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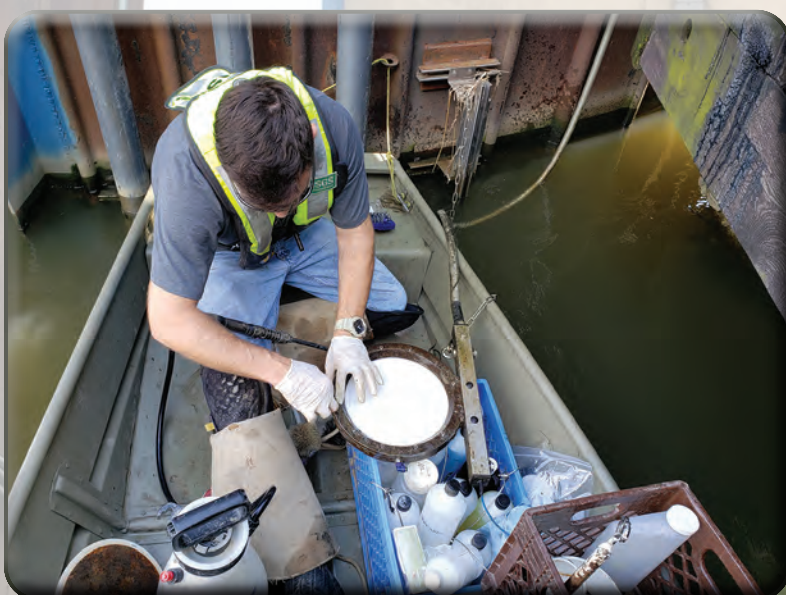
Groundwater and Streamflow Information Program

Continuous Monitoring of Nutrient and Sediment Loads from the Des Plaines River at Route 53 at Joliet, Illinois, Water Years 2018–20



Scientific Investigations Report 2021–5125
Version 1.1, February 2022

U.S. Department of the Interior
U.S. Geological Survey

Cover:

Top left. Repairing the YSI P 700 IQ filter.

Top Right. Looking upstream at the RTE 53 bridge. Photograph by James Duncker.

Bottom. Cleaning the YSI P 700 IQ filter. Photograph by David Fazio.

Back cover top Internal view of the YSI P 700 IQ.

Back cover bottom. See figure 2.

Continuous Monitoring of Nutrient and Sediment Loads from the Des Plaines River at Route 53 at Joliet, Illinois, Water Years 2018–20

By Colin S. Peake and Timothy O. Hodson

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U.S. Geological Survey [USGS], 2021a, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed April 10, 2021, at https://doi.org/10.5066/F7P55KJN.

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Contents

Figures

Tables

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile(mi)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic meter (m^3)	35.31	cubic foot (ft^3)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (t)	1.102	ton, short [2,000 lb]
metric ton (t)	0.9842	ton, long [2,240 lb]

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F = (1.8 × °C) + 32.

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Supplemental Information

Specific conductance is given in millisiemens per centimeter at 25 degrees Celsius (mS/cm at 25 °C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Streamflow is given in cubic feet per second (ft^3/s), which can be converted to cubic meters per second (m^3/s) by multiplying by 0.02832.

A water year is the period from October 1 to September 30 and is designated by the year in which it ends; for example, water year 2018 was from October 1, 2017, to September 30, 2018.

Abbreviations

CSO	combined sewer overflow
IEPA	Illinois Environmental Protection Agency
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
NO23	nitrite plus nitrate as nitrogen
OP	orthophosphate
TP	total phosphorus
USGS	U.S. Geological Survey
WRP	water reclamation plant
WY	water year

Continuous Monitoring of Nutrient and Sediment Loads from the Des Plaines River at Route 53 at Joliet, Illinois, Water Years 2018–20

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Abstract

The Des Plaines River in southern Wisconsin and northern Illinois is the principal conduit for the discharge of wastewater effluent and stormwater runoff from the greater Chicago metropolitan area. In November 2017, the U.S. Geological Survey, in cooperation with the Metropolitan Water Reclamation District of Greater Chicago, installed a continuous monitoring station to measure water quality and streamflow in the Des Plaines River at Joliet, Illinois. Surrogate models encompassing continuous data and discrete water-quality samples were used to estimate loads of nitrate, total phosphorus, and suspended sediment. Comparisons to other major rivers in Illinois show that the Des Plaines River is a substantial contributor to statewide loading estimates for nitrate and total phosphorus but only a minor contributor to suspended sediment. Future loading estimates of total phosphorus could include more research into the effects of combined sewage overflows because these effects likely increased model uncertainty. The results in this report document current loadings and provide a baseline from which to assess future water-quality management decisions.

Introduction

In the 1960s and 1970s, State and Federal water-quality standards, as environmental regulations, were established for the Chicago Area Waterway System (Hines, 2012; Copeland, 2016). The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) operates and maintains a water-quality monitoring network along the system and has done extensive data collection and reporting on the concentrations and loads of nutrients (for example, Abedin, 2016; Minarik and Wasik, 2017). The system's operation procedures incorporate information from the water-quality monitoring network and flow data to help meet the water-quality standards. However, since the completion of the Chicago Sanitary and Ship Canal, which rerouted the Chicago River away from Lake Michigan, demands on the system, as well as its monitoring needs, have expanded through time. Navigation and wastewater discharge regulations have become increasingly stringent and require more monitoring to effectively meet and balance increasing demands for water quality, commercial and recreational navigation, and regional flood control, as well as newer issues such as the threat from aquatic invasive species and the recovery of native species.

In addition to these local water-quality concerns, nutrients from the Des Plaines River contribute to the formation of a large low-oxygen or hypoxic region that develops each summer in the northern Gulf of Mexico. The State of Illinois, as well as other States within the Mississippi River Basin, have voluntarily committed to reduce nitrate-nitrogen and phosphorus loads to the Mississippi River (Illinois Environmental Protection Agency [IEPA] and others, 2015). State regulators assessing progress toward this goal need better documentation and monitoring of the contribution of nutrients to the Illinois River from the greater Chicago metropolitan area to be able to determine the relative contributions from this area to the overall nutrient loading of the Illinois Waterway (monitored by the U.S. Geological Survey [USGS] with continuous nutrient sensors at the Illinois River at Florence, Ill. [Terrio and others, 2015]).

The Des Plaines River originates in southeast Wisconsin and flows south through suburban communities in northeastern Illinois before turning southwest to run parallel to the Chicago Sanitary and Ship Canal for about 32 kilometers. The canal joins the Des Plaines River just north of Joliet, Illinois. The canal is the downstream reach of the Chicago Area Waterway System (fig. 1). The system consists of a combination of natural and man-made channels that form an interconnected navigable waterway of about 145 kilometers in the Chicago metropolitan area of northeastern Illinois. The system is used for commercial and recreational transportation and as the conduit for the discharge of wastewater effluent and stormwater runoff.

In November 2017, the USGS, in cooperation with the MWRDGC, installed a continuous monitoring station to collect water-quality and streamflow data in the Des Plaines River at Route 53 at Joliet, Ill. (USGS station 05537980; fig. 1). Those continuous data, along with discrete water-quality samples, were used to develop models for estimating concentrations and annual loads of dissolved nitrite plus nitrate as nitrogen (NO23), total phosphorous (TP), and suspended sediment at the Des Plaines River at Joliet, Ill., for water years (WYs) 2018–20.

