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MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION

Annual Monitoring Report 2016

MWMO Watershed Bulletin: 2017-1

Protect it. Pass it on.

MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION

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Annual Monitoring Report 2016

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Front Cover: Equipment maintenance at a stormwater tunnel site (top left), Monitoring demonstration at MWMO (top right), Kasota Ponds IBI study (bottom left), Tree trench BMP monitoring at Edison High School (bottom right).

Photographs by N. Busse, B. Faust and B. Jastram, MWMO

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The Mississippi Watershed Management Organization (MWMO) thanks the following groups for their cooperation and assistance with MWMO monitoring activities: City of Minneapolis Department of Public Works, Regulatory Services and Environmental Services; City of Fridley Department of Public Works; City of Saint Anthony Village Public Works Department; City of Columbia Heights Public Works Department; Minnesota Department of Transportation; Anoka Conservation District; Minneapolis Park and Recreation Board; and Saint Anthony Falls Laboratory at the University of Minnesota.

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Mississippi Watershed Management Organization

Abstract

In 2016, the Mississippi Watershed Management Organization (MWMO) continued monitoring the water quantity and quality of stormwater drainage systems to the Mississippi River. A network of precipitation gauges throughout the watershed collected data on rain and snow patterns. Three wetlands (the Kasota Ponds) were monitored for water quality and their vegetation and invertebrate communities were sampled. The MWMO also contracted with the Anoka Conservation District (ACD) to carry out water level and water quality monitoring on Sullivan Lake and Highland Lake in Columbia Heights.

MWMO staff continued collecting water quality samples from three different reaches of the Mississippi River. Bathymetric data were also collected between Lock and Dam 1 and the Canadian Pacific Railway (CPR) Bridge near N. 41st Avenue. In 2016 MWMO staff also began to monitor the efficacy of some recently constructed best management practices (BMPs) within the watershed.

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Acronyms and Abbreviations

1NE	stormwater outfall near the Excel Riverside Plant in Northeast Minneapolis at RM 857.2E
2NNBC	Old Bassett's Creek Tunnel outlet at RM 854.8W
4PP	stormwater outfall near the I-35W Bridge at RM 853.2W
6UMN	stormwater outfall near the University of Minnesota Coal Storage Facility at RM 853.0E
7LSTU	Bridal Veil Tunnel outlet at RM 851.6E
10SA	St. Anthony Village stormwater drainage system sampling location, the outlet to the river is several miles away at RM 853.2E
11CHF	stormwater outfall near the Minneapolis Public Works Fridley Water Treatment Plant's property in the Anoka County Riverfront Regional Park at RM 859E
µS	micro Siemens
ACD	Anoka Conservation District
BMP	best management practice
C	Celsius
cf	cubic foot
cfs	cubic feet per second
CFU	colony forming unit
cm	centimeter
D.O.	dissolved oxygen
DI	deionized
E. coli	*Escherichia coliform*
EPA	U.S. Environmental Protection Agency
EQuIS	Minnesota Pollution Control Agency's water quality database
F	Fahrenheit
ft	foot
GIS	geographic information system
GPS	global positioning system
IBI	Index of Biological Integrity
in	inch
in/hr	inches per hour
KP	Kasota Ponds

L	liter
m	meter
MCES	Metropolitan Council Environmental Services
mg	milligram
mL	milliliter
MPCA	Minnesota Pollution Control Agency
MPN	most probable number
MPRB	Minneapolis Park and Recreation Board
MR	Mississippi River
MS4	municipal separate storm sewer system
MWMO	Mississippi Watershed Management Organization
n/a	not applicable
NAVD88	North American Vertical Datum, 1988
NCHF	North Central Hardwood Forest ecoregion
NGVD29	National Geodetic Vertical Datum, 1929
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OHWL	Ordinary High Water Level
PCBs	polychlorinated biphenyls
ppt	parts per trillion
PVC	polyvinyl chloride
RM	river mile upstream from the confluence of the Mississippi and Ohio Rivers in Cairo, IL
SAFL	St. Anthony Falls Laboratory at the University of Minnesota
TMDL	total maximum daily load
USACE	United States Army Corps of Engineers

Glossary

Automatic sampler: equipment that is programmed to collect water samples based on the parameters in the program. It allows for the collection of samples without staff being present during a precipitation or snow melt event.

Baseflow: sustained flow in the stormwater drainage system that is the result of groundwater seepage or permitted discharge into the system.

Best Management Practice (BMP): technique, measure or structural control that is used to manage the quantity and improve the quality of stormwater runoff.

Composite sample: a water sample that contains water collected during a precipitation or snow melt event at specific intervals throughout the event.

Confined space: a space defined by the existence of all of the following conditions:

- is large enough and so configured that an employee can bodily enter and perform assigned work;
- has limited or restricted means for entry or exit (for example, manholes); and
- is not designed for continuous employee occupancy.

Discharge: rate of flow in a pipe or stream, expressed as a volume per unit time, most commonly cubic feet per second (cfs).

Eutrophication: excessive richness of nutrients in a lake or other body of water. Eutrophic water bodies support high algal growth and can become anoxic.

Flow-paced: water samples collected with the automatic sampler after a specific volume of water has passed by the sensor.

Grab sample: a single water sample submitted for analysis.

Illicit discharge: any discharge to the stormwater drainage system that is not composed entirely of stormwater. Exceptions include discharges allowed under a NPDES permit or water used for firefighting operations.

Impaired: a waterway that is considered too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes in the United States.

Index of Biological Integrity (IBI): a regionally based index used to measure the integrity of waterbodies and to determine the level of their biotic impairment. The IBI relies on multiple parameters (termed "metrics") based on macroinvertebrate or aquatic plant community structure and function, to evaluate a complex biotic system.

Macroinvertebrate: invertebrate fauna that can be captured by a 500 µm net or sieve.

Outfall: the end of a stormwater pipe, where the stormwater enters the receiving waterbody.

Pipeshed: an area of land where water from precipitation or snow melt drains into a waterbody through a man-made conveyance system of stormwater pipes (as opposed to natural systems such as streams). A pipeshed is not as landscape-driven as a watershed.

Rain event: precipitation greater than 0.01 inches occurring eight or more hours after the last precipitation.

Secchi tube: a plastic cylinder 100 cm in length with a small black and white disk attached to a string that is used to measure water clarity. This tube is designed to function like the traditional Secchi disk used in lake monitoring.

Specific conductivity: a measure of how well water can conduct electrical current for a unit length and unit cross-section at a certain temperature. Conductivity increases with the amount of ions in water. These ions come from the breakdown of compounds and conduct electricity because they are positively or negatively charged when dissolved in water. Therefore, specific conductivity is an indirect measure of the presence of dissolved solids such as chloride, nitrate and sulfate, and can be used as an indicator of water pollution.

Stormflow: water flowing in stormwater pipes during storm (precipitation) and snow melt events. Stormflow in pipes is typically short in duration and has a high velocity.

Stormwater: water that is not infiltrated during and immediately following a rain or snow melt event.

Stormwater drainage system: a series of roadways, curbs, catch basins, pipes, and tunnels that carry stormwater or snow melt from the surface to a receiving waterbody. Note: sanitary and stormwater pipes are typically separated in Minnesota.

Tail water: a condition where the Mississippi River water level is high enough to enter stormwater outfalls and mix with outflowing stormwater, which can interfere with data collection.

Trophic State Index: a standardized method of comparing phosphorus and algal concentrations across water bodies, using measures of phosphorus, chlorophyll-a and Secchi depth transparency. Trophic states range from oligotrophic, mesotrophic, eutrophic to hypereutrophic.

Total Maximum Daily Load (TMDL): a calculation of the maximum amount of a pollutant that a waterbody can receive daily and still safely meet water quality standards.

Watershed: an area of land where surface water (from rain or snow melt) runoff and groundwater drain into a waterbody. Watershed boundaries are defined by elevation.

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Annual Monitoring Report 2016

Executive Summary

The annual monitoring report details the monitoring activities of the Mississippi Watershed Management Organization's (MWMO) 2016 monitoring season. Each year, MWMO staff complete an annual monitoring report that summarizes the year's monitoring activities and outlines the next year's work plan. Current and past reports are available on the MWMO website at **mwmo.org/reports/water-quality-monitoring**.

The MWMO monitors water quality in the watershed's stormwater drainage system, the Mississippi River and wetlands. Within these systems, major factors influencing water quality include the amount of precipitation, timing of precipitation events and land use practices in the watershed. Long-term monitoring is necessary to characterize the impact of various land use practices on surface water runoff within the MWMO and, ultimately, the Mississippi River. Water quality in the Mississippi River is also influenced by precipitation and land use practices in the entire Mississippi River basin upstream of the MWMO. Long-term monitoring of the river will aid the understanding of upstream weather patterns and land use impacts on the MWMO watershed.

The 2016 monitoring season included: collection of precipitation data from eight monitoring locations, collection of bacteria samples from seven locations in the Mississippi River and five stormwater drainage system sites, automated collection of water quantity and water quality data from six stormwater outfall sites draining to the Mississippi River and one stormwater pipe at the jurisdictional boundary of the Cities of Saint Anthony Village and Minneapolis, collection of water quality samples from the Mississippi River, and collection of water quality samples from three wetlands. The Anoka Conservation District (ACD) collected water elevation and water quality data at Sullivan Lake and Highland Lake for the MWMO.

Portions of the 14-mile stretch of the Mississippi River in the MWMO are listed on the Federal Clean Water Act's Section 303(d) list of impaired waters for fecal coliform. The Minnesota Pollution Control Agency (MPCA) has moved from a fecal coliform standard to an *Escherichia coliform* (*E. coli)* standard; therefore, all fecal coliform impairments are now evaluated with *E. coli* data. Long-term monitoring of both the river and the stormwater drainage system is necessary to evaluate *E. coli* inputs from within the watershed compared to those inputs from upstream sources. The MPCA initiated the Upper Mississippi River Bacteria Total Maximum Daily Load (TMDL) Project in 2008 to develop daily *E. coli* load limits for the Mississippi River (MPCA, 2012). In 2014, the MPCA released its Upper Mississippi River Bacteria TMDL Study and Protection Plan (MPCA, 2014). This document designated the stretch of the Mississippi River within the MWMO as a Protection Reach and deferred it for a TMDL study.

MWMO staff began collecting water quality samples from the Mississippi River during 2014 and continued this sampling in 2015 and 2016. The purpose of monitoring the water quality of the Mississippi River is to establish baseline water quality data that can be used for the management of the river. Water quality measurements and samples were collected at eight sites, twice per month in April – November and once per month during December – March. Monitoring sites on the Mississippi River and within the MWMO's boundaries were selected to represent three distinct reaches of the river. Samples were collected from the middle of the river at three feet below the water surface and were analyzed for nutrients, sediment, inorganics, organics and metals.

The MWMO continued monitoring water quantity and water quality of the watershed's stormwater drainage system by monitoring baseflow, snow melt events and rain events in six stormwater tunnels draining to the Mississippi River. Samples were analyzed for nutrients, sediment, inorganics, organics and metals. Water quality standards do not exist for stormwater; therefore, data were not compared to standards but are summarized in subsequent sections of the annual monitoring report. The MWMO will continue to monitor stormwater drainage systems to develop a record of baseline data with which to characterize stormwater quality within the watershed. The MWMO also provides stormwater data to the MPCA for TMDL projects within the watershed.

The MWMO contracted with the ACD to conduct water level and water quality monitoring activities on Sullivan Lake and Highland Lake in Columbia Heights. A volunteer, in coordination with ACD, conducted regular water level monitoring during 2016 between April and September. ACD also collected monthly water quality samples at each lake. Samples were analyzed for indicators of lake status such as nutrient levels and water clarity. Summaries of these data are included in this report.

The MWMO also continued monitoring three wetlands known as Kasota Ponds. Samples were collected for nutrients, sediment, inorganics and metals analyses. The MPCA water quality criteria indicate that wetland water quality should maintain background conditions. MWMO staff also conducted wetland vegetation and macroinvertebrate surveys in each of the three wetlands. The results of this survey are used to assess the relative condition of the wetlands

MWMO staff continued to collect bathymetric data on the Mississippi River between Lock and Dam 1 and the Canadian Pacific Railway (CPR) Bridge in line with N. 41st Avenue. The purpose of collecting Mississippi River bathymetric data is to provide baseline data on the morphology of the river bed. In 2016, the MWMO also began to monitor the effectiveness of some newly installed best management practices (BMPs) within the watershed. This year, BMPs were instrumented with water quality and quantity sampling equipment in order to assess the efficacy of each BMP at removing pollutants from stormwater. The first complete year of data will be collected and analyzed in 2017.

Introduction

The MWMO established the monitoring program to provide a scientific basis for identifying and evaluating water quality and quantity issues, implementing solutions to improve water quality, and reestablishing natural water regimes in the watershed. The objectives of the monitoring program are to:

- Monitor biological, chemical, and physical parameters of water resources in the watershed
- Monitor water quality within the watershed
    - Develop a record of baseline data to characterize water quality and identify pollutants that exceed water quality standards
    - Assess water resources for pollutants listed on the Minnesota Impaired Waters list for the TMDL process
- Collect rate and volume data for the Mississippi River and key subwatersheds
- Monitor performance of stormwater management practices
- Collaborate with stakeholders to identify and apply a standardized data collection and assessment approach
- Develop partnerships and collaborate with other organizations and/or agencies, both inside and outside the watershed boundaries, to improve water quality in the Mississippi River
- Assess land use impact on water quality
- Participate in the technical development and update of statewide monitoring databases
- Make data accessible to the public and public entities and to MWMO staff for use as an education tool (e.g., BMP performance data)
- Develop an emergency monitoring plan in case of emergencies affecting water resources

New BMPs within the watershed were monitored for their effectiveness at pollutant removal and bathymetric data were collected for the Mississippi River. Refer to Figure 1 below for a map of the MWMO boundary. Descriptions of the sampling sites are found in subsequent sections of this report.

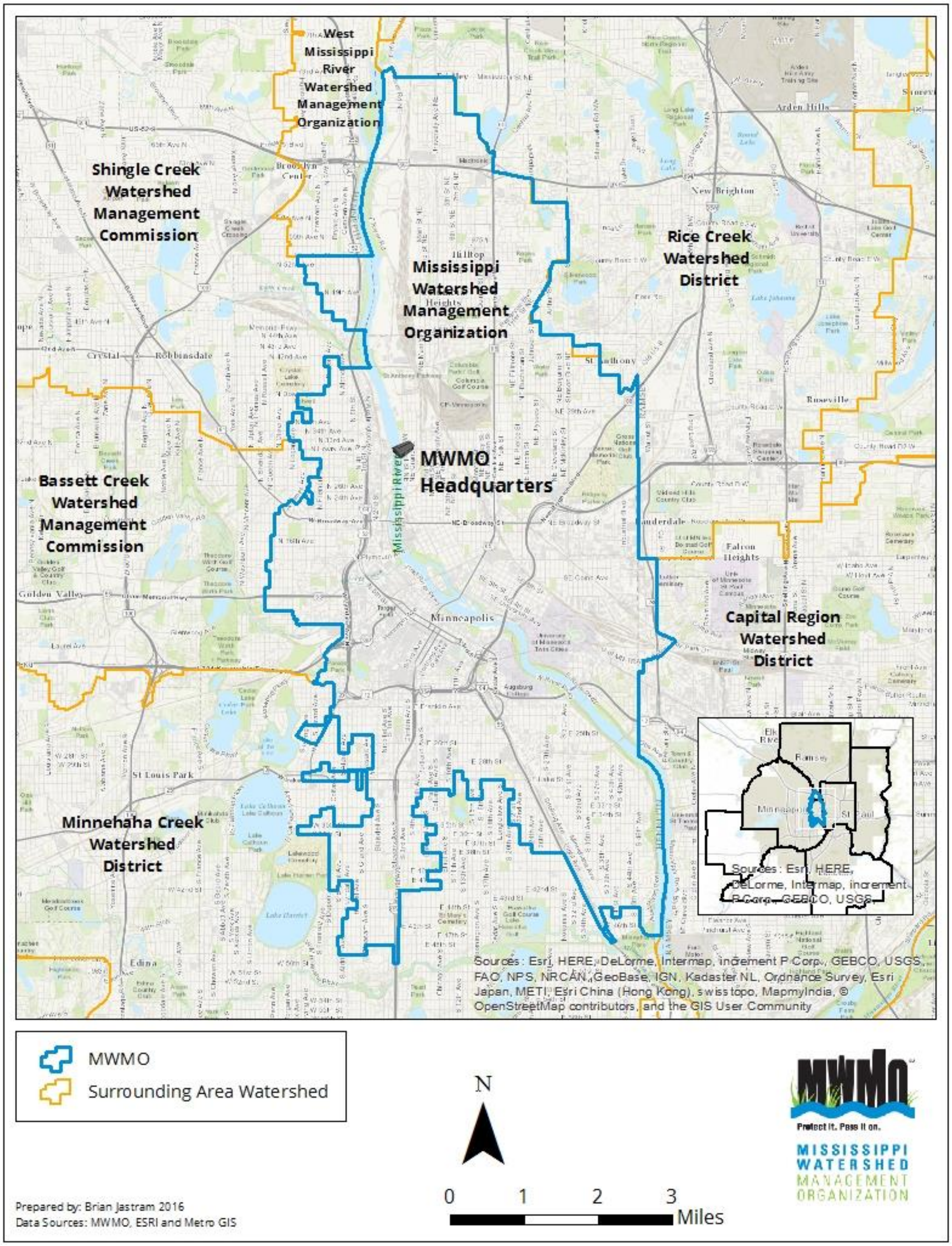

Figure 1. MWMO watershed boundary and Headquarters.

Background

The MWMO was established in 1985 by a Joint Powers Agreement among member organizations. In 2012, the MWMO boundaries expanded to include portions of the Cities of Fridley and Columbia Heights and the entire City of Hilltop. The MWMO watershed boundaries are shown in Figure 1. The MWMO is a unique organization in that it includes a 14 mile stretch of the Mississippi River as it runs through Minneapolis and St. Paul. The reach of the Mississippi River included in the MWMO extends from 1.25 miles upstream of the Interstate-694 (I-694) bridge in Fridley to Lock & Dam No. 1 (Ford Dam). There are three lakes within the MWMO's boundaries: Loring Pond in Minneapolis, Sullivan Lake (formerly known as Sandy Lake) and Highland Lake in Columbia Heights.

Minnesota regulations require that the MWMO protect water quality in the watershed. Minnesota Rules Chapter 7050 requires that all waterbodies comply with state water quality standards. Furthermore, section 303(d) of the Federal Water Pollution Control Act (commonly known as the Clean Water Act) requires states to develop TMDLs for waters with impaired uses. Impaired waters are those waters that exceed water quality standards for their classified use. Some typical classifications include drinking water, aquatic life, and recreation (swimming and fishing). According to Minnesota Rules Chapter 7050, the stretch of the Mississippi River within the MWMO watershed is divided into two reaches for classification. Table 1 highlights the most restrictive classifications.

The MWMO's stretch of the Mississippi River is listed on MPCA's 303(d) list of impaired waters for fecal coliform/*E.coli*, mercury, and polychlorinated biphenyls (PCBs). The MPCA divided the stretch of the Mississippi River flowing through the MWMO into three reaches. Table 2 lists the impaired reaches of the river and the corresponding pollutants of concern. The MPCA has written a statewide TMDL for mercury (MPCA, 2007). Both Sullivan Lake and Highland Lake are listed on the 303(d) list of impaired waters for nutrient/eutrophication and biological indicators. All three of the Kasota Ponds and Loring Pond are listed on the 2014 Impaired Waters List for chloride impairments.

Protecting water quality in the Mississippi River is a complicated task. The Mississippi River flowing through the MWMO is densely urbanized with commercial, industrial, residential, park lands, and downtown Minneapolis land uses, all of which contribute to the volume and quality of the water entering the river through the stormwater drainage systems. The MWMO monitors stormwater drainage systems to determine the water quantity and water quality contributions of surface runoff from the watershed to the river. However, the entire Mississippi River basin upstream of the MWMO watershed boundary also contributes to water quality in the MWMO's stretch of the river.

Table 1. Water use classifications for waterbodies in the MWMO

Waterbody	Water Use Classification
Mississippi River, MWMO upstream boundary to Upper Saint Anthony Falls	1C, Domestic consumption (drinking water) 2Bd Aquatic life and recreation and source of drinking water
Mississippi River, Upper Saint Anthony Falls to Lock & Dam 1 (Ford Dam)	2B Aquatic life and recreation
Loring Pond	2B Aquatic life and recreation
Sullivan (Sandy) Lake	2B Aquatic life and recreation
Highland (Unnamed) Lake	2B Aquatic life and recreation
Mallard Marsh (Kasota Pond East)	2D Aquatic life and recreation
Kasota Pond North	2D Aquatic life and recreation
Kasota Pond West	2D Aquatic life and recreation

Table 2. Pollutants in impaired waters

Impaired Waterbody	Pollutant
Mississippi River, MWMO upstream boundary to Upper Saint Anthony Falls	Fecal coliform/*E.coli*, mercury in fish tissue, polychlorinated biphenyls (PCBs) in fish tissue
Mississippi River, Upper Saint Anthony Falls to Lower Saint Anthony Falls	Mercury in fish tissue, PCBs in fish tissue
Mississippi River, Lower Saint Anthony Falls to Lock & Dam 1 (Ford Dam)	Fecal coliform/*E.coli*, mercury in fish tissue
Loring Pond	Chloride
Sullivan (Sandy) Lake	Nutrient/eutrophication biological indicators
Highland (Unnamed) Lake	Nutrient/eutrophication biological indicators
Mallard Marsh (Kasota Pond East)	Chloride
Kasota Pond North	Chloride
Kasota Pond West	Chloride

The Upper Mississippi River is a large, dynamic river system that includes runoff from forested areas near the source at Lake Itasca, agricultural runoff from the central region of Minnesota, and the urbanized areas of Saint Cloud and the Twin Cities Metro area. Since precipitation produces surface runoff, precipitation differences throughout the upper Mississippi River basin can affect water flow and water quality in the MWMO's stretch of the Mississippi River.

Thus, if large amounts of rainfall have washed pollutants from upstream into the river, it is possible that flows could increase and water quality could decline, even though it has not rained in the MWMO watershed. In cooperation with other federal and state agencies as well as watershed management organizations and districts, the MWMO plans to investigate the upstream impact on water quality to discern the effect of precipitation in other portions of the state on water quality in the MWMO's stretch of the Mississippi River.

Further complicating the investigation of water volume and quality in the river are the groundwater connections. Groundwater may carry pollutants from upstream in the Mississippi River basin to the MWMO's stretch of the river. Conversely, pollutants may also leach from the river into the groundwater system. It is quite difficult to track potential groundwater inputs from an area as large as the Mississippi River basin upstream of the MWMO to the MWMO's stretch of the river. The MWMO has long-term plans to coordinate with organizations and agencies in the upper portion of the basin to improve water quality in the Mississippi River.

Precipitation Monitoring

Precipitation determines surface runoff and is arguably the greatest factor controlling surface water quality. As stated in the Background section of this monitoring report, water quality in the MWMO's stretch of the Mississippi River is affected by precipitation in the entire Mississippi River basin upstream of the MWMO, including tributary watersheds to the river.

The MWMO collects precipitation data from a variety of sources, including gauges installed and operated by external entities, as well as those operated by the MWMO itself. Figure 2 shows locations of all precipitation gauges utilized by the MWMO. Tables 3 and 4 show 2016 monthly precipitation values for several locations in the Upper Mississippi River Basin between St. Cloud and the Minneapolis-St. Paul (MSP) International Airport. Table 3 includes data from non-MWMO gauges only. Precipitation data at the St. Anthony Falls Laboratory (SAFL) site were collected by SAFL personnel. Precipitation data from precipitation monitoring sites in St. Cloud, Becker, Elk River, New Hope, Chanhassen and the Minneapolis-St. Paul International Airport were downloaded from either **www.dnr.state.mn.us/climate/historical/acis_stn_meta.html** or **climate.umn.edu/mapClim2007/MNlocApp.asp**.

Table 4 shows monthly precipitation data from the MWMO network of precipitation gauges, located primarily within the MWMO watershed. Precipitation data at sites 1NE, 10SA, 11CHF, Edison High School, Columbia Golf Course, Waite Park Elementary School, and the MWMO Weather Station were collected by MWMO staff. Precipitation data at the 6th Street NE site were recorded and submitted by MWMO citizen volunteers. Figure 3 shows 2016 monthly precipitation at the 1NE site in comparison to the 30-year monthly precipitation normals at Minneapolis-St. Paul International Airport.

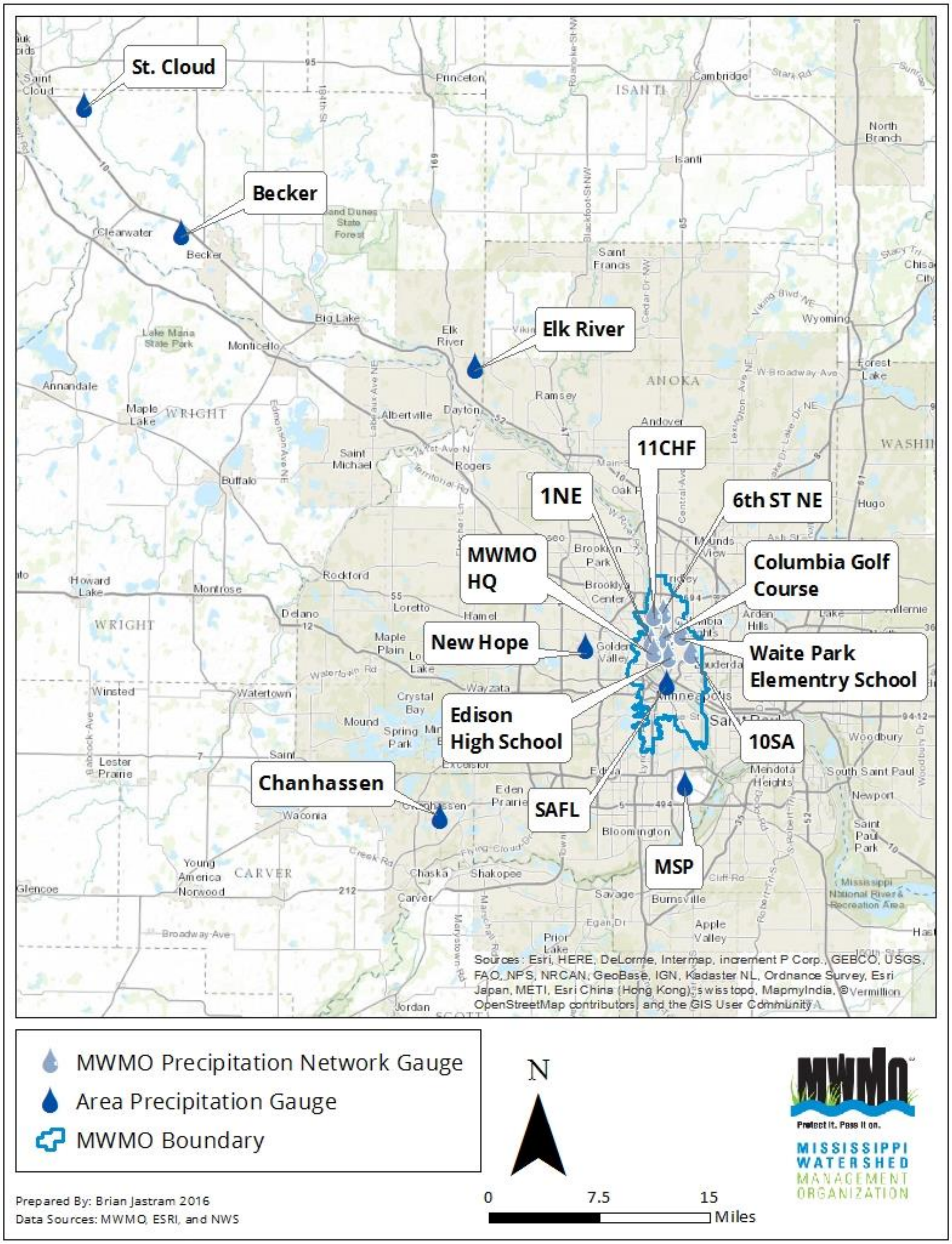

Figure 2. Precipitation gauges in the Upper Mississippi River Basin and MWMO boundary.

