NUTRIENT ASSESSMENT REDUCTION PLAN FOR LOWER KANKAKEE RIVER WATERSHED

Prepared for

City of Wilmington
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

ACRONYMS AND ABBREVIATIONS

$CBOD_5$	5-day Carbonaceous Biochemical Oxygen Demand
CFS	Cubic Feet per Second
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
KRMA	Kankakee River Metropolitan Agency
MGD	Million Gallons per Day
NARP	Nutrient Assessment Reduction Plan
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
POTW	Publicly Owned Treatment Works
ROE	Risk of Eutrophication
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USGS	United States Geological Survey
WRP	Water Reclamation Plant

1. INTRODUCTION

This section describes the purpose of the Nutrient Assessment Reduction Plan (NARP). It also describes the study area for the City of Wilmington's (City) NARP within the context of the larger Kankakee River watershed.

1.1 Purpose of the Nutrient Assessment Reduction Plan

The Illinois Environmental Protection Agency (Illinois EPA) has incorporated a special condition requirement to develop a NARP in many Illinois National Pollutant Discharge Elimination System (NPDES) permits for major publicly owned treatment works (POTWs). The NARP requirements apply to POTWs discharging upstream of water bodies determined to have a phosphorus-related impairment[1] or to be at "risk of eutrophication"[2]. The purpose of the NARP is to identify phosphorus input reductions and other measures necessary to address phosphorus-related impairments. Illinois EPA recognizes that other measures (such as dam removal, stream restoration, riparian buffers, or constructed wetlands) may be needed to eliminate impairments in addition to point source and nonpoint source (NPS) nutrient reductions.

The current NPDES permit for the City's water reclamation plant (WRP) includes Special Condition 18 to develop a NARP by December 31, 2023 (IL0026085, issued on August 29, 2019). The WRP discharge is upstream of the Lower Kankakee River segment, which Illinois EPA has determined to be at risk of eutrophication. The objective of the City's NARP is to determine phosphorus reductions and other measures to address the risk of eutrophication that will or may cause a violation of a water quality standard.

The City hired Geosyntec Consultants, Inc. (Geosyntec) to develop a work plan to identify the scope, schedule, and budget for subsequent work required to produce the NARP (Geosyntec Consultants, 2022). Geosyntec presented the work plan to Illinois EPA on September 14, 2022, and the Agency generally concurred with the workplan.

This report documents the work conducted by Geosyntec in close collaboration with the City and Chamlin & Associates to execute the work plan for the NARP. Following this introductory chapter, Chapter 2 provides an overview of the risk of eutrophication, nutrient sources, and other factors impacting water quality and details previous water quality studies. The NARP development process, which included collecting and analyzing data, model development and calibration, and evaluation of watershed management strategies is described in Chapter 3. Chapter 4 recommends an implementation plan and schedule to address the risk of eutrophication.

1.2 Study Area

The Kankakee River watershed drains 2,989 square miles in northwest Indiana, 2,169 square miles in northeast Illinois, and about seven square miles in southwest Lower Michigan. The Kankakee River rises approximately five miles southwest of South Bend, Indiana, then flows westward into

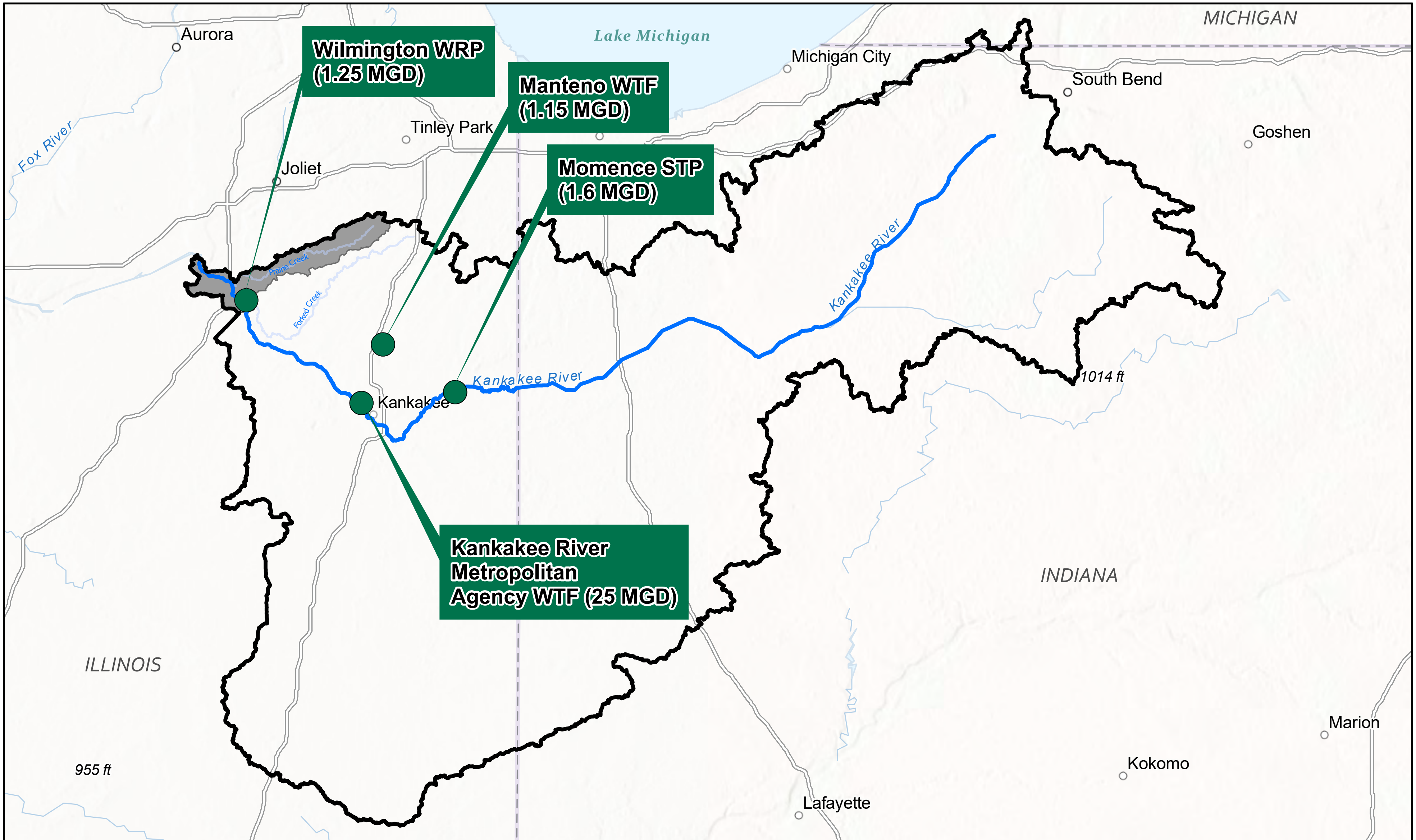
[1] A water body with a phosphorus-related impairment means it is listed by Illinois EPA as impaired because of the presence of dissolved oxygen or "offensive conditions" (e.g., algae or aquatic plant growth).
[2] A water body is determined to be at risk at eutrophication if the levels of sestonic chlorophyll-a, pH, and dissolved oxygen are above the thresholds set by Illinois Risk of Eutrophication Committee.

Illinois, where it joins with the Des Plaines River at the City of Wilmington to form the Illinois River (IDNR, 1990). The Study Area for the Wilmington NARP is the portion of the Kankakee River immediately downstream of its confluence with Forked Creek and upstream of its confluence with the Illinois River. This area is referred to as the Study Area in this report henceforth (**Figure 1**).

Land use in the Study Area is predominantly cropland, accounting for more than three-fourths of the total land area. Forest land occurs primarily as small parcels scattered among cropland, while urban areas are concentrated in the basin's cities and towns and around some large lakes based on the 2022 National Land Cover Database (NLCD, **Figure 2**).

The climate of the Study Area is classified as temperate continental, which describes areas with warm summers, cool winters, and the absence of a pronounced dry season. The long-term precipitation average for the period of 2000 to 2022 recorded at Joliet National Weather Station (NMW) is 37.7 inches. During this period, the lowest precipitation was recorded in 2002 (27.1 inches), and the maximum precipitation was recorded in 2007 (43.0 inches). The average monthly temperature recorded at Joliet ranged from 24.2 to 73.9 degrees Fahrenheit from 2000 to 2022 (National Oceanic and Atmospheric Administration, 2023).

According to the 2020 United States Census, the population of the City is 5,664 (US Census Bureau, 2020). The population is anticipated to increase by 25% by 2050 (Chicago Metropolitan Agency for Planning, 2023).



Legend

- NARP Study Area
- Kankakee River Watershed
- Kankakee River
- Tributary
- Major Publicly Operated Treatment Works

Nutrient Assessment Reduction Plan (NARP) Study Area

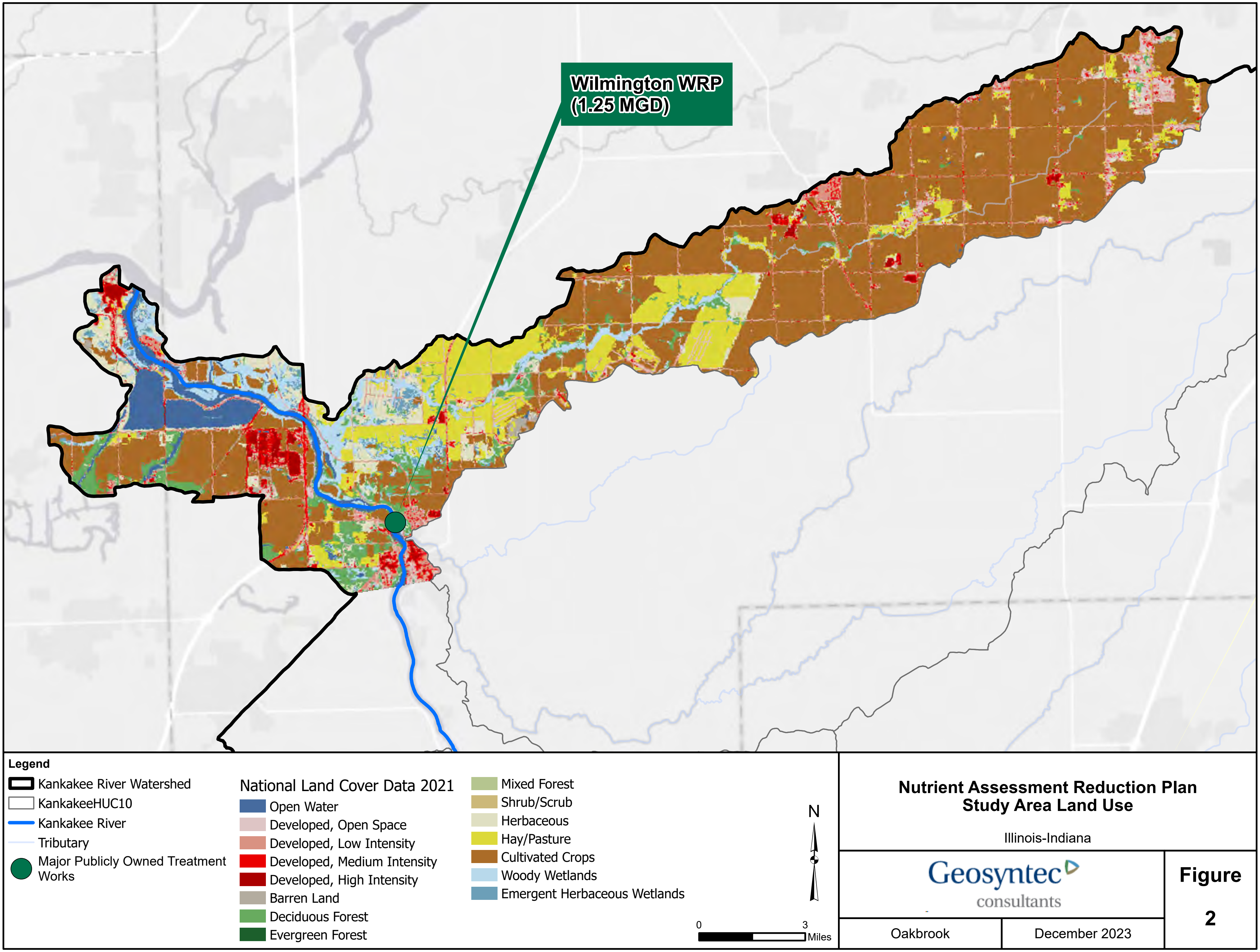
Illinois-Indiana

Geosyntec consultants

Oakbrook

December 2023

Figure 1



Nutrient Assessment Reduction Plan
Study Area Land Use

Illinois-Indiana

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Figure 2

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2. RISK OF EUTROPHICATION FACTORS

Illinois EPA defines the "risk of eutrophication" as reasonable suspicion that plant, algal, or cyanobacterial growth is causing or will cause violation of a water quality standard in a stream segment. The Illinois EPA Risk of Eutrophication Committee developed a simple decision process to assess the "risk of eutrophication" by using numeric thresholds of chlorophyll-*a*, pH, and dissolved oxygen (DO) saturation **(Figure 3**). The numeric thresholds for pH, chlorophyll-*a*, and DO saturation levels were determined by analyzing the relationships between pH, chlorophyll-*a*, and DO data at Illinois EPA stations located throughout the state.

Illinois EPA staff applied this methodology for determining the risk of eutrophication in the Kankakee River using the data collected between 2010 and 2016 (**Figure 4**). The results of the analysis determined that the risk of eutrophication was low and present both upstream and downstream of the City's WRP. At Illinois EPA location F-04, which is 12.1 miles upstream of the WRP), the pH (8.35) and DO saturation (110%) thresholds were exceeded for five days. At location F-16, which is 1.1 miles upstream of the WRP, the thresholds were exceeded 10 days. At location F-01, located 3.6 miles downstream of the WRP, the thresholds were exceeded for three days. Illinois EPA incorporated NARP special conditions in the NPDES permit for the City's WRP based on the results at location F-01.

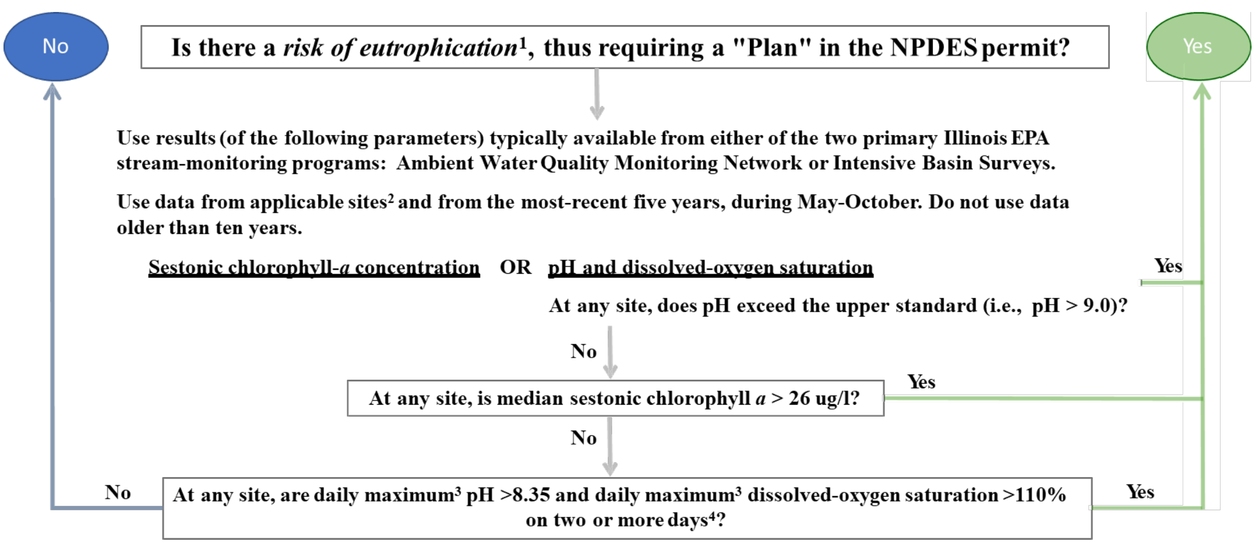
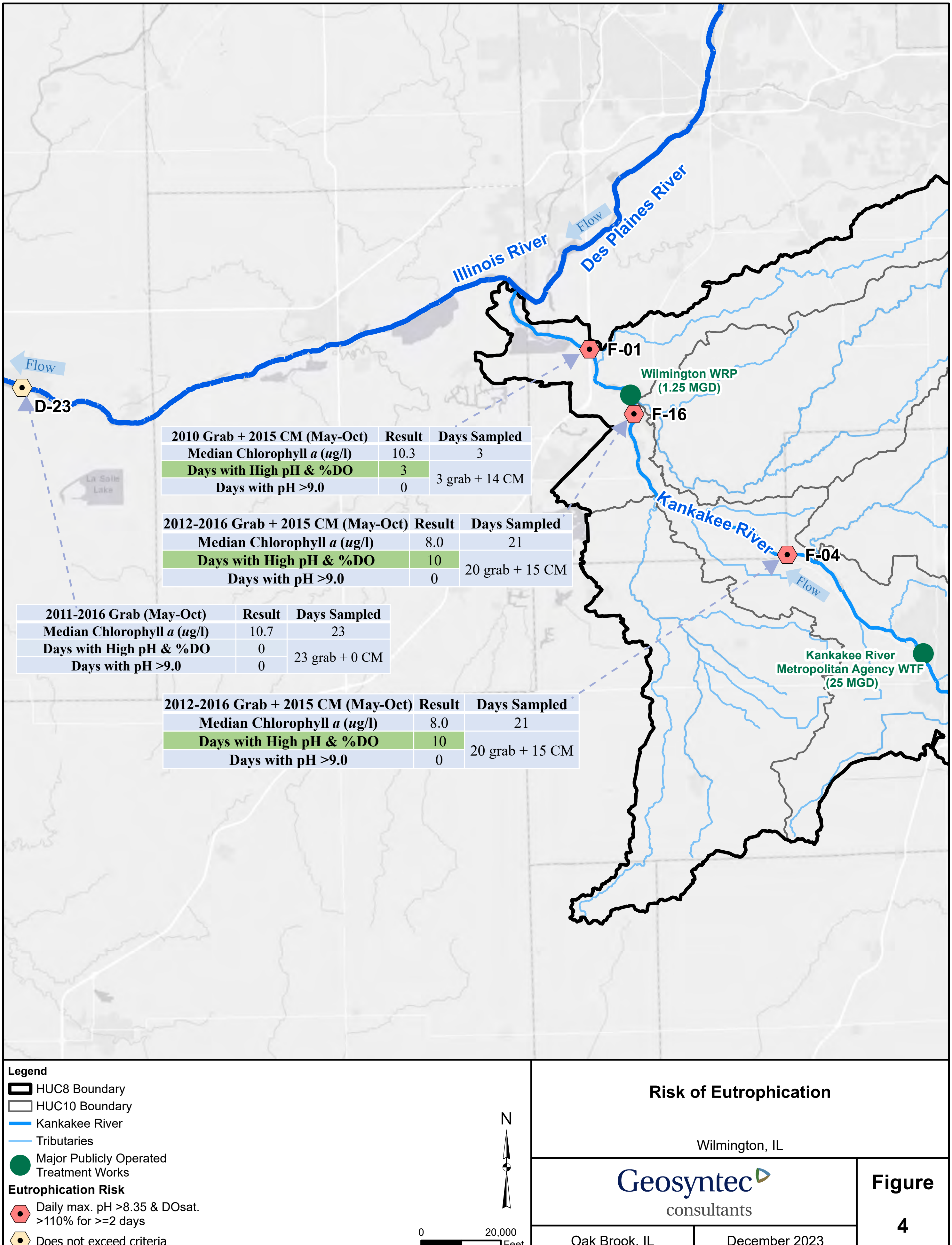


Figure 3: Illinois EPA Procedure for Determining Risk of Eutrophication

[1] *Risk of eutrophication* means reasonable suspicion that plant, algal, or cyanobacterial growth is causing or will cause violation of a water-quality standard.
[2] To be determined, case by case.
[3] For one-per-day results, "*daily maximum*" is represented by the single result. For many-per-day (i.e., continuously monitored) results, "*daily maximum*" is the maximum result in a discrete 24-hour period.
[4] For many-per-day (i.e., continuously monitored) results, a "*day*" means a discrete 24-hour period.



2010 Grab + 2015 CM (May-Oct)	Result	Days Sampled
Median Chlorophyll *a* (ug/l)	10.3	3
Days with High pH & %DO	3	3 grab + 14 CM
Days with pH >9.0	0	

2012-2016 Grab + 2015 CM (May-Oct)	Result	Days Sampled
Median Chlorophyll *a* (ug/l)	8.0	21
Days with High pH & %DO	10	20 grab + 15 CM
Days with pH >9.0	0	

2011-2016 Grab (May-Oct)	Result	Days Sampled
Median Chlorophyll *a* (ug/l)	10.7	23
Days with High pH & %DO	0	23 grab + 0 CM
Days with pH >9.0	0	

2012-2016 Grab + 2015 CM (May-Oct)	Result	Days Sampled
Median Chlorophyll *a* (ug/l)	8.0	21
Days with High pH & %DO	10	20 grab + 15 CM
Days with pH >9.0	0	

Risk of Eutrophication

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Figure 4

3. NARP DEVELOPMENT PROCESS

This section describes the effluent and instream data used to develop the NARP and a nutrient mass balance to put the City's WRP phosphorus load into context with other sources. It also provides an analysis of the instream data and the subsequent development and calibration of a steady-state water quality model. This section also discusses the selection of three phosphorus-reduction management scenarios and their evaluation.

3.1 Data Acquisition and Monitoring

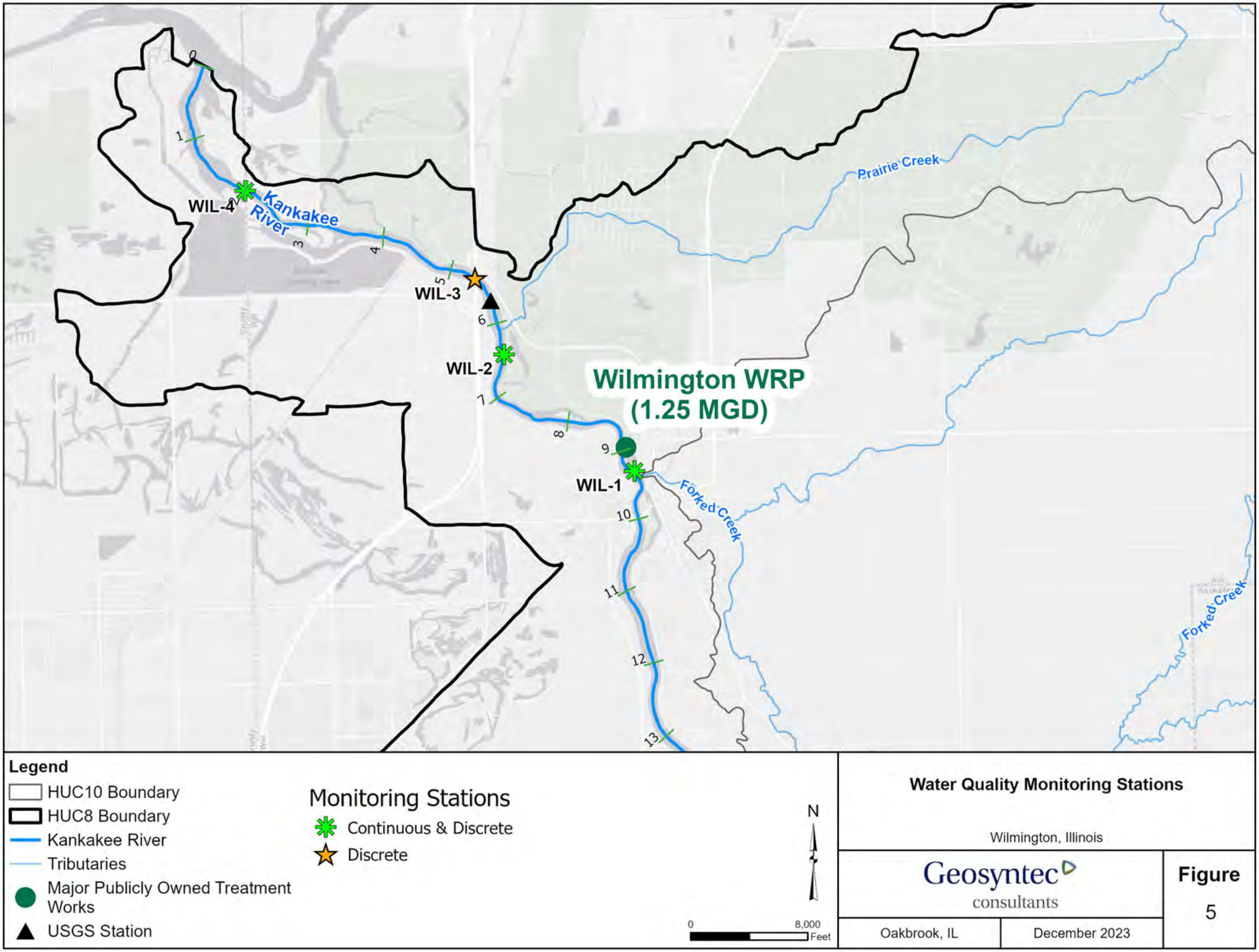
The City's WRP measured the plant effluent flow on a daily basis. Ammonia, total phosphorus (TP), five-day carbonaceous biochemical oxygen demand ($CBOD_5$), and total suspended solids (TSS) were measured three times a week. Total Kjeldahl nitrogen, nitrate, and nitrite were measured once a month.

The City conducted NARP-focused monitoring at four locations in the mainstem of the Kankakee River (Figure 5) in June 2023. Location WL-1 is 0.4 miles upstream of the City's WRP, while locations WL-2, WL-3, and WL-4 are 2.5, 3.6, and 6.8 miles downstream of the City's WRP, respectively. Monitoring consisted of the following two components:

- **Continuous monitoring:** Three sondes were deployed at locations WL-1, WL-2, and WL-4 in the mainstem of the Kankakee River to measure DO, temperature, pH, turbidity, and specific conductivity. The sondes were deployed from June 13 to June 27, 2023.
- **Discrete sampling:** Discrete measurements were taken for nutrients, $CBOD_5$, TSS, and sestonic chlorophyll-*a* at all four locations on the mainstem of the Kankakee River. Samples were collected on June 13 and June 27, 2023.

Results of the City's sampling program are included in *Attachment A: Wilmington NARP Presentation*.

The Kankakee River Metropolitan Agency (KRMA) is conducting continuous monitoring of a portion of the Kankakee River upstream of the City. This included the Warner Bridge Road location (river mile 21.4) that is 12.1 miles upstream of the City's location WL-1. The data for this location is discussed in Section 3.4 below.



Water Quality Monitoring Stations

Wilmington, Illinois

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Figure 5

3.2 Nutrient Loading Mass Balance

The nutrient sources in the NARP Study Area include point source loading from the City's WRP, upstream sources, and NPS loading from surface runoff. NPS loading includes tributary inflow from Prairie Creek. As shown in **Figure** 1, there are three major POTWs in Illinois that discharge upstream of the City's WRP.

The average daily phosphorus loading from the City WRP was estimated using the effluent flows and TP concentrations from June 2023. The average daily loading from NPS within the Study Area was estimated using the United States Environmental Protection Agency Pollutant Load Estimation Tool (Tetra Tech, 2022) based on the 2011 land cover data from the National Land Cover Database (Homer, et al., 2015). The average daily loading from NPS upstream of the Study Area was estimated using the TP concentrations measured at location WL-1 from June 2023. The estimated annual TP loadings from various sources are shown in **Figure 6**.

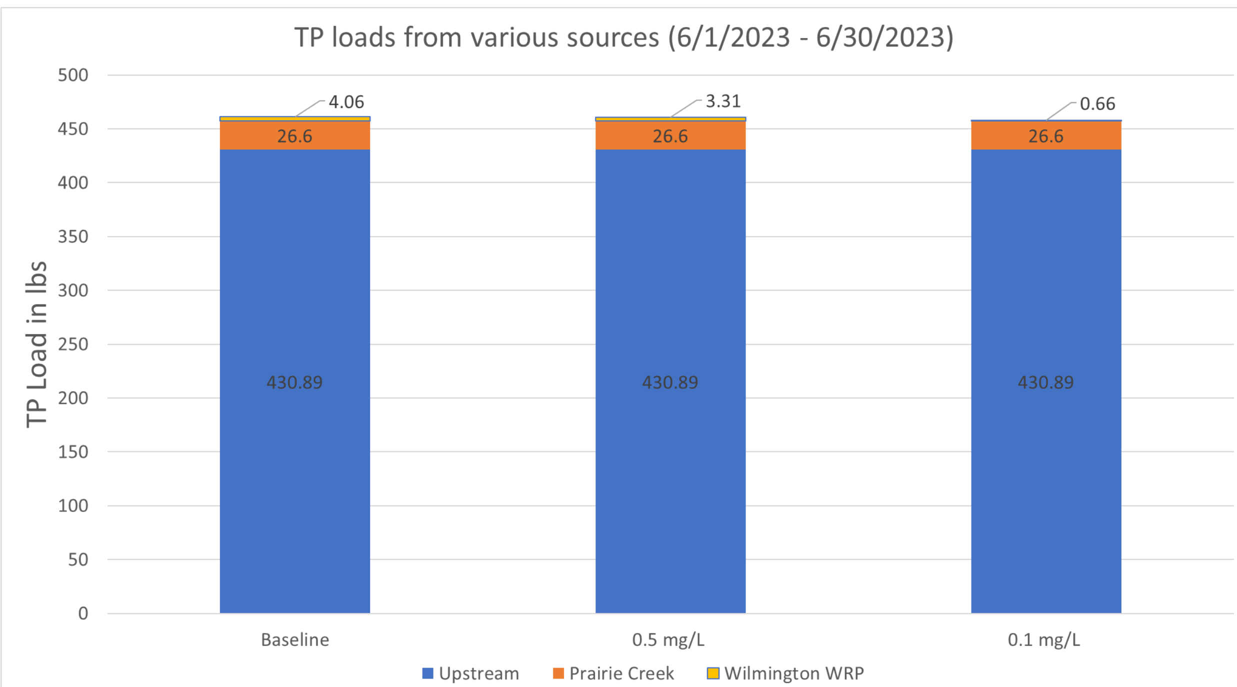

Figure 6: Estimated Total Phosphorus Loading from Various Sources for June 2023

3.3 Data Analysis

Data collected for June 2023 was analyzed to assess the longitudinal trends along the mainstem Kankakee River and to determine the linkage between nutrient inputs and risk of eutrophication.

Figure 7 and **Figure 8** show the longitudinal plots for measured instream TP and sestonic chlorophyll-*a* on June 13 and June 27, 2023. The x-axes on these graphs represent river miles along the Kankakee River, with location WL-1 being the most upstream and location WL-4 being the most downstream. The TP concentrations were lower downstream of the City's WRP (location WL-2) compared to upstream (location WL-1) during both sampling events. This indicates that the City WRP did not increase TP concentrations in the Kankakee River.

Sestonic chlorophyll-*a* concentrations were lower downstream of the City's WRP at location WL-2 compared to upstream at location WL-1. Sestonic chlorophyll-*a* was consistently highest at the most downstream monitoring location (WL-4), though all measurements are well below the Illinois EPA's risk of eutrophication threshold of 26 micrograms per liter (µg/L). The higher chlorophyll-*a* concentrations observed at location WL-4 may be due to slower-moving water in that reach and the time of the day during which the samples were collected.

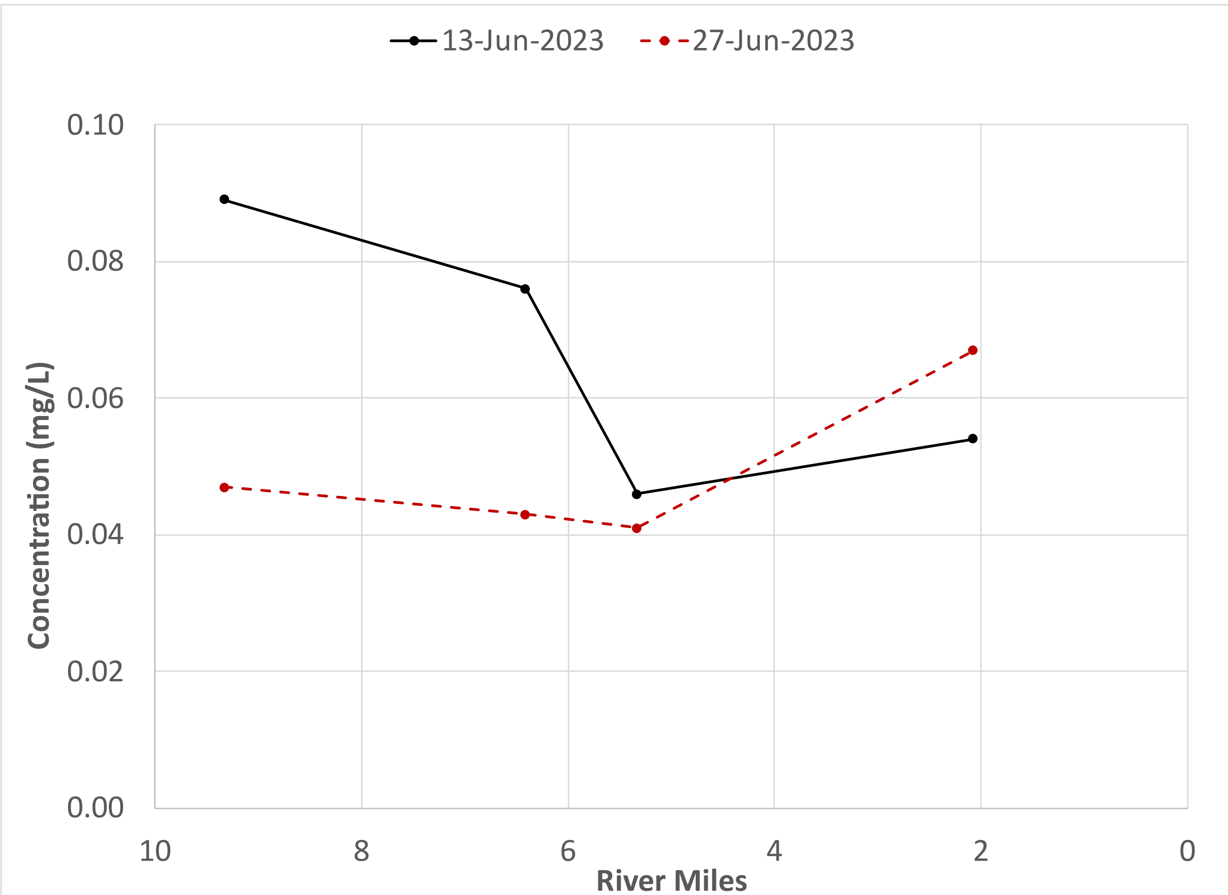

Figure 7: Longitudinal Variation of Measured Total Phosphorus in the Lower Kankakee River

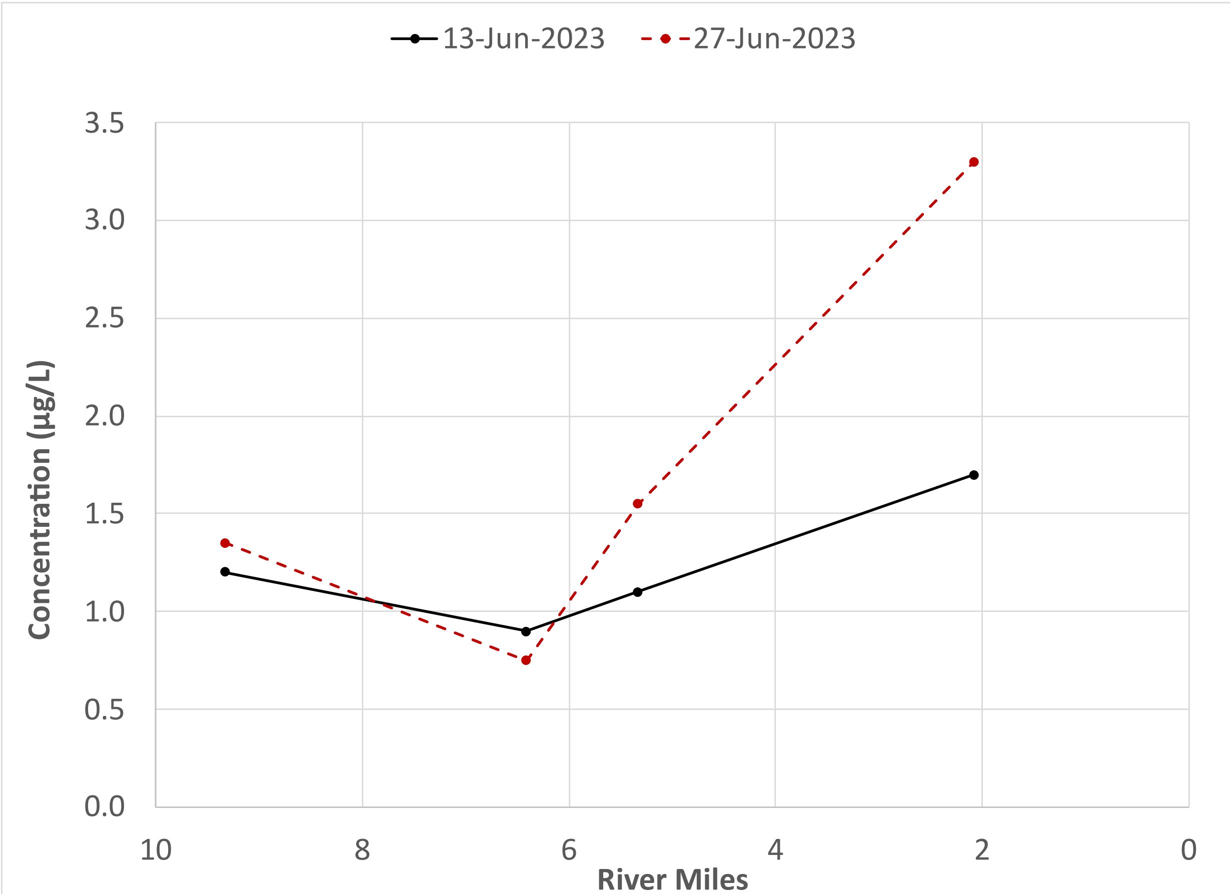

Figure 8: Longitudinal Variation of Measured Sestonic Chlorophyll-a in the Lower Kankakee River

Figure 9 shows the continuous DO concentrations at locations WL-1, WL-2, and WL-4. **Table** 1 presents the continuous monitoring DO data statistics at these three locations. **Table 2** present the diurnal DO swing statistics at these locations. Higher average DO and larger diurnal DO range at WL-1 suggest large algal activity (photosynthesis and respiration) is occurring upstream of the City's WRP. The diurnal fluctuation of DO becomes smaller downstream of the WRP. Together with the low chlorophyll-*a* measurements sampled at locations WL-2, WL-3, and WL-4, it can be inferred that these fluctuations were primarily driven by the upstream inflows.

