Fox River Implementation Plan

A Plan to Improve Dissolved Oxygen and Reduce Nuisance Algae in the Fox River

The Fox River Study Group

December 17, 2015

Blank

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Blank

Executive Summary

The Fox River Implementation Plan (FRIP) has been developed by the Fox River Study Group (FRSG) in partnership with Illinois Environmental Protection Agency (IEPA) and represents an innovative, stakeholder-driven approach to water quality improvement, as an alternative to the traditional Total Maximum Daily Load (TMDL) approach. The primary goal of the FRIP is to provide a road map to address water quality impairments for dissolved oxygen and excessive algal growth in the Fox River below the Stratton dam in McHenry, Illinois and, ultimately, achieve water quality standards. The FRIP is the product of more than a decade of extensive planning, data collection, scientific assessment and modeling undertaken by the FRSG with the support of the IEPA, the Illinois State Water Survey (ISWS), county and municipal governments, water reclamation districts, watershed and environmental groups.

The Fox River originates in Waukesha County, Wisconsin and flows through Illinois into the Illinois River at Ottawa, Illinois. The entire Fox River watershed encompasses 938 square miles in Wisconsin and 1720 square miles in Illinois (Figure ES-1). This FRIP focuses on the portion of the Fox River located between the Stratton Dam and the Illinois River. This spatial area is referred to as the “FRIP study area” and is approximately 98 miles long with a corresponding watershed of approximately 1,405 square miles.

The overarching goal of the FRIP is to define steps to be taken to attain the water quality standards for the Fox River, specifically with respect to aquatic life impairments associated with dissolved oxygen, total phosphorus and nuisance algae. As listed in the 2014 Illinois 303(d) list, these include:

- six segments of the Fox River within the FRIP study area listed as having dissolved oxygen as a cause of impairment with respect to the designated aquatic life use, totaling nearly 35 miles of the river
- nine segments with aquatic algae and total phosphorus as a cause of impairment with respect to the designated aquatic life use, totaling more than 65 miles of the river

The intent is to eliminate all water quality impairment listings associated with dissolved oxygen, total phosphorus and nuisance algae for the Fox River from the Illinois 303(d) list by causing the Fox to come into compliance with water quality standards. This outcome will meet the goal of the Clean Water Act, “to restore and maintain the chemical, physical, and biological integrity” of the Fox River with respect to dissolved oxygen, total phosphorus and nuisance algae.

By agreement between the IEPA and the FRSG, the FRIP will take the place of a traditional TMDL for dissolved oxygen and nuisance algae in the Fox River. No written agreement has been implemented between the IEPA and the FRSG regarding the FRIP, but the IEPA has worked closely with the FRSG in developing the FRIP since 2001. Because the IEPA’s authority to implement and enforce the Clean Water Act comes from the federal government, the FRIP will need to be approved by the U.S. EPA before it officially replaces the TMDL process. The need for a TMDL will be revisited by IEPA after implementation of the FRIP, by evaluating whether the listed reaches are still impaired.

With more than 1,200 square miles of upstream watershed, a portion of the annual phosphorus load to the FRIP study area comes from upstream. Within the FRIP study area there are 13 major municipal wastewater dischargers (major dischargers are facilities which discharge wastewater at levels greater than one million gallons per day) to the Fox River main stem, as well as nine major municipal wastewater dischargers on tributaries, all of which discharge phosphorus to the river in their effluent. Tributaries also carry phosphorus loads from agricultural areas and urban stormwater (MS4s) to the Fox River. These sources contribute a total phosphorus load of approximately 1.29 million pounds per year to the Fox River downstream of Stratton Dam. The distribution of annual average load of phosphorus among these sources is shown graphically in Figure ES-2.

Figure ES-1: Fox River Watershed, Showing the FRIP Study Area

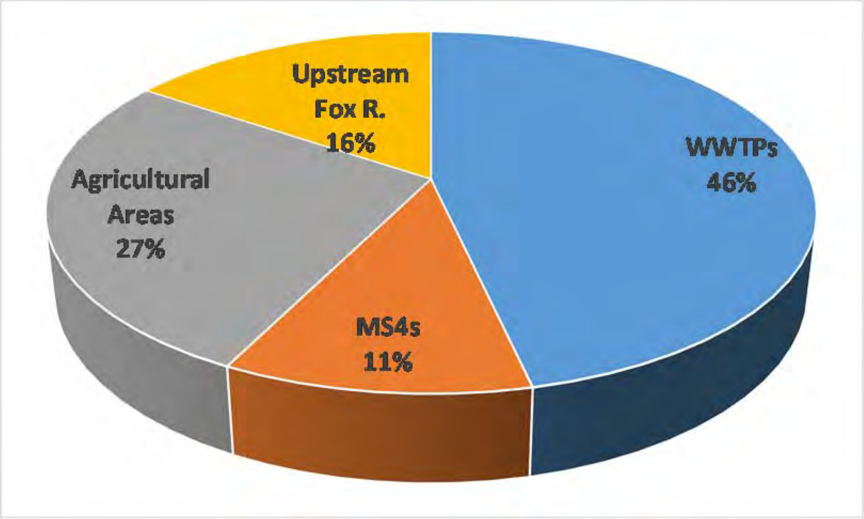


Figure ES-2: Distribution of Annual Average TP Load to the Fox River within the FRIP Study Area by Source – Current Conditions (1,291,000 lbs/yr).

Between the Stratton Dam, which forms the upstream boundary of the FRIP study area and the Dayton Dam, which is its downstream boundary, there are 11 dams on the Fox River which significantly alter the river and contribute to dissolved oxygen and algae growth conditions.

The main actions considered in the FRIP to improve dissolved oxygen and reduce nuisance algae are:

- Reduction of phosphorus loading from upstream
- Reduction of phosphorus loading from wastewater treatment plants (WWTPs)
- Reduction of phosphorus loading from non-point sources (agricultural areas and urban areas (MS4s))
- Dam removal

To evaluate the potential effects of these actions, the Illinois State Water Survey (ISWS) developed a calibrated QUAL2K water quality model application for the Fox River (Bartosova, 2013). This model was used to simulate future Fox River water quality in response to management actions considered in this FRIP. The ISWS originally calibrated the QUAL2K model using data from an intensive sampling event conducted at 13 locations on the Fox River during low flow conditions in June 2012. In an independent review of the ISWS QUAL2k model conducted by LimnoTech, two issues were identified with the model framework that would limit its utility to evaluate future management actions:

1. The model code was not predicting sediment oxygen demand properly, and
2. The model framework was not well-suited for assessing the water quality impact of non-point source load reductions.

LimnoTech was subsequently tasked by the FRSG to change the QUAL2K model code to correct the above issues and then change model inputs as necessary to provide recalibration to observed water quality data. The recalibrated model matches the calibration data well for total phosphorus, algae (phytoplankton) and ammonia, but as with the original calibration by ISWS, minimum dissolved oxygen (DO) is over-predicted at several locations, indicating a limitation of the model for evaluating impacts of load reduction on minimum DO.

The Fox River QUAL2K water quality model is the primary tool used in development of the FRIP to evaluate alternatives for water quality improvement, but because of the important limitations related to the model's dissolved oxygen calibration, the following notes should be heeded when reviewing the model results presented in the FRIP:

- Model calibration results for DO show that the model significantly over-predicts minimum DO and under-predicts maximum DO in many locations and this model limitation should be taken into account when reviewing all model results for dissolved oxygen.
- The model results show good agreement with calibration data for total phosphorus and algae in the water column. Therefore, there is greater confidence in the model for these constituents.

As a consequence of the first bullet above, the actual minimum DO for a given load reduction scenario presented in this section may be significantly lower than the minimum DO predicted by the model.

In developing the FRIP, a range of scenarios involving different combinations of phosphorus load reductions and dam removals were simulated using the QUAL2K model; many of these are presented in Section 5 of this report. However, because of the limitations of the QUAL2K model, no combination of actions can be identified at this time to meet dissolved oxygen water quality standards in the Fox River at all locations and at all times of the year under critical low flow conditions. (IEPA requires water quality standards by met at all flows at and above the average minimum seven day low flow which occurs once in ten years, abbreviated as 7Q10 flows.)

Because of the model uncertainty, implementation of the FRIP will require an adaptive approach of implementing actions, evaluating the effectiveness of those actions and then planning additional actions deemed most appropriate.

In the near-term, the following actions are planned for implementation:

- Effluent limits on municipal WWTPS – NPDES permits have been, or soon will be, issued for all major (>1.0 MGD) municipal WWTPs in the FRIP study area, containing TP limits of 1.0 mg/l (annual average).
- Upstream TMDL – The IEPA is developing a phosphorus TMDL for the Chain O'Lakes on the Fox River upstream of the FRIP study area. When fully implemented, it is expected that water quality in the Chain O'Lakes will meet the state's water quality standard for total phosphorus (0.05 mg/l) for lakes. Ongoing data collection will be used to show progress in meeting this goal.
- Dam removal –The Forest Preserve District of Kane County and the Village of North Aurora have intergovernmental agreements (IGAs) in place with the Illinois Department of Natural Resources (IDNR) to study and plan the removal of the Carpentersville and North Aurora dams, respectively. These dams could potentially be removed within the next five years, but until the ongoing studies are completed, no schedule can be specified.
- Non-point source (NPS) controls – Each MS4 jurisdiction will track the phosphorus load reduction anticipated from projects they implement to reduce pollution from stormwater runoff and submit a report to the FRSG annually.

The actions described above are expected to reduce total phosphorus loading to the Fox River by an estimated 463,400 lbs. per year on average. In addition to improving water quality in the Fox River, these load reductions will have water quality benefits on downstream water bodies and will reduce the overall export of nutrients from the State of Illinois to the Mississippi River and the Gulf of Mexico. The Illinois

Nutrient Loss Reduction Strategy calls for an overall nutrient reduction of 45% statewide and the actions outlined here will result in approximately a 35% reduction in phosphorus loads to the Fox River.

The near-term actions described above were simulated using the Fox River QUAL2K model to observe the potential effects of the actions on water quality. The results are depicted in Figures ES-3 through ES-5 for the month of July and in Figures ES-6 through ES-8 for August. These two months have been identified as the periods of the year when violations of the dissolved oxygen standard are most pronounced. Current conditions under critical 7Q10 low flows are shown in red; near-term actions are shown in blue.

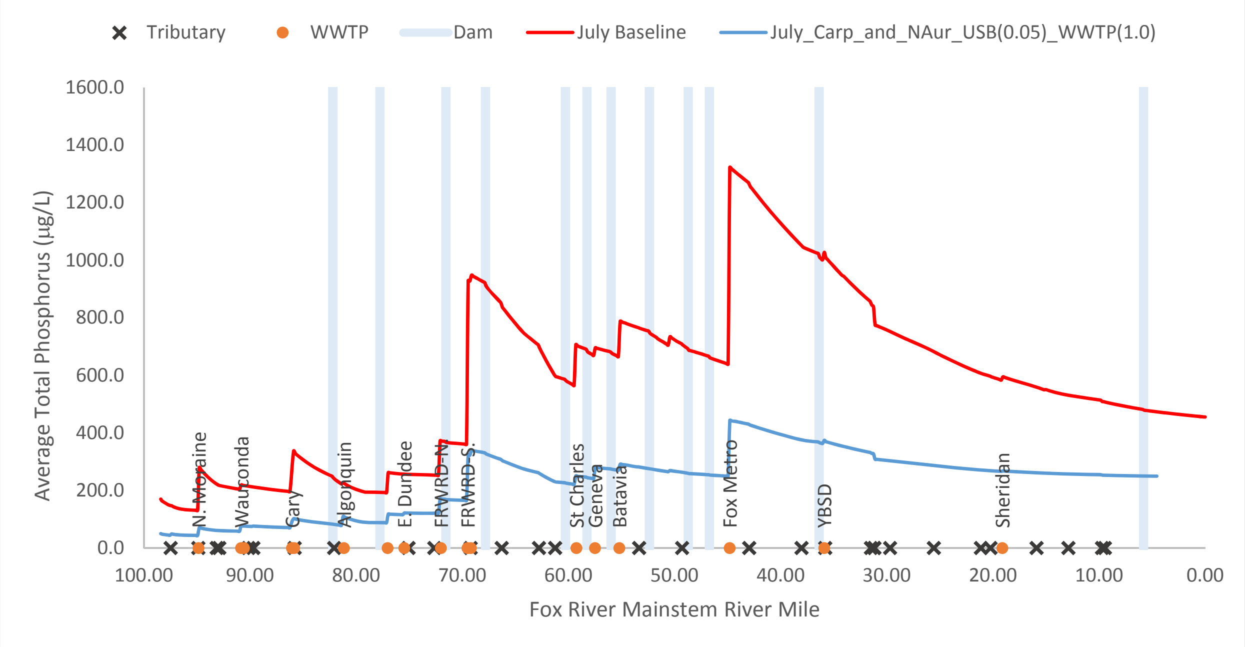
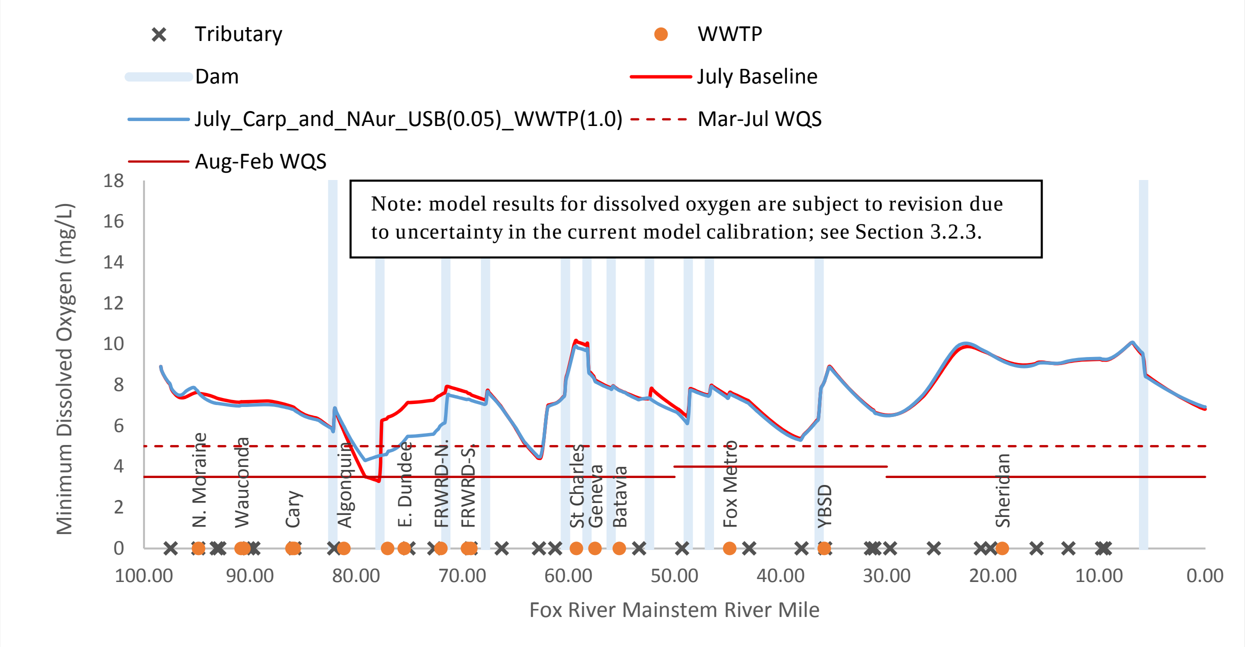


Figure ES-3: QUAL2K Total Phosphorus Results for Near-Term Actions – July.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure ES-4: QUAL2K Minimum Dissolved Oxygen Results for Near-Term Actions – July.

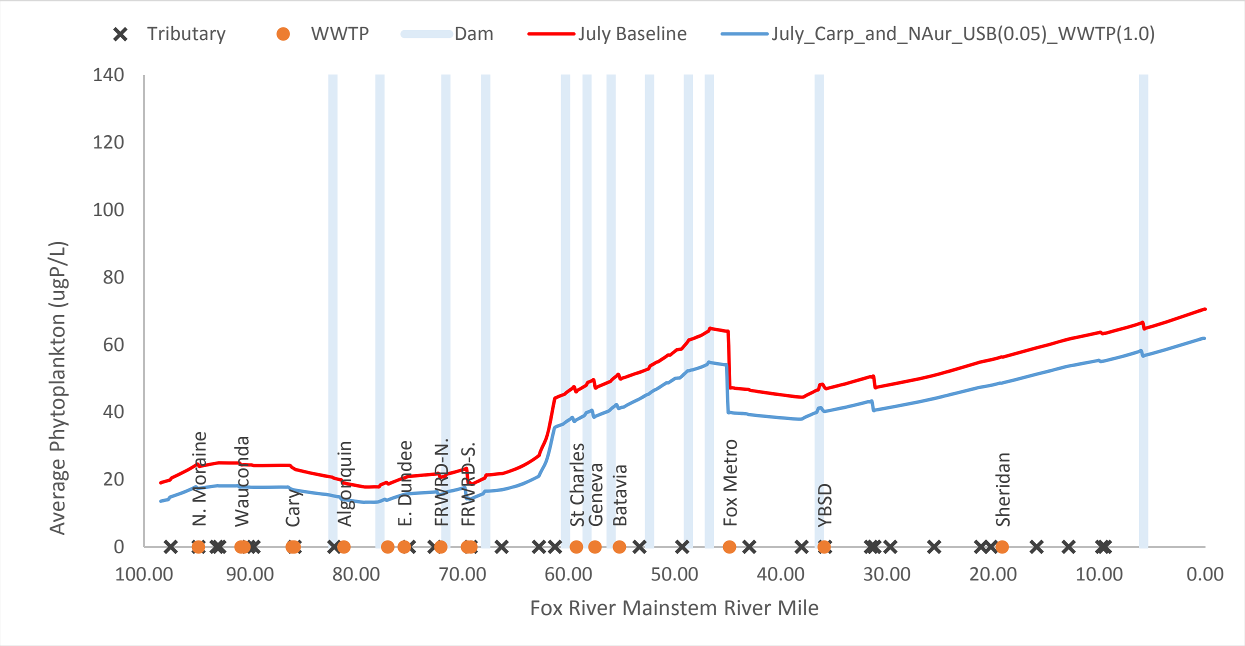


Figure ES-5: QUAL2K Average Phytoplankton Results for Near-Term Actions – July, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading

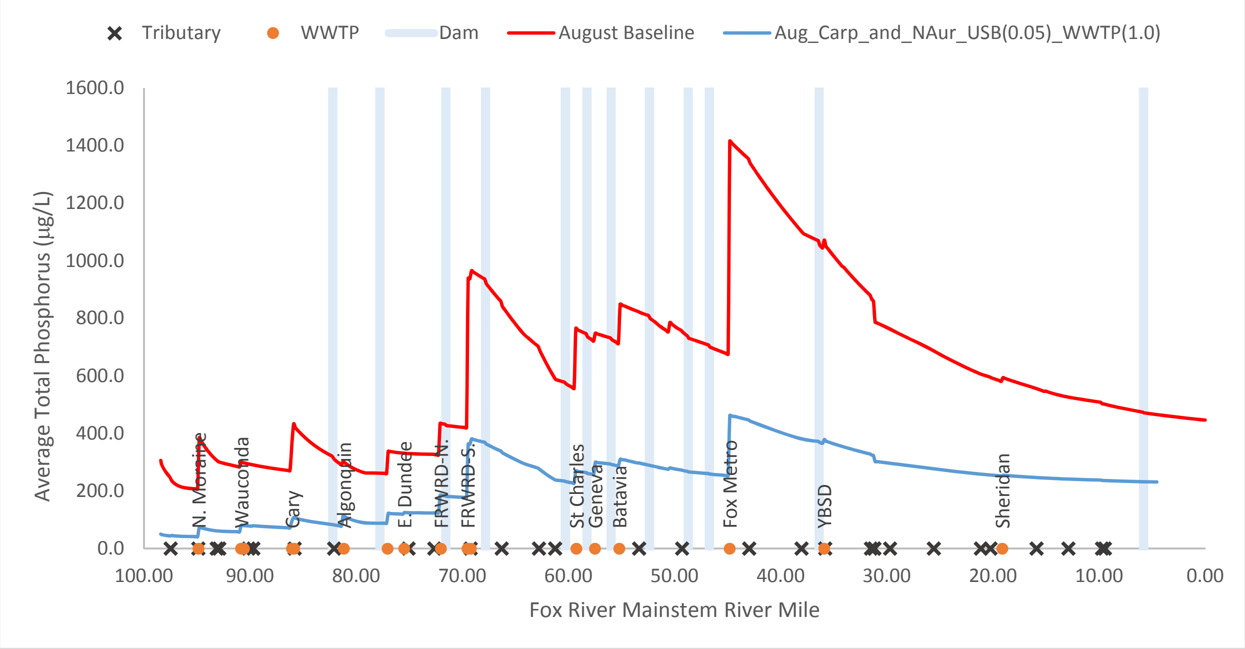
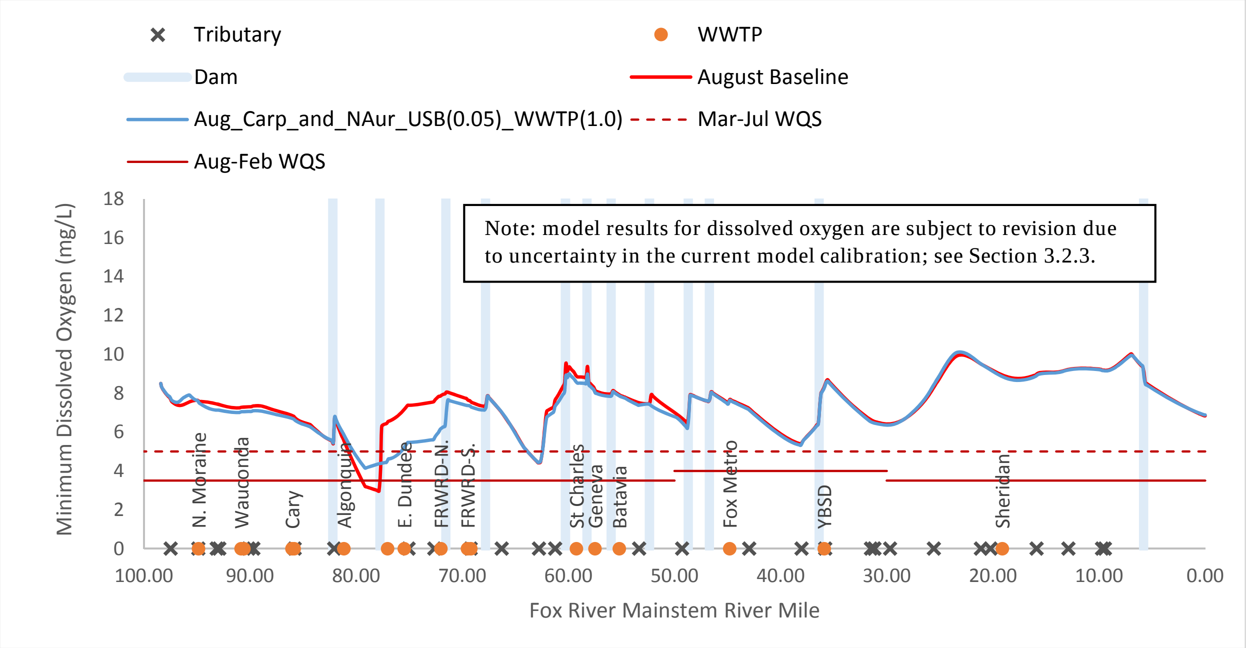


Figure ES-6 QUAL2K Total Phosphorus Results for Near-Term Actions – August.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure ES-7: QUAL2K Minimum Dissolved Oxygen Results for Near-Term Actions – August.

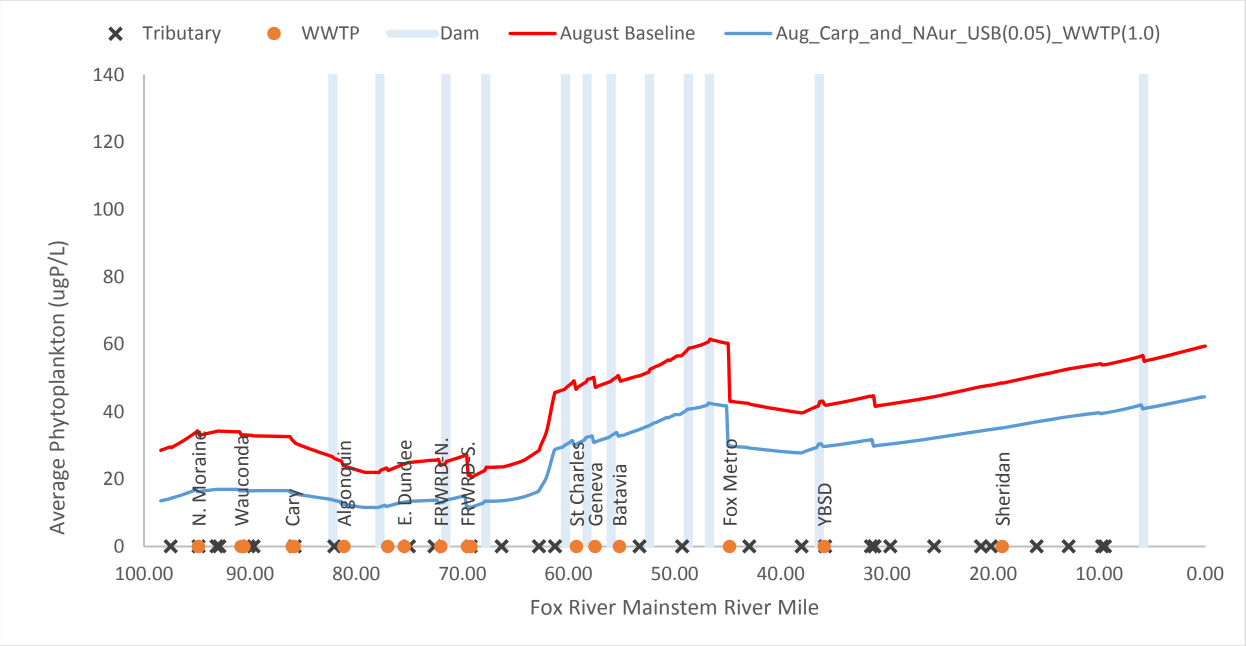


Figure ES-8: QUAL2K Average Phytoplankton Results for Near-Term Actions – August, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading

Based on the model results presented above, the near-term actions described here should result in measurable reductions in total phosphorus concentrations in the river, as well as a significant reduction in algae during July and August under low flow conditions. However, although the actions are to be implemented in the next ten years, it is possible that water quality improvements may take longer to occur, especially those related to the implementation of the TMDL for the Chain O'Lakes upstream of the FRIP study area.

In addition to the actions described above, the FRSG will continue to work towards further water quality improvement and attainment of water quality standards by conducting the following activities:

- Monitoring – The FRSG will continue to be a clearinghouse for relevant water quality data collected by stakeholders and others. Members of the FRSG will submit effluent monitoring and water quality data they collect to the FRSG. The ISWS will continue to update the Fox River database with these new data. The FRSG will coordinate with the Illinois DNR and IEPA regarding data collection associated with the potential removal of dams on the Fox River, including water quality, biotic and physical data. In 2016, the FRSG will develop a strategy for future data collection and prepare written plan(s). The FRSG also plans to coordinate with IEPA and IDNR to discuss Intensive Basin sampling that is scheduled for 2017. Once plans are finalized, the FRSG will update the necessary Quality Assurance Project Plans (QAPPs) to insure data quality and usability.
- Additional modeling - Because of the limitations of the current Fox River QUAL2K water quality model in simulating DO in the river, it is understood that an improved modeling approach is needed. At a minimum, this would involve investigation and correction of the current model's limitations, but other alternatives are possible. Within the next year, the FRSG will solicit expert recommendations on model improvement and develop a plan for future modeling.
- Tracking – The FRSG will track actions taken by municipal WWTPS and MS4 jurisdictions and this information will be reported annually to IEPA. Major municipal WWTPs will report the status of their phosphorus treatment improvements to the FRSG annually and, as part of that report, will provide estimates of annual average phosphorus load reductions from completed actions. MS4 jurisdictions will be required to track and submit annual reports to the FRSG summarizing stormwater management actions that have been implemented, along with the estimated annual average phosphorus load reduction for each action and the total estimated annual load reduction.
- Periodic review – The FRSG will conduct a review of the FRIP every five years to determine the need for an update to the FRIP and, if needed, what that update should include. A summary of the review and the FRSG decision regarding the need for a FRIP update will be submitted in writing to the IEPA.
- Reporting - The FRSG will submit an annual letter report to the IEPA summarizing relevant new information. The annual report will be submitted by the end of March for each preceding calendar year.
- Public engagement – Development of the FRIP has been a stakeholder-driven process and its implementation will continue to rely on dissemination of information to the public. Public engagement activities to be continued by the FRSG will include web site maintenance and updates, monthly FRSG meetings and the annual Fox River Study Group meeting.

1

Introduction

The Fox River Implementation Plan (FRIP) has been developed by the Fox River Study Group (FRSG) in partnership with Illinois Environmental Protection Agency (IEPA) and represents an innovative, stakeholder-driven approach to water quality improvement, as an alternative to the traditional Total Maximum Daily Load (TMDL) approach. The primary goal of the FRIP is to provide a road map to address water quality impairments for dissolved oxygen and excessive algal growth in the Fox River, , below the Stratton dam in Illinois and, ultimately, achieve water quality standards. The FRIP is the product of more than a decade of extensive planning, data collection, scientific assessment and modeling undertaken by the FRSG with the support of the IEPA, the Illinois State Water Survey (ISWS), the regulated community and environmental groups.

This introductory section provides the following information:

- An overview of the FRIP study area
- The water quality impairments addressed by the FRIP
- The water quality goals set for the Fox River in this planning effort

Further, the Introduction describes the FRSG and the FRIP process selected by the group to address the targeted water quality impairments in the Fox River. Finally, a description of the contents and organization of the FRIP document is given.

1.1 Extent of the FRIP Study Area

The Fox River originates in Waukesha County, Wisconsin and flows through Illinois into the Illinois River at Ottawa, Illinois. The entire Fox River watershed encompasses 938 square miles in Wisconsin and 1720 square miles in Illinois (see Figure 1-1). This FRIP focuses on the portion of the Fox River located between the Stratton Dam and the Illinois River. This spatial area is referred to as the “FRIP study area” and is shown in Figure 1-2. This stretch of the river is approximately 98 miles long with a corresponding watershed of approximately 1,405 square miles. Section 2 provides an overview of characteristics of the FRIP planning area.

Figure 1-1: Fox River Watershed

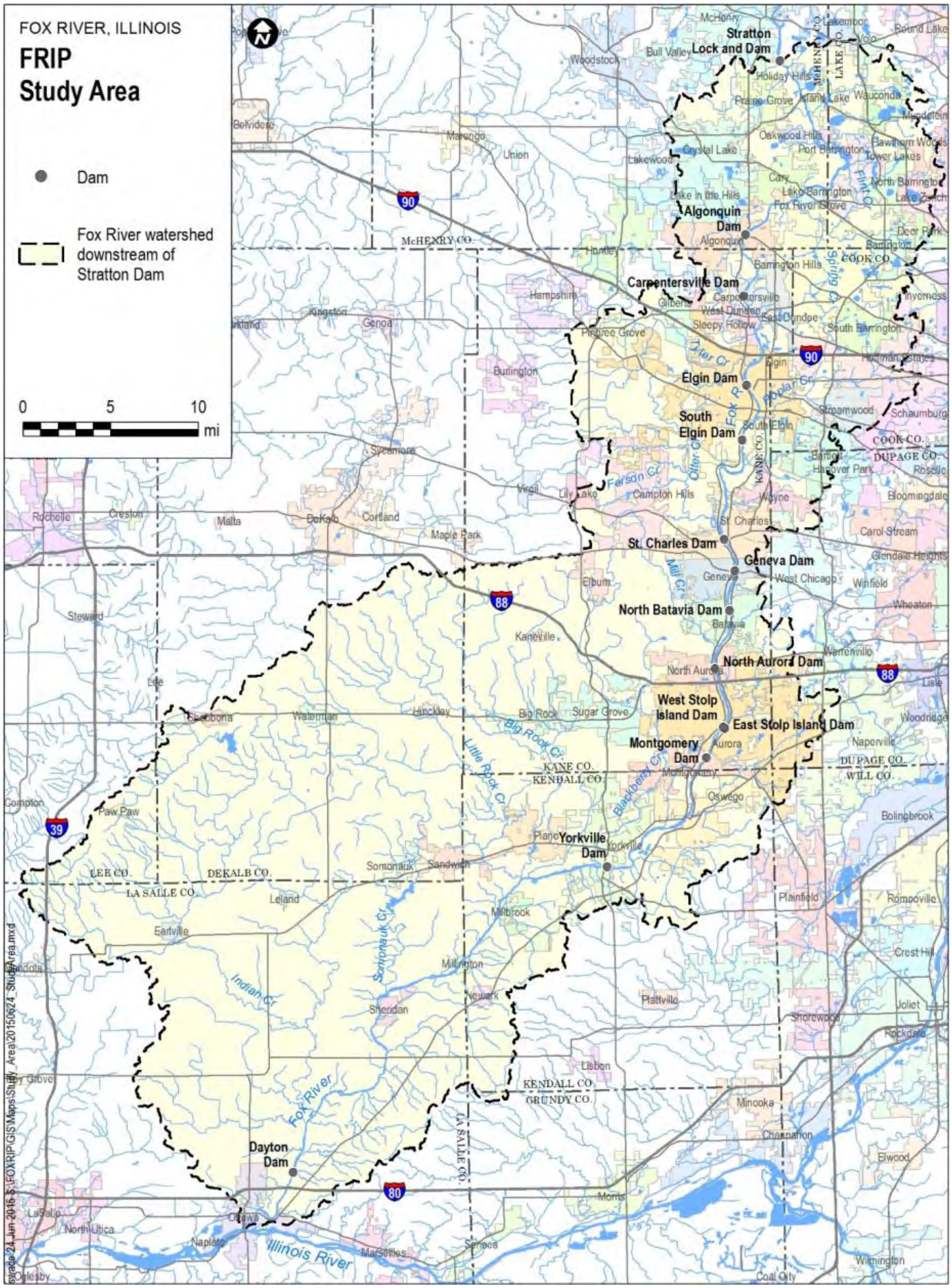


Figure 1-2: FRIP Study Area within the Fox River Watershed

1.2 Water Quality Impairments

Section 303(d) of the 1972 Clean Water Act requires States to define "water-quality limited" (impaired) waters and identify them on a list, termed the 303(d) list. States are also required to identify pollutants causing or expected to cause water quality violations in the waters. The State of Illinois submitted its final 2014 303(d) list to USEPA for approval on March 24, 2014 in the *Illinois Integrated Water Quality Report and Section 303(D) List* (IEPA 2014).

The 2014 303(d) list identifies numerous segments of the Fox River that are impaired within the FRIP planning area. These segments are listed as impaired for a number of designated uses caused by a variety of pollutants. However, the FRIP is focused solely on impairments to the aquatic life designated use by low dissolved oxygen and excessive plant and algal growth.

1.2.1 Impairment Assessment Methodology

The 2014 Integrated Report (IEPA 2014) describes the process IEPA uses to assess whether waterbodies are meeting their designated uses. Assessments are completed for each of the designated uses assigned to a waterbody. For the aquatic life use, assessments are typically based on biological information (including fish and macroinvertebrate data), water quality data, and physical habitat information from the Intensive Basin Survey, Ambient Water Quality Monitoring Network, or Facility-Related Stream Survey programs (IEPA 2014).

For each waterbody/designated use combination, there are two possible use support levels concluded:

- Fully Supporting (the designated use is attained); or,
- Not Supporting (the designated use is not attained).

When sufficient data are available, each applicable designated use in each segment is assessed as Fully Supporting (good), Not Supporting (fair), or Not Supporting (poor). Waters in which at least one applicable use is not fully supported are called "impaired." Waters identified as impaired based on biological, water quality, and physical habitat data are placed on the 303(d) list.

Potential causes and sources of impairment are also identified for impaired waters. The following sections describe the water quality standards applicable to the Fox River in the context of this FRIP, followed by a description of the listed impairments.

1.2.2 Listed Water Quality Impairments for the Fox River

The 2014 Illinois 303(d) list has six segments of the Fox River within the FRIP planning area listed as having dissolved oxygen as a cause of impairment with respect to the designated aquatic life use and six segments with total phosphorus as a cause of impairment with respect to the designated aquatic life use. These segments are listed in Table 1-1. Figure 1-3 shows a map of the river segments listed for dissolved oxygen and Figure 1-4 shows a map of the river segments listed for total phosphorus.

Table 1-1: 303(d) Listings for Dissolved Oxygen, Aquatic algae and Total Phosphorus in the Fox River Mainstem

Reach ID and Description	Length (mi)	Listed Cause of Impairment	Downstream River Mile	Upstream River Mile
IL_DT-35 From: Grass Lake To: IL/IN state line	5.03	aquatic algae	110.1	115.1
IL_DT-23 From: about 0.52 miles downstream Stratton Dam To: Pistakee Lake	7.77	aquatic algae	97.7	105
IL_DT-22 From: Confluence with Flint Creek To: Stratton Dam	7.86	aquatic algae		97.7
IL_DT-06 From: Crystal Lake Outlet To: Flint Creek	8.06	DO, aquatic algae	84.55	92.6
IL_DT-20 From: Confluence with Jelkes Creek To: Confluence with Crystal Lake Outlet	9.95	DO	74.6	84.55
IL_DT-18 From: Confluence with Poplar Creek To: Confluence with Jelkes Creek	5.8	DO	68.8	74.6
IL_DT-09 From: Confluence with Ferson Creek To: Confluence with Poplar Creek	7.9	total phosphorus, aquatic algae	60.9	68.8
IL_DT-58 From: Confluence with Whites Creek To: Confluence with Ferson Creek	3.76	DO	59.5	63.25
IL_DT-69 From: Confluence with Mill Creek To: Confluence with Whites Creek	4.51	total phosphorus, aquatic algae	55	59.5
IL_DT-38 From: Confluence with Waubonsee Creek To: Mill Creek	12.3	total phosphorus, aquatic algae	42.7	55
IL_DT-03	7.1	DO, total	35.6	42.7

From: Confluence with Blackberry Creek To: Confluence with Waubonsee Creek		phosphorus, aquatic algae		
IL_DT-11 From: Confluence with Big Rock Creek To: Confluence with Blackberry Creek	4.6	total phosphorus, aquatic algae	31.0	35.6

In addition to the dissolved oxygen, aquatic algae and total phosphorus listings above, the IEPA has listed various reaches of the Fox River for other impairments, including the following:

- Total suspended solids
- Mercury
- Polychlorinated biphenyls (PCBs)
- Manganese
- Fecal coliform bacteria
- Aldrin
- Sedimentation/siltation
- Hexachlorobenzene
- Methoxychlor
- Chloride
- Copper
- pH

Again it should be noted that the FRIP is not intended to address these other impairments.

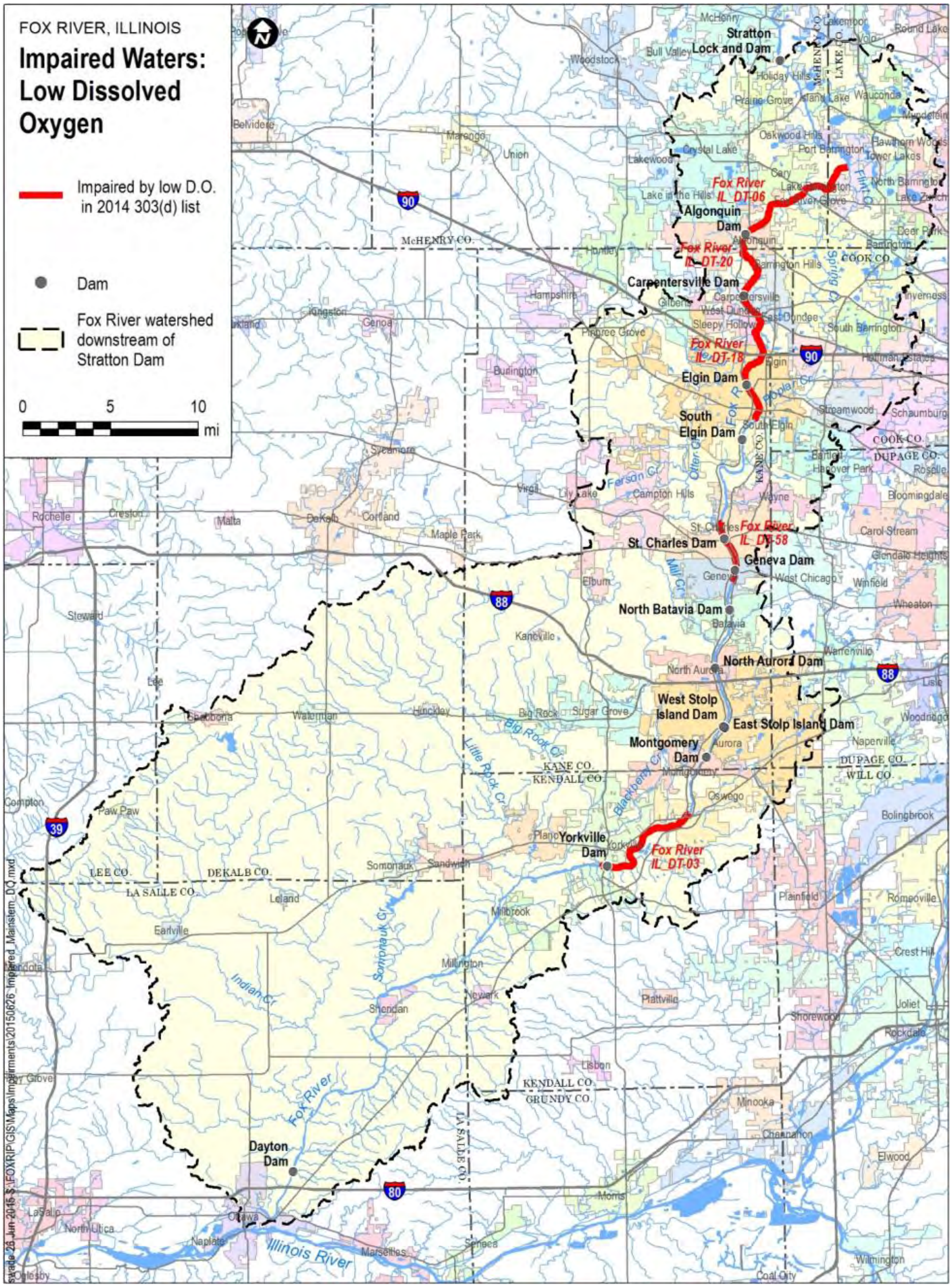


Figure 1-3: Fox River Dissolved Oxygen Impairments from the 2014 Illinois 303(d) List

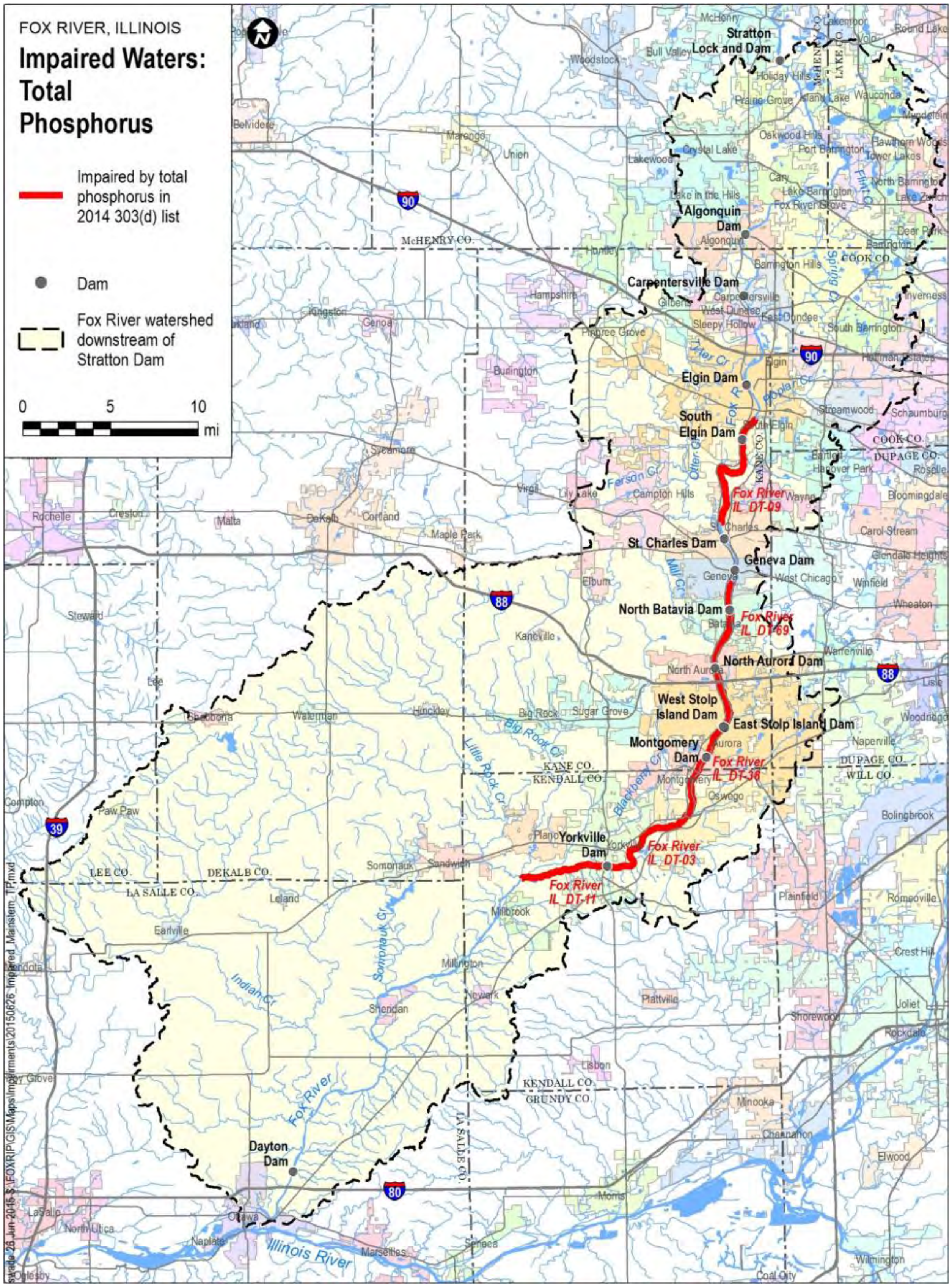


Figure 1-4: Fox River Total Phosphorus Impairments from the 2014 Illinois 303(d) List

1.2.3 Applicable Water Quality Standards

The water quality standards and criteria applicable to the Fox River are identified in Illinois Administrative Code (IAC) Title 35, Subtitle C, Chapter I, Parts 302 and 303. The Fox River must meet the general use standards of Subpart B of Part 302. As stated above, the FRIP is intended to address only the following water quality conditions:

- dissolved oxygen (water quality standards Section 302.206)
- plant or algal impairments (water quality standards in Section 302.203)

Section 302.206(c) of the State water quality regulations list enhanced dissolved oxygen criteria for the reach of the Fox River from river mile 30.4 to river mile 50.8. The "enhanced" status of this reach is based on findings by the Illinois Department of Natural Resources (IDNR) that the reach contains fish species requiring higher levels of dissolved oxygen. The applicable dissolved oxygen criteria for the Fox River are given in Table 1-2.

Table 1-2: Dissolved Oxygen Criteria for the Fox River in the FRIP Planning Area

	Stratton Dam to Illinois River, except RM 30.4 to 50.8		RM 30.4 to 50.8 (Segment 270)	
Criteria Description	**March thru July**	**August thru February**	**March thru July**	**August thru February**
At any time, mg/l	5.0	3.5	5.0	4.0
Daily mean averaged over 7 days, mg/l	6.0	4.0	6.25	4.5
Daily Mean Averaged over 30 days, mg/l	No criterion	5.5	No criterion	6.0

The dissolved oxygen criteria apply at all times except when flows are below critical low flows, defined as flows less than the average minimum seven day low flow which occurs once in ten years (7Q10), as defined in Section 302.103.

The water quality standards applicable to algal growth are found in Section 302.203 as follows:

> ***Section 302.203 Offensive Conditions***
>
> *Waters of the State shall be free from sludge or bottom deposits, floating debris, visible oil, odor, plant or algal growth, color or turbidity of other than natural origin. The allowed mixing provisions of Section 302.102 shall not be used to comply with the provisions of this Section.*

The U.S. Environmental Protection Agency (U.S. EPA) has mandated that States develop numeric nutrient criteria, in part to address algal growth issues. The IEPA is currently working through this process with consultation by U.S. EPA. For the purposes of the FRIP, required reductions in phosphorus loads will be assessed to meet dissolved oxygen criteria, as tabulated above and shown in Figure 1-5, and impacts on plant and algal levels.

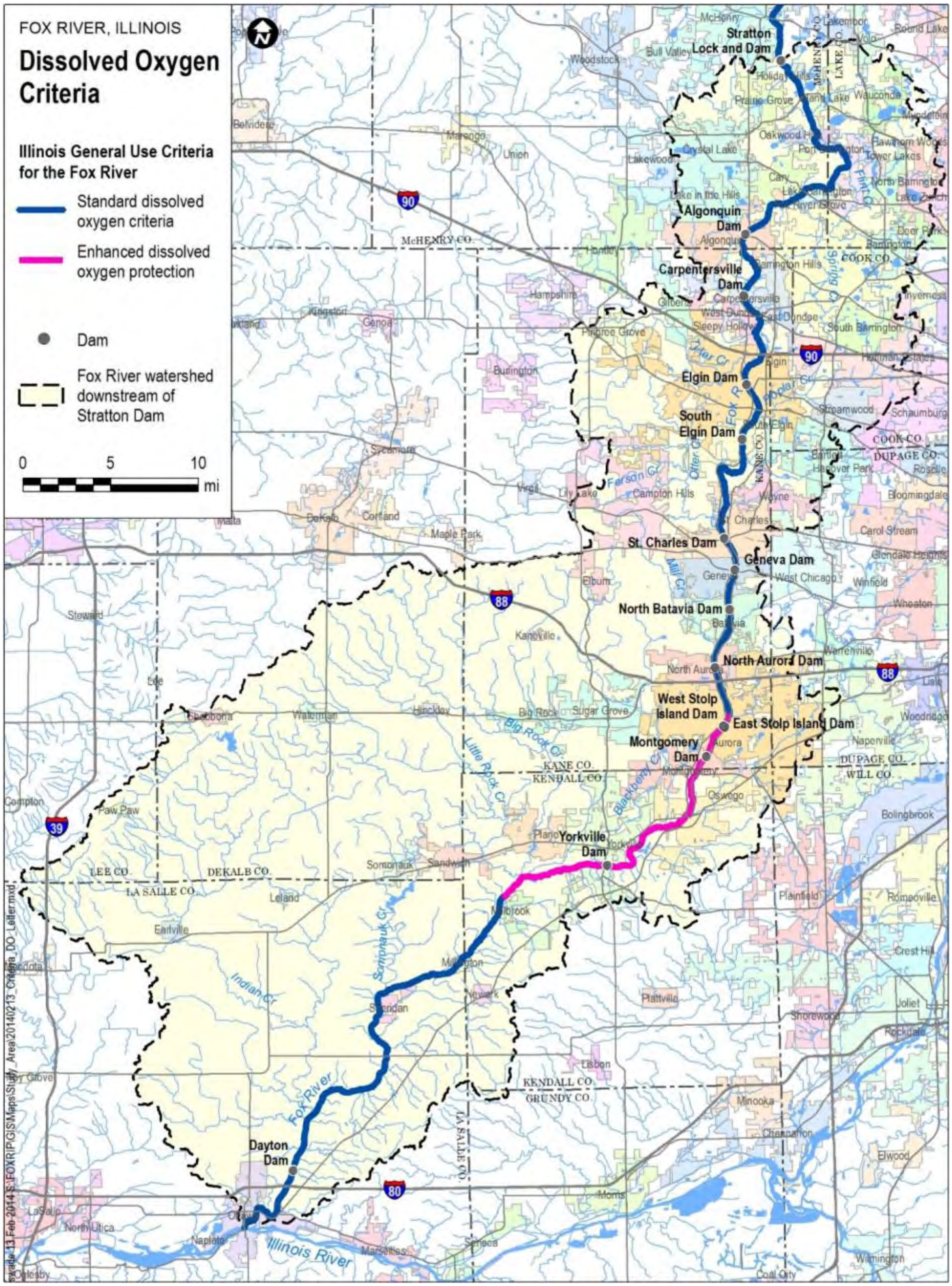


Figure 1-5: Dissolved Oxygen Criteria Applicable to the FRIP Study Area

1.3 Water Quality Goal

The overarching goal of the FRIP is to define steps to be taken to attain the water quality standards for the Fox River, specifically with respect to aquatic life impairments associated with dissolved oxygen, total phosphorus and nuisance algae. The end result of this is to eliminate all water quality impairment listings associated with dissolved oxygen, total phosphorus and nuisance algae for the Fox River from the Illinois 303(d) list. This outcome will signify that the goal of the Clean Water Act, "to restore and maintain the chemical, physical, and biological integrity" of the Fox River with respect to dissolved oxygen, total phosphorus and nuisance algae, has been met.

1.4 Fox River Study Group

The Fox River Study Group (FRSG) is a collaborating group of stakeholders, formed in 2001, with interest in improving water quality and other conditions in the Fox River. The FRSG began meeting in the summer of 2001 to prepare for upcoming Total Maximum Daily Load (TMDL) studies to be performed by the IEPA as required by the Clean Water Act. The mission of the FRSG is "to bring together a diverse coalition of stakeholders to work together to preserve and/or enhance water quality in the Fox River watershed" (Fox River Study Group, 2015). Participants include Friends of the Fox River, Sierra Club, Fox River Water Reclamation District (Elgin), Fox Metro Water Reclamation District (Aurora), Fox River Ecosystem Partnership, IEPA as well as representatives from counties, municipalities and other water reclamation districts in the Fox River watershed.

To date, the FRSG has completed the following activities:

- Collected a large and extensive data set that includes:
    - Extensive volunteer monitoring for 18 water quality parameters on the mainstem and tributaries, sampling at up to 14 locations. Fox Metro Water Reclamation District (FMWRD), Fox River Water Reclamation District (FRWRD), and City of Elgin laboratories have been donating their analytical services as in-kind contributions. All of this work is conducted in accordance with a Quality Assurance Protection Plan (QAPP), which was prepared and updated by FRWRD. FMWRD provides data processing and database updates. – monthly from April 2002 to present
    - Biweekly and storm event sampling of 18 water quality parameters at 20 sites on the mainstem and select tributaries for use in calibration and validation of the HSPF model. Seven precipitation gages and 5 flow gages were installed and used for this monitoring effort. Data was also collected from 3 Combined Sewer Overflows (CSOs) in Elgin. FMWRD and City of Aurora contributed CSO data for use in the HSPF model. Monitoring was performed by the Illinois State Water Survey – during water years 2010 and 2011
    - A three-day intensive monitoring event to calibrate and validate the QUAL2K model with continuous readings of dissolved oxygen, temperature, pH, and conductivity and nine discrete water quality samples (three samples each day) at 13 locations on the Fox River mainstem. Nine discrete water quality samples and instantaneous readings of dissolved oxygen, temperature, pH, and conductivity were also collected in 10 tributaries near their confluence with the Fox River. All discrete water samples were analyzed for nutrients and supporting parameters. Sediment oxygen demand and benthic algae were measured at three and five mainstem locations, respectively. Mainstem stage and discharge measurements were collected by the United States Geological Survey (USGS). Also during this event, many NPDES permit holders voluntarily participated in the sampling event by either providing nutrient analyses of their effluents or providing effluent samples to the

FMWRD or FRWRD laboratories for nutrient analyses as an in-kind contribution to the FRSG. Public water supply facilities in Aurora and Elgin also contributed data on withdrawal and intake sampling. Monitoring was performed by the Illinois State Water Survey and Deuchler Environmental– completed June 2012

- Conducted a critical review of existing water quality data – completed by Illinois State Water Survey in March 2004 that found:
    - Data were consistent with IEPA's assessment of low dissolved oxygen concentrations and high pH on the mainstem of the Fox River, fecal coliform levels exceeding standards, high nutrient concentrations, and siltation.
    - Total phosphorus increases steadily from the Wisconsin border to Yorkville, where the trend reverses and total phosphorus concentrations decline toward Ottawa.
    - Dissolved oxygen concentrations less than the standard occur from Johnsburg to Oswego, typically in impounded areas upstream of dams during summer low-flow conditions.
    - Measurements of pH have exceeded the IEPA standard of 9 from Algonquin to South Elgin and from Montgomery to Ottawa.
    - Suspended solids levels tend to be highest between April and August. Both concentrations and loads increase with flow.
    - Fecal coliform counts exhibited at almost all stations downstream of Johnsburg indicate a high likelihood of noncompliance with the water quality standards.
    - Algal mass at stations monitored since 2001 by the FRSG show concentrations far exceeding USEPA guidance for eutrophic conditions.
    - Findings are available in ISWS Contract Report 2004-06, Fox River Watershed Investigation – Stratton Dam to the Illinois River: Water Quality Issues and Data Report to the Fox River Study Group, Inc.
- Supported development of an HSPF watershed model and a QUAL2K water quality model by the Illinois State Water Survey – starting 2003 to present
    - The watershed and water quality models for the Fox River are described in Section 3.
    - Further detail on the development and calibration of the models can be found in the following reports:
        - Phase II, Part 1: Methodology and Procedures for HSPF Model Development
        - Phase II, Part 2: Blackberry and Poplar Creek HSPF Models, Calibration and Initial Simulation Results.
        - Phase II, Blackberry Creek and Poplar Creek Hydrologic and Water Quality Simulation Methods: Executive Summary.
        - Phase II, Part 3: Validation of Hydrologic Model Parameters, Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek Watersheds.
        - Phase II, Part 4: Fox River Watershed Hydrology Using the HSPF Model
        - Phase III, Evaluation of Watershed Management Scenarios
- Supported development of this FRIP by LimnoTech, starting November 2013 to present - To support preparation of this FRIP, the FRSG hired a consultant, LimnoTech, to refine and apply

the models developed by the ISWS and guide the FRSG through development of management alternatives to address the dissolved oxygen and algal impairments presented in this FRIP.

1.5 Agreement on FRIP process

By agreement between the IEPA and the FRSG, the FRIP will take the place of a traditional TMDL for dissolved oxygen and nuisance algae in the Fox River. No written agreement has been implemented between the IEPA and the FRSG regarding the FRIP, but the IEPA has worked closely with the FRSG in developing the FRIP since 2001. Because the IEPA's authority to implement and enforce the Clean Water Act comes from the federal government, the FRIP will need to be approved by the U.S. EPA before it officially replaces the TMDL process. The need for a TMDL will be revisited by IEPA after implementation of the FRIP, by evaluating whether the listed reaches are still impaired.

It should be noted that, as discussed elsewhere in this document, it will likely be necessary for water entering the FRIP study area to meet water quality standards before water quality standards can be met within the FRIP study area. For purposes of the FRIP, it will be assumed that upstream waters of the Fox River will eventually meet water quality standards through development and implementation of TMDLs. This assumption is similar to the approach commonly used in developing waste load allocations and load allocations for TMDLs, wherein the modeler can assume that upstream water quality standards are being met through implementation of Clean Water Act requirements.

