METROPOLITAN COUNCIL

Environmental Services

2012

REGIONAL WATER QUALITY ASSESSMENT

Purpose of the Report

This report assesses the region's water quality of the major rivers in the Twin Cities metropolitan area – the Mississippi, the Minnesota, and the St. Croix – as well as the streams that flow into them. It examines the load of pollutants that go into the rivers from point sources (identifiable entry points) and nonpoint sources (broad land runoff). The information is drawn from data collected by Metropolitan Council Environmental Services, including from its wastewater treatment plants, as well as from partner organizations.

Under Section 208 of the federal Clean Water Act, the Metropolitan Council is designated the area-wide water quality planning agency for the seven-county Twin Cities metropolitan area. To fulfill this mandate, the Council is committed to identifying and addressing regional water quality challenges, using an approach that emphasizes reducing and managing pollution from point and nonpoint sources, and bringing together agencies and organizations for planning and implementation.

This report includes summaries of the following for 2012:

- Select pollutant parameters: total suspended solids (TSS), total phosphorus (TP), nitrate (NO_3), and chloride (Cl), defined on page 2.
- Potential pollutant sources
- The relative contributions of point and nonpoint source pollution for the metropolitan area

Report Highlights

- In 2012, the precipitation totals were one inch below the normal precipitation for the area, and the river flows were close to their 10-year averages, except for the Minnesota River, which was below average.
- Even with below average flows, the largest TSS and NO_3 loads entered the metro area from the Minnesota River.
- The largest Cl loads entered from the Mississippi River, and both the Mississippi and Minnesota Rivers enter the metro area with similar TP loads.
- The St. Croix River consistently has the lowest pollutant load of the three major rivers, which is not surprising considering its smaller drainage area and primarily forested watershed.
- TSS, TP, and Cl loads increased as the rivers flowed through the metropolitan area. These changes are due to the nonpoint and point sources in the metropolitan area.
- The Mississippi River's NO_3 levels did not change significantly downstream of the confluence with the Minnesota River.
- Based on observations from MCES-monitored watersheds, the highest TSS annual yield (load per area of drainage section) came from watersheds in the southwestern metropolitan area,
- The highest TP and NO_3 yields originated from primarily agricultural watersheds, and the highest Cl yields came from the urban watersheds.
- MCES wastewater treatment plants contributed to the river loads of TSS (0.1%), TP (5.1%), and NO_3 (14.3%). Of these contributions, only the treatment plants' NO_3 load was greater than the nonpoint source contribution.

Water Quality Partnerships & Collaboration

To achieve Metropolitan Council objectives related to surface water quality, MCES collaborates with various federal, state, and local agencies and groups to evaluate the health of the water resources. The groups include:

- United States Geological Survey (USGS)
- University of Minnesota
- Minnesota Pollution Control Agency (MPCA)
- Minnesota Department of Natural Resources (DNR)
- municipalities
- watershed districts, and
- watershed management organizations (WMOs)

In addition, MCES relies on the U.S. Environmental Protection Agency and MPCA to provide guidance on federal and state regulations governing wastewater treatment plant effluent and pollutant limits for the Council's seven treatment plants.

Pollutant Stresses on Surface Water

Pollutants from point and nonpoint sources can stress the health of the region's rivers and streams. The U.S. Environmental Protection Agency and the Minnesota Pollution Control Agency enforce water quality standards for these stressors to ensure that they do not jeopardize beneficial uses, such as for drinking water, sustaining aquatic life, and human recreation.

The majority of water quality impairments are currently managed through plans based on Total Maximum Daily Loads (TMDL) and Watershed Restoration and Protection Strategies (WRAPS), which aim to identify sources and limit pollutants from entering the surface waters through watershed assessments.

The *pollutant concentration* is the mass, or weight, of a pollutant per unit of water volume, usually expressed as milligrams of pollutant per liter of water (mg/L). State and federal water quality standards describe the maximum allowable pollutant concentrations in the region's surface waters. (For more information about the river and stream pollutant concentrations for 2012, please see the Annual Stream or River Water Quality Summaries.)

Another commonly used indicator is the quantity of a stream or river's pollutant load – the amount of pollution it carries. A *pollutant load* is the mass (total weight) of specific pollutants transported by water during a specific time period (for example, day, month, or year). This measure helps identify the amount of pollution entering into water bodies. If the load is great enough, it may produce pollutant concentrations that degrade the water quality of a stream or river.

MCES calculates the regional pollutant loads of many stream or river stressors including:

Total Suspended Solids (TSS)

TSS are any organic or inorganic material suspended in the water depth that can be removed by filtration. Elevated TSS concentrations in surface waters can decrease water clarity, transport excess nutrients such as phosphorus, deplete oxygen levels, and decrease biological diversity. Suspended solids can come from various sources on the landscape, including constructions sites, lawns, agricultural fields, gullies, ravines, and stream banks.

Total Phosphorus (TP)

Phosphorus is a nutrient that is necessary for growth of aquatic organisms, but excessive amounts can lead to algae blooms, decreased oxygen levels, and fish kills. Erosion of fertilized soils is a primary source of phosphorus to streams or rivers.

Nitrate (NO_3)

NO_3 is also a nutrient necessary for aquatic growth, but excessive amounts can lead to problems like those caused by too much phosphorus. In addition, high NO_3 levels in drinking water can lead to methemoglobinemia, a blood condition usually affecting infants that is caused by NO_3 molecules interfering with the ability of red blood cells to transport oxygen efficiently. Common sources of NO_3 include fertilizers, plant debris, and septic and municipal wastewater treatment systems.

Chloride (Cl)

Elevated concentrations of Cl in rivers and streams can be toxic to aquatic and terrestrial organisms. The main sources of Cl – road deicing and water softeners – are typically found in the urban environment.

