Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

BEVENS CREEK

METROPOLITAN COUNCIL

December 2014

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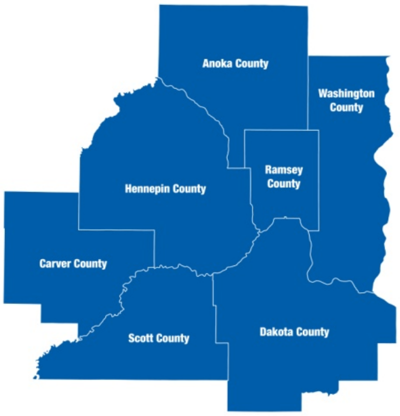

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide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

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About the Study

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

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

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

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

About This Section

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

Cover Photo

The photo on the cover of this section depicts Bevens Creek downstream of the lower monitoring site (Bevens Lower 2.0). It was taken by Metropolitan Council staff.

Recommended Citations

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Introduction

Bevens Creek is located in the southwestern metropolitan area and is a tributary to the Minnesota River. It drains approximately 133 square miles of mixed agricultural land, open space, bluff land, and urban areas (including all or parts of the cities of Green Isle, Hamburg, Norwood Young America, and Cologne) in Sibley and Carver Counties. The Carver County portion of the watershed is in Metropolitan Council District 4; the Sibley County portion is outside the seven-county metro area.

Figure BE-1: Upper Bevens Creek Monitoring Station (Mile 5.0)

Figure BE-2: Lower Bevens Creek Monitoring Station (Mile 2.0)

This report:

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

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

Partnerships

MCES has supported water quality monitoring of Bevens Creek since1989 at the Lower Bevens Creek station and since 1992 at the Upper Bevens Creek station. MCES staff maintains the rating curves and operates the monitoring stations at both sites.

Monitoring Station Descriptions

The Metropolitan Council operates two monitoring stations on Bevens Creek. The Upper Bevens Creek monitoring station is located near the intersection of Bevens Creek and Maplewood Road in Dahlgren Township in Carver County, about 5.0 miles upstream from the Bevens Creek confluence with the Minnesota River. The Lower Bevens Creek monitoring station is located near the CSAH (County State Aid Highway) 40 bridge over Bevens Creek in San Francisco Township in Carver County, about 2.0 miles upstream from the creek's confluence with the Minnesota River. The Upper Bevens Creek station is located just below the Minnesota River valley bluff line and the Lower Bevens Creek station is located near the bottom of the bluff line. The upper station was added to provide data on potential sediment loading from erosion of gullies, ravines, and streambanks as the stream descends the bluff as well as loading from Silver Creek.

Both stations include continuous flow monitoring, event-based composite sample collection, and on site conductivity and temperature probes. The Lower Bevens Creek station (mile 2.0) also includes an in-stream turbidity sensor (Forest Technology Systems DTS-12). There is a rain gauge at the lower station, however it is rarely used due to infrequent calibration; there is no rain gauge at the upper station. Precipitation data are obtained from the Minnesota Climatology Working Group, Jordan Station Number 214176, Chaska Station Number 211468, and Chanhassen Station Number 211448. Daily precipitation totals from these stations 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 watershed (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 Bevens Creek watershed is located at the western edge of the Twin Cities Metropolitan Area. About 70% of the watershed is in Carver County; the remainder is located outside the metropolitan area in Sibley County. The Sibley County portion of the watershed is very flat and ditched with several large, shallow wetlands. The Carver County portion is a little steeper with fewer wetlands, but also ditched.

The watershed is composed of two major subwatersheds: the Bevens Creek main stem and Silver Creek. The main stem of Bevens Creek begins in Green Isle Township of Sibley County and flows east through several wetlands and then continues north and east before turning south in eastern Dahlgren Township in Carver County. Silver Creek starts in southern Hancock Township of Carver County and flows northeasterly until it joins the mainstem of Bevens Creek in northeastern San Francisco Township in Carver County (see Figure BE-3). Silver Creek joins Bevens Creek between the upper and lower monitoring stations.

The entire Bevens Creek watershed is about 85,361 acres, or 133 square miles. About 55,213 acres (64.7% of the entire watershed) drains to the upper Bevens Creek monitoring station. Water from an additional 27,523 acres (the Silver Creek watershed) enters Bevens Creek at the confluence about a mile upstream of the Lower Bevens Creek monitoring station. Measurements at the lower monitoring station represent 96.9% of the area of the entire Bevens Creek watershed.

About 56,328 acres (66 percent) of the entire watershed is in agricultural land use, 6.9 percent (5,892 acres) is developed urban land, 13.8 percent of the watershed is wetlands, 7.8 percent is grassland or open, and 4.8 percent is forested (Table BE-1). The developed land includes the cities of Green Isle and Hamburg, the majority of Norwood Young America, and a portion of Cologne.

Of the agricultural land use, 43.4% is corn, 36.2% soybeans, and 11.7% is pasture/hay. Based on soil type and slope, 35.8% of the agricultural land in the watershed is likely drain tiled (D. Mulla, University of Minnesota, personal communication, 2012).

Since 2000, the Carver SWCD has assisted landowners in the Carver and Bevens Creeks watersheds with installing:

- 39.4 miles (339.2 acres) of CRP (Conservation Reserve Program) buffers
- 16.9 miles (102.8 acres) of permanent RIM (Reinvest In Minnesota) buffers
- 12.7 miles (48 acres) of harvestable buffers

In addition, landowners have restored 91.8 acres of wetlands through CRP. The wetlands serve to store excess runoff during large storm events.

Table BE-1: Bevens Creek Land Cover Classes[1]

Land Cover Class	Upper Bevens		Lower Bevens (Cumulative)		Unmonitored		Bevens Total	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	287	0.5%	431	0.5%	37	1.4%	467	0.5%
11-25% Impervious	1,335	2.4%	1,827	2.2%	71	2.7%	1,898	2.2%
26-50% Impervious	1,078	2.0%	1,445	1.7%	43	1.7%	1,489	1.7%
51-75% Impervious	563	1.0%	736	0.9%	28	1.1%	764	0.9%
76-100% Impervious	850	1.5%	1,241	1.5%	33	1.3%	1,274	1.5%
Agricultural Land	35,630	64.5%	55,029	66.5%	1,299	49.5%	56,328	66.0%
Forest (all types)	2,086	3.8%	3,683	4.5%	410	15.6%	4,092	4.8%
Open Water	195	0.4%	226	0.3%	0	0.0%	226	0.3%
Barren Land	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Shrub land	277	0.5%	335	0.4%	0	0.0%	335	0.4%
Grasses/Herbaceous	4,545	8.2%	6,484	7.8%	198	7.5%	6,681	7.8%
Wetlands (all types)	8,367	15.2%	11,301	13.7%	505	19.2%	11,806	13.8%
Total	**55,213**	**100.0%**	**82,736**	**100.0%**	**2,625**	**100.0%**	**85,361**	**100.0%**

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

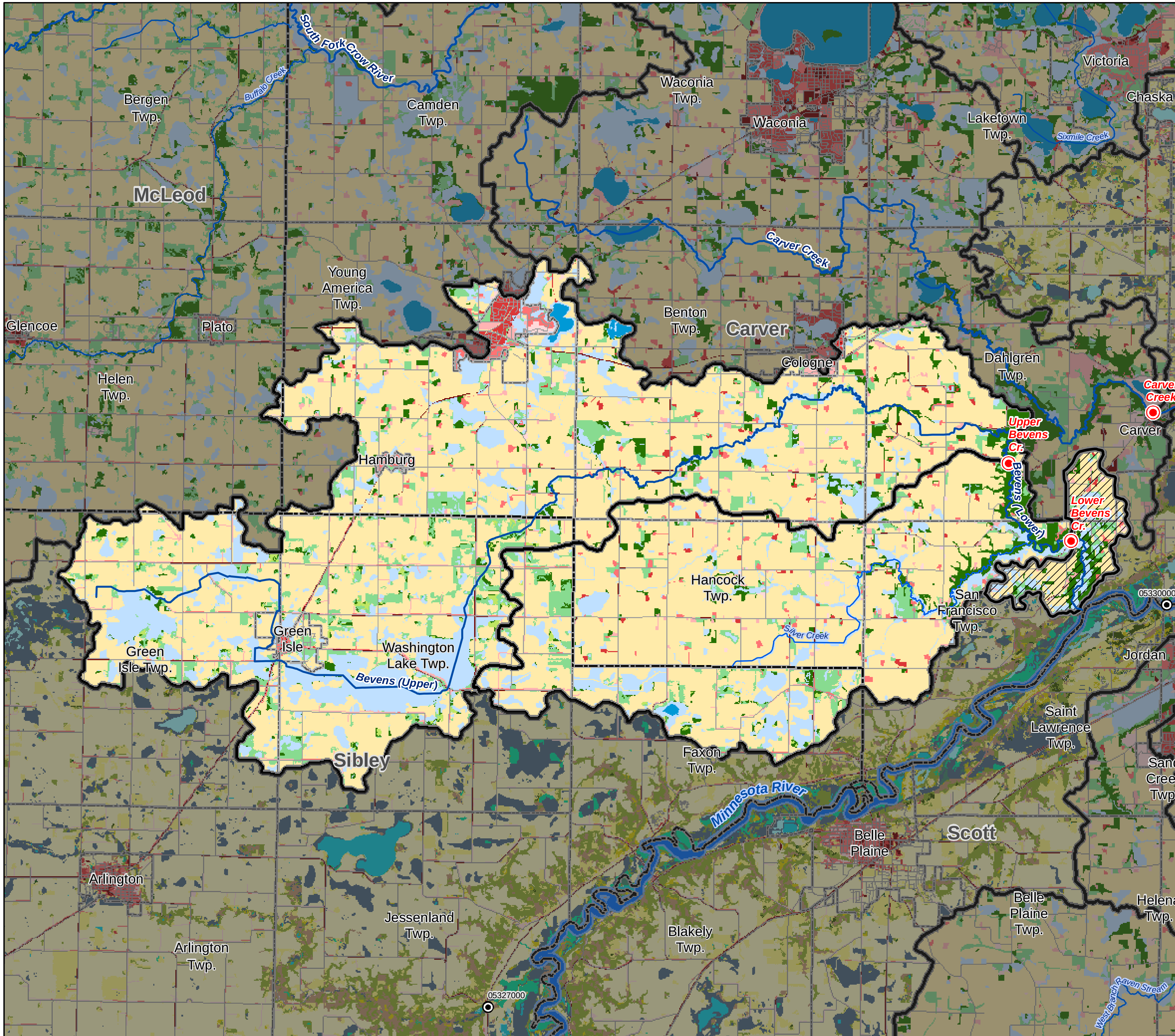

Figure BE-3

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MLCCS-NLCD Hybrid Land Cover

Upper and Lower Bevens 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
Bevens, Lower and Upper

	Monitored		Unmonitored		Total	
Land Cover Class	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**
5-10% Impervious	430	0.5%	37	1.4%	467	0.5%
11-25% Impervious	1,827	2.2%	71	2.7%	1,898	2.2%
26-50% Impervious	1,445	1.7%	43	1.7%	1,489	1.7%
51-75% Impervious	736	0.9%	28	1.1%	764	0.9%
76-100% Impervious	1,241	1.5%	33	1.3%	1,274	1.5%
Agricultural Land	55,029	66.5%	1,299	49.5%	56,328	66.0%
Forest (all types)	3,683	4.5%	410	15.6%	4,092	4.8%
Open Water	226	0.3%	0	0.0%	226	0.3%
Barren Land	0	0.0%	0	0.0%	0	0.0%
Shrubland	335	0.4%	0	0.0%	335	0.4%
Grasses/Herbaceous	6,483	7.8%	198	7.5%	6,681	7.8%
Wetlands (all types)	11,301	13.7%	505	19.2%	11,806	13.8%
Total	**82,736**	**100.0%**	**2,625**	**100.0%**	**85,361**	**100.0%**

Bevens, Upper

	Monitored	
Land Cover Class	**Acres**	**Percent**
5-10% Impervious	287	0.5%
11-25% Impervious	1,335	2.4%
26-50% Impervious	1,078	2.0%
51-75% Impervious	563	1.0%
76-100% Impervious	850	1.5%
Agricultural Land	35,630	64.5%
Forest (all types)	2,086	3.8%
Open Water	195	0.4%
Barren Land	0	0.0%
Shrubland	277	0.5%
Grasses/Herbaceous	4,545	8.2%
Wetlands (all types)	8,367	15.2%
Total	**55,213**	**100.0%**

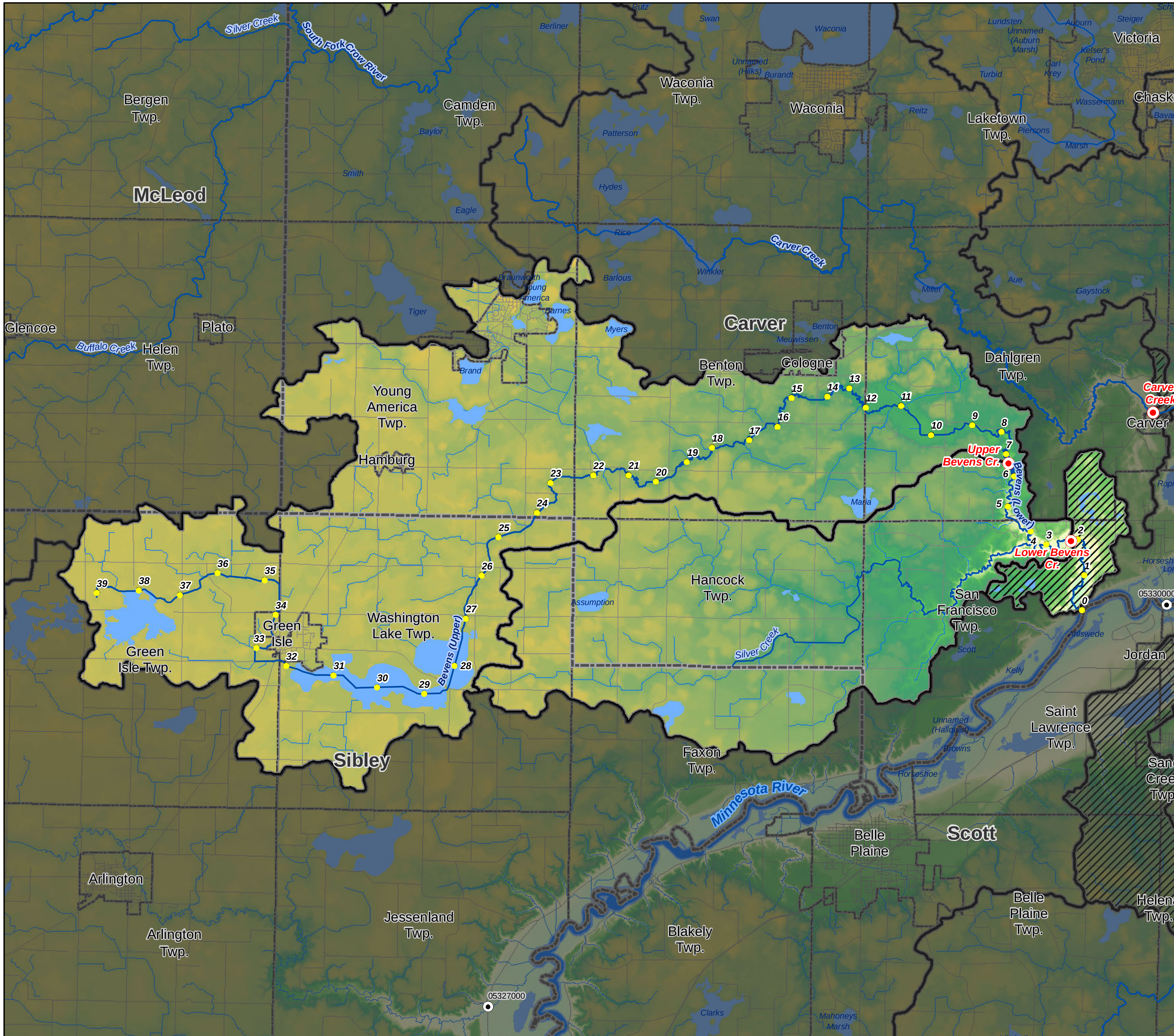
N

0 1 2 3 4 5

Miles

Figure BE-4

Watershed Topography
Upper and Lower Bevens Creek

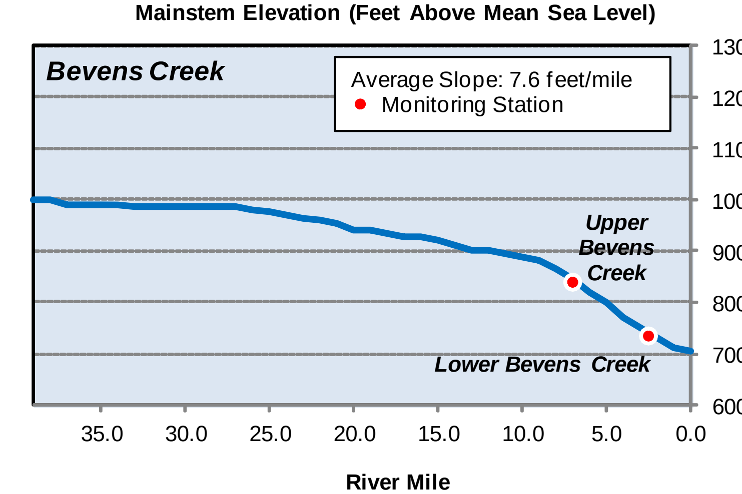


- MCES Stream Monitoring Sites
- USGS Flow Stations
- Stream Mile Markers
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- County Boundary
- City and Township Boundaries
- NCompass Street Centerlines, 2012
- Public Waters Inventory
- Other Rivers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

Elevation
Feet Above Mean Sea Level
High : 1594
1400
1200
1000
800
Low : 643

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

Mainstem Elevation (Feet Above Mean Sea Level)



0 1 2 3 4 5 6
Miles

The watershed topography is generally fairly flat ground moraine until the Minnesota River bluffs, where there is a steep drop through terraced deposits (Figure BE-4). The maximum watershed elevation is 1039.4 MSL and the minimum elevation is 735.4 MSL within the monitored area. Within the monitored area, 0.8% of the slopes are considered steep, and an additional 0.4% are considered very steep (MnDNR, 2011).