The FRIP will be implemented through requirements contained in the National Pollutant Discharge Elimination System (NPDES) permits issued to regulated point source dischargers to the Fox River and its tributaries. All NPDES permittees in the Fox River watershed will be required to comply with specific language in their permits relating to the FRIP. This language is provided in Attachment A for ease of reference.

In 2014, the IEPA began issuing NPDES permits with this language to major (design average flow of 1.0 MGD or greater) municipal wastewater treatment plants (WWTPs) that join the FRSG. As part of the Special Conditions referenced above, each major WWTP is being given a total phosphorus limit of 1.0 mg/l (annual average), which will become effective, depending on the their permit, between four and half years (54 months) to six years (72 months) from the effective date of their permit. Major WWTPs that opt not to join the FRSG will still be given a total phosphorus limit, but they will have to negotiate their limit on a permit-specific basis. Minor WWTPs are not being given limits at this time, but they will be required to monitor for total phosphorus. A special condition of each permit requires the permittee to prepare a feasibility study on the treatment of phosphorus to meet monthly average effluent concentrations of 1.0 mg/l, 0.5 mg/l and 0.1 mg/l.

Jurisdictions covered by the State's General NPDES permit for municipal separate storm sewer systems (MS4s) will also be affected by the FRIP. The Illinois General NPDES permit for MS4s, Part III, Section C, states that:

> *If a total maximum daily load (TMDL) allocation or watershed management plan is approved for any water body into which you discharge, you must review your storm water management program to determine whether the TMDL or watershed management plan includes requirements for control of storm water discharges. If you are not meeting the TMDL allocations, you must modify your storm water management program to implement the TMDL or watershed management plan within eighteen months of notification by the Agency of the TMDL or watershed management plan approval. Where a TMDL or watershed management plan is approved, you must:*
>
> 1. *Determine whether the approved TMDL is for a pollutant likely to be found in storm water discharges from your MS4.*

2. *Determine whether the TMDL includes a pollutant waste load allocation (WLA) or other performance requirements specifically for storm water discharge from your MS4.*
3. *Determine whether the TMDL addresses a flow regime likely to occur during periods of storm water discharge.*
4. *After the determinations above have been made and if it is found that your MS4 must implement specific WLA provisions of the TMDL, assess whether the WLAs are being met through implementation of existing storm water control measures or if additional control measures are necessary.*
5. *Document all control measures currently being implemented or planned to be implemented to comply with TMDL waste load allocation(s). Also include a schedule of implementation for all planned controls. Document the calculations or other evidence that shows that the WLA will be met.*
6. *Describe and implement a monitoring program to determine whether the storm water controls are adequate to meet the WLA.*
7. *If the evaluation shows that additional or modified controls are necessary, describe the type and schedule for the control additions/revisions.*
8. *Continue Paragraphs 4 above through 7 until two continuous monitoring cycles show that the WLAs are being met or that WQ standards are being met.*

1.6 Description of the FRIP

The Fox River Implementation Plan (FRIP) is intended to be a roadmap for watershed decision makers that will define goals for phosphorus discharge reduction and in-stream projects that, when implemented, will improve the water quality of the Fox River. As previously stated, the FRIP is intended to address dissolved oxygen and nuisance algae and plant growth as related to aquatic life use and offensive conditions, and is not intended to address any other water quality or environmental issues.

Specifically, the FRIP is not intended to address any of the following:

- dissolved oxygen issues at higher flows[1]
- other potential water quality impairments related to aquatic life use in the Fox River, such as pesticides and other organic pollutants, metals, temperature, or other impairments other than dissolved oxygen and nuisance algae
- impairments related to fish consumption, human health protection and water supply
- water quality issues on tributaries to the Fox River

Although the FRIP is not intended to directly address the issues listed above, some actions taken as a result of the FRIP are likely to have beneficial water quality impacts on tributaries in the Fox River watershed. In some cases, analyses conducted to date have not identified clear linkages between potential

---

[111] Most dissolved oxygen issues in the Fox River occur at lower flows, based on long-term monitoring. For example, the Fox River database contains 3,675 dissolved oxygen measurements at the Route 62 bridge in Algonquin, just upstream of the Algonquin Dam. Comparing those data to the daily average flows obtained from the USGS gage at that site shows that nearly 5% of the measurements at flows less than 1,000 cfs were below the water quality standard of 5 mg/L, while at flow over 1,000 cfs, only 1% of the dissolved oxygen samples were below 5 mg/L. However, reductions in phosphorus loadings that do not eliminate violations of water quality standards under low flow conditions may do so under less severe flow conditions.

actions and desired water quality outcomes. Consequently, the FRIP recommends further study to better define future actions and expected outcomes of those actions.

In addition to actions to be taken by wastewater treatment plants discussed in the preceding section, the FRIP recommends potential phosphorus load reduction goals from non-point sources to improve water quality in the Fox River, as well as general actions that could be taken to attain those load reduction goals. However, the FRIP does not attempt to prescribe specific projects in specific locations for those parties controlling the land that contributes non-point source phosphorus. Ultimately those parties will need to design projects on the lands under their control to contribute to improving water quality in the Fox River.

Similarly, the FRIP discusses the potential removal of dams from the Fox River and how the removal of dams may improve water quality. The information related to dam removal that is contained in the FRIP is intended to inform stakeholders and dam owners. It has been well documented that dams can contribute to low DO and increased algal growth, as well as prevent fish passage. There are, of course, other factors that are considered when deciding the fate of dams. Ultimately, the Fox River dams will be kept or removed based on state and federal law and factors important to the owners, which must include dams' effects on water quality in the river and the shared responsibility of dam owners to help resolve the water quality problems of the Fox River.

Once the FRIP is approved, the IEPA will classify the Fox River as "category 5Alt", which is a new alternative to the traditional TMDL approach that has not previously been implemented in Illinois. USEPA has developed a Category 5-alt as part of the 303(d) List. Instead of a TMDL waters on the 5-alt list are using an alternative restoration approach which can include a plan and/or a set of actions to be pursued that are designed to meet water quality standards; the impaired waters will remain on the CWA 303(d) list until water quality standards are achieved or a TMDL is developed. This approach is being implemented by IEPA as an outgrowth of U.S. EPA's recently published "Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program" (Stoner, 2013). This new regulatory approach is intended to "encourage States to develop tailored strategies to implement their CWA 303(d) program responsibilities in the context of their overall water quality goals" and use "alternative restoration or protection approaches" (Stoner, 2013). The FRIP differs from a traditional TMDL in that it is a stakeholder-driven plan (rather than State-prepared) that allows for the evaluation of alternatives that are tailored to the specific conditions and circumstances of the Fox River and the FRSG. At the same time, it is fundamentally similar to a TMDL in that it is designed to achieve the goals of the Clean Water Act.

1.7 FRIP Layout

There are five major sections of the FRIP, following this introduction:

- Section 2 (Watershed Overview) provides some basic information about the FRIP study area for ease of reference, with a focus on the physical aspects of the watershed that are of primary relevance to the problems of dissolved oxygen improvement and nuisance algae reduction. These include agricultural non-point sources, MS4 non-point sources, municipal wastewater treatment plants and dams. The role of phosphorus flux from river sediments is also discussed.
- Section 3 (Assessment and Planning Tools) describes three tools specially developed for the FRIP. These include a suite of watershed models developed for the FRIP study area using the HSPF model; a river water quality model that simulates dissolved oxygen and algae, developed using the QUAL2K model; and a spreadsheet-based tool that uses HSPF-generated phosphorus loads, designed to facilitate scenario testing for non-point source control measures.
- Section 4 (Current Conditions) provides information on the key factors affecting dissolved oxygen and algae conditions in the Fox River: phosphorus loading from upstream of the FRIP study area, internal

phosphorus loading from municipal wastewater treatment plants and non-point sources, and dams. Estimates of annual phosphorus loading to the river are described in this section.

- Section 5 (Evaluation of Water Quality Improvement Alternatives) describes the results of several scenarios that were modeled to evaluate their relative effects on dissolved oxygen and algae in the river.
- Section 6 (Implementation) lays out the actions and activities that are planned to meet the goals of the FRIP.

2

Watershed Overview

This section presents an overview of the Fox River watershed within the FRIP planning area. A thorough and detailed description of the watershed, including climate, hydrology, geology, soils, and topography is provided by the ISWS in McConkey, et al. (2004). The section is intended to provide an overview of the primary physical aspects of the watershed that impact phosphorus, dissolved oxygen, and algae in the river:

- Agricultural nonpoint sources - runoff from agricultural cropland located outside of municipal boundaries
- Municipal separate storm sewer systems (MS4s) –areas served by storm sewer systems within urbanized areas which are regulated under U.S. Environmental Protection Agency's stormwater regulations
- Municipal wastewater treatment plants (WWTPs) – WWTPs treat municipal sewage within urbanized areas
- Dams on the Fix River main stem, in the context of their potential effect on dissolved oxygen and nuisance algae

In addition, a brief discussion of sediment phosphorus flux is included in this section.

2.1 Land Use/Land Cover Overview

Within the approximately 1,405 square miles of the FRIP study area, land uses are both urban (29.6%) and rural (58.9%), with the remaining 11.5% of the area being surface water, wetlands and forest. The overall distribution of land use/land cover[2] in the FRIP study area is presented in Table 2-1 and depicted in map form in Figure 2-1.

Table 2-1: Overall Land Use/Land Cover in the FRIP Study Area.

Land Use/Land Cover*	Area (sq. miles)	Area (%)
Crop	687	48.9%
Rural Grassland	140	10%
Forest	138	9.8%
Urban Open Space	166	11.8%
Urban Low-Medium Density	236	16.8%
Surface Water	23	1.6%
Urban High Density	14	1%
Wetlands	1	0.1%

---

[2] 2009 Illinois Cropland Data Layer obtained from the U.S. Department of Agriculture National Agricultural Statistics Service

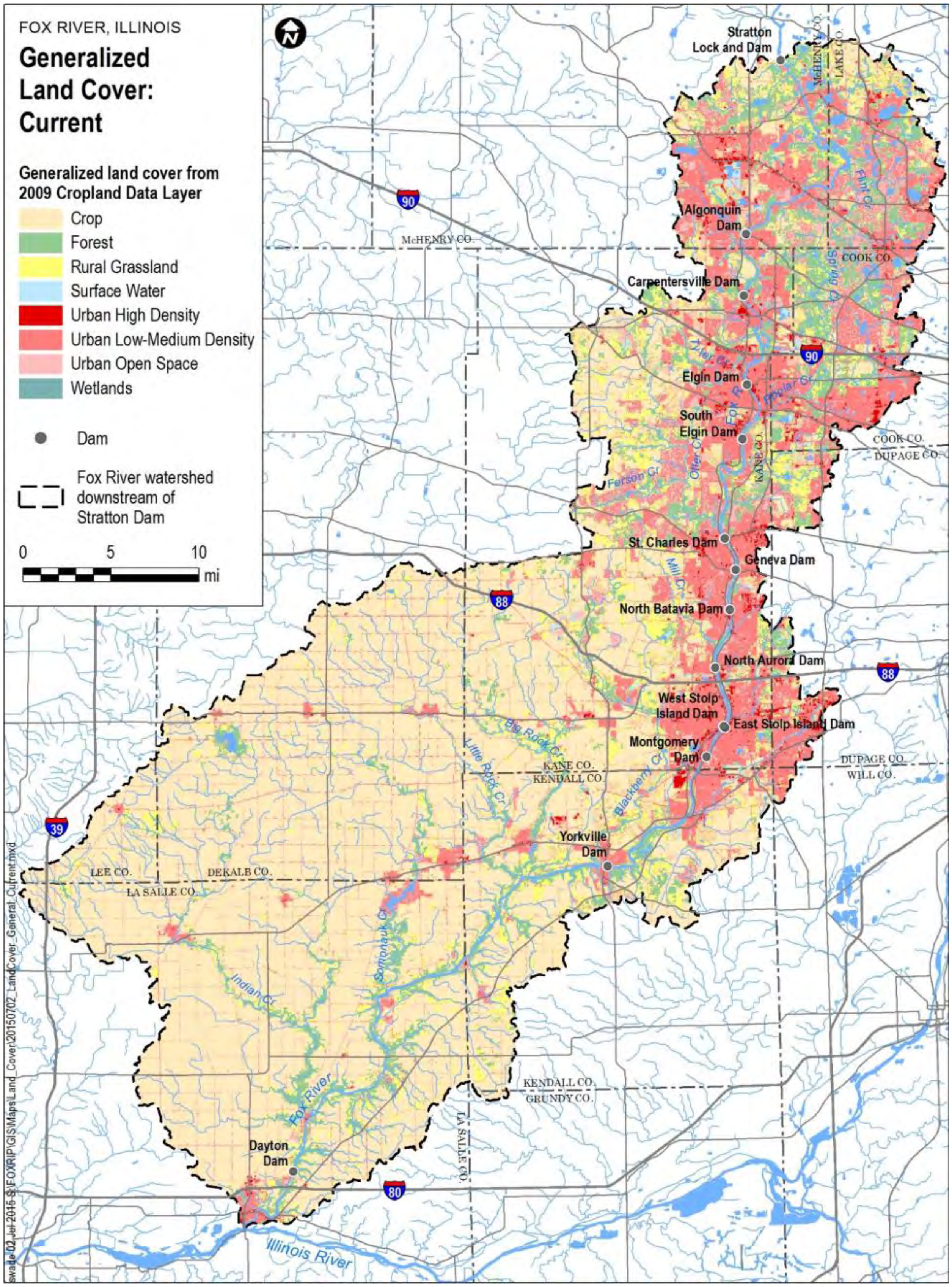


Figure 2-1: Land Use/Land Cover in the FRIP Planning Area

2.2 Agricultural Area Nonpoint Sources

Land use/land cover in the agricultural areas in the FRIP study area (defined as areas outside of municipal MS4 jurisdictions) is dominated by agricultural cropland (predominantly corn and soy beans) followed by lesser percentages of rural grassland and forest. These areas constitute approximately 900 square miles (64%) of the FRIP study area. A breakdown of agricultural area land use/land cover[3] outside of MS4s is provided in Table 2-2.

Table 2-2: Land Use/Land Cover in Agricultural Areas within the FRIP Study Area

Land Use/Land Cover*	Area (sq. miles)	Area (%)
Crop	640	71%
Rural Grassland	81	9.0%
Forest	71	7.9%
Urban Open Space	64	7.1%
Urban Low-Medium Density	35	3.9%
Surface Water	8.6	1.0%
Urban High Density	0.8	0.1%

Based on the fact that 71% of agricultural area land is used for crops, it is likely that this is the major source of total phosphorus loading from agricultural areas. Stream bank erosion in agricultural areas may also be a significant contributor of total phosphorus. Based on output from the HSPF watershed models developed by the ISWS for the Fox River watershed, non-point source runoff from agricultural areas outside of MS4 jurisdictions in the FRIP study area contribute approximately 360,000 pounds of phosphorus per year to the Fox River, on average.

There are a number of state and federal programs available to assist agricultural landowners with funding for implementation of voluntary or incentive-based nonpoint source (NPS) controls. Brief descriptions of these are provided below.

- *Illinois Nutrient Management Planning Program*, cosponsored by the Illinois Department of Agriculture (IDOA) and IEPA (http://age-web.age.uiuc.edu/bee/Outreach/lwmc/lwm21.htm). This program targets funding to Soil and Water Conservation Districts (SWCDs) for use in impaired waters. The nutrient management plan practice cost share is only available to landowners/operators with land in impaired watersheds.
- *Partners for Conservation Fund* (http://www.agr.state.il.us/C2000) is a program designed to take a broad-based, long-term ecosystem approach to conserving, restoring, and managing Illinois' natural lands, soils, and water resources while providing additional high-quality opportunities for outdoor recreation. This program includes the Priority Lake and Watershed Implementation Program and the Clean Lakes Program.
- *Conservation Practices Cost-Share Program*. Another component of Partners for Conservation Fund, the Conservation Practices Program (CPP) focuses on conservation practices, such as terraces, filter strips and grass waterways that are aimed at reducing soil loss on Illinois cropland to tolerable

---

[3] 2009 Illinois Cropland Data Layer obtained from the U.S. Department of Agriculture National Agricultural Statistics Service

levels. IDOA distributes funding for the cost-share program to Illinois' SWCDs, which prioritize and select projects. Construction costs are divided between the state and landowners.

- *Conservation Reserve Program* administered by the Farm Service Agency (http://www.nrcs.usda.gov/programs/crp/). The Conservation Reserve Program (CRP) provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. CRP is administered by the Farm Service Agency, with NRCS providing technical land eligibility determinations, conservation planning and practice implementation.
- *Agricultural Conservation Easement Program* http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/easements/acep/). NRCS's Agricultural Conservation Easement Program (ACEP) is a voluntary program offering landowners the opportunity to protect, restore, and enhance agricultural and wetlands on their property. The NRCS provides technical and financial support to help landowners with their restoration efforts. This program offers landowners an opportunity to establish long-term conservation and wildlife practices and protection.
- *Environmental Quality Incentive Program (EQIP)* sponsored by NRCS (general information at http://www.nrcs.usda.gov/PROGRAMS/EQIP/; Illinois information and materials at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/il/programs/financial/eqip/). EQUIP is a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. Financial and technical assistance is offered to eligible participants to install or implement structural and management practices on eligible agricultural land. EQIP may cost-share up to 75 percent of the costs of certain conservation practices. Incentive payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the incentive.
- *Keep it for the Crop (KIC)* is a comprehensive, collaborative program of the Illinois Council on Best Management Practices' (CBMP) (http://www.illinoiscbmp.org) for science-based outreach and education. The program is designed to promote enhanced nutrient stewardship and the implementation of voluntary agricultural BMPs to reduce nutrient losses and improve water quality.
- *Keep it 4R Crop Program* is a nutrient stewardship program by the Illinois Fertilizer and Chemical Association. It focuses on education and in-field work with agriculture retailers and farmers to support fertilizer management practices focused on using the right source at the right rate at the right time in the right place.

Some of the potential actions that can be taken to reduce total phosphorus loading from croplands include the following:

- Conservation tillage
- Constructed wetlands
- Field borders
- Grassed waterways
- Nutrient management
- Cover crops

These actions, along with discussion of potential effectiveness and costs, are discussed further in Attachment B. In addition, where stream bank erosion is occurring in agricultural areas, bank stabilization and overall stream restoration can be effective in reducing phosphorus loading.

2.3 MS4s

Phase I of U.S. EPA's stormwater regulations require National Pollutant Discharge Elimination System (NPDES) permits for medium and large communities operating MS4s. Phase II of U.S. EPA's stormwater regulations requires that small communities operating MS4s within urbanized areas obtain NPDES permits and implement Six Minimum Measures to reduce the impact of stormwater runoff on receiving waters. The U.S. Census Bureau delineates the boundaries of urbanized areas, defined as a densely settled territory that contains 50,000 or more people, within each state based on census data.

There are 76 Phase II MS4s covering 504 square miles (36%) of the FRIP study area, which are listed with their respective land areas in Attachment C. The spatial extent of these MS4 jurisdictions is depicted in Figure 2-2. While by definition, MS4s are located within "urbanized areas", a combination of urban, open, and agricultural land use/land cover exists within the MS4s[4] (Table 2-3). Approximately 40% of the MS4 area is urban low-medium density and 2.6% is urban high-density. Land use/land cover in the remaining 57.5% is a combination of urban open space, forest, grassland, crop, surface water, and wetlands. Based on output from the HSPF watershed models developed by the ISWS for the Fox River watershed, non-point source runoff from MS4 jurisdictions in the FRIP study area contribute approximately 130,000 pounds of phosphorus per year to the Fox River, on average.

Table 2-3: Land Use/Land Cover within MS4 Areas

Land Use/Land Cover*	Area (sq. miles)	Area (%)
Urban High Density	13	2.6
Urban Low-Medium Density	201	39.9
Urban Open Space	102	20.2
Forest	67	13.3
Rural Grassland	59	11.7
Crop	47	9.3
Surface Water	15	2.9
Wetlands	0.4	0.1

The Phase II stormwater permit requires each MS4 to develop a stormwater management program that implements the six minimum measures , provides measureable goals for each measure, and specifies best management practices (BMPs) for each measure. The minimum measures are:

- Public education and outreach on storm water impacts
- Public involvement and participation
- Illicit discharge detection and elimination
- Construction site storm water runoff control
- Post construction storm water management in new development and redevelopment
- Pollution prevention/good housekeeping for municipal operations

Support for implementing controls for runoff in MS4s has been provided by the IEPA through the Illinois Green Infrastructure Program, which is described below.

---

[4] 2009 Illinois Cropland Data Layer obtained from the U.S. Department of Agriculture National Agricultural Statistics Service

- *Illinois Green Infrastructure Grant Program for Stormwater Management (IGIG)* (http://www.epa.illinois.gov/topics/grants-loans/water-financial-assistance/igig/index) is a program administered by IEPA. The program is currently in a state of change. However, the program has funded 36 grant projects (totaling almost $15 million) since 2011 to demonstrate green infrastructure BMPs to control stormwater runoff for water quality protection. Three IGIG grants totaling $2.2 million have been awarded to projects in the Fox River watershed. All IGIG projects are located within either MS4s or combined sewer overflow areas.

There are several potential actions (commonly referred to as “best management practices” or BMPs) that can be taken to reduce non-point total phosphorus loading from MS4 areas. Some of the most common are:

- Bioretention
- Street sweeping
- Vegetated swales
- Constructed wetlands
- Dry and wet detention

These BMPs, along with discussion of potential effectiveness and costs, are discussed further in Attachment B. In addition, where stream bank erosion is occurring in MS4 areas, bank stabilization and overall stream restoration can be effective in reducing phosphorus loading.

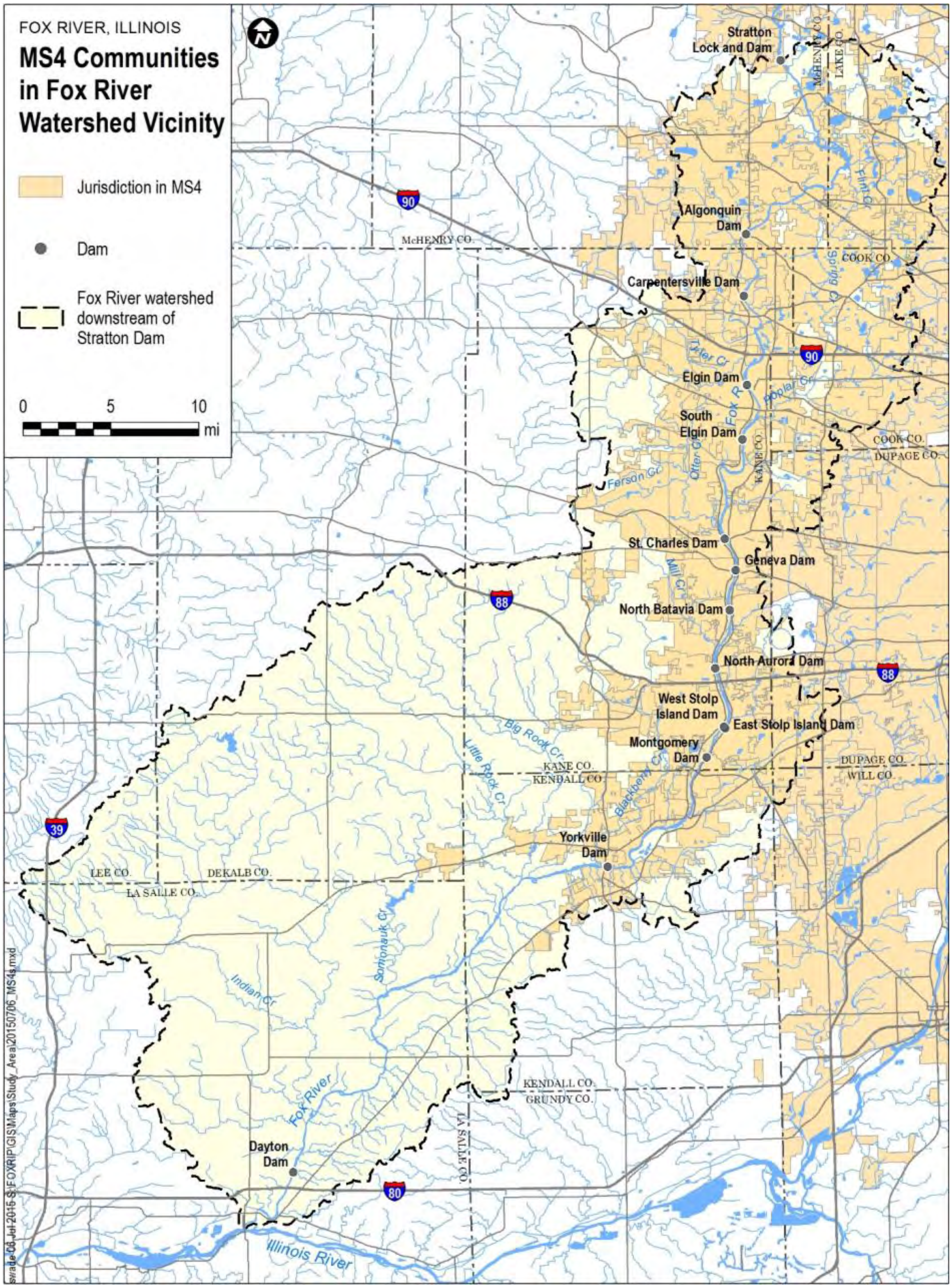


Figure 2-2: MS4s within the FRIP Planning Area

2.4 Municipal WWTPs

There are several permitted municipal WWTPs, both major (design average flow equal to or greater than 1.0 MGD) and minor dischargers (<1 MGD), that discharge to the main stem of the Fox in the FRIP study area. The 15 major municipal WWTPs discharging to the Fox River main stem (Table 2-4 and Figure 2-3) have design average flows for permitted outfalls ranging from 1.25 to 42 MGD. In addition, there are nine major dischargers to Fox River tributaries, as listed in Table 2-5.

Table 2-4: Major Municipal WWTPs Discharging to the Fox River Main Stem in the FRIP Study Area

Facility Name	NPDES Permit No.	Outfall ID	Outfall Name	Design Average Flow (MGD)	Effective Date of Annual Average 1.0 mg/l TP Limit
Village of Carpentersville Main STP	IL0027944	1	STP Outfall	4.5	July 8, 2019
City of Batavia WWTF	IL0022543	1	STP Outfall	4.2	August 1, 2019
City of St. Charles-Eastside WWTF	IL0022705	1	STP Outfall	9	May 1, 2019
East Dundee WWTP	IL0028541	1	WWTP Plant Outfall	2.3[5]	January 1, 2020
Fox Metro Water Reclamation District STP	IL0020818	1	STP Outfall	42	June 1, 2021
Fox River Grove WWTP	IL0020583	1	STP Outfall	1.25	November 1, 2019
Fox River Water Reclamation Dist.--North WRF	IL0028665	1	STP Outfall	7.75	June 1, 2019
Fox River Water Reclamation Dist.--Pagorski WRF	IL0028657	1	STP Outfall	25	October 1, 2019
Fox River Water Reclamation Dist.--West WRF	IL0035891	1	STP Outfall	5	May 1, 2019
City of Geneva WWTP	IL0020087	1	STP Outfall	5	July 8, 2019
Northern Moraine Water Reclamation District WWTP	IL0031933	1	STP Outfall	2	May 1, 2019[6]
Village of Algonquin WWTP	IL0023329	1	STP Outfall	5	[7]
Village of Cary WWTP	IL0020516	1	STP Outfall	2.8	May 1, 2019

---

[5] The Village of East Dundee NPDES permit has required the plant to operate biological nutrient removal since the plant expanded in the early 2000's.

[6] The Northern Moraine Water Reclamation District's previous permit, issued November 12, 2008, had a total phosphorus limit of 1.0 mg/L, with an effective date of December 1, 2008.

[7] The Village of Algonquin NPDES permit currently contains a total phosphorus limit of 1.0 mg/L as a monthly average, with an effective date of April 1, 2012.

Facility Name	NPDES Permit No.	Outfall ID	Outfall Name	Design Average Flow (MGD)	Effective Date of Annual Average 1.0 mg/l TP Limit
Village of Wauconda WWTP	IL0020109	1	STP Outfall	1.9	October 1, 2011[8]
Yorkville-Bristol Sanitary District STP	IL0036412	1	STP Outfall	3.62	May 1, 2019

---

[8] The Village of Wauconda was issued their current permit on September 13, 2011, which contained a monthly average total phosphorus limit of 1.0 mg/L, with an effective date of October 1, 2011.

Table 2-5: Major Municipal WWTPs Discharging to Fox River Tributaries in the FRIP Study Area[9]

Facility Name	NPDES Permit No.	Outfall ID	Outfall Name	Design Average Flow (MGD)	Effective Date of Annual Average 1.0 mg/l TP Limit[10]	Tributary
Barrington WWTF	IL0021598	B02	STP internal Outfall	3.68	January 1, 2020	Unnamed tributary of Flint Creek
Crystal Lake WWTP #2	IL0028282	1	STP Outfall	5.8	See footnote	Crystal Creek
Crystal Lake WWTP #3	IL0053457	1	STP Outfall	1.7	See footnote	Unnamed tributary of Sleepy Hollow Creek
Village of Elburn WWTP	IL0062260	1	STP Outfall	1.266	July 7, 2019	Welch Creek
Village of Gilberts WWTP	IL0068764	1	STP Outfall	1.0	See footnote	Tyler Creek
Lake in the Hills SD STP	IL0021733	1	STP Outfall	4.5	See footnote	Crystal Lake Outlet
City of Plano STP	IL0020052	1	STP Outfall	2.44	See footnote	Big Rock Creek
City of Sandwich STP	IL0030970	3	STP Outfall	1.5	[11]	Harvey Creek tributary to the Little Rock Creek
Terra Cotta STP	IL0038202	1	STP Outfall	1.0	See footnote	Sleepy Hollow Creek

---

[9] In addition to the major WWTPs discharging to tributaries listed here, the St. Charles Westside WWTP will be considered a major after the planned expansion occurs, and it is anticipated a limit on phosphorus will be included in its new permit.

[10] The current permits for Crystal Lake WWTP #2, Crystal Lake WWTP #3, Village of Gilberts WWTP, Lake in the Hills SD STP, City of Plano STP, and Terra Cotta STP have a monthly average total phosphorus limit of 1.0 mg/L.

[11] The current permit for the City of Sandwich STP has a "monitor only" requirement for total phosphorus. It is anticipated the annual average total phosphorus limit of 1.0 mg/L will be included in the next permit cycle for this facility.

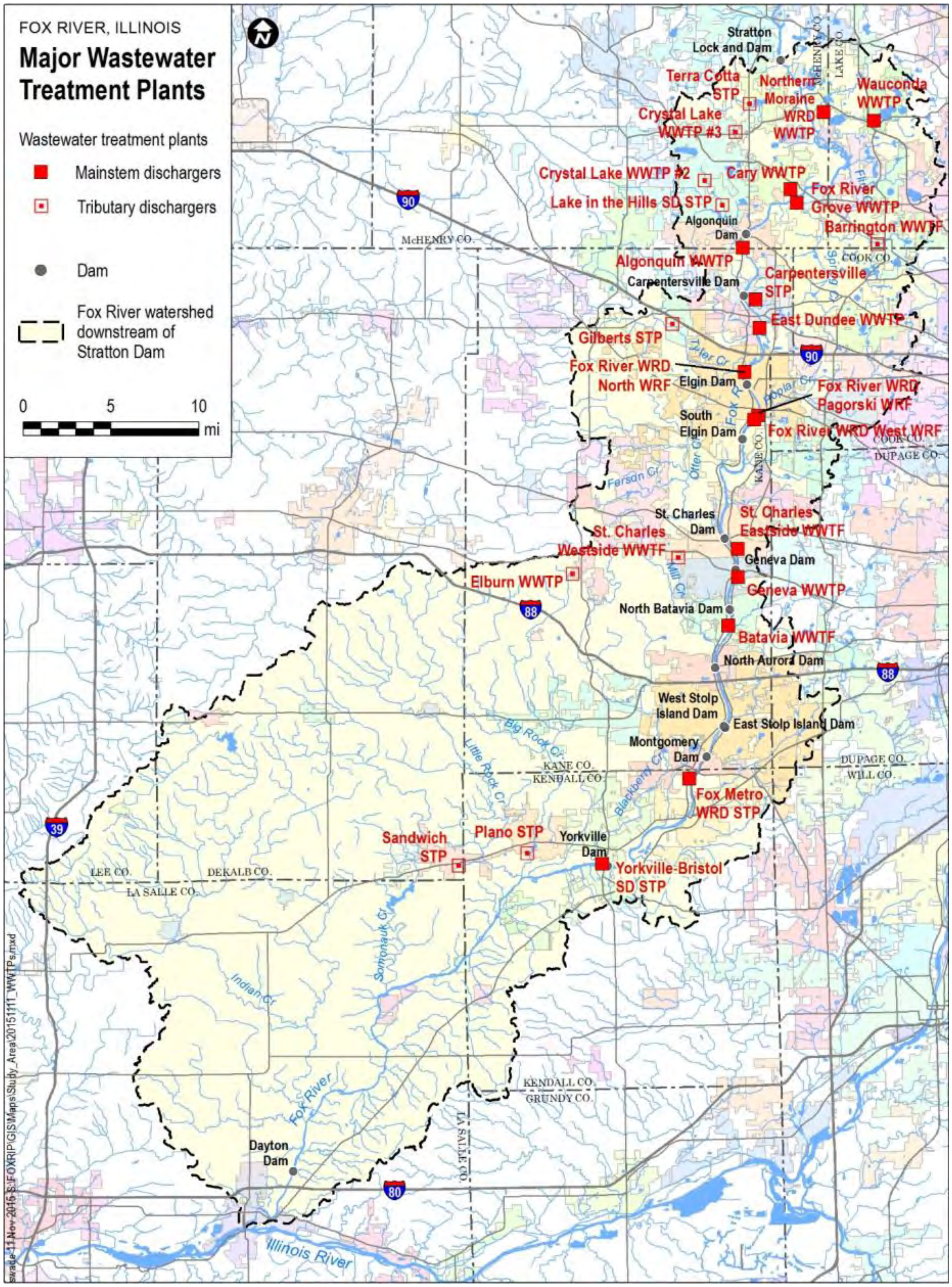


Figure 2-3: Major Municipal WWTPs Discharging to the Fox River Main Stem and Tributaries in the FRIP Planning Area

In developing the HSPF watershed models for the Fox River watershed, the ISWS compiled data on WWTP flows and effluent quality from WWTPs in the FRIP study area. Based on this data compilation, assuming the period of 2003 through 2011 is representative of current conditions, the WWTPs in the FRIP study area contribute approximately 600,000 pounds of phosphorus per year on average to the Fox River.

An annual average total phosphorus (TP) discharge limit of 1.0 mg/l is being included in NPDES permits for any major facility (defined as design average flow of 1 MGD or greater) that is part of the FRSG, as indicated in Tables 2-4 and 2-5. Permits reissued with the annual TP limit are being issued for a three year period (instead of the standard five year period), after which the discharge limit will be reevaluated to determine if different limits are appropriate (Dragovich, 2015).

Major WWTPs that opt not to join the FRSG will still be given a total phosphorus limit, but they will have to negotiate their limit on a permit-specific basis based on the requirements of 35 Ill. Adm. Code 309. 141 and 143. Illinois EPA does not currently plan to give minor WWTPs total phosphorus limits at this time, but they will be required to monitor for total phosphorus.

2.5 Dams

There are 13 dams located on the main stem of the Fox River within the FRIP Study Area. Many of the dams were built along the river to power lumber and grist mills; most are no longer serving their original purpose (Santucci and Gephard 2003). Dam locations by river mile are listed in Table 2-7, with original functions, dam heights, year built, and ownership.

2.5.1 Environmental Effects of Dams

Santucci and Gephard (2003) studied the ecological effects of low-head dams on the Fox River between July and September 2000. A total of 40 stations were located up- and down-stream of each of 15 dams and at 10 locations in impounded and free-flowing areas between the dams. Impacts on water quality, as well as fish, macroinvertebrates, and habitat were investigated.

Overall, the study showed adverse impacts on both a local and system-wide scale. Local effects were largely related to the impoundments that formed upstream of each dam; system-wide effects were due to the fragmentation of the river causing restrictions in fish movement (Santucci et al. 2005). Degraded conditions were consistently found in habitat, water quality, and biotic communities throughout impounded reaches, while good habitat and water quality and healthy biotic communities were observed in free-flowing reaches.

The quality of fish communities was found to be higher in free-flowing versus impounded reaches based on Index of Biologic Integrity (IBI) scores (Santucci 2005). Fish communities did not vary within reaches of the same type. Sport fish were more abundant and larger in free flowing reaches than in impounded reaches. In impounded reaches, pollution-tolerant and omnivorous fish species were more prevalent. Dams were also found to alter the distribution of individual fish species. With respect to macroinvertebrate communities, higher quality communities were found in free-flowing reaches than impoundments. Similar community structure was found among stations of similar type (i.e. free-flowing or impounded). Figure 2-4 illustrates this finding, based on data presented by Santucci et al (2005). Fish community intactness scores were also found to be better in free-flowing reaches, compared with impounded reaches (Santucci and Gephardt, 2003) as shown in Figure 2-5. Figure 2-6 shows the locations of the dams on the Fox River. In addition, studies of fish populations before and after dam removal, such as at the River Road dam on Blackberry Creek, a tributary to the Fox River, show significant improvements resulting from dam removal. At the Blackberry Creek dam, the number of fish species found after removal was 25, compared with only 6 species before removal (Pescitelli, 2014).

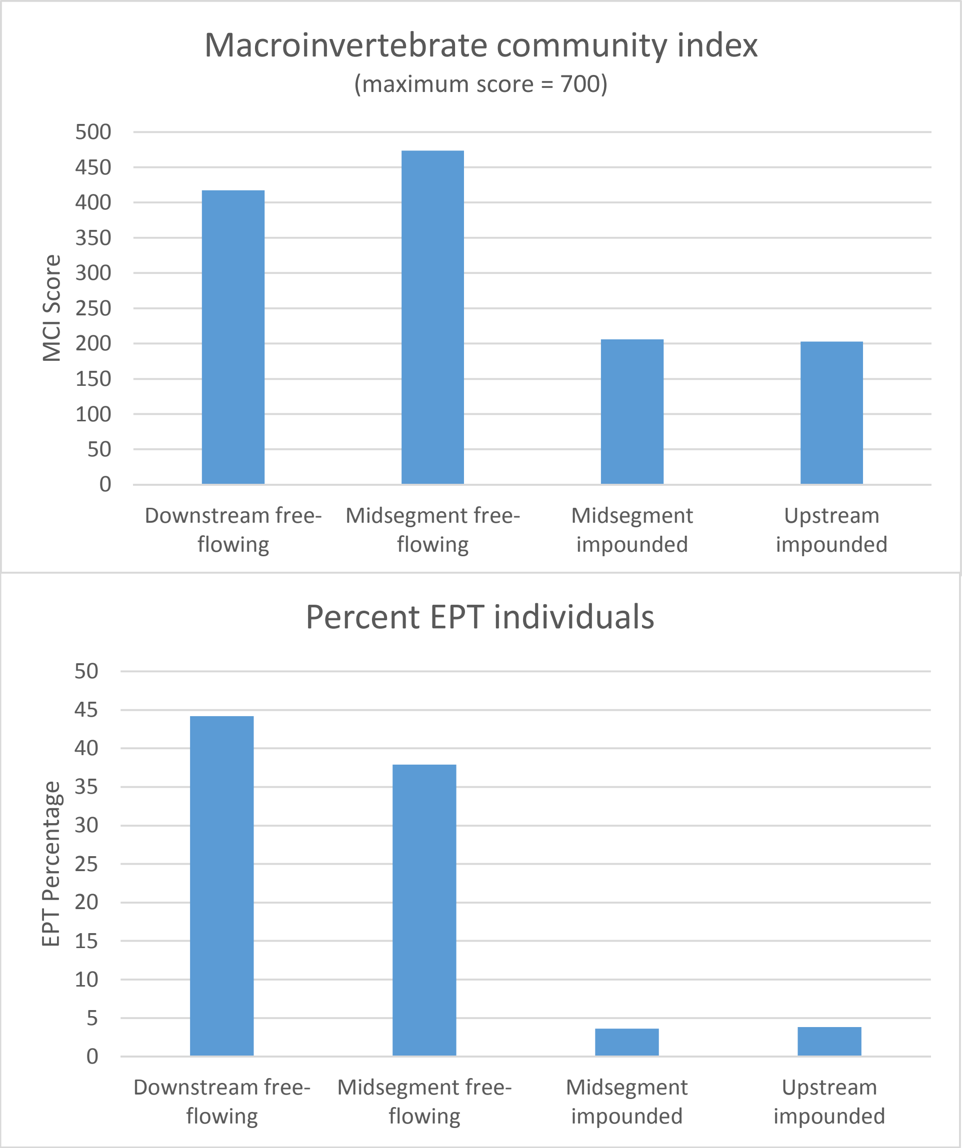


Figure 2-4: Macroinvertebrate Community Metrics in Free-Flowing vs. Impounded Reaches of the Fox River (prepared with data from Table 1 in Santucci, et al., 2005)

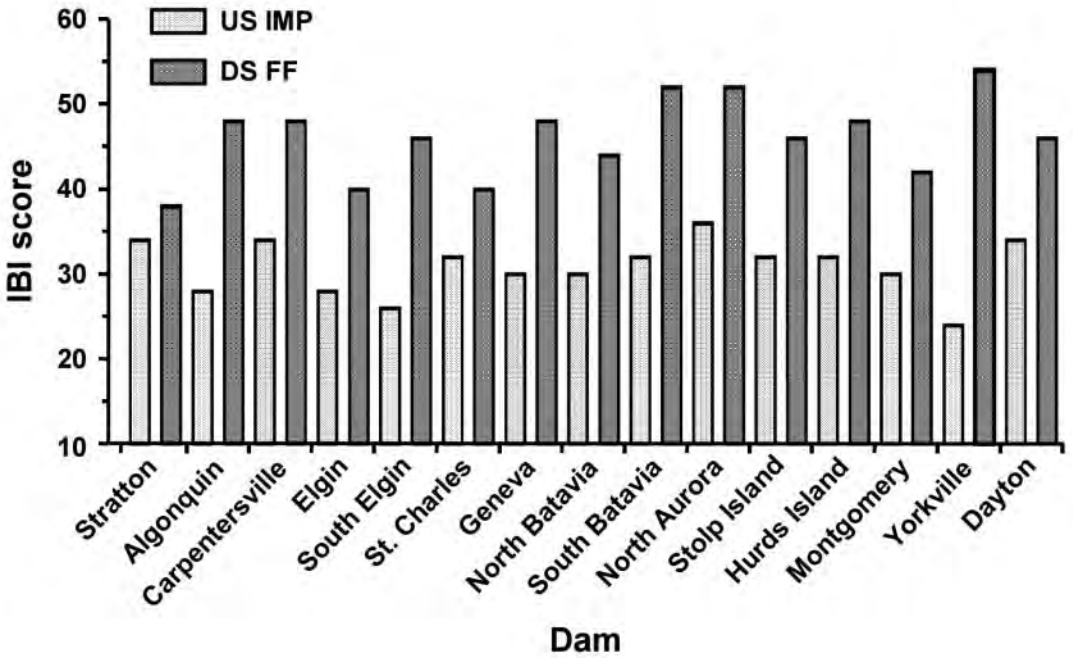


Figure 2-5: Index of Biotic Integrity (IBI) scores for upstream-impounded (US IMP) and downstream free-flowing (DS FF) stations at 15 Fox River dams between McHenry and Dayton, Illinois (from Santucci & Gephardt, 2003)

Table 2-5: River Mile Locations and Original Function of Dams on the Fox River Mainstem in the FRIP Planning Area (Adapted from Santucci and Gephard 2003)

Dam	River Mile	Original Function	Height (ft)	Year Current Dam Constructed*	Ownership*
Stratton	98.9	Navigation	7.0	1939	State of Illinois
Algonquin	82.6	Recreation	10.5	1947	State of Illinois
Carpentersville	78.2	Milldam/Hydropower	9.0	Uncertain	Kane County Forest Preserve District
Elgin	71.9	Milldam	13.0	1901	City of Elgin
South Elgin	68.2	Milldam	8.3	1961	State of Illinois
St. Charles	60.7	Recreation/Hydropower	10.3	1916	State of Illinois
Geneva	58.7	Milldam	13.0	1961	State of Illinois
North Batavia	56.3	Milldam	12.0	1872	City of Batavia
North Aurora	52.6	Milldam	9.0	mid-1970’s	State of Illinois
Stolp Island	48.9	Milldam	11.0 (east) 15.0 (west)	pre-1923	State of Illinois (east spillway) City of Aurora (west spillway)
Montgomery	46.6	Navigation	8.0	1969	State of Illinois
Yorkville	36.5	Recreation	7.0	1961	State of Illinois
Dayton	5.7	Hydropower	29.6	Uncertain (~1925)	Midwest Hydro, Inc.

*Santucci and Gephard (2003)

These studies found aquatic habitat to be severely degraded in impounded areas based on Qualitative Habitat Evaluation Index (QHEI) scores. Free flowing reaches had good quality habitat, even within urban reaches where concrete banks were present. Habitat quality was found to be a good predictor of both fish and macroinvertebrate communities (Santucci et al. 2005). Impacts of dams in the Fox River on water quality, as found by Santucci and Gephard, are described in Section 4.3.

The results described above are consistent with findings from other river systems regarding the environmental effects of dams. In a recent study published by the Minnesota Department of Natural Resources (MnDNR, 2015), fish populations upstream and downstream of 32 dams were evaluated. The study found that species richness was 41% lower, on average, upstream of complete barrier dams, compared to downstream of the dams. The study also looked at the effects of removal of 11 dams on fish populations and found that upstream colonization occurred following dam removal for 66% of the species that were missing upstream prior to dam removal.

In addition to impacting river ecology, dams can also cause public safety concerns. Low-head or “run of river” dams, such as those on the Fox River, span the width of the river and water flows continuously over the dam’s crest. This configuration can cause two significant safety hazards (CTE 2007): 1) the dam is not clearly identifiable to an individual traveling towards the dam from upstream, and 2) the dam may produce dangerous flow conditions downstream, known as a submerged hydraulic jump with a reverse roller. According to a recent study (CTE 2007), there are no official statistics on dam-related deaths in Illinois, but the study states that, in the summer of 2006 alone, there were several reported drowning deaths at Illinois dams. However, Brigham Young University maintains a database of deaths at low-head dams like those present on the Fox River. Twelve drownings at dams on the Fox River in Illinois over the past 40 years are recorded including two at the Algonquin dam in 1984: three at the Kimball St. dam in Elgin, including two rescued firemen in 1974 and a power skier wearing a life vest in 1995; three individual drownings at the Geneva dam in 1993, 2011 and 2014; one at the North Aurora dam in 1993; and three kayakers at the Yorkville dam in 2006. The Yorkville Police Department has stated that an additional 15 people have drowned at that dam since 1982.

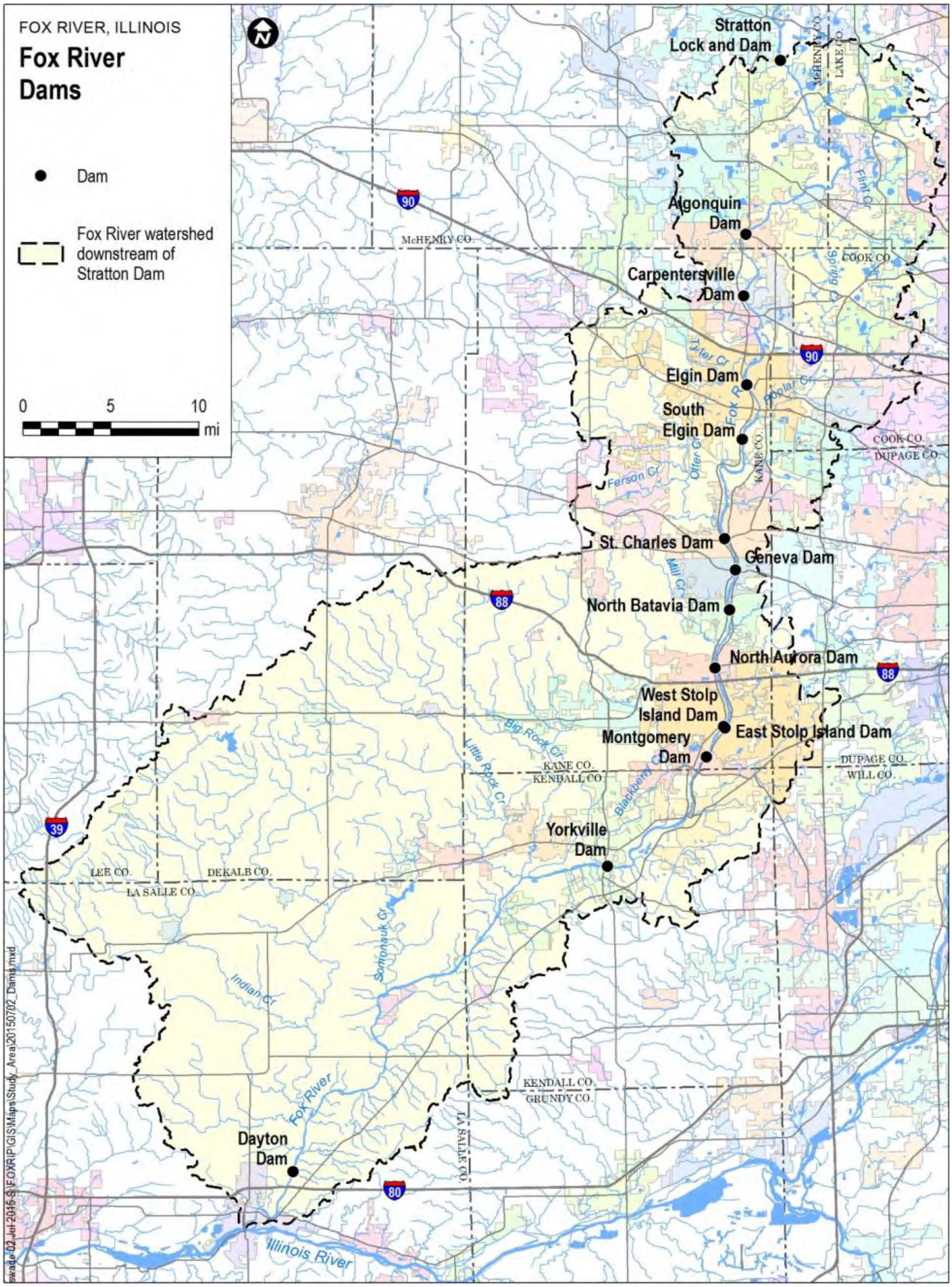


Figure 2-6: Locations of Dams on the Fox River Mainstem in the FRIP Planning Area

In a presentation to FRSG, Steve Pescitelli of the Illinois Department of Natural Resources summed up the benefits of dam removal in these bullets (Pescitelli 2014):

- Eliminates safety and liability problems
- Restores habitat, water quality, and connectivity
- Increases productivity for game and non-game fishes
- Removes maintenance costs
- Provides canoe/kayak passage

Findings presented of the 26 dam projects completed in Illinois, including 23 dam removals and 3 fish passage projects, include (Pescitelli 2014):

- Fish passage can work but structures require maintenance; does not address habitat and water quality problems in the dam pool
- Dam removal is more effective reconnection, no maintenance, less expensive and restores habitat and water quality
- Response of fish to dam removal is rapid: species increase by 3x, abundance increases 6-fold, IBI improves by 40%
    - In five dam removal projects studied, the average number of fish species found in dam pools increased from eight prior to dam removal to 24 following dam removal, and the average number of total fish found increased from 98 to 651
- Fish species re-populate streams and river segments following barrier removal
    - After removal of Hoffman Dam, 13 species of fish not previously recorded in the dam pool were found
    - Two weeks after dam removal in Brewster Creek in Spring 2013, the first spring spawning run Shorthead redhorse and quillback carpsucker was documented

The Fox River was identified as a priority for habitat restoration and fish passage by the U.S. Army Corps of Engineers (USACE) and the Illinois Department of Natural Resources (IDNR) in the 2007 Illinois River Basin Comprehensive Plan. As a result the USACE is currently conducting a feasibility study to examine dam removal and fish passage alternatives for ten Fox River dams. The study, titled the “519 Illinois River Ecosystem Restoration Program” is being conducted in cooperation with IDNR, local communities, and the Fox River Study Group. After completion of the study (scheduled for July 2017), selected projects will be submitted for funding if approved by local communities. The State of Illinois is a co-sponsor of the study, providing a 35% cost share.

2.5.2 Non-Environmental Benefits of Dams

The information summarized above makes clear that dams can have a net negative environmental effect, but there are other non-environmental considerations that require consideration when evaluating the removal of dams. For example, in some cases dams still provide utility related to their original intended uses, most often flood control, hydroelectric power generation, or water supply.

In addition, dams can provide recreational opportunities which can provide an economic benefit to the local community. Some dams may also have cultural, historical and/or aesthetic value to local residents. These considerations will need to be balanced against the negative environmental effects of dams as decisions are made whether to keep or remove them.

2.6 Sediment Flux

Sediment phosphorus release is a naturally occurring phenomenon in which there is a net flux of phosphorus from the bed sediments to the water column during certain times of the year. The flux is driven by diffusion across a concentration gradient of dissolved phosphorus concentration between sediment pore water and the water column. The phosphorus that is released to the water column originates from the contributing watershed, and is delivered to the sediments via the settling of particulate-bound phosphorus from the water column to the sediment. A portion of this particle-bound phosphorus may be released in the sediments, creating a concentration gradient and subsequent release into the water column. The direction of phosphorus exchange between sediments and the overlying water varies temporally in most systems. During periods of elevated particulate-bound phosphorus runoff in the water column (e.g. runoff events, algal blooms), the net movement of phosphorus is from the water column to the sediments. During periods of low solids concentration, the net movement of phosphorus is from the sediments to the water column.

Human activities can exacerbate sediment phosphorus release, via two primary mechanisms. The first mechanism is activities that increase particulate bound phosphorus concentration in the water column, and the subsequent delivery of phosphorus to the sediments. These activities primarily consist of either elevated erosion of watershed soils, or discharge of dissolved phosphorus from wastewater treatment plants that is converted into algal tissue or sorbed to inorganic particulate matter. The second mechanism is activities that lower dissolved oxygen concentrations near the sediment-water interface. As oxygen concentrations approach zero, inorganic solids which strongly bind phosphorus such as iron- and manganese oxides are reduced and dissolved. This releases the bound phosphorus to sediment pore waters from which it can diffuse into the overlying water column.

Elevated levels of phosphorus release can cause violation of water quality standards. The dissolved phosphorus that is released from sediments is immediately available for algal growth, such that an increase in sediment phosphorus release can cause an increase in algae concentrations. Increased algae concentrations can subsequently cause violation of water quality standards for dissolved oxygen, as the algae consume oxygen either directly via respiration or indirectly via sediment oxygen demand after the algae settle out of the water column. Sediment oxygen demand was measured by the ISWS at several locations as part of past Fox River investigations and was found to vary in a range of 1.65 to 3.1 g $O_2/m^2/day$, which are relatively high levels.

Sediment phosphorus release can be directly measured, and there are also predictive tools (called sediment diagenesis models) that predict subsequent sediment phosphorus flux as a function of particulate phosphorus delivery to the sediments.

3

Assessment and Planning Tools

To support development of this FRIP and the evaluation of potential actions to improve dissolved oxygen and reduce nuisance algae in the Fox River, specialized assessment and planning tools have been developed. These include the following:

- A suite of watershed models of the FRIP study area developed by the ISWS
- A water quality model of the Fox River main stem developed by the ISWS and modified by LimnoTech
- A non-point source load reduction tool developed by LimnoTech to help MS4 jurisdictions and other entities perform screening-level assessments

The FRSG began supporting the development of assessment and planning tools in 2003. Support was provided to the ISWS to develop watershed models for 31 subbasins in the Fox River watershed and two main stem segments using the Hydrologic Simulation Program – FORTRAN (HSPF, see Figure 3-1). The FRSG also provided support to the ISWS for development of a QUAL2k water quality model of the Fox River main stem in order to simulate dissolved oxygen conditions in the river. The QUAL2k model was modified by LimnoTech during development of the FRIP, with model updates peer-reviewed by ISWS. As part of the FRIP development, LimnoTech developed the Fox River TP Load Reduction Tool to allow users to evaluate load reduction strategies for nonpoint sources for individual jurisdictions or watersheds.

Documentation of the HSPF and QUAL2k models exists in other reports; therefore, this section provides a brief description of each tool and provides references to existing documentation. An overview of the use and capabilities of the Fox River Total TP Reduction Tool is provided below.

3.1 Watershed (HSPF) Model

The HSPF hydrological modeling package incorporates watershed-scale aquatic resource management (ARM) and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels, lakes, or reservoirs. Water quality simulation is organized in modules defined largely by pollutant categories; conservative tracers, sediments in three size classes, pesticides, nutrients, and general quality constituents. Phosphorous and nitrogen are modeled with complete on-land and in-stream nutrient cycles involving oxygen, heat balance, phytoplankton, and periphyton. HSPF is distributed by U.S. EPA Office of Water as part of the BASINS 4.0 software package[12].

The ISWS developed an application of the HSPF model for the Fox River watershed intended to support the development of an implementation plan. HSPF model development has been thoroughly documented by the ISWS (Bartosova 2007a, 2007b, 2007c, 2011, 2013a, 2013b; Singh et al. 2007). The selection of the HSPF model within the BASINS (Better Assessment Science Integrating point & Non-point Sources) framework for the Fox River watershed modeling was based on the following justification:

- Mixed land use within the study area;
- Anticipated growth of population and urbanization;

---

[12] http://water.epa.gov/scitech/datait/models/basins/BASINS4_index.cfm

- The capability to simulate pollution processes that occur in both pervious and impervious lands;
- The fairly fine level of spatial and temporal detail that can be accommodated;
- Ability to simulate the constituents of interest;
- The flexibility to use hourly or daily time steps; and
- The capability to model both storm events and long-term continuous simulations (McConkey et al. 2004).

The Fox River watershed HSPF model consists of 33 individual models with 31 tributary models and two (2) Fox River main stem models. The study area was divided into an upper and lower section, with 13 tributaries contributing to the upper section and 18 tributaries contributing to the lower section (Bartosova 2013a). Model outputs from the 13 upper tributaries serve as inputs to the upper main stem model (Bartosova 2013a). Model outputs from the upper Fox main stem and the 18 downstream tributaries serve as inputs to the lower Fox main stem model (Bartosova 2013a). The HSPF models have been calibrated and validated to simulate daily streamflow and selected water quality constituents (i.e., sediment, phosphorus, nitrogen; Bartosova 2007a, 2007b, 2011, 2013a, 2013b).

The HSPF models underwent an initial and final calibration and validation by the ISWS. An initial model calibration was performed using water quality data collected from the Fox River and its tributaries by various organizations (e.g., IEPA, FRSG) during water years 1991-1999 and validated using data from water years 2000-2003 (Bartosova 2007a, 2007b, 2011; Singh et al. 2007). The Land Cover of Illinois 1999-2000 spatial dataset was used in the initial calibration phase. The final calibration was performed from water years 2004-2010 and validated using data from 2011. The 2009 U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL) spatial dataset was used in the final calibration phase.