Sources of Water Pollution

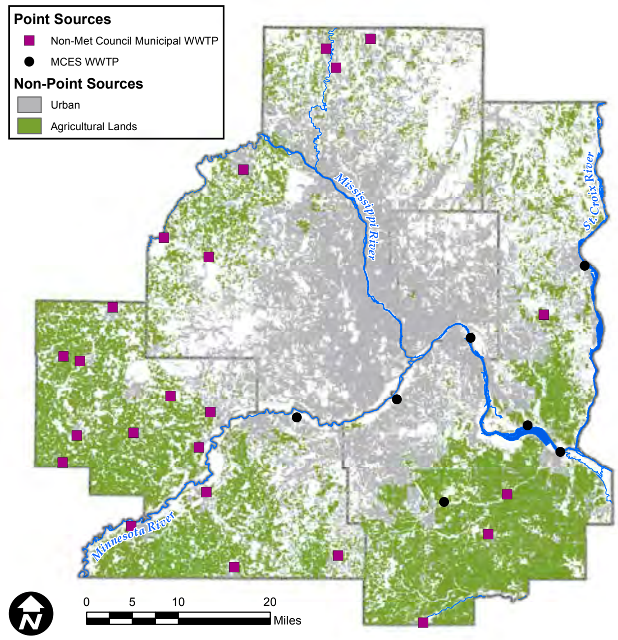
Sources of water pollution vary throughout the metropolitan area. For regulatory purposes as defined by the federal Clean Water Act, the source of water pollution is categorized as point or nonpoint (Figure 1).

Point Source Pollution

Point source pollution originates from an identifiable end-of-pipe source, typically treated or untreated wastewater, called effluent, from WWTP or industrial facilities. MCES owns and operates the region's seven largest WWTPs, which discharge treated effluent into the Mississippi, Minnesota, and St. Croix rivers. Additionally, there are approximately 200 other MPCA permitted point sources such as industrial facilities and small municipal WWTPs throughout the metropolitan area.

Nonpoint Source Pollution

Nonpoint source pollution results from the transport of pollutants across the landscape via runoff into waterways. While there is some transport of pollutants from natural landscapes, increases in nonpoint source pollution result from agricultural production and urban development that alters the landscape. Nonpoint source pollution can originate from diffuse sources such as stormwater runoff from parking lots and lawns, and erosion from farm fields, construction areas, and highways.



Note: Other industrial and commercial point sources not shown.

Figure 1: Point Source and Potential Non-Point Source Lands within the Metropolitan Area. [1]

Factors Affecting Water Quality in 2012

The origins of water pollution depend on multiple variables throughout the region, including precipitation, topography, land management, and population.

Precipitation

The transport of pollutants to rivers and streams is mainly driven by precipitation. The amount, intensity and timing of precipitation influence water quality. For example, heavy rainfall or rapid snowmelt increases the risk of water pollution from agricultural and urban runoff. During dry years, flows in rivers and streams decline and water quality may degrade when nutrients and contaminants become more concentrated. Precipitation patterns depend on prevailing wind patterns, land cover, and topography, leading to uneven distribution of rain and snowfall across the metropolitan area (Figure 2). In 2012, the northern portion of the region received less precipitation than the southern portion. The greatest amount of snow and rain fell in the southeastern part of the metropolitan area.

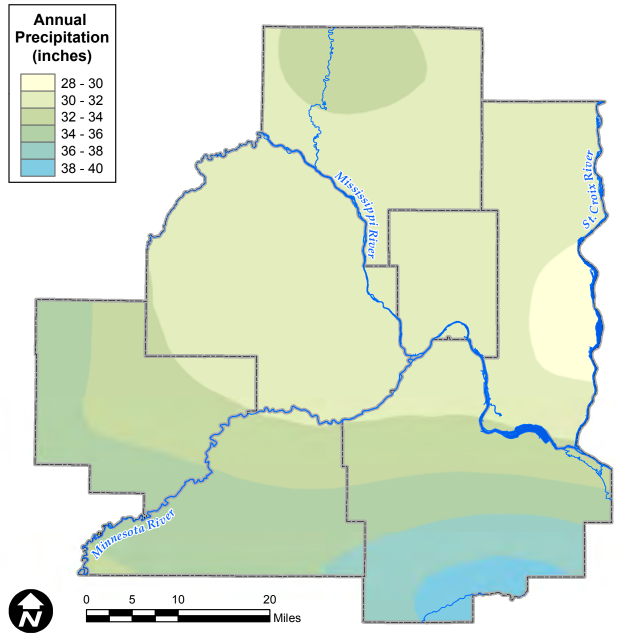


Figure 2: 2012 Annual Precipitation Distribution within the Metropolitan Area. [2]

[1] 2011 coverage provided by University of Minnesota Remote Sensing Geospatial Laboratory, WWTP data from MPCA.
[2] Precipitation data obtained from the Minnesota Climatology Working Group on 7/30/2013.

Precipitation in the metropolitan area during 2012 was about 1 inch below the NOAA 1981-2010 normal precipitation for the area (30.61 inches), though departures from normal levels differed greatly between the beginning and end of 2012 (Figure 3). Precipitation in the metropolitan area from January through July was 6.5 inches above normal. In May alone, the Twin Cities experienced over 9.3 inches of precipitation, an anomaly of approximately 6 inches. The second half of the year was a stark contrast, with a drought beginning in late July that lasted through the winter, resulting in an August-December precipitation deficit of 7.5 inches.