Purpose and Scope

This report documents the development and application of surrogate models for estimating concentrations and loads of NO23, TP, and suspended sediment at the Des Plaines River at Route 53 at Joliet, Ill., using data collected during WYs 2018–20. The models apply a method documented in Hodson and others (2021a) to statistically relate in situ, continuous water-quality data with analytical results from discrete water samples. The data collected are available in the USGS National Water Information System database (USGS, 2021b).

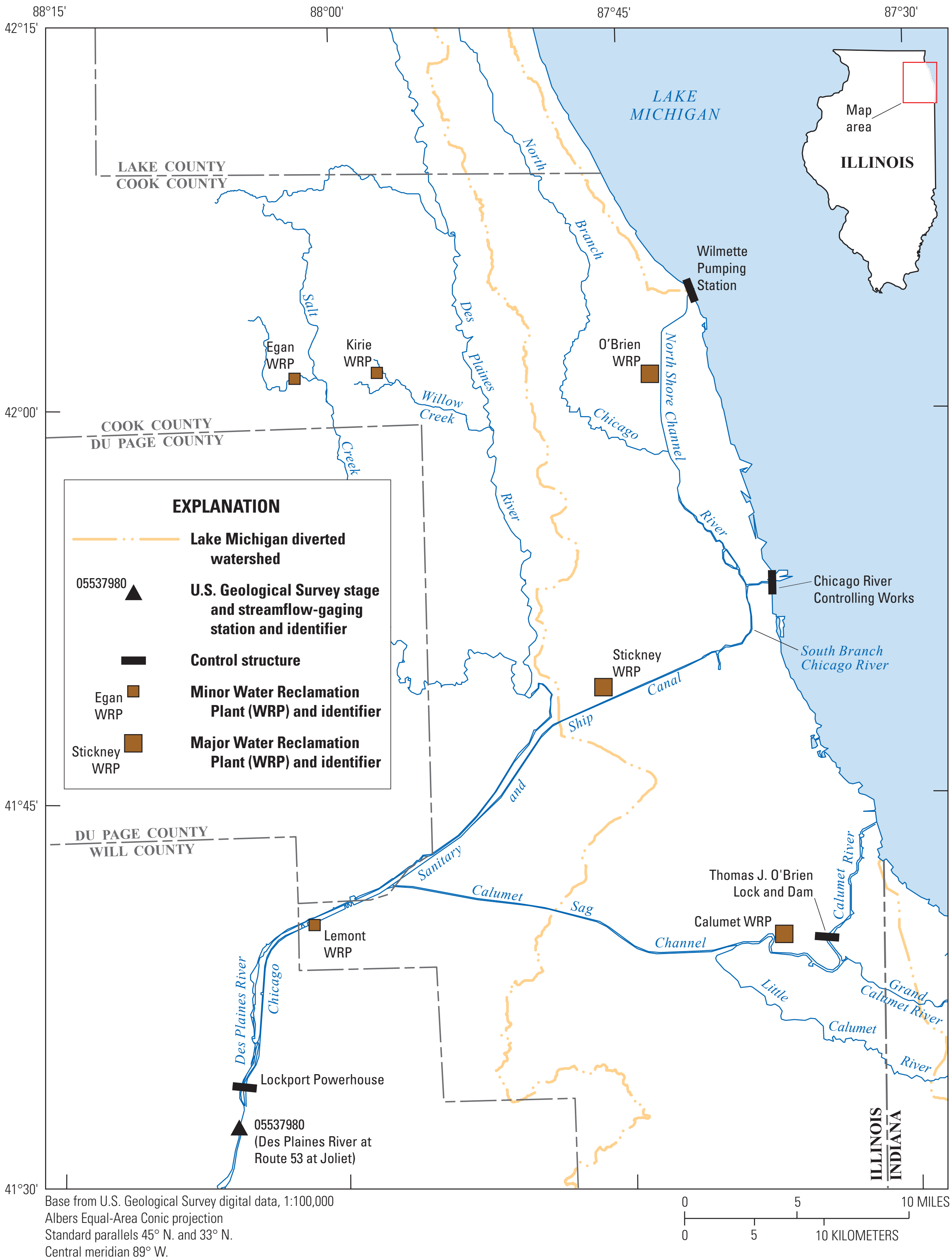

Figure 1. The continuous water-quality monitoring station and water reclamation plants in the Chicago Area Waterway System, Illinois.

Methods

In-stream sensors were used to record water temperature, specific conductance, dissolved oxygen, pH, turbidity, nitrate, and orthophosphate at 15-minute intervals during WYs 2018–20. From that data, concentrations of NO23, TP, and suspended sediment were estimated using covariate-based Bayesian imputation (Hodson and others, 2021a). Loads were calculated by multiplying daily mean concentration and streamflow with a unit conversion factor, where annual loads are the summation of daily loads.

Data Collection

Monitoring instrumentation was on the upstream side of the central pier protection cell of the Route 53 bridge. This mounting location allowed for adequate depth under all streamflow conditions while protecting the instrumentation from boat traffic and in-stream debris. YSI EXO 2 (YSI, Inc., Yellow Springs, Ohio), Hach Nitratax plus sc (Hach, Loveland, Colorado), and Hach Solitax sensors were installed in separate 4-inch polyvinyl chloride conduits. The YSI P 700 IQ orthophosphate (OP) analyzer has a larger rectangular filter that was installed on a railing system welded to the pier-protection cell. Detailed descriptions of the sensors and analyzers are provided in table 1. All water properties were measured at 15-minute intervals beginning in November 2017, except for OP, which was initially measured hourly but switched to a 15-minute interval in August 2018.

To assist with discrete sample collection, a ISCO autosampler (Teledyne ISCO, Lincoln, Nebraska) was installed in spring 2019 to sample based on turbidity and OP concentration thresholds.

The continuous data record for each property was analyzed, approved, and audited according to established USGS protocols and methods (Wagner and others, 2006). These protocols included removal of obvious erroneous data, correction for sensor fouling and calibration drift, and comparison of continuous sensor data with periodic discrete verification samples that were analyzed by the USGS National Water Quality Laboratory in Denver, Colorado. Continuous data and annual summaries of the minimum, maximum, and mean concentrations for the water-quality properties at the monitoring station are in the USGS National Water Information System database (USGS, 2021b).

Surrogate Modeling

A challenge with using continuous data in modeling is the uncertainty that is created from periods of missing data, and how that uncertainty affects predictions derived from the data, such as annual loading rates. This study uses covariate-based Bayesian imputation (Hodson and others, 2021a), which imputes missing data based on other covariates monitored during the study, including water temperature, pH, dissolved oxygen, specific conductance, turbidity, streamflow, season, and time. The approach assumes the joint distribution of the data is multivariate lognormal, learns the joint distribution from observations, and then simulates missing observations using

Table 1. Manufacturer specifications for each instrument used for data collection.