An independent review of the HSPF models completed for development of the FRIP concluded that, while sediment and TP loads from the land side may be biased slightly high for urban land use types and biased slightly low for agricultural land use types, the HSPF models appear to be calibrated for instream streamflow and TP in a manner that results in a “good” to “fair” level of accuracy in model predictions (Donigian et al. 1984, Donigian 2000, 2002), which is consistent with professional standards for watershed modeling.

LimnoTech programmed several additional utilities to facilitate running the 31 Fox River HSPF models, which allow the user to do the following:

- Set-up a new batch simulation framework to facilitate running all 33 HSPF models in a single run sequence (i.e., batch mode)
- Export and summarize the model outputs for all 33 models as well as all constituents modeled with single database queries (as opposed to exporting results for each model one-by-one).
- Easily vary the model simulation period using a single database entry rather than 33 individual model input files.
- Easily calculate TSS, TN, TP delivery ratios at the outlet of each of the 33 models.
- Easily export and summarize all of the point source inputs for the baseline simulation.
- Modify all WWTP constituents represented (i.e., total phosphorus) in the models to a single constant concentration value.
- Automated calculation of TSS, TN, and TP Unit Area Loads (UALs) for each of the 33 models (this used to require manual calculation post-processing for each model one-by-one).

- Update the land segment areas in each of the 33 models by populating a single database table rather than 33 individual model input files.

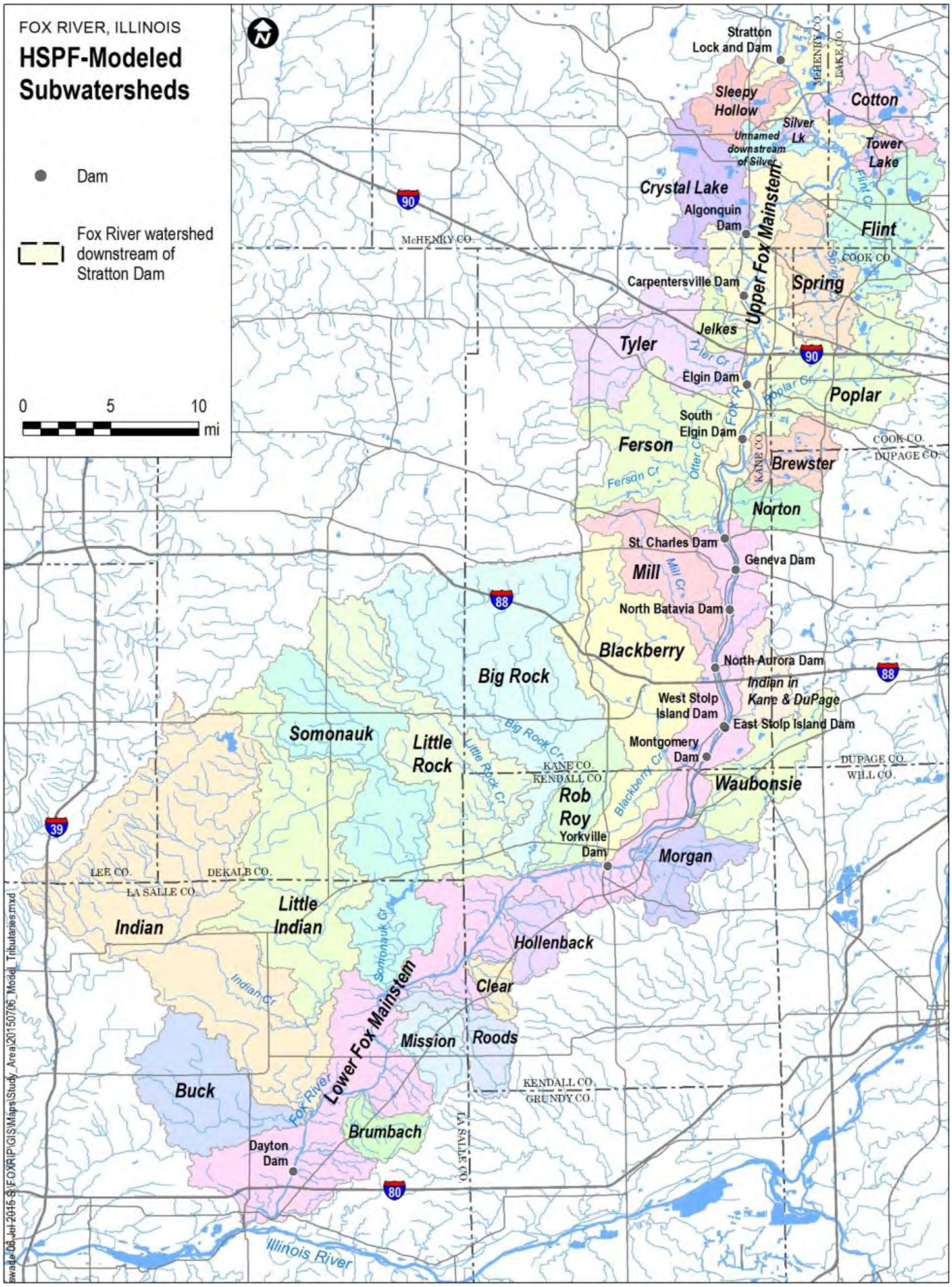


Figure 3-1: Subwatershed and Main Stem HSPF Models for the Fox River Watershed

3.2 QUAL2K

QUAL2K is a river water quality model that simulates water temperature, nutrients, biochemical oxygen demand, dissolved oxygen, sediment oxygen demand, phytoplankton, and attached algae. It is one-dimensional, simulating the change in concentration along the length of the river. It is a steady-state framework, so it is not capable of simulating how concentrations change over time. QUAL2K is a modernized version of the QUAL2E model that was used by many state regulatory agencies for conducting wasteload allocations for oxygen demanding materials. The model is distributed by U.S. EPA Watershed & Water Quality Technical Support Center[13] and Tufts University[14].

3.2.1 QUAL2K Model Description

The ISWS developed a calibrated QUAL2K water quality model application for the Fox River (Bartosova, 2013). This model was used to simulate future Fox River water quality in response to management actions considered in this FRIP, as presented in Section 5. The ISWS calibrated the QUAL2K model using data from an intensive sampling event conducted at 13 locations on the Fox River during low flow conditions in June 2012. Monitoring of dissolved oxygen, temperature, pH, and conductivity was conducted continuously during the event, and discrete water quality sampling was conducted three times per day (Bartosova, 2013).

The spatial extent of the Fox River QUAL2K model is shown in Figure 3-2. The upstream boundary of the model is at Stratton Dam and the downstream boundary is at the confluence with the Illinois River, approximately 5.5 miles downstream of the Dayton Dam.

---

[13] www.epa.gov/athens/wwqtsc/html/qual2k.html
[14] www.qual2k.com

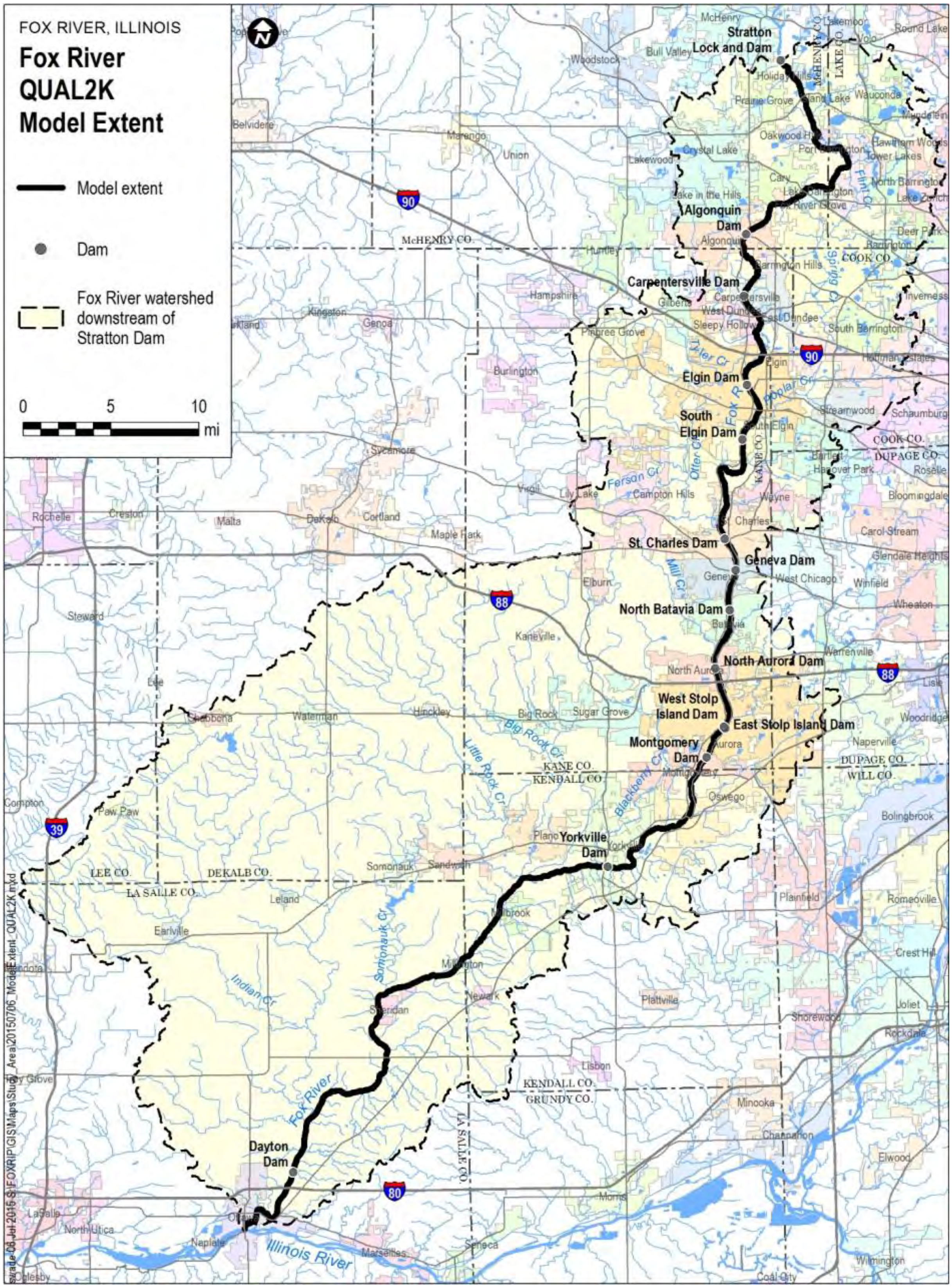


Figure 3-2: Extent of the Fox River QUAL2K Model

The dams listed in Table 2-6 are included in the QUAL2K model (with the exception of Stratton Dam), as are the municipal WWTPs listed in Table 3-1.

Table 3-1: Municipal WWTP Discharges Represented in the Fox River QUAL2K Model

WWTP
Algonquin
Batavia
Carpentersville
Cary
E. Dundee
Fox Metro
Fox-Grove
Fox River Water Reclamation District-North
Fox River Water Reclamation District -South
Fox River Water Reclamation District -West
Geneva
Northern Moraine
Port Barrington
Sheridan
St. Charles
Wauconda
Yorkville-Bristol

Water withdrawals from the Elgin Water Treatment Plant and Aurora Water Treatment Plant are also represented in the model. Tributaries represented in the model are listed in Table 3-2.

Table 3-2: Tributaries Represented in the Fox River QUAL2K Model

Tributary
Sleepy Hollow Creek
Cotton Creek
Silver Lake outlet
creek below Silver Lake outlet
Tower Lake outlet
Flint Creek
Spring Creek
Crystal Lake outlet
Jelkes Creek
Tyler Creek
Poplar Creek
Brewster Creek
Norton Creek
Ferson Creek
Mill Creek
Indian Creek Aurora

Tributary
Waubonsie Creek
Morgan Creek
Blackberry Creek
Rob Roy Creek
Big Rock Creek
Little Rock Creek
Hollenbach Creek
Clear Creek
Roods Creek
Somonauk Creek
Mission Creek
Brumbach Creek
Indian Creek south
Buck Creek

In an independent review of the ISWS QUAL2k model conducted by LimnoTech, two issues were identified within the model framework that would limit its utility to evaluate future management actions:

3. The model code was not predicting sediment oxygen demand properly, and
4. The model framework was not well-suited for assessing the water quality impact of non-point source load reductions.

LimnoTech was subsequently tasked by the FRSG to change the QUAL2K model code to correct the above issues and then change model inputs as necessary to provide recalibration to observed water quality data. Model modification and recalibration is documented in LimnoTech (2014b), which is provided as Appendix A.

Related to sediment oxygen demand, because the original ISWS calibration had undergone extensive review, the objective of the recalibration effort was to allow the corrected model code to generate expected levels of sediment oxygen demand, while changing as little of the original model calibration as possible. Three categories of changes were made to the original model inputs (LimnoTech 2014b):

1. Inputs representing “prior season” contribution to sediment phosphorus concentrations were added.
2. Corrections to original model inputs identified as necessary during the model review process were implemented.
3. Algal settling velocities were increased (and other processes adjusted accordingly), in order to allow more settling of organic material to Fox River sediments while maintaining water column concentrations consistent with the calibration data set.

3.2.2 QUAL2K Model Calibration

After making the changes to the QUAL2K model described above, model parameters were adjusted to recalibrate the model to a state that was at least as good as the original ISWS calibration. The recalibrated model shows total phosphorus concentrations that match the calibration data very well (Figure 3-3). Similar to the original calibration by ISWS, minimum DO is over-predicted at several locations, indicating a limitation of the model for evaluating impacts of load reduction on minimum DO (Figure 3-4). However, model-predicted algae (phytoplankton) concentrations match calibration data well (Figure 3-5). The revised model predicts significantly different SOD than the original calibration due to the newer software version used, but the recalibrated results compare well to the observed data. Ammonia concentrations match the observed data, as well as the original calibration results. Model modification and recalibration is documented in LimnoTech (2014b) which is provided as Attachment D.

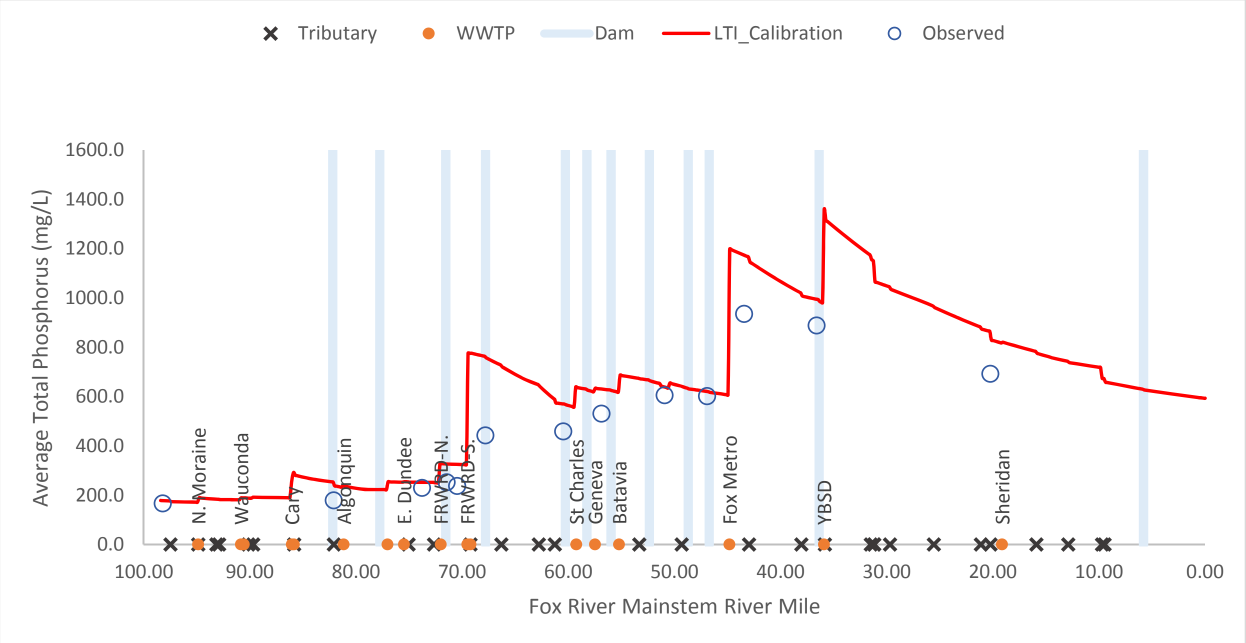


Figure 3-3: QUAL2K Calibration for Average Total Phosphorus

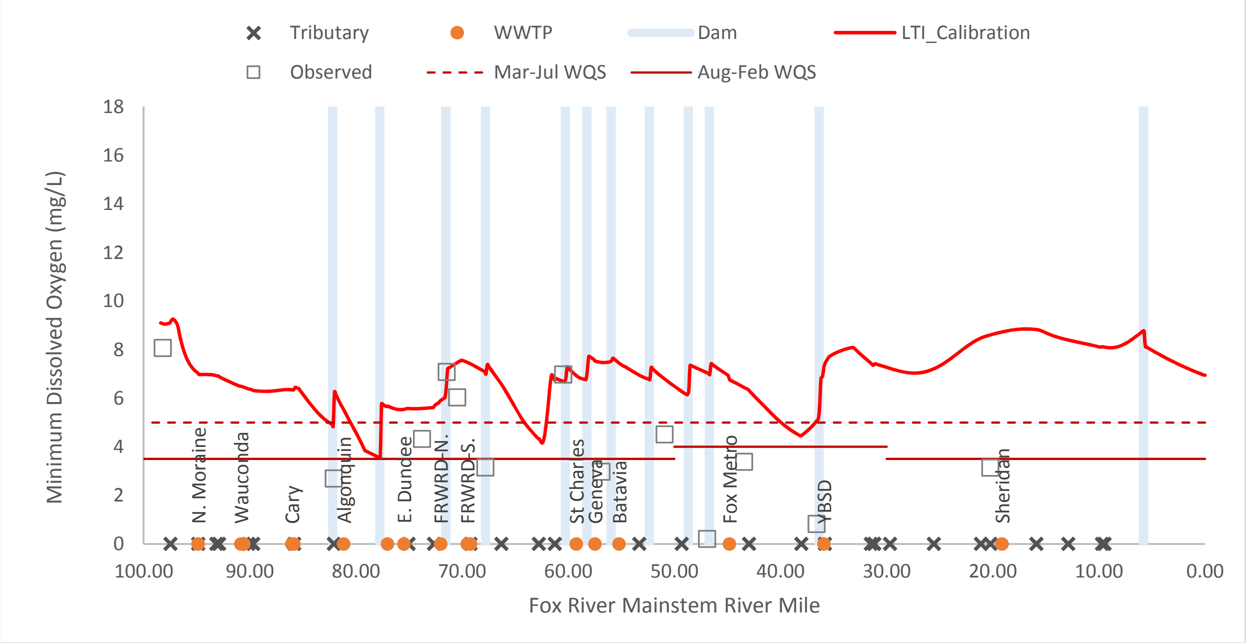


Figure 3-4: QUAL2K Calibration for Minimum Dissolved Oxygen

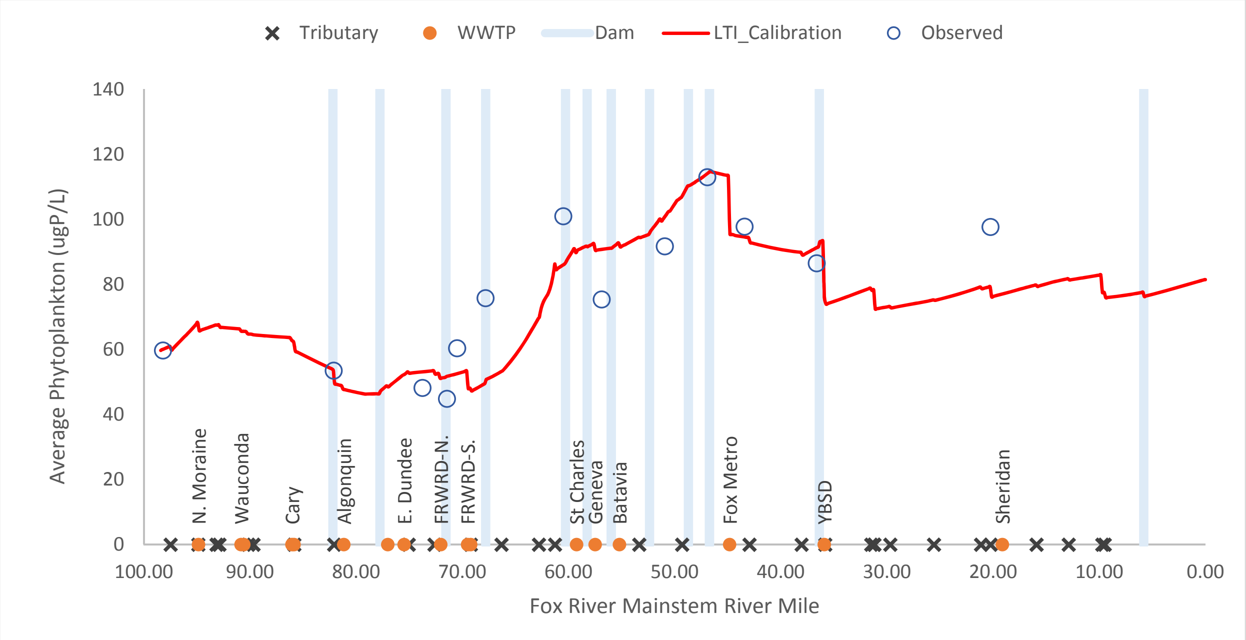


Figure 3-5: QUAL2K Calibration for Average Phytoplankton

3.2.3 QUAL2K Model Limitations

Although the calibration results show good agreement between model results and data for total phosphorus (Figure 3-3) and algae (Figure 3-5), the comparison of model results to data for minimum dissolved oxygen is less satisfactory (Figure 3-4). At some locations in the river, the minimum DO is over-predicted by 2 to 8 mg/l. At the same time, maximum DO is under-predicted by even greater amounts. As stated in the ISWS Phase III report which discussed the original model calibration, the model “does not represent the diurnal variation of dissolved oxygen well…” (Bartosova, 2013). As part of the original calibration process, as well as LimnoTech’s recalibration, reaeration coefficients in the model were reduced to maximize the diurnal dissolved oxygen variation in the model and better replicate the calibration data. Ultimately, reaeration coefficients at the extreme low end of the possible range of values were used.

The reason for the inability of the model to reproduce the diurnal variation in the calibration data set is not known with certainty. Typically, model calibration can be limited by three things:

1. The calibration data may be incomplete, flawed or contain some anomaly that limits calibration;
2. The way the data are synthesized from the original results for use in calibration may be causing issues (for example, average multiple measurements in time and space into a single calibration point); or
3. The model framework is unable to represent some process that is occurring in the real world.

In this case, there is no reason to suspect a problem with the data, so the problem probably lies in the combination of the second two points above. For example, in the real world, aquatic plant density and productivity are changing over time and can vary across the width of the river, but for the QUAL2K model it is necessary to collapse everything into temporal and spatial averages. For things like periphyton, there are not enough data to distinguish longitudinal trends. As for the suitability of the model framework, unfortunately, there is currently not sufficient data to determine what processes are missing that may be affecting DO (e.g. rooted plants).

Consequently, the model's limitation should be taken into account when reviewing all model results for dissolved oxygen. When, for example, the minimum DO for a given load reduction scenario is evaluated, the actual minimum DO may be significantly lower than that minimum DO predicted by the model. Because the model calibration for total phosphorus and algae was much better than for DO, there is greater confidence in those model results.

3.3 Fox River Non-Point Source (NPS) Phosphorus Load Reduction Screening Tool

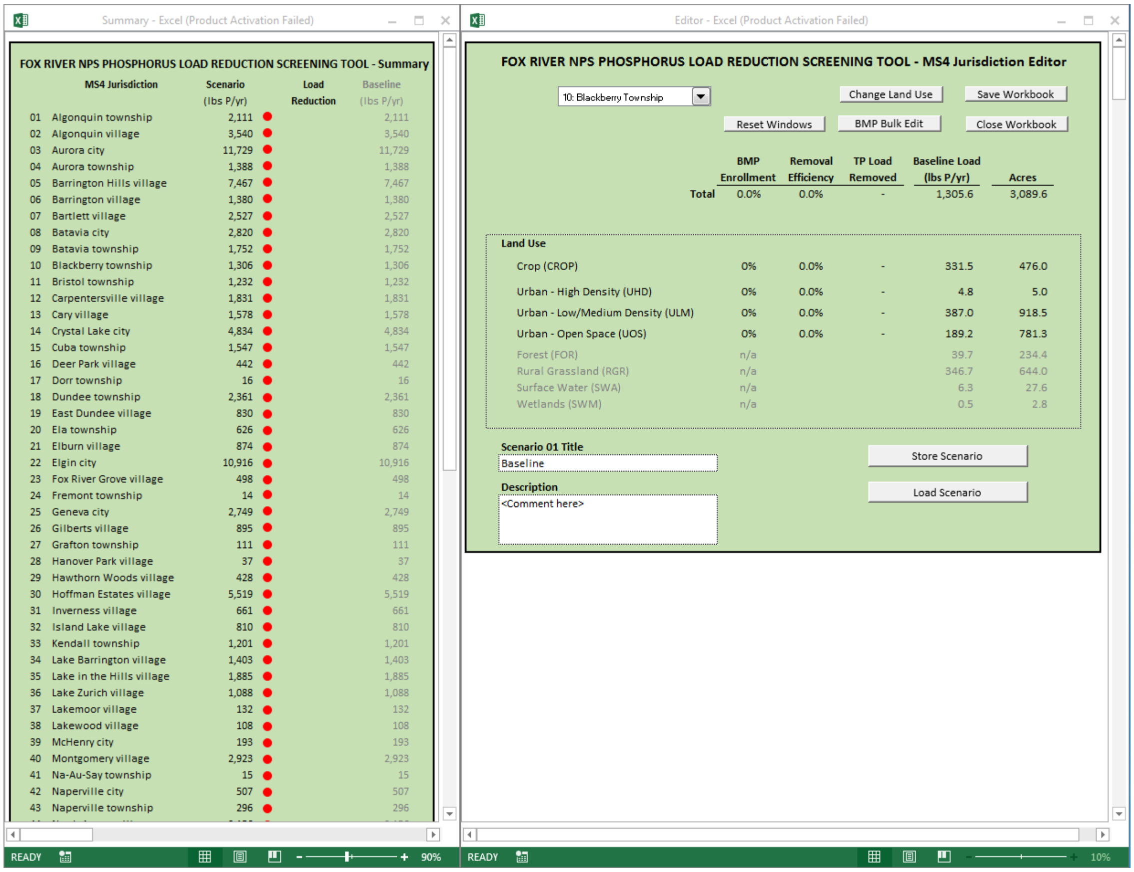
The Fox River Non-Point Source (NPS) Phosphorus Load Reduction Screening Tool is a spreadsheet-based custom user interface (Figure 3-6) that allows users to develop and evaluate different NPS management scenarios within the FRIP study area. The tool uses unit area loads (UALs) for TP (pounds per acre per year) derived from HSPF model output. These UALs are specific to land cover types in the HSPF model, as well as subwatershed. Two versions of the tool were developed:

- A subwatershed-based version that allows the user to test load reduction scenarios on a subwatershed basis (potentially of interest for tributary watershed groups and others)
- A version based on MS4 jurisdictions that allows the user to test load reduction scenarios for specific MS4 jurisdictions

The tool calculates baseline TP loads for each land use in each subwatershed or MS4 jurisdiction, and then allows the user to select from a menu of NPS control measures to evaluate how different TP reduction scenarios will impact the TP load delivered to the Fox River. Specifically, the tool has three main functions:

1. The modification of TP loads on an MS4 jurisdiction or subwatershed basis via the implementation of NPS controls;
2. The presentation of summary information by MS4 jurisdiction or subwatershed basis to allow the user to understand changes in loadings; and,
3. The storage and retrieval of scenarios.

Both versions of the tool use the same user interface and perform the same functions. Both tools use average annual UALs derived from the HSPF models (averaged for the 1991 to 2011 simulation period) to calculate baseline TP loads. The following subsections provide some details about the use of the tools.



FOX RIVER NPS PHOSPHORUS LOAD REDUCTION SCREENING TOOL - Summary

	MS4 Jurisdiction	Scenario (lbs P/yr)		Load Reduction	Baseline (lbs P/yr)
01	Algonquin township	2,111	●		2,111
02	Algonquin village	3,540	●		3,540
03	Aurora city	11,729	●		11,729
04	Aurora township	1,388	●		1,388
05	Barrington Hills village	7,467	●		7,467
06	Barrington village	1,380	●		1,380
07	Bartlett village	2,527	●		2,527
08	Batavia city	2,820	●		2,820
09	Batavia township	1,752	●		1,752
10	Blackberry township	1,306	●		1,306
11	Bristol township	1,232	●		1,232
12	Carpentersville village	1,831	●		1,831
13	Cary village	1,578	●		1,578
14	Crystal Lake city	4,834	●		4,834
15	Cuba township	1,547	●		1,547
16	Deer Park village	442	●		442
17	Dorr township	16	●		16
18	Dundee township	2,361	●		2,361
19	East Dundee village	830	●		830
20	Ela township	626	●		626
21	Elburn village	874	●		874
22	Elgin city	10,916	●		10,916
23	Fox River Grove village	498	●		498
24	Fremont township	14	●		14
25	Geneva city	2,749	●		2,749
26	Gilberts village	895	●		895
27	Grafton township	111	●		111
28	Hanover Park village	37	●		37
29	Hawthorn Woods village	428	●		428
30	Hoffman Estates village	5,519	●		5,519
31	Inverness village	661	●		661
32	Island Lake village	810	●		810
33	Kendall township	1,201	●		1,201
34	Lake Barrington village	1,403	●		1,403
35	Lake in the Hills village	1,885	●		1,885
36	Lake Zurich village	1,088	●		1,088
37	Lakemoor village	132	●		132
38	Lakewood village	108	●		108
39	McHenry city	193	●		193
40	Montgomery village	2,923	●		2,923
41	Na-Au-Say township	15	●		15
42	Naperville city	507	●		507
43	Naperville township	296	●		296

FOX RIVER NPS PHOSPHORUS LOAD REDUCTION SCREENING TOOL - MS4 Jurisdiction Editor

10: Blackberry Township

	BMP Enrollment	Removal Efficiency	TP Load Removed	Baseline Load (lbs P/yr)	Acres
Total	0.0%	0.0%	-	1,305.6	3,089.6
Land Use					
Crop (CROP)	0%	0.0%	-	331.5	476.0
Urban - High Density (UHD)	0%	0.0%	-	4.8	5.0
Urban - Low/Medium Density (ULM)	0%	0.0%	-	387.0	918.5
Urban - Open Space (UOS)	0%	0.0%	-	189.2	781.3
Forest (FOR)	n/a			39.7	234.4
Rural Grassland (RGR)	n/a			346.7	644.0
Surface Water (SWA)	n/a			6.3	27.6
Wetlands (SWM)	n/a			0.5	2.8

Scenario 01 Title
Baseline

Description
<Comment here>

Figure 3-6: Fox River Non-Point Source (NPS) Phosphorus Load Reduction Screening Tool

3.3.1 Editor Window

The editor window is used to create TP management scenarios by allowing the user to define simple representations of NPS controls that might be installed in each MS4 jurisdiction (Figure 3-7). The user can select one of the MS4 jurisdictions from the dropdown list in the upper left corner.

Controls can be applied to four different land use categories:

- Crop
- Urban-high density
- Urban- low/medium density
- Urban – open space

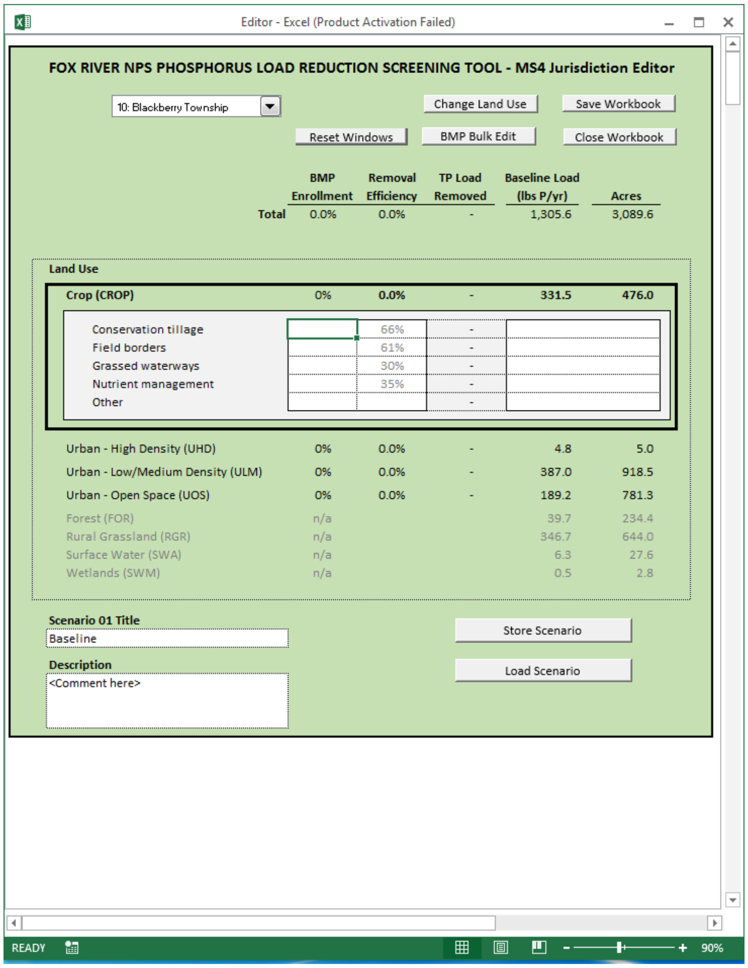
The possible NPS controls that can be applied in each land use category are given in Table 3-3. These NPS controls were selected based on best professional judgement and input from FRSG members. Documentation of selection of the NPS controls is provided in LimnoTech (2014), which is provided in Attachment B.

It should be noted that streambank and stream bed stabilization are likely to be beneficial control measures to reduce phosphorus loading to the Fox River, but they are not included in the phosphorus load reduction tool for three reasons. First, streambank and bed erosion were not modeled explicitly as phosphorus sources in the Fox River HSPF models but rather are included implicitly (Bicknell, et al., 2005). Therefore, since the phosphorus load reduction tool is based on HSPF phosphorus loading rates, there are no model-derived loading rates for erosion. Second, no comprehensive evaluation of stream erosion as a phosphorus source has been conducted in the Fox River watershed to provide information on the extent of erosion or to quantify the phosphorus load resulting from the erosion. Last, there is significantly less information available in the technical literature to provide estimates of the unit load reduction benefits from streambank and bed stabilization.

Table 3-3: NPS Control Measures by Land Use Type

Land Use	NPS Control Measure
Crop	Conservation tillage
	Field borders
	Grassed waterways
	Nutrient management
Urban--High Density	Bioretention
	Street sweeping (weekly)
	Vegetated swales
Urban--Low/Medium Density	Bioretention
	Constructed wetland
	Dry detention
	Detention basin retrofit
	Street sweeping
	Vegetated swales
	Wet detention
Urban--Open Space	Bioretention
	Constructed wetland
	Dry detention
	Street sweeping (weekly)
	Vegetated swales
	Wet detention

For each land use category, the user can enter the percentage of total acres where each type of NPS control is installed, along with the TP removal efficiency of each control. If the user does not enter a removal efficiency, then the default value (in gray) is used to calculate the TP load removed. Once NPS control application percentages and removal efficiencies are entered, the editor then calculates the TP load removed, as well as the composite TP removal efficiency, for each land use and for the entire MS4 jurisdiction.



FOX RIVER NPS PHOSPHORUS LOAD REDUCTION SCREENING TOOL - MS4 Jurisdiction Editor

10: Blackberry Township

	BMP Enrollment	Removal Efficiency	TP Load Removed	Baseline Load (lbs P/yr)	Acres
Total	0.0%	0.0%	-	1,305.6	3,089.6
Land Use					
Crop (CROP)	0%	**0.0%**	-	**331.5**	**476.0**
Conservation tillage		66%	-		
Field borders		61%	-		
Grassed waterways		30%	-		
Nutrient management		35%	-		
Other			-		
Urban - High Density (UHD)	0%	0.0%	-	4.8	5.0
Urban - Low/Medium Density (ULM)	0%	0.0%	-	387.0	918.5
Urban - Open Space (UOS)	0%	0.0%	-	189.2	781.3
Forest (FOR)	n/a			39.7	234.4
Rural Grassland (RGR)	n/a			346.7	644.0
Surface Water (SWA)	n/a			6.3	27.6
Wetlands (SWM)	n/a			0.5	2.8

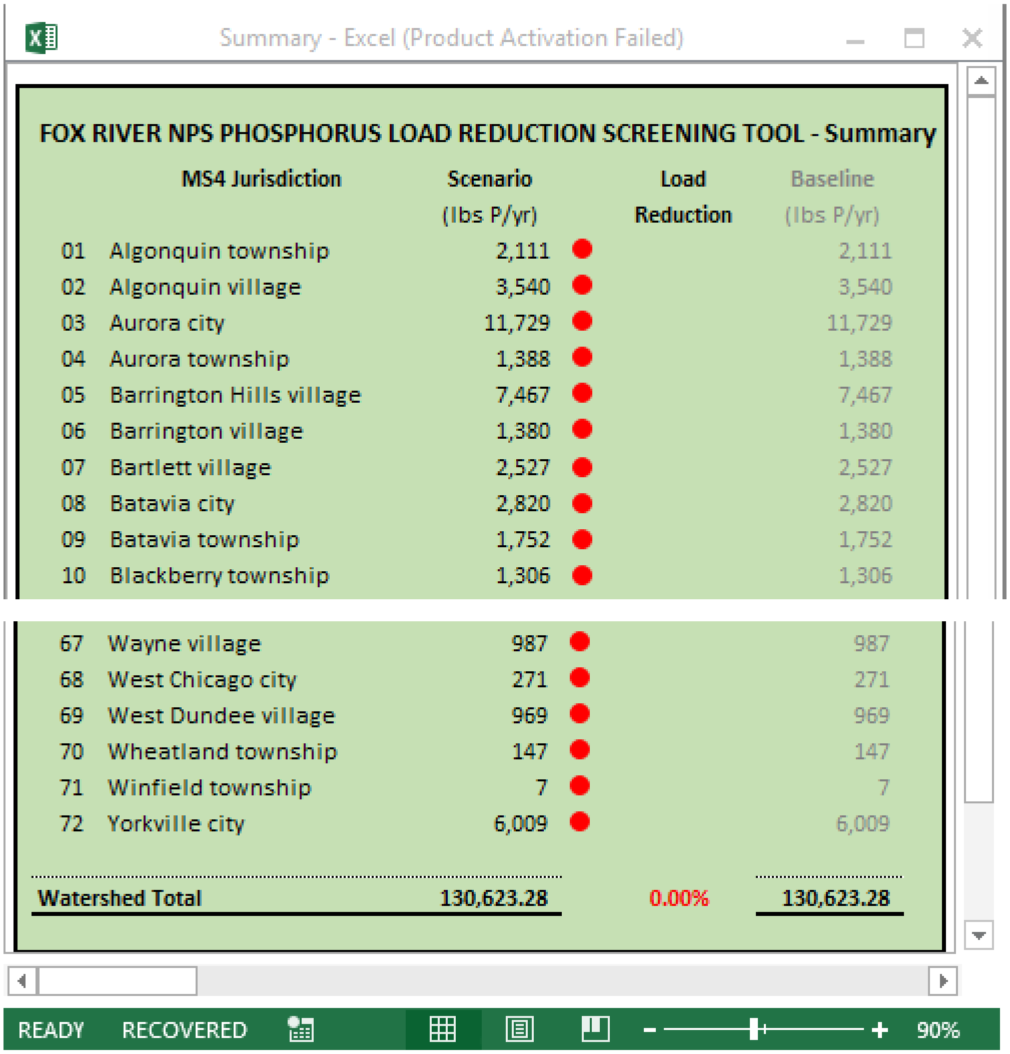
Scenario 01 Title
Baseline

Description
<Comment here>

Figure 3-7: Editor Window for the Fox River Non-Point Source (NPS) Phosphorus Load Reduction Screening Tool

3.3.2 Summary Window

The summary window summarizes phosphorus loads for all 76 municipal and township MS4 jurisdictions in FRIP planning area (Figure 3-8). The window displays the TP load from the baseline scenario, the current scenario that the user has created, and the percent load reduction between the two scenarios. These values are calculated on a MS4-jurisdiction basis and on a watershed basis (bottom row of Table 3-8). If a difference in TP load is detected between the baseline scenario and the current one, the circle next to the corresponding MS4 jurisdiction will change from red to green. This provides the user a quick visual reference of progress. The summary window automatically updates when the user changes from one MS4 jurisdiction to another in the editor window. Details on the calculation method used for each column can be found in Appendix B.



FOX RIVER NPS PHOSPHORUS LOAD REDUCTION SCREENING TOOL - Summary

	MS4 Jurisdiction	Scenario (lbs P/yr)		Load Reduction	Baseline (lbs P/yr)
01	Algonquin township	2,111	●		2,111
02	Algonquin village	3,540	●		3,540
03	Aurora city	11,729	●		11,729
04	Aurora township	1,388	●		1,388
05	Barrington Hills village	7,467	●		7,467
06	Barrington village	1,380	●		1,380
07	Bartlett village	2,527	●		2,527
08	Batavia city	2,820	●		2,820
09	Batavia township	1,752	●		1,752
10	Blackberry township	1,306	●		1,306
67	Wayne village	987	●		987
68	West Chicago city	271	●		271
69	West Dundee village	969	●		969
70	Wheatland township	147	●		147
71	Winfield township	7	●		7
72	Yorkville city	6,009	●		6,009
	Watershed Total	130,623.28		0.00%	130,623.28

Figure 3-8: Top and Bottom Portions of the Summary Window for the Fox River Non-Point Source (NPS) Phosphorus Load Reduction Screening Tool, Including the Total TP Load for all MS4 Jurisdictions.

3.3.3 Storage and Retrieval of Scenarios

Scenarios are stored and retrieved within the Fox River TP Load Reduction Tool workbook and can be done from the editor window; no external files are created (Figure 3-9). In the lower left corner of the editor window, the user has the option to name the scenario and to add a brief description (Figure 3-9). The "Store Scenario" button allows the user to store the current scenario. The workbook is capable of storing up to ten scenarios (Figure 3-10). The "Load Scenario" button will load any one of the stored scenarios (Figure 3-11).


Scenario 01 Title: Baseline

Description: <Comment here>

Figure 3-9: Portion of the Editor Window Associated With the Storage and Retrieval of Scenarios.

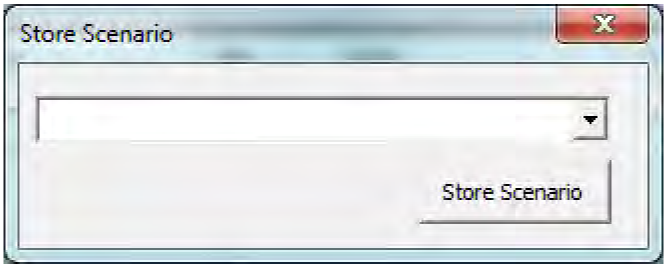


Figure 3-10: Store Scenario Pop-up Window

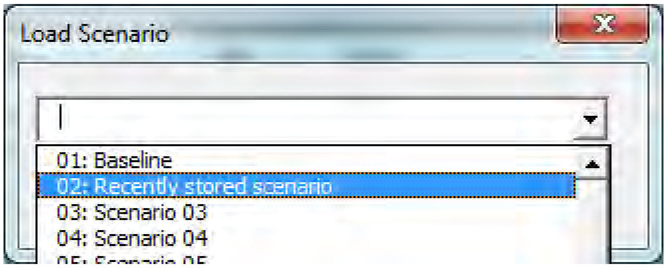


Figure 3-11: Load Scenario Pop-up Window

3.3.4 Summary of NPS Control Removal Efficiencies and Costs

For the suite of eleven NPS controls possible for application in the Fox River NPS Phosphorus Reduction Screening Tool, the recommended BMP removal efficiencies were either a U.S. EPA-approved value for IEPA projects or they were based on a review of the current literature. The default removal efficiencies for each NPS control used in the tool are summarized in Table 3-3. Unit cost estimates for each NPS control were based on a literature review and comparison to Illinois NPS projects where data was available. Additional details about the removal efficiencies and costs reported can be found in Attachment B.

Table 3-4: TP Removal Efficiencies and Units Costs for NPS Controls (see Attachment B for more information)

Land Use	NPS Control Measure	TP Removal (%)	Median Cost
Crop	Conservation tillage	66	$14.30/ac. treated
	Constructed Wetland	44	$6/ft^3 treated
	Field borders	61	$11.30/ac. treated
	Grassed waterways	30	$135/ac. treated
	Nutrient management	35	$38/ac. treated
Urban--High Density	Bioretention	65	$20/ac. treated
	Street sweeping (weekly)	6	$2,100/curb mi. treated
	Vegetated swales	25	$8/ft^3 treated
Urban--Low/Medium Density	Bioretention	65	$20/ac. treated
	Constructed wetland	44	$6/ft^3 treated
	Dry detention	26	$3/ft^3 treated
	Detention basin retrofit	26	*No data*
	Street sweeping	6	$2,100/curb mi. treated
	Vegetated swales	25	$14.80/ft^3 treated
	Wet detention	68	$6/ft^3 treated
Urban--Open Space	Bioretention	65	$20/ac. treated
	Constructed wetland	44	$6/ft^3 treated
	Dry detention	26	$6/ft^3 treated
	Street sweeping (weekly)	6	$2,100/curb mi. treated
	Vegetated swales	25	$14.80/ft^3 treated
	Wet detention	68	$6/ft^3 treated

Blank

4

Current Conditions

This section of the FRIP describes water quality conditions upstream of the FRIP study area, as well as phosphorus loading sources to the Fox River. This information is used to provide a basis for assessing load reductions in water quality improvement alternatives presented in Section 5.

It is stated earlier in the FRIP that the focus of the FRIP is on dry weather, low flow periods where low DO and nuisance algal growth are more likely to occur. It has been noted that non-point source loads from MS4s and agricultural areas mainly occur during wet weather periods. While this is true, some of the wet weather phosphorus load from MS4s and agricultural areas accumulates in river sediments and can contribute to dissolved oxygen conditions and algal growth during dry weather, low flow periods, therefore it is relevant to consider non-point source loads and their control in the FRIP.

4.1 Upstream Conditions

The upstream boundary of the FRIP study area is the Stratton Dam. Water quality in the Fox River within the FRIP study area is significantly affected by water coming over Stratton Dam, so some discussion of it is warranted here. The main water quality constituents discussed here are dissolved oxygen, total phosphorus and chlorophyll-*a*, which is sometimes used as a surrogate measurement for algae in the water column. These are the three water quality parameters most relevant to the water quality goals of the FRIP, as described in Section 1. Upstream concentrations of DO, TP, and chlorophyll *a* entering the FRIP planning area were established based on monitoring data collected by multiple organizations (including FRSG, IEPA, ISWS, and McHenry County Health Department) for the period of 1980 to 2010 at sampling locations located at Burtons Bridge, IL. The data was extracted from the Fox River Watershed Water Quality Database. Details about sampling organizations, sampling programs, and the database can be found in the Fox River Watershed Investigation Phase I report on water quality and data (ISWS 2004).

Levels of DO measured at the upstream boundary of the FRIP planning area are above Illinois water quality standards (WQS) for most of the year, with a few measurements in July falling below the March-July WQS (Figure 4-1). Dissolved oxygen levels reach peak concentrations in January and steadily decrease until reaching a minimum during the summer months. TP levels follow an inverse pattern, with peak concentrations occurring in the summer and minimum concentrations occurring in January and December (Figure 4-2). Similar seasonal changes are also seen in chlorophyll *a* concentrations, with elevated levels of phosphorus most likely driving the increased concentrations of chlorophyll *a* in summer and fall months (Figure 4-3).

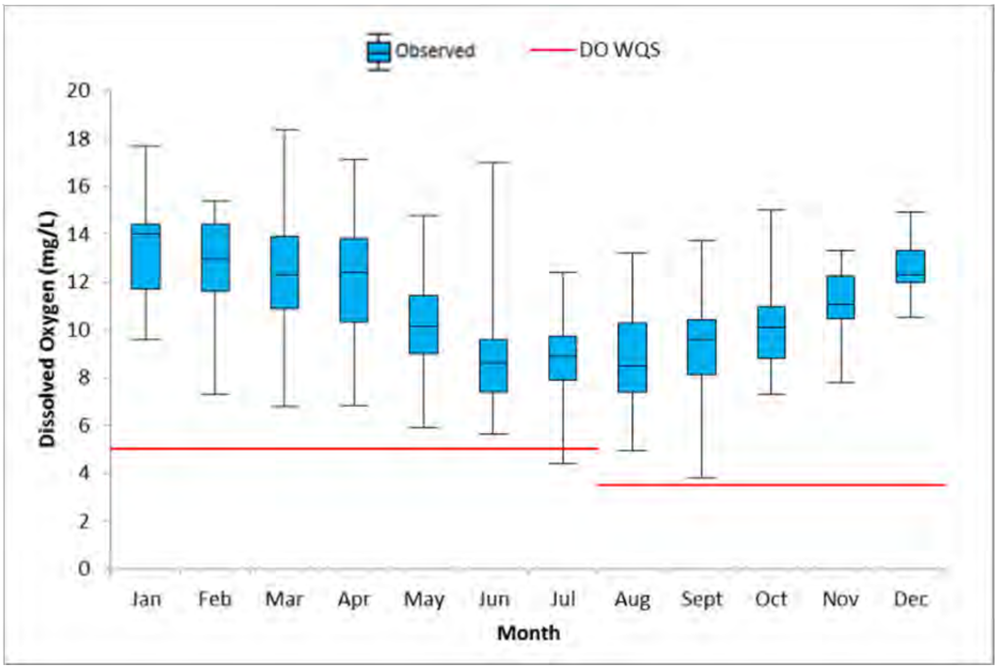


Figure 4-1: Monthly Dissolved Oxygen Measured at Burtons Bridge, IL (1980-2010)

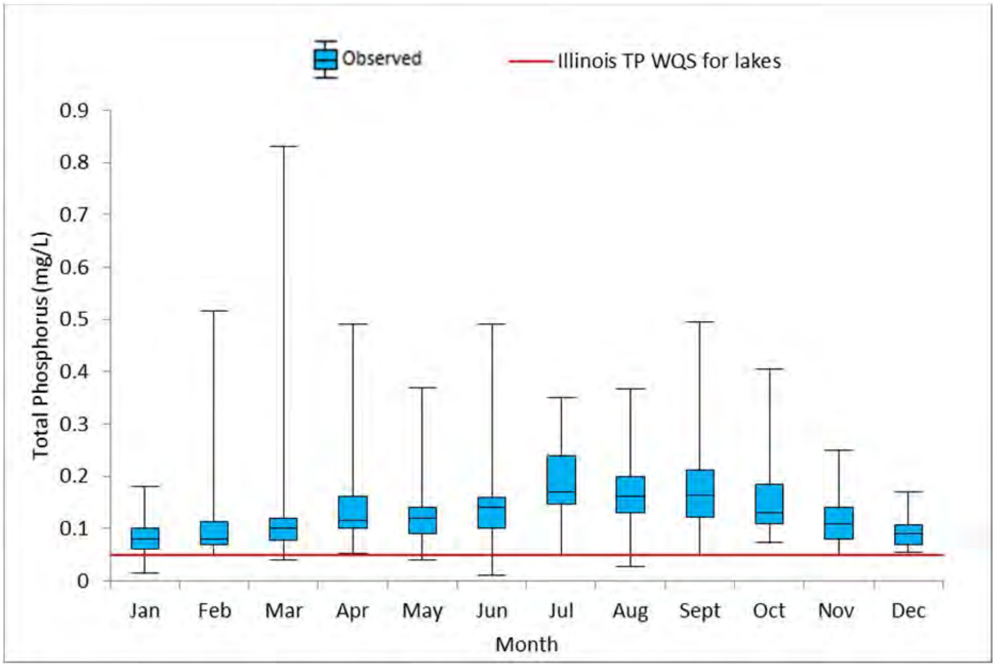


Figure 4-2: Monthly Total Phosphorus Measured at Burtons Bridge, IL (1980-2011)

NOTE: The water quality standard shown above is the standard for lakes in Illinois. There is no standard for total phosphorus in rivers at this time.

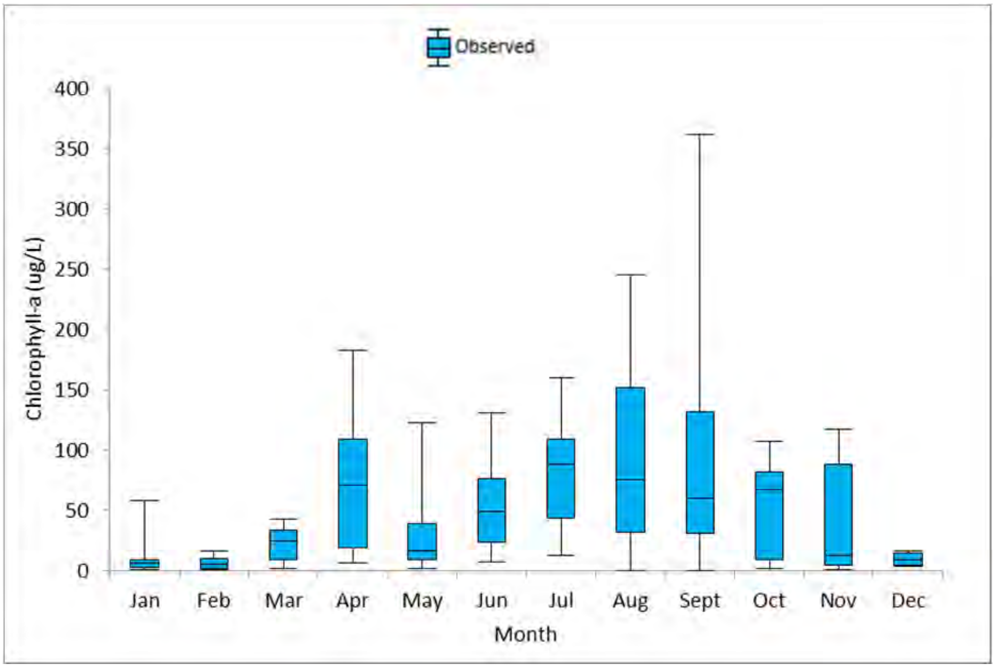


Figure 4-3: Monthly Chlorophyll a Measured at Burtons Bridge, IL (2002-2011)

While DO at the upstream boundary of the FRIP planning area generally meets water quality standards, the TP concentration of the water entering system is elevated, with a median summer concentration of 0.16 mg/l. The major source of the excessive phosphorus is most likely the Chain O'Lakes system located upstream of the planning area. Many of the lakes within the Chain O'Lakes system do not meet the aesthetic quality designated use and are listed for DO and TP impairments (AECOM 2010). TP concentrations in waters leaving the Chain O'Lakes system exceed the lake-specific TP WQS, which ultimately results in elevated concentrations of TP entering the FRIP planning area. The summer median TP concentration of 0.16 mg/l at Burtons Bridge is slightly higher than the median TP concentration in Pistakee Lake, the furthest downstream lake in the Chain O'Lakes system (AECOM 2010). As a result, median TP values at the upstream boundary of the FRIP planning area exceed the water quality standard for lakes every month of the year with the summer median value being more than triple the 0.05 mg/L standard (Figure 4-2).

4.2 Phosphorus Loads

In addition to phosphorus loads entering the FRIP study area from upstream at Stratton Dam (see Section 4.1), phosphorus loading to the Fox River also comes from non-point sources (NPS) and wastewater treatment plants during both dry and wet weather conditions. For purposes of the FRIP, NPS loads were estimated for all land uses occurring in the watershed. It should be noted that NPS loads are really wet weather loads and, as such, are not active during the summer low flow conditions modeled in the FRIP. Each of these loading sources is briefly described below.

4.2.1 Upstream TP Load

Data from Burton's Bridge show that the average annual TP concentration at the upstream boundary of the FRIP is 0.118 mg/l. Using this value along with a long-term average annual flow (calculated by the Illinois Streamflow Assessment Model, ILSAM at Burton's Bridge), an average annual load of 201,000 lb/yr was estimated.

4.2.2 MS4 Non-Point Source TP Load

MS4 jurisdictions contribute phosphorus loading to the Fox River during wet weather events. While this wet weather runoff does not occur during the critical summer low flow conditions evaluated for the FRIP, some of the wet weather phosphorus load from MS4s accumulates in river sediments and can contribute to dissolved oxygen conditions and algal growth during dry weather, low flow periods (see Section 2.5). This is an indirect effect, but can be significant and should be taken into account when evaluating total phosphorus load reductions. In addition, these wet weather loads from MS4 jurisdictions can contribute to other adverse water quality conditions in the Fox River and its tributaries during wet weather events, although these are not the subject of the FRIP. In general, however, it is desirable to reduce non-point source loading of phosphorus from MS4 jurisdictions where feasible.

Although the Fox River HSPF models were not developed specifically to isolate loads from MS4 jurisdictions, a methodology was created during development of the FRIP to estimate phosphorus loading on an MS4 jurisdiction basis using output from the HSPF models. First, the land use/land cover distribution within each MS4 jurisdiction was identified using spatial data in GIS. Then long-term average (1991-2011) UALs generated by the HSPF model, which are specific to land use/land cover categories in each tributary HSPF model, were applied to each MS4 jurisdiction, which allowed the calculation of total load from the MS4.

Using this methodology, annual average TP loads were estimated based on the HSPF model output. These TP loads represent annual average loads for the 1991-2011 model simulation period under current (2009) land use/land cover conditions. Estimates were also made for future (2040) land use/land cover conditions, as described in Section 4.2.5. It should be noted that, in estimated loads from MS4 jurisdictions and agricultural areas (see Section 4.2.2), landside loads from HSPF were used, meaning total phosphorus loads from the land to the tributaries, as opposed to loads from the tributaries to the Fox River main stem. It was necessary to use the landside loads delivered to the tributaries rather than the tributary loads delivered to the Fox River main stem in this process. It is not possible to attribute total phosphorus loads delivered to the Fox River main stem to MS4 jurisdictions using HSPF tributary loads, because there is no accurate way to track tributary loads back to the specific land segment categories (i.e., unique land cover, soils, and slope combinations) used in the HSPF model.

Using the approach described above, which relies on output from the Fox River HSPF watershed models developed by the ISWS, non-point source runoff from MS4 jurisdictions in the FRIP study area contributes approximately 141,000 pounds of phosphorus per year to the Fox River, on average. It should be noted that, because MS4 jurisdictions include all land use/land cover types, this loading estimate will likely differ from estimates based solely on land use/land cover types. For example, a load estimate for “urban areas” may be limited to loading from urban high density, urban low-medium density and urban open space categories, but as described in Section 2.2, current land use/land cover data for the FRIP study area shows that these categories would only account for 62.7% of the area in MS4 jurisdictions. Also, these land use/land cover types will occur outside of MS4 jurisdictions.