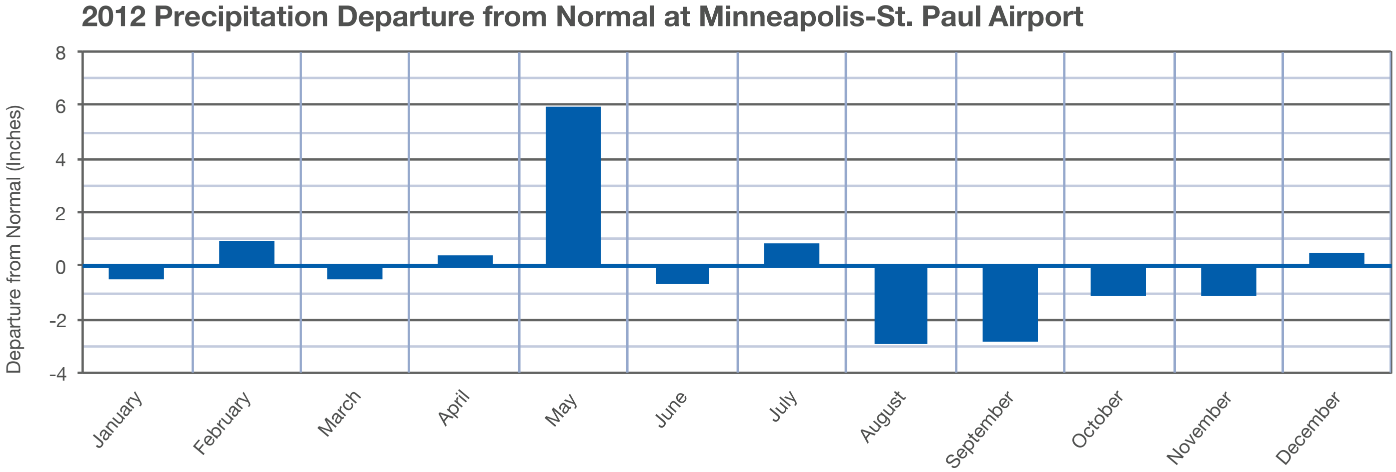


Figure 3: 2012 Monthly Departure from Normal. [3]

Topography

Steep slopes can cause greater runoff and erosion. When coupled with an impervious land surface such as a street, slopes can increase the amount of runoff entering streams and rivers, and aggravate erosion along stream and river banks. Within the metropolitan area, steep gradients can be found within the major river valleys as well as within stream sections that feed the major rivers.

Land Use

A large percentage of rain that falls onto grassland or forests infiltrates into the ground and contributes to the groundwater supply. However, modifications of the landscape to accommodate city streets, new housing subdivisions, and agricultural practices can all promote runoff, the volume of wastewater discharges, and ultimately the pollutant loads entering the rivers and streams. Infiltration of rain water into the ground is hindered by artificially drained agricultural lands or impervious surfaces such as typical parking lots or roofs. The runoff water from agricultural and impervious lands concentrates and transports a large number of pollutants that would otherwise remain on the landscape if the rainwater were able to infiltrate into the ground.

Satellite imagery from 2011, processed by the University of Minnesota, shows that almost two-thirds of the region's land area is influenced by impervious, urbanized surfaces (34.1%) and agriculture land uses (27.2%). The remaining land is generally grassland, forests, wetlands, and open water.

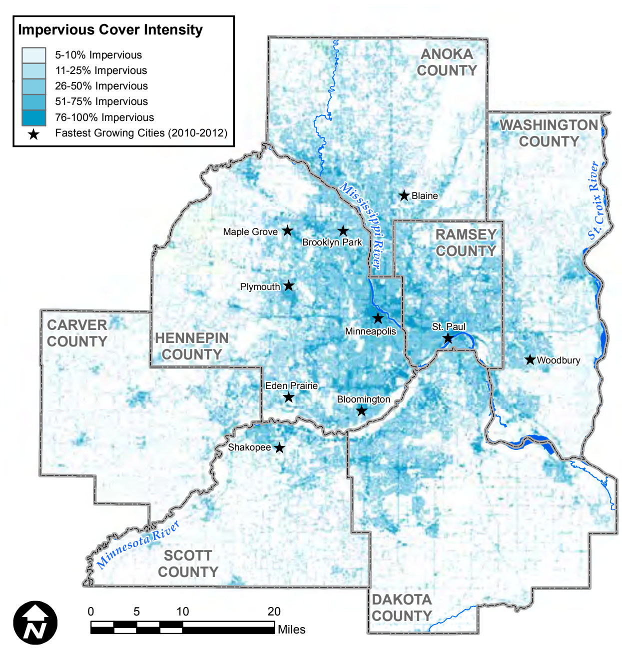


Figure 4: 2011 Impervious Cover Percentage [5]

As an indicator of landscape changes, population estimates within the metropolitan area show an increase of 18,000 households (59,000 people) between 2010 and 2012[4]. The

[3] Precipitation data retrieved from the Minnesota Climatology Working Group (http://climate.umn.edu/text/historical/msppre.txt) and NOAA 1981-2010 climate normals at Minneapolis-St. Paul Airport.
[4] Metro Stats – July 2013, Publication No. 74-13-024
[5] 2011 coverage analysis provided by University of Minnesota Remote Sensing Geospatial Laboratory.

communities that have experienced the greatest population growth during that time period include Minneapolis, St. Paul, Blaine, Bloomington, Maple Grove, Woodbury, Plymouth, Brooklyn Park, Eden Prairie, and Shakopee. Regionally, Hennepin County noted the greatest population increase, followed by Ramsey and Anoka counties (Figure 4).

2012 River Pollutant Loads

MCES has an extensive network of river monitoring sites to detect seasonal and annual changes in water quality throughout the metropolitan area. The river monitoring program serves a wide array of needs, including:

- Providing water quality data to meet permit requirements for MCES wastewater treatment plants under the National Pollutant Discharge Elimination System
- Assessing the performance and effectiveness of MCES wastewater treatment plants
- Measuring compliance with state water quality standards and criteria

The river monitoring sites are placed at locations where the rivers enter and exit the metropolitan area, as well as upstream and downstream of the MCES wastewater treatment plants. The stations identify the pollutants within the region's three major drainage areas for the Minnesota, Mississippi, and St. Croix rivers. In 2012, the pollutant loads in these rivers were estimated at nine sites as shown in Figure 5.

Evaluating the amount of the load and the change in loads between contiguous sites provides insight into how natural characteristics and human-related actions can positively or negatively influence the water quality of the large rivers as they flow through the region.