Table 3. 2016 monthly precipitation (inches) at several locations in the Upper Mississippi River basin

Month	St. Cloud[1]	Becker[2]	Elk River[3]	New Hope[4]	SAFL[5]	Chanhassen[7]	Minneapolis St. Paul International Airport[8]	MSP 30 YR MO Normal[9]
January	0.31	0.56	0.27	0.31	0.17	0.31	0.31	0.90
February	0.63	1.07	0.54	1.02	0.23	1.18	1.09	0.77
March	1.50	1.15	1.90	1.92	1.59	1.42	2.26	1.89
April	1.74	2.67	2.76	3.73	3.45	3.31	2.84	2.66
May	2.17	3.97	3.11	2.13	1.36	2.03	2.42	3.36
June	3.37	3.18	2.61	3.47	3.60	4.58	4.49	4.25
July	6.74	7.57	7.34	5.74	3.76	5.43	5.09	4.04
August	8.36	5.46	7.11	9.15	8.00	9.70	7.82	4.30
September	3.08	5.30	4.44	7.08	3.90	5.15	5.47	3.08
October	2.68	2.11	2.70	3.25	2.31	3.46	3.41	2.43
November	1.69	1.47	2.13	2.92	2.02	1.71	2.98	1.77
December	1.58	1.43	0.16	1.26	1.23	2.25	2.14	1.16
Total	33.85	35.94	35.07	41.98	31.62	40.53	40.32	30.61

[1] Location: Latitude 45.5441 Longitude -94.0708, Source: http://www.dnr.state.mn.us/climate/historical/acis_stn_meta.html
[2] Location: Latitude 45.4206 Longitude -93.9333, Source: http://climate.umn.edu/hidradius/radius_new.asp
[3] Location: Latitude 45.5272 Longitude -93.7110, Source: http://www.dnr.state.mn.us/climate/historical/acis_stn_meta.html
[4] Location: Latitude 45.0167 Longitude -93.3667, Source: http://www.dnr.state.mn.us/climate/historical/acis_stn_meta.html
[5] Location: Latitude 44.9823 Longitude -93.2549, Source: C Ellis, Saint Anthony Falls Laboratory (SAFL)
[6] Location: Latitude 44.9149 Longitude -93.2549, Source: http://www.mvp-wc.usace.army.mil/projects/Lock1.shtml
[7] Location: Latitude 44.8514 Longitude -93.5650, Source: http://www.dnr.state.mn.us/climate/historical/acis_stn_meta.html
[8] Location: Latitude 44.8830 Longitude: -93.2288, Source: http://www.dnr.state.mn.us/climate/historical/acis_stn_meta.html
[9] Location: Latitude 44.8830 Longitude: -93.2288, Source: http://www.ncdc.noaa.gov/cdo-web/datasets/NORMAL_MLY/stations/GHCND:USW00014922/detail

Table 4. 2016 monthly precipitation (inches) at several locations in the MWMO precipitation monitoring network

Month	1NE[1]	10SA[2]	11CHF[3]	Edison High School[4]	Columbia Golf Course[5]	Waite Park Elementary School[6]	6th ST NE[7]	MWMO Weather Station[8]
January	0.20	0.26	0.10	0.20	0.12	0.13	0.33	0.10
February	0.48	0.37	0.14	0.32	0.39	0.50	0.90	0..24
March	1.59	1.69	1.51	0.93	1.75	1.76	1.13	1.83
April	3.47	3.35	3.08	3.97	2.32	3.78	3.43	3.32
May	2.11	1.68	2.06	2.33	2.63	2.34	2.18	1.79
June	2.42		2.69	3.46	2.54	2.92	2.72	2.84
July	5.14		4.84	6.84	6.58	3.71	5.77	5.47
August	7.35		7.12	8.54	8.08	8.63	7.32	7.44
September	4.97		5.05	6.23	5.91	5.88	5.26	5.19
October	2.81	3.35	2.49	3.01	3.28	2.89	2.77	2.60
November	2.38	2.42	2.18	2.59	2.87	2.50	2.59	2.26
December	1.49	1.25	1.15	1.41	1.42	1.61	2.11	1.96
Total	34.41	NA	32.41	39.83	37.89	36.65	36.51	35.05

[1] Location: Latitude 45.023 Longitude -93.277, Source: MWMO data, 1NE
[2] Location: Latitude 45.012 Longitude -93.220, Source: MWMO data, 10SA
[3] Location: Latitude 45.050 Longitude -93.274, Source: MWMO data, 11CHF
[4] Location: Latitude 45.012 Longitude -93.22, Source: MWMO Data, Edison High School
[5] Location: Latitude 45.027 Longitude -93.255, Source: MWMO Data, Columbia Golf Course
[6] Location: Latitude 45.030 Longitude -93.234, Source: MWMO Data, Waite Park Elementary School
[7] Location: Latitude 45.053 Longitude -93.259, Source: Citizen Volunteer, Minneapolis MN
[8] Location: Latitude 45.013 Longitude -93.272, Source: MWMO Data, MWMO Weather Station

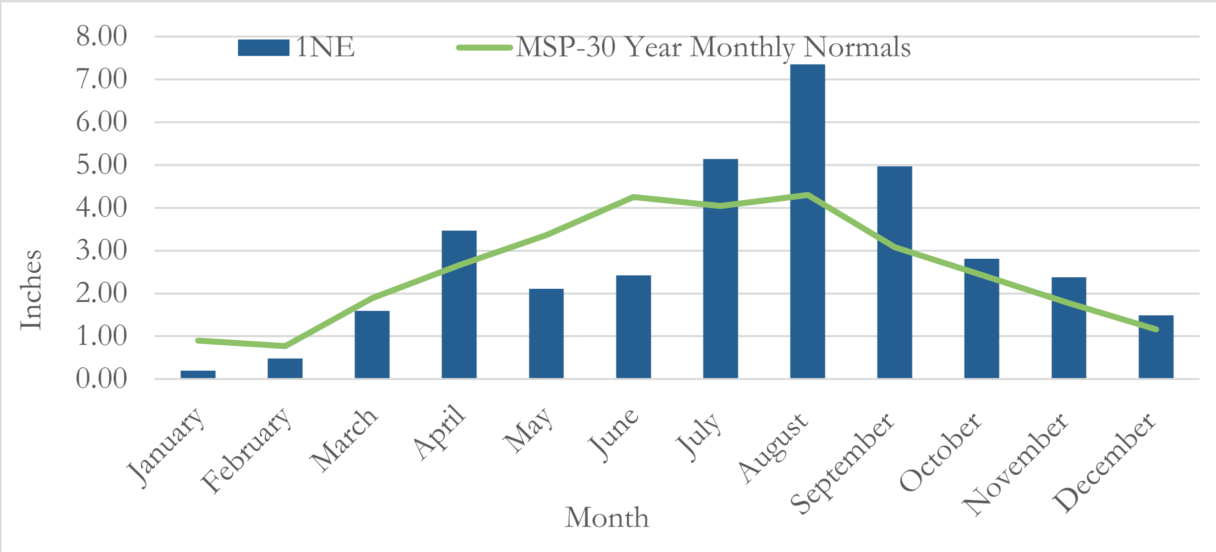

Figure 3. 2016 monthly precipitation totals at the 1NE heated rain gauge compared to 30-year monthly precipitation normals at the Minneapolis-St. Paul International Airport.

Stormwater Monitoring

The MWMO monitors water quantity and quality at six stormwater outfalls into the Mississippi River and one stormwater pipe at the jurisdictional boundary of the Cities of Saint Anthony Village and Minneapolis. The monitored locations were chosen because they are the most extensive stormwater drainage systems (pipesheds) within the watershed and they are accessible for equipment installation. A stormwater drainage system refers to the area that drains to one stormwater outfall. Land uses in the stormwater drainage systems affect water quality. The amount of impervious surface and potential pollution differs between industrial, residential, and commercial land uses. Refer to Figure 4 for a map of the MWMO's stormwater sampling sites and pipesheds.

Site descriptions and water quantity data for each stormwater site are provided in the following pages. Six of the MWMO's stormwater sites are monitored for continuous automated level and discharge measurements as well as water quality during both storm and baseflow conditions. Water quality data from the stormwater sites are discussed at the end of this section. MWMO monitoring staff will provide complete water quality and quantity data upon request (contact info at mwmo.org).

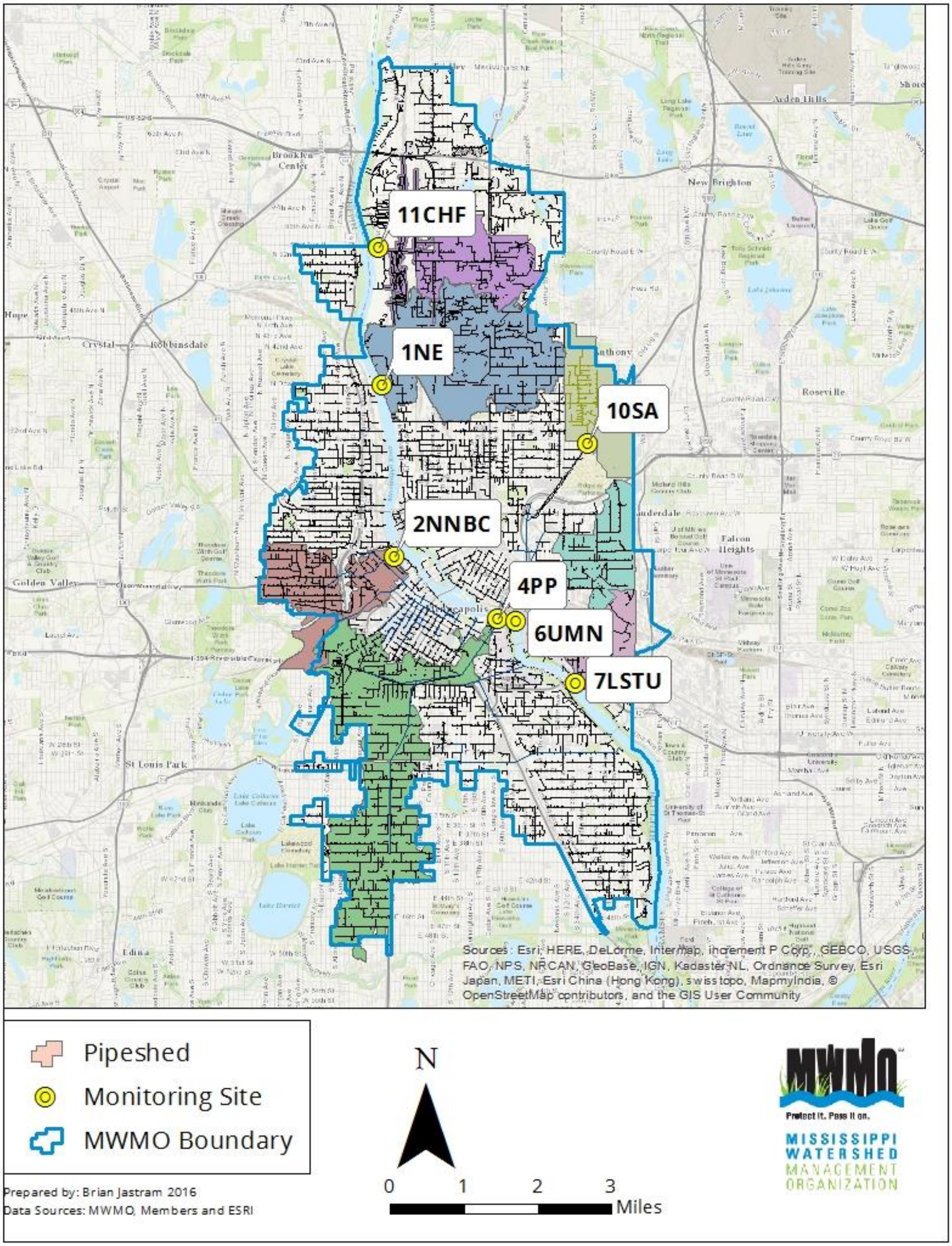

Figure 4. Stormwater pipesheds monitored by the MWMO and corresponding monitoring site locations.

Methodology

Water Level and Discharge Monitoring

Water level in a stormwater pipe is very different from water level in the Mississippi River. Stormwater pipes respond quickly to rainfall, so water levels may rise many feet within a few minutes, depending on the size and intensity of the storm event. Some stormwater pipes only contain water during precipitation events, while others have baseflow throughout the year. Most stormwater pipes monitored by the MWMO have varying levels of baseflow year round.

Six MWMO stormwater monitoring sites are equipped with Isco 6712 automatic samplers (Teledyne Isco, Inc., Lincoln, NE). An Isco Area/Velocity sensor is installed in each of the six pipes and connected via cable to an Isco 750 Area/Velocity Flow Module which is attached to the automated sampler. The sensor and flow module provide water level and velocity data which are then used with pipe area dimensions to compute discharge from the stormwater pipe. A typical automated stormwater site set-up is shown in Figures 5 and 6.

Figure 5. Example of a typical MWMO stormwater monitoring site cabinet setup, including automated sampling and continuous automated monitoring equipment.

Figure 6. Typical area/velocity sensor (black rectangle) and cable and tubing configuration in a monitored stormwater tunnel.

Sample Collection, Handling, and Preservation

Grab and composite samples were collected from five stormwater sites in the MWMO watershed. Staff followed sampling procedures outlined in the MWMO's Standard Operating Procedure for Stormwater Sampling (2011). For the majority of parameters, samples were collected in laboratory-cleansed (non-sterile) plastic bottles. Samples were either collected directly into the bottle as grab samples or with automatic samplers as described below.

The Isco 6712 automatic samplers house twenty-four one-liter plastic bottles for composite sample collection. Samplers were programmed such that once the water level reached a certain value above baseflow, the sampler triggered to start sampling. Once triggered, the sampler rinsed the sample tubing before drawing the sample into the containers. Samples were collected on a flow-paced basis. Once collected, the bottles were composited by a monitoring specialist by pouring an equal amount of water from each sampler bottle into a plastic bottle.

Dissolved oxygen, conductivity, salinity, temperature, and pH data were measured in the field using a YSI ProPlus sonde (YSI Inc., Yellow Springs, OH). Transparency was measured using a Secchi tube.

Stormwater composite samples were collected for a minimum of three precipitation events per month, as long as that many events occurred. If baseflow conditions were present, samples were collected twice per month year round.

Sampling Quality Control

The MWMO staff followed the quality control protocol outlined in the MWMO Ambient Surface Water Monitoring Quality Assurance Project Plan (MPCA, 2010). Blank samples of DI water were submitted to laboratories quarterly to verify that sample containers were clean and samples were not contaminated during travel. In addition, ten percent of samples were collected in duplicate to verify that sampling and laboratory procedures did not jeopardize the data. The Isco bottles were rinsed twice with tap water and once with DI water between sample events.

Laboratory Analyses

Samples were analyzed at the Metropolitan Council Environmental Services (MCES) Laboratory. The laboratory follows strict protocols for quality assurance and quality control. Information regarding laboratory protocol is available from MWMO staff. Refer to Table A.1 in Appendix A for a list of sample parameters, the laboratories used for analysis, the analysis methods, and information regarding certification.

Data Analysis

The following data cleaning techniques were used to ensure quality data:

- Suspect data were flagged and verified with the laboratory
- Statistical regression techniques were used to interpolate automated flow data that were missing due to equipment problems (MWMO, 2013)

Continuous Automated Water Monitoring Network

In 2008 the MWMO, in collaboration with scientists at the University of Minnesota Saint Anthony Falls Laboratory, designed and deployed a Continuous Automated Water Monitoring Network. The network was built to achieve three main goals: continuous monitoring of stormwater flow, data collection and display, and flow paced sampling of stormwater runoff. The three main elements of this system are: stormwater and environmental sensors, radio networked dataloggers and automated samplers. Stormwater and environmental data are collected and transmitted by the network to a web service that creates graphs and tables describing current and past conditions. Automated samplers are remotely controlled to collect flow paced samples on demand with custom inputs from operators that adjust sample collection parameters to changing conditions.

Refer to Figure 7 for a map of the network. Details about the specific hardware and software used in the network are included in the MWMO Annual Monitoring Report 2013 (MWMO, 2014).

Stormwater Water Quality Monitoring Results

The MPCA does not have water quality criteria for stormwater drainage systems; therefore, data are not compared with standards. The MWMO monitors stormwater to characterize surface runoff in the watershed and determine land contributions to water quality in the Mississippi River. Samples are collected for bacteria, nutrients, sediment, inorganics, organics and metals analyses. The MWMO will not draw conclusions or make assumptions based on this data until several years of accurate flow-weighted composite data are available. The MWMO has begun calculating annual pollutant loads at some stormwater monitoring sites where several years of data do exist. The 2016 water quality data have been submitted to the MPCA's water quality database (EQuIS) and are available upon request from MWMO monitoring staff. Stormwater bacteria data are discussed in the Bacteria Monitoring section of this report. Specific information regarding individual stormwater sites can be found in the following pages.

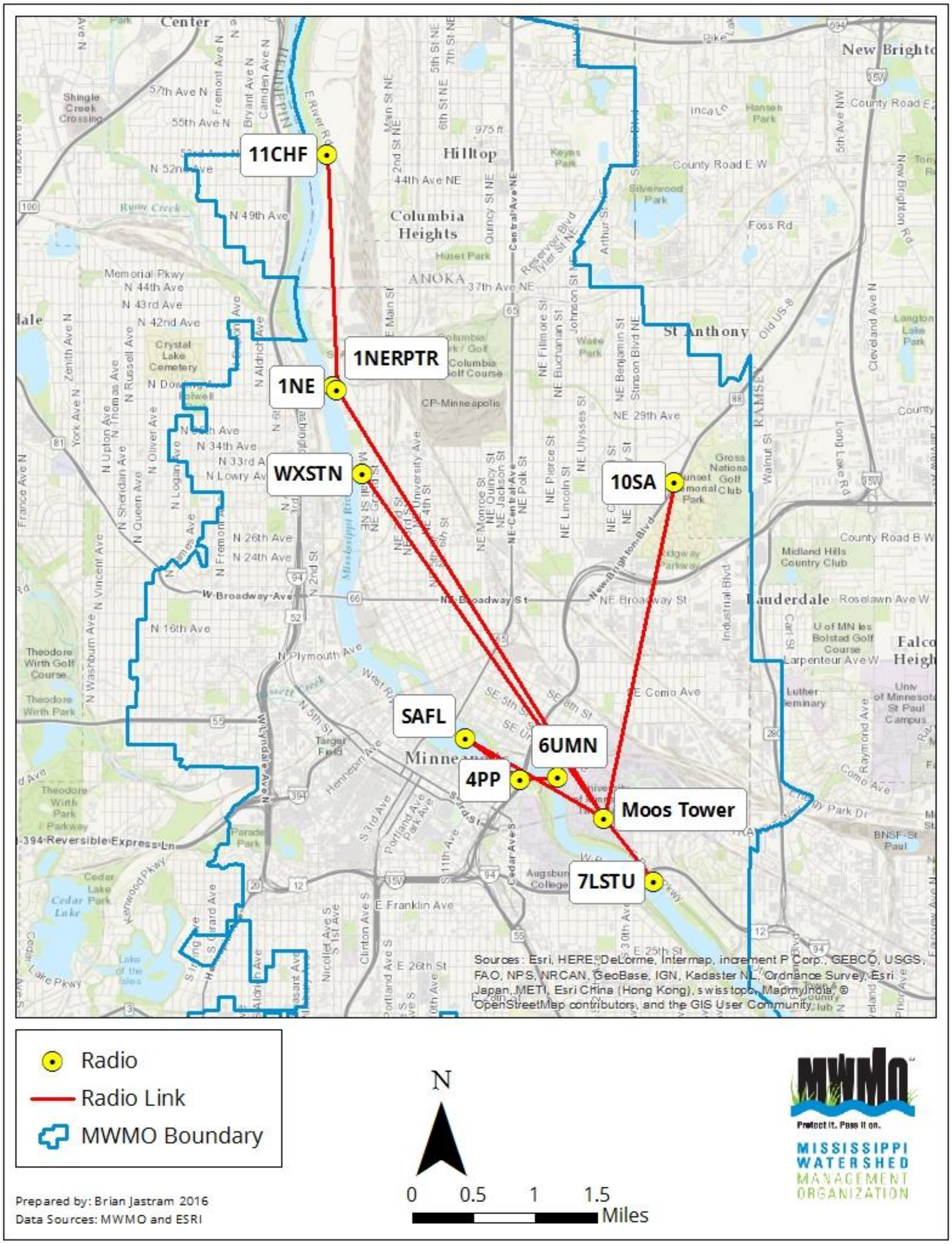

Figure 7. Continuous Automated Water Monitoring Network.

Stormwater Site Descriptions and Water Quantity Results

11CHF

This site is the northernmost outfall monitored by the MWMO. Installation of the site was completed in October 2014. The outfall is located on the east bank of the Mississippi River at RM 859, about 50 feet upstream from the northernmost edge of the Minneapolis Public Works Fridley Water Treatment Plant's property in the Anoka County Riverfront Regional Park. The outfall is a seven-foot diameter, round concrete pipe (Figure 8). The nearest intersection is 44th Avenue NE and East River Road. The monitoring equipment is located 1,880 feet up the tunnel from the outfall on BAE Systems Inc. property just west of the Burlington Northern Santa Fe rail yard and north of the rail yard's associated stormwater reservoir. This stormwater drainage system drains water from approximately 1,310 acres of parts of the cities of Columbia Heights, Hilltop, and Fridley (Figure 9). The pipeshed includes mainly industrial and residential land uses. The stormwater drainage system has continuous baseflow.

Figure 8. Site 11CHF outfall to the Mississippi River

Stormwater discharge and precipitation data from the 11CHF site are shown in Figure 10. Extremely cold temperatures caused the automatic sampler to shut off occasionally, resulting in short gaps in discharge data during winter months. 11CHF data are also affected by periodic, controlled releases of water from a stormwater reservoir into the tunnel through a pipe located just upstream of the area/velocity sensor location. An automated precipitation gauge is also operated at this site.

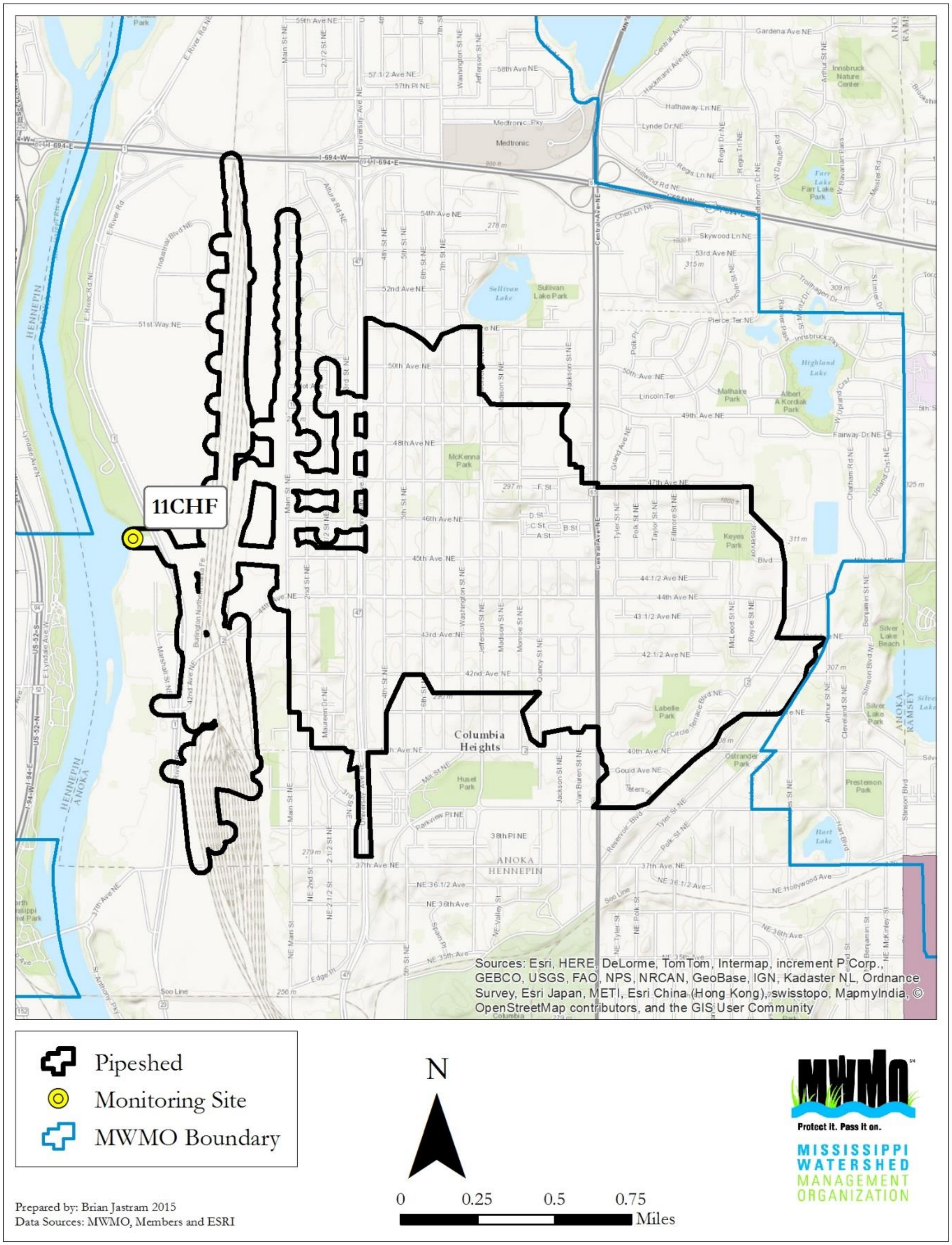

Figure 9. 11CHF pipeshed boundary and monitoring site location.