The monitoring data was used to develop and calibrate the model, which is described in the **Section 3.5** below.

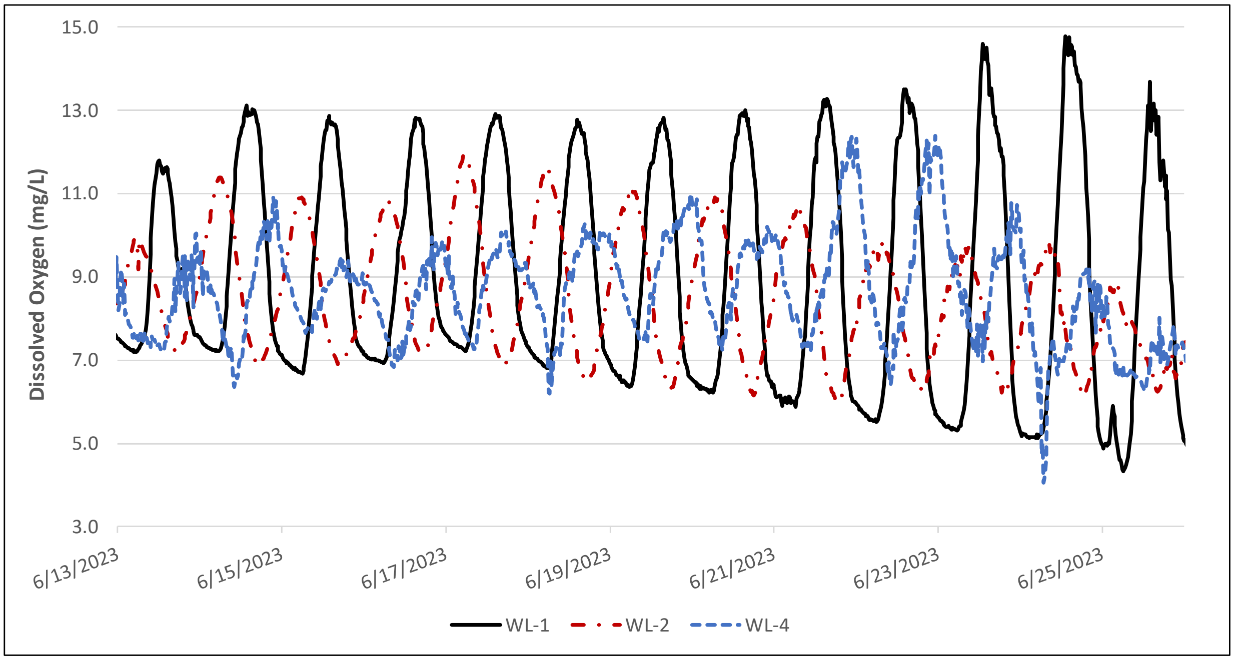

Figure 9: Measured Continuous Dissolved Oxygen Concentrations in the Lower Kankakee River

Table 1: Continuous Dissolved Oxygen Data Statistics for June 13 to June 27, 2023

Statistics	WL-1		WL-2		WL-4	
	Dissolved Oxygen	Dissolved Oxygen Saturation	Dissolved Oxygen	Dissolved Oxygen Saturation	Dissolved Oxygen	Dissolved Oxygen Saturation
	mg/L	%	mg/L	%	mg/L	%
Count	1,418	1,418	1,358	1,358	1,335	1,335
Minimum	4.3	52.3	6.0	72.7	4.1	51.0
25th Perc.	6.7	76.7	7.2	84.3	7.5	89.5
Average	8.8	105.3	8.4	101.3	8.6	103.4
Median	8.1	93.1	8.2	97.9	8.6	101.5
75th Perc.	11.4	135.9	9.6	117.6	9.5	115.0
Maximum	14.8	198.5	11.9	143.8	12.4	159.3

Table 2: Diurnal Dissolved Oxygen Swing Statistics for June 13 to June 27, 2023

Statistics	WL-1	WL-2	WL-4
Count	16	15	15
Minimum	4.4	0.9	0.9
Average	6.7	3.7	3.4
Maximum	9.8	4.8	6.0

3.4 Comparison with Kankakee River Metropolitan Agency Data

KRMA measured continuous temperature, pH, DO, chlorophyll-*a*, conductivity, and turbidity data periodically at Warner Bridge Road upstream of the City's WRP (**Figure 10**) from October 2021 to October 2023. The measured pH and DO saturation data during the growing season in 2022 indicate a high level of risk of eutrophication, as shown in **Figure 11**. Limited data measured at Warner Bridge Road between May and June 2023 also agreed well with the field data Geosyntec collected at the upstream end (WL-1) of the Study Area in terms of diurnal swing magnitude (**Figure 12** and **Figure 13**). While the median chlorophyll-*a* in the 2022 growing season (May to October) was 2 µg/L, the median in 2023 was 71 µg/L. This data suggests that unless water quality conditions are improved at upstream, there's very little that the City can do to reduce the risk of eutrophication downstream of the City WRP.

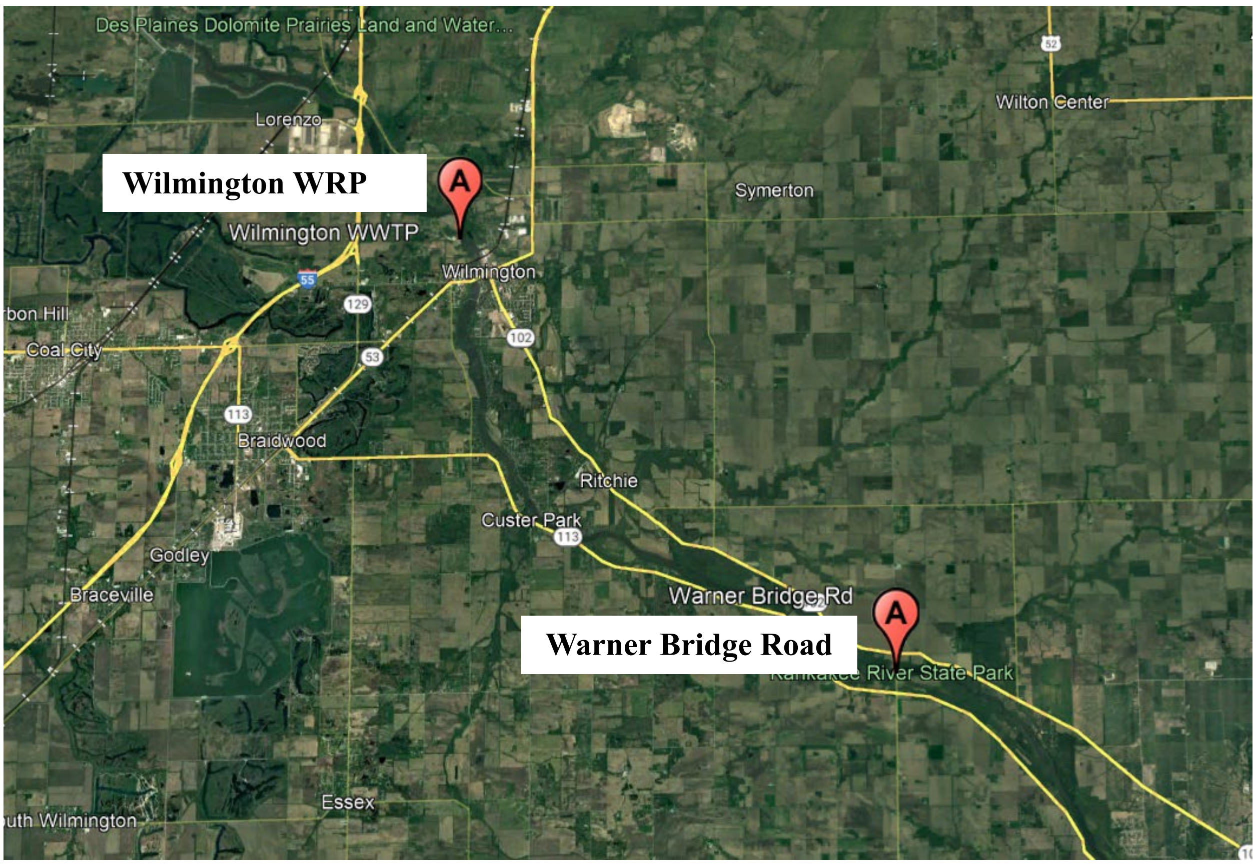

Figure 10: Location of KRMA's Warner Bridge Road Sonde

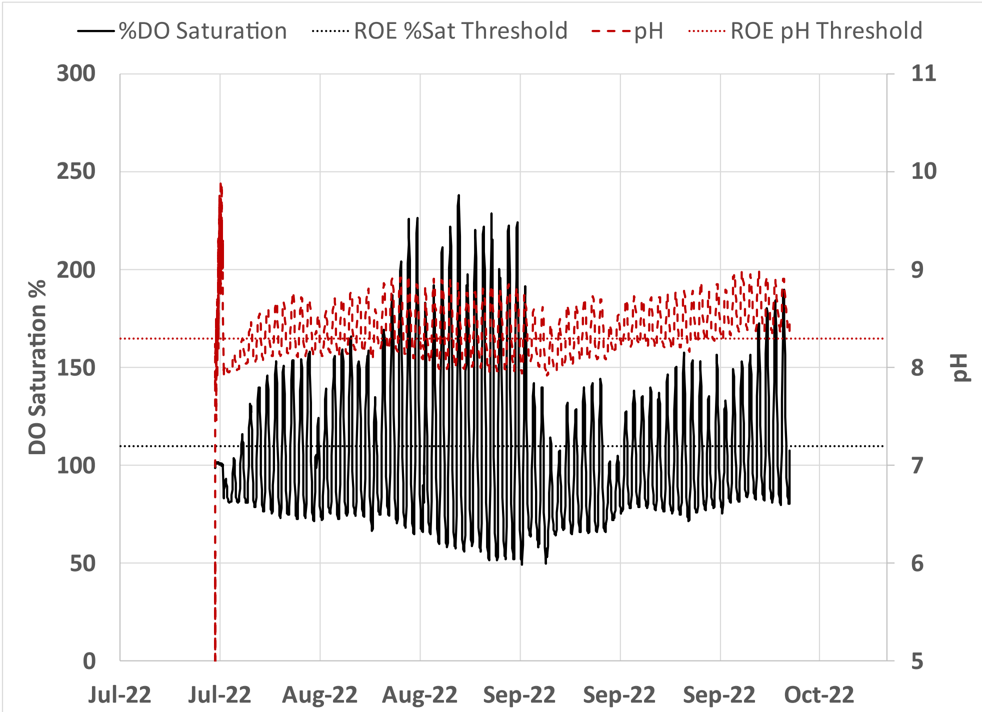

Figure 11: Dissolved Oxygen and pH data at Warner Bridge Road (obtained from Kankakee River Metropolitan Agency)

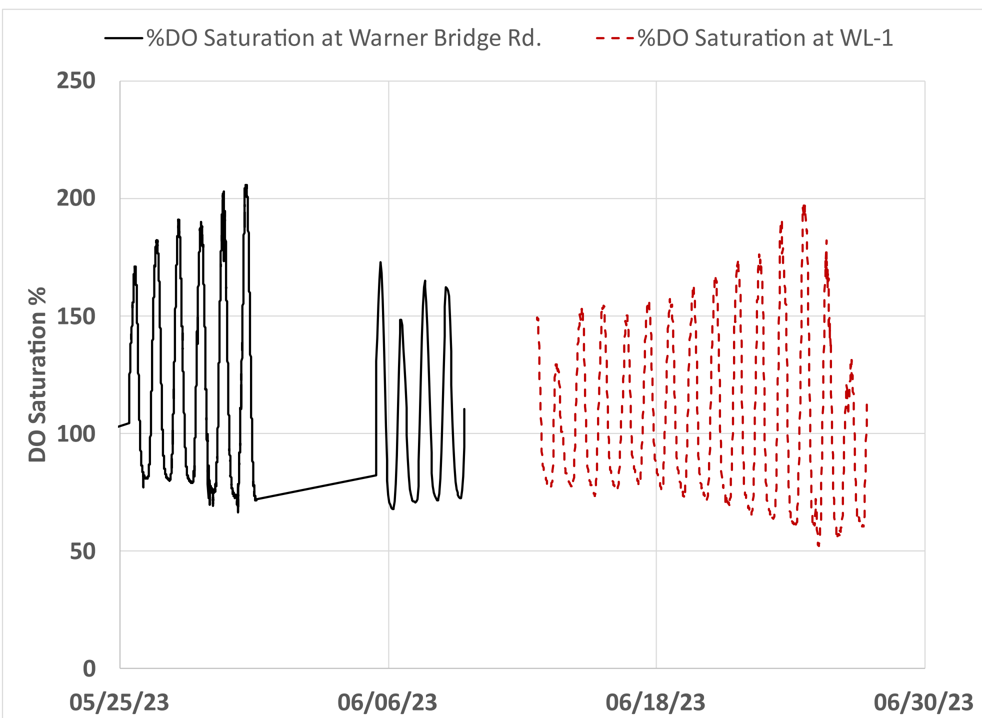

Figure 12: Comparison of Percent Dissolved Oxygen Saturation Measurements between Warner Bridge Road and Station WL-1.

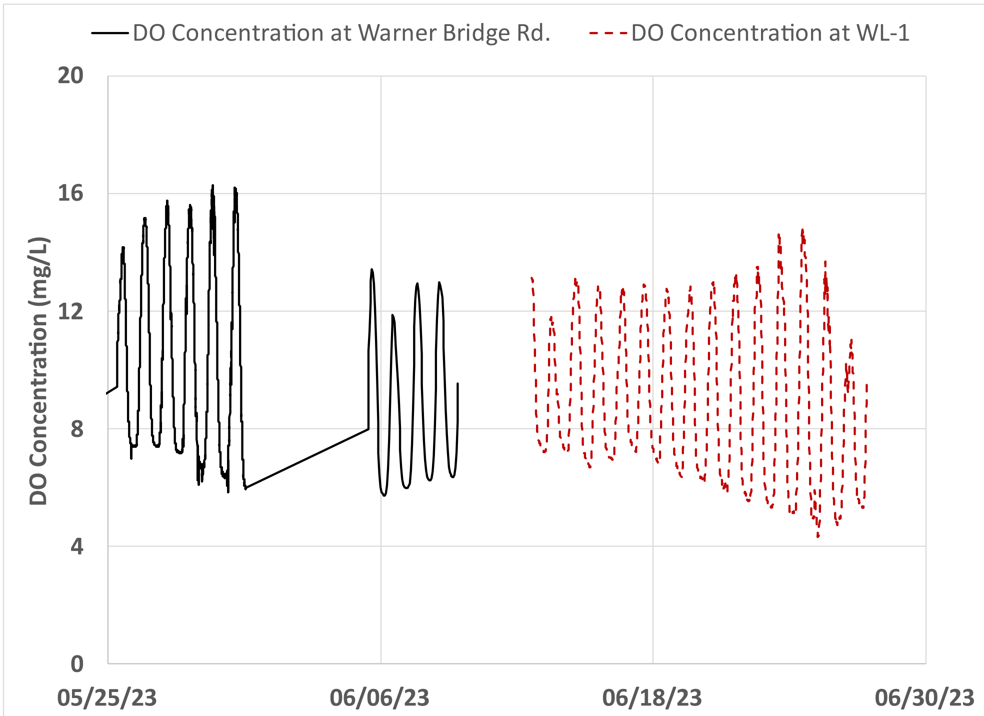

Figure 13: Comparison of Dissolved Oxygen Measurements between Warner Bridge Road and Station WL-1.

3.5 Model Development

The NARP requires the identification of phosphorus input reductions and other necessary measures to address the risk of eutrophication in the Lower Kankakee River. Models can be used to define the linkage between the phosphorus inputs and related impairments such as DO and nuisance algae, evaluate the effectiveness of different watershed management scenarios in reducing or removing impairments, and provide useful information to decision-makers as they decide which projects to prioritize in implementing NARP recommendations.

A steady-state instream model was developed using the QUAL2K framework (Chapra, Pelletier, & Tao, 2008). As described in Geosyntec (2022), a steady-state model was chosen because the City was developing an individual NARP; the City's WRP and Prairie Creek are a small fraction of the phosphorus load; and identifying a condition with low flow and high TP will be representative of conservative conditions. The modeled reaches include the lower Kankakee River mainstem from river mile 9.3 to 0, with Prairie Creek and the Wilmington WRP modeled as point source inputs. The instream model development and calibration are described in *Attachment B: QUAL2k Model Presentation* and are summarized below.

3.5.1 Development

The inputs into the instream model included meteorology, channel characteristics, and time series of flows and water quality constituents from the upstream boundary and point sources. For the steady-state model, only hourly data for a single day is required. Discrete measurements collected on June 13 and June 27, 2023, for each water quality parameter were averaged to represent the steady-state condition, and the constant averaged values were applied for the entire day. Continuous data collected on June 17, 2023, were used to calculate the average hourly data to represent the steady-state condition based on flow data observed at United States Geological Survey (USGS) Kankakee River Near Wilmington, IL - 05527500. The discharge in the Kankakee River remained low and stable for more than five days from June 13 to June 19, 2023, which is a good representation of steady-state conditions, as shown in **Figure 14**.

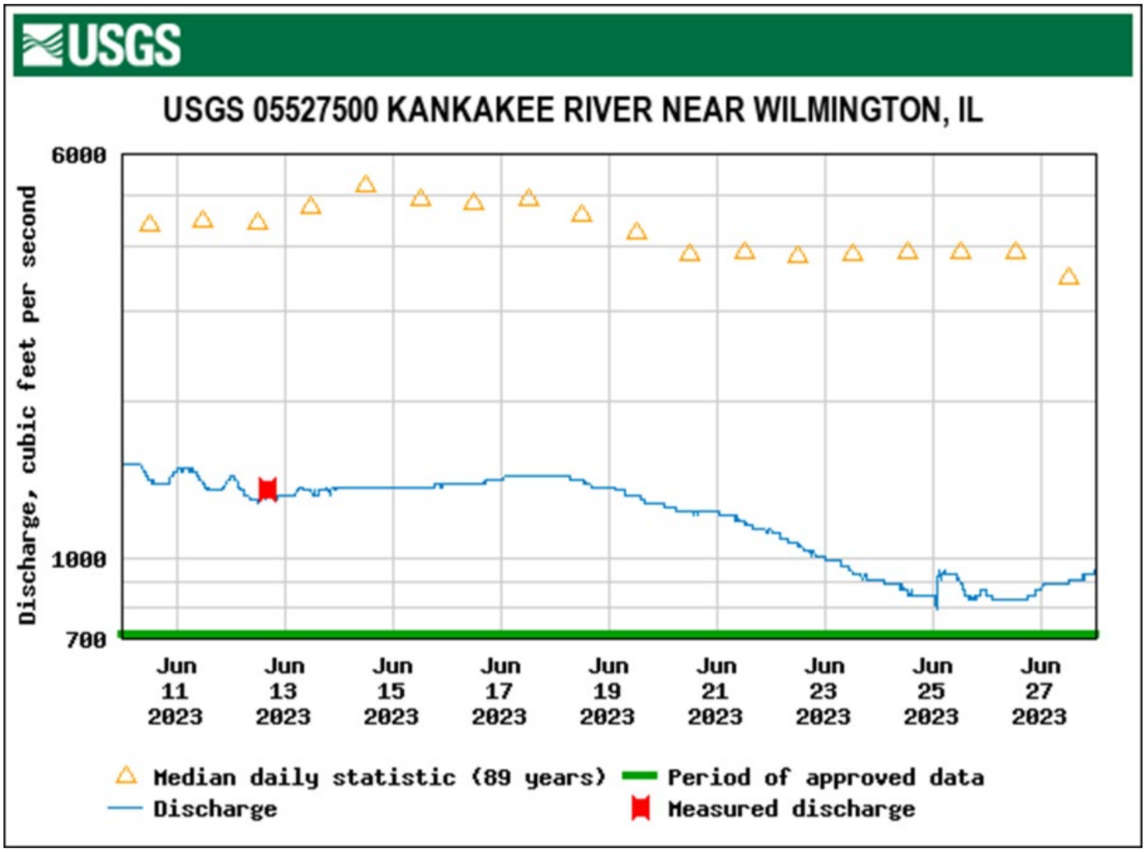

Figure 14: Measured Flow at USGS 05527500 Kankakee River Near Wilmington, IL from June 10 to June 27, 2023

3.5.2 Calibration

The instream model was calibrated to available flow and water quality data for the two surveys in June 2023 using a steady-state simulation of 17 days. Flow was low and relatively constant throughout the month (flow ranged from 793 to 2,320 cfs based on the continuous data collected at USGS Station Kankakee River Near Wilmington, IL – 05527500[3]), representing a steady-state

[3] The seven day once in ten-year low flow (7Q10) of the Kankakee River is 476 cfs as reported in the NPES Permit No. IL0026085.

condition. The temperature was warm, and solar radiation was abundant, which provides the ideal environment for algal growth. The calibration process involved updating the model parameters to measured data.

Figure 15 compares measured and simulated total nitrogen (TN) concentrations along the Kankakee River. The left-hand side of the figure represents data collected at the upstream (location WL-1), and data on the right-hand side of the figure represents data collected at the downstream (location WL-4). The City's WRP discharges at river mile 8.9 and Prairie Creek enters the river at river mile 6.1. For the simulation, the three lines represent the minimum, maximum, and average concentrations during the simulation. The model does a good job of simulating the measurements.

Figure 16 compares measured and simulated TP along the Kankakee River. The model simulation captured the measured TP well at locations WL-1 and WL-4 but overestimated TP at locations WL-2 and WL-3. This is likely due to the measurement being near the reporting limit for the analytical method (which is 0.05 milligrams per liter [mg/L]) and inherent variation in the measurements when dealing with low concentrations. **Figure 17** compares simulated and measured inorganic phosphorus along the Kankakee River, and the simulation captured the measured values well.

Figure 18 compares simulated and measured $CBOD_5$ along the Kankakee River. The model simulations captured the measured $CBOD_5$ well at all stations.

Figure 19 compares simulated and measured sestonic chlorophyll-*a* data along the Kankakee River. The model simulations captured the measured chlorophyll-*a* reasonably well at WL-1, WL-2, and WL-3 but underestimated the measurements at WL-4.

Figure 20 to **Figure 23** show comparisons of measured and simulated diel temperature and diel DO at sites WL-2 and WL-4, respectively, on June 17, 2023. The model simulation captures the diurnal fluctuations in water temperature and DO at both stations reasonably well.

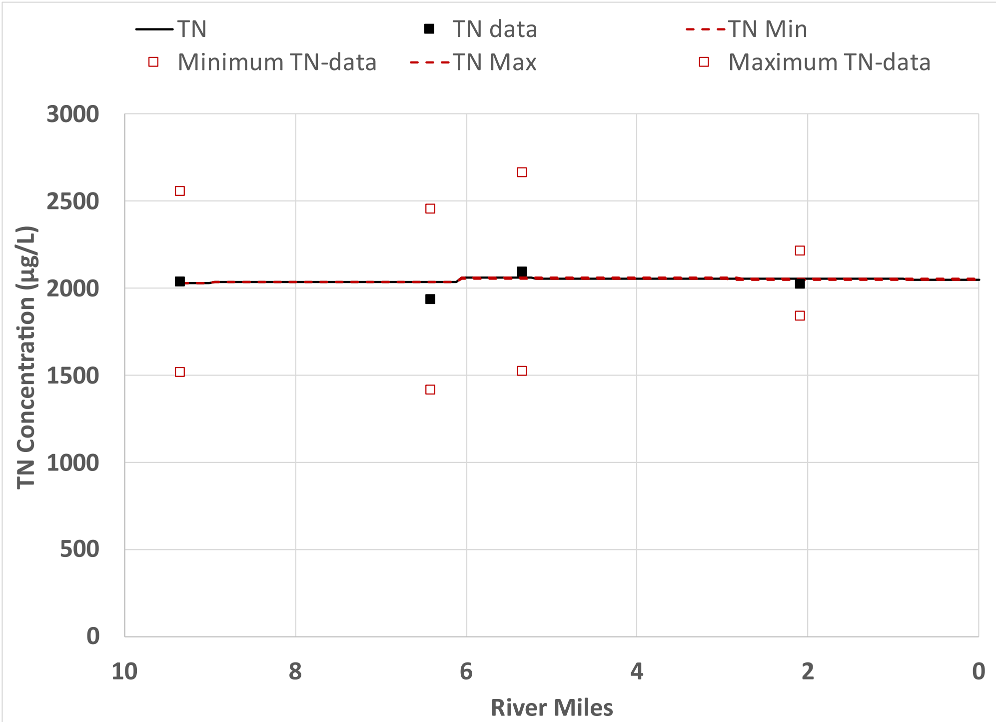

Figure 15: Comparison of Measured and Simulated Total Nitrogen along the Kankakee River

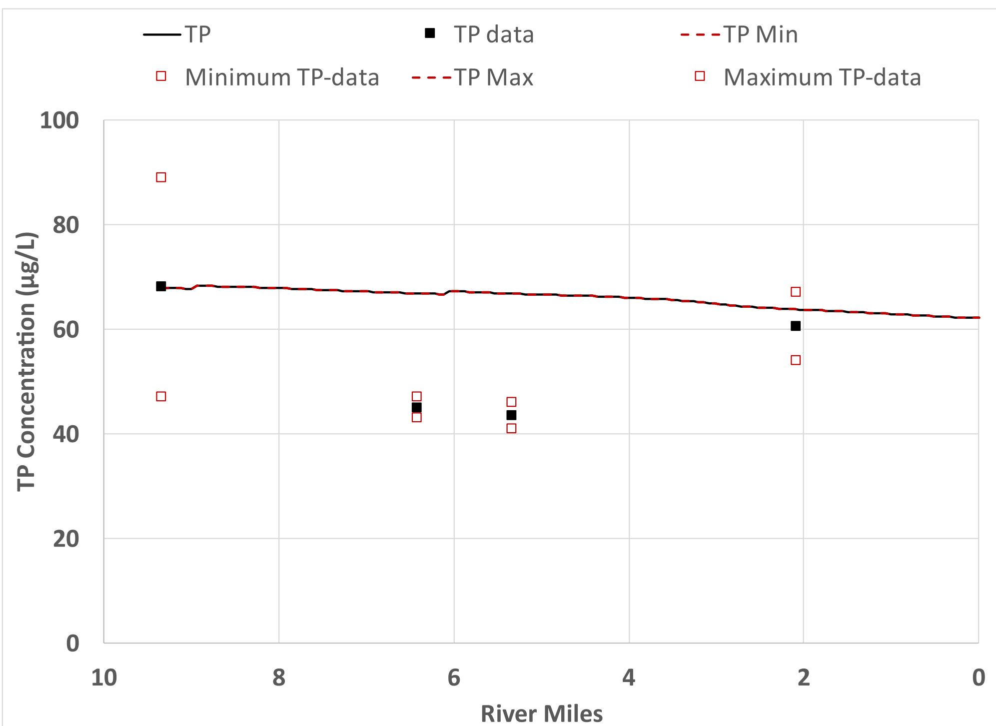

Figure 16:Comparison of Measured and Simulated Total Phosphorus along the Kankakee River

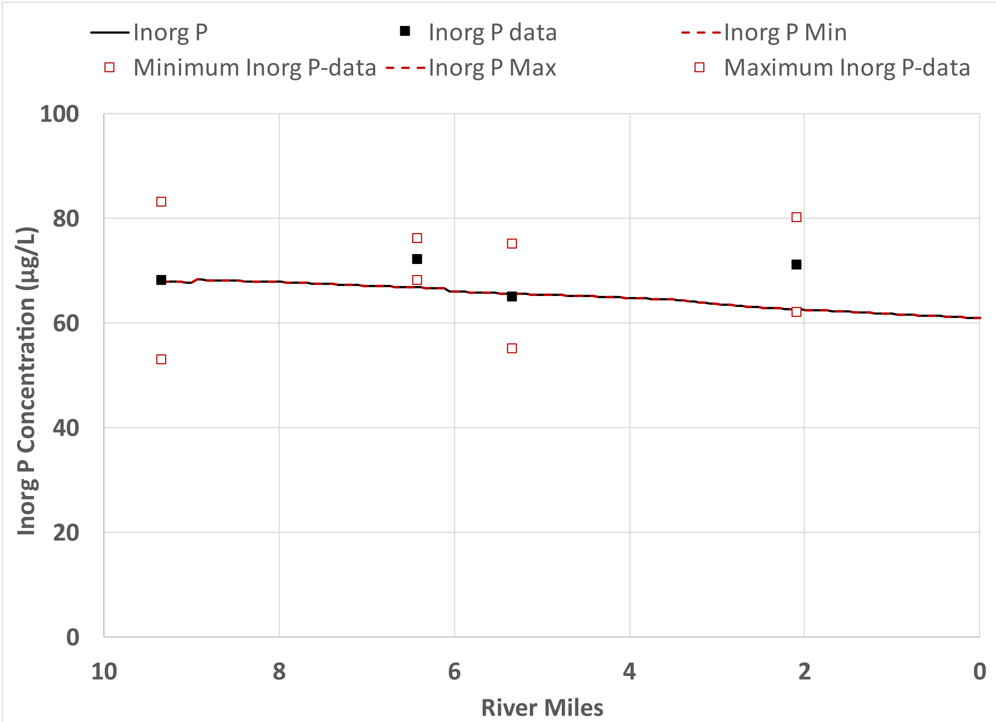

Figure 17: Comparison of Measured and Simulated Inorganic Phosphorus along the Kankakee River

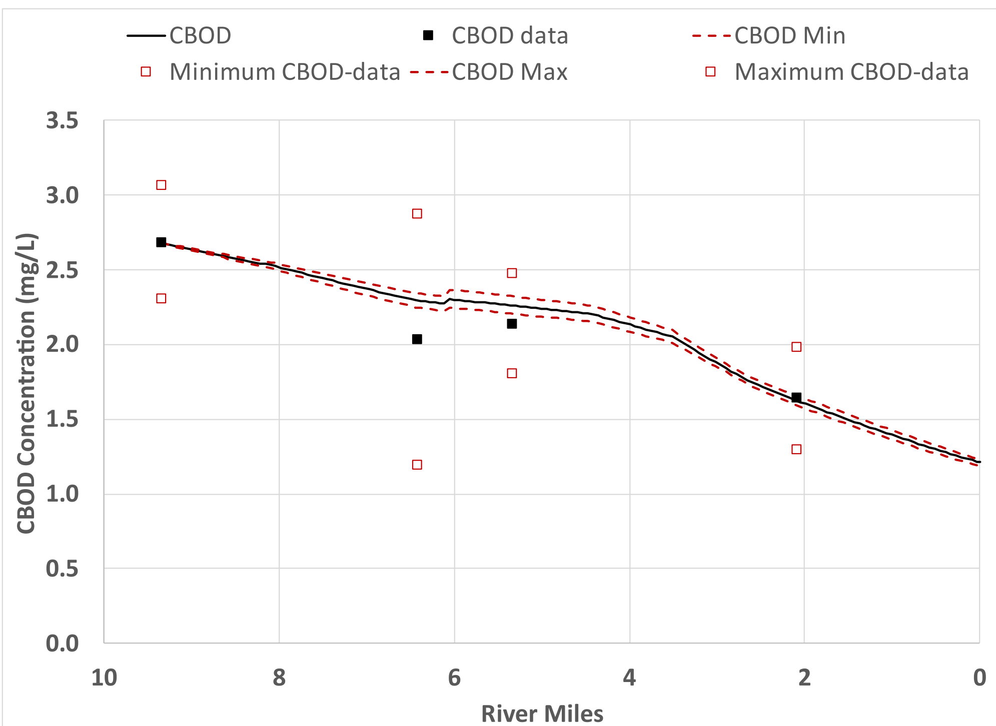

Figure 18: Comparison of Measured and Simulated CBOD along the Kankakee River

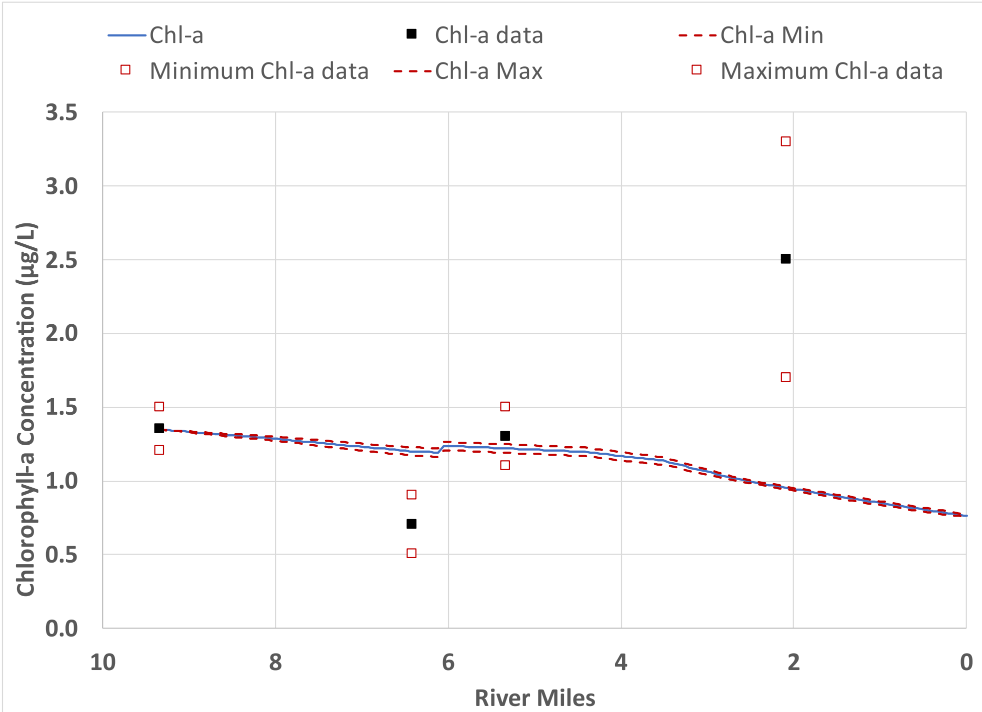

Figure 19: Comparison of Measured and Simulated Chlorophyll-a along the Kankakee River