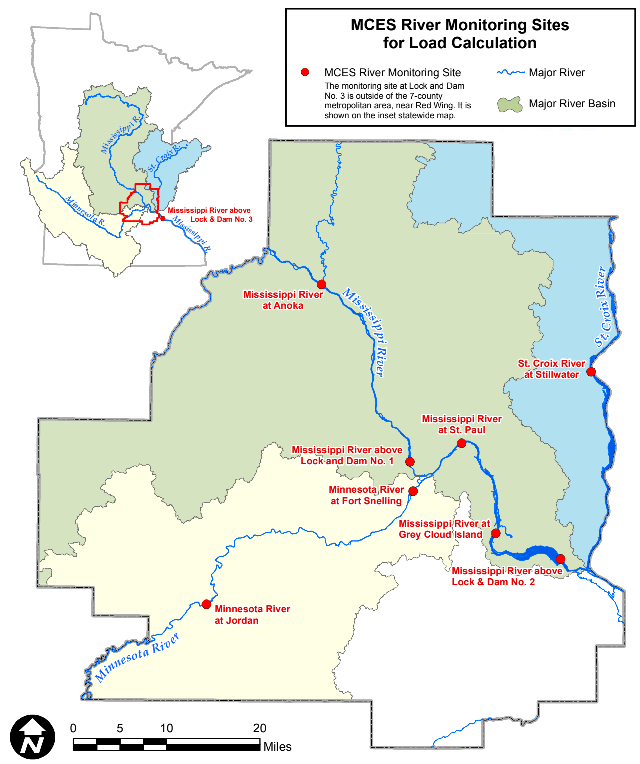


Figure 5: MCES 2012 River Sites

Figure 6 shows the average annual pollutant loads at the river station Sites 1 through 9 for TSS, TP, NO_3, and Cl. Stacked bar plots (A and B) allow for the comparison of the confluence of two major rivers to downstream river loads. For example, the data shown at location A is a combination of the two estimated loads from upstream MCES river stations, Sites 2 and 4. Each estimated load has an associated 95% confidence interval, represented by the error bar. When there is an overlap of the error bars between sites it is not possible to determine the statistical difference in the loads, as they fall within the error of analysis. For the purposes of this report the St. Croix River loads are estimated at Stillwater, but MCES has future plans to model loads at Prescott, Wisconsin.

The 2012 river flows were close to their 10-year averages, except for the Minnesota River at Jordan, which was significantly below average.[6] Even with its low flows, the largest TSS and NO_3 loads enter the metropolitan area from the Minnesota River (Site 3). The largest Cl loads enter from the Mississippi River (Site 1). Both the Mississippi and Minnesota rivers enter the metropolitan area with similar TP loads. The St. Croix River (Site 8) consistently has the lowest pollutant load of the three major rivers.

The Mississippi River above Lock and Dam No. 1 (Site 2) and the St. Croix River (Site 8) have lower TSS loads than the other monitored river sites. This difference can be due to variations in geology between the sections of the river basins. The upper portion of the Mississippi and the lower St. Croix flow through a limestone and a basalt gorge, respectively, which were cut by glacial rivers. These rock formations are less likely to erode than the dominant sandstone in the central and southern parts of the metropolitan area. While the erosion process is a natural event, Shottler and others[7] have shown that this erosion is being exacerbated

[6] MCES 2012 River Water Quality Summary for the Twin Cities Metropolitan Area. July 2013. Publication No. 32-13-023.
[7] Schottler, S.P., J. Ulrich, P. Belmont, R. Moore, J.W. Lauer, D.R. Engstrom, and J.E. Almendinger. 2013. Twentieth century agricultural drainage creates more erosive rivers. Hydrological Processes DOI: 10.1002/hyp.9738.

by artificial drainage that increases river flows in southern Minnesota.

Phosphorus can adhere to soil particles, so patterns in TP loads usually match TSS patterns in surface waters. The soil and sediments are transported by moving waters, but as the velocity of water slows, TSS and TP can settle out. This scenario most likely explains the decrease in TSS and TP loads between the Mississippi River at Anoka (Site1) and the Mississippi River above Lock and Dam No. 1 (Site 2). The lock and dam structures reduce the velocity of the river and decrease the ability of the river to carry the loads.

Downstream of the confluence at Fort Snelling, there is not a statistical difference in TP loads between subsequent sites. However, the significant increase in the load occurring between St. Paul (Site 5) and Lock and Dam No. 3 (Site 9) shows that the metropolitan area is a source of this pollutant.

The greatest amount of NO_3 enters the metro area from the agriculturally dominant Minnesota River basin. The average NO_3 load appears to decrease as the Mississippi River enters St. Paul, but this difference falls within the error of the loading model. When the combined loads of the Mississippi and Minnesota Rivers (Site A) are compared to the load at Lock and Dam No. 3 (Site 9), there is not a difference in NO_3, showing that the incoming NO_3 load from outside of the metropolitan area drowns the NO_3 load from the urban areas.

The Mississippi (Sites 1 and 2) and the Minnesota (Sites 3 and 4) gain in Cl load as they flow towards their confluence at Fort Snelling. This elevated Cl signal may be attributed to road salt use in the metropolitan area during winter months. The Mississippi River Cl load increases again between St. Paul (Site 5) and Grey Cloud Island (Site 6). This change may be attributed to the Cl used for domestic (foods and water softening) and the wastewater of industrial activities that are processed through the Metropolitan WWTP and enter the Mississippi River as effluent.

