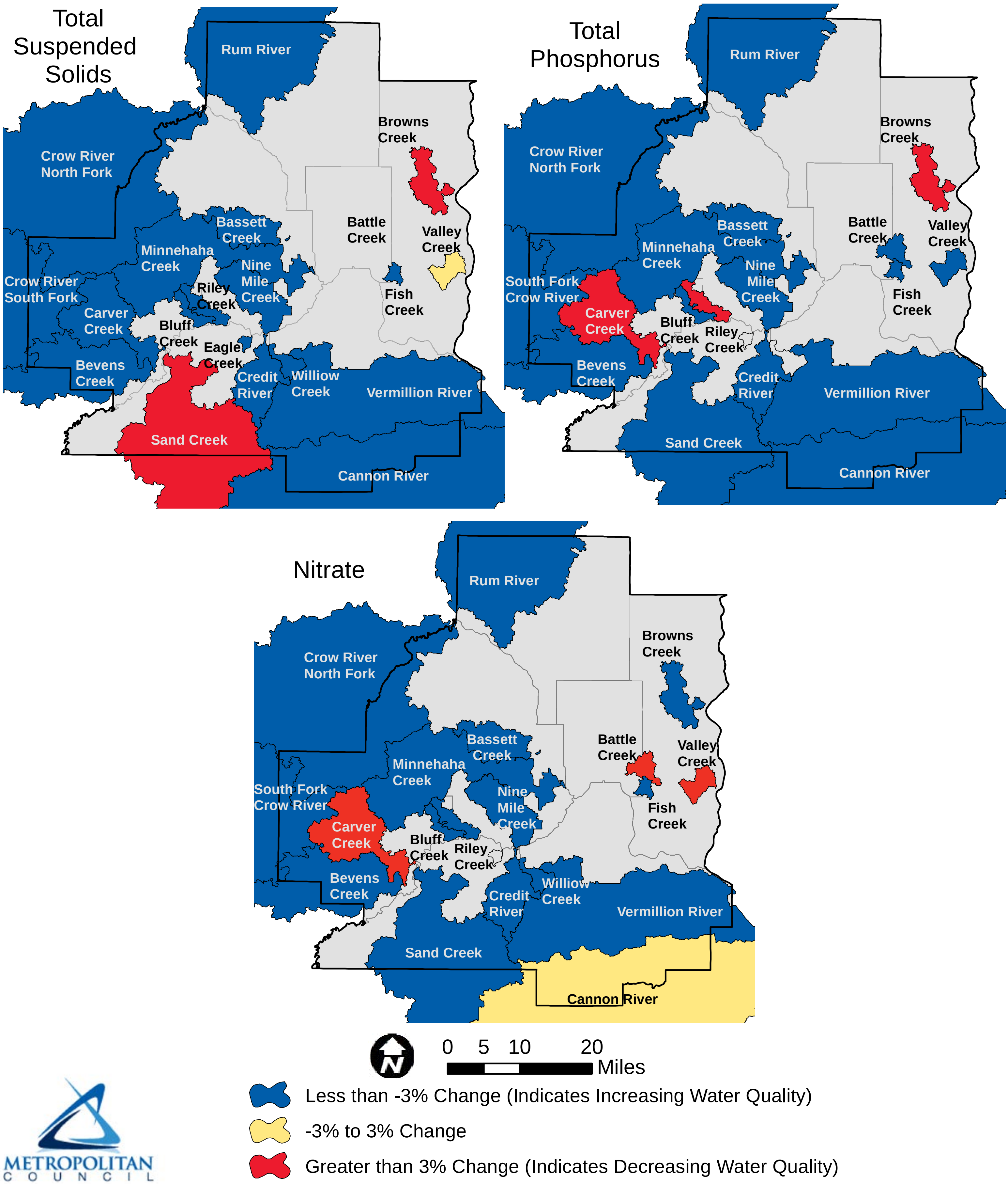
Blue arrows indicate improved water quality; Red arrows indicate declining water quality.

"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 RUM-19: Regional Maps of Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO3, 2008-2012

(As estimated by QWTrend)



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Conclusions

The Rum River is a tributary to the Mississippi River and drains portions of Crow Wing, Aitkin, Mille Lacs, Morrison, Kanabec, Benton, Isanti, Chisago, Sherburne, and Anoka Counties and contains runoff from the cities of Onamia, Milaca, Princeton, Cambridge, Isanti, St. Francis, Bethel, Nowthen, Oak Grove, Andover, and Anoka. The watershed is primarily a mix of forest lands, agricultural, various wetlands and open water, and small pockets of urbanized areas. The northern portion of the watershed is undeveloped and forested gradually transitioning to agricultural and large lot residential in the middle of the watershed and to highly urbanized areas in the southern portion of the watershed.