[°C, degree Celsius; ±, plus or minus; mS/cm, millisiemens per centimeter; %, percent; mg/L, milligram per liter; CT, calibration temperature; FNU, Formazin Nephelometric Unit; <, less than; mm, millimeter; mg N/L, milligrams of nitrogen per liter; mg P/L, milligrams of phosphorus per liter]

Property	Instrument	Range	Accuracy	Resolution
Water temperature	YSI EXO2 Multiparameter Sonde	−5–50 °C	−5–35 °C: ±0.01 °C; 35–50 °C: ±0.05 °C	0.001 °C
Specific conductance	YSI EXO2 Multiparameter Sonde	0–200 mS/cm	0–100 mS/cm: ±0.5%; 100–200 mS/cm: ±1%	0.0001–0.01 mS/cm, range dependent
Dissolved oxygen	YSI EXO2 Multiparameter Sonde	0–50 mg/L	0–20 mg/L: ±1.0%; 20–50 mg/L: ±5.0%	0.1 mg/L
pH	YSI EXO2 Multiparameter Sonde	0–14 standard units	±0.1 standard units within ±10 °C of CT, ±0.2 standard units otherwise	0.01 standard units
Turbidity	YSI EXO2 Multiparameter Sonde	0–4,000 FNU	0–999 FNU: ±2%; 1,000–4,000 FNU: ±5%	0–999 FNU: 0.01 FNU; 1,000–4,000 FNU: 0.1 FNU
Turbidity	Hach Solitax	0–4,000 FNU	0–1,000 FNU: <1% with calibration	0.01 FNU
Nitrate plus nitrite	Hach Nitratax plus sc 2 mm	0–50 mg N/L	±3% or 0.5 mg N/L, whichever is greater	0.1 mg N/L
Orthophosphate	YSI P 700 IQ	0.05–15 mg P/L	±2% or 0.05 mg P/L, whichever is greater	0.01 mg P/L

the learned joint distribution of the data. Additional detail about the model is provided in Hodson and others (2021a), but the basic structure of the model is represented in its likelihood:

$$z=[\log c, \log q, \sin 2\pi t, \cos 2\pi t, t, \log x] \quad (1)$$

$$z \sim \mathrm{lognormal}(\mu,\Sigma) \quad (2)$$

where

- z is the true state of the system,
- c is concentration of the constituent of interest,
- q is daily mean streamflow,
- t is time in decimal years,
- x are other covariates,
- μ is a vector containing the median value for each element in z, and
- Σ is the covariance of z.

The model underlying the Bayesian method is somewhat analogous to regressing logarithmic transformed concentration against the logarithmic transformed covariates, but the Bayesian version has several advantages, such as being less prone to certain biases caused by missing data. If only streamflow, season, and time are available, the model is analogous to the five-parameter model from Cohn and others (1992) but with regularization to minimize overfitting. Data is available in the National Water Information System (USGS, 2021a), and modeled data is available from Hodson, 2021b. For more details on the method and modeled data, see Hodson and others (2021a, b).

Data Coverage

Continuous water-quality data collection began after equipment installation on November 17, 2017, and continued through September 30, 2020. The percentage of continuous data coverage for each property is separated by streamflow quartile and shown in table 2. Data coverages across the streamflow quartiles for temperature, specific conductance, dissolved oxygen, both turbidity sensors, and NO23 were 94 percent or higher for each quartile. OP was 80 percent or higher, whereas pH was 75 percent or higher. OP and pH had lower percentages largely because of the use of consumable parts that resulted in lost data.

Table 2. Percentage of record with continuous data coverage from November 17, 2017, to September 30, 2020, by streamflow quartile.

[SC, specific conductance; DO, dissolved oxygen; OP, orthophosphate]

Streamflow quartile	Percentage of record with continuous data coverage							
	Temperature	SC	DO	pH	Turbidity (YSI EXO2 Multiparameter Sonde)	Turbidity (Hach Solitax)	Nitrate	OP
First quartile	100	100	100	79	94	98	99	80
Second quartile	99	95	99	76	96	98	99	96
Third quartile	100	95	100	75	96	98	100	94
Fourth quartile	100	97	100	79	94	95	100	86
Overall	100	96	100	77	95	97	99	90

Streamflow and Discrete Water-Quality Data

Streamflow measurements began at the Des Plaines River at Joliet in 2005. During WYs 2006–17, mean annual streamflow was 3,461 million cubic meters (Mm^3), whereas mean annual streamflow during the study period (WYs 2018–20) was 23 percent higher at 4,485 Mm^3. Annual streamflow rankings for 2018, 2019, and 2020 were the second, first, and fourth highest mean annual streamflows, respectively, since monitoring began in 2005. Streamgages upstream at the Des Plaines River near Lemont (USGS station 05533600), the Chicago Sanitary and Ship Canal near Lemont (USGS station 05536890), and the Des Plaines River at Riverside (USGS station 05532500; not shown on a map) all experienced above-average streamflow during the study period; and 2019 was the highest annual streamflow across the period of record for all sites (USGS, 2021a).

Discrete water-quality samples were collected during maintenance visits, scheduled routine sampling, or with the automated ISCO sampler. These samples allow for direct comparison between nutrient sensors and surrogate models and help quantify errors in continuous monitors. Analytical method information for the discrete water-quality samples is provided in table 3. Discrete samples were typically collected using a weighted-bottle sampler with a 1-liter pre-cleaned polypropylene bottle suspended by a rope. The sampler was lowered as quickly as possible to the depth of the continuous sensors and allowed to fill. Samples were collected immediately next to the sensors, and the ISCO intake was also next to the sensors. Cross-sectional samples were depth- and width-integrated and characterize whether the location of the sensors was representative of the entire width of the river. During the study, two cross-sectional samples were collected. Mean differences between discrete point and cross-sectional samples were 15, 13, and 25 percent for NO23, TP, and suspended sediment, respectively. Further sampling is planned to fully assess potential bias over the full range of streamflow conditions. Summary statistics of the discrete water-quality samples are provided in table 4 (USGS, 2021a).

Table 3. Analytical method information for discrete water-quality samples.

[µm, micrometer; mg/L, milligram per liter; sulfuric acid, H_2SO_4; <, less than]

Constituent	Preservation	Analysis method	Limit detection method
Nitrate plus nitrite as nitrogen	Filtered (0.45 µm), chilled, dark bottle	Colorimetry, enzymatic reduction-diazotization (Patton and Kryskalla, 2011)	0.04 mg/L
Total phosphorus	Chilled, H_2SO_4 acid to pH<2	Colorimetry, alkaline persulfate digestion (Fishman, 1993)	0.01 mg/L
Orthophosphate	Filtered (0.45 µm), chilled, dark bottle	Colorimetry, phosphomolybdate reduction (Patton and Kryskalla, 2003)	0.004 mg/L

Table 4. Summary of discrete water-quality samples collected during water years 2018–20.