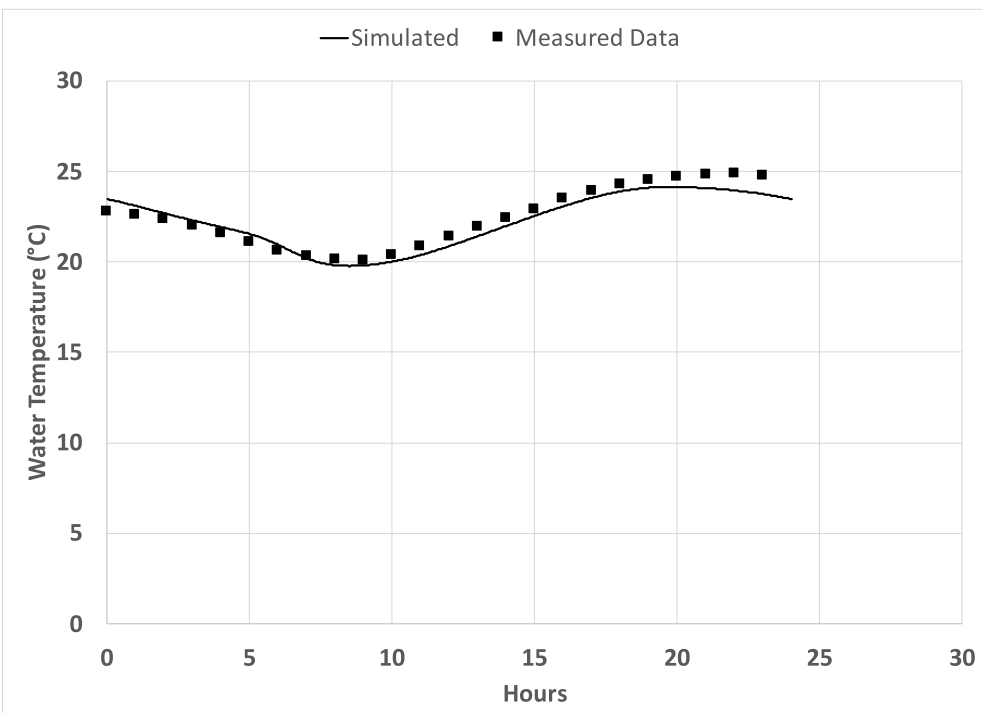

Figure 20: Comparison of Measured and Simulated Water Temperature at WL-2 on 06/17/2023

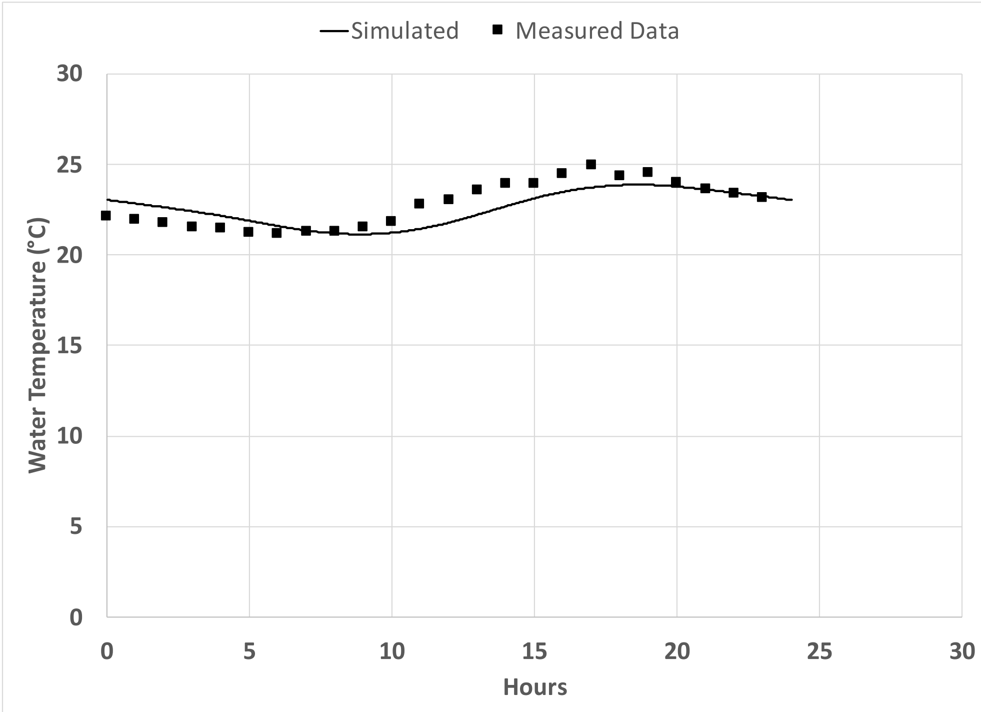

Figure 21: Comparison of Measured and Simulated Water Temperature at WL-4 on 06/17/2023

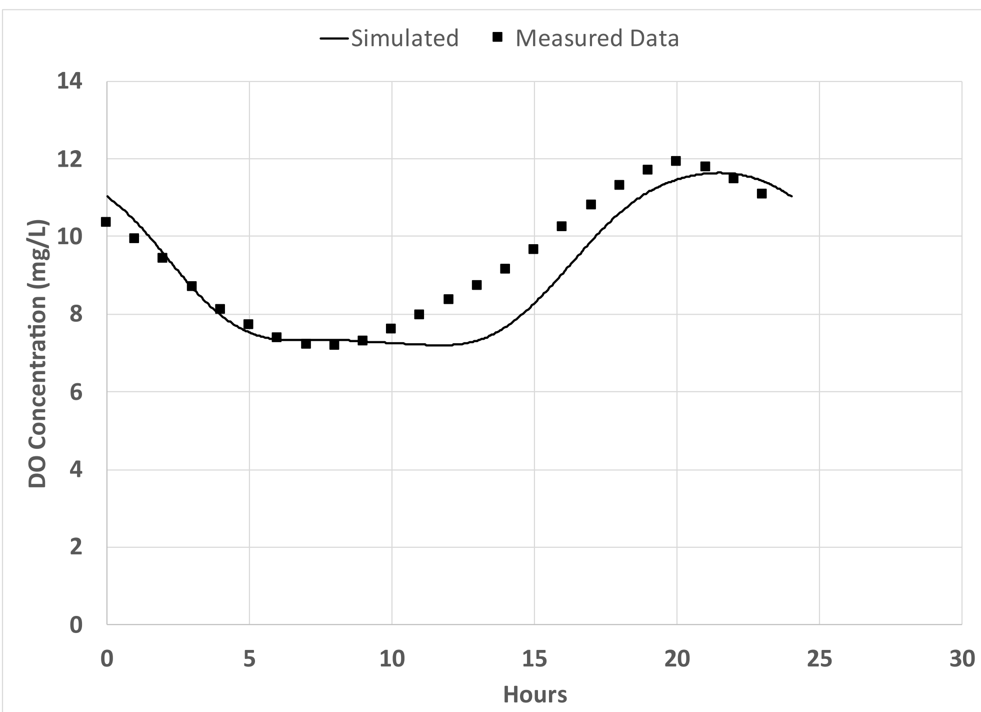

Figure 22: Comparison of Measured and Simulated Dissolved Oxygen at WL-2 on 06/17/2023

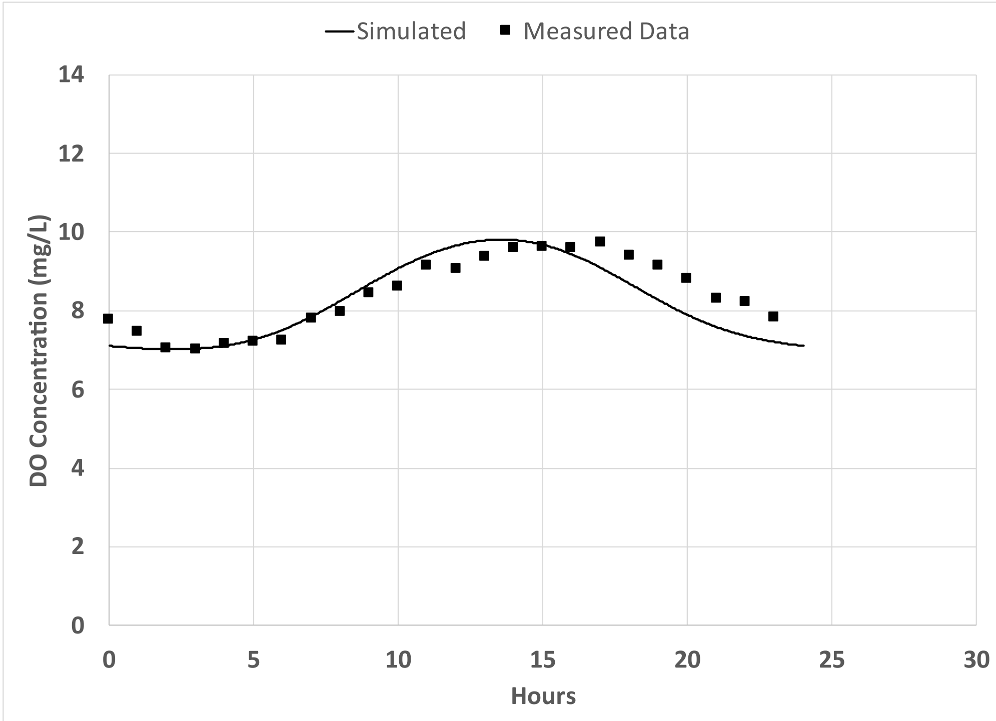

Figure 23: Comparison of Measured and Simulated Dissolved Oxygen at WL-4 on 06/17/2023

3.6 Management Scenarios

The model was used to simulate several scenarios to evaluate the effectiveness of watershed-based strategies in improving the water quality in the Kankakee River. These scenarios were compared with the baseline scenario, which represents the existing condition of the system. The calibrated steady-state instream model for June 2023 was used as the baseline scenario for evaluating watershed management actions.

The watershed management scenarios are described briefly below.

3.6.1 Baseline Scenario

The baseline scenario represents the existing condition of the system for the period of June 2023. The effluent TP concentrations for the City WRP in June 2023 range from 0.3 to 0.9 mg/L and an average value of 0.6 mg/L was used in the baseline scenario.

3.6.2 WRP Load Reduction

The instream model was run to simulate the impact of Wilmington WRP TP load reduction scenarios by capping the TP effluent concentrations to constant values of 0.5 mg/L and 0.1 mg/L.

3.6.3 Upstream Sources Load Reduction

The upstream load constitutes approximately 94% of the total TP load into the Study Area for the period of June 2023. The instream model was run for scenarios with a 25% and a 50% reduction in upstream TP load. The reductions were simulated by proportionally reducing the upstream concentrations of organic phosphorus, inorganic phosphorus, and internal phosphorus within sestonic algae (i.e., algae suspended in the water column). The upstream boundary sestonic chlorophyll-*a* value for the baseline scenario was 1.35 µg/L. For the 25% reduction scenario, the upstream sestonic chlorophyll-*a* was 1.01 µg/L, and for the 50% reduction scenario, the upstream sestonic chlorophyll-*a* was 0.68 µg/L.

3.7 Evaluation of Management Scenarios

The model was used to evaluate the watershed management scenarios by comparing the results to the baseline scenarios for the period of June 2023. The modeling results and key findings are summarized below.

Key Takeaway #1: Reducing phosphorus concentrations in the City's WRP TP beyond the current levels will have minimal impact on water quality in the Kankakee River.

The impact of load reductions associated with more stringent effluent TP limits for Wilmington WRP was simulated by capping the plant effluent TP concentrations to 0.5 mg/ L and 0.1 mg/L in the model.

Figure 24 shows the simulated results for the baseline scenario (black solid line) were compared with a scenario with plant effluent TP capped at 0.5 mg/L (red dashed line), and a scenario with plant effluent TP capped at 0.1 mg/L (blue dashed line) for June 2023. The results show that decreasing the City WRP TP beyond the current levels (represented by the baseline scenario) has an insignificant impact on instream TP in the downstream Kankakee River. Similarly, the reduction in City WRP would have a negligible impact on the already low chlorophyll-*a* concentrations, as shown in **Figure 25**. Therefore, further reductions in the City's WRP TP concentrations beyond the current levels are not recommended.

Key Takeaway #2: Improving upstream water quality conditions for Dissolved Oxygen and pH is required to address the risk of eutrophication in the Lower Kankakee River.

Figure 26 and **Figure 27** show the simulated TP and sestonic chlorophyll-*a* results for the baseline scenario (black solid line), the 25% upstream reduction (red dashed line), and the 50% upstream reduction (blue dashed line) scenarios. The results show that reducing the upstream TP load reduces the instream TP (**Figure 26**) and sestonic chlorophyll-*a* (**Figure 27**) concentrations. However, because the chlorophyll-*a* concentrations in the baseline scenario are low, the reduction in instream chlorophyll-*a* has very little impact on DO swings at locations WL-2 and WL-4, as shown in **Figure 28** and **Figure 29**, respectively. The results suggest that the nutrient inputs from the Study Area were low, and the risk of eutrophication is mainly driven by the upstream boundary conditions for Dissolved Oxygen and pH.

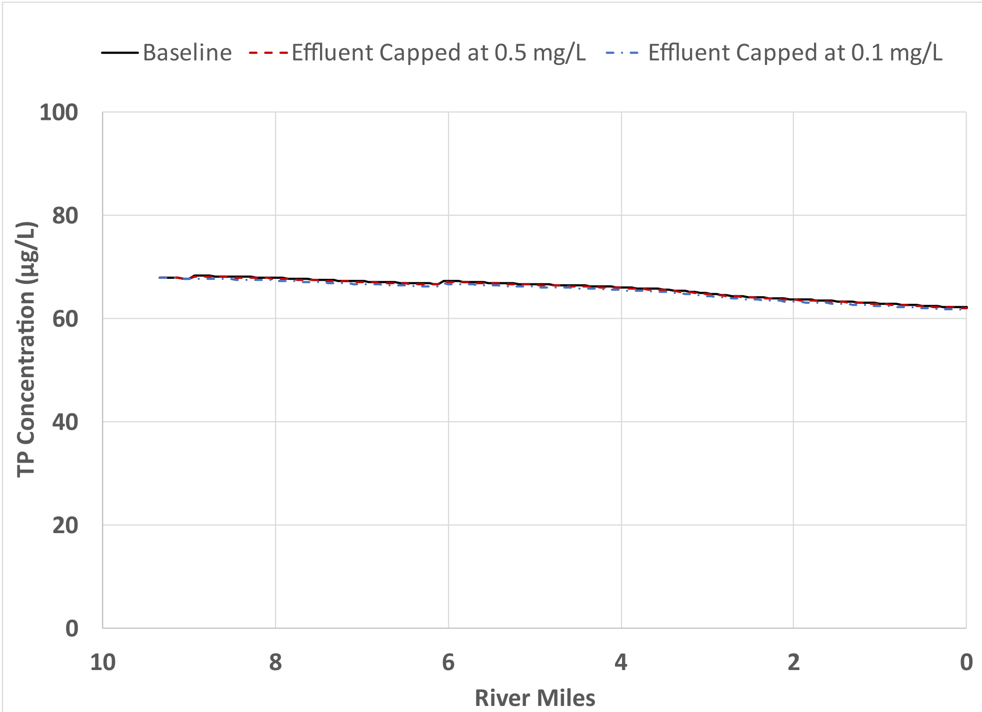

Figure 24: Total Phosphorus Concentrations along the Kankakee River for the Baseline, Effluent Capped at 0.5 mg/L, and Effluent Capped at 0.1 mg/L Scenarios

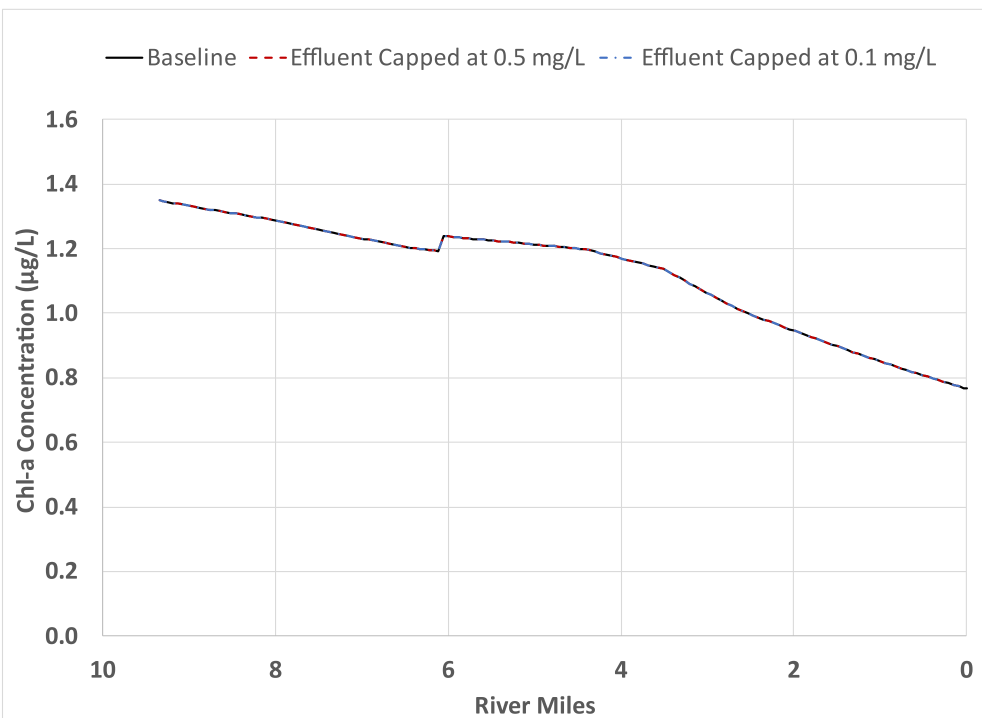

Figure 25: Chlorophyll-a Concentrations along the Kankakee River for the Baseline, Effluent Capped at 0.5 mg/L, and Effluent Capped at 0.1 mg/L Scenarios

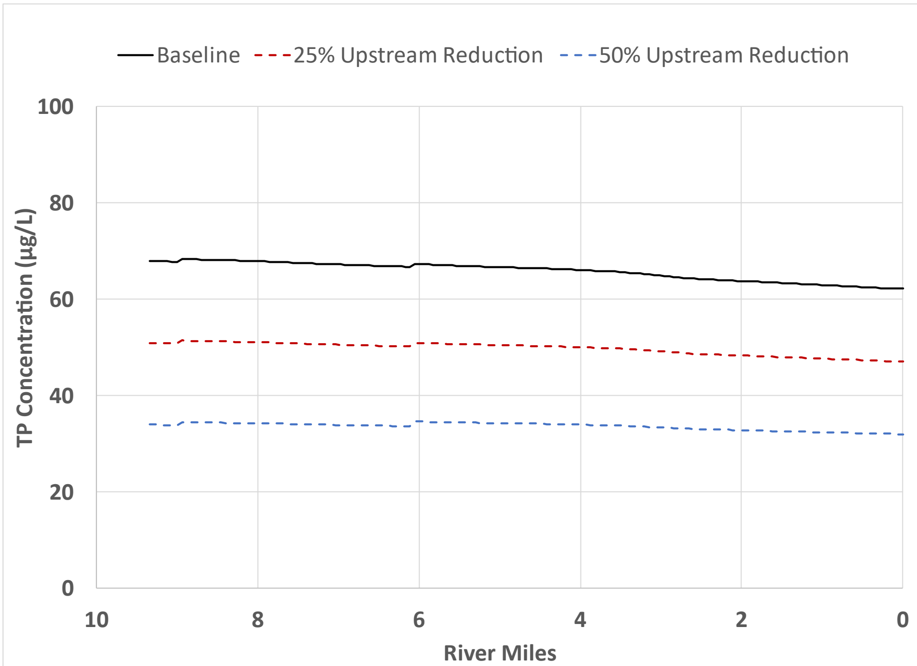

Figure 26: Total Phosphorus Concentrations along the Kankakee River for the Baseline, 25% Upstream Reduction, and 50% Upstream Reduction Scenarios

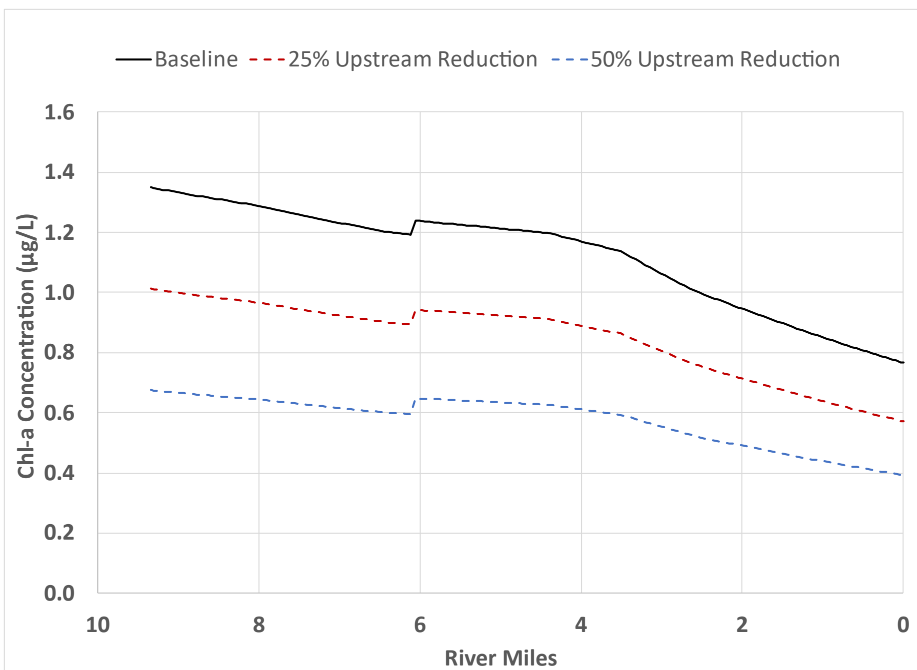

Figure 27: Chlorophyll-a Concentrations along the Kankakee River for the Baseline, 25% Upstream Reduction, and 50% Upstream Reduction Scenarios

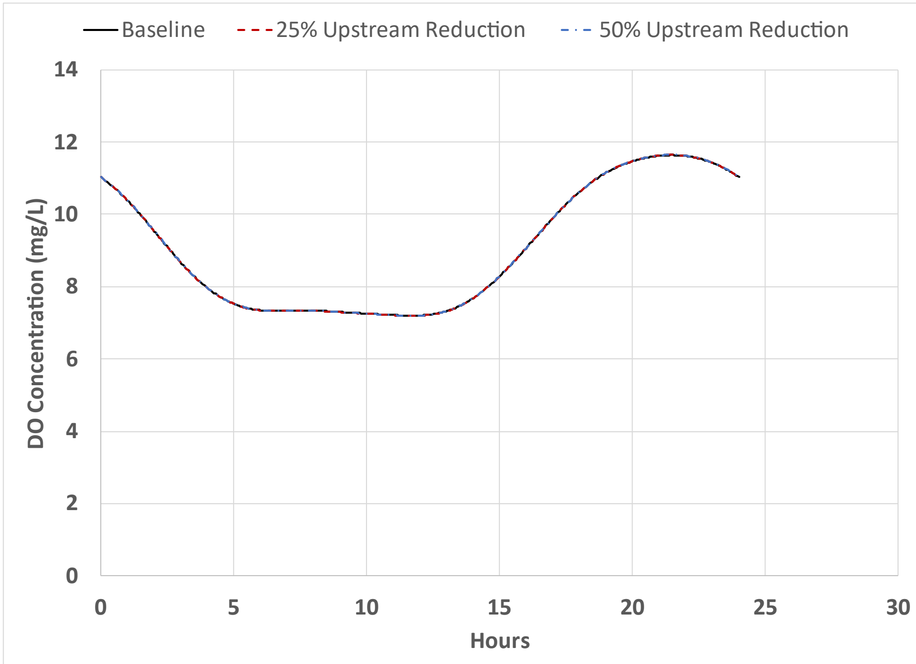

Figure 28: Diel Dissolved Oxygen Concentrations at Location WL-2 for the Baseline, 25% Upstream Reduction, and 50% Upstream Reduction Scenarios

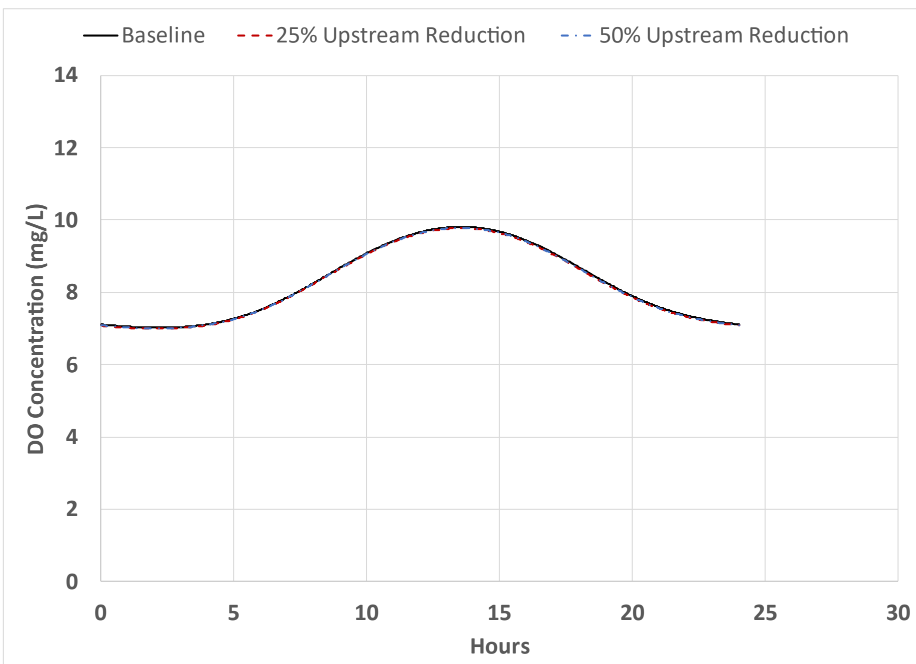

Figure 29: Diel Dissolved Oxygen Concentrations at Location WL-4 for the Baseline, 25% Upstream Reduction, and 50% Upstream Reduction Scenarios

4. IMPLEMENTATION PLAN AND SCHEDULE

4.1 Management Actions

The recommended management actions for the NARP are described below.

4.1.1 Water Reclamation Plant Phosphorus Reduction

The City's WRP uses chemical addition for TP reduction and is currently meeting the required TP monthly average effluent limit of one mg/L per Special Condition of 17 B (4) of the NPDES permit. The results of data analysis and modeling scenarios show that reducing the WRP effluent TP beyond the current TP effluent limit of one mg/L would not address the risk of eutrophication in the Lower Kankakee River. Hence, continuing to achieve a TP limit of one mg/L is recommended for the WRP.

4.1.2 Load Reduction from Upstream Sources

The NARP study determined that upstream water quality has a significant impact on the risk of eutrophication in the Lower Kankakee River. The KRMA is in the process of developing its own NARP to address the risk of eutrophication in the Kankakee River downstream of its discharge. Based on existing information, implementation of KRMA's NARP should address the impairments downstream of the City's WRP.

The City collaborated with KRMA for its NARP development. As part of the collaboration, the City participated in the stakeholder engagement workshop organized by KRMA on June 14, 2023. The City and KRMA have also shared monitoring data collected for the development of the respective NARPs. The City plans to engage with KRMA for NARP implementation as upstream sources, which include KRMA discharges, have a significant impact on instream water quality downstream of the WWRP implementation plan and schedule.

4.1.3 Monitoring Studies

The City will continue to undertake monitoring to meet the requirements of the City WRP's NPDES permit.

5. REFERENCES

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Attachment A

Wilmington NARP Presentation

Geosyntec consultants

WILMINGTON NARP

2023 FIELD DATA ANALYSIS SUMMARY

Project Overview

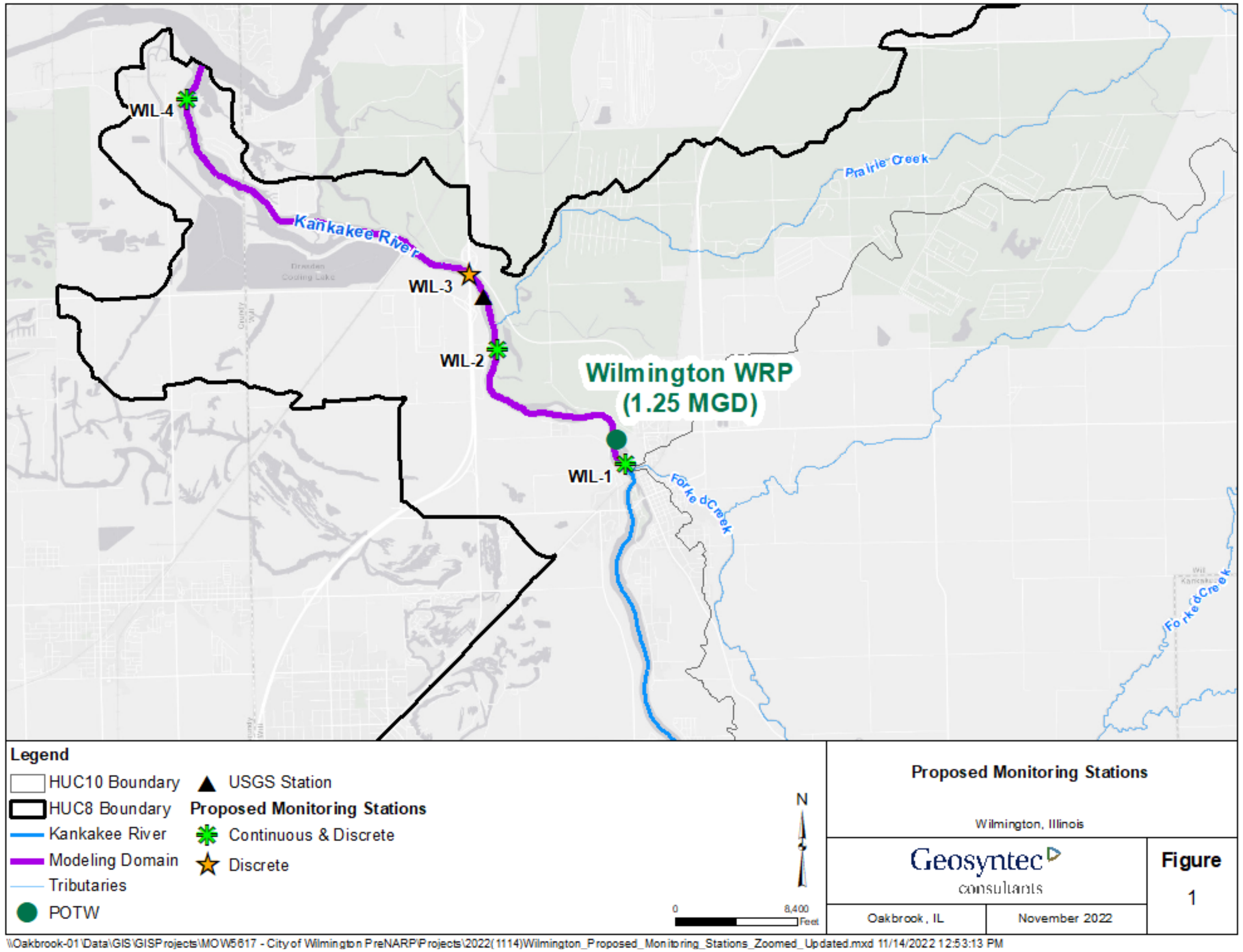
Project Overview

- Nutrient Assessment Reduction Plan (NARP)
- Determine phosphorus reductions required to remove risk of eutrophication downstream of the Wilmington Water Reclamation Plant (WWRP) in the Kankakee River watershed
- Assessed dissolved oxygen levels during critical summer conditions (low flow, high water temperature, and high biological productivity period)
- Data collected during the 2023 water quality monitoring period will be used to develop and calibrate models which will be used to determine the required phosphorus reductions

Photo 1: Monitoring Site WL-2 Equipment on 6/27/23

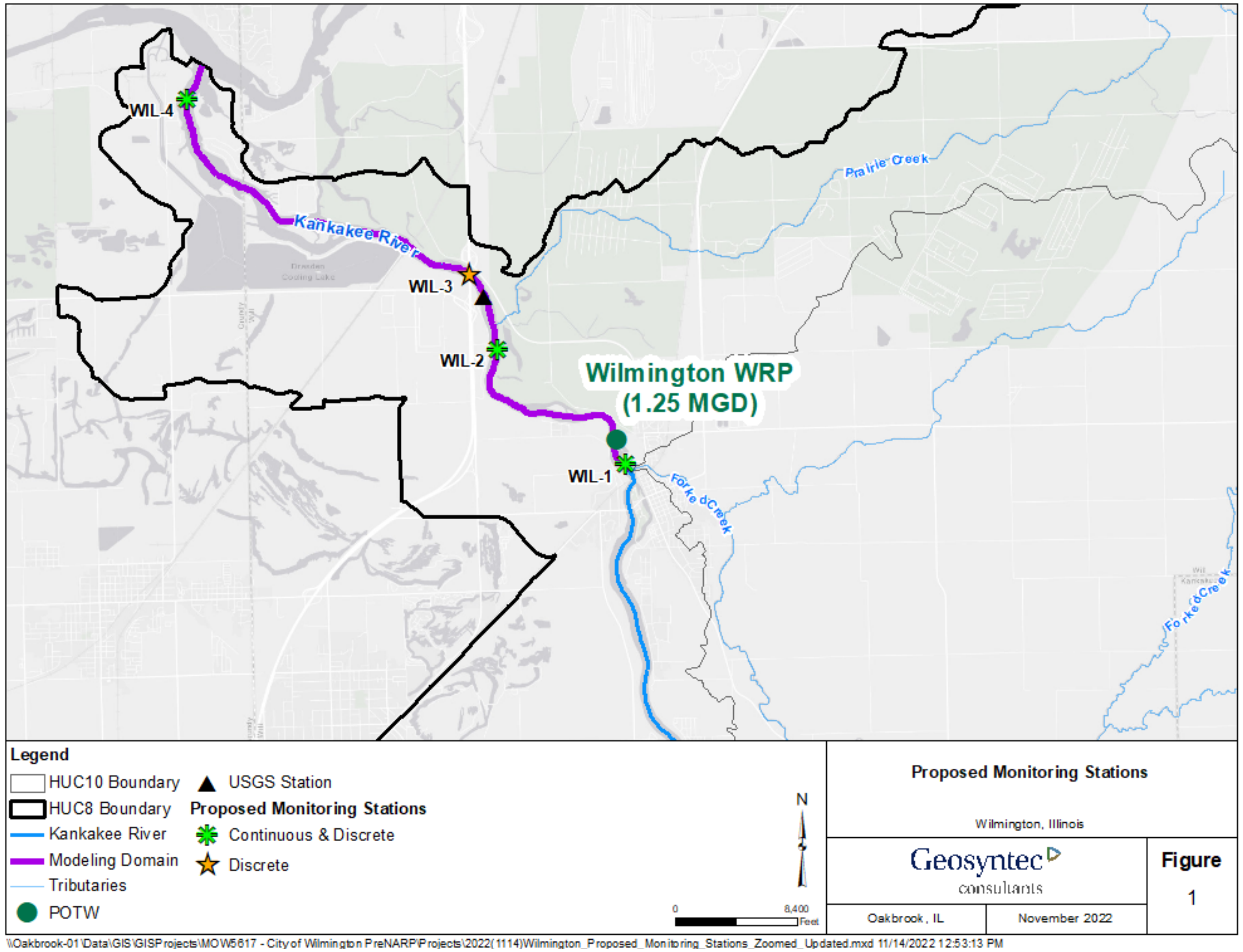
Water Quality Monitoring – Discrete Analytical Samples

- Discrete water quality samples collected twice at 4 locations
- Samples were analyzed for 10 laboratory water quality parameters:
  - Ammonia
  - Nitrate
  - Nitrite
  - Carbonaceous Biochemical Oxygen Demand (CBOD)
  - Total Kjeldahl Nitrogen (TKN)
  - Total Phosphorus
  - Dissolved Orthophosphate
  - Total Suspended Solids (TSS)
  - Sestonic Chlorophyll-a



Water Quality Monitoring – Continuous Data Collection

- Deployed and maintained YSI EXO3 Sondes at 3 locations for continuous in-stream monitoring:
  - 1 station upstream of WWRP (WL-1)
  - 2 stations downstream of WWRP (WL-2, WL-4)
- Measured 5 water quality parameters continuously:
  - Dissolved oxygen (DO)
  - Temperature
  - pH
  - Turbidity
  - Specific conductivity
- Collected measurements in 15-minute increments for 2 weeks



Water Quality Analytical Data

Discrete Water Quality Analytical Results

- Total Phosphorus concentrations were lower downstream of WWRP at WL-2 than upstream WWRP at WL-1 during both sampling events
- WWRP did not increase Total Phosphorus concentrations at downstream monitoring stations in the Kankakee River