Twelve major WWTPs discharge to the Rum River. The watershed topography is generally fairly flat, except for the hilly end moraines near Lake Mille Lacs, and in the southwest portion of the watershed encompassing the city of Nowthen. The majority of the southern part of the watershed is in the Anoka Sand Plain. The flow monitoring station is located above the Anoka Dam in Anoka, Minnesota. As of 2013, the water quality monitoring site is immediately downstream of the Anoka Dam and the flow monitoring station, and may be affected by backflows from the Mississippi River.

The water quality in the Rum River is affected by several factors: the water quality of its headwaters (Mille Lacs); land-use change; agricultural activity; WWTP effluent; and the loss of wetlands and upland storage. TSS in the stream (both FWM concentration and load) was low, both in comparison to the Mississippi River and the other MCES-monitored metropolitan area tributaries. The headwater lakes (Mille Lacs, Ogechie, Shakopee, and Onamia Lakes) help to settle out suspended sediments from the upper watershed, and the management activities due to the Wild, Scenic, and Recreational River designation help to reduce the amount of suspended sediments in the lower watershed.

The NO_3 loads and concentrations are likely driven by agricultural activity in the watershed. The concentration and loads in the Rum River are lower than those in the Mississippi River, and are lower than most of the other MCES-monitored metropolitan area tributaries. Trend analysis indicates one trend of falling concentration in the Rum River, although MCES staff believe NO_3 trends may be affected by periods of saturated and unsaturated soil conditions related to periods of high and low precipitation, agricultural crop rotations and fertilizer application rates, rather than response to intentional implementation practices. MCES staff plan to repeat the trend analysis in 5 – 10 years, and in the mean time will continue to investigate NO_3 dynamics with local and state agency partners.

The Rum River phosphorus loads and concentrations are likely affected by agricultural activity and effluent discharge from the twelve WWTPs that discharge effluent into the river. The concentration in the Rum River is equal to that in Mississippi River, and is generally lower than the MCES-monitored tributaries in the Minnesota and St. Croix River basins. This can most likely be attributed to the Wild and Scenic River designation that restricts the expansion or introduction of new sewage, industrial waste, or other wastes unless there is not a prudent or feasible alternative (Minnesota Rule 7050.0180). Trend analysis indicates a decrease in TP since 2002. Changes in TP are likely due to increased implementation of agricultural practices and the implementation of P-removal at the WWTPs.

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

Trend analysis indicated both upward and downward trends in TSS and TP concentrations since 1996; the most recent trend is of decreasing TSS and TP concentrations and thus increasing water quality. These improvements may reflect the level of management practices, including stream bank stabilization, WWTP TP-removal, conservation tillage, agricultural buffer strips, field terracing, etc. implemented by municipalities, WMOs, WWTP operators, farmers, and citizens within the Rum River watershed. This study did not identify causative actions affecting water quality trends. The trend analysis will be repeated in 5 -10 years; in the meantime, MCES staff will work with local and state agency partners to identify factors that may be affecting water quality dynamics and trends.

Recommendations

This section presents recommendations for monitoring and assessment of the Rum River, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations are ideally suited to target and implement volume reduction, pollutant removal, and stream restoration projects within the watershed. It is beyond the scope of this document to suggest locations for implementation projects. Instead, MCES encourages the local water management organizations to use the results of this report to leverage funding and partnerships to target, prioritize, and implement improvement projects. MCES will repeat its analysis of water quality trends in 5 -10 years, to assess potential changes in water quality.

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

- MCES should work with our partners to indentify all of the water quality and flow monitoring that is occurring on the Rum River and its tributaries on a regular basis, to avoid duplicating efforts.
- MCES and partners (especially MnDNR, Anoka Conservation District, URRWMO, and LRRWMO) 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 plans to repeat the water quality trend analysis in 5 – 10 years.
- MCES should collaborate with MPCA and MnDNR to enhance the presence of wild rice stands, especially those within the 7-county metropolitan area. One potential action would be to increase collection of sulfate data at the monitoring station.
- As resources allow, MCES should provide local partners with information about the heightened potential for surface waters to be impacted by groundwater changes in the Rum River watershed. This information should be included in watershed and local surface water management plan updates.
- MCES and partners should host educational outreach meetings to provide citizens with information about surface water - groundwater interactions and how groundwater

withdrawals may affect lake levels in the watershed. These meetings could easily be tied to the importance of water conservation in reducing water withdrawals from the region's aquifers.

- MCES should consider collaborating with the St. Francis High School students and staff to add annual macroinvertebrate sampling to the Rum River stations. MCES and partners should also consider adding a Stream Habitat Assessment similar to the habitat surveys performed by the MPCA.
- Prior to the 2013, MCES collected sulfate concentrations at the Rum River at Anoka Dam. Since the Rum River has now been transferred to the MCES River Program, the water collected is not analyzed for sulfate. MCES should resume sulfate analysis due to the current interest in sulfate concentrations and wild rice abundance.

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