In general, the watershed is flat with medium to fine textured soils. The land elevation gently slopes from west to east across the watershed until about mile 20, when it begins to slope more steeply. Over the years, drain tiles and ditches have been installed and built to improve drainage for agriculture.

The slope of the channel generally follows that of the land. From about mile 10 it descends steeply from the top of the bluff to the confluence with the Minnesota River. The major wetland complexes through which the stream flows are ditched, especially in the western portion of the watershed, and many of the agricultural fields in the watershed are tiled and/or ditched. Outfalls from some ditches are pumped to the stream.

The monitored Bevens Creek watershed contains two domestic wastewater treatment plants (WWTPs): Norwood Young America and Hamburg (Table BE-2, Figure BE-5). There is an industrial stormwater permit holder and an industrial wastewater permit holder in the watershed. There are also many small permitted feedlots in the watershed.

Table BE-2: Permitted domestic wastewater treatment facilities discharging to Bevens Creek at County Rd 40 (BE2.0)

Permit #	Permit Holder	Design Flow (mgd)	Class	Phosphorus removal[2]	General Notes[1]
MN0024392	Norwood Young America WWTP	0.908	B	---	No significant reduction.
MN0025585	Hamburg WWTP	0.063	D	---	Stabilization pond WWTP. No P limit. Relatively low conc. since start of records (12/2000)

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

Figure BE-5

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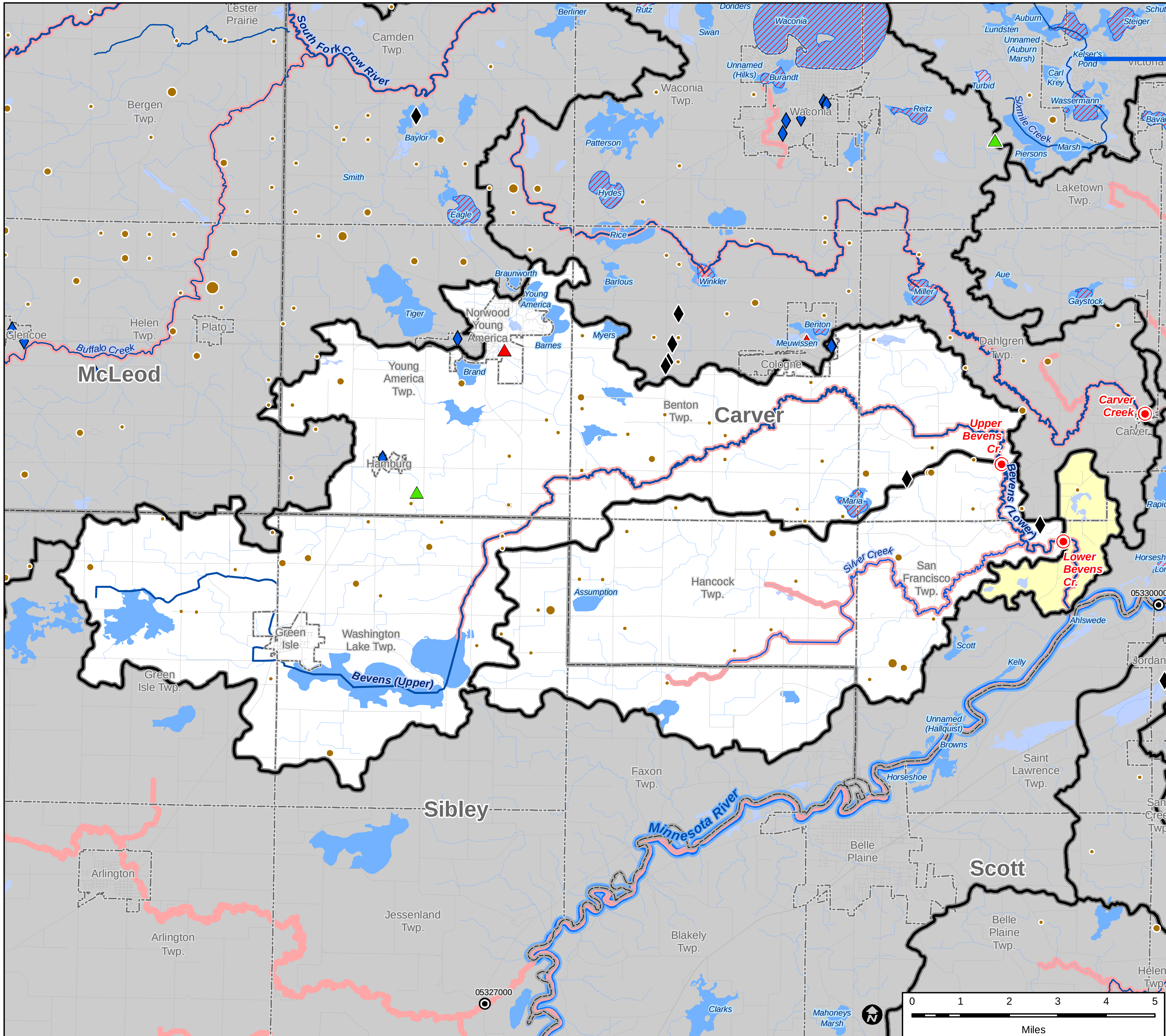
Public and Impaired Waters and Potential Pollution Sources

Upper and Lower Bevens 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

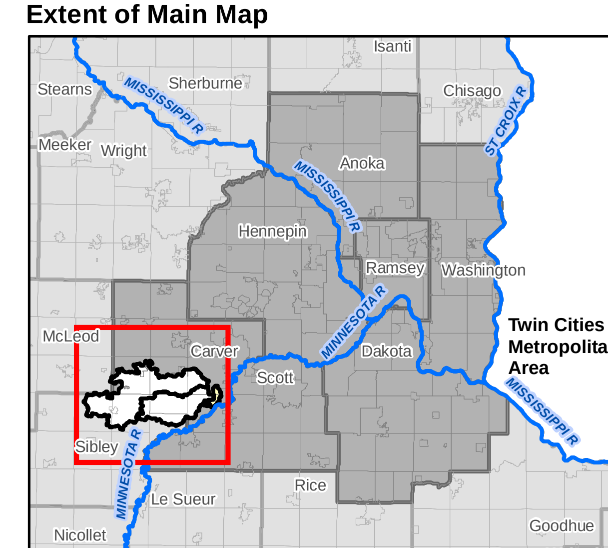
Feedlots with 100 or more animal units **

- 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 Bevens Creek watershed contains five stream reaches and one lake that are included on the MPCA's 2014 impaired waters list (Figure BE-5; Tables BE-3 and BE-4).

Table BE-3: Bevens 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[2]	Needs Plan[2]
Bevens Creek	Silver Cr to Minnesota R	07020012-514	AQR, AQL	FC, T	---
Bevens Creek	Headwaters (Washington Lk 72-0017-00) to Unnamed cr	07020012-717	AQR, AQL	FC, T	---
Bevens Creek	Unnamed cr to Silver Cr	07020012-718	AQR, AQL	FC, T, Cl (stream was delisted for Cl in 2012)	---
Judicial Ditch 22	Unnamed cr to Silver Cr	07020012-629	AQR	---	FC
Silver Creek	CD 32 to Bevens Cr	07020012-523	AQR, AQL	FC, T	---

[1] AQR = Aquatic Recreation; AQL = Aquatic Life; [2] FC = Fecal Coliform; T = Turbidity; Cl = Chloride;

Table BE-4: Bevens Creek watershed impaired lakes as identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Affected Use(s)[1]	Approved Plan	Needs Plan
Maria	10-0058-00	AQR	---	Nutrients

[1] AQR = Aquatic Recreation

Hydrology

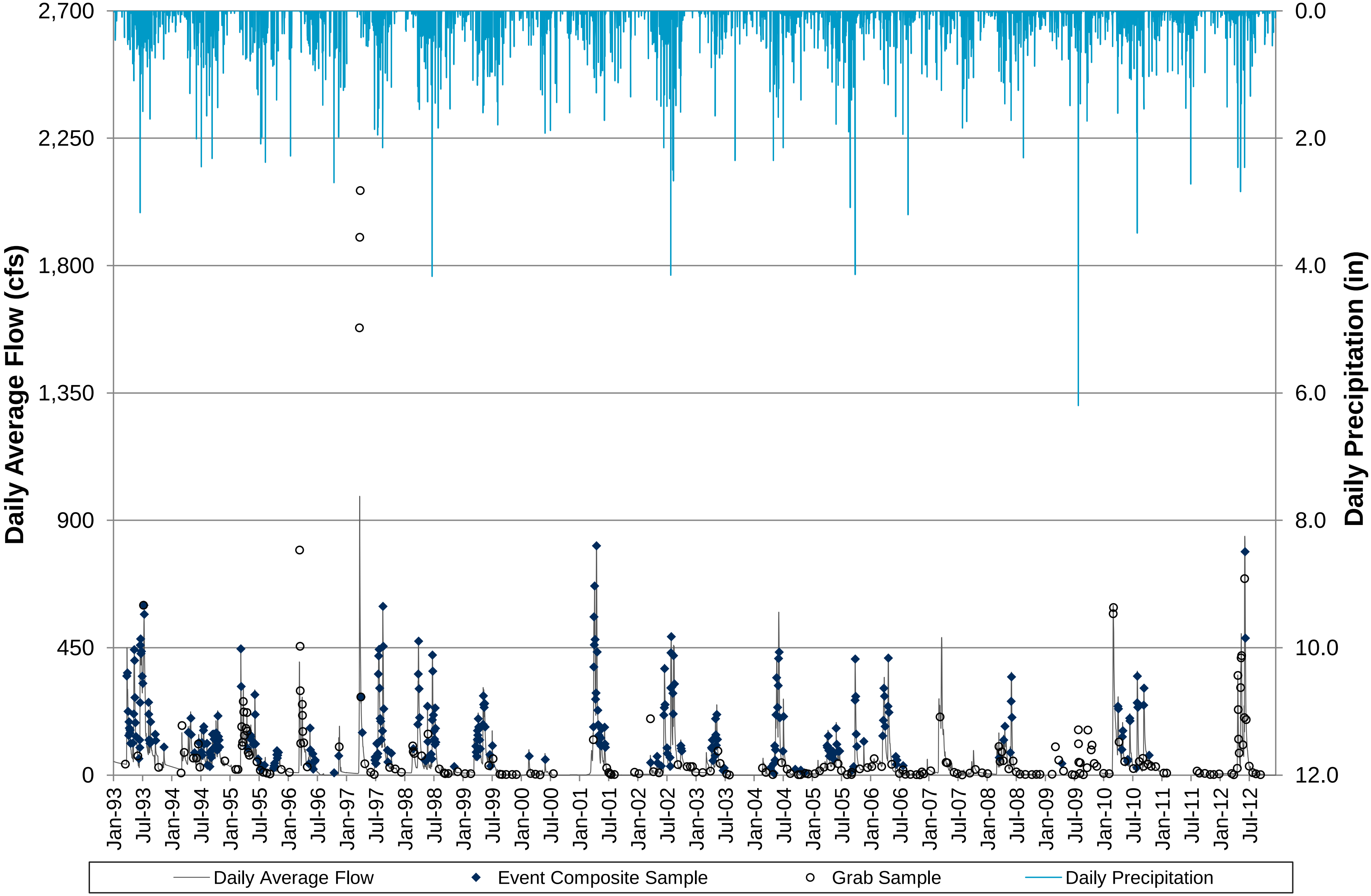
MCES has monitored flow on Bevens Creek since1989 at the Lower Bevens Creek station and since 1992 at the Upper Bevens Creek station. Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrograph of Upper and Lower Bevens Creek, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variations in flow rates from season to season and from year to year, and the effect of precipitation events on flow (Figures BE-6 and BE-7).

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

Analysis of the duration of daily average flows at the lower monitoring station indicates the upper 10th percentile flows for period 1989-2012 ranged between approximately 185 -1,564 cfs, while the lowest 10th percentile flows ranged from 0.5-2.9 cfs (See Figure BE-20 in the ***Flow and Load Duration Curves*** section of this report).

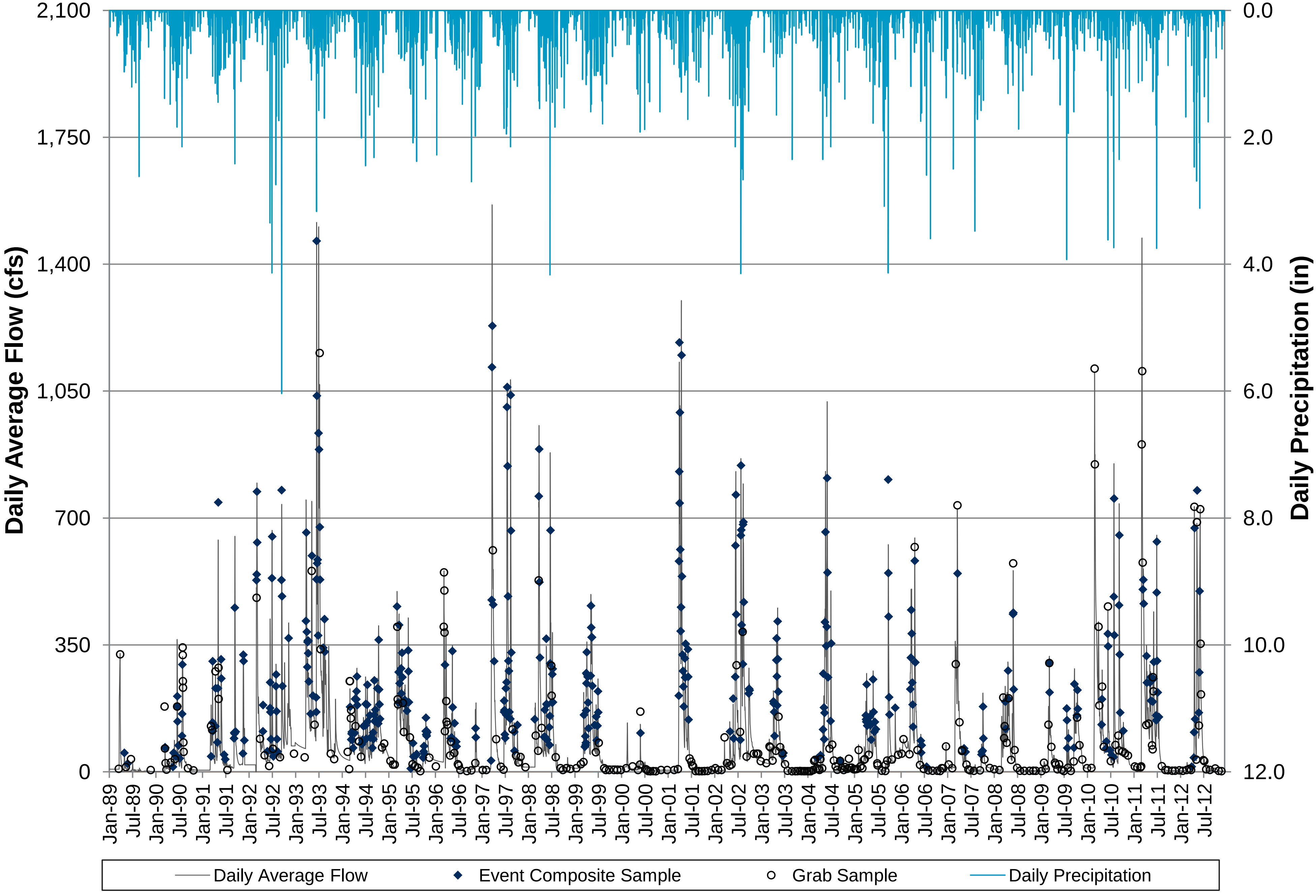
Additional annual flow/volume metrics are shown on Figures BE-8 to BE-15, along with the annual pollutant load parameters. The first graph on each sheet illustrates an annual flow metric consisting of 1) average annual flow (a measure of annual flow volume); 2) areal-weighted flow; and 3) the fraction of annual precipitation ending up as flow, respectively.

Figure BE-6: Upper Bevens Creek Daily Average Flow, Sample Flow, and Precipitation, 1993-2012*



*2009 and 2011 flows unreliable due to equipment problems; precipitation record was acquired from NWS COOP stations: 211468-Chaska 2NW , 214176-Jordan 1 S, and 211448- Chanhassen WSFO

Figure BE-7: Lower Bevens Creek Daily Average Flow, Sample Flow, and Precipitation, 1989-2012*



*Precipitation record was acquired from NWS COOP stations: 214176-Jordan 1 S, 211468-Chaska 2NW, and 211448-Chanhassen WSFO

Vulnerability of Stream to Groundwater Withdrawals

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

To assess the vulnerability of Bevens Creek to groundwater withdrawals, MCES staff examined spatial datasets of vulnerable stream segments and basins created as part of the 2010 regional groundwater analysis. Results were available only for that portion of the Bevens Creek watershed located within the seven-county metropolitan area boundary (i.e. the Carver County portion; no data is available for Sibley County). Within Carver County, thirteen stream segments were identified as potentially vulnerable. These include the lower part of Silver Creek in San Francisco Township to its confluence with the mainstem of Bevens Creek, and a portion of the mainstem of Bevens Creek starting in Dahlgren Township and extending to the confluence with the Minnesota River. A few small unnamed wetlands in the lower part of the watershed were also identified as vulnerable to groundwater withdrawals.

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

Pollutant Loads

The U.S. Army Corps of Engineers program Flux32 (Walker, 1999) was used to convert daily average flow, coupled with grab and event-composite sample concentrations, into annual and monthly loads and flow-weighted mean concentrations. Loads were estimated for total suspended solids (TSS), total phosphorus (TP), total dissolved phosphorus (TDP), nitrate ($NO_{3)}$, ammonia (NH3), and chloride (Cl) for each year of monitored data in Bevens Creek (upper, 1993-2012; lower 1998-2011). (Due to persistent equipment problems in 2009 and 2011, flow data collected at the upper Bevens monitoring station was unreliable; therefore load results are not presented for those years.) Figures BE-8 through BE-15 illustrate annual loads at both monitoring stations 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 two hydrological metrics (annual average flow rate and the fraction of annual precipitation as flow). A later section in this report (***Comparison with Other Metro Area Streams***) offers graphical comparison of the Bevens Creek loads and FWM concentrations with the other MCES-monitored metropolitan area tributaries.