Figure 2: 6/13/23 Water Quality Analytical Results

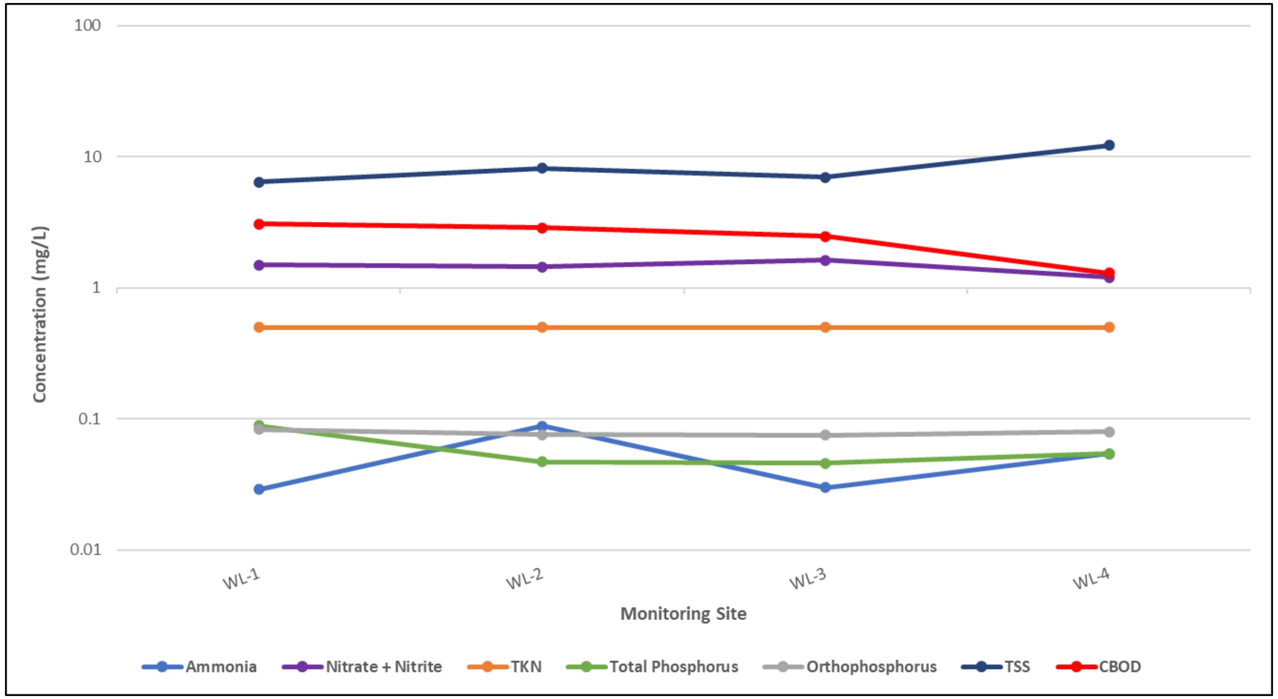
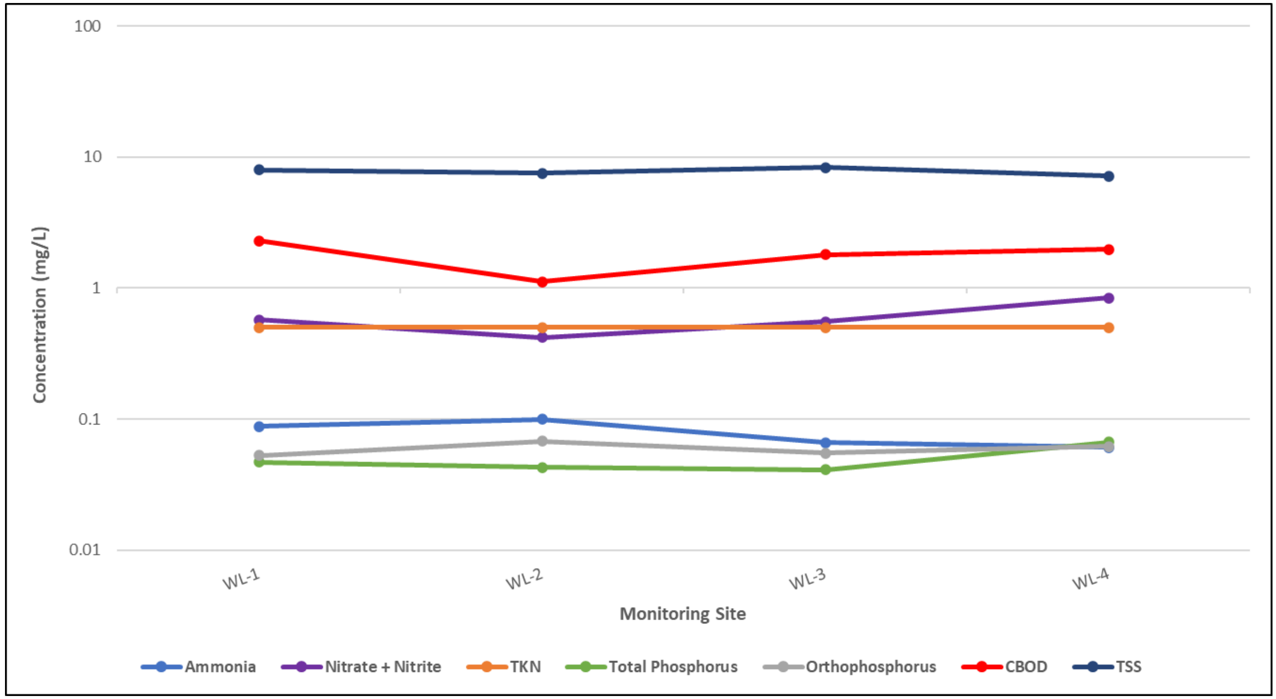


Figure 3: 6/27/23 Water Quality Analytical Results



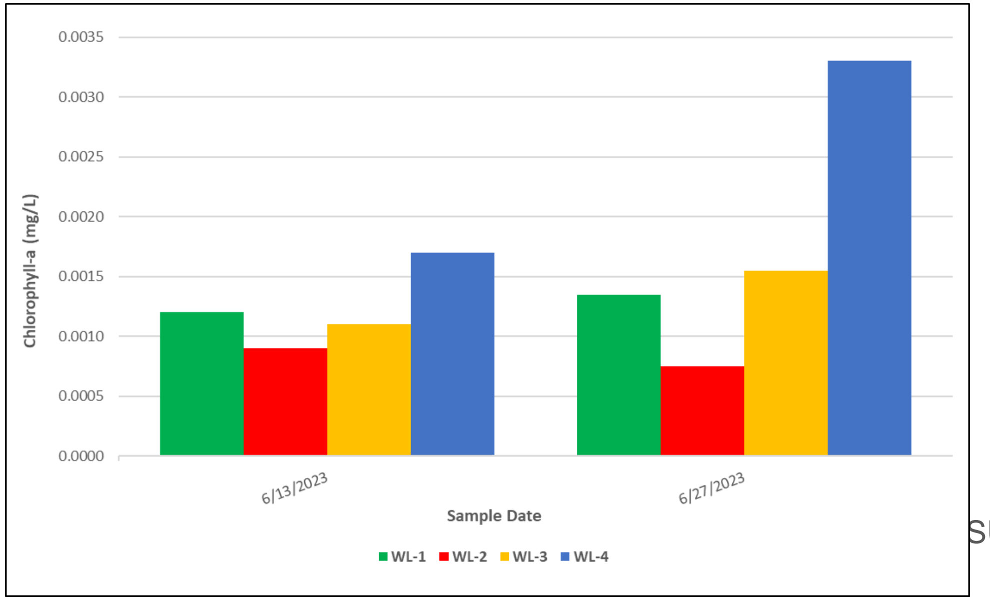
Chlorophyll-a Results

- Sestonic Chlorophyll-a concentrations were lower downstream of WWRP at WL-2 than upstream WWRP at WL-1
- Sestonic Chlorophyll-a was consistently highest at the furthest downstream monitoring site WL-4, though all measurements are below the Illinois Environmental Protection Agency risk of eutrophication criteria (0.026 mg/L). The concentrations observed at WL-4 may be due to stagnant water and are unlikely to be the result of WWRP activities.

Table 1: Sestonic Chlorophyll-a Analytical Results

Monitoring Site	Sample Date	Chlorophyll-a (mg/L)
WL-1	6/13/2023	0.0012
WL-2	6/13/2023	0.0009
WL-3	6/13/2023	0.0011
WL-4	6/13/2023	0.0017
WL-1	6/27/2023	0.0014
WL-2	6/27/2023	0.0008
WL-3	6/27/2023	0.0016
WL-4	6/27/2023	0.0033

Figure 4: Sestonic Chlorophyll-a Analytical Results at Each Monitoring Site



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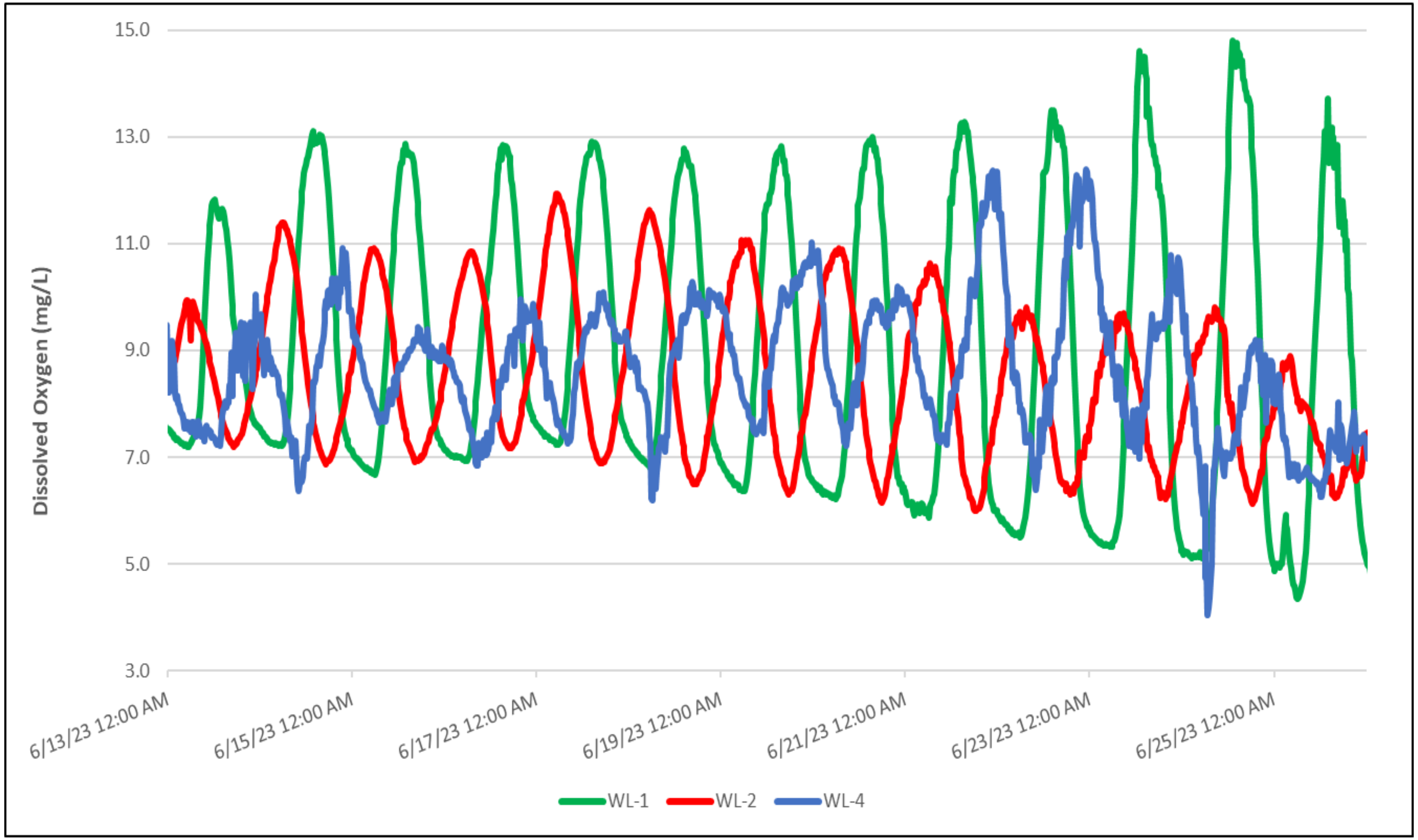
Continuous Monitoring Data

Dissolved Oxygen Monitoring

Figure 5: Continuous Dissolved Oxygen Concentrations Per Monitoring Site



- While DO is highest upstream of WWRP at WL-1, larger diurnal patterns suggest photosynthesis and respiration is present upstream WWRP
- DO levels drop below 5.0 mg/L at WL-1 and WL-4

Table 2: Dissolved Oxygen Continuous Data Statistics

Monitoring Site	Dissolved Oxygen (mg/L)		
	Maximum	Minimum	Average
WL-1	14.79	4.34	8.83
WL-2	11.92	5.99	8.44
WL-4	12.38	4.05	8.58

WL-1 Continuous Data

Figure 6: WL-1 Continuous Monitoring Data

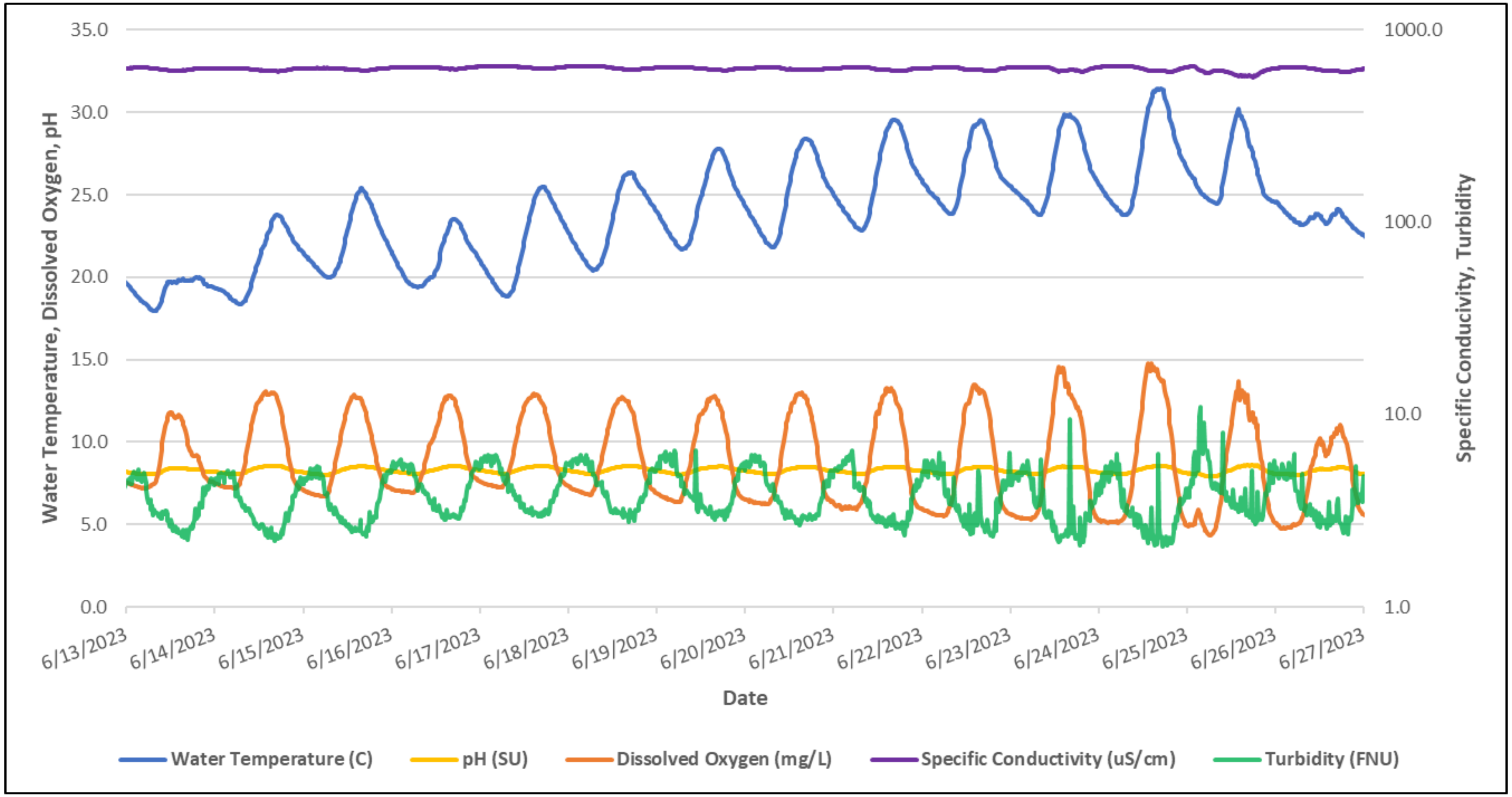


Table 3: WL-1 Continuous Monitoring Data Statistics

Statistic	Water Temperature	Dissolved Oxygen	pH	Turbidity
	°C	mg/L	S.U.	FNU
Minimum	18.0	4.3	7.9	2.1
Maximum	31.5	14.8	8.6	10.9
Median	23.8	8.1	8.3	3.6
Average	23.8	8.8	8.3	3.8
25th Percentile	21.5	6.7	8.1	2.9
75th Percentile	25.6	11.4	8.4	4.7

WL-2 Continuous Data

Figure 7: WL-2 Continuous Monitoring Data

Table 4: WL-2 Continuous Monitoring Data Statistics

Statistic	Water Temperature	Dissolved Oxygen	pH	Turbidity
	°C	mg/L	S.U.	FNU
Minimum	19.4	6.0	8.0	2.5
Maximum	28.7	11.9	8.5	26.1
Median	24.7	8.2	8.2	4.4
Average	24.4	8.4	8.2	4.6
25th Percentile	22.7	7.2	8.2	3.8
75th Percentile	26.5	9.6	8.3	5.2

WL-4 Continuous Data

Figure 8: WL-4 Continuous Monitoring Data

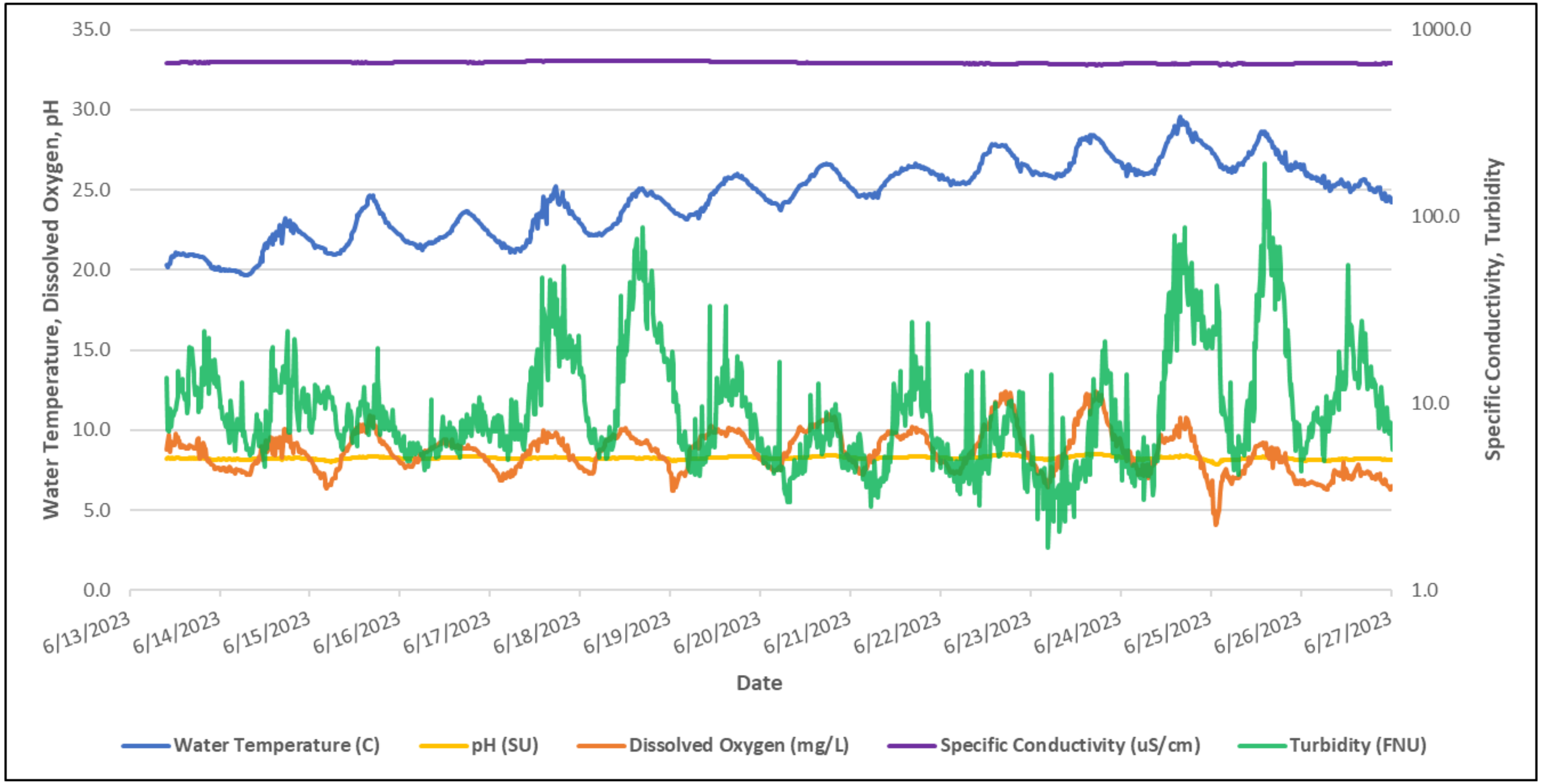


Table 5: WL-4 Continuous Monitoring Data Statistics

Statistic	Water Temperature °C	Dissolved Oxygen mg/L	pH S.U.	Turbidity FNU
Minimum	19.7	4.1	7.8	1.7
Maximum	29.6	12.4	8.5	191.4
Median	24.8	8.6	8.2	7.7
Average	24.5	8.6	8.2	12.2
25th Percentile	22.6	7.5	8.2	5.6
75th Percentile	26.2	9.5	8.3	12.8

Quality Assurance & Quality Control

Quality Assurance & Quality Control

- Three data quality objectives:
    1. Data must be sufficient to characterize summer DO and chlorophyll-a conditions in the waterbody upstream and downstream of the WWRP.
    2. Data must be sufficient to characterize nutrient concentrations in the waterbodies upstream and downstream of the WWRP.
    3. Data must be suitable for use in the development and calibration of the Water Quality Analysis Simulation Program.
- Data quality is assessed by evaluating analytical data, sampling methods, and analytical methods relative to the following criteria:
    - Precision
    - Accuracy
    - Completeness
    - Representativeness
    - Comparability
    - Sensitivity

Quality Assurance & Quality Control

- Field duplicate analytical results indicate acceptable data precision and representativeness
  - Average relative percent difference between parent and duplicate samples on 6/13/23 and 6/17/23 were 5.3% and 11.2% respectively, which met the 30% criteria in the study plan.
- Field blank analytical results indicate acceptable data accuracy
  - All analyses were below the method detection limit (MDL) outside of Ammonia, which was near the MDL.
  - Absence of cross contamination indicates acceptable data representativeness.
- 100% of discrete analytical samples met hold time, preservation, and laboratory acceptance criteria
  - Indicates acceptable completeness of analytical sample data and meets the 75% data completeness criteria in the study plan.
- 100% of expected continuous data records resulted in valid data
  - Indicates acceptable completeness of continuous data and meets the 75% data completeness criteria in the study plan.
- Appropriate sampling techniques and analytical methods listed in the study plan were implemented, resulting in acceptable data comparability
- Analytical methods used by laboratory meet sensitivity criteria in study plan

Summary of NARP Data Analysis

Summary of NARP Data Analysis

- Total Phosphorus and Sestonic Chlorophyll-a concentrations were higher immediately upstream of WWRP than at the first monitoring site downstream of WWRP
- Larger DO diurnal patterns at WL-1 suggest photosynthesis and respiration may be present upstream WWRP. At downstream monitoring sites, the lack of diurnal DO fluctuations, lower DO concentrations, and increased Chlorophyll-a concentrations are likely results of less aeration and more stagnant water.
- WWRP was not increasing Total Phosphorus concentrations at downstream monitoring stations in the Kankakee River

Photo 2: View of Algae Growth at WL-1 Upstream of WWRP on 6/27/23

Attachment B

QUAL2k Model Presentation

CITY OF WILMINGTON NARP DEVELOPMENT

Qual2K Model Setup – Hydraulic Results

July 28, 2023

AGENDA

Stream Segmentation

Qual2K Model Setup

- Manning’s Value Estimation
- Model Inputs

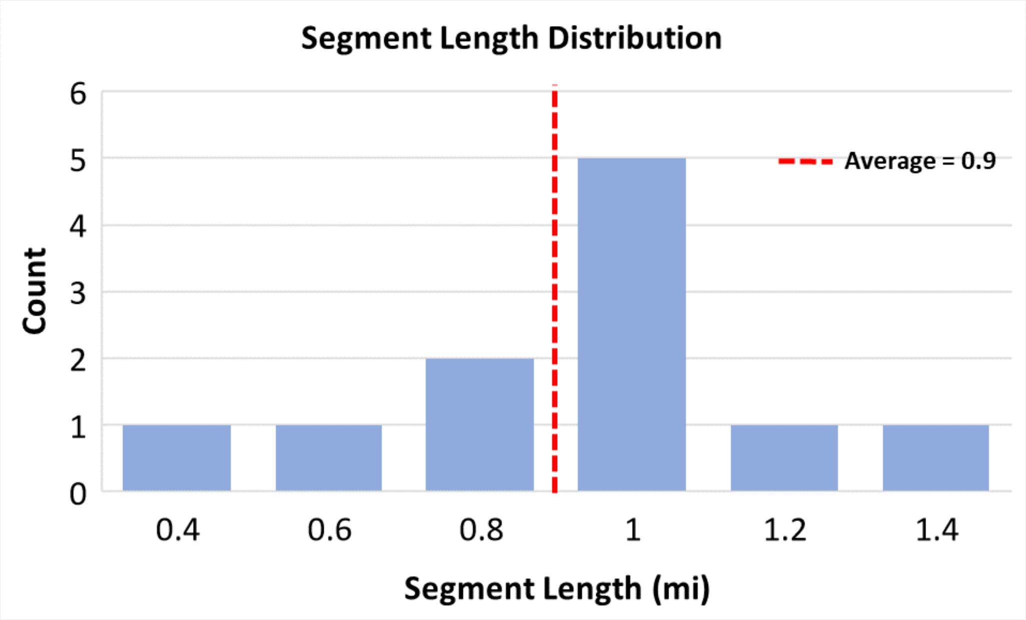
Hydraulic Results

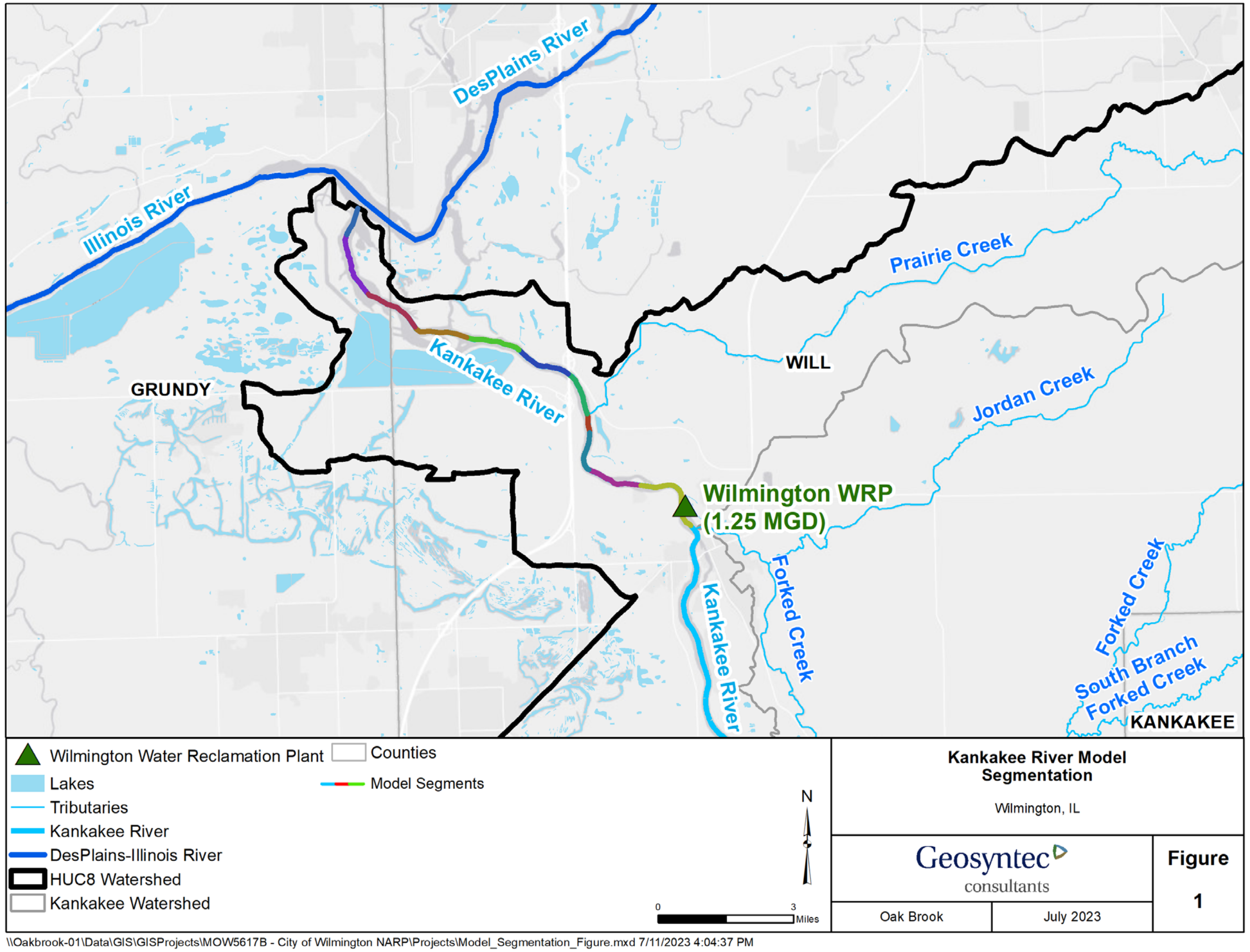
Open Discussion

Stream Segmentation

Stream Segmentation

- 11 Segments
  - Average 0.9 mi
  - Minimum 0.3 mi
  - Maximum 1.3 mi





Stream Segmentation

- ## Reach Characteristics
  - Cross-section data: FIRM by FEMA (rectangular section)*
  - Elevation data: LiDAR database**

	..	...	..	Reach_number	Length_mi	Length_km	US_Length_km	DS_Length_km	Reach_Width	US_Ele_LiDAR	DS_Ele_LiDAR	Reach_Slope_LiDAR	..	...	..	DS_Lat	DS_Lon	...
1	6	P	..	1	1.327742	2.136799	0	12.889023	154.849443	158.642426	158.272614	0.000173	6	8	2	41.323453	-88.168642	8
2	2	P	..	2	0.940673	1.513544	1.612028	11.375479	251.360111	158.272614	158.092056	0.000119	7	6	7	41.327244	-88.185378	8
3	7	P	..	3	0.656566	1.056414	3.125572	10.319065	209.896347	158.092056	157.962326	0.000123	8	7	1	41.336085	-88.185121	4
4	3	P	..	4	0.324688	0.522424	4.181986	9.796641	176.493097	157.962326	157.689468	0.000522	2	8	9	41.34073	-88.18591	5
5	4	P	..	5	0.754463	1.213931	4.70441	8.58271	231.076387	157.689468	155.49733	0.001806	2	2	3	41.350346	-88.191996	5
6	8	P	..	6	0.944034	1.518951	5.918341	7.063759	191.507608	155.49733	153.82515	0.001101	5	2	7	41.356113	-88.207823	4
7	9	P	..	7	0.911994	1.467398	7.437292	5.596361	276.454239	153.82515	153.741638	0.000057	9	5	4	41.359076	-88.224572	4
8	1	P	..	8	0.913898	1.470461	8.90469	4.1259	590.467068	153.741638	153.741638	0	4	9	6	41.361634	-88.241229	4
9	1	P	..	9	0.972796	1.565229	10.375151	2.56067	312.426673	153.741638	153.771332	-0.000019	6	4	7	41.369467	-88.256073	4
10	1	P	..	10	1.109914	1.785851	11.940381	0.774819	325.243631	153.771332	153.722519	0.000027	9	6	7	41.383792	-88.263038	7
11	5	P	..	11	0.481553	0.774819	13.726232	0	322.215035	153.722519	153.722519	0	9	9	0	41.390166	-88.259443	4

0.01% slope was assumed for **orange** reaches

* FIRM: Flood Insurance Rate Map   FEMA: Federal Emergency Management Agency
** clearinghouse.isgs.illinois.edu/data/elevation/illinois-height-modernization-ilhmp

Geosyntec consultants

Qual2K Model Setup

Manning's Value Estimation

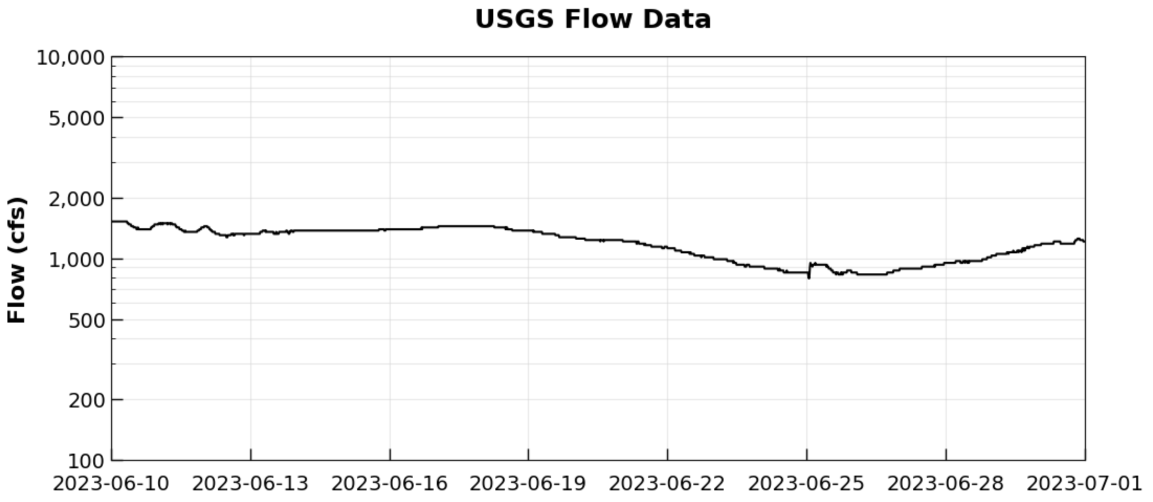
- Calibration Approach:
  - Using USGS **Observed** data