4.2.3 Agricultural Non-Point Source TP Load

As with MS4 jurisdictions, agricultural areas in the FRIP study area contribute phosphorus loading to the Fox River during wet weather events. More than 70% of the agricultural areas in the FRIP study area are classified as cropland according to spatial data from the 2009 Cropland Data Layer (CDL) from U.S. Department of Agriculture National Agricultural Statistics Service. The Illinois Nutrient Loss Reduction Strategy states that 48% of the TP exported from the State via rivers is attributable to agricultural sources, which underscores the importance of controlling phosphorus loading from these areas.

As stated above, this wet weather runoff does not occur during the critical summer low flow conditions evaluated for the FRIP, but the wet weather phosphorus load from agricultural areas can accumulate in river sediments and can contribute to dissolved oxygen conditions and algal growth during dry weather. In addition, these wet weather loads from agricultural areas can contribute to other adverse water quality conditions in the Fox River and its tributaries during wet weather events, although these are not the subject of the FRIP. Therefore, it is desirable to reduce non-point source loading of phosphorus from agricultural areas where feasible.

Based on output from the HSPF watershed models developed by the ISWS for the Fox River watershed, and using the approach described in the preceding section, non-point source runoff from agricultural areas outside of MS4 jurisdictions in the FRIP study area contribute approximately 360,000 pounds of phosphorus per year to the Fox River, on average. As with the average annual loading estimate for MS4 jurisdictions, this estimate will differ from estimates solely based on land use/land cover, due to the fact that this estimate includes loading from urban land use/land cover categories as well as cropland.

4.2.4 Municipal WWTP Loads

In developing the HSPF watershed models for the Fox River watershed, the ISWS compiled data on WWTP flows and effluent quality from WWTPs in the FRIP study area. Based on this data compilation, WWTP effluent flows and TP concentrations were extracted to support calculation of average annual loading. The HSPF models were developed with hydrologic data for the period of 1991 through 2011, so one alternative was to calculate an annual average TP load based on that period. However, WWTP flows are influenced by population growth and the annual average for 1991 through 2011 might underestimate the current annual average load. For this reason, the period of 2003-2011 was selected as being recent enough to reflect current conditions but long enough to capture potential year-to-year variability in the average. The average annual load calculated for this period is 600,000 pounds per year.

4.2.5 Phosphorus Loads from Stream Erosion

Erosion of stream banks and beds is a known problem in Illinois and one that can be a significant source of phosphorus load to receiving waters. It is a significant component of nutrient load reduction initiatives elsewhere. The extent of stream erosion in the FRIP study area has not been studied and the HSPF watershed models are not designed to simulate stream erosion, nor is there any model output explicitly related to stream erosion. However, because it may be a significant source of phosphorus to the Fox River, it should be maintained as a potential action to address phosphorus loading.

4.2.6 Estimates of Future Loads

As part of the FRIP development, it is of interest to understand how the TP loading described in the preceding sections will change in the future as a result of changes in land use and land cover. No estimates of future land use/land cover were available for the FRIP study area prior to development of the FRIP, so estimates were developed based on population growth estimates developed by the Chicago Metropolitan Agency for Planning (CMAP) for the year 2040. The forecast was part of CMAP's "GO TO 2040 Comprehensive Regional Plan", which was adopted in October 2010. LimnoTech obtained GIS data from CMAP depicting the future population projections and Figures 4-4 and 4-5 show the coverage of these population projections. From 2010 to 2040, CMAP projects a population increase of 480,000 people within the FRIP study area, which represents an increase of 46%.

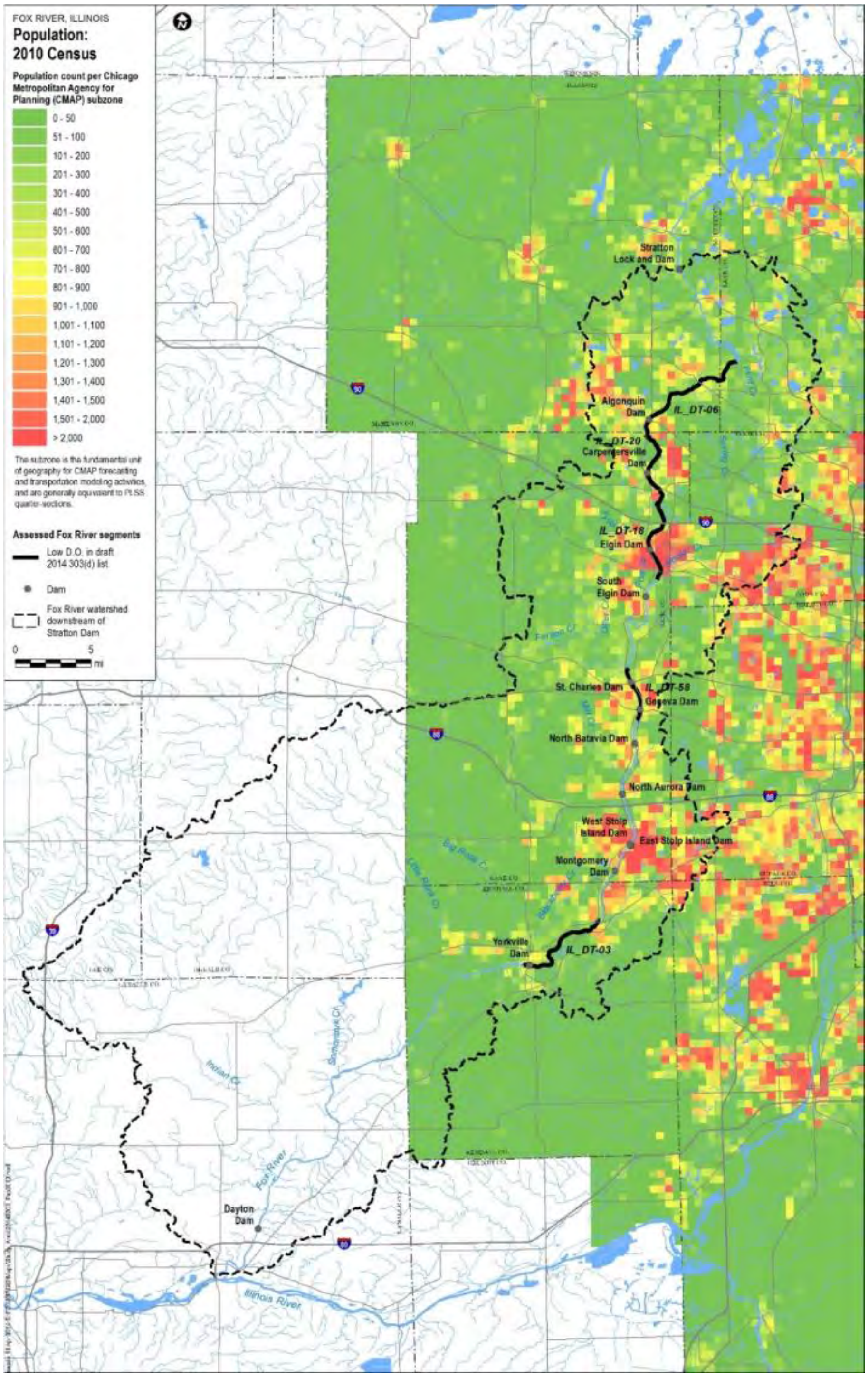


Figure 4-4: Current (2010) Population Density Estimates (per subzone) from CMAP.

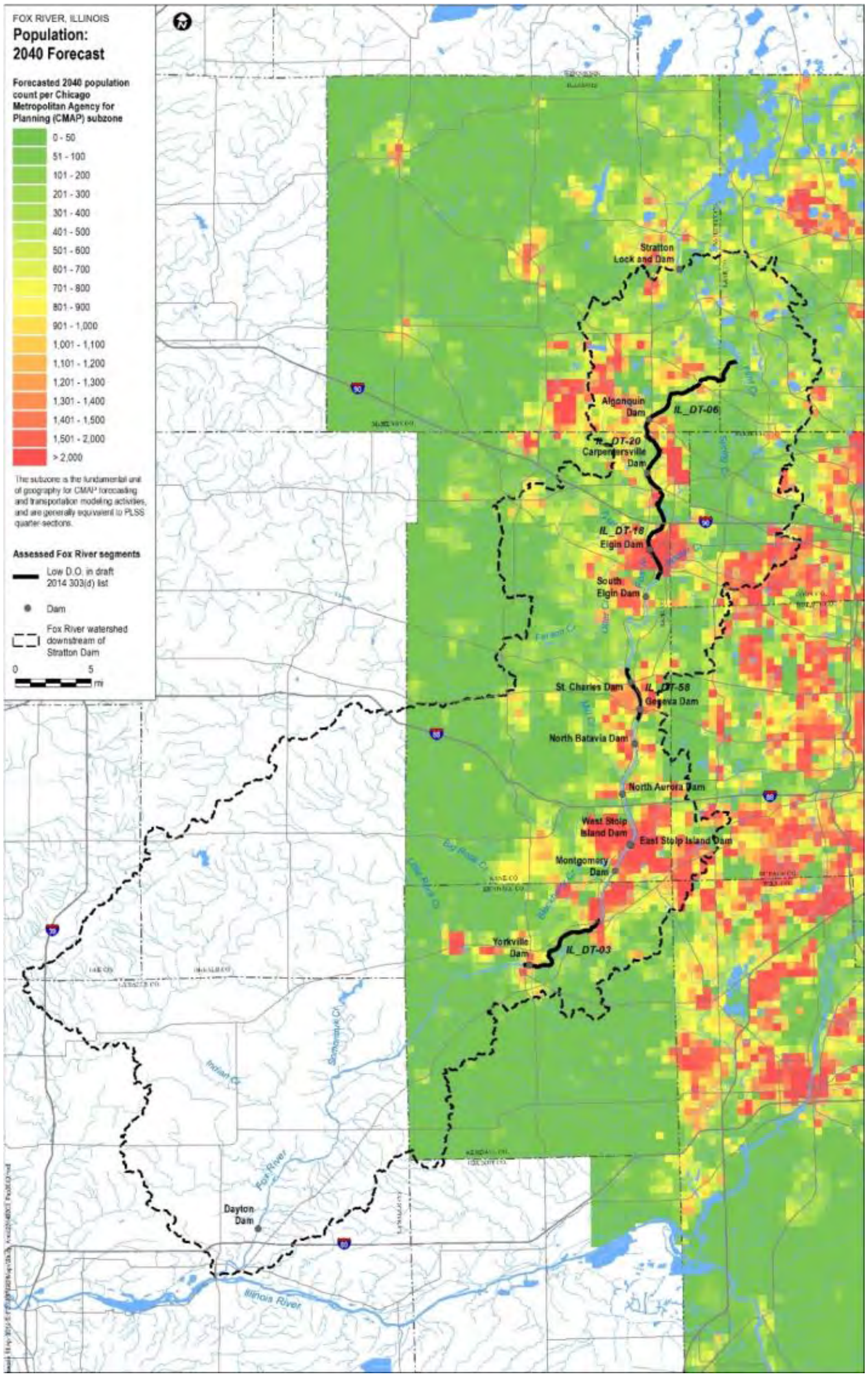


Figure 4-5: Future (2040) Population Density Estimates (per subzone) from CMAP.

These population growth estimates have been produced for most, but not all of the Fox River watershed, because the southern and southwestern parts of the Fox River watershed are outside of the CMAP area. No population forecasts or land cover change predictions were identified for the part of the FRIP study area outside of the CMAP planning area.

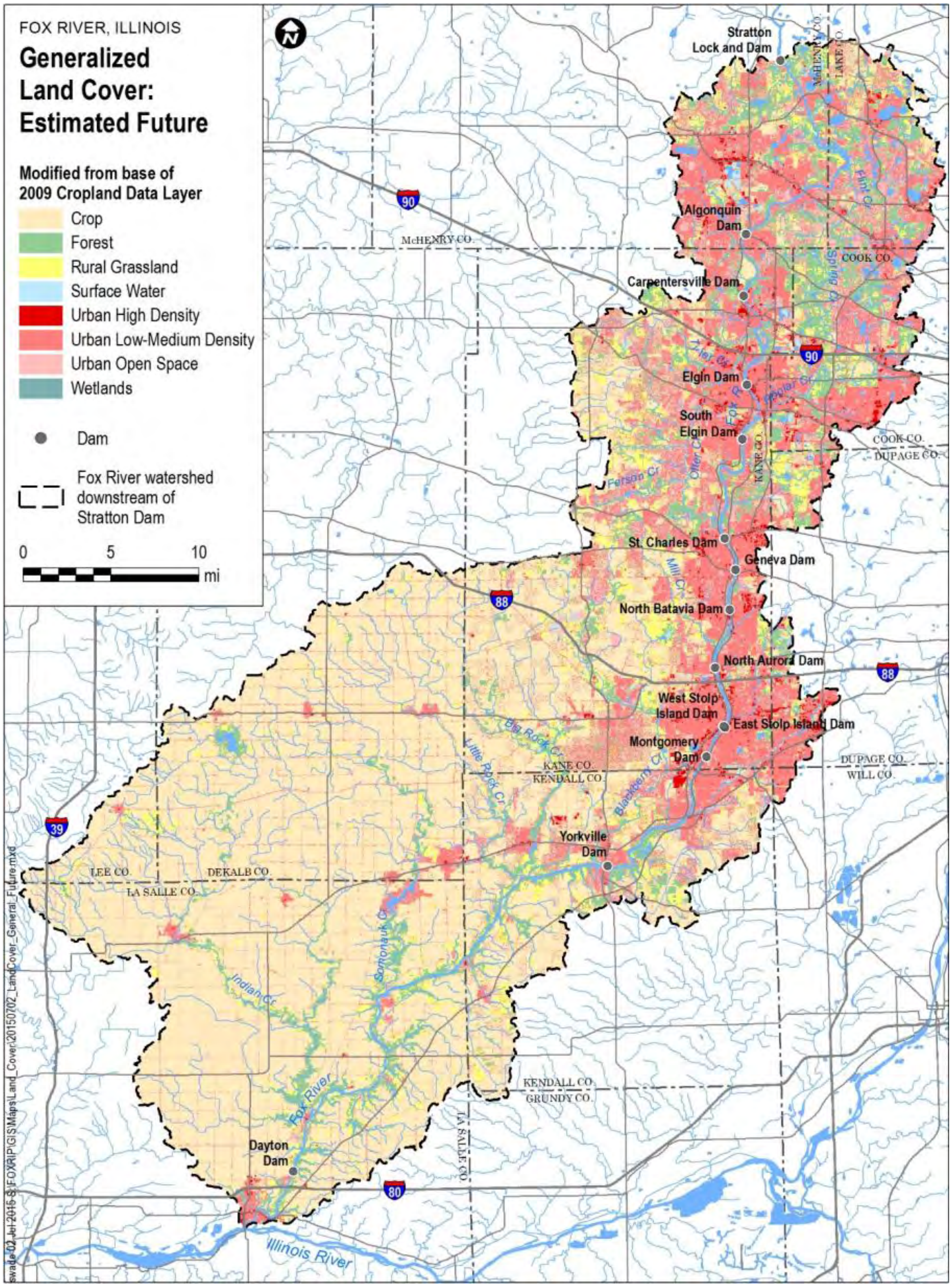


Figure 4-6: Estimated Future (2040) Land Cover for the FRIP Study Area.

The change in population estimated by CMAP from 2010 to 2040 was compared to current (2009) land cover in GIS. Wherever population increase was predicted by CMAP and the current (2009) land cover is classified as cropland or rural grassland, the land cover was converted to urban low-medium density development. In currently developed areas where population change is predicted, no land cover change was made from 2009 to 2040. The resulting land cover projection is shown in Figure 4-6.

The estimated future land cover developed in this process was then used with the Fox River HSPF models to generate estimates of future TP loading from non-point sources. The future-condition HSPF models were run for the same hydrologic periods (1991-2011) as the existing-condition models developed by ISWS. This period likely represents an adequate range of precipitation conditions, although it does not account for potential changes due to climate change. However, running the models with the same precipitation has the advantage of isolating the effects of land use change on TP loading. Model estimates of current and future non-point source TP loading are presented in Table 4-1.

Table 4-1: Estimated Annual Average Non-Point Source TP Loads to the Fox River, Under Current Conditions and Under Future Growth Conditions (assuming no action)

TP Load Source[15]	Average Annual TP Load Under Current Conditions (lbs/yr)	Average Annual TP Load Under Future Conditions (lbs/yr)	Percent Change
MS4 jurisdictions	141,000	138,000	-2%
Agricultural areas	349,000	346,000	-0.8%
Total	490,000	484,000	-1.2%

Slight overall decreases in TP loading are predicted because the land use changes result in the conversion of cropland to developed land, due to changes in modeled UALs; the average TP UAL for cropland, based on HSPF model output, is 0.735 lbs/acre/yr, compared with an average TP UAL of 0.468 lbs/acre/yr for low-medium density urban land.

The projected change in WWTP loading can also be estimated using the projected increase in population, assuming that WWTP effluent flows increase linearly with population. Under that assumption, a 46% increase in population will cause a 46% increase in WWTP flows and, if no treatment changes occur, a 46% increase in TP loading will occur. Based on this approach, the estimated 2040 WWTP TP loading to the Fox River will be 876,000 lbs/yr.

4.2.7 Phosphorus Load Summary

Using the TP loading estimates presented in the preceding sections, the overall distribution of average annual external TP loading to the Fox River can be compiled as shown in Table 4-2 and Figures 4-7 and 4-8.

---

[15] Note: The loads attributed to MS4 jurisdictions include loads from all land use categories contained within the jurisdictional limits of municipal MS4s. Similarly, loads attributed to agricultural areas, although predominantly from croplands, include loads from all land use categories in rural areas.

Table 4-2: Estimated Annual Average External TP Loads to the Fox River, Under Current Conditions and Under Future Growth Conditions (assuming no action)

TP Load Source	Average Annual TP Load Under Current Conditions (lbs/yr)	Percent of Total Load	Average Annual TP Load Under Future Conditions (lbs/yr)	Percent of Total Load
Upstream boundary	201,000	15.6%	201,000	12.9%
MS4 jurisdictions	141,000	10.9%	138,000	9%
Agricultural areas	349,000	27%	346,000	22.2%
WWTPs	600,000	46.5%	876,000	56.1%
Total	1,291,000		1,561,000	

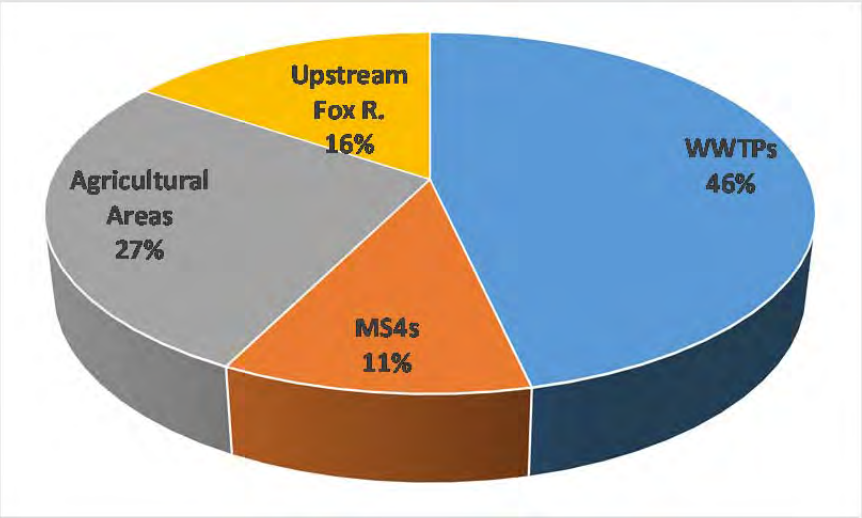


Figure 4-7: Distribution of Annual Average TP Load by Source – Current Conditions (1,291,000 lbs/yr).

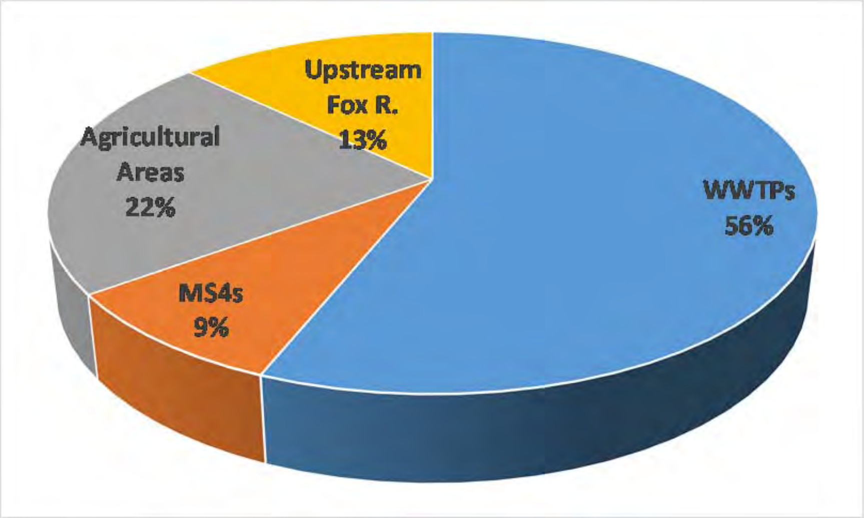


Figure 4-8: Distribution of Annual Average TP Load by Source – Future Conditions with No Load Reduction Implemented (1,561,000 lbs/yr). NOTE: this does not include reductions in WWTP loads already required for future implementation in current NPDES permits.

4.3 Dams and Water Quality

Dams can have a significant impact on the dissolved oxygen conditions in a river due to their disruption of the river's natural hydraulics. Sediment and nutrients are trapped in the reservoirs formed behind dams. Algae proliferate in the stagnant nutrient-rich waters in warm weather, producing large amounts of oxygen in the surface waters during photosynthesis. Reservoir waters then become laden with algae, depleted of nutrients, and relatively high dissolved oxygen concentrations prevail. At night, oxygen is depleted in the reservoir during respiration by algae and decay of dying algae that have settled to the bottom of the reservoir.

As described in Section 2.4, the ecological effects of low-head dams in the Fox River was studied by Santucci and Gephard (2003) in July to September 2000 at 40 locations along the river. Dams were found to impact water quality in several ways (Santucci and Gephard 2003; Santucci 2005):

- The magnitude of daily oxygen fluctuations was higher in impounded reaches;
- Dissolved oxygen (DO) and pH concentrations failed to meet water quality standards in impounded areas at eight out of eleven stations, with periods of more than 15 hours of noncompliance in 24-hours during low flow and warm water temperature conditions. In contrast, DO and pH in free flowing reaches failed to meet standards at only two stations (for a maximum duration of 1.75 hours) and one station, respectively; and,
- Dams were found to oxygenate the river at night but cause release of oxygen to the atmosphere during the day. Overall, a net loss of oxygen in the river was found to occur during a 24-hour period. Surplus oxygen produced by algal photosynthesis during the day was lost as water flowed over dams, causing the oxygen surplus to be unavailable to respiring algae at night.

Santucci et al. (2005) outlines several options for removal of dams and reconnection of the river:

- Removing dams completely
- Building rocky ramps at dams
- Constructing traditional fishways
- Constructing more natural fish and canoe bypass channels

Dam removal is considered by Santucci et al. (2005) to be the most preferable option for improving the overall ecological health of the river (as well as cost); while the options that only improve fish migration do not address the negative water quality and habitat impacts of impounded river water.

5

Evaluation of Water Quality Improvement Alternatives

As discussed in Section 1, the focus of the FRIP is the reduction of phosphorus loading to improve dissolved oxygen in the Fox River and reduce nuisance algae. In addition, the potential effects of dam removal on these water quality parameters were considered in developing the FRIP. The phosphorus load reduction and dam removal scenarios modeled in the process of developing the FRIP will be described in this section.

The Fox River QUAL2K water quality model is the primary tool used in development of the FRIP to evaluate alternatives for water quality improvement. As discussed in Section 3.2.3, the model has some important limitations that bear repeating here and that are important to keep in mind when reviewing the model results presented in the FRIP:

- Model calibration results for DO show that the model significantly over-predicts minimum DO and under-predicts maximum DO in many locations and this model limitation should be taken into account when reviewing all model results for dissolved oxygen.
- The model results show good agreement with calibration data for total phosphorus and algae in the water column, therefore there is greater confidence in the model for these parameters.

As a consequence of the first bullet above, the actual minimum DO for a given load reduction scenario presented in this section may be significantly lower than the minimum DO predicted by the model. Because the model calibration for total phosphorus and algae was much better than for DO, this concern does not apply to model results for these parameters.

5.1 Summer Critical Season Baseline Scenario

For purposes of evaluating the effect of potential actions on Fox River water quality using the QUAL2K model, a baseline scenario was developed to represent worst-case summer conditions. These conditions include the longest day (maximum daylight), warm water temperatures and the 7Q10 flow, which is the statistical low flow used by regulatory agencies to evaluate attainment of water quality standards. It should be noted that this summer critical season baseline represents a rare combination of factors that exacerbate dissolved oxygen depletion and algal growth in the river. In addition to the summer critical season baseline scenario, monthly scenarios were developed with the model, as discussed in Section 5.2.

5.1.1 Summer Critical Season Baseline Upstream Conditions

The upstream flow for the summer critical baseline scenario is the 7Q10 value for flow (92.98 cfs), extracted from the Illinois Streamflow Assessment Model and consistent with previous modeling performed by the ISWS (Bartosova, 2013b). Total phosphorus, chlorophyll *a*, dissolved oxygen and other water quality parameters needed for the QUAL2K model were median values calculated from data for

Burton's Bridge obtained from the ISWS Fox River database. These key parameter values are summarized in Table 5-1.

Table 5-1: Key Water Quality Parameter Values Used for the Summer Critical Season Upstream Boundary Condition.

Parameter	Value Used in Summer Critical Season Baseline Scenario
Total phosphorus	160 μg/L
Dissolved oxygen	8.78 mg/L
Chlorophyll *a*	43 μg/L

5.1.2 Summer Critical Season Baseline Tributary Conditions

Where available, 7Q10 flow values were used for each of the tributaries represented in the QUAL2K model for the summer critical season baseline scenario. Median TP values were calculated from available data for key water quality parameters. For other parameters and for tributaries where no data were available, the values used in the calibration scenario were retained. Table 5-2 summarizes tributary input values for the baseline scenario.

Table 5-2: Tributary Flow and TP Values for the Summer Critical Season Baseline Scenario.

Tributary	Flow (MGD)	Total Phosphorus (mg/l)
Big Rock Creek	9.05	0.08
Blackberry Creek	1.68	0.14
Brewster Creek	0.97	0.09
Brumbach Creek	0.00	0.08
Buck Creek	0.26	0.08
Clear Creek	0.03	0.08
Cotton Creek	0.32	0.09
Creek below Silver Lake outlet	0.10	0.09
Crystal Lake outlet	0.19	0.16
Ferson Creek	0.39	0.11
Flint Creek	0.71	0.78
Hollenbach Creek	0.08	0.08
Indian Creek Aurora	0.14	0.04
Indian Creek south	1.36	0.08
Jelkes Creek	0.06	0.09
Little Rock Creek	2.39	0.18
Mill Creek	0.13	0.23
Mission Creek	0.00	0.08
Morgan Creek	0.19	0.09
Norton Creek	0.78	0.09
Poplar Creek	1.23	0.05
Rob Roy Creek	1.03	0.09
Roods Creek	0.10	0.08
Silver Lake outlet	0.03	0.05
Sleepy Hollow Creek	1.68	0.16
Somonauk Creek	0.26	0.08
Spring Creek	1.10	0.09
Tower Lake outlet	0.09	0.09
Tyler Creek	0.45	0.11
Waubonsie Creek	0.52	0.09

5.1.3 Summer Critical Season Baseline WWTP Conditions

There are 14 WWTPs represented in the Fox River QUAL2K model. WWTP flows in the summer critical season baseline scenario were set at the design average flow (DAF) for each facility. Although most of the

WWTPs do not normally operate at their DAF, especially under low flow, dry weather conditions, these are the effluent flow values typically used by regulatory agencies in developing permits, so they were used for this baseline scenario. Median concentrations for TP and other effluent quality parameters were calculated from summer effluent data for each plant, where available. Where data were not available, values from the ISWS baseline model were used. Table 5-3 summarizes the flow and TP values used for each WWTP in the baseline scenario.

Table 5-3: Major WWTP Flow and Total Phosphorus Values for the Summer Critical Season Baseline Scenario.

WWTP	Flow (MGD)	Total Phosphorus (mg/l)	Total Phosphorus Based on Data or Estimated
Algonquin	5.0	0.58	Data
Batavia	4.2	4.93	Data
Carpentersville	4.5	2.32	Data
Cary	2.8	3.96	Data
East Dundee	2.3	0.34	Data
Fox River Grove	1.2	5.50	Data
Fox Metro	42.0	3.37	Data
FRWRD--North	7.7	2.22	Data
FRWRD--South	25.0	3.26	Data
FRWRD--West	5.0	2.14	Data
Geneva	5.0	1.25	Data
Northern Moraine WW Rec. Dist.	2.0	5.5	Estimated
St. Charles	9.0	4.34	Data
Wauconda	1.9	1.00	Estimated
Yorkville-Bristol Sanitary District	3.62	2.36	Data

5.1.4 Summer Critical Season Baseline Model Results

Once all inputs were determined, the summer critical season baseline QUAL2K model was run. The results for total phosphorus, minimum dissolved oxygen and algae are shown graphically in Figures 5-1 through 5-3, respectively.

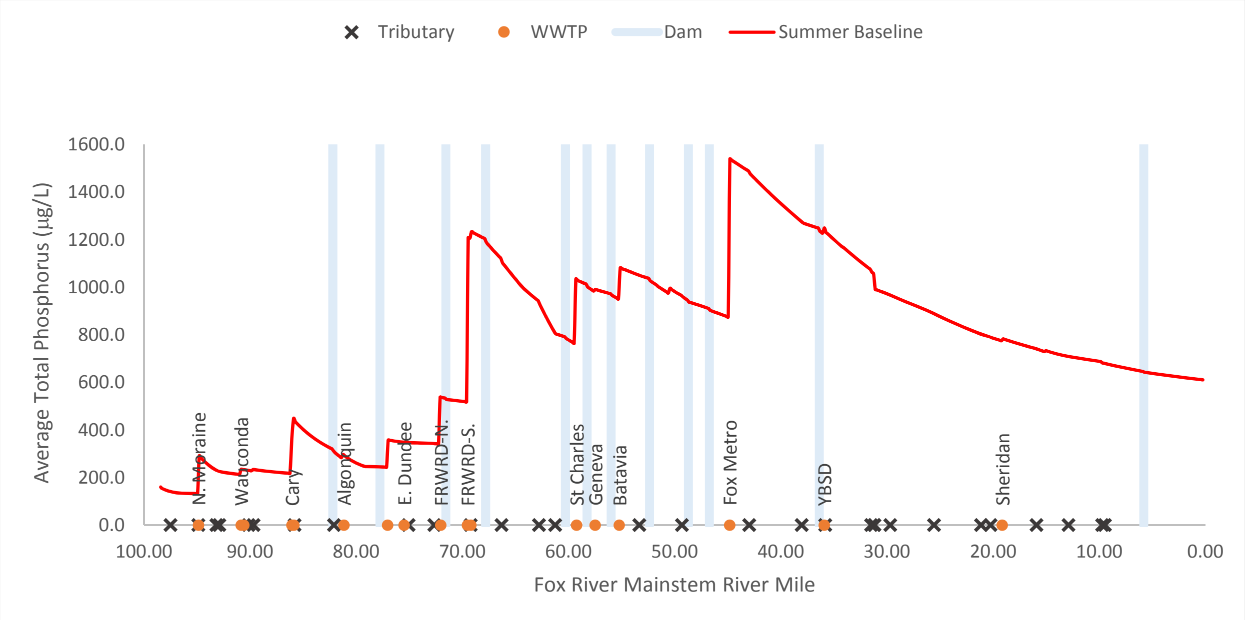
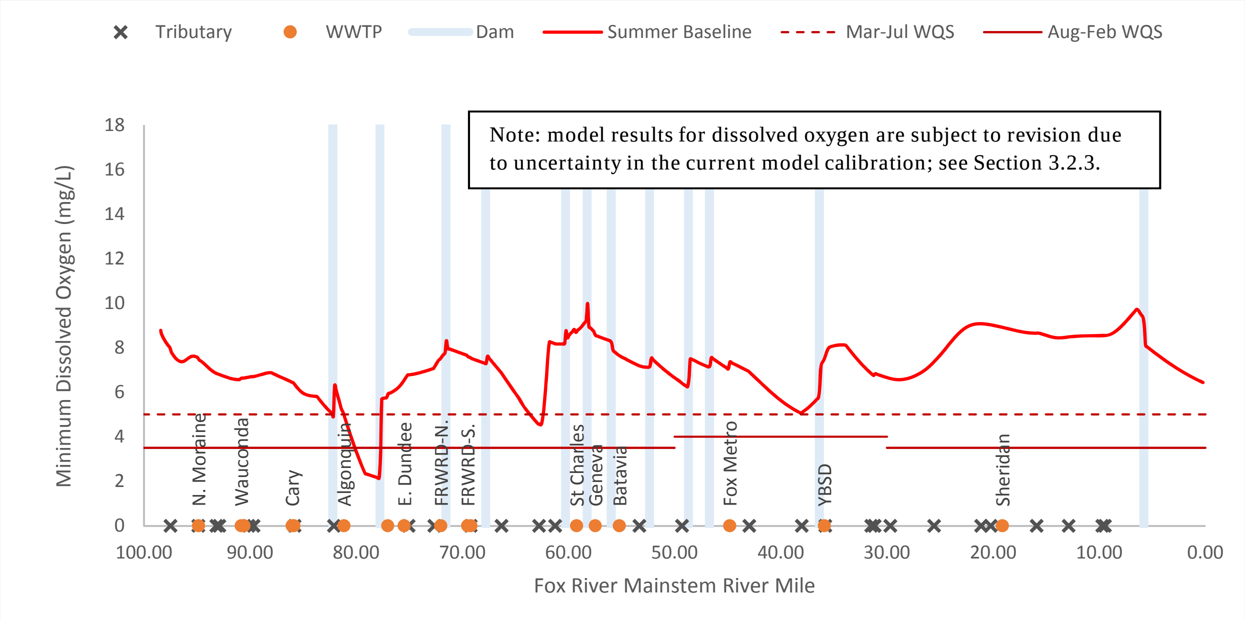


Figure 5-1: QUAL2K Summer Critical Season Baseline Results for Total Phosphorus



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-2: QUAL2K Summer Critical Season Baseline Results for Minimum Dissolved Oxygen

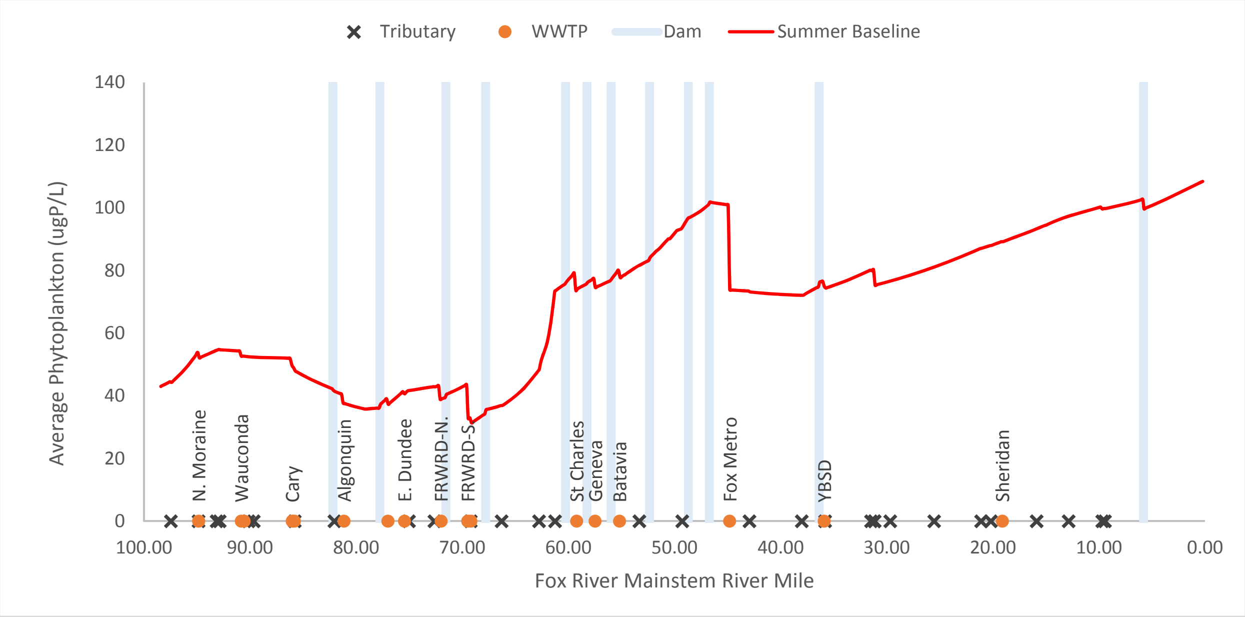


Figure 5-3: QUAL2K Summer Critical Season Baseline Results for Average Phytoplankton

This scenario represents the current, worst-case scenario of summer low flow, warm temperatures and long days. Because the Illinois water quality standard for dissolved oxygen changes mid-summer (i.e., different numeric criteria apply in June and July than apply in August and September), both criteria are depicted in Figure 5-2. From this plot, three pronounced dips are apparent at three different locations in the river:

- Upstream of the Carpentersville Dam (~river mile 78)
- Upstream of the St. Charles Dam (~river mile 63)
- Upstream of the Yorkville Dam (~river mile 37)

These locations were key points in the river to look for improvement as different water quality improvement scenarios were modeled, as described later in this section. When viewing the model results for minimum DO, it should be noted, as discussed elsewhere, that the model is known to over-predict minimum DO.

The model results for phytoplankton (Figure 5-3) show that the average algae concentration in the river increases with distance downstream, mainly as a result of increasing phosphorus loads.

5.2 Individual Summer Month Baseline Runs

Because the summer critical season baseline run represents a four-month period with worst-case conditions and two different sets of water quality criteria for DO apply during this four-month period, the four summer months were also modeled separately. For these simulations, inputs were modified as follows:

- The same 7Q10 values as in Summer Critical Season Baseline were used.
- Month-specific median water quality parameters were calculated for the upstream boundary and for each tributary where data were available; otherwise the summer critical season baseline scenario value was used.
- WWTP flows were maintained at DAF, but month-specific effluent quality was calculated where data were available; otherwise the summer critical season baseline scenario value was used.
- Day length was set at the 90th percentile for each month.

- Median monthly air temperature and dew point were calculated from available data for each month.

The results for total phosphorus, minimum dissolved oxygen and algae are shown graphically in Figures 5-4 through 5-6, respectively.

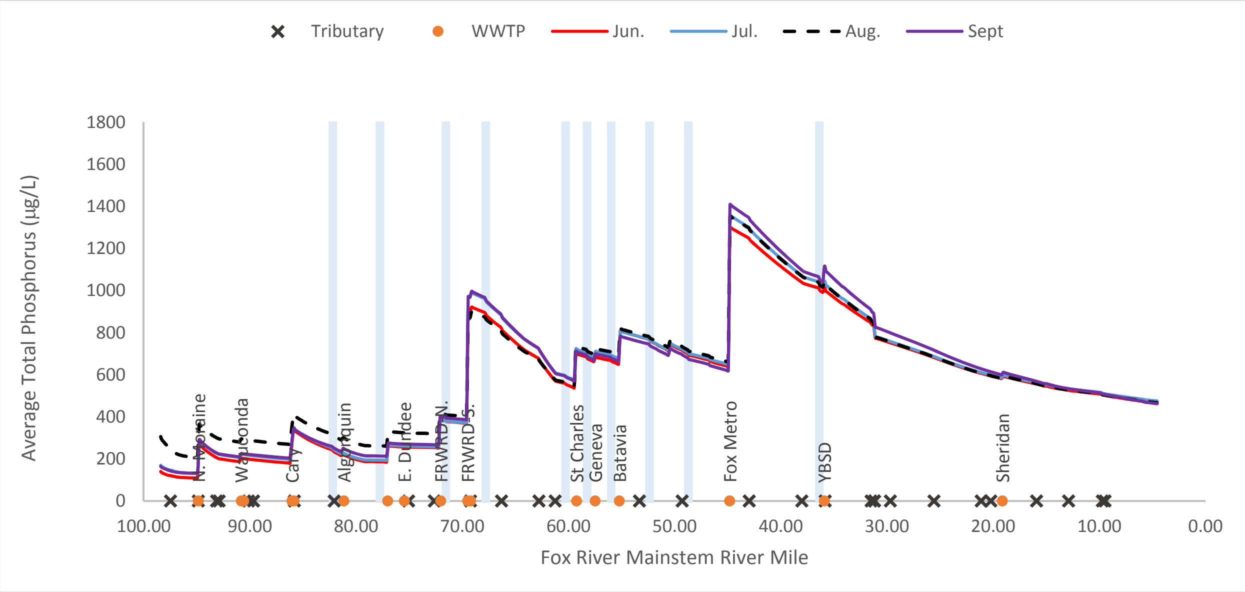
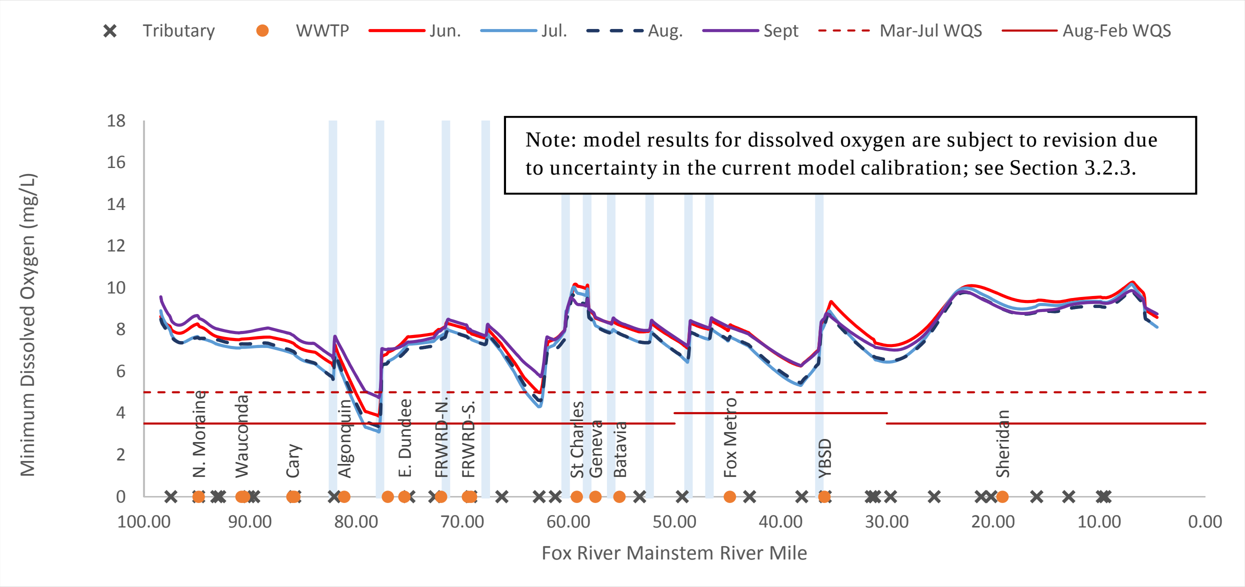


Figure 5-4: QUAL2K Individual Summer Month Results for Total Phosphorus



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-5: QUAL2K Individual Summer Month Results for Minimum Dissolved Oxygen

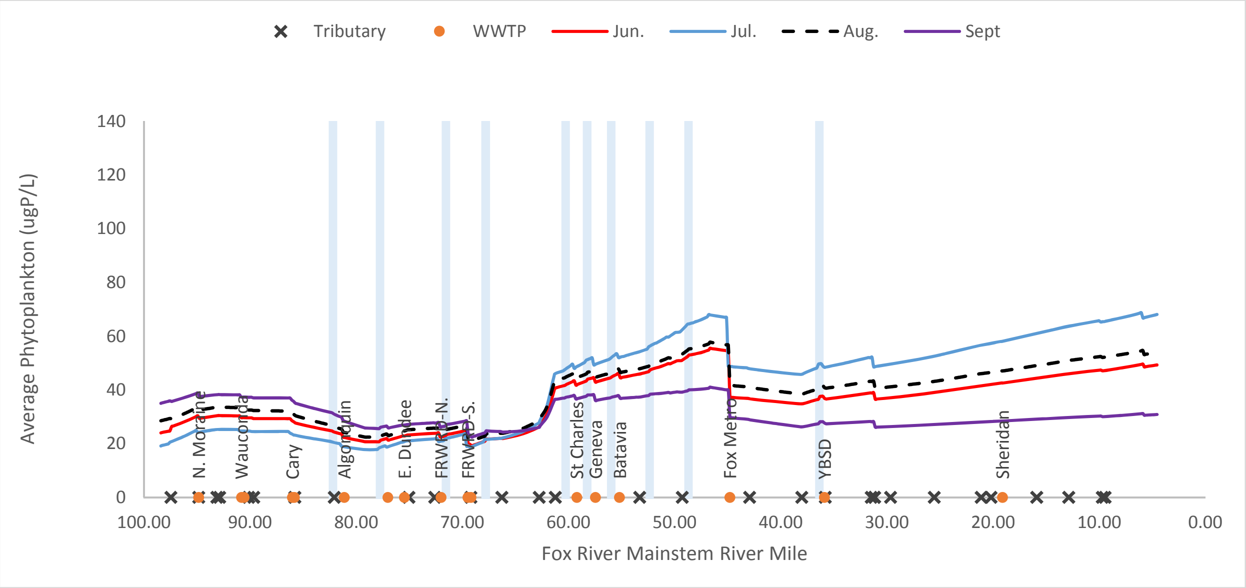


Figure 5-6: QUAL2K Individual Summer Month Results for Average Phytoplankton

The model output for minimum DO reveals that, when the individual summer months are modeled separately, the results are somewhat different than for the critical summer baseline scenario described in Section 5.1:

- The minimum DO value for June dips slightly below the water quality criterion of 5 mg/l just upstream of the Carpentersville Dam.
- In July, the minimum DO is predicted to drop below the DO water quality criterion of 5 mg/l at two locations, upstream of the Carpentersville Dam and upstream of the St. Charles Dam.
- The results for August show minimum DO dropping below the water quality criterion of 3.5 mg/l at only one location, upstream of the Carpentersville Dam.
- In September, minimum DO is predicted to stay above the water quality criterion of 3.5 mg/l at all locations.

These results indicate that June, July and August are the critical summer months for dissolved oxygen, with July and august having the most pronounced excursion below the water quality criteria. The modeled algae concentrations vary slightly more than DO.

- The highest upstream phytoplankton concentrations occur in September and the lowest upstream concentrations occur in July, but these positions are reversed downstream of the South Elgin Dam, with the highest algal growth occurring in July and lowest in September.
- Although the highest upstream phytoplankton concentrations occur in September, the algal concentration remains relatively steady over the length of the river for that month, likely the result of shorter day lengths and cooler temperatures which limit algal growth.

Although the critical season summer baseline results are used for comparison of the various alternatives modeled and discussed later in this section, the final planned actions will be compared to the July and August baselines presented here.

5.3 Non-Summer Baseline Model Results

In addition to the individual summer month scenarios described above, the Fox River QUAL2K model was used to evaluate the potential for dissolved oxygen and nuisance algae to be a problem during non-summer months. Each month was modeled as follows:

- 7Q10 values were calculated for the upstream boundary and for each tributary.
- Month-specific median water quality parameters were calculated for the upstream boundary and for each tributary where data were available; otherwise the summer critical season baseline scenario value was used.
- WWTP flows were maintained at DAF, but month-specific effluent quality was calculated where data were available; otherwise the summer critical season baseline scenario value was used.
- Day length was set at the 90th percentile for each month.

The results for total phosphorus, minimum dissolved oxygen and algae are shown graphically in Figures 5-7 through 5-9, respectively, for the months of October through December and in Figures 5-10 through 5-12, respectively, for the months of January through May.

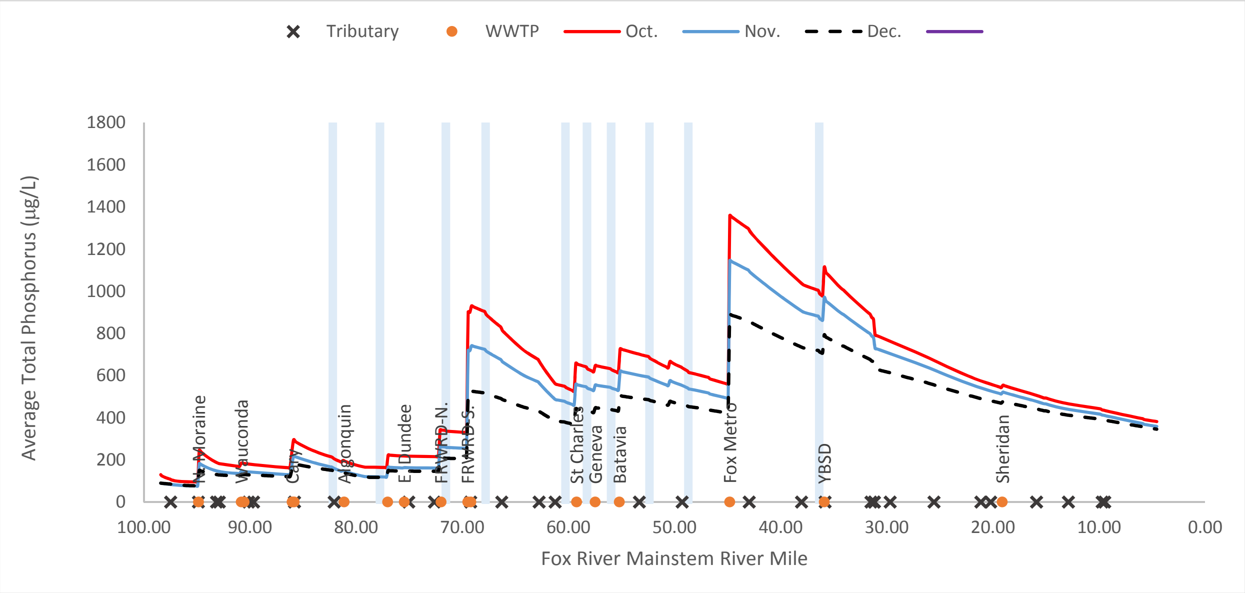
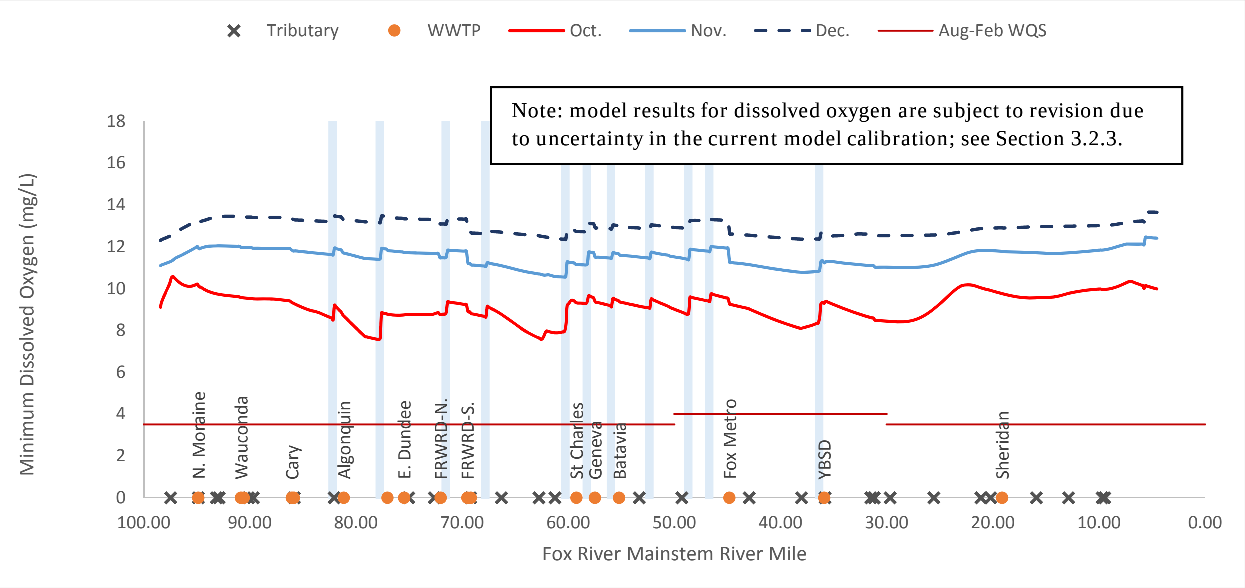


Figure 5-7: QUAL2K Individual Month Results for Total Phosphorus (October – December)



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-8: QUAL2K Individual Summer Month Results for Minimum Dissolved Oxygen (October – December)

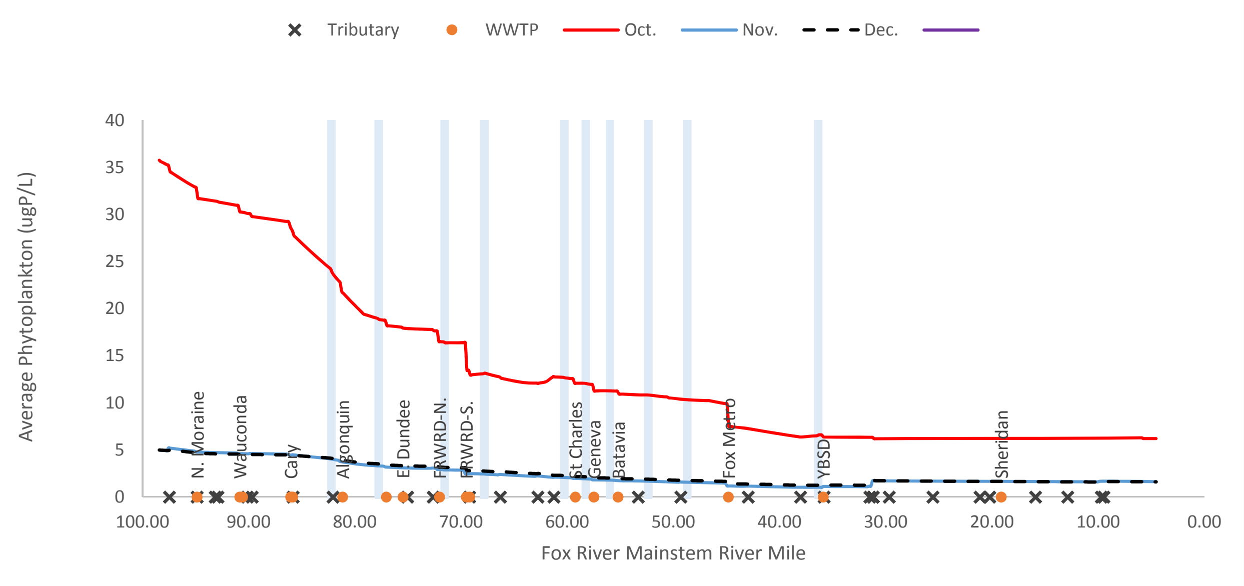


Figure 5-9: QUAL2K Individual Summer Month Results for Average Phytoplankton (October – December)

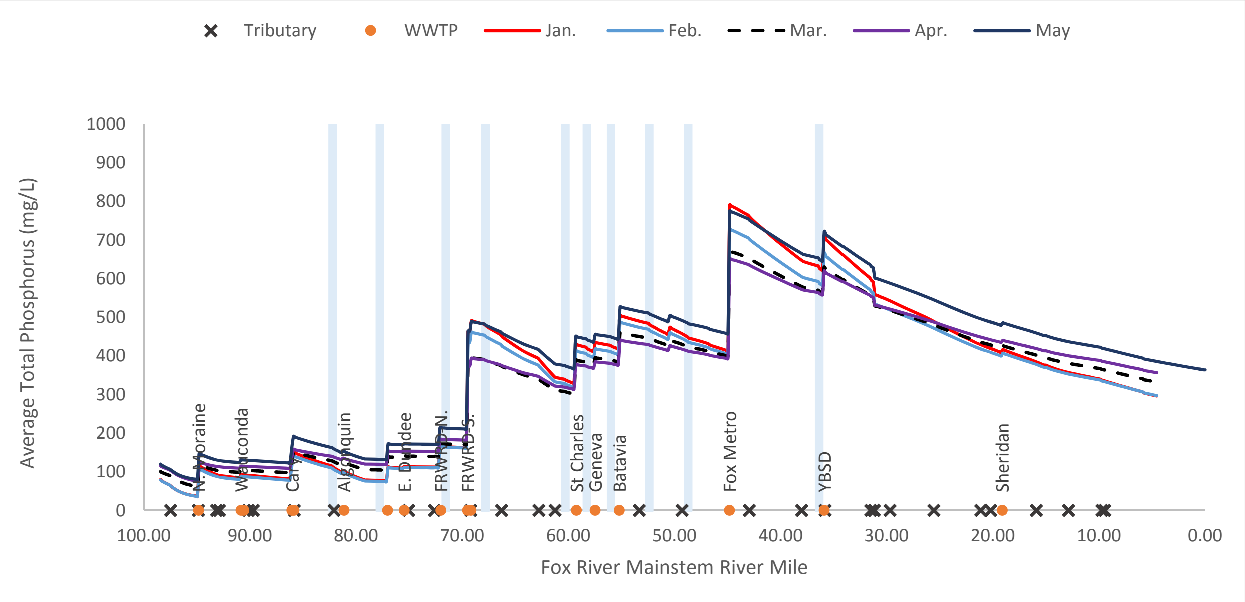
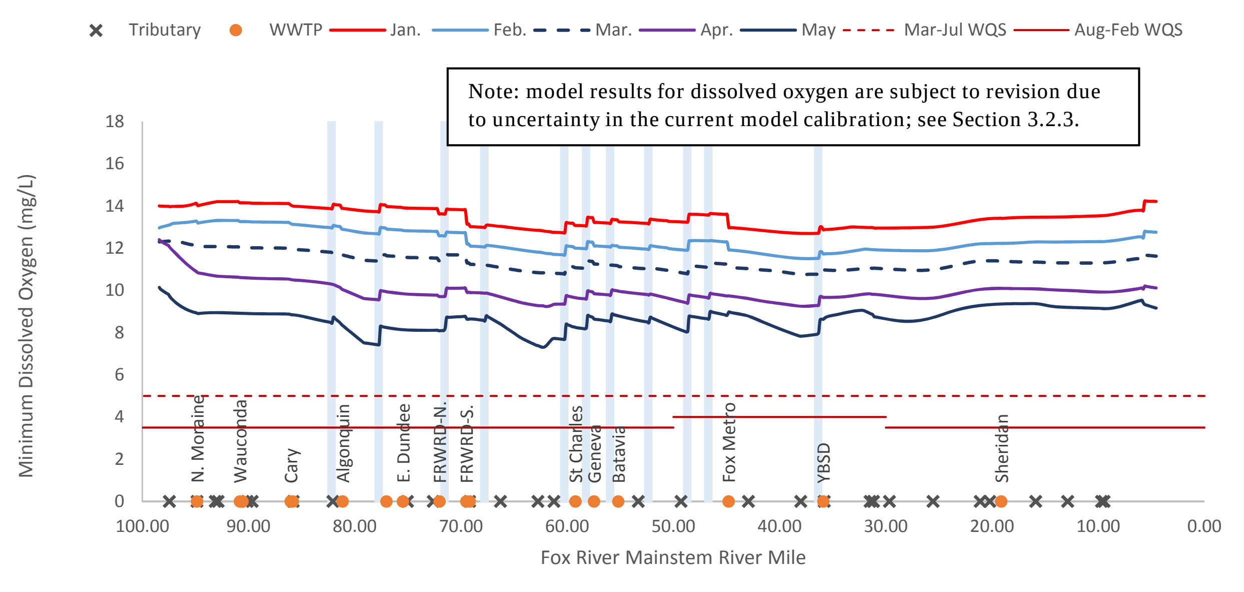


Figure 5-10: QUAL2K Individual Summer Month Results for Total Phosphorus (January – May)



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-11: QUAL2K Individual Summer Month Results for Minimum Dissolved Oxygen (January – May)

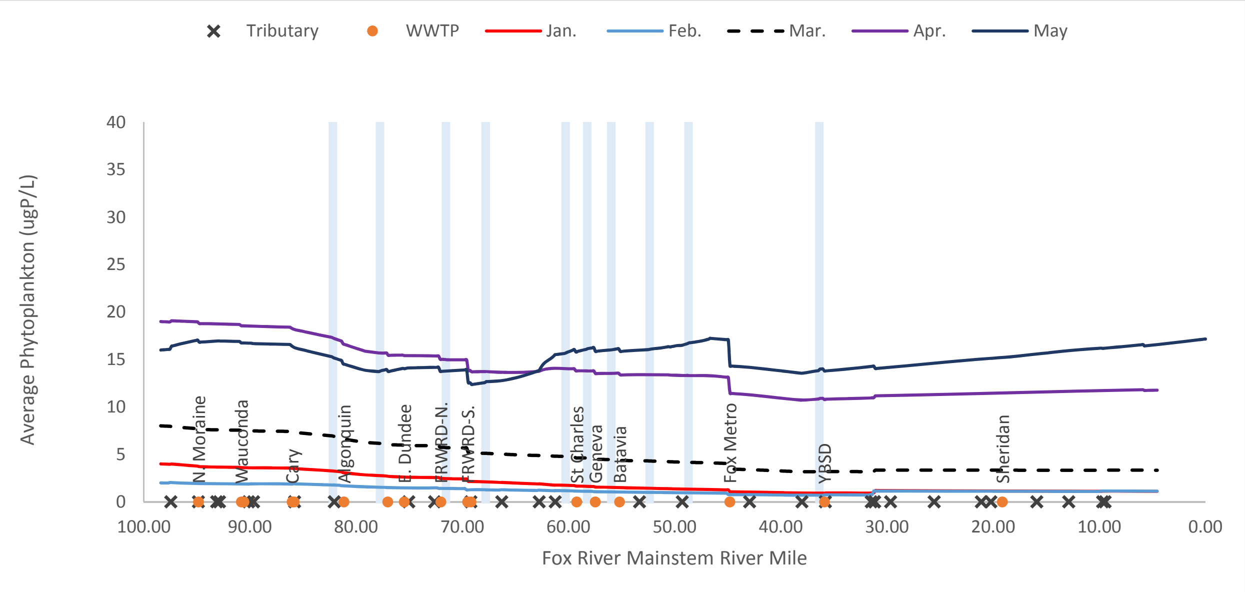


Figure 5-12: QUAL2K Individual Summer Month Results for Average Phytoplankton (January – May)

From these results for the individual non-summer months, the following observations can be made:

- Total phosphorus loading to the river varies only slightly from month to month.
- In spite of continued, relatively high total phosphorus loading to the river during non-summer months, algae in the water column (average phytoplankton) is significantly lower than during summer months. This is due to the reduced amount of sunlight (i.e., shorter day length) and lower temperatures during these months, which inhibit algal growth.
- As a result of the reduced algal growth, minimum dissolved oxygen in the river is relatively high during non-summer months, compared to summer months. Even with the potential for model over-

prediction of minimum dissolved oxygen, these results suggest that dissolved oxygen problems are unlikely to occur during the months of October through March. The model results for April and May show increasing algal levels and declining minimum DO concentrations with predicted values approaching the water quality criterion of 5.0 mg/l. Although the model does not predict minimum DO below the criterion in April and May, the results are close to the criterion and given the potential for the model to be over-predicting minimum DO, the possibility of lower values cannot be ruled out.

