Nitrate and Total Phosphorus Loads in Illinois Rivers: Update Through the 2017 Water Year

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Note: A previous version of this report dated May 28, 2019 included some erroneous values for the Des Plaines River HUC that are corrected in this version. Additionally, the statewide total phosphorus load for 2013-17 was reported to be 28% greater than the load during the 1980-96 baseline period. This percentage increase was calculated without rounding the statewide load estimates to the nearest million pounds per year. The 26% increase reported in this version was calculated based on the 2013-18 and baseline period average annual load estimates rounded to the nearest million pounds per year. The difference between the two percentages is not considered to be significant. The 26% value is reported here to be consistent with the reported statewide loads that are rounded to the nearest million pounds.

Acknowledgements
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Nitrate and Total Phosphorus Loads in Illinois Rivers: Update Through the 2017 Water Year

Executive Summary

The purpose of this report was to update estimates and quantify changes in riverine nitrate-N and total phosphorus (TP) loads and yields in Illinois as part of the Illinois Nutrient Loss Reduction Strategy (NLRS) process. Using river flow data from the USGS and concentration data from IEPA, USGS, Metropolitan Water Reclamation District of Greater Chicago (MWRD), the Fox River Study Group (FRSG) and University of Illinois, nitrate-N and total phosphorus (TP) loads for the eight major rivers draining Illinois were calculated through the 2017 water year and aggregated to estimate statewide annual losses. For the five year period from 2013-17 the statewide water flow, nitrate-N loads and TP loads were estimated to be 13%, 7% and 26% above the 1980-96 baseline period. Much of the increase in the nitrate load occurred in the Rock River while much of the increase in TP load occurred in the Illinois River. Point source discharges of total N (TN) and TP for the 2017 calendar year were provided by IEPA. Statewide, point source TN discharge was about 75 million lb/yr, or about 14% less than the previous estimate for 2011. TP discharge from point sources for 2017 was estimated to be 14 million lb/yr or about 22% less than the 2011 estimate of 18 million lb/yr. Nitrate and TP yields were also estimated for the eight digit hydrologic units (HUC 8s). In general, 2012-17 nitrate-N yields were similar to values calculated for 1997-2011. For HUCs with nitrate-N yield greater than 11 lb N/ac-yr, changes in nitrate yield were correlated with change in water yield. For three HUCs in northwestern Illinois (Mackinaw, Spoon, and Flint Henderson) there appeared to be some reduction in nitrate-N yield independent of changes in water yield. Changes in estimation methods used for the Lower Illinois River and Lower Sangamon River resulted in lower estimates of nitrate-N loads for these HUCs. Reductions in TP yield from the Des Plaines and Chicago HUCs of 15 and 27%, respectively, corresponded to reductions in point source discharges in those HUCs. On the other hand, increases in TP yield were calculated for the Upper Sangamon, Macoupin and several other HUCs. Suggestions for improving future nutrient loss assessments include more frequent river sampling, especially for phosphorus at high flows, and identifying relationships between monitored nutrient loads and watershed characteristics to estimate loads from unmonitored areas.

Introduction

As discussed in the Illinois Nutrient Loss Reduction Strategy (NLRS) and the 2017 Biennial Progress Report, nitrate-N and total phosphorus (TP) concentrations and loads in Illinois rivers contribute to a variety of water quality impairments within the state and downstream in the northern Gulf of Mexico. The NLRS presented estimates of nitrate and TP loads draining from the state during the baseline period of 1980-96, and for 1997-2011. Additionally, annual average nitrate-N and TP yields from the eight-digit hydrologic units (HUC8s) were calculated for the 1997-2011 period. The 2017 Biennial Progress Report updated the statewide load estimates through the 2015 water year. Based on similar methods, this report presents statewide nitrate-N and TP loads as well as updated nutrient yields and loads for the HUC8s through the 2017 water year.

Methods

Riverine nitrate and TP loads are the product of nutrient concentration and river flow and often expressed in terms of pounds of nutrient per day or per year.

Load = Concentration x flow [EQ 1]

Nitrate and TP yields from watersheds are often expressed in terms of pounds per acre per year and are the riverine loads divided by the contributing watershed area.

Yield = Load/ Drainage Area [EQ 2]

Load and yield estimates for this report were based on daily stream flow data from the US Geological Survey (USGS), and nitrate and TP concentration data from multiple sources. Most of the concentration data came from the IEPA Ambient Water Quality Monitoring Network (AWQMN), with additional data at a few locations from USGS, Fox River Study Group (FRSG), Metropolitan Water Reclamation District (MWRD) of Greater Chicago, and Lowell Gentry at University of Illinois.