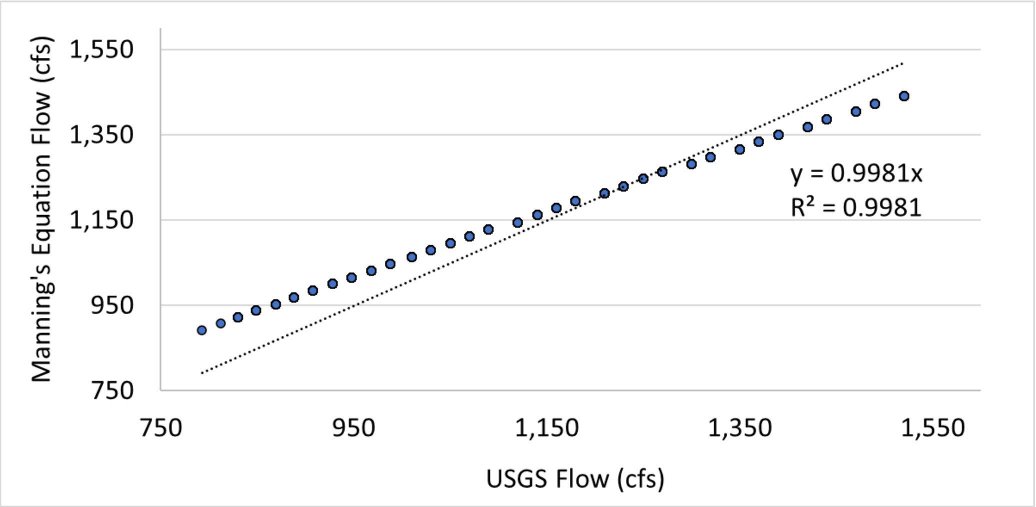
USGS flow

Manning's Equation flow ← Width, Depth "stage", Slope

Minimize error difference → n = 0.053

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080

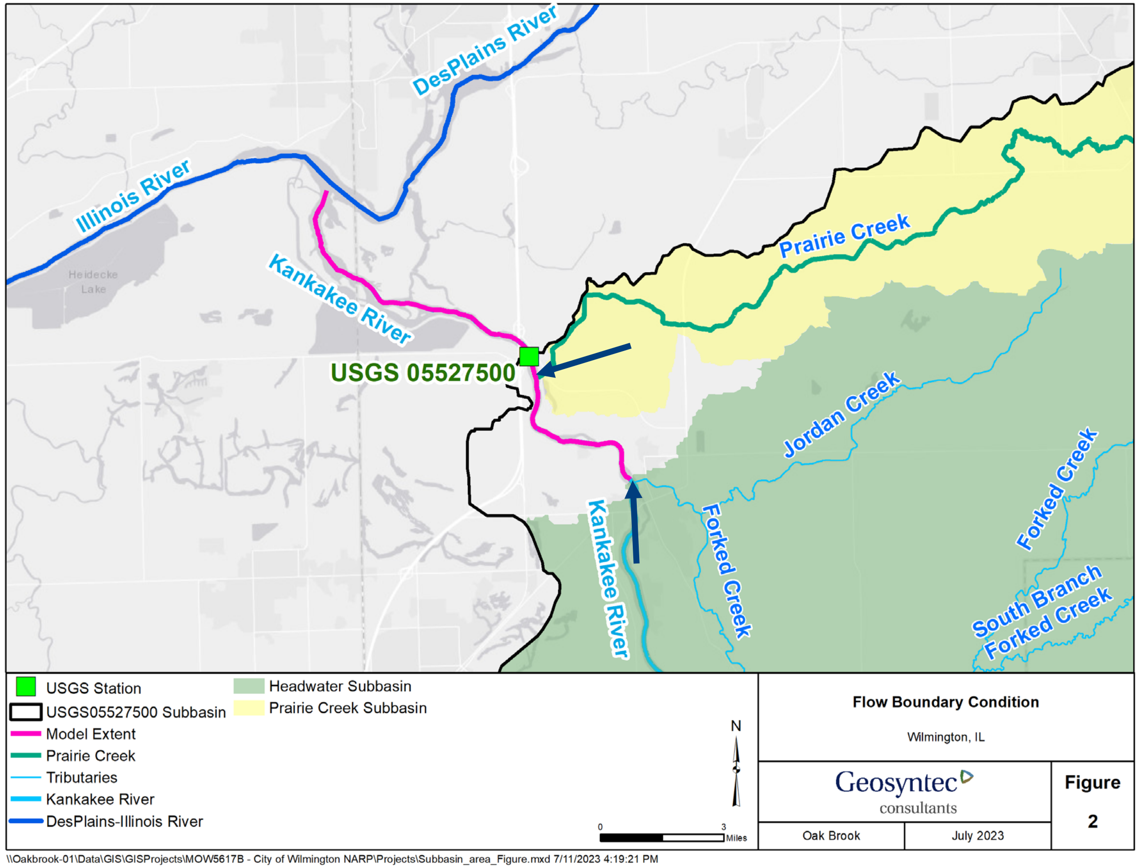




Model Inputs

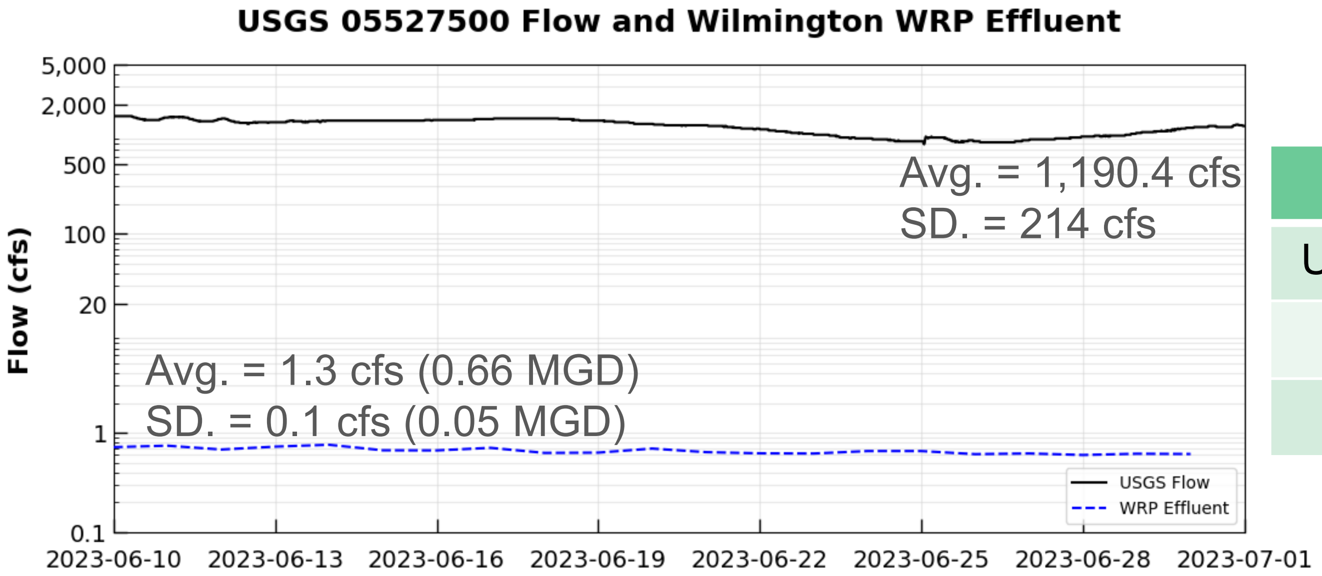
- ## Flow Boundary Condition:

  The USGS 05527500 flow was area-weighted to calculate the **Headwater** and **Prairie Creek** flows



Model Inputs

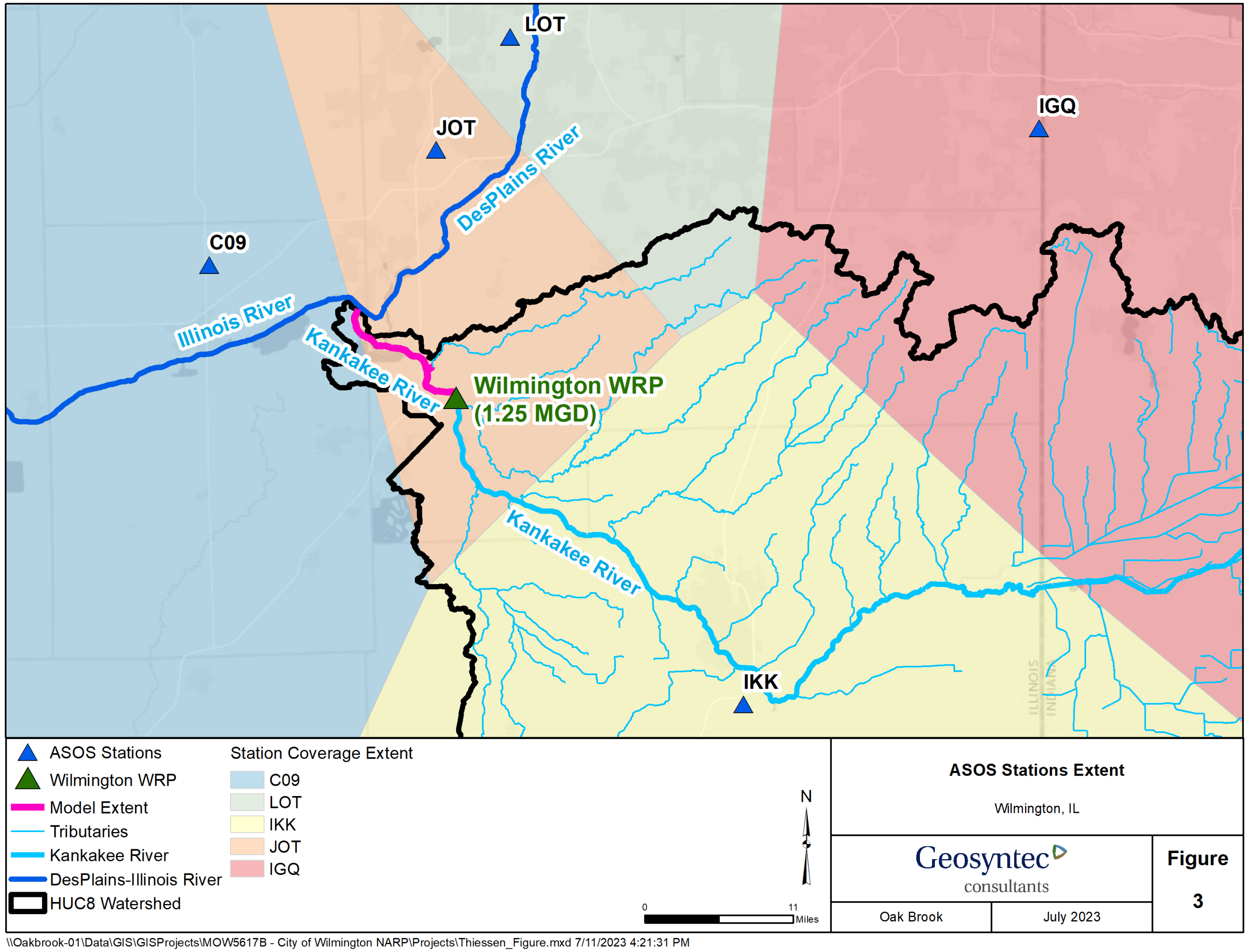
- Boundary Condition Calculations:
  - USGS 05527500 Kankakee River, Wilmington, IL
  - Wilmington Water Reclamation Plant (WRP) Effluent



Subbasin	Area (mi^2)	Flow (cfs)
USGS 05527500	5,150	1,190.4 – 1.3 = 1,189.1
Headwater	5,087	1,174.8
Prairie Creek	52	12

Model Inputs

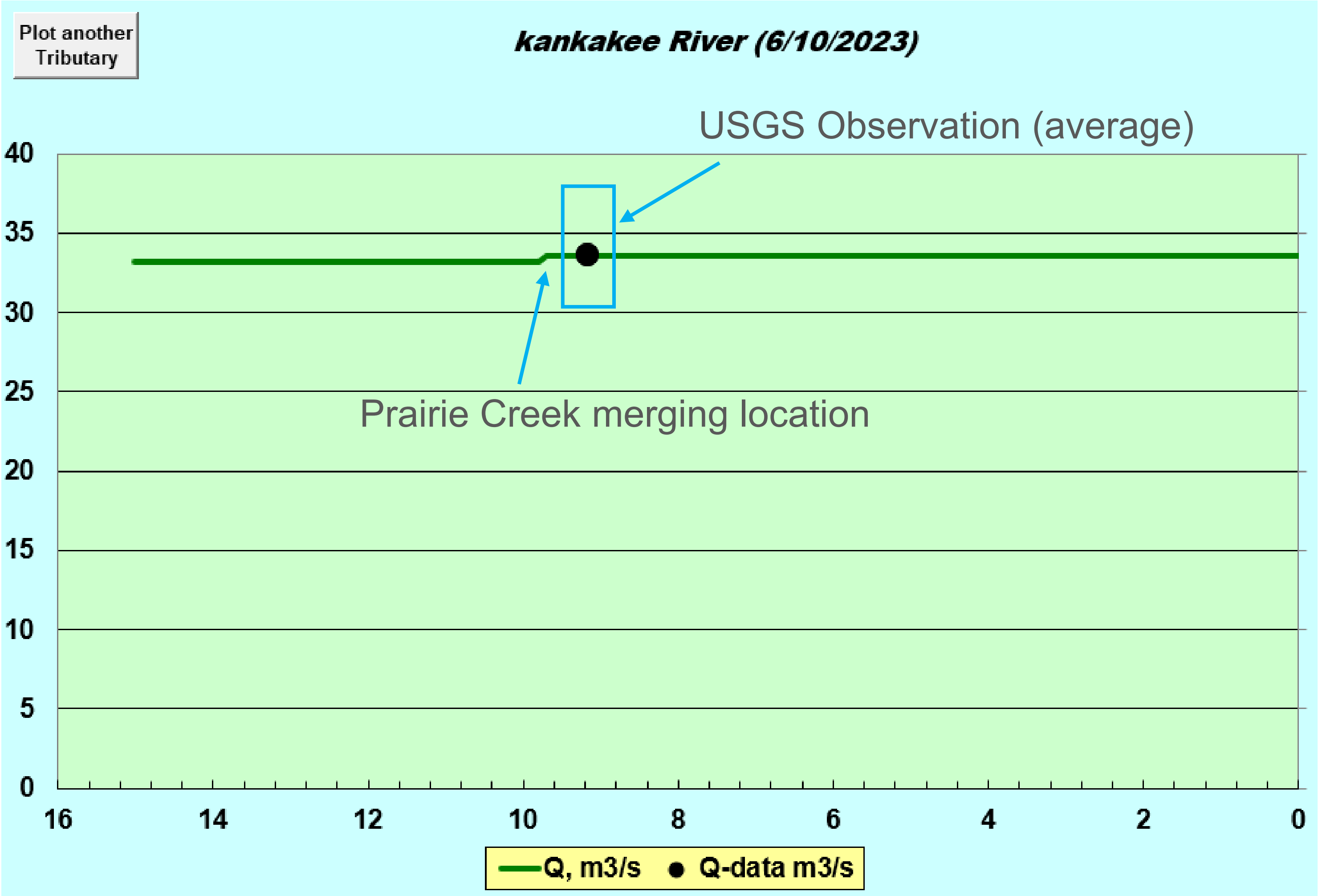
- Meteorological Data:
  - Five ASOS stations*
    - Air temperature
    - Dewpoint temperature
    - Wind speed
    - Sky cover
  - JOT covers the model extent



* ASOS: Automated Surface Observing System - mesonet.agron.iastate.edu/

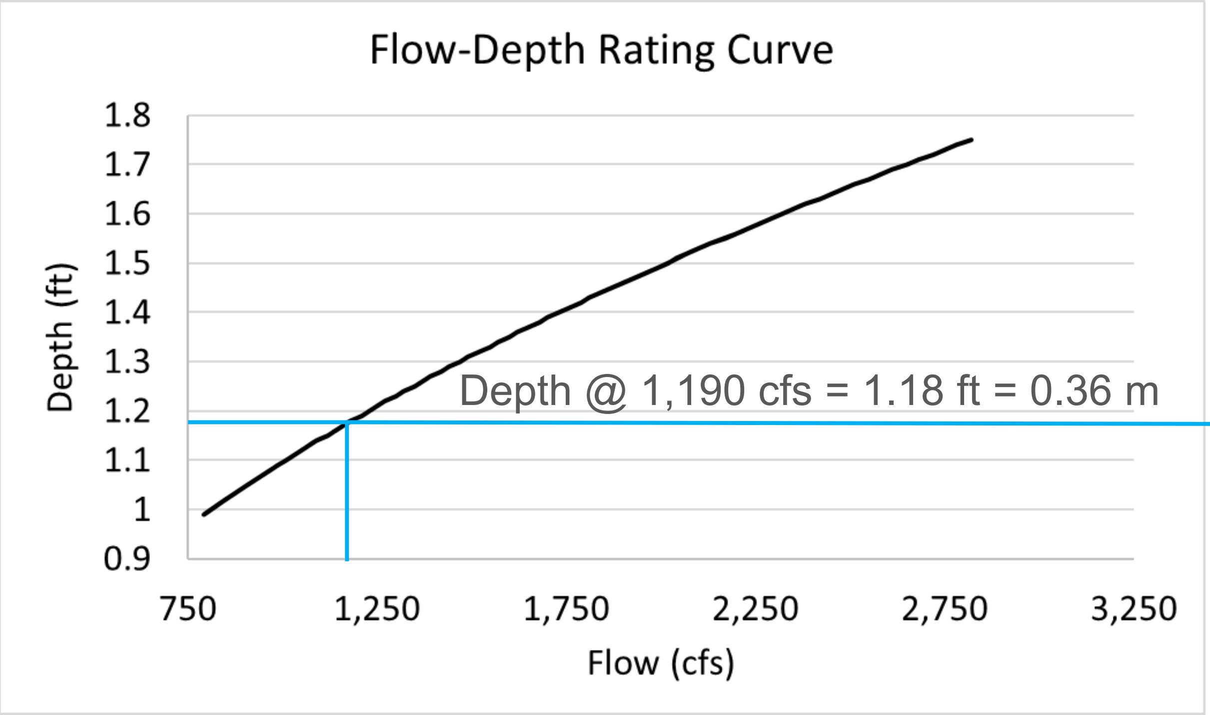
Hydraulic Results

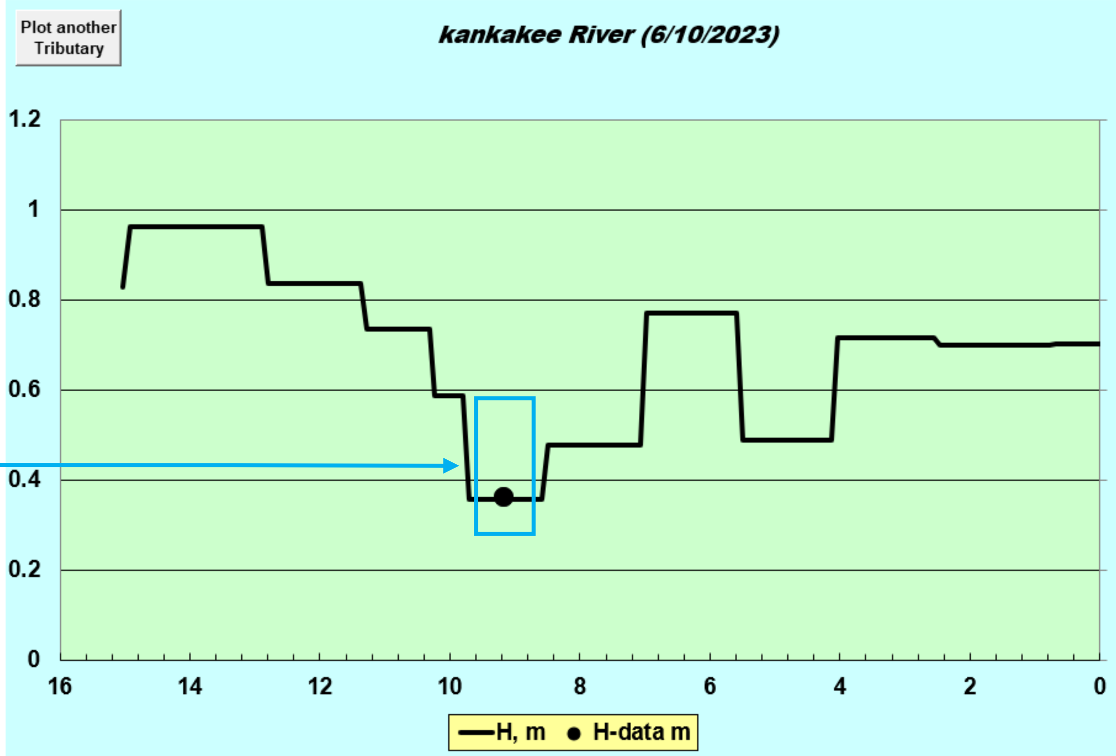
Flow Results



Hydraulic Results

- Depth Results:

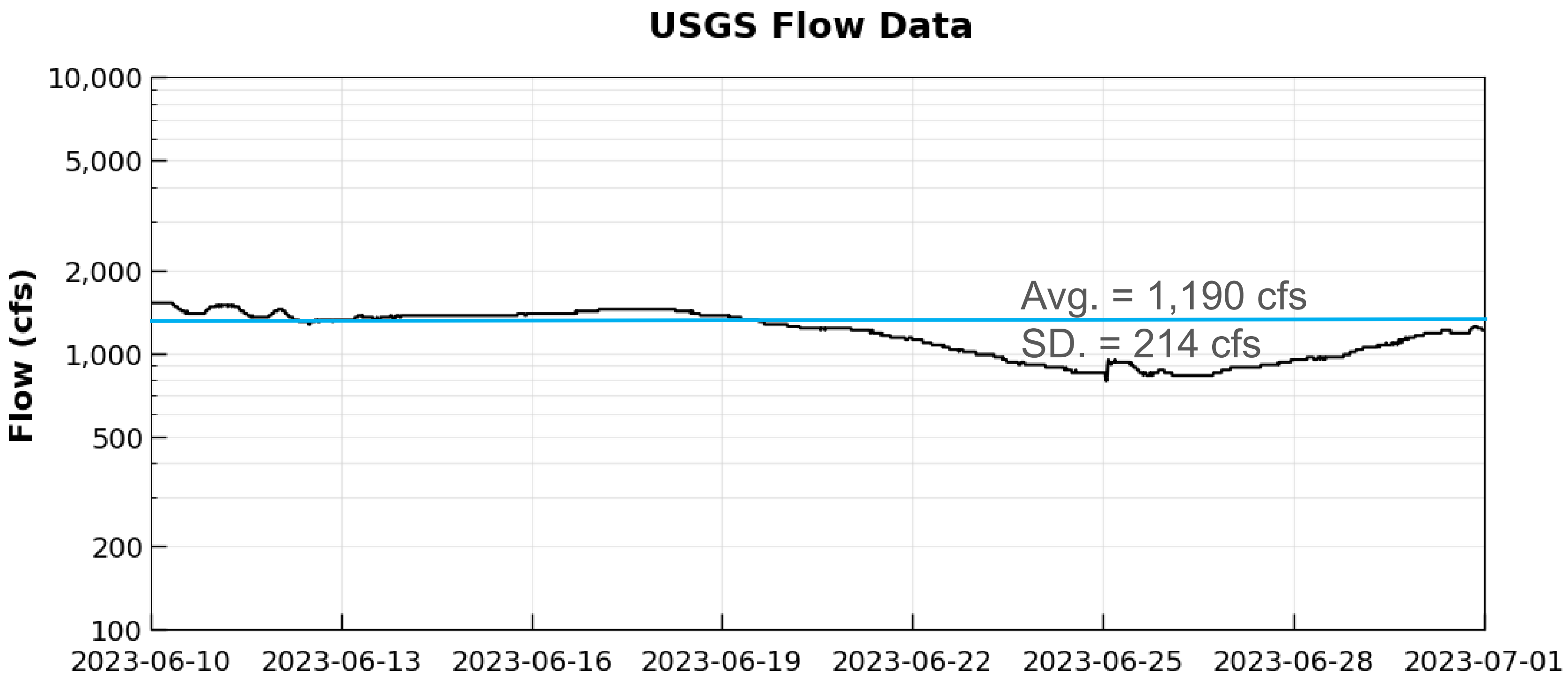




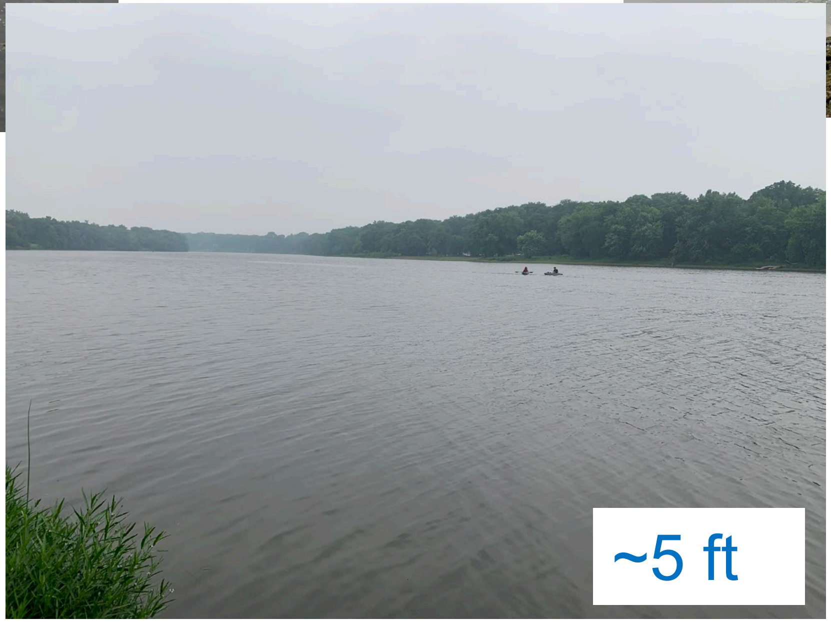
Open Discussion

Simulation Period

- Data Collected From 6/12 to 6/27
  - Simulation Period: 6/10 to 6/30?



Depth Observation



Open Discussion

Questions?

Geosyntec consultants

CITY OF WILMINGTON NARP DEVELOPMENT

Qual2K Model Setup – Water Quality Results

October 19, 2023

WILMINGTON THE ISLAND CITY

AGENDA

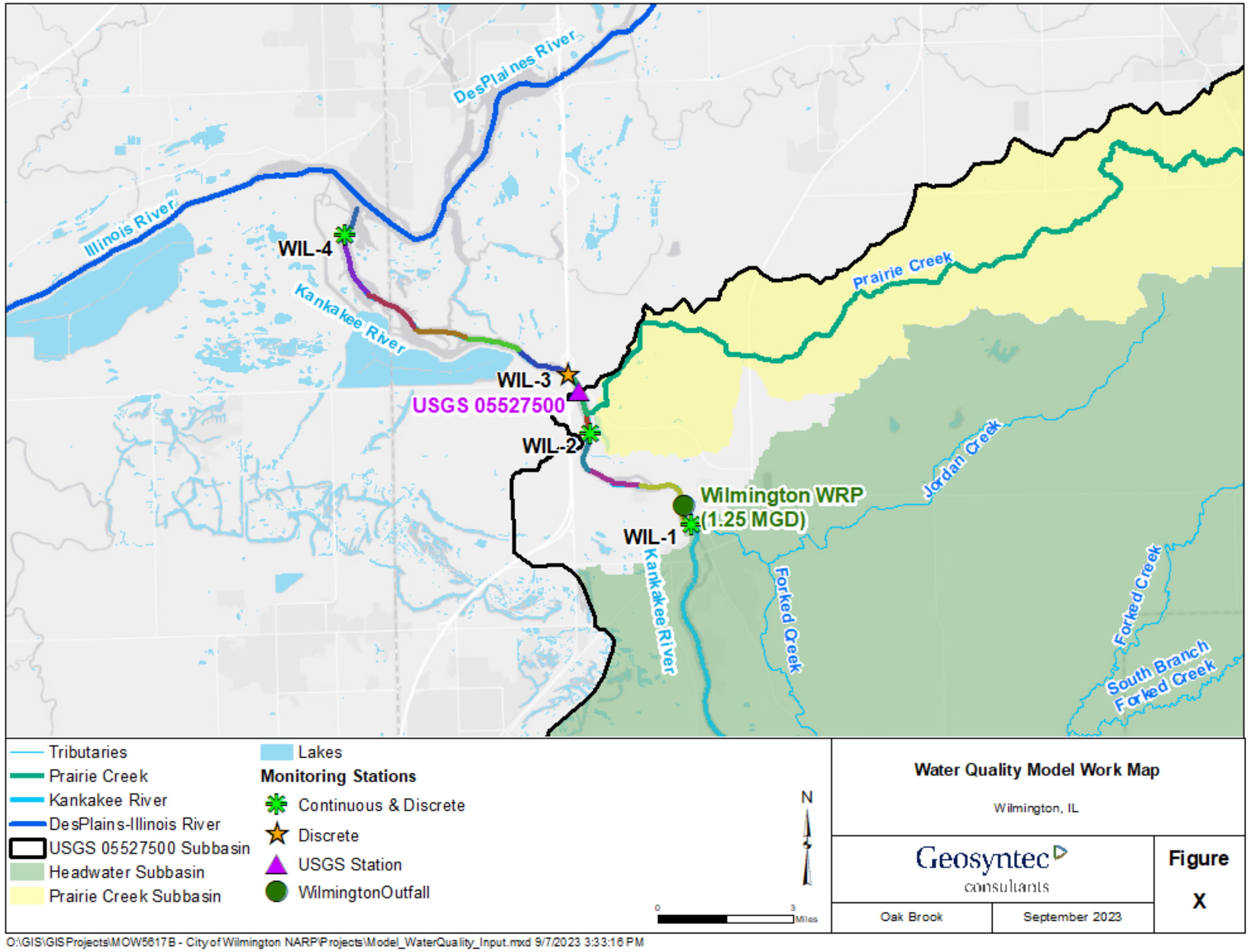
Qual2K Model Setup

- Water Quality Model Inputs
  - Headwater Boundary Condition
  - Point Sources
- Calibration

Qual2K Water Quality Model Setup

Water Quality Model Overview

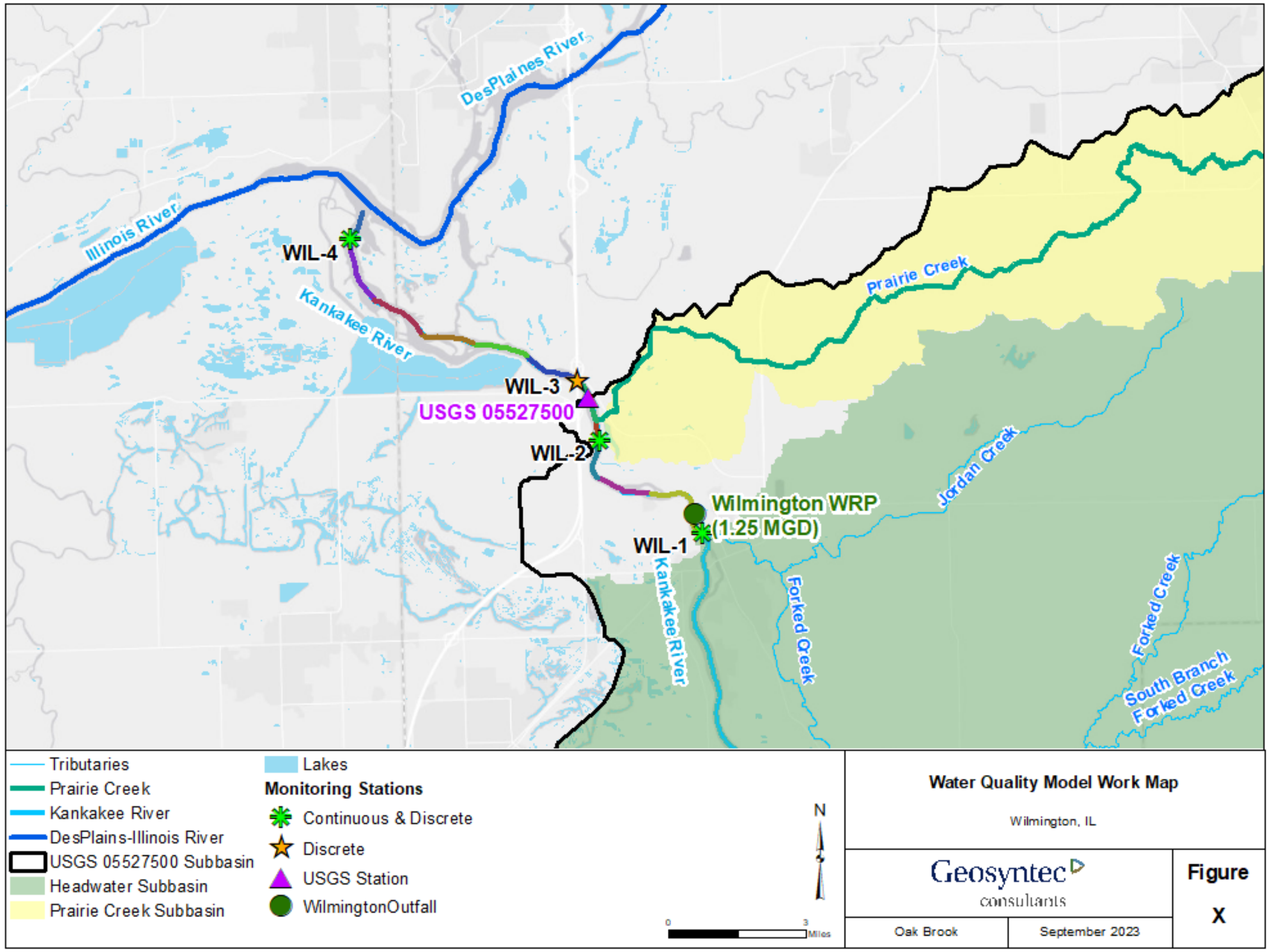
- ## Model Input:
  - Headwater Boundary
    - WL-1
  - Point Sources
    - Wastewater Treatment Plant
      - Wilmington WRP
    - Tributary
      - Prairie Creek
  - Calibration
    - WL-1, WL-2, WL-3,WL-4
    - Max & min



Headwater Boundary Condition

Headwater Boundary Condition

- ## Headwater Input:
  - Headwater Flow =1,174.8 cfs
  - WL-1
    - Simulation Period: 6/10 to 6/30
    - Continuous data :
      - Collected from 6/12/23 to 6/27/23
      - Model only accepts 1 day of data
      - Calculated the average hourly data for each day
      - Derived a single-day hourly representation by averaging these daily values for each hour across the entire period
      - Continuous data input changes with time in the model
    - Discrete data
      - collected on 6/13/2023 and 6/27/2023
      - input uses average of the two samples collected
      - input is constant with time in the model



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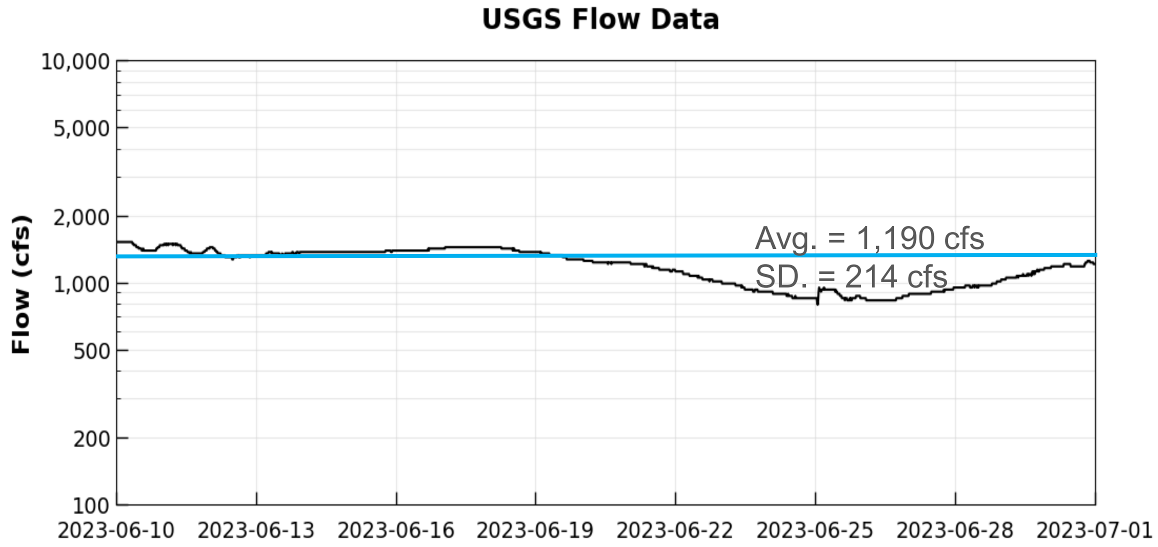
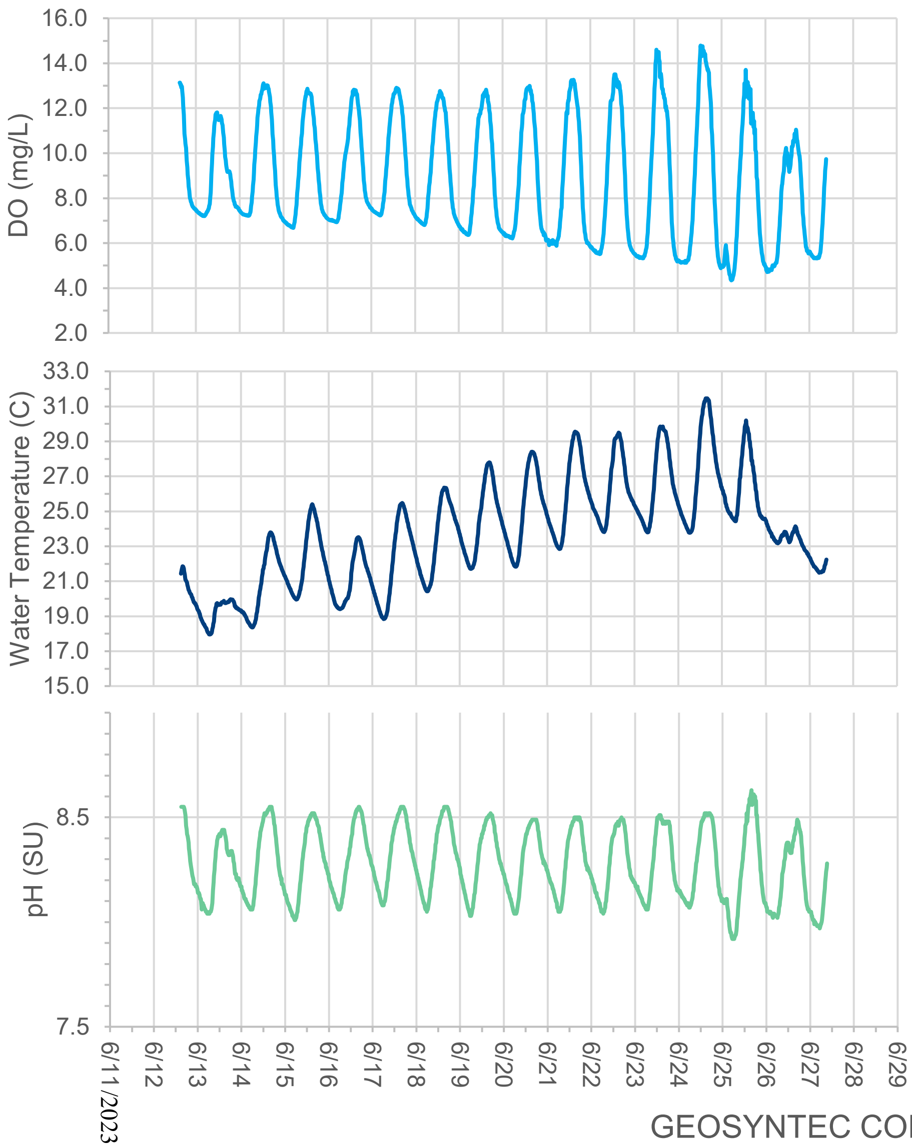
Headwater Boundary Condition

