Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

FISH CREEK

METROPOLITAN COUNCIL

December 2014

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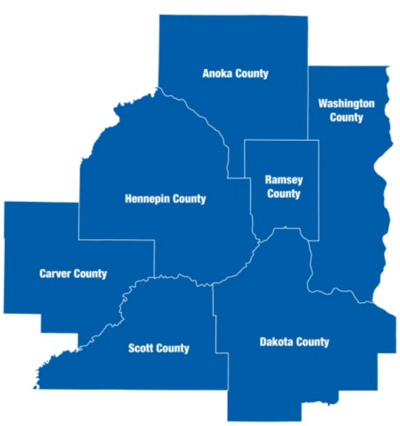

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide 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 cooperators conducted the stream monitoring work, while MCES staff performed the data analyses, compiled the results and prepared the report.

About This Section

This section of the report, *Fish Creek*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located in Ramsey and Washington counties, Fish Creek is one of the eight Mississippi River tributaries examined. This section discusses a wide range of factors that have affected the condition and water quality of Fish Creek.

Cover Photo

The photo on the cover of this section depicts Fish Creek. It was taken by the City of Maplewood.

Recommended Citations

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Content

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Introduction

Fish Creek is located in the central eastern metropolitan area and is a tributary to the Mississippi River, below the Mississippi's confluence with the Minnesota River. It drains approximately 4.6 square miles of mostly urban areas through portions of the cities of Woodbury, Maplewood, Newport, and Saint Paul, in Ramsey and Washington Counties.

Figure FC-1: Fish Creek Natural Area Greenway

Photo Credit: City of Maplewood

This report:

- documents those characteristics of Fish 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 Fish 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 summary reports.

Partnerships and Funding

MCES has supported water quality monitoring of Fish Creek since 1995 as part of the Watershed Outlet Monitoring Program. MCES partners with the Ramsey-Washington Metro Watershed District (RWMWD) to operate the station.

Monitoring Station Description

The monitoring station is located on Fish Creek in Saint Paul, Minnesota, 0.2 mile upstream from the creek confluence with the Mississippi River. The monitoring station is located about 300 feet east of Hwy 61. The station includes continuous-stage monitoring, collection of base-flow grab samples, and collections of event-based composite samples. Stage is measured with a gas-purge bubbler system. Stage is calibrated on-site visits with an onsite staff gauge. A continuous discharge record is obtained by relating stage to flow with a rating curve unique to the site. Stage-discharge measurements are made with an acoustic Doppler velocimeter several times a year, and the rating curve is adjusted when rating points fall significantly off the existing rating curve, or a change in the station cross-section is observed.

There is no rain gauge at this station; daily precipitation totals from Minnesota Climatology Working Group stations 217377-Saint Paul, 218450-University of Minnesota Saint Paul, and 217379-Saint Paul 3SW were used to create the hydrograph in the ***Hydrology*** section of this report. For the analysis of precipitation-weighted loads, MCES used the Minnesota Climatological Working Group's monthly 10-kilometer gridded precipitation data to ensure the variability of rainfall within the watersheds was represented (Minnesota Climatology Working Group, 2013). This data is generated from Minnesota's HIDEN (High Spatial Density Precipitation Network) dataset. The gridded data was aerially-weighted based on the watershed boundaries.

The Fish Creek station has been in operation continuously since June 1995, with the first full year of sample collection beginning in 1996, with the exception of 2000 when there was an equipment failure. This report will use flow data beginning in June 1995, and water quality sampling data from 1996-2012.

Stream and Watershed Description

Fish Creek is almost two miles long and originates at the outlet of Carver Lake in northwestern Woodbury. It then flows through Maplewood and Saint Paul before discharging into Eagle Lake and ultimately into the Mississippi River.

The Fish Creek watershed contains one major lake. The entire eastern part of the watershed, 2,242 acres, or about 77% of the watershed first drains to Carver Lake (surface area 49 acres) in Woodbury (RWMWD, 2007). The western part of the watershed downstream of Carver Lake, 685 acres, or about 23% of the watershed, drains directly to Fish Creek through overland flows and storm sewer. Water quality in Fish Creek is partially driven by water quality in Carver Lake, which tempers creek flashiness somewhat and evens out peaks in pollutant concentration.

The Fish Creek watershed is a total of 2,952 acres, with 2,932 acres (99.3%) of the watershed upstream of the monitoring station (Figure FC-2; Table FC-1). The watershed is mostly developed, with 1,730 acres/58.6% (1,719 acres/58.6% monitored) of urban land and only 37 acres/1.3% (37 acres/1.3% monitored) of agricultural land. The watershed encompasses portions of the cities of Woodbury and Maplewood, a small part of Newport, and at the very downstream end, a small portion of Saint Paul. The entirety of the Fish Creek watershed is within the Metropolitan Council's jurisdiction (Council Districts of 11, 12, and 13).

The watershed is most heavily urbanized in the eastern, upstream portion of the watershed, and has more undeveloped forests, meadows, and wetlands nearer to the stream outlet. There is a large nursery in the south central portion of the watershed. Other primary land covers in the watershed are forest, grasses/herbaceous, and wetlands. The Fish Creek watershed lies within with the Ramsey-Washington Metro Watershed District, an independent governmental unit responsible for protecting the water resources of the watershed.

Table FC-1: Fish Creek Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	194	6.6%	0	1.1%	194	6.6%
11-25% Impervious	116	3.9%	9	48.3%	125	4.2%
26-50% Impervious	563	19.2%	0	0.0%	563	19.1%
51-75% Impervious	470	16.0%	0	1.1%	470	15.9%
76-100% Impervious	376	12.8%	2	9.2%	378	12.8%
Agricultural Land	37	1.3%	0	0.0%	37	1.3%
Forest (all types)	429	14.6%	8	40.2%	437	14.8%
Open Water	48	1.7%	0	0.0%	48	1.6%
Barren Land	0	0.0%	0	0.0%	0	0.0%
Shrubland	27	0.9%	0	0.0%	27	0.9%
Grasses/Herbaceous	472	16.1%	0	0.0%	472	16.0%
Wetlands (all types)	200	6.8%	0	0.0%	200	6.8%
Total	**2,932**	**100.0%**	**20**	**100.0%**	**2,952**	**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 seven-county metro area; and the 2001 NLCD (National Land Cover Data), which covered the outstate areas not included in the 2008 MLCCS.

Figure FC-2

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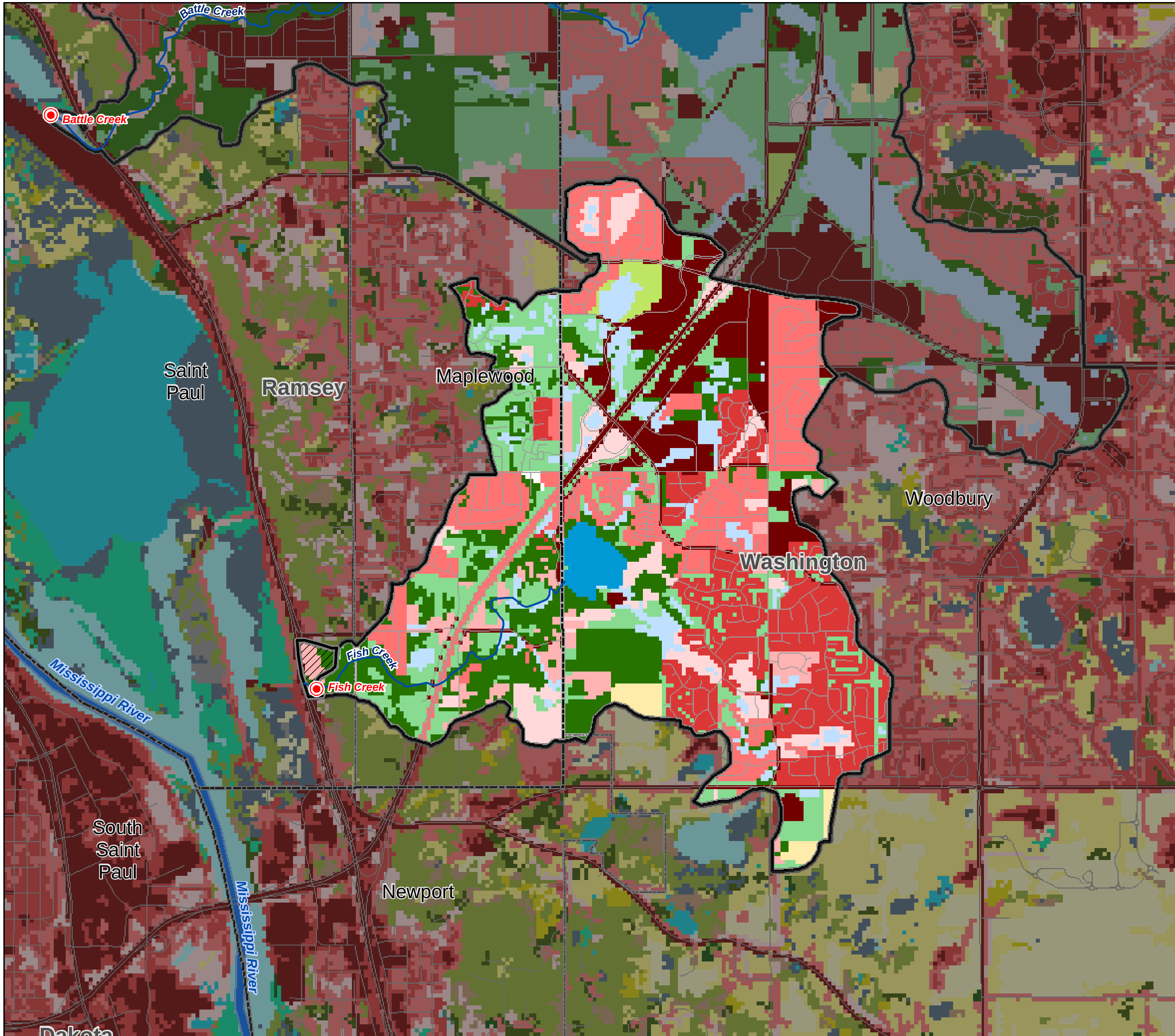
MLCCS-NLCD Hybrid Land Cover

Fish 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						
Fish Creek						
	Monitored		**Unmonitored**		**Total**	
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Wetlands (all types)	200	6.8%	0	0.0%	200	6.8%
Total	**2,932**	**100.0%**	**20**	**100.0%**	**2,952**	**100.0%**

0 0.25 0.5 0.75 1

Miles

According to the STATSGO soils data of the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), nearly all (99.7%) of native soils in the monitored part of the Fish Creek watershed are type B soils, which have moderately low runoff potential (USDA, 2009). Small pockets of type A soil, which have low runoff potential, exist at the very western edge of the watershed, within the floodplain. Because the Fish Creek watershed is heavily urbanized, many of the native soils have been disturbed, and the STATSGO database may not be representative of actual conditions. For installation of infiltration practices, soil borings should be taken from the exact location of the proposed site location to assess level of soil filling or disturbance.

The watershed surficial geology is sandy, hummocky till in the eastern part of the watershed, with glacial outwash in the western part of the watershed (Meyer, 2007). Fish Creek discharges to the Mississippi River floodplain on an alluvial fan. The maximum watershed elevation is 1092.2 MSL and the minimum elevation is 737.2 MSL within the monitored area (Figure FC-3). The watershed is highest along its northern border, and lowest in the west, where the creek enters the Mississippi River floodplain. Slopes in the watershed are generally gradual: 7% of slopes within the monitored area are considered steep, and an additional 4% are considered very steep. Steep slopes are those between 12-18%, and very steep slopes are those 18% or greater (MnDNR, 2011). The majority of steep slopes in the watershed are around Carver Lake, and in a ravine that carries Fish Creek through the Mississippi River bluffs. The creek average gradient is 100.6 feet/mile.

There are few pollutant point sources within the Fish Creek watershed (Figure FC-4). The watershed contains two facilities holding industrial stormwater permits, both of which are within the monitored part of the watershed, upstream of Carver Lake. Both facilities have multiple discharge points shown on Figure FC-4. There are no cooling, potable water, dewatering facilities, industrial or domestic wastewater facilities, or any feedlots in the watershed.

RWMWD and the cities within its borders have undertaken a number of capital improvement projects in the Fish Creek watershed to address water quality since the advent of the MCES monitoring station. In 2006, the watershed completed a pilot project to replace the pavement in two cul-de-sacs in Woodbury, southeast of Carver Lake, with porous pavers (RWMWD, n.d.a). The pavers encourage infiltration of stormwater that would have previously discharged untreated to Carver Lake. In 2007, the watershed district completed improvements in the Fish Creek ravine, just upstream of the MCES monitoring station, where a major storm event had caused considerable damage (RWMWD, n.d.b). Channel and drop structures were reinforced, and a flood diversion pipeline was extended, which carries high velocity, damaging flood flows in a pipe to protect the natural channel. Low flows continue to be routed around the diversion pipeline to sustain the creek.

The City of Maplewood, along with partners including RWMWD and Ramsey County, has also worked to preserve the entire corridor along Fish Creek as the Fish Creek Natural Area Greenway (City of Maplewood, n.d.). The vision for the greenway calls for protection and stewardship of natural areas along the creek.

Figure FC-3

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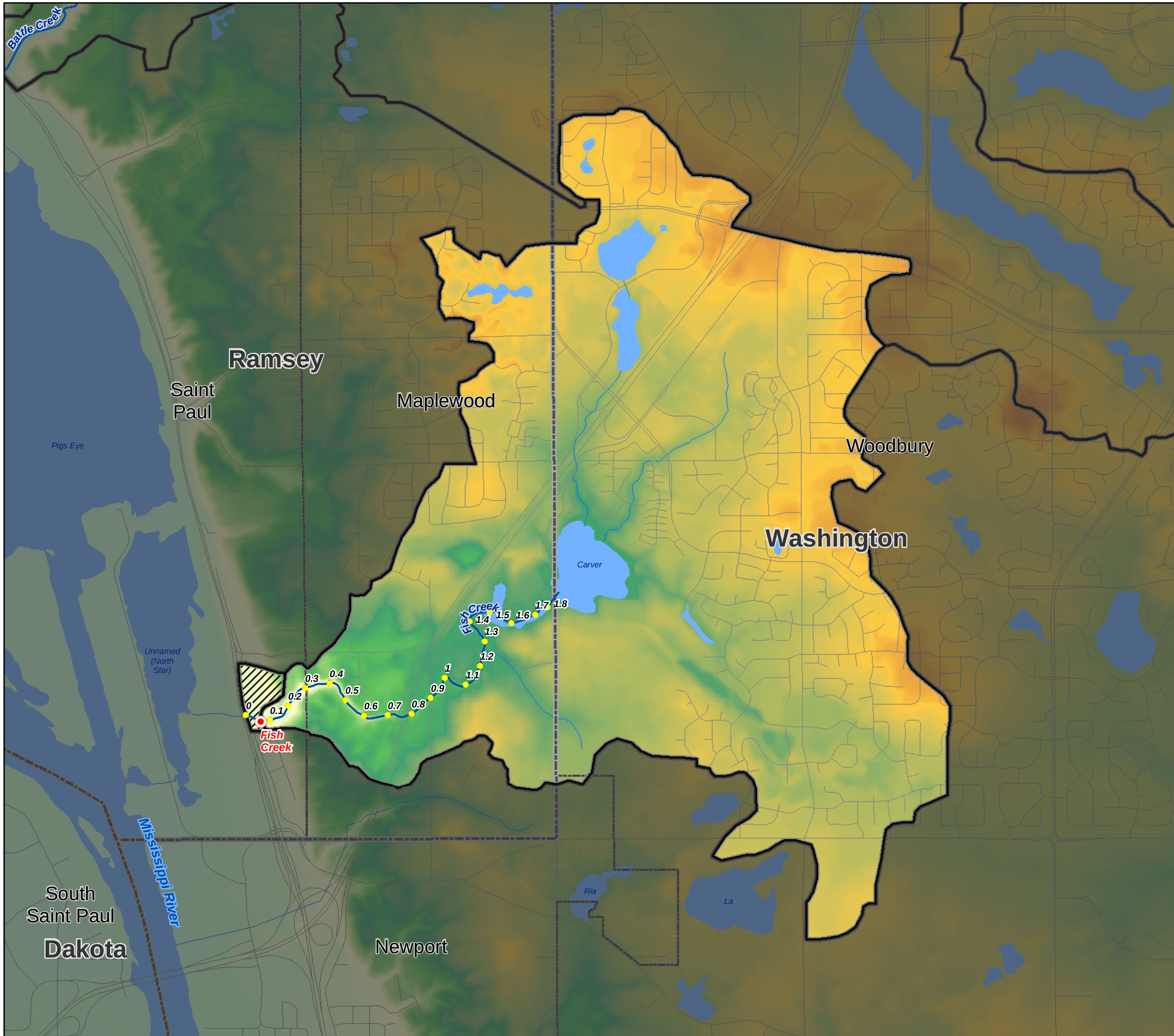
Watershed Topography

