

Technical Support Document A

Monitoring Results for the Fox Illinois River Basin TMDL

Supporting the Fox Illinois River Basin Total Maximum Daily Load (TMDL) for Phosphorus and Total Suspended Solids

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CONTENTS

1. Project Background	1
2. TMDL Monitoring Methods	3
2.1. Chemistry Sampling	3
2.2. Stage and Flow Monitoring	5
3. TMDL Monitoring Results	7
3.1. Surface Water Chemistry	7
3.2. Stage and Flows	11
3.2.1. Stage	11
3.2.2. Flows	12
4. Supplemental data	13
4.1. WDNR LTT Sites	13
4.2. Additional Water Chemistry Data	13
4.3. USGS Gages	19
4.3.1. Stage	21
4.3.2. Flow	21
5. Monitoring Data Applications	23
5.1. Rating Curve Development	23
5.2. Load Estimation	23
5.3. Watershed Model Development and Calibration	23
5.4. Next Steps for the FOXIL TMDL	23
Acknowledgements	24
References	24

FIGURES

FIGURE 1.1 The Fox Illinois TMDL Study Area and Impairments	2
FIGURE 2.1 Fox Illinois River TMDL Chemistry Monitoring Locations	4
FIGURE 2.2 Fox Illinois River TMDL Stage and Flow Monitoring Locations	6
FIGURE 3.1 Explanation of Boxplots	7
FIGURE 3.2 Total Phosphorus Concentrations at TMDL Monitoring Sites	8
FIGURE 3.3 Orthophosphate Concentrations at TMDL Monitoring Sites	9
FIGURE 3.4 Total Suspended Solids Concentrations at TMDL Monitoring Sites	10
FIGURE 3.5 Distribution of Stage Measurements during Monitoring Period	11
FIGURE 3.6 Flow Measurements Collected during the Monitoring Period	12
FIGURE 4.1 Additional Monitoring Stations in the Fox Illinois River Study Area	15
FIGURE 4.2 Total Phosphorus Concentrations at River Monitoring Sites	16
FIGURE 4.3 Total Phosphorus Concentrations at Lake Monitoring Sites	17
FIGURE 4.4 Orthophosphate Concentrations at River Monitoring Sites	18
FIGURE 4.5 Orthophosphate Concentrations at Lake Monitoring Sites	18
FIGURE 4.6 Total Suspended Solids Concentrations at River Monitoring Sites	18
FIGURE 4.7 Location of USGS Gages in the Fox Illinois River Study Area	20
FIGURE 4.8 Distribution of Stage Measurements at USGS Monitoring Sites	21

FIGURE 4.9 Distribution of Flow Rates at USGS Monitoring Sites	22
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TABLES

TABLE 2.1 Fox Illinois River TMDL Chemistry Monitoring Sites	3
TABLE 2.2 Laboratory Methods for Sample Analysis	5
TABLE 2.3 Fox Illinois Rivers TMDL Stage and Flow Monitoring Sites	5
TABLE 4.1 Seasonal Concentrations at Fox River Long-Term Trends Sites	13
TABLE 4.2 USGS Stations in the Fox Illinois River TMDL Study Area	19

APPENDICES

Appendix A Cadmus Report on Water Quality Monitoring	
Appendix B Water Quality Monitoring Results for the FOX Illinois River Basin TMDL	
Appendix C Stage Monitoring Results for the FOX Illinois River Basin TMDL	
Appendix D Flow Monitoring Results for the FOX Illinois River Basin TMDL	
Appendix E WDNR Long-Term Trends Data in the Fox Illinois River Basin TMDL Study Area	
Appendix F Supplemental Water Quality Data from SWIMS	
Appendix G USGS Stage and Flow Data	

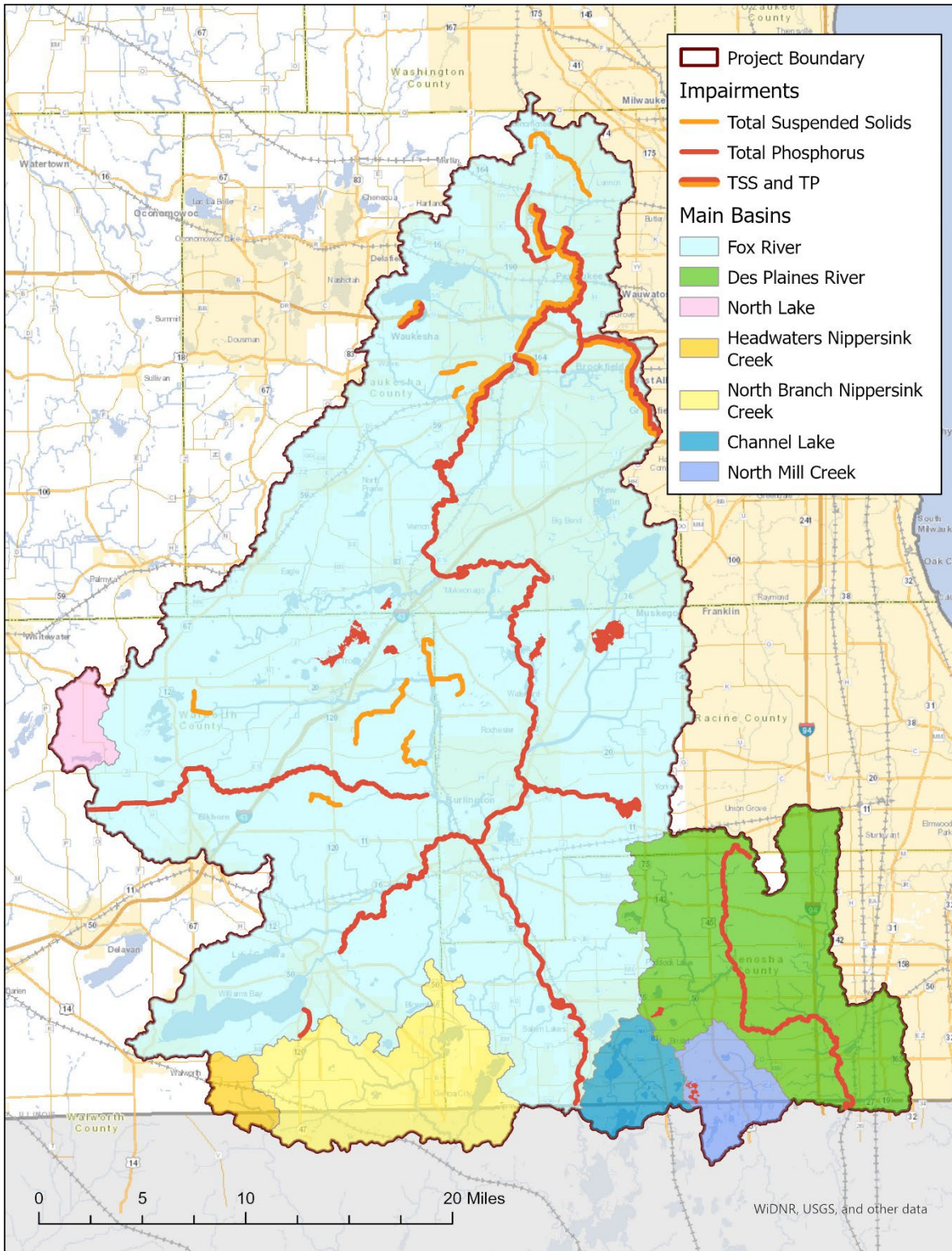
1. PROJECT BACKGROUND

The Department of Natural Resources (DNR), together with many partners, is working to improve the surface water quality of tributaries, streams, rivers, and lakes within the Fox Illinois River Basin. To strengthen these ongoing efforts, the Department will be developing a Total Maximum Daily Load (TMDL) for the river basin. The TMDL for this study area, referred to as the Fox Illinois River TMDL, will be a multi-year effort to address surface water quality impairments caused by phosphorus and total suspended solids. The TMDL study will provide a strategic framework and pollutant reduction goals for surface water quality improvement within the river basins.

The first step in developing a TMDL is collecting monitoring data to characterize existing conditions in the watershed and to support modeling efforts. The monitoring efforts for this project included chemistry, stage, and flow data collection for many sites in the TMDL basin. Monitoring was directed by the DNR and was supported by an outside contractor.

The Fox Illinois River TMDL study area is located in southeastern Wisconsin. The study area includes the Fox River, the Des Plaines River, Nippersink Creek, North Mill Creek, and Channel Lake watersheds. The study area is primarily located in Racine, Kenosha, Walworth, and Waukesha counties. It is approximately bounded by Waukesha to the north, Lake Geneva to the southwest, and the western portions of Kenosha to the southeast. The TMDL study area covers approximately 1,060 square miles within Wisconsin, which is approximately 2 percent of the state. Within the study area, some lakes and streams are impaired (WDNR, 2022b), which means they are not meeting their water quality criteria. The extent of the TMDL and the waterbodies that are currently impaired are shown in Figure 1.1.

FIGURE 1.1
The Fox Illinois TMDL Study Area and Impairments



2. TMDL MONITORING METHODS

Prior to this project, existing flow and chemistry data were available within the study area. However, there was not sufficient data to develop a model to estimate flows and loads throughout the watersheds. To supplement existing data, a large-scale monitoring program was conducted. The monitoring program lasted from December 2019 through May 2022. Water chemistry, water level, and flow data was collected. The following sections describe the methods used for the monitoring program.

2.1. Chemistry Sampling

Thirteen locations in the study area that required chemistry monitoring were identified. Monitoring was conducted by both the DNR and a private consultant, Cadmus. The DNR was responsible for five sites, and Cadmus was responsible for eight sites. Chemistry samples for total phosphorus, orthophosphate, and total suspended solids were collected. Two of DNR's sites, the Fox River at Cth I Bridge and the Fox River near New Munster, were already being monitored as part of the long-term trends program, and these sites were incorporated into the sampling efforts. A list of the monitoring stations is provided in Table 2.1, and the location of the stations is displayed in Figure 2.1. A monitoring report that summarizes Cadmus' efforts was developed by Cadmus and is provided in Appendix A.

Samples were analyzed by the Wisconsin State Lab of Hygiene, which is a certified lab affiliated with the University of Wisconsin at Madison. The State Lab of Hygiene uses approved methods for their analyses. A summary of their methods is provided in Table 2.2.

TABLE 2.1
Fox Illinois River TMDL Chemistry Monitoring Sites

SWIMS ID	SWIMS Station Name	Monitoring Entity	Chemistry Parameters
683205	Fox River - Ds Sunset Dr Bridge (Waukesha)	DNR	TP, TSS
683096	Fox River at Cth I Bridge	DNR	TP, TSS, TN, DOP, NO3, NH4
10046937	Fox River at CTH ES	Cadmus	TP, TSS, DOP
303066	Fox River (II) - Nr New Munster Cthjb	DNR	TP, TSS, TN, DOP, NO3, NH4
10032437	Fox River at STH 20/30 Waterford	Cadmus	TP, TSS, DOP
10053867	Fox River at Case Eagle Park Bridge ¹	Cadmus	TP, TSS, DOP
10010534	Mukwonago River (1) - Upstream of HWY 83	Cadmus	TP, TSS, DOP
643555	Muskego (Big Muskego) Lake - Outlet Near Wind Lake	DNR	TP, TSS
10013090	Wind Lake Canal_Wind Lake Upstream To Ceasars Dam	DNR	TP, TSS
10040134	Honey Creek at CTH DD/Academy Rd	Cadmus	TP, TSS, DOP
10029083	Sugar Creek at Potter Road	Cadmus	TP, TSS, DOP
10012203	White River - 10 M Upstream Of Hwy 36	Cadmus	TP, TSS, DOP
303054	Des Plaines River at Cth ML	Cadmus	TP, TSS, DOP

1. The Fox River at Case Eagle Park replaced an original monitoring site at Fox River above Rochester Dam at Highway D (10021230) due to unsatisfactory conditions at the original site.

Parameters: DOP = Dissolved orthophosphate, NH4 = Ammonium, NH3 = Nitrate, TN = Total Nitrogen, TP = Total Phosphorus, TSS = Total Suspended Solids

**FIGURE 2.1
Fox Illinois River TMDL Chemistry Monitoring Locations**

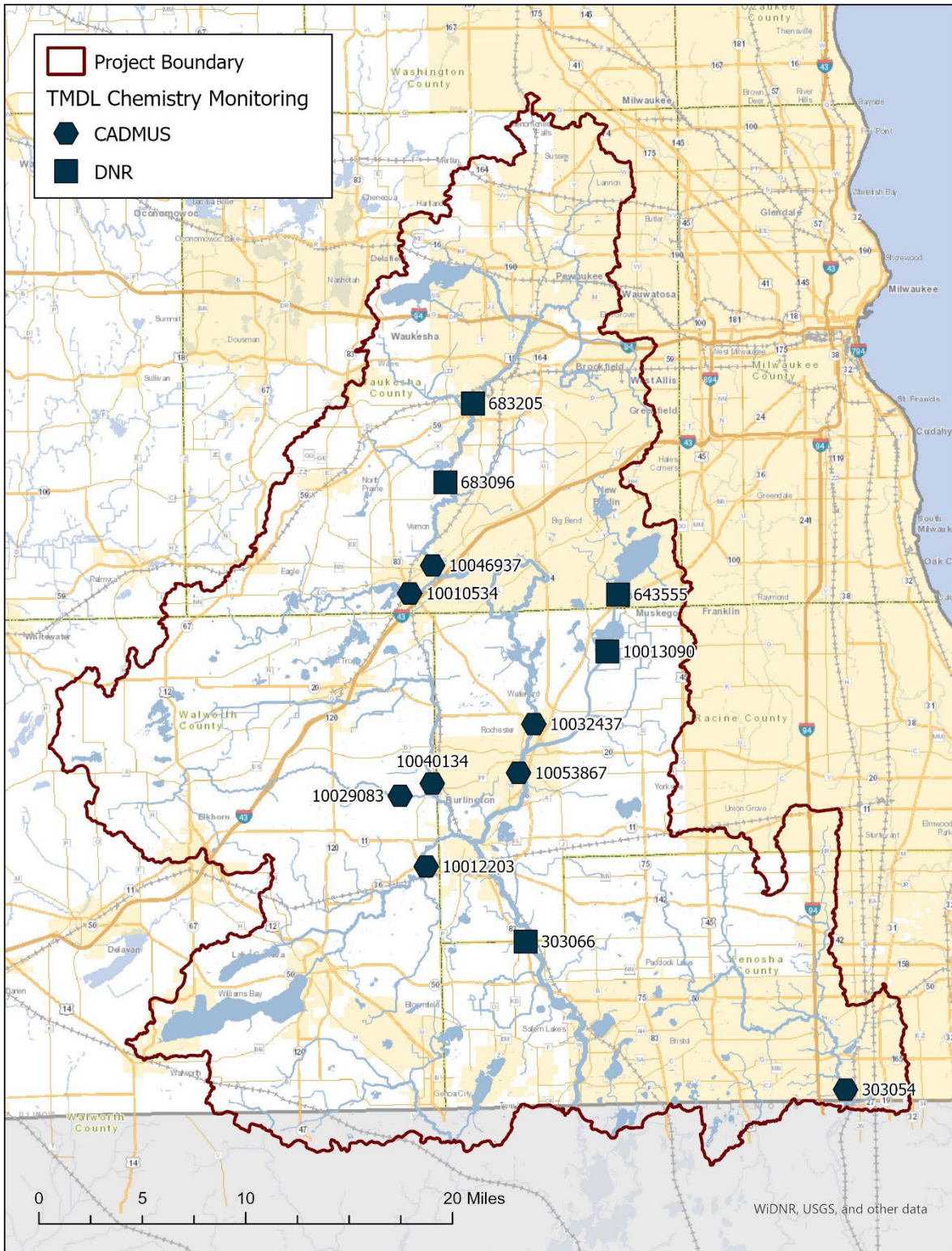


TABLE 2.2
Laboratory Methods for Sample Analysis

Parameter	Parameter Code	Method	Units	LOD	LOQ
Total Suspended Solids	530	SM2540D	MG/L	2.5	2.5
Phosphate Ortho DISS	671	EPA 365.1	MG/L	0.00400	0.0130
Phosphorus Total	665	EPA 365.1	MG/L	0.00900	0.0300

2.2. Stage and Flow Monitoring

In addition to chemistry monitoring, stage and flow monitoring was required. The DNR monitored both flow and stage data at five sites and monitored only flow data at four sites. The sites with only flow measurements were located near gages maintained by the United States Geological Survey (USGS) that had available stage data. A summary of the stage and flow monitoring sites is provided in Table 2.3, and the location of each site is provided in Figure 2.2.

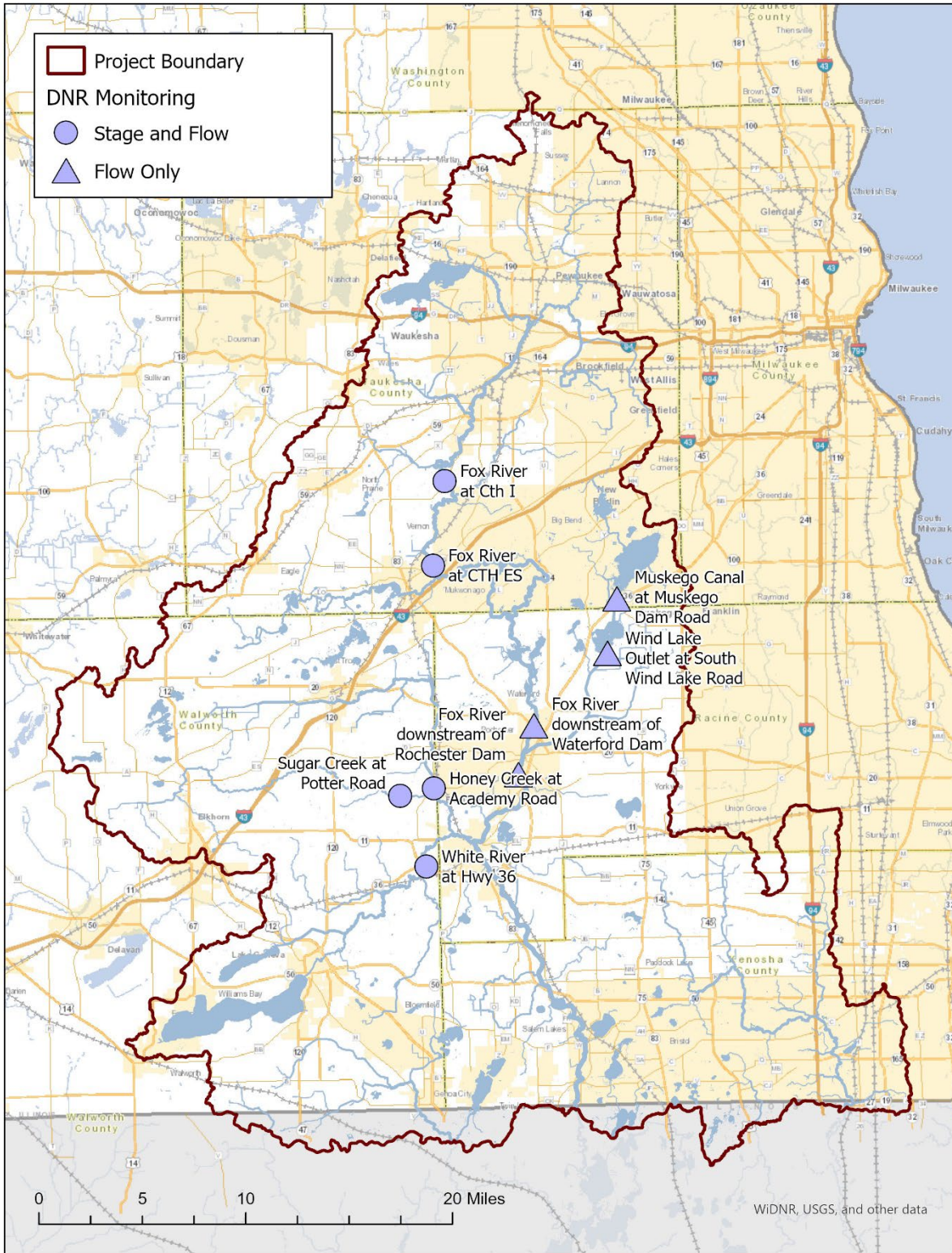
TABLE 2.3
Fox Illinois Rivers TMDL Stage and Flow Monitoring Sites

Stage and Flow Measurement Location	Stage data	Flow Data
Fox River at Cth I	DNR	DNR
Fox River at CTH ES	DNR	DNR
Honey Creek at Academy Road	DNR	DNR
Sugar Creek at Potter Road	DNR	DNR
White River at Hwy 36	DNR	DNR
Fox River downstream of Waterford Dam	USGS	DNR
Fox River downstream of Rochester Dam	USGS	DNR
Muskego Canal at Muskego Dam Road	USGS	DNR
Wind Lake Outlet at South Wind Lake Road	USGS	DNR

Continuous stage data were measured using HOB0 pressure transducers. The pressure transducers were installed in the water, and the elevation of the transducers were surveyed relative to a specified benchmark to establish a water surface elevation. Sites were periodically visited so staff could download data and resurvey the pressure transducer elevation to evaluate any movement of the transducer. The pressure transducers measured water temperature and total pressure at 15-minute intervals. The data were corrected for atmospheric pressure to calculate total water depth above the transducer.

Flow monitoring data were collected using a Teledyne Acoustic Doppler Current Profiler (ADCP). The ADCPs were deployed from a boat traveling perpendicular to the current and measured cross-section geometry and flow velocities to calculate a total flow rate. Multiple passes across the river were completed until an adequate flow measurement was established. Flow measurements were collected on a monthly basis with a goal of measuring the river or stream at low, average, and high flow rates.

**FIGURE 2.2
Fox Illinois River TMDL Stage and Flow Monitoring Locations**



3. TMDL MONITORING RESULTS

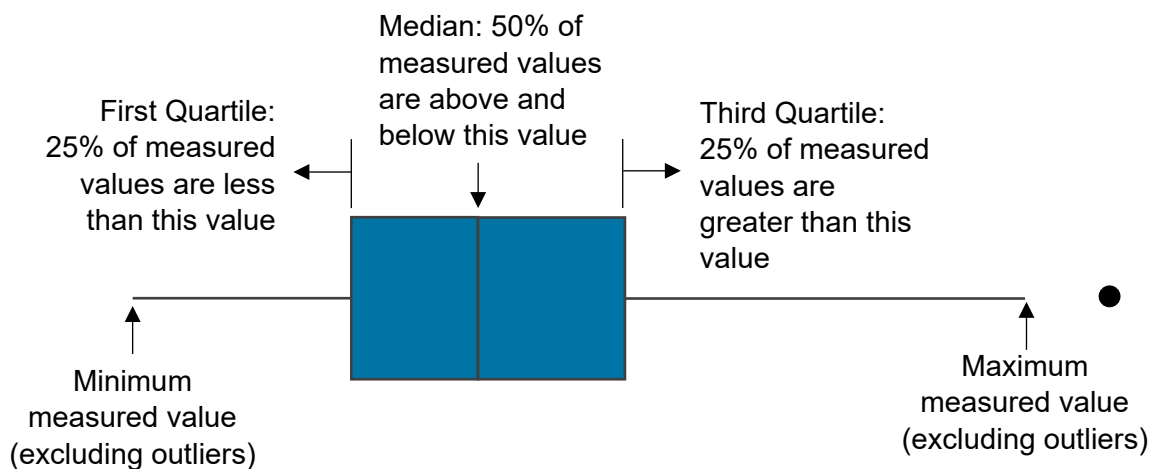
The monitoring strategy described in the previous section resulted in a large dataset that will be used to develop a model to estimate the loadings and concentrations in surface waters in the study area. The dataset includes both chemistry data and stage and flow data. The following sections summarize the results of the monitoring.

3.1. Surface Water Chemistry

Surface water chemistry is commonly evaluated for different time periods. First, data over the course of the entire year can be combined and compared to estimate average annual water quality. Additionally, data can be summarized using only data from the growing season, which spans from May 1 to October 31 for flowing waters. Both methods provide insights about the sources and dynamics of nutrients and sediment in surface water.

The distribution of measured samples is visualized using boxplots, which are explained in Figure 3.1. Results from the water quality monitoring for the TMDL are provided in Figure 3.2 for total phosphorus, Figure 3.3 for orthophosphate, and Figure 3.4 for total suspended solids. The figures display the distribution of results for both samples collected for all months of the year and samples collected during the growing season. Additional information about the water chemistry sampling is provided in Appendix B.

FIGURE 3.1
Explanation of Boxplots



Note: Points indicate outliers, which are measured values that are a abnormal distance from other values

FIGURE 3.2
Total Phosphorus Concentrations at TMDL Monitoring Sites

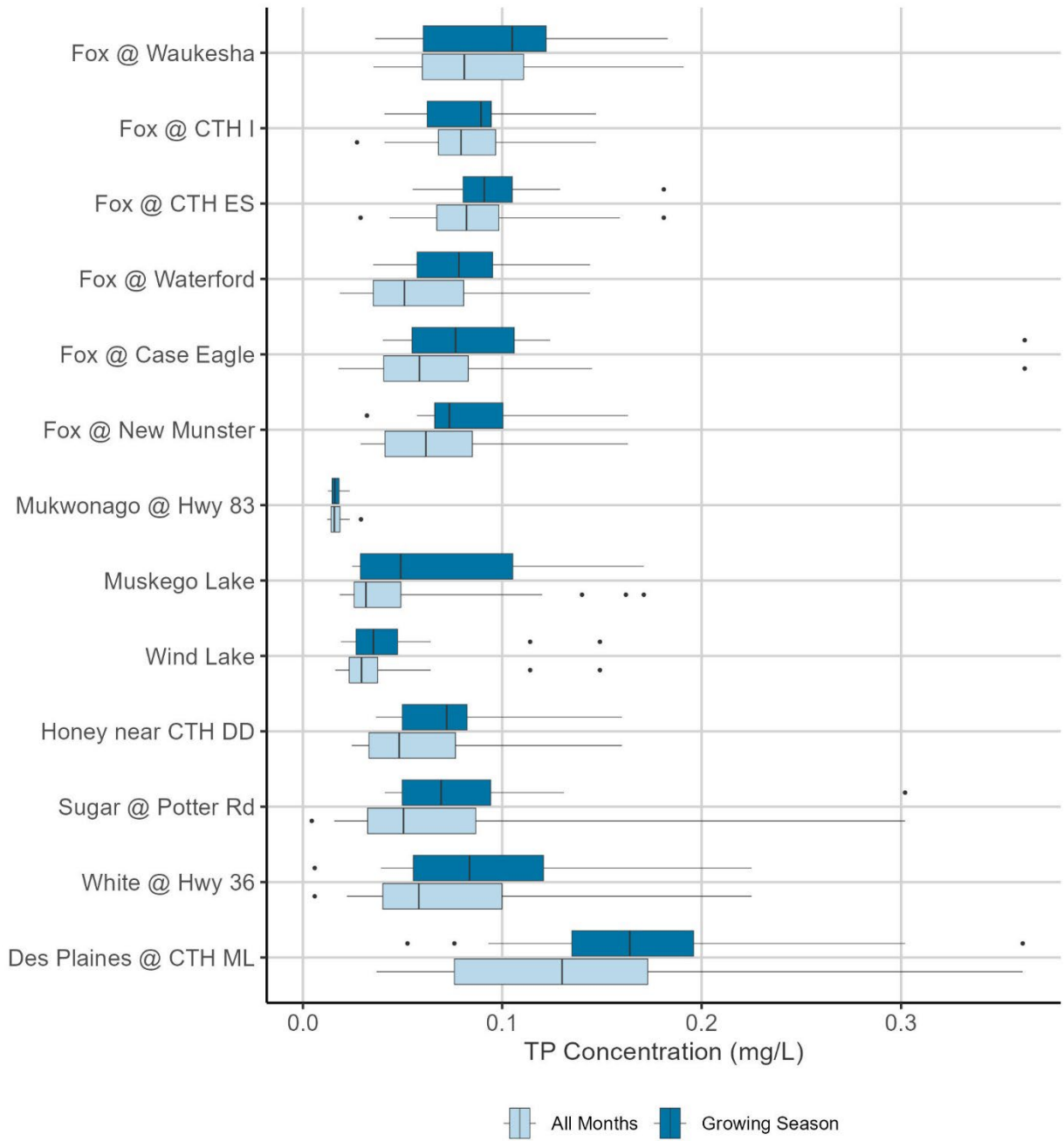


FIGURE 3.3
Orthophosphate Concentrations at TMDL Monitoring Sites

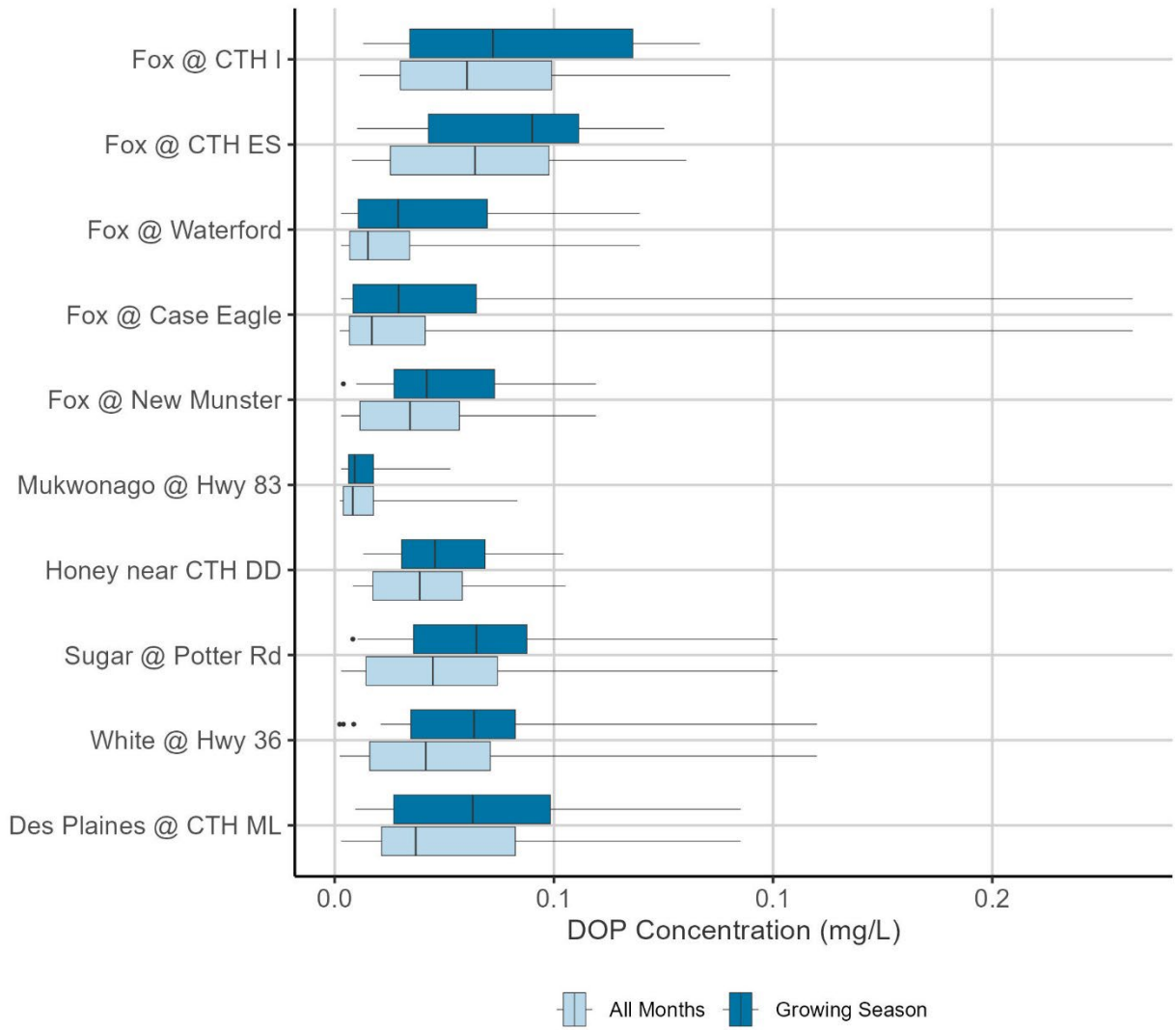
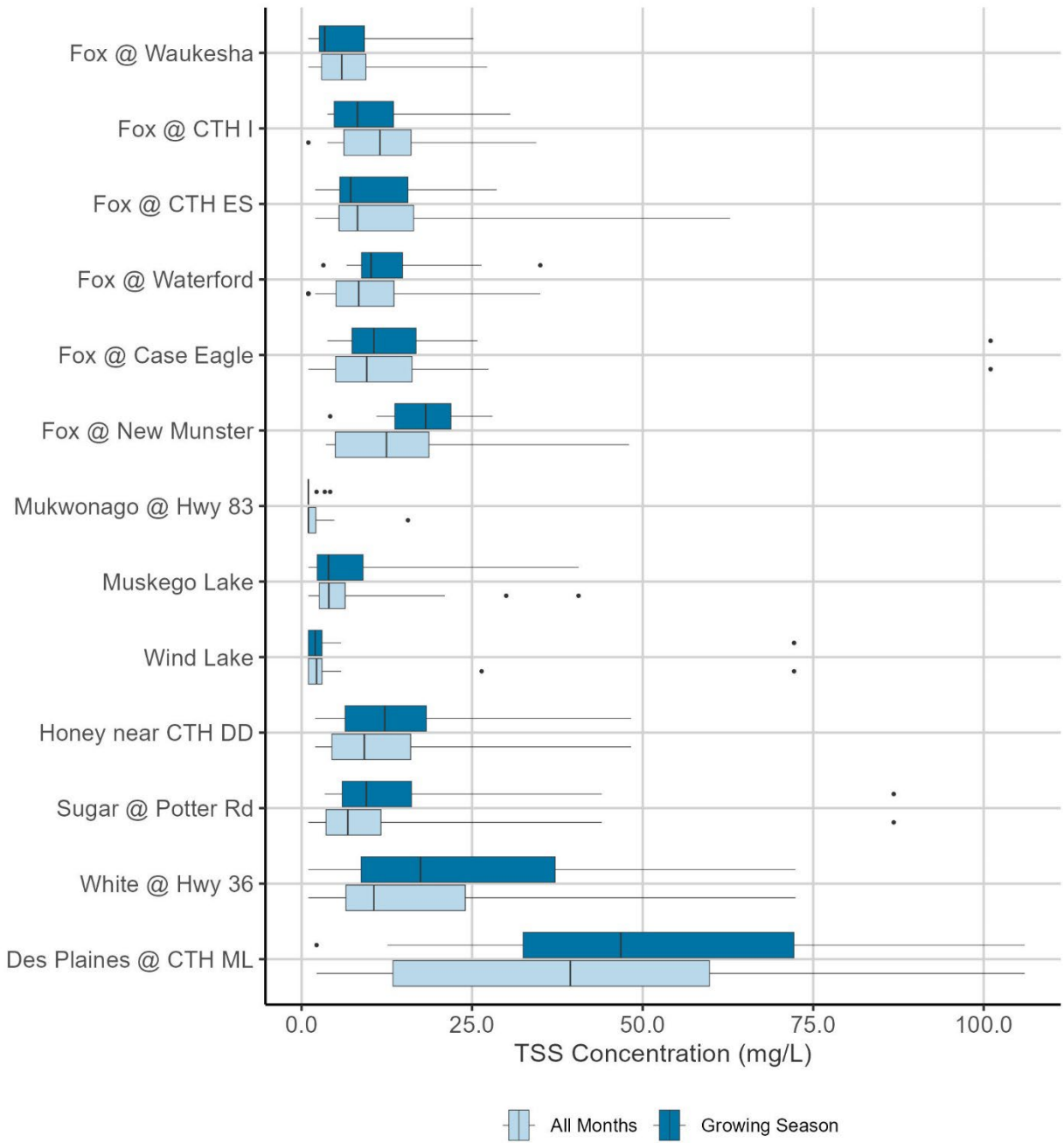


FIGURE 3.4
Total Suspended Solids Concentrations at TMDL Monitoring Sites



3.2. Stage and Flows

Stage and flow data were measured at the sites identified in Section 2. The following sections summarize the results of the stage and flow measurements.