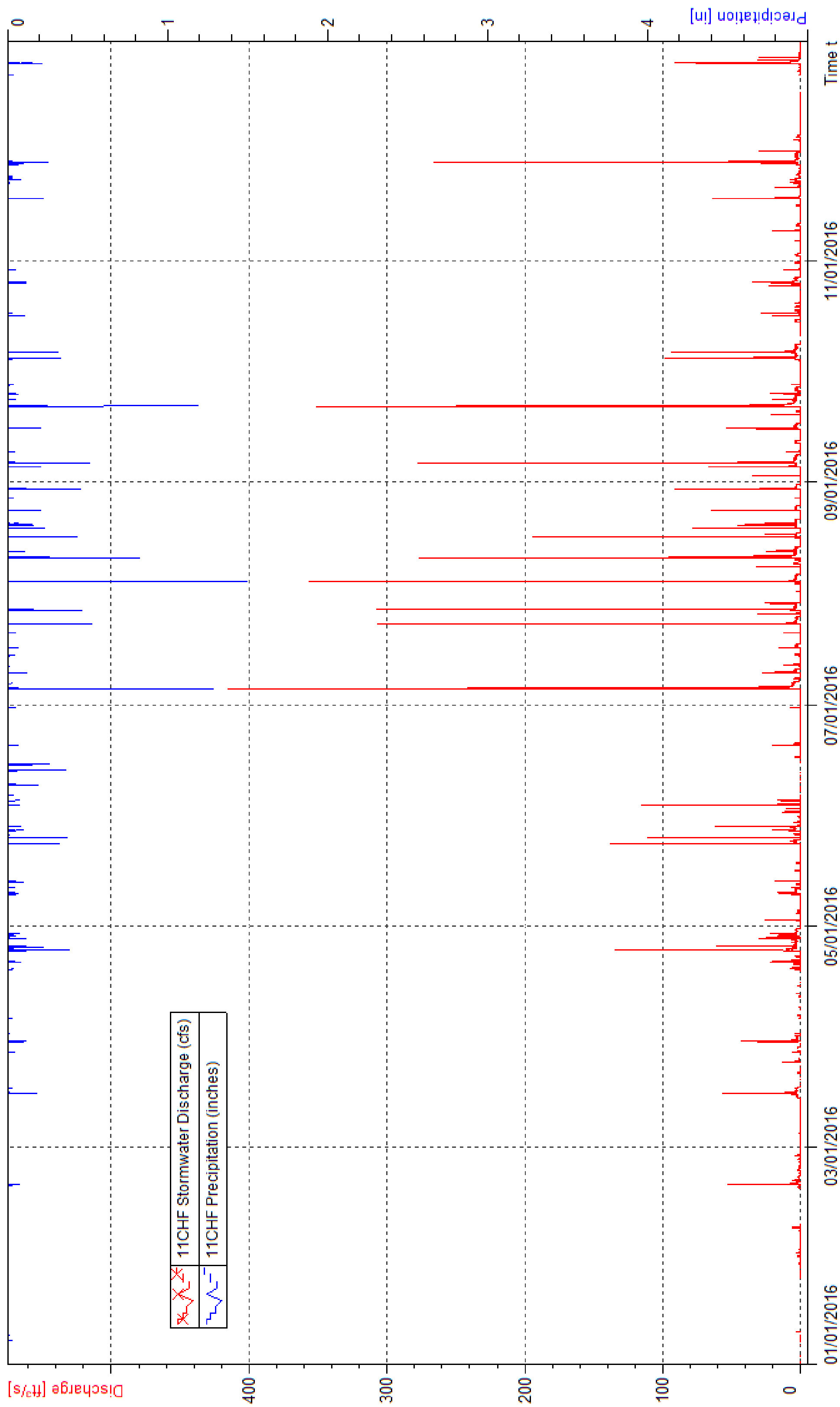

Figure 10. Stormwater discharge and hourly precipitation totals at the 11CHF monitoring site in 2016.

1NE (Xcel Riverside Plant)

Stormwater monitoring equipment was initially installed at the 1NE outfall site in 2006. The outfall is located on the east bank of the Mississippi River on the Xcel Riverside Power Plant property at RM 857.2 and is an eight-foot diameter, corrugated iron pipe (Figure 11). The stormwater drainage system drains water from approximately 2,240 acres of the Northeast Minneapolis neighborhood as well as portions of Columbia Heights and Fridley (Figure 12). The pipeshed includes mainly residential and industrial land uses. The stormwater drainage system has continuous baseflow.

Figure 11. Outfall to the Mississippi River for the 1NE pipeshed. Monitoring cabinet can be seen in the upper right corner (green box).

Stormwater discharge and precipitation data collected with automated equipment are presented in Figure 13. Cold weather caused the automated sampler to shut off occasionally, resulting in brief gaps in level and discharge data. During periods of time when the baseflow water level was very low (typically winter and fall) the sensor could not measure stormwater discharge. Those periods are represented as gaps in the discharge data.

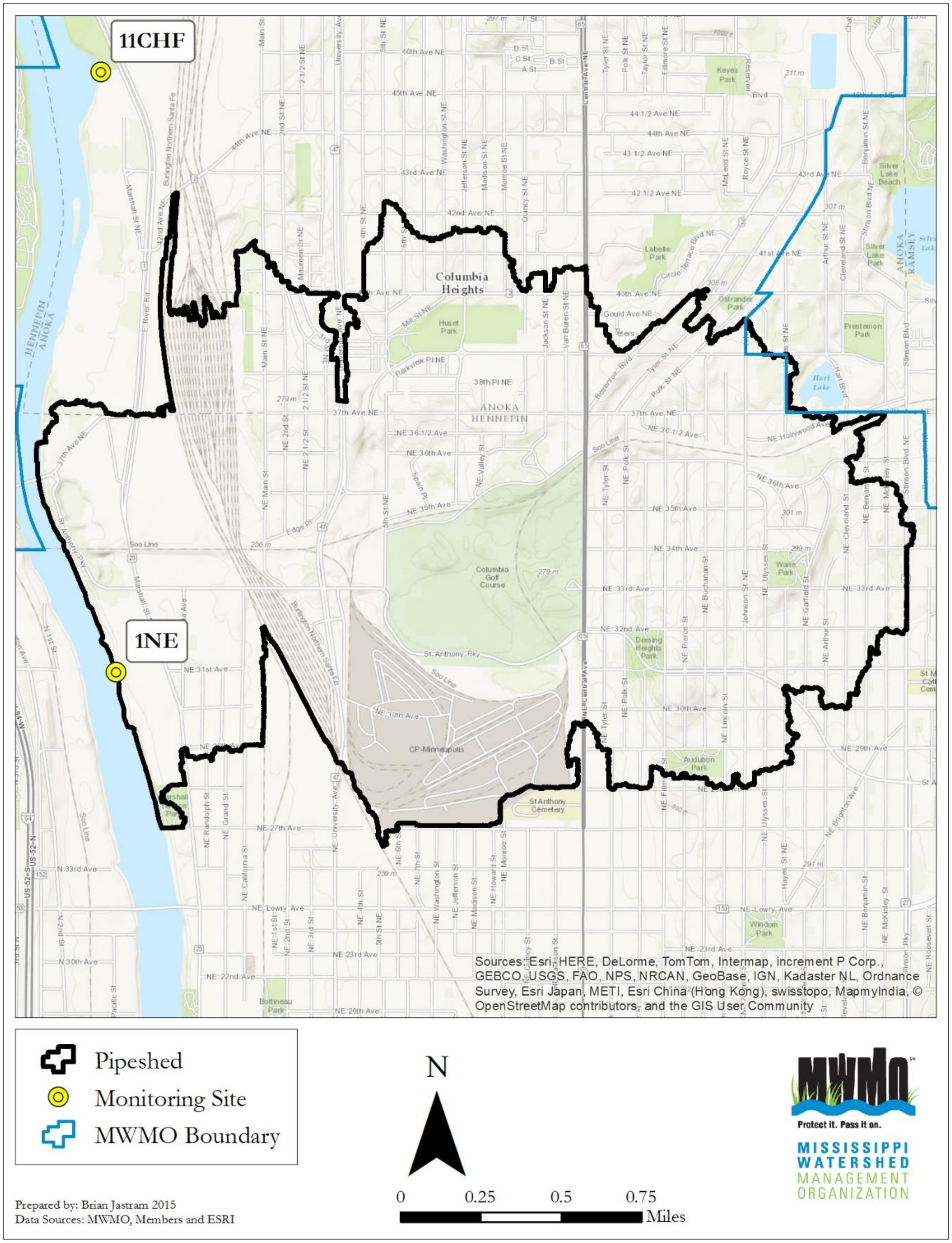

Figure 12. 1NE pipeshed boundary and monitoring site location.

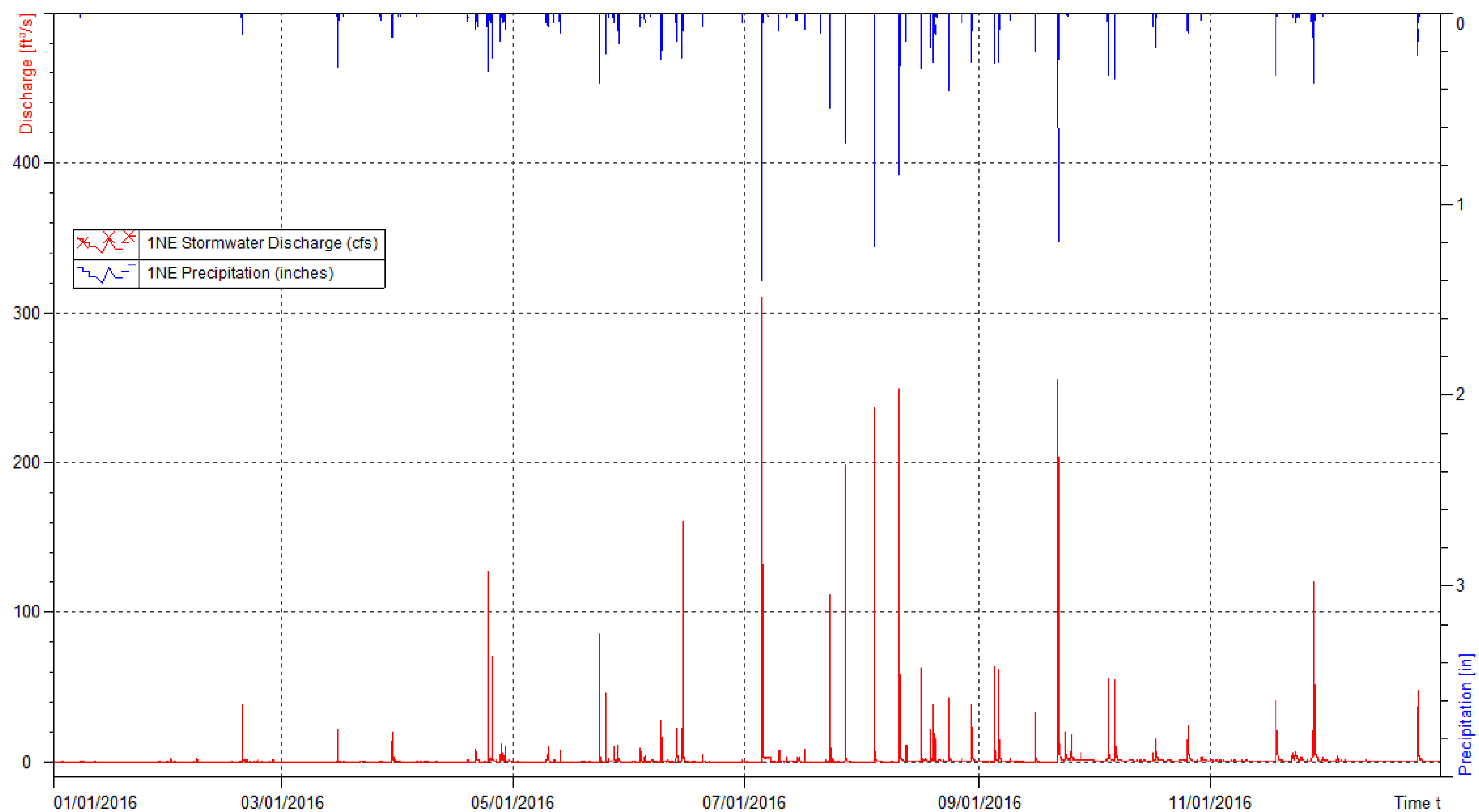

Figure 13. Stormwater discharge and hourly precipitation totals at the 1NE monitoring site in 2016.

2NNBC (Old Bassett's Creek Tunnel Outlet)

The 2NNBC outfall drains water from 1,067 acres of the Near North Minneapolis neighborhood and Bassett's Creek overflow. It enters the river in a park in the North Loop neighborhood of Minneapolis on the west bank of the Mississippi River at RM 854.8. Land use in the pipeshed is primarily residential and commercial. The semi-elliptical outfall is approximately 11 feet high and 15 feet wide (Figure 14). Bassett's Creek was buried and routed through this tunnel in 1890. In 1992, the creek was rerouted through a new tunnel that enters the Mississippi River below the surface water level, just downstream from Upper Saint Anthony Falls. Water from Bassett's Creek only flows through the original outfall during overflow periods. The 2NNBC pipeshed is shown in Figure 15.

Figure 14. The 2NNBC outfall to the original Basset's Creek channel before it enters the Mississippi River.

The 2NNBC site does not have an automated sampler or area/velocity sensor but grab samples are collected during rain events and baseflow when possible. Throughout much of 2016, river water was present in the tunnel. Samples were not collected during that time unless, during precipitation or melt events, stormwater pushed the river water out of the tunnel such that stormwater could be sampled. An In-Situ Level Troll 500 (In-Situ Inc., Ft. Collins, CO) was installed at the outfall in October 2014 in order to obtain hourly water level measurements at the outfall.

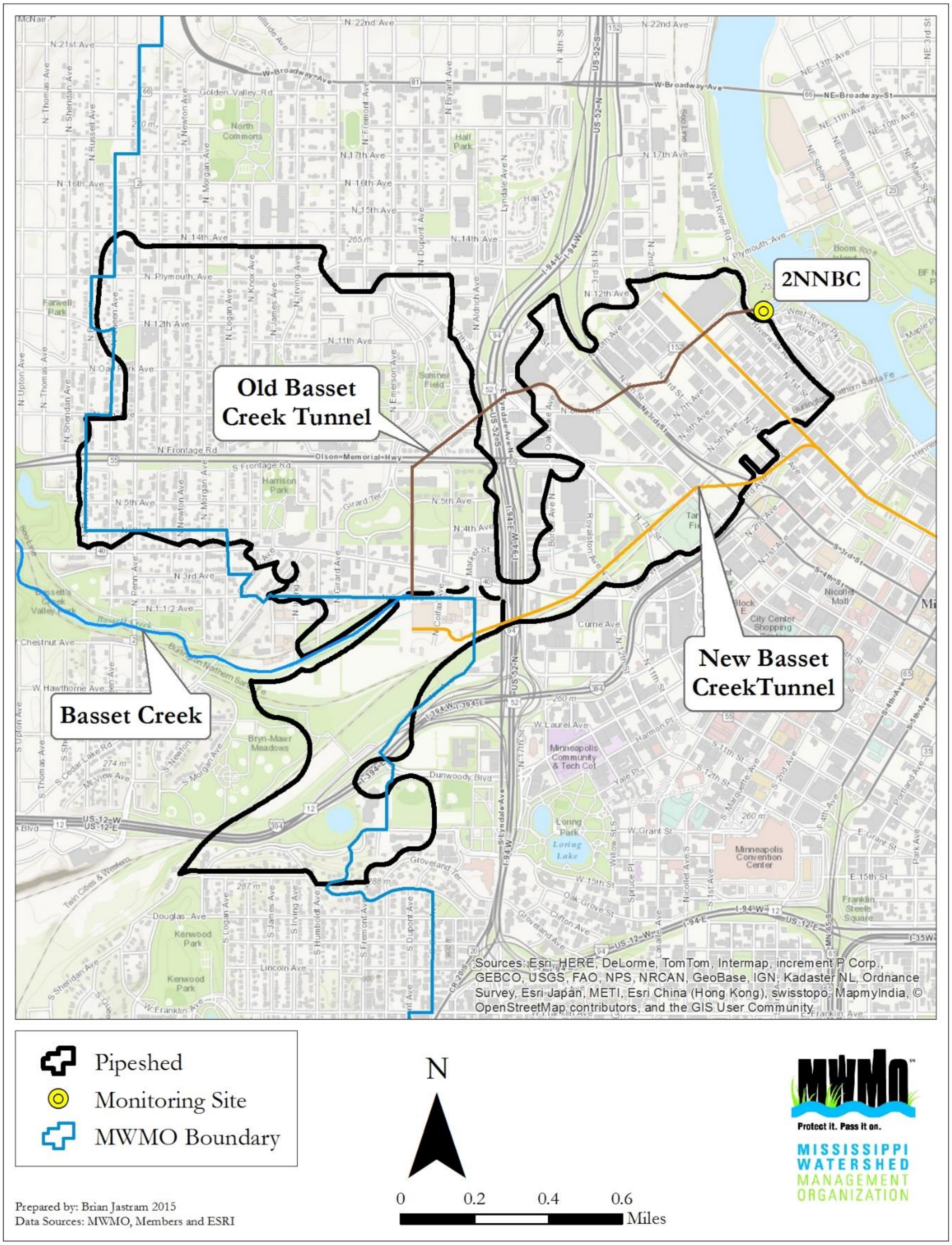

Figure 15. 2NNBC pipeshed boundary and monitoring site location

10SA (St. Anthony Village)

The 10SA monitoring site was established in 2007. 10SA differs from the other MWMO stormwater monitoring sites as it is located at the jurisdictional boundary between St. Anthony Village and Minneapolis, rather than at an outfall to the Mississippi River. The MWMO chose to monitor this location to investigate the quantity and quality of stormwater from the southern portion of St. Anthony Village (602 acres) as it enters Minneapolis. The concrete stormwater pipe is four and a half feet in diameter and is accessed at a manhole within an open space in a residential neighborhood (Figure 16). The tunnel eventually drains into the Mississippi River several miles away on the east bank at RM 853.2. The monitored pipeshed is shown in Figure 17. Land uses are mainly residential, commercial, and industrial. There is generally continuous baseflow in this stormwater drainage system although the amount is negligible in winter. In 2016, the original equipment cabinet was replaced with a new one in conjunction with the installation of monitoring cabinets just upstream of the 10SA site at the new St. Anthony Regional Stormwater Treatment and Research System (see BMP monitoring section).

Figure 16. Monitoring cabinet and access manhole at the 10SA stormwater site.

Stormwater discharge data for the 10SA site are shown in Figure 18. Due to sensor limitations, discharge cannot be calculated during periods of very low baseflow. These periods are displayed as gaps in the discharge data. During much of 2016, stormwater discharge at the 10SA site was affected by construction and testing activities surrounding the installation of the St. Anthony Regional Stormwater Treatment and Research System (see BMP monitoring section). Monitoring equipment at the 10SA site was removed in early June and reinstalled in early August of 2016, due to these construction activities. Diversion and retention of stormwater related to BMP construction affected baseflow conditions throughout the rest of the year.

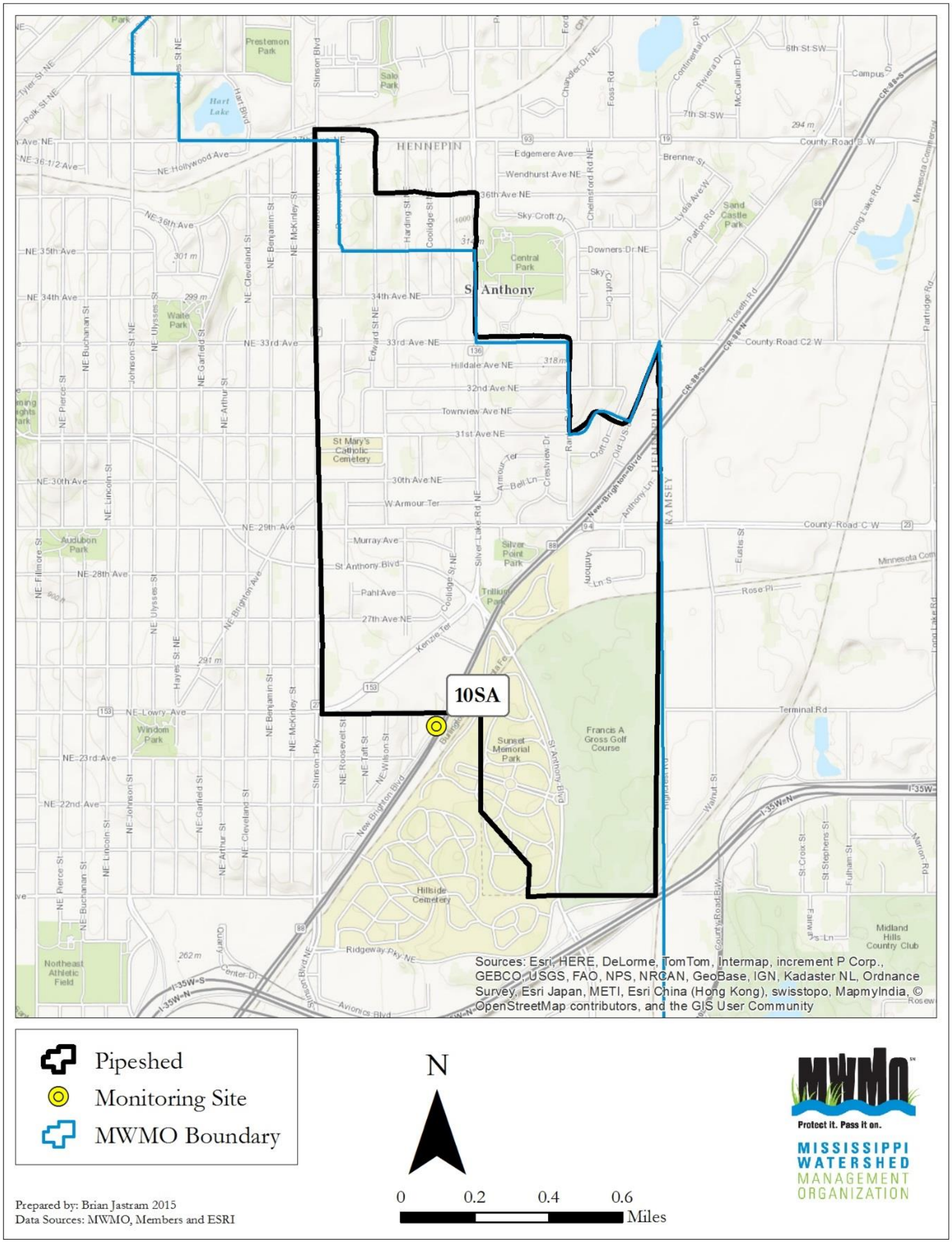

Figure 17. 10SA pipeshed boundary and monitoring site location.

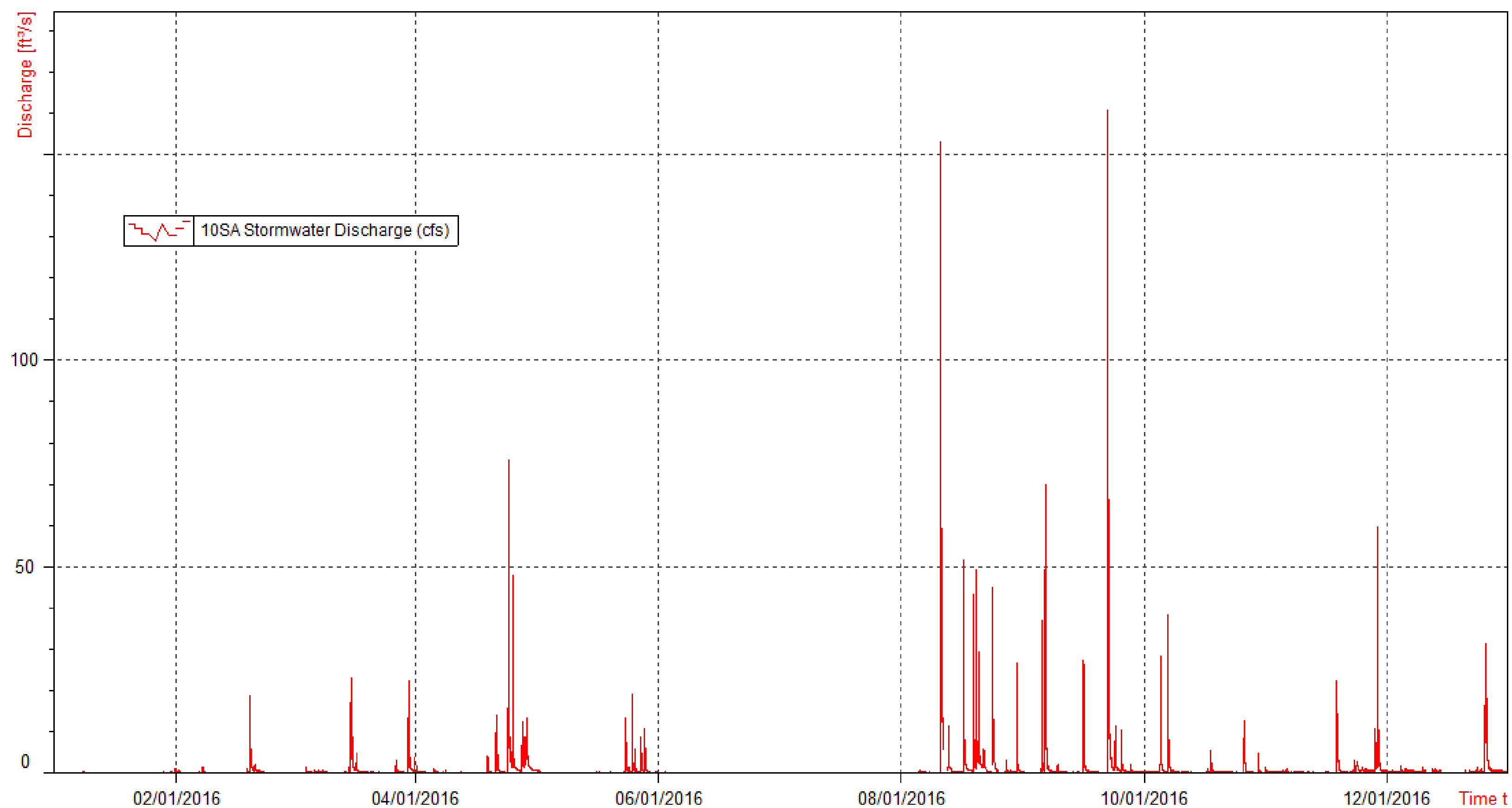

Figure 18. Stormwater discharge data for the 10SA monitoring site in 2016. Gaps in the data are due to BMP construction activities.

4PP (I-35W Bridge)

Established in 2008, this stormwater outfall monitoring site is located below Lower Saint Anthony Falls Lock and Dam on the west bank of the Mississippi River at RM 853.2. The semi-elliptical tunnel is 14 feet high and 14 feet wide (Figure 19). The system drains stormwater from approximately 2,780 acres of the Phillips and Powderhorn Neighborhoods and the southern portion of the Central neighborhood in Minneapolis, as well as water from the I-35W interstate highway (Figure 20). Land use is primarily residential, commercial, and heavy industry. There is continuous baseflow in this stormwater drainage system.

Figure 19. 4PP outfall to the Mississippi River.

The City of Minneapolis and Minnesota Department of Transportation (MnDOT) have been conducting maintenance activities in the 4PP tunnel during winter and spring months over the past couple of years. In 2016, the work in the tunnel went late into the spring and high river levels in the outfall prevented reinstallation of the monitoring equipment until late summer. The equipment was again removed for construction work in late fall of 2016. The limited discharge data for the 4PP site are available upon request. Though composite sampling was not possible during much of the year, due to equipment removal, baseflow grab samples were taken when possible.