The flow metrics indicate year-to-year variation in annual flow rate that is likely driven by variation in annual precipitation amount as well as by variation in frequency of intense storm events. The fraction of annual precipitation delivered as flow varies between years; year-to-year variation is likely influenced by drought periods, by low soil moisture caused by dry periods, by increased capacity in upland storage areas during drought periods, and other factors.

As would be expected, average annual flows are higher at the lower monitoring site than at the upper site due to the additional drainage area encompassed at the lower site. However, the annual flows follow the same general pattern at both Bevens Creek monitoring stations.

The annual mass loads for all parameters exhibit significant year-to-year variation, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream. Again, the annual loads at the two stations follow the same general pattern, echoing the annual flows, but the absolute quantities are significantly higher at the lower station due to the increased watershed area monitored.

The annual FWM concentrations for all parameters also fluctuate year-to-year and are likely influenced by annual precipitation and flow. The FWM concentrations are generally lower at the upper station than at the lower, however there are exceptions, and all the average annual FWM Cl concentrations from 1999-2012 were higher at the upper station than the lower.

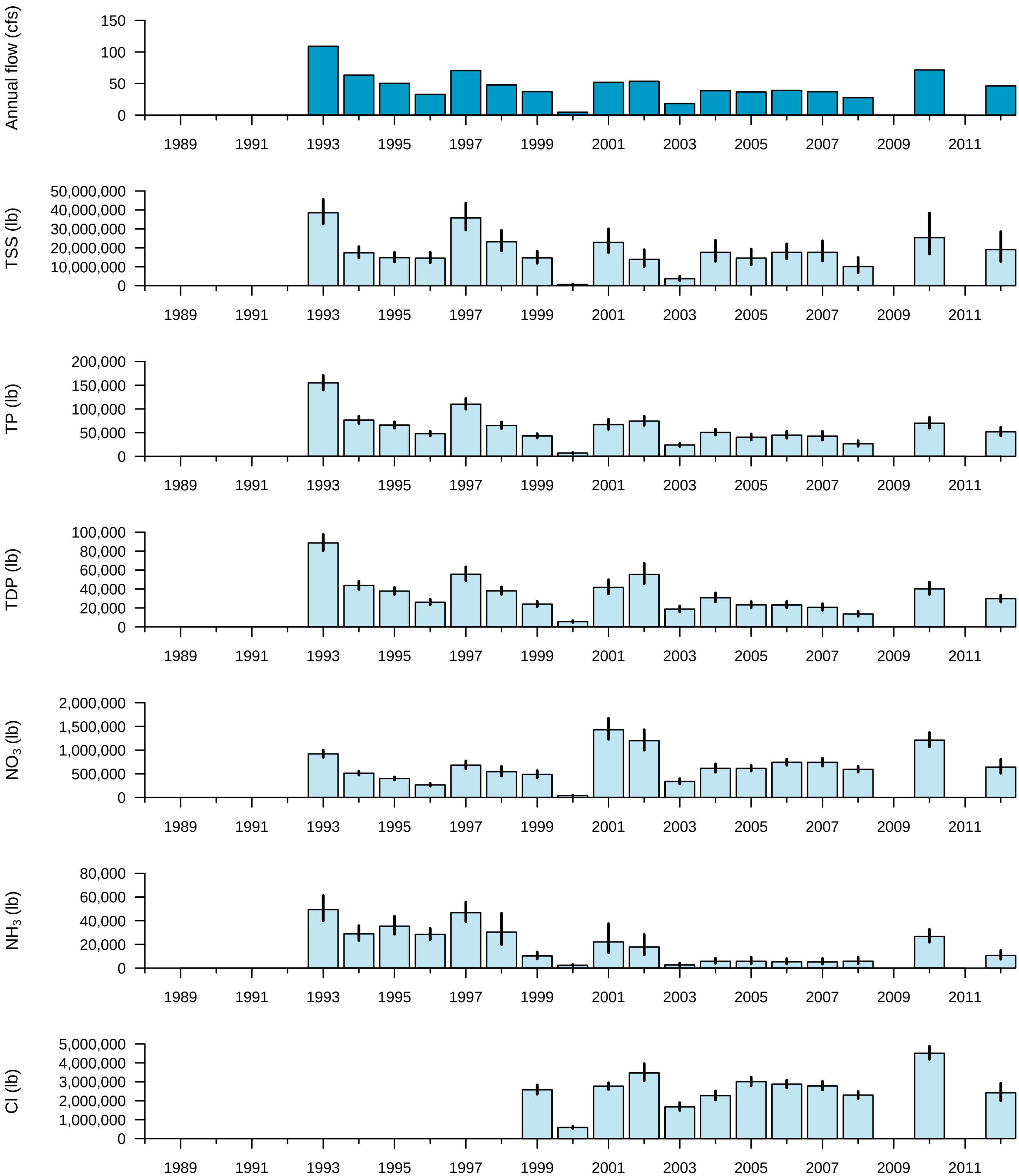
Figures BE-12 through BE-15 present the areal and precipitation-weighted loads for both Bevens Creek monitoring stations. These graphics are presented to assist local partners and watershed managers, and will not be discussed here.

The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of temporal patterns in the loads in Bevens Creek (Figures BE-16 - BE-19). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for upper and lower Bevens Creek) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month).

Over the 2003-2012 period, highest average flows, and in turn mass loads, generally occur in the spring or early summer of each year, likely due to effects of snow melt and spring rains. Flows then generally decrease each subsequent month until late summer or fall, when a secondary flow/load pulse often occurs. The most recent years' loads at both Bevens Creek stations follow this pattern. Monthly mass loads are generally higher at the lower station than the upper station, reflecting the greater drainage area at the downstream site.

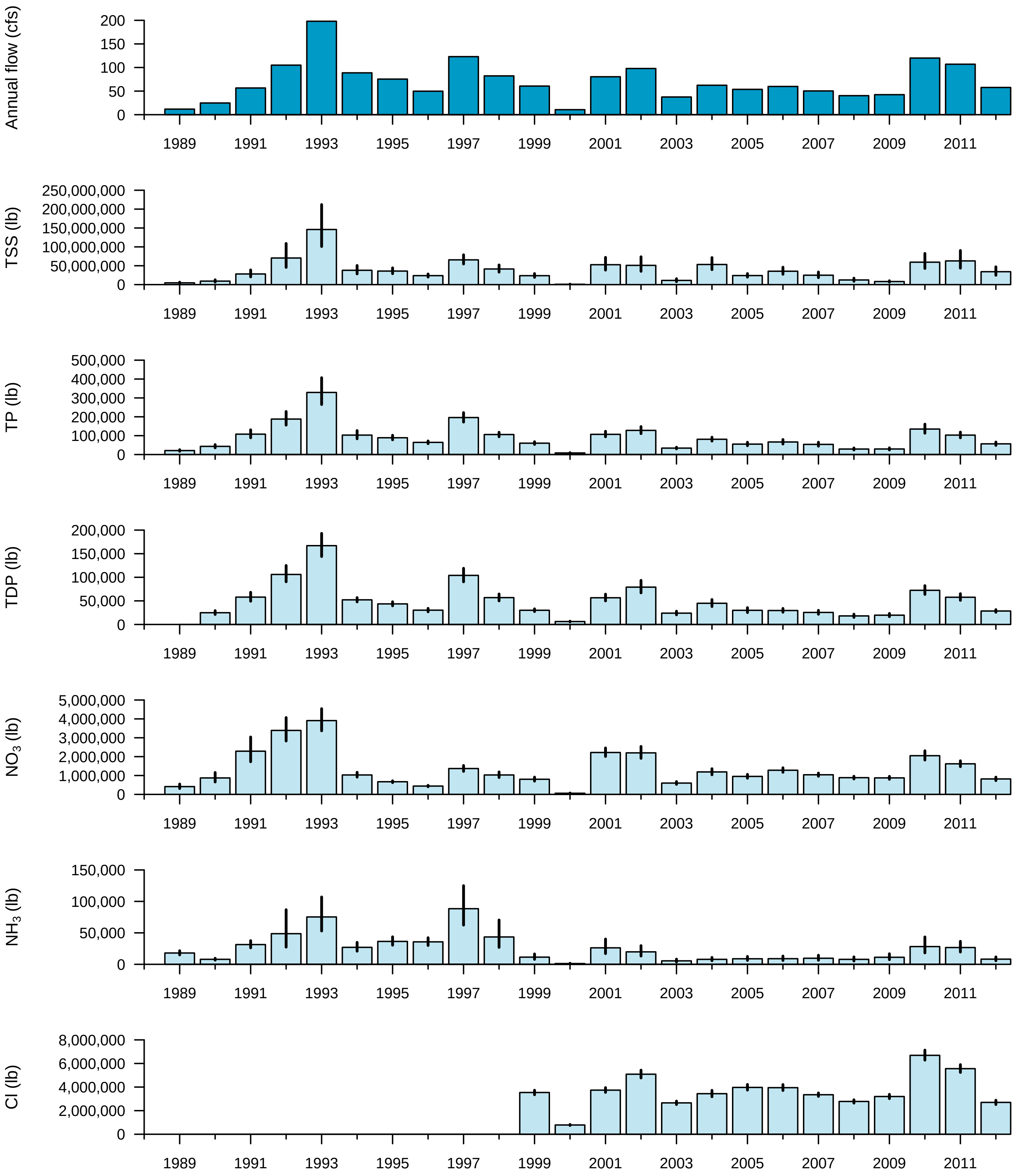
The FWM concentrations generally show less month-to-month variability than the loads. TSS concentrations are generally higher at the lower station that at the upper station, while TP, TDP and chloride concentrations are generally higher at the upper station than at the lower station.

Figure BE−8: Upper Bevens Creek*
Annual Mass Load



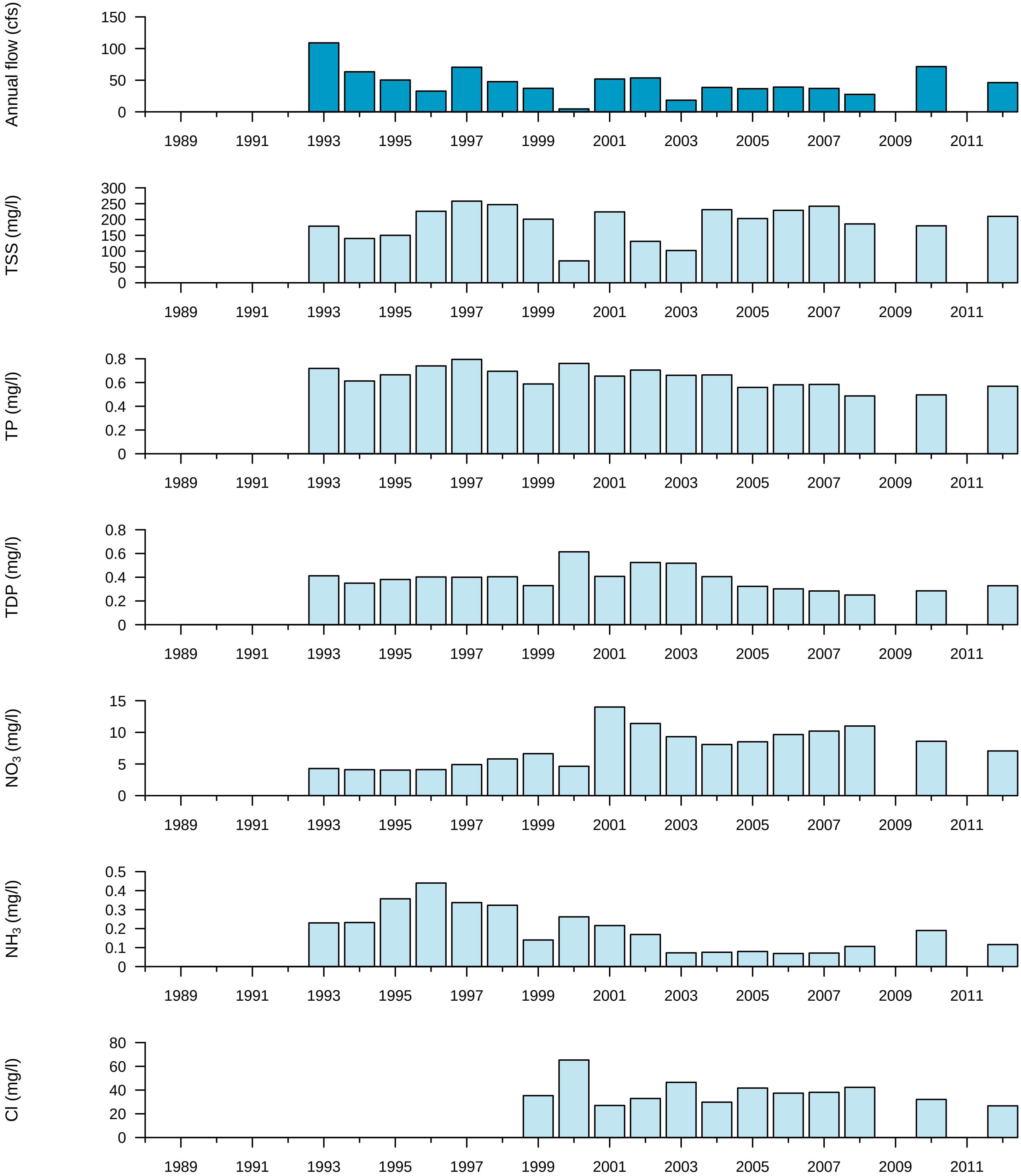
*TSS, TP, TDP, NO3, and NH3 sampling began in 1993, Cl began in 1999. The station was down in 2009 and 2011 so no loads could be calculated.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure BE−9: Lower Bevens Creek* Annual Mass Load



*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure BE−10: Upper Bevens Creek* Annual Flow−Weighted Mean Concentration

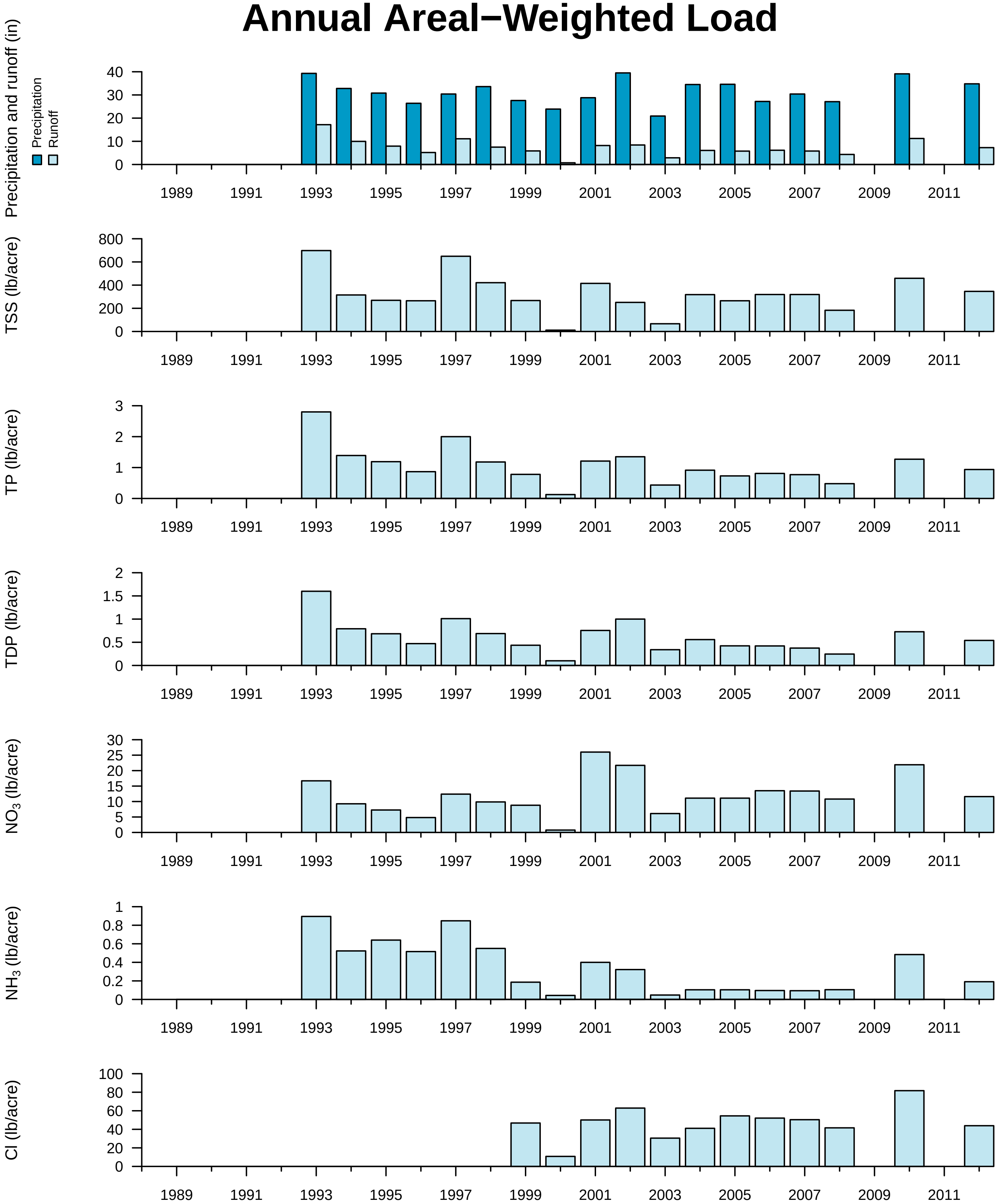


*TSS, TP, TDP, NO3, and NH3 sampling began in 1993, Cl began in 1999. The station was down in 2009 and 2011 so no loads could be calculated.