The USGS estimates daily flow values based on water depths measured at 15 minute intervals and flow rating relationships developed from water profile velocities measured approximately monthly at each flow gauging station. At most AWQMN sites, IEPA determines nitrate and TP concentration in water samples collected approximately every six weeks (approximately 9 samples per year), and many of the sites are collocated with a USGS flow gage. Sampling frequency at some sites was reduced in winter due to ice cover. There was very limited sampling in 2007-08 and sample collection at a few sites was discontinued after 2007.

At sites where USGS, MWRD and FRSG monitor nutrient concentrations, samples were generally collected on a monthly frequency, with occasional periods of more frequent sampling. The U of IL collects samples of the Embarras River at Camargo on a weekly basis and more frequently during high flow events. There was no coordination of timing of sample collection between IEPA and these other agencies. Usually, samples were collected on different dates, which provided greater temporal resolution of variation in concentrations, and better estimates of nutrient loads.

At a few monitoring sites, USGS has deployed sensors capable of measuring nitrate and phosphate concentrations every 15 minutes when they are operational (USGS 2018). A comparison between the nitrate sensor concentrations and point sample concentrations indicated that the sensors produce systematically higher concentrations than point samples collected in the vicinity of the sensor. To avoid changes in load estimates caused by changes in methodology, the semi-continuous sensor data was not used for estimating the statewide loads or HUC 8 yields. The results of the phosphate sensor were not used because the focus of this analysis was total phosphorus, not phosphate. The USGS has developed some relationships to estimate TP from phosphate and turbidity measurements, but this appears to be a work in progress. For the sake of consistency with the historical record, only concentrations based on traditional methods of sample collection and analysis were used to estimate nutrient loads and yields in this report. Comparisons among these different methods of measuring concentrations and the impact on estimated loads is provided in a later section of this report.

Prior to calculating riverine load estimates, concentration values were plotted as a function of time and discharge to identify unusually high or low values. When such values were identified, a judgement was made about the likelihood that the values were the result of errors in processing or data entry. In some cases unusual concentration values were excluded from the load calculations (Appendix 3).

To estimate annual nutrient loads, daily loads were calculated from the product of daily water flow and daily concentration estimated from measured values. Daily concentrations for nitrate were estimated by linear interpolation of measured concentrations between sampling dates (Lee et al. 2016). Daily concentrations of TP were estimated using Weighted Regressions on Time Discharge and Seasonality (WRTDS) a technique developed by USGS (Hirsch and De Cicco 2015). Annual load estimates were calculated by adding up daily load estimate. In addition to annual loads, WRTDS also produces a flow-normalized annual load. This is an estimate of the annual load expected to occur at average flow.

With WRTDS, the accuracy of the estimated annual TP loads was evaluated by the flux bias statistic. A flux bias statistic of 0.10 suggests that the estimated annual loads are approximately 10% greater than the true loads; a flux bias statistic of -0.10 suggests the estimated annual loads are on average 10% less than the true loads. If the absolute value of the flux bias statistic was greater than 0.05, then adjustments to the default settings in WRTDS were made and used to produce new estimates of annual loads and flow-normalized loads. The parameter adjustments were suggested by the lead developer of WRTDS (Hirsch, personal communication) and referred to as the “narrow model” because it focused on narrower ranges of concentration samples and discharge. If the narrow model produced a flux bias statistic between -0.10 and 0.10, then those results were used and no further analysis was conducted. If the flux bias statistic was outside this range, then alternative regression models were developed and evaluated. These models were evaluated by comparing the regression of measured daily load (based on measured concentration and flow) to estimated daily loads produced by WRTDS and the alternative regression approach. The approach producing the greatest coefficient of determination (R^2) and a regression coefficient closest to 1.0 was used.