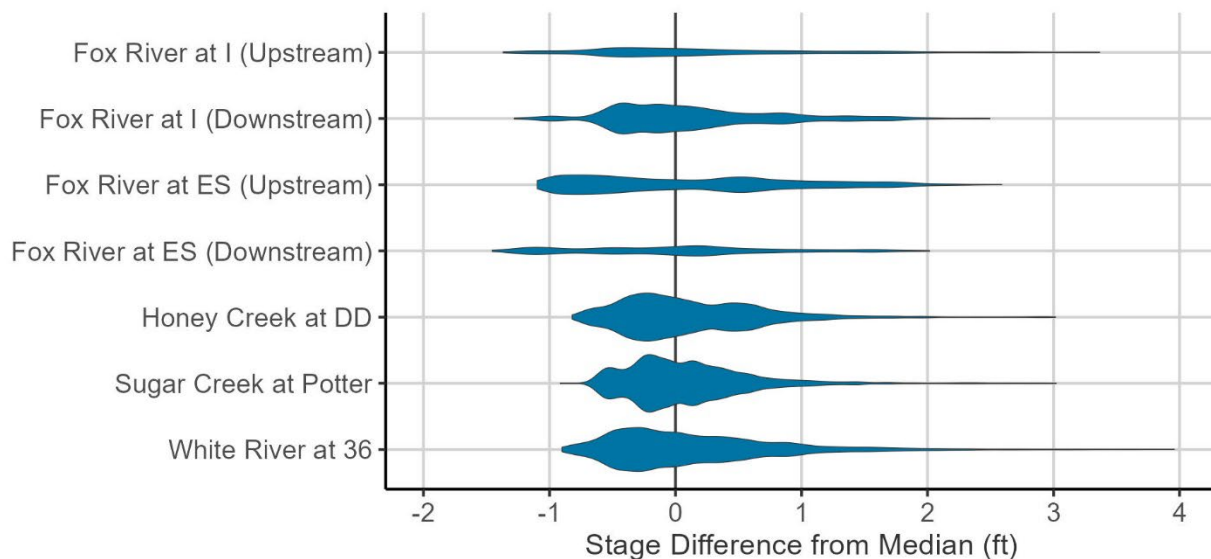
3.2.1. Stage

Stage data were calculated using the measurements from the pressure transducers described in Section 2. The pressure transducers were deployed near the sites listed in Table 2.3. Pressure transducers for the Fox River at Highway I and the Fox River at ES were relocated during the monitoring period due to site conditions. A summary of stage data and data notes for the pressure transducers over the monitoring period are provided in Appendix C.

Calculating the depth of water above the pressure transducer and a corresponding stage requires adjusting the pressure measurements from the pressure transducers. The adjustment requires data about atmospheric pressure, air temperature, and water temperature. Stage represents the height of water above the water surface relative to a specified benchmark. A detailed summary of the process of converting measurements from the pressure transducers to depth and stage data is provided in Appendix C.

The range of stages measured at each site is provided in Figure 3.5. The figure shows the distribution of measurements relative to the median measured stage during the monitoring period. The thickness of the blue areas in the figure represents the frequency of measurements at that specific stage. Thicker areas in the figure indicate many measurements at that stage, and thinner areas indicate few measurements at that stage. The total width of the measurements represents the total range in depth differences measured. For example, the depth of Honey Creek varied by about 3.5 feet during the monitoring period, and the depth of the White River varied by about 5 feet during the monitoring period.

FIGURE 3.5
Distribution of Stage Measurements during Monitoring Period

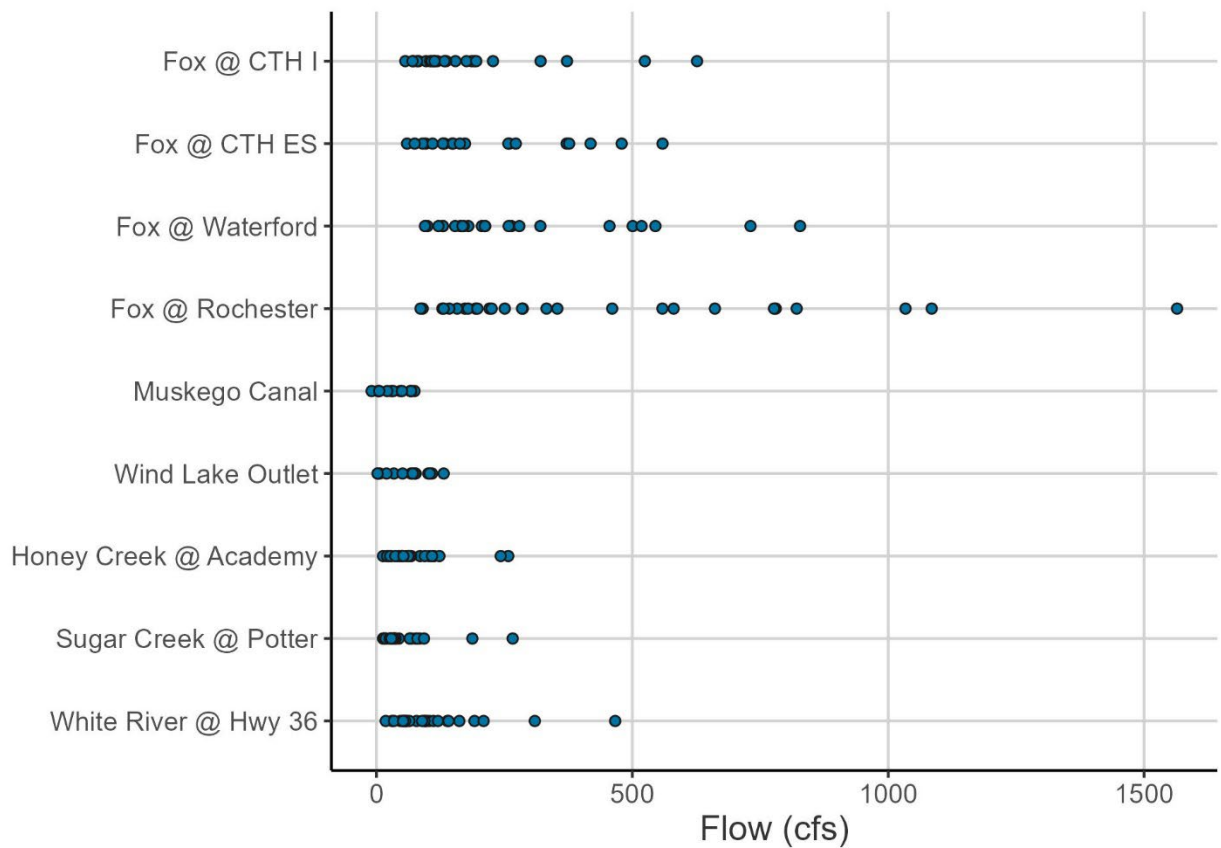


3.2.2. Flows

Flow data were collected between December 2019 and May 2022. The monitoring strategy aimed to obtain monthly flow measurements at each of the 9 stations across the 30 month monitoring period. Additional measurements were collected in September 2020 and April 2022. Throughout the monitoring period, some measurements were not collected. The challenges leading to data not being collected are summarized in Appendix D.

A summary of flow measurements collected during the monitoring period is provided in Figure 3.6. Each of the points on the graph represent a single flow measurement. Additional details about the flow measurements are provided in Appendix D.

FIGURE 3.6
Flow Measurements Collected during the Monitoring Period



4. SUPPLEMENTAL DATA

The data collected for the project were required to ensure proper development and calibration of a watershed model. However, additional water chemistry and flow data are available in the basin. This supplemental data may also be incorporated into model development, and the available data are described in the following sections.

4.1. WDNR LTT Sites

The DNR maintains long-term trends (LTT) sites for major water bodies throughout the state. Water chemistry data are collected at these sites on a regular basis to track water quality changes over time. Two LTT sites are located within the study area: one at the Fox River below Waukesha and one at the Fox River near New Munster. Parameters at these sites include total phosphorus, orthophosphate, and total suspended solids. The DNR maintains an online viewer to visualize the changes in water quality over time (WDNR, 2022a). A summary of seasonal concentration estimates provided in the viewer are displayed in Table 4.1. Detailed outputs from the viewer are provided in Appendix E.

TABLE 4.1

Seasonal Concentrations at Fox River Long-Term Trends Sites

Location	Location	Trend since 2012	Seasonal Estimate of River Concentration (mg/L) at Mean Flow (2020)			
			Winter	Spring	Summer	Fall
Total Phosphorus	Waukesha	Decreasing	0.071	0.095	0.12	0.088
	New Munster	Decreasing	0.035	0.071	0.11	0.057
Orthophosphate	Waukesha	Decreasing	0.030	0.018	0.058	0.049
	New Munster	No Trend	0.008	0.018	0.047	0.020
Total Susp. Solids	Waukesha	No Trend	10.8	24.7	16.6	10.7
	New Munster	Decreasing	4.23	12.6	27.8	11

4.2. Additional Water Chemistry Data

The Department of Natural Resources and other entities – such as USGS, citizen monitors, sewer utilities, and watershed groups – have collected data in the Fox Illinois TMDL project area that are separate from the targeted monitoring that was conducted for the TMDL project. Additional water chemistry data were downloaded from the DNR’s Surface Water Integrated Monitoring System, which is also known as SWIMS (WDNR, 2023a). SWIMS consolidates water quality data collected by a number of partners and entities performing water quality monitoring in Wisconsin. These data will be used to supplement the data described in Sections 2 and 3.

Data from SWIMS for stations within the project area were downloaded for samples collected between 2011 through 2022. The timeframe was chosen because it corresponds with the time period that will be modeled with the watershed model. These data were further filtered to only include data from lake stations with two or more years with four or more samples and river stations with 12 or more samples. The thresholds for the number of samples were chosen because they correspond to the data requirements for classifying total phosphorus impairments (WDNR, 2023b)

and river load estimation (Runkel and others, 2004). The supplemental data may be used during the calibration and validation of the watershed model.

Locations of the SWIMS monitoring sites are shown in Figure 4.1. Data are available for both lakes and rivers. Total phosphorus measurements for rivers and lakes are summarized in Figures 4.2 and 4.3. Orthophosphate measurements for rivers and lakes are summarized in Figures 4.4 and 4.5. Total suspended solids measurements for rivers are summarized in Figure 4.6. The summaries present results for samples collected during all months and samples collected during the growing season. The growing season is defined as May 1st through October 31st for rivers and June 15th through September 15th for lakes. Additional information about the water quality data available for the study area is provided in Appendix F.

FIGURE 4.1
Additional Monitoring Stations in the Fox Illinois River Study Area

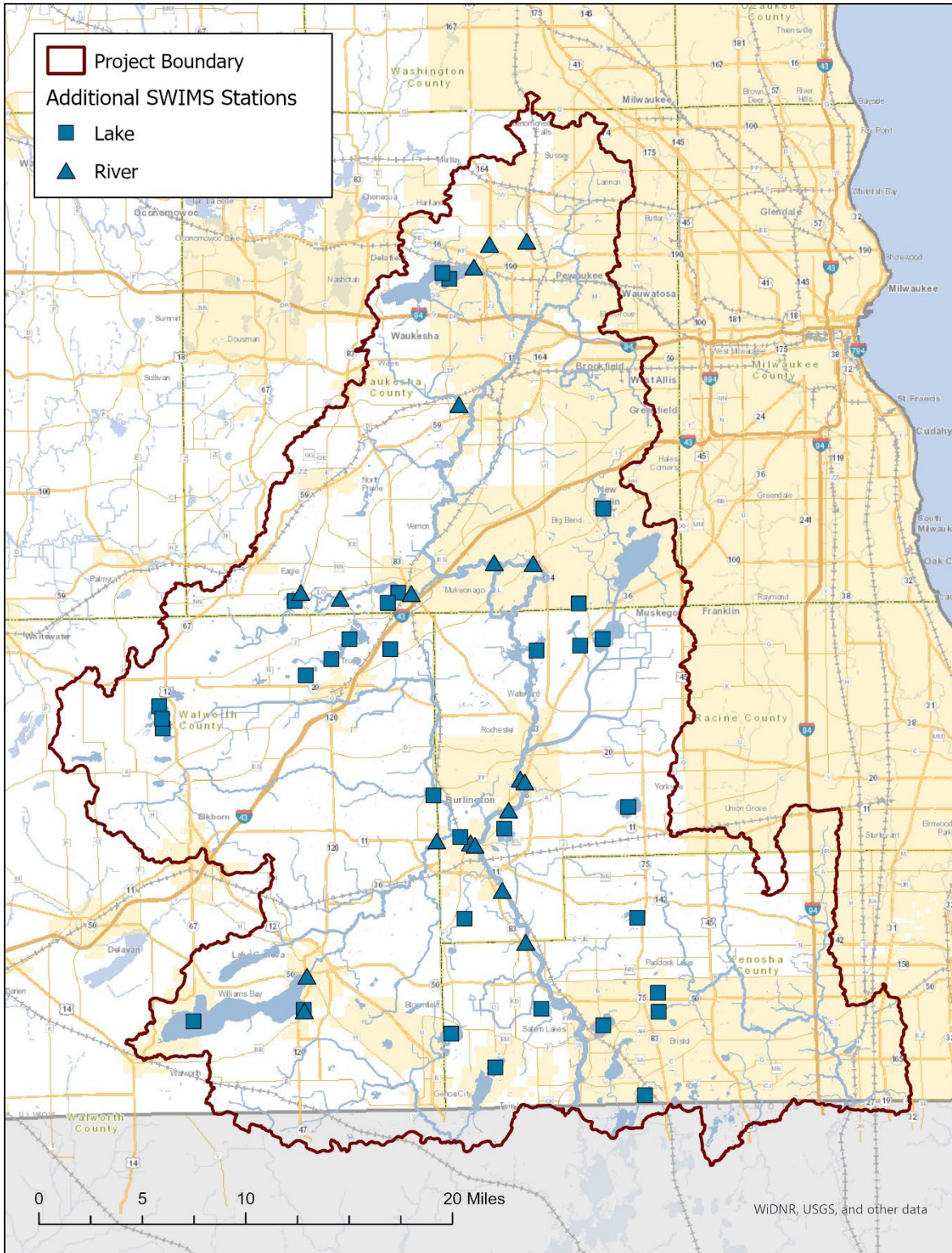


FIGURE 4.2

Total Phosphorus Concentrations at River Monitoring Sites

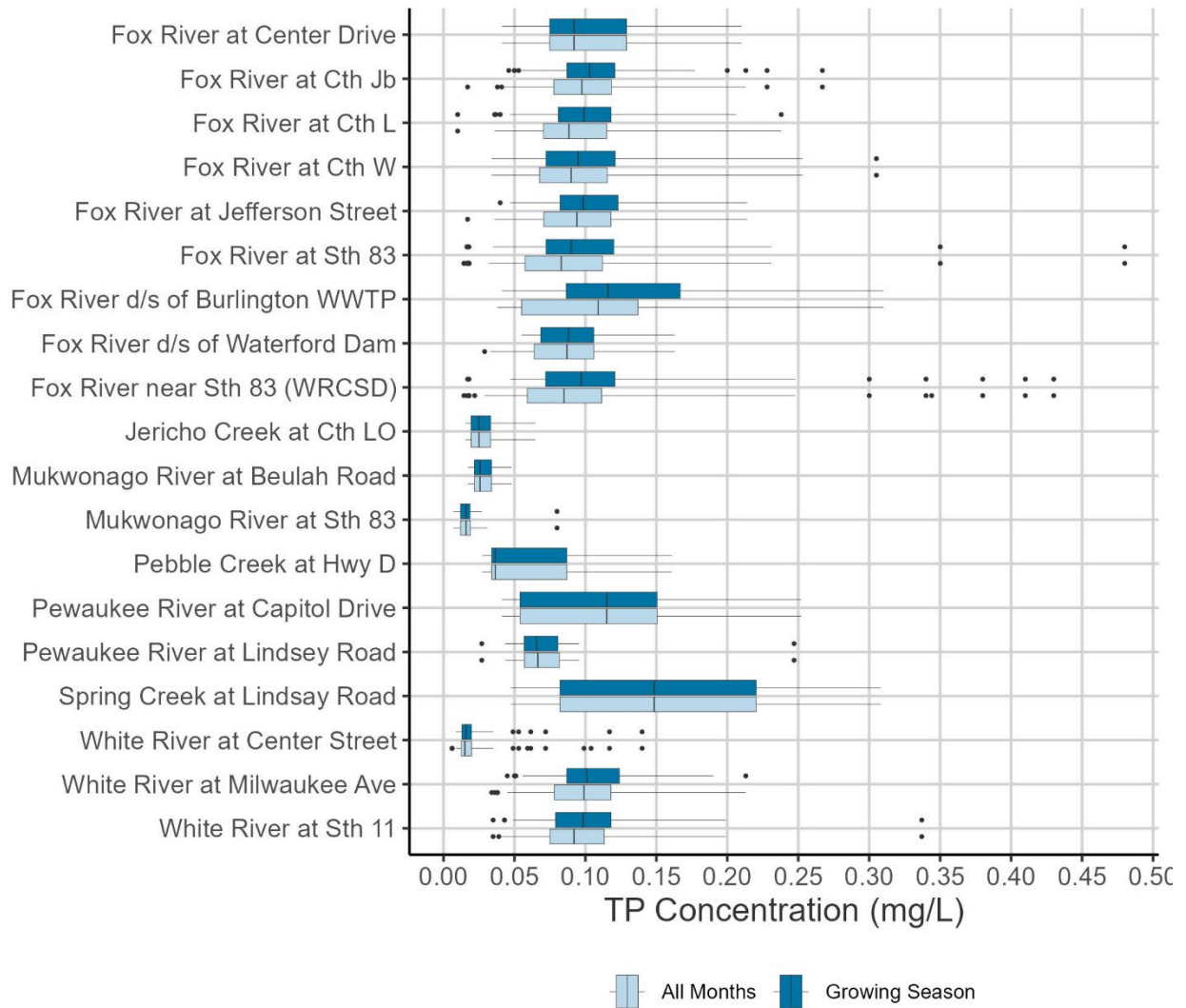
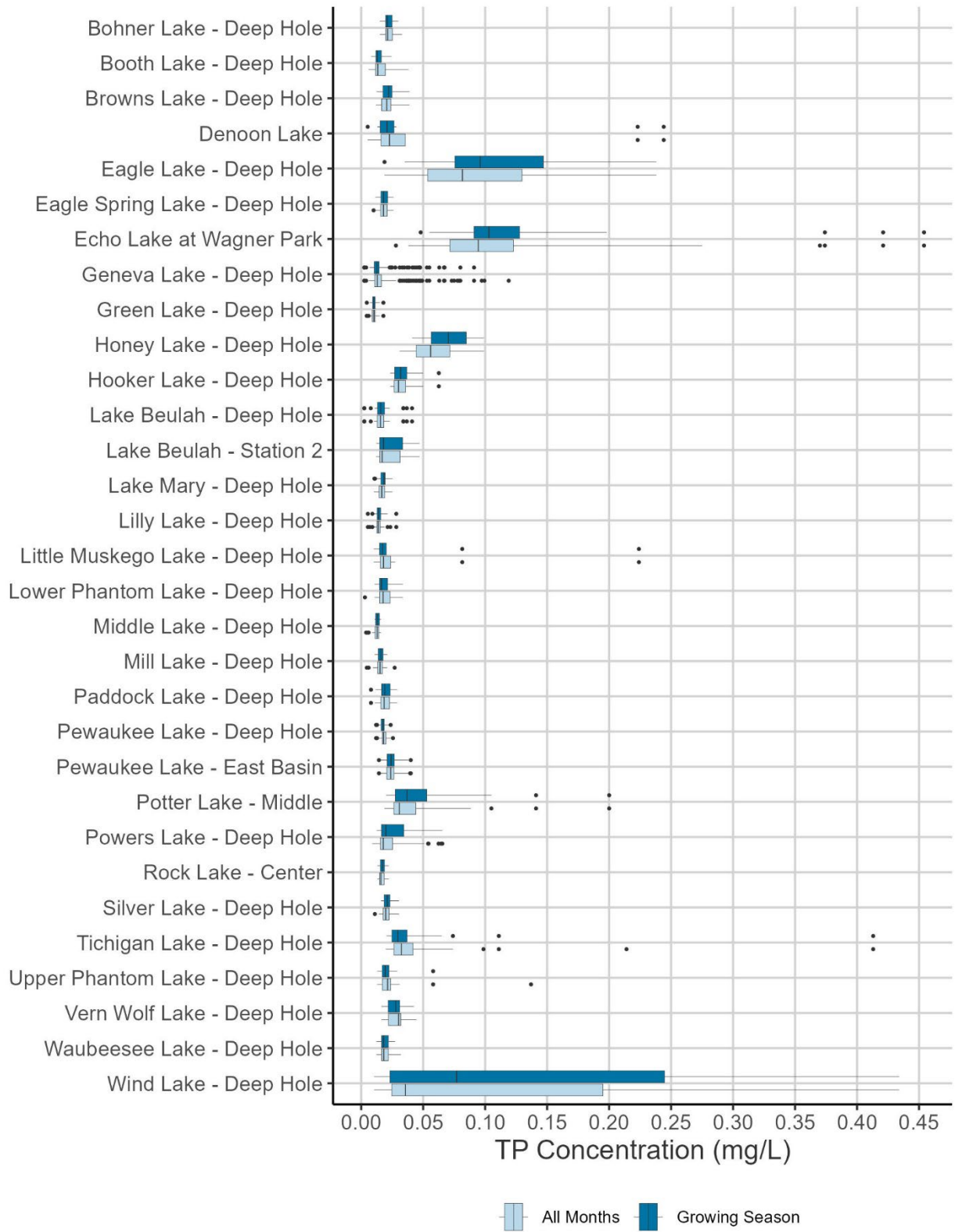
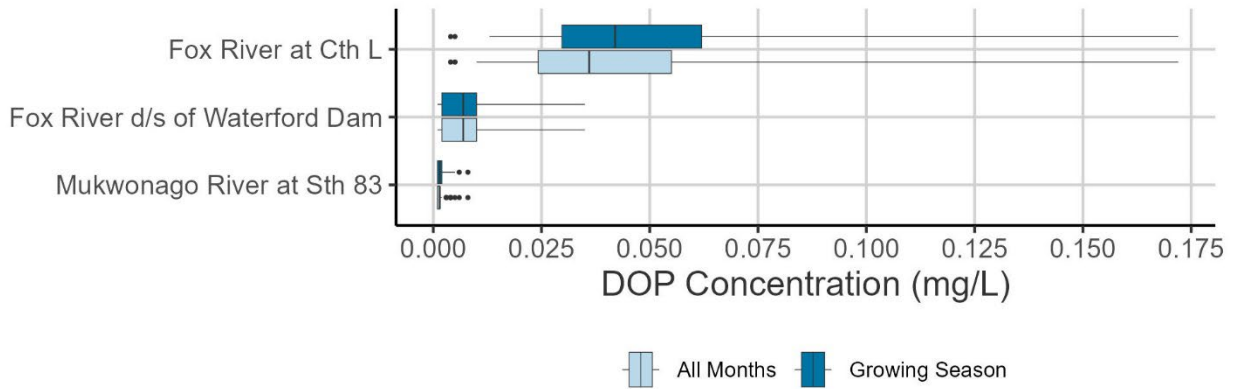


FIGURE 4.3

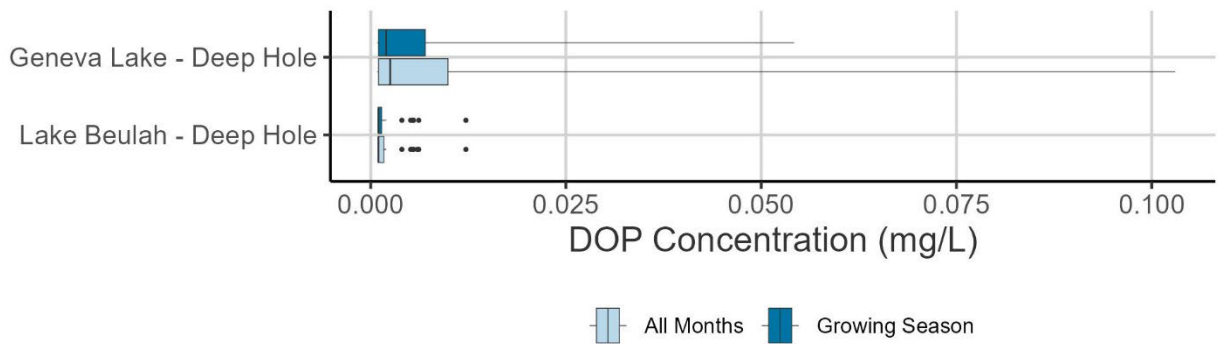
Total Phosphorus Concentrations at Lake Monitoring Sites



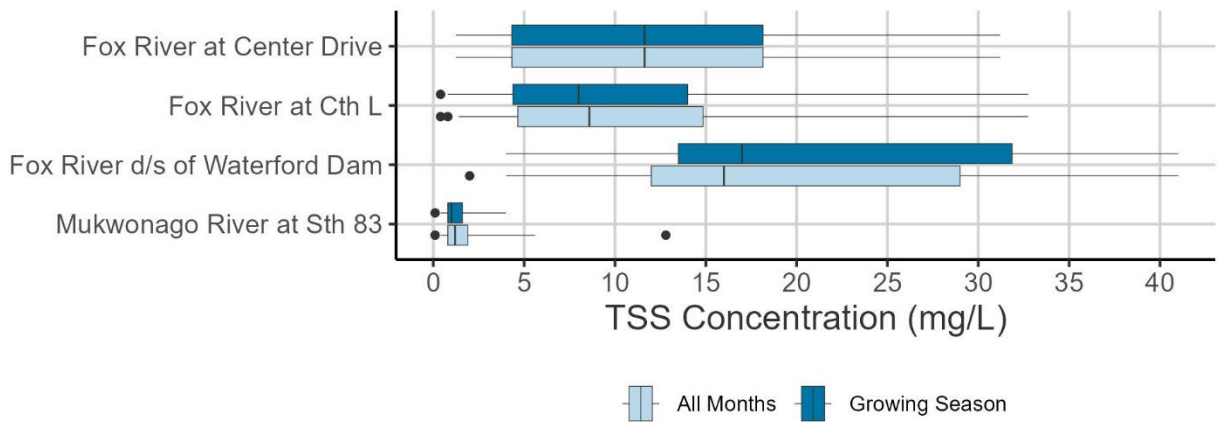
**FIGURE 4.4
Orthophosphate Concentrations at River Monitoring Sites**



**FIGURE 4.5
Orthophosphate Concentrations at Lake Monitoring Sites**



**FIGURE 4.6
Total Suspended Solids Concentrations at River Monitoring Sites**



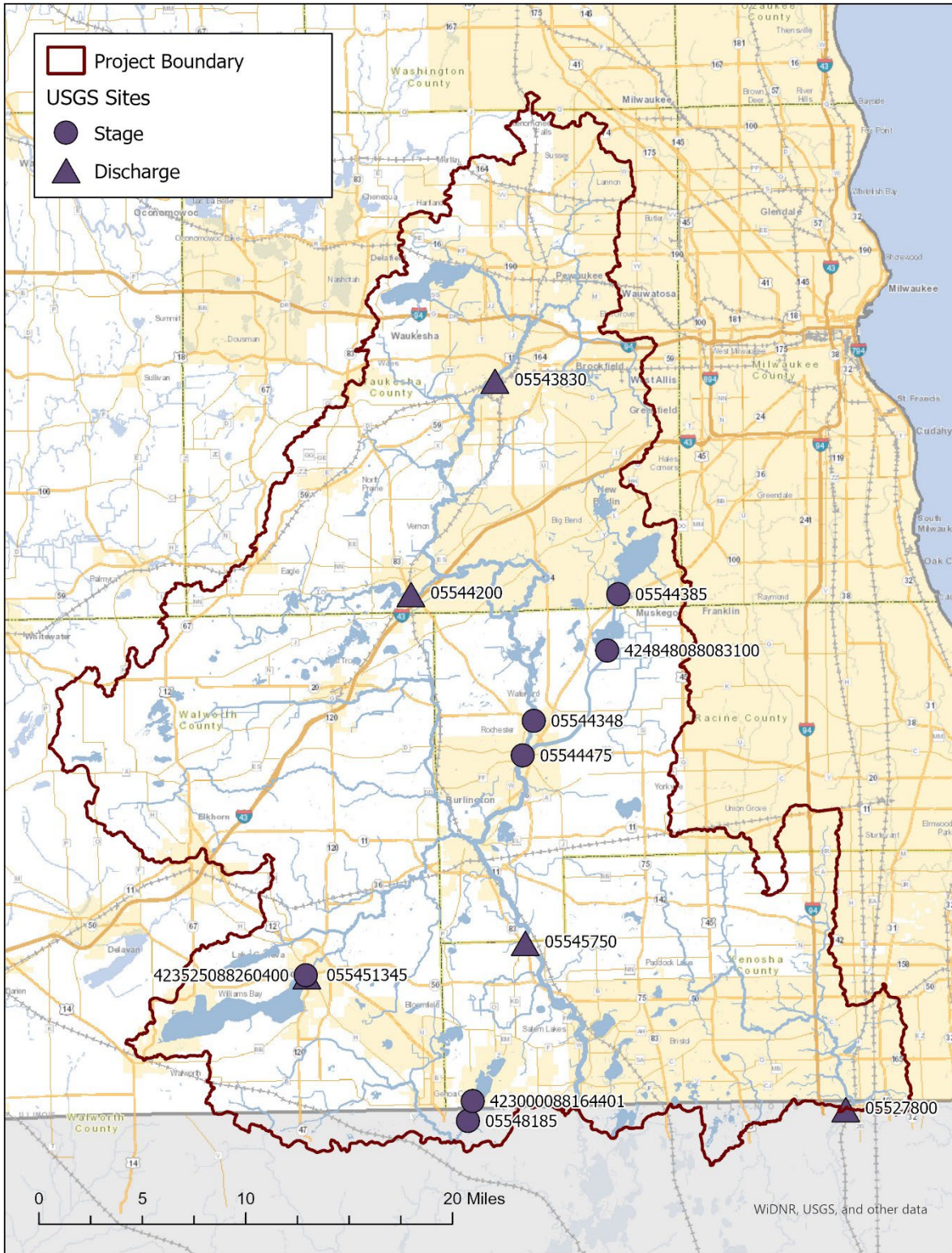
4.3. USGS Gages

The United States Geological Survey (USGS) maintains a number of gages in the study area (USGS, 2023). Data from the gages are reported as stage, flow, or stage and flow. Gages with stage data provide continuous measurements of the depth of water above a pre-specified point. Gages with flow data provide continuous measurements of flow based on the stage and a calculated rating curve that relates stage to flow. Twelve USGS gages in the study area are active and report data that are useful for assessing the watersheds. The USGS gages evaluated are listed in Table 4.2, and the location of the gages is provided in Figure 4.7.