2012 Metropolitan Area River Pollutant Loads

Mississippi River | Minnesota River | St. Croix River

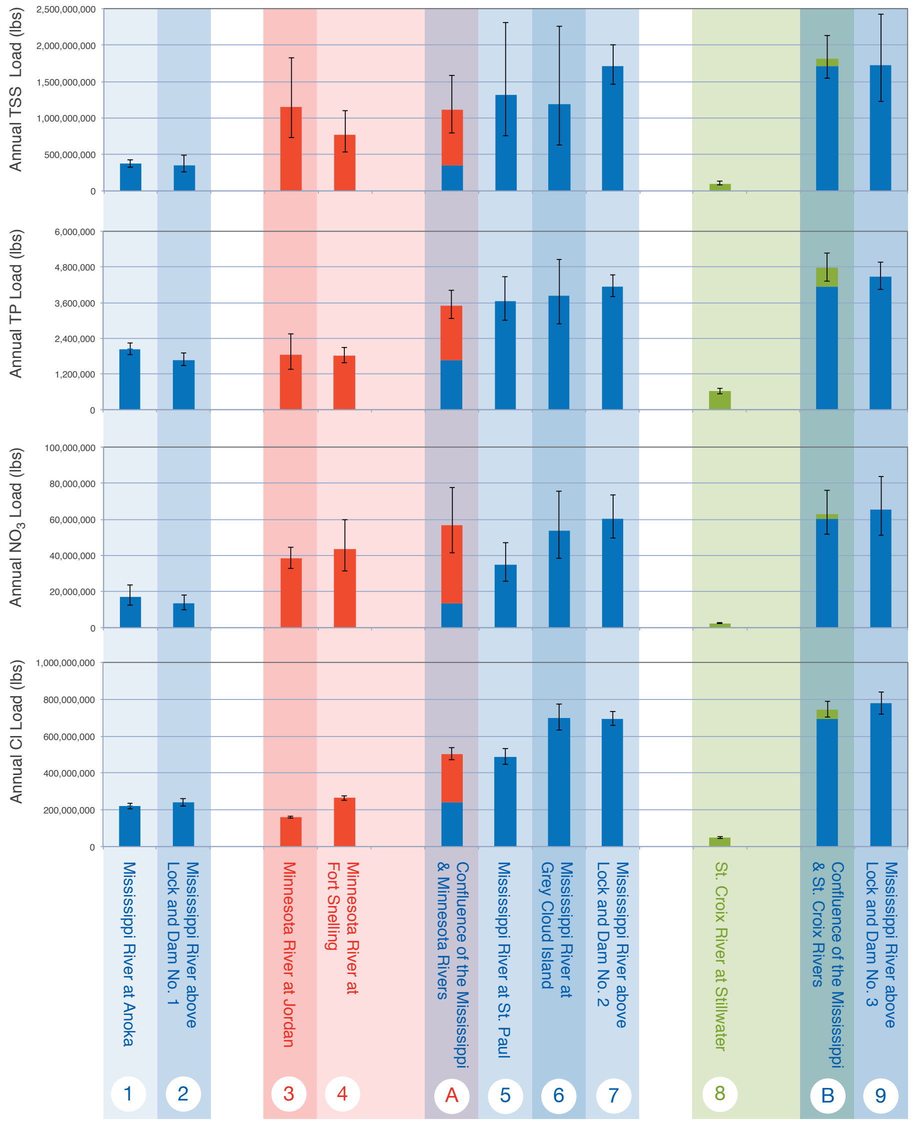


Figure 6: MCES 2012 River Loads
NOTE: Numbers 1-9 correspond to MCES sites identified on the map; letters A-B refer to river confluences.

2012 Stream Pollutant Loads

The smaller tributary streams that contribute to the river water quality are monitored by MCES and partners for three reasons. The first is to determine the extent of nonpoint source pollution loading from tributaries to the Mississippi, Minnesota, and St. Croix rivers. The second is to assist the MPCA and watershed districts and watershed management organizations by providing the information necessary to develop TMDLs or WRAPS studies for these tributary watersheds, as required by Minnesota Statute 473.157. The third reason is to evaluate the effectiveness of watershed management practices for reducing nonpoint source pollution and improving water quality in streams and rivers. In 2012, flow and various water quality parameters were monitored at 22 stations on 20 streams in the metropolitan area as shown in Figure 7.

Figure 7: MCES Stream Monitoring Sites

Of the many tributary watersheds that extend into the metropolitan area, 21 MCES watersheds had adequate monitoring data to calculate and evaluate the pollutant yields in 2012. A *pollutant yield* is determined by dividing the pollutant load (mass) by the contributing watershed area, allowing a relative comparison to be made between watersheds. Pollutant yields primarily depend on soil type, land use, landscape characteristics, and the amount, timing, and intensity of precipitation. Due to variations in these factors from year to year, a single year of pollutant yields does not likely represent the long-term average yields. This is especially true for Minnehaha Creek, as it had low or nonexistent flows for the majority of the second half of 2012.

Yields of total suspended solids ranged from 3.45 lbs. per acre in the Minnehaha Creek watershed to 903 lbs. per acre in the Bluff Creek watershed (Figure 8). By yield, the highest TSS contributors included the Bluff, Carver, Sand, and Upper and Lower Bevens Creek watersheds in the Minnesota River basin. The TSS yield for the Silver Creek watershed could not be calculated due to poor data. The total phosphorus yields ranged from the lowest

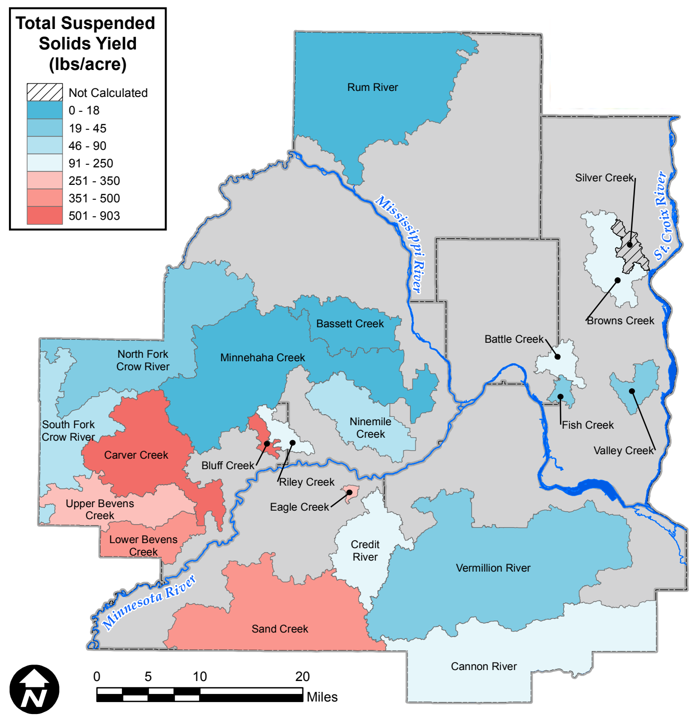


Figure 8: 2012 MCES Monitored Stream TSS Yield

yield in Minnehaha Creek, 0.03 lbs. per acre, to the highest yield in the Upper Bevens Creek watershed, 0.94 lbs. per acre (Figure 9). The watersheds with the highest total phosphorus yields were Upper Bevens, Eagle, Carver, Sand, and Bluff Creek watersheds. The TP yield for Silver Creek could not be calculated due to poor data.