As discussed above, caution must be taken when interpreting the minimum DO results from the Fox River QUAL2K model, because it likely over-predicts minimum dissolved oxygen.

5.4 WWTP Load Reduction Effects

As described in Section 1, the IEPA has already started writing a total phosphorus limit of 1.0 mg/l (annual average) into newly issued NPDES permits for major (design average flow > 1.0 MGD) WWTPs. Therefore, it is of interest to observe the predicted effect of this action on water quality in the Fox River. In addition, the IEPA has indicated the potential for lower total phosphorus limits in the future, so scenarios were run using the QUAL2K model wherein the effluent concentration of the major WWTPs was set at 1.0 mg/l, 0.5 mg/l and 0.1 mg/l. The results for total phosphorus, minimum dissolved oxygen and algae are shown graphically in Figures 5-13 through 5-15, respectively.

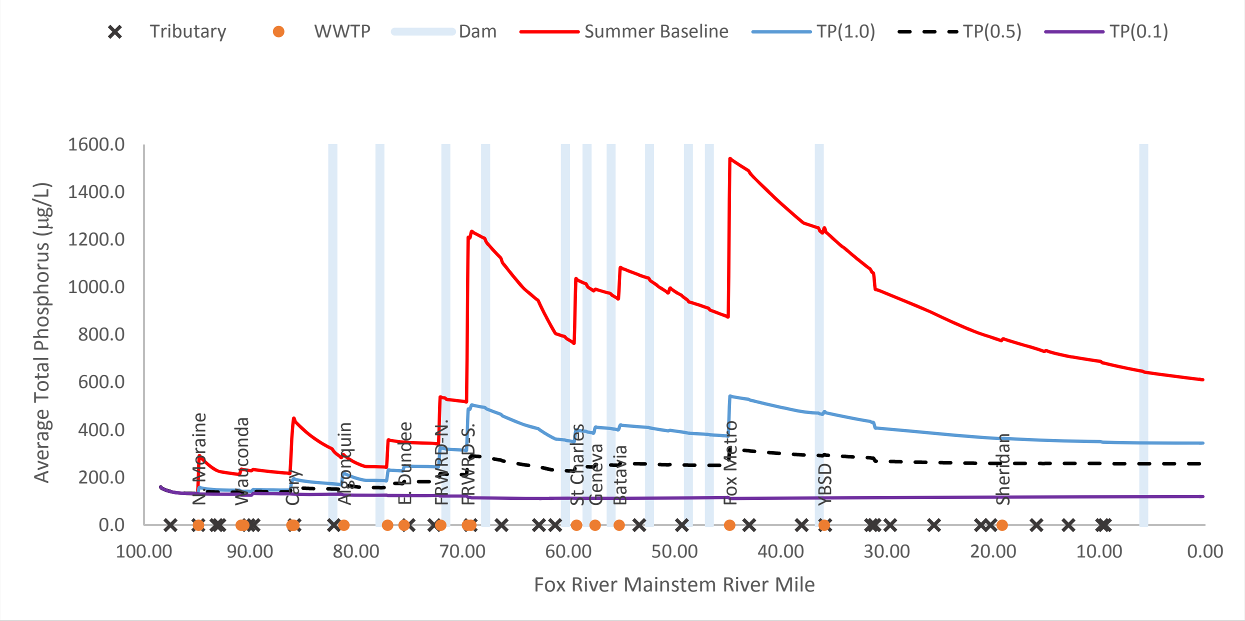
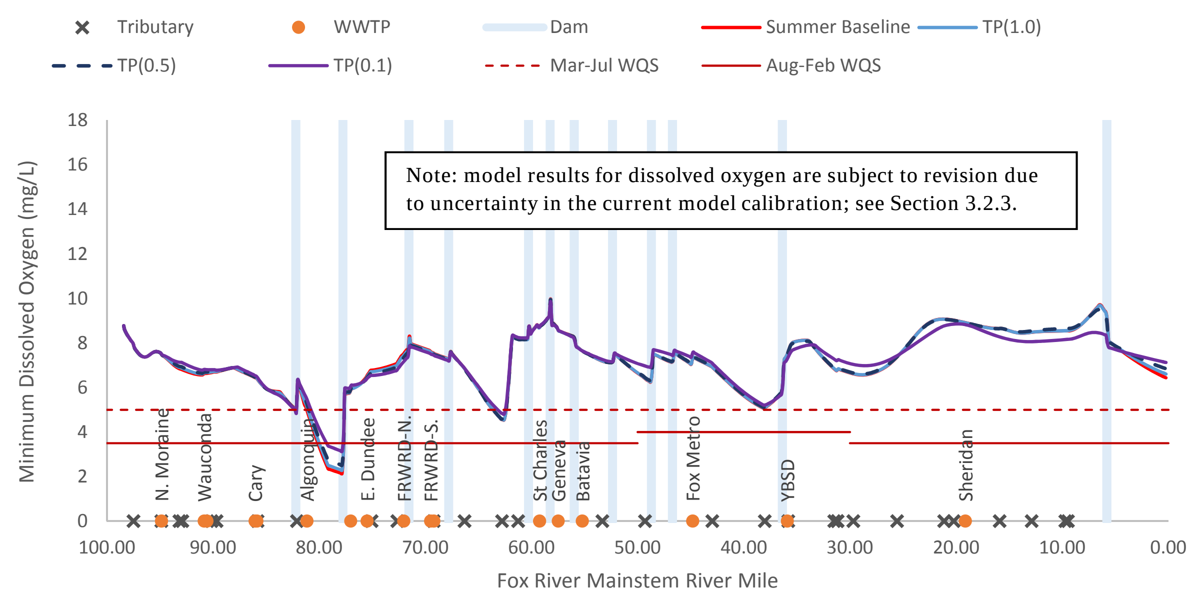


Figure 5-13: QUAL2K Total Phosphorus Results for Reduction of Total Phosphorus from Major WWTPs, Showing Decreases in Total Phosphorus in the River as Phosphorus Loading Decreases.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-14: QUAL2K Minimum Dissolved Oxygen Results for Reduction of Total Phosphorus from Major WWTPs, Showing Little Response in DO to Reduced Phosphorus Loading.

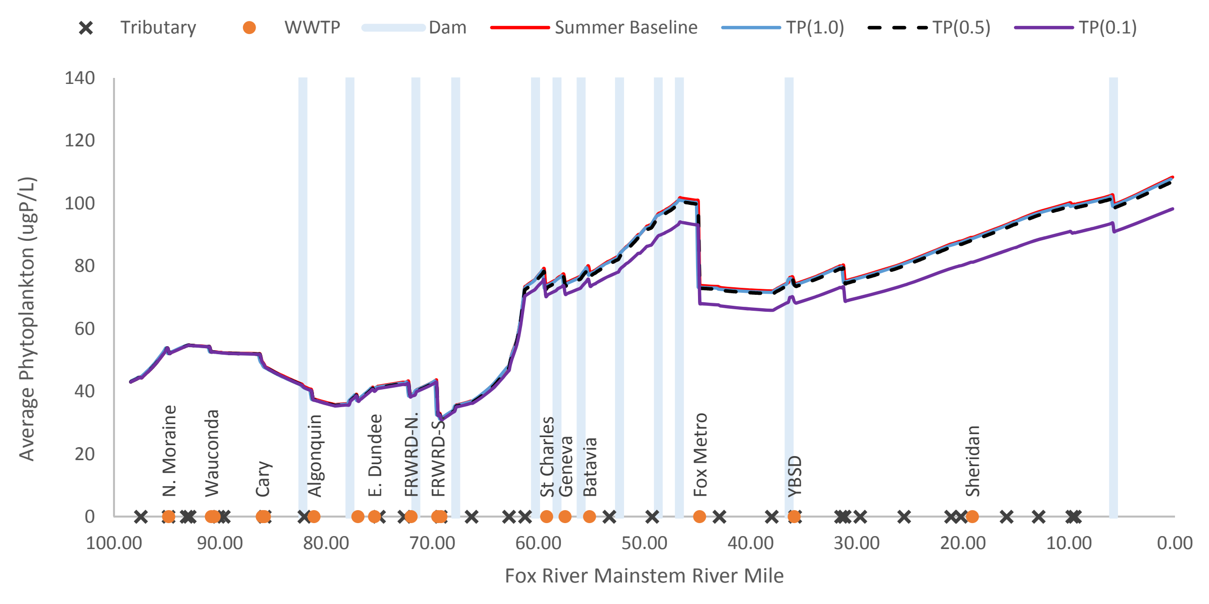


Figure 5-15: QUAL2K Average Phytoplankton Results for Reduction of Total Phosphorus from Major WWTPs.

The following observations are supported by these results:

- As expected, reduction of total phosphorus loading from major WWTPs results in a significant reduction in the total phosphorus load to the river during the summer. Compared to the total load calculated using actual summer average flows (not DAF) and TP concentrations for major WWTPs (based on 2010-2013 data), limiting TP in WWTP effluent to 1.0 mg/l results in approximately a 75% reduction in TP loading during summer months (see Table 5-4). Later in this document, scenarios that combine WWTP load reduction with upstream load reduction will be presented.

Table 5-4: Estimated WWTP Total Phosphorus Load Reduction Based on Actual Summer Average Flows and TP Concentrations for Effluent Limits of 1.0, 0.5 and 0.1 mg/l.

WWTP Effluent Total Phosphorus Limit	Average Summer WWTP Phosphorus Load Reduction Achieved, Compared to 2010-2013 Average Load
1.0 mg/l	75%
0.5 mg/l	87%
0.1 mg/l	97%

- In spite of very large decreases in total phosphorus loading, the model predicts almost no change in dissolved oxygen in the river as a result of reduced total phosphorus in WWTP effluent. This result may be attributable to model limitations, but excessive phosphorus loading from upstream may also be a factor. However, it should be noted that simulations with significant reductions in TP loading from upstream did not result in significant improvement in DO either.
- It is important to recognize that the numerous dams on the Fox River and their impoundments make long reaches of the river behave less like a free-flowing river and more like a sequence of lakes. It is most appropriate to determine target phosphorus levels on a water body specific basis, but USEPA guidance indicates TP concentrations as low as 25 µg/L might be needed "to prevent the development of biological nuisances and to control accelerated or cultural eutrophication" in lakes and reservoirs (USEPA, 1986). Review of literature by the USEPA for purposes of providing guidance to States in the development of nutrient criteria indicates that TP concentrations below 100 µg/L are recommended to "prevent nuisance conditions and water quality degradation in streams" (USEPA, 2000). These different guidance values for phosphorus for lakes and streams illustrate the need to address the impounded nature of the Fox River along with reductions in phosphorus loading.
- Similarly, the model predicts that reductions in TP loading from WWTPs will have little effect on algae. As the model calibration for algae is believed to be sound, this is a significant observation. This is because the levels of total phosphorus reductions achieved through the reduced effluent limits on WWTPs does not reduce TP in the river to the point of limiting algal growth. As discussed above, caution must be taken when interpreting the minimum DO results from the Fox River QUAL2K model, because it over-predicts minimum dissolved oxygen.

It is worth noting that the model predicts minimum DO to dip below the applicable water quality criterion for DO at only one or two locations in the river in June, July and August, and for limited spatial extent (see Section 5.2). Since these limited excursions below water quality criteria are predicted to occur at the 7Q10 low flow, which has an exceedance probability of about 99%, it is worth examining the frequency with which the model predicts these sags will dip below the criteria during July and August. To do this, the July and August baseline scenarios were modeled with gradually increasing upstream flow until the model-predicted minimum DO was above the criteria everywhere. This flow was then plotted against the flow duration curve for the river to obtain an exceedance probability value for that flow condition. This process was repeated for the WWTP effluent limits of 1.0 mg/l, 0.5 mg/l and 0.1 mg/l. The results are plotted in Figures 5-16 and 5-17 for July and August, respectively.

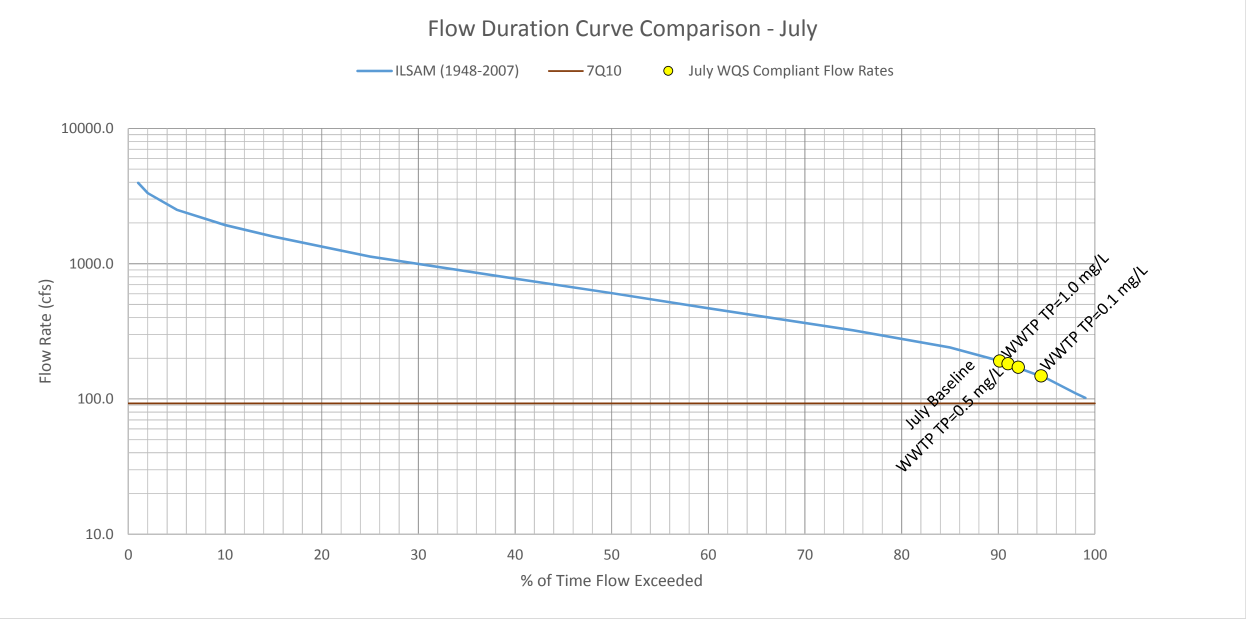


Figure 5-16: Exceedance Probability Curve for Attainment of DO Water Quality Standard in July.

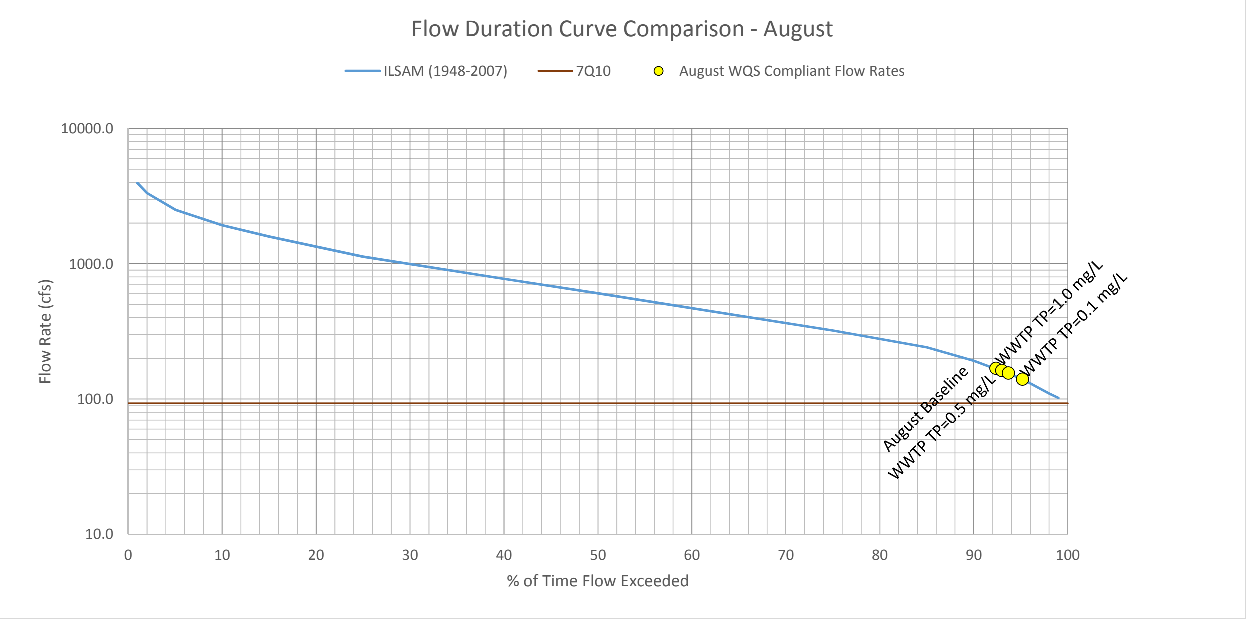


Figure 5-17: Exceedance Probability Curve for Attainment of DO Water Quality Standard in August.

These comparisons of model results to the Fox River flow duration curve indicate that reducing the TP limit at major municipal WWTPs has small incremental effects on the percent of time the DO water quality standard is met under critical low flow conditions. Table 5-5 summarizes these findings in terms of percent of days when the DO water quality standards are met for the July and August baseline conditions and translates those percentages, which are flow-based, into the number of days per year for each WWTP effluent limit.

Table 5-5: Modeled DO Water Quality Standard Attainment Rates for July and August

Sceanrio	% of Days Attaining DO WQS for July Conditions	# Days Attaining DO WQS for July Conditions*	% of Days Attaining DO WQS for August Conditions	# Days Attaining DO WQS for August Conditions*
Baseline (7Q10 flow)	90.1	28	92.4	29
WWTP TP = 1.0 mg/l	91.0	28	93.0	29
WWTP TP = 0.5 mg/l	92.0	29	93.7	29
WWTP TP = 0.1 mg/l	94.4	29	95.2	30

*The number of days presented here are based on the total number of days in July and August, respectively (31). The calculated number of days is rounded to the nearest integer to avoid implying an inappropriate degree of precision.

These results show the estimated number of additional days of attainment of the DO water quality standard in the months of July and August for each level of TP limit for major municipal WWTP, according to the model which, as cautioned elsewhere, tends to over-predict minimum DO.

5.5 Upstream Load Reduction Effects

As noted in Section 4, phosphorus loading from the upstream boundary of the FRIP study area is significant, approximately 201,000 pounds per year on average. The IEPA is currently developing TMDLs for total phosphorus in the Chain O'Lakes upstream of Stratton Dam; the Illinois water quality criterion for total phosphorus in lakes is 0.05 mg/l. In addition, the State of Wisconsin is imposing stricter water quality standards in the Fox River head waters. It is reasonable to expect that these activities may eventually result in a reduced phosphorus load entering the FRIP study area from upstream. To evaluate the effects of this, scenarios were modeled using the Fox River QULA2K model, with upstream concentrations of TP reduced to 0.1 mg/l and 0.05 mg/l. The results for these scenarios for total phosphorus, minimum dissolved oxygen and algae are shown graphically in Figures 5-18 through 5-20, respectively.

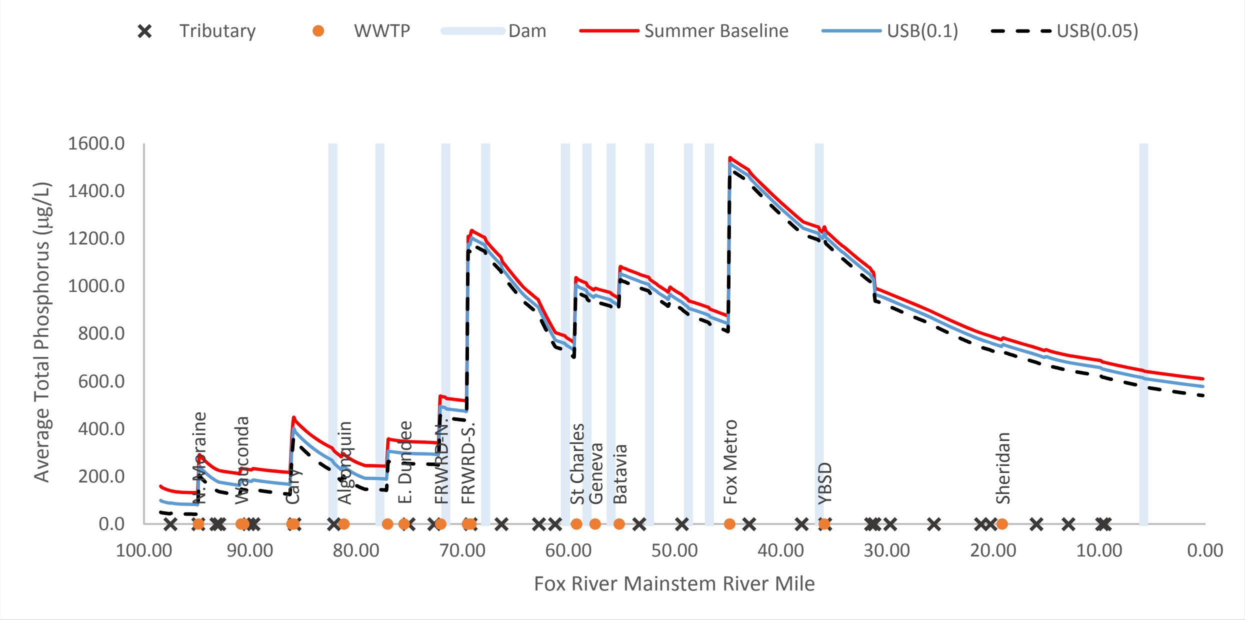
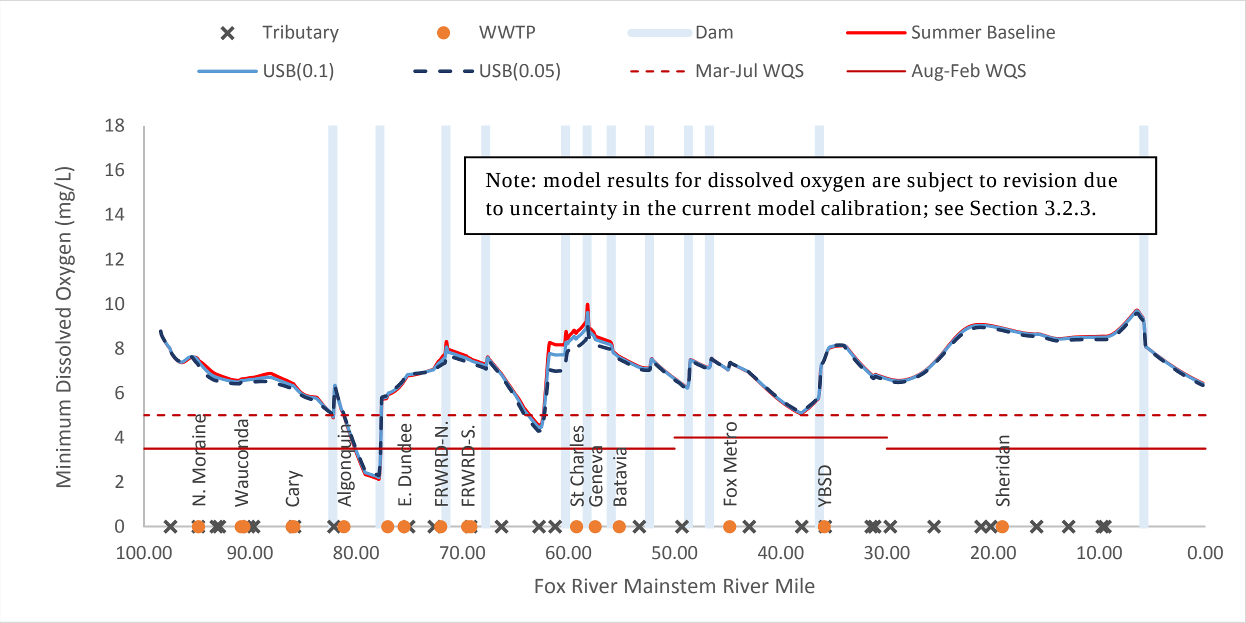


Figure 5-18: QUAL2K Total Phosphorus Results for Reduction of Total Phosphorus from Upstream.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-19: QUAL2K Minimum Dissolved Oxygen Results for Reduction of Total Phosphorus from Upstream, Showing Little Response in DO to Reduced Phosphorus Loading.

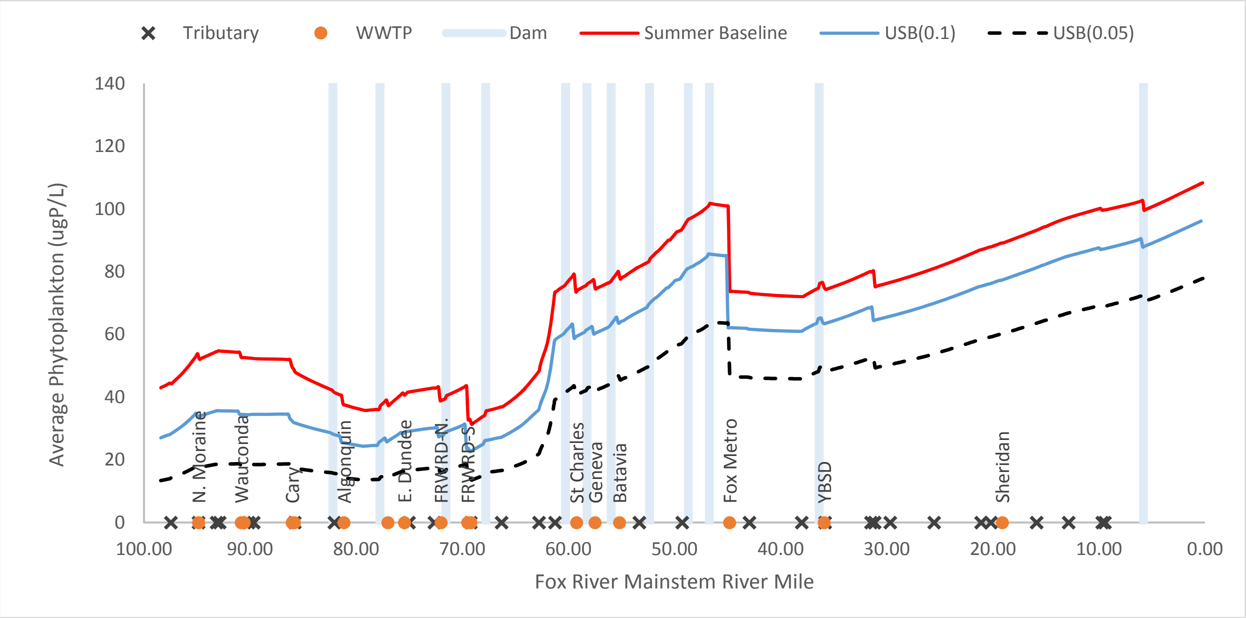


Figure 5-20: QUAL2K Average Phytoplankton Results for Reduction of Total Phosphorus from Upstream, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

The following observations are supported by these results:

- Reduction in total phosphorus entering the system from upstream alone has a minor effect on total phosphorus in the Fox River.

- Model predictions indicate that reducing the upstream total phosphorus concentration will have almost no effect on dissolved oxygen in the river.
- Reducing total phosphorus at the upstream boundary has a significant effect on algae in the river. This is because it is assumed that reduced phosphorus upstream will result in reduced algae upstream and, as a result, there will be less algal mass entering the system from upstream. This is reflected in the lower average phytoplankton concentration shown at the far left (upstream) side of Figure 5-20. This suggests that upstream phosphorus reduction will be important in reducing nuisance algae in the Fox River.

As stated in earlier sections, the Fox River QUAL2K model likely over-predicts minimum dissolved oxygen, so the results for dissolved oxygen must be viewed with caution.

5.6 NPS Load Reduction Effects

While NPS loads from tributaries are not significant during the summer dry weather, low flow conditions modeled for the FRIP, they do contribute to the mass of phosphorus in sediments in the Fox River and, as described in Section 2.6, this phosphorus can be released into the water column under low flow conditions, thereby contributing to water quality effects such as reduced dissolved oxygen and nuisance algae. As described in Section 3.2.1 and Attachment D, the QUAL2K model was modified to incorporate the ability to reflect the effects of wet weather NPS load reduction on sediment phosphorus flux. Using this capability, the effects of NPS load reduction was evaluated for hypothetical NPS TP load reductions of 25% and 50%. The results for these scenarios for total phosphorus, minimum dissolved oxygen and algae are shown graphically in Figures 5-21 through 5-23, respectively.

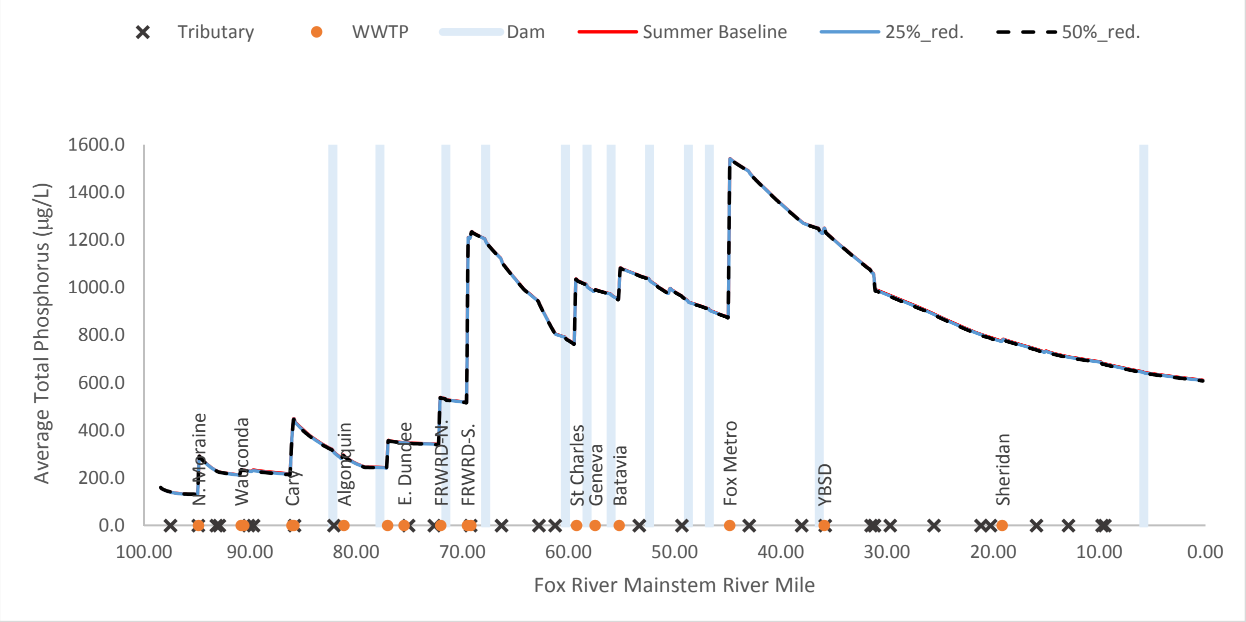


Figure 5-21: QUAL2K Total Phosphorus Results for Reduction of NPS Phosphorus Loading.

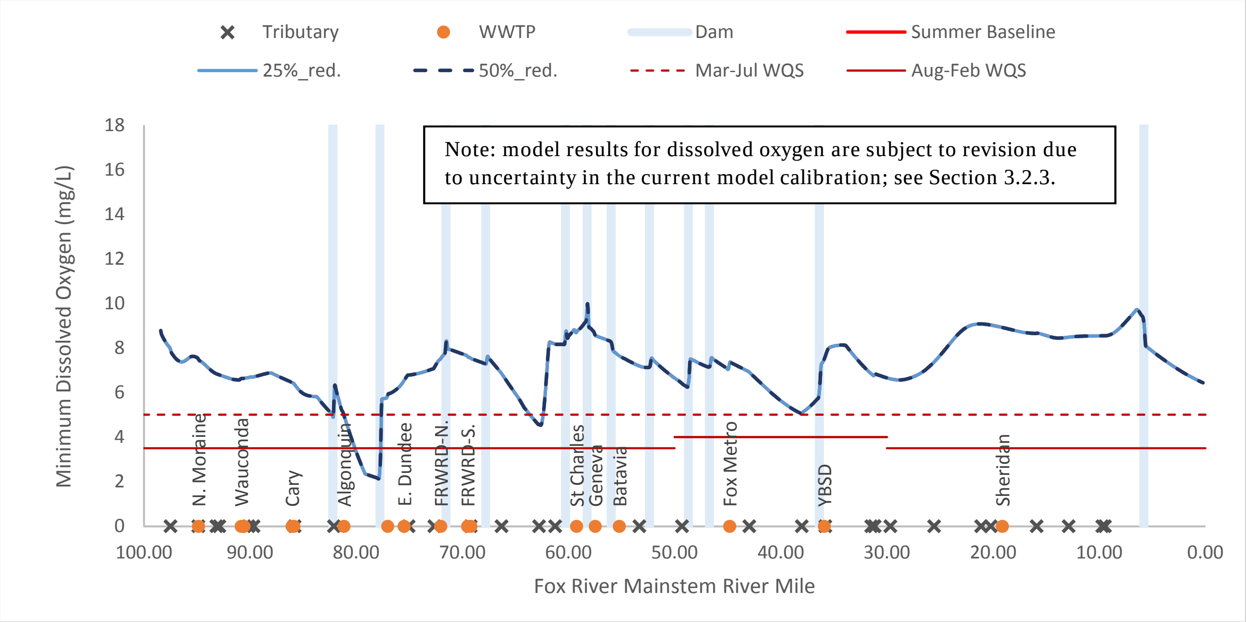


Figure 5-22: QUAL2K Minimum Dissolved Oxygen Results for Reduction of NPS Phosphorus Loading, Showing Little Response in Dissolved Oxygen to Reduced Tributary Phosphorus Loading.

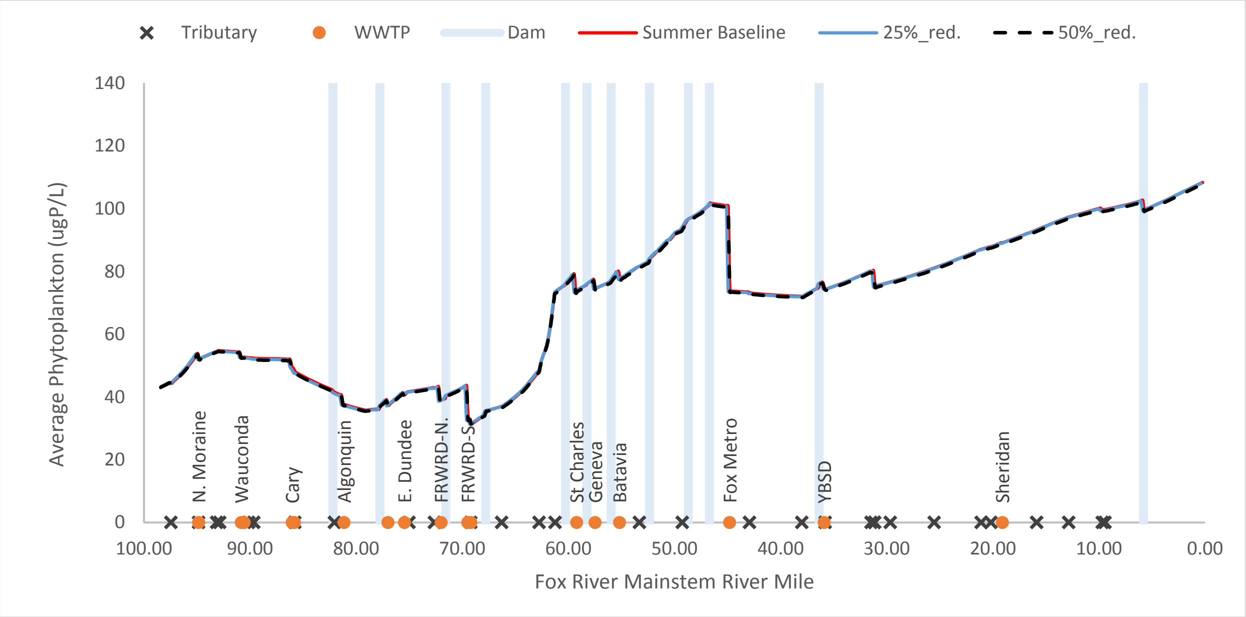


Figure 5-23: QUAL2K Average Phytoplankton Results for Reduction of NPS Phosphorus Loading, Showing Little Response in Phytoplankton to Reduced Tributary Phosphorus Loading.

As shown in Figures 5-21 through 5-23, model results indicate that the reduction of NPS phosphorus loads alone has no discernible effect on water quality in the Fox River during summer critical low flow conditions. The benefit of reducing NPS phosphorus loads may become more significant as loads from other sources are reduced, but significant reductions in other sources may be necessary before the benefit of NPS load reduction have an effect on water quality under summer low flows. Figures 5-24 through 5-26 show results for upstream TP reduction to 0.05 mg/L and WWTP effluent reduction to 0.1 mg/L, with and without a 25 % reduction in NPS loads. The model results for the scenarios with and without the NPS load reductions appear to be identical. It should also be noted that reduction of NPS phosphorus loads may have benefits to water quality in tributaries to the Fox River and to water quality in the Fox River under wet weather conditions, but these are beyond the scope of the FRIP.

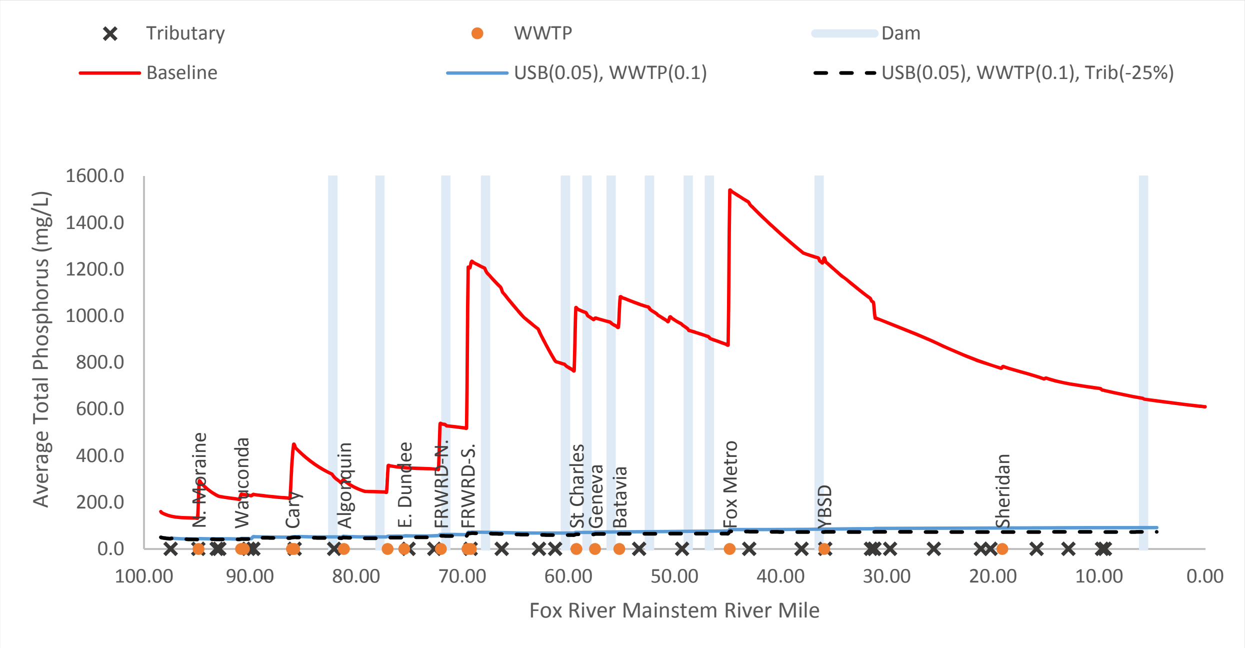


Figure 5-244: QUAL2K Total Phosphorus Results for Reduction of NPS Phosphorus Loading in addition to load reductions from WWTPs and Upstream.

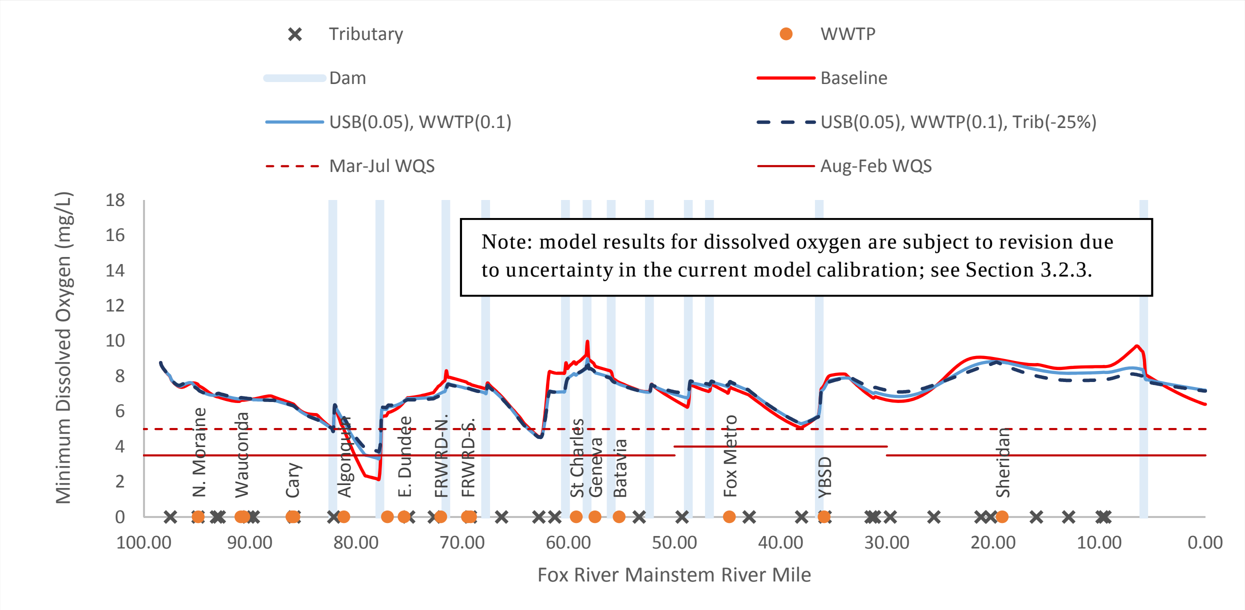


Figure 5-255: QUAL2K Minimum Dissolved Oxygen Results for Reduction of NPS Phosphorus Loading in addition to load reductions from WWTPs and Upstream, Showing Little Response in DO to Reduced Phosphorus Loading.

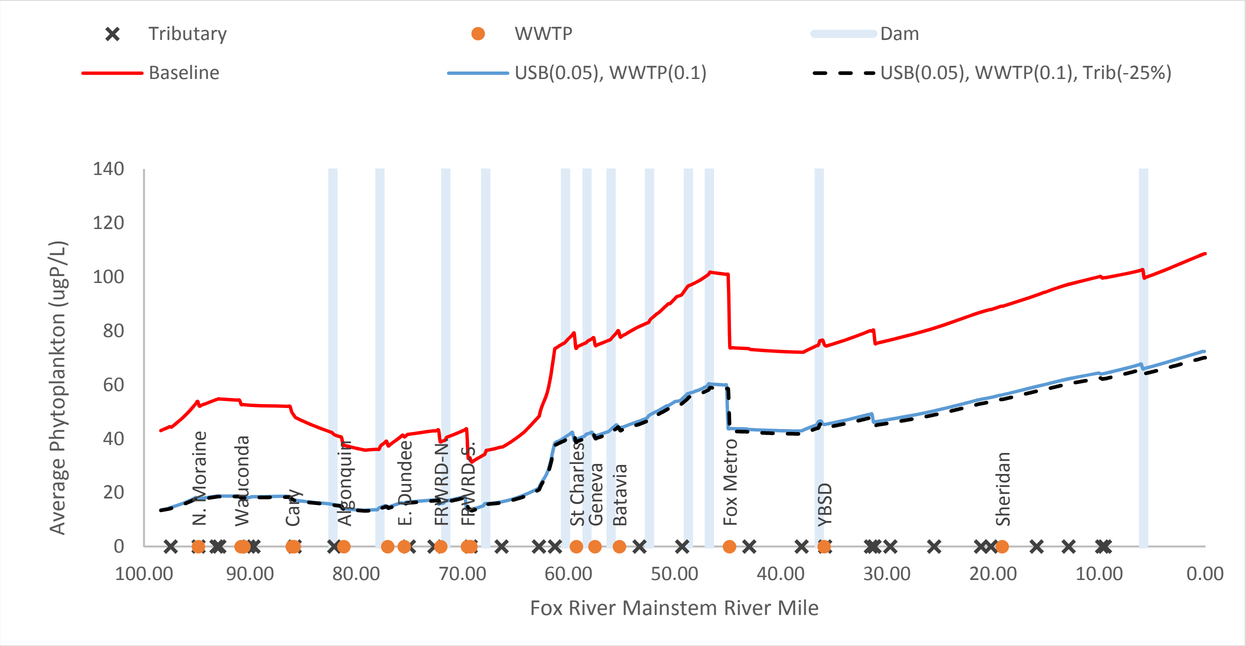


Figure 5-26: QUAL2K Average Phytoplankton Results for Reduction of NPS Phosphorus Loading in addition to load reductions from WWTPs and Upstream, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

5.7 Dam Removal Effects

There has been recent discussion of removal of some of the dams that currently exist on the Fox River. Currently, the Forest Preserve District of Kane County and the Village of North Aurora have intergovernmental agreements (IGAs) in place with the Illinois Department of Natural Resources (IDNR) to plan the removal of the Carpentersville and North Aurora dams, respectively. These dams could potentially be removed within the next five years. To evaluate the potential effects of dam removal on water quality in the Fox River, two scenarios were simulated. The first involves removal of the Carpentersville and North Aurora Dams and the second simulates the hypothetical removal of all dams from Carpentersville to Montgomery. The results for these scenarios for total phosphorus, minimum dissolved oxygen and algae are shown graphically in Figures 5-27 through 5-29, respectively.

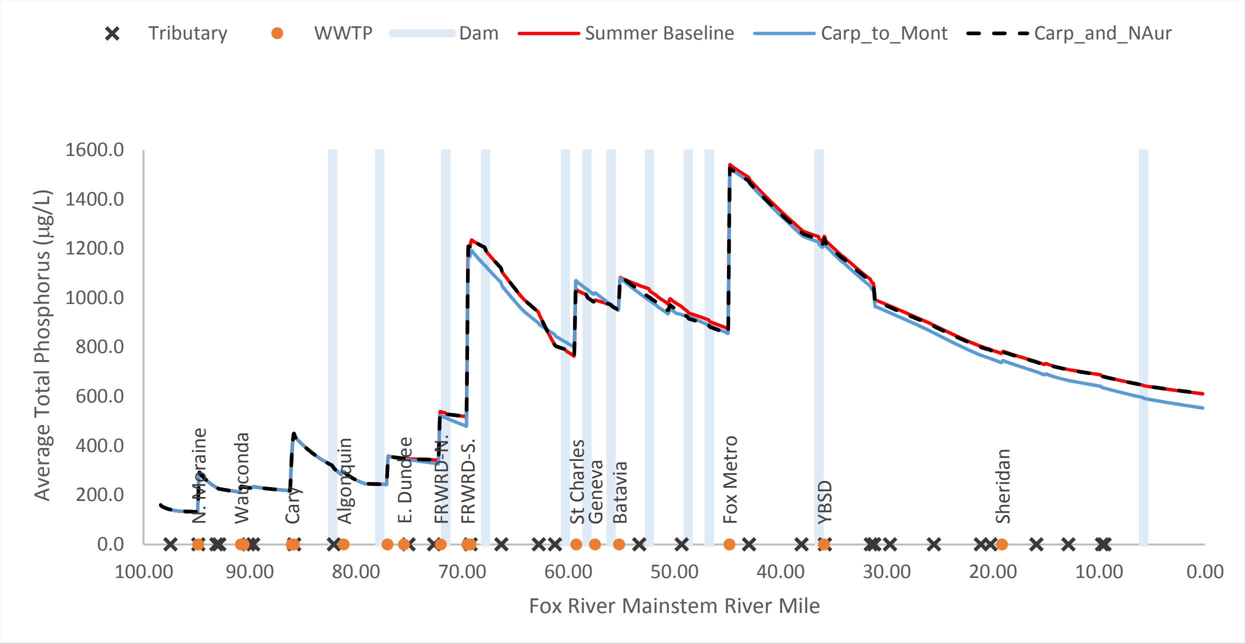
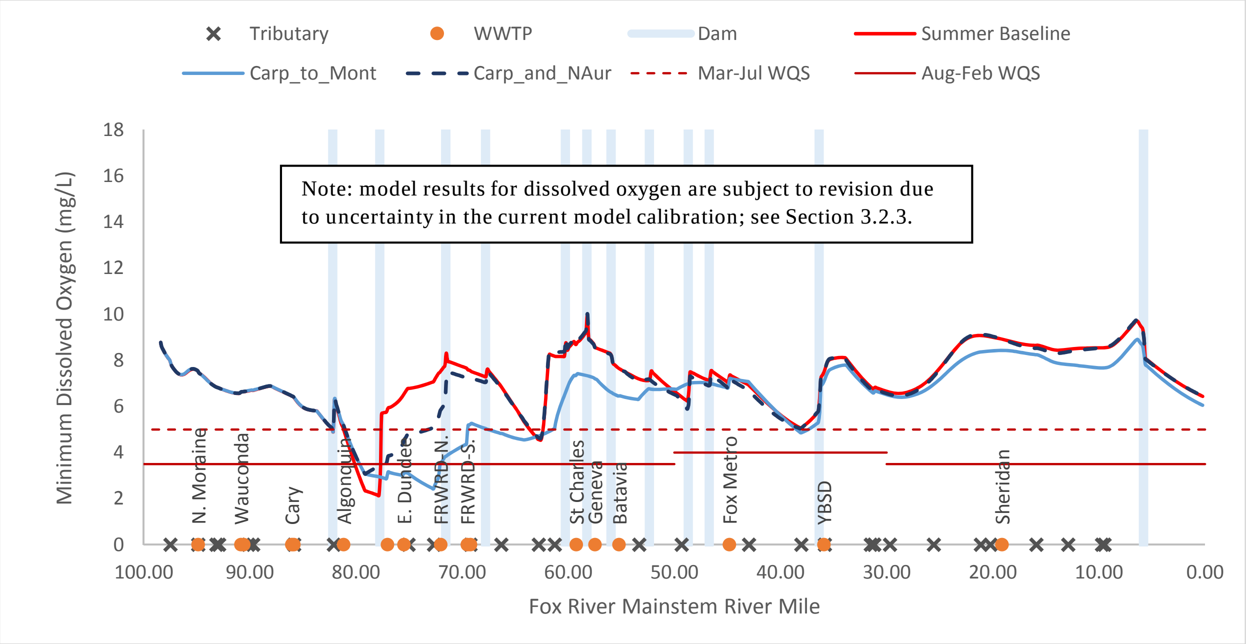


Figure 5-27: QUAL2K Total Phosphorus Results for Dam Removal Scenarios.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-28: QUAL2K Minimum Dissolved Oxygen Results for Dam Removal Scenarios, Showing More Extensive Dissolved Oxygen Depletion as a Result of Dam Removal, Which is Not the Expected Result.

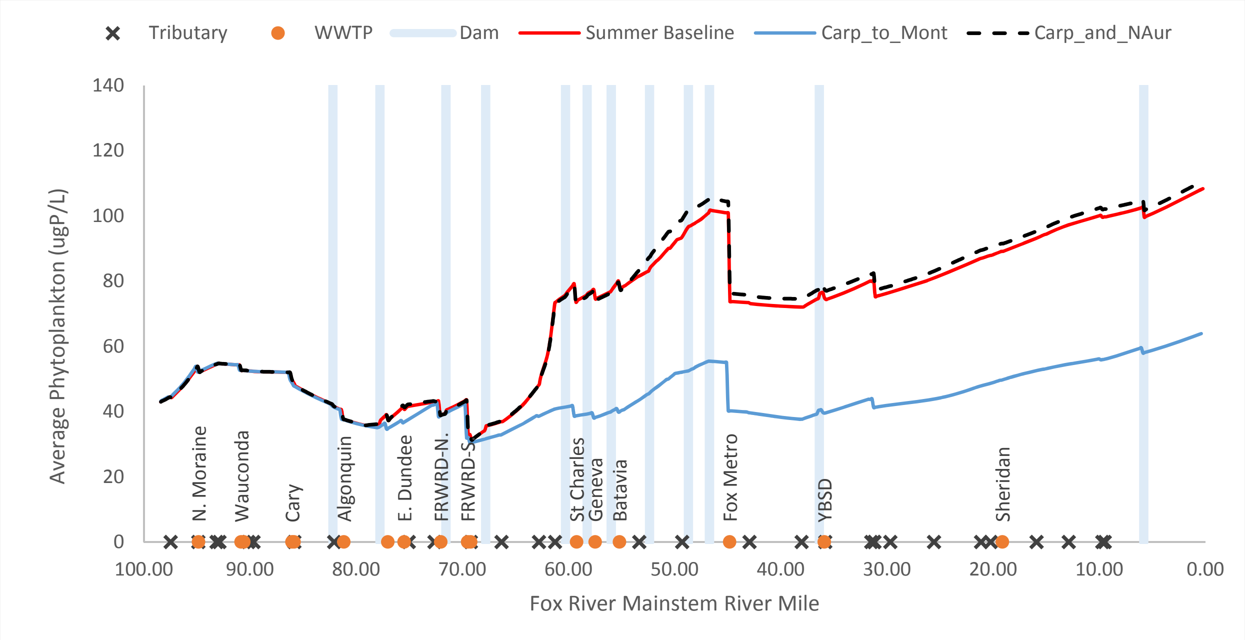


Figure 5-29: QUAL2K Average Phytoplankton Results for Dam Removal Scenarios, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

Before discussing the results of these modeled dam removal scenarios, it is important to point out the changes that are made to the model to conduct these dam removal simulations. There are two major aspects of this use of the model that significantly limit the utility of the results:

- First, the way the model calculates velocity and water depth needs to be modeled to reflect the removal of the dams in question and the elimination of the dam impoundments. Dam removal will result in faster moving and shallower water, but the QUAL2K model does not directly simulate river hydraulics. Instead, it relies on simple rating curve equations that relate velocity and water depth to flow rate. To simulate the change in water velocity and depth that might result from dam removal, those equations need to be changed for the affected reaches of the model. For the FRIP, this was done by replacing the hydraulic equations in the impounded reaches with equations from free-flowing reaches. This implies the assumption that, following dam removal the former dam impoundments will have the same hydraulic characteristics as the free-flowing reaches from which the hydraulic equations are copied.
- The second aspect of dam removal simulation with QUAL2K has to do with reaeration. It can be expected that reaeration will increase with dam removal as a result of faster flowing and shallower water , but there is no way to accurately predict that increase in reaeration. For the dam removal scenarios presented here, post-removal reaeration rates were calculated using the Tsivoglou equation, which is one of many available empirical formulas for reaeration. This equation was selected because it is a well-accepted methodology, it calculates reaeration as a function of velocity and depth, and it is available in the QUAL2K model itself. The range of reaeration rates calculated as a result are reasonable, neither at the lower or upper ends of the possible range of values.