[Data are summarized from the National Water Information System database (U.S. Geological Survey, 2021a)]

Constituent	Sample count	Summary statistic, in milligrams per liter				
		Minimum	Maximum	Median	1st quartile	3d quartile
Nitrate plus nitrite	30	1.28	6.70	3.97	3.12	4.95
Orthophosphate	42	0.004	2.17	0.50	0.37	0.79
Total phosphorus	42	0.38	2.35	0.66	0.46	1.07
Suspended sediment	43	5	211	13	10	27

Loads and Yields

Modeled annual loading results for WYs 2018–20 for NO23, TP, and suspended sediment are in table 5, and loading timeseries are in figures 2–4, respectively. Using these results, nutrient and sediment loads from the Des Plaines River were compared to the other major rivers in the State, as well as to nutrient loads from water reclamation plant (WRP) effluent data from the MWRDGC (MWRDGC, 2021). Annual WRP loads were estimated by multiplying the mean daily effluent loading for each water year by 365.25 because about 24 percent of daily loads were missing, disproportionally affecting TP and WY 2020. These estimates are used to create a basic relation between WRPs and station loads and were within 20 percent of the selected major municipalities TP loads from the latest Biennial Illinois Nutrient Loss Reduction Strategy Report (IEPA and others, 2019). The estimated WRP annual loadings are in table 5. For WRP suspended-sediment estimates, total suspended solids effluent data were used for comparison with suspended sediment because no direct comparison was available. However, for predominantly fine-grained (particle sizes less than 0.0625 millimeter) systems, this is acceptable for relative comparisons (Gray and others, 2000; Groten and Johnson, 2018).

An estimated 63–76 percent of the annual NO23 load originated from WRPs during WYs 2018–20 (table 5). Storms were associated with increased NO23 loading but typically lower concentration. Lower NO23 concentration during storms is likely due to NO23 in WRP effluent being diluted by stormwater runoff (fig. 2). This dilution is common in urbanized watersheds where WRPs are the largest source of NO23 (Terrio, 1994; Carey and Migliaccio, 2009). The mean NO23 yield during WYs 2018–20 was 4.70 tons per square kilometer (t/km^2) for the Des Plaines River, which is similar to the Chicago and Des Plaines River’s Hydrologic Unit Code-8 yields of 4.58 and 4.29 t/km^2 for point sources, respectively (IEPA and others, 2015).

WRPs were also a large source of TP, contributing an estimated 43–71percent of the annual load during WYs 2018–20. TP is more difficult to ascribe general patterns to because of the differences between the dissolved and particulate forms. In urbanized watersheds, OP is typically a larger part of the load during base-flow conditions, and particulate-associated phosphorus is more prevalent during storm events (IEPA and others, 2015, 2019). An analysis of the discrete samples gives credence to this pattern in that the OP part averaged 49 percent of the TP concentration when streamflow was in the fourth quartile. During all other flows, the OP part averaged about 87 percent of the TP concentration. Figure 3 shows a timeseries of TP concentration and loading and their uncertainties, which were largest during periods of missing continuous OP data. The annual TP yield averaged 0.96 t/km^2 during WYs 2018–20 for the Des Plaines River, which is similar to the estimated TP yields of the Chicago and Des Plaines River’s Hydrologic Unit Code-8 of 1.09 and 0.75 t/km^2 for point sources, respectively (IEPA and others, 2015).

Only 8–15 percent of suspended sediment is estimated to have come from WRPs during WYs 2018–20. Storms were associated with increased suspended-sediment concentrations and therefore loading (fig. 4). The relation between suspended-sediment concentrations and streamflow likely stems from river management during storms.

Table 5. Nutrient and suspended-sediment loads for the Des Plaines River at Joliet, Illinois (U.S. Geological Survey station 05537980), including estimated wastewater reclamation plant annual loads, water years 2018–20.

[Station estimates are based on continuous monitoring with Bayesian imputation. NO23, nitrate plus nitrite as nitrogen; WRP, wastewater reclamation plant; WY, water year]

Water year	Load, in metric kilotons					
	NO23		Total phosphorus		Suspended sediment	
	Station	WRP	Station	WRP	Station	WRP
2018	18.4	11.6	3.7	1.6	128	12.6
2019	17.9	13.0	4.1	2.3	134	20.3
2020	18.6	14.1	3.5	2.5	116	9.6
2018–20 (mean)	18.3	12.9	3.7	2.1	126	14.2

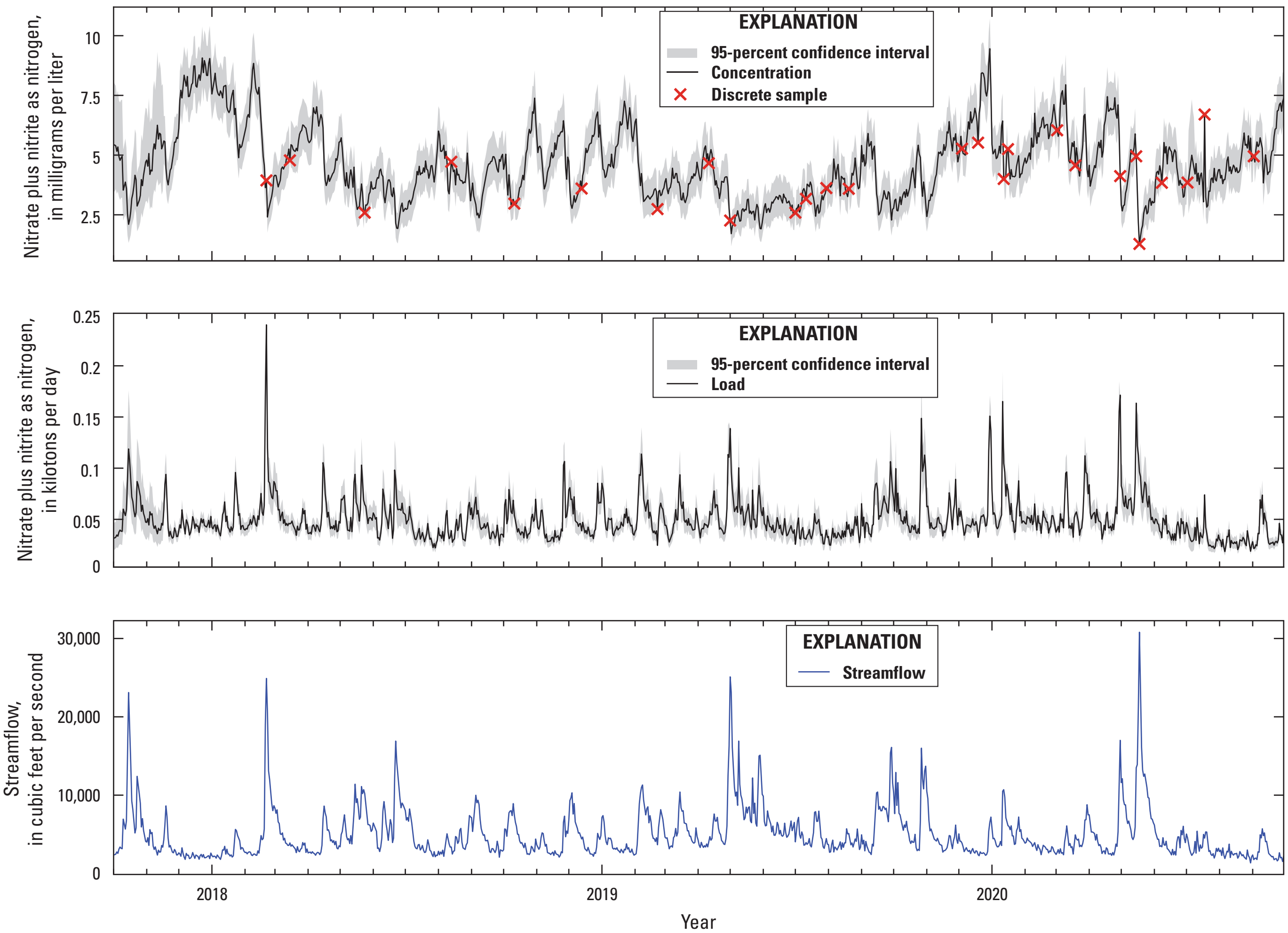

Figure 2. Timeseries of nitrate plus nitrite as nitrogen concentration, nitrate plus nitrite as nitrogen load, and streamflow for the Des Plaines River at Joliet, Illinois (U.S. Geological Survey station 05537980), water years 2018–20. [Data available from Hodson and others, 2021b.]