Fish Creek



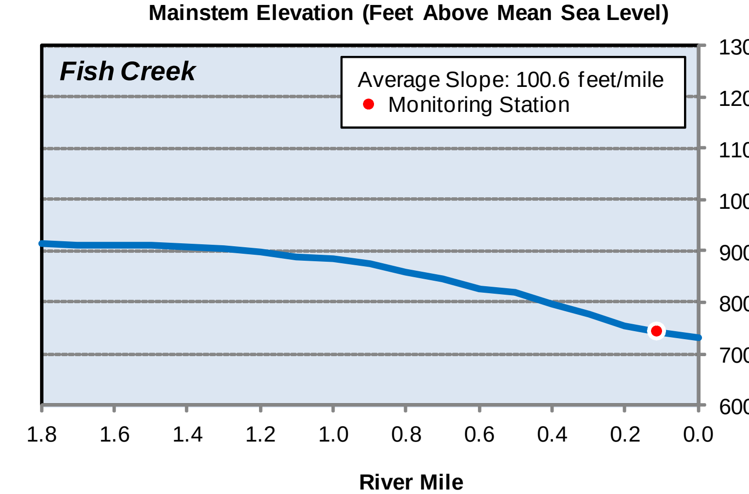
- MCES Stream Monitoring Sites
- USGS Flow Stations
- Stream Mile Markers
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- Public Waters Inventory
- Other Rivers and Streams
- City and Township Boundaries
- County Boundary
- NCompass Street Centerlines, 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 0.2 0.4 0.6 0.8 1 1.2
Miles

Figure FC-4

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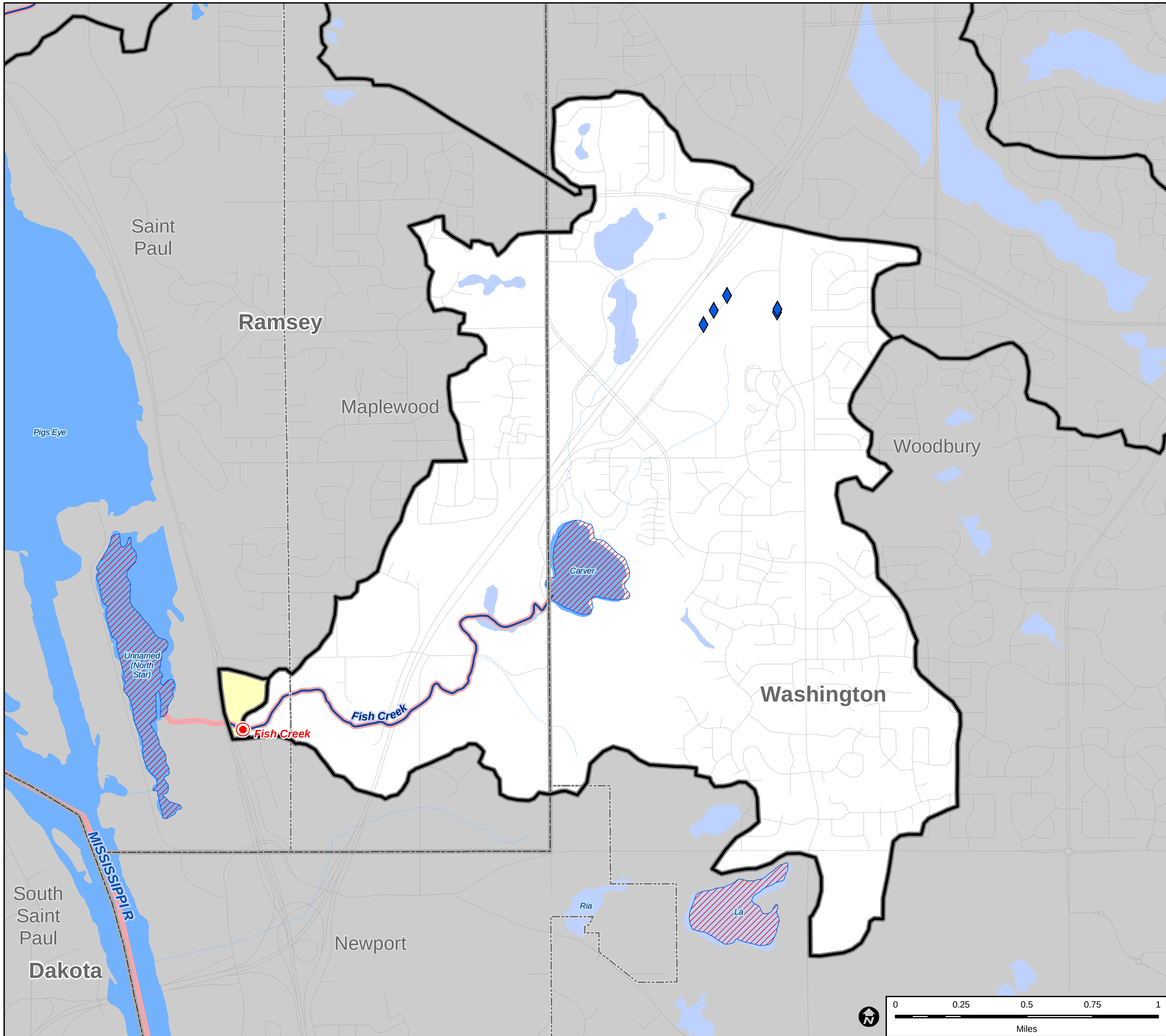
Public and Impaired Waters and Potential Pollution Sources

Fish 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

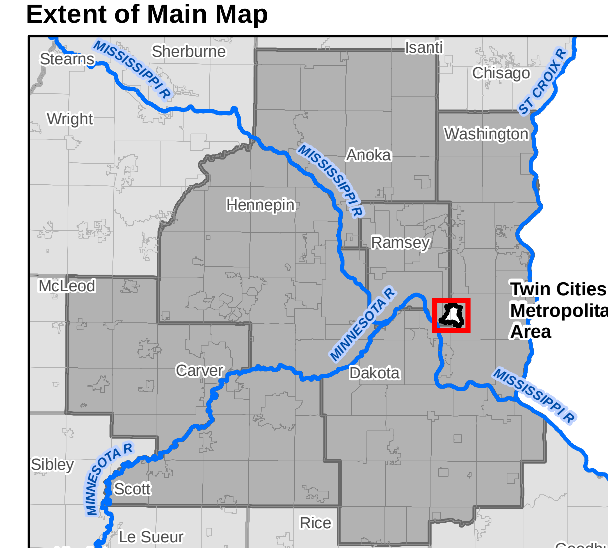
Feedlots with 100 or more animal units **

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

- Impaired Lakes (2014 Draft MPCA 303(d) List) **
- Impaired Streams (2014 Draft MPCA 303(d) List) **
- Other Rivers and Streams *
- Lakes and Other Open Water (PWI) *
- Wetlands (PWI) *
- Designated Trout Streams *
- NCompass Street Centerlines, 2013
- County Boundary
- City and Township Boundaries

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

Extent of Main Map



Water Quality Impairments

The Fish Creek watershed contains one lake that is included on the MPCA 2014 303d list (Figure FC-4; Tables FC-2 and FC-3). Fish Creek is impaired for its entire length from Carver Lake to Eagle Lake for aquatic recreation based on elevated *E. coli* counts.

Table FC-2: Fish Creek Impaired Stream Reaches as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Affected Use(s)[1]	Approved Plan	Needs Plan
Fish Creek	Carver Lake to Unnamed (North Star) lake	07010206-606	AQR	--	*E. coli*

[1] AQR = Aquatic Recreation;

Carver Lake is impaired for aquatic consumption based on mercury and is covered by the statewide Total Maximum Daily Load (TMDL) for mercury. Carver Lake is also impaired for aquatic life based on excess chloride. Carver Lake was previously impaired for aquatic recreation based on excess nutrient levels; however, based on additional monitoring, Carver Lake was delisted for excess nutrients on the 2014 list.

Table FC-3 : Fish Creek Watershed Impaired Lakes as Identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Affected Use(s)[1]	Approved Plan[2]	Needs Plan[2]
Carver	82-0166-00	AQC, AQL	HgF, Nutrients (delisted for Nutrients in 2014)	Cl

[1] AQC = Aquatic Consumption; AQL = Aquatic Life
[2] HgF = Mercury in Fish Tissue; Cl = Chloride

Hydrology

MCES has monitored flow on Fish Creek since June of 1995. Flow measurements are collected at 10-minute increments (sometimes 5-minute increments in earlier years) and aggregated to daily averages. The monitoring equipment on Fish Creek is removed each fall to ensure equipment doesn't freeze, and then reinstalled in the spring. Daily averages during this winter period are estimated using staff gauge readings taken throughout the winter. The hydrograph of Fish Creek, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variation in flow rates both during the year and from year to year (Figure FC-5), and the responsiveness of flow to precipitation events.

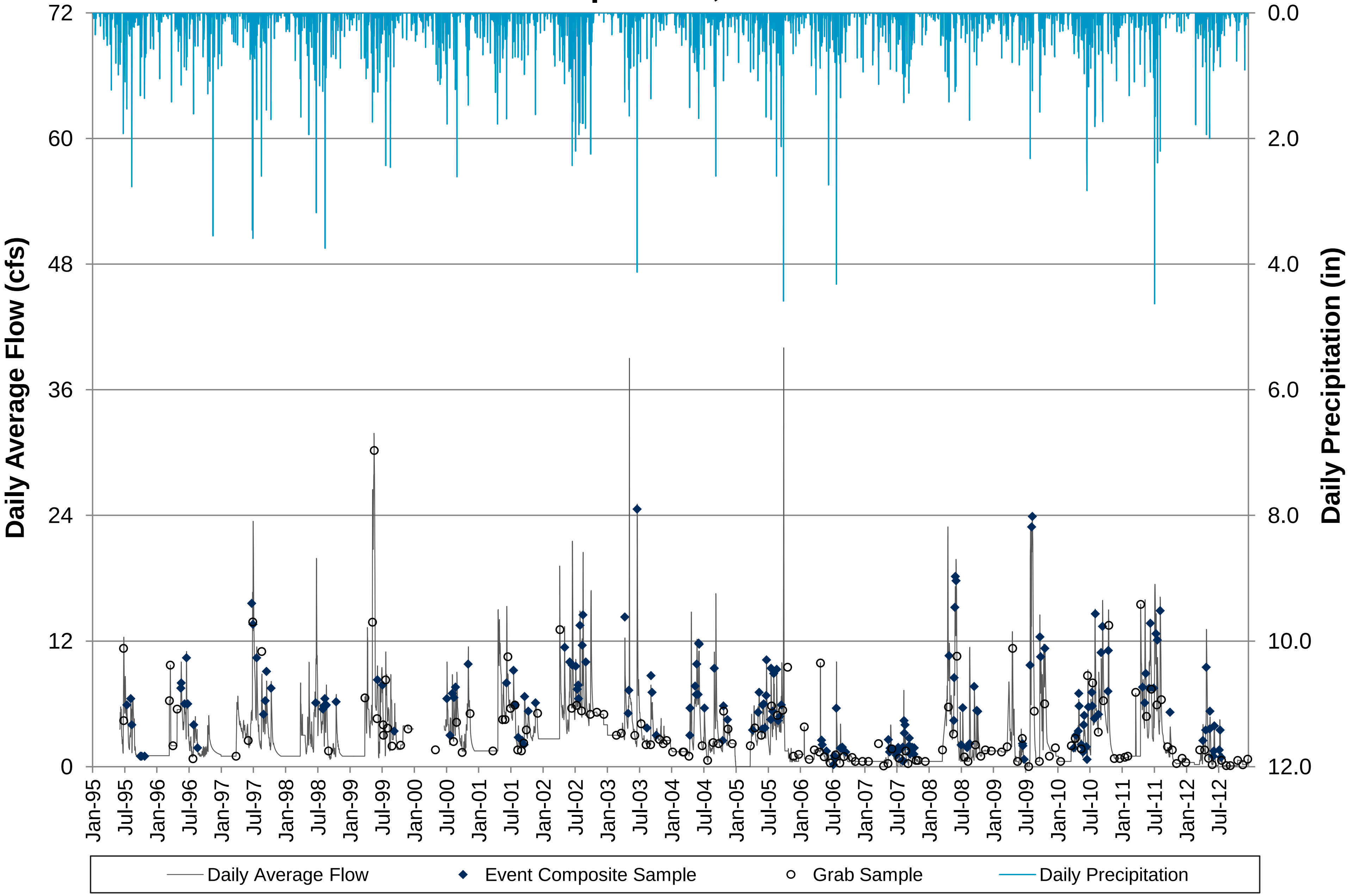
The MCES sampling program specifies collection of baseflow grab samples between events and event-based composites. The hydrograph indicates samples were collected during most events and that baseflow was also adequately sampled.

The MnDNR monitors water levels on Carver Lake. Carver Lake discharges were estimated using the MnDNR water levels (MnDNR, 2013) and a RWMWD rating curve determined from survey information and HEC-RAS modeling (J. Koehler, Barr Engineering, personal communication, July 25, 2013). Carver Lake has an important influence on Fish Creek's hydrology. The discharge from Carver Lake accounts for a median percentage of 105% of Fish Creek flow. On occasions the lake discharges much more flow than recorded in the stream and the water may be impounded or lost upstream. However, there are periods during drought or winter when Carver Lake does not discharge at all.

Flow duration analysis of daily average flows indicates the upper 10th percentile flows for the period 1995-2012 ranged between approximately 6.3 and 40 cfs, while the lowest 10th percentile flows ranged from 0 to 0.5 cfs (See Figure FC-12 in the ***Flow and Load Duration Curves*** section of this report).

Additional annual flow/volume metrics are shown on Figures FC-6 to FC-9, along with the annual pollutant load parameters. The first graph on each sheet illustrates an annual flow metric − average annual flow (a measure of annual flow volume); areal-weighted flow; and fraction of annual precipitation converted to flow. Figure FC-6 indicates that the highest average annual flow (and thus the highest volume of flow) during 1996-2012 occurred during 2002 (approximately 5.5 cfs average annual flow); the lowest in 2007 and 2012 (approximately 0.8 cfs average annual flow).

Figure FC-5: Fish Creek Daily Average Flow, Sample Flow, and Precipitation, 1995-2012*



*Flow data was not available for the first half of 2000; precipitation record was acquired from NWS COOP stations: 217377-St. Paul, 218450-Univ of Minn St. Paul, and 217379-St. Paul 3SW

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 Fish Creek to groundwater withdrawals, MCES staff examined spatial datasets of vulnerable stream segments and basins identified as part of the 2010 regional groundwater analysis. The majority of Fish Creek, Carver Lake, and all ponds and wetlands within the watershed are not identified as being vulnerable, as the water table is modeled below the elevation of each waterbody. However, the last approximately 1500 feet of Fish Creek that cuts down through the Mississippi River bluff line is considered potentially vulnerable, with the estimated creek surface bottom elevation below the water table.

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

Pollutant Loads

The U.S. Army Corps of Engineers program Flux32 (Walker, 1999) was used to convert daily average flow, coupled with concentrations based on grab and event-composite samples, into annual and monthly loads and flow-weighted mean concentrations. Loads were estimated for TSS, TP, TDP, NO_3, NH_3, and Cl for each full year of monitored data in Fish Creek (1996-2012). Flow monitoring and sampling began in June 1995, but loads are calculated beginning in 1996, the first complete year of data collection. (The Fish Creek monitoring station was out of commission in 2000 due to an equipment failure; therefore, results are not presented for that year.)