TABLE 4.2
USGS Stations in the Fox Illinois River TMDL Study Area

Station ID	Station Name	Type
5527800	Des Plaines River at Russell, IL	Flow
5543830	Fox River at Waukesha, WI	Flow
5545750	Fox River near New Munster, WI	Flow
5544200	Mukwonago River at Mukwonago, WI	Flow
55451345	White River at Center Street at Lake Geneva, WI	Flow
423000088164401	Elizabeth Lake at Twin Lakes, WI-IL	Stage
5548185	Elizabeth Lake Drain near Twin Lakes, WI-IL	Stage
5544475	Fox River at Rochester, WI	Stage
5544348	Fox River at Waterford Dam, at Waterford, WI	Stage
423525088260400	Geneva Lake at Lake Geneva, WI	Stage
5544385	Muskego (Big Muskego) Lake Outlet Nr Wind Lake, WI	Stage
424848088083100	Wind Lake at Outlet at Wind Lake, WI	Stage

FIGURE 4.7
Location of USGS Gages in the Fox Illinois River Study Area

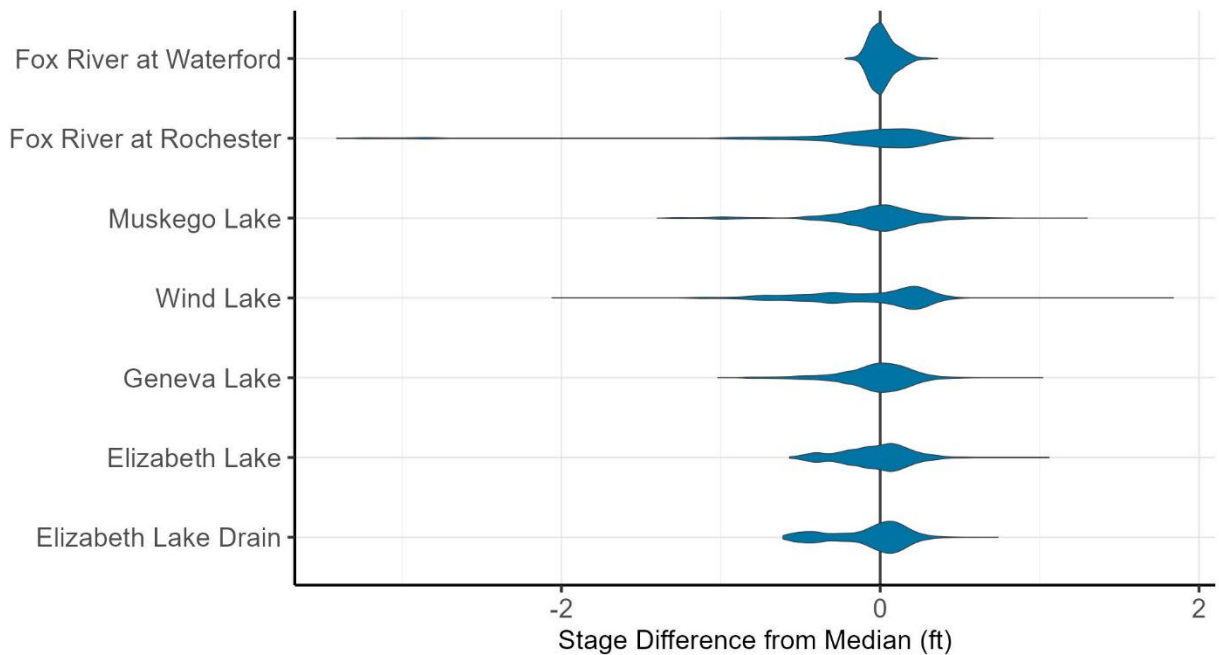


4.3.1. Stage

Seven active stage gages measure the stage at rivers and lakes in the study area. Gages are located in Elizabeth Lake, the Fox River, Geneva Lake, Muskego Lake, and Wind Lake. For the sites on flowing waterbodies that only have stage data, flow data are not estimated because USGS has not defined a rating curve at these sites.

The distribution of stages measured at each USGS site is provided in Figure 4.8. The figure shows the distribution of measurements relative to the median measured stage for the entire period of record. The thickness of the blue areas in the figure represents the frequency of measurements at that specific stage. Thicker areas in the figure indicate many measurements at that stage, and thinner areas indicate few measurements at that stage. The total width of the measurements represents the total range in depth differences measured.

FIGURE 4.8
Distribution of Stage Measurements at USGS Monitoring Sites

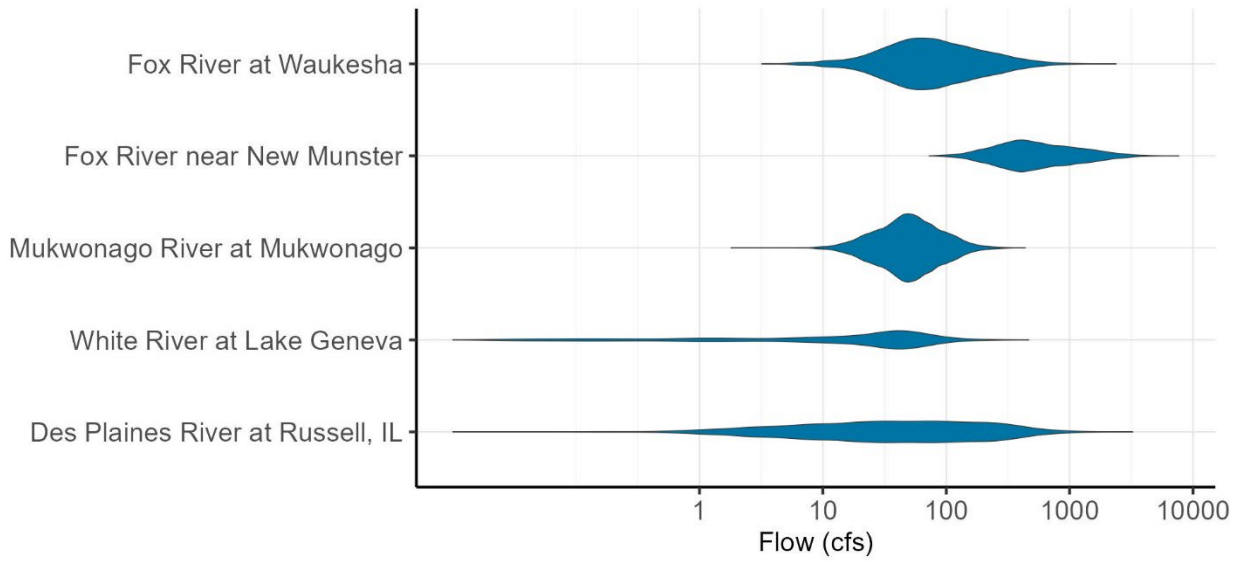


4.3.2. Flow

Five active flow gages measure the flow on rivers in the study area. The gages are located in the Fox River, the Mukwonago River, the White River, and the Des Plaines River. Flow data are estimated by applying a rating curve to measured stage data. The rating curve describes the relationship between stage and flow in a specific river. Rating curves for the five flow gages are provided in Appendix G.

The distribution of flow data for each site is displayed in Figure 4.9. The figure shows the distribution of flow rates over the period of record. The thickness of the blue areas in the figure represents the frequency of flows at that specific stage. Thicker areas in the figure indicate many measurements at that flows, and thinner areas indicate few measurements at that flow. The total width of the measurements represents the total range in flows for each site. Note that the figure is plotted on a logarithmic scale.

FIGURE 4.9
Distribution of Flow Rates at USGS Monitoring Sites



5. MONITORING DATA APPLICATIONS

The chemistry and flow data collected during the TMDL monitoring period and the supplemental data available from other sources are essential for the development and calibration of a watershed model. In order to use the data in watershed modeling, additional transformations and calculations are required. The transformations and calculations required include development of rating curves load estimates. The following sections summarize these steps.

5.1. Rating Curve Development

Continuous stage data are collected at a high frequency, but flow data are only collected periodically. A continuous record of estimated flow can be developed by combining observed stage data with observed flow data to create rating curves. A rating curve establishes a relationship between flow and stage over a range of flow conditions. After rating curves are developed, they are applied to the stage data to provide a continuous estimate of flow during the entire monitoring period.

5.2. Load Estimation

When a large dataset of chemistry data and flow data is available, estimates of continuous pollutant loads can be determined. The following steps outline the process for load estimation:

1. Identify the flow on the dates of all pollutant concentration measurements.
2. Calculate a relationship between flow and pollutant concentration.
3. Combine the flow/concentration relationship with the continuous flow dataset to estimate continuous pollutant concentrations.
4. Combine the estimates of continuous pollutant concentrations with the continuous flow data to estimate continuous pollutant loads.

5.3. Watershed Model Development and Calibration

Watershed models are tools that represent and simulate natural processes that occur on the landscape. The first step in the development of a watershed model is splitting a study area into smaller watersheds. Watersheds are delineated using information about topography, hydrography, point sources, land use, and monitoring locations. The delineated watersheds and data about point sources, land use, soils, agricultural practices, and weather are incorporated into the model.

Results from the model are compared to water quality data, continuous flow estimates, and continuous load estimates to evaluate how closely the model is matching observed conditions. Model parameters are adjusted to ensure the model will better represent observations. The process of adjusting model parameters to better match observed data is known as calibration and validation.

5.4. Next Steps for the FOXIL TMDL

The steps described in the previous sections will be completed for the Fox Illinois River TMDL basin study area. For the TMDL study, the watershed model will be developed using the Soil and Water Assessment Tool, or SWAT. Like other watershed models, SWAT uses information about watershed characteristics and weather to estimate nonpoint source loadings from background sources, agricultural sources, and urban stormwater sources (Neitsch and others, 2011).

First, the results from the SWAT model will be used to calculate existing loads from the watershed. Second, the model will be used to estimate a loading capacity, which is the maximum amount of a pollutant a waterbody can receive without exceeding water quality standards. Finally, the loading capacity will be compared to existing loads from the watershed and information about permitted point sources to determine reductions that must occur for waters to meet water quality criteria.

ACKNOWLEDGEMENTS

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- Wisconsin Department of Natural Resources, 2023b, Wisconsin 2024 Consolidated Assessment and Listing Methodology (WisCALM): WDNR Guidance #3200-2023-04, 99 p., accessed at <https://dnr.wisconsin.gov/topic/SurfaceWater/WisCALM.html>.

APPENDIX A

CADMUS REPORT ON WATER QUALITY MONITORING

APPENDIX B

WATER QUALITY MONITORING RESULTS FOR THE FOX ILLINOIS RIVER BASIN TMDL

1. WATER QUALITY SAMPLES FOR ALL MONTHS

Samples at the monitoring sites were collected during every month of the year. Table B.1 summarizes the number of samples collected at each site, and Figure B.1 shows the dates at which samples were collected at each site. The gap in samples between March and July 2020 was due to field activities being stopped due to COVID-19.

Total phosphorus, orthophosphate, and total suspended solids concentrations for all samples in all months collected are summarized in Tables B.2 to B.4. In the tables, 'Min' is the minimum value measured, 'Q1' is the value at which 25% of sample were smaller, the 'Median' is the median, 'Q3' is the value at which 25% of the samples were greater, and 'Max' represents the maximum value measured. Figures B.2 to B.4 provide a visual summary of the values in the tables. The vertical lines represent – from left to right – Q1, the median, and Q3. The vertical bars represent the approximate spread of the data. The points on the figure represent outliers based on a log-transformed measurements.

TABLE B.1
Summary of Samples Collected During Monitoring Period

SWIMS ID	Station Name	# of Samples		
		TP	Ortho-P	TSS
683205	Fox River - Ds Sunset Dr Bridge (Waukesha)	40	-	40
683096	Fox River at Cth I Bridge	24	23	24
10046937	Fox River at CTH ES	43	41	43
10032437	Fox River at STH 20/30 Waterford	46	45	46
10053867	Fox River at Case Eagle Park Bridge	43	42	43
303066	Fox River (II) - Nr New Munster Cthjb	24	24	24
10010534	Mukwonago River (1) - Upstream of HWY 83	35	34	35
643555	Muskego (Big Muskego) Lake - Outlet Near Wind Lake	41	-	41
10013090	Wind Lake Canal_Wind Lake Upstream To Ceasars Dam	38	-	38
10040134	Honey Creek 1400ft N of CTH DD/Academy Rd	46	45	46
10029083	Sugar Creek at Potter Road	44	43	44
10012203	White River - 10 M Upstream Of Hwy 36	46	45	46
303054	Des Plaines River at 122nd St (CTH ML)	37	37	37

FIGURE B.1

Timing of Samples Collected During Monitoring Period

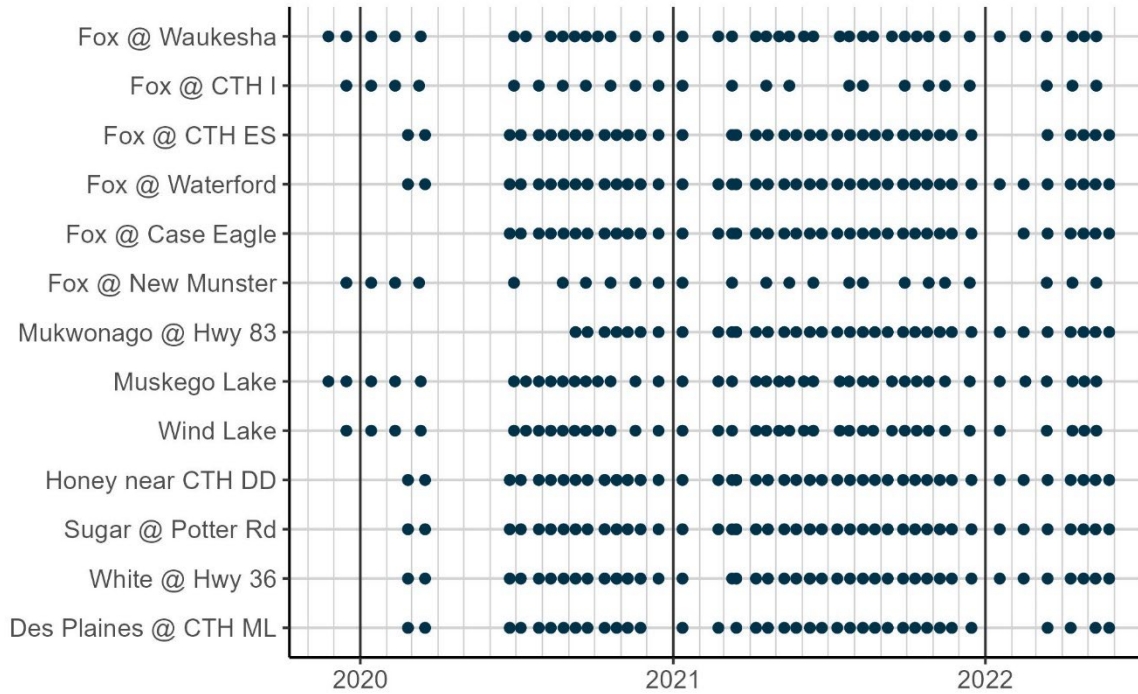


TABLE B.2

Total Phosphorus Concentrations at Monitoring Sites (All Samples)

SWIMS ID	Station Location	TP Concentration (µg/L)				
		Min	Q1	Median	Q3	Max
683205	Fox @ Waukesha	36	60	81	111	191
683096	Fox @ CTH I	27	68	79	97	147
10046937	Fox @ CTH ES	29	67	82	98	181
10032437	Fox @ Waterford	19	35	51	81	144
10053867	Fox @ Case Eagle	18	41	59	83	362
303066	Fox @ New Munster	29	41	62	85	163
10010534	Mukwonago @ Hwy 83	12	14	16	19	29
643555	Muskego Lake	19	26	32	49	171
10013090	Wind Lake	16	23	29	38	149
10040134	Honey near CTH DD	25	33	48	77	160
10029083	Sugar @ Potter Rd	5	33	51	87	302
10012203	White @ Hwy 36	6	40	58	100	225
303054	Des Plaines @ CTH ML	37	76	130	173	361

FIGURE B.2

Total Phosphorus Concentrations at Monitoring Sites (All Samples)

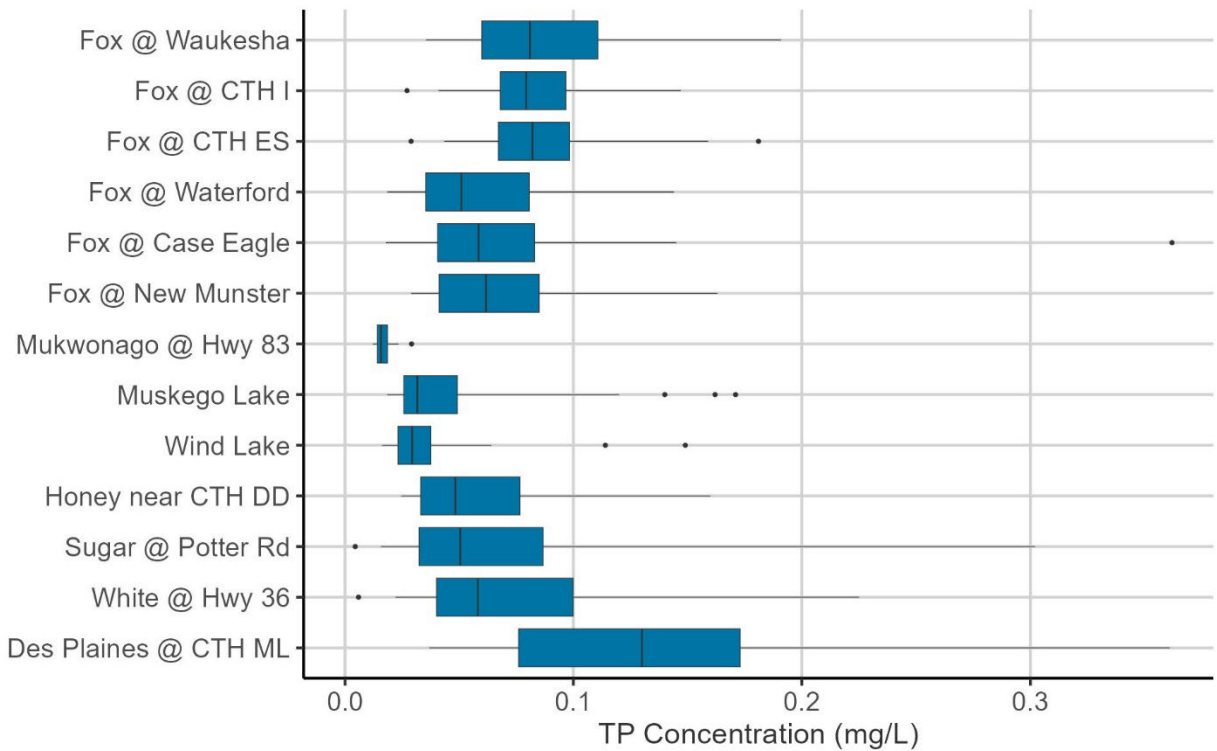


TABLE B.3

Orthophosphate Concentrations at Monitoring Sites (All Samples)

SWIMS ID	Station Location	DOP Concentration (µg/L)				
		Min	Q1	Median	Q3	Max
683096	Fox @ CTH I	5.7	15.1	30.2	49.9	90.2
10046937	Fox @ CTH ES	4.0	12.7	32.0	48.9	80.2
10032437	Fox @ Waterford	1.5	3.4	7.6	17.1	69.6
10053867	Fox @ Case Eagle	1.2	3.4	8.5	20.9	182.0
303066	Fox @ New Munster	1.5	5.8	17.2	28.5	59.6
10010534	Mukwonago @ Hwy 83	1.2	2.0	4.1	8.9	41.7
10040134	Honey near CTH DD	4.2	8.7	19.4	29.1	52.7
10029083	Sugar @ Potter Rd	1.5	7.2	22.4	37.2	101.0
10012203	White @ Hwy 36	1.2	8.0	20.8	35.5	110.0
303054	Des Plaines @ CTH ML	1.5	10.7	18.5	41.2	92.6

FIGURE B.3

Orthophosphate Concentrations at Monitoring Sites (All Samples)

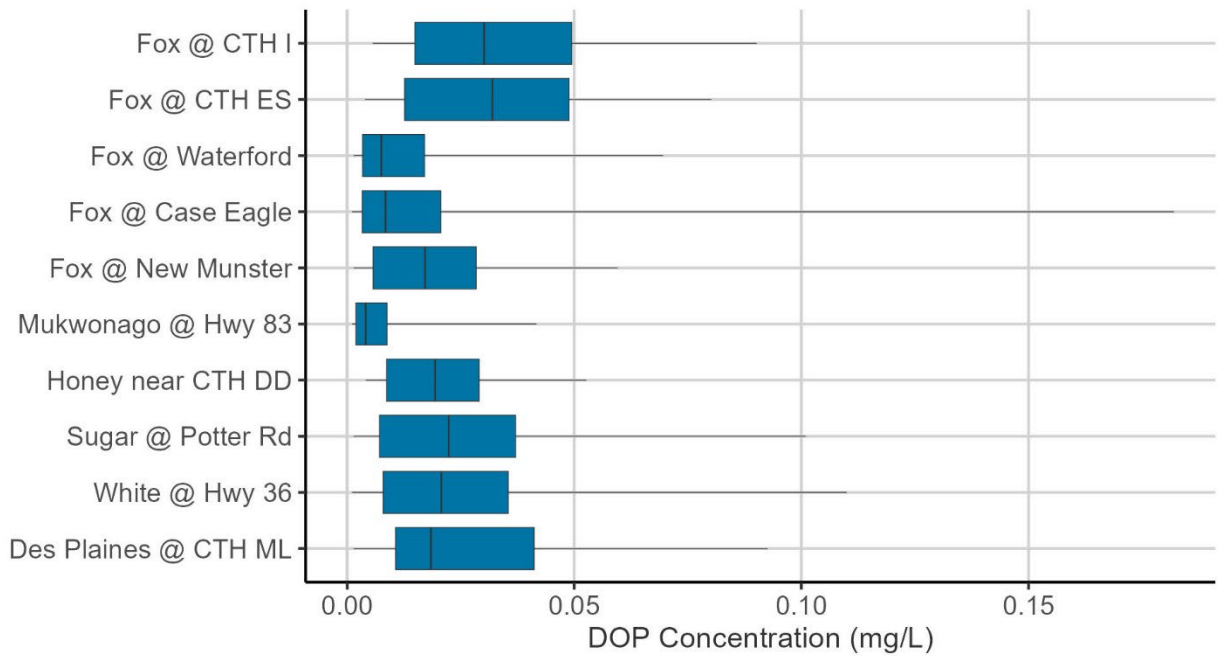
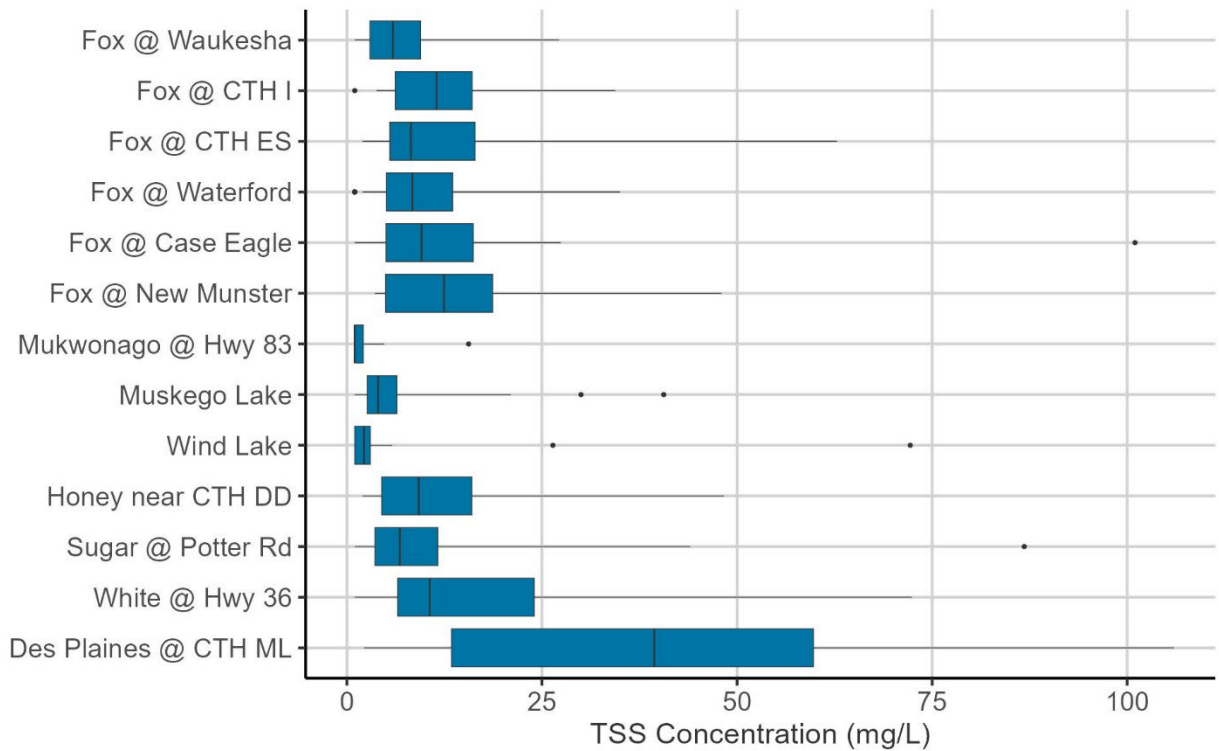


TABLE B.4

TSS Concentrations at Monitoring Sites (All Samples)

SWIMS ID	Station Location	TSS Concentration (mg/L)				
		Min	Q1	Median	Q3	Max
683205	Fox @ Waukesha	1.0	3.0	5.9	9.5	27.2
683096	Fox @ CTH I	1.0	6.2	11.5	16.1	34.4
10046937	Fox @ CTH ES	2.0	5.5	8.2	16.5	62.8
10032437	Fox @ Waterford	1.0	5.1	8.4	13.6	35.0
10053867	Fox @ Case Eagle	1.0	5.0	9.6	16.2	101.0
303066	Fox @ New Munster	3.6	5	12.5	18.7	48
10010534	Mukwonago @ Hwy 83	1.0	1.0	1.0	2.1	15.6
643555	Muskego Lake	1.0	2.6	4.0	6.4	40.6
10013090	Wind Lake	1.0	1.0	2.2	3.0	72.2
10040134	Honey near CTH DD	2.0	4.5	9.2	16.0	48.3
10029083	Sugar @ Potter Rd	1.0	3.6	6.8	11.7	86.8
10012203	White @ Hwy 36	1.0	6.5	10.6	24.0	72.4
303054	Des Plaines @ CTH ML	2.2	13.4	39.4	59.8	106.0

FIGURE B.4
TSS Concentrations at Monitoring Sites (All Samples)



2. GROWING SEASON

Samples at the monitoring sites were collected during every month of the year, but they are summarized for only the months during the growing season, which spans from May 1st through October 31st. Table B.5 summarizes the number of samples collected during the growing season at each site. Results for samples collected during the growing season are summarized in Tables B.6 to B.8. In the tables, 'Min' is the minimum value measured, 'Q1' is the value at which 25% of sample were smaller, the 'Median' is the median, 'Q3' is the value at which 25% of the samples were greater, and 'Max' represents the maximum value measured. Figures B.5 to B.7 provide a visual summary of the values in the tables. The vertical lines represent - from left to right - Q1, the median, and Q3. The vertical bars represent the approximate spread of the data. The points on the figure represent outliers based on a log-transformed measurements.