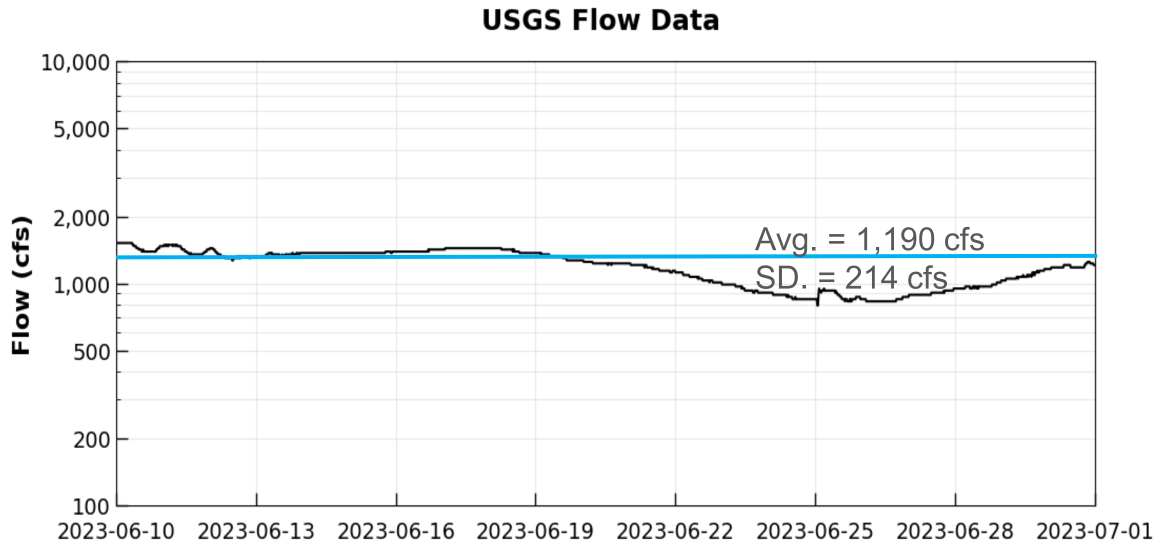
- Dissolved Oxygen, Temperature, & pH:
  - WL-1
  - Continuous data

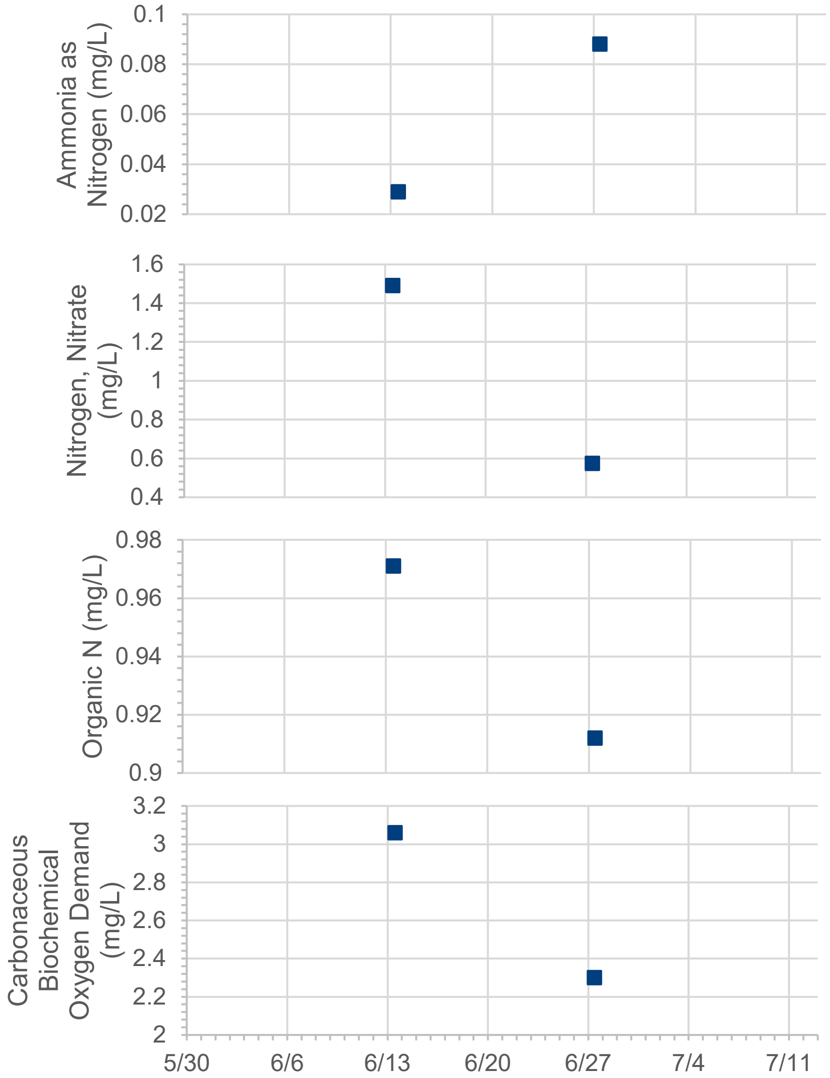




Headwater Boundary Condition

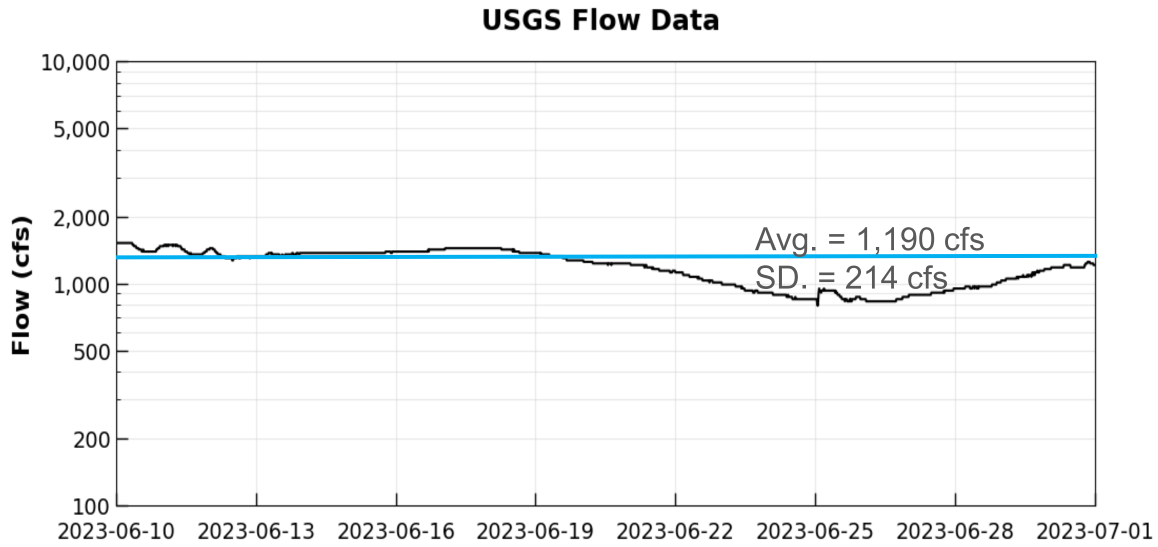
- Nitrogen & CBOD:
  - WL-1
    - Discrete data
    - $Org_N = TKN - Ammonia\ as\ N$

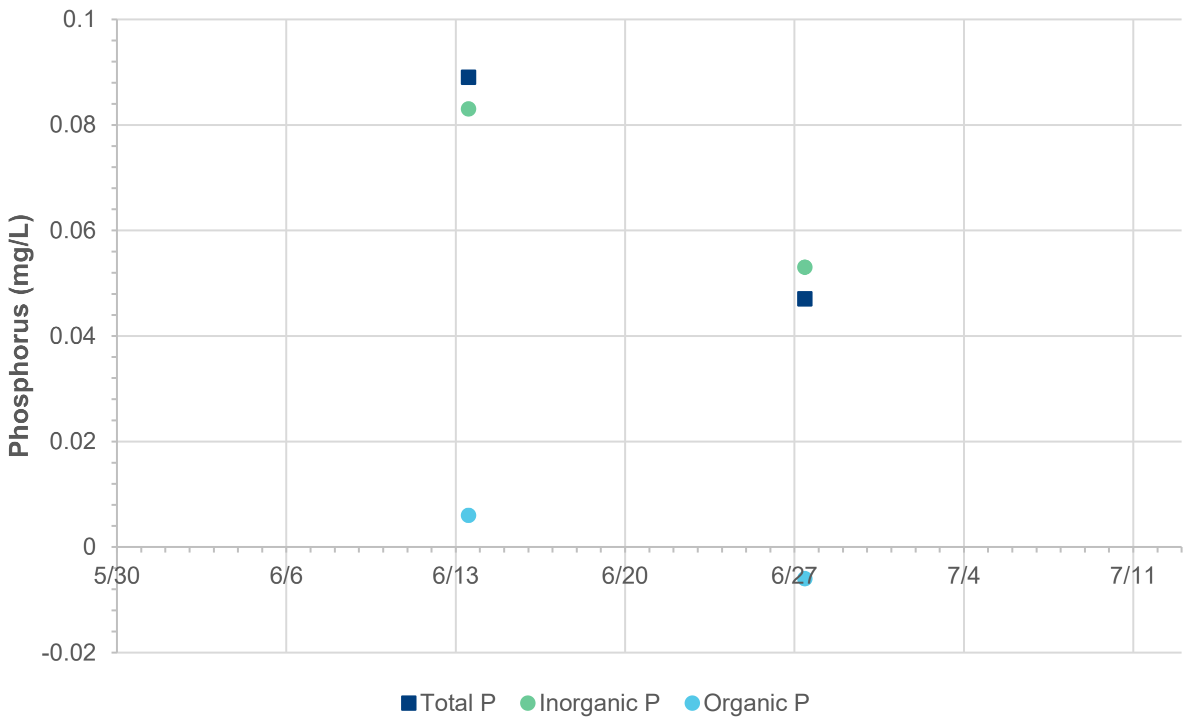




Headwater Boundary Condition

- Phosphorus:
  - WL-1
  - Phosphorus separation
    - Total P
    - Inorganic P
    - $Org_P = TP - Inorg_P$

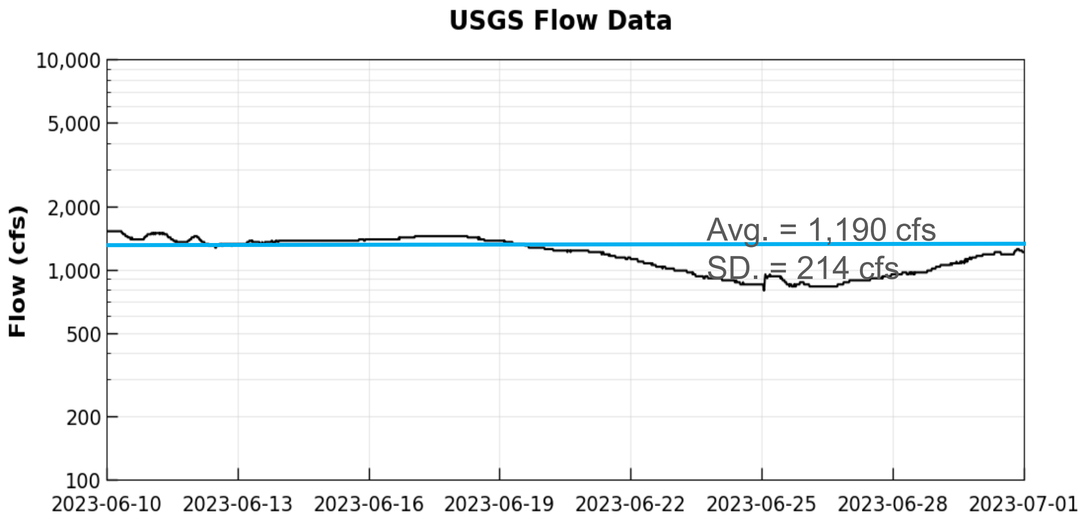


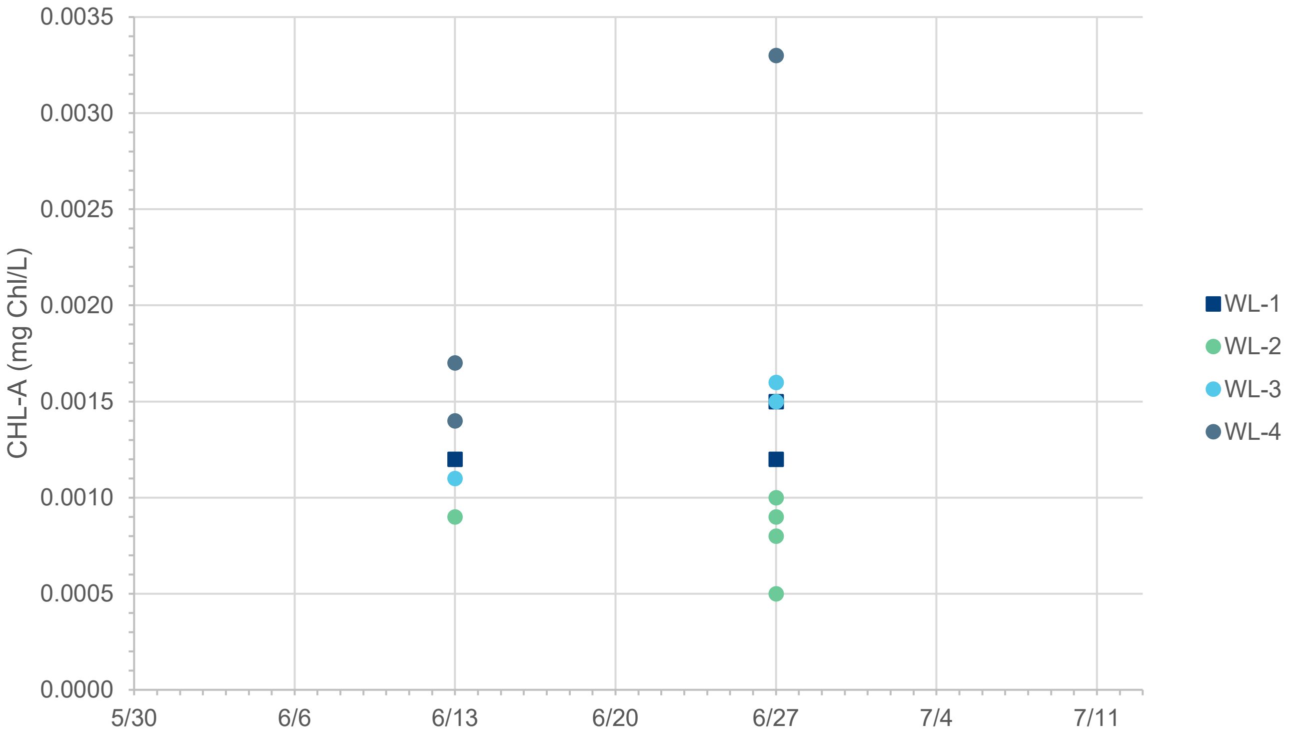


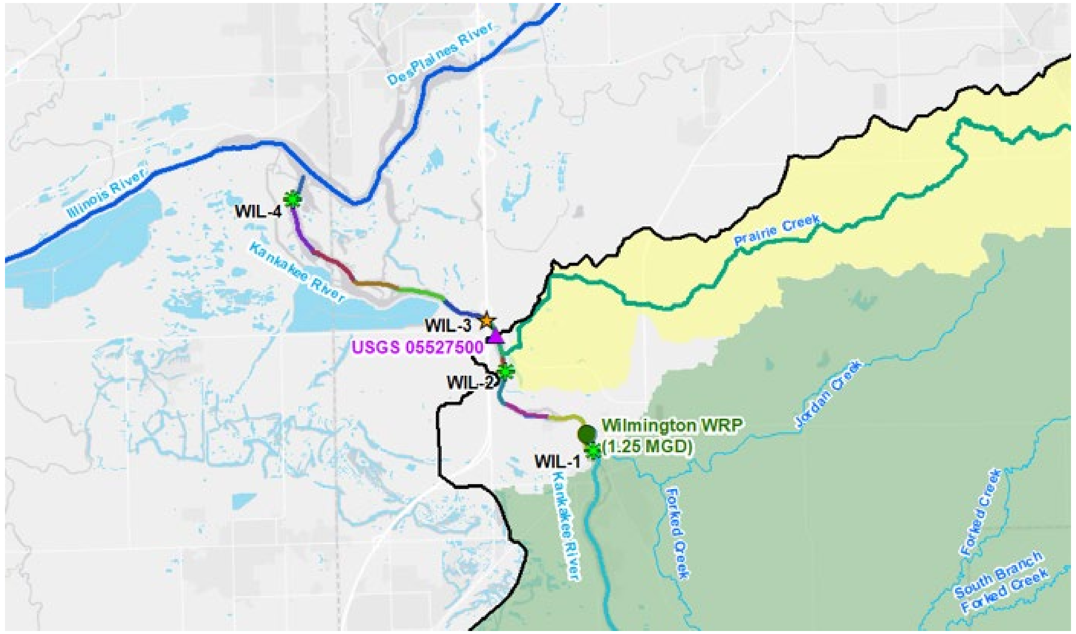
Chlorophyll *a* Review

Chlorophyll *a* Review

- Chlorophyll *a*:



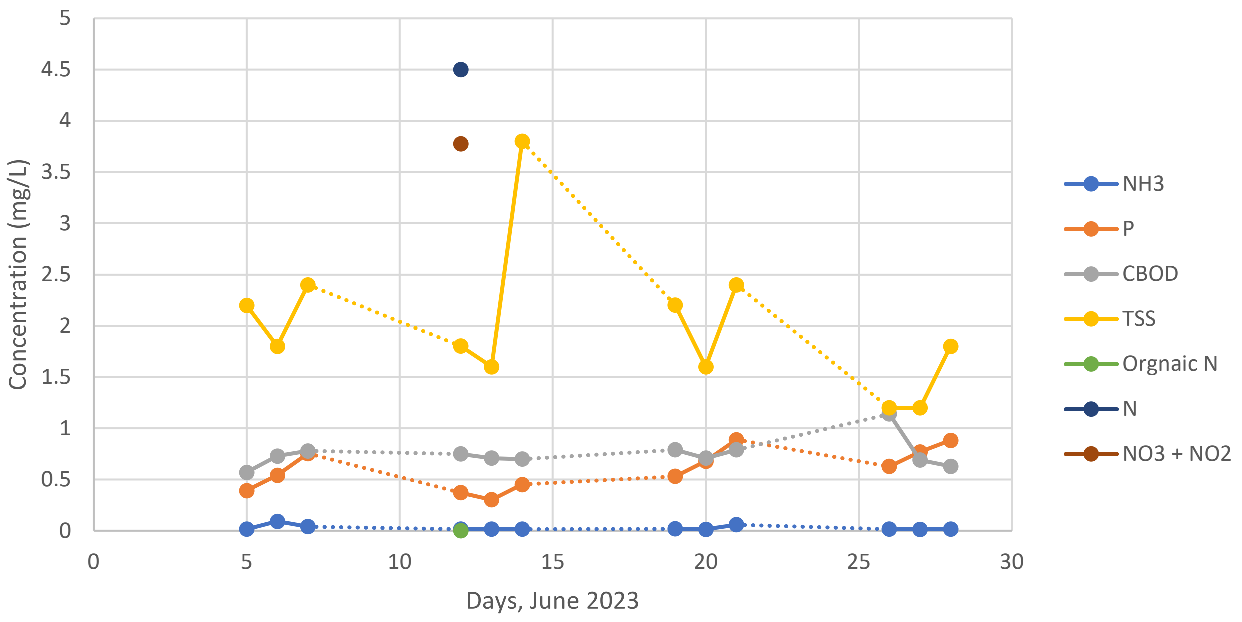


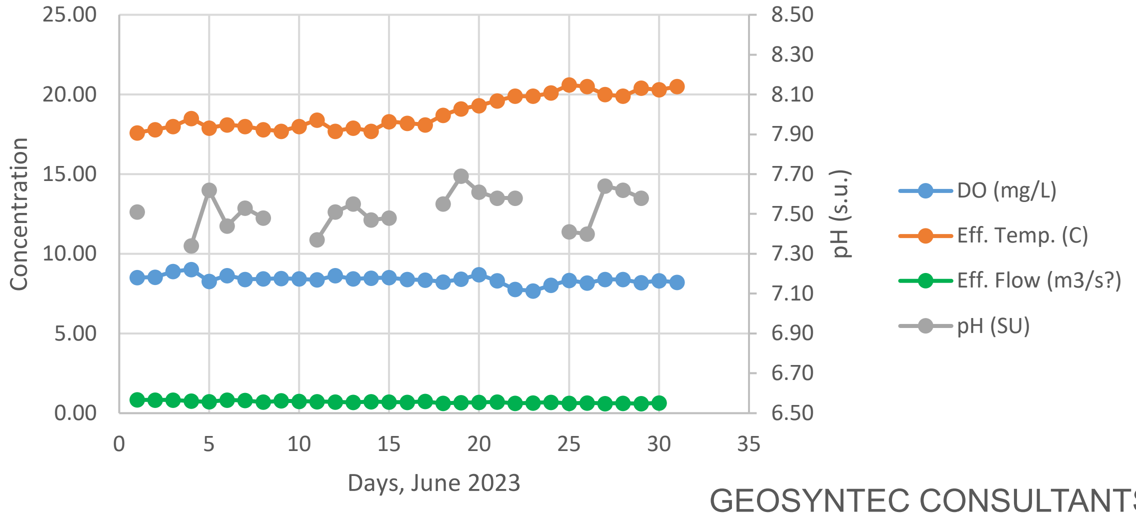


Point Sources

Point Sources

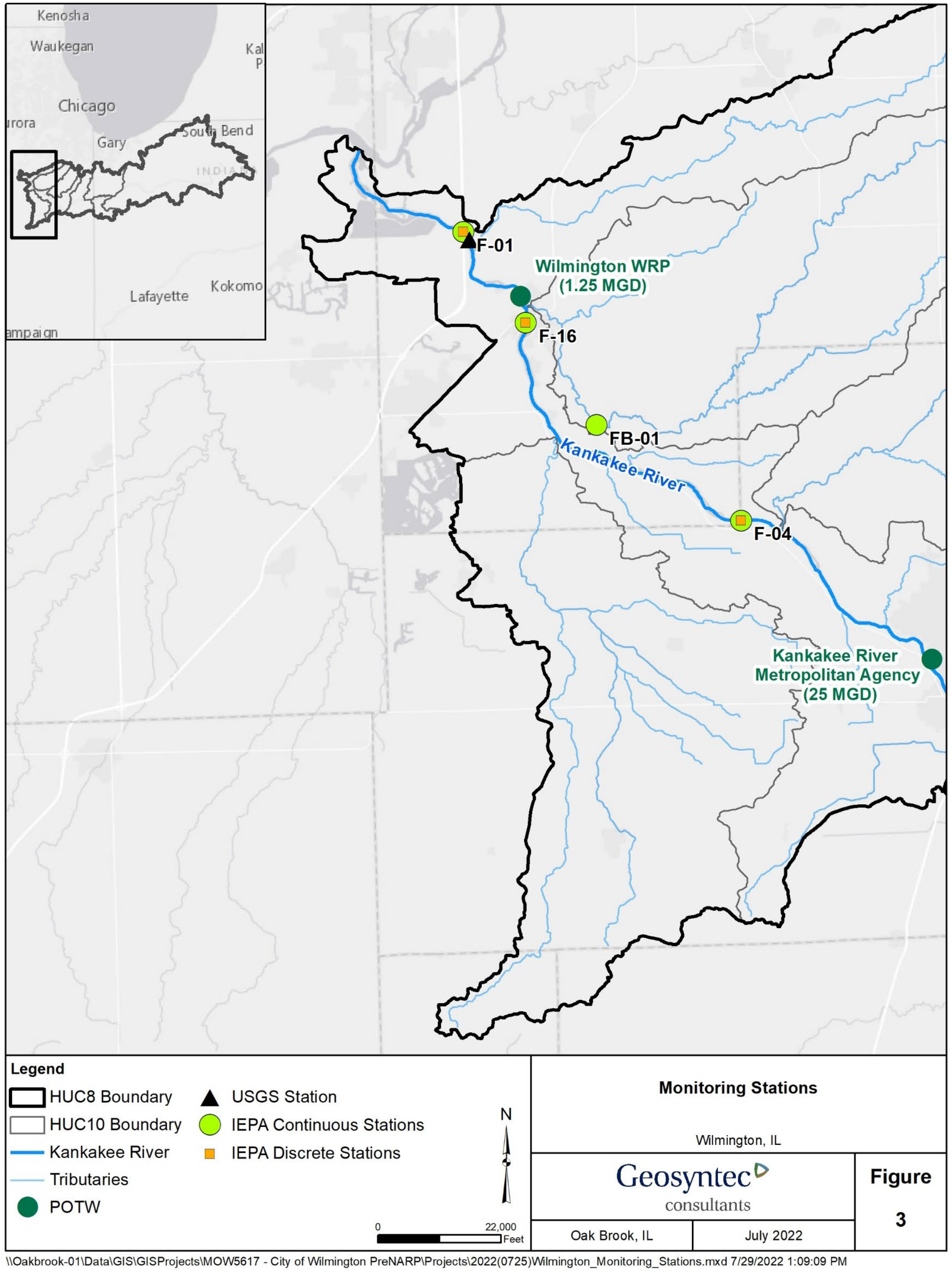
- **Wastewater Treatment Plant:**
  - Wilmington WRP Flow = 1.3 cfs
  - WWTP DMR
    - DMR data is for June 2023
    - Assumes concentrations are mg/L
    - Average calculated from June 10, 2023, to June 30, 2023, corresponding to the model length of 20 days
    - Assumes values report as 0.00 were "not sampled"
    - Average values were calculated without 0.00 values
    - Uses 10% and 90% of P concentration for organic and inorganic P, respectively





Point Source

- Tributary:
  - Prairie Creek Flow = 12 cfs
  - USGS 05527500 = Q_{gage} = 1190.4 cfs
  - FB-01 – Forked Creek



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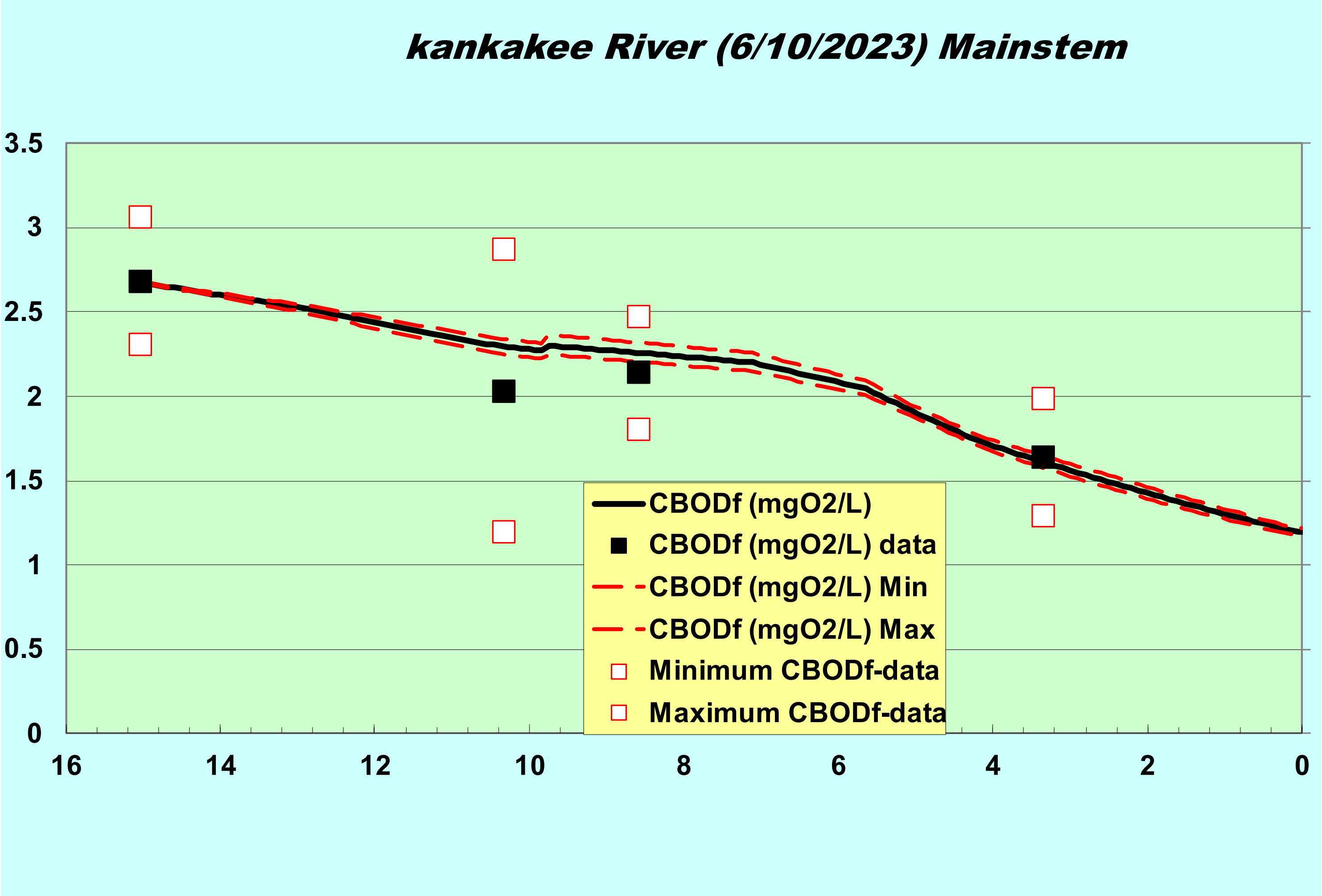
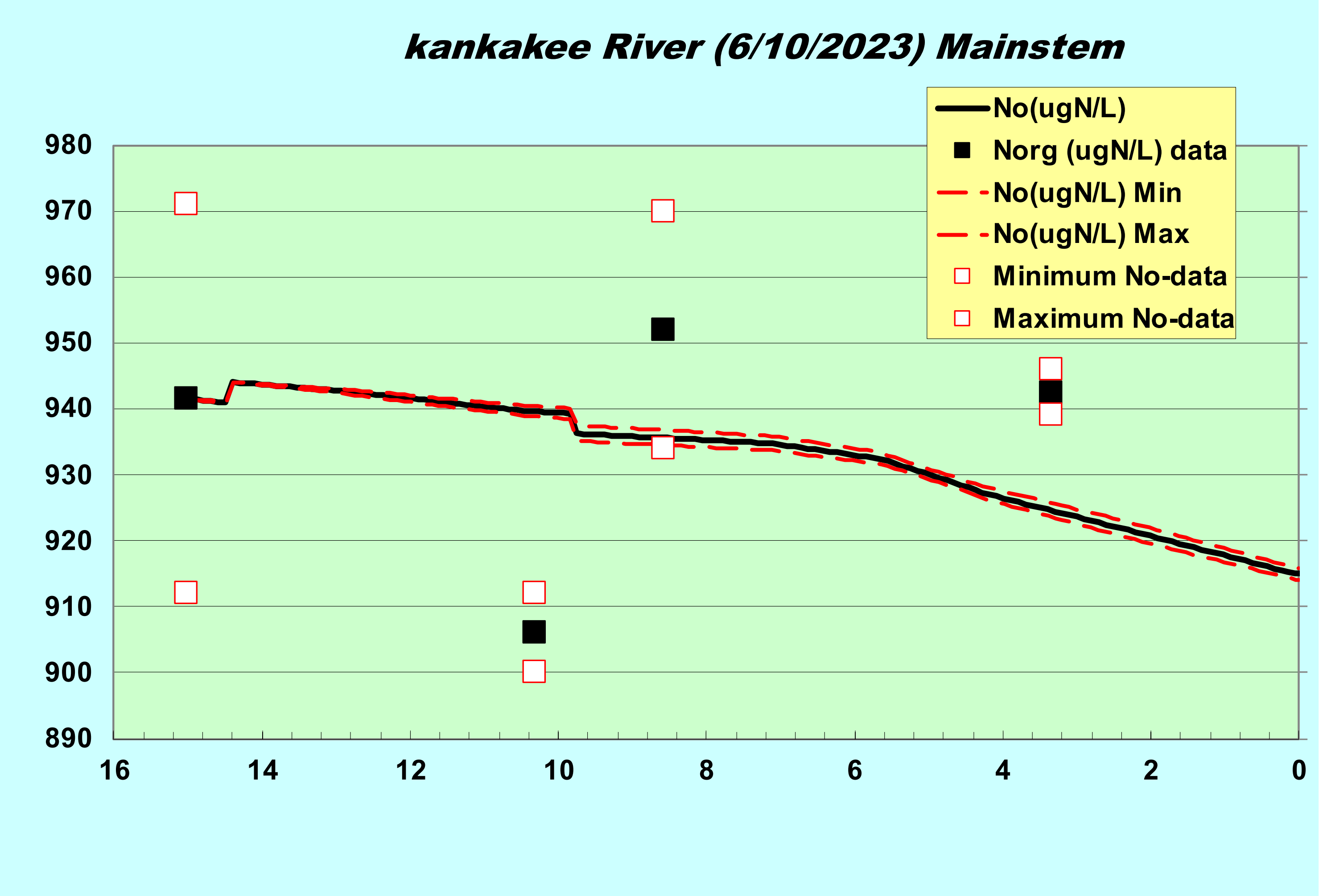
Calibration