Figures 5 and 6 compare loads and yields from the Des Plaines River to those from other major rivers in Illinois using data from Hodson and others (2021a, b). Figure 5 shows the part of loading from the Des Plaines River relative to that from the other tributaries of the Illinois River and other major rivers in the State of Illinois. For nitrate and phosphorus loading, the Des Plaines River contributes 9 and 19 percent, respectively, to the Illinois River (fig. 5). Suspended sediment from the Des Plaines River was a smaller fraction of the State and Illinois River load. An important caveat is that nutrient cycling likely plays a substantial role in altering nutrient loads between stations, meaning one cannot assume loading estimates from the Des Plaines River will leave the State. For example, the Illinois River flows about 438 kilometers within the State of Illinois from its origin (confluence of the Des Plaines and Kankakee Rivers; not shown) to the Mississippi River, allowing for considerable nutrient uptake and deposition. By yield, the Des Plaines River has the largest NO23 and TP yields of the major rivers in the State and the second lowest suspended-sediment yield (fig. 6). This agrees with previous research where the Des Plaines River is known to have some of the highest point-source nutrient loadings in the State of Illinois (IEPA and others, 2015, 2019). Streamflow from the Des Plaines River, as well as Illinois rivers statewide, was above average during the study period (Hodson and others, 2021a), and the relative contributions from each watershed may differ under other conditions.

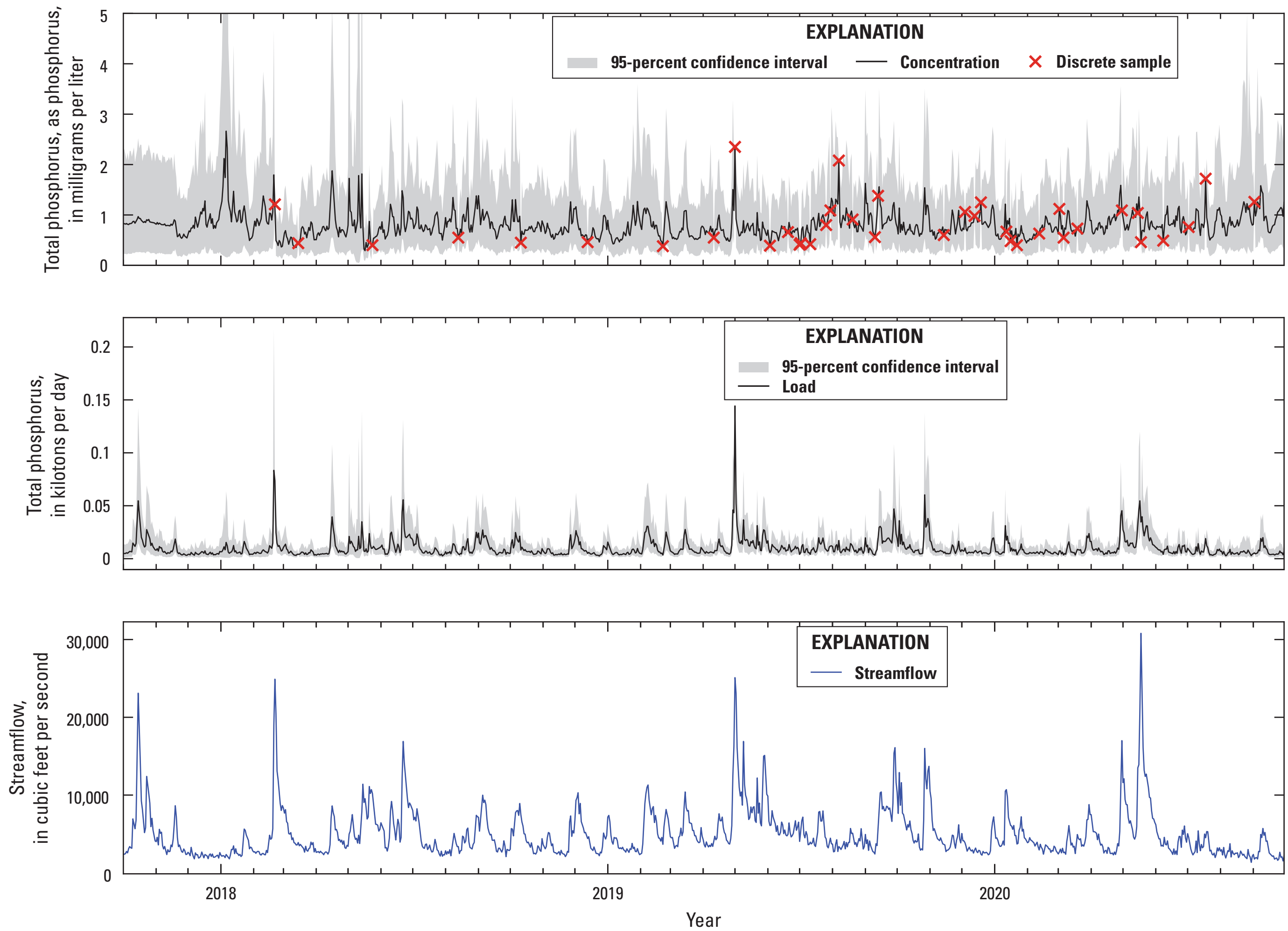

Figure 3. Timeseries of total phosphorus concentration, total phosphorus load, and streamflow for the Des Plaines River at Joliet, Illinois (U.S. Geological Survey station 05537980), water years 2018–20. [Data available from Hodson and others, 2021b.]