Figure BE−11: Lower Bevens Creek* Annual Flow−Weighted Mean Concentration

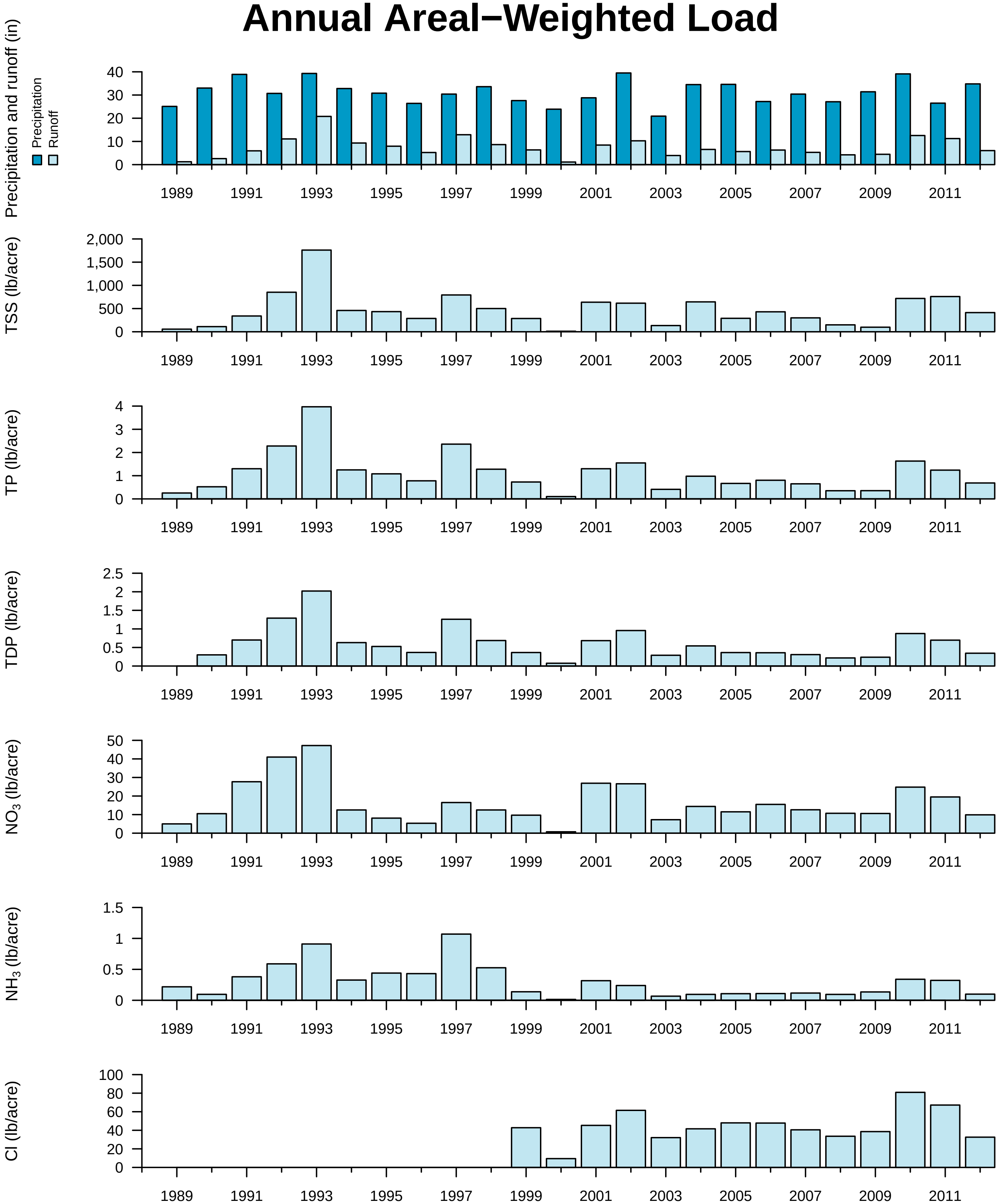
*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.

Figure BE−12: Upper Bevens Creek*
Annual Areal−Weighted Load



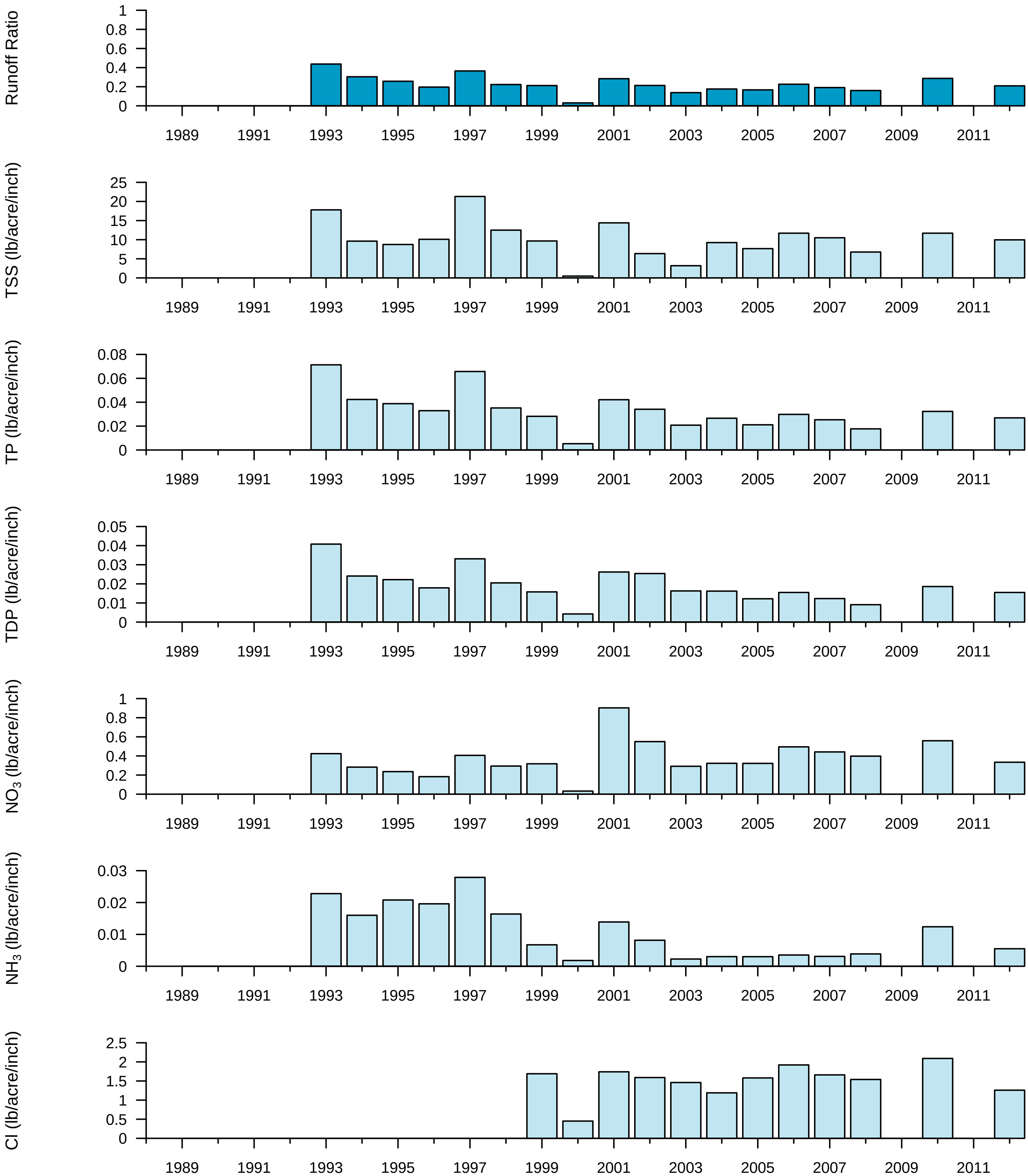
*TSS, TP, TDP, NO3, and NH3 sampling began in 1993, Cl began in 1999. The station was down in 2009 and 2011 so no loads could be calculated.

Figure BE−13: Lower Bevens Creek*
Annual Areal−Weighted Load



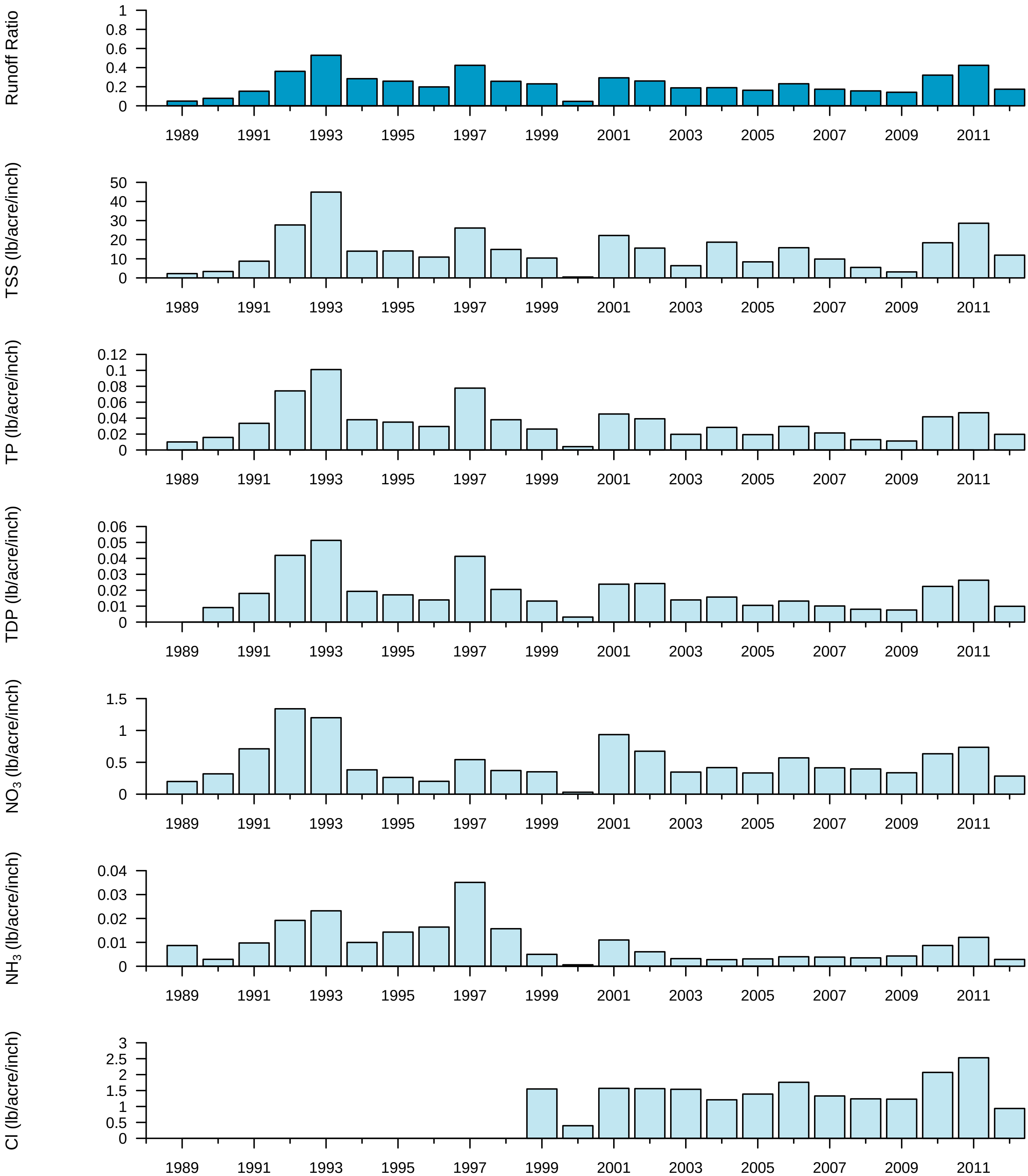
*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.

Figure BE−14: Upper Bevens Creek*
Annual Precipitation−Weighted Areal Load



*TSS, TP, TDP, NO3, and NH3 sampling began in 1993, Cl began in 1999. The station was down in 2009 and 2011 so no loads could be calculated.

Figure BE−15: Lower Bevens Creek*
Annual Precipitation−Weighted Areal Load



*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.