Although the model changes described above are necessary to simulate dam removal, they essentially result in a version of the model that can no longer be considered calibrated. In spite of this, the results can be informative for planning purposes, although they should not be relied upon for final decision making. With that in mind, the following observations can be made from the results presented here:

- As expected, the model does not predict any significant change in total phosphorus in the river as a result of dam removal.
- The effect of dam removal on minimum dissolved oxygen in these simulations is not as beneficial as might be expected. The results show that, although the lowest minimum DO concentration upstream of the Carpentersville dam is slightly higher after dam removal, the downstream extent of that low DO concentration is greater. Examination of other model output indicates that this is likely the result of a modeled increase in benthic (bottom growing) algae, which increases as a result of the shallower water that results from dam removal (Figure 5-30). The increase in benthic algae following dam removal is something that should be investigated in the future when dams are removed from the Fox River. There is no evidence that increased benthic algae growth occurred as a result of the removal of the South Batavia or Hurds Island dams.

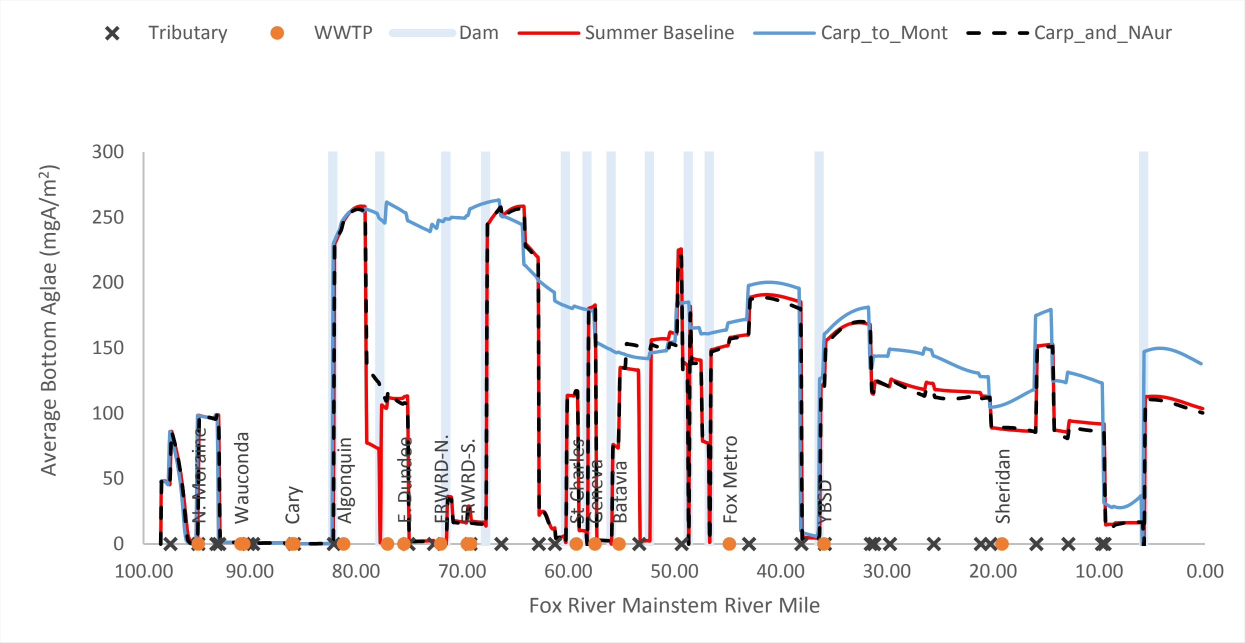


Figure 5-30: QUAL2K Benthic Algae Results for Dam Removal Scenarios.

- The model results for algae in the water column show little change as a result of the Carpentersville/North Aurora Dams removal scenario, but a significant decrease in downstream algae as a result of the removal of all dams from Carpentersville to Montgomery. As illustrated in Figure 5-29, the model predicts that removal of the St. Charles Dam causes the greatest decrease in average phytoplankton.

As stated above, these model results must be viewed with the understanding that the changes necessary to simulate dam removal void the model calibration.

5.8 Combined Scenario Results

The model results for various potential water quality improvement actions were presented in the preceding section, simulated independently. In this section, model results for the following alternative combinations of actions are presented:

- WWTP effluent total phosphorus reduced to 1.0; Carpentersville & North Aurora Dams removed (Alternative 1) and the same actions combined with reduction of TP at the upstream boundary to 0.1 mg/l (Alternative 2)
- WWTP effluent total phosphorus reduced to 0.5; Carpentersville & North Aurora Dams removed (Alternative 3) and the same actions combined with reduction of TP at the upstream boundary to 0.1 mg/l (Alternative 4)
- WWTP effluent total phosphorus reduced to 0.5; Carpentersville & North Aurora Dams removed and reduction of TP at the upstream boundary to 0.05 mg/l (Alternative 5)
- WWTP effluent total phosphorus reduced to 0.1; all dams removed from Carpentersville to Montgomery and reduction of TP at the upstream boundary to 0.05 mg/l (Alternative 6)

Model results for each of these alternative scenarios are described in the following subsections. All plots of model results include the summer critical season baseline results for comparison.

5.8.1 Alternatives 1 and 2

Alternative 1 represents the most realistic near-future alternative, in which total phosphorus in WWTP effluent is limited 1.0 mg/l and the Carpentersville and North Aurora Dams are removed. Alternative 2 is combines the actions of Alternative 1 with a reduction of total phosphorus at the upstream boundary of the FRIP study area to 0.1 mg/l. The reduction in phosphorus at the upstream boundary is contingent on implementation of the phosphorus TMDL for the Fox River chain of lakes upstream of the FRIP study area. It assumes that water quality will improve as a result of TMDL implementation and that total phosphorus entering the FRIP study area from upstream will eventually reach an average of 0.1 mg/l on the way to the ultimate target of the 0.05 mg/L water quality criterion for TP in lakes. It also assumes that nothing occurs between the chain of lakes and the Stratton Dam to increase TP concentrations. The Alternative 1 and 2 results for total phosphorus, minimum DO and average phytoplankton are shown in Figures 5-31 through 5-33, respectively.

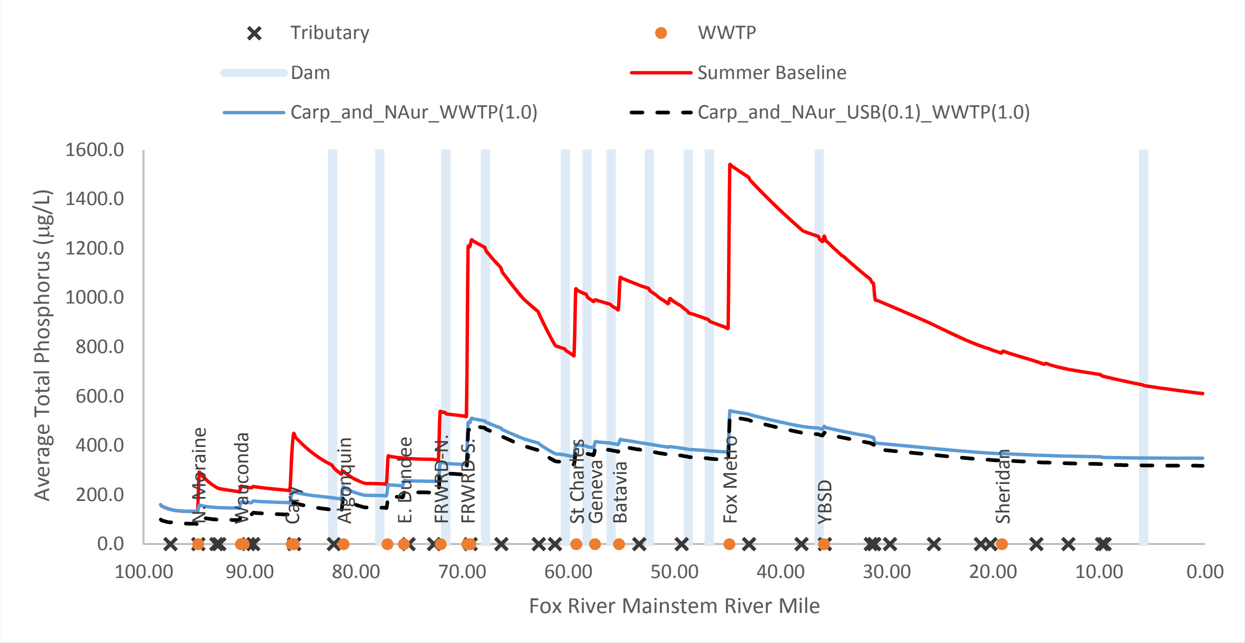


Figure 5-31: QUAL2K Total Phosphorus Results for Alternatives 1 and 2.

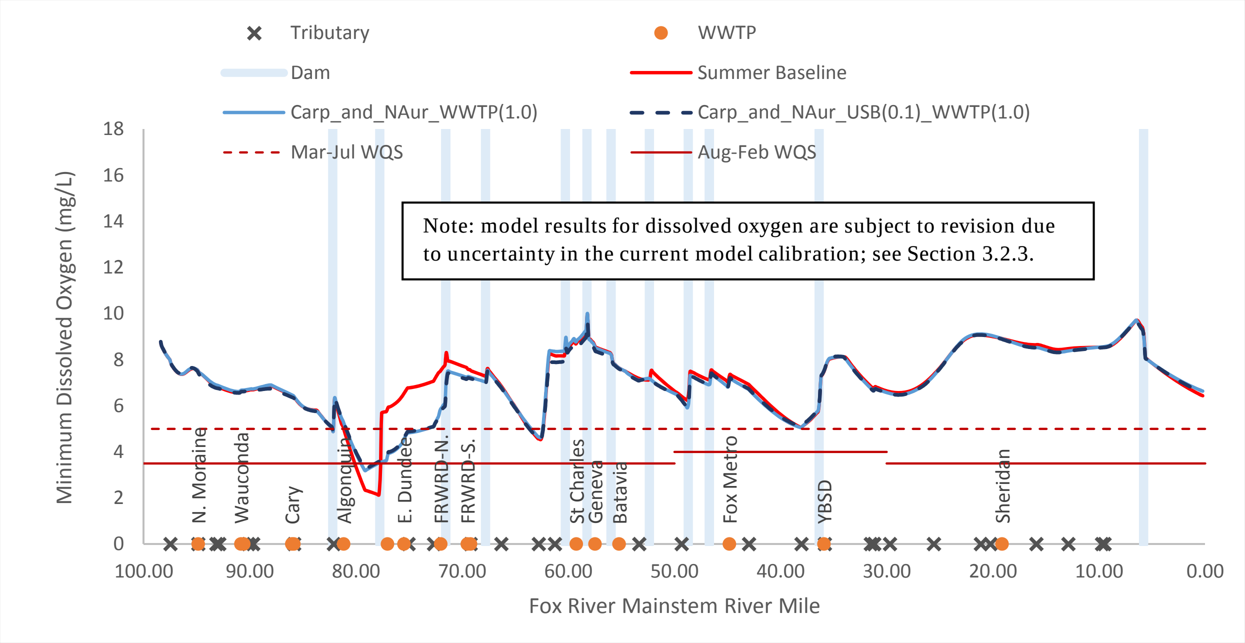


Figure 5-32: QUAL2K Minimum Dissolved Oxygen Results for Alternatives 1 and 2, Showing Little Response in DO to Reduced Phosphorus Loading and Counterintuitive Results from Dam Removal.

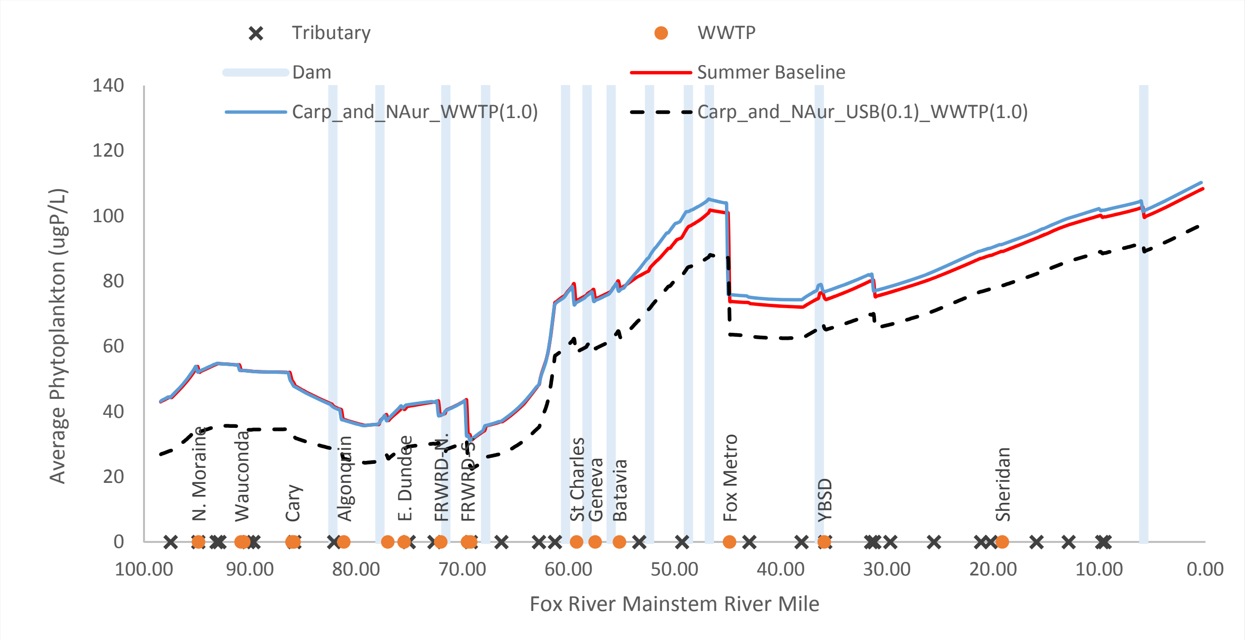


Figure 5-33: QUAL2K Average Phytoplankton Results for Alternatives 1 and 2, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

As expected, the combination of reduced TP in WWTP effluent and reduced upstream TP concentrations achieves the benefits of these two actions taken separately (discussed in Section 5.4 and 5.5) and adds the modeled effects of removal of the two dams.

- The model predicts only very slight improvement in minimum DO as a result of upstream TP concentration reduction, as compared to WWTP effluent reductions and dam removal alone.
- As seen in previous model results, algae in the river is predicted to respond most favorably to significant reductions in upstream TP concentrations with little additional effect from WWTP

effluent phosphorus reductions to the 1 mg/L level and removal of just two of the dams in the study area. Under this scenario, the Fox River is still behaving more like a series of lakes where phosphorus levels are well about the level that will limit algae growth.

5.8.2 Alternative 3 and 4

Alternatives 3 and 4 reflect reduction of total phosphorus in WWTP effluent to 0.5 mg/l and the Carpentersville and North Aurora Dams are removed. The difference between the scenarios is that Alternative 3 retains current upstream conditions and Alternative 4 represents a reduction of upstream phosphorus to 0.1 mg/l. The Alternative 3 and 4 results for total phosphorus, minimum DO and average phytoplankton are shown in Figures 5-34 through 5-36, respectively.

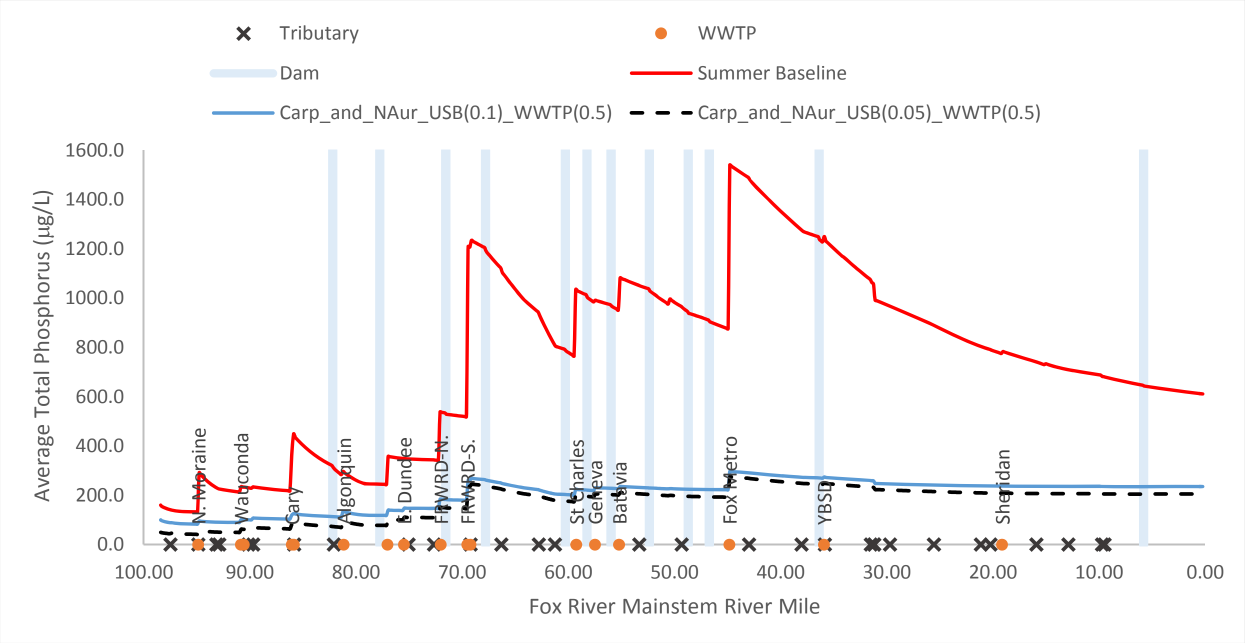
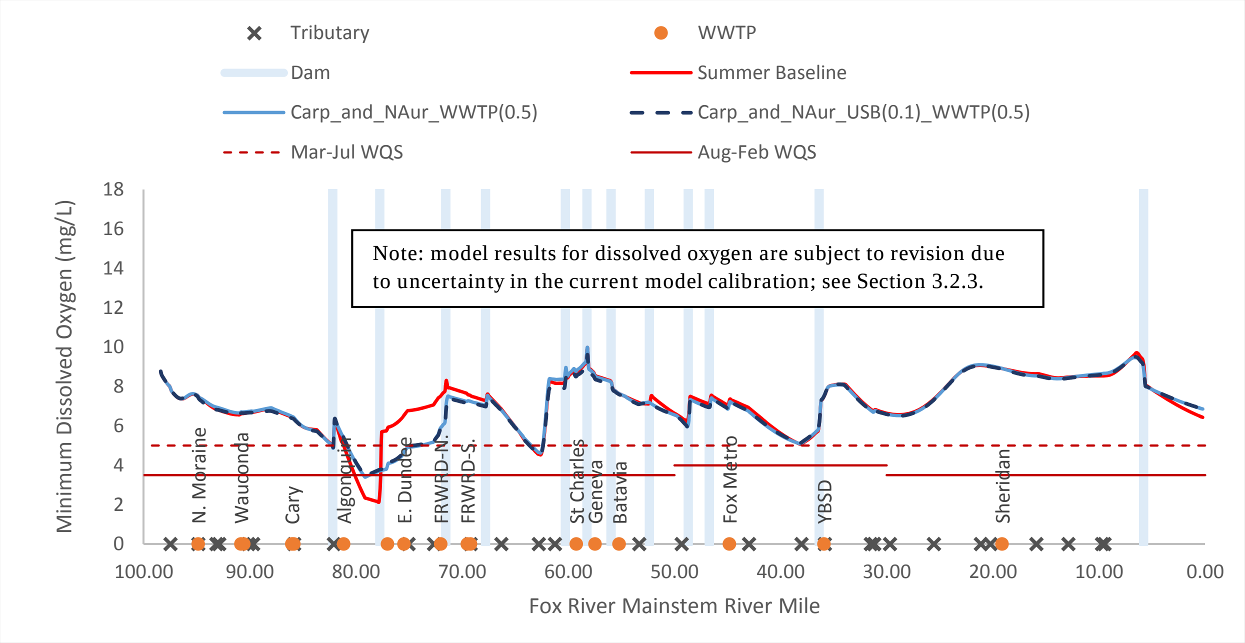


Figure 5-34: QUAL2K Total Phosphorus Results for Alternatives 3 and 4.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-35: QUAL2K Minimum Dissolved Oxygen Results for Alternatives 3 and 4, Showing Little Response in DO to Reduced Phosphorus Loading and Counterintuitive Results from Dam Removal.

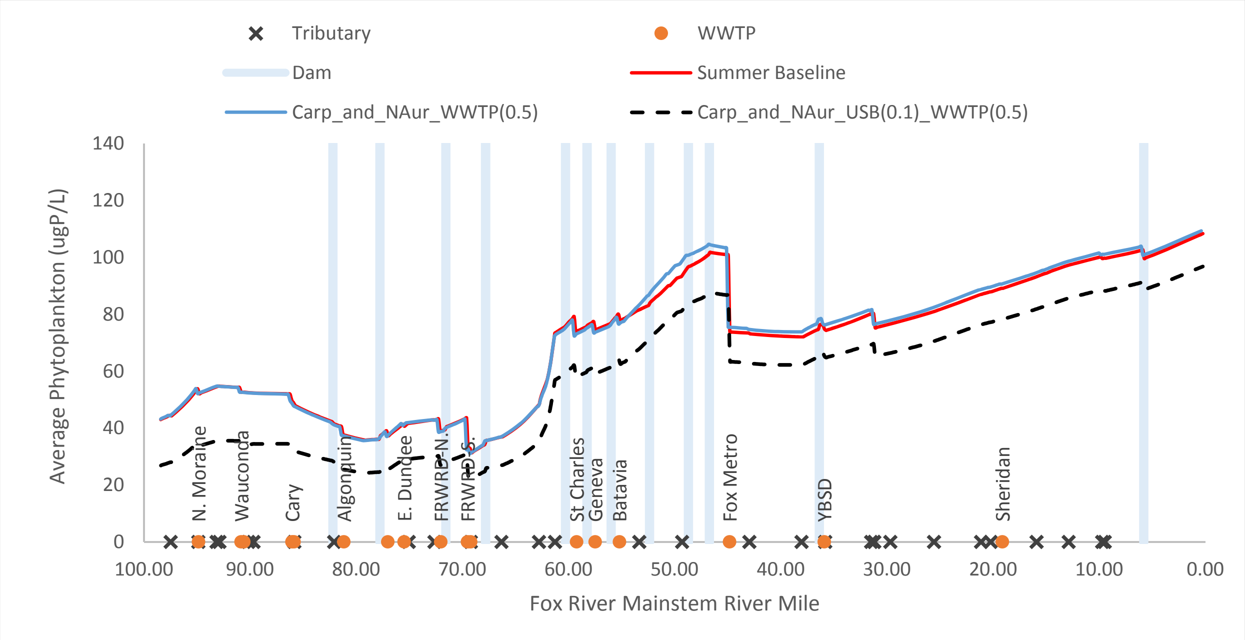


Figure 5-36: QUAL2K Average Phytoplankton Results for Alternatives 3 and 4, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

In spite of the significant increase in TP load reduction achieved by reducing WWTP effluent TP from 1.0 mg/l to 0.5 mg/l, the model shows almost no change in results for dissolved oxygen and algae from Alternatives 1 and 2. This is not unexpected as phosphorus levels in the river under this scenario still remain well above the levels expected to limit algal growth and much of the river remains impounded by dams, providing stagnant water in the dam pools that provide an ideal environment for algae to flourish.

5.8.3 Alternative 5

Alternative 5 is similar to Alternative 4 in most respects, except that TP at the upstream boundary is further reduced to 0.05 mg/l. The Alternative 5 results for total phosphorus, minimum DO and average phytoplankton are shown in Figures 5-37 through 5-39, respectively.

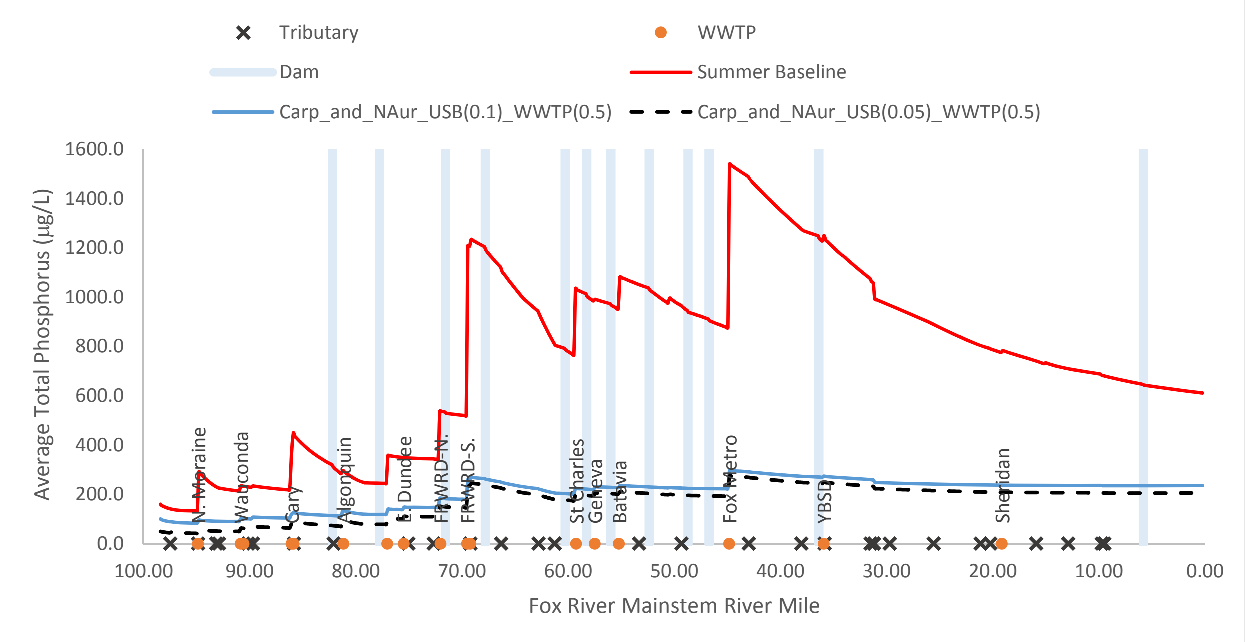
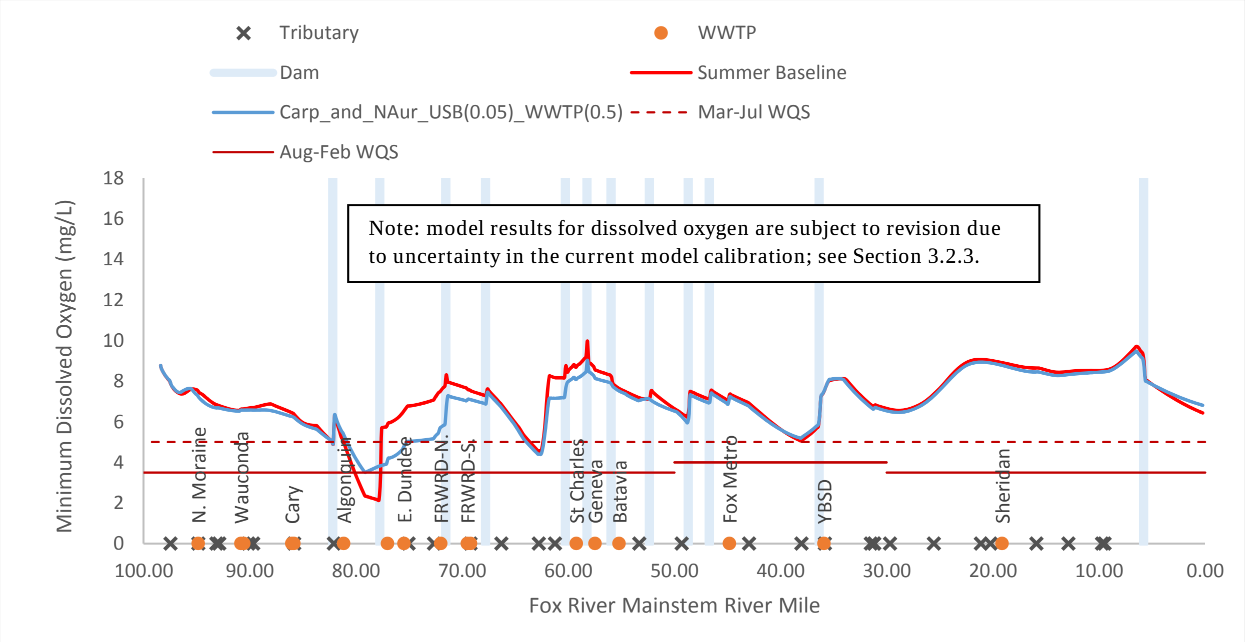


Figure 5-37: QUAL2K Total Phosphorus Results for Alternative 5.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-38: QUAL2K Minimum Dissolved Oxygen Results for Alternative 5, Showing Little Response in DO to Reduced Phosphorus Loading and Counterintuitive Results from Dam Removal.

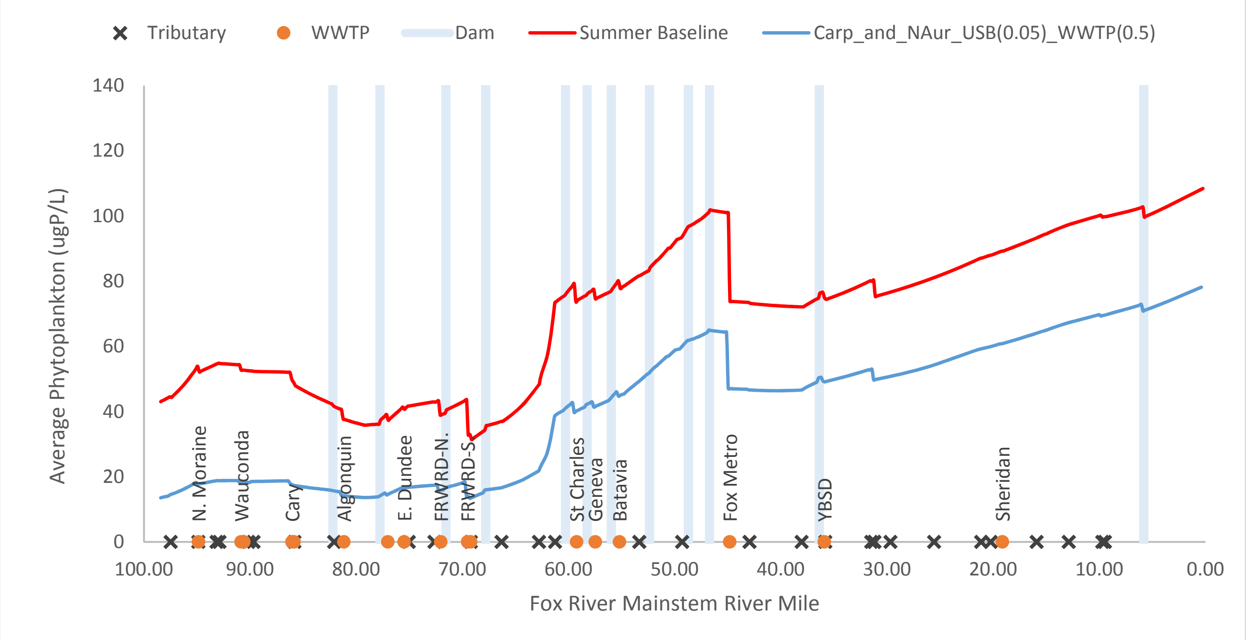


Figure 5-39: QUAL2K Average Phytoplankton Results for Alternative 5, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

The minimum DO model results for Alternative 5 are not significantly different from other alternatives. Model predictions of algae are lower than the preceding alternatives as a result of the reduced upstream boundary TP.

5.8.4 Alternative 6

Alternative 6 represents a combination of the most extreme actions considered in the FRIP including reduction of WWTP effluent total phosphorus to 0.1 mg/l, all dams removed from Carpentersville to Montgomery and reduction of TP at the upstream boundary to 0.05 mg/l. The Alternative 6 results for total phosphorus, minimum DO and average phytoplankton are shown in Figures 5-40 through 5-42, respectively.

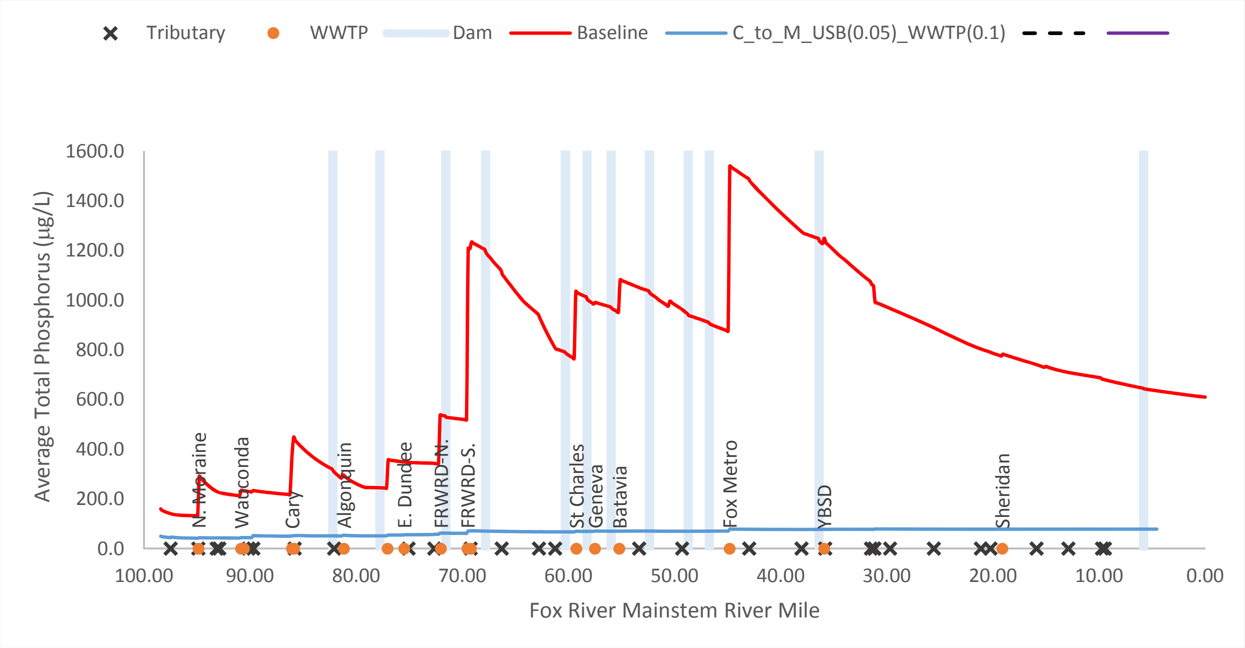
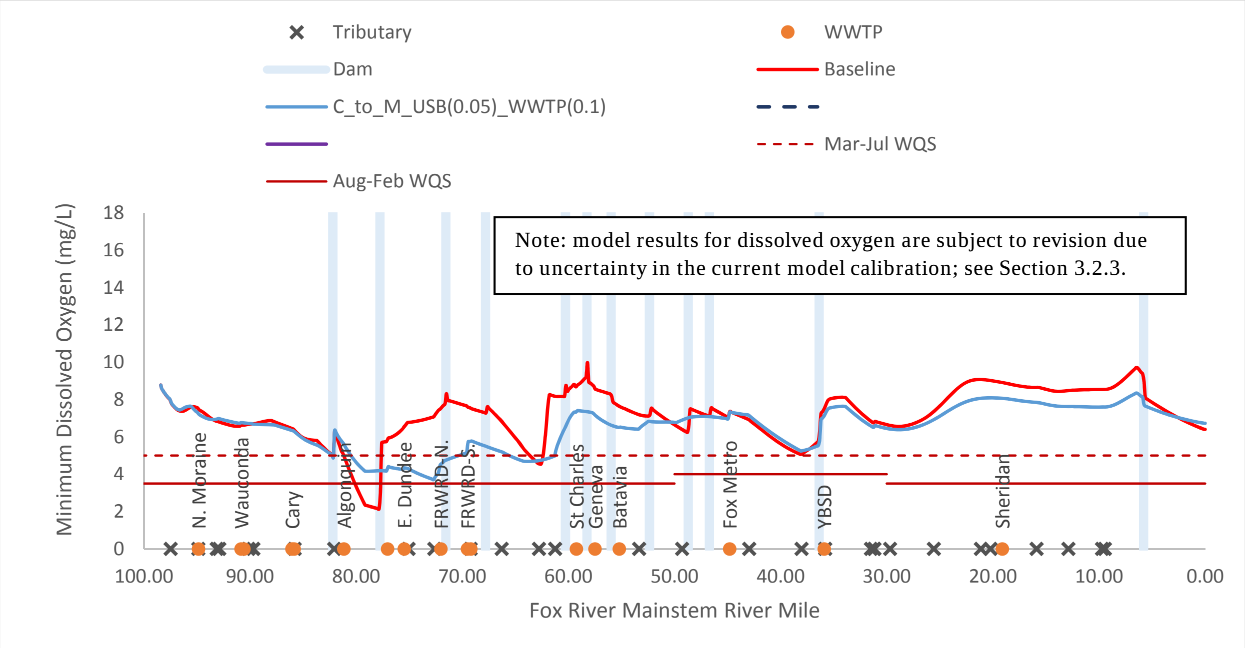


Figure 5-40: QUAL2K Total Phosphorus Results for Alternative 6.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 5-41: QUAL2K Minimum Dissolved Oxygen Results for Alternative 6, Showing Little Response in DO to Reduced Phosphorus Loading and Counterintuitive Results from Dam Removal.

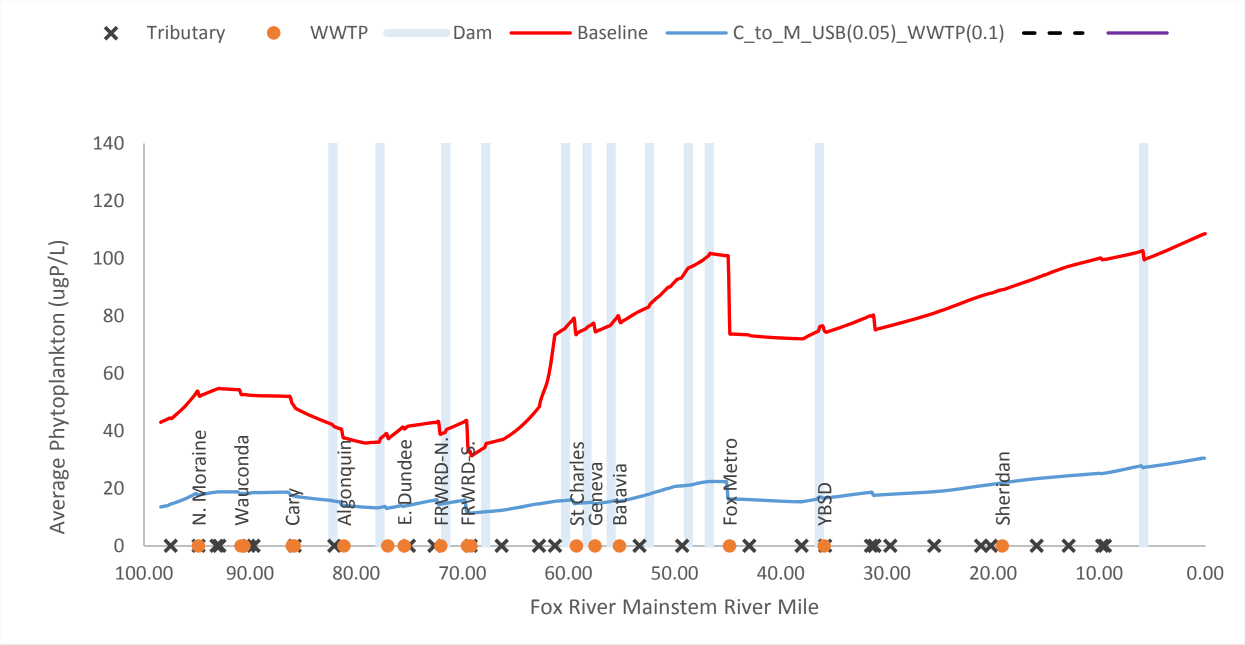


Figure 5-42: QUAL2K Average Phytoplankton Results for Alternative 6, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

The minimum DO model results for Alternative 6 are actually slightly lower than for Alternative 5, due to the aforementioned benthic algae growth that results from simulated dam removal. As previously stated, investigation of this phenomenon is recommended with future dam removal projects in the Fox River. Model predictions of algae are the lowest of any alternative as a result of reductions in phosphorus to low levels at both the upstream boundary and from WWTPs, combined with removal of dams.

5.8.5 Non-Point Source TP Load Reduction as a Component of the FRIP

As illustrated by the model results presented in Section 5.6, reduction of NPS phosphorus loading in the Fox River watershed has no discernible effect on water quality in the Fox River during summer low flow conditions. However, the draft Nutrient Loss Reduction Strategy for the State of Illinois (IEPA, 2015) indicates that 48% of the annual average total phosphorus load from the state is attributable to agricultural sources, along with 4% from urban runoff. This combined total of 52% on a statewide basis supports the need for control of NPS loading of phosphorus in the Fox River watershed.

In addition to considerations related to the statewide Nutrient Loss Reduction Strategy, control of these NPS sources of phosphorus will likely contribute to improved water quality in tributaries and to improvements in water quality in the Fox River during wet weather conditions. In addition, some of the NPS phosphorus load accumulates in river sediments and can contribute to low dissolved oxygen conditions and algal growth during dry weather, low flow periods. As described in Section 4.2.5, it is estimated that annual average total phosphorus load entering the Fox River from agricultural areas and MS4 jurisdictions account for about 37% of the total annual average phosphorus load to the river. For these reasons, the FRIP recommends NPS phosphorus load reduction.

At this time, there is no scientific basis for establishing numeric phosphorus NPS load reduction targets for agricultural areas and MS4s but, as described in Section 6, those entities will be encouraged to do what they can to reduce phosphorus loads and to track and report their load reduction efforts.

The model results for NPS load reductions are not shown in combination with other potential actions in this report because they would not result in a discernible difference for the dry weather, low flow conditions modeled.

5.8.6 Total Phosphorus Load Reductions from Potential Actions

The TP load reductions resulting from the various actions described were estimated as described below.

For WWTPs, the actions involve enhanced phosphorus removal to reach target concentrations in effluent. Therefore, assuming flow rates are unaffected by the action, the load reduction will be proportional to the change in TP concentration in effluent. Available WWTP effluent data were compiled for the period of 2010-2013 and the average effluent TP concentration for all major WWTPs combined was 2.2 mg/l. If all major WWTPs reduce their effluent to an annual average of 1.0 mg/l, this will result in a 55% reduction in TP concentration and load. Similarly, reduction of effluent TP to 0.5 mg/l would result in a 77% reduction in TP concentration and load. Reduction of effluent TP to 0.1 mg/l would result in a 95% reduction in TP concentration and load. These load reductions and the resulting total loads are presented in Table 5-6.

Table 5-6: Estimated Load Reduction for Enhanced TP Removal at WWTPs.

Action	Estimated TP Load Reduction (lb/yr)	TP Load from WWTPs (lb/yr)
No Action	0	600,000
WWTP Effluent TP = 1.0 mg/l	330,000	270,000
WWTP Effluent TP = 0.5 mg/l	462,000	138,000
WWTP Effluent TP = 0.1 mg/l	570,000	30,000

Loading reduction at the upstream boundary of the FRIP study area can be calculated in the same manner. An average concentration of 0.118 mg/l was used in estimating the annual average load at the upstream boundary, as described in Section 4.2.1. Again assuming load reduction will be proportional to concentration reduction, the load reductions and the resulting total loads are presented in Table 5-7 for reduction of upstream TP to 0.1 mg/l and 0.05 mg/l.

Table 5-7: Estimated Load Reduction for Upstream TP Reduction as a Result of TMDL Implementation.

Action	Estimated TP Load Reduction (lb/yr)	Upstream TP Load (lb/yr)
No Action	0	201,000
Reduce TP to 0.1 mg/l	30,700	170,300
Reduce TP to 0.05 mg/l	115,900	85,100

Dam removal will not result in reduced phosphorus loading to the Fox River.

5.9 Costs of Alternatives

Cost is an essential consideration is evaluating the feasibility of water quality improvement actions and will be important not only in determining which actions will be implemented, but when they will be implemented and with what priority. The estimation of costs for the actions included in the alternatives described in the preceding section are discussed below.

5.9.1 Estimated Cost of Enhanced TP Removal at WWTPs

The cost of enhanced phosphorus removal at municipal WWTPs has been the focus of many recent reports and studies, both nationally and in Illinois (Symbiont, 2011; USEPA, 2007; USEPA, 2008). As discussed in Section 1.5, the new NPDES permit for each major WWTP contains a special condition requiring the permittee to prepare a feasibility study on the treatment of phosphorus to meet monthly average effluent concentrations of 1.0 mg/l, 0.5 mg/l and 0.1 mg/l. When all of these studies are complete, robust estimates of enhanced phosphorus reduction will be available. At this time, the only available, completed studies are:

- City of Geneva
- Northern Moraine Wastewater Reclamation District
- Village of Elburn
- Yorkville-Bristol Sanitary District
- Fox River Water Reclamation District

Ultimately, the cost of reducing phosphorus loading from major WWTPs will rely on the cost estimates provided by each permittee, per the special condition. In the meantime, a preliminary estimate of cost can be developed using available references including those cited at the beginning of this section.

Based on the cost information in these references, the engineering firm of Crawford, Murphy & Tilly, Inc. (CMT) prepared graphs for estimating the range of capital costs for enhanced phosphorus removal, based on WWTP design flow. Although these are not as accurate as plant-specific estimates, they are useable until all the major dischargers complete their respective feasibility studies. Two cost estimating graphs are shown below: one is for retrofitting with chemical removal to meet limits of 1.0 mg/l (Figure 5-43) and the other is for expansion to add an anaerobic/oxic (A/O) process (Figure 5-44). Both graphs allow estimation of a range of costs based on design flow, from 1 to 10 MGD. An overall range of estimated cost can be obtained by using the lower end of the range in Figure 5-43 and the upper end of the range on Figure 5-44. At this time there is insufficient data available to prepare similar cost estimate graphs for treating to 0.5 mg/l and 0.1 mg/l.

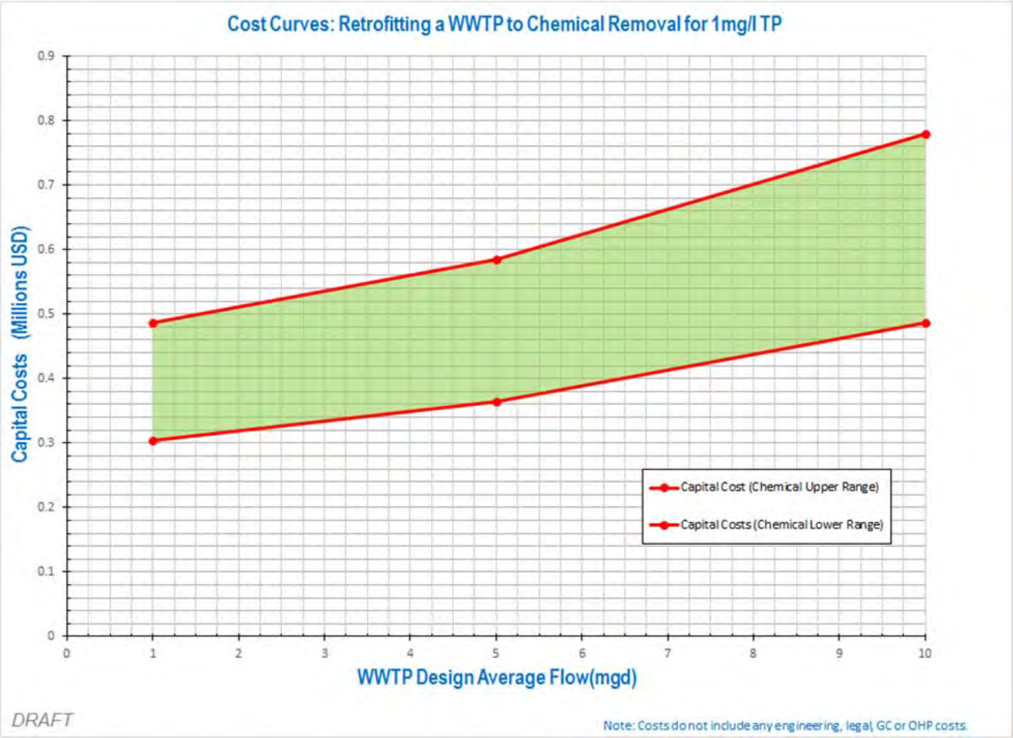


Figure 5-43: Estimated Cost Range for Enhanced Phosphorus Removal to 1.0 mg/l with Chemical Oxidation.

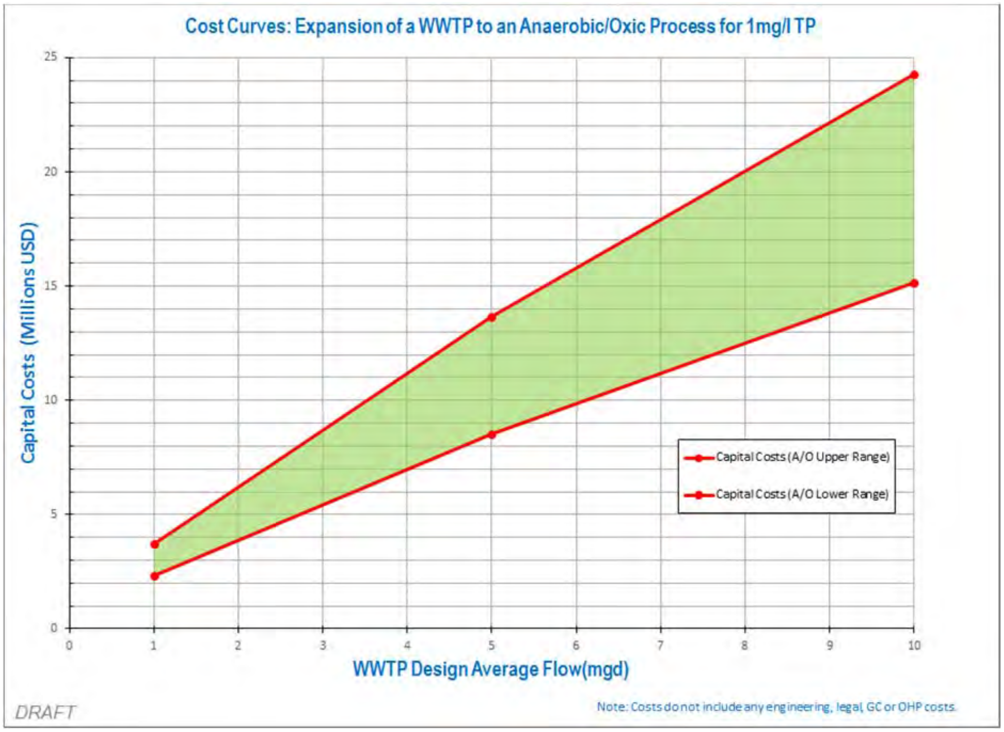


Figure 5-44: Estimated Cost Range for Enhanced Phosphorus Removal to 1.0 mg/l with Anaerobic/Oxic Process.

Ranges of costs for implementing phosphorus removal at major municipal WWTPs are summarized in Table 5-8.

Table 5-8: Estimated Capital Cost of Enhanced Phosphorus Removal from Major WWTPs.

Permittee	DAF (MGD)	Estimated Cost to Treat to 1.0 mg/l		Estimated Cost to Treat to 0.5 mg/l		Source of Cost Inform-ation
		Low End	High End	Low End	High End	
Algonquin, Village of	5.0	Already meet 1 mg/L monthly ave.		Not available		
Barrington, Village of	3.68	$350,000	$10,380,000	Not available		Figs. 5-43 & 5-44
Batavia, City of	4.2	$350,000	$11,670,000	Not available		Figs. 5-43 & 5-44
Cary, Village of	2.8	$350,000	$8,200,000	Not available		Figs. 5-43 & 5-44
Carpentersville, Village of	4.5	$360,000	$12,410,000	Not available		Figs. 5-43 & 5-44
East Dundee, Village of	2.3	Already upgraded to BNR		Not available		
Elburn, Village of	1.266	$7,650,000		$9,970,000		Plant Study
Fox Metro Water Reclamation District	42	$84,000,000		$87,500,000		Plant Study
Fox River Grove, Village of	1.25	$310,000	$4,360,000	Not available		Figs. 5-43 & 5-44
Fox River Water Reclamation District	37.75 (combined)	$39,800,000		$89,100,000		Plant Study
Geneva, City of	5.0	$651,000	$1,608,000	$3,860,000	$5,668,000	Plant Study
Northern Moraine Water Reclamation District	2.0	$158,000	$579,000	$5,100,000		Plant Study
St. Charles, City of	9.0	$7,370,000		$15,418,000		Plant Study
Wauconda, Village of	1.9	Already meet 1 mg/L monthly ave.		Not available		
Yorkville-Bristol Sanitary District	3.62	$592,000		$636,000		Plant Study
Total Est. Cost		**$142,251,000**	**$192,979,000**	Not available		

Table 5-9: Estimated Capital, O&M and Present Worth Costs of Enhanced Phosphorus Removal from Major WWTPs with Effluent Limit of 1.0 mg/L[16].

Permittee	Estimated Capital Cost to Treat to 1.0 mg/l	Estimated Annual Operation and Maintenance Costs	Estimated Present Worth Cost
Algonquin, Village of	Already meet 1 mg/L monthly ave.		
Barrington, Village of	$5,365,000	Not available	Not available
Batavia, City of	$6,010,000	Not available	Not available
Cary, Village of	$4,275,000	Not available	Not available
Carpentersville, Village of	$6,385,000	Not available	Not available
East Dundee, Village of	Already upgraded to BNR		
Elburn, Village of	$7,650,000	$980,000	$9,891,500
Fox Metro Water Reclamation District	$84,000,000	$1,941,000	$116,500,000
Fox River Grove, Village of	$2,335,000	Not available	Not available
Fox River Water Reclamation District	$39,800,000	$410,000	$40,300,000
Geneva, City of	$811,000	$24,000	$1,300,000
Northern Moraine Water Reclamation District	$158,000	$116,000	$1,448,500[17]
St. Charles, City of	$7,370,000	$42,000	$8,216,000
Wauconda, Village of	Already meet 1 mg/L monthly ave.		
Yorkville-Bristol Sanitary District	$592,000	$284,000	$876,000
Total Est. Cost	**$164,751,000**	**$3,797,000+**	**$178,531,500+**

Based on currently available information, the estimated total capital cost for major WWTPs to upgrade their facilities to meet a 1.0 mg/l effluent TP limit will range from $142,251,000 to $192,979,000. Currently, there is insufficient information available to generate generalized estimates for treatment to 0.5 mg/l or 0.1 mg/l. In addition, most of the available plant-specific studies do not provide estimates for treating to 0.1 mg/l. When this information becomes available in the future, it will be incorporated into the FRIP.

Annual operating cost estimates and present worth estimates are currently available for the facilities that have completed their phosphorus removal feasibility study reports, as shown in Table 5-9. Using the available present worth estimates and the expected portion of total load removal attributable to these facilities, the expected cost per pound of phosphorus removed is $47 per pound over 20 years. Similarly, using the available present worth estimates and the expected portion of total load removal attributable to these facilities, as well as the estimated numbers of people they serve, the cost per capita per year for phosphorus removal to meet a 1.0 mg/L limit is $15 per person per year.

---

[16] Where source costs are presented as a range of values, the median value is presented in this table. Present worth costs are those estimated by each facility.

[17] Present worth estimate for Northern Moraine was calculated using n = 20 years and i = 6%.

5.9.2 Estimated Cost of Dam Removal

Due to the number of site-specific factors involved in dam removal, the range of potential costs is large and it is not practical to apply rules of thumb. As stated bv Santucci and Gephard (2003), the cost of each project "...appears to be driven by its own unique set of circumstances." In most cases, estimation of dam removal costs involve some level of site investigation and engineering evaluation. Some of the primary factors affecting dam removal are listed below (Santucci and Gephard, 2003):

- General plan – The components of the dam targeted for removal has a direct impact on cost. Removal may involve only partial or total spillway removal or it may involve removal of embankments as well.
- Volume of material – The cost of removal is proportional to the size of the dam.
- Nature of dam materials – More durable dams will be more expensive to remove; for example, removal of a reinforced concrete dam will likely cost more than removal of a timber crib dam.
- Water control – The greater the flow at the time of removal and the larger the river, the more expensive the removal will be.
- Sediment management – Dredging of sediments accumulated behind dams can increase cost, particularly if the sediments are contaminated.
- Construction access – As with any construction project, difficult access conditions can increase costs significantly.

As stated previously, Kane County Forest Preserve District and the Village of North Aurora have IGAs in place with the IDNR to further evaluate the removal of the Carpentersville and North Aurora Dams. These efforts will likely result in fairly robust estimates of removal costs. Removal cost estimates were previously developed as part of a study of public safety at dams, conducted by the engineering firm CTE on behalf of the IDNR (CTE, 2007). For purposes of the FRIP, it is reasonable to use these cost estimates until other information becomes available. The estimated costs for Fox River dams are presented in Table 5-10.

Table 5-10: Estimated Cost of Dam Removal for Carpentersville and North Aurora Dams (CTE, 2007).

Dam	Estimated Removal Cost (CTE, 2007)
Algonquin Dam	Dam removal cost estimate not provided
Carpentersville Dam	$940,000
Elgin Dam	$3,290,000
South Elgin Dam	$720,000
St. Charles Dam	$2,250,000
Geneva Dam	$2,380,000
North Batavia Dam	$2,030,000
North Aurora Dam	$1,550,000
Stolp Island Dam	$2,900,000
Montgomery Dam	$670,000
Total Dam Removal Estimate	$16,730,000

It should be noted that the removal of these dams is not being directed or managed by the FRSG, but these actions are included here as they as likely to occur in the near future and will likely have a beneficial impact on water quality in the Fox River. These cost estimates will be updated with new information after completion of the USACE study in 2017.

5.9.3 Estimated Cost of NPS Controls

Although no numeric NPS phosphorus load reduction targets are included in the FRIP for agricultural areas and MS4s, those entities will be encouraged to do what they can to reduce phosphorus loads and to track and report their load reduction efforts. As part of the FRIP, a literature review was completed to estimate load reduction benefits from NPS control measures, as well as unit costs, as documented in Attachment B. Using these recommended removal efficiencies and unit costs, in conjunction with unit area loading rates developed from the Fox River HSPF model, cost estimates were developed for varying load reduction targets from 1% to 20% of total NPS load from each category. These results are summarized in Tables 5-11 and 5-12.

Table 5-11: Estimated Costs for NPS Phosphorus Load Reductions from MS4s.

Load Reduction (% of total)	Load Reduction (lbs/yr)	Estimated Cost	Estimated Unit Cost ($/lb)
1%	1,383	$40,875,000	$29,555
5%	7,013	$179,430,000	$25,585
10%	14,035	$321,292,000	$22,892
20%	28,219	$927,167,000	$32856

Table 5-12: Estimated Costs for NPS Phosphorus Load Reductions from Agricultural Areas.