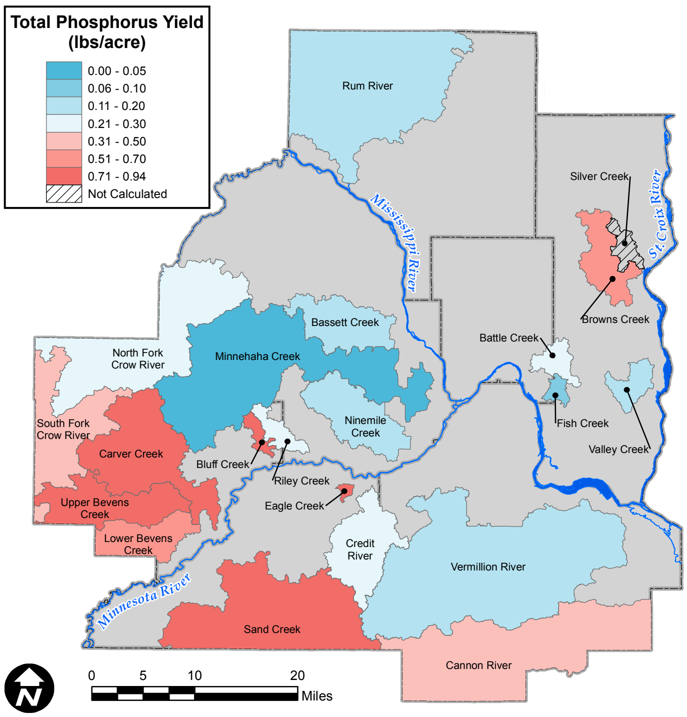


Figure 9: 2012 MCES Monitored Stream TP Yield

NO_3 yields ranged from 0.03 lbs. per acre in the Minnehaha Creek watershed to 20.4 lbs. per acre in the Valley Creek watershed (Figure 10). By yield, the highest NO_3 contributors included the Valley Creek, Upper and Lower Bevens Creek, the Cannon River, and Sand Creek watersheds.

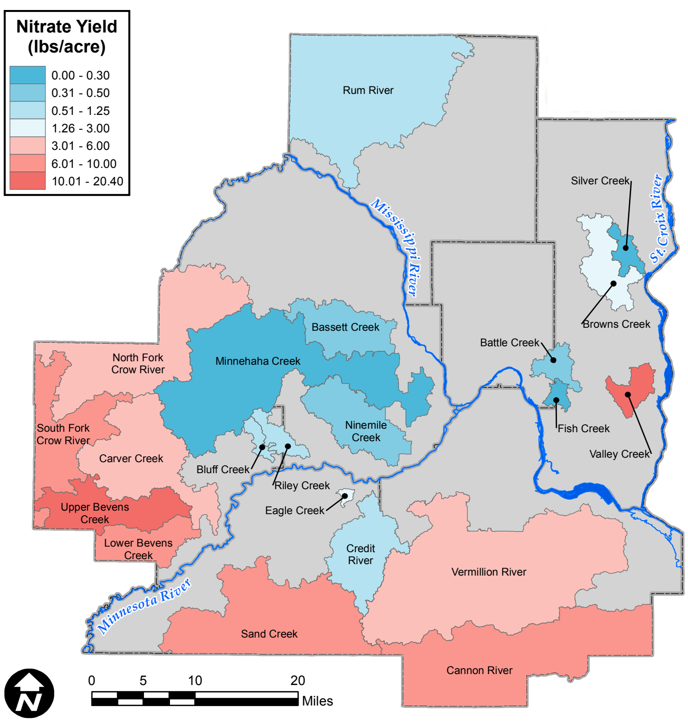


Figure 10: 2012 MCES Monitored Stream NO_3 Yield

The Cl loads ranged from 5.17 lbs. per acre in the Silver Creek watershed to 605.4 lbs. per acre in the Eagle Creek watershed. The watersheds with the highest Cl contributions by yield were the following creeks: Eagle, Bassett, Battle, Bluff, and Nine Mile (Figure 11).

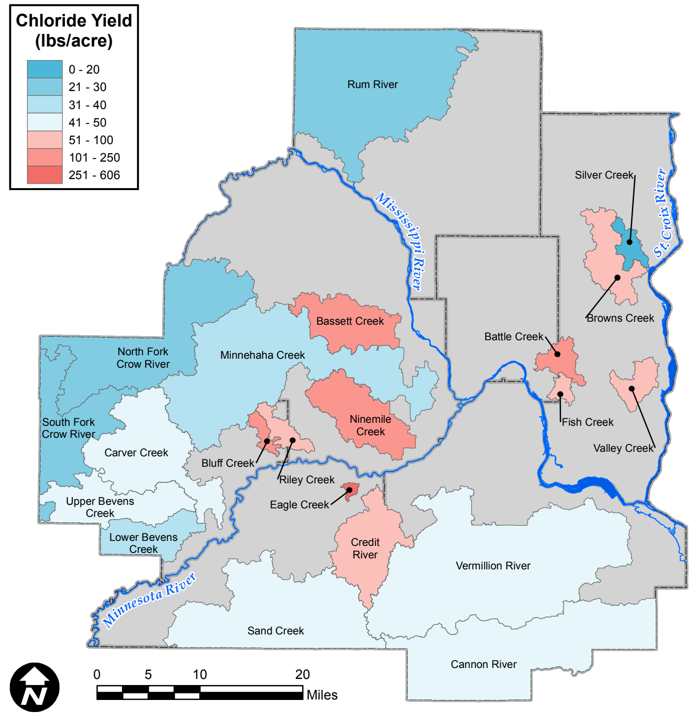


Figure 11: 2012 MCES Monitored Stream Cl Yield

It is important to note that some watersheds, such as Eagle and Valley Creeks, receive a large amount of their flow from groundwater. The watersheds used in this report are the surface-water watersheds, defined topographically. Groundwater watersheds are defined by the geologic and hydrologic characteristics or aquifer formation. For groundwater-fed streams, this can result in a relatively larger contributing area (groundwater-watershed) compared to that used to determine the pollutant yield cited in this report (surface water-watershed).