Figure BE−16: Upper Bevens Creek Mass Load by Month

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

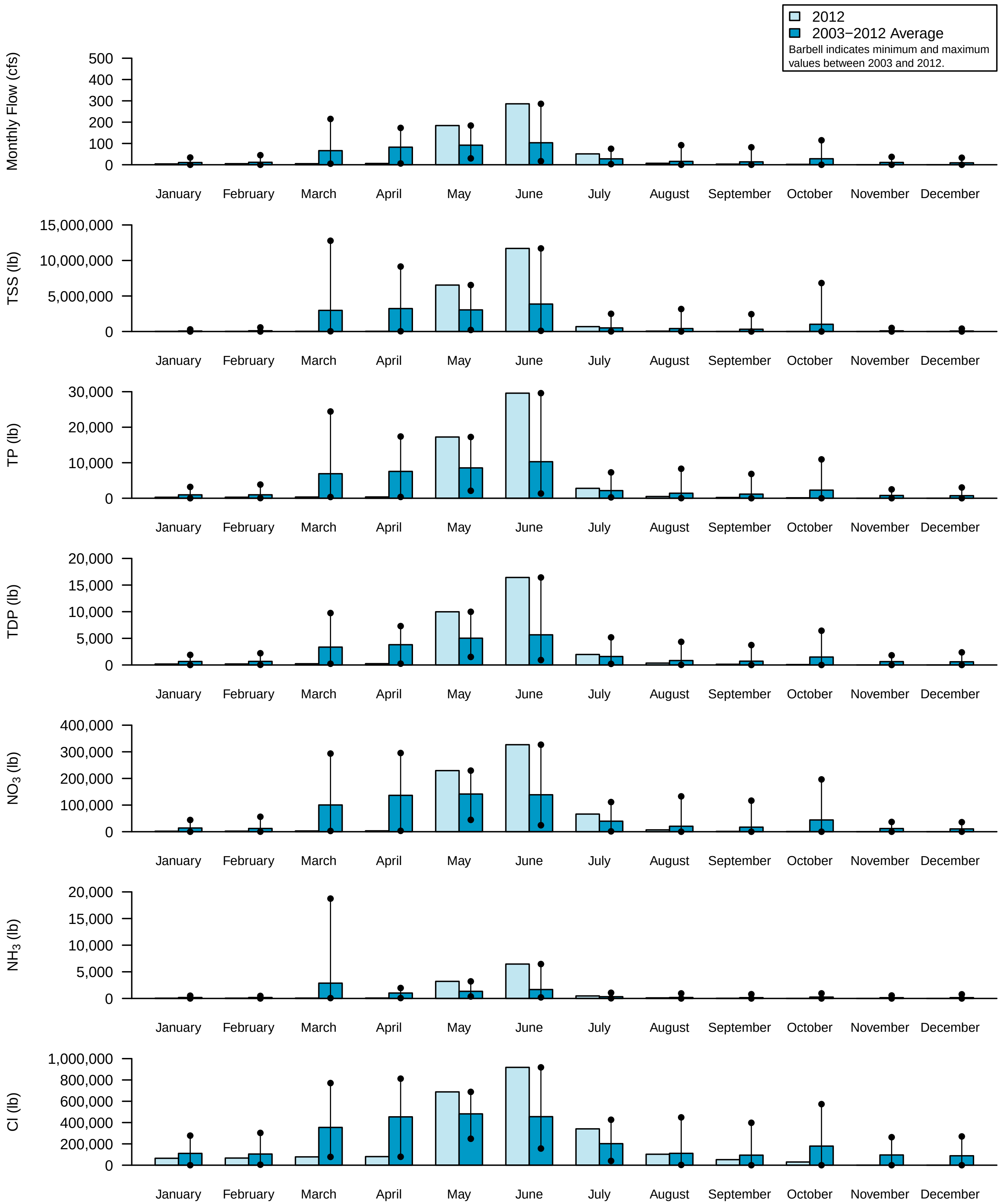


Figure BE−17: Lower Bevens Creek Mass Load by Month

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

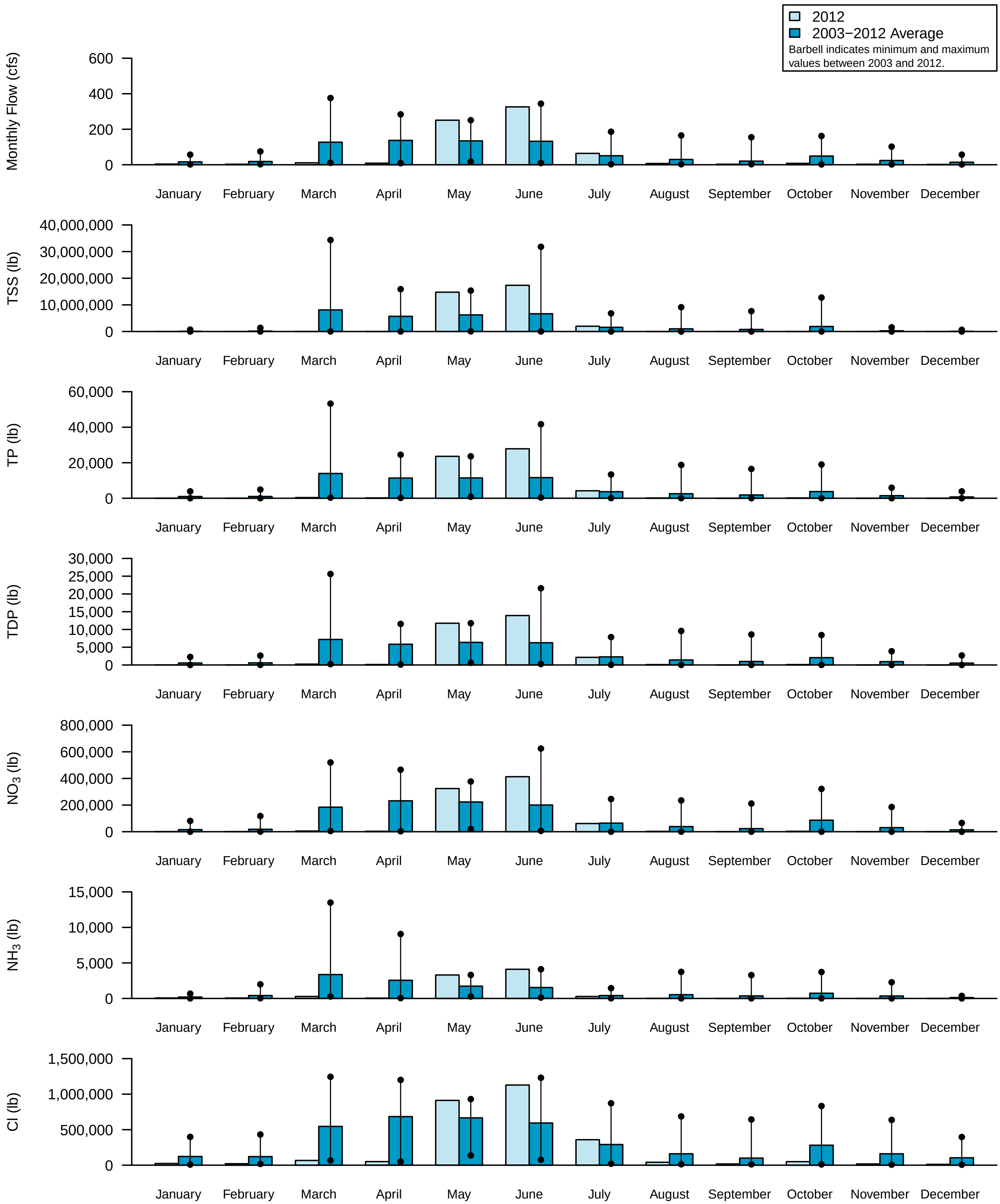


Figure BE−18: Upper Bevens Creek Flow−Weighted Mean Concentation by Month

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

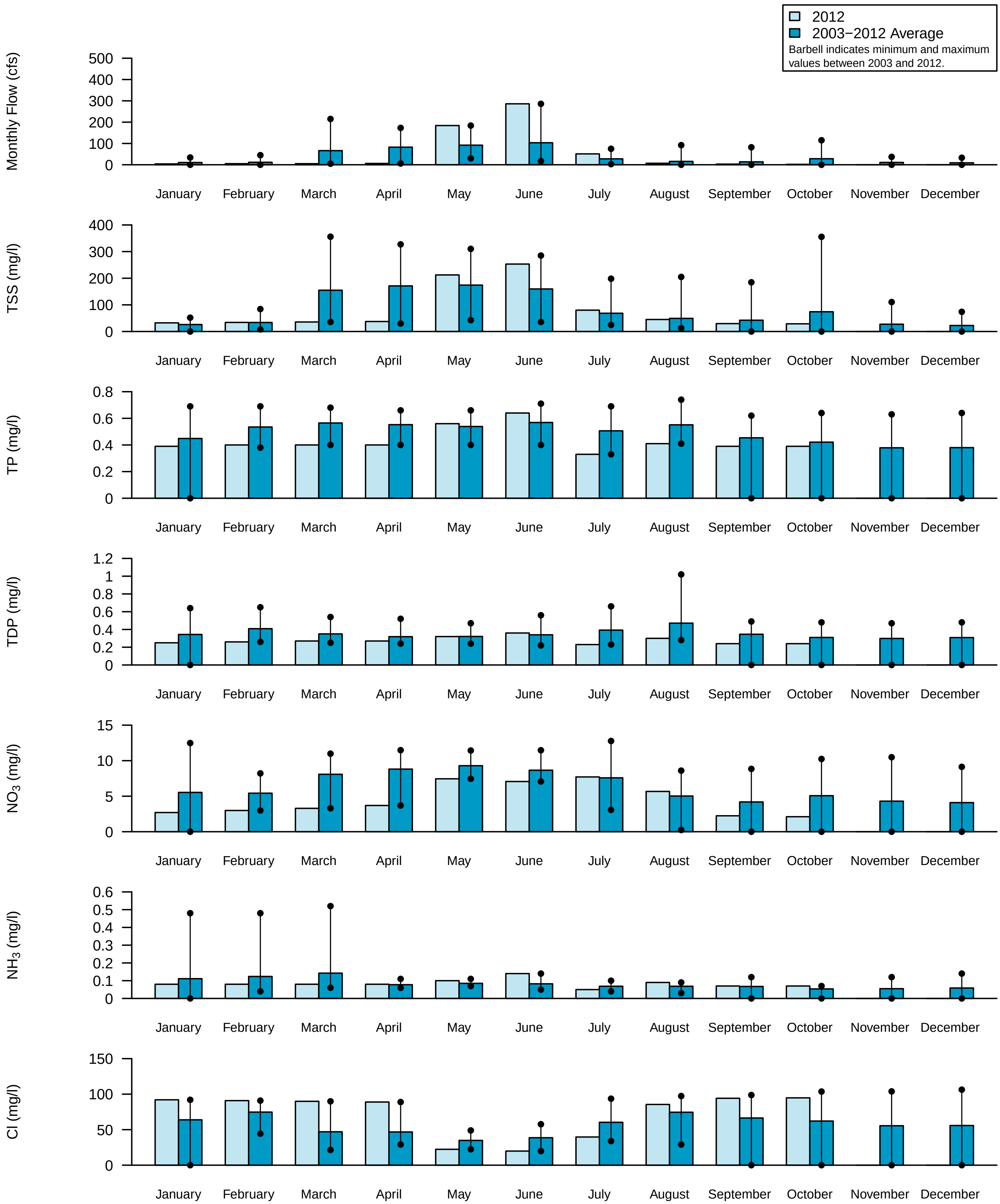
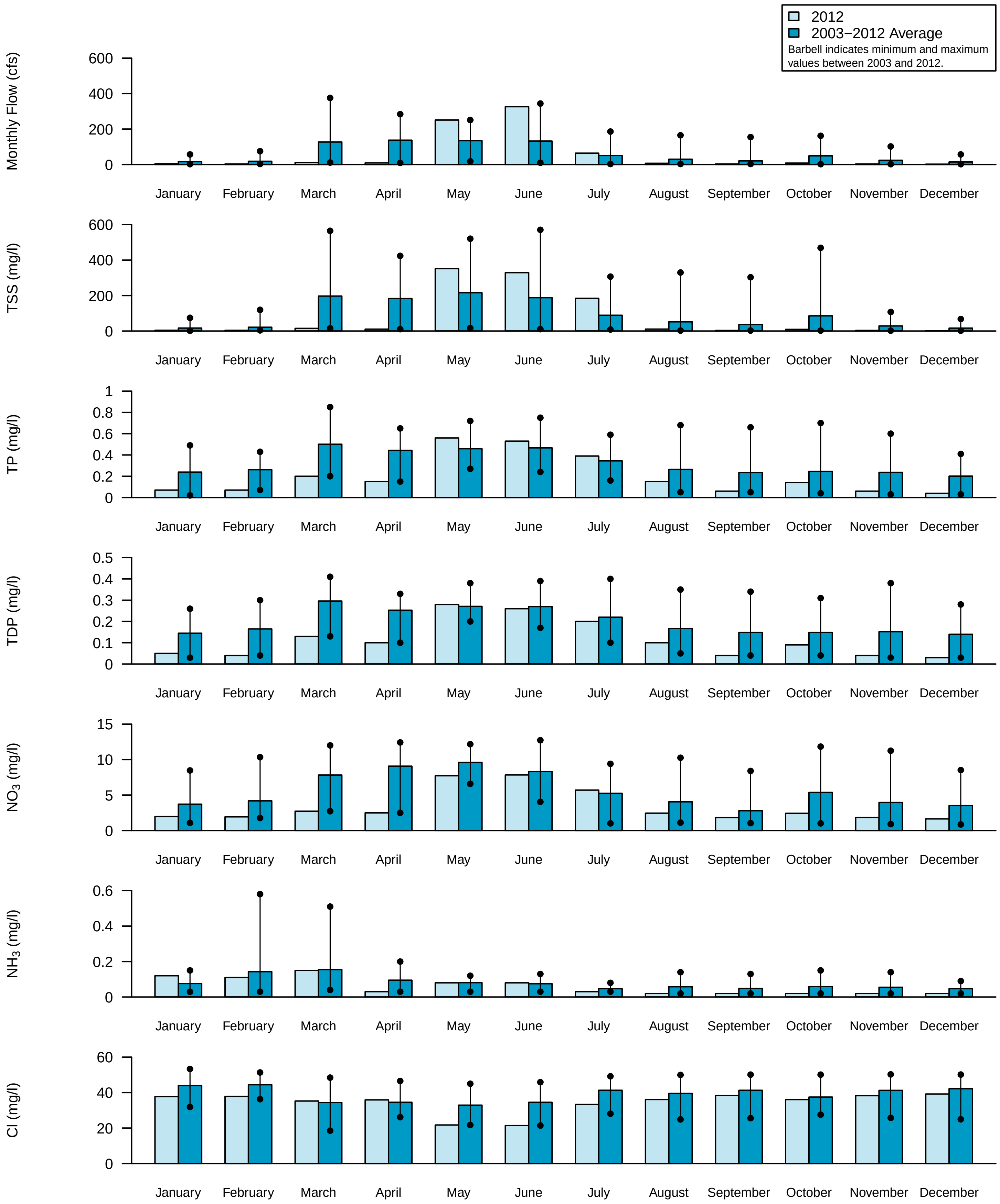


Figure BE−19: Lower Bevens Creek Flow−Weighted Mean Concentation by Month

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



Flow and Load Duration Curves

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

MCES developed flow and load duration curves for each stream locations 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 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles, respectively.
- Multiply concentration and flow for each sampling event for period of record, to result in approximate daily mass loads included on the curve as points.
- Multiply water quality standard concentration and monitored flow to form a line indicating allowable load. Sample load points falling below the line meet the standard; those falling above the line exceed the standard.

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

MCES selected four parameters to assess using load duration curves: TSS, TP, NO_3, and Cl. Each of the parameters was plotted using Bevens Creek lower monitoring station (mile 2.0) daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table BE-5. No draft standard has been set for NO_3, so MCES used the drinking water standard of 10 mg/l.

Most of the draft standards proposed by MPCA have accompanying criteria that are difficult to show on the load duration curves. For example, for a water body to violate the draft TP river criteria, the water body must exceed the causative variable (TP concentration), as well as one or more response variables: sestonic (suspended) chlorophyll, biochemical oxygen demand ($BOD_{5)}$, dissolved oxygen (DO) flux, and/or pH (MPCA, 2013a). Thus for this report, the load duration curves are used as a general guide to identify flow regimes at which water quality violations may occur. The MPCA is responsible for identifying and listing those waters not meeting water quality standards; the results of this report in no way supersede MPCA's authority or process.

The 1989–2012 flow duration curve and load duration curves for TSS, TP, NO_3, and Cl for the lower Bevens Creek monitoring station (mile 2.0) are shown in Figure BE-20. The TSS load duration curve shows that most of the violations of the proposed 30 mg/l TSS standard occur at the high flow and moist conditions regimes, with few exceedances at the lower flow regimes.

This response is consistent with other streams in the Minnesota River watershed, where high flows lead to streambank, bluff, and ravine erosion.

For total phosphorus, there are violations of the proposed standard at all flow regimes, but during high flow, moist conditions, and mid-range flows almost all samples exceed the standard. Sources of phosphorus in the watershed may include eroded soil and feedlot runoff, as well as WWTP and septic system effluent.

Most of the NO_3 concentrations at the low flow, dry conditions, and mid-range flow regimes met the drinking water standard of 10 mg/l. A number of samples exceeded the standard at moist conditions, and many samples exceeded it at high flow conditions. The final river nutrient standard for NO_3 will likely be much less than the 10 mg/l drinking water standard, and will probably be exceeded at the higher flow regimes. The likely sources of nitrate in the watershed are wastewater effluent and nitrogen fertilizer applications on crop land.

The chloride load duration curve shows no exceedances of the proposed standard at any of the flow regimes, and thus Bevens Creek is probably not impaired for chloride. This likely reflects the rural nature of the watershed, and relatively smaller amount of salt applied for road deicing compared to more developed watersheds.

Table BE-5: Bevens 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 Criteria[5] (ug/l)	NO_3 DW Stnd[6a] (mg/l)
Lower Bevens Creek at Co. Rd. 40 (BE2.0)	2B	Central	230	30	100	10
Upper Bevens Creek at Maplewood Rd. (BE5.0)	2B	Central	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430

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

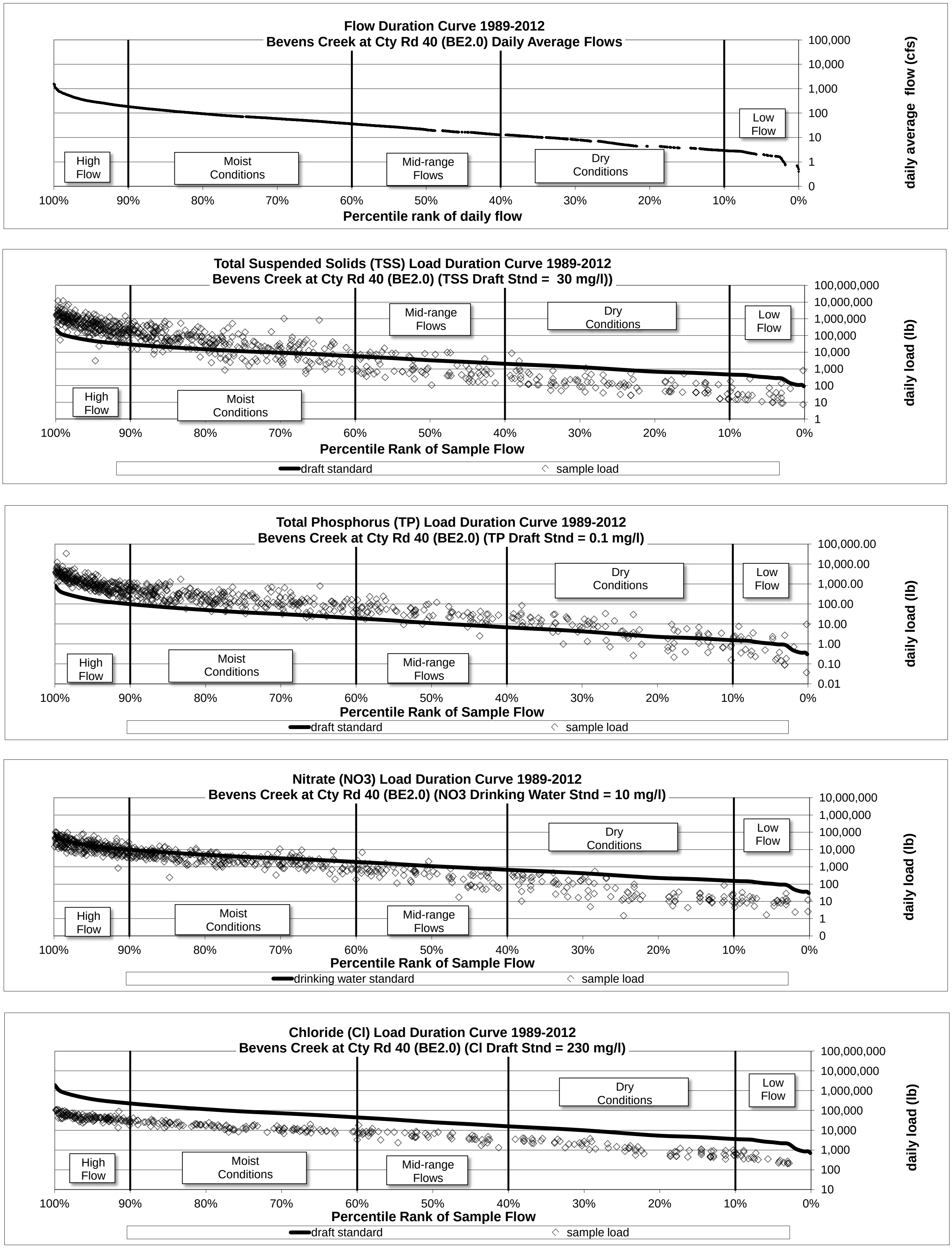
[3] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft chloride standard pending results of EPA toxicity tests.

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

Figure BE-20: Lower Bevens Creek Flow and Load Duration Curves, 1989-2012



Aquatic Life Assessment Based on Macroinvertebrates

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

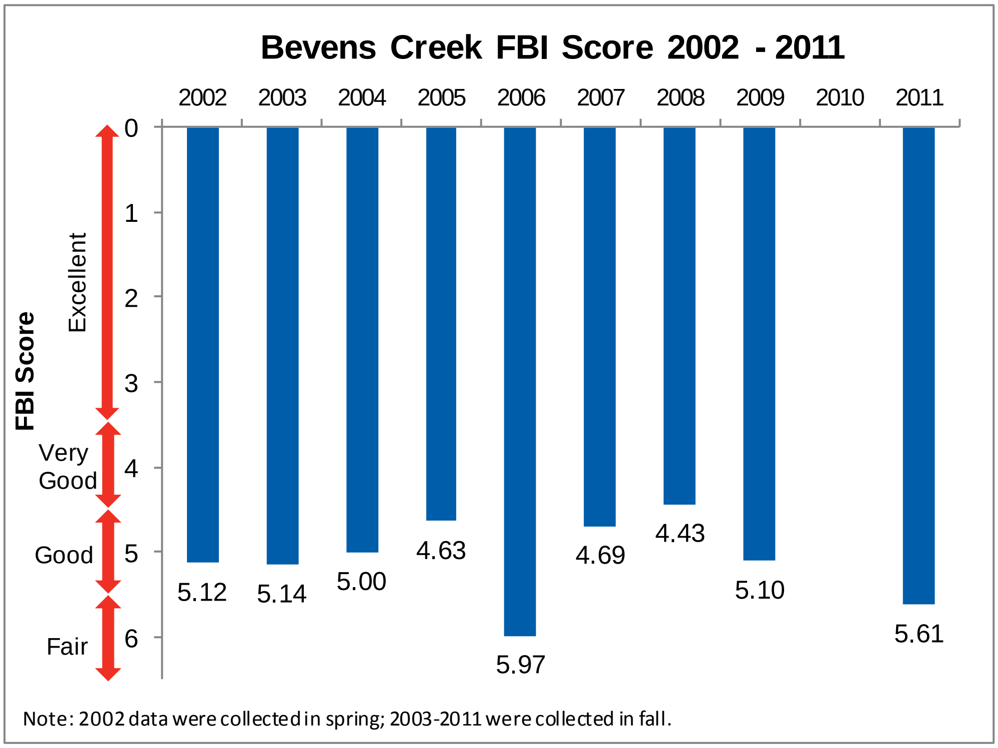
Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. However, integrating the individual metrics into a multi-metric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

MCES has been sampling macroinvertebrates at the Lower Bevens Creek site since 2002. Biological monitoring is not performed at the Upper (mile 5.0) Bevens Creek site. 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 common 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 comparison from year to year. The majority of the Bevens Creek FBI scores show good water quality, with the exceptions of very good (2008) to fair (2006, 2011) water quality, indicating the presence of some organic pollution during most years (Figure BE-21). Note macroinvertebrate samples were collected in spring of 2002; all other macroinvertebrate samples were collected in the fall of each year. The metrics calculated for 2002 are valid, but they are not directly comparable to those calculated for the other years.