Figures FC-6 through FC-9 illustrate annual loads expressed as mass, as flow-weighted mean (FWM) concentration, as mass–per unit area (lb/ac), and as mass per unit 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, and runoff ratio). A later section in this report (***Comparison with Other Metro Area Streams***) offers graphical comparison of the Fish 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 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 was relatively stable except in 2006, 2007, and 2012 when it dipped substantially. Year-to-year variation is likely influenced by drought periods, by low soil moisture during prior dry periods, by increased capacity in upland storage areas during drought periods, as well as other factors. Because the creek originates at Carver Lake, drought effects can be prolonged. A drop in Carver Lake water level can take several years to recover, causing low creek flows to persist even through wet years.

The annual mass loads for all parameters exhibited significant year-to-year variation, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream.

The annual FWM concentrations for all parameters also fluctuated from year to year and were likely influenced by annual precipitation and flow. TSS, TP, TDP, and NH_3 generally decreased since 2008. The NO_3 concentration decreased consistently from 2005 to 2011, before ticking up slightly in 2012. NH_3 also had an observable decrease from the 2001-2007 period to the 2009-2012 period, with an anomalous high concentration in 2008. There was not adequate monitoring data available for Carver Lake to indicate whether changes in the NO_3 and NH_3 concentration in the stream are related to changes in the lake. Cl concentrations increased slightly over time. The increase in Cl concentrations was likely due to application of road salt during winter, as well as export of salt that has built up in Carver Lake.

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

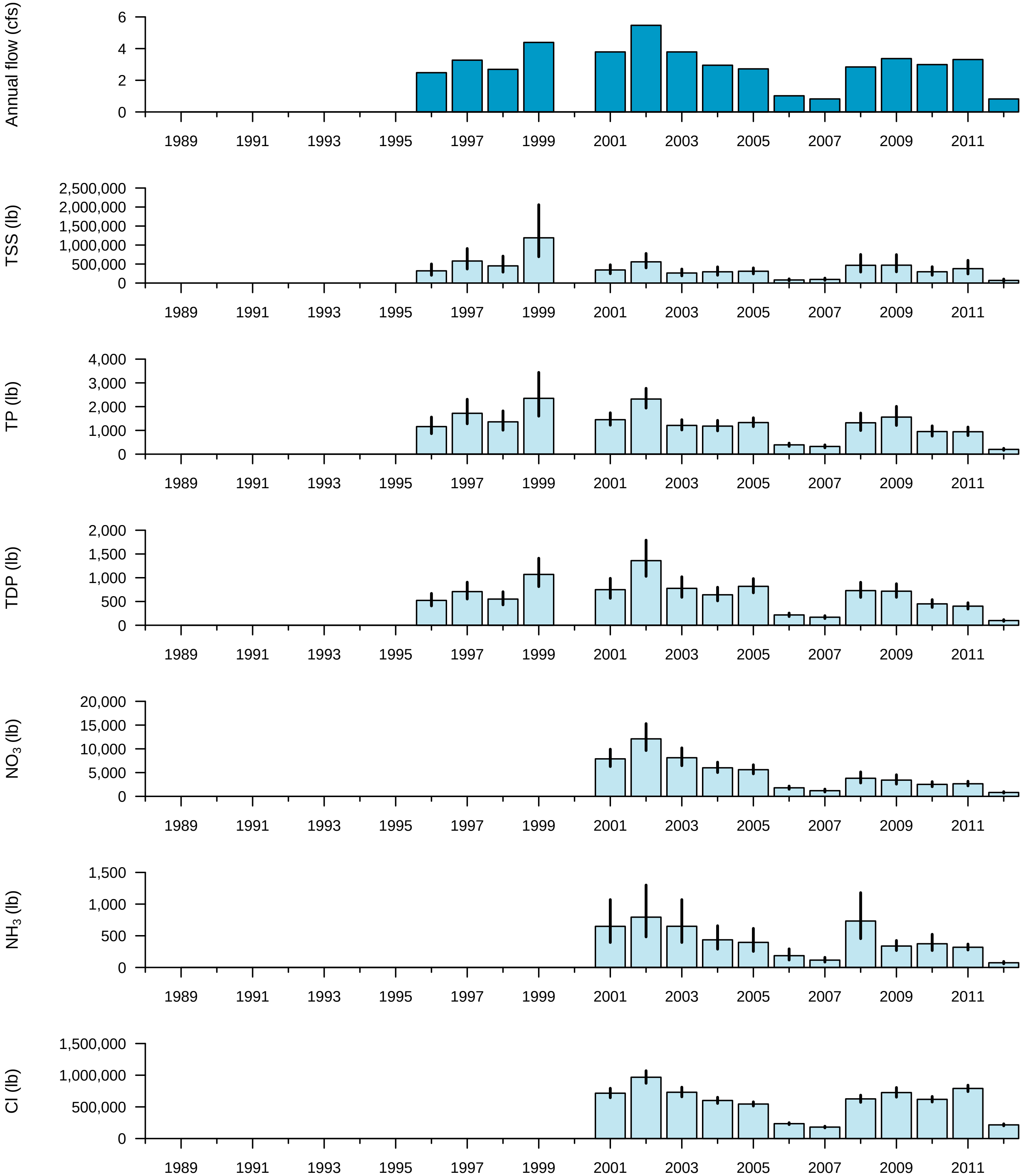
The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of time-related patterns in the loads in Fish Creek (Figure FC-10 and FC-11). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for Fish Creek) and the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

For all constituent pollutants in Fish Creek, the mass load was low in the months of January through March and then increased in April, likely due to effects of snow melt and spring rains. Mass load usually peaked in May or June before decreasing slightly in July. The mass peak was likely later in the season than many other MCES monitored streams because flow and concentration in Fish Creek are largely lake driven. Mass load then peaked again in August and decreased slightly in September and October. This secondary load pulse is likely due to later summer storms and then fall precipitation occurring after tree leaf fall and vegetation die-off. Loads fell off in November and December as Carver Lake froze and snowpack began to build.

The FWM concentration showed less month-to-month variability than the loads. TSS and TP concentrations were highest in spring and fall, corresponding to high flow periods. TDP concentrations were fairly stable, but a little lower in the winter as compared to the rest of the year. NO_3 concentrations were very stable throughout the year. Cl concentrations were lower in the summer than the rest of the year, likely reflecting the impact of road de-icers during winter months. There was not as great a difference in Cl concentrations between months as might be expected, however, which may indicate buildup of Cl in Carver Lake during the winter months and then release from lakes throughout the year. An examination of RWMWD and MPCA monitoring data from Carver Lake (downloaded from the MPCA EDA webpage) shows that chloride concentrations in Carver Lake have routinely exceeded 100 mg/l throughout the summer months of recent years, which is close to the Fish Creek summer average FWM concentration.

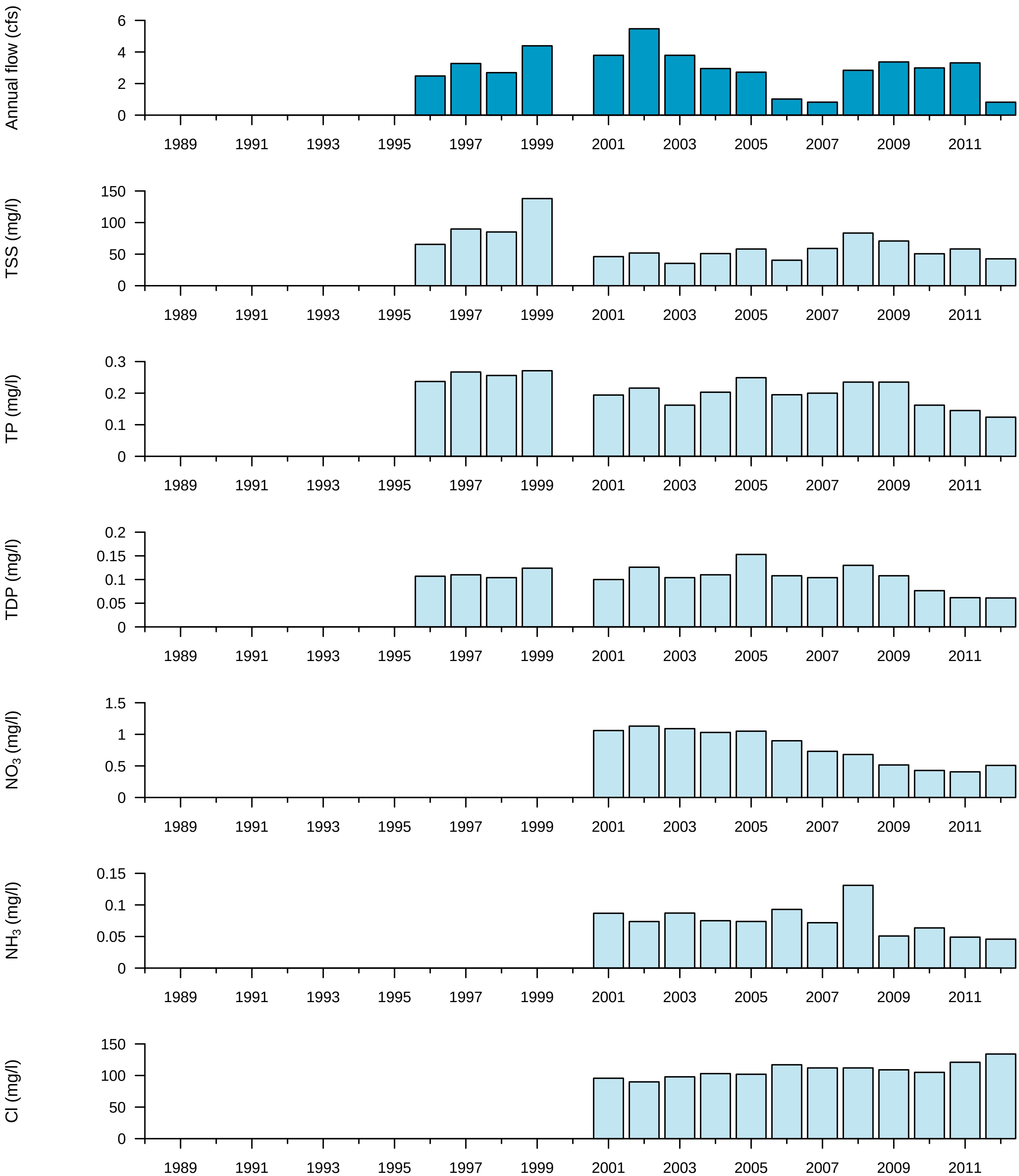
NH_3 concentration patterns were significantly different than the other pollutants. Ammonia concentrations were highest in December-April, peaked in February and March, and then dropped off steeply in May. The high ammonia concentrations may have been caused by lower rates of nitrification due to lower temperatures, and limited algal assimilation because of low temperature and light limitation caused by snow cover (Lee *et al.*, 2012). There may also have been increased nitrogen mineralization of decaying organisms in the reducing environment of stream bottom sediments when the creek was frozen or partially frozen.

Figure FC−6: Fish Creek*
Annual Mass Load



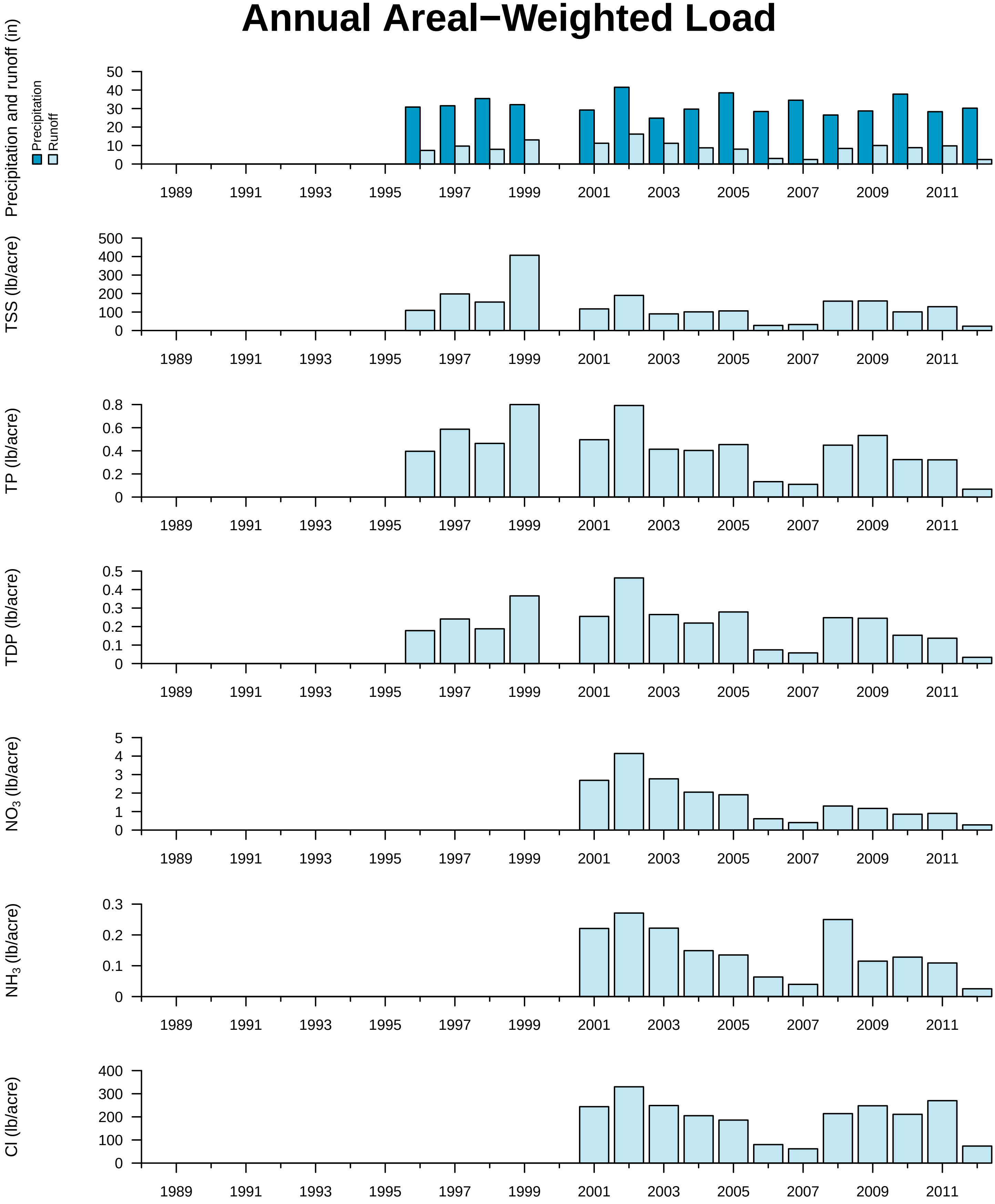
*First full year of sampling for TSS, TP, and TDP began in 1996, NO3 and NH3 began in 2000, and Cl began in 2001.
The station was down in 2000 so no loads could be calculated.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure FC−7: Fish Creek*
Annual Flow−Weighted Mean Concentration