2012 River Pollutant Load Contributors

An assessment of the metropolitan area pollutant loads contributing to the river reaches was conducted to help identify potential corrective actions. Two pollution categories were examined: the point source pollutant loads processed through the seven MCES WWTPs, and the nonpoint source pollutant loads contributed by the metropolitan area stream tributaries. In addition, the area-wide total incoming loads were shown for comparison to the inputs from MCES WWTPs and tributaries.
Of the 22 tributary watersheds that are monitored

by MCES in the metropolitan area, 15 tributary watershed contributions, with a total area of 2,452 sq. mi., are downstream of the three major river entry points to the metropolitan area. This accounts for 46% of the total contributing area (5,310 sq. mi.) that drain into a major river in the metropolitan area. The nonpoint source loads were proportionally adjusted to account for the contribution of the other 54% of the metropolitan area tributaries that were not monitored by MCES.

The WWTPs discharge effluent into the major rivers of the metropolitan area. Two of the plants contribute effluent to the Minnesota River, four to the Mississippi River, and one to the St. Croix River.

MCES monitors the effluent for TSS, TP, and NO_3 on a weekly basis. Currently, MCES does not monitor for Cl. These concentrations were multiplied by each WWTP's flow rate to calculate an annual load for each pollutant. The sum of each pollutant load represents the MCES point source load.

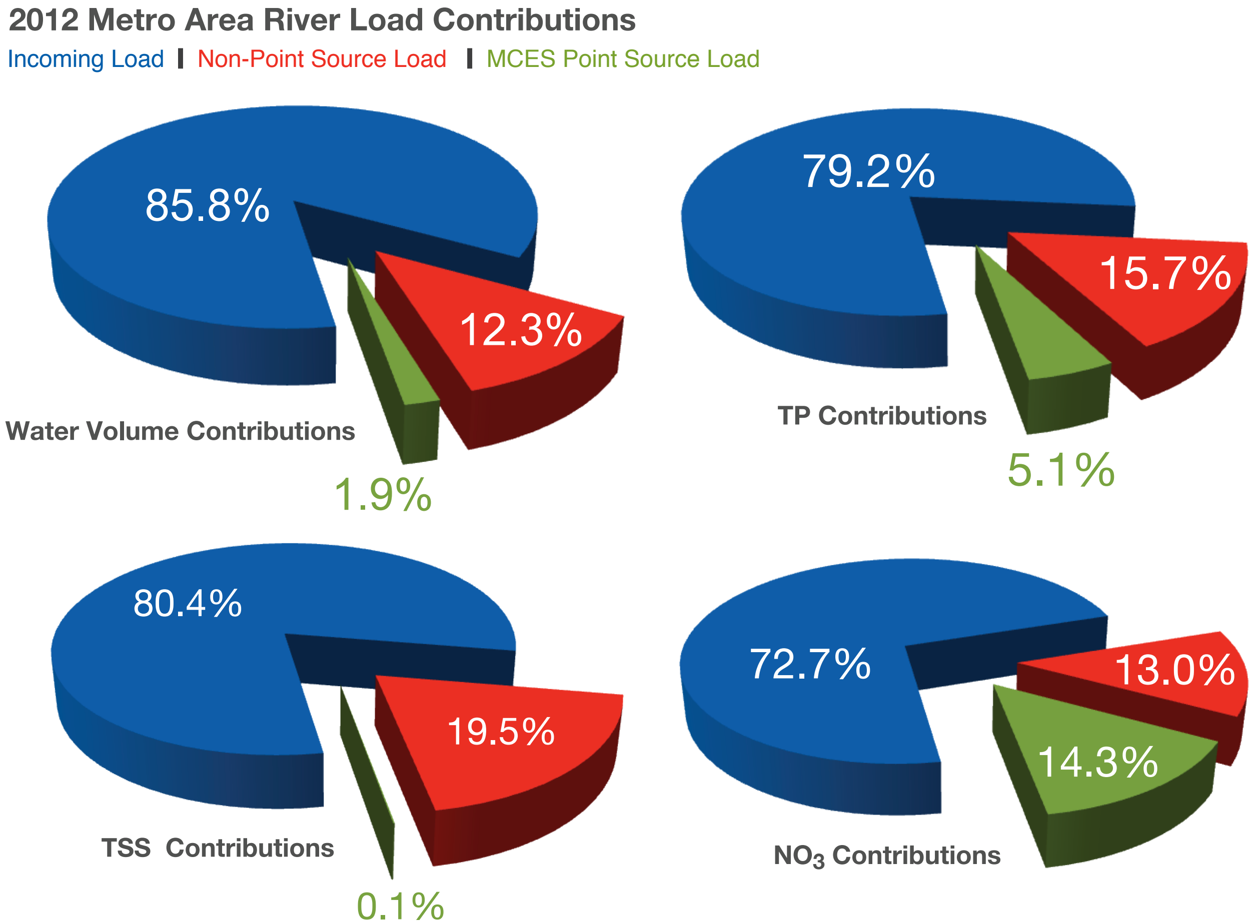


Figure 12: 2012 Percent River Load Contribution by Source

In 2012, only the estimated NO_3 loads from the MCES WWTPs were greater than the load contributions from the metropolitan area tributaries (Figure 12). The total suspended solids and total phosphorus loads were much higher from tributary sources than from the treatment plants.

All of the river pollutant loads in 2012 were below the 2000-2012 average pollutant loads (Figure 13). This is most likely due to the lower precipitation levels, which restricted the movement of pollutants into the rivers in the second half of the year. The 2012 regional water volume was ranked the fifth lowest, with eight years having more water since 2000. This condition influenced the relative contributions of point and nonpoint sources to the river loads.

The amount of TSS load has varied over the period of record, but has been on the decline since 2010. Historically, the treatment plants' TSS contributions have been minimal (<0.5%) in comparison to the contributions of the tributary watersheds (4-22%). Consistently, the largest contributor to the TSS load is the incoming load to the metropolitan area (78-96%).