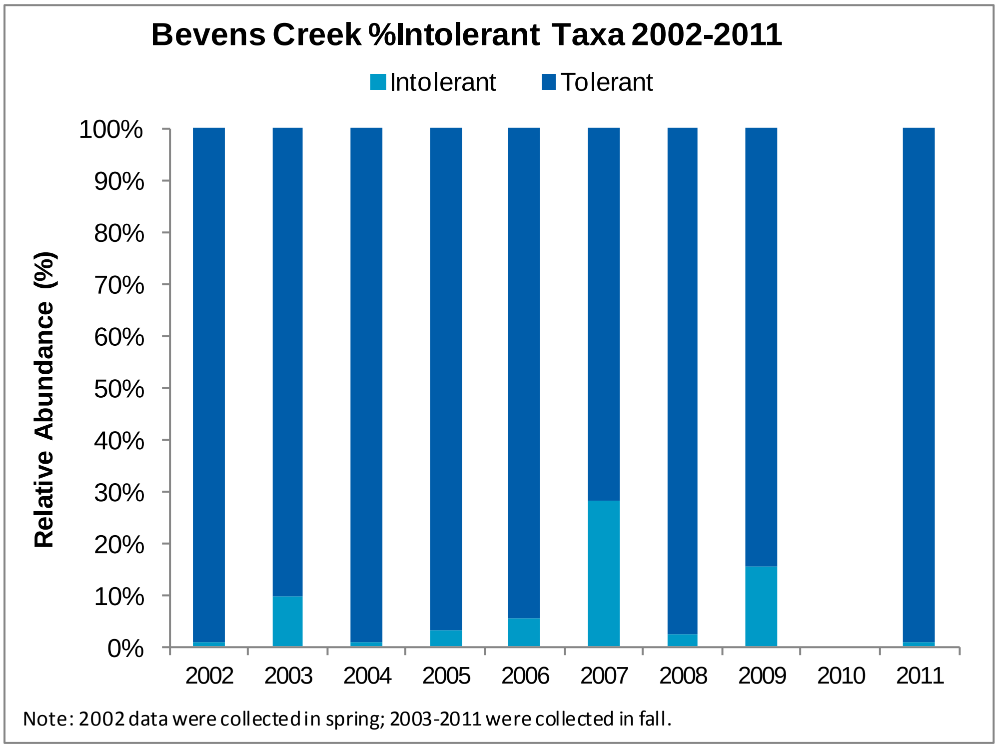
Figure BE-21: Lower Bevens Creek Annual Family Biotic Index (FBI) Scores, 2002-2011



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 BE-22). The presence of moderate numbers of intolerant taxa is an indicator of good aquatic health (Chirhart, 2003). Bevens Creek intolerant taxa were greater than 10% of the sample in 2003, 2007, and 2009. The highest Percent intolerant taxa, 28%, occurred in 2007. Intolerant taxa were present in all samples.

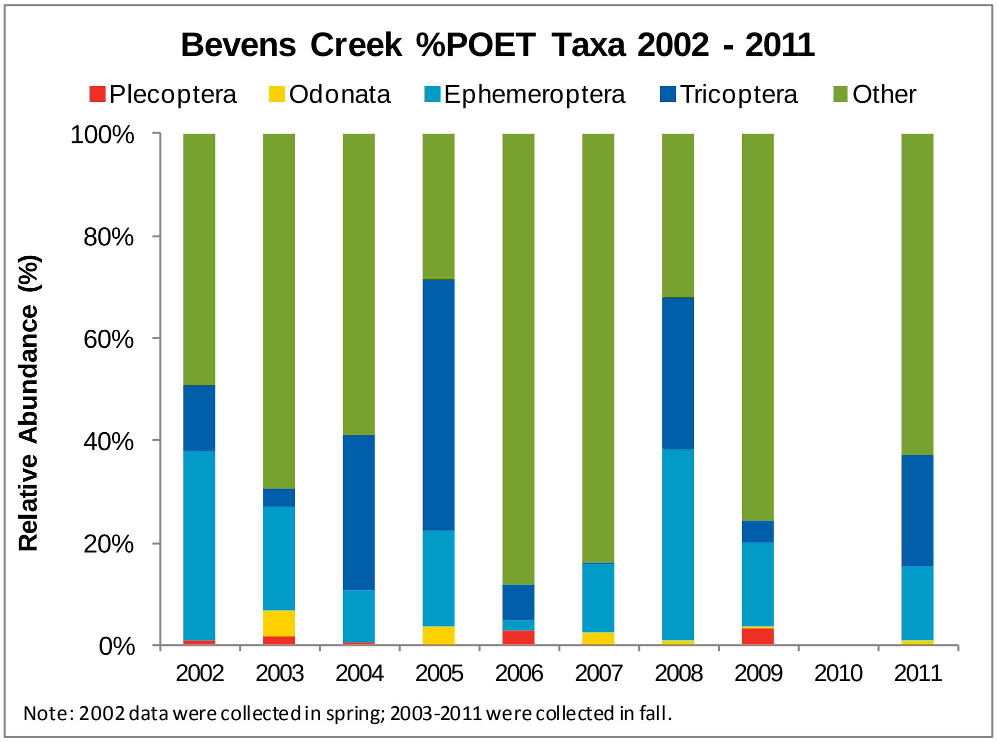
Figure BE-22: Lower Bevens Creek Percent Abundance of Pollution Intolerant Taxa, 2002-2011



Percent POET Taxa

The taxonomic richness metric, Percent POET Taxa (Figure BE-23), 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 2005 at 71%, and lowest in 2006 at 12%.

Figure BE-23: Lower Bevens Creek Percent Abundance of POET Taxa, 2002-2011



Macroinvertebrate Index of Biotic Integrity (M-IBI)

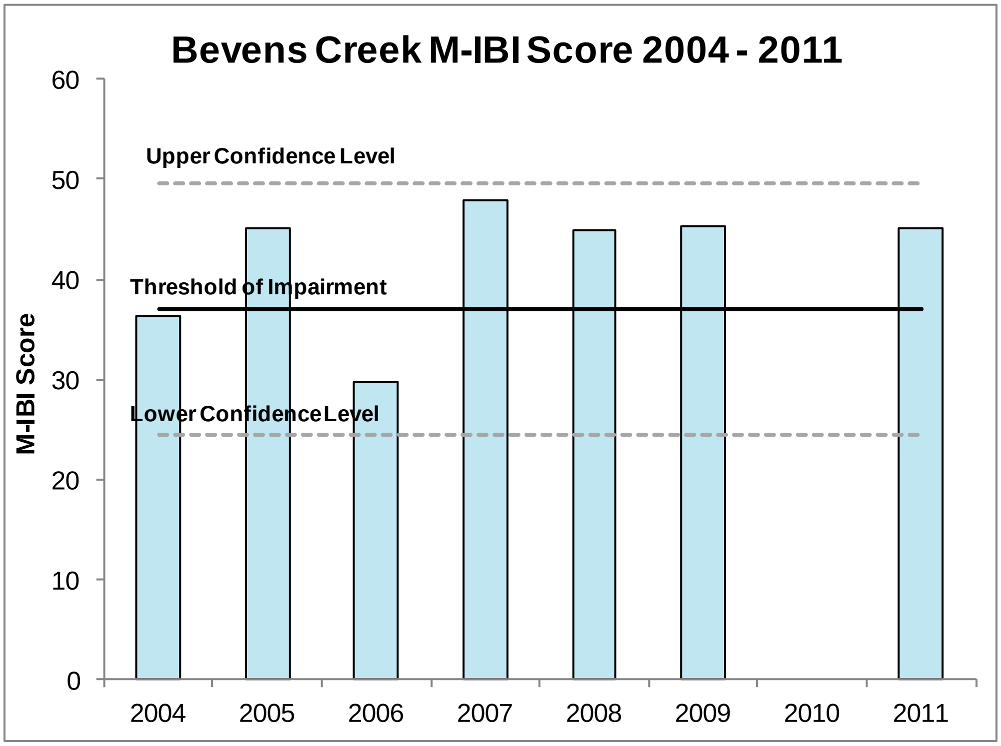
The M-IBI score integrates community richness and composition, pollution tolerance, life histories, trophic interactions, and physical and other parameters that all are components of the biological integrity of the stream. These composite scores are usually shown in context with a threshold value and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

Six of the seven years of monitoring Bevens Creek resulted in M-IBI scores at or above the impairment threshold (Figure BE-24). None of the scores exceeded the upper confidence level of impairment. The 2006 score was between the impairment threshold and the lower confidence level. When the scores fall between the threshold and the confidence levels it is difficult to confidently assess the water quality by biological assessment alone, and it is necessary to incorporate other monitoring information, such as hydrology, water chemistry, land use change, etc. (MPCA, 2014b).

The most recent four data points, 2007-2009 and 2011, exhibit a stable trend in M-IBI scores. This suggests a lack of negative stressors affecting the macroinvertebrates community. This stream reach is likely to be able to sustain the needs of aquatic life.

MCES is planning additional future analysis to fully investigate the biological monitoring data.

Figure BE-24: Lower Bevens Creek Annual Macroinvertebrate Index of Biological Integrity (M-IBI) Scores



Trend Analysis

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

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 periods of from 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 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 1989-2012 at Lower Bevens Creek for TSS, TP, and NO_3.The results are presented below and shown in Figure BE-25. Note that trends were not assessed for the upper monitoring station.

Total Suspended Solids (TSS)

One trend was identified for TSS flow-adjusted concentration in Lower Bevens Creek from 1989 to 2012 (Figure BE-25, top panel). The assessment was performed using QWTREND without precedent 5-year flow setting. The trend identified was statistically significant (p=0.002).

- Trend 1: 1989 to 2012, TSS flow-adjusted concentration decreased from 17.3 mg/l to 10.6 mg/l (-39%) at a rate of -0.28 mg/l/yr.

The five-year trend in TSS flow-adjusted concentration at the Lower Bevens Creek station (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 11.3 mg/l to 10.6 mg/l (-6%) at a rate of -0.14 mg/l/yr. Based on these QWTREND results, the water quality at Lower Bevens Creek in terms of TSS improved during 2008-2012.

Total Phosphorus (TP)

One trend was identified for TP flow-adjusted concentration in Lower Bevens Creek from 1989 to 2012 (Figure BE-25, middle panel). The assessment was performed using QWTREND without precedent 5-year flow setting. The trend identified was statistically significant ($p=4.2x10^{-5}$)

- Trend 1: 1989 to 2012, TP flow-adjusted concentration decreased from 0.35 mg/l to 0.17 mg/l (-51%) at a rate of -0.0074 mg/l/yr.

The five-year trend in TP flow-adjusted concentration at the Lower Bevens Creek station (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 concentration decreased slightly from 0.19 mg/l to 0.17 mg/l (a 9% decrease) at a rate of -0.0034 mg/l/yr. Based on these QWTREND results, the water quality at Lower Bevens Creek in terms of TP improved during 2008-2012.

Nitrate (NO_3)

Three trends were identified for NO_3 flow-adjusted concentration in Lower Bevens Creek from 1989 to 2012 (Figure BE-25, bottom panel). The assessment was performed using QWTREND without precedent 5-year flow setting. The trends identified were statistically significant ($p=7.6x10^{-5}$).

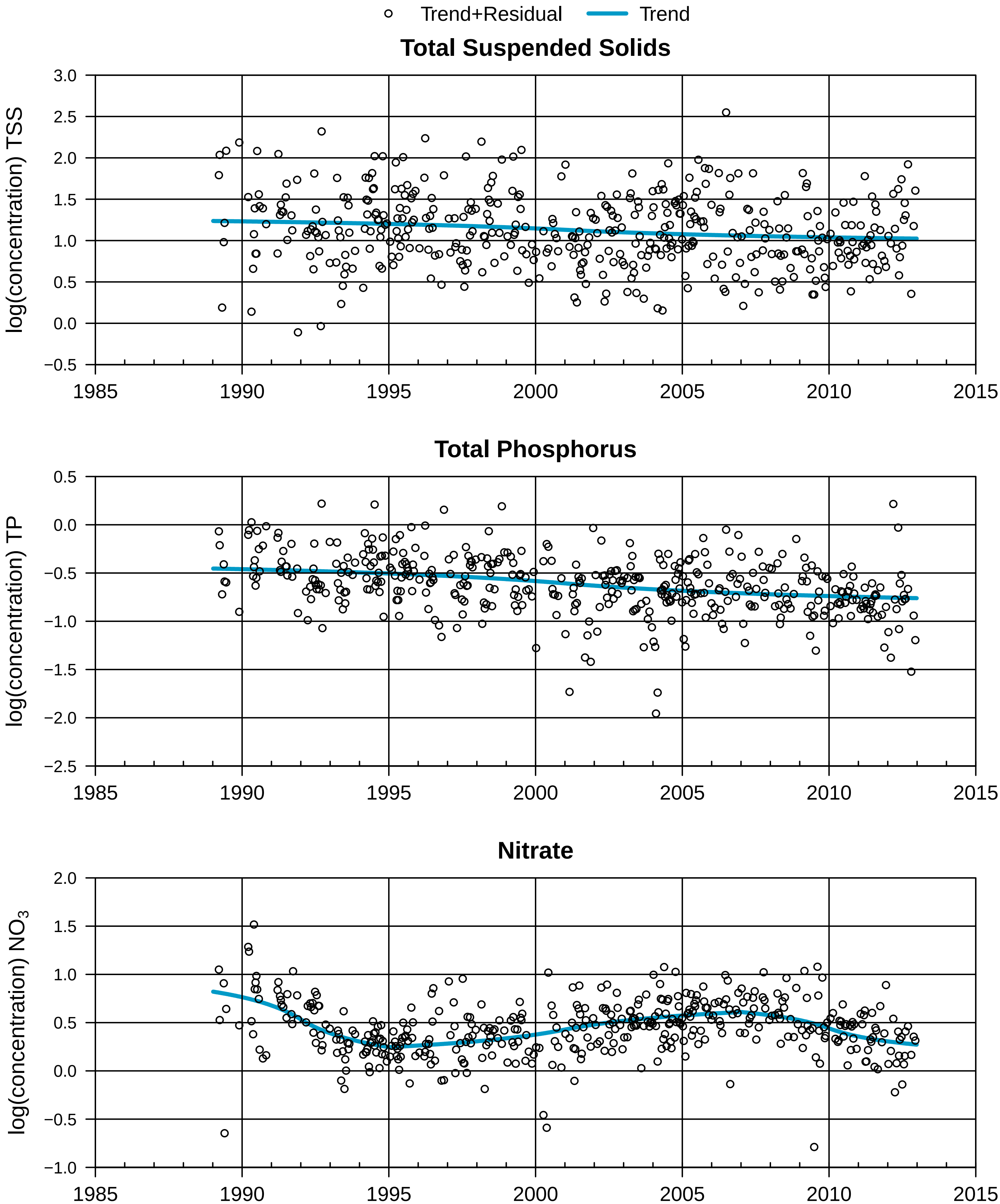
- Trend 1: 1989 to 1984 NO_3 flow-adjusted concentration decreased from 6.6 mg/l to 1.8 mg/l (-73%) at a rate of -0.81 mg/l/yr.

- Trend 2: 1995 to 2006, NO_3 flow-adjusted concentration increased from 1.8 mg/l to 4.1 mg/l (131%) at a rate of 0.19 mg/l/yr.

- Trend 3: 2007 to 2012, NO_3 flow-adjusted concentration decreased again from 4.1 mg/l to 1.9 mg/l (-54%) at a rate of -0.017 mg/l/yr.

The five-year trend in NO_3 flow-adjusted concentration at the Lower Bevens Creek station (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 3.8 mg/l to 1.9 mg/l (-50%) at a rate of -0.38 mg/l/yr. Based on these QWTREND results, the water quality at Lower Bevens Creek in terms of NO_3 improved during 2008-2012.

Figure BE−25: Lower Bevens Creek Trends for TSS, TP and NO_3



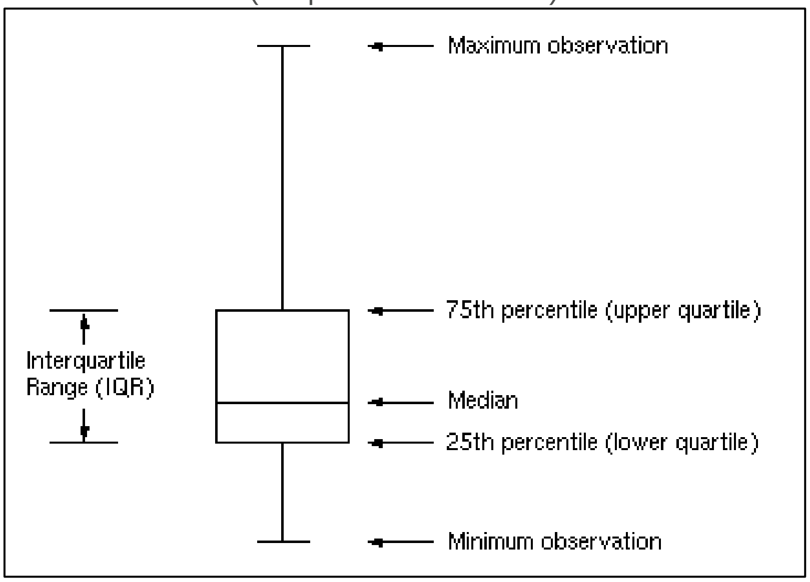
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots are used to summarize the comparison of the historical flow, TSS, TP, NO_3, and Cl data for Bevens Creek with the other metropolitan area streams monitored by MCES and with the major receiving water (in this case the Minnesota River). The comparisons are show in Figure BE-27 to Figure BE-30.

Figure BE-26 shows the formatted legend of the box-and-whisker plots used in this report. Note that 50% of data points fall within the box (also known as the interquartile range), with the centroid delineated by the median line. The outer extents of the whiskers designate the maximum and minimum values.