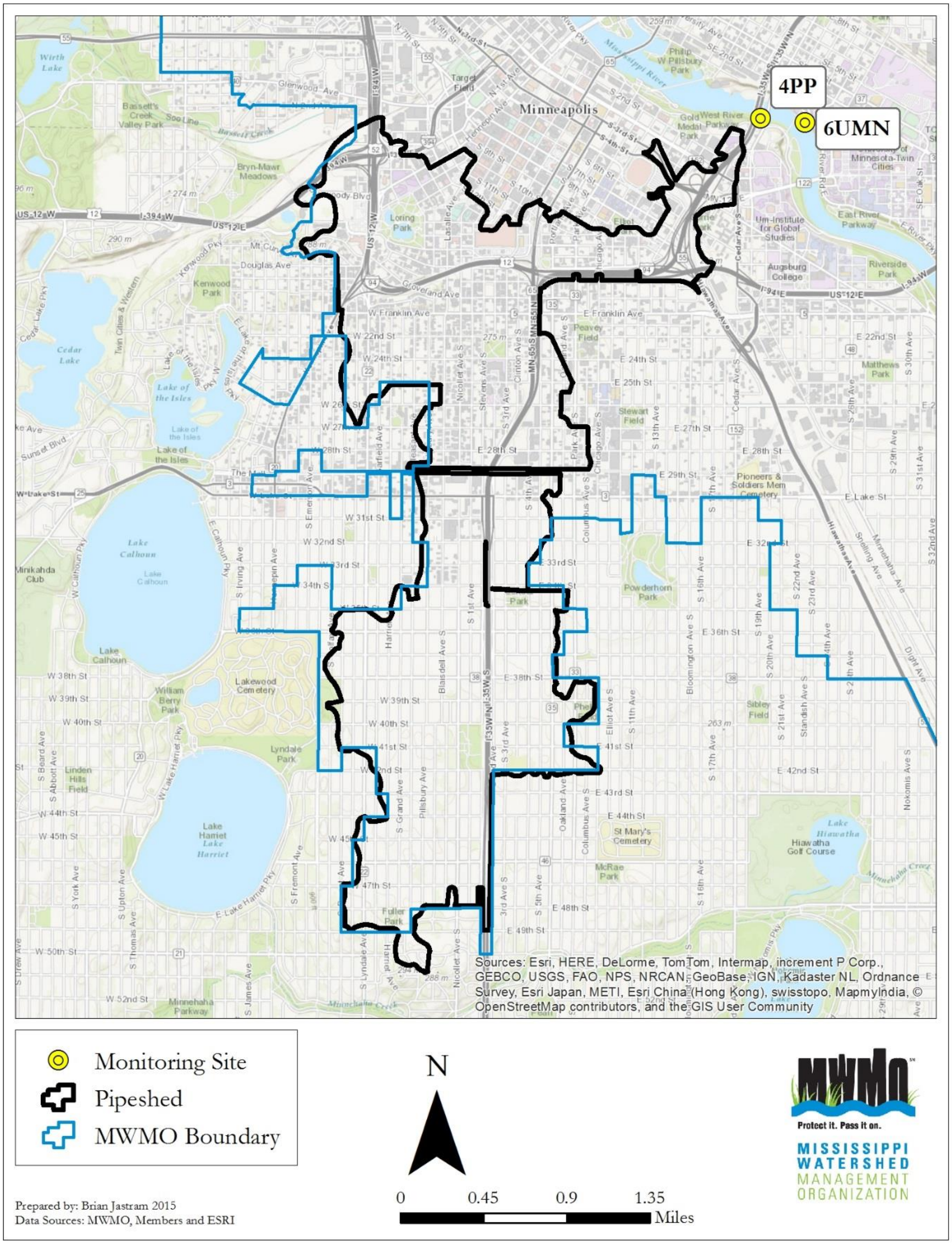

Figure 20. 4PP pipeshed boundary and monitoring site location.

6UMN (University of Minnesota Main Energy Plant)

The 6UMN outfall site is located on the east bank of the Mississippi River at RM 853.0, downstream from Saint Anthony Falls, behind the University of Minnesota Main Energy Plant. The monitoring site was established in 2006. This semi-elliptical tunnel is eight feet high and eight feet wide with a rounded top and slightly U-shaped base (Figure 21). The outfall drains water from approximately 765 acres of the City of Minneapolis and the University of Minnesota, Minneapolis Campus (Figure 22). Land use is primarily residential and commercial. There is continuous baseflow in this stormwater drainage system.

Figure 21. 6UMN outfall to the Mississippi River.

Stormwater discharge data from 2016 for the 6UMN site are shown in Figure 23. Similar to other sites, level and discharge data at 6UMN were affected by high river levels. There were periods of tailwater in the tunnel during March, May and most of July. These sections are represented by gaps in the stormwater discharge data (Figure 23).

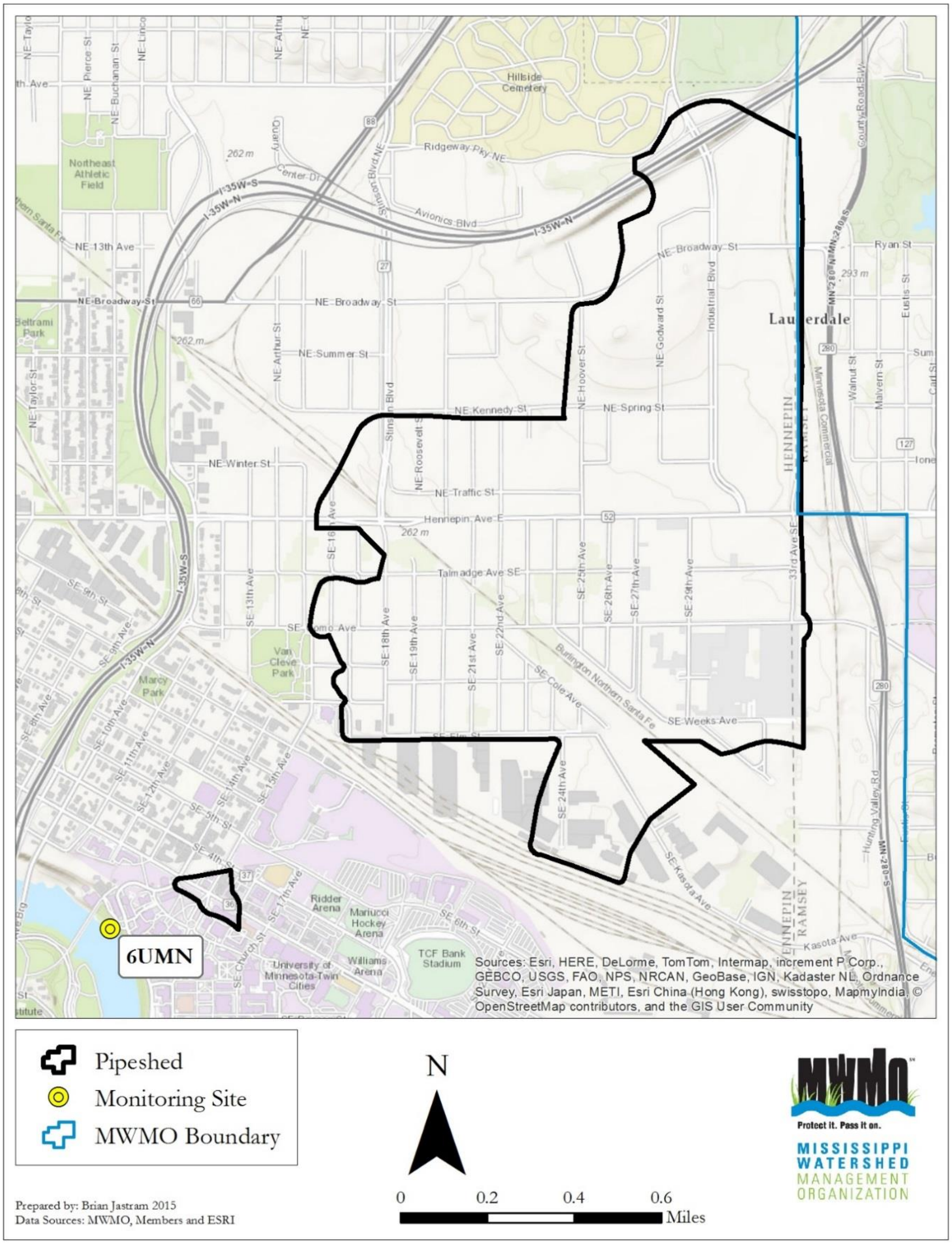

Figure 22. 6UMN pipeshed boundary and monitoring site location. The two seemingly separate pipeshed boundaries are connected underground via stormwater pipes.

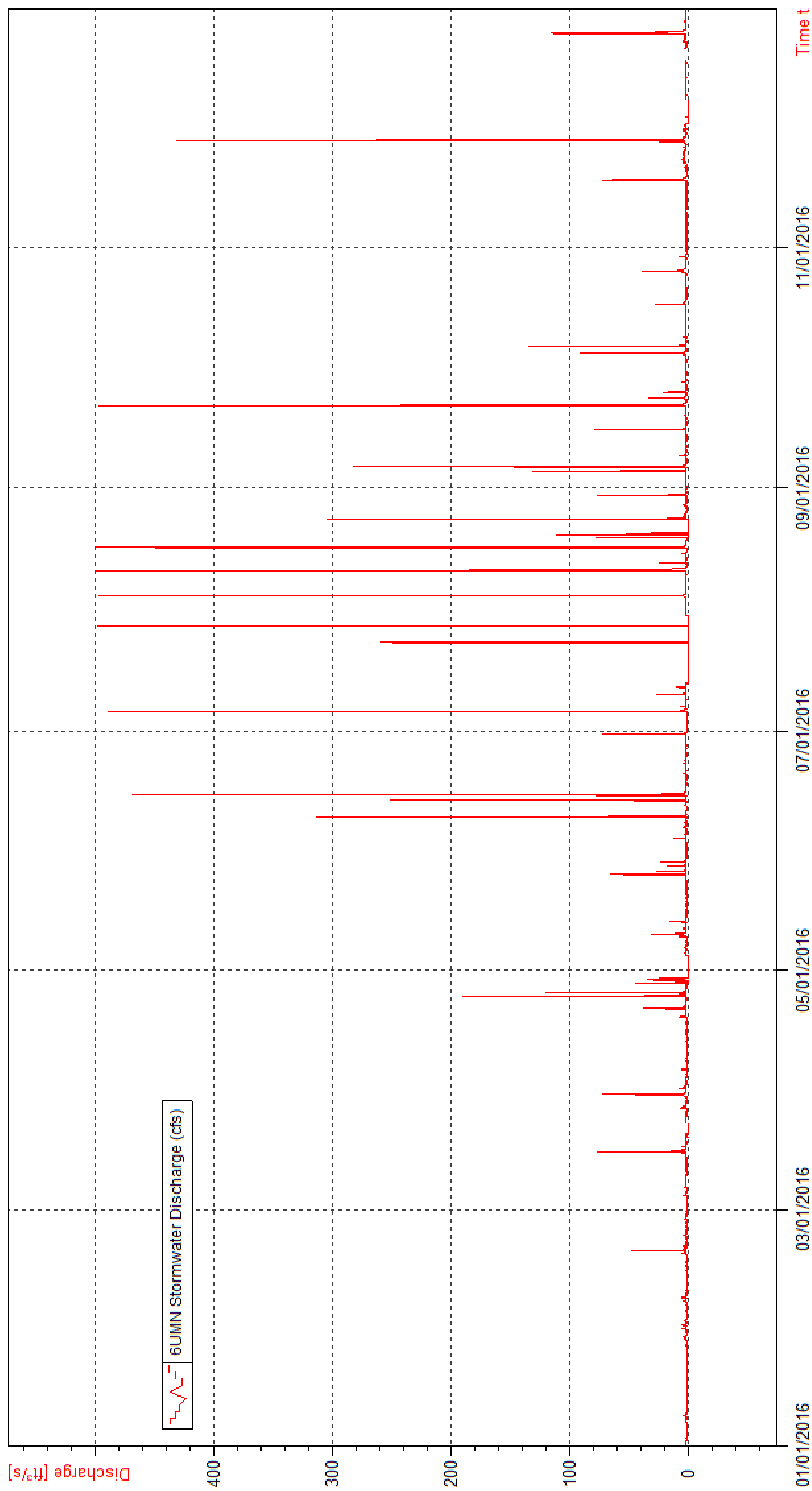

Figure 23. Stormwater discharge data for the 6UMN monitoring site in 2016.

7LSTU (Bridal Veil Tunnel)

7LSTU is the farthest downstream stormwater outfall monitored by the MWMO. The monitoring site was established in 2008 and is located on the east bank of the Mississippi River at RM 851.6, between the I-94 Bridge and Franklin Avenue Bridge. The cathedral-shaped tunnel is 10.37 feet high and 6.67 feet wide at its base (Figure 24). At the mouth of the outfall, five square, concrete pillars baffle (slow) water flow, and an iron stilling basin captures floatable debris. The outfall drains water from approximately 600 acres of the City of Minneapolis and the University of Minnesota's Minneapolis Campus (Figure 25). Land uses within the pipeshed are a mix of residential, commercial and industrial.

Figure 24. 7LSTU outfall to the Mississippi River.

The 7LSTU monitoring site is equipped with an automated sampler and area/velocity sensor; however, river water is almost constantly present in the tunnel, affecting discharge values. Therefore, discharge data are not displayed here but were used to determine appropriate times to take grab samples during events. In the fall of 2016, an area velocity sensor was installed farther up the tunnel in order to obtain more consistent discharge data.

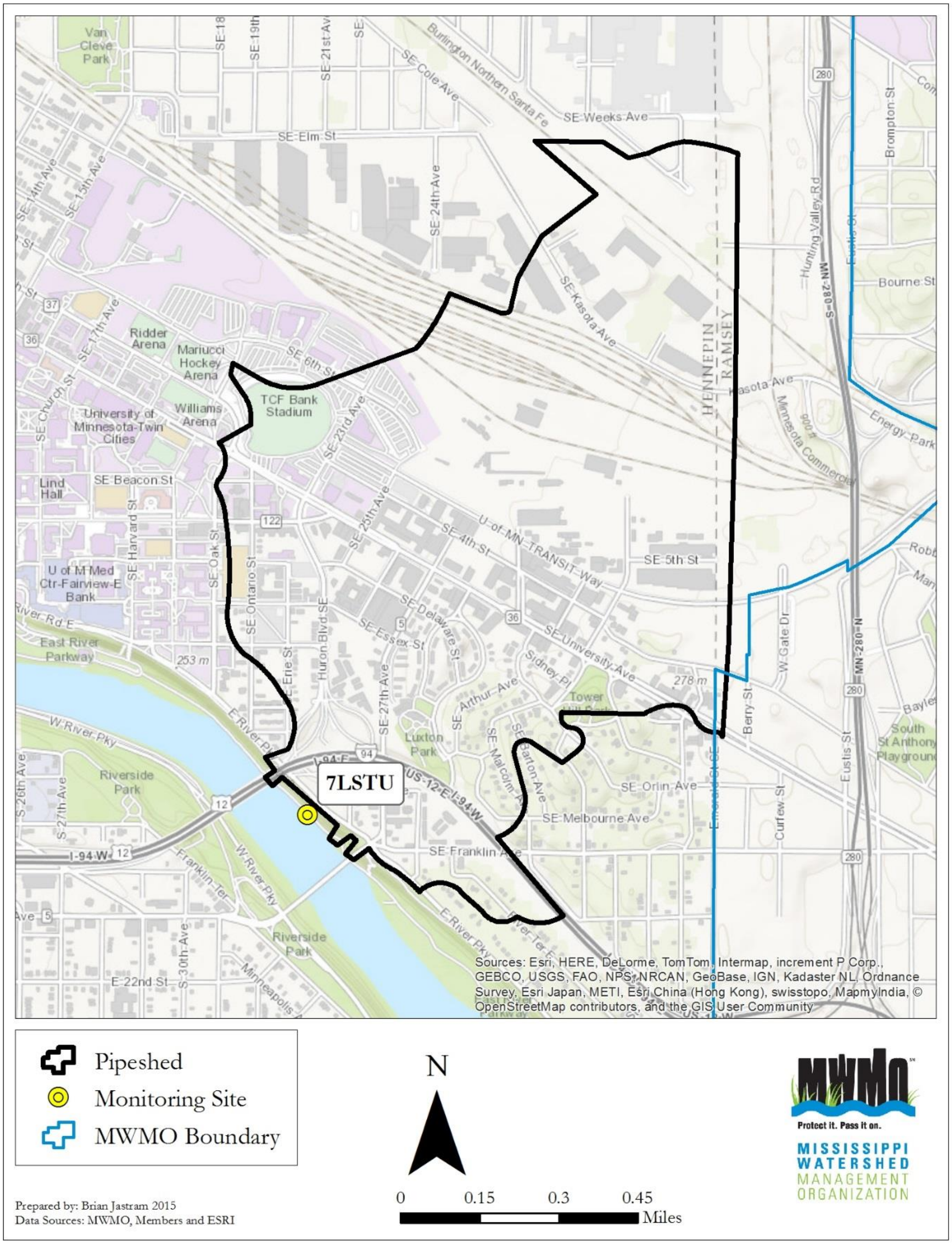

Figure 25. 7LSTU pipeshed boundary and monitoring site location.

Lake Monitoring

There are three lakes within the MWMO watershed boundary: Loring Pond in the City of Minneapolis, and Sullivan and Highland Lakes in the City of Columbia Heights (Figure 26). The lakes are monitored by the Minneapolis Park and Recreation Board (MPRB) and the Anoka Conservation District (ACD) respectively, for lake level and water quality.

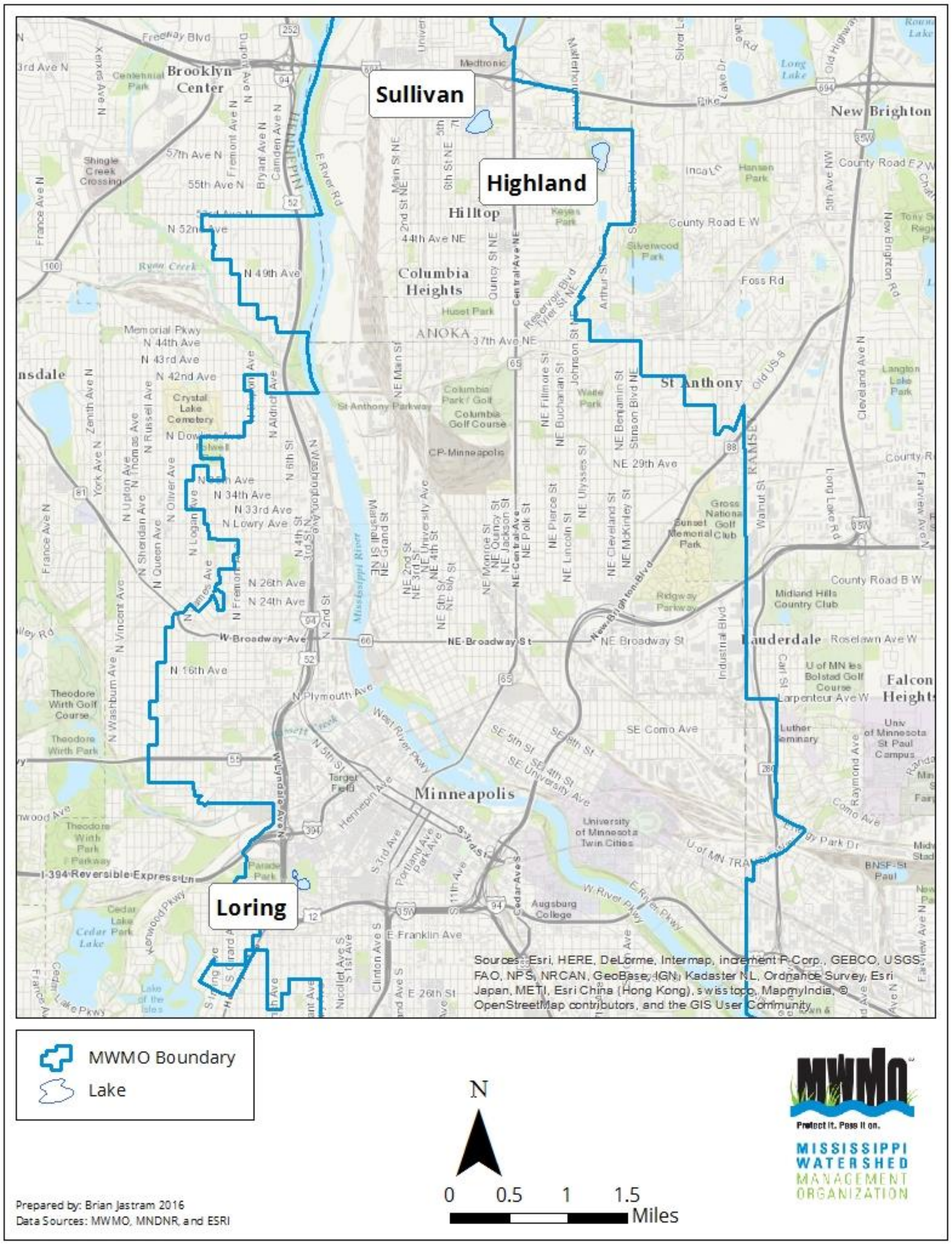

Figure 26. Lakes located within the MWMO watershed.

Loring Pond Monitoring

Loring Pond, located in Loring Park in Minneapolis is part of the MWMO 4PP pipeshed. The MWMO previously monitored Loring Pond for water quality and *E. coli* starting in 2006 until the Minneapolis Park and Recreation Board (MPRB) took over monitoring of the pond. MPRB monitors the lake level, water quality, ice cover, phytoplankton and zooplankton, and fish stocking of Loring Pond. Monitoring data for Loring Pond can be found in the Water Resources Reports on the MPRB website at www.minneapolisparks.org/park_care__improvements/water_resources/.

Sullivan Lake and Highland Lake Monitoring

Methodology

Water Elevation Monitoring

A volunteer, in coordination with ACD, conducted water level monitoring at the lakes from June through November. Water elevation data for 2016, as well as all additional historical data, are available on the Minnesota DNR website using the “LakeFinder” feature at **www.dnr.state.mn.us/lakefind/index.html**.

Sample Collection, Handling and Preservation

Anoka Conservation District (ACD) sampled Sullivan Lake and Highland Lake monthly between May and August. Sampling was conducted by canoe at the deepest part of the lake. A portable depth finder or global positioning system (GPS) was used to determine the sampling location. Conductivity, pH, turbidity, salinity, dissolved oxygen (D.O.) and temperature were measured using a Hydrolab Quanta multi-probe at a depth of one meter below the water surface. Water quality samples were also collected at one meter below the water surface. Water transparency or clarity was measured using a Secchi disk. ACD staff lowered the disk over the shaded side of the boat until it disappeared and then pulled up to the point where it reappeared again. The midpoint between these two depths was recorded as the Secchi disk measurement. Minnesota Valley Testing Laboratories (MVTL) analyzed the water quality samples for chlorophyll-a, chloride and total phosphorus. Information regarding laboratory analysis methods can be found in Table A.1 in Appendix A.

Data Analysis

To evaluate lake conditions, ACD compared sampling results to historical readings and other lakes in the region. Comparisons to other lakes are based on the Metropolitan Council’s lake quality grading system (Osgood, 1989) and the Carlson’s Trophic State Index for the North Central Hardwood Forest ecoregion (NCHF) (Carlson, 1977). Historical data can be obtained from the MPCA’s water quality database (EQuIS).

The Metropolitan Council developed the lake water quality report card in 1989 (Table 5). A lake receives a letter grade that is based on average summertime (May - September) chlorophyll-a, total phosphorus and Secchi depth. In the same way that a teacher would grade students on a "curve," the lake grading system compares each lake only to other lakes in the region. The goal of this grading system is to provide a single, easily understandable description of lake water quality.

Table 5. Metropolitan Council lake quality grading system

Grade	Percentile	TP (μg/L)	Chlorophyll-a (μg/L)	Secchi Disk (m)
A	<10	<23	<10	>3.0
B	10 – 30	23 - 32	10 – 20	2.2 – 3.0
C	30 – 70	32 - 68	20 – 48	1.2 – 2.2
D	70 – 90	68 – 152	48 – 77	0.7 – 1.2
F	>90	>152	>77	<0.7

Carlson's Trophic State Index (TSI) is a number used to describe a lake's stage of eutrophication and is based upon a relationship between Secchi depth and surface water concentrations of algal chlorophyll and total phosphorus. The index values range from 0 (clear, nutrient-poor, oligotrophic lakes) to 100 (green, nutrient overloaded hypereutrophic lakes). Unlike the lake letter grading system, the Carlson's TSI does not compare lakes only within the same ecoregion; it is a scale used worldwide. For Sullivan Lake and Highland Lake, TSI values were calculated for each monthly lake sampling and then averaged at the conclusion of the monitoring season (May-September).

Sullivan Lake Results

Site Description

Sullivan Lake, also known as Sandy Lake, is located in south central Anoka County. The lake has a surface area of approximately 16.8 acres and a maximum depth of 9 feet (2.7 m). A walking trail circumscribes the lake with a mix of residential, commercial, and retail properties adjacent to the trail. The walking trail around the lake is used extensively, but due to lack of open water access, the lake is seldom used for swimming, fishing, or boating. Sullivan Lake's watershed is highly urbanized, and the lake essentially serves as a flow-through stormwater pond. The lake is connected directly to the curb and gutter stormwater system which heavily influence its water quality (Figure 27). Water exiting Sullivan Lake is discharged to the Mississippi River via stormwater conveyances. A staff gauge is located on the west side of the lake near the outflow. The gauge is surveyed each year by ACD and the Minnesota DNR using datum NGVD 29 in feet. The Minnesota DNR lake ID for Sullivan (Sandy) Lake is 02008000.

Sullivan Lake was monitored for water quality parameters from 1993 to 2005 by the Metropolitan Council. In 2013, the MWMO contracted the Anoka Conservation District (ACD) to conduct water elevation and water quality monitoring in order to gain an understanding of more current lake conditions. This water quality monitoring was conducted again in 2016 as part of a three-year cycle. During other years ACD conducts only water elevation monitoring.

Figure 27. Image of Sullivan Lake (left) from 2013. Image of Sullivan Lake's outlet (right).

Water Elevation Results

Sullivan Lake water elevation was measured 9 times during 2016. Sullivan Lake's water elevations fluctuate widely in response to rainfall, routinely bouncing by half a foot. The lake receives a large amount of stormwater relative to its size and its outlet releases in all but the lowest water conditions. The Ordinary High Water Level (OHWL), the elevation below which a

DNR permit is needed to perform work, is 880.60 feet. Table 6 shows the average, minimum, and maximum water elevations of the lake for 2012 through 2016, as well as the 5-year average elevation.

Table 6. Sullivan Lake water elevation statistics from 2012 through 2016 and the 5-year average.

Year	Average	Minimum	Maximum
2012	879.86	878.91	881.15
2013	880.00	879.23	880.93
2014	880.05	879.60	880.76
2015	880.14	879.69	880.85
2016	880.76	879.88	881.56
5-year	880.06	878.91	881.56

Water Quality Monitoring Results Summary

The ACD monitored water quality in Sullivan Lake monthly from May to August 2016. ACD monitored the following parameters: total phosphorus, chlorophyll-a, chloride, Secchi depth, D.O., turbidity, temperature, conductivity, pH, and salinity. Figure 28 illustrates 2016 total phosphorus, chlorophyll-a, and transparency data.