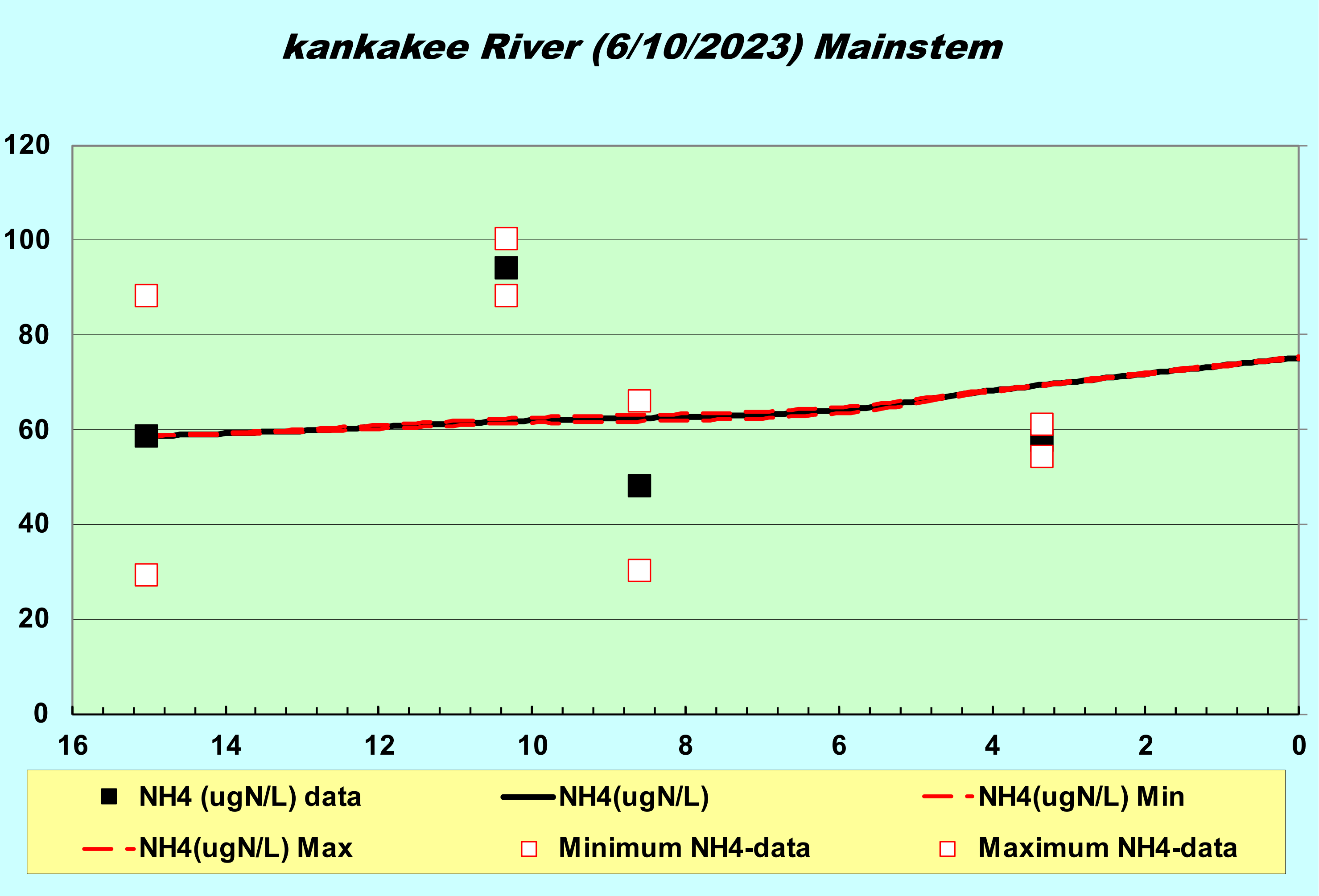
Calibration Results - CBOD



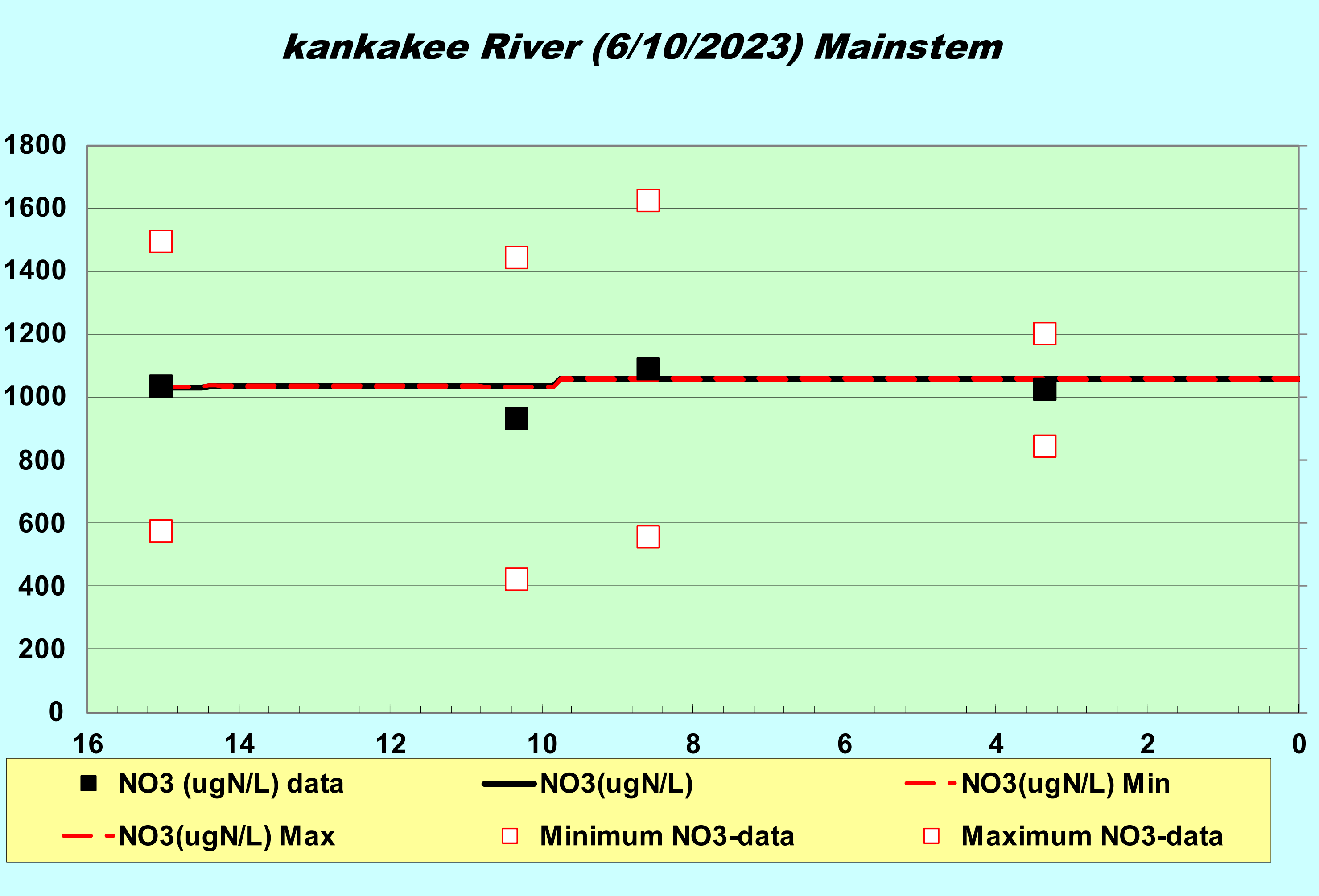
Calibration Results – Organic Nitrogen



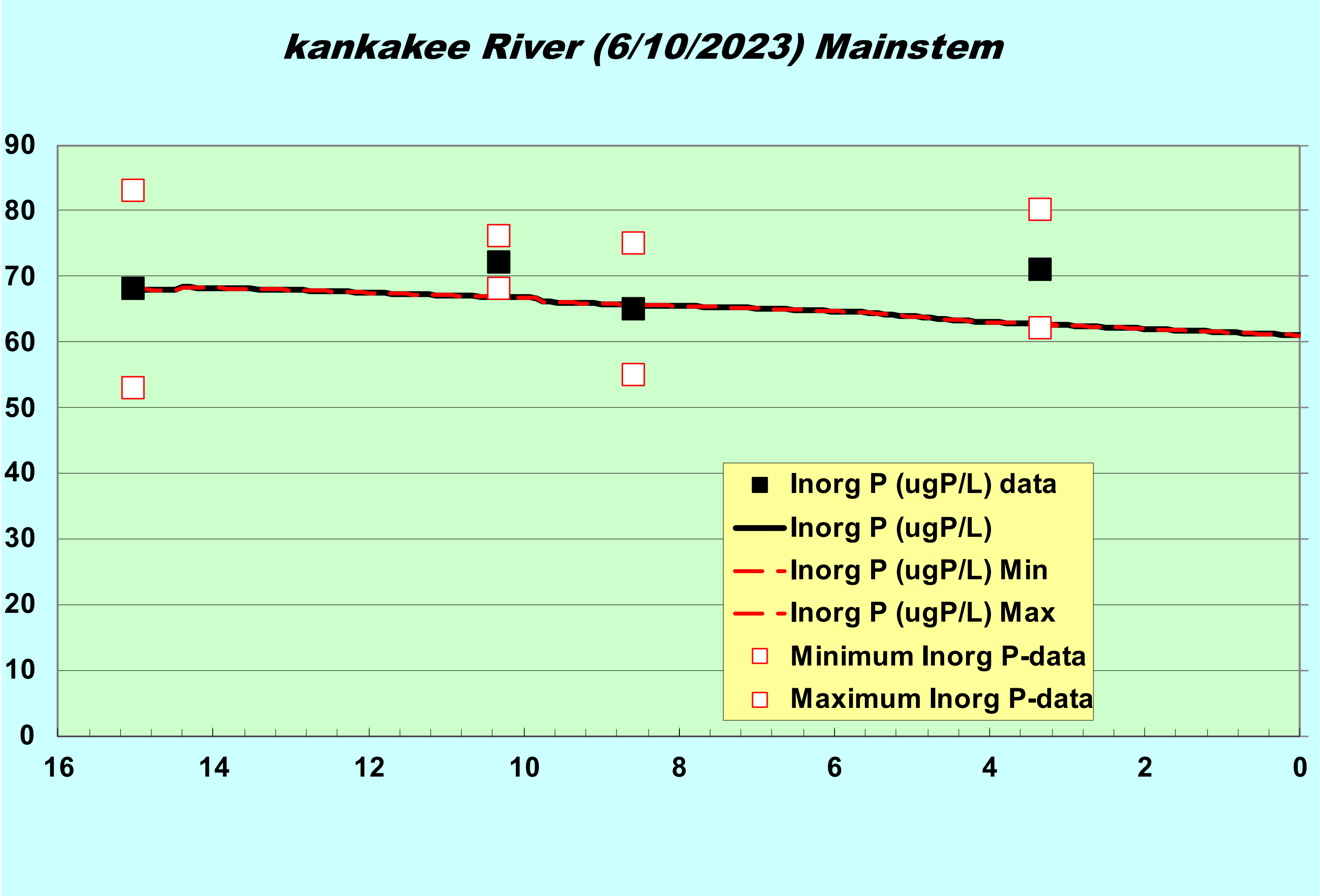
Calibration Results – NH4



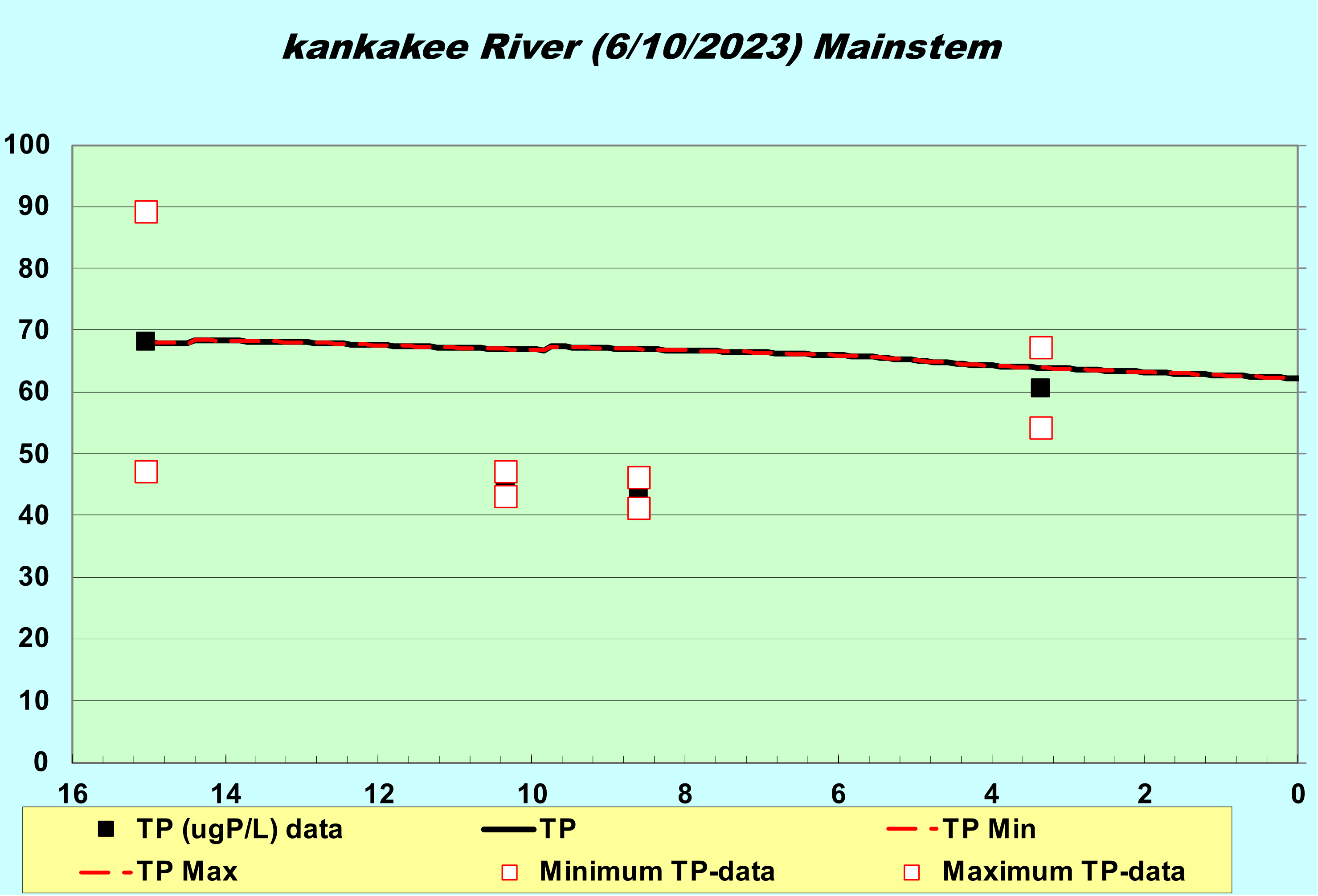
Calibration Results – NO3



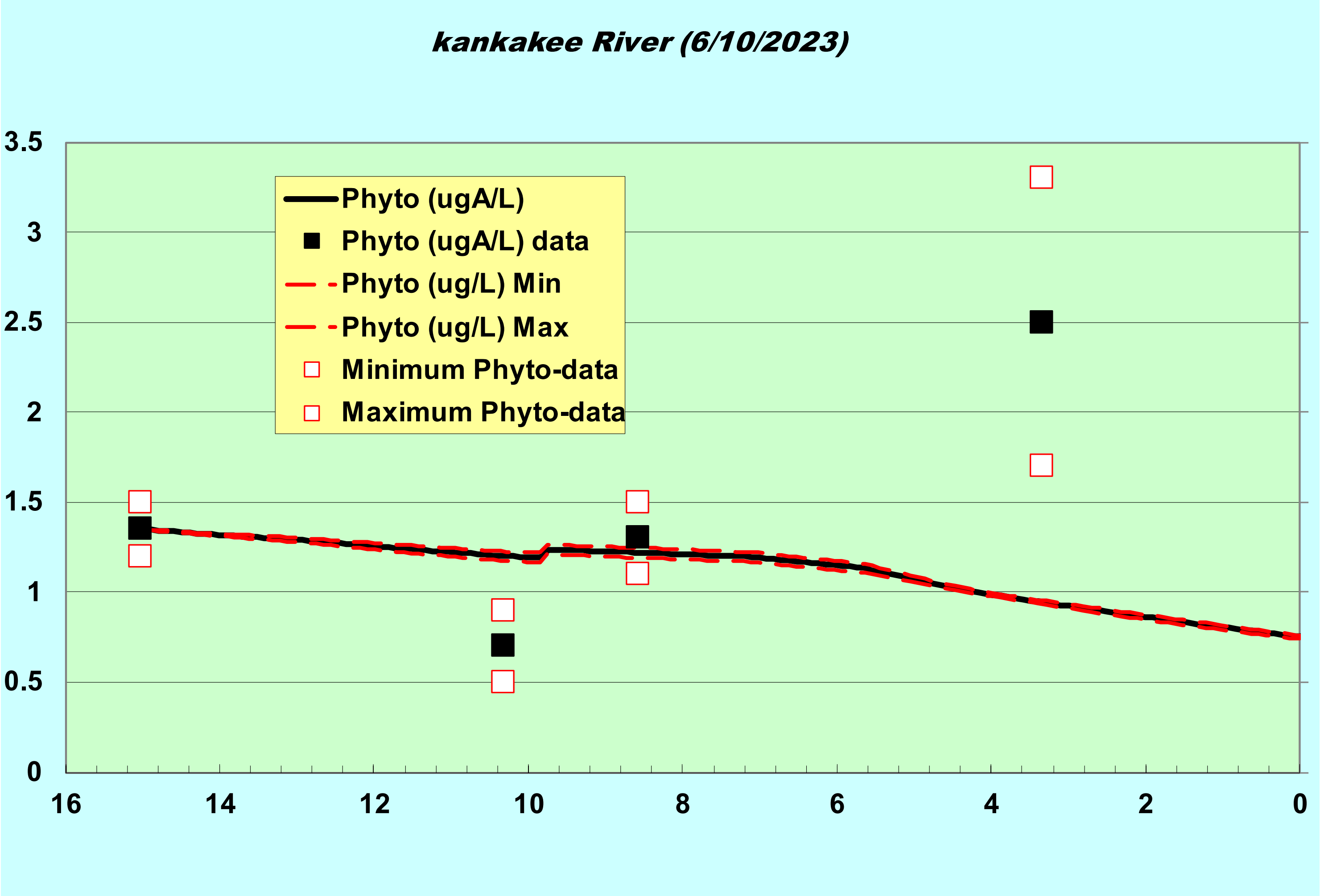
Calibration Results – Inorganic Phosphorus



Calibration Results – Total Phosphorus

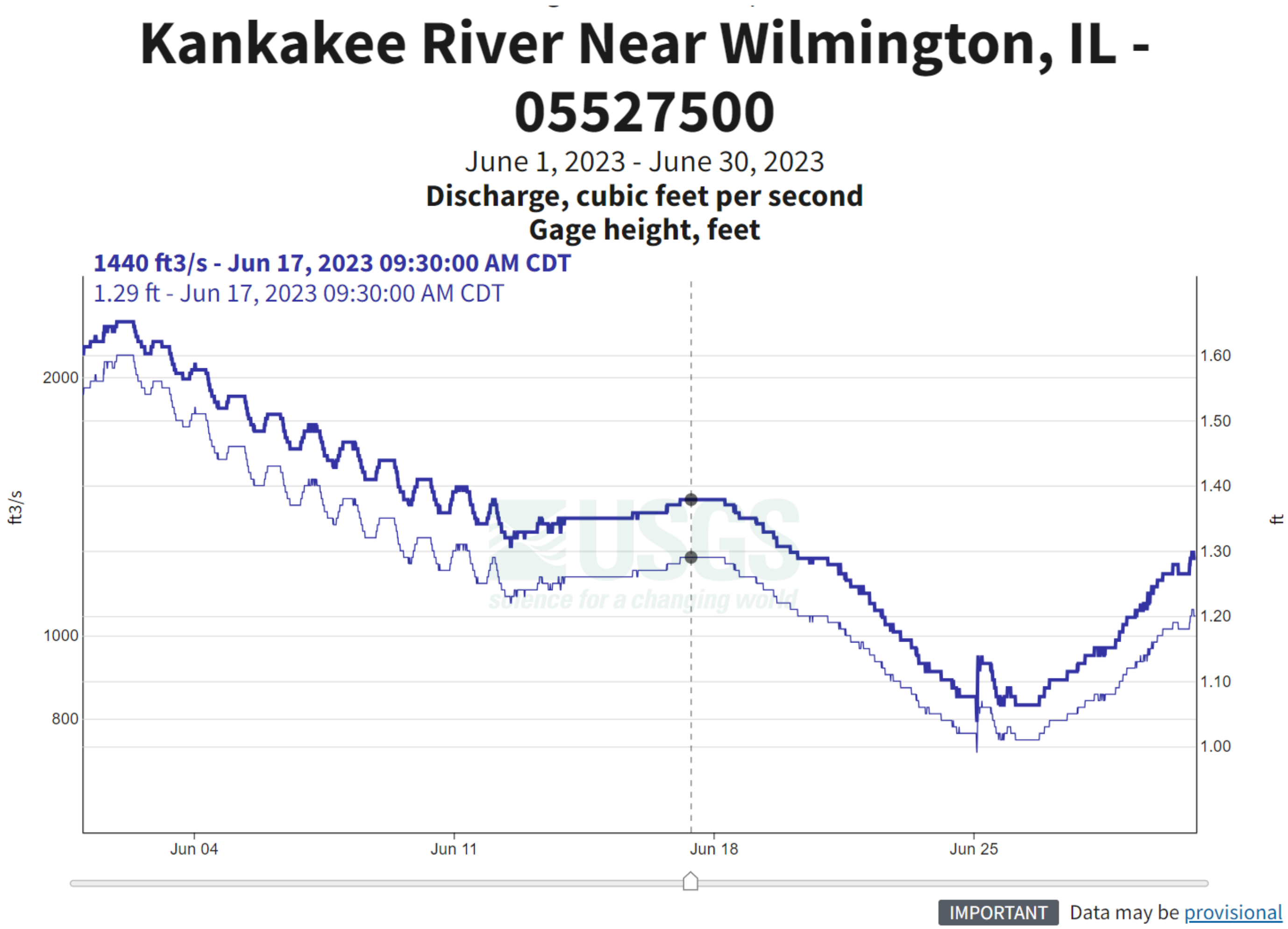


Calibration Results – Chlorophyll *a*

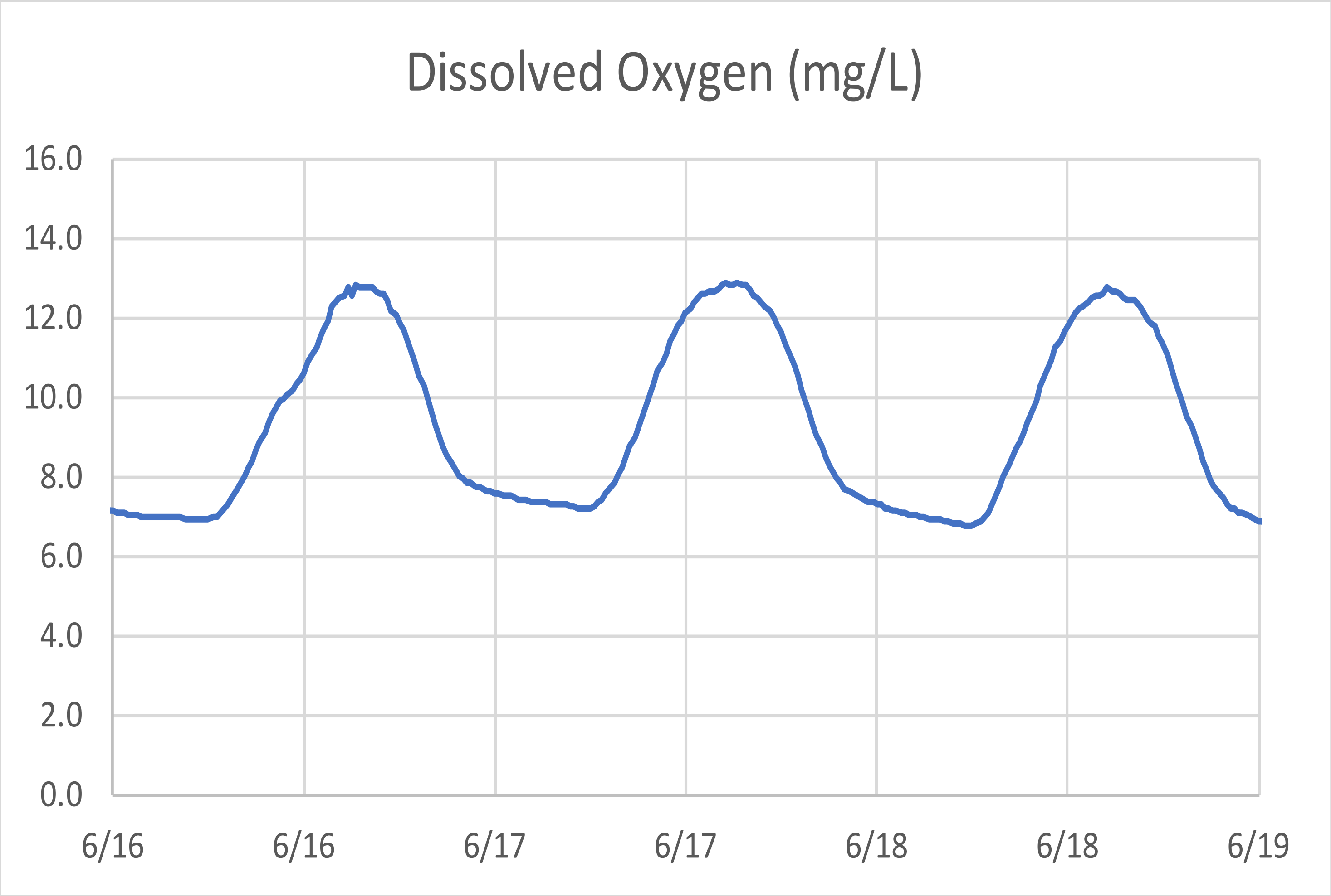


Calibration Diel Results

Jun 17, 2023, was selected based on USGS flow data

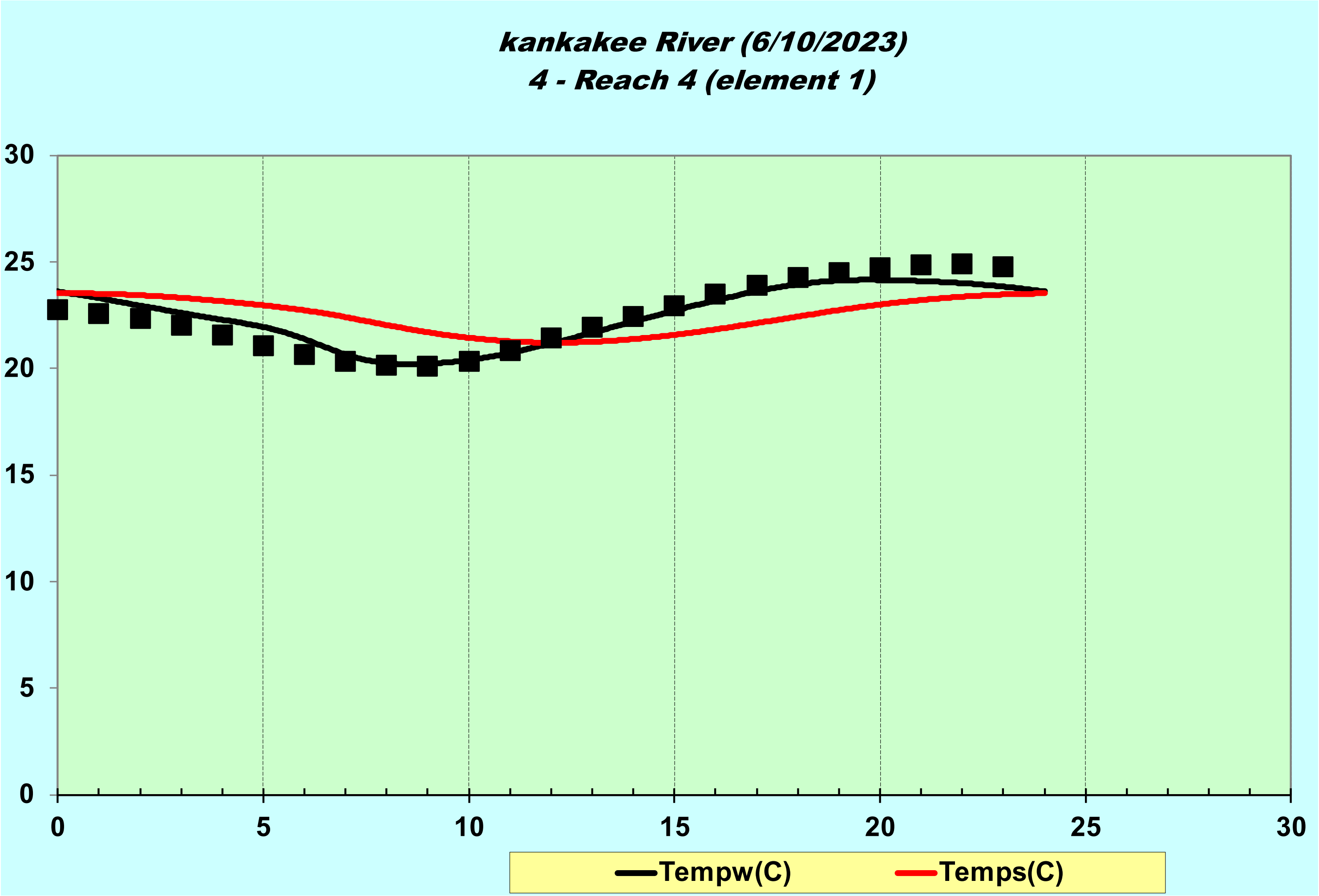


DO at WL-1

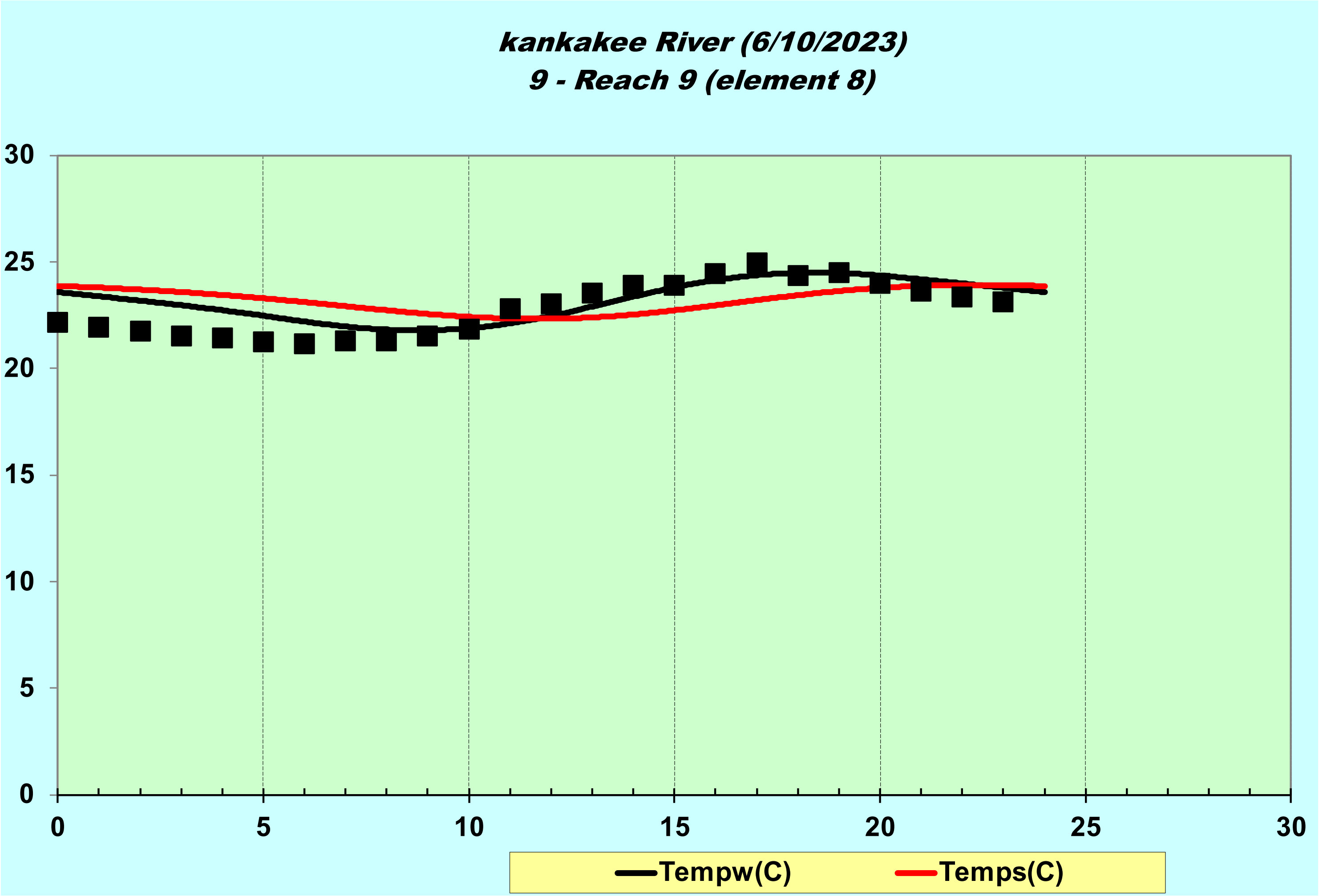


Dissolved Oxygen (mg/L)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
6/16
6/16
6/17
6/17
6/18
6/18
6/19

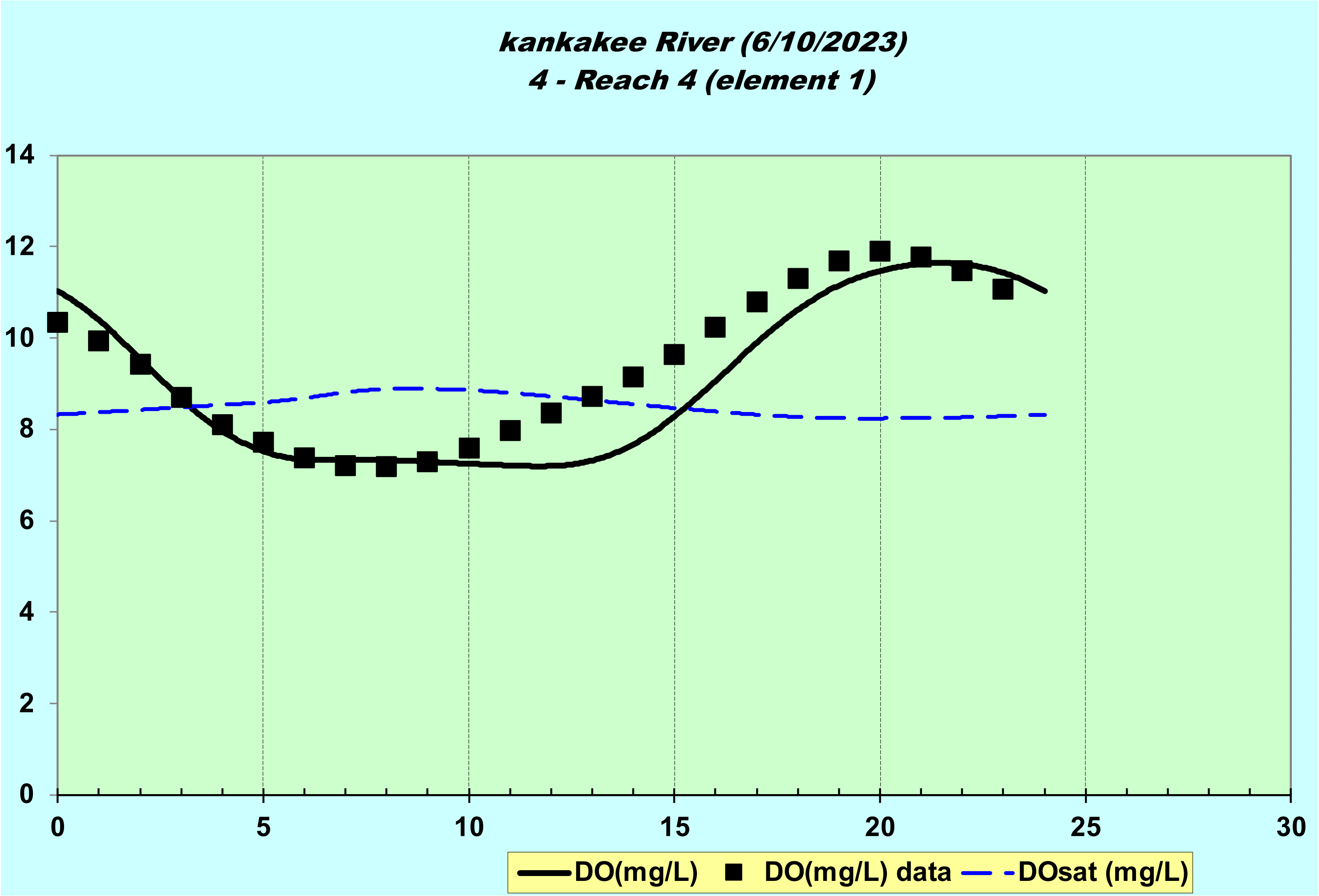
Calibration Results – Diel Temp at WL-2



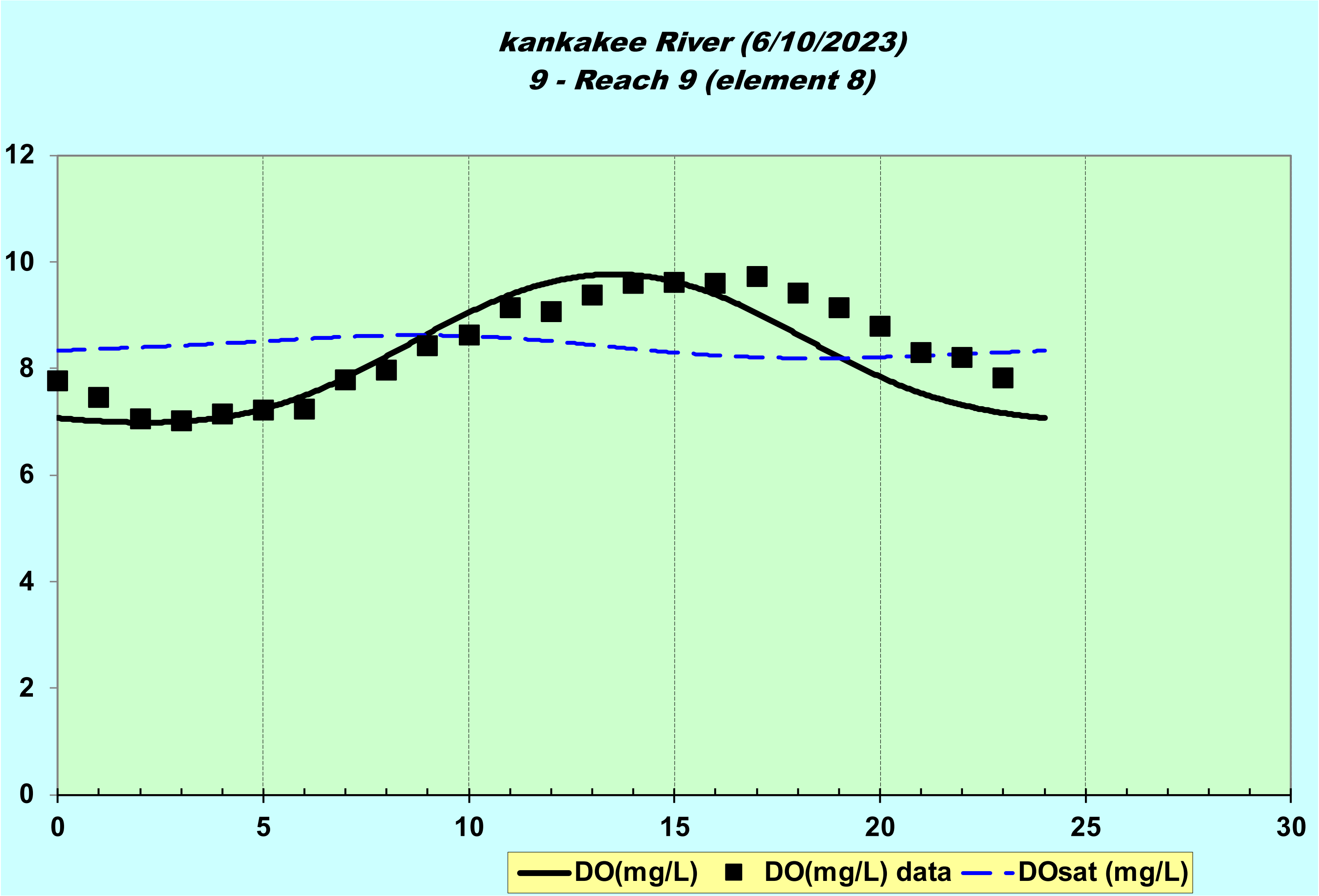
Calibration Results – Diel Temp at WL-4



Calibration Results – Diel DO at WL-2



Calibration Results – Diel DO at WL-4



Issues related to the hydraulics

- The model was showing time-lag between the simulated and measured DO at WL-4
- This was likely caused by overestimation of flow velocities during the low flow period
- A uniform channel slope of 0.01% was assumed for the last 4 segments in the previous model because Lidar data was showing flat WSE
- After changing the channel slope for the last 4 segments to 0.001% and increased manning's n slightly from 0.053 to 0.06, the time-lag is almost gone