Figure BE-26: General Schematic of a Box-and-Whisker Plot
(adapted from *sas.com*)



Comparisons for each chemical parameter for period 2003-2012 are shown in Figures BE-27 – BE-30, 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 numbers plotted in these figure are listed in Table BE-6.

Total Suspended Solids. While the median annual FWM concentrations for TSS at both Bevens Creek stations are similar to other Minnesota River tributaries like Sand Creek and Riley Creek, they are higher than those for tributaries closer to the convergence of the Minnesota River and the Mississippi River, e.g. Eagle Creek, Credit River, Willow Creek, and Nine Mile Creek (Figure BE-27; Table BE-6). The FWM concentrations at both Bevens Creek stations are also higher than that in the Minnesota River (as measured at Jordan Minnesota; (207 mg/l and

252 mg/l compared to 142 mg/l, respectively), indicating that Bevens Creek is serving to increase the TSS concentration in the Minnesota River.

Although the FWM TSS concentrations are similar to other monitored Minnesota River tributaries, the median annual loads rank among the highest of these creeks; higher than all other monitored Minnesota River watersheds, except Sand Creek (17,600,000 pounds per year, 29,550,000 pounds per year, and 74,200,000 pounds per year, respectively). The upper station drains about 66.7 percent of the total watershed monitored at the lower station, and the median annual load at the upper station is about 59.6% of the load at the lower station. Stated another way, the Silver Creek subwatershed contributes about 40.4% of the median TSS load monitored at the lower station.

The median annual areal TSS yields calculated for the Bevens Creek stations are lower than those of Sand and Bluff Creeks. Of the monitored Minnesota River tributaries, Sand Creek has the highest annual TSS load and largest area; while Bluff Creek has a moderate load and a very small watershed area. The median annual TSS yields are similar to the other western monitored Minnesota River tributaries. The yields for these tributaries are substantially higher than those in the Mississippi or St. Croix River basins.

It is apparent from Figure BE-27 that those tributaries entering the Minnesota River nearest Jordan have significantly higher FWM TSS concentrations and annual yields (expressed in lb/acre) than the other tributaries to the Minnesota River or any of the tributaries entering the Mississippi or St. Croix Rivers monitored by MCES. This probably reflects the relatively unstable landform within the Minnesota River watershed, where tributaries channels and associated gullies and ravines are still down-cutting towards geographic equilibrium (Jennings, 2010).

Total Phosphorus. The median annual FWM TP concentrations at the Bevens Creek stations are among the highest of any of the MCES monitored streams (0.58 mg/l at the upper station, and 0.51 mg/l at the lower station). As with TSS, the median annual FWM TP concentrations at the Bevens stations are higher than that of the Minnesota River, and thus serve to increase the TP concentration in the river (Figure BE-28; Table BE-6). The median annual TP FWM concentrations of the monitored western metropolitan area Minnesota River tributaries are higher than those of the Mississippi and St. Croix River basin tributaries, with the exceptions of the Crow and Cannon rivers.

At 43,650 and 55,950 pounds per year, respectively, the upper and lower Bevens Creek median annual TP loads are the highest of the monitored Minnesota River tributaries, with the exception of Sand Creek (106,000 pounds per year). However, the median annual TP loads of the Crow River main stem, Cannon River, South Fork of the Crow River, Rum River, and Vermillion River are all higher than either Bevens station (496,000 lb/year, 589,000 lb/year, 322,500 lb/year, 193,000 lb/year, and 49,000 lb/year, respectively). This is likely due to the larger watershed areas these Mississippi River tributaries drain, as the median annual TP yield for upper and lower Bevens are 0.791 and 0.677 pounds per acre per year while those of the Crow River, Cannon River, South Fork of the Crow River, Rum River, and Vermillion River are 0.29, 0.69, 0.44, 0.19, and 0.33 pounds per acre per year, respectively.

Nitrate. The median annual FWM NO_3 concentrations at the Bevens Creek stations (Figure BE-29; Table BE-6) are the highest of any of the MCES monitored metro area streams (8.95 mg/l, and 9.34 mg/l at the upper and lower stations, respectively), and higher than that of the Minnesota River (6.8 mg/l).

Median annual NO_3 loads from Bevens Creek are 628,000 pounds per year at the upper station and 996,500 pounds per year at the lower station. These loads are higher than any other monitored Minnesota River stream except Sand Creek, which is between them at 886,000 pounds per year. The load from the upper station is about 63% of the load monitored at the lower station. Median annual NO_3 loads are much higher at Vermillion River, Crow River, Crow River South Fork, and Cannon River stations in the Mississippi River basin, but again, this is largely due to the much larger size of these watersheds.

The median annual NO_3 yields at the upper and lower Bevens Creek stations are 11.4 and 12.1 pounds per acre per year, respectively. These areal NO_3 yields are higher than any of the other monitored Minnesota River streams, and also higher than any of the MCES monitored streams except Valley Creek in the St Croix basin (19.9 lb/ac/yr). The high Bevens Creek watershed yields are probably due to fertilizer applications to row crops and tile drainage of agricultural land, while the Valley Creek yields probably reflect contributions of groundwater with high NO_3 concentrations.

Chloride. Cl FWM concentrations in Bevens Creek (upper, 38 mg/l; lower, 34 mg/l) are higher than that of the Minnesota River but at the low end of the other monitored Minnesota River streams (Figure BE-30; Table BE-6). These low Cl concentrations likely reflect the rural nature of the watershed compared to some of the more urbanized Minnesota River streams. The Bevens Creek median annual Cl loads are near the high end of the monitored Minnesota River streams. The median annual Cl yields from the upper and lower monitoring stations are among the lowest of the monitored Minnesota River streams (47.2 and 41.1 lb/ac/yr); so it appears that the high annual loads are due to the relatively large watershed area. Upper Bevens Creek accounts for about 77 percent of the total median chloride load monitored at the lower station.

Macroinvertebrates

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

The M-IBI scores for the lower Bevens Creek station intersect the MPCA impairment threshold (Figure BE-31). This shows the monitored reach scored values both above and below the threshold of impairment during the period of study. However, the interquartile range was above the threshold which suggests that this stream reach’s habitat and water quality typically were able to sustain the needs for aquatic life. These results are similar to other agricultural watersheds in both the Minnesota and Mississippi River basins, and higher than the more urban stream reaches. This suggests the agricultural macroinvertebrate communities are less stressed than the urban macroinvertebrates in the metropolitan area.