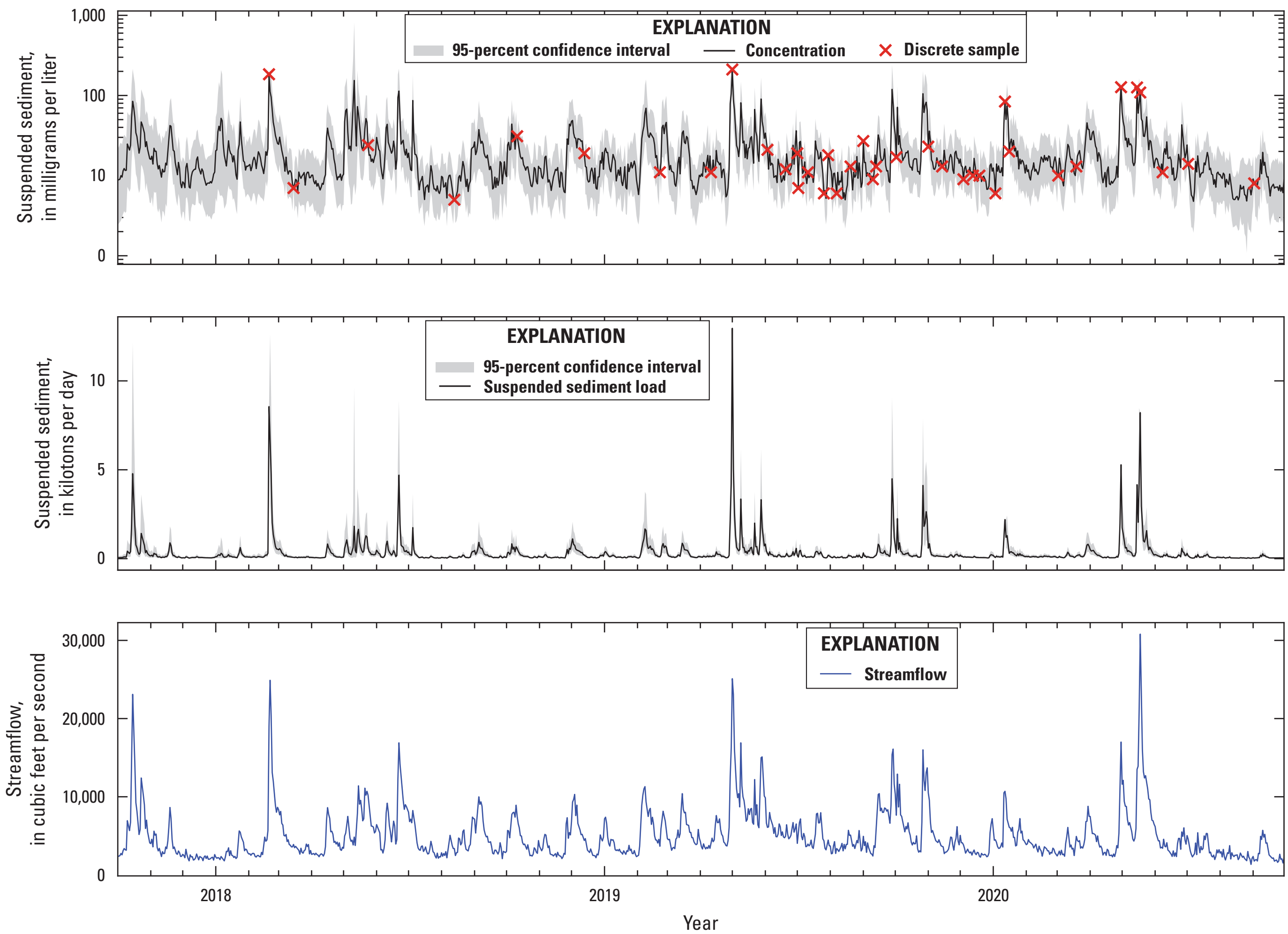

Figure 4. Timeseries of suspended-sediment concentration, suspended-sediment load, and streamflow for the Des Plaines River at Joliet, Illinois (U.S. Geological Survey station 05537980), water years 2018–20. [Data available from Hodson and others, 2021b.]

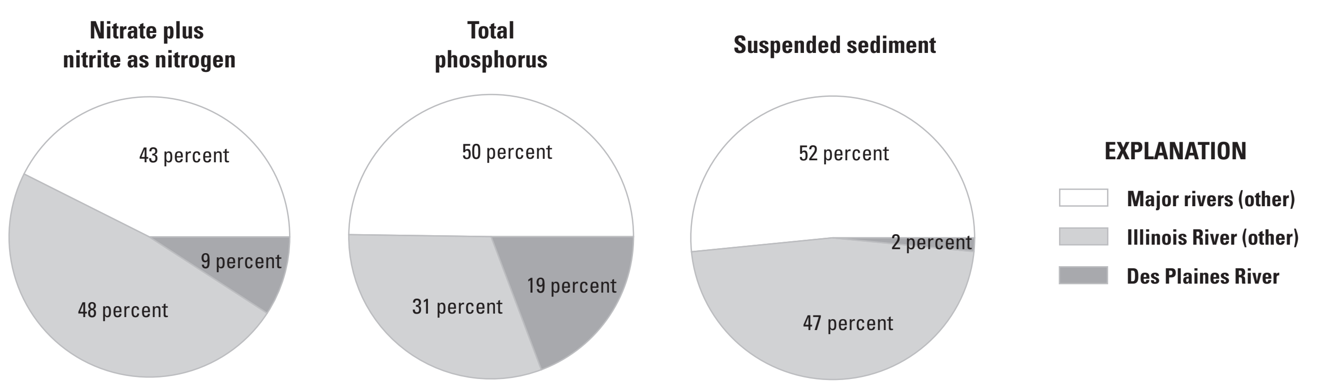

Figure 5. Percentage annual load from Illinois' major rivers for water years 2018–20, divided among the contributions from other major rivers in the Illinois River Basin, the Illinois River, and the Des Plaines River. [Data for other rivers are from Hodson and others, 2021a.]