CITY OF WILMINGTON NARP DEVELOPMENT

Watershed Management Scenarios

October 19, 2023

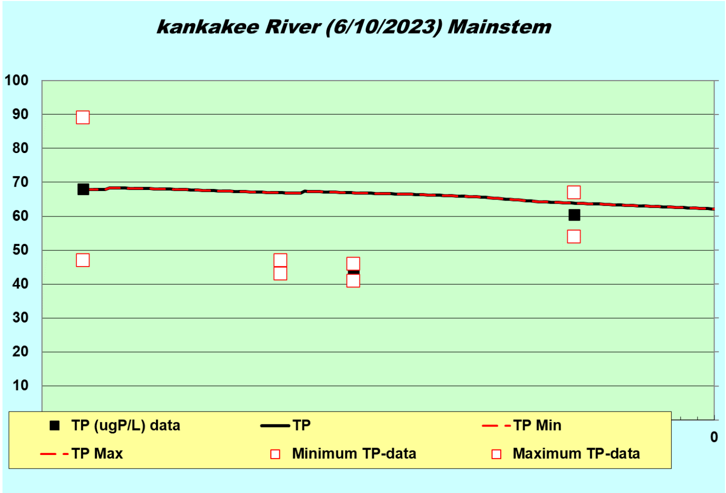
Geosyntec consultants

Watershed Management Scenarios

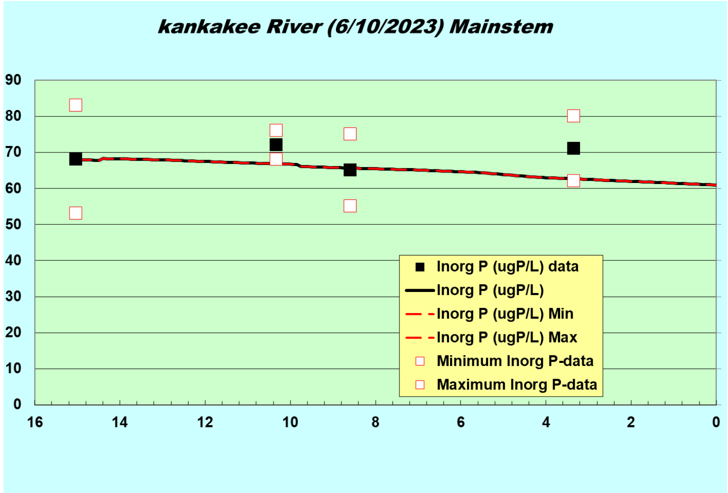
Point Source

Scenario : WWTP Effluent TP= 0.5 mg/L

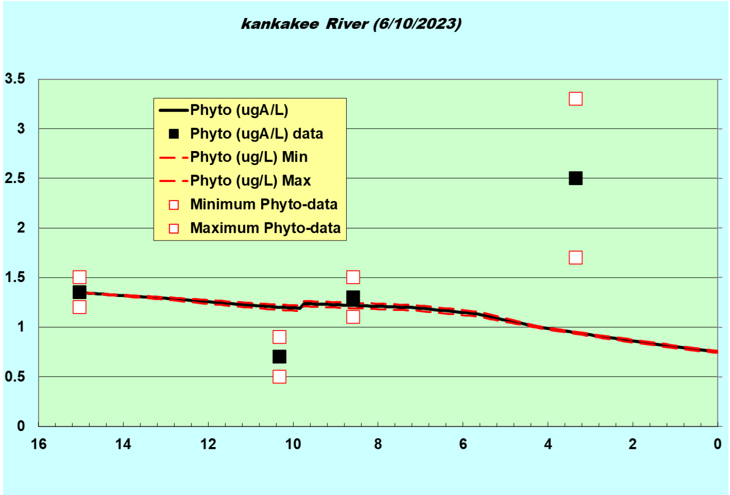
Baseline Total Phosphorus



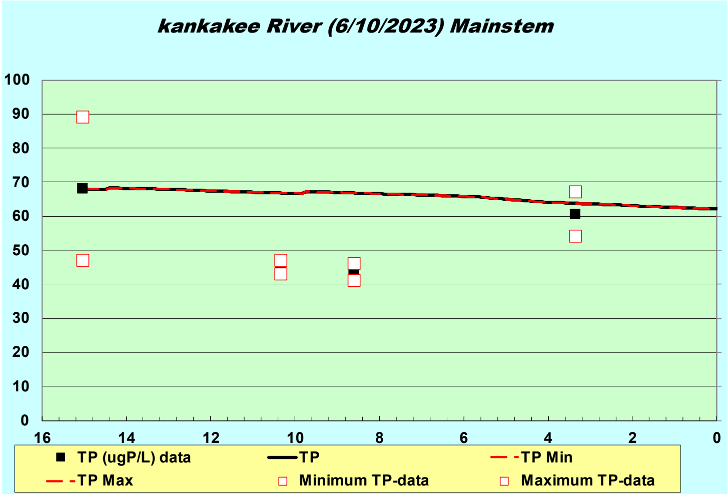
Baseline Inorganic Phosphorus @ 90% of TP



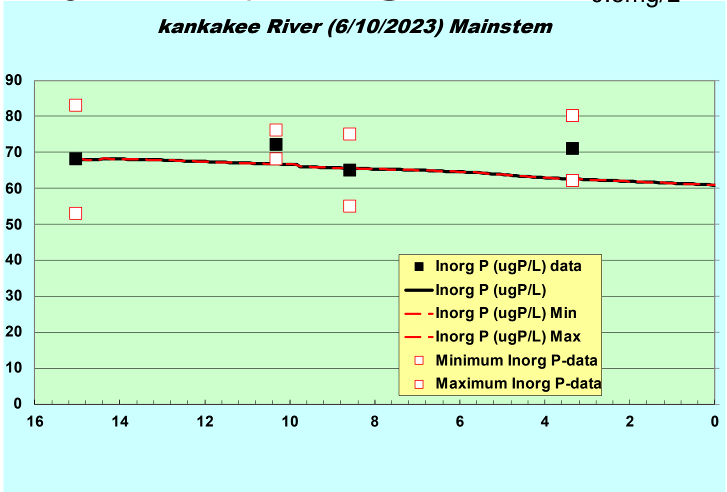
Baseline Chlorophyll - *a*



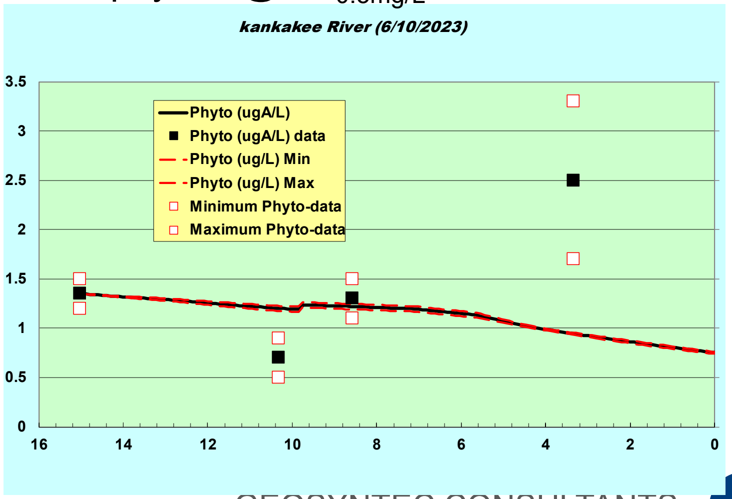
Total Phosphorus @ $TP_{0.5mg/L}$



Inorganic Phosphorus @ 90% of $TP_{0.5mg/L}$

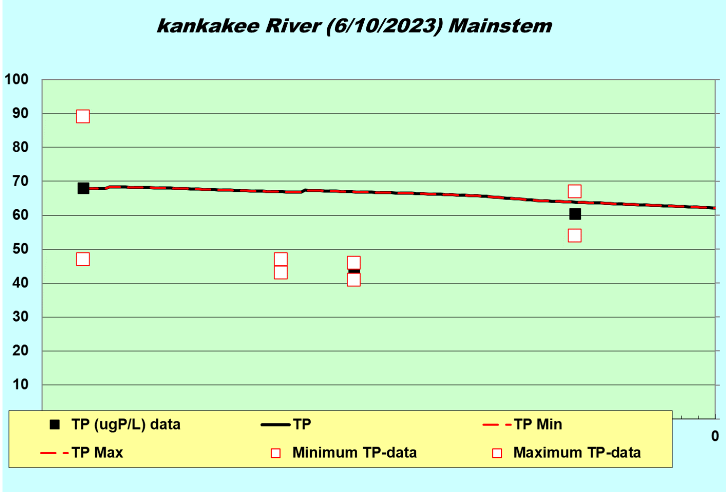


Chlorophyll- *a* @ $TP_{0.5mg/L}$

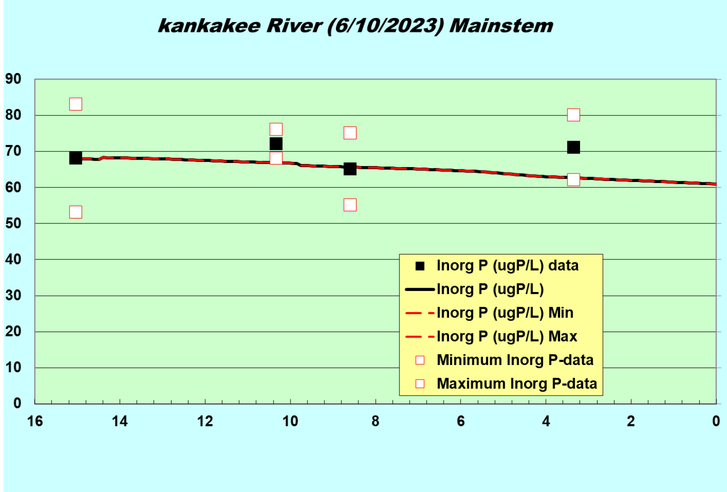


Scenario : WWTP Effluent TP= 0.1 mg/L

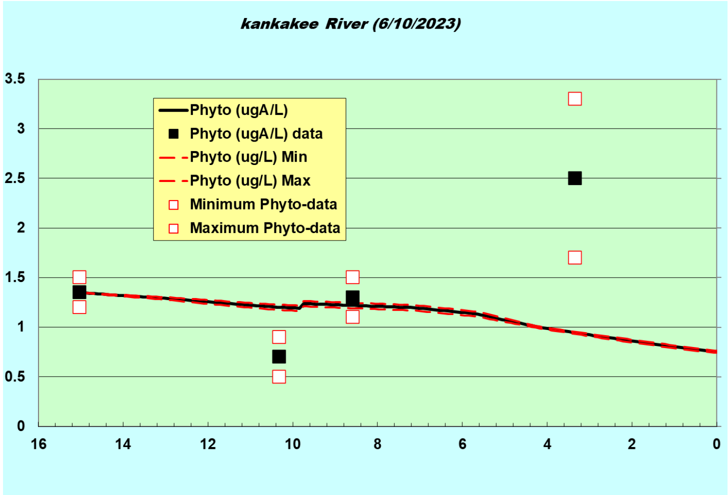
Baseline Total Phosphorus



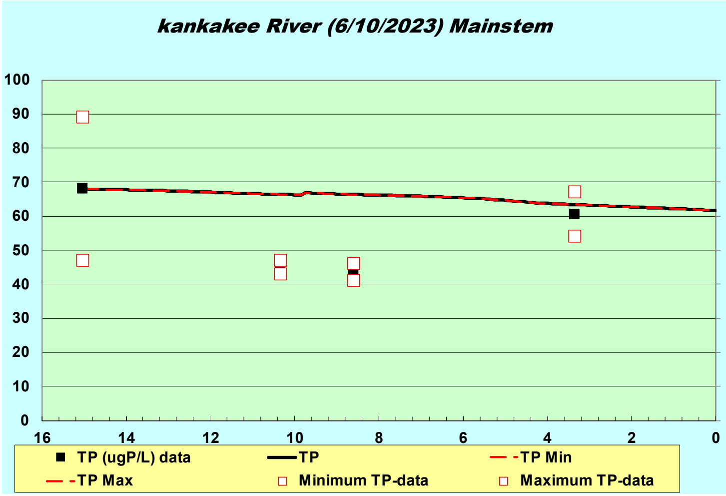
Baseline Inorganic Phosphorus @ 90% of TP



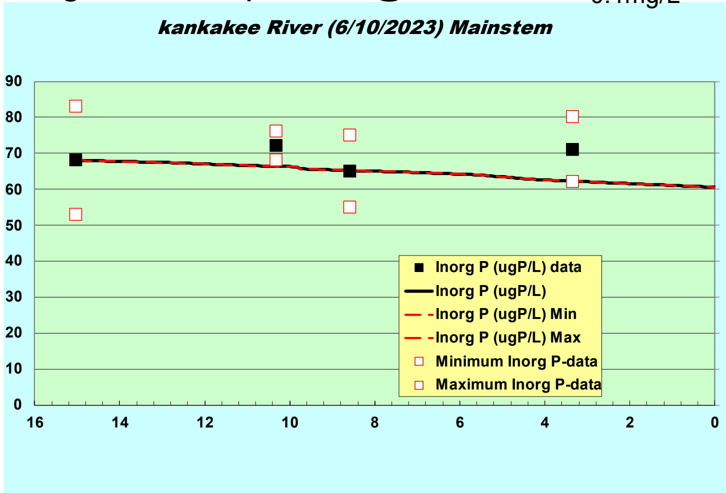
Baseline Chlorophyll - *a*



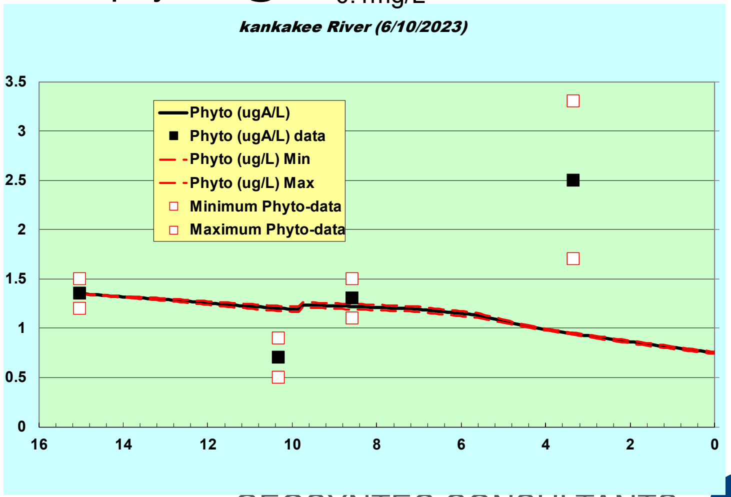
Total Phosphorus @ $TP_{0.1mg/L}$



Inorganic Phosphorus @ 90% of $TP_{0.1mg/L}$

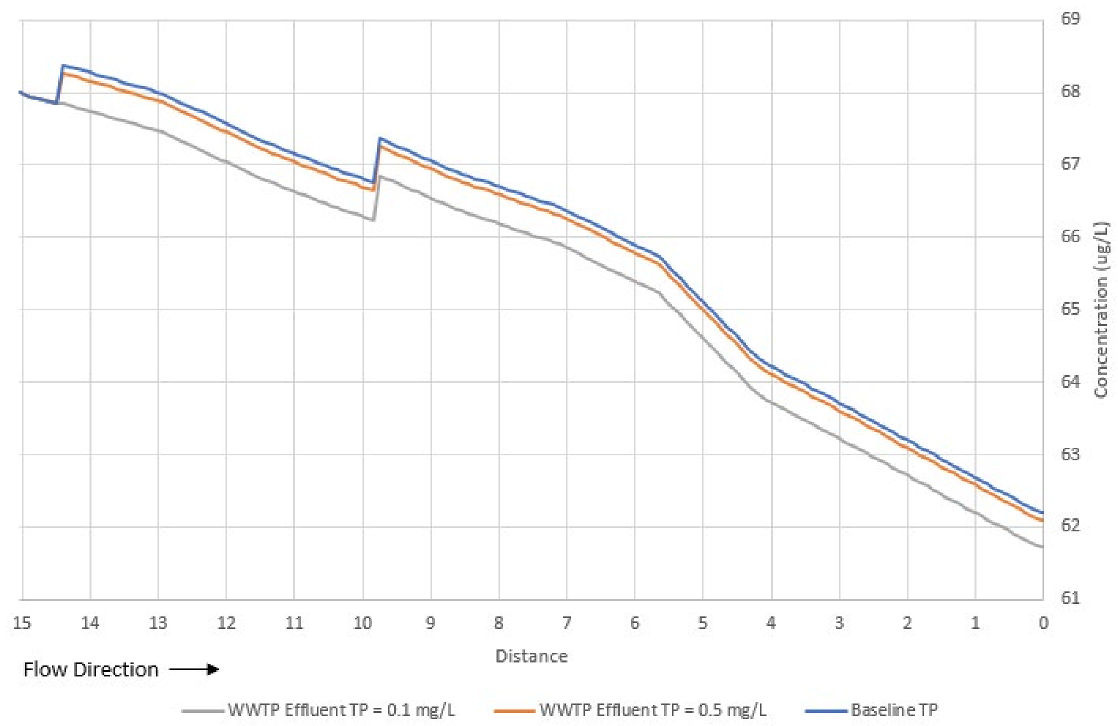


Chlorophyll- *a* @ $TP_{0.1mg/L}$

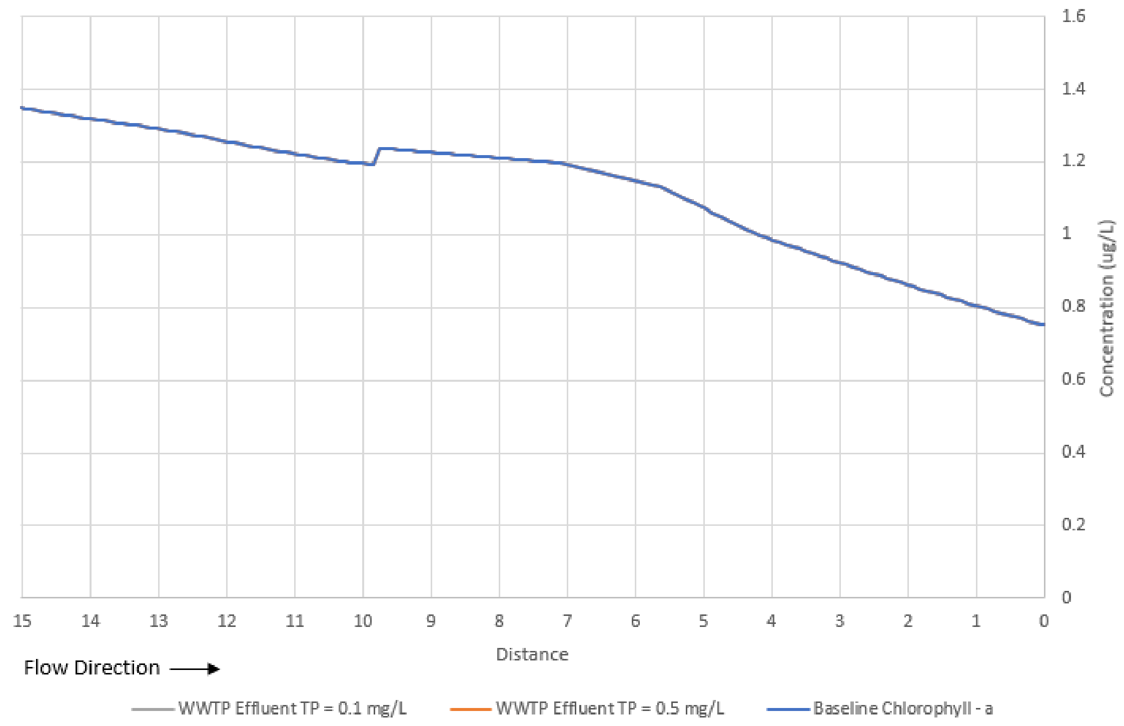


Scenario : Point Source Reduction Summary Plot

Total Phosphorus



Chlorophyll - *a*



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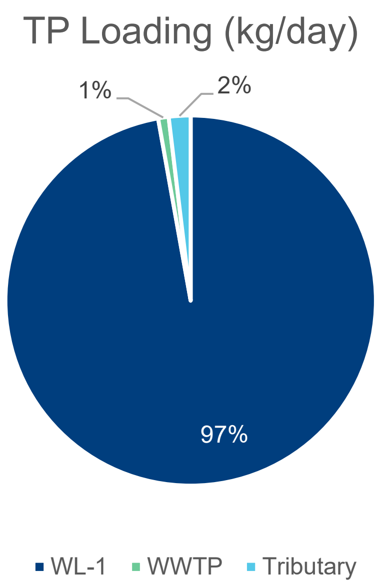
Watershed Management Scenarios

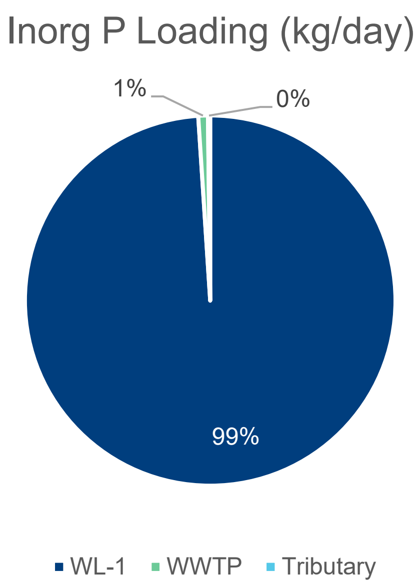
Non-Point Source

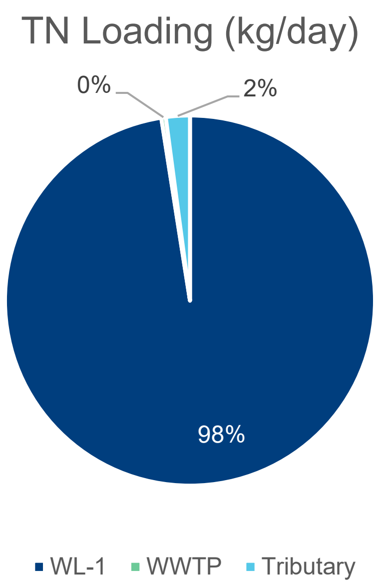
Loading

Table 1: Water Quality Parameter input into Qual2K model				
Location	**TP (ug/L)**	**Inorg P (ug/L)**	**TN (ug/L)**	**Flow (m3/s)**
WL-1	68.00	68.00	2032.00	33.267
WWTP	611.78	550.60	7735.00	0.035
Tributary	130.00	13.00	4270.00	0.340

Table 2: Loading Results (plotted)			
Location	**TP Loading (kg/day)**	**Inorg P Loading (kg/day)**	**TN Loading (kg/day)**
WL-1	195.45	195.45	5840.51
WWTP	1.84	1.66	23.26
Tributary	3.82	0.38	125.44

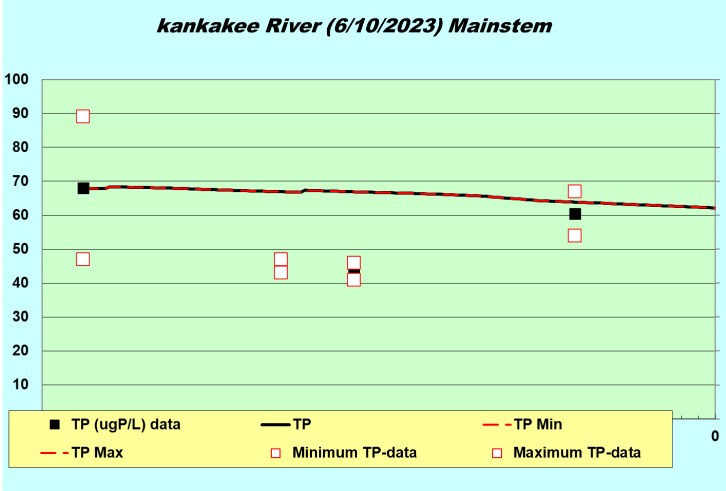




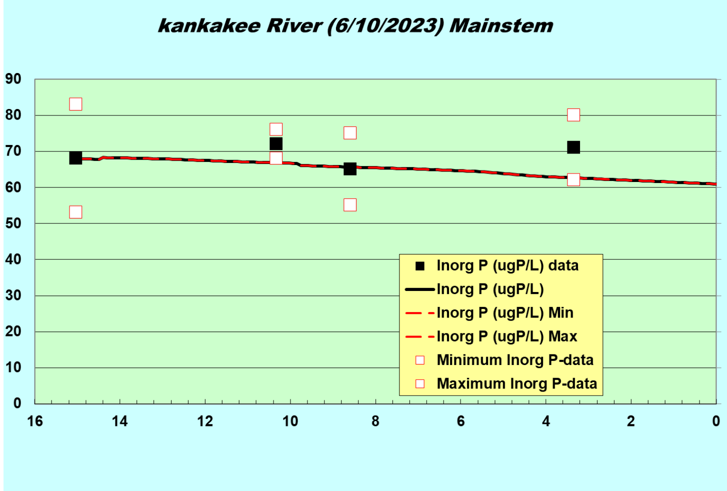


Scenario : TP reduction of 25% at WL-1

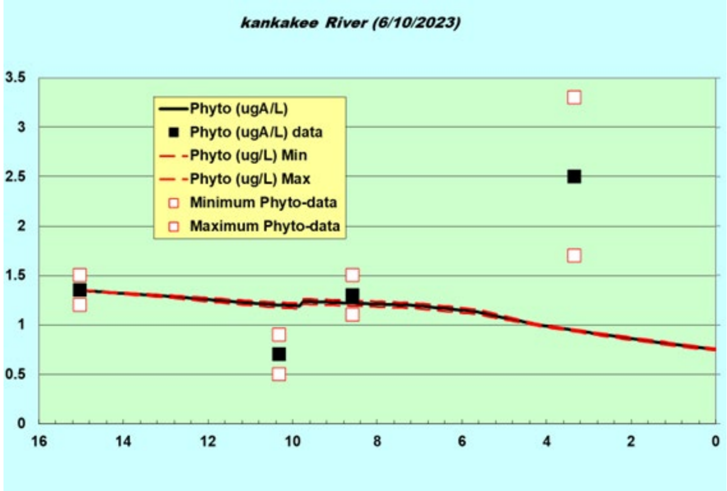
Baseline Total Phosphorus



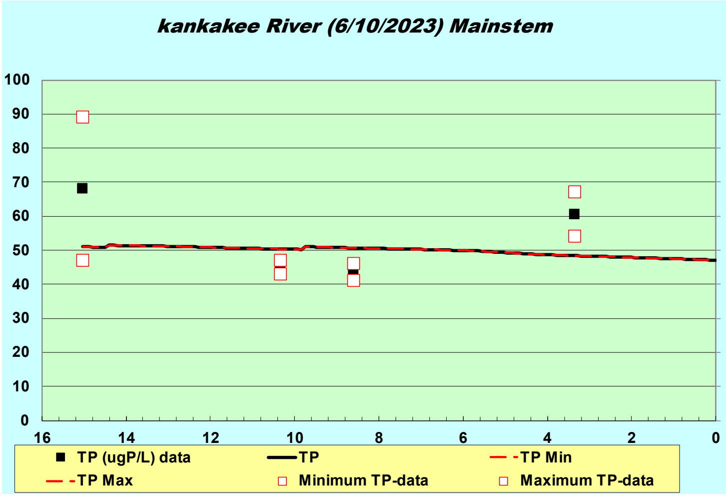
Baseline Inorganic Phosphorus @ 90% of TP



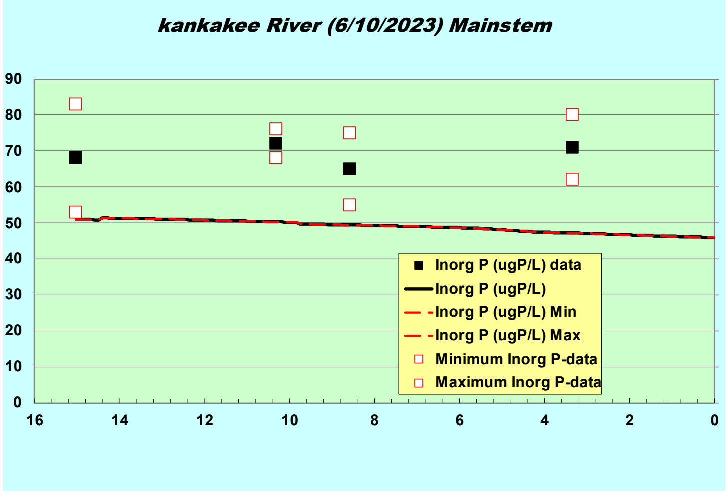
Baseline Chlorophyll-*a*



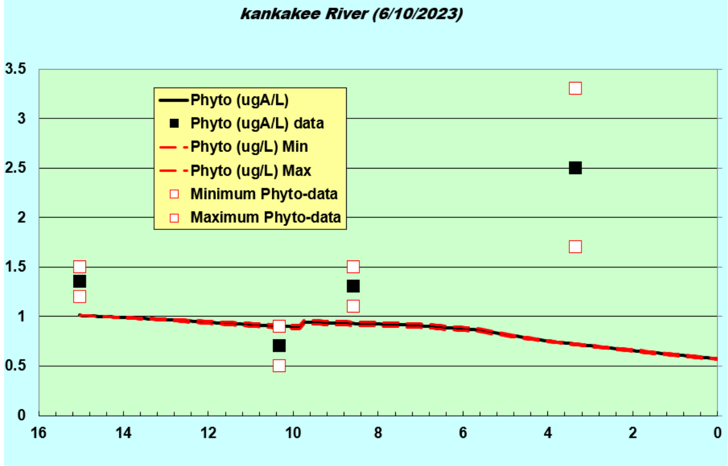
Total Phosphorus @ 25 % Reduction



Inorganic Phosphorus @ 25 % Reduction

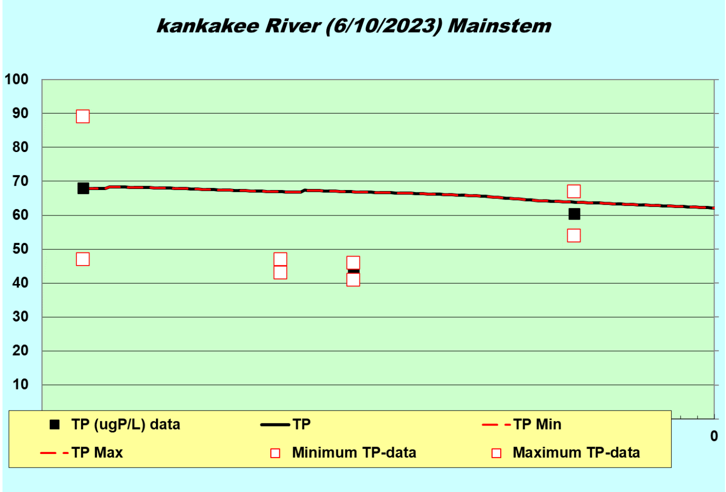


Chlorophyll-*a* @ 25 % TP Reduction

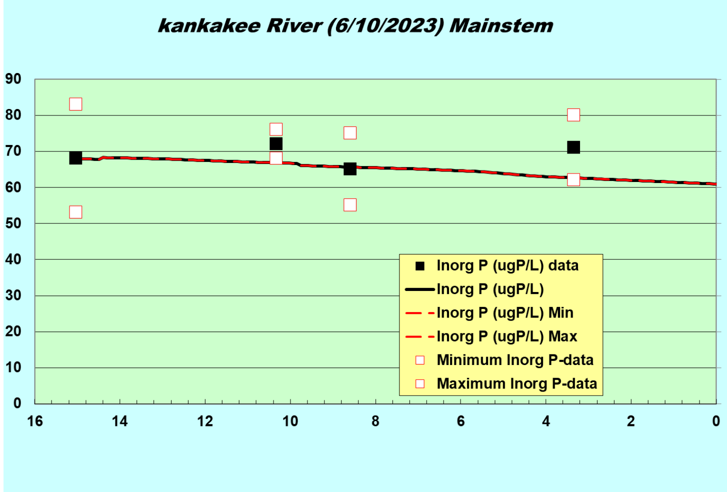


Scenario : TP reduction of 50% at WL-1

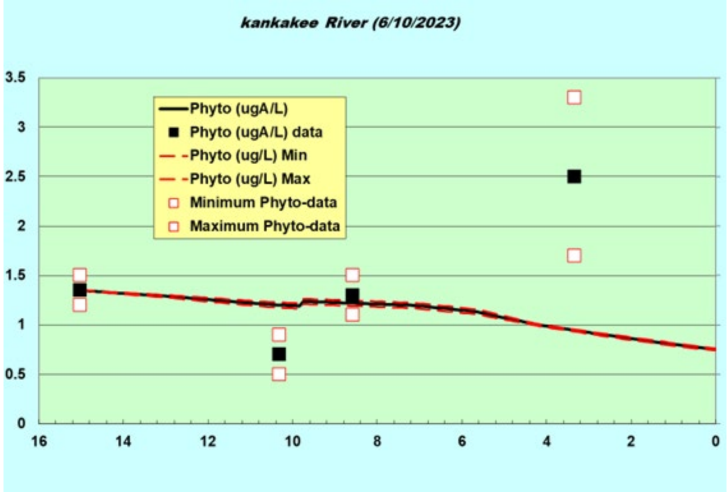
Baseline Total Phosphorus



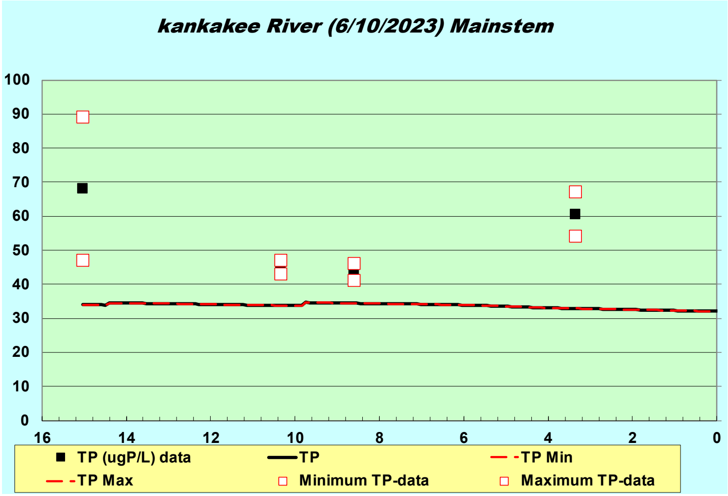
Baseline Inorganic Phosphorus @ 90% of TP



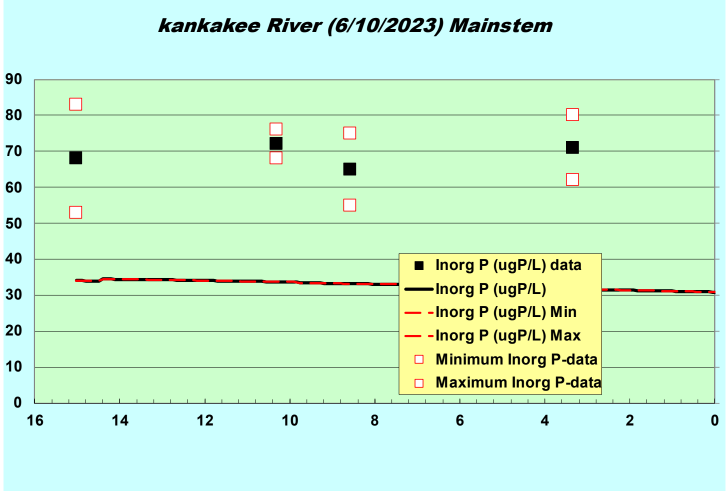
Baseline Chlorophyll-*a*



Total Phosphorus @ 50 % Reduction



Inorganic Phosphorus @ 50 % Reduction



Chlorophyll-*a* @ 50 % TP Reduction