TABLE B.5
Samples Collected During the Growing Season

SWIMS ID	Station Name	TP	# of Samples	
			Ortho-P	TSS
683205	Fox River - Ds Sunset Dr Bridge (Waukesha)	21	-	21
683096	Fox River at Cth I Bridge	11	11	11
10046937	Fox River at CTH ES	25	24	25
10032437	Fox River at STH 20/30 Waterford	25	25	25
10053867	Fox River at Case Eagle Park Bridge	25	25	25
303066	Fox River (II) - Nr New Munster Cthjb	11	11	11
10010534	Mukwonago River (1) - Upstream of HWY 83	18	18	18
643555	Muskego (Big Muskego) Lake - Outlet Near Wind Lake	22	-	22
10013090	Wind Lake Canal_Wind Lake Upstream To Ceasars Dam	21	-	21
10040134	Honey Creek 1400ft N of CTH DD/Academy Rd	25	25	25
10029083	Sugar Creek at Potter Road	24	24	24
10012203	White River - 10 M Upstream Of Hwy 36	26	26	26
303054	Des Plaines River at 122nd St (CTH ML)	23	23	23

TABLE B.6
Total Phosphorus Concentrations at Monitoring Sites (Growing Season)

SWIMS ID	Station Location	TP Concentration (µg/L)				
		Min	Q1	Median	Q3	Max
683205	Fox @ Waukesha	36	60	105	122	183
683096	Fox @ CTH I	41	64	89	95	147
10046937	Fox @ CTH ES	55	80	91	105	181
10032437	Fox @ Waterford	35	57	78	95	144
10053867	Fox @ Case Eagle	40	55	77	106	362
303066	Fox @ New Munster	32	66	74	100	163
10010534	Mukwonago @ Hwy 83	13	15	16	18	24
643555	Muskego Lake	25	29	49	105	171
10013090	Wind Lake	19	27	35	48	149
10040134	Honey near CTH DD	37	50	72	82	160
10029083	Sugar @ Potter Rd	41	50	70	94	302
10012203	White @ Hwy 36	6	56	84	121	225
303054	Des Plaines @ CTH ML	53	135	164	196	361

FIGURE B.5
Total Phosphorus Concentrations at Monitoring Sites (Growing Season)

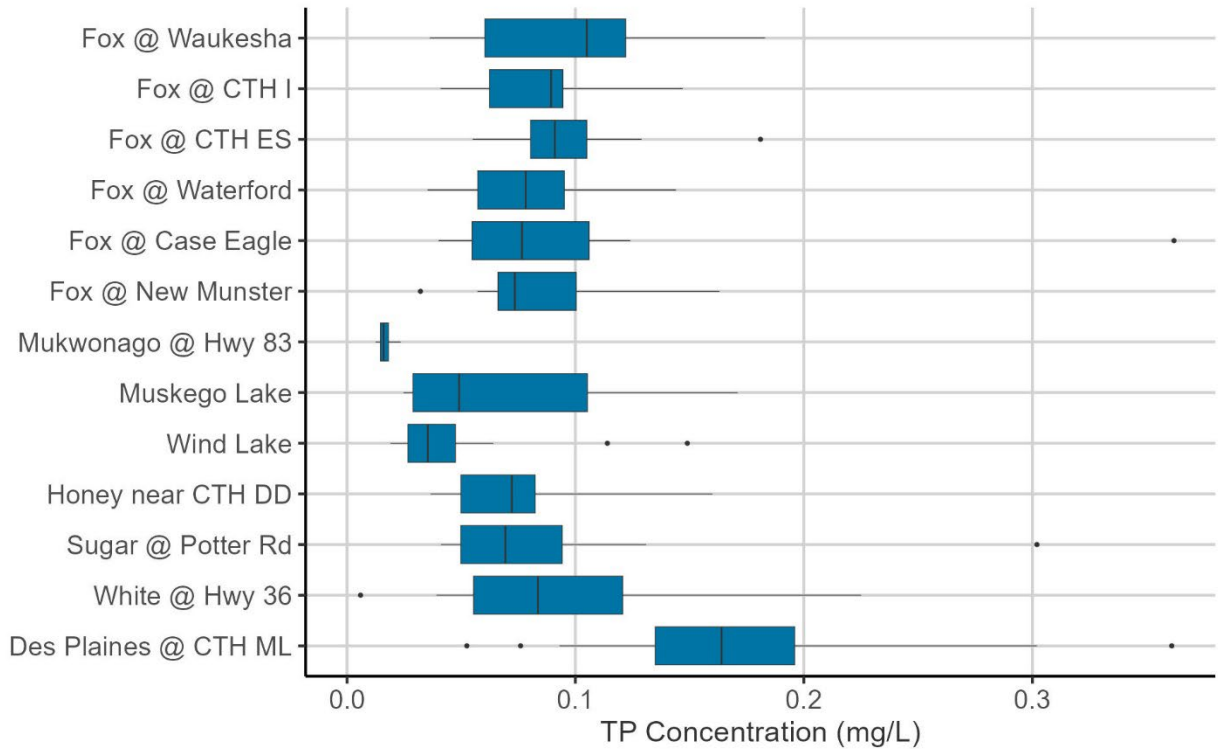


TABLE B.7
Orthophosphate Concentrations at Monitoring Sites (Growing Season)

SWIMS ID	Station Location	DOP Concentration ($\mu\text{g/L}$)				
		Min	Q1	Median	Q3	Max
683096	Fox @ CTH I	6.5	17.2	36.1	68.0	83.3
10046937	Fox @ CTH ES	5.2	21.4	45.1	55.7	75.2
10032437	Fox @ Waterford	1.5	5.4	14.5	34.8	69.6
10053867	Fox @ Case Eagle	1.5	4.2	14.6	32.3	182.0
303066	Fox @ New Munster	2	14.2	21	37.5	59.6
10010534	Mukwonago @ Hwy 83	1.5	3.2	4.6	8.9	26.4
10040134	Honey near CTH DD	6.5	15.3	22.9	34.3	52.2
10029083	Sugar @ Potter Rd	4.2	18.2	32.4	43.9	101.0
10012203	White @ Hwy 36	1.2	17.5	31.8	41.2	110.0
303054	Des Plaines @ CTH ML	4.7	13.5	31.5	49.2	92.6

FIGURE B.6
Orthophosphate Concentrations at Monitoring Sites (Growing Season)

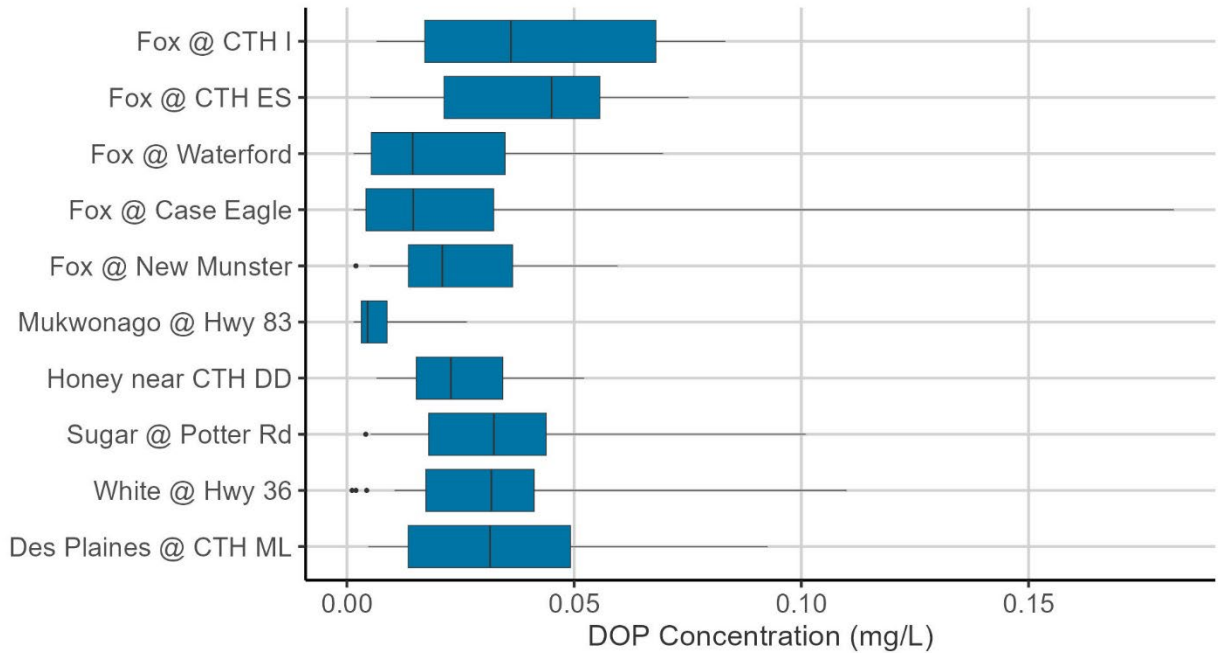
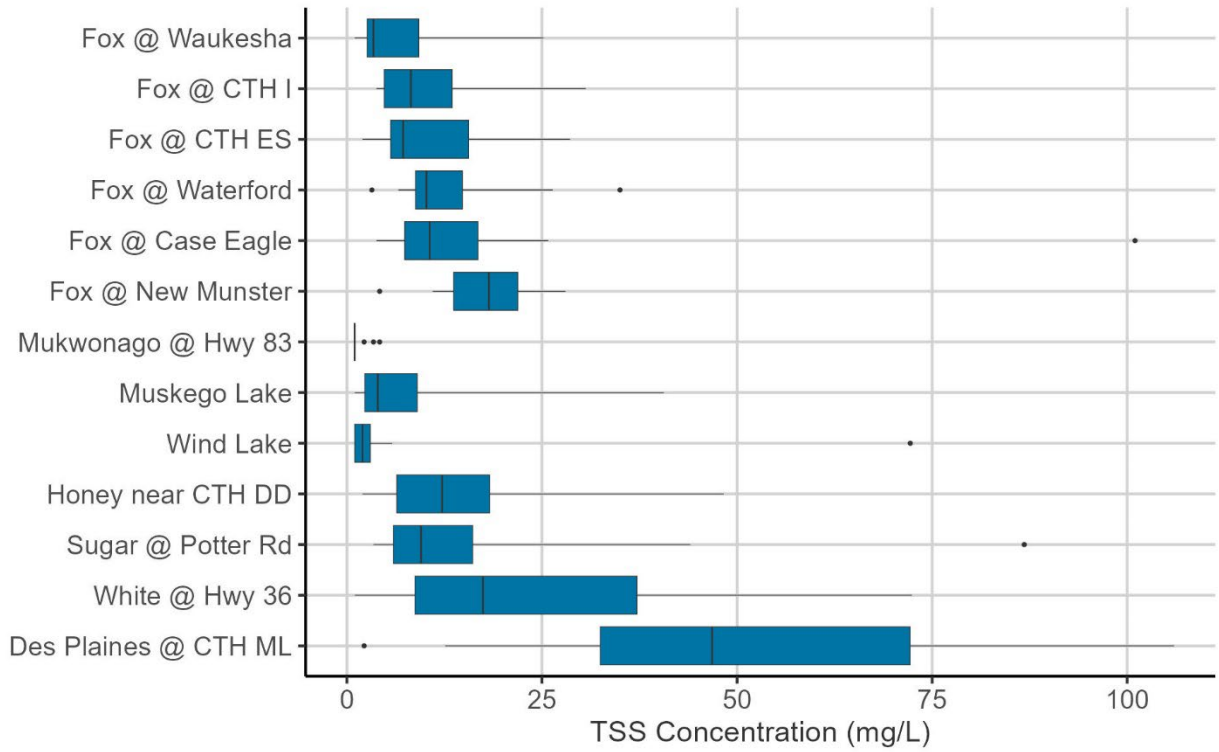


TABLE B.8
TSS Concentrations at Monitoring Sites (Growing Season)

SWIMS ID	Station Location	TSS Concentration (mg/L)				
		Min	Q1	Median	Q3	Max
683205	Fox @ Waukesha	1.0	2.6	3.4	9.2	25.2
683096	Fox @ CTH I	3.8	4.8	8.2	13.5	30.6
10046937	Fox @ CTH ES	2.0	5.6	7.2	15.6	28.6
10032437	Fox @ Waterford	3.2	8.8	10.2	14.8	35.0
10053867	Fox @ Case Eagle	3.8	7.4	10.6	16.8	101.0
303066	Fox @ New Munster	4.2	13.8	18.2	21.9	28
10010534	Mukwonago @ Hwy 83	1.0	1.0	1.0	1.0	4.2
643555	Muskego Lake	1.0	2.3	4.0	9.2	40.6
10013090	Wind Lake	1.0	1.0	2.0	3.0	72.2
10040134	Honey near CTH DD	2.0	6.4	12.2	18.3	48.3
10029083	Sugar @ Potter Rd	3.4	6.0	9.5	16.2	86.8
10012203	White @ Hwy 36	1.0	8.8	17.6	37.3	72.4
303054	Des Plaines @ CTH ML	2.2	32.7	46.8	72.2	106.0

FIGURE B.7

TSS Concentrations at Monitoring Sites (Growing Season)



APPENDIX C

STAGE MONITORING RESULTS FOR THE FOX ILLINOIS RIVER BASIN TMDL

1. CALCULATION OF STAGE DATA FROM PRESSURE TRANSDUCERS

Calculating the depth of water above the pressure transducer required four primary sources of data: barometric pressure, air temperature, pressure from the pressure transducer, and water temperature. Barometric pressure and air temperature data were downloaded from the National Centers for Environmental Information for the Kenosha Regional Airport (GHCND:USW00004845). The difference in pressure between the pressure measured at the pressure transducer and the barometric pressure was calculated, and the pressure difference was converted to a water depth.

After the depth of water above the pressure transducer was calculated, the estimated stage was calculated. Stage refers to the water level relative to a fixed benchmark. When the pressure transducers were deployed and maintained, detailed surveys were conducted to determine if elevation of the pressure transducer changed since the previous survey. Details of the steps used to convert pressure transducer to stage data are provided below.

Step 1: Download pressure and water temperature data from pressure transducers and calculate hourly averages

Step 2: Download barometric pressure and temperature data from Kenosha airport weather station

Station Information:

Name: Kenosha Regional Airport
Site ID: GHCND:USW00004845; 7265004845
Latitude: 42.59529
Longitude: -87.9383
Elevation: 223.47 meters

Data source: <https://www.ncei.noaa.gov/data/global-hourly/access/>

Step 3: Adjust barometric pressure by elevation (Barometric formula)

$$P = P_b \times \exp \left[\frac{-g_0 \times M \times (h - h_b)}{R \times T_b} \right]$$

P: Pressure (kPa)
P_b: Reference pressure (kPa)
T_b: Reference temperature (K)
h: Adjusted elevation (m)
h_b: Reference elevation (m)
g₀: Gravitational acceleration (9.80665 m/s²)
M: Molar mass of Earth's air (0.028964 kg/mol)
R: Universal gas constant (8.3144598 J/(mol*K))

Step 4: Calculate water density at the measured temperature (Kell, 1975)

$$\rho = (999.83952 + 16.945176 \times T - 7.9870401 \times 10^{-3} \times T^2 - 46.170461 \times 10^{-6} \times T^3 + 105.56302 \times 10^{-9} \times T^4 - 280.54253 \times 10^{-3} \times T^5) \div (1 + 16.8978550 \times 10^{-3} \times T)$$

ρ : Density (kg/m³)

T: Temperature (deg-C)

Kell, G.S., 1975, Density, thermal expansivity, and compressibility of liquid water from 0C to 150C: Corrections and tables for atmospheric pressure and saturation reviewed and expressed on 1968 temperature scale: Journal of Chemical Engineering Data, v. 20, 97-105.

Step 5: Calculate depth of water above the pressure transducer by calculating difference between barometric pressure and pressure transducer data

$$d = \frac{(P_{pt} - P_{bp}) \times \alpha_{psi-kPa}}{\rho_w} \times \alpha_{in2-ft2}$$

d: Depth of water (ft)

P_{pt} : Pressure of pressure transducer (kPa)

P_{bp} : Barometric pressure at pressure transducer (Pa)

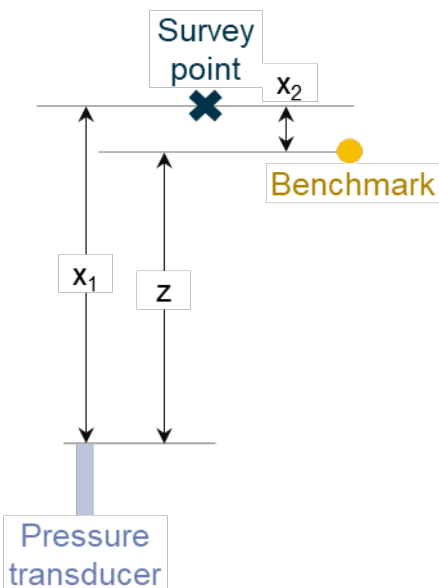
ρ_w : Density of water at measured water temperature (lb/ft³)

$\alpha_{psi-kPa}$: Conversion factor for kPa to psi (0.1450377 psi/kPa)

$\alpha_{in2-ft2}$: Conversion factor for in² and ft² (144 in²/ft²)

Step 6: Calculate stage data using water depth and pressure transducer surveys

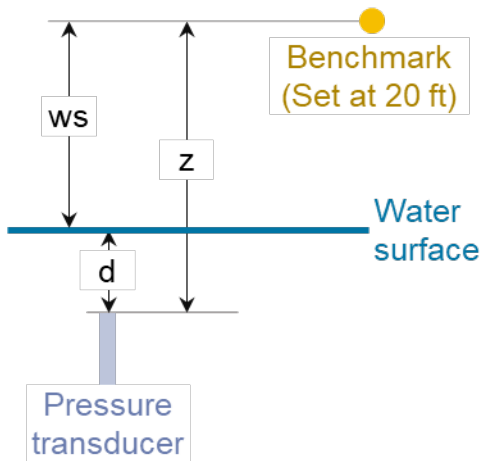
Step 6a: Calculate difference in elevation between benchmark and pressure transducer using survey data



x_1 : Height difference between survey point and pressure transducer

x_2 : Height difference between survey point and benchmark
 z : Height difference between pressure transducer and benchmark ($x_1 - x_2$)

Step 6b. Determine stage by calculating difference between benchmark and water surface elevation



z : Height difference between pressure transducer and benchmark
 d : Depth of water above pressure transducer (calculated in Step 5)
 ws : Height difference between benchmark and water surface ($z - d$)

Note: The stage is calculated by subtracting the height difference between the benchmark and water surface (ws) from the benchmark elevation, which is set at an arbitrary value of 20 ft to maintain a positive value of stage for all gages.

Step 6c. Adjust stage data to reflect the movement of the pressure transducer over time

Assuming the change in pressure transducer elevation over time is constant, the difference in pressure transducer elevation at the beginning and end of the deployment can be linearly interpolated over time. The stage is calculated over time by subtracting the depth from the elevation of the pressure transducer.

2. SUMMARY OF RESULTS FROM PRESSURE TRANSDUCER DATA

A summary of pressure transducer data at the five sites is provided in Table C.1. Note that the pressure transducers at the Fox River at CTH I and The Fox River at CTH ES have multiple rows in the table. The pressure transducers at these locations were moved for various reasons, which are outlined in the notes. The stage data corresponding to each row of Table C.1 are provided in Figures C.1 through C.8.

TABLE C.1
Summary of Pressure Transducer Data

Location	Start Date	End Date	Stage (ft)			Notes
			Mean	Min	Max	
Fox River at CTH I (Upstream)	1/9/2020	9/22/2020	5.44	3.83	8.57	The location of the pressure transducer was moved to a more suitable location on 9/22/2020
Fox River at CTH I (Downstream)	9/22/2020	6/22/2022	4.89	3.47	7.24	The original benchmark was lost between 5/10/2021 and 9/22/2021. The change in elevation of the pressure transducer could not be determined due to the missing benchmark. To account for the missing benchmark, an assumption was made that the pressure transducer did not change elevation during this time period. Additionally, on 9/22/2021, the pressure transducer was lowered by approximately 0.475 ft.
Fox River at CTH ES (Downstream #1)	11/18/2019	8/20/2020	5.28	3.84	7.31	Data between 11/18/2019 and 8/20/2020 may not be reliable due to malfunctions with the pressure transducer. Additionally, the pressure transducer was exposed to air at various times during the deployment, so data does not accurately reflect river stage. An additional pressure transducer was deployed to a more suitable site upstream of CTH ES on 11/19/2020.
Fox River at CTH ES (Downstream #2)	8/20/2020	6/22/2020	-	-	-	The pressure transducer was exposed to air at various times during the deployment, so data does not accurately reflect river stage. An additional pressure transducer was deployed to a more suitable site upstream of CTH ES on 11/19/2020.
Fox River at CTH ES (Upstream)	11/19/2020	6/22/2022	7.39	6.17	9.85	The pressure transducer was installed upstream of CTH ES to replace the original pressure transducer.
Honey Creek at Academy Road	11/11/2019	6/22/2022	8.91	7.97	11.81	Data from 7/10/2020 to 8/20/2020 are missing. Data from 9/6/2020 to 10/7/2020 are unusable due to issues with instrumentation.

Location	Start Date	End Date	Mean	Stage (ft)		Notes
				Min	Max	
Sugar Creek at Potter Road	11/11/2019	6/22/2022	8.59	7.58	11.51	Data from 7/10/2020 to 8/20/2020 are missing. Data from 1/20/2022 to 2/20/2022 are unusable due to ice impacts.
White River at Hwy 36	11/18/2019	6/22/2022	2.23	1.17	6.33	Data from 7/10/2020 to 8/20/2020 are missing.

FIGURE C.1
Stage Data for Fox River Upstream of Hwy I

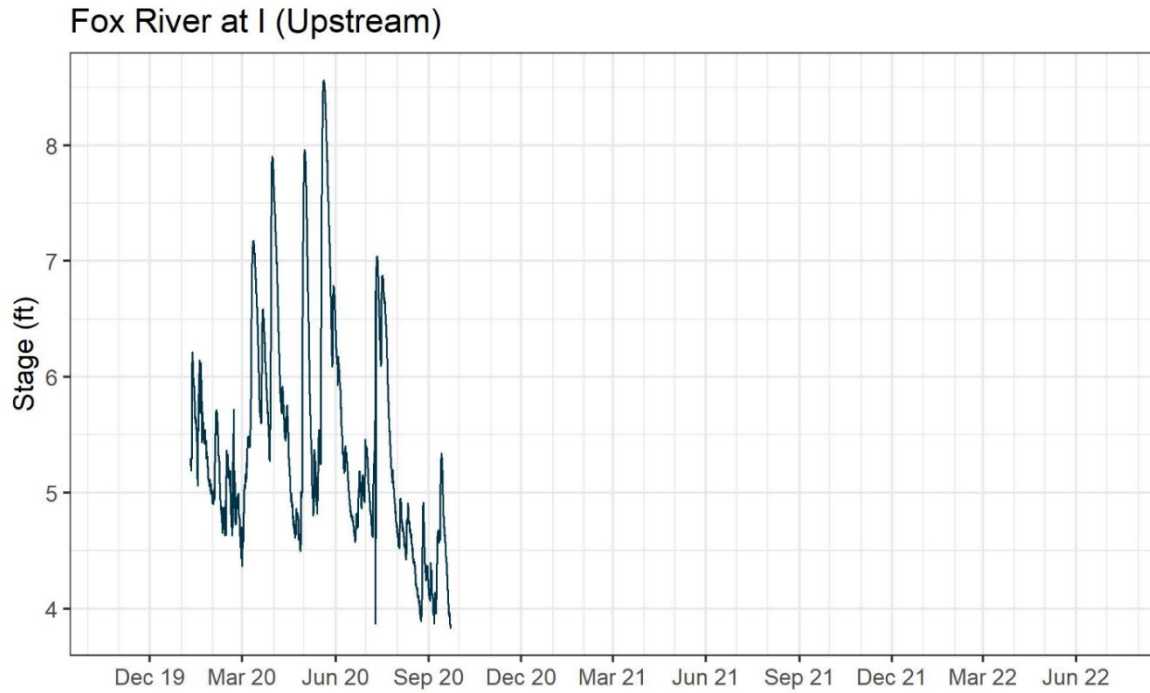


FIGURE C.2
Stage Data for Fox River Downstream of Hwy I

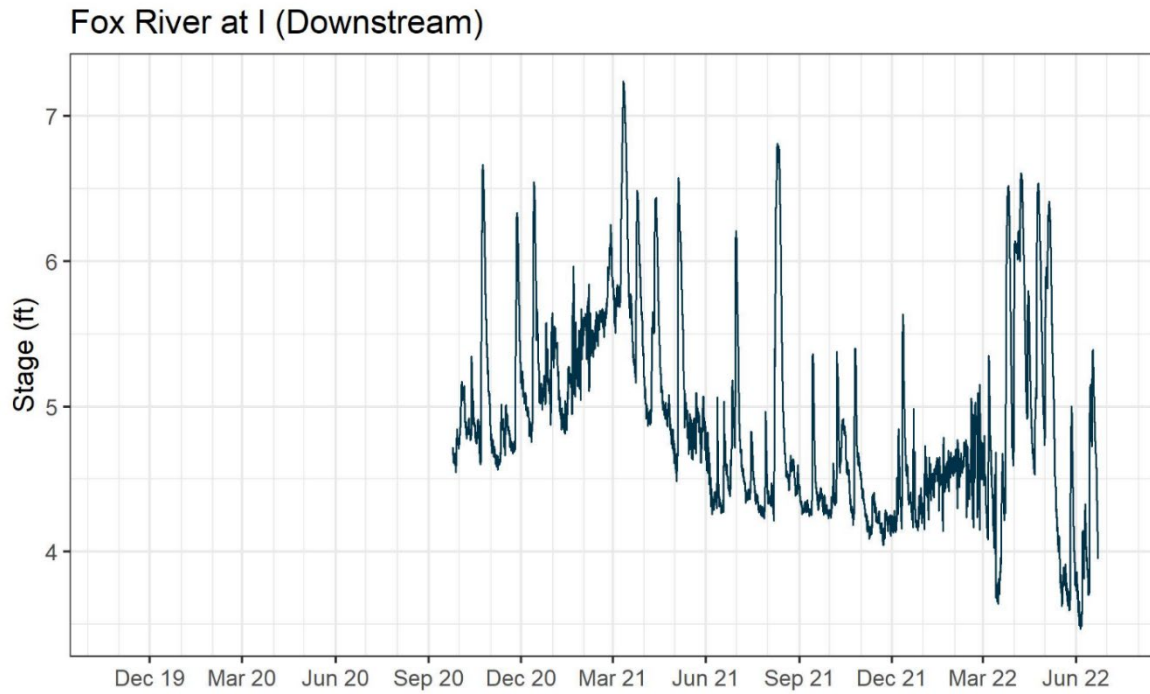


FIGURE C.3

Stage Data for Fox River Downstream of ES (Deployment #1)

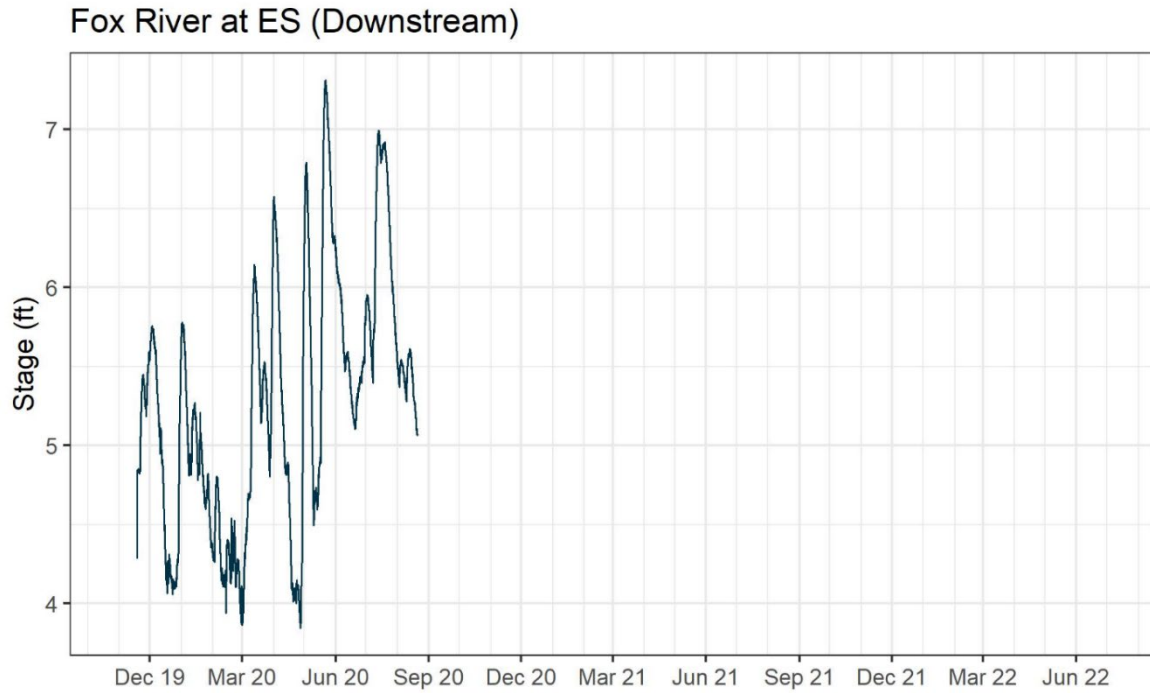


FIGURE C.4

Stage Data for Fox River Downstream of ES (Deployment #2)