Figure BE−27: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

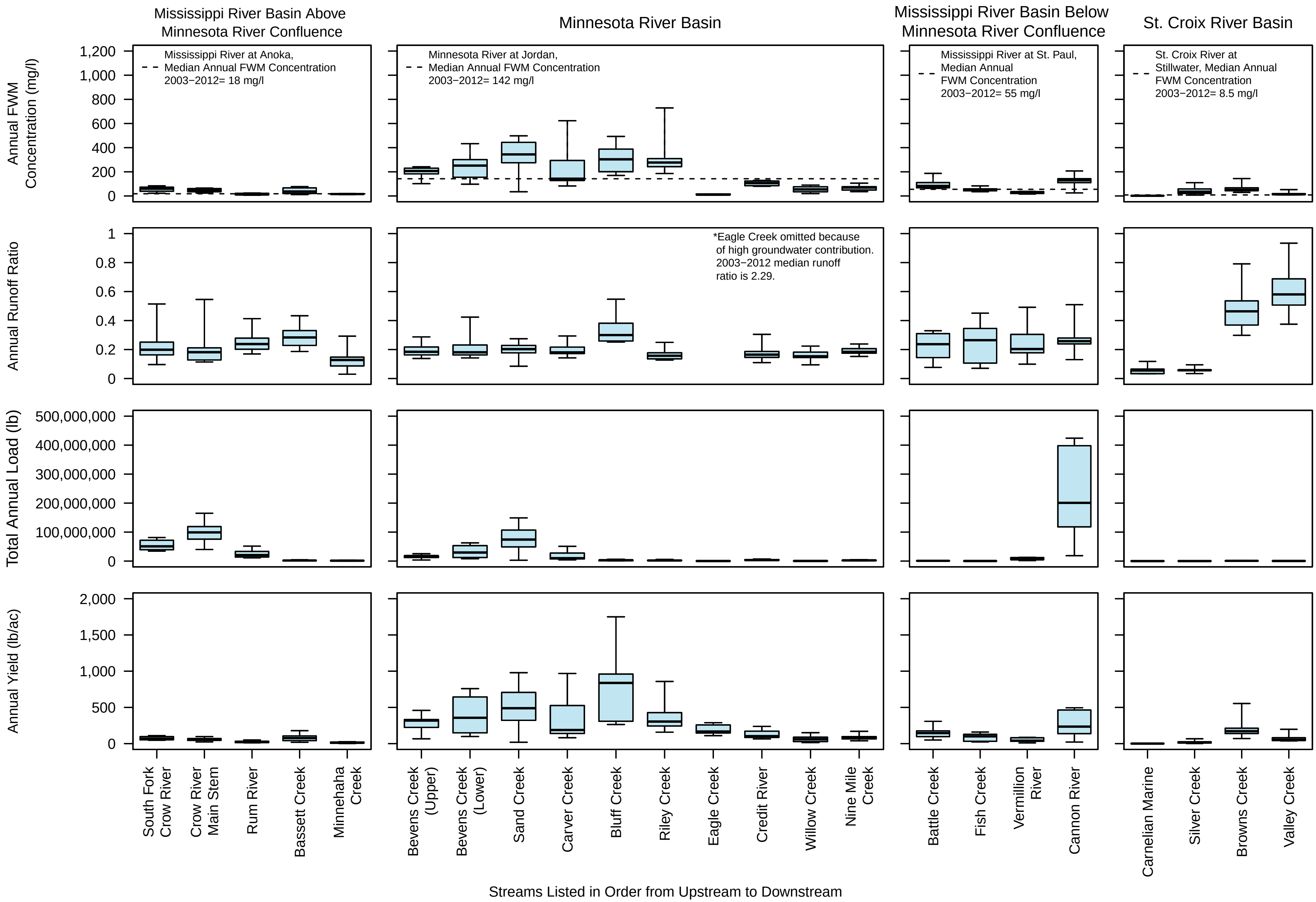


Figure BE−28: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

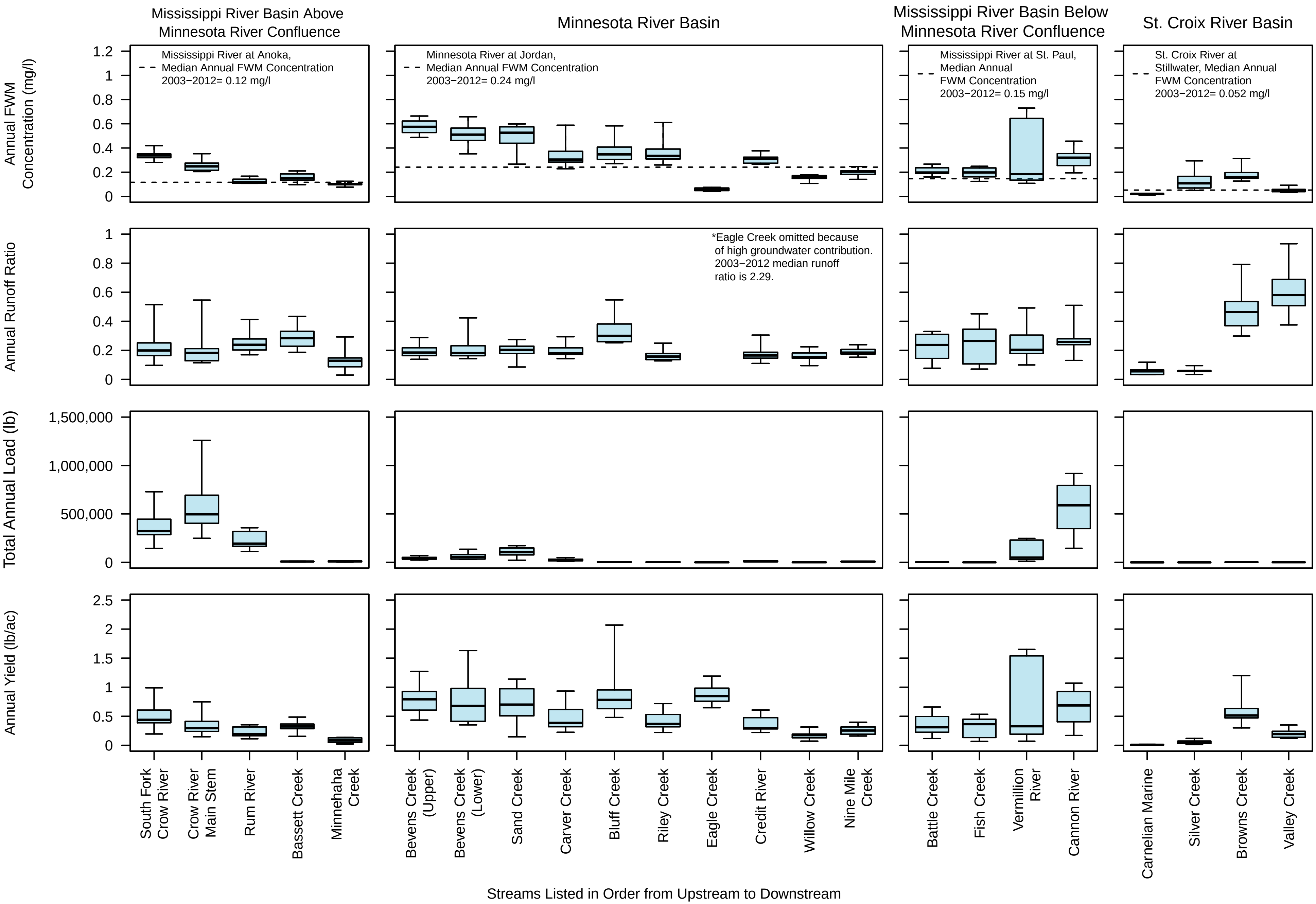


Figure BE−29: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

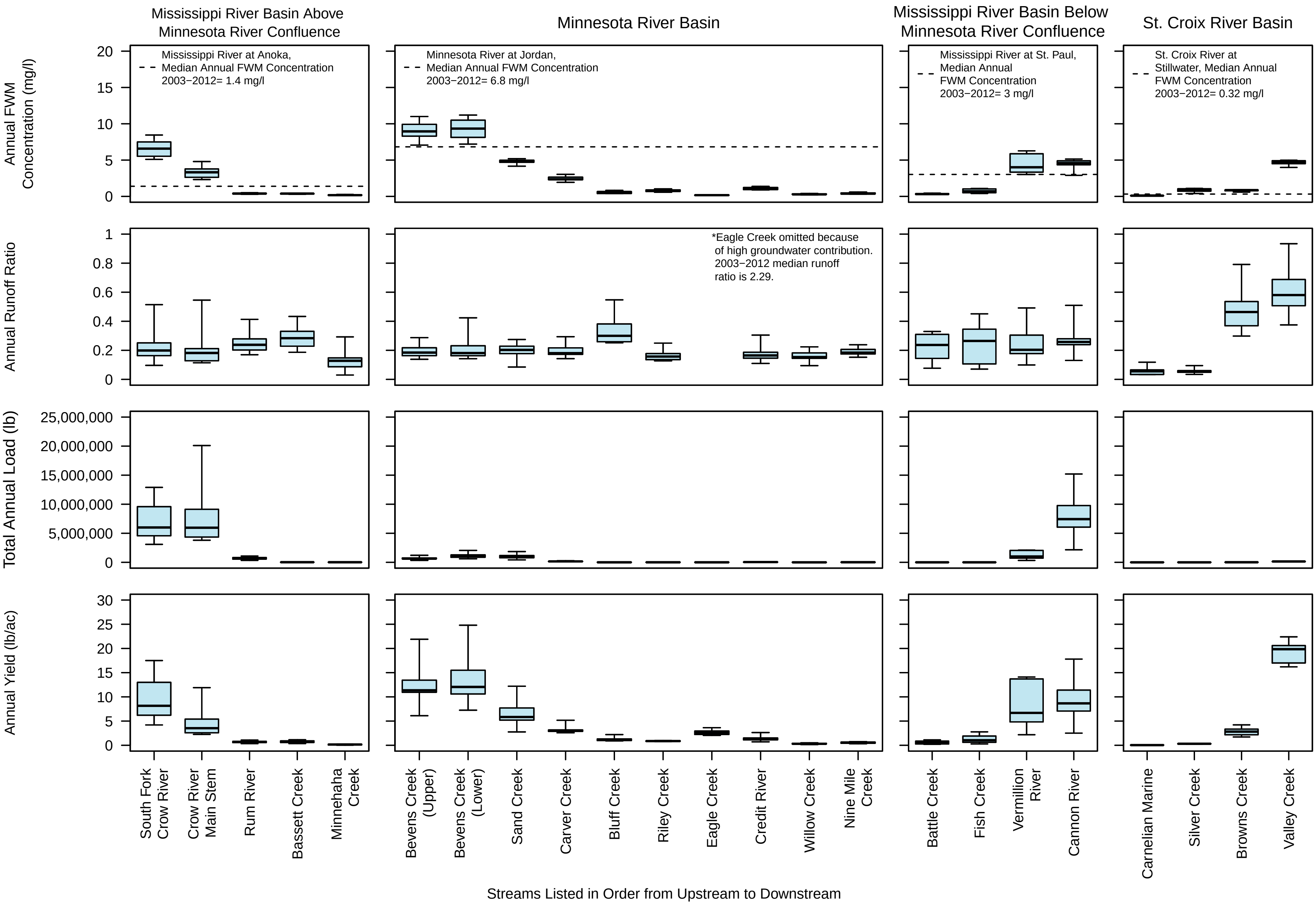


Figure BE−30: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

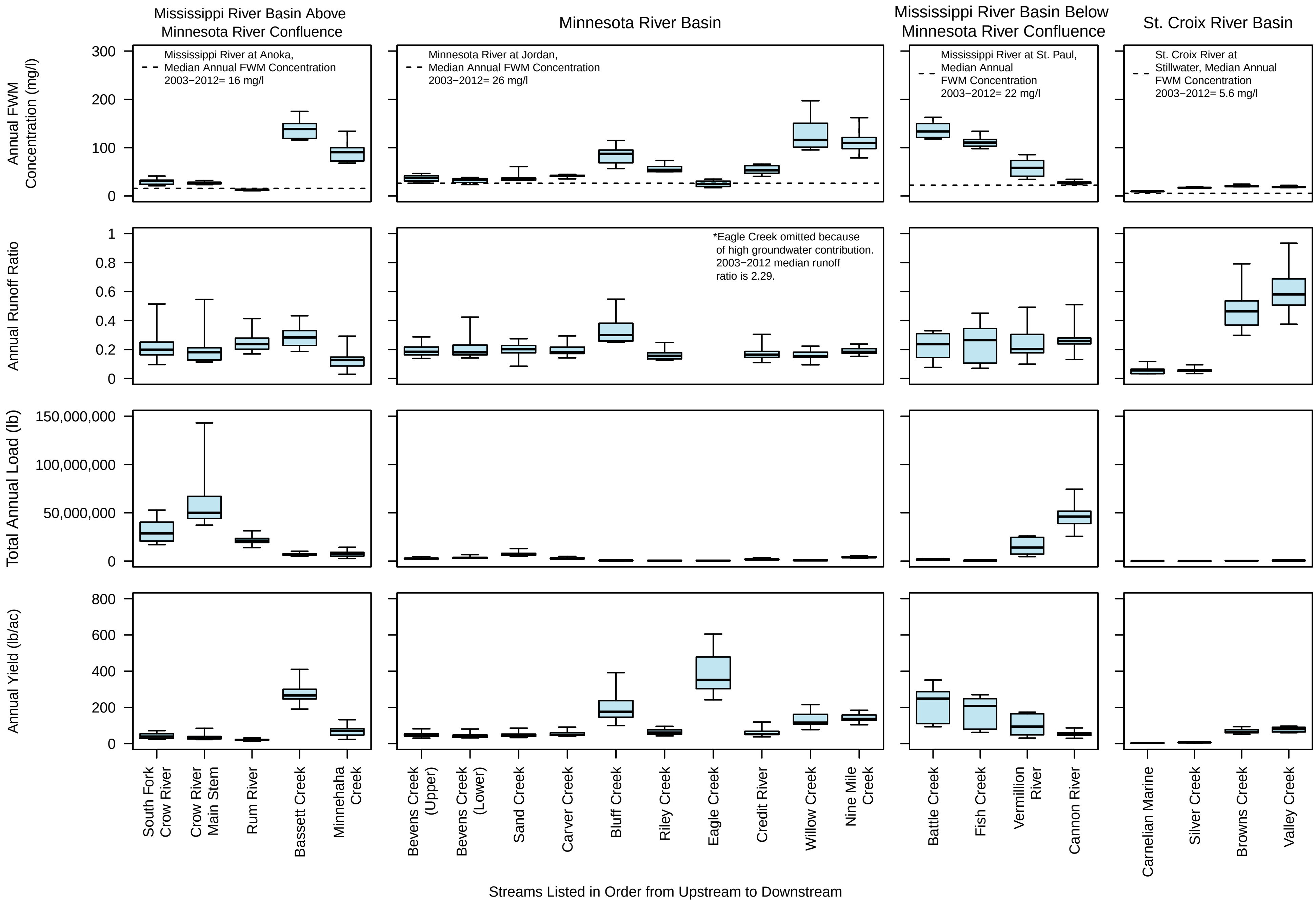


Table BE-6: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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

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

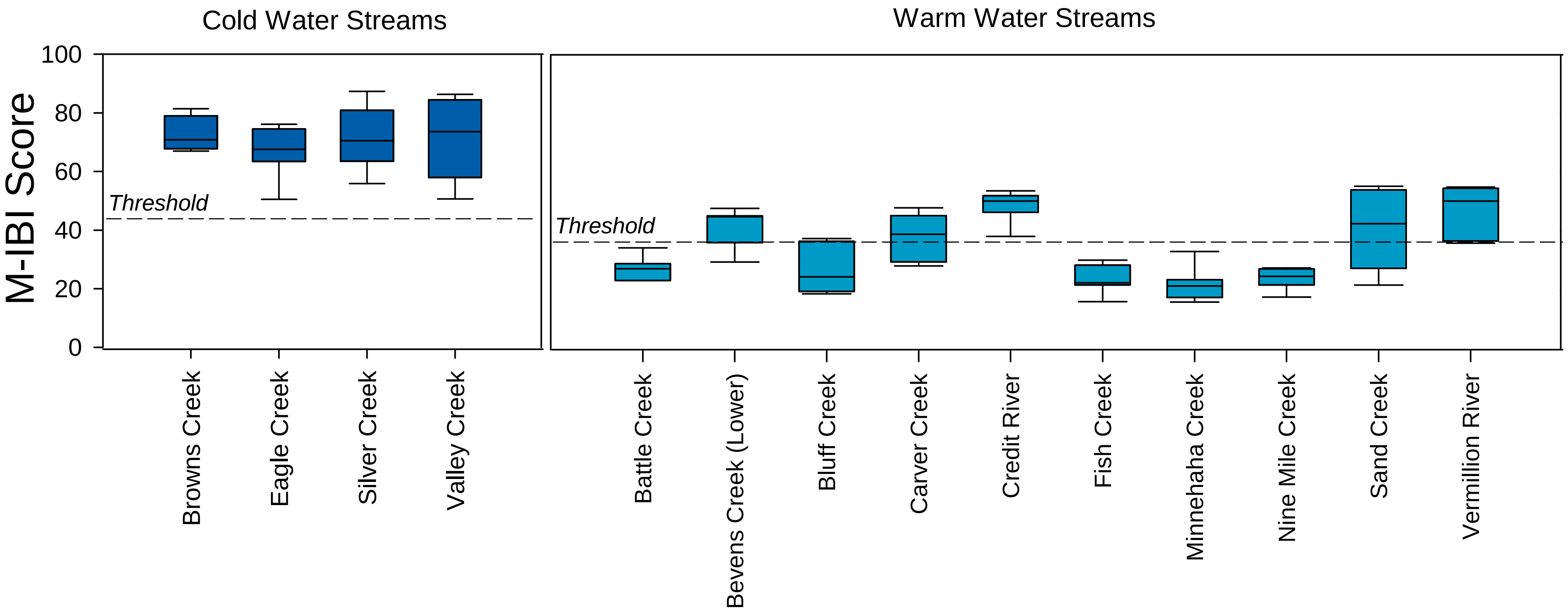
[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

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

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

Figure BE-31: M-IBI Results for MCES-Monitored Streams, 2004-2011

Organized by Stream Type



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

Metropolitan Area Trends Analysis

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

Estimated changes for TSS, TP, and NO_3 in MCES-monitored streams are presented below in two ways. First, tabulated results with directional arrows indicating improving (blue upward arrow) and declining (red downward arrow) water quality paired with percent change in flow-adjusted concentration estimated for 2008-2012 (Figure BE-32). Second, 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 BE-33). In both figures no trend was reported for those QWTREND analyses with poor quality of statistical metrics ($p>0.05$).

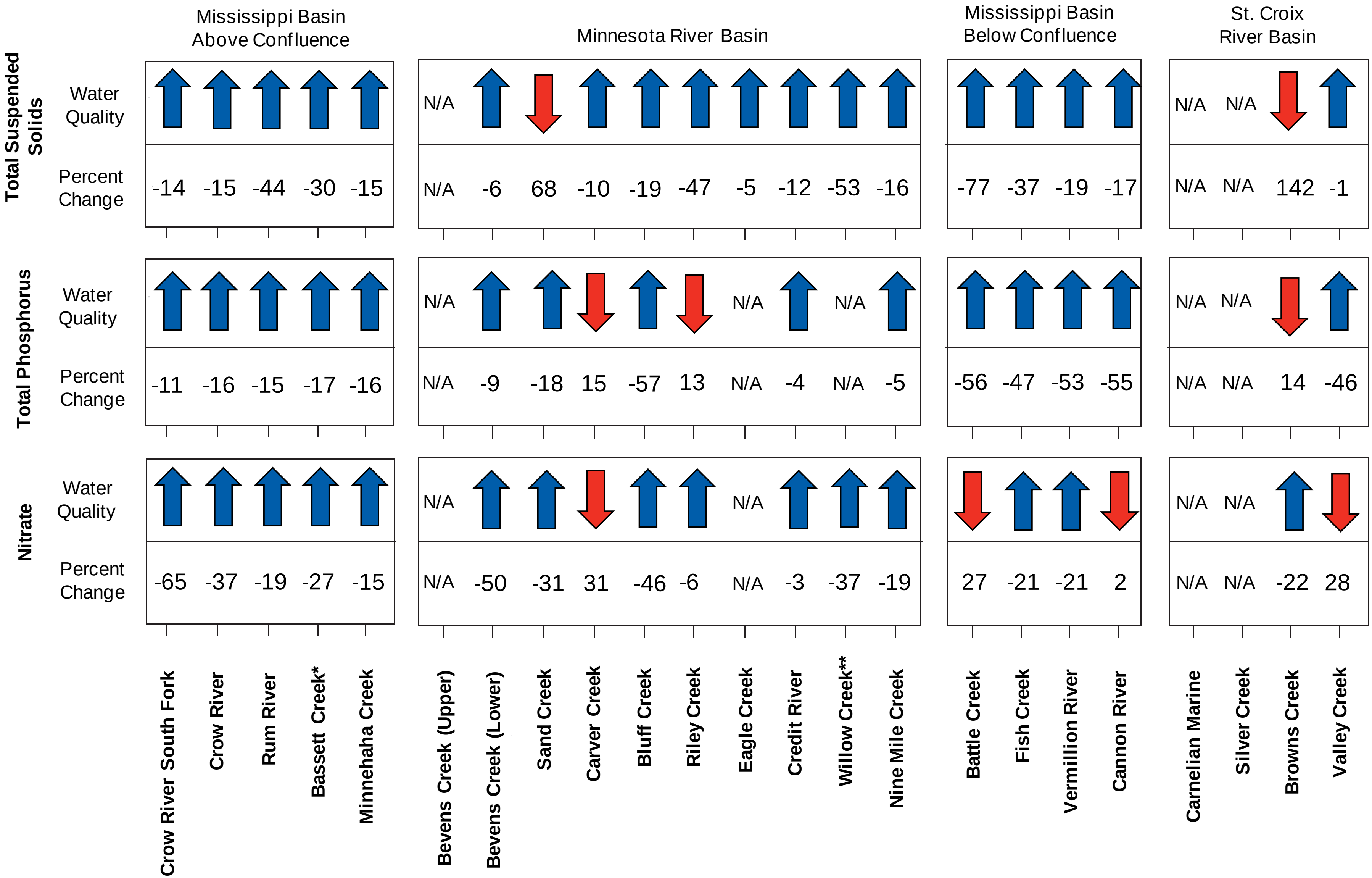
In general, of the 20 monitoring stations assessed, most exhibited improving water quality (and thus decreasing flow-adjusted concentration) for TSS, TP, and NO_3. There does not appear to be a spatial pattern for those few stations with declining water quality. There is no station with declining water 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).

As stated earlier, trend analysis was not performed on the Upper (mile 5.0) Bevens Creek monitoring data. Results for the Lower Bevens Creek station indicate improving water quality for all three constituents; with a 6% reduction in TSS flow-adjusted concentrations, a 9% reduction in TP flow-adjusted concentrations, and a 50% reduction in NO_3 flow-adjusted concentrations over the five year period.

The Minnesota River and its tributaries typically have had higher TSS concentrations than the Mississippi or St. Croix Rivers and associated tributaries. The trend analysis results indicate decreasing TSS flow-adjusted concentrations in all Minnesota River tributaries with the exception of Sand Creek. In addition to decreasing TSS concentrations, Lower Bevens Creek also had decreasing TP and NO_3 concentrations over the last five years.

Figure BE-32: Regional Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO_3, 2008-2012

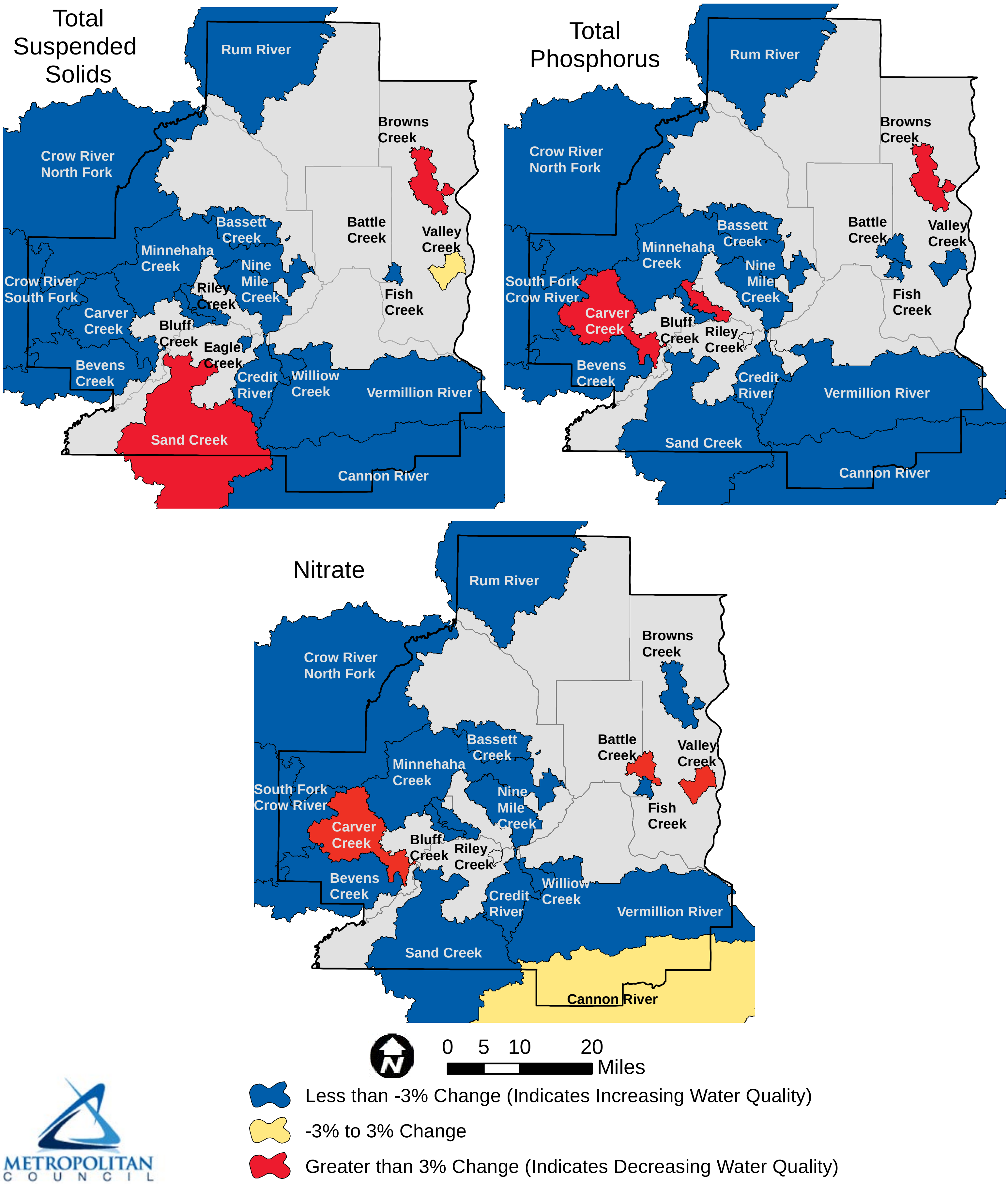
(Grouped by Major River Basin; As estimated by QWTrend)



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 BE-33: 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

Bevens Creek is a tributary to the Minnesota River located in the southwestern metropolitan area. It drains approximately 133 square miles of mixed agricultural land, open space, bluff land, and urban areas (including all or parts of the cities of Green Isle, Hamburg, Norwood Young America, and Cologne) in Carver and Sibley Counties. The Carver County portion of the watershed is in Metropolitan Council District 4; the Sibley County portion is outside the seven-county metro area. The watershed is primarily rural in nature with agricultural land as the largest land cover class. Most of the watershed is very flat with large amounts of drain tile and drainage ditches. Bevens Creek flows through a number of large wetlands that have been channelized to improve drainage. The entire watershed consists of two large subwatersheds: Upper Bevens Creek and Silver Creek. MCES operates two monitoring stations on the creek (Upper and Lower Bevens Creek stations) to attempt to quantify the relative contributions of both subwatersheds.

The water quality in Bevens Creek is affected by several factors: agricultural activity; WWTP effluent; channelization of wetlands, extensive drainage from tiles and ditches, and ravine and streambank erosion. The median annual TSS, TP, and NO_3 flow weighted mean concentrations, and total loads are among the highest of the MCES-monitored Minnesota River tributaries.

Indices for macroinvertebrate sampling data generally show fair to good water quality and that the stream reach at the lower monitoring station is generally able to sustain the needs of aquatic life.

Trend analysis for the most recent five years of data that are available indicates decreasing flow-adjusted concentrations of TSS, TP, and NO_3 at the lower monitoring station and thus improving water quality for those pollutants.

Recommendations

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

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

- MCES should continue monitoring of Bevens Creek and should partner with Sibley County and Carver WMO to investigate possible sources of pollutants in the creek.
- MCES and partners (especially Sibley County and Carver WMO) should create a timeline of past projects and management activities that may have improved or altered stream flow and/or water quality. This information would allow more accurate assessment and interpretation of trends.

- As resources allow, MCES should provide Sibley County, Carver WMO, and other local water managers with information about the heightened potential for surface waters to be impacted by groundwater changes in the Bevens Creek watershed. This information should be included in watershed and local surface water management plan updates.
- 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.
- MCES should continue macroinvertebrate monitoring in Bevens Creek and further investigate the lack of intolerant species. MCES should continue to analyze and evaluate the biomonitoring program. Potential additions should include a Stream Habitat Assessment similar to the habitat surveys performed by the MPCA or the addition of fish population and algal community data.
- The trend analysis should be repeated in 5 years, expanding the list of assessed parameters to include NH3, bacteria, and chlorophyll. Sufficient data should exist at that time to also assess trends in Cl and flow. At that time, trend analysis of the Upper Bevens Creek data should be performed to help estimate changes in Silver Creek.

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