Load Reduction (% of total)	Load Reduction (lbs/yr)	Estimated Cost	Estimated Unit Cost ($/lb)
1%	3,619	$751,000	$208
5%	17,757	$2,422,000	$136
10%	36,192	$4,991,000	$138
20%	74,872	$10,055,000	$134

5.9.4 Summary of Alternatives and Costs

The alternatives described in Section 5.8 are summarized in Table 5-13.

Table 5-13: Total Phosphorus Load Reductions for Modeled Alternatives (not including NPS controls).

Alternative	Reduction of TP in WWTP Effluent to 1.0 mg/l	Reduction of TP in WWTP Effluent to 0.5 mg/l	Reduction of TP in WWTP Effluent to 0.1 mg/l	Reduction of Upstream TP Conc. To 0.1 mg/l	Reduction of Upstream TP Conc. To 0.05 mg/l	Removal of Carpentersville and North Aurora Dams	Removal of All Dams from Carpentersville to Montgomery	TP Load Reduction (lb/yr)
1	X					X		330,000
2	X			X		X		364,500
3	X	X				X		462,000
4	X	X		X		X		496,500
5	X	X		X	X	X		595,400
6	X	X	X	X	X	X	X	703,400

Cost ranges and TP load reduction estimates are presented in Table 5-14.

Table 5-14: Estimated Capital Costs and TP Load Removal for Alternatives.

Alternative	Estimated Capital Cost Range	TP Load Reduction Over 20 Years (lb)	Cost per Pound Over 20 Years
1	$145,887,000 - $223,614,000	6,600,000	$22 - $34
2	$145,887,000 - $223,614,000*	7,290,000	$20 - $31
3	**	9,240,000	**
4	**	9,930,000	**
5	**	11,908,000	**
6	**	14,068,000	**

*Costs for reducing upstream phosphorus not included.

**Estimated total costs for treatment to 0.5 and 0.1 mg/l not available.

6

Implementation

This section describes the overall approach to implementing actions and management measures to meet goals of the FRIP. The main topics covered here include the following:

- Need for Progressive Implementation and Monitoring
- Near-Term Actions
- Monitoring
- Additional Modeling
- Tracking of Actions
- Periodic Review
- Reporting
- Public Engagement

6.1 Need for Progressive Implementation and Monitoring

As discussed in Section 5, there are several significant limitations preventing clear selection of actions to meet the goals of the FRIP, including:

- There is significant uncertainty about the accuracy of the QUAL2K model used to simulate potential actions, particularly with respect to its prediction of dissolved oxygen in the river. Specifically, the model has been shown to over-predict minimum DO and under-predict maximum DO. In addition, the modeled DO is relatively insensitive to changes in phosphorus loading. This means there is uncertainty regarding the actual effects of recommended actions on DO, such as enhanced phosphorus removal at WWTPs and upstream water quality improvement. This concern does not apply to model predictions of total phosphorus and algae in the water column. The model DO limitations in predicting algae behavior may be due to a range of causes potentially including model code, specific characteristics of the river that are not represented in the model, or some combination of these. Further investigation will be required to resolve the problems if the QUAL2K model is used in the future.
- In addition to the model limitation noted above, simulations of dam removal using the current water quality model are not behaving as expected based on the dam removal literature. As the effects of dam removal may be significant, this is another issue that will require further investigation.
- Because of the limitations of the QUAL2K model, no combination of actions can be identified at this time to meet dissolved oxygen water quality standards in the Fox River at all locations and at all times of the year under 7Q10 low flow conditions.
- Because of this uncertainty, implementation of the FRIP will require an adaptive approach of implementing actions, evaluating the effectiveness of those actions and then planning additional actions deemed most appropriate.

6.2 Near-Term Actions

The actions planned for implementation are described below.

6.2.1 Municipal WWTPs

As described elsewhere in this document, NPDES permits have been, or soon will be, issued for all major (>1.0 MGD) municipal WWTPs in the FRIP study area, containing TP limits of 1.0 mg/l (annual average). The majority of these limits will go into effect in 2019 (Fox Metro's limits will go into effect in 2021).

6.2.2 Upstream TMDL

The IEPA has contracted for the development of a phosphorus TMDL for the Chain O'Lakes on the Fox River upstream of Stratton Dam. This TMDL is scheduled for completion by December 2016. When fully implemented, it is expected that water quality in the Chain O'Lakes will meet the State water quality standard for phosphorus (0.05 mg/l). Ongoing data collection will be used to show progress in meeting this goal.

6.2.3 Dam Removal

Kane County Forest Preserve District and the Village of North Aurora have intergovernmental agreements (IGAs) in place with the Illinois Department of Natural Resources (IDNR) to study and plan the removal of the Carpentersville and North Aurora Dams, respectively. These dams could potentially be removed within the next five years, but until the ongoing studies are completed, no schedule can be specified.

6.2.4 NPS Controls

The FRIP does not include numeric phosphorus load reductions for MS4's at this time. Specific MS4 actions will be evaluated in the future as improvements to modeling tools and additional data acquisition are completed. MS4 phosphorus load reductions will indirectly result from compliance with NPDES Phase II permit requirements and local and county wide stormwater management ordinances, as well as CSO abatement efforts. MS4 jurisdictions will track their NPS load reduction projects and submit a report to the FRSG annually, as described in Section 6.5. The FRSG will compile all voluntarily submitted information on NPS control measures implemented in agricultural areas.

6.2.5 Expected Load Reduction for Near-Term Actions

The actions described above are expected to reduce total phosphorus loading to the Fox River by at least 463,400 lbs. per year on average, as broken down in Table 6-1. In addition to improving water quality in the Fox River, these load reductions will have water quality benefits on downstream water bodies and will reduce the overall export of nutrients from the State of Illinois to the Mississippi River and the Gulf of Mexico. The Illinois Nutrient Loss Reduction Strategy calls for an overall nutrient reduction of 45% statewide, and the actions outlined here will result in approximately a 35% reduction in phosphorus loading to the Fox River. .

Table 6-1: Expected Annual Average Total Phosphorus Load Reduction for Near-Term Actions.

Action	Current Annual TP Load (lb/yr)	TP Load Reduction (lb/yr)
Major WWTP TP Limits of 1.0 mg/l	600,000	330,000
Upstream TMDL Implemented	201,000	133,400
Carpentersville and North Aurora Dams Removed	0	0
MS4 NPS Load Reduction	141,000	Unknown
Agricultural NPS Load Reduction	349,000	Unknown
Total Load Reduction	1,320,000	463,400+

6.2.6 Water Quality for Near-Term Actions in July and August

As discussed in Section 5, when each month of the year was modeled independently, July and August were the only months when minimum DO was predicted to sag below the applicable DO water quality criterion for each month. The near-term actions described above were simulated using the Fox River water quality model to observe the potential effects of the actions on water quality. The results are depicted in Figures 6-1 through 6-3 for the month of July and in Figures 6-4 through 6-6 for August.

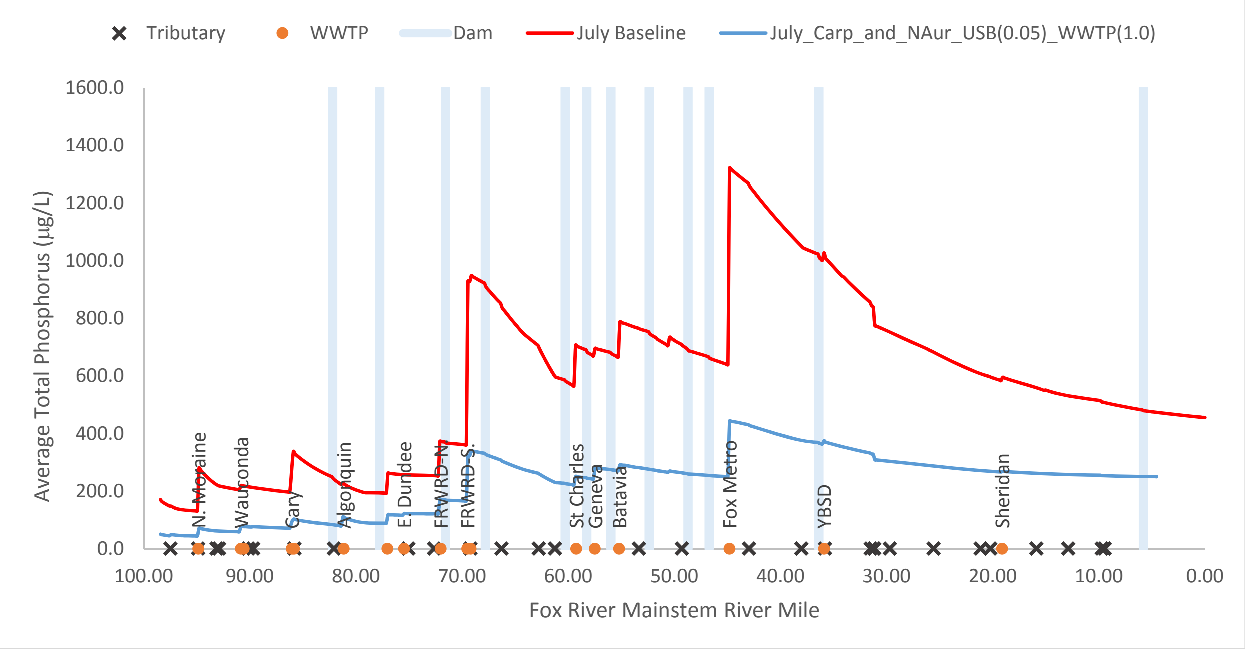
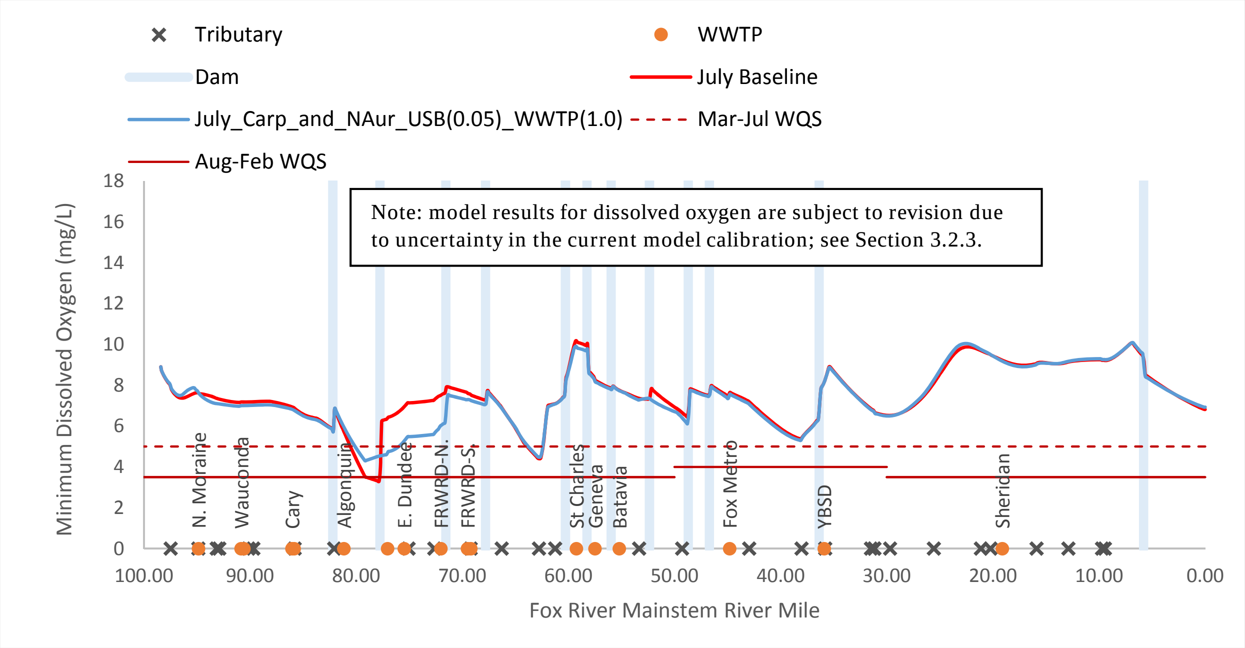


Figure 6-1: QUAL2K Total Phosphorus Results for Near-Term Actions – July.



Note: model results for dissolved oxygen are subject to revision due to uncertainty in the current model calibration; see Section 3.2.3.

Figure 6-2: QUAL2K Minimum Dissolved Oxygen Results for Near-Term Actions – July.

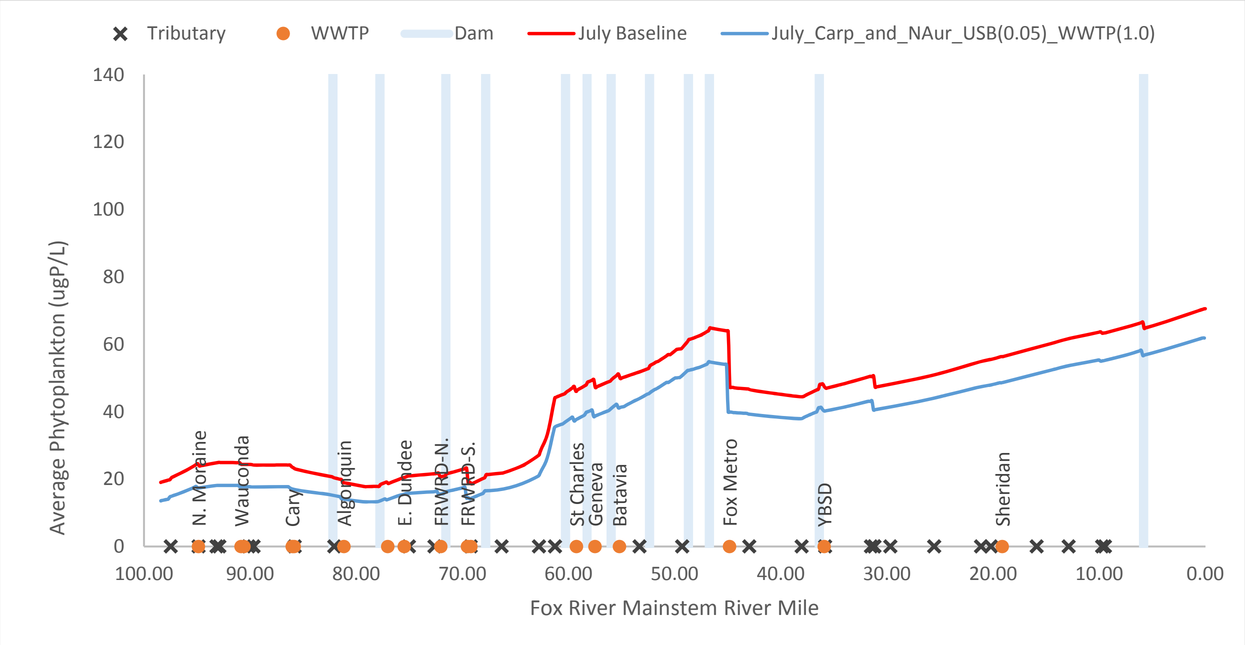


Figure 6-3: QUAL2K Average Phytoplankton Results for Near-Term Actions – July, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

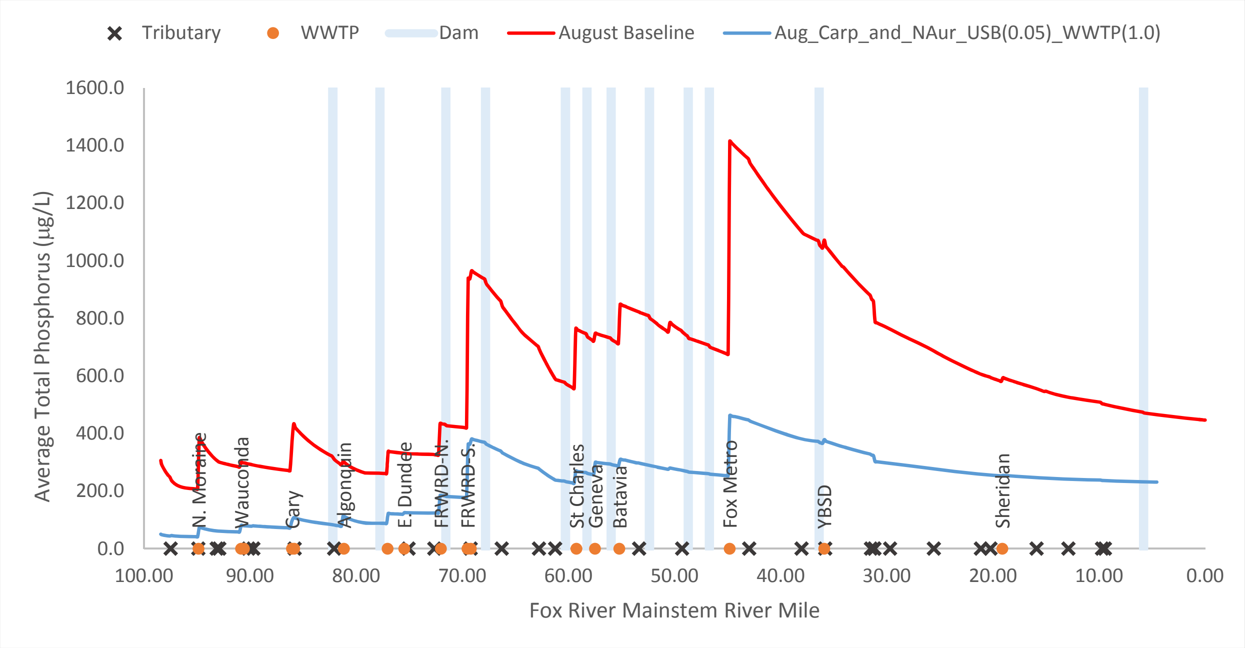


Figure 6-4: QUAL2K Total Phosphorus Results for Near-Term Actions – August.

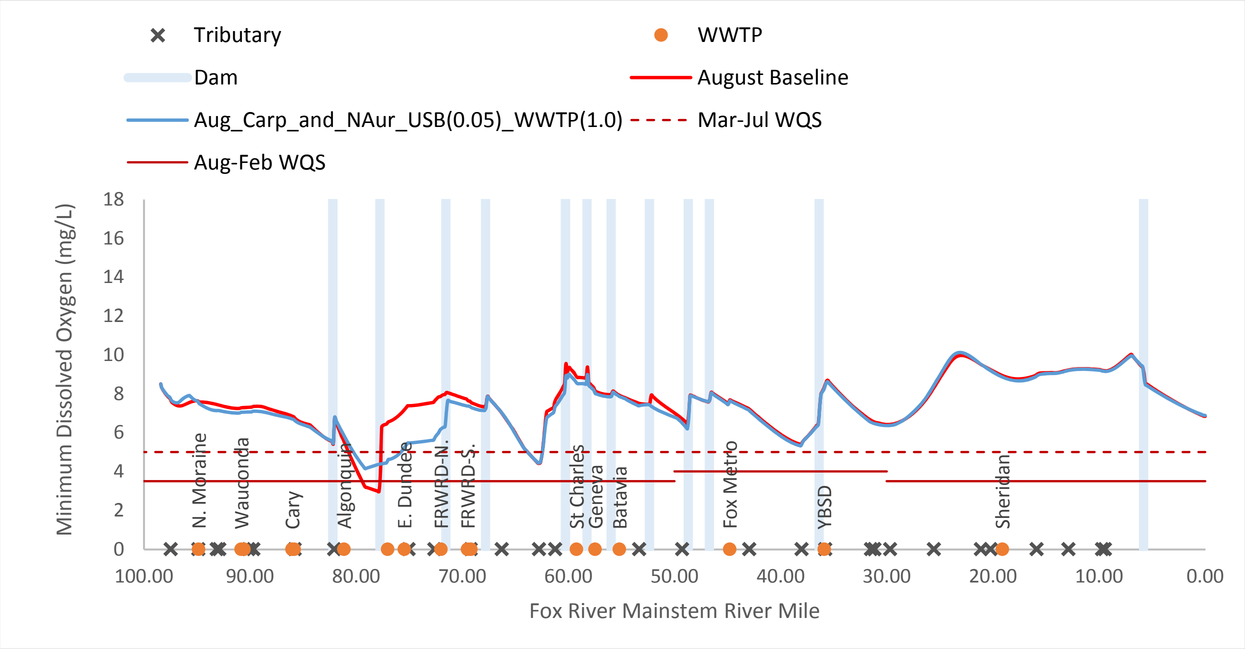


Figure 6-5: QUAL2K Minimum Dissolved Oxygen Results for Near-Term Actions – August, Showing Little Response in DO to Reduced Phosphorus Loading and Counterintuitive Results from Dam Removal.

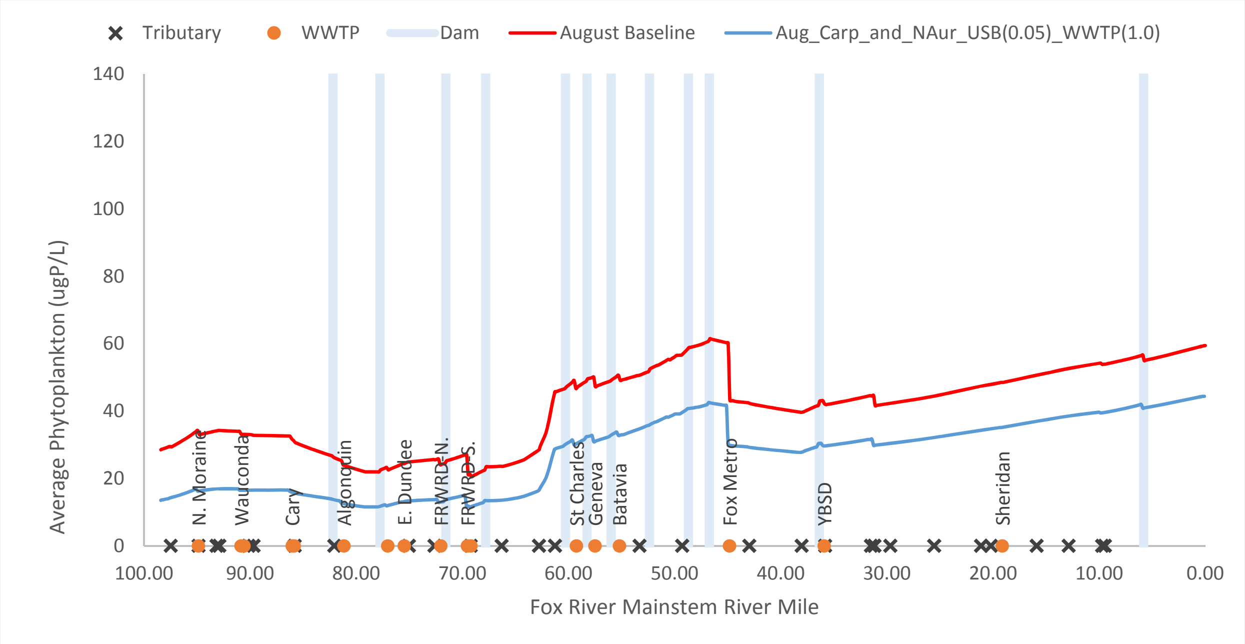


Figure 6-6: QUAL2K Average Phytoplankton Results for Near-Term Actions – August, Showing Decrease in Phytoplankton with Decreased Phosphorus Loading.

Based on the model results presented above, the near-term actions described here should result in measurable reductions in total phosphorus concentrations in the river, as well as some reduction in algae during July and August under low flow conditions. However, although the actions are to be implemented in the next ten years, it is possible that water quality improvements may take longer to occur, especially those related to the implementation of the TMDL for the Chain O'Lakes upstream of the FRIP study area.

6.3 Monitoring

The FRSG will continue to be a clearinghouse for relevant water quality data collected by stakeholders and others. Members of the FRSG will submit effluent monitoring and water quality data they collect to the FRSG. The ISWS will continue to update the Fox River database with these new data.

Collection of data upstream and downstream of the Carpentersville and North Aurora Dams, both before and after removal (if they are removed), can be extremely valuable in better understanding the potential effects of dam removal in the Fox River. The FRSG will coordinate with the Illinois DNR regarding data collection associated with the potential removal of these dams, including water quality, biotic and physical data.

In 2016, the FRSG will develop a strategy for future data collection and prepare written plan(s) that may potentially include the following:

- Additional water quality monitoring
- Investigation in the vicinity of Algonquin and South Elgin Dams to verify low-DO, high benthic algae areas predicted by current model
- Discussion with IEPA and IDNR of biological data to assess actual condition of aquatic community and potentially identify gaps in existing biological data.

- In partnership with government agencies such as the IEPA, IDNR, and USACE collect water quality and biological data around the Carpentersville and North Aurora dams to assess the impacts of removal of those dams

The FRSG also plans to coordinate with IEPA and IDNR to discuss Intensive Basin sampling that is scheduled for 2017. Once plans are determined, the FRSG will update the necessary Quality Assurance Project Plans (QAPPs) to insure data quality and usability.

6.4 Additional Modeling

Because of the limitations of the current Fox River QUAL2K water quality model in simulating DO in the river, it is understood that an improved modeling approach is needed. At a minimum, this would involve investigation and correction of the current model's limitations, but other alternatives are possible. Within the next year, the FRSG will solicit expert recommendations on model improvement and develop a plan for future modeling.

6.5 Tracking of Actions

The FRSG will track actions taken by municipal WWTPs and MS4 jurisdictions and this information will be reported annually to the IEPA (see Section 6.7). Major municipal WWTPs will report the status of their phosphorus treatment improvements to the FRSG annually and, as part of that report, will provide estimates of annual average phosphorus load reductions from completed actions.

MS4 jurisdictions will be required to track and submit annual reports to the FRSG summarizing stormwater management actions that have been implemented, along with the estimated annual average phosphorus load reduction for each action and the total estimated annual load reduction. A spreadsheet-based tracking and reporting tool has been developed for use by the MS4 jurisdictions for this purpose (Attachment E).

In addition to the above tracking activities, the FRSG will issue an annual request to parties not regulated by NPDES or MS4 permits to submit information on activities they have completed that may result in load reductions and/or water quality improvements in the Fox River.

6.6 Periodic Review

The FRSG will conduct a review of the FRIP every five years to determine the need for an update to the FRIP and, if needed, what that update should include. The five-year FRIP review will include, but not necessarily be limited to, the following:

- A review of data collected since completion of the FRIP and an evaluation of whether that data indicates new findings or the need for additional actions.
- An evaluation of the need to revisit the modeling needed for FRIP implementation.
- Comparison of water quality improvement actions implemented with those that were planned in the prior version of the FRIP.
- Assessment of new information leading to additional water quality improvement actions or changes in previously planned water quality improvement actions.

A summary of the review and the FRSG decision regarding the need for a FRIP update will be submitted in writing to the IEPA. Note that, under this schedule, the first FRIP review and update will occur in 2019-2020. Since the new TP limit of 1.0 mg/l for most of the major WWTPs will not be effective until 2019, it is unlikely that monitoring data will reveal all the benefits of scheduled phosphorus reductions.

6.7 Reporting

The FRSG will submit an annual letter report to the IEPA summarizing the following information:

- A description of water quality improvement actions completed in the preceding year, the cost of those actions and the expected reduction in annual total phosphorus loading that will occur as a result.
- A status update on ongoing water quality improvement actions underway.
- A description of water quality improvement actions expected to be completed in the coming year.
- A summary of data collected in the preceding year, along with a description of changes in planned data collection and the reason for changes, if any.
- Identification of problems encountered with water quality improvement actions and potential remedies identified, if any.
- A summary of public engagement activities conducted during the year.

The annual report will be submitted by the end of March for each preceding calendar year.

6.8 Public Engagement

Development of the FRIP has been a stakeholder-driven process and its implementation will continue to rely on dissemination of information to the public. The following public engagement activities will be continued by the FRSG:

- The FRSG will continue to maintain and update its web site (http://www.foxriverstudygroup.org/). Reports, presentations and other materials of interest will be made available for download from the web site.
- The monthly FRSG meetings will continue to be open to the public. This meeting is currently held the fourth Thursday of each month, except in November and December when the meeting is held on the third Thursday. Schedule changes will be posted on the FRSG web site.
- The FRSG will continue to hold an annual meeting at which updated presentations of recent activities will be presented to the public.

Additional public engagement activities may be conducted if deemed necessary by the FRSG Board.

6.9 Ten-Year FRIP Action Plan

The planned activities described above items are summarized on a ten-year timeframe in the Action Plan presented as Table 6-2.

Table 6-2 Ten-Year FRIP Action Plan.

Year	Actions To Be Taken by FRSG
2016	• Develop strategy for monitoring/investigation/sampling; prepare written plan(s) to potentially include: o Collection of additional water quality data o Collection of dissolved oxygen data in the vicinity of Algonquin and South Elgin to verify low-DO areas predicted by current model o Discussion with IEPA and IDNR of biological data to assess actual condition of aquatic community; identify gaps o In partnership with IEPA, IDNR, ACE, collection of water quality and biological data around the Carpentersville and North Aurora dams to assess the impacts of removal of those dams, if implemented • Begin implementing the monitoring/investigation/sampling plan(s) as appropriate; coordinate with IEPA and IDNR to discuss Intensive Basin sampling in 2017 • Update/modify Quality Assurance Project Plan (QAPP) for planned data collection activities • Solicit expert recommendations on model improvement and develop plan for model improvement • Develop plan to further investigate issues related to river flow, including augmentation, potential upstream diversions, and the levels of flows when we see problems with DO and algae in the river • Major WWTPs design plant modifications to attain annual effluent TP limit of 1.0 mg/L and continue to assess feasibility of reducing phosphorus to lower levels • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • MS4 permittees shall begin documenting phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Develop strategy with farm bureaus and SWCDs for yearly collection of information on control measures implemented on farmland • Participate in Upper Fox/Chain O'Lakes and Upper Fox/Flint TMDL • Develop 10-year funding plan; update FRSG's structure for financial support from watershed communities • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS • Coordinate with FREP efforts to establish a bistate Fox River National Water Trail • Present FRIP at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA

Year	Actions To Be Taken by FRSG
2017	• Conduct monitoring/investigation/sampling as appropriate; coordinate with intensive sampling scheduled to be conducted by IEPA and IDNR • Implement plan for model improvement as appropriate • Investigate issues related to river flows • Major WWTPs begin plant modifications to attain annual effluent TP limit of 1.0 mg/L • MS4 permittees shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Agricultural community begins reporting phosphorus reductions reached through use of best management practices • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Review the findings of ACE's study of dams and incorporate into recommendations • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS • Coordinate with FREP efforts to establish a bistate Fox River National Water Trail • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA
2018	• Review 2017 Intensive Basin Survey results • Continue monitoring/investigation/sampling as appropriate • Implement plan for model improvement and use improved model to reevaluate water quality improvement scenarios as appropriate • Major WWTPs continue plant modifications to attain annual effluent TP limit of 1.0 mg/L • MS4 permittees and agricultural community continue implementing runoff control measures and report phosphorus reductions achieved • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA

Year	Actions To Be Taken by FRSG
2019	• Annual TP limit of 1.0 mg/L becomes effective at all major WWTPs except Fox Metro • Continue monitoring/investigation/sampling • MS4 permittees and agricultural community continue implementing runoff control measures and report phosphorus reductions achieved • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Begin updating FRIP based on improved modeling & new data as appropriate • Re-evaluate goals and progress • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA
2020	• Continue monitoring/investigation/sampling • MS4 permittees and agricultural community continue implementing runoff control measures and report phosphorus reductions achieved • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Complete FRIP update using improved modeling & new data, submit to IEPA • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA
2021	• Annual TP limit of 1.0 mg/L becomes effective at Fox Metro • Continue monitoring/investigation/sampling as needed • Coordinate with IEPA and IDNR to discuss Intensive Basin sampling in 2022 • MS4 permittees and agricultural community continue implementing runoff control measures and report phosphorus reductions achieved • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Parties evaluate means for further load reduction called for in updated FRIP, if different from original recommendations • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA

Year	Actions To Be Taken by FRSG
2022	• Continue monitoring/investigation/sampling as needed; coordinate with intensive sampling scheduled to be conducted by IEPA and IDNR • MS4 permittees and agricultural community continue implementing runoff control measures and report phosphorus reductions achieved • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Parties evaluate means for further load reduction called for in updated FRIP, if different from original recommendations • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA
2023	• Review 2022 Intensive Basin Survey results • Continue monitoring/investigation/sampling as needed • Parties begin implementing actions called for in updated FRIP • MS4 permittees and agricultural community continue to report phosphorus reductions achieved from implemented runoff control measures • WWTPs shall document phosphorus load reductions and shall report such reductions to the FRSG on an annual basis. • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA
2024	• Continue monitoring/investigation/sampling as needed • Parties implement actions called for in updated FRIP • MS4 permittees and agricultural community continue to report phosphorus reductions achieved from implemented runoff control measures • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA • Begin preparing updated FRIP

Year	Actions To Be Taken by FRSG
2025	• Continue monitoring/investigation/sampling as needed • Parties implement actions called for in updated FRIP • MS4 permittees and agricultural community continue to report phosphorus reductions achieved from implemented runoff control measures • Seek funding, as appropriate, for educational efforts and NPS projects from sources such as NREC, NRCS. • Update at Fox River Summit • Hold annual meeting • Prepare annual update for IEPA • Complete updated FRIP and submit to IEPA

Blank

7

References

Bartosova, A., 2013a. Basic documentation of ISWS HSPF Fox River Watershed models developed for the Fox River Study Group. Illinois State Water Survey, Champaign, IL. December 10, 2013.

Bartosova, A., 2013b. Fox River Watershed Investigation: Stratton Dam to the Illinois River, Phase III, Evaluation of Watershed Management Scenarios. Contract Report CR 2013-07, Illinois State Water Survey, Champaign, IL.

Bartosova, A., 2014. “Phosphorus in the Fox River Watershed.” Basic documentation of ISWS HSPF Fox River Watershed models developed for the Fox River Study Group. Illinois State Water Survey, Champaign, IL. December 10, 2013.

Bartosova, A., J. Singh, M. Rahim, and S. McConkey. 2011. Fox River Watershed Investigation: Stratton Dam to the Illinois River, PHASE II, Hydrologic and Water Quality Simulation Models, Part 4: Fox River Watershed Hydrology using the HSPF Model.

Bartosova, A., J. Singh, M. Rahim, and S. McConkey. 2007a. Fox River Watershed Investigation: Stratton Dam to the Illinois River PHASE II, Hydrologic and Water Quality Simulation Models Part 2, Blackberry Creek and Poplar Creek HSPF Models Calibration and Initial Simulation Results. Illinois State Water Survey Contract Report 2007-04, Champaign, IL.

Bartosova, A., J. Singh, M. Rahim, and S. McConkey. 2007b. Fox River Watershed Investigation: Stratton Dam to the Illinois River PHASE II, Blackberry Creek and Poplar Creek Hydrological and Water Quality Simulation Models, Calibration and Initial Simulation Results. Illinois State Water Survey Contract Report 2007-05, Champaign, IL.

Bartosova, A., J. Singh, M. Rahim, and S. McConkey. 2007c. Fox River Watershed Investigation: Stratton Dam to the Illinois River PHASE II, Hydrologic and Water Quality Simulation Models, Part 3: Validation of Hydrologic Simulation Models for the Brewster, Ferson, Flint, Mill, and Tyler Creek Watersheds. Illinois State Water Survey Contract Report 2007-07, Champaign, IL.

Bicknell, B.R, Imhoff, J.C., Kittle, J.L. Jr., Jobes, T.H. and A.S. Donigian. 2005. HYDROLOGICAL SIMULATION PROGRAM – FORTRAN, HSPF Version 12.2 User's Manual. Prepared by AQUA TERRA Consultants, Mountain View, CA. In Cooperation with the U.S. Geological Survey, Reston, VA and the U.S. Environmental Protection Agency, Athens, GA. July 2005.

CTE. 2007. Evaluation of Public Safety at Run of River Dams: An Illinois Statewide Program.

CDM Smith. 2015. Final Report: Phosphorus Removal Evaluation for the Geneva Wastewater Treatment Facility. March 2015.

Donigian, A.S. 2002. Watershed Model Calibration and Validation: The HSPF Experience. WEF National TMDL Science and Policy 2002, November 13-16, 2002. Phoenix, AZ. WEF Specialty Conference Proceedings on CD-ROM.

Donigian, A.S. 2000. HSPF Training Workshop Handbook and CD. Lecture #19. Calibration and Verification Issues, Slide #19-22. EPA Headquarters, Washington Information Center, 10-14 January, 2000. Presented and prepared for U.S. EPA, Office of Water, Office of Science and Technology, Washington, D.C.

Donigian, A. S., Imhoff, J.C., B. R. Bicknell, B.R. and J. L. Kittle. 1984. Application Guide for the Hydrological Simulation Program–FORTRAN, EPA 600/3-84-066, Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA.

Dragovich, Amy. IEPA. Personal communication, May 6 2015.

Engineering Enterprises, Inc. 2013. 2013 Facilities Plan for Village of Elburn, Kane County, Illinois.

Fox River Study Group. Mission Statement. http://www.foxriverstudygroup.org/mission.htm. Accessed July 1, 2015.

Illinois Environmental Protection Agency Bureau of Water (IEPA). 2014. Illinois Integrated Water Quality Report and Section 303(D) List. Clean Water Act Sections 303(d), 305(b) and 314. Water Resource Assessment Information and List of Impaired Waters. Volume I: Surface Water.

LimnoTech, 2014a. Memorandum to Fox River Study Group Board of Directors. DRAFT: Review of HSPF Application to the Fox River Watershed. February 13, 2014.

LimnoTech, 2014b. Memorandum to Fox River Study Group Board of Directors. DRAFT: Recalibration of Fox River QUAL2K Model in Response to Revised Sediment Code. August 22, 2014.

LimnoTech, 2014c. Memorandum to Fox River Study Group Board of Directors. Removal Efficiencies and Construction Costs for NPS control Measures. December 18, 2014.

McConkey, S., Bartosova, A., Lin, Lian-Shin, Andrew K., Machesky, M., and C. Jennings. 2004. Fox River Watershed Investigation – Stratton Dam to the Illinois River: Water Quality Issues and Data Report to the Fox River Study Group, Inc. Prepared by the Illinois State Water Survey, Watershed Science Section, Champaign, IL. Prepared for the Fox River Study Group, Inc. and the Illinois Environmental Protection Agency. March 2004.Santucci, V.J. and S. R. Gephard. 2003. Fox River Fish Passage Feasibility Study Final Report. Submitted to Illinois Department of Natural Resources.

Minnesota Department of Natural Resources (MnDNR). 2015. Barrier Effects on Native Fishes of Minnesota.

Pescitelli, Steve. 2014. Dam Fish Stories Status of Fox River Fishery: Effects of Dams and Benefits of Dam Removal. Illinois Dept. of Natural Resources. Presentation to the Fox River Study Group Annual Meeting. October 30, 2014.

Santucci, et. al. 2005. Effects of Multiple Low-Head Dams on Fish, Macroinvertebrates, Habitat, and Water Quality in the Fox River, Illinois. North American Journal of Fisheries Management 25:975–992.

Singh, J., A. Bartosova, M. Rahim, and S. McConkey. 2007. Hydrologic and Water Quality Simulation Models Part 1: Methodology and Procedures for Development of HSPF Models. Illinois State Water Survey Contract Report 2007-02, Champaign, IL.

Stoner, Nancy K. “A New Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program.” U.S. EPA memorandum to Regional Administrators. December 5, 2013.

Symbiont, Inc. 2011. Evaluation of Practical Technology-Based Effluent Standards for Phosphorus and Nitrogen in Illinois. Prepared for the Illinois Association of Wastewater Agencies, Urbana & Champaign Sanitary District. October 18, 2011.

U.S. EPA, Office of Water. 2007. Biological Nutrient Removal Processes and Costs. EPA-823-R-07-002. Washington, DC. June 2007.

U.S. EPA, Office of Watershed Management, Municipal Support Division, Municipal Technology Branch. 2008. Municipal Nutrient Removal Technologies, Reference Document. Volume 1 - Technical Report. EPA 832-R-08-006. September 2008.

Walter E. Deuchler Associates, Inc. 2014. Phosphorus Removal Feasibility Report. October 10, 2014.

Blank

Attachment A
FRIP NPDES Permit Language

Blank

<u>Language to Appear in all Fox River NPDES permits:</u>

SPECIAL CONDITION 15. This Permit may be modified to include alternative or additional final effluent limitations pursuant to either an approved Total Maximum Daily Load (TMDL) Study or an approved Fox River lmplementaf1on Plan.

SPECIAL CONDITION 16. The Permittee shall participate in the Fox River Study Group (FRSG). The Permittee shall work with other watershed members of the FRSG to determine the most cost effective means to remove dissolved oxygen (DO) and offensive condition impairments in the Fox River. This Permit may be modified to include additional conditions and effluent limitations to include implementation measures based on the Fox River Implementation Plan (Implementation Plan). The following tasks will be completed during the life of this permit:

a. The Permittee shall prepare a phosphorus removal feasibility report specific to its plant(s) on the method, time frame and costs for reducing its loading of phosphorus to levels equivalent to monthly average discharges of 1 mg/l, 0.5 mg/l, and 0.1 mg/l on a seasonal basis and on a year round basis. The feasibility report shall be submitted to the IEPA twelve (12) months from the effective date of the Permit. The feasibility report shall also be shared with the FRSG.

b. The Permittee shall submit the Fox River Study Group Watershed Investigation Phase Ill Report, which includes stream modeling, to the IEPA within 1 month of the effective date of this Permit.

c. The FRSG will complete an Implementation Plan that identifies phosphorus input reductions by point source discharges, non-point source discharges and other measures necessary to remove DO and offensive condition impairments in the Fox River. The Implementation Plan shall be submitted to the IEPA by December 31, 2015. The Permittee shall initiate the recommendations of the Implementation Plan that are applicable to said Permittee during the remaining term of this Permit. This Permit may be modified to include additional pollutant reduction activities necessary to implement the Implementation Plan.

d. In its application for renewal of this permit, the Permittee shall consider and incorporate recommended FRSG phosphorus input reduction implementation projects that the Permittee will implement during the next permit term.

e. The Permittee shall operate the existing facilities to optimize the removal of phosphorus.

SPECIAL CONDITION 18. A phosphorus limit of 1.0 mg/l (Annual Average) shall become effective six (6) years from the effective date of this Permit.

In order for the Permittee to achieve the above limit, it will be necessary to modify existing treatment facilities to include phosphorus removal, reduce phosphorus sources or explore other ways to prevent discharges that exceed the limit. The Permittee must implement the following compliance measures consistent with the schedule below:

A. Interim Report on Phosphorus Removal Feasibility Report	6 months from the effective date of this Permit
B. Phosphorus Removal Feasibility Report submitted	12 months from the effective date of this Permit
C. Progress Report on Phosphorus Input Reductions and Implementation Plan	18 months from the effective date of this Permit
D. Progress Report on Recommendations of Implementation Plan	24 months from the effective date of this Permit
E. Plans and specifications submitted	29 months from the effective date of this Permit

F. Progress Report on Construction	36 months from the effective date of this Permit
G. Progress Report on Construction	42 months from the effective date of this Permit
H. Progress Report on Construction	48 months from the effective date of this Permit
I. Progress Report on Construction	54 months from the effective date of this Permit
J. Complete Construction	60 months from the effective date of this Permit
K. Progress Report on Optimizing Treatment System	66 months from the effective date of this Permit
L. Achieve Annual Concentration and Loading Effluent Limitation for Total Phosphorus	72 months from the effective date of this Permit

Compliance dates may be modified based on the results of the Phosphorus Removal Feasibility Report required by Special Condition 16 of this Permit. All modifications of this Permit must be in accordance with 40 CFR 122.62 or 40 CFR 122.63.

Reporting shall be submitted on the DMR's on a monthly basis.

REPORTING

The Permittee shall submit progress reports for items A, B, C, D, E, F, G, H, I J, K, and L of the compliance schedule indicating: a) the date the item was completed, or b) that the item was not completed, the reasons for non-completion and the anticipated completion date to the Agency Compliance Section.

Attachment B

Removal Efficiencies and Construction Costs for NPS Control Measures

Blank

LimnoTech
Water Environment | Scientists Engineers

501 Avis Drive
Ann Arbor, MI 48108
734.332.1200
www.limno.com

Memorandum

From: Virginia Breidenbach
Scott Bell
To: Fox River Study Group Board of Directors

Date: April 17, 2015
Project: Fox River Implementation Plan
CC:

SUBJECT: **Removal Efficiencies and Construction Costs for NPS Control Measures**

The purpose of this memo is to present draft planning-level total phosphorus (TP) removal efficiencies and unit construction costs for a selected set of cropland and urban non-point source (NPS) control measures for use in the Fox River Implementation Plan (FRIP) phosphorus load reduction alternatives.

The information is presented in the following sections:

- Intended Use and Application of NPS Control Removal Efficiencies and Costs
- Recommended NPS Control Measures
- Approach to Data and Information Collection
- NPS Control Measure Removal Efficiencies
- NPS Control Measure Construction Costs

Intended Application and Use of BMP Removal Efficiencies and Costs

The planning-level TP removal efficiencies and unit construction costs presented in this memo are intended for a specific use, which is to support the feasibility evaluation of hypothetical NPS controls in the FRIP. The FRIP will not recommend the type, location, or design of any specific NPS control measures. However, it will recommend NPS phosphorus load reductions that should be implemented to achieve water quality improvement in the Fox River on a subwatershed and jurisdictional basis. To evaluate whether any given level of phosphorus load reduction is feasible, it must be linked to potential effectiveness and cost.

Removal efficiencies are needed to calculate the load reduction resulting from assumed levels of NPS control measure implementation, which can then be compared to the desired level of load reduction determined through water quality modeling. Unit costs are needed to provide a basis for comparing actions and to assess the feasibility of a given level of implementation, relative to the cost. Because the evaluation does not involve specific projects, it is necessary to use a unit cost methodology that is based on land area treated, as opposed to physical size of the NPS control measure. Because this type of unit cost is not typically available, it was necessary to develop a method for calculating this type of unit cost, as discussed later in this memo.

Recommended Nonpoint Source Control Measures

NPS control measures selected for use in the pollutant load reduction alternatives are described briefly in this section. A set of control measures is given for both cropland and urban applications. The control measures selected for use in the alternatives are meant to be representative of an array of common practices that might be chosen for controlling TP in the watershed. In the future, each jurisdiction and/or landowner will ultimately decide which control measures they will use in order to meet required load reductions.

Cropland

- Conservation tillage – any method of tillage in which the previous year's crop residue is left before and after planting the new crop. To be considered conservation tillage, at least 30% of the previous year's crop residue must remain after planting the New Year's crop.
- Constructed wetland - wetland cells built for runoff treatment through natural processes. Constructed wetlands are shallow depressions with controlled inflow and flow paths. Nutrients are removed in wetlands through physical and biological processes. Wetlands are often desirable due to their aesthetic and habitat value.
- Field borders - a strip of perennial vegetation established at the edge of a field by planting or by converting it from trees to herbaceous vegetation or shrubs (USEPA, 2003).
- Grassed waterways – broad grassed channels designed to reduce erosion while moving water away from adjacent crops. Grassed waterways are often used to stabilize eroding gullies.
- Nutrient management – minimizing nutrient movement through reduction in the amount of nutrients applied to crops. Nutrient management may involve developing nutrient budgets; optimizing type, timing, and method of application of nutrients; and considering environment conditions at a site (USEPA, 2003). Variable rate fertilizer application, which is currently gaining favor in Illinois, is included in this control measure.

Urban

- Bioretention – shallow depressions consisting of planted or mulched surfaces over specifically selected soils that are designed to detain or retain stormwater. Bioretention areas, which include rain gardens, infiltrate stormwater and may discharge it after treatment through an underdrain. Other infiltration BMPs, such as infiltration basins, may also be appropriate in areas of significant sand and gravel.
- Constructed wetland- wetland cells built for stormwater treatment through natural processes. Constructed wetlands are shallow depressions with controlled inflow and flow paths. Nutrients are removed in wetlands through physical and biological processes. Wetlands are often desirable due to their aesthetic and habitat value.
- Dry detention - basins designed to hold stormwater runoff for a minimum time period (e.g. 12 or 24 hours) to allow particles and associated pollutants time to settle before runoff is discharged. Dry basins do not have a large permanent standing pool of water; however, in some cases small pools are designed at the inlet and/or outlet of the basin (USEPA, 2014). Dry detention basins are being used less frequently in practice with

preference given to wet detention. However, there may be applications where dry detention is necessary due to site limitations, such as available surface area.

- Street sweeping – municipal cleaning of streets and/or parking lots by street sweepers on a planned schedule to remove sediment and roadway debris. Several types of street cleaning machines are available (mechanical broom, vacuum-assisted wet broom, and dry vacuum).
- Vegetated swale - vegetated, open-channels designed to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows along these channels, it is treated through vegetation slowing the water to allow sedimentation, filtering through a subsoil matrix, and/or infiltration into the underlying soils (USEPA, 2014).
- Extended wet detention - basins that have a permanent pool of water throughout the year. Water is displaced in the pool as new runoff enters the basin. Treatment of runoff occurs through settling and biological uptake by algae.

Stream restoration is also acknowledged as a potentially effective method for control of phosphorus in both cropland and urban settings. However, deriving a single representative phosphorus load reduction value for stream restoration projects is more difficult than for other control measures because site specific factors such as channel geometry, stream order, length of restored stream, local hydrology, soil conditions and many others, influence the effectiveness of each project in removing nutrients. This is the finding by an expert panel convened for the Chesapeake Bay Total Maximum Daily Load (TMDL) for the purposes of defining nutrient and sediment load reduction targets for stream restoration projects (Berg, et. al., 2013). For “general watershed planning purposes”, the panel recommends use of a 0.068 lb/ft/yr removal rate for total phosphorus (Berg, et. al., 2013). However, this number was determined from six stream restoration monitoring studies in the Chesapeake Bay area and incorporates a sediment delivery ratio of 0.175 calculated for those watersheds. Due to the limitations in of applying a standard TP removal rate for stream restoration projects, it recommended that each project be assessed individually.

Approach to Data and Information Collection

National guidance documents and best management practice (BMP) manuals are available that provide both pollutant removal efficiencies and costs for various urban and rural NPS control measures. However, for the FRIP pollutant reduction alternatives, local information from NPS control measure applications in Illinois was desired wherever possible. Therefore, LimnoTech obtained and reviewed available final project reports from the IEPA Section 319 program and the Illinois Green Infrastructure Grant (IGIG) program for reported removal efficiencies and construction costs. Projects to review were selected from descriptions found in the Section 319 Binnual Report (IEPA, 2014c) and IGIG Biannual Report (IEPA, 2014b). Reports were requested and received from IEPA for projects in which one or more cropland and urban control measures from the list given above were applied. A total of 18 project reports (ten Section 319 and eight IGIG program reports) were reviewed, as listed in the References section. Information on two additional projects (CSO Control IGIG and McCarty Park) was provided to LimnoTech by the City of Aurora (Eric Schoeny, personal communication, October 14, 2014). National and regional guidance documents and manuals were referenced for TP removal efficiencies and construction costs where Illinois-specific information was not available.

NPS Control Measure Removal Efficiencies

This section presents the control measure removal efficiencies for TP that will be applied in the FRIP pollutant reduction alternatives. The available data and information reviewed to select these values and limitations and assumptions are described below.

Available data and information

The IEPA Section 319 and IGIG program final project reports described above were reviewed for TP removal information. For both IEPA programs, project proponents are required to estimate the pounds of nutrients and sediment removed on an annual basis from the project through use of a Microsoft Excel workbook titled “Estimating Pollutant Load Reductions for Nonpoint Source Pollution Control BMPs” (NPS Pollution Control Workbook; IEPA, 2014a), which has been approved by USEPA Region 5. The workbook calculates pollutant removal for both rural and urban BMP applications.

Pollutant removal for rural control measures is generally based on Universal Soil Loss Equation (USLE) calculations using assumed soil phosphorus concentrations by soil type. Therefore, pollutant load reductions are based on reductions in sediment delivery due to watershed alteration vs. treatment efficiencies. For urban control measures, pollutant removal is calculated using a defined set of pollutant removal efficiencies.

All of the urban control measures for the FRIP pollutant reduction scenarios, as well as the cropland control measure field borders, are included in the IEPA workbook. The TP removal efficiencies are given in Table 1. These values are within the range of values found in other BMP manuals.

Table 1: Total Phosphorus Removal Efficiencies for Cropland and Urban NPS Control Measures in NPS Pollution Control Workbook (IEPA, 2014a).

NPS Control Measure	TP Removal Efficiency (%)
Cropland	
Field borders	61[1]
Urban	
Bioretention	65[2]
Constructed wetland	44
Dry detention	26
Street sweeping (weekly)	6
Vegetated swales	25
Extended wet detention	68

[1] Assumed to have same removal efficiency as given for agricultural filter strips.

[2] Assumed to have the same removal efficiency as infiltration basins. This assumption is consistent with Section 319 and IGIG project reports reviewed.

For the cropland control measures with no removal efficiencies in the IEPA workbook, other sources were reviewed. A summary of removal efficiencies for these control measures is given in Table 2.

Table 2: TP Removal Efficiencies and Sources for Other Cropland NPS Control Measures

NPS Control Measure	TP Removal Efficiency (%)	Source
Cropland		
Constructed wetlands	34	Kroeger, et. al., 2007
	20-68[1]	LimnoTech, 2011
Conservation tillage	45[2]	USEPA, 2003
	25-80[3]	USEPA, 1986
	66-91[4]	MDA, 2012
Grassed waterways	30[2,5]	USEPA, 2003
	40-50	USEPA, 1986
Nutrient management	35[2]	USEPA, 2003

[1] Range of literature values from 10 studies of constructed wetlands in agricultural settings

[2] Represents a summary of literature findings.

[3] Range for low-till and no-till.

[4] From a study of no-till corn and soybeans in Iowa.

[5] As given for diversion systems.

Recommended TP removal efficiencies

The TP removal efficiencies that will be used in the FRIP pollutant reduction alternatives for the cropland and urban control measures are given in Table 3 with rational for their selection.

Table 3: Recommended Total Phosphorus Removal Efficiencies for FRIP Pollutant Reduction Scenarios.

NPS Control Measure	TP Removal Efficiency (%)	Rational
Cropland		
Conservation tillage	66	Most recent data; Low end of range from Iowa study with same crops as Fox River watershed
Constructed wetlands	44	Average of literature review values; consistent with IEPA value for urban watersheds
Field borders	61	USEPA approved value for IEPA projects
Grassed waterways	30	Most recent USEPA literature review value
Nutrient management	35	Most recent USEPA literature review value
Urban		
Bioretention	65	USEPA approved value for IEPA projects
Constructed wetland	44	USEPA approved value for IEPA projects
Dry detention	26	USEPA approved value for IEPA projects
Street sweeping (weekly)	6	USEPA approved value for IEPA projects
Vegetated swales	25	USEPA approved value for IEPA projects
Extended wet detention	68	USEPA approved value for IEPA projects

Limitations and assumptions

The TP removal efficiencies given in Table 3 assume that NPS control measures are sized appropriately for water quality treatment of runoff and that control measures are properly maintained for optimum function over time. For the cropland control measures, nutrient removal is dependent on crop type/rotation and fertilizer application. The given removal efficiencies are therefore only appropriate for use on a larger-scale planning basis.

NPS Control Measure Construction Costs

This section presents NPS control measure construction costs that will be used in the FRIP to evaluate load reduction scenarios. The available data and information reviewed to select construction cost values, the approach to developing costs on a per-acre treated basis, and limitations and assumptions are described below.

Available data and information from Illinois sources

Construction costs were available in the Section 319 and IGIG project reports for a number of the cropland and urban control measures. Costs reported were converted to 2014 dollars and are summarized in Table 4 below.

Table 4: Summary of NPS Control Measure Construction Costs from IEPA Section 319 and IGIG Program Projects (2014 dollars)

NPS Control Measure	Cost basis	Median (or single value)	Min	Max	Total area or length represented by data set	Number of BMPs
Cropland						
Conservation tillage	$/acre	$23.52			10,000 acres	1[1]
Constructed wetlands		*Not compiled; BMP added based on FRSG comments*				
Grassed waterways	$/acre	$7,732	$3,919	$15,932	15.1 acres	6
Urban						
Bioretention	$/s.f.	$19.21	$3.64	$57.06	1.4 acres	25
Constructed wetland	$/acre	$188,086	$88,388	$236,519	6.4 acres	3
Dry detention	$/acre	$57,998			4.68 acres	1
Vegetated swales	$/acre	$850,781	$622,567	$1,078,995	1.8 acres	4
	$/l.f.	$54.92	$43.88	$104.85	1,895 feet	6

[1] Strip-till project fields totaling 10,000 acres

No local cost information was obtained through Section 319 and IGIG document review for street sweeping and extended wet detention. Other references were reviewed for street sweeping, as given in Table 5.

Table 5: Summary of Costs for Street Sweeping (2014 dollars)

NPS Control Measure	Cost basis	Median (or single value)	Source
Urban			
Street sweeping (weekly)			
Mechanical	$/curb-mile per year	$2,727[1]	Ramsey-Washington Metro Watershed District, 2005
Vacuum	$/curb-mile per year	$1,537[1]	Ramsey-Washington Metro Watershed District, 2005

[1] Single reported value

For cropland control measures, Environmental Quality Incentives Program (EQIP) payments for FY2014 for Illinois were also compiled. EQUIP provides technical and financial assistance to producers for implementation of conservation practices. The program is administered by the Natural Resources Conservation Service (NRCS). Table 6 summarizes the FY2014 Illinois payments to producers that are available for the selected cropland control measures. The list of payment scenarios from which costs in Table 5 were developed is given in Attachment B.

Table 6. Summary of FY2014 EQUIP Program Illinois Payment Scenarios for Cropland Control Measures (2014 dollars)

NPS Control Measure	Cost basis	Median (or single value)	Min	Max
Cropland				
Conservation tillage[1]	\$/acre	\$14.28[2]		
Constructed wetland	\$/acre	\$8,542[3]	\$7,359	\$9,725
Field border	\$/acre	\$631	\$460	\$660
Grassed waterway[4]	\$/acre	\$4,053	\$2,748	\$5,481
Nutrient management	\$/acre	\$38.18	\$12.57	\$52.14

[1] No-till/strip till.

[2] A single payment value was given for this BMP.

[3] Average of light and dense planting

[4] Includes critical area planting; does not include mulching or underdrain.

Costs on per area treated basis

For the cropland control measures, per acre costs for conservation tillage and nutrient management can be applied directly as costs/acre treated. For field borders and grassed waterways, the following assumptions are necessary to convert cost per acre of control measure to cost per acre treated:

Field borders
- Border width equals 30 feet for water quality benefit (NRCS, 2010a)
- Average field size in watershed is 260 acres (USDA, 2012)
- Area of field borders is 1.8% of field area (30-foot buffer on 260 acre field)

Grassed waterways
- Each grassed waterway treats 75 acres of cropland (USEPA, 1986)
- Area of each waterway is 2.5 acres (average of eight waterways installed in N. Fork Vermilion River project; Vermilion County SWCD, 2013)
- Using these assumptions, a 30-foot wide grassed waterway of 2.5 acres is 3,600 feet in length which is equivalent to the length of two sides of a 75 acre square field

Cost for constructed wetlands in cropland were evaluated as for urban constructed wetlands and adjusted based on the FY2014 EQIP payments, as described below.