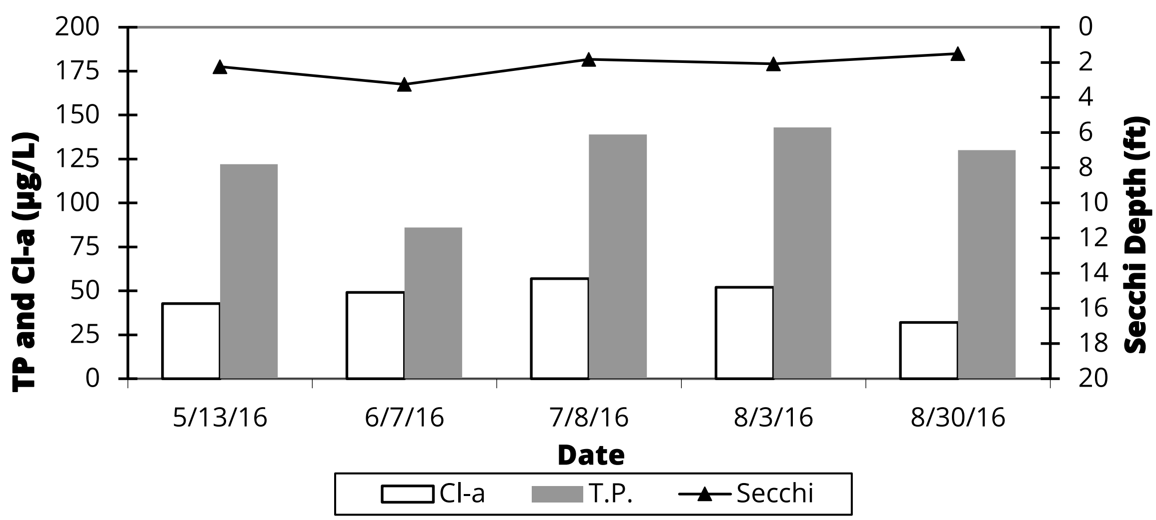

Figure 28. Sullivan Lake chlorophyll-a (µ/L), total phosphorus (µg/L), and Secchi depth (ft) during 2016.

Sullivan Lake maintained a track record of very poor water quality in 2016 compared to other lakes in the region (NCHF Ecoregion), receiving an overall D letter grade for the fifth consecutive year sampled over the last 13 years. Phosphorus levels are routinely two or three times the threshold for an impaired designation by the MPCA. The lake is unsuitable for swimming during the entire growing season. Both phosphorus and chlorophyll-a levels were lower in 2016 than they were when the lake was last sampled in 2013, but both were still very high. Total phosphorus exceeded the shallow lake water quality standard of 60 µg/L in every sample in 2016 with four of five samples more than doubling that standard. Concentrations of chlorophyll-a were also more than double the state standard of 20 µg/L in four out of five samples in 2016. Past depth profiles indicate that Sullivan Lake's dissolved oxygen, at depths greater than four feet, is too low for most fish to survive (<4 mg/L), and near the bottom is too low for most aquatic life to survive (<1 mg/L). This is likely due to oxygen consumption by decomposition of expired algae.

Fourteen years of water quality data have been collected by the Metropolitan Council (1993-2003) and the Anoka Conservation District (2004, 2005, 2013, & 2016) at Sullivan Lake. Historical summertime means of total phosphorus, chlorophyll-a, and transparency from 1993 to 2016 are displayed in Figure 29. Historical summertime means, Carlson Trophic State Index values, and lake grade data are included in Table 7. Figure 30 illustrates the Carlson Trophic State Index values for Highland Lake in 2016.

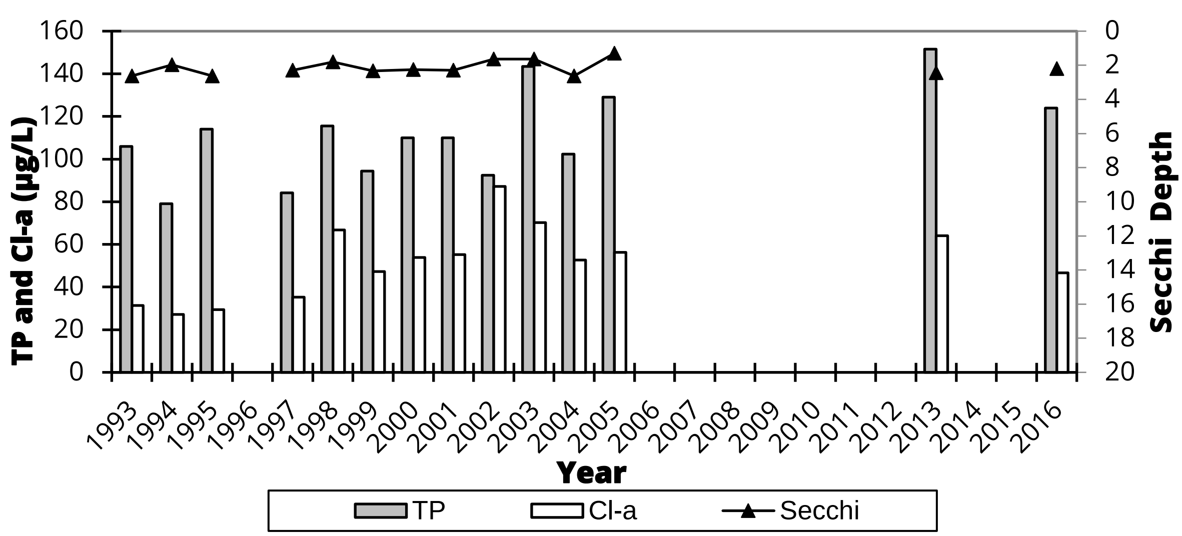

Figure 29. Sullivan Lake historic summertime means of total phosphorus (µg/L), chlorophyll-a (µg/L), and Secchi depth (ft) from 1993 to 2016. The lake was not monitored between 2006 and 2013.

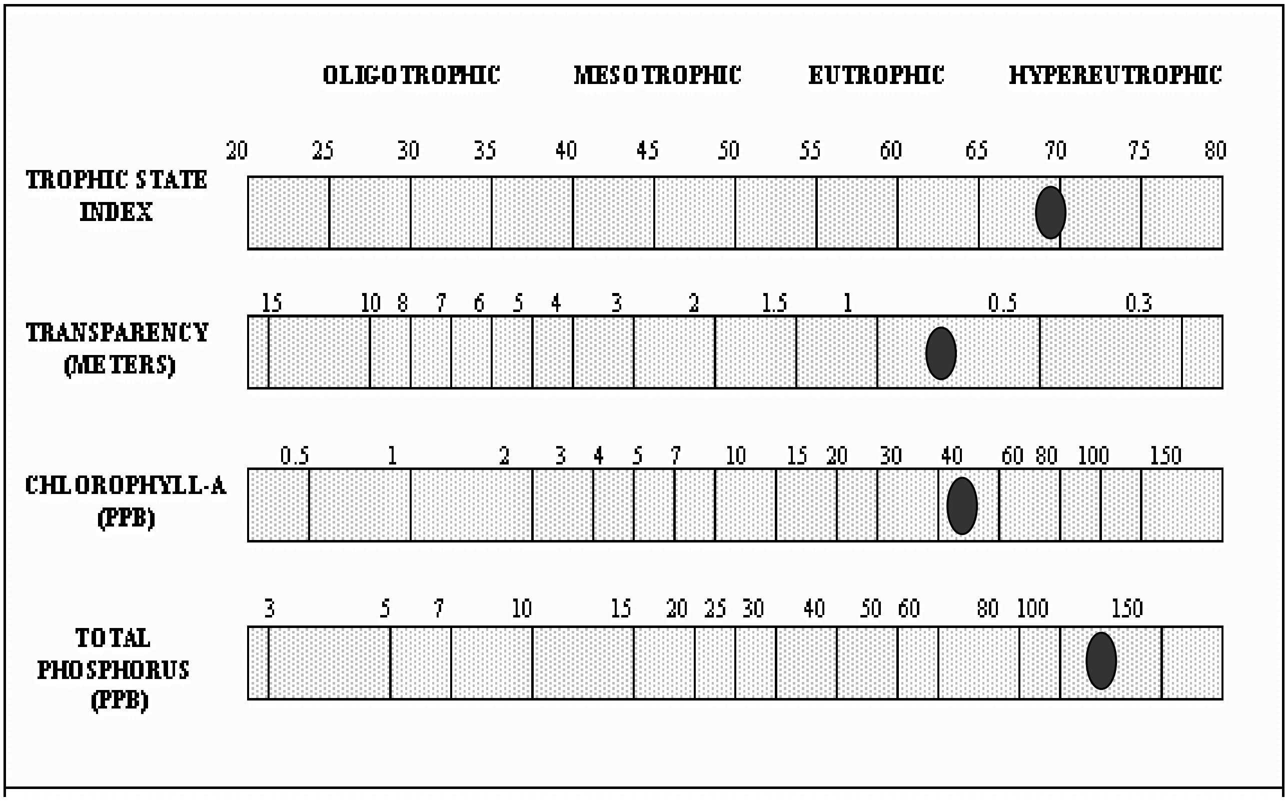

Figure 30. Carlson's Trophic State Index for Sullivan Lake in 2016. The lake scored hypereutrophic or eutrophic for all four measures. Note that PPB and µg/L are equivalent units.

Table 7. Sullivan Lake historic water quality conditions from 1993 through 2005 and 2013 and 2016. MC represents water quality analysis performed by the Metropolitan Council. ACD took over water quality analysis in 2004.

Agency	**MC**	**MC**	**MC**	**MC**	**MC**	**MC**	**MC**	**MC**	**MC**	**MC**	**ACD**	**ACD**	**ACD**	**ACD**
Year	**93**	**94**	**95**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**13**	**16**
							Sullivan Lake Historic Summertime Mean Values							
TP (ug/L)	106.0	79.1	114.0	84.2	115.5	94.4	110.0	110.0	92.4	143.4	102.3	129	151.6	124
Cl-a (ug/L)	31.4	27.2	29.4	35.3	66.8	47.3	53.8	55.2	87.2	70.3	52.6	56.3	64.0	46.6
Secchi (m)	0.80	0.60	0.80	0.70	0.55	0.71	0.69	0.70	0.50	0.50	0.80	0.40	0.7	0.7
Secchi (ft)	2.6	2.0	2.6	2.3	1.8	2.3	2.3	2.3	1.6	1.6	2.6	1.3	2.4	2.2
							Carlson's Trophic State Index							
TSI (0-100)	66	66	67	66	71	68	69	69	71	73	68	73	71	69
							Sullivan Lake Water Quality Report Card							
TP	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Cl-a	C	C	C	C	D	C	D	D	F	D	D	D	D	C
Secchi	D	D	D	D	D	D	D	D	F	D	D	D	D	D
Overall	D	D	D	D	D	D	D	D	F	D	D	D	D	D

Highland Lake Results

Site Description

Highland Lake is a very shallow lake surrounded by a wooded park and residential neighborhood in south central Anoka County. The lake has a surface area of approximately 14 acres with two small islands in the northeastern corner. Similar to Sullivan Lake, Highland Lake's watershed is highly developed, and the lake essentially serves as a flow-through stormwater pond. It is connected directly to the curb and gutter stormwater system (Figure 31). Water exiting this lake is discharged to the Mississippi River via stormwater conveyances. Highland Lake's water level gauge is located on the north side of the lake, near the intersection of Argonne Drive and Innsbruck Parkway.

Highland Lake was monitored by the ACD for the first time in 2016. Prior to 2016, the lake had been monitored through the MPCA citizen volunteer program annually from 2000-2007. The DNR lake ID for Highland Lake is 02007900.

Water Elevation Results

Figure 31. Image of Highland Lake from 2016 (left), the lake's outlet (center) and one of its inlets (right).

Highland Lake water elevation was measured nine times during 2016 between May and November. Highland Lake water elevation fluctuated very little, with a range of 0.51 feet total throughout the season. The OHWL is 996.4. Table 8 shows the average, minimum, and maximum water elevations of the lake for 2012 through 2016.

Table 8. Highland Lake water elevation statistics from 2012 through 2016 and the 5-year average

Year	Average	Minimum	Maximum
2012	996.03	995.59	996.57
2013	996.14	995.79	996.37
2014	996.22	996.05	996.44
2015	996.36	996.05	996.52
2016	996.37	996.17	996.75
5 year average	996.33	995.93	996.53

Water Quality Monitoring Results Summary

Highland Lake has historically exhibited poor water clarity and very high levels of nutrients and chlorophyll-a. The 2016 total phosphorus, chlorophyll-a and transparency data are displayed in Figure 32. In 2016, Highland Lake once again had very poor water quality compared to other lakes in this region (NCHF Ecoregion), receiving an overall F grade according to the Metropolitan Council's grading system (the only grade the lake has achieved since 2002). Total phosphorus levels were two to four times greater than the state water quality standard for shallow lakes in the NCHF Ecoregion (60 µg/L) on every sampling event, averaging over triple that standard at 210 µg/L in 2016. Chlorophyll-a exceeded the state standard of 20 µg/L on three of five sampling events with a maximum of 96.1 µg/L and an average of 49.6 µg/L in 2016.The MPCA has listed Highland Lake as impaired for nutrients and biological indicators.

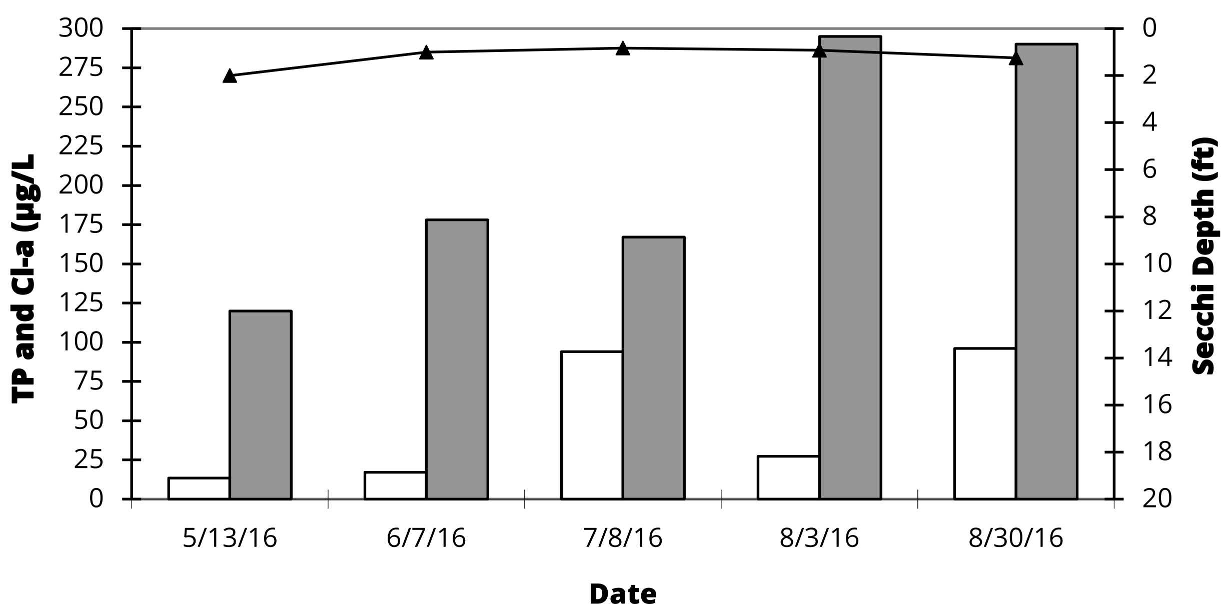

Figure 32. Highland Lake total phosphorus (µg/L), chlorophyll-a (µg/L), and Secchi depth (ft) during 2016.

Nine years of water quality data have been collected by the MPCA (2000-2007) and the Anoka Conservation District (2016). Historical summertime means of total phosphorus, chlorophyll-a, and transparency from 2000 to 2007, and 2016 are shown in Figure 33 and Table 9. 2016 Trophic State Index average values indicate that Highland Lake is highly eutrophic (Figure 34). Historical Trophic State Index values, and lake grade data are shown in Table 9.

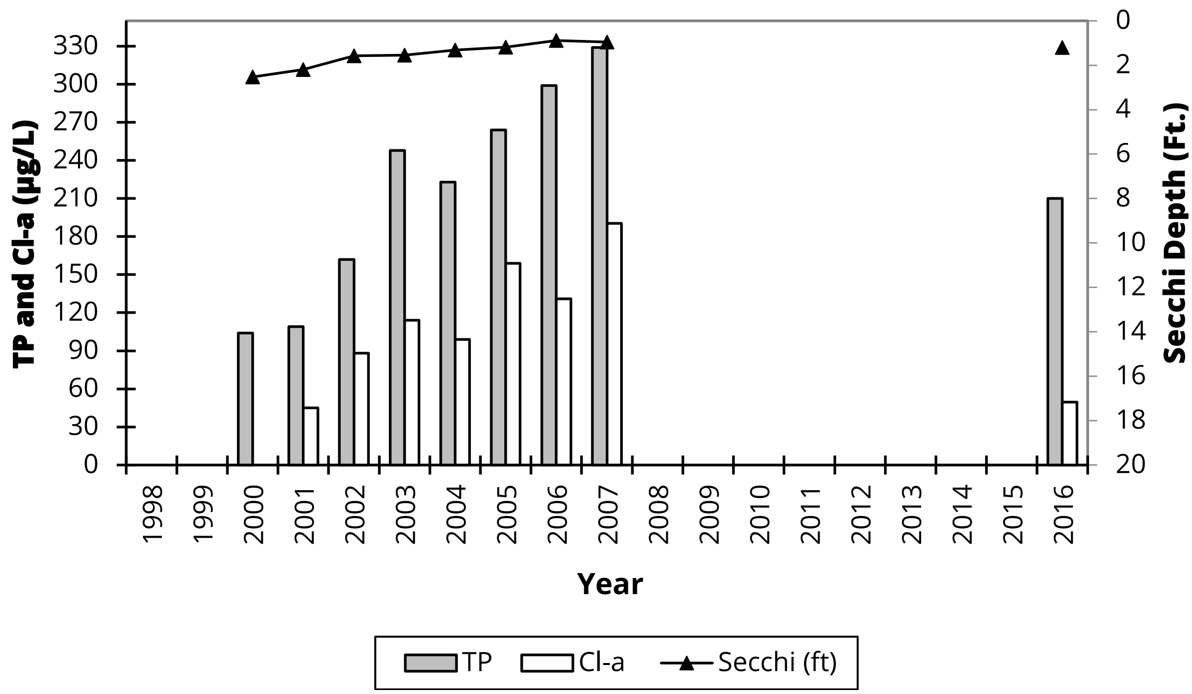

Figure 34. Highland Lake historic summertime means of total phosphorus (µg/L), chlorophyll-a (µg/L), and Secchi depth (ft).

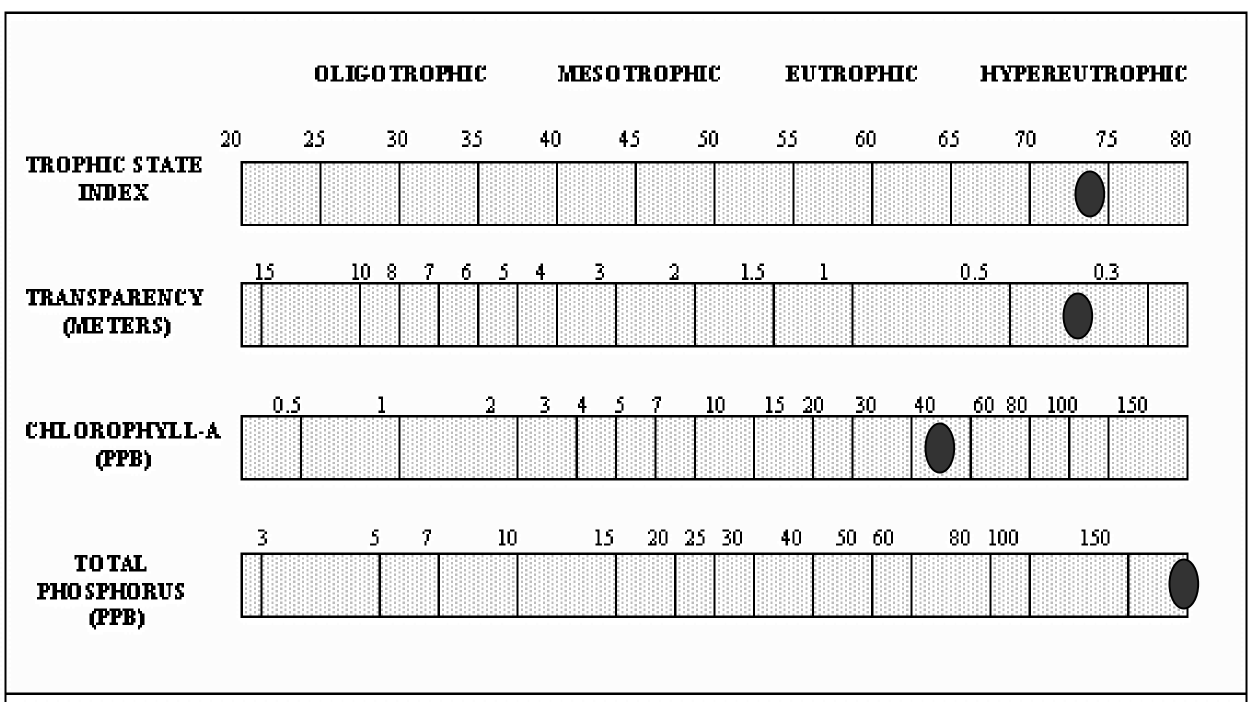

Figure 33. Carlson's Trophic State Index for Highland Lake in 2016. Highland Lake scored hypereutrophic or eutrophic in all four categories. Note that PPB and µg/L are equivalent units.

Table 9. Highland Lake historic water quality conditions from 2000-2007 and 2016

Agency	MPCA	MPCA	MPCA	MPCA	MPCA	MPCA	MPCA	MPCA	ACD
Year	2000	2001	2002	2003	2004	2005	2006	2007	2016
Highland Lake Historic Summertime Mean Values									
TP (ug/L)	104	109	162	248	223	264	299	329	210
Cl-a (ug/L)		45.0	88.0	114.0	99.0	159.0	131.0	190.5	49.6
Secchi (m)	0.77	0.67	0.48	0.47	0.40	0.36	0.27	0.29	0.4
Secchi (ft)	2.5	2.2	1.6	1.5	1.3	1.2	0.9	1.0	1.2
Carlson's Tropic State Index									
TSI (0-100)	67	69	74	77	77	80	81	83	74
Highland Lake Water Quality Report Card									
TP	D	D	F	F	F	F	F	F	F
Cl-a	NA	C	F	F	F	F	F	F	D
Secchi	D	F	F	F	F	F	F	F	F
Overall	D	D	F	F	F	F	F	F	F

Wetland Monitoring (Kasota Ponds)

The MWMO routinely monitors three locations in the Kasota Ponds wetlands (KP) for water quality conditions. (See Figure 35 for wetland sampling locations.) In 2016, the MWMO also conducted biological monitoring in the three wetlands. Biological data were last collected at the wetlands in 2011 and the MWMO currently expects to continue to conduct biological monitoring on a five-year schedule.

Water Quality Monitoring

Methodology

Sample Collection, Handling, and Preservation

Grab samples were collected once a month from three locations in the Kasota Ponds wetlands throughout the year, as conditions allowed. Collection occurred away from shore, in about three feet of water and in approximately the same locations each time. Samples were collected in laboratory-cleansed (non-sterile) plastic bottles. To collect samples, the monitoring specialist plunged an opened, inverted bottle one foot below the water surface, turned it upward to fill, and brought it out of the water. Dissolved oxygen, conductivity, salinity, water temperature and pH data for each site were collected by placing a YSI ProPlus sonde (YSI Inc., Yellow Springs, OH) approximately one foot below the water surface. Transparency was measured using a 100cm Secchi tube. When ice was present, staff conducted sampling activities by drilling a hole in the ice and using a capped, three-inch diameter PVC tube to collect the samples.

Sampling Quality Control

MWMO staff followed the quality control protocol outlined in the MWMO's Ambient Surface Water Monitoring Quality Assurance Project Plan (MPCA, 2010). Blank samples of DI water were regularly submitted to the laboratory to verify that sample containers were clean and samples were not contaminated during travel. In addition, 10 percent of all samples were collected in duplicate to verify that sampling and laboratory procedures did not jeopardize the data.

Laboratory Analyses

Samples were analyzed at the MCES Laboratory. The laboratory followed strict protocols for quality assurance and quality control. Information regarding laboratory protocol is available from MWMO staff. Refer to Table A.1 in Appendix A for a list of the laboratories used for analysis, the analysis methods and information regarding certification.

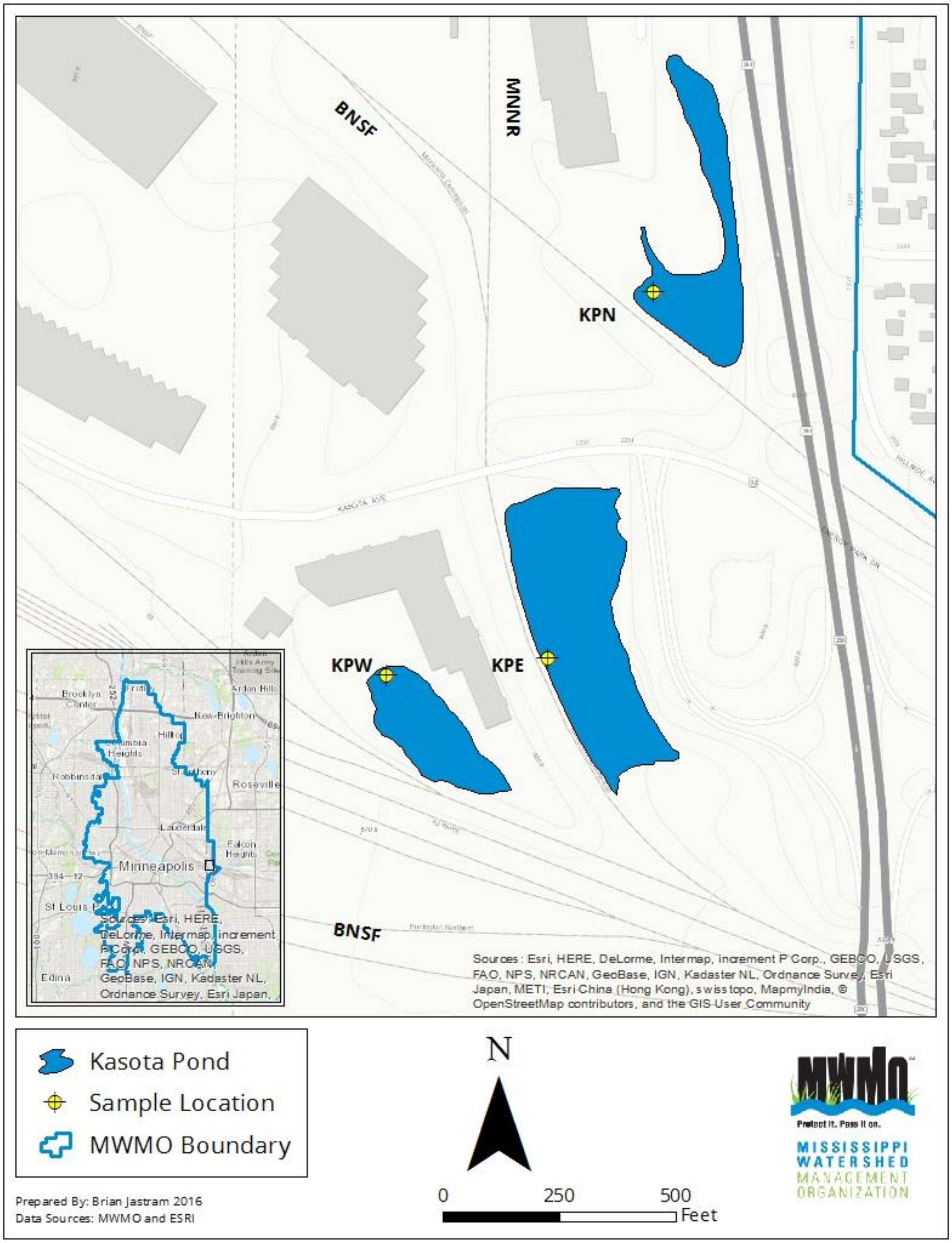

Figure 35. MWMO Kasota Ponds monitoring locations.