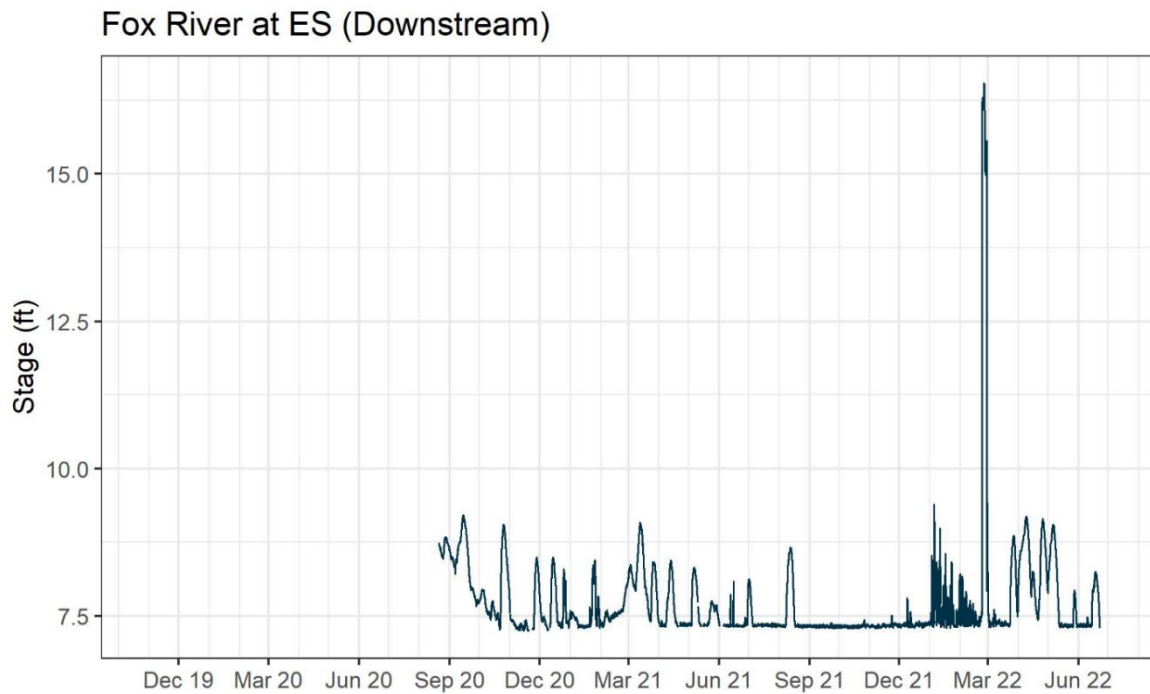


FIGURE C.5
Stage Data for Fox River Upstream of ES

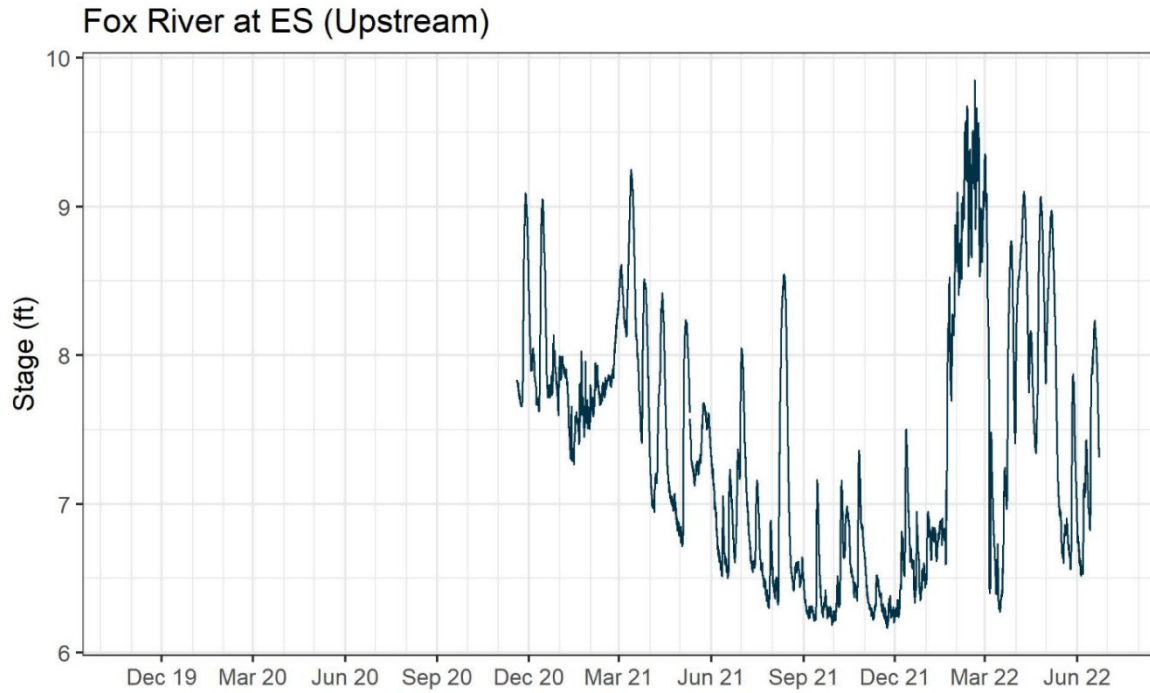


FIGURE C.6
Stage Data for Honey Creek at DD

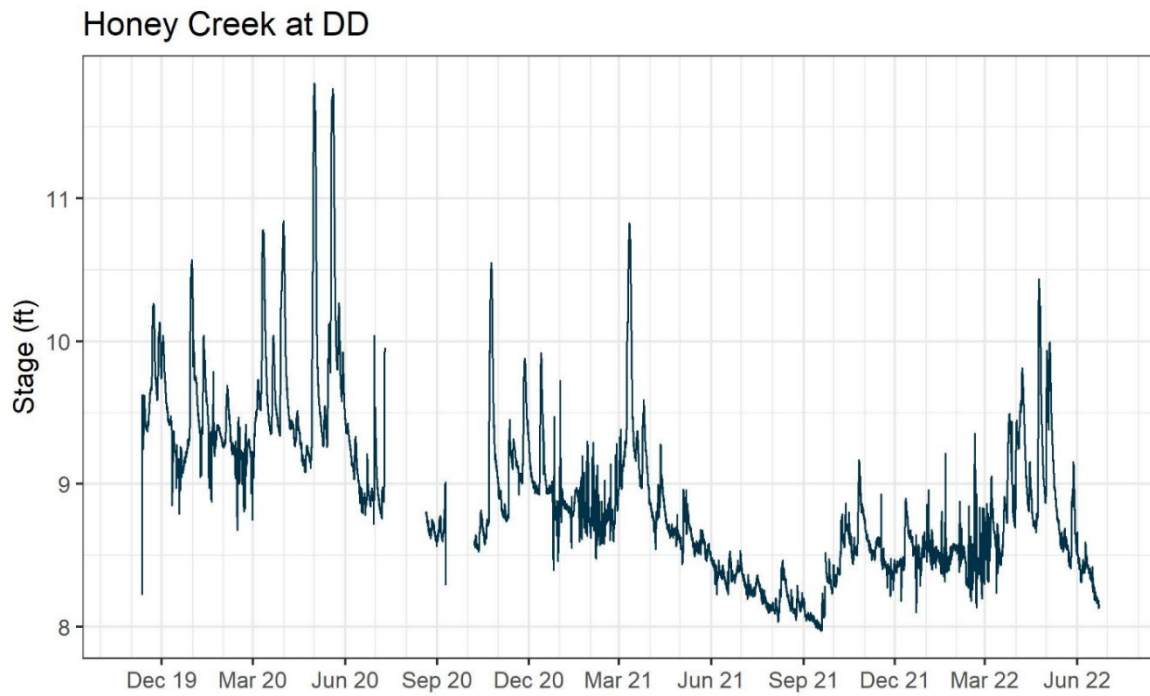


FIGURE C.7
Stage Data for Sugar Creek at Potter

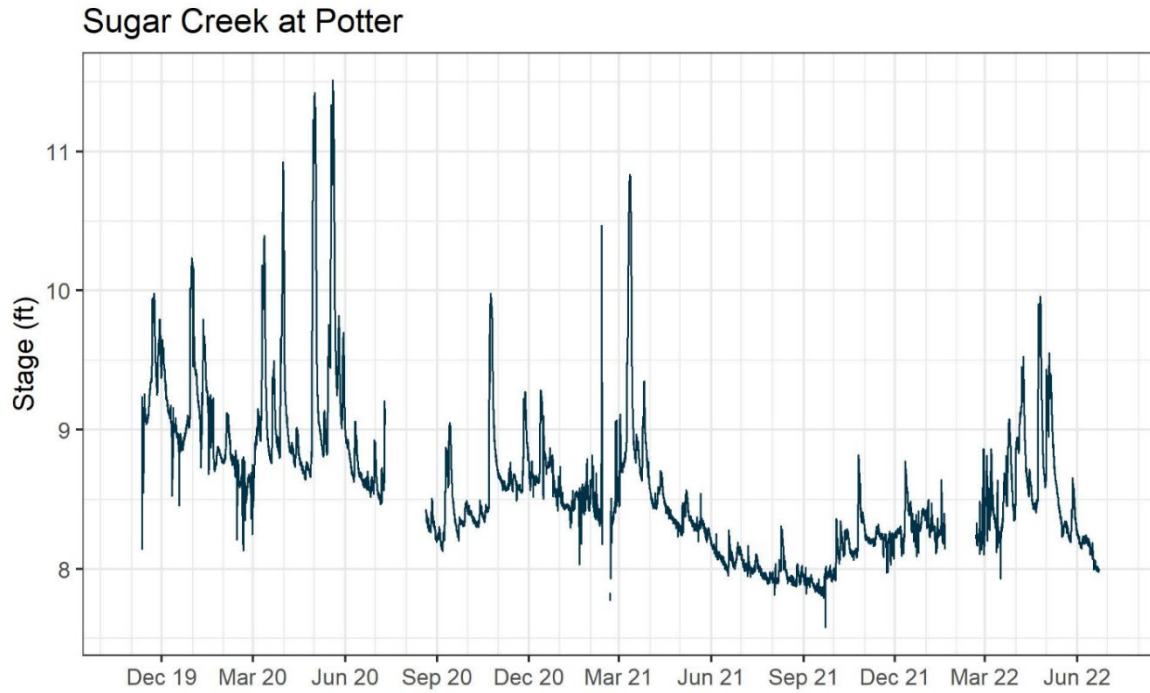
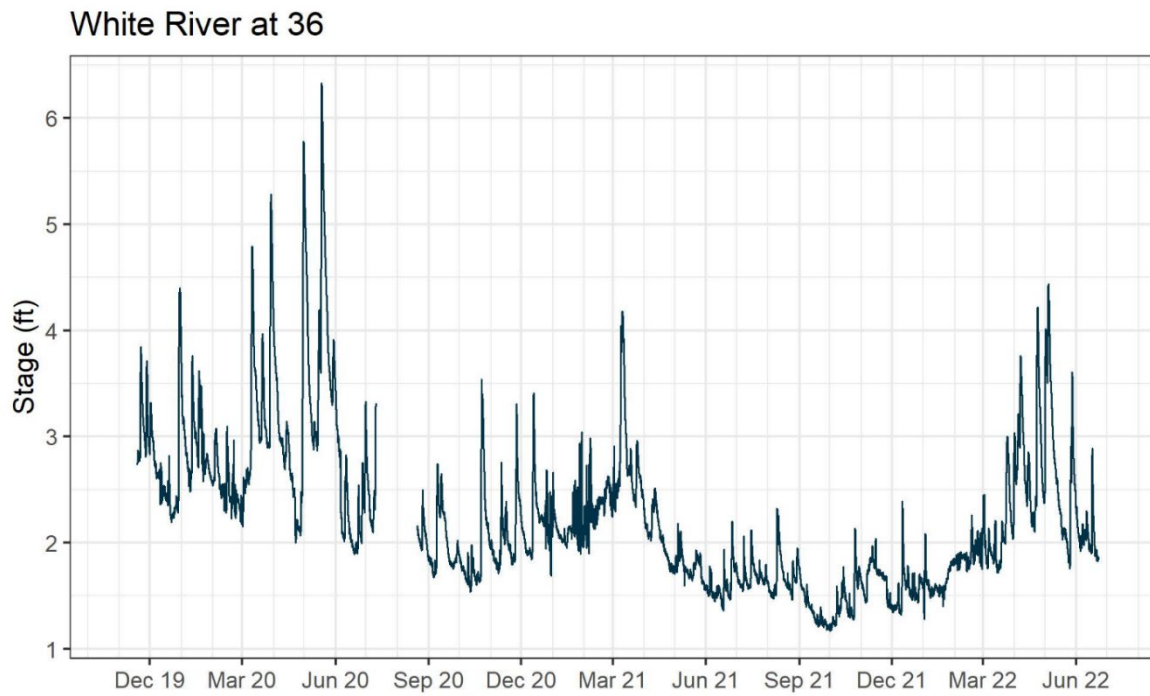


FIGURE C.8
Stage Data for White River at 36



APPENDIX D

FLOW MONITORING RESULTS FOR THE FOX ILLINOIS RIVER BASIN TMDL

Flow measurements were collected by the DNR at nine sites for the duration of the monitoring study. The goal for flow monitoring was to collect a measurement every month, but some barriers prevented samples from being collected in all months. Table D.1 summarizes circumstances that resulted in flow measurements not being collected. The results from the monitoring are summarized in Table D.2, and the results for each location are presented in Figures D.1 through D.9.

TABLE D.1
Causes of Missing Flow Measurements

Station	Missing			Meas. Inaccurate	Site Not Accessible	No/Low Flow	Total
	PT	Ice	COVID				
Fox River at Cth I	2	3	2	0	3	0	10
Fox River at CTH ES	0	3	3	1	5	0	12
Fox River downstream of Waterford Dam	0	2	3	0	4	0	9
Fox River downstream of Rochester Dam	0	2	3	0	0	0	5
Muskego Canal at Muskego Dam Road	0	1	2	3	0	12	18
Wind Lake Outlet at South Wind Lake Road	0	3	3	1	0	9	16
Honey Creek at Academy Road	0	2	3	0	0	1	6
Sugar Creek at Potter Road	0	3	3	0	0	0	6
White River @ Hwy 36	0	3	3	0	0	1	7
Total	2	22	25	5	12	23	89

TABLE D.2
Summary of Flow Measurements Collected By DNR

Location	# Meas.	First Meas.	Last Meas.	Flow (cfs)		
				Median	Min	Max
Fox River at Cth I	23	1/14/2020	5/15/2022	133	56	626
Fox River at CTH ES	20	12/9/2019	5/15/2022	156	60	559
Fox River downstream of Waterford Dam	23	7/13/2020	5/15/2022	212	95	828
Fox River downstream of Rochester Dam	27	12/9/2019	5/15/2022	285	86	1564
Muskego Canal at Muskego Dam Road	13	12/9/2019	4/25/2022	32	-10	74
Wind Lake Outlet at South Wind Lake Road	14	12/9/2019	4/25/2022	69	2	131
Honey Creek at Academy Road	26	12/9/2019	5/15/2022	56	13	258
Sugar Creek at Potter Road	26	12/9/2019	5/15/2022	35	13	266
White River at Hwy 36	25	12/9/2019	5/15/2022	94	18	466

FIGURE D.1
Flow Measurements for Fox River at CTH I

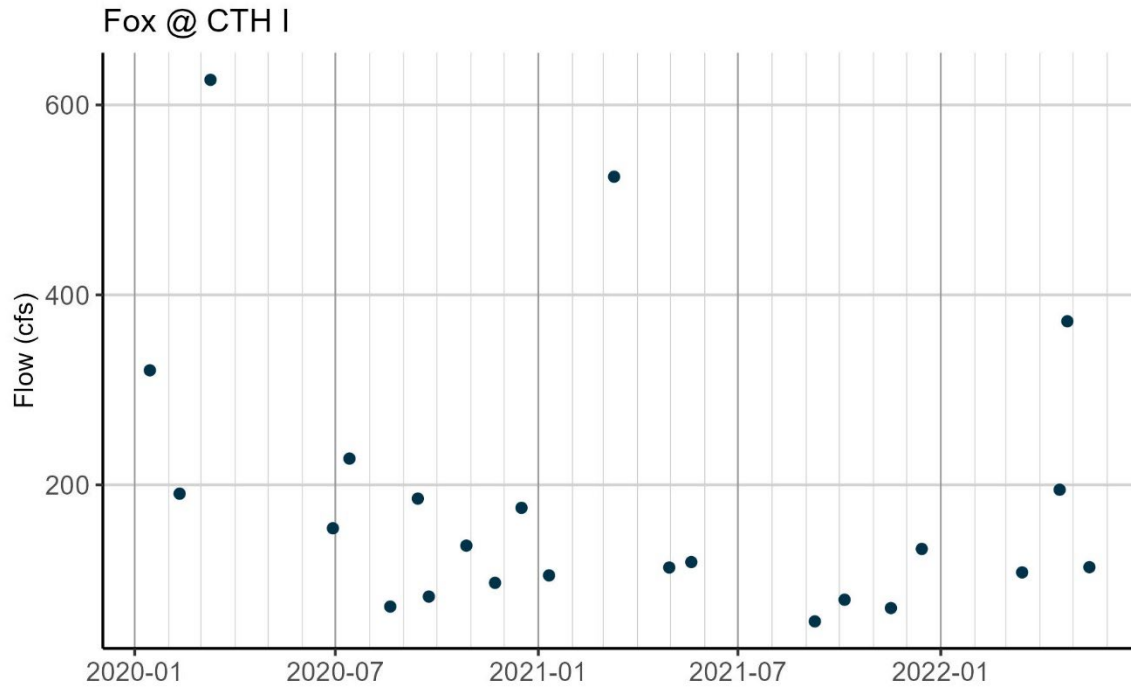


FIGURE D.2
Flow Measurements for Fox River at CTH ES

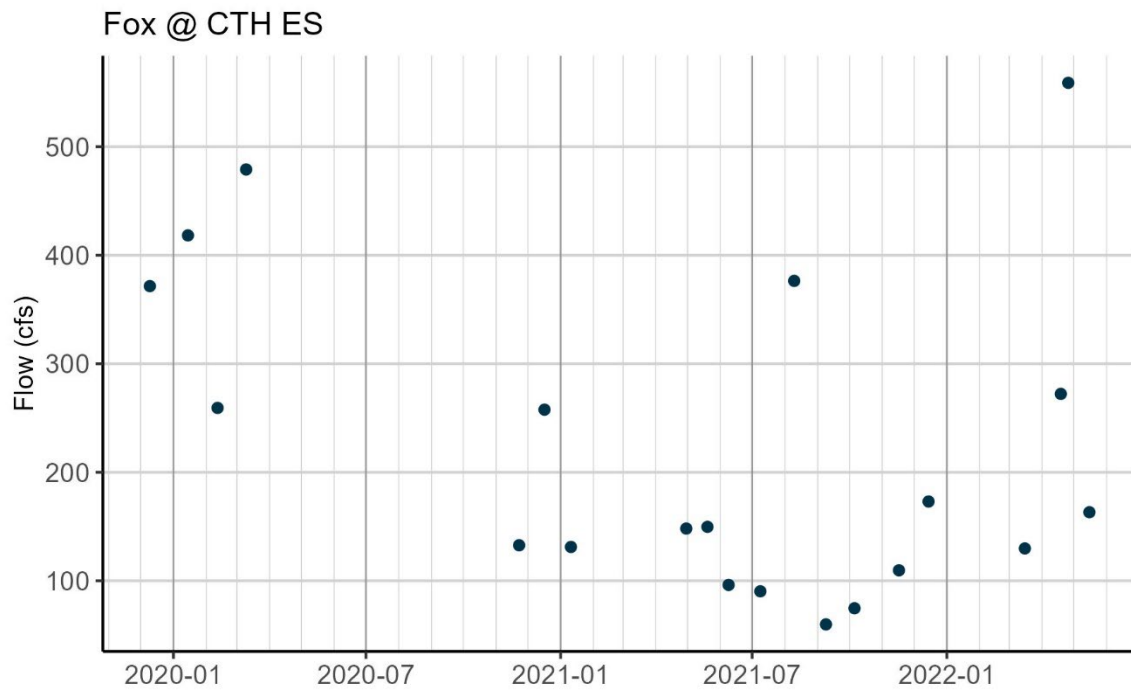


FIGURE D.3
Flow Measurements for Fox River at Waterford

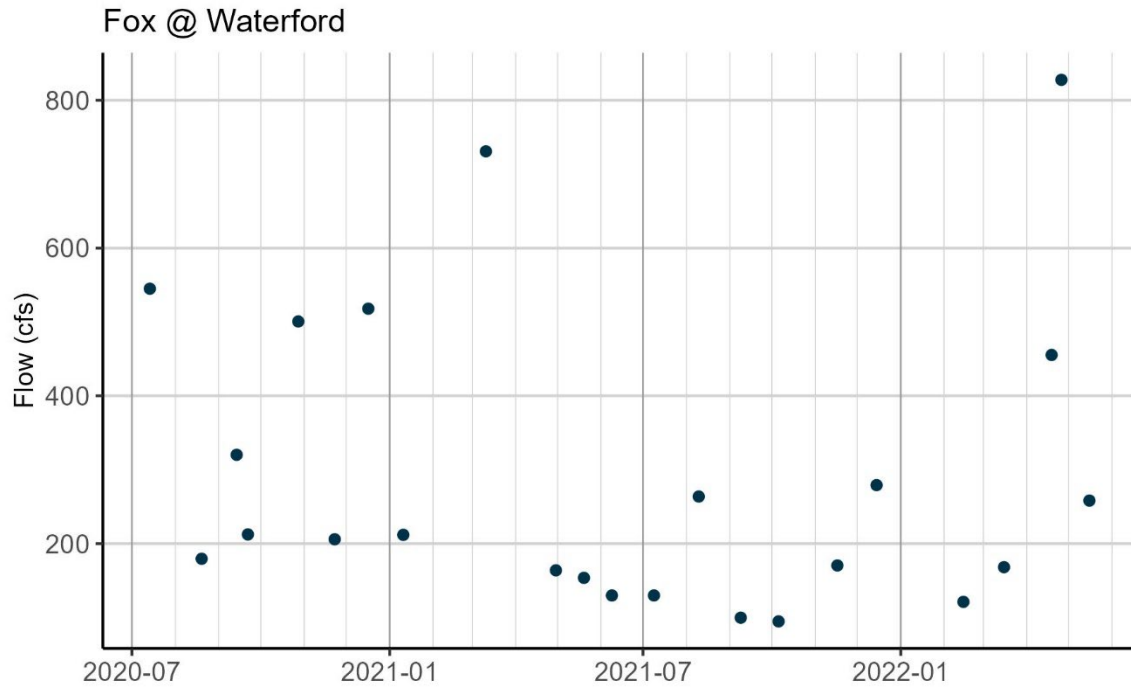


FIGURE D.4
Flow Measurements for Fox River at Rochester

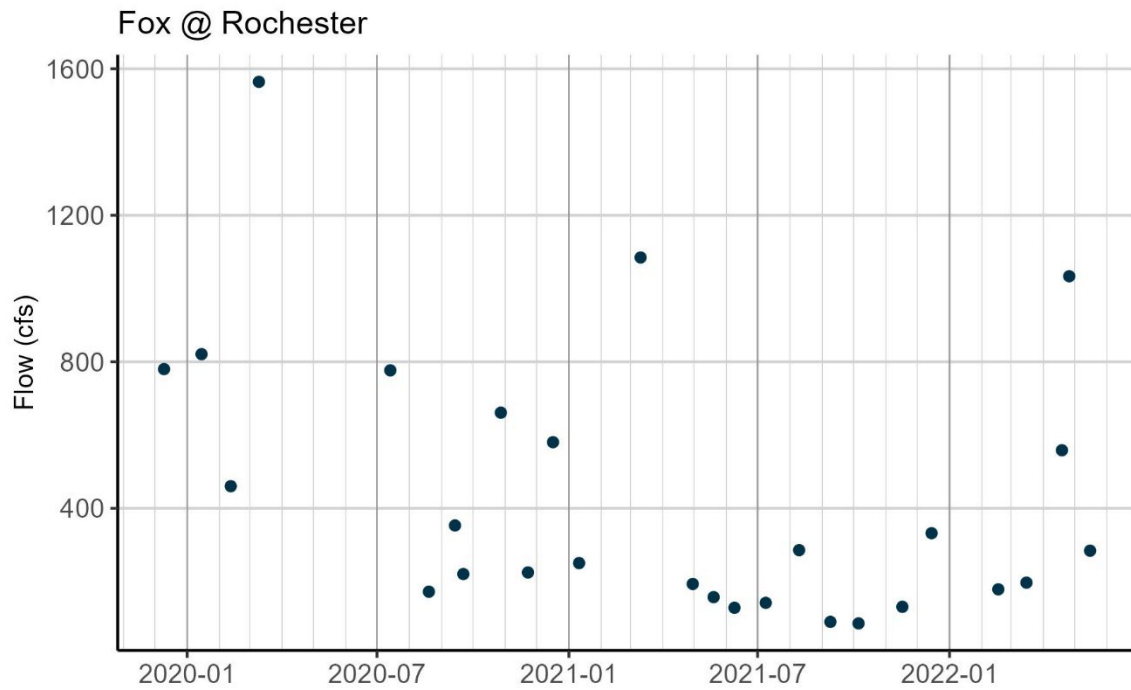


FIGURE D.5
Flow Measurements for Muskego Canal

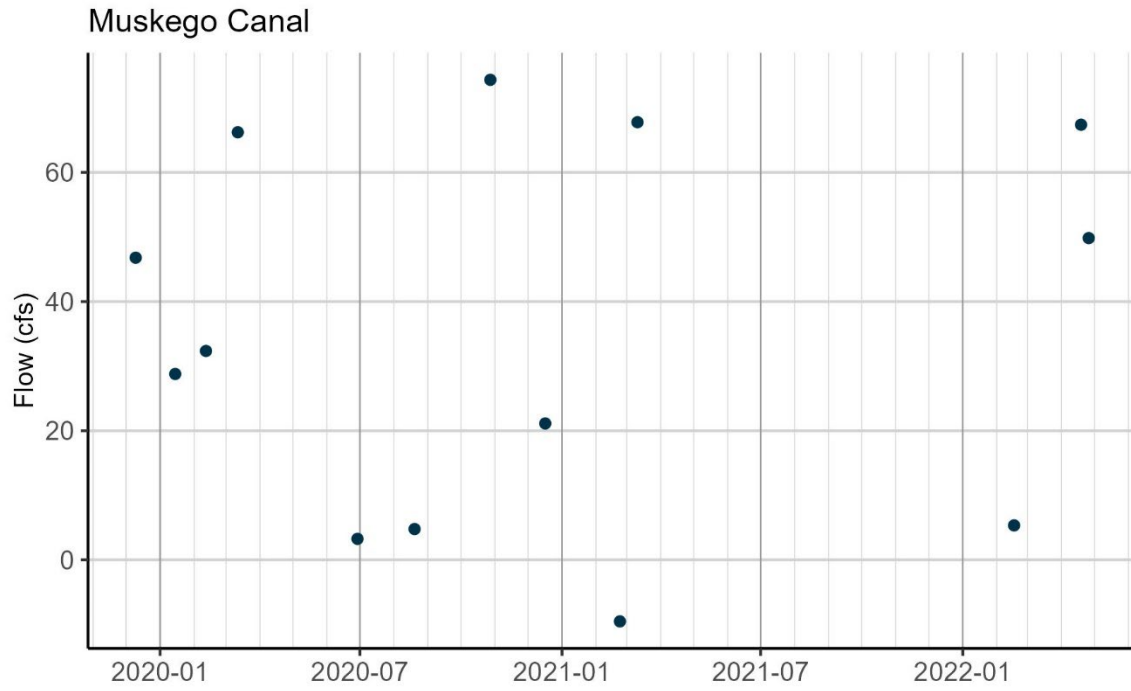


FIGURE D.6
Flow Measurements for Wind Lake Outlet

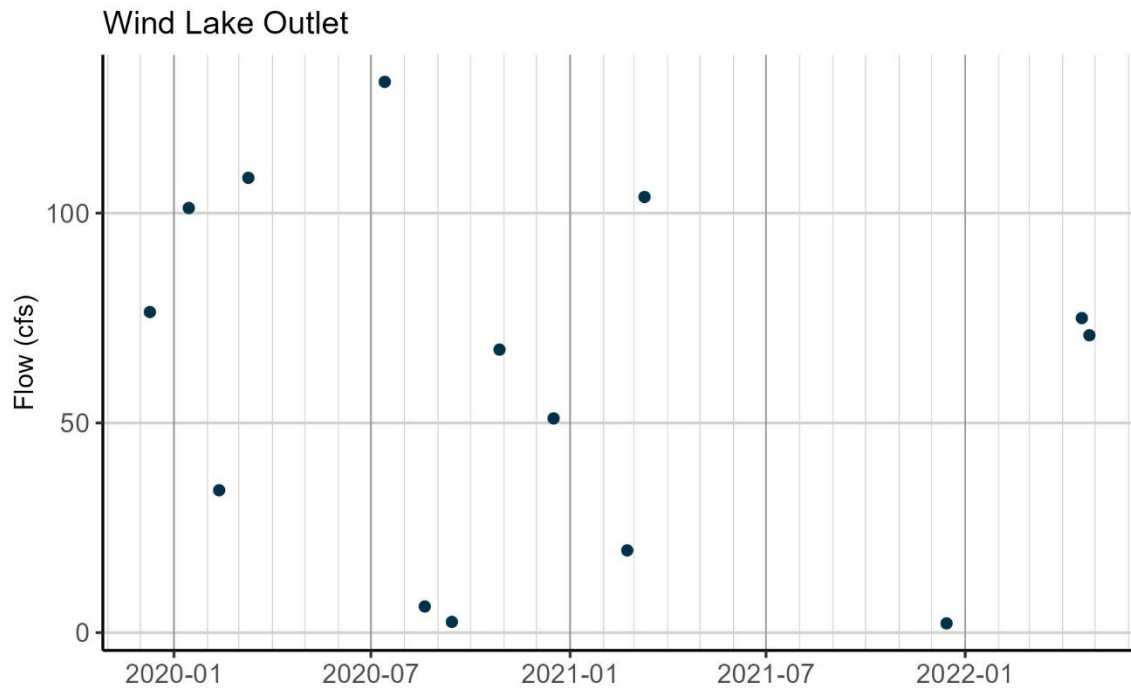


FIGURE D.7

Flow Measurements for Honey Creek at Academy Road

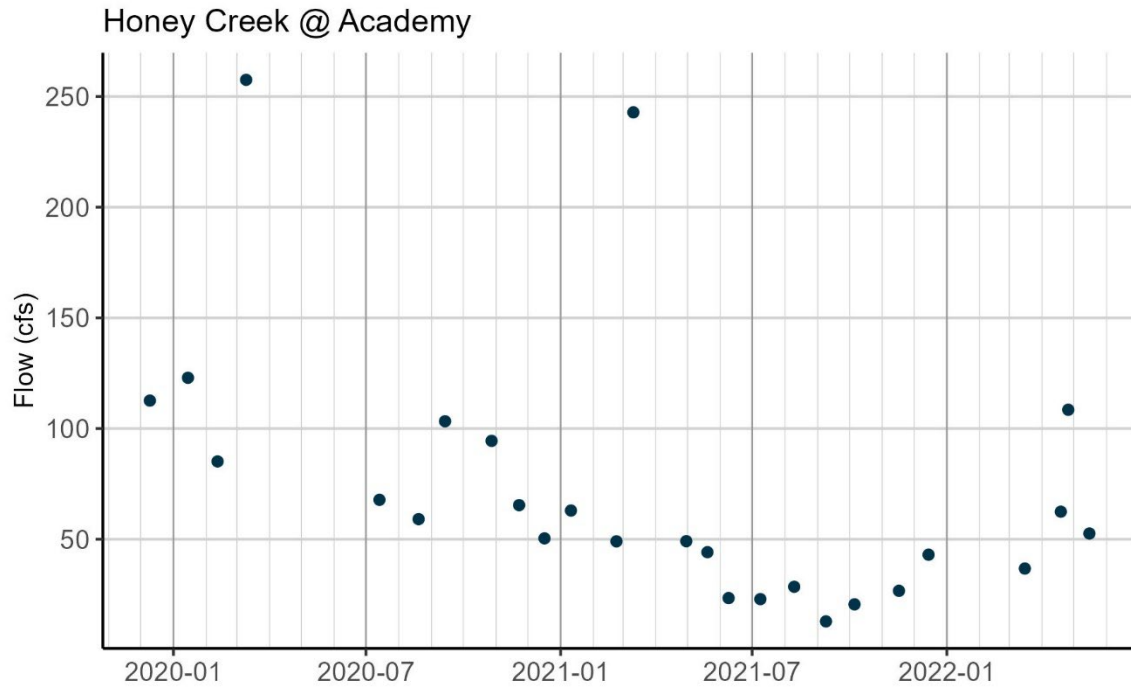


FIGURE D.8

Flow Measurements for Sugar Creek at Potter Road

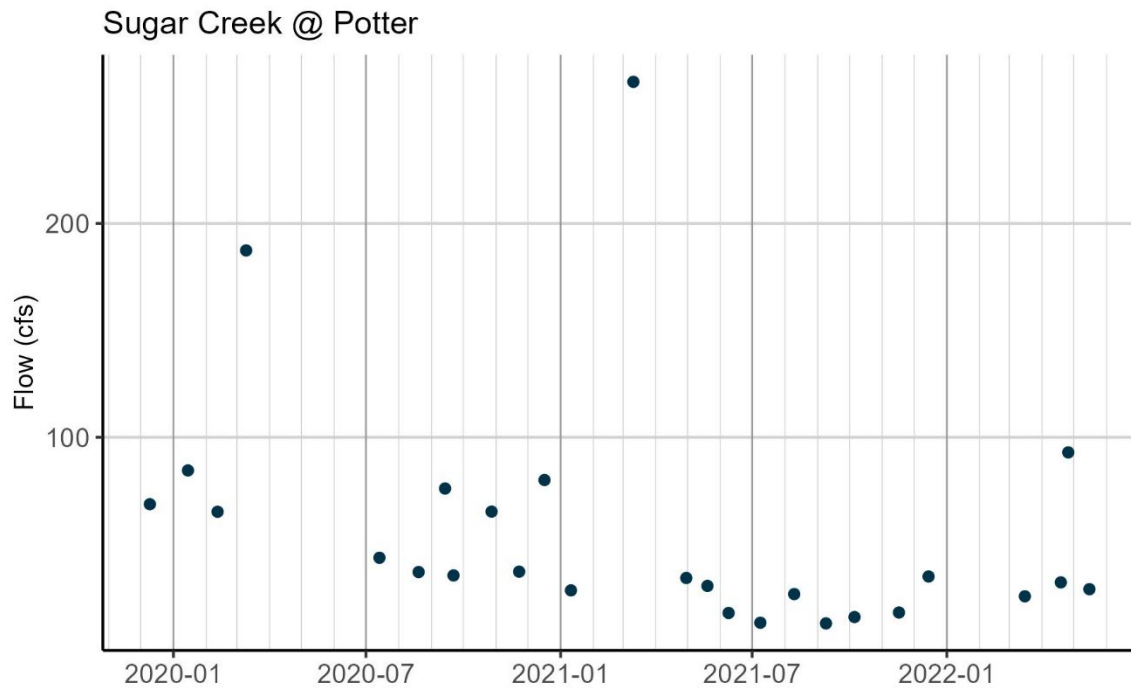
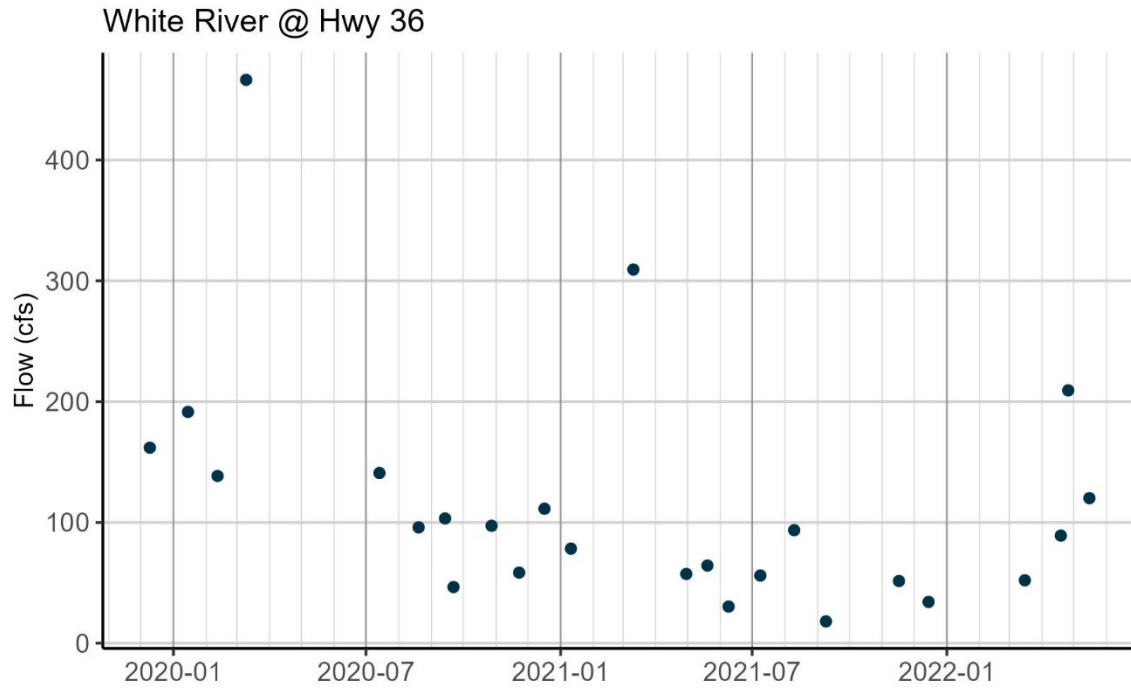


FIGURE D.9
Flow Measurements for White River at Highway 36



APPENDIX E

WDNR LONG-TERM TRENDS DATA IN THE FOX ILLINOIS RIVER BASIN TMDL STUDY AREA

The Department of Natural Resources maintains long-term monitoring stations to evaluate trends over time at specific stations across the state. Two of these locations – the Fox River below Waukesha and the Fox River near New Munster – are within the Fox Illinois River TMDL study site. Results from the long-term trends monitoring are summarized on the DNR’s Long-Term River Water Quality web application. The estimated trends since 2012 for total phosphorus, orthophosphate, and total suspended solids are shown in Figures E.1 through E.3. Estimates of total phosphorus, orthophosphate, and total suspended solids for the two sites are summarized in Figures E.3 through E.15. All figures from the appendix are copied directly from DNR’s Long-Term Trend application.