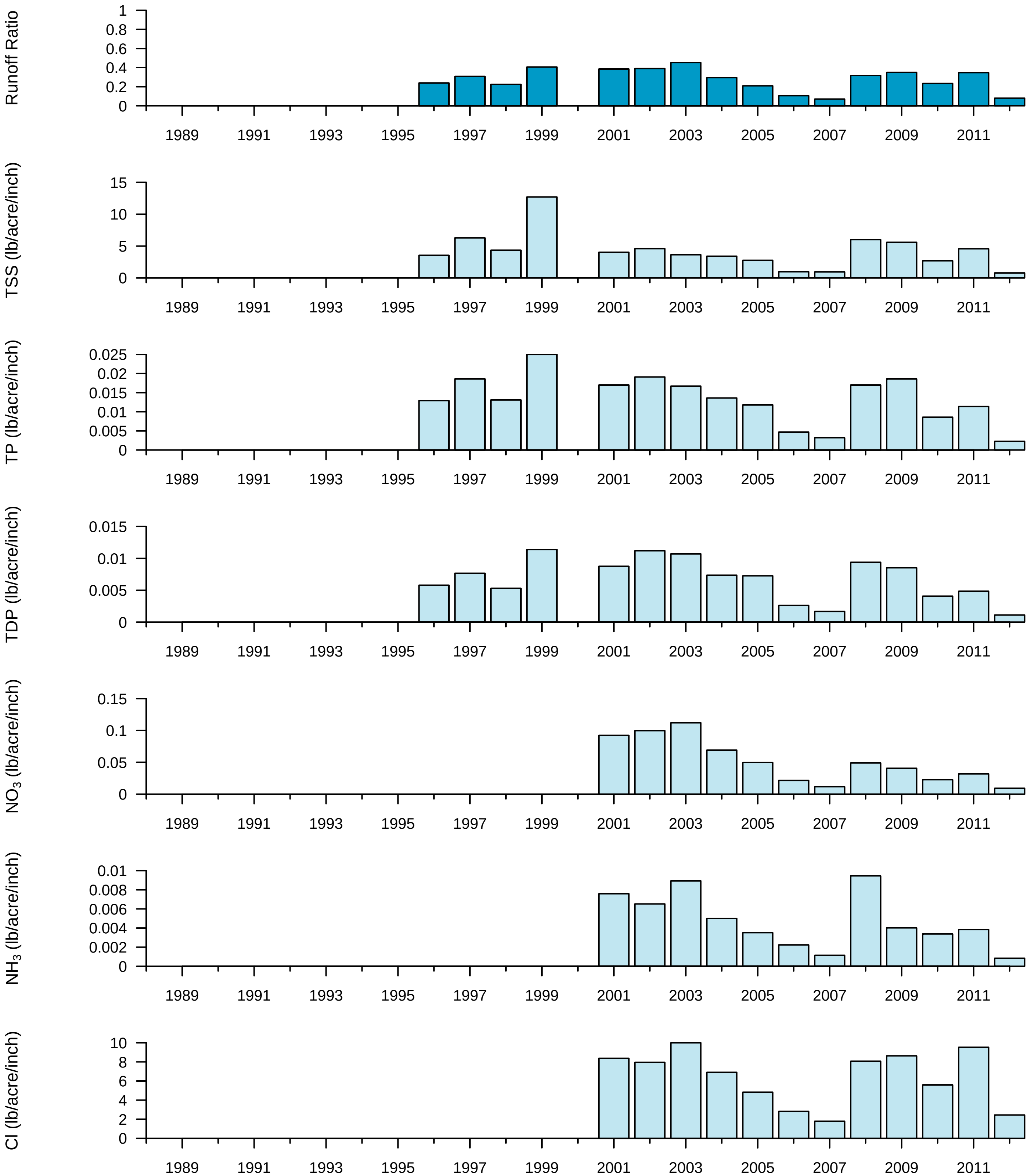
*First full year of sampling for TSS, TP, and TDP began in 1996, NO3 and NH3 began in 2000, and Cl began in 2001. The station was down in 2000 so no loads could be calculated.

Figure FC−8: Fish Creek*
Annual Areal−Weighted Load



*First full year of sampling for TSS, TP, and TDP began in 1996, NO3 and NH3 began in 2000, and Cl began in 2001. The station was down in 2000 so no loads could be calculated.

Figure FC−9: Fish Creek*
Annual Precipitation−Weighted Areal Load



*First full year of sampling for TSS, TP, and TDP began in 1996, NO3 and NH3 began in 2000, and Cl began in 2001. The station was down in 2000 so no loads could be calculated.

Figure FC−10: Fish Creek Mass Load by Month

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

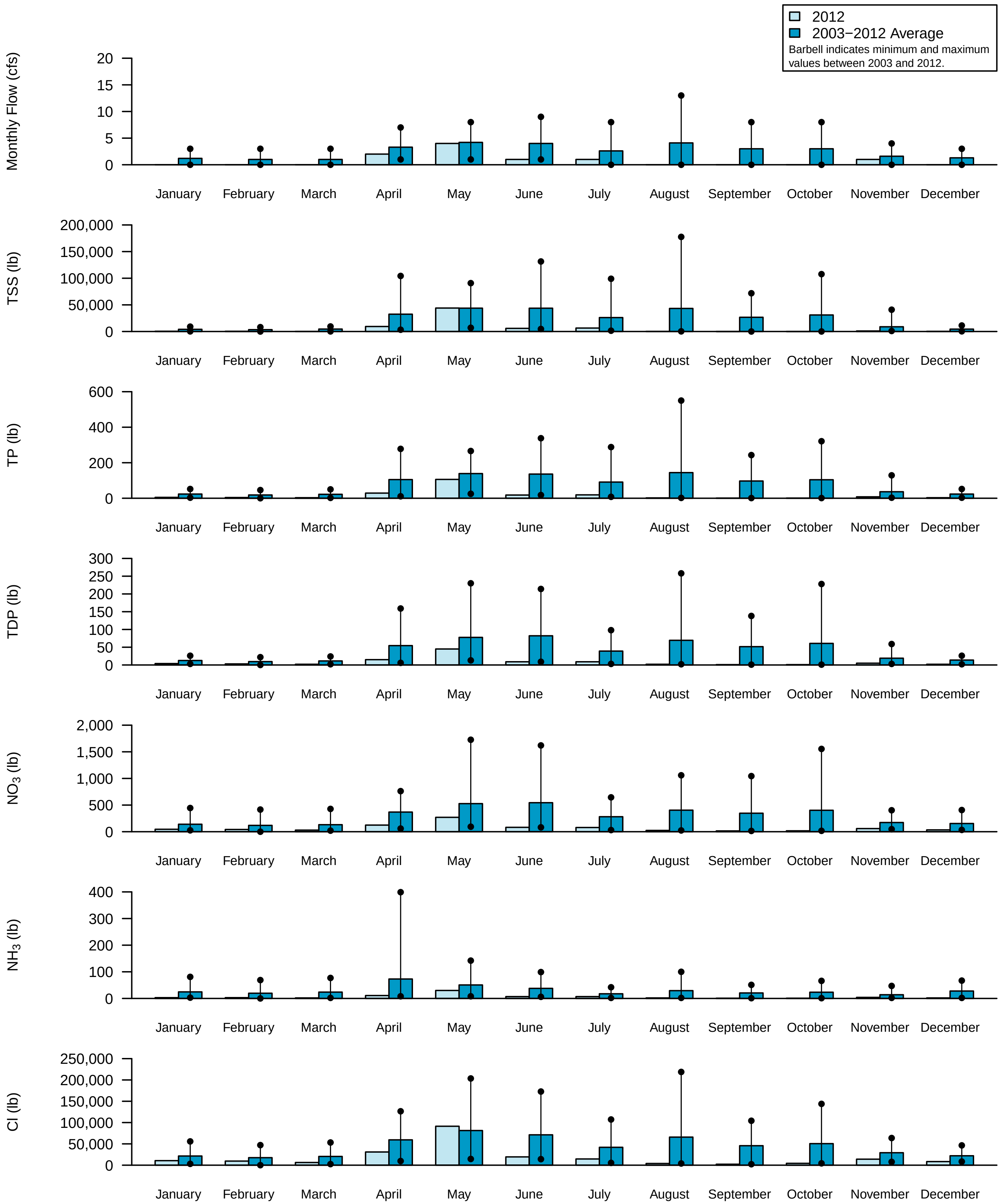
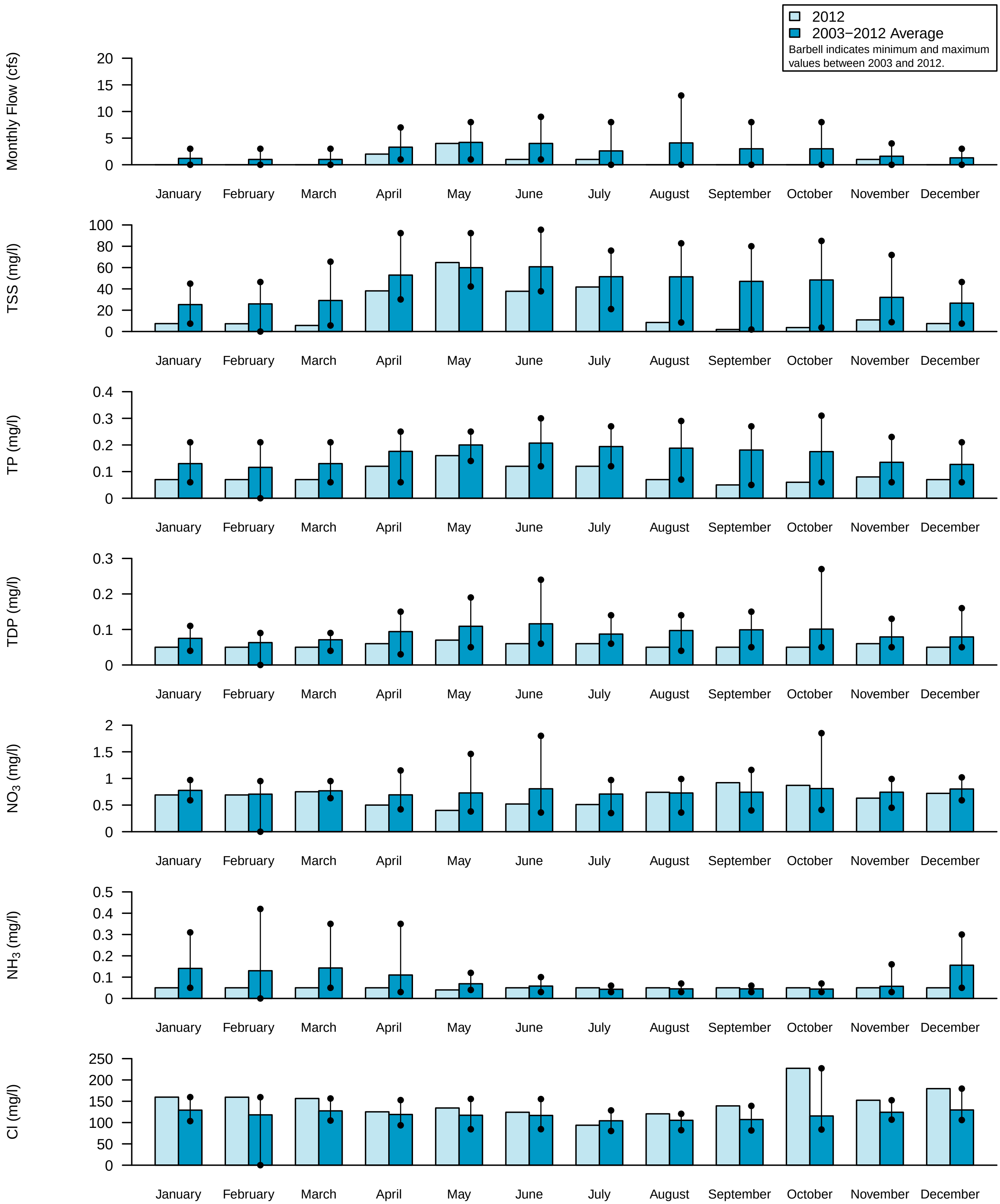


Figure FC−11: Fish Creek
Flow−Weighted Mean Concentation by Month

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. The curves can also be used to provide a visual display of the frequency, magnitude, and flow regime of water quality standard exceedances if standard concentrations are added to the plots (USEPA, 2007).

MCES developed flow and load duration curves for each stream locations using USEPA recommendations, including:

- Develop flow duration curves using average daily flow values for 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 for TSS, TP, NO_3, and Cl. Each of the parameters was plotted using Fish Creek monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table FC-4. No draft standard has been set for nitrate, so MCES used the drinking water standard of 10 mg/l. Most of the draft standards proposed by MPCA have accompanying criteria that are difficult to show on the load duration curves.For example, for a water body to violate the draft TP river standard, the water body must exceed the causative variable (TP concentration), as well as one or more response variables: sestonic chlorophyll, BOD_5, 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 1995–2012 flow duration curve and load duration curves for TSS, TP, NO_3, and Cl for the Fish Creek monitoring station is shown in Figure FC-12. TSS concentrations have consistently exceeded the draft standard at all flow conditions except low flow. Only one sample exceeded the standard during low flow conditions. During dry through moist conditions, a little less than half of the samples exceeded the standard. During high flow, most samples collected exceeded the draft standard.

TP concentrations are very similar to TSS concentrations, with a few exceedences during low flow conditions, and the majority of samples exceeding the standard during dry through high flow conditions. These responses are consistent with other streams that discharge down the Mississippi River bluffs, where high flows lead to streambank, bluff, and ravine erosion.

All NO_3 concentrations at all flow regimes met the drinking water standard of 10 mg/l. The final river nutrient standard for NO_3 will likely be much less than that and NO_3 concentrations in the Fish Creek watershed will need to be reevaluated at that time.

Cl concentrations in Fish Creek were below the standard at all flow regimes, although several samples in the low and high flow regimes came close to the standard.

Table FC-4: Fish Creek Beneficial Use and River Nutrient Region Classifications and Pollutant Draft Standards

Monitoring Station	Use Classification[1] for Domestic Consumption (Class 1) and Aquatic Life and Recreation (Class 2)	River Nutrient Region (RNR)[2] of Monitoring Station	Chloride Draft Stnd[3] (mg/l)	TSS Draft Stnd[4] (mg/l)	TP Draft Stnd[5] (ug/l)	Nitrate DW Stnd[6] (mg/l)
Fish Creek above Hwy 61 (FC0.2)	2B	Central	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430

[2] MPCA, 2010.

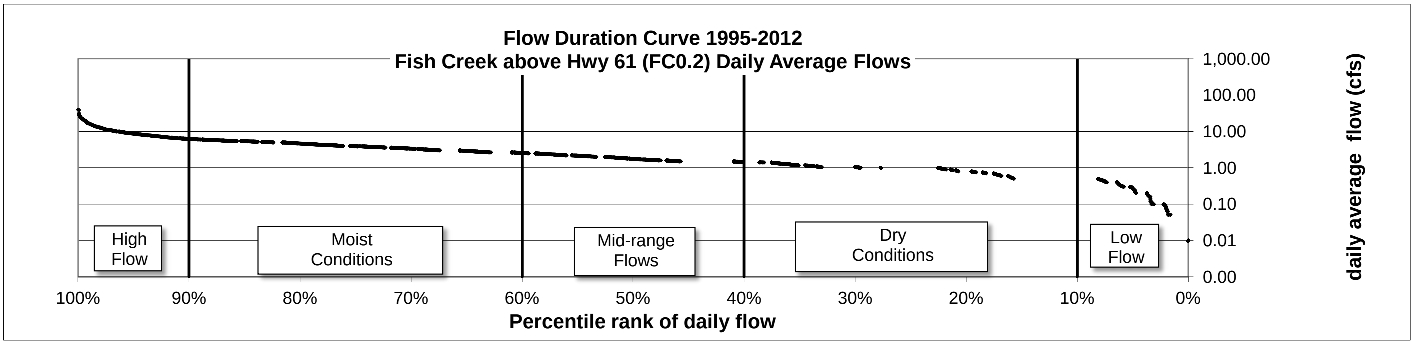
[3] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft chloride standard pending results of EPA toxicity tests.