Site Descriptions

KPN (Kasota Pond North)

KPN is the northernmost pond. It is located west of Highway 280 and south of the intersection of North Hunting Valley Road and West Doswell Avenue. The area surrounding the pond is heavily vegetated with non-native species such as buckthorn and burdock. KPN is dense with cattails and other aquatic plants during the summer months (Figure 36). The bottom of the pond is composed of organic matter, silt and clay.

Figure 36. Kasota Pond North.

KPE (Kasota Pond East)

KPE, also known as Mallard Marsh, is the largest of the ponds. It is located southwest of the intersection of Highway 280 and Kasota Avenue. A grassy buffer area surrounds most of the pond, except for the west side of the pond, where railroad tracks are separated from the waterfront by

Figure 37. Kasota Pond East.

approximately six feet of riprap. Turtles, geese and ducks are frequently observed in KPE. This wetland is dense with cattails and aquatic plants during the summer months (Figure 37). The bottom of the pond is composed of organic matter, silt, and clay.

KPW (Kasota Pond West)

KPW, located just west of KPE, receives runoff from a parking lot and nearby rail yard. Dense algal blooms are observed in KPW during the summer months, while other types of aquatic vegetation are seldom present in this pond (Figure 38). The pond has a sandy bottom.

Figure 38. Kasota Pond West.

Water Quality Monitoring Results

MWMO monitors the Kasota Ponds to characterize water quality in its wetlands. Samples are collected for nutrients, sediment, inorganics, and metals analyses. The MPCA water quality criteria indicate that wetland water quality should maintain background conditions. Kasota Ponds water quality data are available upon request and have been submitted to the MPCA EQuIS database.

Kasota Ponds Biological Monitoring

In 2011, monitoring at the Kasota Ponds wetlands was expanded beyond water quality to include assessment of the biological health of the wetlands. Results from the 2011 biological surveys can be found in the 2011 MWMO Annual Monitoring Report (MWMO, 2011). With the goal of maintaining a five year schedule for biological assessment, the monitoring was repeated in 2016. During June and July, the Kasota Ponds wetlands were sampled for macroinvertebrate and aquatic plant assemblages. These data were used to assess the health of the Kasota Ponds wetlands relative to other wetlands in the state and to establish baseline records for the wetlands.

Wetland Macroinvertebrate Sampling

Sample Collection, Handling and Preservation Methods

Macroinvertebrate samples were collected in June 2016 by following the MPCA's Macroinvertebrate Community Sampling Protocol for Depressional Wetland Monitoring Sites (MPCA, 2014). At each of the three wetlands, two samples were collected from the water column and vegetation above the substrate using dipnets. Unlike the 2011 macroinvertebrate sampling, activity traps were not used in 2016. The MPCA reviewed activity trap use in wetland macroinvertebrate sampling and determined that it required significant staff time relative to its contribution to the IBI score calculation and also had the potential to cause fatalities of non-targeted species such as tadpoles and minnows (Bouchard, Chirhart, and Genet, 2011).

Sample Processing and Data Analysis

After sampling, macroinvertebrates were preserved in 95% ethyl alcohol. Macroinvertebrates were later identified to the genus or family level by staff at Fortin Consulting. An IBI score was calculated for each wetland using methods described in Indexes of Biological Integrity for Large Depressional Wetlands in Minnesota (Gernes and Helgen, 2002).

Due to the omission of activity traps which target specific groups of macroinvertebrates, the number of metrics used to calculate Macroinvertebrate IBI scores has decreased from nine metrics to the following five metrics: Leech Taxa, Odonata (Dragonfly/Damselfly) taxa, ETSD Taxa (genera of mayflies, caddisflies, fingernail claims, dragonflies), Snail Taxa and Total Taxa. Therefore, the range of possible IBI scores shifted from 9–45 in 2011 to 5–25 in 2016.

Aquatic Plant Surveys

Survey Methods

Aquatic plants were surveyed using the relevé sampling method, following the MPCA's Standard Operating Procedure for Aquatic Plant Community Sampling for Depressional Wetland Monitoring Sites (MPCA, 2002). Relevé surveying involves the selection of a 100 square meter plot that contains a representative portion of the entire wetland's vegetation, including emergent and submerged vegetation, when applicable. Surveyors then identify all of the species within the plot and estimate the percentage of the plot covered by each species. Aquatic plant surveys were conducted in July 2016 and an IBI score was calculated by MWMO staff for each wetland, following methods described in Indexes of Biological Integrity for Large Depressional Wetlands in Minnesota (Gernes and Helgen, 2002).

Biological Monitoring Results

Macroinvertebrates

The macroinvertebrate assemblages of KP indicate that the wetlands are in poor health. KP West received the lowest macroinvertebrate IBI score while KP East and KP North received the same macroinvertebrate IBI score (Figure 39). Results from each of the metrics that contribute to the overall IBI score are shown in Tables 10-12 for each pond. In 2016, 18 different macroinvertebrate taxa were identified across all three ponds, whereas 29 taxa were identified in 2011 (MWMO, 2011). Overall IBI scores also decreased from 2011 to 2016. However, it is important to consider the fact that activity traps were not used in 2016. Activity traps target a specific group of macroinvertebrates and, due to the omission of activity traps, the metrics contributing to the IBI calculation and the overall score range have changed since 2011. Therefore, while biodiversity and overall wetland health may have decreased since 2011, it is unlikely that the change is as drastic as the data comparison would suggest.

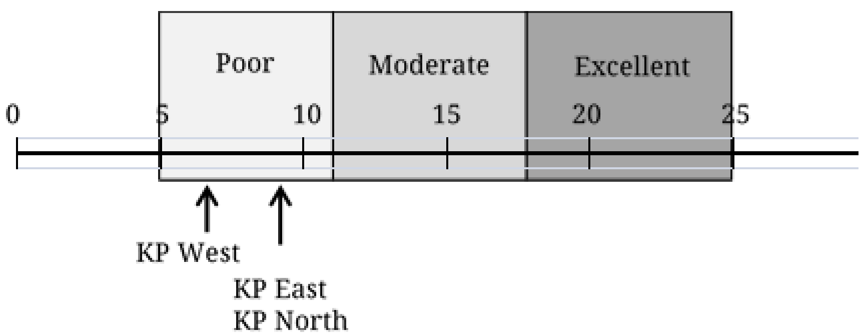

Figure 39. 2016 Aquatic Plant IBI scores showing health relative to other wetlands in MN as set by the MPCA.

Table 10. Macroinvertebrate IBI scores for KP West

Invertebrate Metrics	**Total Taxa**	**IBI Score**[3]
Leech Taxa	1	1
Odonata Taxa [1]	2	1
ETSD Taxa[2]	1	1
Snail Taxa	1	1
Total Taxa	8	3
Total IBI Score		7

1 Dragonfly/Damselfly
2 Number of genera of Mayflies, Caddisflies, Fingernail clams, Dragonflies
3 Possible Score of 1, 3, or 5

Table 11. Macroinvertebrate IBI scores for KP East

Invertebrate Metrics	Total Taxa	IBI Score[3]
Leech Taxa	1	1
Odonata Taxa [1]	2	1
ETSD Taxa[2]	2	3
Snail Taxa	1	1
Total Taxa	9	3
Total IBI Score		**9**

1 Dragonfly/Damselfly
2 Number of genera of Mayflies, Caddisflies, Fingernail clams, Dragonflies
3 Possible Score of 1, 3, or 5

Table 12. Macroinvertebrate IBI scores for KP North

Invertebrate Metrics	Total Taxa	IBI Score[3]
Leech Taxa	1	1
Odonata Taxa [1]	1	1
ETSD Taxa[2]	2	3
Snail Taxa	1	1
Total Taxa	7	3
Total IBI Score		**9**

1 Dragonfly/Damselfly
2 Number of genera of Mayflies, Caddisflies, Fingernail clams, Dragonflies
3 Possible Score of 1, 3, or 5

Aquatic Plants

Aquatic plant assessments showed all three wetlands to be in poor health relative to other wetlands in the state of Minnesota (Figure 40). KP East (Table 13) and KP North (Table 14) were dominated by cattails and lacked diversity. The KP North IBI score improved slightly since the last aquatic plant assessment in 2011, but the KP East score remained the same. As in the 2011 assessment, no aquatic plants were observed in KP West.

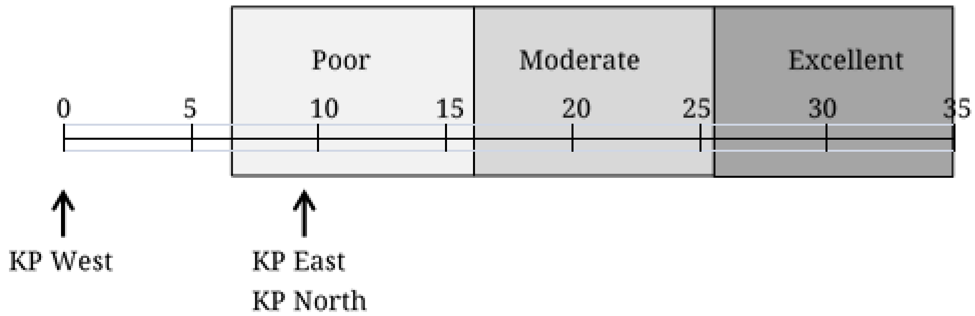

Figure 40. 2016 Aquatic Plant IBI scores showing health relative to other wetlands in the state as set by the MPCA.

Table 13. Aquatic Plant IBI Scores for KP East

Aquatic Plant Metrics	**Metric Value**	**IBI Score[1]**
Vascular Genera	7	1
Nonvascular Genera	0	1
Grass-Like Genera	0	1
Carex Cover	0	1
Utricularia present	No	1
Aquatic Guild Genera	5	3
Persistent Litter	63%	1
Total IBI Score		**9**

1 Possible Score of 1, 3, or 5

Table 14. Aquatic Plant IBI Scores for KP North

Aquatic Plant Metrics	**Metric Value**	**IBI Score[1]**
Vascular Genera	5	1
Nonvascular Genera	0	1
Grass-Like Genera	0	1
Carex Cover	0	1
Utricularia present	No	1
Aquatic Guild Genera	4	3
Persistent Litter	63%	1
Total IBI Score		**9**

1 Possible Score of 1, 3, or 5

Biological monitoring provides a good indicator of the health of the wetlands. Hydrology and water chemistry monitoring report physical and chemical conditions in a wetland, but animals and plants living in the wetlands indicate the overall health of the wetland. Monitoring the ecological condition of wetlands shows how the biota react to changes in their environment.

All of the Kasota Ponds remained in poor health with regards to the aquatic plant and macroinvertebrate communities. These results are unsurprising given the proximity of the ponds to highly disturbed areas including rail yards, industrial centers and Highway 280. Unless efforts are made to restore the wetlands, the IBI scores are not likely to improve.

Bacteria Monitoring

Mississippi River and Stormwater Bacteria Monitoring

The MWMO monitors Mississippi River *E. coli* content at seven locations within Navigation Pool 1 and Reach 1 of the Upper Mississippi River. Six of the Mississippi River sites, described in the following section, have been monitored from April through November since 2003. The seventh site MR853.5E, located at Saint Anthony Falls Laboratory between Upper and Lower Saint Anthony Falls, was added in 2010 to provide data for development of MPCA's Upper Mississippi River Bacteria TMDL project. The monitoring sites are identified by the river mile upstream from the confluence of the Mississippi and Ohio Rivers in Cairo, Illinois, and from the nearest riverbank to the sample collection point. The "E" refers to the eastern river bank and "W" refers to the western river bank. The site with the highest river mile is the farthest upstream.

The MWMO monitors five stormwater outfall locations for *E. coli*, and these sites are sampled concurrently with the river sites. See site descriptions in the Stormwater Monitoring section of this report for details about these locations.

Methodology

Sample Collection, Handling, and Preservation

In 2016, grab samples were collected from seven locations in the Mississippi River (described below) and five stormwater locations at least two times per month. Staff followed sampling procedures outlined in MWMO's Standard Operating Procedure for Surface Water Sampling (2011). Samples were collected in lab-sterilized plastic bottles. Samples collected at the Mississippi River sites occur away from shore, in approximately three feet of water. Samples were taken in positive flow (no back eddies or stagnant water) and upstream of the monitoring specialist to prevent contamination by the disturbed river bottom. To collect samples, the monitoring specialist plunged an opened, inverted bottle one foot below the water surface, turned it upward to fill, and brought it out of the water. At the stormwater monitoring locations, automated samplers were used to collect grab samples. In some situations, a low-flow sampler bottle was used to grab a sample directly from the tunnel. A grab sample was collected only after rinsing the sampling equipment three times. Samples were labeled, stored on ice in a cooler and delivered to the laboratory by the monitoring specialist.

Dissolved oxygen, conductivity, salinity, water temperature and pH values for each site were collected during every sampling event by placing a YSI ProPlus sonde (YSI Inc., Yellow Springs, OH) approximately one foot below the water surface. Transparency was measured using a 100 cm Secchi tube. These parameters serve as basic indicators of the health of a waterbody, due to their effects on the survival of fish, plant and other aquatic organisms.

Sampling Quality Control

MWMO staff followed the quality control protocol outlined in the MWMO's Ambient Surface Water Monitoring Quality Assurance Project Plan (MPCA, 2010). Blank samples of deionized (DI) water were submitted to laboratories at least four times in a year to verify that sample containers were clean and samples were not contaminated during travel. In addition, ten percent of all samples were collected in duplicate to verify that sampling and laboratory procedures did not jeopardize the data.

Laboratory Analyses

Bacteria samples were analyzed at the Three Rivers Park District Laboratory. The laboratory followed strict protocols for quality assurance and quality control. Information regarding laboratory protocol is available from MWMO staff.

Refer to Table A.1 in Appendix A for a list of sample parameters, the laboratories used for analysis, the analysis methods and information regarding certification.

River Site Descriptions

MR859.1W (Camden)

The Camden site is the northernmost bacteria monitoring site in the MWMO's watershed. It is located in the North Mississippi Regional Park in Minneapolis. The terrain surrounding the site is mostly deciduous forest with a grassland transition zone by the road. There is a concrete levy wall and boulders at the sampling site and an outfall just upstream. The river is shallow (three-five foot depth), rocky, and swift with sand and gravel bars up and downstream (Figure 41). Water levels fluctuate at this site more than at any other in the watershed. Waterfowl are commonly seen in the river and on shore. Rabbits, bald eagles, a Blanding's Turtle and a beaver have also been observed.

Figure 41. MWMO bacteria sampling site MR859.1W (Camden) with staff gauge.

MR857.6W (MPRB Boat Launch)

This site is located adjacent to MPRB land. A paved parking lot leads to the river and boat launch. Flat and forested terrain surround the parking lot and boat launch area with some grassy areas and recreational trails leading up and downstream. The river bottom near shore is silty mud and gravel with scattered large stones. The river is deeper here than at MR859.1W, and a swift current can be observed after rainfall. The monitoring site is upstream of the dock foundation and downstream of the mouth of Shingle Creek (Figure 42).

Figure 42. MWMO bacteria sampling site MR 857.6W (MPRB Boat Launch at North Mississippi Regional Park).

MR854.9W (North Loop)

The North Loop site is located downstream from the Plymouth Avenue Bridge. It is adjacent to a shaded park area with picnic tables, trails, grass and trees. The riverbank is steep and covered in brush. The shore and shallows at the sampling site are composed of loose rocks and sand. The monitoring site is at the base of a stairway that leads to the river (Figure 43).

Figure 43. MWMO bacteria sampling site MR 854.9W (North Loop) with staff gauge.

MR853.5E (Saint Anthony Falls Laboratory)

The SAFL site is located between Upper and Lower Saint Anthony Falls. It is located near the bottom of SAFL's outdoor stream laboratory. The shore is rocky (Figure 44).

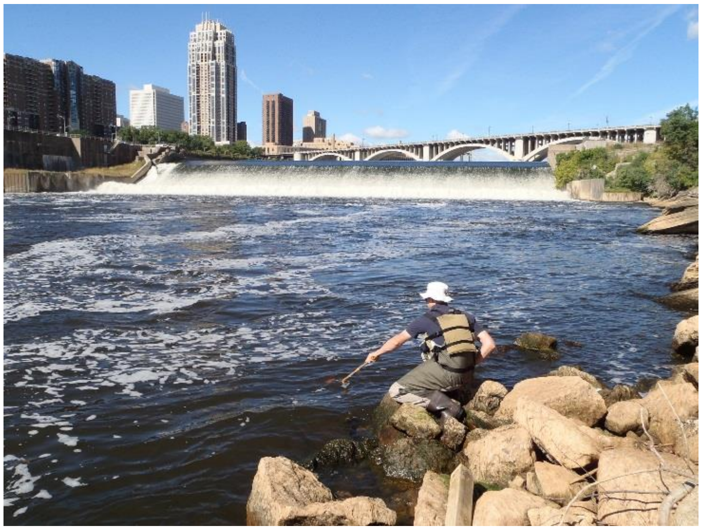

Figure 44. MWMO bacteria sampling site MR853.5 (Near Saint Anthony Falls Laboratory).

MR852.2E (University of Minnesota Boat Launch)

The University of Minnesota Boat Launch site is the first river site downstream from Lower Saint Anthony Falls. It is located in the Mississippi River Gorge, behind Coffman Union on the University of Minnesota East Bank Campus. The sampling site is 100 feet upstream of the boat launch and floating dock that is used by the rowing teams. The surrounding terrain consists of deciduous forest along the river and a large grassy area behind the trees. The gently sloping bank leads to a sandy shore that continues into the river (Figure 45). The site is a regular entrance point to the river for geese that graze on the grass in the open area. Goose droppings are common here.

Figure 45. MWMO bacteria sampling site MR852.2E (University of Minnesota Boat Launch) with staff gauge.

MR849.9W (Lake Street Bridge)

This site is located beneath the Lake Street Bridge, which crosses over the Mississippi River. The elevation drops more than 70 feet from the street to the river. A small stormwater outfall and the Minneapolis Rowing Club boat facility are located just upstream of the site. Tall grass runs along the river and trees on the sides of the gorge can be seen (Figure 46). A steep, three foot riverbank leads to a rocky shore and a sandy river bottom with limestone boulders and gravel (riprap).

Figure 46. MWMO bacteria sampling site MR849.9W (Lake Street Bridge) with staff gauge.

MR848.1W (4300 West River Parkway)

This site is the farthest downstream in MWMO's watershed, located less than one mile upstream from Lock & Dam No. 1. The site is surrounded by hardwood forest and is just upstream from a stormwater outfall. The shore and river bottom are made up of sand and large, flat limestone rocks (Figure 47).

Figure 47. MWMO bacteria sampling site MR848.1W (4300 West River Parkway) with staff gauge.

Mississippi River Bacteria Monitoring Results

E. coli

Portions of the MWMO's reach of the Mississippi River are listed on the MPCA's list of impaired waters for fecal coliform pollution. In 2008, the MPCA changed the bacteria water quality standard from fecal coliform to *E. coli* for bacteria monitoring in Minnesota. The standard for *E. coli* in 2B and 2Bd waters is 126 CFU/100 mL for a monthly geomean of at least five samples. The MPCA *E. coli* standard also states that *E. coli* cannot exceed 1,260 CFU/100mL in more than 10% of the samples taken in one month. In 2016, all river sites exceeded the standard in September, and three exceeded it in August, as shown in Table 6. However, the relatively small number of samples collected each month should be considered when viewing these results. The *E. coli* data are presented in more detail in Figures B.1 through B.7 in Appendix B and may be requested from MWMO staff.

Table 15. Sites that exceeded 1,260 MPN/100mL in >10% of samples for the Mississippi River in 2016

Month	Sites that exceed 1,260 MPN/100 mL in > 10% of samples
April	None
May	None
June	None
July	None
August	MR848.1W, MR849.9W, MR857.6W
September	MR848.1W, MR849.9W, MR852.2E, MR853.5E, MR854.9W, MR857.6W, MR859.1W
October	None
November	None

Prior to 2013, the MWMO collected *E. coli* samples at river sites at least five times per month to compute a monthly geomean. During this time, data were collected to contribute to the MPCA's TMDL assessment of the Upper Mississippi River. In early 2013, the MPCA released its Draft Upper Mississippi River Bacteria TMDL Study and Protection Plan (MPCA, 2013). This document designated the stretch of the Mississippi River within the MWMO as a Protection Reach and deferred it for a TMDL study. Although the reach is now under protection mode, the MWMO continued to sample *E. coli* at the seven river sites at least twice per month during April through November of 2016, with the goal of maintaining a baseline of data.

In previous years, the MWMO has targeted sampling equally during baseflow conditions and local rain events to ascertain the impact of precipitation on river bacteria levels. In 2015, monitoring staff began sampling consistently on every second and fourth Thursday of the month, regardless of precipitation conditions. This protocol was continued in 2016. In samples that happened to be taken during rain events, *E. coli* concentrations were typically an order of magnitude higher than baseflow values, but instances of high baseflow values were also observed. Some potential causes of high baseflow *E. coli* values include water fowl congregating near the sampling site and sanitary overflow into the river. To lower the risk of exposure to high bacteria levels in the river, it is advisable to avoid swimming during rain and for 72 hours after a rain event.

Additional factors should be considered when evaluating these results. First, results are based on an average of two samples per month. Different results may have been observed if more samples had been collected. Second, two unique features of the MWMO's watershed are Upper and Lower Saint Anthony Falls. The Mississippi River water mixes as it flows over the falls, likely affecting water quality.

As these results are highly dependent on precipitation, both in the watershed and upstream, results may differ drastically from year to year. MWMO does not support interpretation or assumptions based solely on one year of data. MWMO will continue to collect data on the Mississippi River to provide information for development of TMDLs in the watershed.

Stormwater Bacteria Monitoring Results

MWMO's stormwater outfalls are monitored for *E. coli* year round. Bacteria are sampled at stormwater outfalls concurrently with river bacteria sampling between April and November. In the winter months between December and March, MWMO collects dry weather bacteria samples from those same outfalls once per month. Stormwater outfall site descriptions can be found in the Stormwater Monitoring section of this report. Sampling methods are detailed in the prior Methodology portion of this section. Rain sample *E. coli* concentrations were typically an order of magnitude higher than baseflow values, however instances of high baseflow values were also observed. The most likely causes of high baseflow *E. coli* values are sanitary flow into the stormwater pipes or wildlife presence within the pipes. MWMO notifies the applicable member city when there are high baseflow *E. coli* values of concern.

For the most part, both baseflow and stormflow bacteria concentrations appear to be higher at the stormwater sites than at the river sites. The data suggest that stormwater may be a large contributor of bacteria to the Mississippi River, particularly during storm events.

Water Elevation Monitoring

The MWMO has monitored Mississippi River water elevations (commonly referred to as stage) at six of the bacteria sampling site locations since 2005. Mississippi River water elevations rise and fall in response to precipitation events and snow melt, and are also influenced by the dams at St. Anthony Falls and Lock & Dam No. 1. Since the river pools behind the dams, control activities at the dam cause changes in river elevation, even in the absence of precipitation. The MWMO data are equivalent to data collected by agencies using the North American Vertical Datum, 1988 (NAVD88).

Staff gauges were installed on March 28, 2016, at the river sampling sites in approximately three feet of water. An additional gauge was installed at each site to accommodate both high and low flow conditions. Mississippi River water elevation data for the three monitoring locations above the Upper Saint Anthony Falls Lock and Dam are shown in Figure 48. Elevation data for the three sites below the lock and dam are shown in Figure 49. Time periods with missing data were the result of either high river water levels (the staff gauges were submerged underwater or pulled out by the current) or low river water levels (water was below the lowest elevation of the staff gauge). Other gaps may be due to less frequent site visits to read a gauge compared with other gauge sites. Water elevation data were not recorded at site MR853.5E because of the site's close proximity to Saint Anthony Falls and deep water. The staff gauges were removed on November 28, 2016.

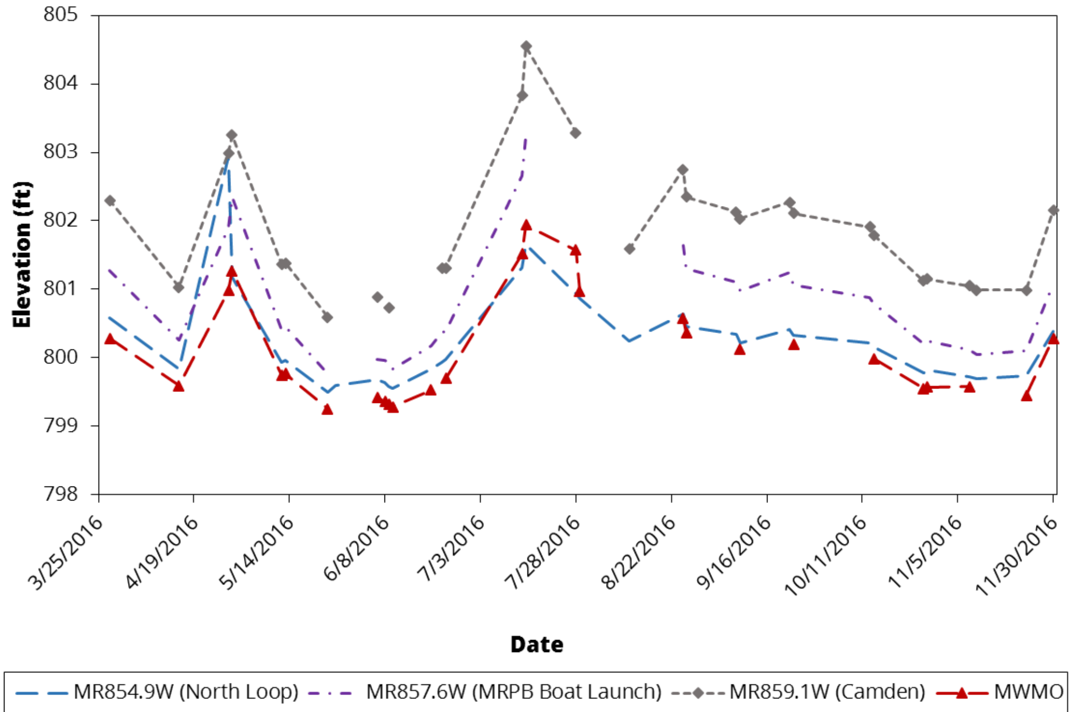

Figure 48. Mississippi River water elevations at four monitoring sites upstream of Saint Anthony Falls, including one near MWMO's office building at RM856.6.