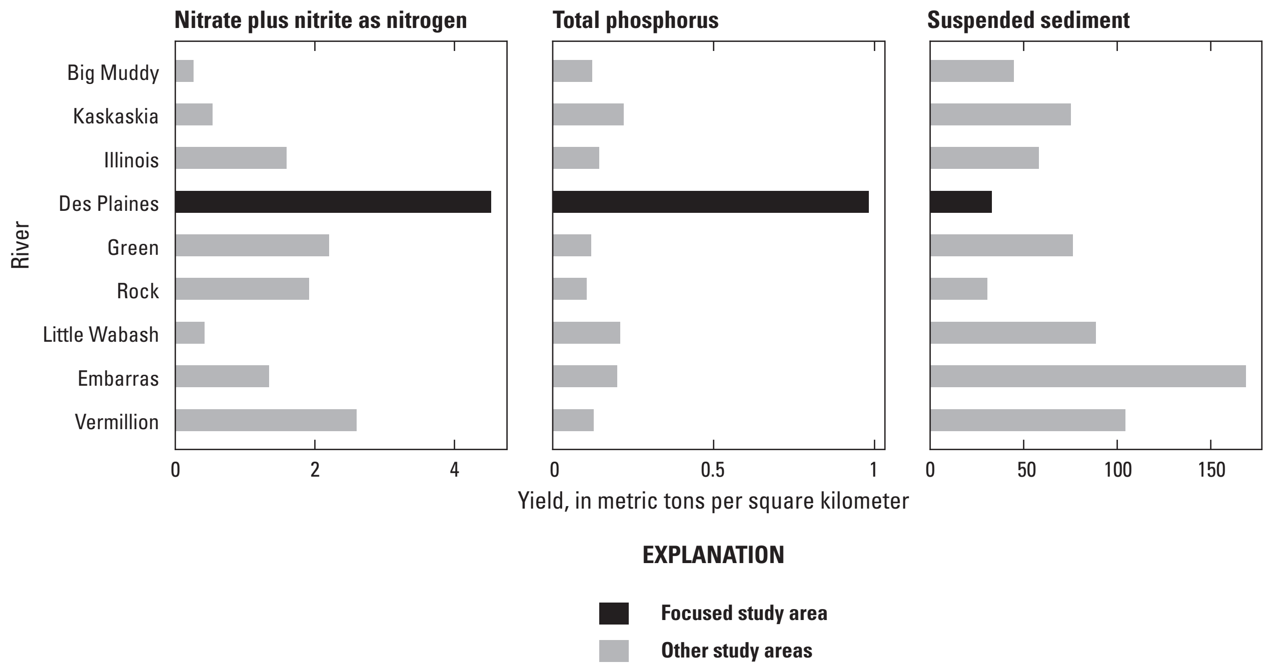

Figure 6. Mean annual yields from the Des Plaines River and other major rivers in Illinois for water years 2018–20. [Data for other rivers are from Hodson and others, 2021a.]

Uncertainty and Future Improvements

An advantage to the surrogate model used in this report is its ability to assess uncertainty in the loading estimates despite having periods of missing data, which is useful in considering the efficacy of management practices or whether management goals have been met. The mean annual loads with their predicted uncertainty (posterior predictive distribution) are shown in figure 7. The figure also shows the highest posterior density of the predicted uncertainty, which is analogous to a frequentist confidence interval. Suggestions on how to reduce loading uncertainty were made by Hodson and others (2021a). Des Plaines River at Joliet, Ill. (USGS station 05537980) used nearly identical instrumentation and followed the same maintenance and operations schedule, making direct comparisons to Hodson and others (2021a) possible. The key difference for the Des Plaines River is TP loading.

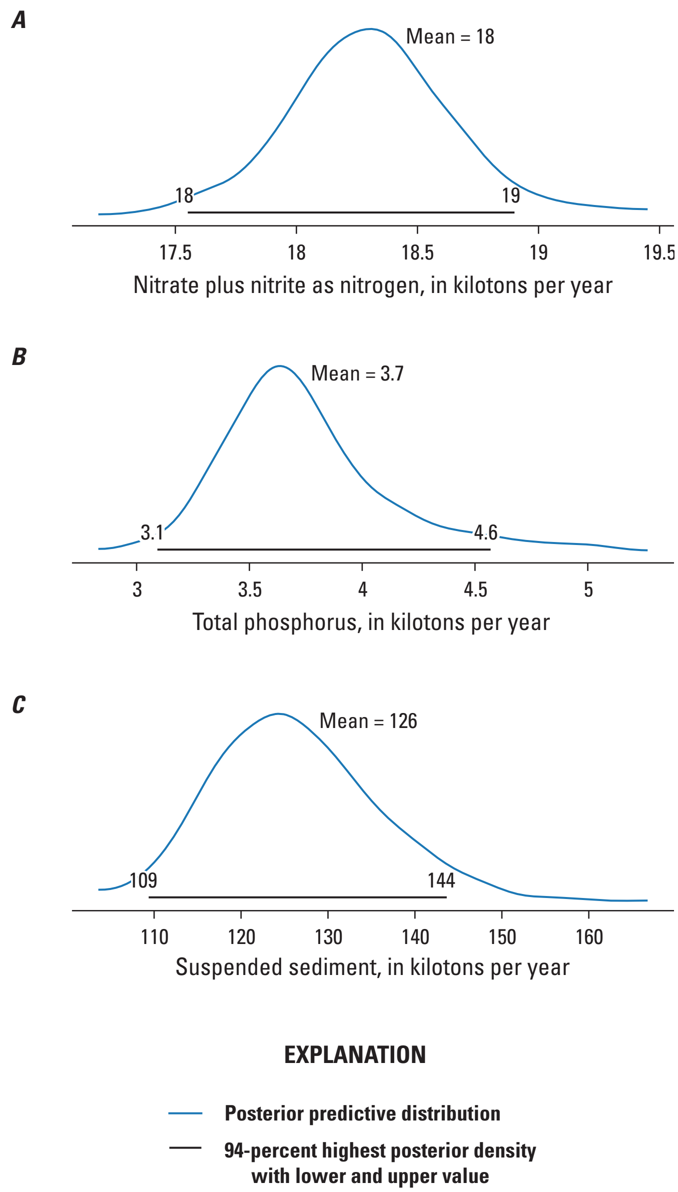

Figure 7. Estimated mean annual load and uncertainty for nitrate, total phosphorus, and suspended sediment at the Des Plaines River at Joliet, Illinois (U.S. Geological Survey station 05537980), water years 2018–20.

TP was particularly difficult to model because it consists of particulate and dissolved fractions. The dissolved fraction can be measured in situ as OP, but the particulate fraction can only be estimated using surrogates, like turbidity, which can have complex (nonlinear and time-varying) relations with particulate phosphorus. A few extreme events were responsible for a large part of the uncertainty in the TP load. Figure 8 shows in situ OP from the continuous monitor was strongly positively correlated with discrete TP, except during periods of high flow (defined as periods within the fourth quartile of streamflow). Even when streamflow was high, only two samples substantially deviate from the regression line; however, these two samples are two of the three collected at the highest streamflow. This indicates that the relative contributions from dissolved and particulate phosphorus fractions change during extreme storms. One explanation may be that combined sewage overflows (CSOs) account for a large part of TP through particulate and organic associated phosphorus during some extreme events. Data retrieved from MWRDGC's public CSO reporting website (https://geohub.mwrd.org/pages/cso) show that multiple CSOs occurred around the time the two TP outlier samples were collected. For example, the two outlier samples were collected the day after major CSO pumping events, so if CSOs are responsible, CSO management decisions could have a large effect on TP loading on the Des Plaines River during extreme storms. CSOs also occurred during several other storms but were not associated with high particulate phosphorus concentration. Thus, the relation between CSOs and TP loading in the Des Plaines River is not straightforward, and the locations, timing, and volumes matter when estimating TP loading. This finding is supported by modeling efforts on the Chicago Area Waterway System that found CSOs associated with extreme storms also caused TP concentration to increase at the Lockport Powerhouse and Controlling Work Dam just north of the water-quality station (fig. 1), but smaller CSO events did not (Quijano and others, 2017). Once they become commercially available, an in situ TP analyzer could reduce loading uncertainty during extreme storms by measuring the parameter of interest directly.