For the urban control measures, the Section 319 and IGIG reports reviewed provided construction costs for numerous BMPs. However, information on drainage areas treated and land uses within the drainage areas was not available in most cases. Therefore, these costs could not be translated from a cost/acre of control measure to a cost/acre treated basis. For this reason, other sources were sought to translate control measure costs to the area treated basis. Compiled Illinois-specific control measure costs were then used to verify the selected volume treated-basis costs as described below.

Urban BMP retrofit construction costs are given in the Center for Watershed Protection's "Urban Stormwater Retrofit Practices Manual" (CWP, 2007) on a cost/volume treated basis, as given in

Table 7. These costs were developed from an extensive national literature review described in CWP, 2007.

Table 7. NPS Control Measure Construction Costs on Volume Treated Basis from CWP, 2007 (2014 dollars)

NPS Control Measure	Median ($/c.f.-treated)	Min ($/c.f.-treated)	Max ($/c.f.-treated)	CWP, 2007 Category
Constructed wetland	$6.00	$3.00	$11.00	New storage retrofit
Dry detention	$6.00	$3.00	$11.00	New storage retrofit
Wet detention	$6.00	$3.00	$11.00	New storage retrofit
Vegetated swale	$14.80	$8.00	$26.00	Water quality swale retrofit
Bioretention	$12.00	$9.00	$20.00	Larger bioretention retrofits
	$35.00	$30.00	$47.00	Small bioretention retrofits
	$5.00	$4.00	$6.00	Rain garden retrofits

Application of the costs in Table 7 requires calculation of the volume to be treated by NPS control measures. This volume will be calculated as the water quality volume (WQv) according to the following equation:

$$\text{WQv (c.f.)} = P*(0.05+0.009*I)*A*43{,}560/12$$

Where,

P = 90th percentile precipitation (inches)

I = percent impervious area of the drainage area (expressed as a whole number)

A = drainage area (acres)

The fraction impervious area will be determined for each land use/land cover in GIS, using the National Land Cover Database (NLCD) impervious surface areas. Total costs calculated using the ‘per volume’ treated costs can then be converted to a per acre treated basis using the drainage area.

Since costs can vary widely across the country, the values in Table 7 were compared to the Illinois-specific BMP construction costs in Table 4 using hypothetical watershed scenarios representing the range of expected applications (i.e., large drainage area, low impervious area and small drainage area, high impervious area) and assumed control measure sizing criteria for each type of BMP. The minimum values from Table 7 were found to best represent the range of costs from the Illinois BMP projects. For bioretention, the range of Illinois project BMP costs were represented best by the “larger bioretention retrofits” costs from CWP, 2007. For constructed wetlands in cropland, one-half of the minimum value from Table 7 best represented the FY2014 EQIP payments given in Table 6.

There is no clear way to determine an area-based unit cost for street sweeping, as it depends on length of curb swept and road widths. For this control measure, it is recommended that costs be determined by each jurisdiction on a project-specific basis.

Recommended NPS control measure costs

The NPS control measure construction costs that will be used in the FRIP pollutant reduction alternatives for the cropland and urban control measures are given in Table 8 with rational for their selection. Note that costs are for construction only; additional costs, such as reduced cropland productivity due to land converted to controls, are not included.

Table 8: Recommended NPS Control Measure Construction Costs for FRIP Pollutant Reduction Scenarios (2014 dollars).

NPS Control Measure	Cost Basis	Cost	Rational
Cropland			
Conservation tillage[1]	$/acre-treated	$14.30	EQIP FY2014 payment
Constructed wetland	$/ c.f.-treated	$6.00	Median value from CWP, 2007
Field border	$/acre-treated	$11.30	Median of EQIP FY2014 payments with sizing assumptions listed above
Grassed waterway	$/acre-treated	$135	Median of EQIP FY2014 payments with sizing assumptions listed above
Nutrient management	$/acre-treated	$38	Median of EQIP FY2014 payments
Urban			
Bioretention	$/c.f.-treated	$20.00	Maximum value for larger bioretention retrofits from CWP, 2007
Constructed wetland	$/c.f.-treated	$6.00	Median value from CWP, 2007
Dry detention	$/c.f.-treated	$6.00	Median value from CWP, 2007
Street sweeping (weekly)	$/curb-mile-per year	$2,100	Median of Table 5 values
Vegetated swales	$/c.f.-treated	$14.80	Median value from CWP, 2007
Extended wet detention	$/c.f.-treated	$6.00	Median value from CWP, 2007

Limitations and assumptions

Site-specific control measure costs depend on a variety of factors that are cannot be represented in this planning level effort. Therefore, costs should be considered appropriate on a watershed scale application. Costs for field borders and grassed waterways are based on the sizing assumptions given above. It is assumed that urban control measures are sized to treat the runoff volume generated by the 90th percentile 24-hour rain event. The 90th percentile daily rainfall was calculated using long-term daily rainfall data from the National Climatic Data Center for the City of Aurora (1955-2015). The calculated 90th percentile daily rainfall value from this data set was 0.86 inches, which is recommended as a default planning value for the water quality volume calculation on the preceding page. Individuals and organizations wishing to use the unit costs in this memo for urban NPS control measures may use this default value or derive their own from local rainfall data.

Imperviousness of the drainage area captured by urban NPS control measures must also be known to use this approach. The median imperviousness for low-medium density and high density urban land cover areas was calculated from the values specified for all tributary areas modeled in the Fox River HSPF models. This calculated median value of 26% can be used as a default in the water quality volume calculation of users can determine their own imperviousness value. Note that this value should be used as a whole number in the calculation (e.g., 26% = 26).

References

Agahi and Miller. 2004. Sequoit Creek Watershed Management Plan.

Applied Ecological Services, Inc. 2007. Flint Creek Watershed-Based Plan Lake,Cook, and McHenry Counties, Illinois.

Applied Ecological Services, Inc. 2012. Spring Creek Watershed-Based Plan A Strategy for Protecting and Restoring Watershed Health.

Berg, et. al. 2013. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects.

Beverly Area Planning Association. August 6, 2013. Beverly Area Planning Association Green Parking Lot & Rain Garden Project.

Center for Watershed Protection. 2007. Urban Subwatershed Restoration Manual Series, Manual 3: Urban Stormwater Retrofit Practices. Version 1.0.

Champaign County Soil & Water Conservation District (Champaign Co. SWCD). 2012. Clean Water: Helping Agriculture Protect the Headwaters. Final Report Agreement Number 3191017.

Champaign County Soil & Water Conservation District (Champaign County SWCD). July 13, 2012. Clean Water: Helping Agriculture Protect the Headwaters.

Chicago Metropolitan Agency for Planning. July 2007. Poplar Creek Watershed Action Plan.

Chicago Metropolitan Agency for Planning. 2011. Blackberry Creek Watershed Action Plan.

Chicago Metropolitan Agency for Planning. 2011. Ferson-Otter Creek Watershed Plan. (pt1)

Chicago Metropolitan Agency for Planning. 2011. Ferson-Otter Creek Watershed Plan (pt2)

Chicago Metropolitan Agency for Planning. 2011. Silver Creek and Sleepy Hollow Creek Watershed Action Plan.

Citizens for Conservation Flint Creek Watershed Partnership. December 2010. Flint Creek Watershed Plan Implementation Projects – Final Report.

City of Aurora's Engineering Division. July 2013. Downer Place Bioinfiltration Project – Final Report.

City of Danville Engineering Division. October 2013. Danville High School Campus Improvement Project.

City of Tuscola. January 31, 2014. City of Tuscola NPS Pollution Reduction Project.

Farnsworth Group Inc. July 14, 2011. Kickapoo Creek Project - Phase 2 – Final Report.

Geosyntec. 2012. Jelkes Creek-Fox River Watershed Action Plan.

HDR. July 2012. Project Evaluation and Final Report - Kinkaid Lake TMDL Best Management Practices Implementation.

Illinois Environmental Protection Agency (IEPA). 2014a. Estimating Pollutant Load Reductions for Nonpoint Source Pollution Control BMPs. Microsoft Excel file.

Illinois Environmental Protection Agency (IEPA). 2014b. Illinois Green Infrastructure Grant Program for Stormwater Management Biannual Report.

Illinois Environmental Protection Agency (IEPA). 2014c. Section 319 Biannual Report.

Joliet Junior College. July 2011. Joliet Junior College Lake Clean-up and Management Project.

Kroeger, et. al., 2007. Efficiency of a small constructed wetland in southern Québec for treatment of agricultural runoff waters. *Moving forward wastewater biosolids sustainability: technical, managerial, and public synergy*. Greater Moncton Sewerage Commission. 1057-1062.

Lake County Stormwater Management Commission. December 2, 2013. North Branch Chicago River Watershed Project Final Report.

LimnoTech, 2011. Memorandum to Jim Gibson. Nutrient Treatment Efficiency of Bioretention Cells, Constructed Wetlands, and Retention Basins.

McDonough County Soil & Water Conservation District. July 13, 2012. Spring Lake TMDL Plan Implementation.

Minnesota Department of Agriculture (MDA). 2012. The Agricultural BMP Handbook for Minnesota.

Natural Resources Conservation Service. 2010a. National Handbook of Conservation Practices. Conservation Practice Standard: Field Borders Code 386.

Natural Resources Conservation Service. 2010b. National Handbook of Conservation Practices. Conservation Practice Standard: Grassed Waterway Code 412.

Natural Resource Conservation Service. 2014. Kane County, Illinois Field Office Technical Guide . FY2014 Payment Scenario Descriptions. http://efotg.sc.egov.usda.gov/references/public/IL/FY2014_IL_Payment_Scenario_Descriptions_Final_less_201_202.pdf

Nelson Land Management LLC. July 18, 2013. Green Infrastructure BMPs at Illinois State Fairgrounds – Final Report.

Obergfell and Miller. 2004. Squaw Creek Watershed Management Plan.

Preservation of Affordable Housing. January 2014. Woodlawn Center North Apartments – Final Report.

Ramsey-Washington Metro Watershed District. June 2005. Street Sweeping – Report No. 1: State of the Practice.

United States Environmental Protection Agency (USEPA). 1986. An Evaluation of the Cost Effectiveness of Agricultural Best Management Practices and Publicly Owned Treatment Works in Controlling Phosphorus Pollution in the Great Lakes Basin.

United States Environmental Protection Agency (USEPA). 2003. National Management Measures for the Control of Nonpoint Source Pollution from Agriculture. Office of Water. EPA-841-B-03-004

United States Environmental Protection Agency (USEPA). 2014. National Menu of Stormwater Best Management Practices. Website: http://water.epa.gov/polwaste/npdes/swbmp/

United States Department of Agriculture (USDA). 2012. 2012 Census of Agriculture. http://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Illinois/

Vermilion County Soil and Water Conservation District (Vermilion County SWCD). October 2013. North Fork Vermilion River Project - Phase IV Final Report.

Village of Franklin Park. January 14, 2014. Village of Franklin Park Police Station Final Report.

Village of Glenview. June 15, 2013. Final Report - Waukegan Road Urban Rain Garden.

Watershed Resource Consultants, Inc., et al. 2008. The Nippersink Creek Watershed Plan

Watershed Resource Consultants, Inc., et al. 2008. The Tyler Creek Watershed Plan.

Wight & Company. February 2011. Early Childhood Center Water Quality Improvement Project.

Wight & Company. August 2012. Greenbriar Elementary School Water Quality Improvements Project.

Attachment A

Detailed BMP Construction Costs for IEPA Section 319 and IGIG Program Projects

BMP	Cost per area (2014 dollars)	BMP Area Basis	Source
Cropland			
Conservation tillage	$24.41	acres	Champaign County SWCD, 2012
Grassed waterways	$5,666	acres	Vermilion County SWCD, 2013
	$3,919	acres	Vermilion County SWCD, 2013
	$6,705	acres	Vermilion County SWCD, 2013
	$15,932	acres	Vermilion County SWCD, 2013
	$11,841	acres	Vermilion County SWCD, 2013
	$8,759	acres	Vermilion County SWCD, 2013
Urban			
Bioretention	$11.78	s.f.	Wight & Company, 2011
	$10.34	s.f.	Lake County Stormwater Management Commission, 2010
	$26.64	s.f.	Lake County Stormwater Management Commission, 2010
	$3.64	s.f.	Wight & Company, 2012
Constructed wetland	$236,519	acre	Lake County Stormwater Management Commission, 2010
	$188,086	acre	Lake County Stormwater Management Commission, 2010
	$88,388	acre	Village of Franklin Park, 2014
Dry detention	$57,998	acre	Village of Franklin Park, 2014
Vegetated swales	$1,078,995	acre	Wight & Company, 2011
	$622,567	acre	City of Danville Engineering Division, 2013
	$54.92	l.f.	Lake County Stormwater Management Commission, 2010
	$43.88	l.f.	Lake County Stormwater Management Commission, 2010
	$48.75	l.f.	Lake County Stormwater Management Commission, 2010
	$100	l.f.	Lake County Stormwater Management Commission, 2010
	$105	l.f.	Village of Franklin Park, 2014

Attachment B

Illinois EQUIP Payment Scenarios for FY2014

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
329	Residue and Tillage Management - No-Till/ Strip Till/ D	No-Till/Strip-Till	Acre	$14.28	This practice typically involves conversion from a clean or mulch-tilled (conventional tilled) system to no-till or strip-till (conservation tilled) system on cropland. This involves managing the amount, orientation and distribution of crop and other plant residue on the soil surface year round while limiting soil-disturbing activities used to grow and harvest crops in systems.
412	Grassed Waterway	<35 foot top width	Acre	$2,553.91	Construct channel for a grassed waterway - earthwork only. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks is greater than 200 ft.
412	Grassed Waterway	35-55 foot topwidth	Acre	$2,712.40	Construct channel for a grassed waterway - earthwork only. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks is

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
412	Grassed Waterway	>55 foot topwidth	Acre	$3,339.33	Construct channel for a grassed waterway - earthwork only. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks is greater than 200 ft.
412	Grassed Waterway	<35 foot topwidth with checks	Acre	$3,263.71	Construct channel for a grassed waterway, including earthwork along with fabric or rock checks to temporarily protect the channel during the vegetative establishment period. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks equals 200 feet or less.
412	Grassed Waterway	35-55 foot topwidth with checks	Acre	$3,515.95	Construct channel for a grassed waterway, including earthwork along with fabric or rock checks to temporarily protect the channel during the vegetative establishment period. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
					equals
412	Grassed Waterway	>55 foot topwidth with checks	Acre	$4,096.01	Construct channel for a grassed waterway, including earthwork along with fabric or rock checks to temporarily protect the channel during the vegetative establishment period. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks equals 200 feet or less.
412	Grassed Waterway	<35 foot top width, crop seasonal construction	Acre	$3,413.27	Construct channel for a grassed waterway - earthwork only, with construction occurring during the cropping season and resulting in crop loss. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks is greater than 200 ft.

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
412	Grassed Waterway	<35 foot topwidth with checks, crop seasonal construction	Acre	$4,123.07	Construct channel for a grassed waterway, with construction occurring during the cropping season and resulting in crop loss. Includes earthwork along with fabric or rock checks to temporarily protect the channel during the vegetative establishment period. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks equals 200 feet or less.
412	Grassed Waterway	35-55 foot topwidth, crop seasonal construction	Acre	$4,001.44	Construct channel for a grassed waterway - earthwork only, with construction occurring during the cropping season and resulting in crop loss. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks is greater than 200 ft.
412	Grassed Waterway	35-55 foot topwidth with checks, crop seasonal construction	Acre	$4,804.99	Construct channel for a grassed waterway, with construction occurring during the cropping season and resulting in crop loss. Includes earthwork along with fabric or rock checks to temporarily protect the channel during the vegetative establishment period. Use 342 - Critical Area Planting for grass establishment. As needed, use 484 - Mulching for mulch or erosion control blanket and 620 - Underground Outlet to safely route trickle flow into a subsurface drain at the

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
					upstream end of the channel. As needed, use 606 - Subsurface Drain not to exceed a 6" diameter, to drain the channel adequately to grow grass. Use this scenario when the waterway length divided by the number of planned checks equals 200 feet or less.
342	Critical Area Planting	Grass or Grass/legume mix-normal tillage	Acre	$194.12	Establishment of permanent vegetation on a site that is void or nearly void of vegetation due to a natural occurrence or a newly constructed conservation practice. Costs include seedbed preparation with typical tillage implements, grass/legume seed, companion crop, and fertilizer and lime with application. Use this scenario for the seeding portion of 412 - Grassed Waterway.
342	Critical Area Planting	Grass or Grass/legume mix-moderate grading	Acre	$676.30	Establishment of permanent vegetation on a site that is void or nearly void of vegetation due to a natural or human disturbance. Costs include a dozer for grading and shaping of small gullies, seedbed preparation with typical tillage implements, grass/legume seed, companion crop, and fertilizer and
484	Mulching	Natural Material, Vegetation Establishment	Acre	$222.82	Apply straw mulch or other approved natural material. Use in conjunction with 342 - Critical Area Planting, where needed to facilitate establishment of vegetative cover on sites such as waterway or diversion channels, embankments and auxiliary spillways.
484	Mulching	Erosion Control Blanket, Vegetation Establishment	Acre	$5,342.67	Install erosion control blanket in concentrated flow areas where the designer with engineering job approval authority determines that typical straw or natural mulch material will not be adequate to stabilize the area during vegetative establishment. Use in conjunction with 342 - Critical Area Planting.

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
386	Field Border	Introduced Grass	Acre	$460.02	A strip of permanent vegetation consisting of introduced species established at the edge or around the perimeter of a field to control erosion and provide wildlife habitat. Includes seedbed preparation, seed, nurse crop, and all required fertilizer.
386	Field Border	Native Grass	Acre	$631.48	A strip of permanent vegetation consisting of native species established at the edge or around the perimeter of a field to control erosion and provide wildlife habitat. Includes seedbed
386	Field Border	Pollinator Habitat	Acre	$659.61	A strip of permanent vegetation consisting of native species established at the edge or around the perimeter of a field to control erosion, benefit pollinators, and provide wildlife habitat. Includes a mix of native grasses, legume, forbs (mix may also include non-native species) with a minimum of 3 species each of early, mid, and late blooming forbs.
104	Nutrient Management Plan	Nutrient Management CAP Less Than or Equal to 100 Acres	Number	$1,665.53	CAP is to be developed by a certified Technical Service Provider (TSP) and meet the technical criteria in Section III of the FOTG.
104	Nutrient Management Plan	Nutrient Management CAP 101 - 300 Acres	Number	$1,982.36	CAP is to be developed by a certified Technical Service Provider (TSP) and meet the technical criteria in Section III of the FOTG.
104	Nutrient Management Plan	Nutrient Management CAP Greater Than 300 Acres	Number	$2,397.89	CAP is to be developed by a certified Technical Service Provider (TSP) and meet the technical criteria in Section III of the FOTG.

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
590	Nutrient Management	Enhanced NM w Deep Placement	Acre	$44.13	This scenario describes a conventional cropping system where either no nutrient management or only a basic level of nutrient management is being practiced. An enhanced nutrient management system includes activities such as split applications, multiple nutrient concentration tests (other than only soil tests) and methods that more concisely enable scheduling of appropriate fertilizer applications. Manure and/or fertilizer phosphorus is injected or placed below the soil surface at least 4 inches deep. Starter fertilizer may be injected 2 inches deep. Nutrients are transported to surface waters through runoff or wind erosion in quantities that degrade water quality and limit use of intended purposes. Inefficient energy utilization occurs due to traditional methods and forms of fertilizer applications.
590	Nutrient Management	Enhanced NM with Tissue Testing	Acre	$52.14	This scenario describes the implementation of an advanced precision nutrient management system on cropland. The planned NM system will meet the current 590 standard. Payment for implementation is to defray the costs of soil testing, analysis, consultant services, skilled labor and specialized nutrient application that provide nutrient proper recommendations based on Land Grant University (LGU) recommendations or crop removal rates and an associated nutrient budget, recordkeeping, and monitoring on a precision level that includes split applications, Normalized Differential Vegetation Index (NDVI) sensing, and aerial imaging. Records are kept demonstrating implementation of the 4 R's of the NM plan. The scenario can improve efficiency and effectiveness of nutrient management by utilizing specialized precision techniques and tools (variable rate applicators, NDVI, aerial photography, yield monitoring, plant tissue testing, or on the go chlorophyll sensors). Precision nutrient

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
					management techniques ensure that the right rate, proper timing, and proper placement of nutrients minimize non-point source pollution and provide proper amounts of nutrients to the crop where it is needed and not applying where it is not needed.
590	Nutrient Management	Basic NM	Acre	$12.57	Nutrient Management will be applied according to NRCS FOTG and U of I Agronomy Handbook requirements. The Nutrient Management must only be planned on the acres where the nutrients are actually applied.
590	Nutrient Management	Basic NM with Manure	Acre	$19.15	Nutrient Management will be applied according to NRCS FOTG and U of I Agronomy Handbook requirements. Current manure tests will be used to determine the nutrient content of the manure being utilized. The Nutrient Management must only be planned on the acres where the nutrients are actually applied.
590	Nutrient Management	Enhanced NM with Manure	Acre	$38.18	Land apply manure and nutrients according to a CNMP or NMP, where the nutrient management represents a positive change to previous nutrient application on the land. All commercial Nitrogen must be spring applied for spring planted crops. Manure can be applied in the fall. This scenario applies where one or more of the following enhancements is to be newly implemented: -----Grid or zone soil testing with variable rate nutrient

Code	Practice Name	Scenario Name	Unit	Traditional Payment Rate	2014 Scenario Description
					application.-Use chlorophyll reader technology (e.g. Greenseeker) to vary nitrogen application.-Use controlled release N fertilizer.-Use a pre-sidedress nitrogen test. Measurement is based on the acres where the nutrients are actually applied

Attachment C
MS4s and Associated Land Areas within the FRIP Planning Area

Blank

MS4s and Associated Land Areas within the FRIP Planning Area[18]

MS4 Jurisdiction	Area (acres)
Algonquin Township	6,186
Algonquin Village	7,600
Aurora City	26,519
Aurora Township	2,958
Barrington Hills Village	17,703
Barrington Village	2,942
Bartlett Village	6,245
Batavia City	6,029
Batavia Township	3,757
Blackberry Township	3,090
Bristol Township	2,744
Carpentersville Village	4,525
Cary Village	4,048
Crystal Lake City	10,460
Cuba Township	4,579
Deer Park Village	1,220
DeKalb County*	1,978
Dorr Township	41
Dundee Township	6,315
East Dundee Village	1,927
Ela Township	1,675
Elburn Village	1,987
Elgin City	24,236
Fox River Grove Village	1,111
Fremont Township	37
Geneva City	6,144
Gilberts Village	2,200
Grafton Township	190
Hanover Park Village	40
Hawthorn Woods Village	1,189
Hoffman Estates Village	9,867
Inverness Village	1,392
Island Lake Village	2,301
Kane County*	19,749

---

[*] Note: The county land areas listed here represent total land area in each county, exclusive of other listed jurisdictions, not necessarily the areas the counties have storm water responsibility for. For example, Kane County currently has responsibility for only about 3,978 acres.

MS4 Jurisdiction	Area (acres)
Kendall County*	3,558
Kendall Township	2,201
Lake Barrington Village	3,995
Lake in the Hills Village	4,169
Lake Zurich Village	2,631
Lakemoor Village	360
Lakewood Village	314
McHenry City	374
McHenry County*	110
Montgomery Village	6,079
Na-Au-Say Township	45
Naperville City	924
Naperville Township	719
North Aurora Village	4,780
North Barrington Village	3,105
Nunda Township	8,275
Oakwood Hills Village	806
Oswego Township	3,904
Oswego Village	10,019
Palatine Township	309
Plainfield Village	10
Port Barrington Village	826
Schaumburg Village	1,720
Sleepy Hollow Village	1,295
South Barrington Village	4,895
South Elgin Village	4,583
St. Charles City	9,008
St. Charles Township	9,921
Streamwood Village	4,533
Sugar Grove Township	2,619
Sugar Grove Village	6,670
Tower Lakes Village	661
Volo Village	486
Wauconda Township	2,277
Wauconda Village	3,479
Wayne Township	994
Wayne Village	3,576
West Chicago City	759

MS4 Jurisdiction	Area (acres)
West Dundee Village	2,445
Wheatland Township	271
Winfield Township	26
Yorkville City	11,808
Total Area	**322,525 acres**

Blank

Attachment D

QUAL2K Model Modification and Recalibration

Blank

LimnoTech
Water | Scientists
Environment | Engineers

501 Avis Drive
Ann Arbor, MI 48108
734.332.1200
www.limno.com

Memorandum

From: Dave Dilks, Julie Padilla
Date: August 22, 2014
Project: FOXRIP
To: Fox River Study Group Board
CC: Scott Bell

SUBJECT: DRAFT: Recalibration of Fox River QUAL2K Model in Response to Revised Sediment Code

Summary

Following discovery of significant limitations in the existing version of QUAL2K for use in developing the Fox River Implementation Plan (FRIP) on behalf of the Fox River Study Group (FRSG), LimnoTech implemented two changes to the QUAL2K model code:

1. Correction of issues related to sediment oxygen demand (SOD).
2. Addition of a "prior season" contribution to sediment phosphorus concentrations

Because these changes significantly affected model calculations, LimnoTech recommended, and the FRSG agreed, that the Fox River QUAL2K model that was previously developed and calibrated by the Illinois State Water Survey (Bartosova, 2013) should be recalibrated. The objective of the recalibration effort was to allow the corrected model code to generate expected levels of sediment oxygen demand, while still providing accurate simulation of the original calibration data. Three categories of changes were made to the original model inputs:

1) Inputs representing "prior season" contribution to sediment phosphorus concentrations were added.
2) Corrections to original model inputs identified as necessary during the model review process were implemented.
3) Algal settling velocities were increased (and other processes adjusted accordingly), in order to allow more settling of organic material to Fox River sediments while maintaining water column concentrations consistent with the calibration data set.

This recalibrated model will be suitable for addressing the water quality benefit of future load reduction scenarios in the Fox River and for development of the FRIP.

Background

The ISWS developed a calibrated QUAL2K water quality model application to the Fox River (Bartosova, 2013). This model will be used to simulate future Fox River water quality in response to nutrient load reductions considered as part of the Fox River Implementation Plan. LimnoTech had identified two issues with the QUAL2K model framework that would limit its utility to evaluate future management actions:

1. The model code was not predicting sediment oxygen demand properly
2. The model framework was not well-suited for assessing the water quality impact of non-point source load reductions

LimnoTech was subsequently tasked by the FRSG to change the QUAL2K model code to correct the above issues, and then change model inputs as necessary to provide recalibration to observed water quality data.

This memorandum: 1) describes the changes that have been made to the model code, 2) describes how model inputs were changed as part of recalibration, and 3) present model recalibration results.

Changes to Model Sediment Oxygen Demand Code

LimnoTech, in applying this model in a preliminary investigation of load reduction scenarios, discovered counter-intuitive model results regarding model predictions of sediment oxygen demand (SOD). Specifically, model results showed that future predicted SOD did not change at all in response to changes in algal concentrations. This was counter-intuitive, because the settling of particulate organic matter from algae is known to be a primary source of SOD.

A review of the model code showed that QUAL2K was also generating SOD through exchange of dissolved carbonaceous biochemical oxygen demand (CBOD) from the water column. This contribution is an artifact of the code, as this process is not expected to contribute to SOD. LimnoTech conducted model sensitivity analyses to determine the sources of SOD in the calibrated model, and found that more than 99% of the SOD predicted by the model resulted from the inappropriate CBOD exchange, while less than 1% of the SOD predicted by the model resulted from the settling of particulate organic material. These findings were presented to the Fox River Study Group, who subsequently determined that the QUAL2K code should be modified to remove the inappropriate SOD, and the model re-calibrated with the revised code.

Modification of the QUAL2K code to correct this issue was relatively simple, consisting of the adjustment of two equations:

1. The equation that originally defined the flux of methane between sediments and the water column was modified to set the water column methane concentration to zero (as opposed to assuming that the water column methane was equal to CBOD.
2. Deleting the equation that added sediment methane flux to the CBOD.

Changes to Model Sediment Phosphorus Flux Code

LimnoTech's earlier review of the QUAL2K model framework indicated that the steady state nature of the model code made it poorly suited for assessing the water quality impact of non-point source load reductions. LimnoTech, working in cooperation with the Illinois State Water Survey, identified changes that to the QUAL2K model code that reflect prior-season loadings to the sediment phosphorus compartment. Specifically, the QUAL2K variable representing user-specified phosphorus flux was changed to represent a constant phosphorus flux *to* the anaerobic sediment compartment, as opposed to its original purpose of representing phosphorus flux *out of* the sediments and into the water column.

Re-Calibration Process

Because the original ISWS calibration had undergone extensive review, the objective of the recalibration effort was to allow the corrected model code to generate expected levels of sediment oxygen demand, while changing as little of the original model calibration as possible. Three categories of changes were made to the original model inputs:

1) Inputs representing "prior season" contribution to sediment phosphorus concentrations were added.
2) Corrections to original model inputs identified as necessary during the model review process were implemented.

3) Algal settling velocities were increased (and other processes adjusted accordingly), in order to allow more settling of organic material to Fox River sediments while maintaining water column concentrations consistent with the calibration data set.

"Prior Season" Contribution to Sediment Phosphorus Concentrations

The first change made to the model calibration input file was to specify model inputs representing the contribution of loadings prior to summer flow conditions on summer sediment phosphorus concentrations. These loadings were estimated using the following equation:

$$J_{wet} = J_{dry} \text{ x } [\ (\text{Annual external P loading rate} \div \text{Dry weather external P loading rate}) - 1] \qquad (1)$$

where:

J_{wet} = Additional phosphorus flux to QUAL2K sediments representing loading from prior season (mg P/m^2/day)

J_{dry} = Gross phosphorus flux to QUAL2K sediments predicted for dry weather conditions (mg P/m^2/day)

The external P loading rate represents all sources of phosphorus to a model segment, including cumulative upstream sources, tributaries, and point sources. Annual tributary loadings were taken from HSPF model results, while point source loadings and dry weather tributary flows were calculated from the QUAL2K model inputs. The gross phosphorus flux to QUAL2K sediments predicted for dry weather conditions was taken directly from QUAL2K outputs, by summing the amount of settling from organic phosphorus, inorganic phosphorus, and algal phosphorus.

Equation 1 was applied over three different regions of the QUAL2K spatial domain, representing spatial differences in the relative contribution of point and nonpoint source to annual and dry weather loads. The segments, and the resulting ratio of 'Annual external P loading rate ÷ Dry weather external P loading rate', are shown in Table 1.

Table 1. Ratio of Annual:Dry weather External P Loading Rate

Segment	Ratio
Stratton Dam to FRWRD	2.89
FRWRD to Roods Creek	1.64
Roods Creek to Downstream Boundary	1.74

The ratios in Table 1 were applied in conjunction with Equation 1 to define the additional phosphorus flux to each QUAL2K element. For example, wet weather fluxes for each model reach between Stratton Dam and FRWRD were set to 1.89 (i.e. 2.89 – 1) the calculated dry weather flux for that reach.

Correction of Original Model Inputs

The QUAL2K model review process had earlier identified two aspects of the original ISWS input file that required correction:

- Certain point source inputs
- Parameters related to nutrient limitation of phytoplankton growth

LimnoTech received input from stakeholders based on their previous review of the original QUAL2K model point source inputs for the calibration period, which lead to a review of all point source inputs in the model. As a result, several adjustments were made to point source flows and phosphorus concentrations, based on LimnoTech's review of data provided by the FRSG, as described in Table 2.

Table 2. Point Source Inputs Changed during Recalibration Process

WWTP	Flow (MGD)		TP (mg/L)	
	ISWS	LTI	ISWS	LTI
Algonquin	2.37	no change	0.36	0.72
Batavia	2.60	2.47	4.93	no change
Carpentersville	1.99	2.01	2.32	no change
Cary	1.37	1.38	5.50	4.22
E. Dundee	0.79	0.42	5.50	0.92
Fox Metro	26.91	26.92	4.48	no change
Fox-Grove	0.83	0.78	5.50	no change
FRWRD-North	3.55	3.55	2.95	2.95
FRWRD-South	14.06	14.07	4.58	4.58
FRWRD-West	2.54	no change	1.16	no change
Geneva	3.76	3.76	1.24	no change
Northern Moraine	0.42	no change	5.50	no change
Port Barrington	0.01	no change	5.50	no change
Sheridan	0.27	no change	5.50	no change
St Charles	0.40	3.21	4.34	no change
Wauconda	1.02	no change	0.71	no change
Yorkville-Bristol	1.84	1.78	5.50	3.00

Where actual data were available for the calibration period (6/26/12-6/28/12), those data were used to calculate flow and phosphorus inputs. If calibration period data were unavailable, then the average values for month of June 2012 were used. In the absence of any WWTP data for the calibration period, the original values specified by ISWS were maintained.

Input values for the phytoplankton subsistence quota for phosphorus, maximum uptake rate for phosphorus, and the internal phosphorus half-saturation constant were set to zero in the calibration input file. While these input values do not significantly affect model results during calibration conditions, they will become increasingly important when evaluating future scenarios that consider nutrient load reduction. LimnoTech conducted a literature review of other water quality model applications that use these phytoplankton growth parameters, and selected the median literature value for use in the model recalibration. This corresponded to a phytoplankton subsistence quota of 0.1 mg P/mg algae, a maximum uptake rate of 10 mg P/mg algae/day, and an internal phosphorus half-saturation constant of 0.13 mg P/mg algae.

Generation of SOD

Generation of expected levels of SOD requires an increase in the amount of particulate organic matter that is settled out of the water column. The majority of particulate organic material in the Fox River during summer low flow conditions comes from algal tissue; therefore, the primary method for increasing the amount of settling of particulate organic matter is through an increase in algal settling velocities. An increase in algal settling velocities will also cause a decrease in predicted phytoplankton concentration, requiring a counter-balancing change somewhere else to maintain the existing phytoplankton levels. This counter-balancing change can be obtained via a decrease in factors that reduce phytoplankton levels, specifically the respiration, death, and excretion rates. A similar counter-balancing was required for phosphorus, as the increase in algal settling velocities led to a decrease in predicted total phosphorus. This counter-balancing was achieved by decreasing the settling velocity specified for inorganic phosphorus.

The QUAL2K model was run for the calibration data set examining different combinations of values for the settling velocity, respiration rate, death rate, excretion rate, and inorganic phosphorus settling velocity. All recalibration values were kept within the range of values for each coefficient reported in the scientific literature. Acceptable comparisons to data were achieved for SOD, algae, and both forms of phosphorus, but the resulting predicted ammonia concentrations were higher than the observed data. The nitrification rate was subsequently increased until an acceptable fit to the observed ammonia data was achieved.

Table 2 presents the model coefficients that best matched the available data.

Table 3. Model Coefficients Changed during Recalibration Process

Model Coefficient	Units	ISWS Value	Re-calibration Value
Phytoplankton settling velocity	m/d	0	0.1-0.45*
Death rate	/d	0.1	0.05
Excretion rate	/d	0.3	0.04
Respiration rate	/d	0.15	0.04
Inorganic P settling velocity	m/d	0.8	0.6
Nitrification rate	/d	0.08	0.35

*Settling velocity set at 0.1 m/d for Reaches 1-8 and 52-72; 0.45 m/d for 9-51

Results

Results of the model recalibration are shown in Figures 1 through 5, with each figure showing: 1) Results of the recalibrated model, 2) Results of the original ISWS calibration, and 3) Observed data. In general, the recalibrated model results are very similar to the original calibration results. As seen in Figure 1, the recalibrated model predicts higher average dissolved oxygen for the upper twenty miles of the modeled system, very similar dissolved oxygen for the next fifty miles, and slightly higher dissolved oxygen for the final thirty miles. The predicted minimum dissolved oxygen is slightly higher than the original calibration throughout the model domain, The recalibrated model shows similar phytoplankton concentrations to the original calibration (Figure 2) The revised model predicts significantly different SOD than the original calibration (Figure 3), but the recalibrated results compare well to the observed data. Phosphorus (Figure 4) and ammonia (Figure 5) concentrations match the observed data as well as the original calibration results.

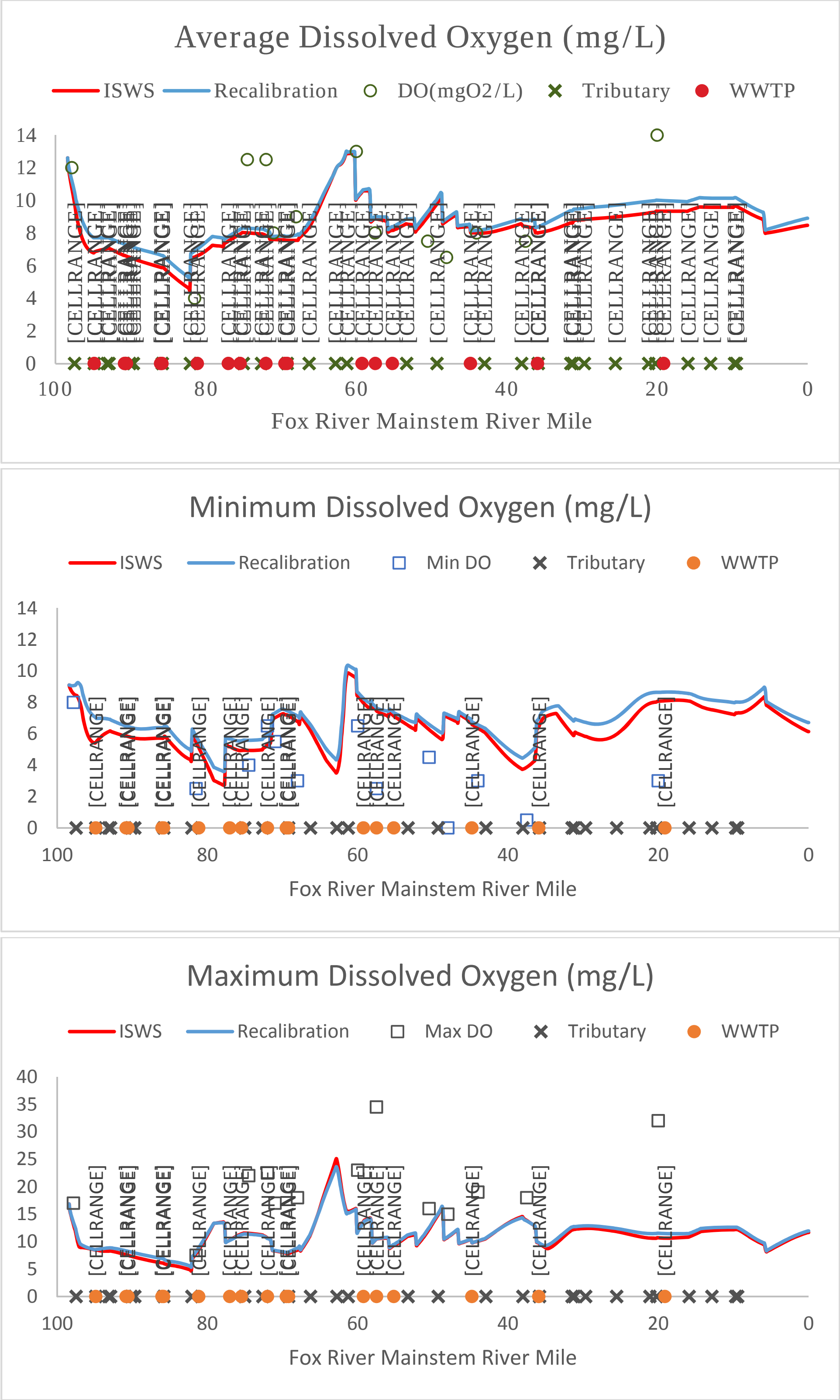


Figure 1. Model Recalibration Results for Dissolved Oxygen

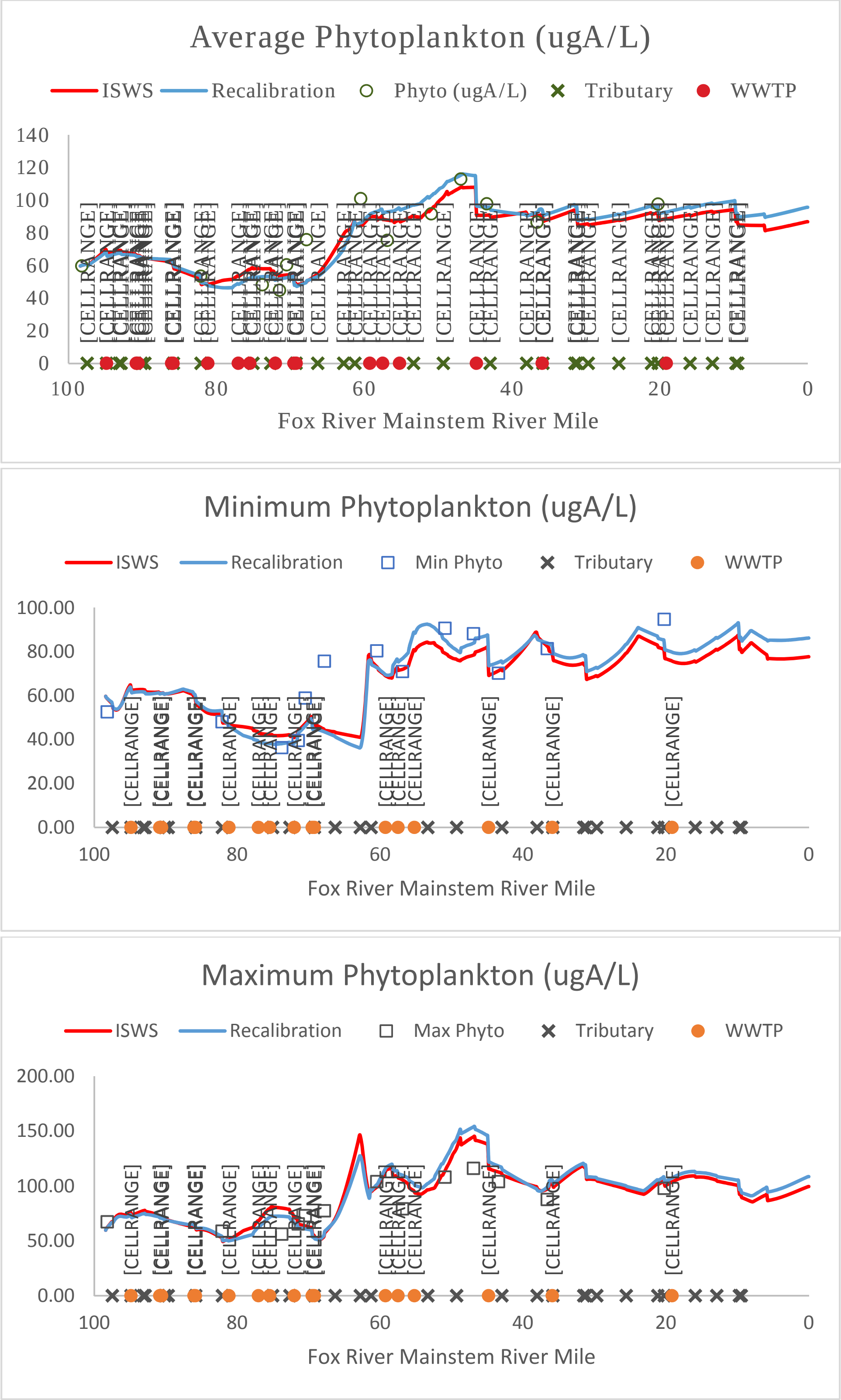


Figure 2. Model Recalibration Results for Phytoplankton

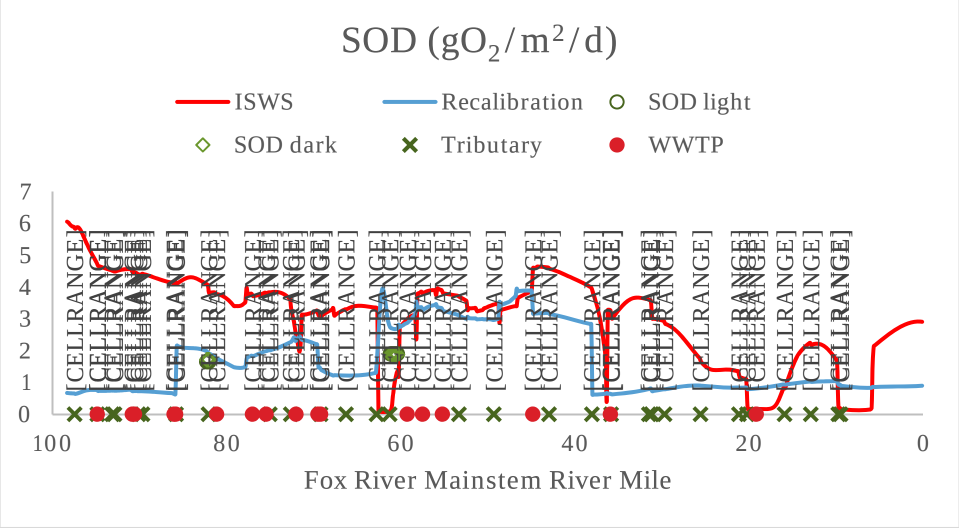
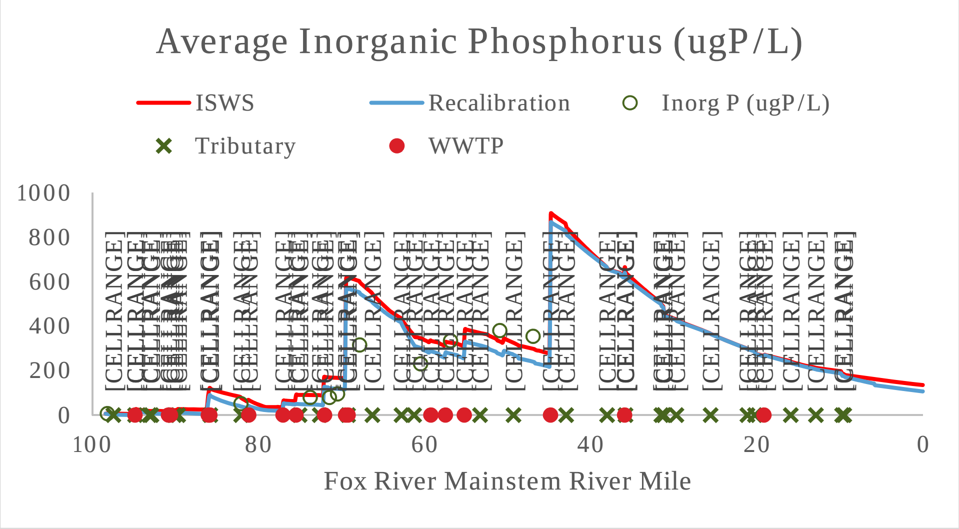


Figure 3. Model Recalibration Results for Sediment Oxygen Demand



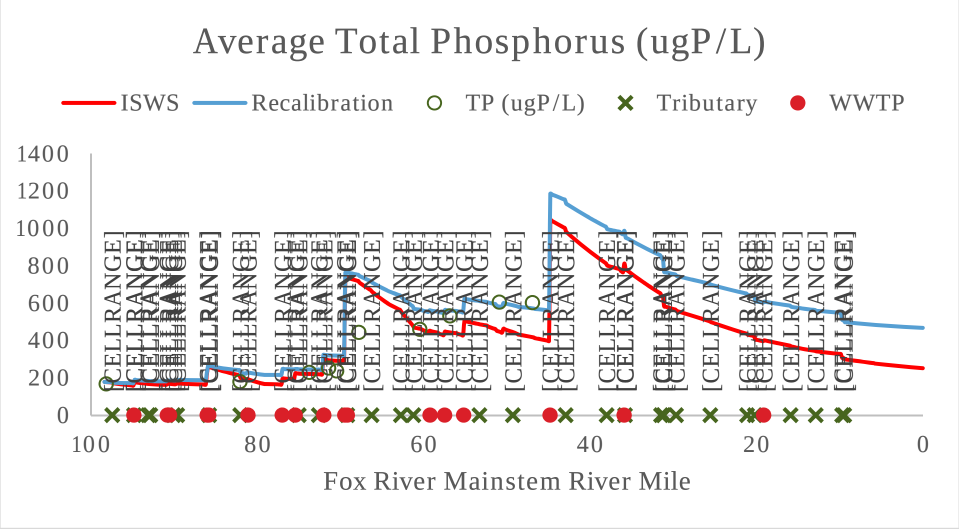


Figure 4. Model Recalibration Results for Phosphorus

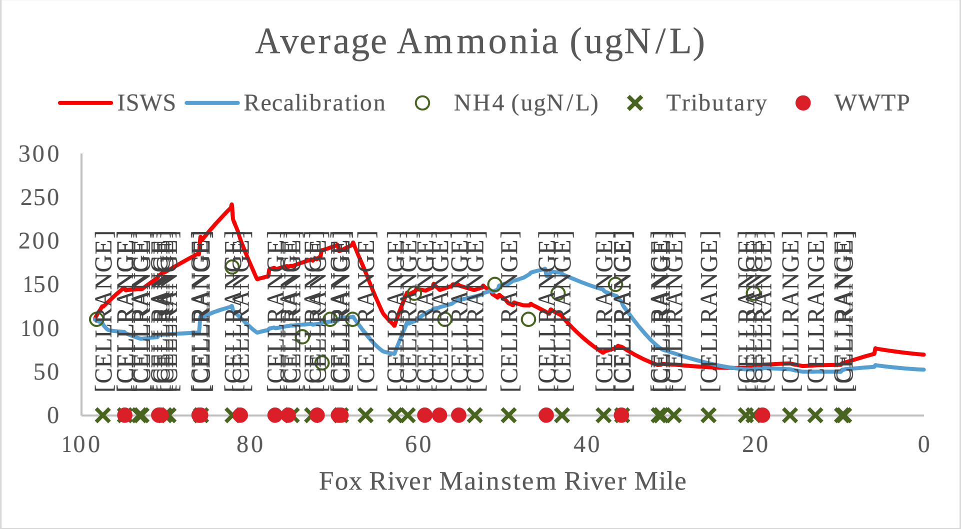


Figure 5. Model Recalibration Results for Ammonia

References

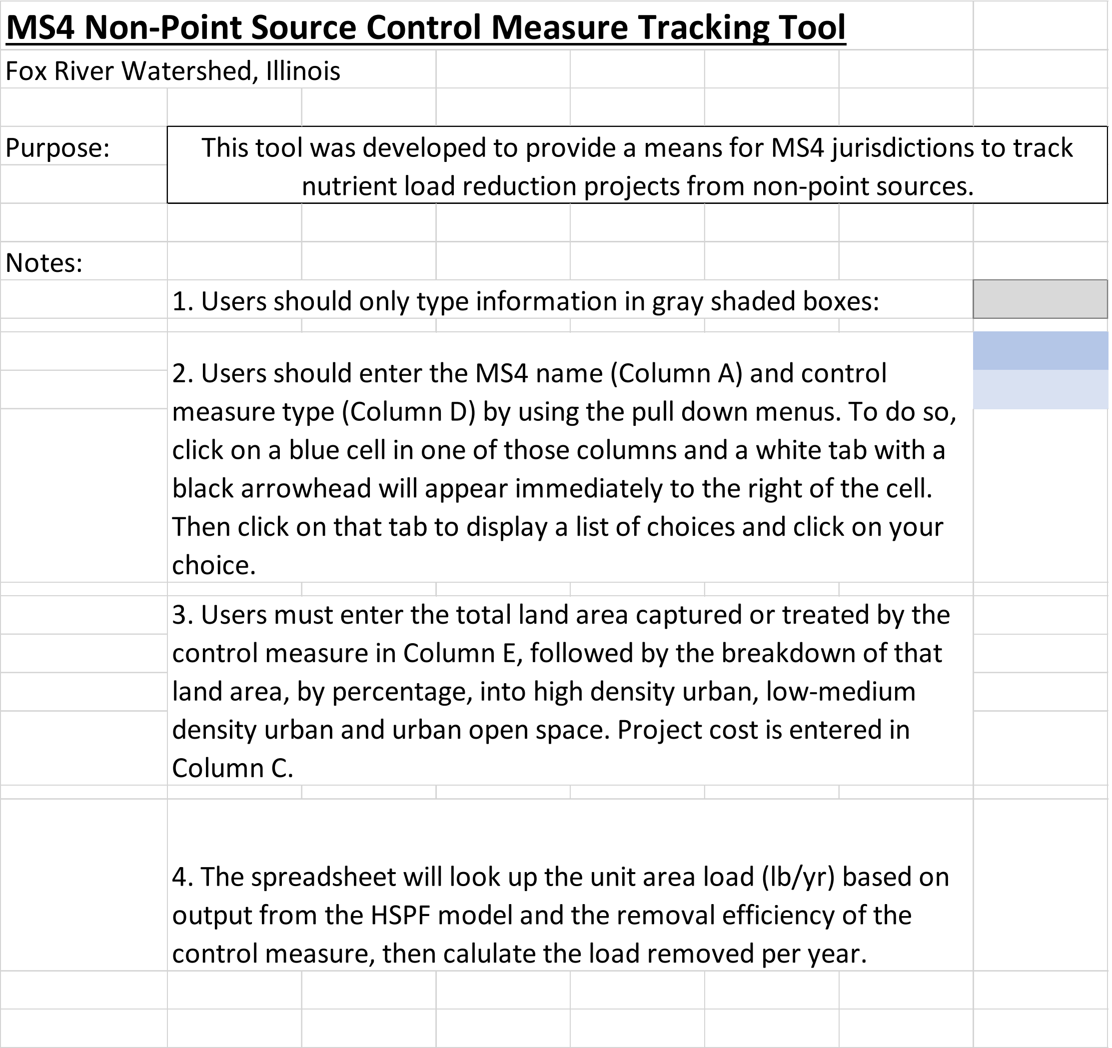
Bartosova, A. 2013. Fox River Watershed Investigation: Stratton Dam to the Illinois River. PHASE III. Evaluation of Watershed Management Scenarios. DRAFT. Illinois State Water Survey. July, 2013.

Attachment E

Fox River MS4 Non-Point Source Control Measure Tracking Tool

Blank

The Fox River MS4 Non-Point Source Control Measure Tracking Tool is an Excel spreadsheet-based form that allows MS4s to enter basic information about their non-point source (NSP) control measures and report them to the FRSG. The tool will calculate an estimate of annual average total phosphorus removal based on user-specified information. The first page of the spreadsheet is the “Read Me” tab and gives basic instructions for use:



MS4 Non-Point Source Control Measure Tracking Tool

Fox River Watershed, Illinois

Purpose: This tool was developed to provide a means for MS4 jurisdictions to track nutrient load reduction projects from non-point sources.

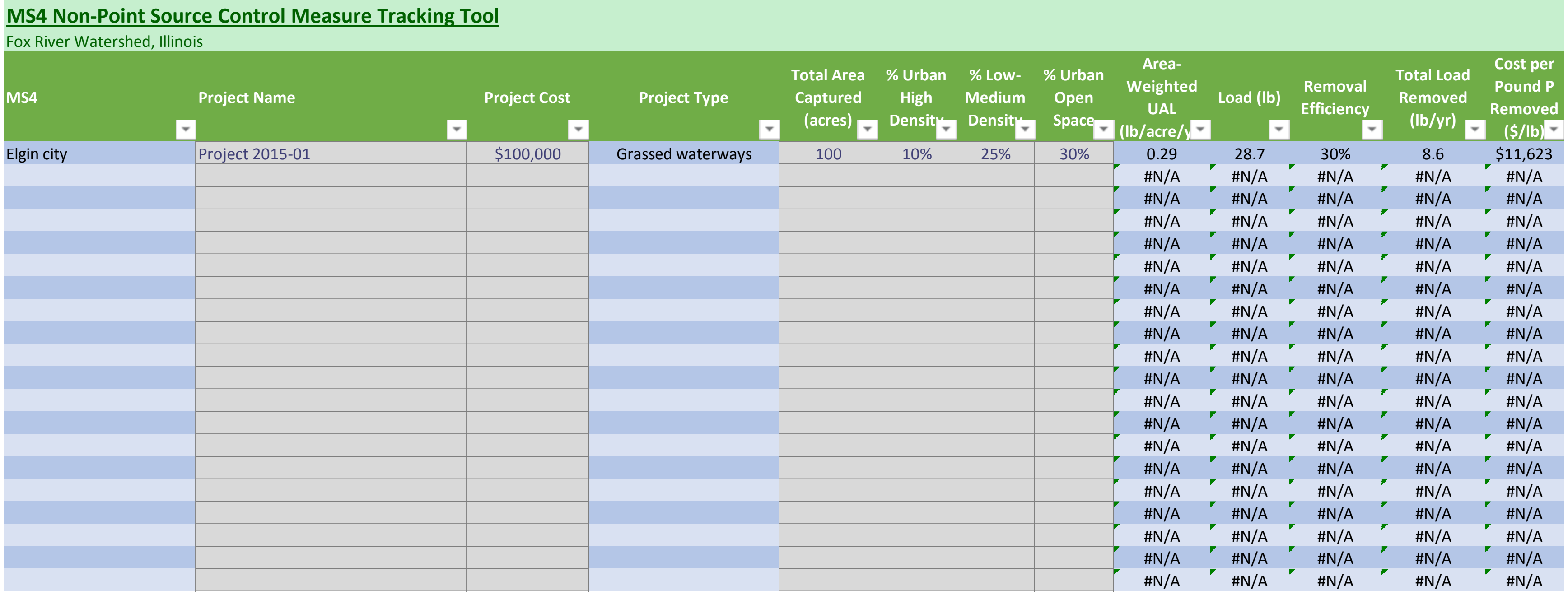
Notes:

1. Users should only type information in gray shaded boxes:
2. Users should enter the MS4 name (Column A) and control measure type (Column D) by using the pull down menus. To do so, click on a blue cell in one of those columns and a white tab with a black arrowhead will appear immediately to the right of the cell. Then click on that tab to display a list of choices and click on your choice.
3. Users must enter the total land area captured or treated by the control measure in Column E, followed by the breakdown of that land area, by percentage, into high density urban, low-medium density urban and urban open space. Project cost is entered in Column C.
4. The spreadsheet will look up the unit area load (lb/yr) based on output from the HSPF model and the removal efficiency of the control measure, then calulate the load removed per year.

The second page of the spreadsheet allows the user to enter project information and calculates the following:

- Area-weighted unit area load (UAL) of total phosphorus (based on the land area percentages specified by the user and UALs calculated by the Fox River HSPF watershed models developed by the ISWS.
- Total phosphorus load into the project based on the land area captured and the area-weighted UAL.
- Removal efficiency based on the project type (from a look up table on the 3rd sheet).
- Total annual average load removed, based on the total load and the removal efficiency.
- Cost per pound of phosphorus, based on the user-specified project cost and the calculated total load removed.

A screen shot of the second page of the tool is provided below.



MS4 Non-Point Source Control Measure Tracking Tool

Fox River Watershed, Illinois

MS4	Project Name	Project Cost	Project Type	Total Area Captured (acres)	% Urban High Density	% Low-Medium Density	% Urban Open Space	Area-Weighted UAL (lb/acre/y	Load (lb)	Removal Efficiency	Total Load Removed (lb/yr)	Cost per Pound P Removed ($/lb)
Elgin city	Project 2015-01	$100,000	Grassed waterways	100	10%	25%	30%	0.29	28.7	30%	8.6	$11,623
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A
								#N/A	#N/A	#N/A	#N/A	#N/A