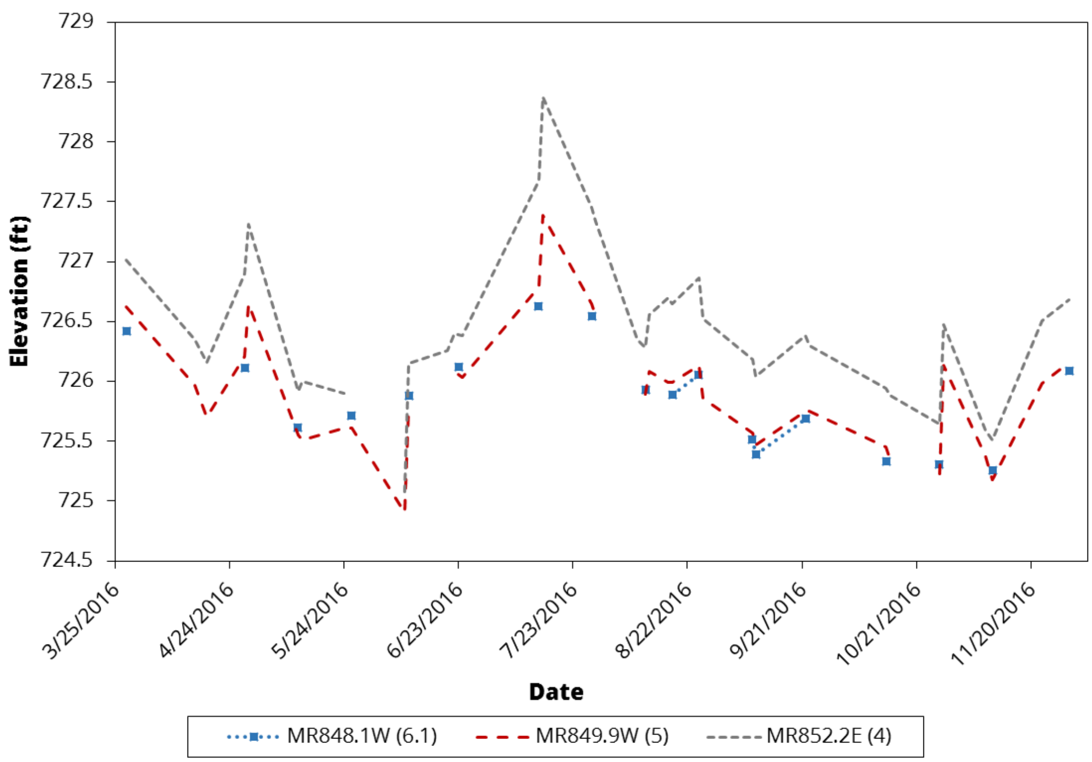

Figure 49. Mississippi River water elevations at three monitoring sites downstream of Saint Anthony Falls.

Mississippi River Water Quality Monitoring

MWMO staff began collecting water quality samples from the Mississippi River during 2014. The purpose of monitoring the water quality of the Mississippi River is to establish baseline water quality data that can be used for the management of the river. In 2016, water quality measurements and samples were collected 1-2 times per month at eight sites (see Figure 50). Monitoring sites on the Mississippi River and within the MWMO's boundary were selected to represent three distinct reaches of the river. Each site is located within, at the beginning of, or at the end of a river reach. Samples were collected from the middle of the river, 3 feet below the surface as conditions allowed. Sampling occurred progressively from the most downstream site to the most upstream site.

Methodology

Sample Collection, Handling, and Preservation

Samples were collected from the front of the boat in the middle of the river, three feet below the surface, using a Wildco® Beta Plus Horizontal Water Sampler (Wildco, Yulee, FL). The sampler was rinsed three times with river water and then was filled three times to collect enough water to fill a laboratory-cleansed (non-sterile) plastic bottle. The physical water parameters were collected from the river by lowering a YSI ProPlus sonde (YSI Inc., Yellow Springs, OH) into the water from the boat. The samples were stored in a cooler for transport to the laboratory. When boating to the sample site was not possible, samples were collected by lowering the Wildco® Beta Plus Horizontal Water Sampler from bridges or by filling a laboratory-cleansed (non-sterile) plastic bottle from riverbanks.

Sampling Quality Control

The MWMO staff followed the quality control protocol outlined in the MWMO Ambient Surface Water Monitoring Quality Assurance Project Plan (MPCA, 2010). Blank samples of DI water were submitted to laboratories regularly to verify that sample containers were clean and samples were not contaminated during travel. Additionally, 10 percent of all samples were collected in duplicate to verify that sampling and laboratory procedures did not jeopardize the data.

Laboratory Analyses

All samples were analyzed at the (MCES) Laboratory. MCES followed strict protocols for quality assurance and quality control. Information regarding laboratory protocol is available from MWMO staff. Refer to Table A.1 in Appendix A for a list of sample parameters, the laboratories used for analysis, the analysis methods, and information regarding certification.

Site Descriptions

River water quality samples were taken at eight locations above the Ford Dam and below Highway 694. All samples are collected from the middle of the channel when possible. During winter months, some of the sampling locations were adjusted based upon access to open river water.

MR859.1 (Camden)

This site is just upstream of the beginning of Reach #1 (RM 859.0-RM 857.8) and is the farthest upstream section in the MWMO's watershed. The cross-section is 840 feet wide.

MR857.6 (Shingle Up and Shingle Down)

Shingle Up is upstream of where Shingle Creek enters the Mississippi River. Shingle Down is downstream of where Shingle Creek enters the Mississippi River. The cross-section is 525 feet wide.

MR856.6 (MWMO)

This site is located mid-river near the MWMO office, just upstream of the Lowry Avenue Bridge. The cross-section is 700 feet wide.

MR854.9 (Boom Island)

This site is sampled midway between the two farthest upstream barge tie-up piers and the concrete steps on Boom Island. The cross-section is 575 feet wide.

MR852.2 (Washington Avenue Bridge)

This site is just downstream from the Washington Avenue Bridge and is between Bohemian Flats Park and a rectangular tunnel structure in the opposite bank. The river is 525 feet wide.

MR850.6 (Meeker)

This site is located near the remnants of the old Meeker Dam site, downstream of the Washington Avenue Bridge. The cross-section is 610 feet wide.

MR848.1 (Ford)

This site is upstream of the Ford Dam, and in between monitoring site MR848.1W (marked by a staff gauge) and the two small dead trees that are close together on the opposite bank. At this point, the river is 1,060 feet wide.

Mississippi River Water Quality Monitoring Results

Samples were collected for nutrients, sediment, inorganics, organics, and metals analyses. Data are submitted annually to the MPCA's water quality database (EQuIS) and are also available upon request from MWMO monitoring staff (www.mwmo.org).

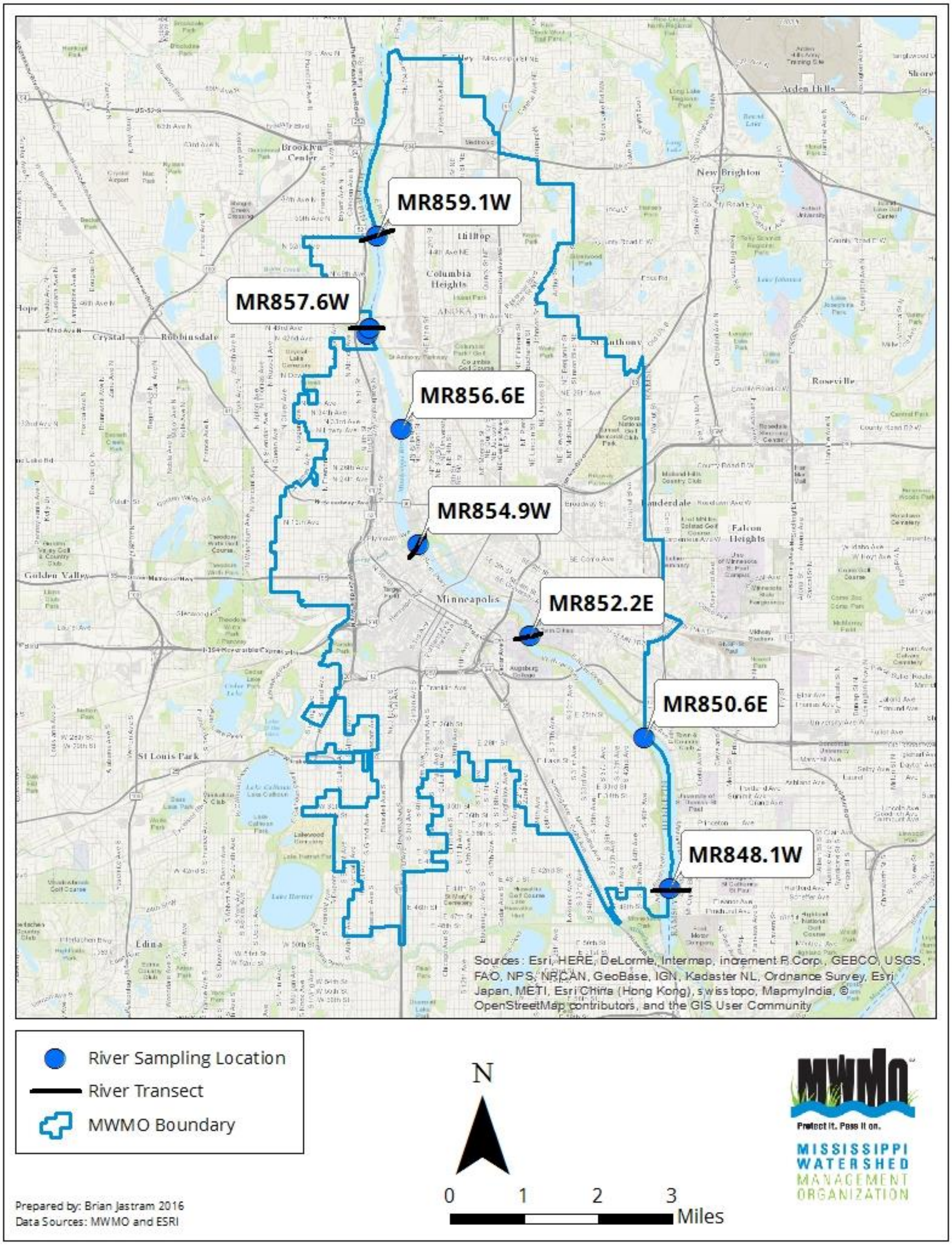

Figure 50. River water quality sampling locations.

Mississippi River Bathymetry Mapping

The purpose of collecting Mississippi River bathymetric data is to provide baseline data on the Mississippi River. This mapping project recorded the morphology of the river bed. Rock piles, deep holes, navigation channels, dunes, pilings and other structures were mapped. The mapping produced data that show one-foot contours, hardness, track, and vegetation.

Methodology and Results

Data collection in 2016 began on June 6 and concluded on August 18. Data were collected on the Mississippi River between Lock and Dam No. 1 and the CPR Bridge just downstream from the N. 42nd Ave Bridge. Bathymetric data were collected with a Lowrance HDS-5 Gen2 Fishfinder/Chartplotter (Navico, Inc.) and stored on an SD card. A Lowrance Point-1 GPS/HDG Antenna (Navico, Inc.) was used in combination with the HDS-5 to increase position accuracy. The boat was navigated along a course of parallel (25 meters apart) tracks covering the area between river banks. Data files were recorded for a maximum of one hour before starting a new file. The speed of the boat was kept at or below 5 miles per hour to ensure high quality data. The recorded data files were uploaded to a BioBase (Navico) server via the ciBioBase Upload Tool and merged to form a single map of the river bottom (Figure 51).

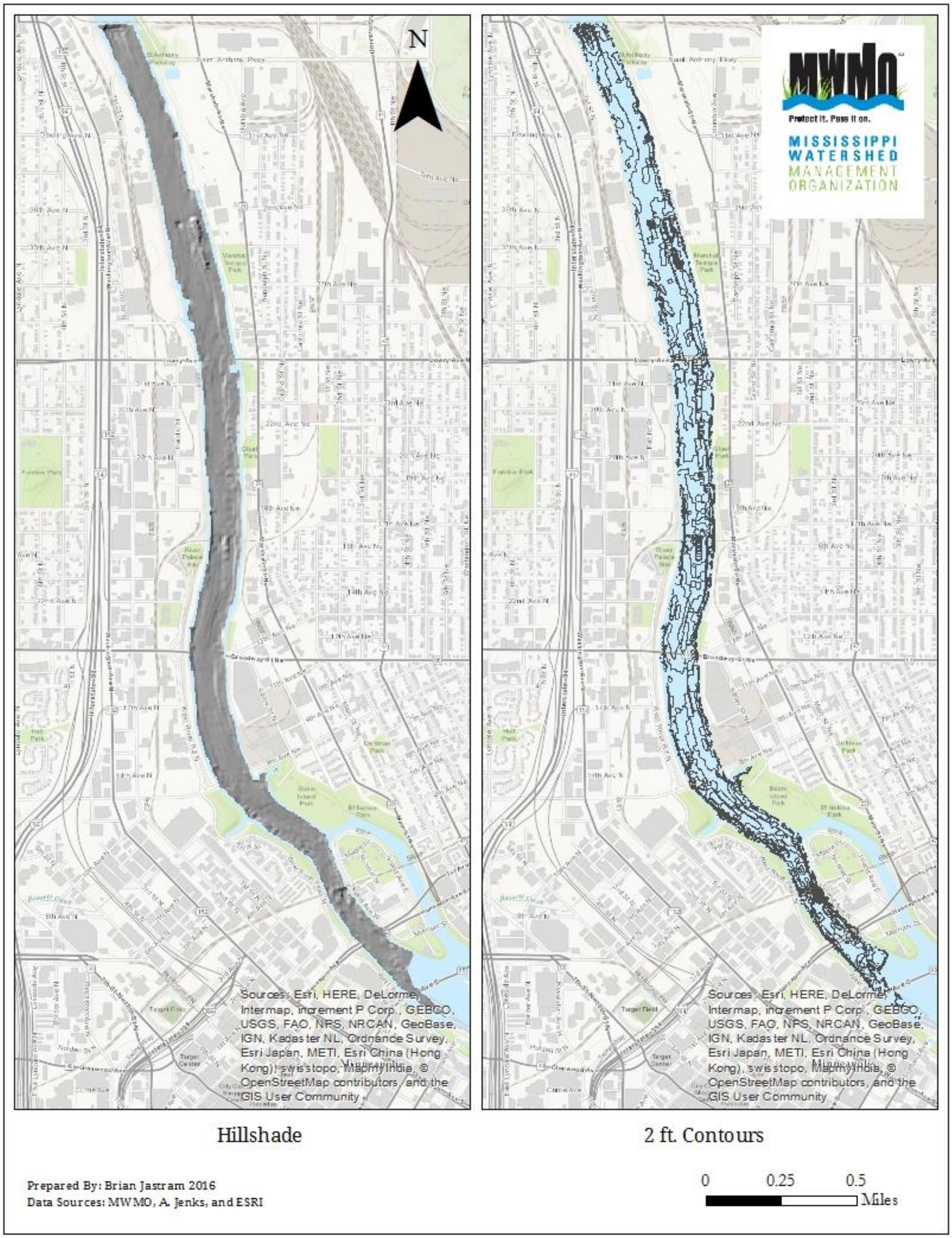

Figure 51. Section of Mississippi River in the MWMO that was mapped as part of the bathymetry project. Left side of the figure shows the river bottom in grayscale 3-D. The right side shows 2 foot contour lines.

Best Management Practice (BMP) Monitoring

In 2016, the MWMO began to monitor some recently installed best management practices (BMPs) within the watershed. Some information about these BMPs is included below. Please visit the Projects page at the MWMO website (mwmo.org/projects) for more details about these and other MWMO projects.

St. Anthony Regional Stormwater Treatment and Research System

The St. Anthony Regional Stormwater Treatment and Research System is a large-scale BMP and research site that diverts and treats stormwater as it leaves the City of St. Anthony Village and enters the City of Minneapolis. This facility is designed to treat stormwater runoff from about 600 acres of St. Anthony Village before it continues through the stormwater drainage system and enters the Mississippi River. Stormwater is first diverted into an underground swirl chamber that traps sediment and floating debris. Figure 52 shows the inside of the swirl chamber during construction. Some of this treated water is then pumped through one of two filters — an iron-enhanced sand filter or a Stormfilter® cartridge chamber— while the rest flows back into the stormwater tunnel. Both filters are designed to remove phosphorus from stormwater. The water treated by the filters reenters the stormwater tunnel. The two filter chambers are designed in such a way that the current treatments may be swapped out and replaced with other innovative stormwater treatment media. In this way, the facility also acts a research resource for testing out new, emerging technologies in stormwater treatment. Figure 53 shows a schematic of the facility.

Figure 52. View inside the swirl chamber vault.

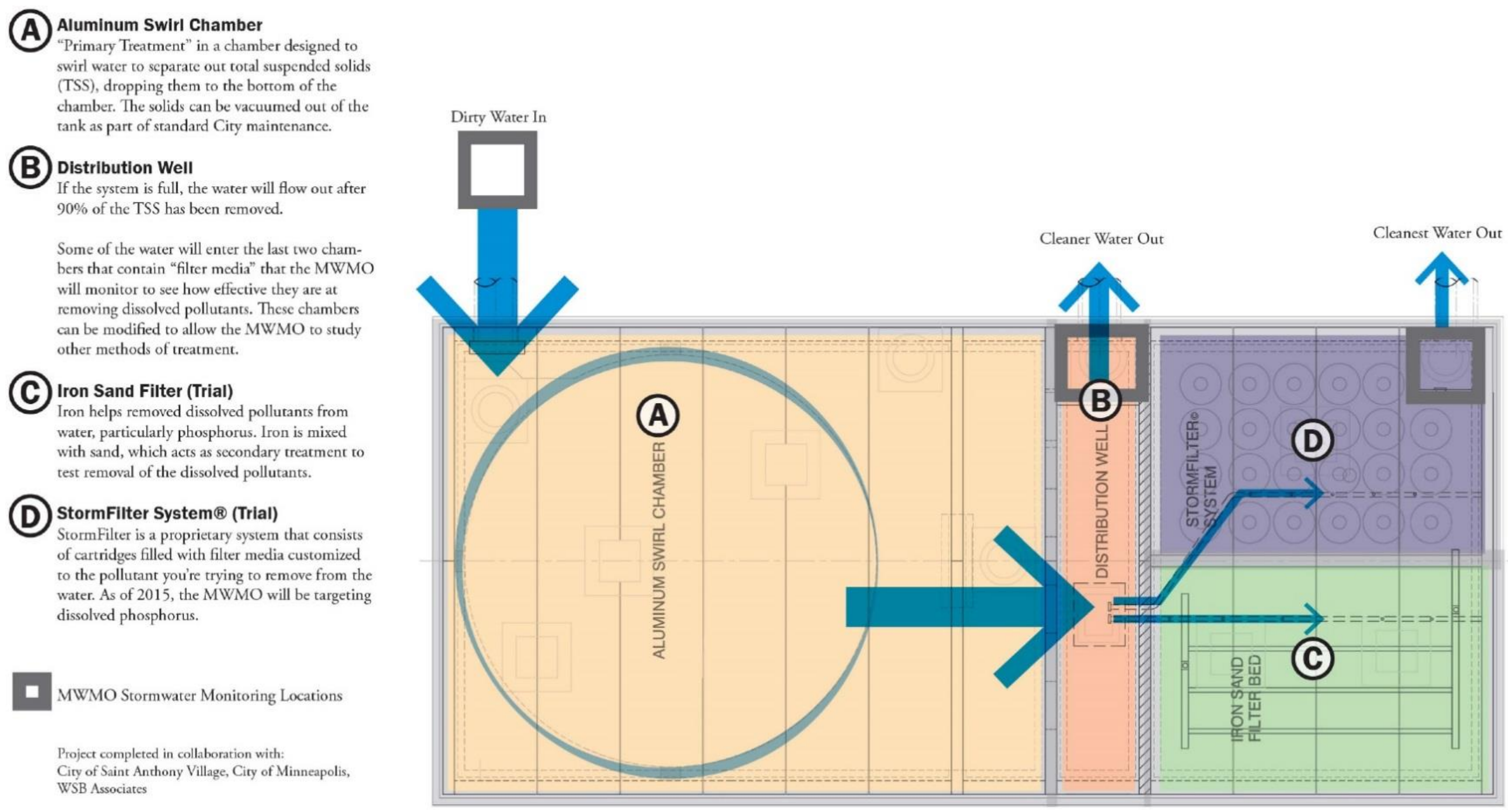

Figure 53. Simplified diagram of stormwater flow through the St. Anthony Regional Stormwater Treatment and Research System.

The MWMO has installed monitoring equipment within the St. Anthony facility with the goal of addressing some initial research objectives:

1. Evaluate the efficiency of providing stormwater treatment on a regional scale.

2. Quantify the pollutant removal efficiency of each of the treatment components: swirl chamber, iron-enhanced sand filter, and Stormfilter® cartridge chamber.

3. Assess differences in pollutant removal in the system between baseflow and storm events.

The first complete year of monitoring and analysis will occur in 2017.

Edison High School Green Campus

As part of a larger Northeast Green Campus Initiative, the MWMO has collaborated with partners to construct various stormwater BMPs at Edison High School. In order to both determine the efficacy of the BMPs and to provide educational opportunities to students, monitoring equipment has been installed in them to measure water quality and water quantity entering and exiting the BMPs.

Parking Lot Tree Trench

The first BMPs installed on the Edison Green Campus were a tree trench, pervious pavers and a raingarden within a parking lot (Figure 54). The tree trench collects runoff from 7,930 square feet of parking lot. The volume of parking lot runoff entering the tree trench is measured using a weir and pressure transducer. Sample bottles for water quality analysis are also installed at the inlet to the tree trench and are analyzed for constituents such as total phosphorus, suspended sediments, total metals and other typical stormwater pollutants. Volume and water quality are also monitored at the outlet to the tree trench with the goal of assessing its effectiveness at infiltrating and treating stormwater.

Figure 54. Edison High School parking lot tree trench.

Athletic Complex Underground Stormwater Reuse Tank

As part of a major reconstruction of the high school athletic track and field complex, an underground stormwater reclamation system was installed. The water collected by the system will be used to irrigate the athletic field. The underground storage tank collects runoff from the gymnasium roof, athletic field, a new pedestrian plaza and a future parking lot (see Figure 55). Monitoring equipment to measure flow from each runoff source into the tank has been installed, and data collected by that equipment will be transmitted to a public digital display on a new concession building. The amount of water reused from the storage tank will also be monitored to determine the amount of potable water savings provided by the reuse system. The first complete year of monitoring data will be collected in 2017.

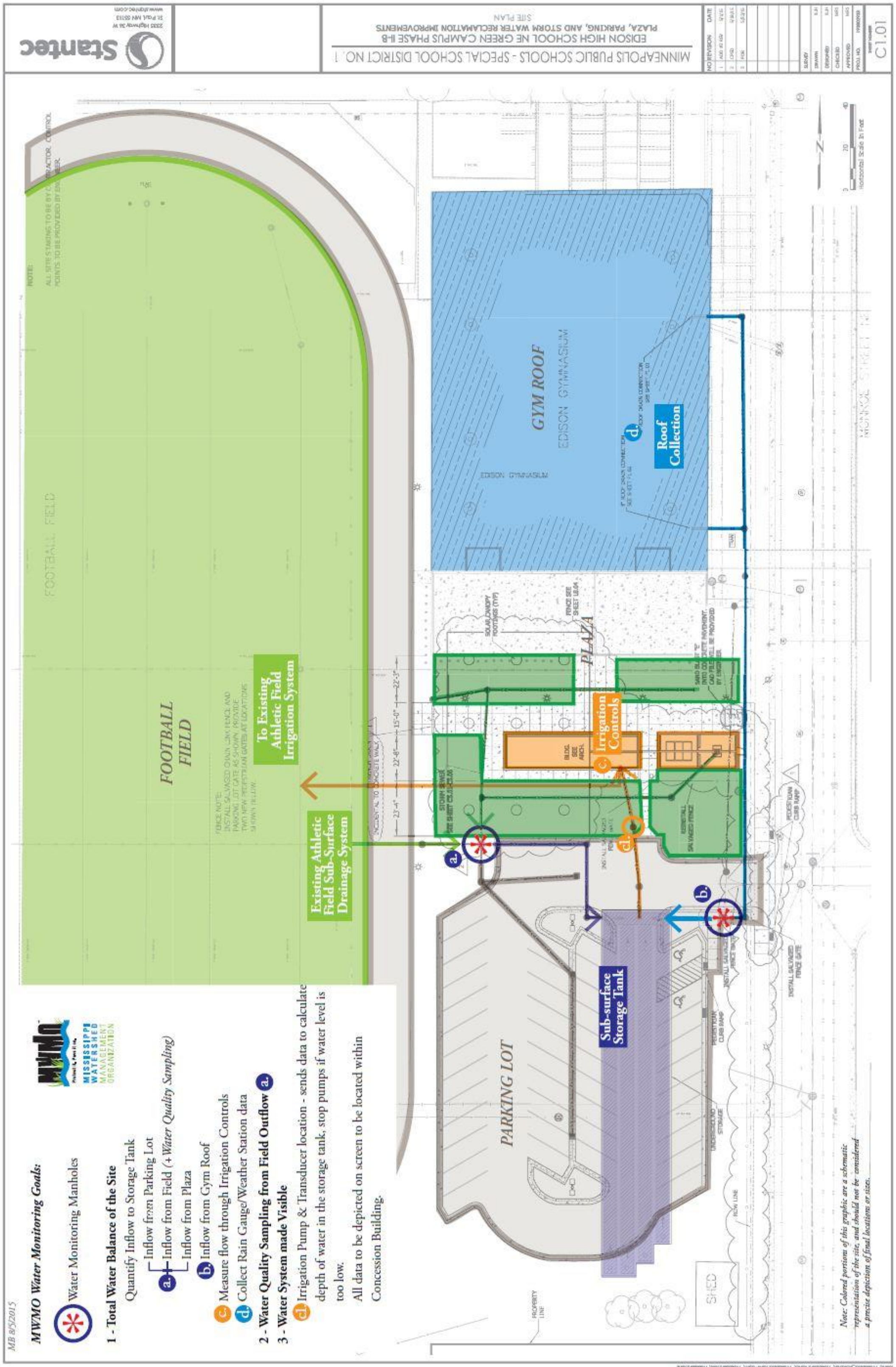

Figure 55. Edison High School underground storage tank flow and monitoring diagram.

Work Plan

2016 Work Plan Accomplishments

New Initiatives

- Installed monitoring equipment in the St. Anthony Regional Stormwater Treatment and Research System.
- Supported the Capital Improvement Project Implementation team to manage the contract for monitoring equipment and systems installation and setup at the Stormwater Harvest and Reuse project for the Edison High School Green Campus.
- Supported the MWMO and City of Minneapolis's Hydrologic and Hydraulic (H and H) Modeling effort by collecting flow data from two subwatersheds in three cities (Bridal Veil Falls in Minneapolis and 11CHF in Fridley and Columbia Heights).
- Implemented Kister's WISKI database for greater efficiency in data management and optimization of monitoring data for analysis.
- Conducted the second biological survey of the Kasota Ponds wetlands which occurs on a five year cycle.
- Installed erosion measurement pins and scour chains to assess the stream bank erosion potential at the Nicollet Island restoration project.
- Developed project objectives, solicited proposals, received approval from the board for, and signed an agreement with the University of Minnesota Bio-products and Biosystems Engineering (BBE) department to study the runoff from four types of impervious surfaces in downtown Minneapolis.
- Organized an Erosion Control Inspection and Installation course for MWMO staff and City of Minneapolis Erosion Control interns.
- Installed a flow logger in the MWMO's Stormwater Park and Learning Center to monitor the surface runoff volume from the parking lot.
- Worked collaboratively with faculty, staff, and students from the University of Minnesota BBE department to complete field work and install monitoring equipment for multiple projects.