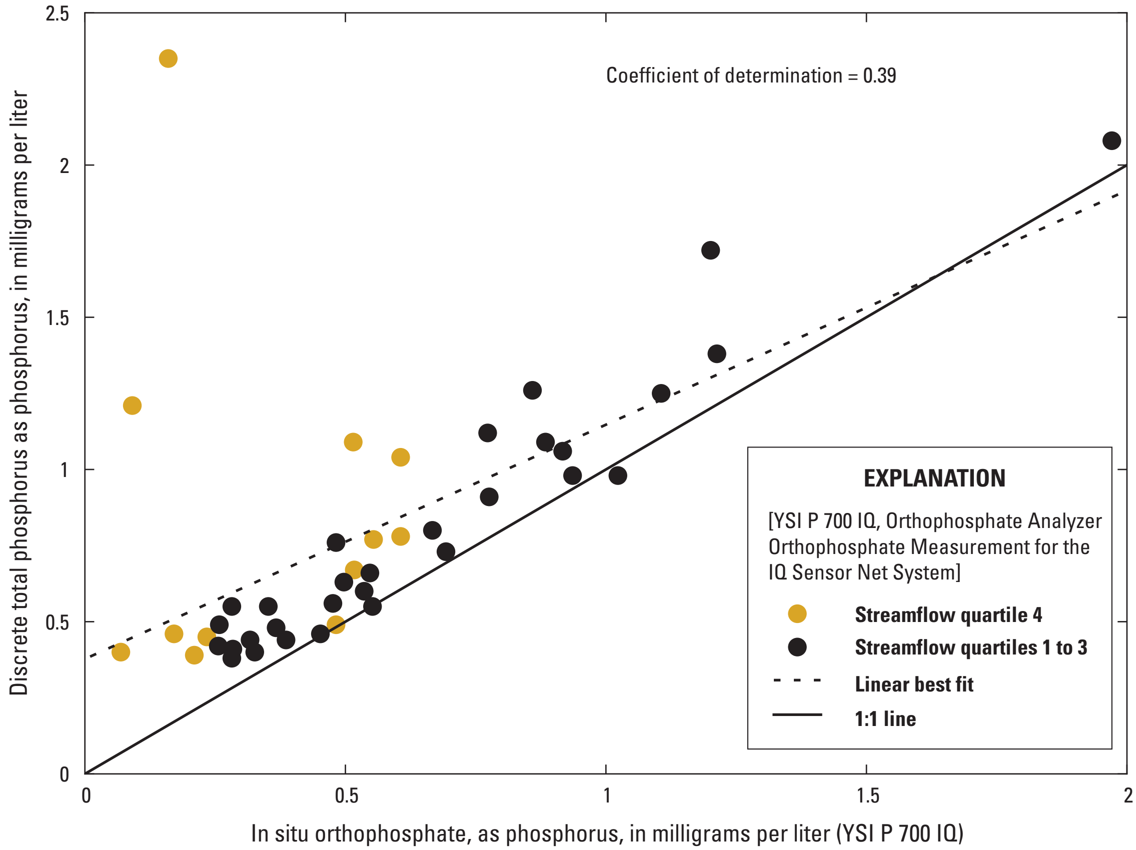

Figure 8. Discrete total phosphorus concentration regressed against analyzer-measured, in situ orthophosphate concentration.

Summary

During water years 2018–20, the U.S. Geological Survey operated a continuous monitoring station on the Des Plaines River at the Route 53 bridge in Joliet, Illinois (U.S. Geological Survey station 05537980). Using discrete and continuous water-quality and streamflow data, surrogate models were used to estimate loads of nitrate, total phosphorus, and suspended sediment. These estimates fill a critical gap in Illinois water-quality monitoring networks by providing continuous water-quality monitoring downstream from the greater Chicago metropolitan area. In addition, these results serve to document current conditions and provide a baseline from which to assess future changes in water quality within this area. Future modeling and monitoring efforts could target combined sewer overflow events, especially for total phosphorus because this may reduce model uncertainty.

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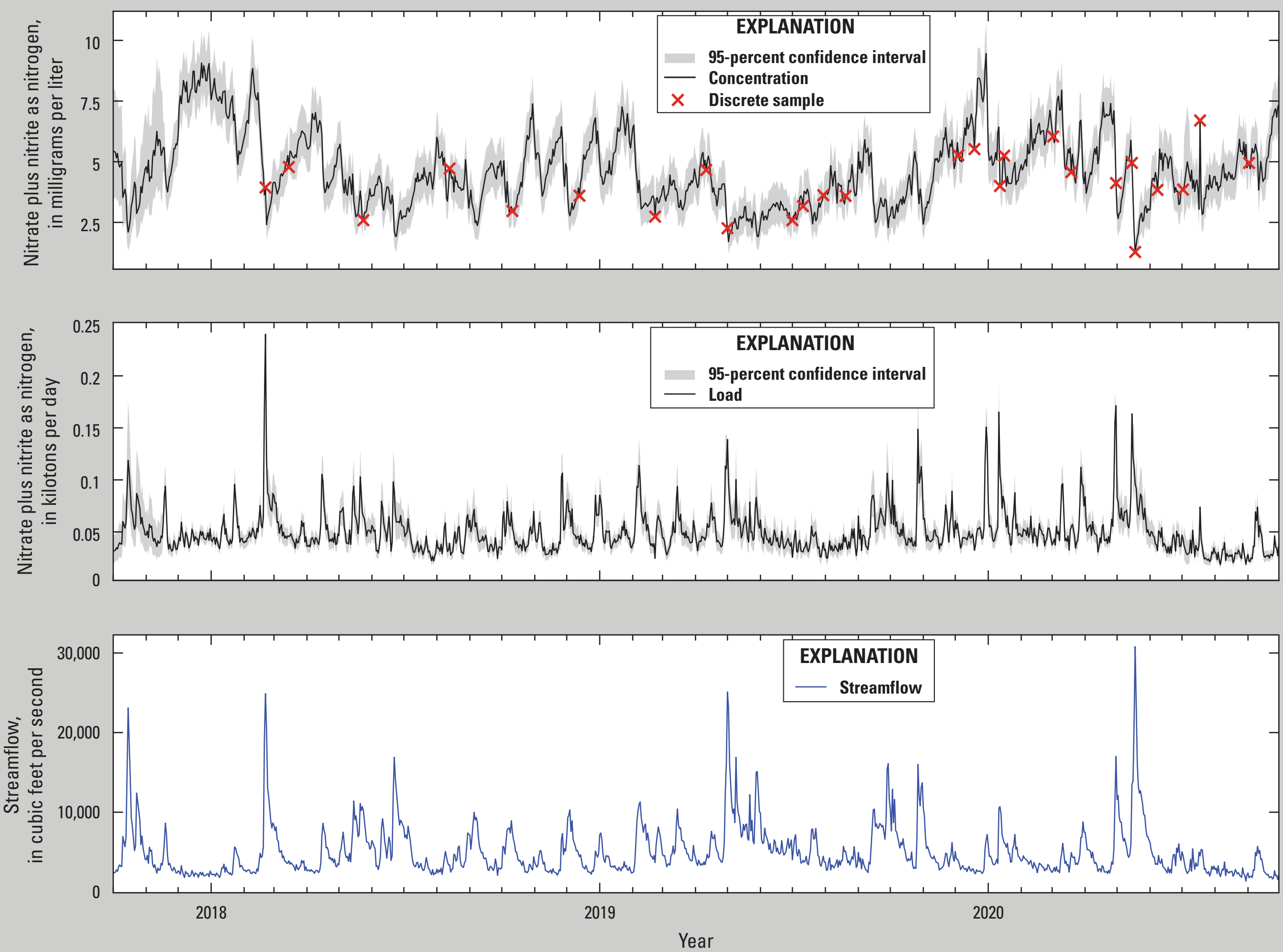

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