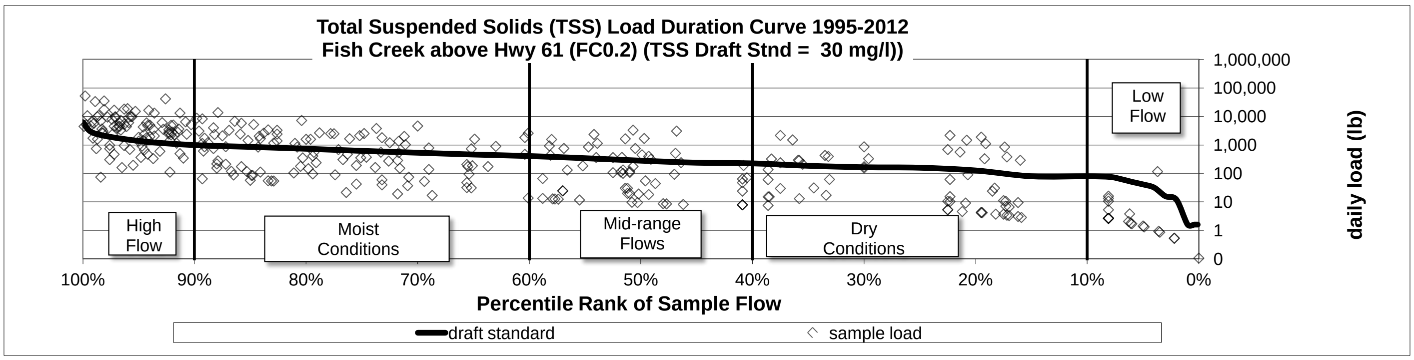
[4] MPCA, 2011. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

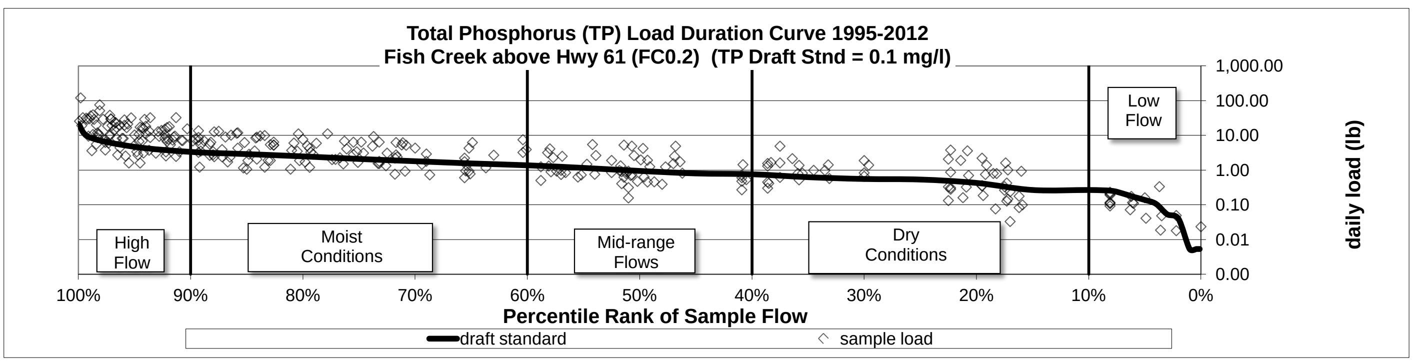
[5] MPCA, 2013a. To violate standard, concentration of causative variable (TP) must be exceeded, as well as one or more response variables: sestonic chlorophyll, BOD_5, DO flux, and/or pH.

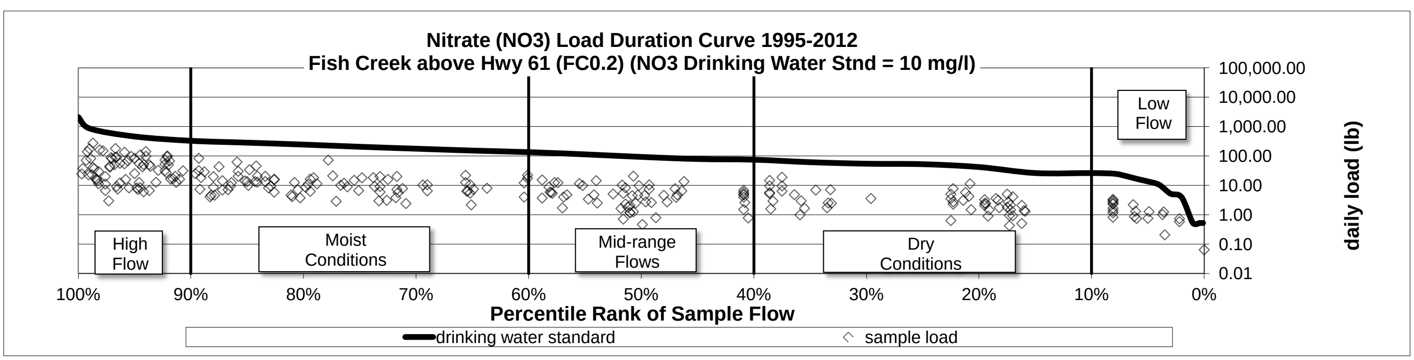
[6] MCES used the nitrate drinking water standard of 10 mg/l pending results of EPA toxicity tests and establishment of a draft nitrate standard for rivers and streams.

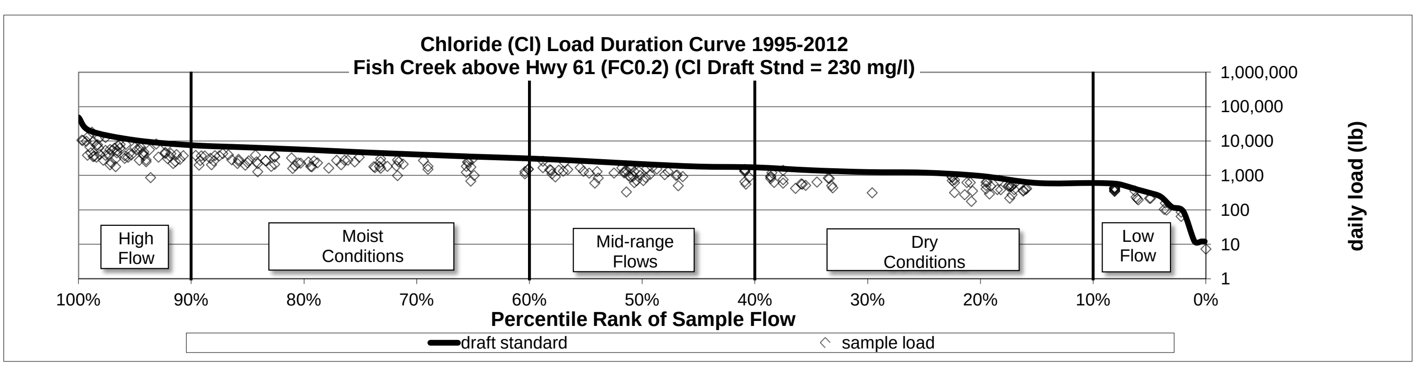
Figure FC-12: Fish Creek Flow and Load Duration Curves, 1995-2012











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.

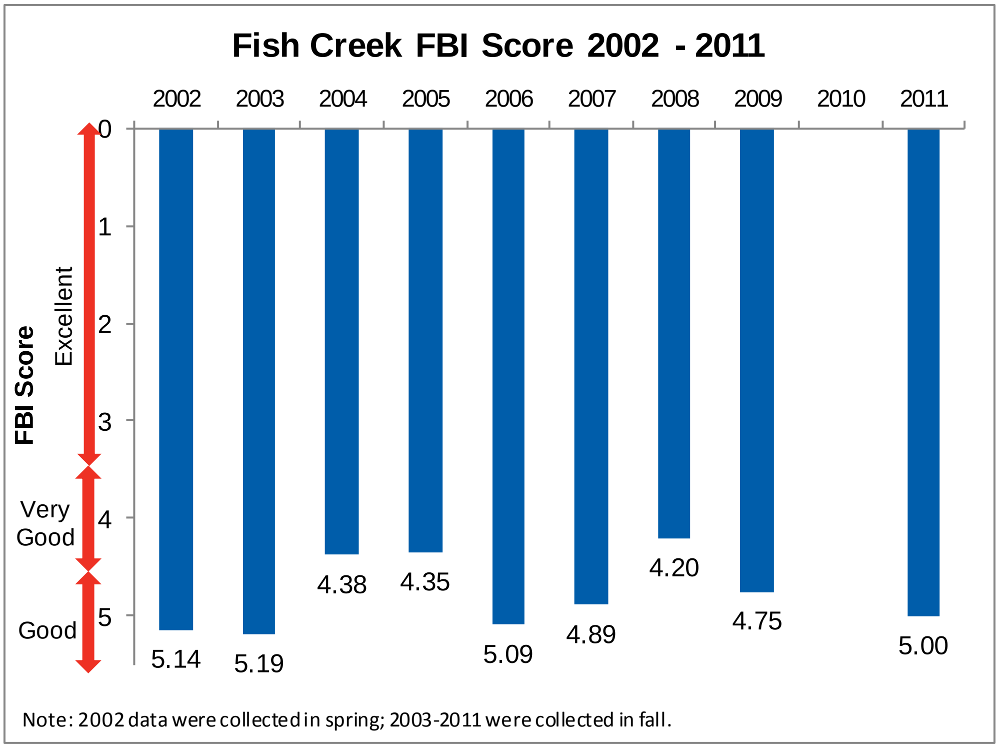
Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. However, integrating the individual metrics into a multi-metric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

MCES has been sampling for macroinvertebrates in Fish 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, ten is quite tolerant of pollution. The tolerance values are used to calculate a weighted average tolerance value for the sample, allowing for inter-annual comparison. The Fish Creek FBI scores show very good (2004, 2005, 2008) to good (2002, 2003, 2006, 2007, 2009, 2011) water quality, indicating slight organic pollution (Figure FC-13).

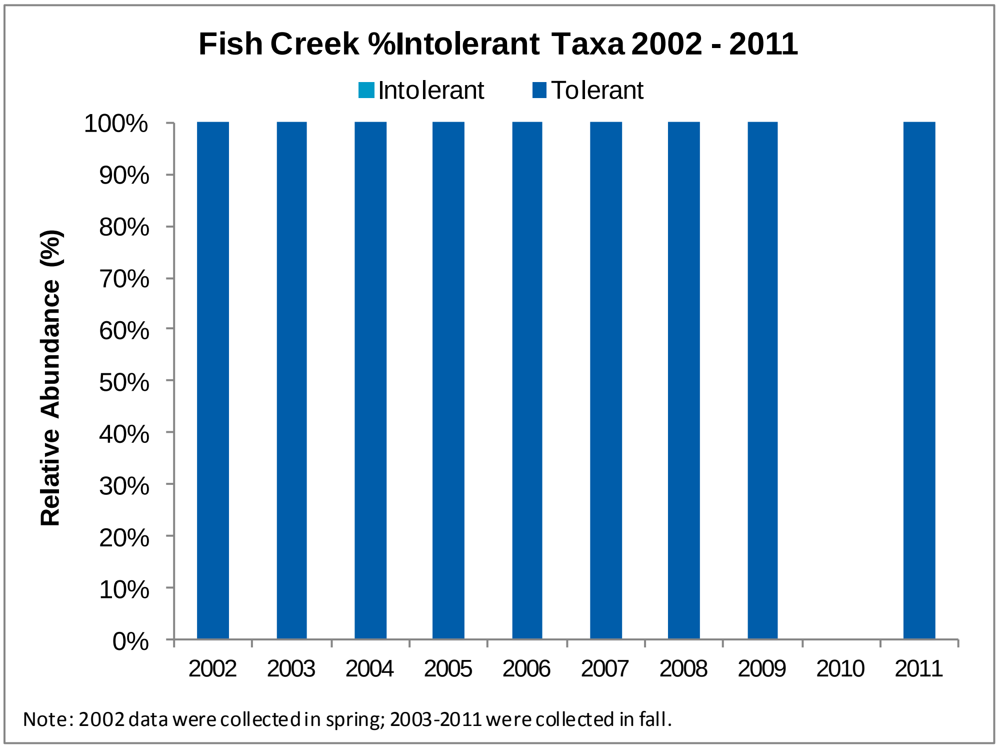
Figure FC-13: Fish Creek Annual Family Biotic Index (FBI) Scores, 2002-2011



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 FC-14). The presence of moderate numbers of intolerant taxa is an indicator of good aquatic health (Chirhart, 2003). There are no intolerant taxa present in any Fish Creek sample in the period of record. The lack of these macroinvertebrates strongly suggests that the pollution load is consistently high enough to influence the macroinvertebrate community at this stream reach.

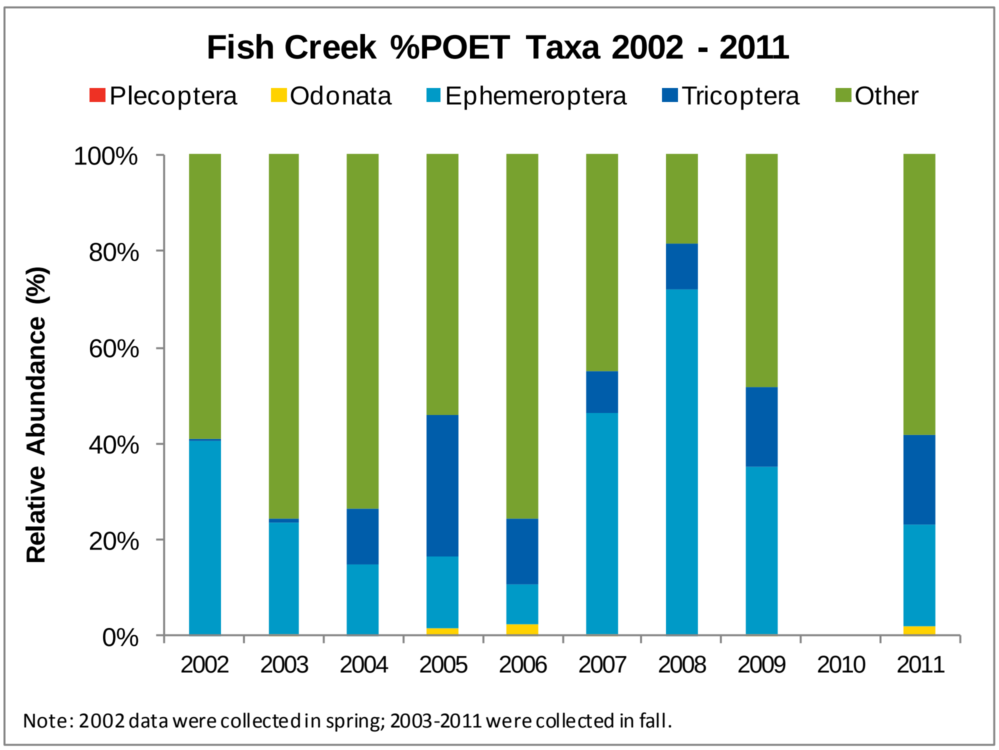
Figure FC-14: Fish Creek Percent Abundance of Pollution Intolerant Taxa, 2002-2011



Percent POET Taxa

The taxonomic richness metric, Percent POET Taxa (Figure FC-15), is the percent of individuals in the sample which belong to the orders **P**lecoptera (stoneflies), **O**donata (dragonflies and damselflies), **E**phemeroptera (mayflies), and **T**richoptera (caddisflies). Individuals in these orders vary in sensitivity to organic pollution and sedimentation. High percent POET values indicate high community diversity due to good water quality. The Percent POET Taxa value was highest in 2008 at 82%, and lowest in 2006 at 24%. The Odonata taxa tend to be more dominant in slow moving water, and Plecoptera tend to be present in fast moving waters. Biological sampling at Fish Creek has generally occurred in low to mid-range conditions based on the average daily flow record and flow duration curve (Figure FC-12) which may partly explain the dearth of Plecoptera.

Figure FC-15: Fish Creek Percent Abundance of POET Taxa, 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.

All seven years of monitoring Fish Creek included in the M-IBI assessment resulted in M-IBI scores below the impairment threshold (Figure FC-16). In 2005, 2008, 2009, and 2011, scores were also below the lower confidence level. This suggests the stream reach during those years may not have been able to sustain the needs of aquatic life.