FIGURE E.1
Trend of Total Phosphorus for Sites in the Study Area (Since 2012)

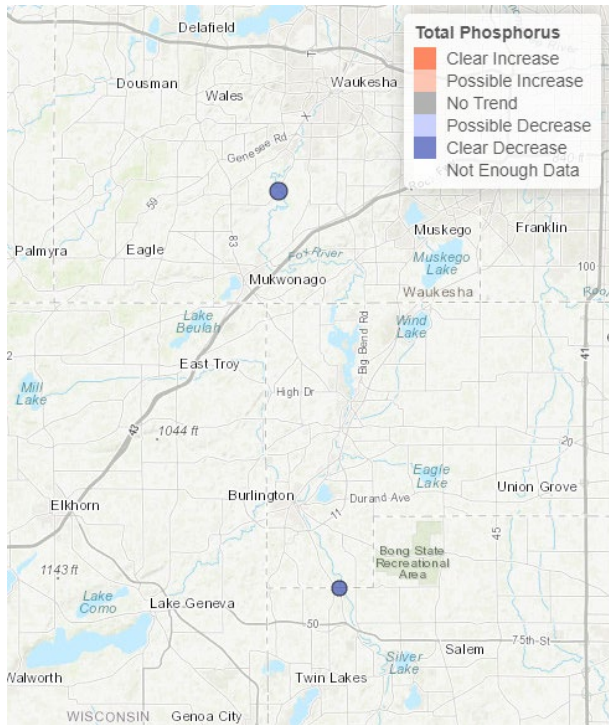


FIGURE E.2
Trend of Orthophosphate for Sites in the Study Area (Since 2012)

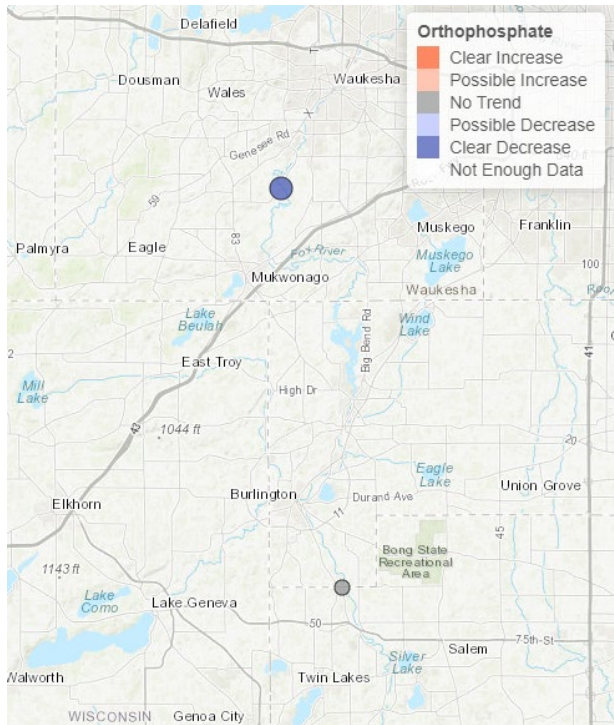


FIGURE E.3
Trend of Total Suspended Solids for Sites in the Study Area (Since 2012)

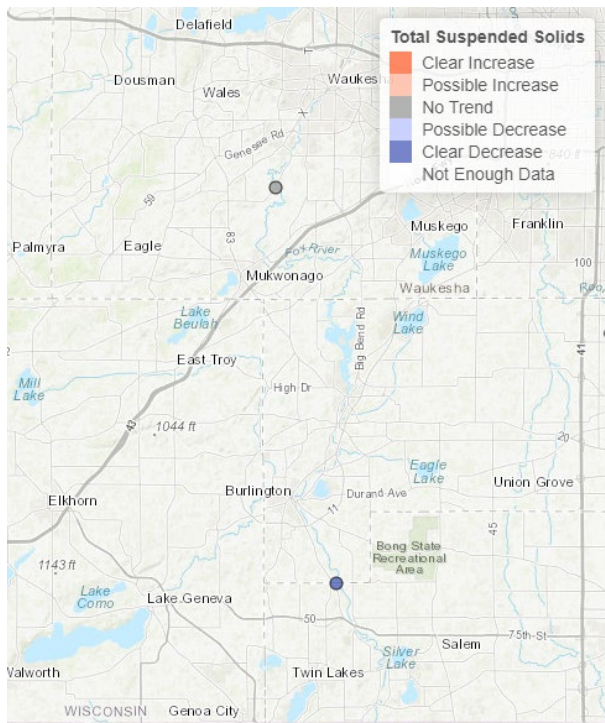


FIGURE E.4
Annual Trend of Total Phosphorus at Fox River below Waukesha

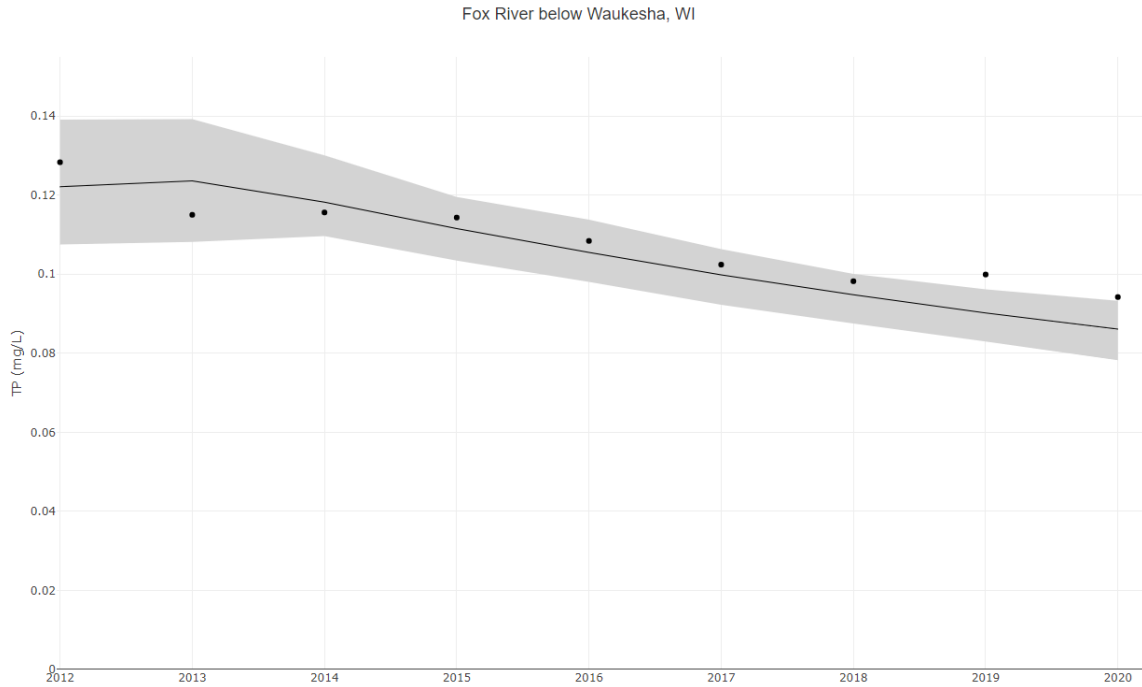


FIGURE E.5
Daily Total Phosphorus and Flows at Fox River below Waukesha

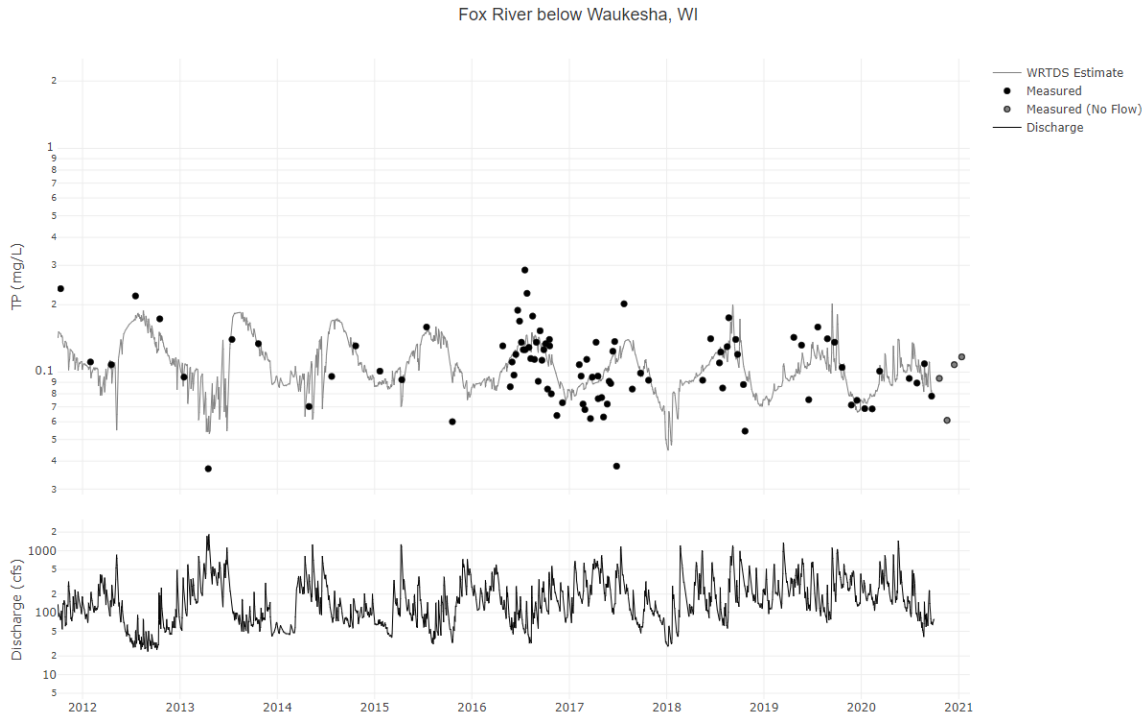


FIGURE E.6
Annual Trend of Total Phosphorus at Fox River near New Munster

Fox River near New Munster, WI

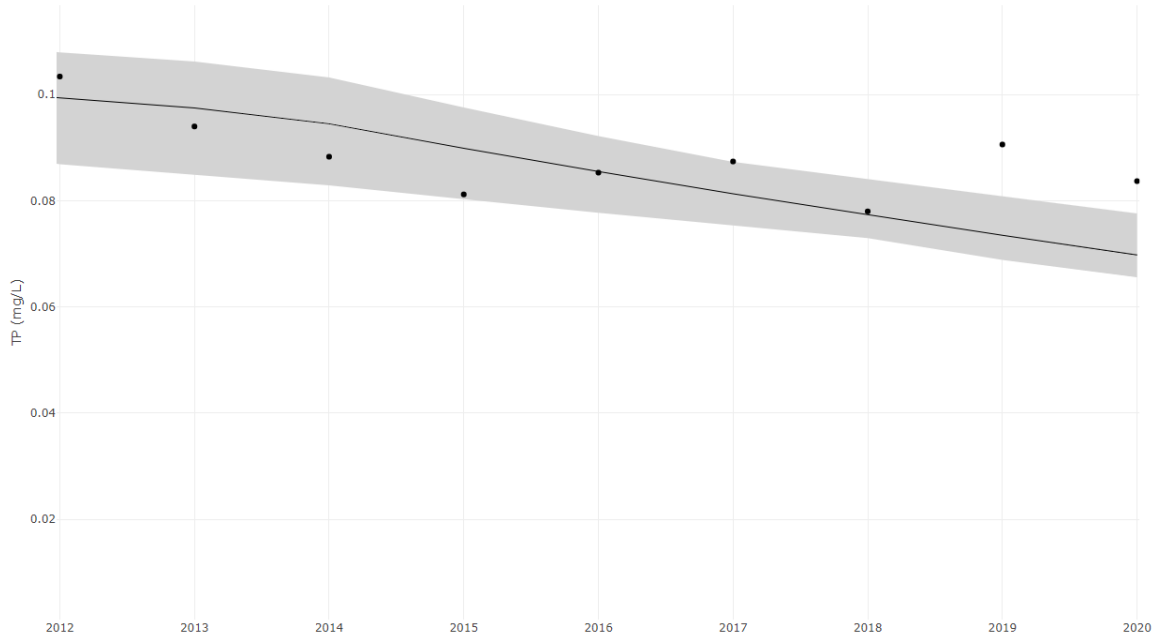


FIGURE E.7
Daily Total Phosphorus and Flows at Fox River near New Munster

Fox River near New Munster, WI

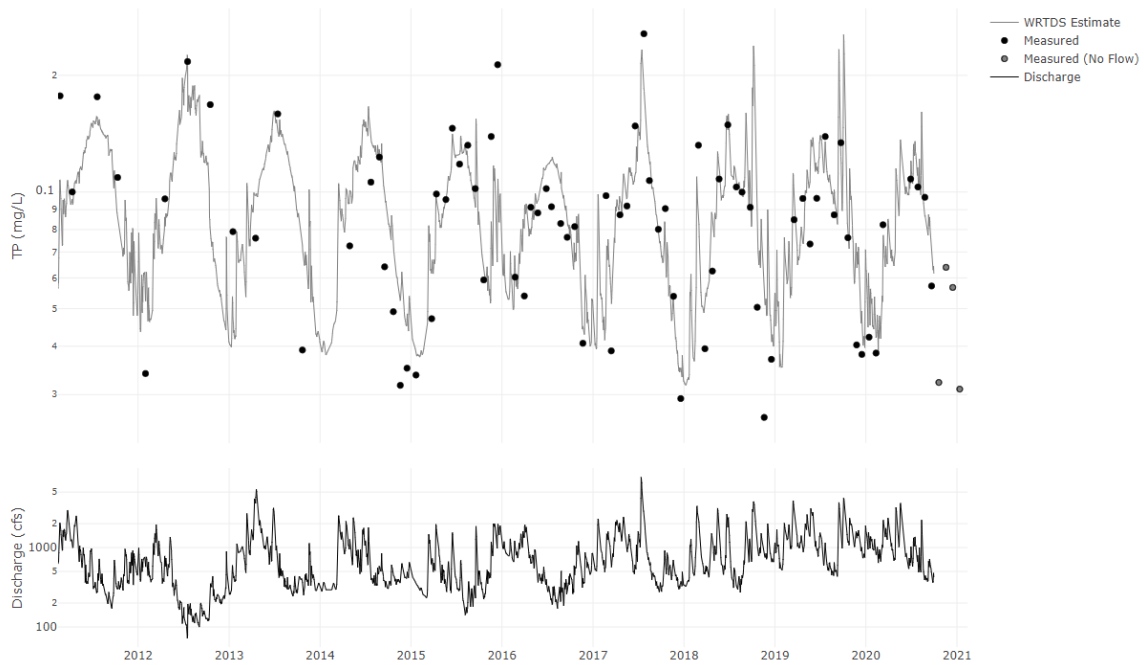


FIGURE E.8
Annual Trend of Orthophosphate at Fox River below Waukesha

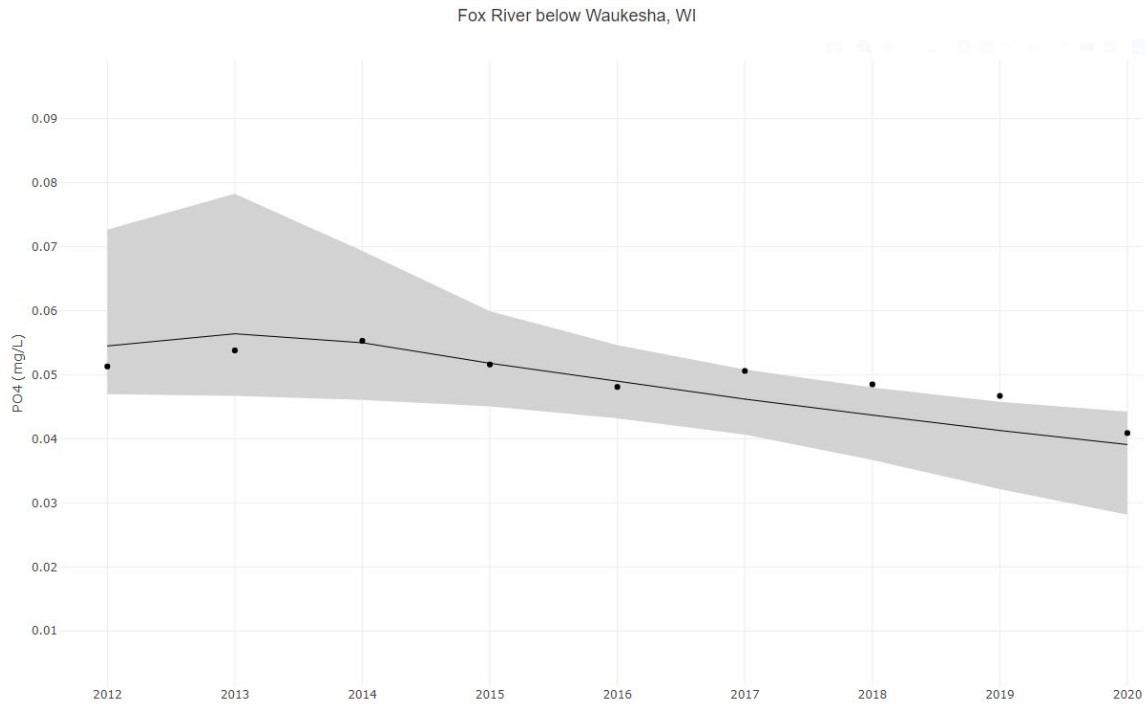


FIGURE E.9
Daily Orthophosphate and Flows at Fox River below Waukesha

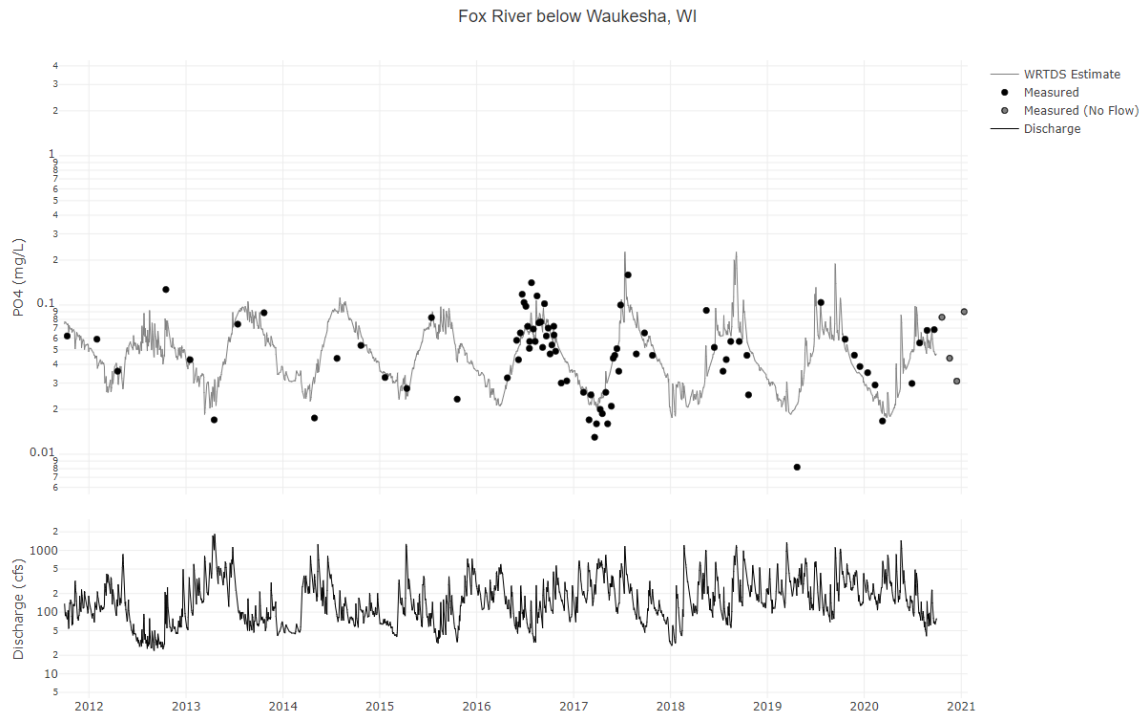


FIGURE E.10
Annual Trend of Orthophosphate at Fox River near New Munster
 Fox River near New Munster, WI

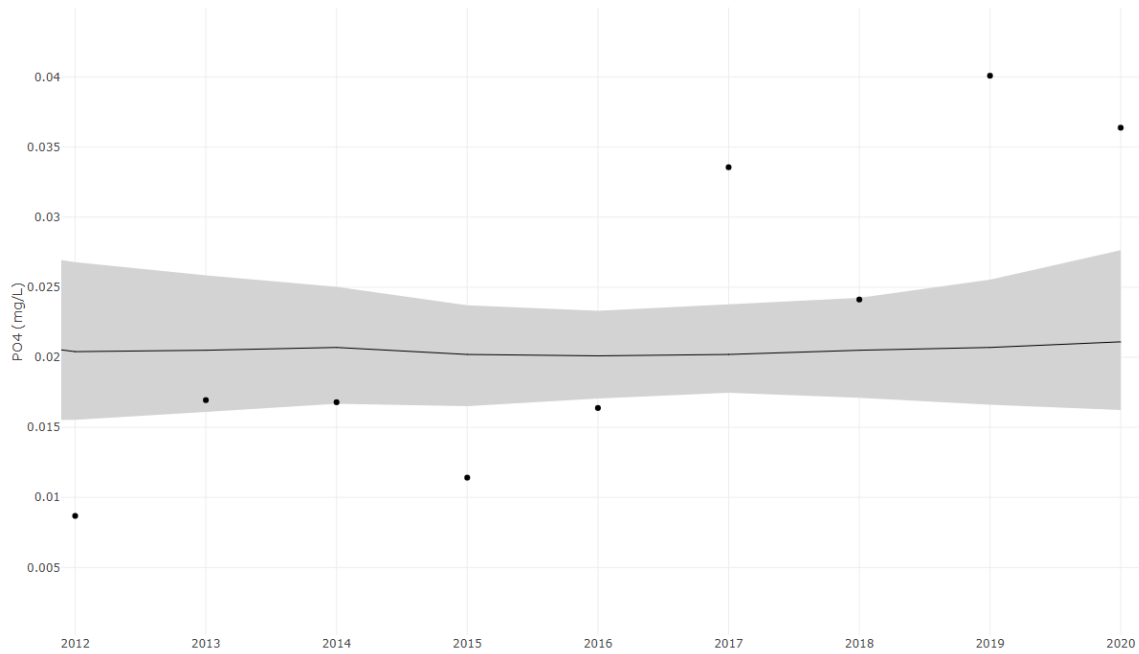


FIGURE E.11
Daily Orthophosphate and Flows at Fox River near New Munster
 Fox River near New Munster, WI

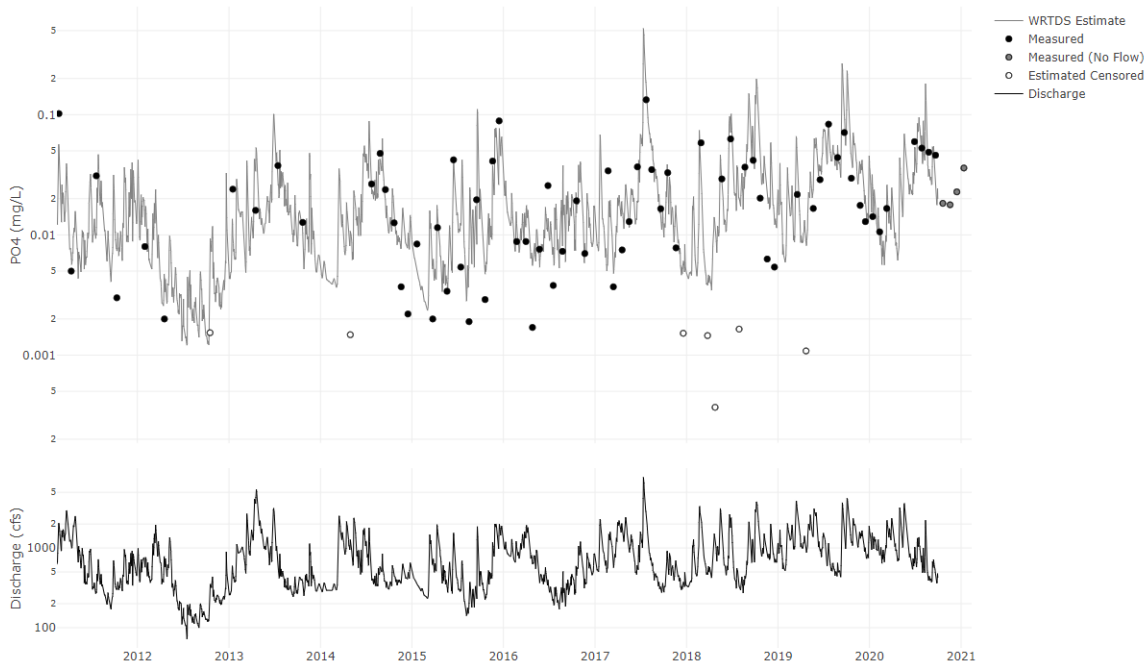


FIGURE E.12
Annual Trend of TSS at Fox River below Waukesha

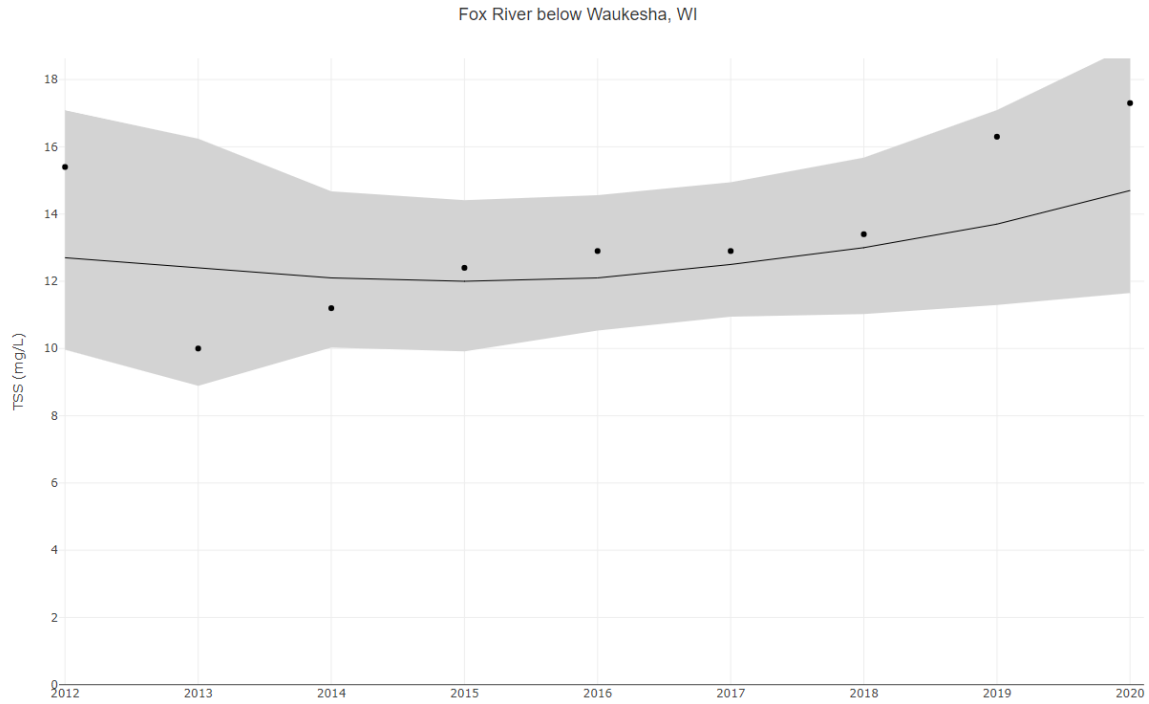


FIGURE E.13
Daily TSS and Flows at Fox River below Waukesha

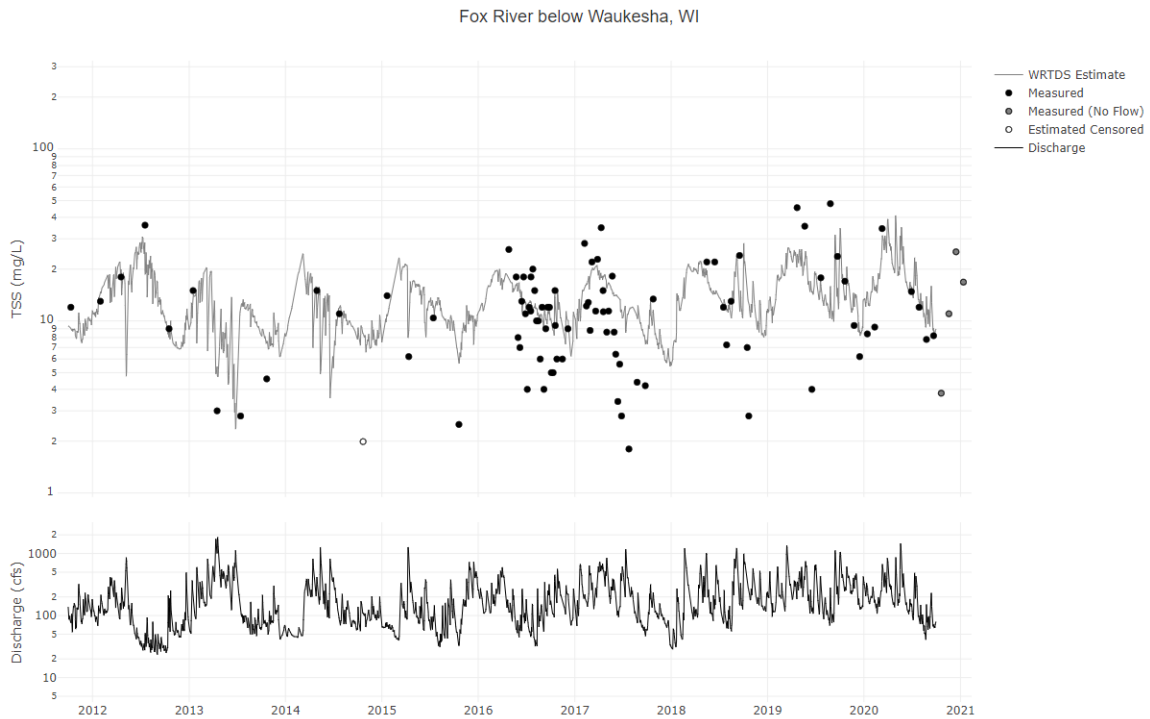


FIGURE E.14
Annual Trend of TSS at Fox River near New Munster
 Fox River near New Munster, WI