The TP load also varies from year to year; however, the relative source contributions have changed over time. The incoming load and nonpoint source contributions have fluctuated between 54 and 84% and between10 and 25%, respectively. More recently, since the late-1990s, MCES has invested in newer technologies that greatly reduced the amount of phosphorus leaving the treatment plants. This effort has resulted in an 88% system-wide phosphorus reduction since 2000.

The majority of the NO_3 load comes from outside the metropolitan area, which accounts for 61-87% of the annual NO_3 load. Throughout the years, contributions from point sources (4-20%) and nonpoint sources (7-20%) have similar ranges of relative contributions to the river NO_3 load.

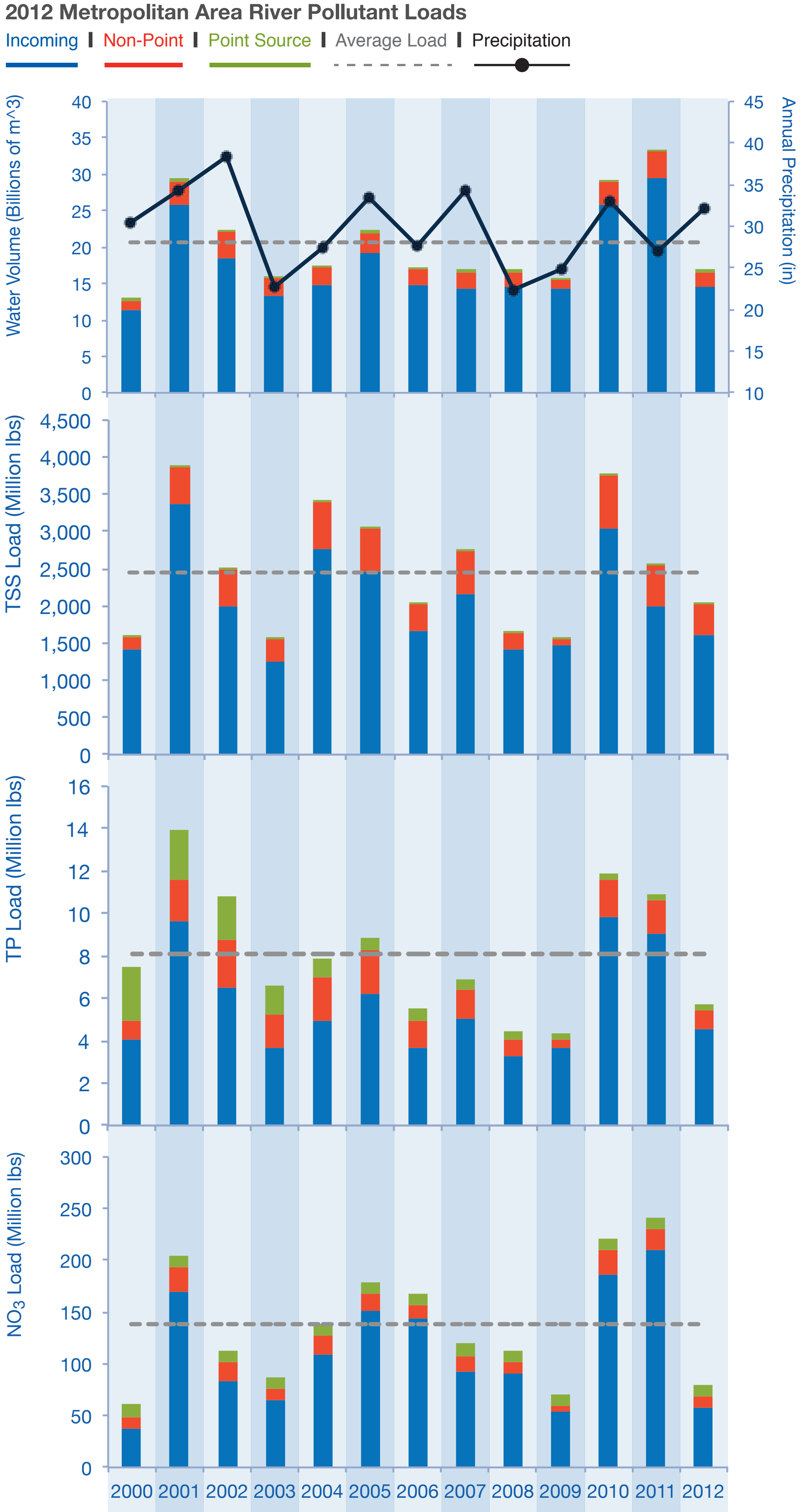


Figure 13: Metropolitan Area River Load Source Contributions 2000-2012

MCES Water Resources Reports

More detailed information related to the region's surface water (streams, rivers, and lakes) quality, water supply, and water resources management policy plan can be found within supplemental Council publications:

2012 Stream Water Quality Summary - Publication Number 32-13-022

2012 River Water Quality Summary - Publication Number 32-13-023

2012 Lake Water Quality Summary - Publication Number 32-13-027

Master Water Supply Plan - Publication Number 32-09-065

2030 Water Resources Management Policy Plan - Publication Number 32-04-065

The MCES Water Resources Assessment Section plans to release the following synthesis report in early 2014:

- Twin Cities Metropolitan Area Stream Assessment
    - Watershed Descriptions
    - Historic Pollutant Loads
    - Trend Analysis
    - Biological Monitoring Results

Report Data Sources

The 2012 Regional Water Quality Assessment Report relied on several information resources. Monitoring data, including flow and water chemistry, originated from MCES and its partners, the USGS, and the DNR. The watersheds cited in this report were delineated by the DNR and watershed areas were calculated by MCES staff to reflect the area contributing to the monitoring sites. The funding for the spatial definition of the metropolitan area impervious areas was provided by MCES; University of Minnesota Remote Sensing and Geospatial Analysis Laboratory performed its analysis.

Information related to data and the analysis methodology used in the development of this report can be obtained from the MCES Water Resources Assessment Section members:

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