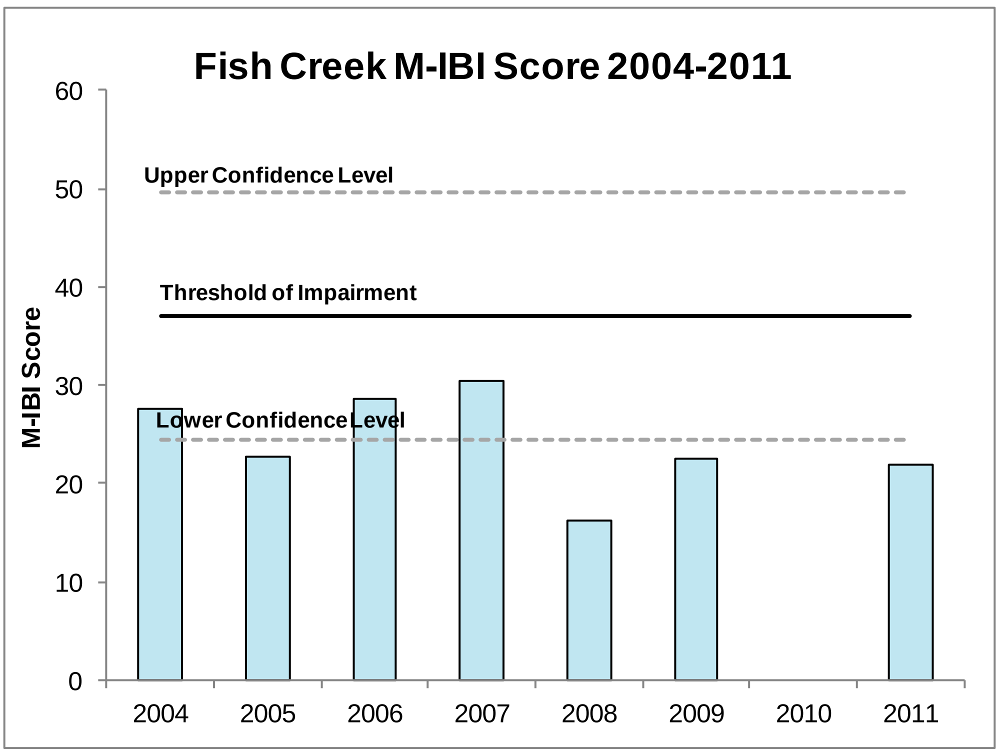
In 2004, 2006, and 2007, Fish Creek M-IBI scores were between the threshold of impairment and the lower confidence level. When the scores fall between the confidence levels, it is difficult to confidently assess the water quality by biological assessment alone. It is necessary to incorporate other monitoring information, such as hydrology, water chemistry and land use change (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 2006 and 2007, higher M-IBI scores correspond with lower flow. Lower flows likely reduced solids, nutrient, and chloride loads (Figure FC-7). Pollutant load reduction likely had a positive effect on the macroinvertebrate community, resulting in higher scores.

The most recent M-IBI scores, 2008, 2009, and 2011, are below the lower confidence level. Most likely, stressors are negatively affecting the macroinvertebrate community. MCES is planning additional future analysis to fully investigate our biological monitoring data.

Figure FC-16: Fish Creek Annual Macroinvertebrate Index of Biological Integrity (M-IBI) Scores, 2004-2011



Trend Analysis

Trend analysis was completed for the historical record of TP, NO_3, and TSS using the 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 alterations in flow rate; their results can be used to form general assumptions about changes in flows in the metropolitan area streams. Novotny and Stefan (2007) assessed flows from 36 USGS monitoring stations across Minnesota over periods of 10 to 90 years, finding that peak flow due to snowmelt was the only streamflow statistic that has not changed at a significant rate.

Peak flows due to rainfall events in summer were found to be increasing, along with the number of days exhibiting higher flows. Both summer and winter baseflows were found to be increasing, as well. Novotny and Stefan 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 depressional storage. MCES staff plan to repeat the following trend analyses in 5-10 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 1995-2012 on Fish 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)

Three trends were identified for TSS flow-adjusted concentrations in Fish Creek during the assessment period from 1995 to 2012 (Figure FC-17, top chart). Based on a run without the precedent five-year flow, the p value was 4.0×10^{-4}, indicating the trends identified are statistically significant.

- Trend 1: 1995 to 2000, TSS flow-adjusted concentrations decreased 86%, from 30.5 mg/l to 4.3 mg/l, at a rate of -4.4 mg/l/yr.
- Trend 2: 2001 to 2005, TSS flow-adjusted concentrations increased 107%, from 4.3 mg/l to 9.0 mg/l, at a rate of 0.93 mg/l/yr.
- Trend 3: 2006-2012, TSS flow-adjusted concentrations decreased 43%, from 9.0 mg/l to 5.1 mg/l, at a rate of -0.11 mg/l/yr.

In order to compare the TSS trends in Fish Creek with other MCES-monitored streams in report section ***Comparison with Other Metro Area Streams***, the five year trend for period 2008-2012 was calculated. From 2008 to 2012, the flow-adjusted TSS concentration decreased 37%, from 8.0 mg/l to 5.1 mg/l, at a rate of -0.59 mg/l/yr. Based on the QWTREND results, the water quality in Fish Creek in terms of TSS improved during 2008-2012.

Total Phosphorus (TP)

Three trends were identified for TP flow-adjusted concentrations in Fish Creek during the assessment period from 1995 to 2012 (Figure FC-17, middle chart). Based on a run without the precedent 5-year flow, the p value was 8.5×10^{-12}, indicating the trends identified are statistically significant. These trends align very closely with the TSS trends.

- Trend 1: 1995 to 2000, TP flow-adjusted concentration decreased 42%, from 0.13 mg/l to 0.08 mg/l, at a rate of -0.0093 mg/l/yr.
- Trend 2: 2001 to 2005, TP flow-adjusted concentration increased 107%, from 0.08 mg/l to 0.13 mg/l, at a rate of 0.011 mg/l/yr.
- Trend 3: 2006-2012, TP flow-adjusted concentration decreased 55%, from 0.13 mg/l to 0.06 mg/l, at a rate of -0.0026 mg/l/yr.

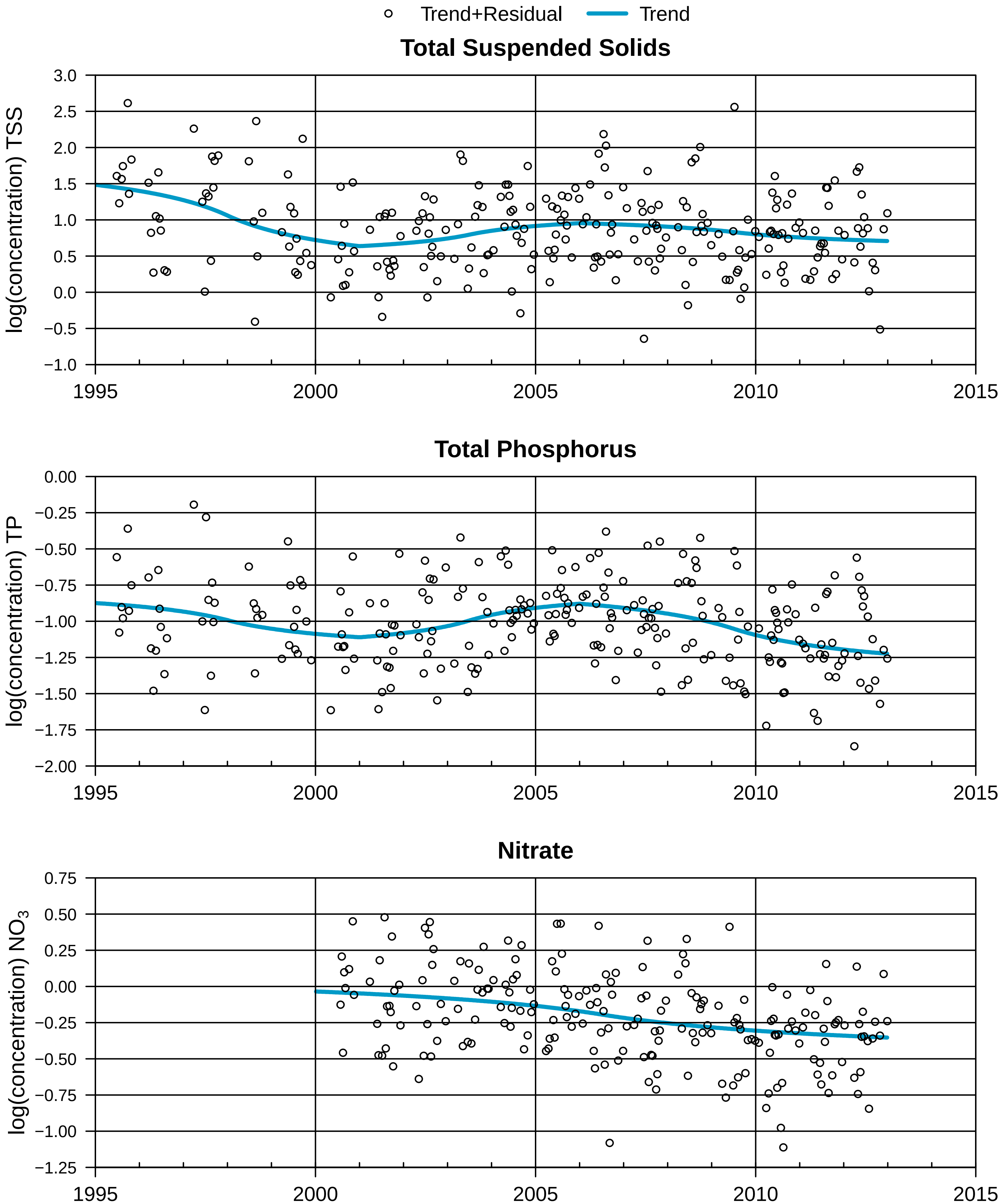
In order to compare the TP trends in Fish Creek with other MCES-monitored streams in report section ***Comparison with Other Metro Area Streams***, the five year trend for period 2008-2012 was calculated. From 2008 to 2012, TP flow-adjusted concentration decreased 47%, from 0.11 mg/l to 0.06 mg/l, at a rate of -0.011 mg/l/yr. Based on the QWTREND results, the water quality in Fish Creek in terms of TP improved during 2008-2012.

Nitrate (NO_3)

One trend was identified for NO_3 flow-adjusted concentrations in Fish Creek during the assessment period from 2000 to 2012 (Figure FC-17, bottom chart). Based on a run without the precedent 5-year flow, the p value was 0.0004, indicating the trends identified are statistically significant. For the entire trend period, NO_3 flow-adjusted concentrations decreased 52%, from 0.92 mg/l to 0.44 mg/l, at a rate of -0.037 mg/l/yr.

In order to compare the NO_3 trends in Fish Creek with other MCES-monitored streams in report section ***Comparison with Other Metro Area Streams***, the five year trend for period 2008-2012 was calculated. From 2008 to 2012, NO_3 flow-adjusted concentrations decreased 21%, from 0.56 mg/l to 0.44 mg/l, at a rate of -0.023 mg/l/yr. Based on the QWTREND results, the water quality in Fish Creek in terms of NO_3 improved during 2008-2012.

Figure FC−17: Fish Creek Trends for TSS, TP and NO_3



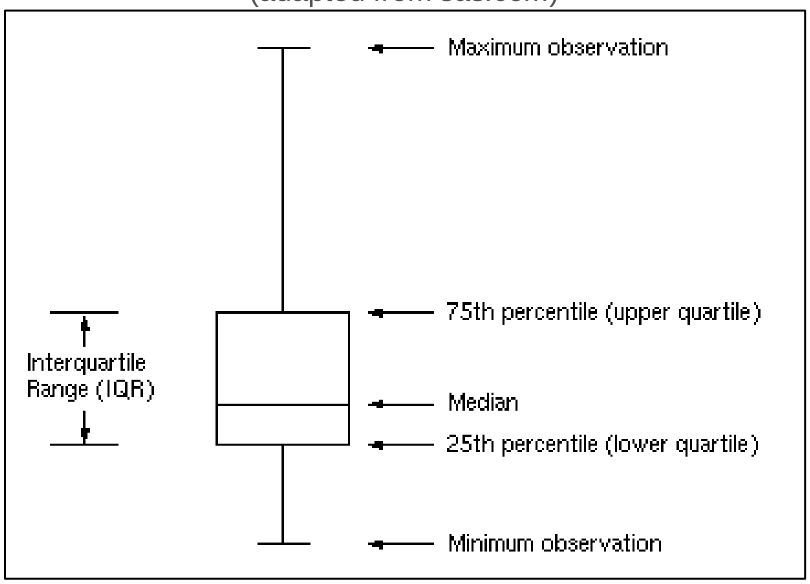
Comparison with Other Metro Area streams

Chemistry

To compare the historical flow, TSS, TP, and NO_3, and Cl data for Fish Creek with the other metropolitan area streams monitored by MCES and with the major receiving water (in this case the Mississippi River below the confluence with the Minnesota 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 FC-18. 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 FC-18: General Schematic of a Box-and-Whisker Plot
(adapted from *sas.com*)



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

The median annual FWM concentration for TSS in Fish Creek is slightly lower than that in the Mississippi River (as measured at Mississippi River at Saint Paul; 55 mg/l vs. 58 mg/l, respectively), indicating that Fish Creek contributes to a lower TSS concentration in the Mississippi River downstream (Figure FC-19). The median annual FWM concentration for TSS in Fish Creek is similar compared to other highly urbanized watersheds (higher than Bassett, about the same as Willow, lower than Nine Mile and Battle), and is lower than many of the agricultural watersheds. The elevated concentrations in Fish Creek may be due to erosion along the steep slopes in the downstream portion of the watershed. There has in the past been severe damage to the ravine through which Fish Creek enters the Mississippi River floodplain due to high flow events. Restoration and improvement projects have since stabilized the slope.

Median annual runoff ratio for Fish Creek is on the high side of the metropolitan area urban streams: higher than Willow and Nine Mile creeks, slightly higher than Battle Creek, and slightly lower than Bassett Creek. For streams that are highly influenced by wetlands, lakes, or other impoundments on the stream channel, one would expect a relatively lower runoff ratio (as with Minnehaha Creek and Carnelian-Marine). If the flow was highly influenced by shallow groundwater inflow, one would expect a relatively higher runoff ratio (as with Eagle Creek and Valley Creek). Fish Creek flow is highly impacted by Carver Lake water levels, but the runoff ratio is quite a bit higher than for Minnehaha Creek or Carnelian Marine. This may be because of a groundwater influence at the downstream part of the watershed, below the bluff.

The FWM TP concentration in Fish Creek is higher than for the Mississippi River (0.20 mg/l vs. 0.15 mg/l, respectively) and thus increases its concentration downstream (Figure FC-20). Fish Creek's FWM TP concentration is in the middle of the highly urban watershed concentrations − slightly below Nine Mile Creek, about the same as Fish Creek, and slightly higher than Willow and Bassett Creeks. All of the highly urbanized streams have significantly lower FWM TP concentrations than the more agricultural watersheds monitored by MCES.

NO_3 FWM concentration in Fish Creek is significantly lower than in the Mississippi River (0.7 mg/l vs. 3 mg/l, respectively) and thus dilutes the river concentration downstream (Figure FC-21). All urban watersheds have very low nitrate concentrations, though Fish Creek's is almost twice the concentration of the other urban watersheds.

The higher nitrate concentration may be due to higher nitrate concentration in Carver Lake, a groundwater component, or contribution from the nursery in the watershed. Nitrate is not routinely monitored in Carver Lake, so it is not possible to tell if the elevated nitrate levels are from the lake or direct drainage to the creek. The areal load and annual yield of NO_3 in Fish Creek are also low and similar to the streams with more urban watersheds, which are dwarfed by the streams with primarily agricultural watersheds, such as the Crow River, Vermillion River, and Cannon River.

Cl FWM concentration in Fish Creek is significantly higher than in the Mississippi River (111 mg/l vs. 22 mg/l) and so increases the Cl concentration in the Mississippi River downstream (Figure FC-22). Fish Creek's Cl concentration is less than Bassett and Battle creek's Cl concentration, and very similar to Willow and Nine Mile creeks. 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). Fish Creek does not have any domestic WWTPs, but has a network of roads and highways that are de-iced in the winter. The Fish Creek watershed includes a portion of I-494, which may contribute to the high Cl concentration because the entities responsible for major highways (Hennepin County and MnDOT) have the highest application rates of road de-icers (Shingle Creek Watershed Management Commission, 2006). Fish Creek has a smaller amount of highway surface than Bassett and Battle Creeks, which may explain its lower chloride concentration.

Because of its relatively small size, the annual load of each of TSS, TP, NO_3, and Cl from the Fish Creek watershed is small relative to the larger watersheds, especially the Crow, Crow South, and Cannon River watersheds. This is true for parameters where the Fish Creek concentration is high relative to most other watersheds (Cl) or low (NO_3).