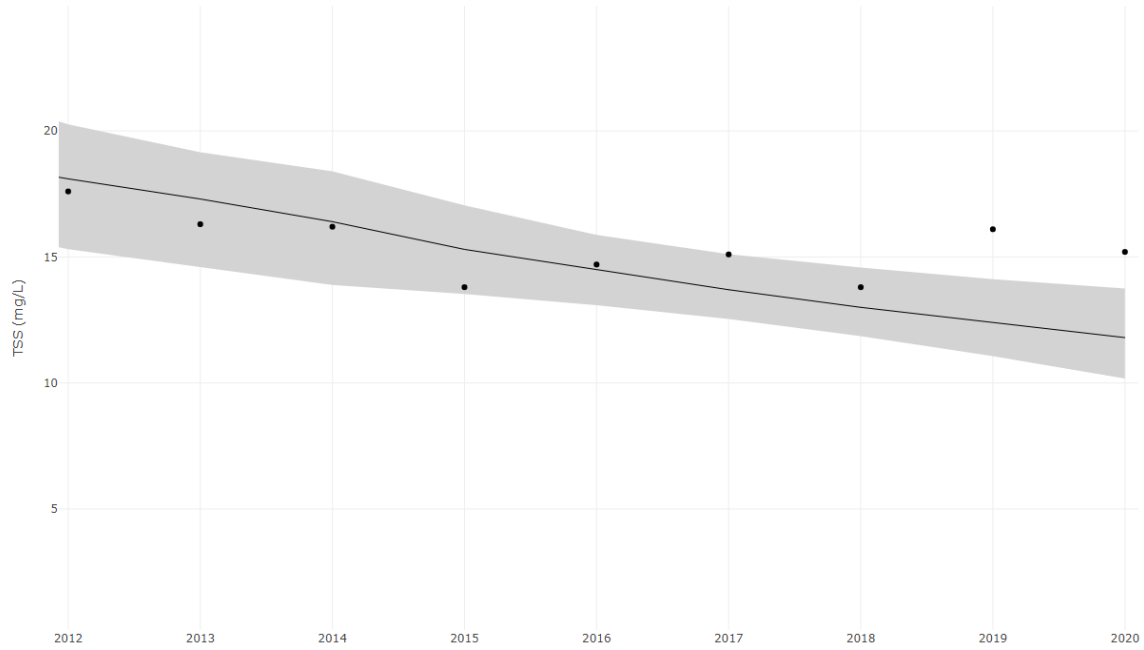
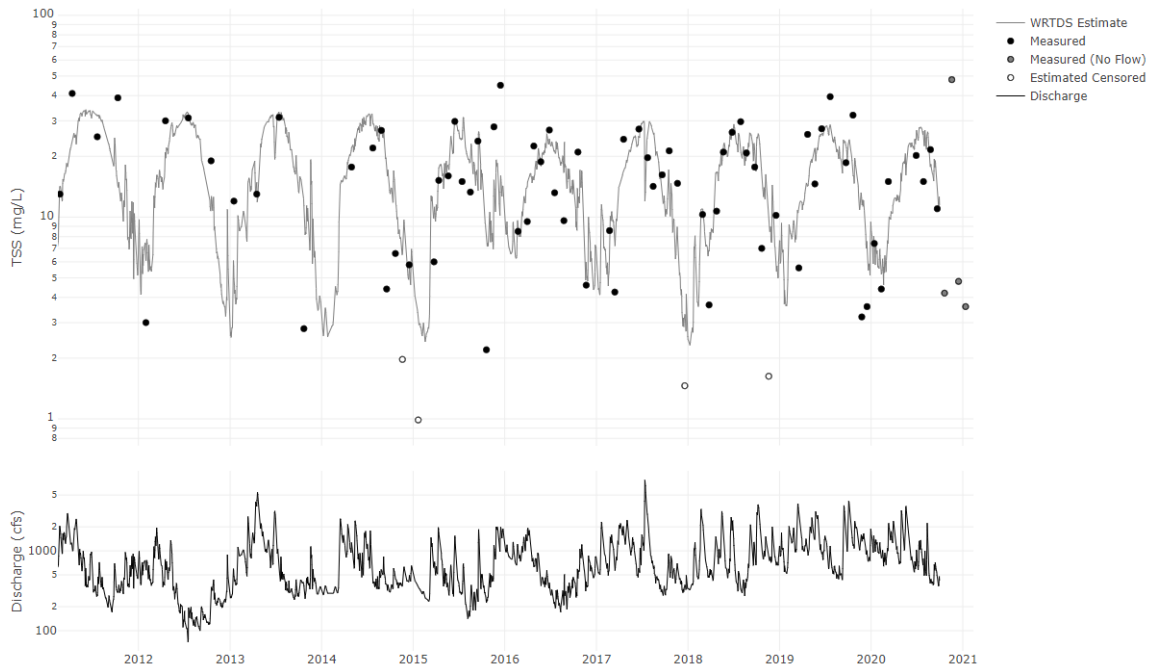


FIGURE E.15
Daily TSS and Flows at Fox River near New Munster
 Fox River near New Munster, WI



APPENDIX F

SUPPLEMENTAL WATER QUALITY DATA FROM SWIMS

In addition to the water quality data collected during the monitoring project for the TMDL, water quality sampling at a variety of sites in the basin was performed by the DNR and other entities. Total phosphorus, orthophosphate, and total suspended solids data from 19 river sites and 31 lake sites were downloaded from the DNR's Surface Water Integrated Monitoring System. A summary of the locations and the number of available samples are provided in Table F.1 for rivers and Table F.2 for lakes. Results from the downloaded data are summarized in Tables F.3 through F.15. The summaries are presented for samples collected during all months and samples collected during the growing season. The growing season is defined as May 1st through October 31st for rivers and June 15th through September 15th for lakes.

**TABLE F.1
River SWIMS Samples for Simulation Period (All Months)**

SWIMS ID	Station Location	# Samples - All Months		
		TP	Ortho-P	TSS
683207	Fox River at Center Drive	17	-	12
523093	Fox River at Cth Jb	124	-	-
10046947	Fox River at Cth L	56	54	58
523092	Fox River at Cth W	124	-	-
10052246	Fox River at Jefferson Street	124	-	-
10052205	Fox River at Sth 83	187	-	-
10054212	Fox River d/s of Burlington WWTP	49	-	-
10042192	Fox River d/s of Waterford Dam	25	24	25
10052207	Fox River near Sth 83 (WRCSD)	187	-	-
683299	Jericho Creek at Cth LO	17	-	-
10029281	Mukwonago River at Beulah Road	12	-	-
10032435	Mukwonago River at Sth 83	57	54	58
683458	Pebble Creek at Hwy D	13	-	-
10029788	Pewaukee River at Capitol Drive	12	-	-
10029789	Pewaukee River at Lindsey Road	11	-	-
10039464	Spring Creek at Lindsay Road	12	-	-
653267	White River at Center Street	93	-	-
10052247	White River at Milwaukee Ave	122	-	-
653104	White River at Sth 11	124	-	-

TABLE F.2

Lake SWIMS Samples for Simulation Period (All Months)

SWIMS ID	Station Location	# Samples - All Months	
		TP	Ortho-P
523132	Bohner Lake - Deep Hole	23	-
653219	Booth Lake - Deep Hole	56	-
523120	Browns Lake - Deep Hole	42	-
10014964	Denoon Lake	13	-
523131	Eagle Lake - Deep Hole	28	-
683258	Eagle Spring Lake - Deep Hole	42	-
10052245	Echo Lake at Wagner Park	122	-
653122	Geneva Lake - Deep Hole	281	130
653123	Green Lake - Deep Hole	49	-
653289	Honey Lake - Deep Hole	11	-
303053	Hooker Lake - Deep Hole	23	-
653121	Lake Beulah - Deep Hole	69	30
653135	Lake Beulah - Station 2	21	-
303121	Lake Mary - Deep Hole	43	-
303126	Lilly Lake - Deep Hole	41	-
683127	Little Muskego Lake - Deep Hole	16	-
683260	Lower Phantom Lake - Deep Hole	59	-
653124	Middle Lake - Deep Hole	48	-
653125	Mill Lake - Deep Hole	48	-
303122	Paddock Lake - Deep Hole	45	-
683143	Pewaukee Lake - Deep Hole	44	-
10033632	Pewaukee Lake - East Basin	41	-
653220	Potter Lake - Middle	58	-
303050	Powers Lake - Deep Hole	107	-
10029908	Rock Lake - Center	10	-
303123	Silver Lake - Deep Hole	28	-
523122	Tichigan Lake - Deep Hole	53	-
683259	Upper Phantom Lake - Deep Hole	27	-
303130	Vern Wolf Lake - Deep Hole	18	-
523117	Waubeesee Lake - Deep Hole	35	-
523124	Wind Lake - Deep Hole	168	-

TABLE F.3

Total Phosphorus Concentrations at River SWIMS Sites (All Months)

SWIMS ID	Station Location	TP Concentration (µg/L) - All Months				
		Min	Q1	Median	Q3	Max
683207	Fox River at Center Drive	41	75	92	129	210
523093	Fox River at Cth Jb	17	78	98	118	267
10046947	Fox River at Cth L	10	71	89	115	238
523092	Fox River at Cth W	34	68	90	116	305
10052246	Fox River at Jefferson Street	17	71	94	118	214
10052205	Fox River at Sth 83	15	58	83	112	480
10054212	Fox River d/s of Burlington WWTP	38	55	109	137	310
10042192	Fox River d/s of Waterford Dam	29	64	87	106	163
10052207	Fox River near Sth 83 (WRCSD)	15	59	85	112	430
683299	Jericho Creek at Cth LO	16	20	25	33	65
10029281	Mukwonago River at Beulah Road	17	22	26	34	48
10032435	Mukwonago River at Sth 83	7	12	16	19	80
683458	Pebble Creek at Hwy D	27	34	37	87	161
10029788	Pewaukee River at Capitol Drive	41	54	115	151	252
10029789	Pewaukee River at Lindsey Road	27	57	67	82	247
10039464	Spring Creek at Lindsay Road	47	82	149	221	308
653267	White River at Center Street	6	13	15	20	140
10052247	White River at Milwaukee Ave	34	78	99	118	213
653104	White River at Sth 11	35	75	92	113	337

TABLE F.4

Total Phosphorus Concentrations at Lake SWIMS Sites (All Months)

SWIMS ID	Station Location	TP Concentration (µg/L) - All Months				
		Min	Q1	Median	Q3	Max
523132	Bohner Lake - Deep Hole	15	20	21	25	33
653219	Booth Lake - Deep Hole	6	12	13	20	38
523120	Browns Lake - Deep Hole	12	16	21	24	39
10014964	Denoon Lake	5	16	23	36	244
523131	Eagle Lake - Deep Hole	19	54	82	130	238
683258	Eagle Spring Lake - Deep Hole	10	16	18	21	26
10052245	Echo Lake at Wagner Park	28	72	95	123	454
653122	Geneva Lake - Deep Hole	3	11	13	16	119
653123	Green Lake - Deep Hole	5	9	10	11	18
653289	Honey Lake - Deep Hole	31	45	56	72	99
303053	Hooker Lake - Deep Hole	23	27	30	36	63

SWIMS ID	Station Location	Min	Q1	Median	Q3	Max
653121	Lake Beulah - Deep Hole	3	13	16	18	41
653135	Lake Beulah - Station 2	12	15	17	31	47
303121	Lake Mary - Deep Hole	10	14	17	19	25
303126	Lilly Lake - Deep Hole	5	13	14	15	28
683127	Little Muskego Lake - Deep Hole	10	15	18	24	224
683260	Lower Phantom Lake - Deep Hole	3	15	18	23	34
653124	Middle Lake - Deep Hole	4	11	13	14	16
653125	Mill Lake - Deep Hole	5	13	15	17	27
303122	Paddock Lake - Deep Hole	8	16	19	23	29
683143	Pewaukee Lake - Deep Hole	12	17	18	20	26
10033632	Pewaukee Lake - East Basin	14	21	24	26	40
653220	Potter Lake - Middle	19	26	31	44	200
303050	Powers Lake - Deep Hole	9	15	18	25	65
10029908	Rock Lake - Center	13	15	16	18	22
303123	Silver Lake - Deep Hole	11	18	20	22	30
523122	Tichigan Lake - Deep Hole	20	26	32	42	413
683259	Upper Phantom Lake - Deep Hole	13	17	21	24	137
303130	Vern Wolf Lake - Deep Hole	16	22	30	32	45
523117	Waubeesee Lake - Deep Hole	12	16	18	22	32
523124	Wind Lake - Deep Hole	10	25	36	195	434

TABLE F.5
Orthophosphate Concentrations at River SWIMS Sites (All Months)

SWIMS ID	Station Location	DOP Concentration (µg/L) - All Months				
		Min	Q1	Median	Q3	Max
10046947	Fox River at Cth L	4.0	24.3	36.0	55.0	172.0
10042192	Fox River d/s of Waterford Dam	1.0	2.0	7.0	10.0	35.0
10032435	Mukwonago River at Sth 83	1.0	1.0	1.5	1.5	8.0

TABLE F.6
Orthophosphate Concentrations at Lake SWIMS Sites (All Months)

SWIMS ID	Station Location	DOP Concentration (µg/L) - All Months				
		Min	Q1	Median	Q3	Max
653122	Geneva Lake - Deep Hole	0.9	1.0	2.5	9.9	103.0
653121	Lake Beulah - Deep Hole	1.0	1.0	1.0	1.8	12.2

TABLE F.7

TSS Concentrations at River SWIMS Sites (All Months)

SWIMS ID	Station Location	TSS Concentration (mg/L) - All Months				
		Min	Q1	Median	Q3	Max
683207	Fox River at Center Drive	1.3	4.4	11.7	18.2	31.2
10046947	Fox River at Cth L	0.4	4.7	8.6	14.9	32.8
10042192	Fox River d/s of Waterford Dam	2.0	12.0	16.0	29.0	41.0
10032435	Mukwonago River at Sth 83	0.1	0.8	1.2	1.9	12.8

TABLE F.8

River SWIMS Samples for Simulation Period (Growing Season)

SWIMS ID	Station Location	# Samples - Growing Season		
		TP	Ortho-P	TSS
683207	Fox River at Center Drive	17	-	12
523093	Fox River at Cth Jb	98	-	-
10046947	Fox River at Cth L	45	46	47
523092	Fox River at Cth W	98	-	-
10052246	Fox River at Jefferson Street	98	-	-
10052205	Fox River at Sth 83	126	-	-
10054212	Fox River d/s of Burlington WWTP	35	-	-
10042192	Fox River d/s of Waterford Dam	23	22	23
10052207	Fox River near Sth 83 (WRCSD)	126	-	-
683299	Jericho Creek at Cth LO	17	-	-
10029281	Mukwonago River at Beulah Road	12	-	-
10032435	Mukwonago River at Sth 83	46	46	47
683458	Pebble Creek at Hwy D	13	-	-
10029788	Pewaukee River at Capitol Drive	12	-	-
10029789	Pewaukee River at Lindsey Road	10	-	-
10039464	Spring Creek at Lindsay Road	12	-	-
653267	White River at Center Street	51	-	-
10052247	White River at Milwaukee Ave	98	-	-
653104	White River at Sth 11	98	-	-

TABLE F.9

Lake SWIMS Samples for Simulation Period (Growing Season)

SWIMS ID	Station Location	# Samples - Growing Season	
		TP	Ortho-P
523132	Bohner Lake - Deep Hole	18	-
653219	Booth Lake - Deep Hole	28	-
523120	Browns Lake - Deep Hole	31	-
10014964	Denoon Lake	11	-
523131	Eagle Lake - Deep Hole	19	-
683258	Eagle Spring Lake - Deep Hole	35	-
10052245	Echo Lake at Wagner Park	62	-
653122	Geneva Lake - Deep Hole	208	65
653123	Green Lake - Deep Hole	38	-
653289	Honey Lake - Deep Hole	6	-
303053	Hooker Lake - Deep Hole	21	-
653121	Lake Beulah - Deep Hole	57	27
653135	Lake Beulah - Station 2	18	-
303121	Lake Mary - Deep Hole	31	-
303126	Lilly Lake - Deep Hole	31	-
683127	Little Muskego Lake - Deep Hole	12	-
683260	Lower Phantom Lake - Deep Hole	41	-
653124	Middle Lake - Deep Hole	37	-
653125	Mill Lake - Deep Hole	37	-
303122	Paddock Lake - Deep Hole	37	-
683143	Pewaukee Lake - Deep Hole	33	-
10033632	Pewaukee Lake - East Basin	34	-
653220	Potter Lake - Middle	37	-
303050	Powers Lake - Deep Hole	70	-
10029908	Rock Lake - Center	8	-
303123	Silver Lake - Deep Hole	22	-
523122	Tichigan Lake - Deep Hole	36	-
683259	Upper Phantom Lake - Deep Hole	14	-
303130	Vern Wolf Lake - Deep Hole	12	-
523117	Waubeesee Lake - Deep Hole	27	-
523124	Wind Lake - Deep Hole	120	-

TABLE F.10

Total Phosphorus Concentrations at River SWIMS Sites (Growing Season)

SWIMS ID	Station Location	TP Concentration ($\mu\text{g/L}$) - Growing Season				
		Min	Q1	Median	Q3	Max
683207	Fox River at Center Drive	41	75	92	129	210
523093	Fox River at Cth Jb	46	87	103	121	267
10046947	Fox River at Cth L	10	81	99	118	238
523092	Fox River at Cth W	34	72	95	121	305
10052246	Fox River at Jefferson Street	40	82	99	123	214
10052205	Fox River at Sth 83	17	72	90	120	480
10054212	Fox River d/s of Burlington WWTP	41	87	116	167	310
10042192	Fox River d/s of Waterford Dam	55	69	88	106	163
10052207	Fox River near Sth 83 (WRCSD)	17	72	97	121	430
683299	Jericho Creek at Cth LO	16	20	25	33	65
10029281	Mukwonago River at Beulah Road	17	22	26	34	48
10032435	Mukwonago River at Sth 83	7	12	16	19	80
683458	Pebble Creek at Hwy D	27	34	37	87	161
10029788	Pewaukee River at Capitol Drive	41	54	115	151	252
10029789	Pewaukee River at Lindsey Road	27	57	66	81	247
10039464	Spring Creek at Lindsay Road	47	82	149	221	308
653267	White River at Center Street	9	13	16	20	140
10052247	White River at Milwaukee Ave	45	87	101	124	213
653104	White River at Sth 11	35	79	99	118	337

TABLE F.11

Total Phosphorus Concentrations at Lake SWIMS Sites (Growing Season)

SWIMS ID	Station Location	TP Concentration ($\mu\text{g/L}$) - Growing Season				
		Min	Q1	Median	Q3	Max
523132	Bohner Lake - Deep Hole	15	20	21	25	30
653219	Booth Lake - Deep Hole	8	12	13	16	25
523120	Browns Lake - Deep Hole	12	18	22	25	39
10014964	Denoon Lake	5	15	21	27	244
523131	Eagle Lake - Deep Hole	19	76	96	147	238
683258	Eagle Spring Lake - Deep Hole	12	16	18	21	26
10052245	Echo Lake at Wagner Park	48	91	103	128	454
653122	Geneva Lake - Deep Hole	3	11	13	14	91
653123	Green Lake - Deep Hole	5	9	10	11	18

SWIMS ID	Station Location	Min	Q1	Median	Q3	Max
653289	Honey Lake - Deep Hole	41	57	71	85	99
303053	Hooker Lake - Deep Hole	23	27	32	37	63
653121	Lake Beulah - Deep Hole	3	13	16	19	41
653135	Lake Beulah - Station 2	12	15	18	33	47
303121	Lake Mary - Deep Hole	11	16	18	19	25
303126	Lilly Lake - Deep Hole	5	13	14	16	28
683127	Little Muskego Lake - Deep Hole	10	15	17	20	224
683260	Lower Phantom Lake - Deep Hole	11	15	16	21	34
653124	Middle Lake - Deep Hole	11	12	13	15	16
653125	Mill Lake - Deep Hole	11	14	16	18	21
303122	Paddock Lake - Deep Hole	8	17	19	23	29
683143	Pewaukee Lake - Deep Hole	12	16	18	19	24
10033632	Pewaukee Lake - East Basin	14	21	24	27	40
653220	Potter Lake - Middle	20	28	37	53	200
303050	Powers Lake - Deep Hole	13	16	20	34	65
10029908	Rock Lake - Center	13	16	17	19	22
303123	Silver Lake - Deep Hole	16	18	21	23	30
523122	Tichigan Lake - Deep Hole	20	25	30	37	413
683259	Upper Phantom Lake - Deep Hole	13	17	19	22	58
303130	Vern Wolf Lake - Deep Hole	16	22	28	31	43
523117	Waubeesee Lake - Deep Hole	12	16	18	22	27
523124	Wind Lake - Deep Hole	10	23	77	245	434

TABLE F.13
Orthophosphate Concentrations at River SWIMS Sites (Growing Season)

SWIMS ID	Station Location	DOP Concentration ($\mu\text{g/L}$) - Growing Season				
		Min	Q1	Median	Q3	Max
10046947	Fox River at Cth L	4.0	29.8	42.0	62.0	172.0
10042192	Fox River d/s of Waterford Dam	1.0	2.0	7.0	10.0	35.0
10032435	Mukwonago River at Sth 83	1.0	1.0	1.5	2.0	8.0

TABLE F.14

Orthophosphate Concentrations at Lake SWIMS Sites (Growing Season)

SWIMS ID	Station Location	DOP Concentration ($\mu\text{g/L}$) - Growing Season				
		Min	Q1	Median	Q3	Max
653122	Geneva Lake - Deep Hole	0.9	1.0	2.0	7.0	54.2
653121	Lake Beulah - Deep Hole	1.0	1.0	1.0	1.5	12.2

TABLE F.15

TSS Concentrations at River SWIMS Sites (Growing Season)

SWIMS ID	Station Location	TSS Concentration (mg/L) - Growing Season				
		Min	Q1	Median	Q3	Max
683207	Fox River at Center Drive	1.3	4.4	11.7	18.2	31.2
10046947	Fox River at Cth L	0.4	4.4	8.0	14.0	32.8
10042192	Fox River d/s of Waterford Dam	4.0	13.5	17.0	32.0	41.0
10032435	Mukwonago River at Sth 83	0.1	0.8	1.0	1.6	4.0

APPENDIX G

USGS STAGE AND FLOW DATA

USGS maintains stage and flow gages throughout the study area. Stage data are available at seven locations, and flow data are available at five locations. Table G.1 summarizes the available stage data, and Table G.2 summarizes the available flow data. The start date in the tables represent the date of the earliest available data. An end date is not provided because all gages are still active. The tables also include some summary variables. 'Min' is the minimum value measured, 'Q1' is the value at which 25% of sample were smaller, the 'Median' is the median, 'Q3' is the value at which 25% of the samples were greater, and 'Max' represents the maximum value measured.

Average daily stage data for the seven stage gages are presented in Figures G.1 through G.7. Stage in the figures is presented for November 2019 through the end of 2022, which roughly corresponds with the timeframe of DNR's modeling. Stage-discharge curves – also known as rating curves – for the five USGS flow gages are presented in Figures G.8 through G.12. The rating curves show the relationship between depth and flow. Average daily flow for the five flow gages is presented in Figures G.12 through G.16. Data for these figures are also presented from November 2019 through the end of 2022.

TABLE G.1
Summary of Stage Data at USGS Gages in the Study Area

Site Number	Site Location	Start Date	Stage (ft)				
			Min	Q1	Med	Q3	Max
5544348	Fox River at Waterford	10/22/2015	1.44	1.62	1.66	1.72	2.02
5544475	Fox River at Rochester	3/19/2011	1.02	4.2	4.43	4.6	5.14
5544385	Muskego Lake	6/3/2010	10.3	11.54	11.7	11.84	13
424848088083100	Wind Lake	3/6/1985	5.96	7.66	8.02	8.23	9.86
423525088260400	Geneva Lake	9/10/1997	1.47	2.35	2.49	2.61	3.51
423000088164401	Elizabeth Lake	9/19/2018	793.58	793.98	794.15	794.26	795.21
5548185	Elizabeth Lake Drain	9/21/2018	793.44	793.81	794.05	794.15	794.79