Monitoring stations utilized

The monitoring stations used for the statewide load estimates appear in Table 1. For the Rock River Basin the difference between the load at Joslin and the load at Rockton is used to remove the contribution from Wisconsin. For the Illinois River, the load at Valley City is reduced by 16% to approximate removing contributions from Wisconsin and Indiana. The load for the Vermilion River at Danville was reduced by seven percent to remove contributions from Indiana. To estimate the loads from areas within Illinois that are outside of the major river basins, the sum total of the estimated nutrient loads from Illinois in these rivers was multiplied by the ratio of the area of Illinois to the Illinois area draining to the monitoring locations. (Note that the percentage of the drainage areas in Illinois for the Illinois and the Vermilion River basins are slightly smaller than the values that appeared in the NLRS. Incorrect percentages where used in the NLRS. Correcting these percentages decreased the estimated baseline nitrate load by for the state from 404 to 397 million lb N/yr and had negligible impact on the TP loads.) The monitoring stations for the Embarras and the Kaskaskia Rivers (St. Marie and Venedy Station, respectively), differ from the USGS superstations for these rivers (Lawrenceville and New Athens, respectively). In both rivers, the USGS stations are further downstream with drainage areas about 800 square miles larger. The St. Marie and Venedy Station locations were used for statewide load estimates because monitoring data at these sites dates back to the 1980s, and was used to establish the 1980-96 baseline loads. Similar data do not exist at New Athens or Lawrenceville.

Table 1. Monitoring stations used to estimate the statewide nitrate-N and TP loads.

River system	Gage location	IEPA station	USGS station number	Drainage area (sq. mi)	drainage area in Illinois (%)	% of IL represented (%)
Rock	Joslin	P-04	05446500	9,549	43	7.3
Rock	Rockton	P-15	05437500	6,362	13	1.4
Green	Geneseo	PB-04	05447500	1,003	100	1.8
Illinois	Valley City	D-32	05586100	26,743	84	39.9
Kaskaskia	Venedy Station	O-20	05594100	4,393	100	7.8
Big Muddy	Murphysboro	N-12	05599490	2,169	100	3.8
Little Wabash	Carmi	C-23	03381500	3,102	100	5.5
Embarras	Ste. Marie	BE-07	03345500	1,516	100	2.7
Vermilion	Danville	BP-01	03339000	1,290	93	2.1

The monitoring stations used for the HUC8 analysis are illustrated in Figure 1 and described in Appendix 1.