Chloride FWM concentration in Fish Creek is significantly higher than in the Mississippi River (107 mg/l vs. 22 mg/l), and thus serves to increase the river concentration (Figure FC-22). The concentration is very similar to Nine Mile Creek, and less than other highly urbanized streams Willow, Bassett, and Battle Creeks. The most prevalent source of chloride to steams in urban areas is road surfaces (from chloride application as a de-icer). The concentration of chloride may be lower in Fish than other watersheds because the majority of road surfaces and other impervious surfaces drain to Carver Lake before discharging to Fish Creek.

Macroinvertebrates

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

The M-IBI scores for Fish Creek all lie below the MPCA impairment threshold (Figure FC-23). This suggests that the habitat and water quality of this stream reach typically were not able to sustain the needs for aquatic life.

These results are similar to other highly urban watersheds in the Minnesota and Mississippi river basins, including Battle and Nine Mile creeks, and lower than primarily agricultural watersheds. This suggests the urban macroinvertebrate communities are more stressed than the agricultural macroinvertebrates in the metropolitan area.

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

Organized by Major River Basin

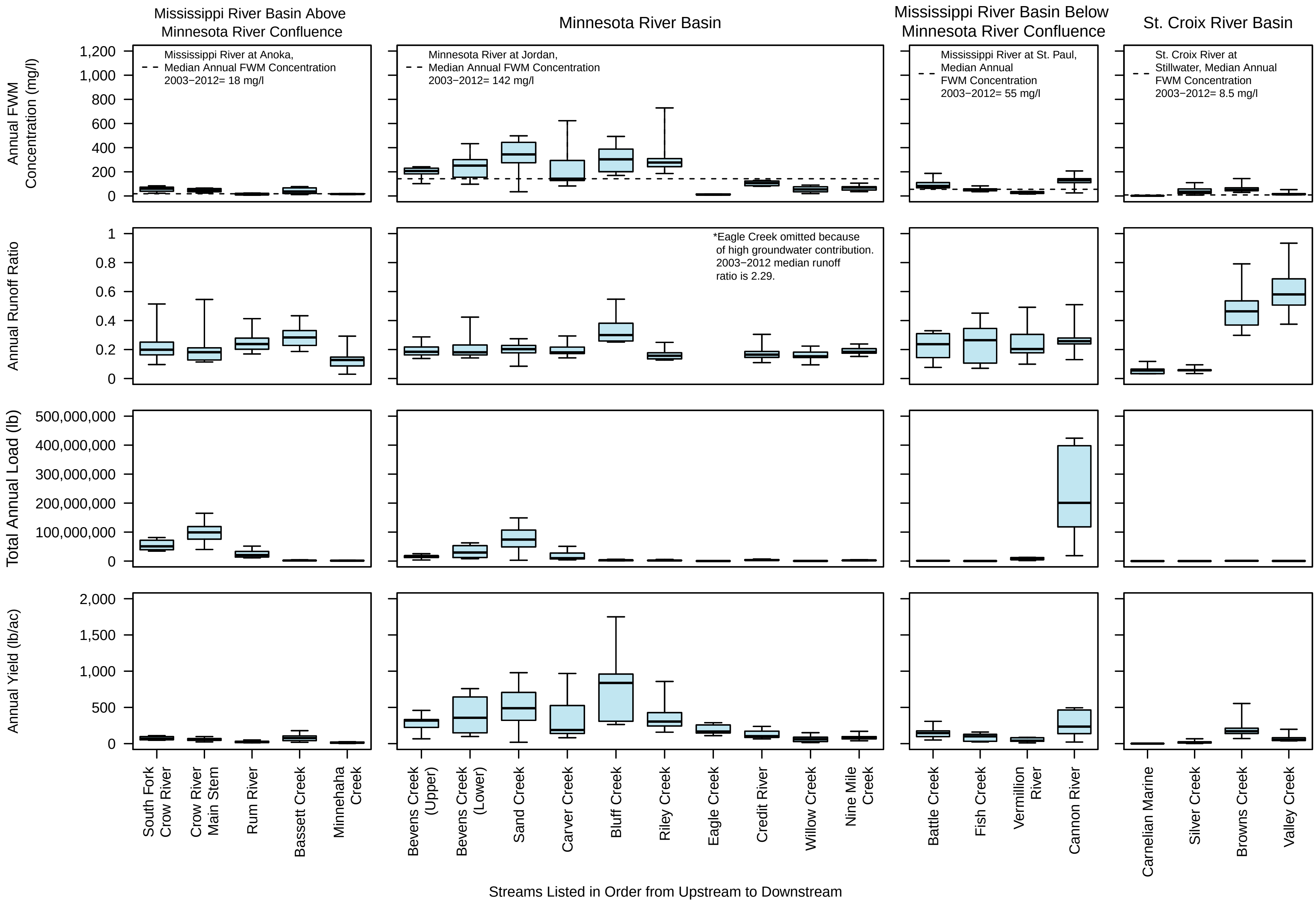


Figure FC−20: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

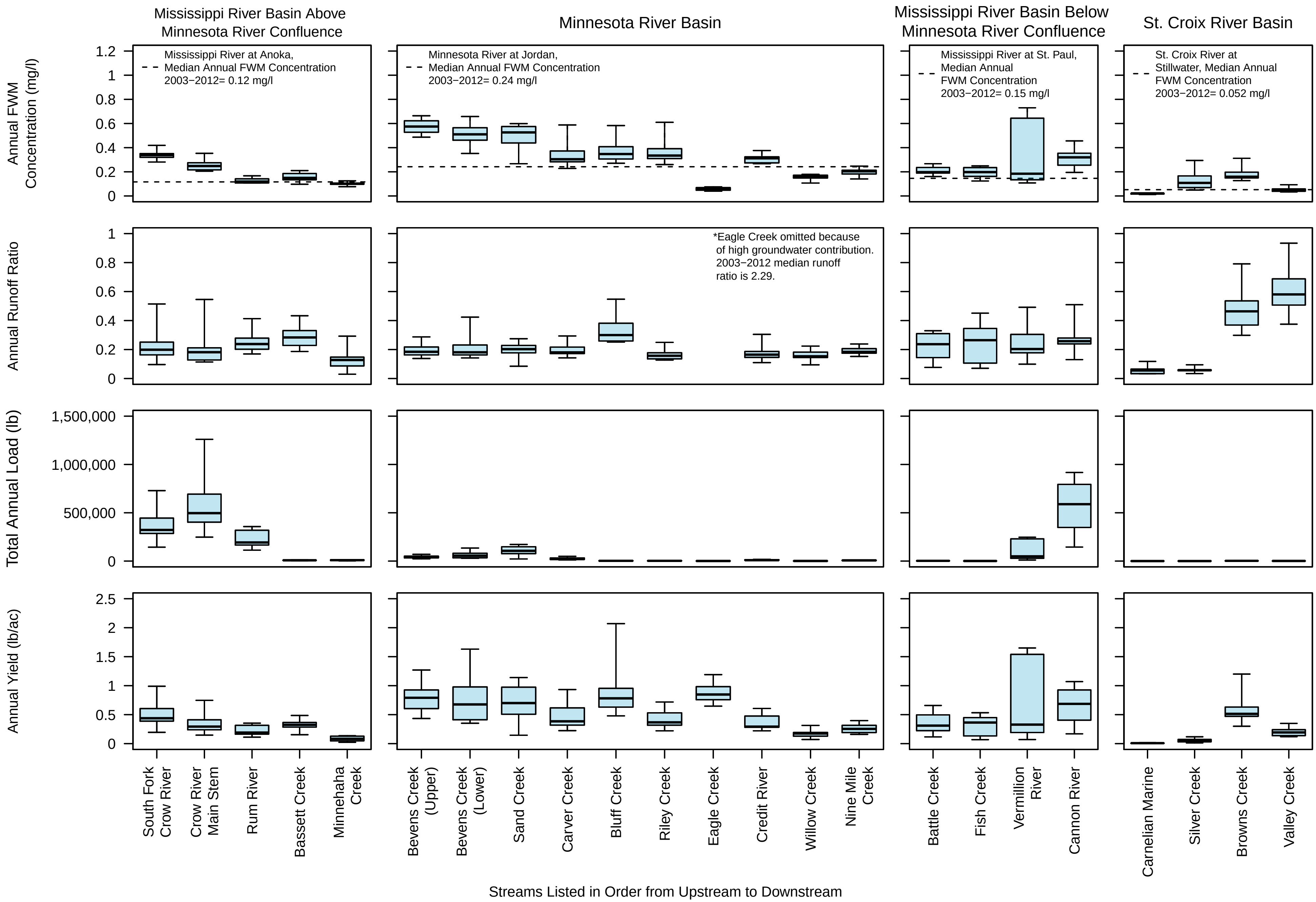


Figure FC−21: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

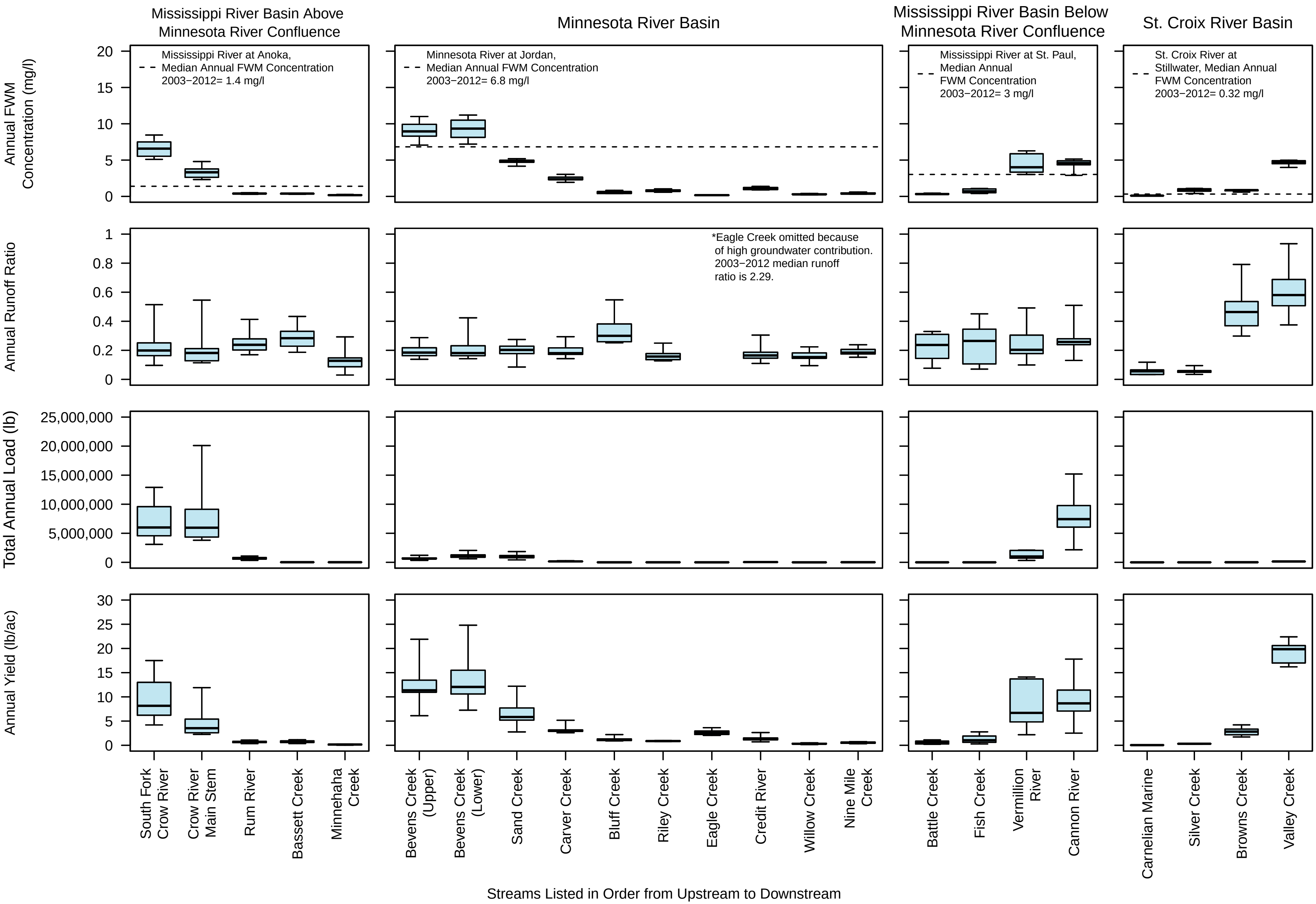


Figure FC−22: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

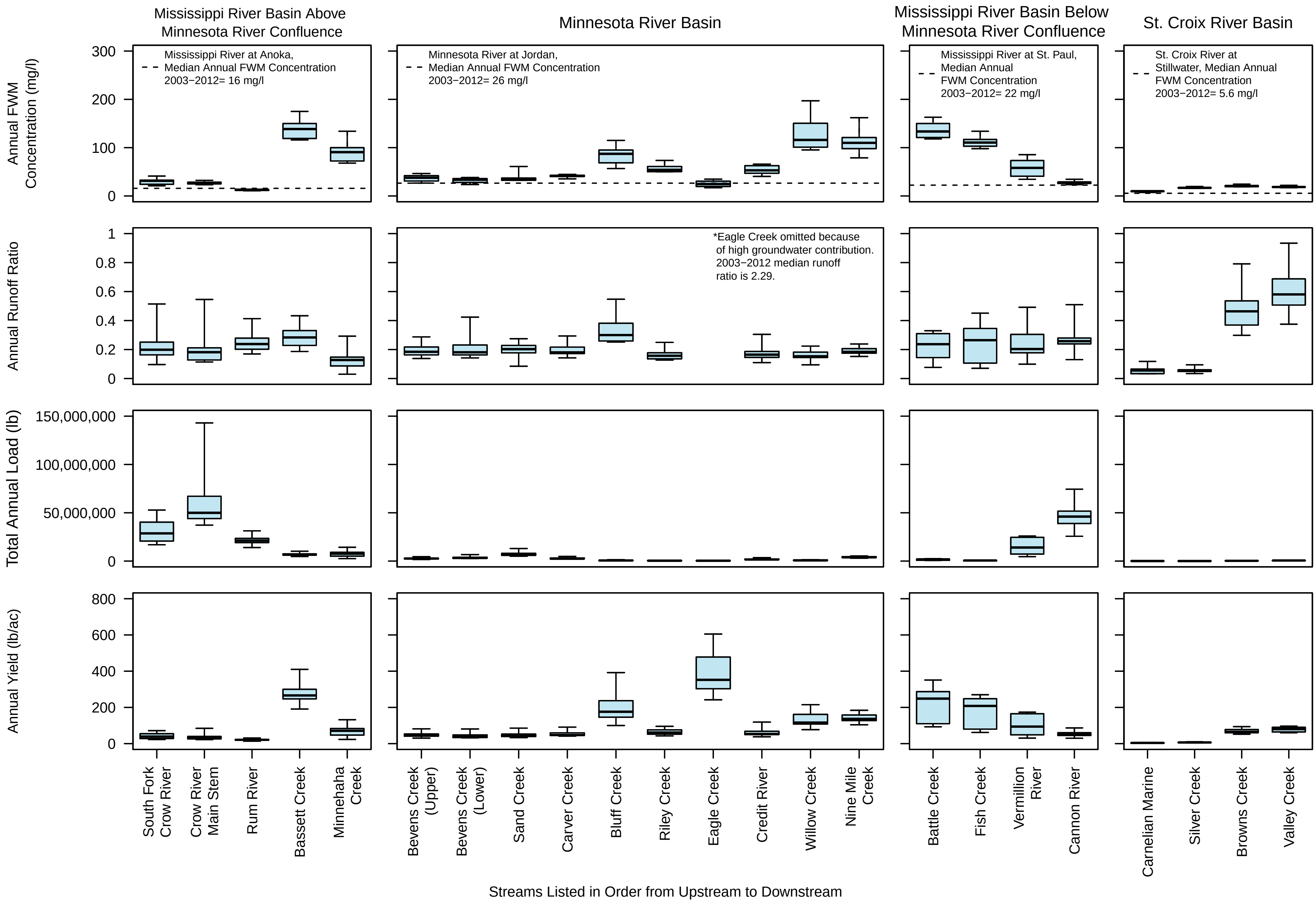


Table XX-X: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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