Ongoing Monitoring Efforts

- Continued collecting water samples from the MWMO's steel, rubber, and green roofs.
- Assisted with preparation of MWMO's Annual Activity and Financial Report to Board of Water and Soil Resources.
- Worked with MWMO member cities to assess their monitoring needs and develop plans for stormwater and lake monitoring.
- Collected flow data from three different monitoring locations in the 1NE subwatershed to enhance H and H model calibration.
- Collected precipitation data from eight locations using five heated precipitation gauges, two non-heated gauges, and an additional non-heated gauge operated by citizen volunteers.
- Monitored the Edison High School Tree Trench project to assess the effectiveness of the BMP.
- Worked with an Edison High School science teacher and the MWMO's Youth and Community Outreach Specialist to continue to use the project site for high school science education.
- Continuously monitored five stormwater outfalls with automated samplers.
- Collected continuous water level data at the mouth of Bassett Creek.
- Calculated preliminary pollutant load estimates from stormwater outfalls.
- Monitored the Kasota Ponds wetlands in St. Paul.
- Sampled the Mississippi River at eight locations for water quality analysis.
- Collected bathymetric data from the river covering an area from Lock and Dam No. 1 to the CPR Bridge just downstream from the 42nd Ave N Bridge.
- Completed the Old Bassett Creek Tunnel Water Reuse and Water Quality Improvement project feasibility study.
- Prepared and signed a professional services agreement with Anoka Conservation District to coordinate water quality and water level monitoring for Sullivan Lake and Highland Lake.

- Collaborated with the City of Minneapolis on their illicit discharge monitoring program and spill response activities.

- Worked with the City of Minneapolis Health Department's staff to enhance their erosion and sediment control inspections program by providing funding to support two summer internships.

- Shared MWMO data through the MPCA's EQuIS database, the MWMO's annual monitoring report, and data requests.

- Collaborated with Minneapolis Riverfront Partnership to complete the Legislative Citizens Commission on Minnesota Resources (LCCMR) funded grant project to assess the ecological impacts of the St. Anthony Falls Lock Closure.

- Provided job-shadowing opportunities to high school and college students.

- Worked with a multidisciplinary team of researchers from University of Minnesota's BBE department on their joint project with Mizoram University in northeastern India to provide technical expertise and training related to integrated watershed management and planning to a visiting scientist.

- Continued to work with partner water quality monitoring staff to collaborate on monitoring work and confined space entry training.

2017 Work Plan

New Initiatives

- Conduct bathymetric mapping of the Kasota Pond wetlands.

- Provide continuous automated water monitoring at the St. Anthony Regional Treatment and Research facility to provide water quality and quantity data to evaluate the effectiveness of the system's innovative treatment technologies.

- Provide water quantity and quality monitoring assistance at the Edison High School Green Campus Stormwater Harvest and Reuse project.

- Monitor the MWMO Stormwater Park and Learning Center outdoor BMPs to determine the effectiveness of the filter media and use the instrumented facility for research, education, and outreach.

- Design, build, and install a weir and level logger in the outlet of a newly constructed storage, treatment, and reuse facility to monitor the overflow volumes to the University of Minnesota's stormwater pipe network.

Ongoing Monitoring Efforts

- Complete the 2016 Annual Monitoring Report
- Work with the MWMO member cities to assess their monitoring needs and assist in developing additional monitoring plans for stormwater monitoring and lake monitoring.
- Look for opportunities to expand the precipitation monitoring network using heated precipitation gauges and citizen precipitation recorders.
- Continuously monitor five stormwater outfalls using automated samplers. The 2NNBC site will be monitored by grab sampling when there is positive flow from the tunnel to the river. The 7LSTU site will be monitored by grab sampling depending on the presence of tailwater in the outfall.
- Monthly monitoring of the Kasota Ponds wetlands in St. Paul.
- Collection and submittal of biweekly *E. coli* data from seven rivers sites and five stormwater sites to the MPCA.
- Support the MWMO and City of Minneapolis's H and H Modeling effort by collecting flow data in targeted pipesheds.
- Continue development of monitoring protocols for the Mississippi River.
- Water quality sampling and data collection at eight Mississippi River sites.
- Finalize Mississippi River bathymetric data from 2014-2016 and collect additional bathymetry data.
- Calculate pollutant loading for stormwater outfalls.
- Work with the MPCA on the Upper Mississippi River Bacteria TMDL Project and the Twin Cities Metro Area Chloride Project.
- Work with the City of Minneapolis Health Department staff to enhance their erosion and sediment control inspections program.
- Share MWMO data through the MPCA's EQuIS database, the MWMO's annual monitoring report, and data requests.

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Appendix A – Laboratory Methods and Certification

Table A.1. Laboratory methods and certification for each analyte

Analyte	Lab	Method	Certified
Total Metals (Copper, Nickel, Lead, Zinc, Cadmium, Chromium, Mercury)	Metropolitan Council	EPA 200.8 with ATP, Rev. 5.4 (Mercury) EPA 245.7	Yes
Total Soluble Metals	Metropolitan Council	EPA 200.8 with ATP, Rev. 5.4 (Mercury) EPA 245.7	Yes
Total Chemical Oxygen Demand	Metropolitan Council	EPA 410.4 Rev 2.0	Yes
Carbonaceous Biological Oxygen Demand (CBOD) 5-Day	Metropolitan Council	SM 5210 B-2001, Hach 10360 Rev. 1.1	Yes
Chlorophyll -a	Metropolitan Council	ASTM D3731-87	Yes
Total 5-day BOD	Metropolitan Council	SM 5210 B-2001, Hach 10360 Rev. 1.1	No*
Total Organic Carbon	Metropolitan Council	SM 5310 A & C	n/a
Total & Volatile Suspended Solids	Metropolitan Council	SM 2540 D and E - 1997	Yes
Total Dissolved Solids	Metropolitan Council	SM 2540 C	No
Total Alkalinity	Metropolitan Council	EPA 310.2, Rev. 1974	Yes
Total Hardness	Metropolitan Council	SM 2340 C-97	Yes
Total Chlorides	Metropolitan Council	SM 4500-CI E-97	Yes
Total Sulfates	Metropolitan Council	EPA 300.0 Rev 2.1	Yes

*No = Indicates that the lab follows standard certification test methods but has not sought certification from the Minnesota Department of Health.

Table A.1 continued. Laboratory methods and certification for each analyte

Analyte	**Lab**	**Method**	**Certified**
Fluoride	Pace Analytical Services, Inc.	SM 4500-F SPADNS Method, Ref SM 20th ed. P 4-82 and EPA 300.1, Rev. 2.1	Yes
Total Phosphorus plus Total Kjeldahl Nitrogen	Metropolitan Council	EPA 365.4 & EPA 351.2 Rev 2.0	Yes
Dissolved Phosphorus	Metropolitan Council	EPA 365.4	Yes
Orthophosphorus	Metropolitan Council	SM 4500-P E	Yes
Total Ammonia Nitrogen	Metropolitan Council	EPA 350.1 Rev 2.0	Yes
Nitrate & Nitrite Nitrogen	Metropolitan Council	4500 NO3 H-00	Yes
Total Volatile Organic Compounds	Metropolitan Council	EPA 624/625	Yes
Oil and Grease	Metropolitan Council	SM 5520 D	n/a
E. coli	Three Rivers Park District Water Resources Laboratory and Metropolitan Council	SM 9223 B and Colilert 18 with Quanti Tray/ 2000, IDEXX Laboratories, Inc.	Yes
Chlorophyll-a	Minnesota Valley Testing Laboratories	APHA 10200-H	
Total Phosphorus	Minnesota Valley Testing Laboratories	EPA 365.1	

Appendix B – Mississippi River Site *E. coli* Figures

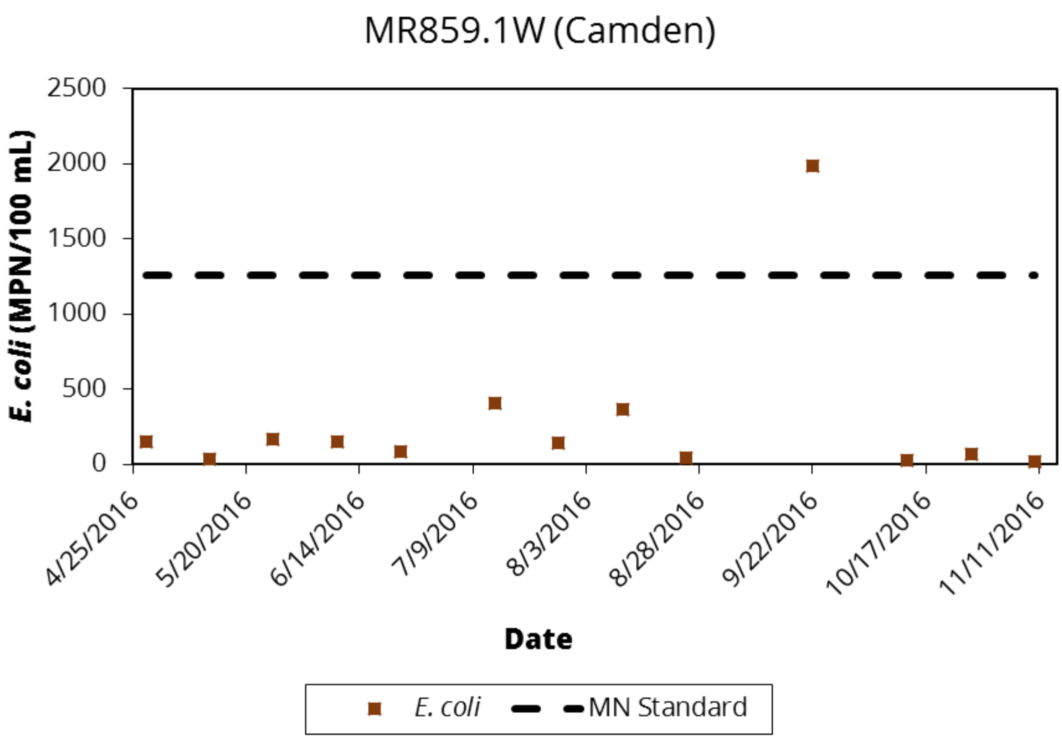

Figure B.1. *E. coli* data for MR859.1W.

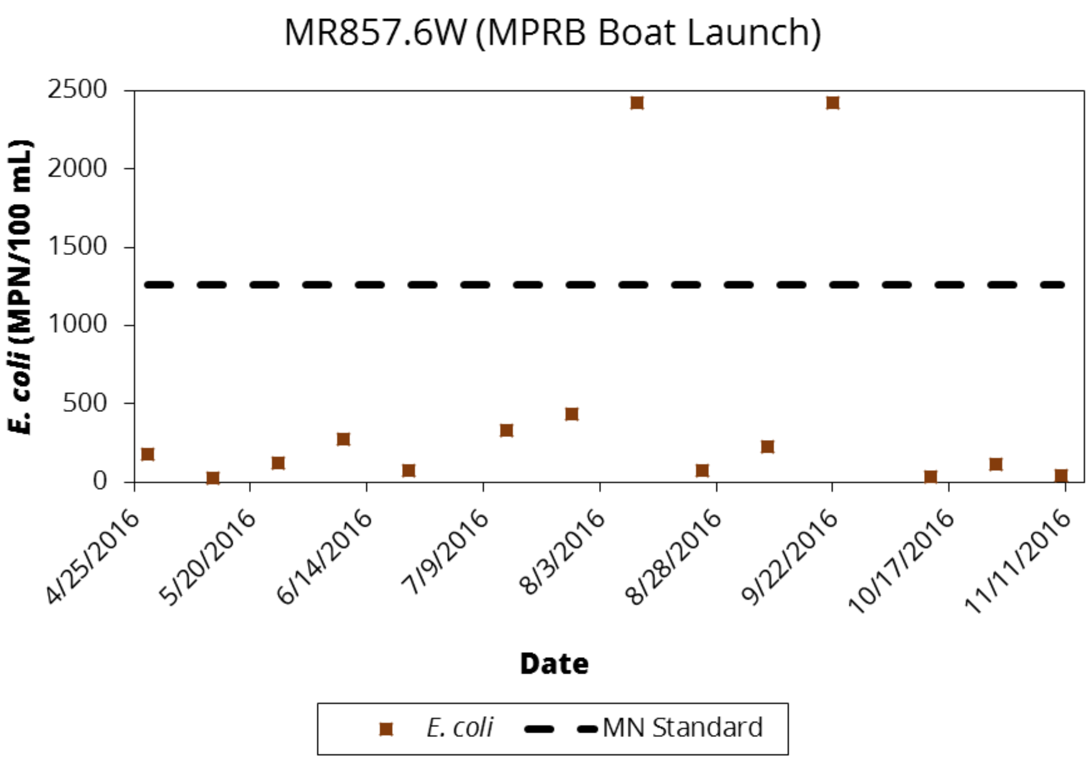

Figure B.2. *E. coli* data for MR857.6W.

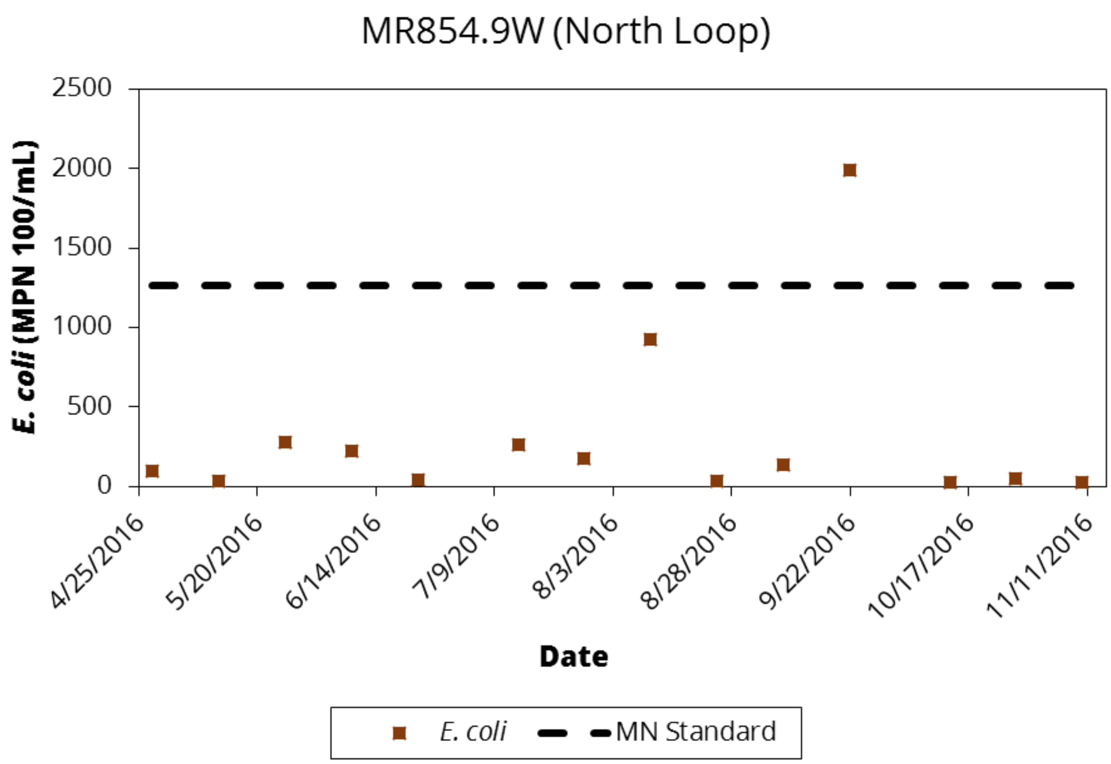

Figure B.3. *E. coli* data for MR854.9W.

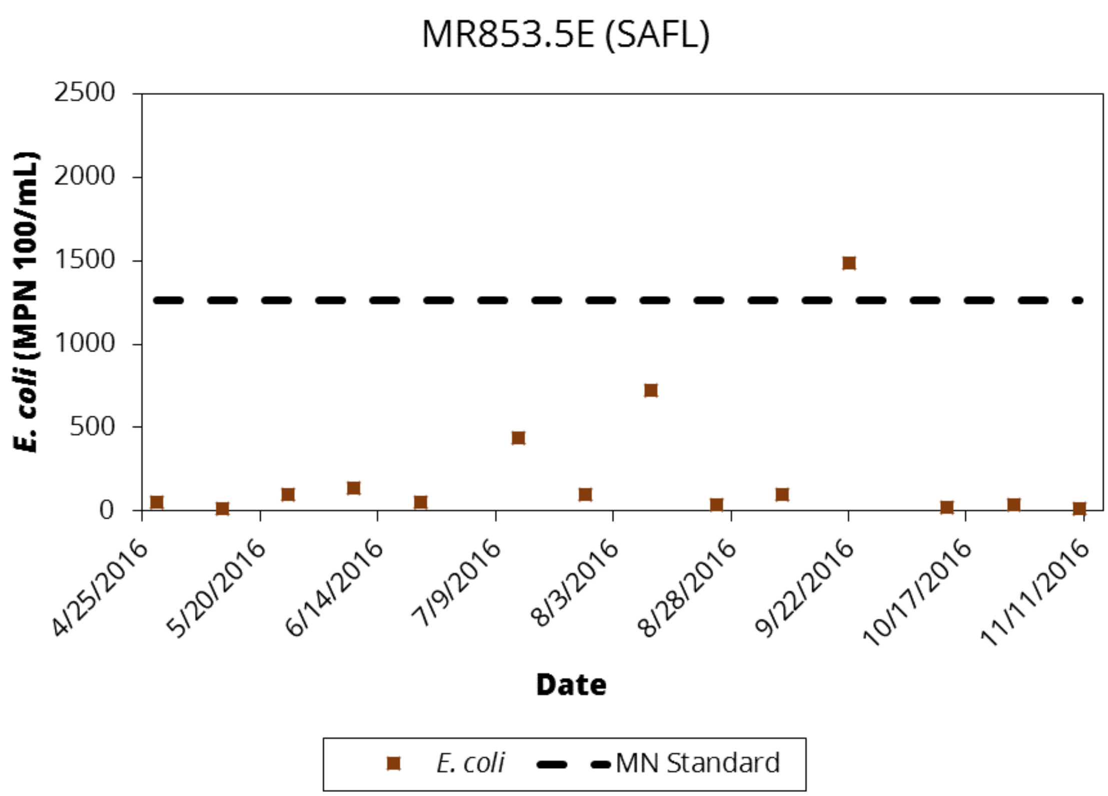

Figure B.4. *E. coli* data for MR853.5E.

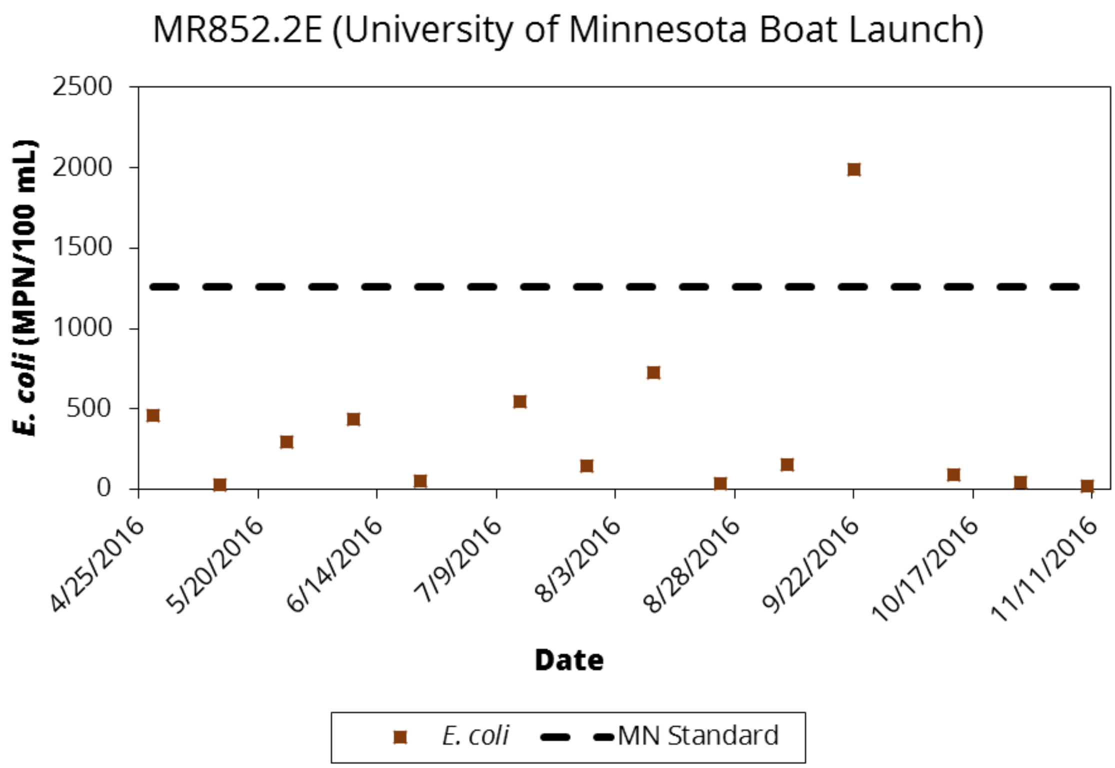

Figure B.5. *E. coli* data for MR852.2E.

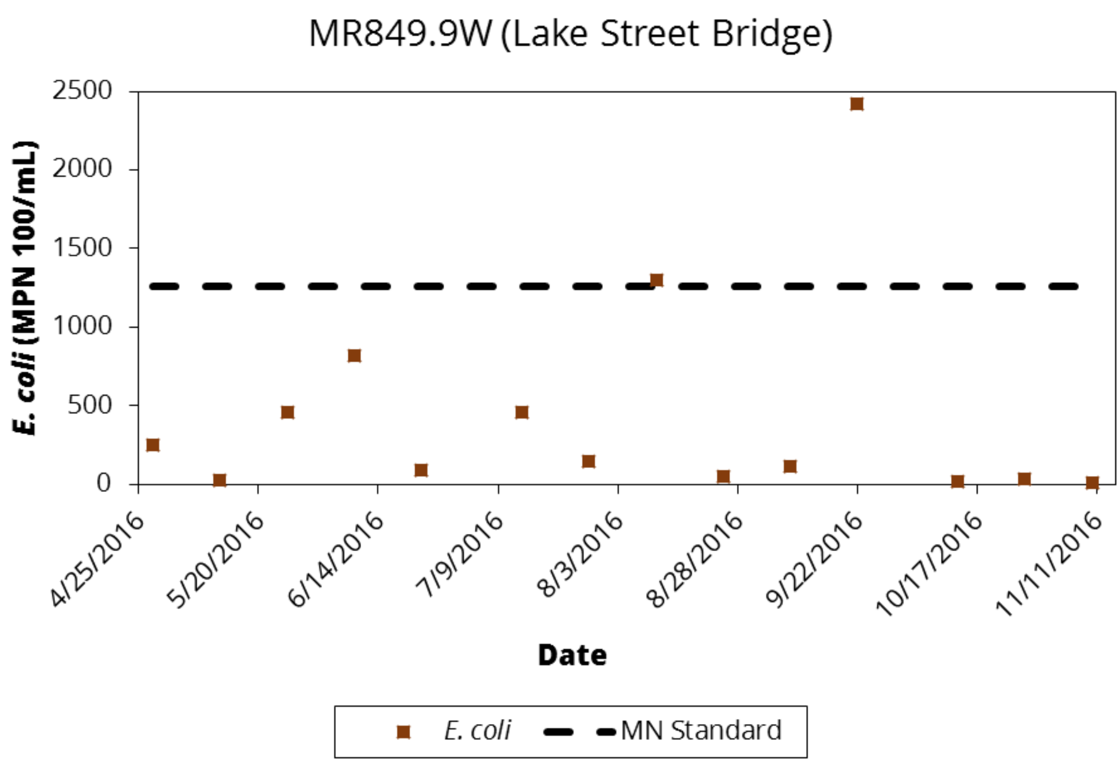

Figure B.6. *E. coli* data for MR849.9W.

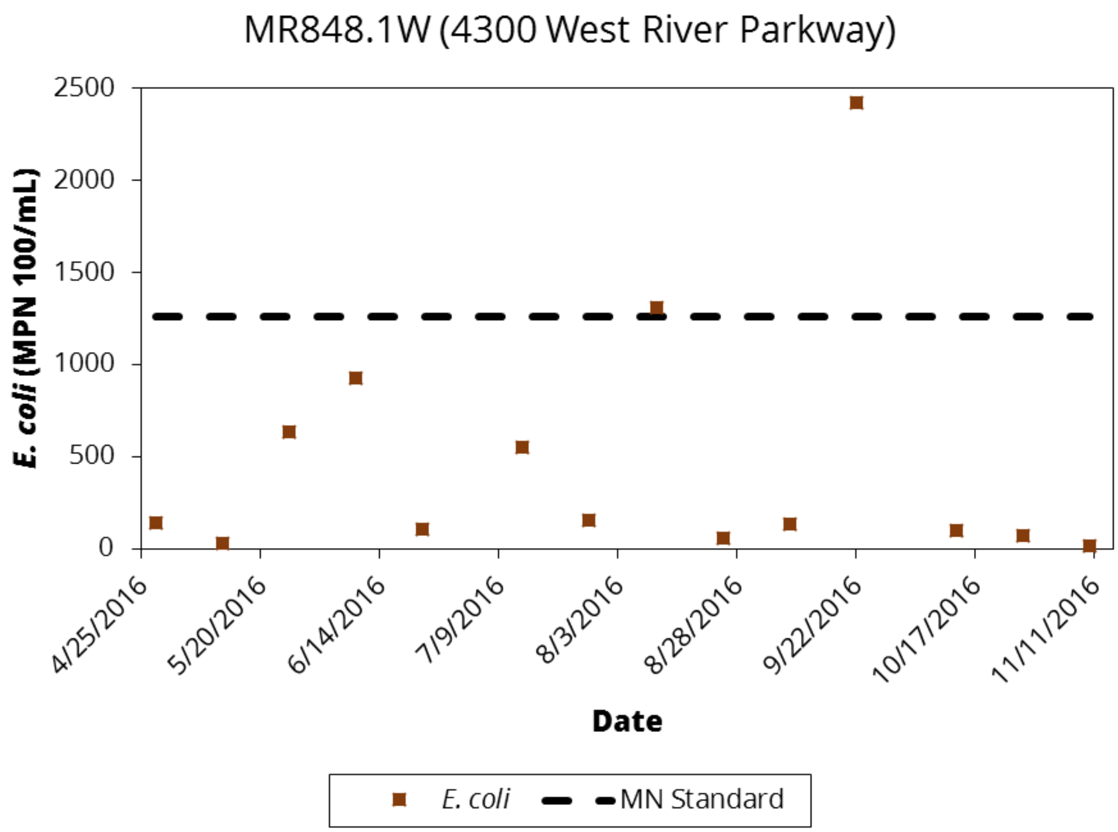

Figure B.7. *E. coli* data for MR848.1W.

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