FIGURE G.1
Average Daily Stage at USGS Gage in Fox River at Waterford Dam

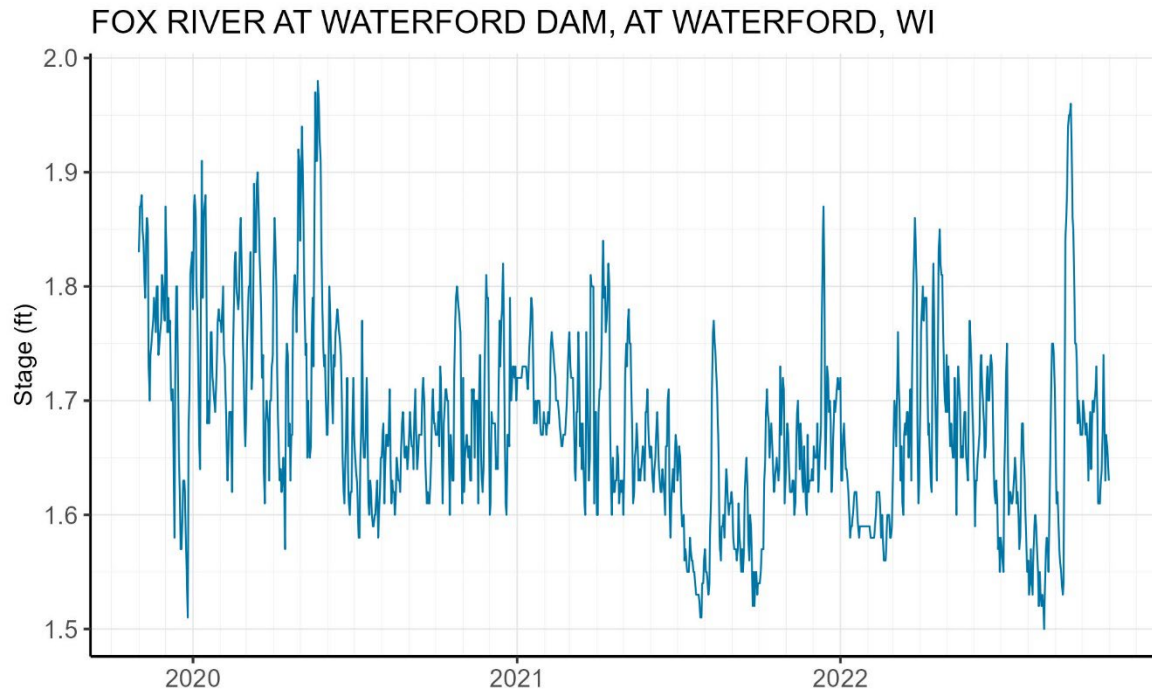


FIGURE G.2
Average Daily Stage at USGS Gage in Fox River at Rochester

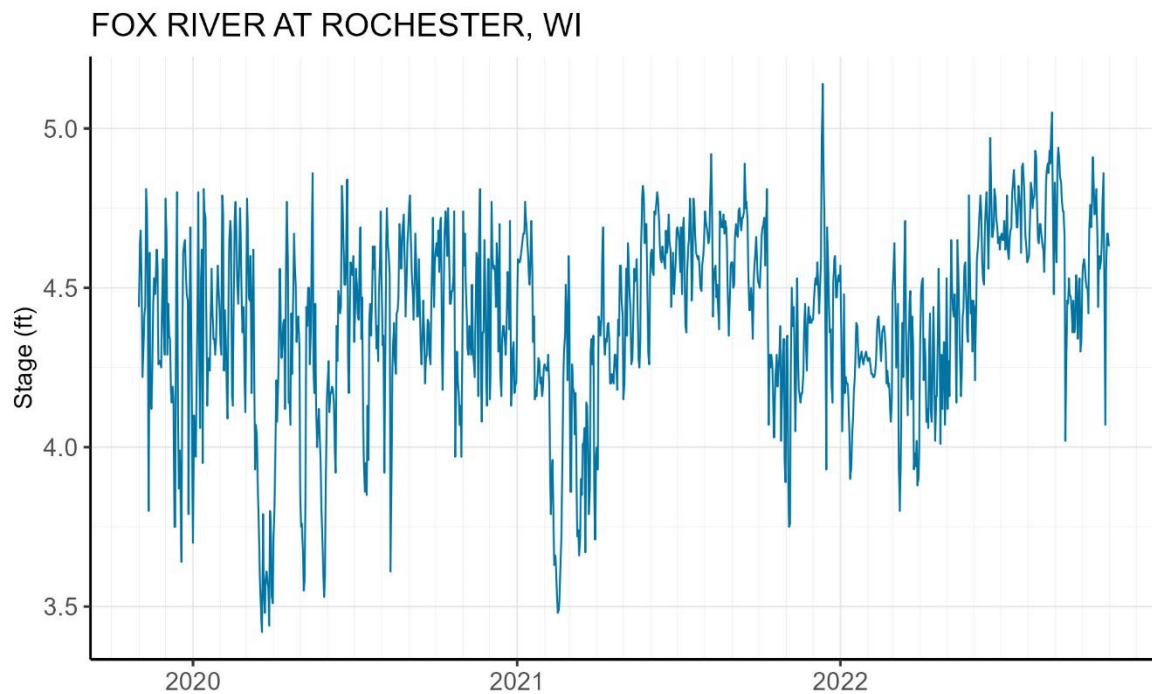


FIGURE G.3

Average Daily Stage at USGS Gage in Muskego Lake

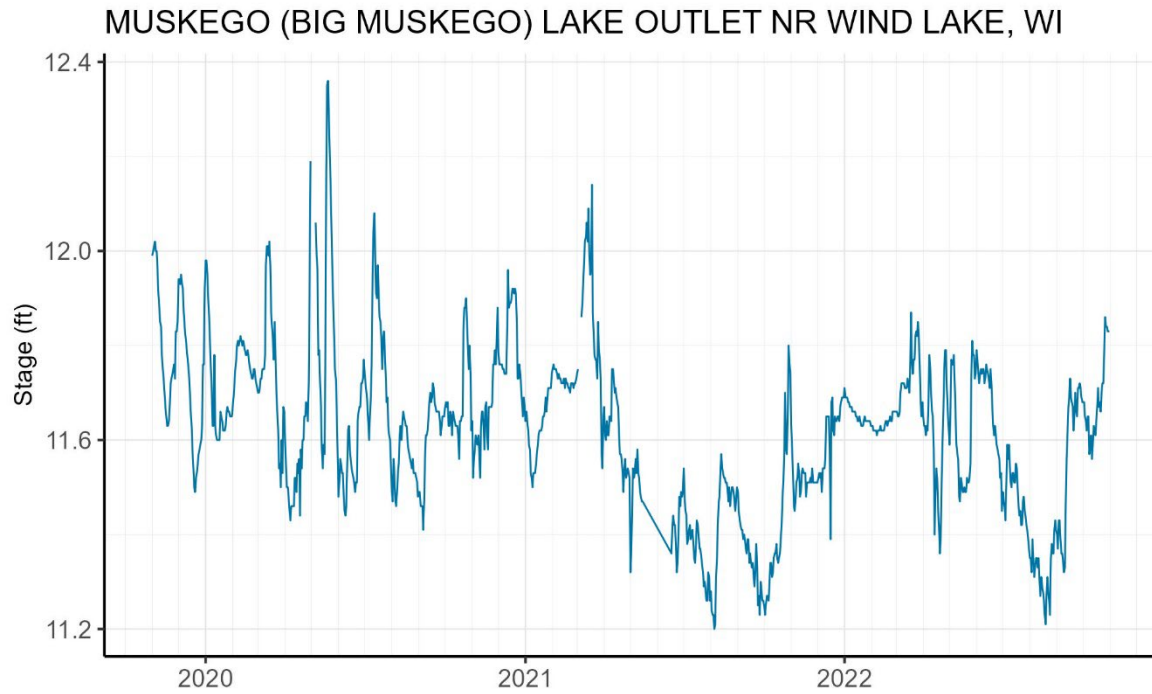


FIGURE G.4

Average Daily Stage at USGS Gage at Wind Lake Outlet

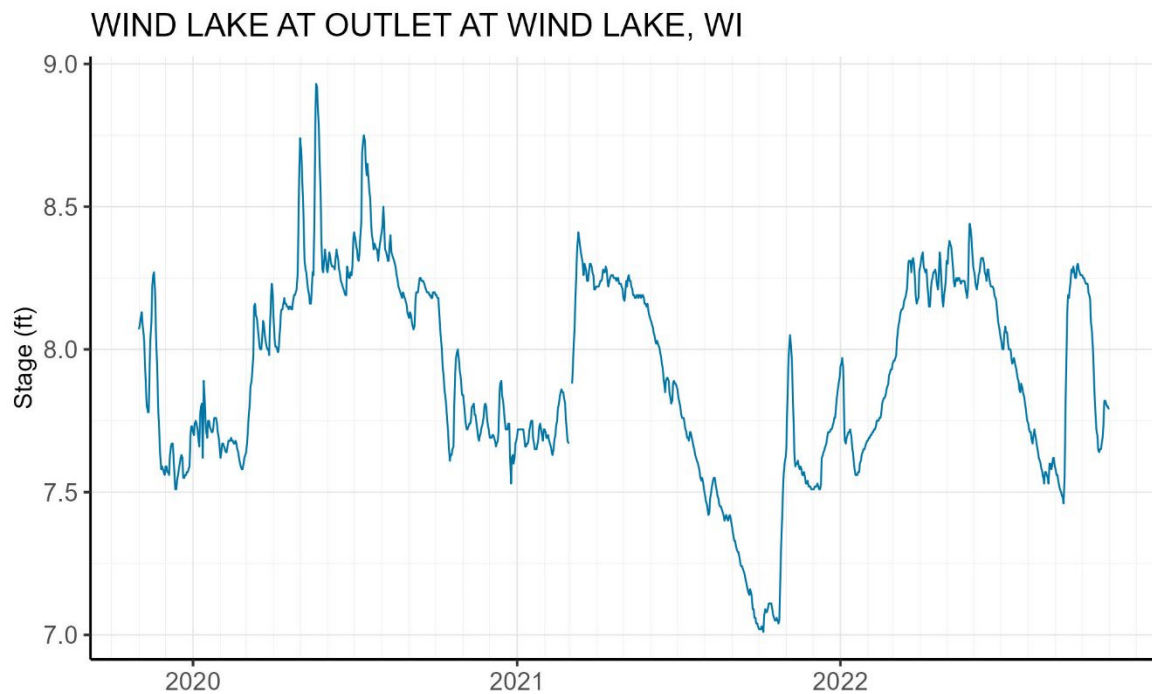


FIGURE G.5

Average Daily Stage at USGS Gage at Geneva Lake

GENEVA LAKE AT LAKE GENEVA, WI

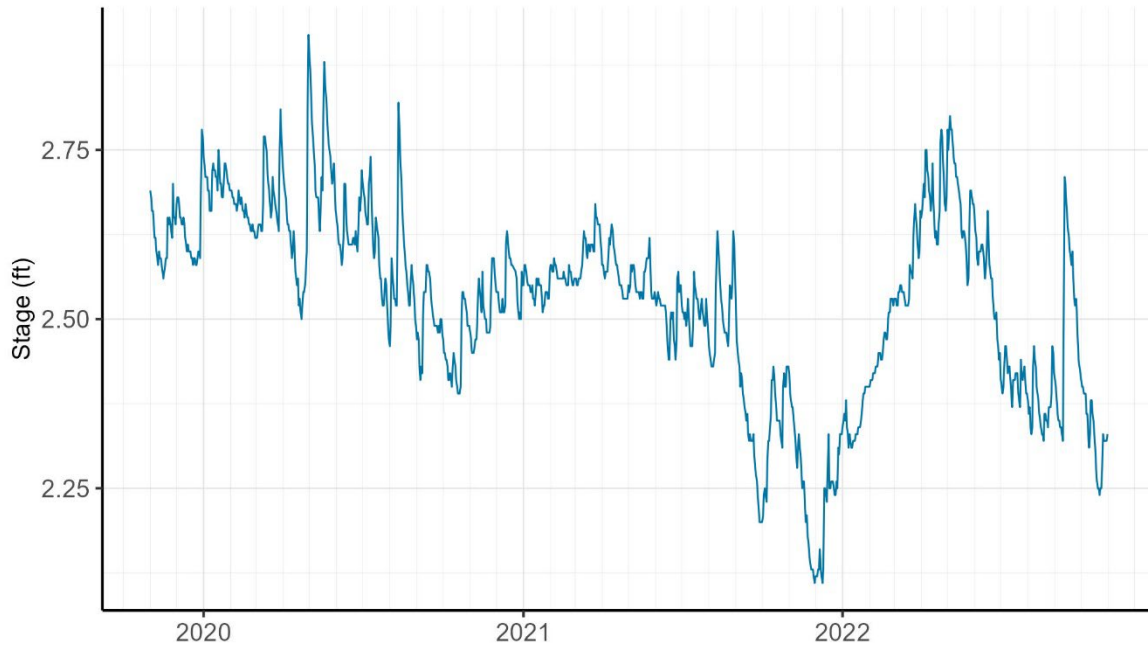


FIGURE G.6

Average Daily Stage at USGS Gage at Elizabeth Lake

ELIZABETH LAKE AT TWIN LAKES, WI-IL

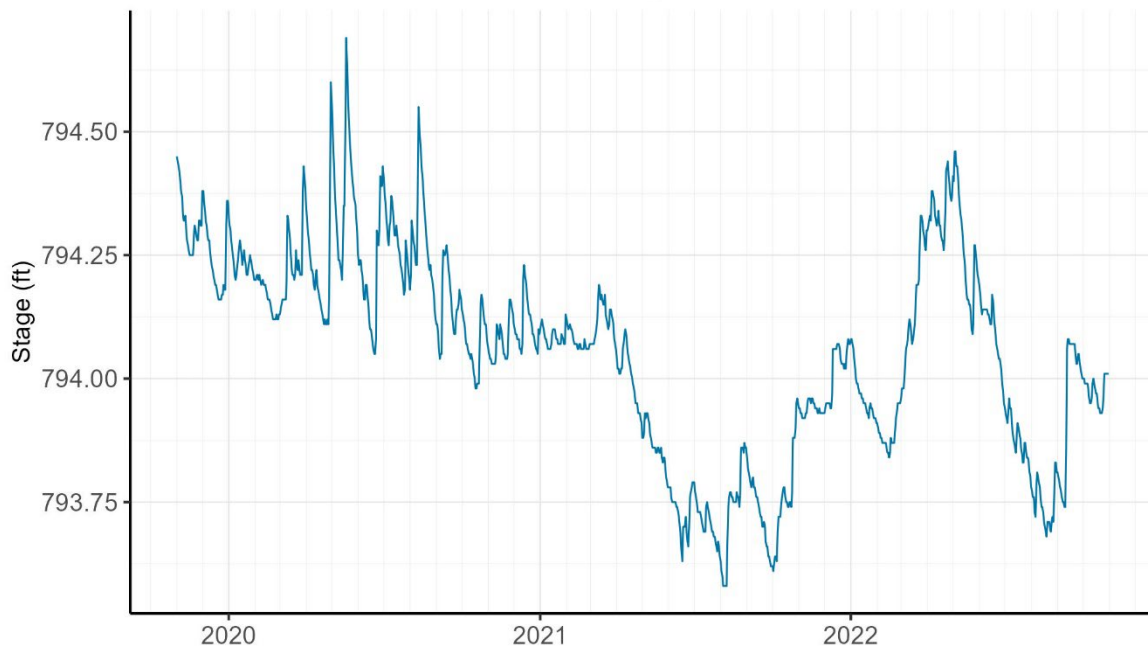


FIGURE G.7

Average Daily Stage at USGS Gage at Elizabeth Lake Drain

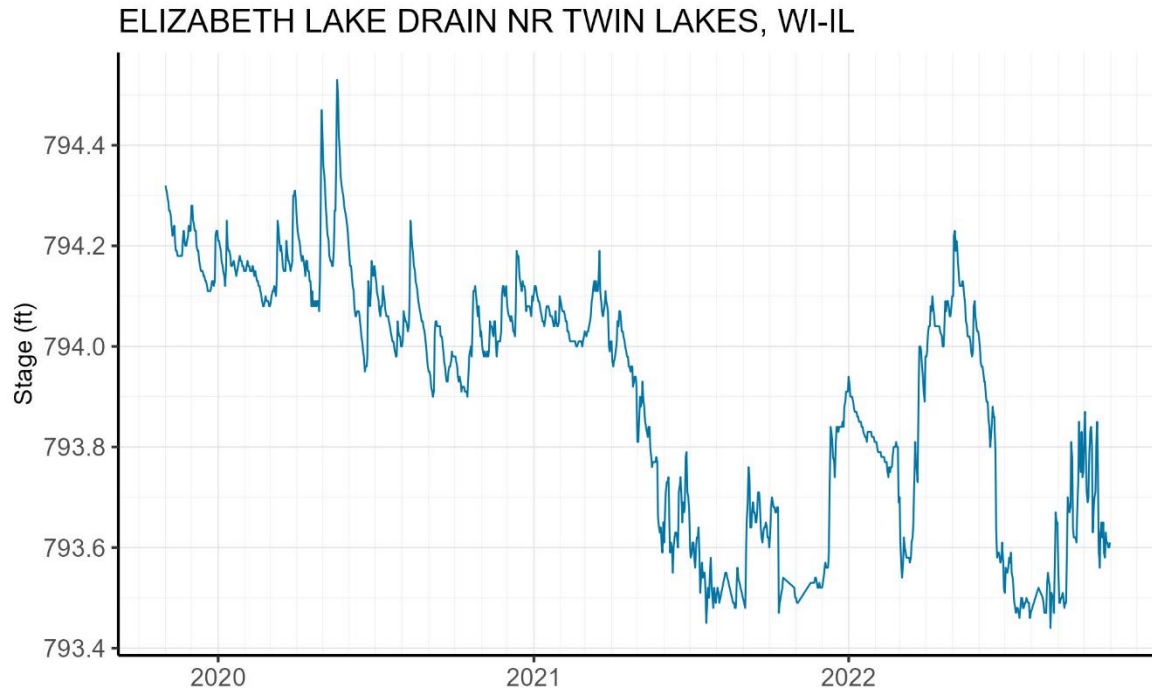


TABLE G.2

Summary of Flow Data at USGS Gages in the Study Area

Site Number	Site Location	Start Date	Flow (cfs)					
			Mean	Min	Q1	Med	Q3	Max
05543830	Fox R. at Waukesha	1/1/1963	116	3	41	73	139	2390
005545750	Fox R. near New Munster	9/30/1993	723	72	315	495	901	7710
05544200	Mukwonago R.	6/20/1973	59	2	33	50	74	439
055451345	White R. at Lake Geneva	9/30/1997	31	0	2	24	45	467
05527800	Des Plaines R. at Russell	7/1/1967	105	0	9	36	126	3260

FIGURE G.8
USGS Rating Curve for Fox River at Waukesha, WI

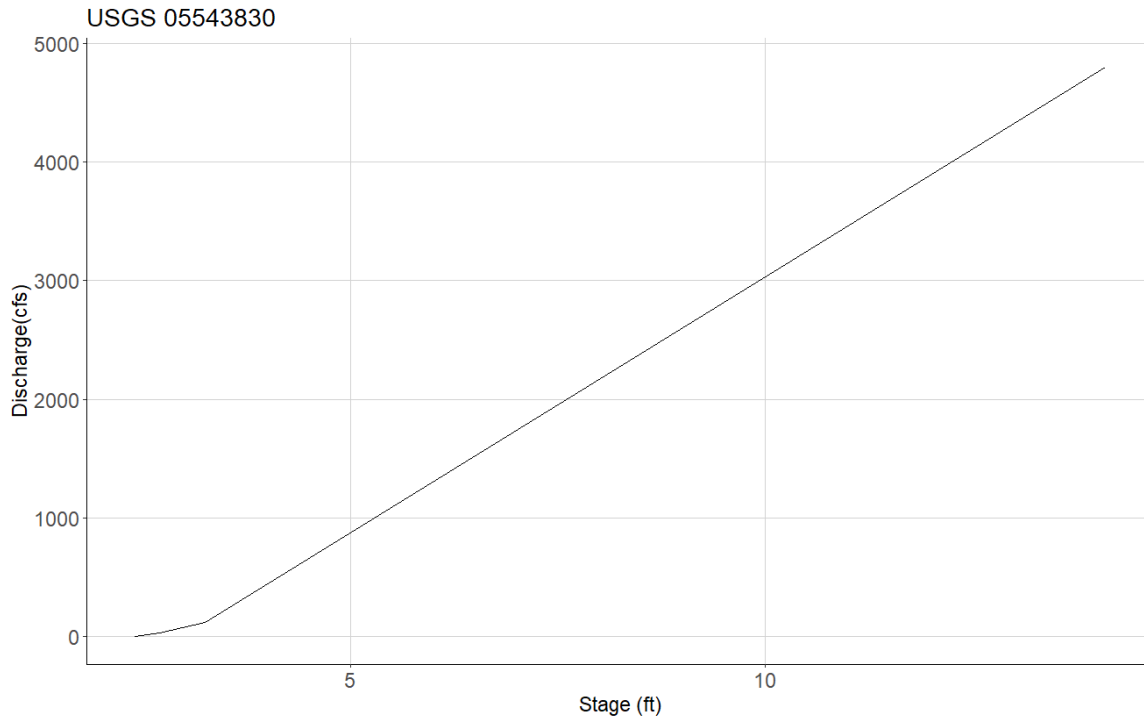


FIGURE G.9
USGS Rating Curve for Fox River at New Munster, WI

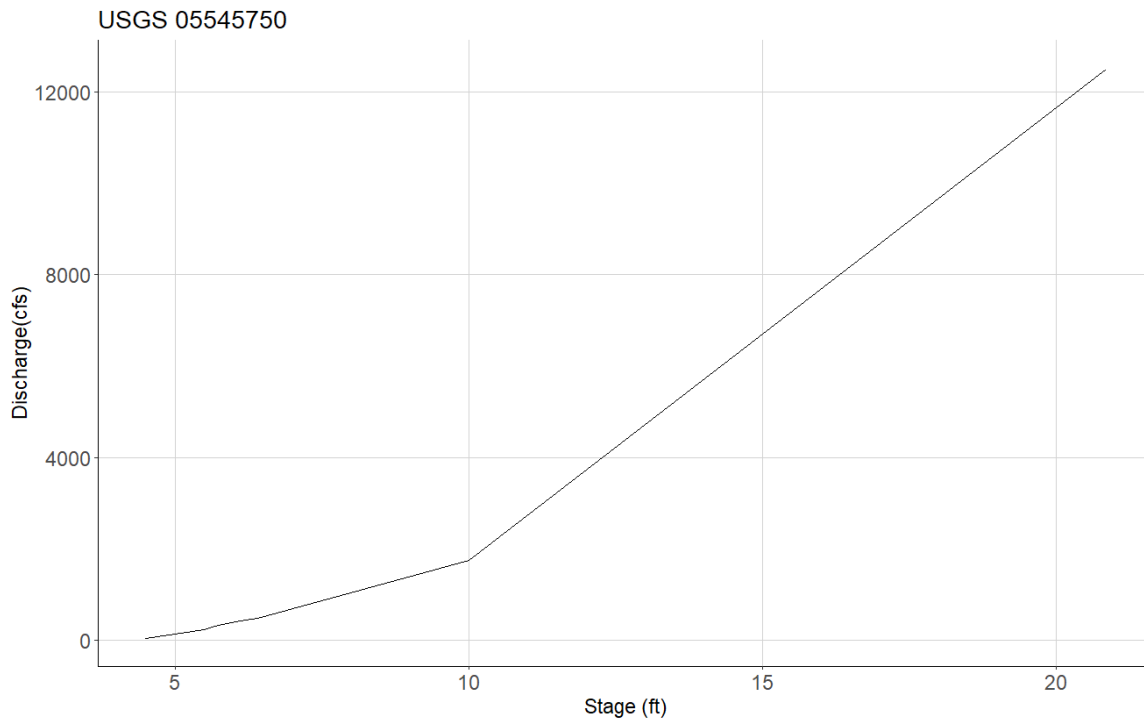


FIGURE G.10
USGS Rating Curve for Mukwonago River at Mukwonago, WI

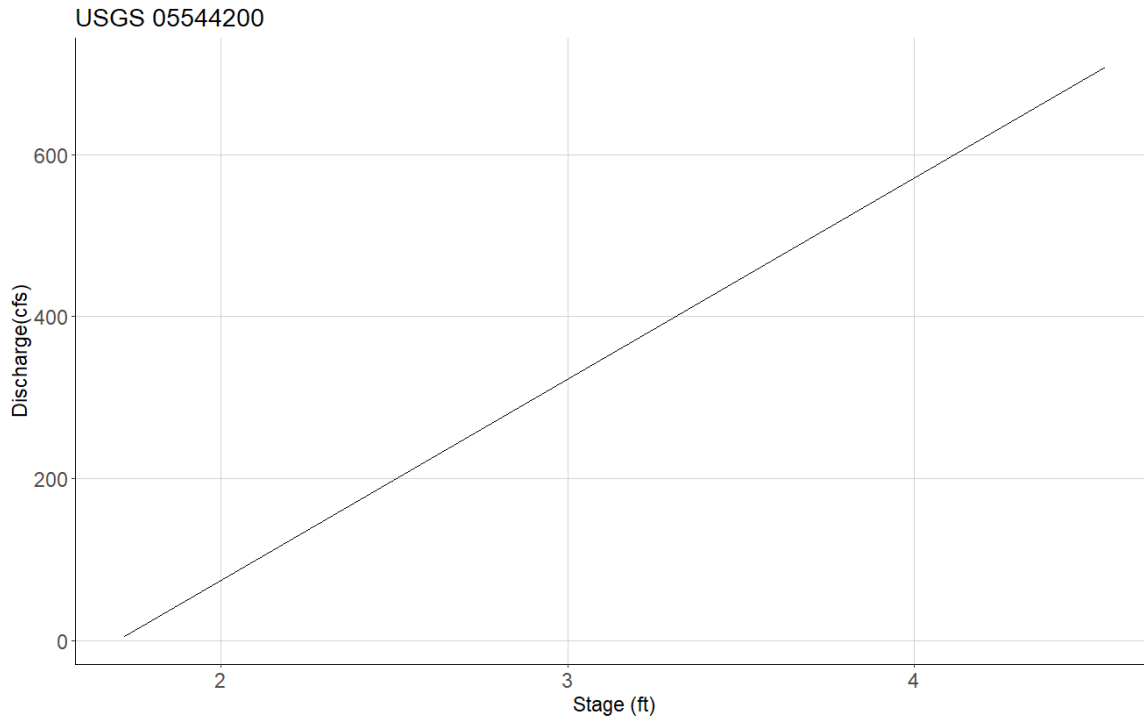


FIGURE G.11
USGS Rating Curve for White River at Lake Geneva, WI

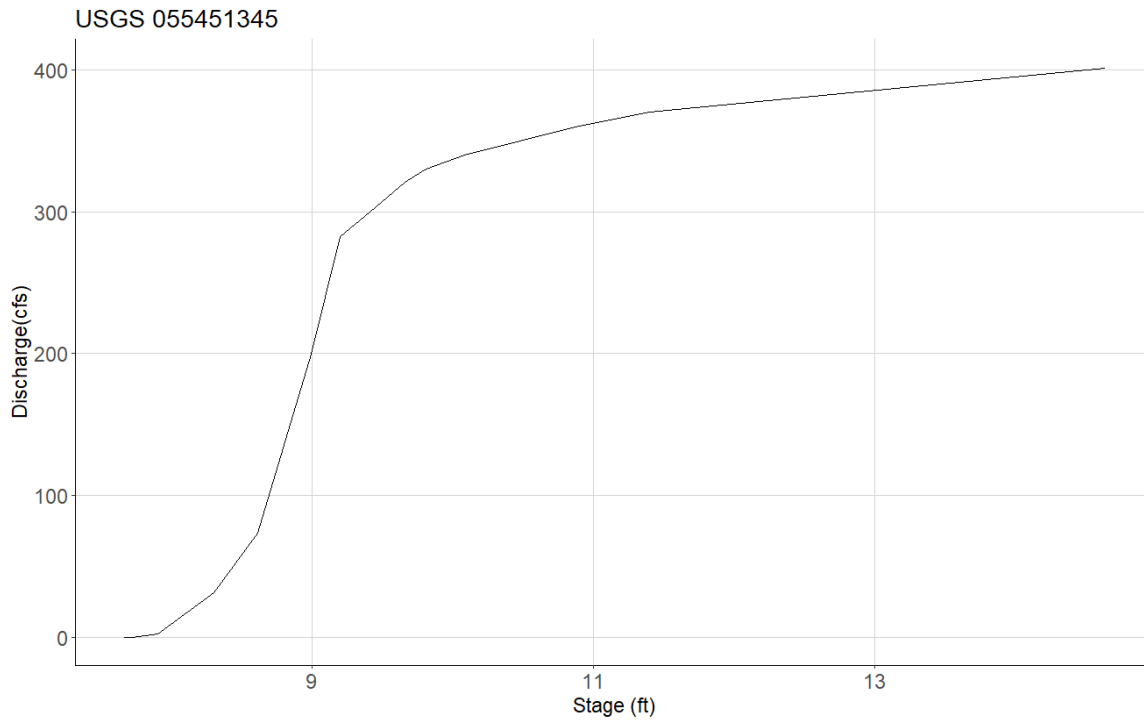


FIGURE G.12
USGS Rating Curve for Des Plaines River at Russell, IL

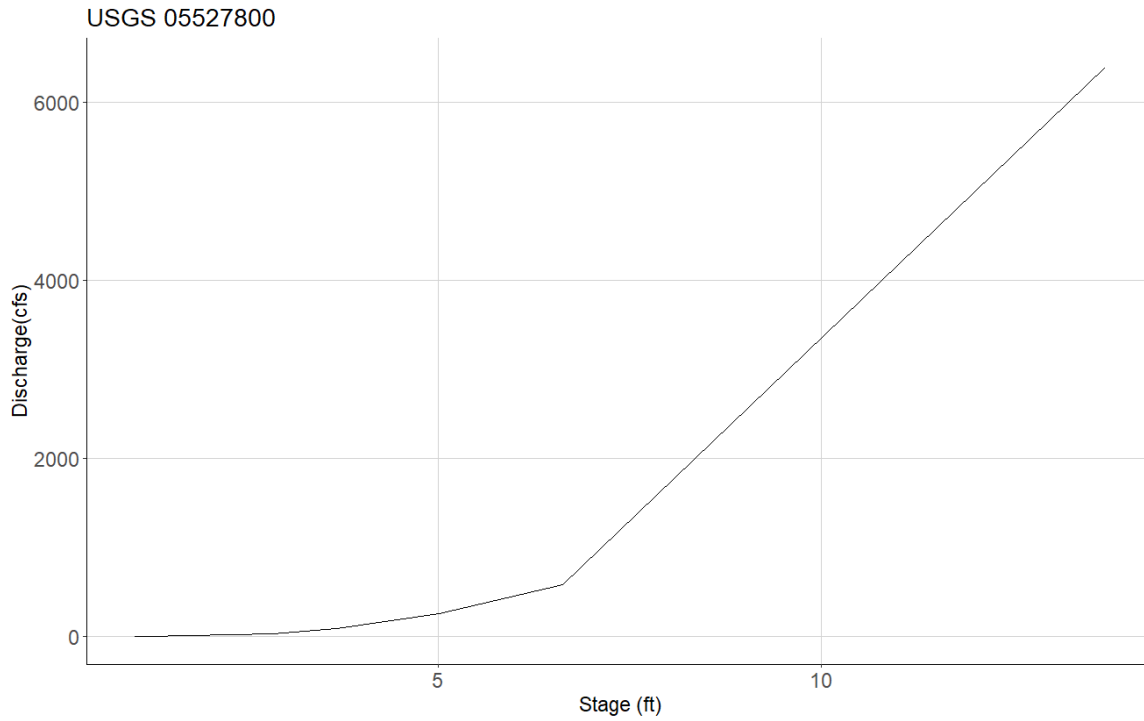


FIGURE G.13
Average Daily Flow at USGS Gages in the Fox River

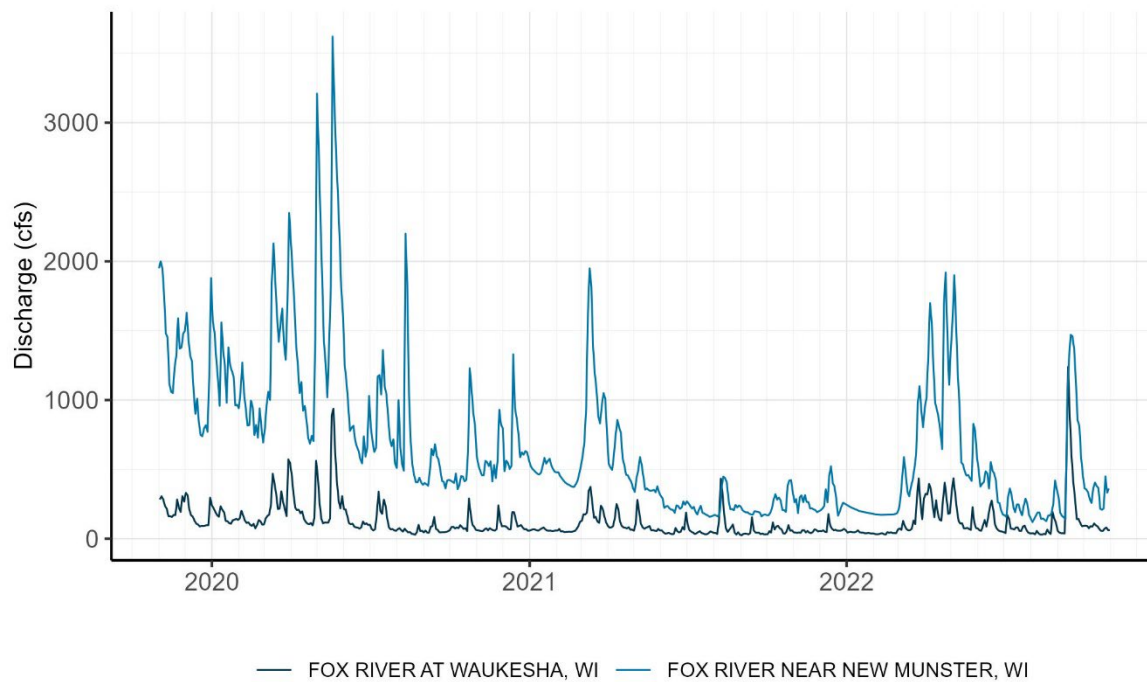


FIGURE G.14

Average Daily Flow at USGS Gage in the Mukwonago River

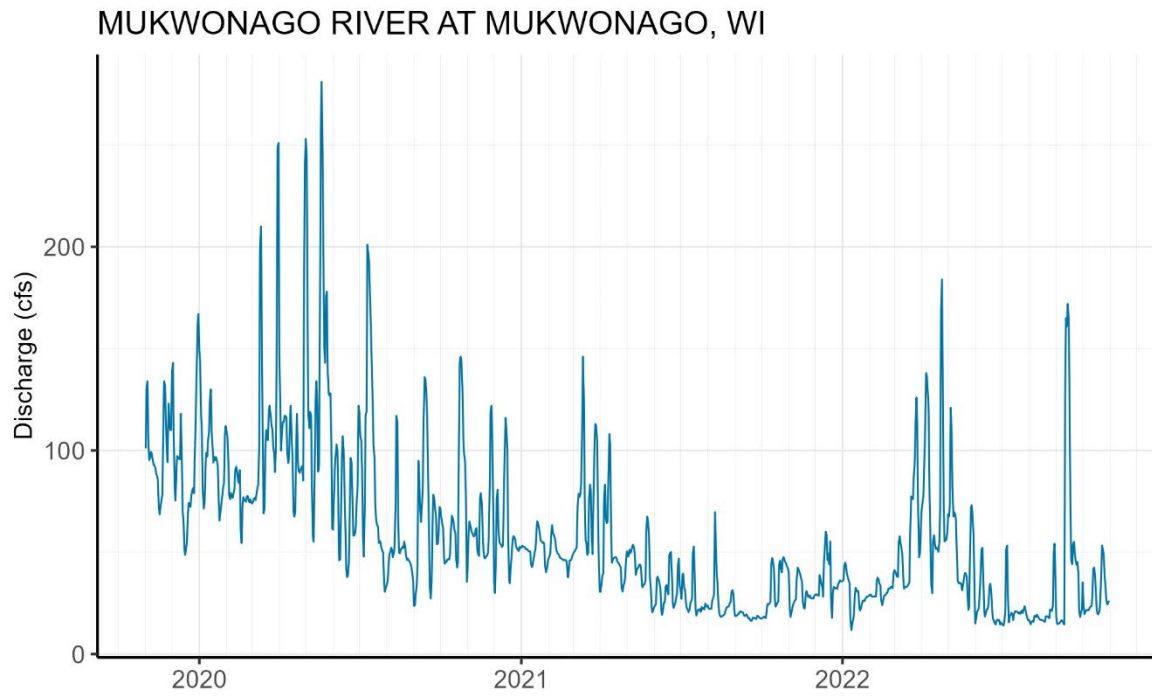


FIGURE G.15

Average Daily Flow at USGS Gage in the White River

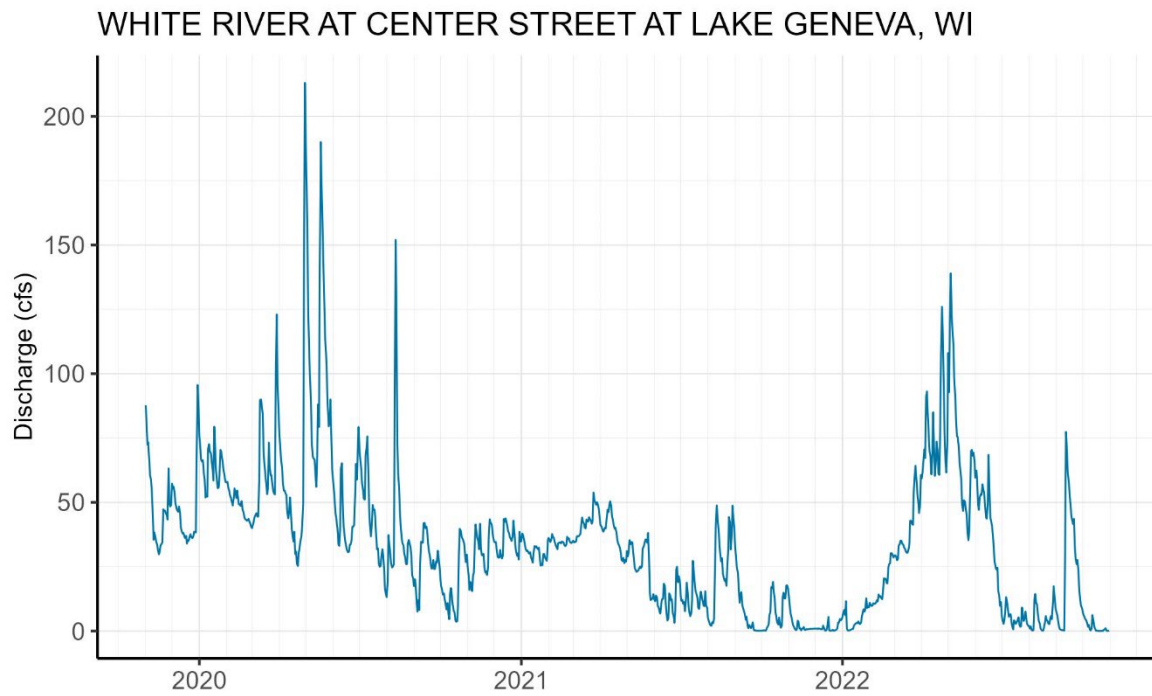


FIGURE G.13

Average Daily Flow at USGS Gage in the Des Plaines River