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

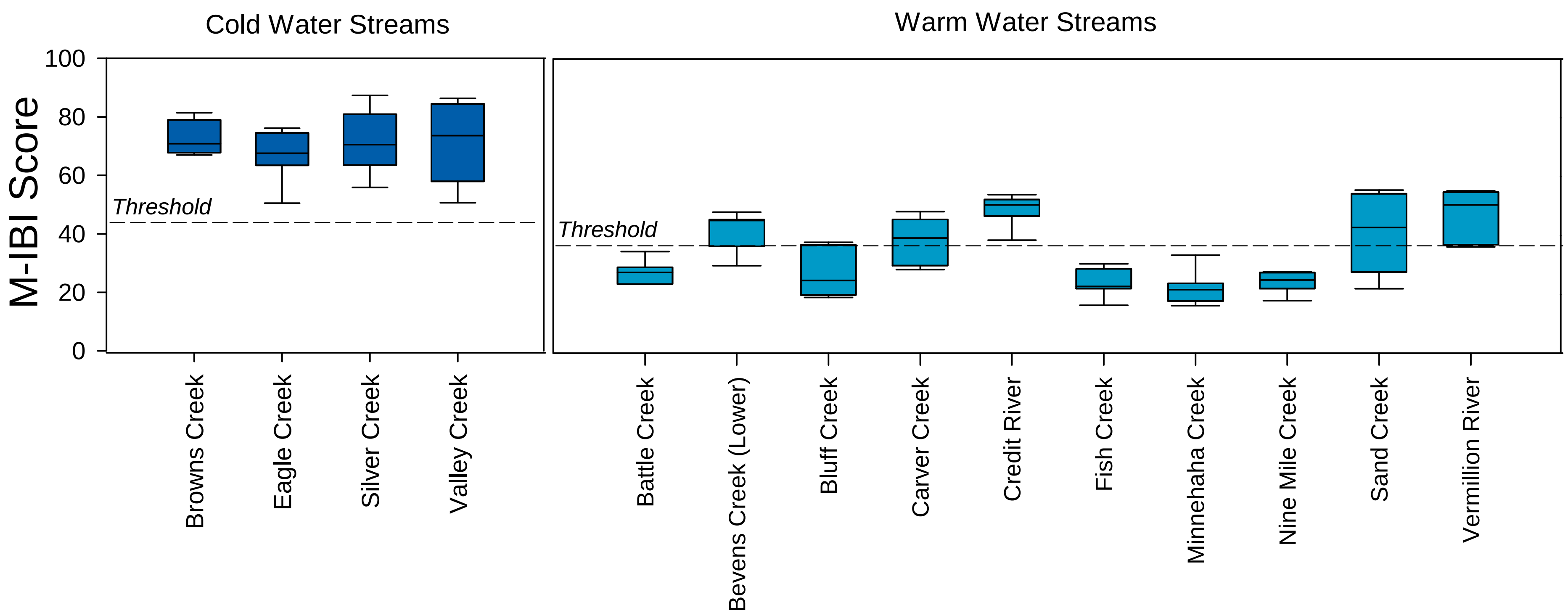
[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

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

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

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

Organized by Stream Type



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

Metropolitan Area 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 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 concentration estimated for 2008-2012 (Figure FC-24). Second, changes are shown by three seven-county metropolitan area maps (one each for TSS, TP, and NO_3 trends), with stream watersheds colored to represent improving and declining water quality (Figure FC-25).In both figures no trend was reported for those QWTREND analyses with poor quality of statistical metrics (e.g. $p>0.05$).

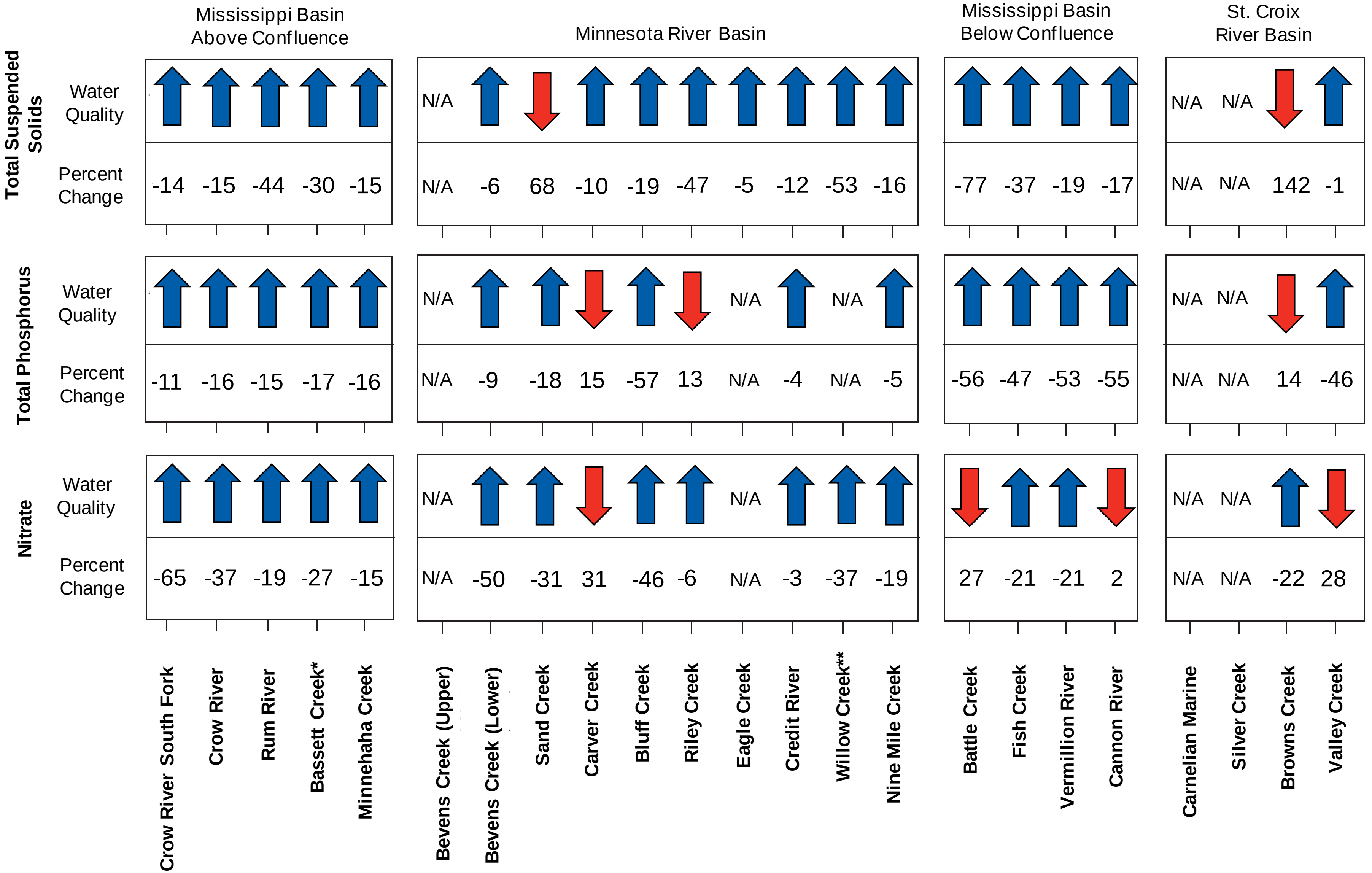
In general, of the 20 monitoring stations assessed, most exhibited improving water quality (and thus decreasing flow-adjusted concentration) for TSS, TP, and NO_3. There does not appear to be a spatial pattern for those few stations with decreasing water quality. There is no station with declining water 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 monitored tributaries to the Mississippi River below the confluence with the Minnesota River generally contribute waters higher in concentration in TSS and TP than the Mississippi River itself. The trend analysis results indicate decreasing flow-adjusted concentrations in TSS and TP for each of these sites, which could ultimately lead to cleaner water quality in the Mississippi River. Of the monitored tributaries to the Mississippi below the confluence with the Minnesota, both Battle Creek and the Cannon River had increasing NO_3 flow-adjusted concentrations.

Fish Creek shows improving trends in water quality for TSS, TP, and NO_3.

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

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



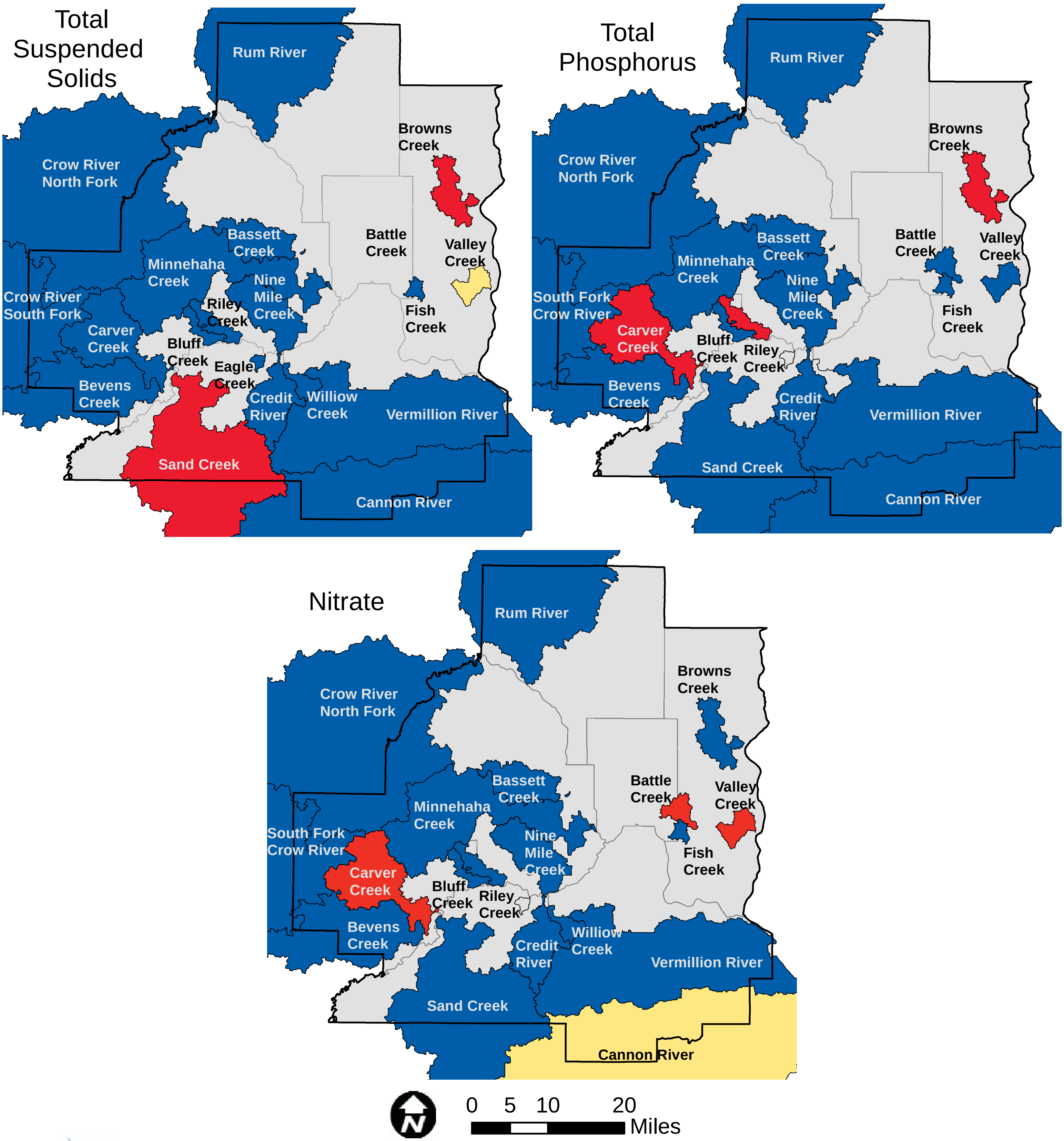
Blue arrows indicate improved water quality; Red arrows indicate declining water quality.

"N/A" indicates analysis was not performed as data were not appropriate for analysis by QWTrend.

* Bassett Creek TSS Trends were assessed over 2009-2013. **Monitoring at Willow Creek was suspended in 2009.

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

(As estimated by QWTrend)



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

-3% to 3% Change

Greater than 3% Change (Indicates Decreasing Water Quality)

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Conclusions

Fish Creek is a tributary to the Mississippi River and drains portions of the cities of Woodbury, Maplewood, Newport, and Saint Paul within Washington and Ramsey Counties. The watershed is primarily developed, with small pockets of open space. There are no major point sources in the watershed.

The upper part of the watershed is relatively flat, while the topography steepens at the transition from the Mississippi River bluff to the river floodplain. Over three-quarters of the watershed drains to Carver Lake, which forms the headwaters of Fish Creek. The remaining part of the watershed drains directly to Fish Creek.

The monitoring station is located just east of Hwy. 61. Downstream of the monitoring station, Fish Creek continues through the floodplain before discharging to Eagle Lake, a Mississippi River floodplain lake. The monitoring data presented in this report does not reflect the potential increases or decreases in water quality that may occur downstream of the monitoring station, though there are thought to be no substantial contributions below the monitoring station.

The water quality in Fish Creek is clearly affected by urban runoff, including reasonably high TSS and TP concentrations and very high Cl concentrations. Fish Creek is affected by several factors: highly urbanized areas with increased runoff and high de-icing applications, erosion along streambanks, and Carver Lake water quality. TP in the stream is slightly higher than the concentration in the Mississippi River, and TSS is slightly lower; both are comparable and in the middle of values for other highly urbanized streams monitored by MCES.

NO_3 concentrations in the Fish Creek watershed remain very low and significantly below the Mississippi River median concentration, though higher than the other urban streams. The reason for the comparatively elevated concentration may be due to Carver Lake processes or groundwater contributions in the downstream part of the watershed along and below the Mississippi bluff line.

The Cl concentrations in Fish Creek were high, but lower than the concentrations in most similar monitored urban streams. This may reflect a lower percentage of heavily urbanized land in the watershed, less road surface, and also dilution of chloride in Carver Lake. All of the pollutant loads from the Fish Creek watershed were very small compared to loads from the very large watersheds (e.g., Cannon, Crow, and Vermillion River watersheds).

Trend analysis indicated both improving and declining trends in TSS and TP flow-adjusted concentrations since 1995; the most recent trends are of decreasing TSS and TP flow-adjusted concentration and thus improving water quality. Trend analysis indicated one decreasing trend in NO_3 concentration since 1995, and thus improving water quality. All trends will be revisited in 5 years when Cl trends will also be investigated.

Analysis of macroinvertebrate samples indicated the presence of some organic pollution during the monitored period, possibly significant organic pollution. No pollution intolerant species have been collected for the past seven years and community diversity has been low. All of the M-IBI scores were below the impairment threshold, which suggests that the habitat and water quality of this stream reach were typically unable to sustain all of the needs for aquatic life.

Recommendations

This section presents recommendations for monitoring and assessment of Fish Creek, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like RWMWD, 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 organization 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 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 continue to evaluate the effects of groundwater withdrawal on surface waters, including updating analyses with the best available data and linking results to predictive groundwater modeling and the comprehensive planning process involving local communities.

- MCES should continue to analyze and evaluate the biomonitoring program. Potential additions could include a Stream Habitat Assessment similar to the habitat surveys performed by the MPCA or the addition of fish population and algal community data.

- MCES and partners (especially RWMWD, the City of Woodbury, and the City of Maplewood) 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.

- RWMWD routinely monitors Carver Lake as part of its Lake Monitoring Program. RWMWD should consider adding nitrate and ammonia to the suite of parameters it monitors to aid in understanding sources and trends of pollutants in Fish Creek.

- MCES staff should continue to serve on technical advisory committees and other work groups to aid in management of Fish Creek.

- The Fish Creek watershed is highly urbanized and many of the native soils have been disturbed. Therefore, published soil surveys may not be representative of actual conditions at specific locations. For installation of infiltration-based stormwater practices (like bioinfiltration basins, raingardens, and pervious pavers), soil borings should be taken from the exact location of the proposed location to assess level of soil filling or disturbance. Based on the boring results, best management practices designs should be customized and appropriate soil amendments added.

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