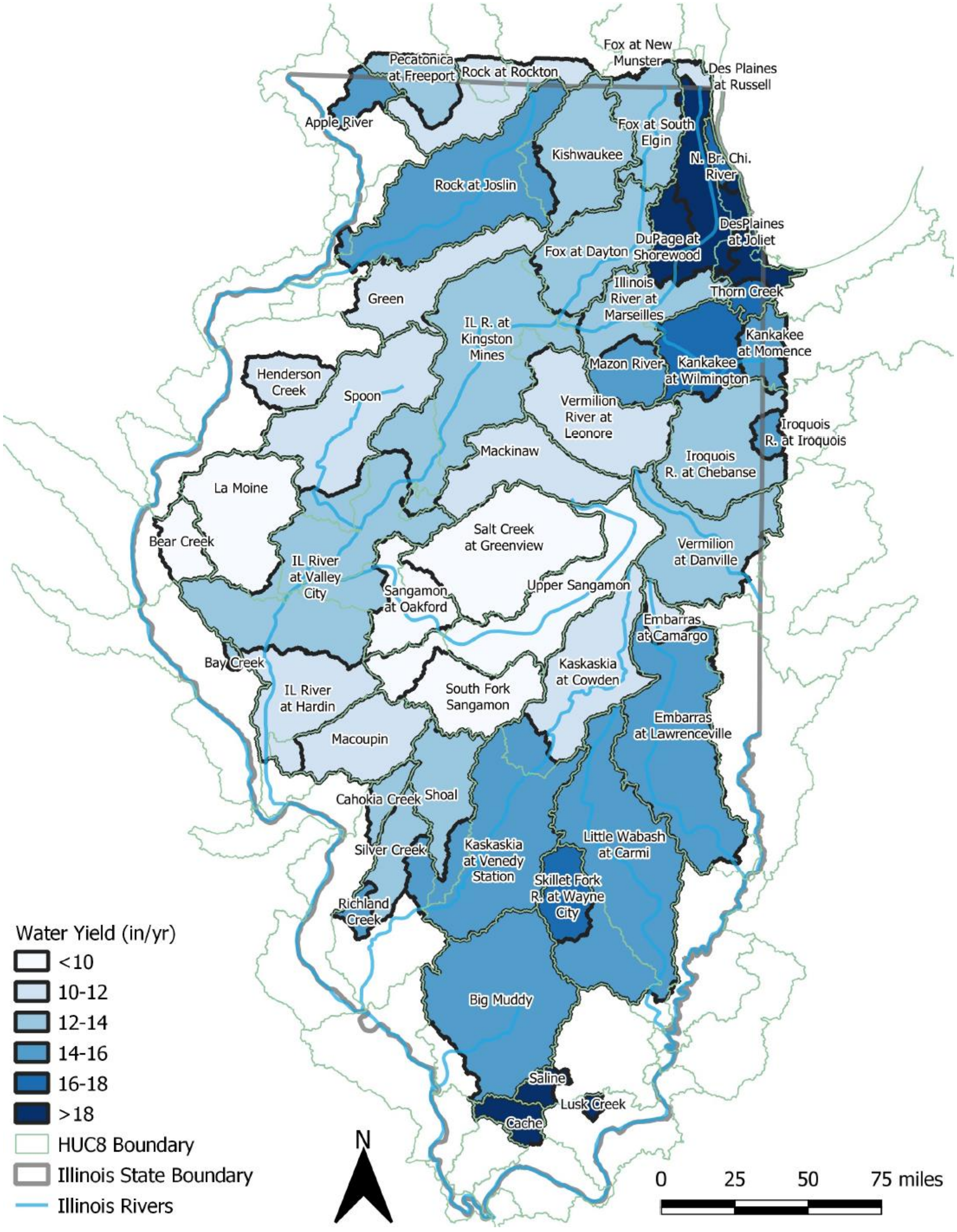

Figure 1. Average annual water yield 2012-17 for USGS stations used to estimate HUC 8 nutrient yields and loads (sources: Natural Earth Rivers + Lakes centerlines; ISGS state boundary).

The downstream outlets of the HUC 8s often occur at the confluence of two major streams or rivers. Because of the complexity of the water flow at river confluences, accurately monitoring flow or concentrations at these locations is difficult. Consequently, flow and concentration monitoring locations are rarely located at HUC outlets. For the NLRS and this report, monitoring locations were selected to approximate the HUC 8s. For some HUC 8s, there was little difference between the monitored area and the HUC 8. But in several cases, the differences between the HUC 8 area and the monitored area are large (e.g., Bay Creek in the Sny HUC and Lusk Creek in the Lower Ohio-Bay HUC). Generally, the same methods for matching monitoring locations to HUC areas were used in this report as in the NLRS, except for where monitoring has been discontinued, and where a change in locations seemed to provide a more realistic nutrient yield estimate. These changes are noted in the discussion of results. For some HUCs there was little or no river monitoring data within the HUC and in these cases nutrient yields were estimated as an average of neighboring HUCs.

Point-source Discharges and Non-Point Source Load Estimates

Point source TP and nitrogen discharges for the 2017 calendar were provided by IEPA. The data were retrieved from the USEPA ECHO compliance database by conducting a water pollution search of the water pollutant loading tool using DMR data. Search criteria included all forms of nitrogen and phosphorus discharge from major publicly owned treatment works (POTWs) and some non-POTWs. The classification of “major” generally refers to facilities permitted to discharge more than one million gallons of wastewater per day. Search results identified 213 major POTWs discharging both N and P, 505 minor POTWs and non-POTWs discharging N, and 90 minor POTWs and non-POTWs discharging P that were included in the analysis. These results were provided in two separate spreadsheets and duplication of sites across the spreadsheets was eliminated. Electric power generating facilities that discharge cooling water were excluded because much of their nutrient discharge comes from river intake cooling water and does not represent a net addition. Some of these facilities may add P to reduce pipe corrosion, but quantities are unknown.

The 2017 point source discharge data from the facilities described above were a combination of updates from the 2011 values for facilities included in the NLRS in addition to facilities that had not been included in the NLRS. For facilities included in the NLRS but not updated in the above categories, the 2011 discharge values used in the NLRS were assumed to have continued through 2017. Point source discharge values from 2011 were used to estimate 2017 discharges for 1,068 facilities discharging P and 170 facilities discharging N.

The outfall locations for the Major POTWs were identified by latitude and longitude. Latitude and longitude information was also available for most other facilities, although there is some uncertainty whether these refer to outfall locations or facility locations.

Non-point source yields from each HUC were estimated by two different methods. First, following the method generally used in the NLRS, the sum total of point source discharges within a HUC 8 were divided by the HUC area to provide a point source yield. The difference between the monitored yield and the point source yield was assumed to be the non-point source yield. With this method, point source discharges within a HUC but downstream of the monitoring location will lead to an underestimation of the non-point source yield. To address this problem, a second approach was developed using latitude and longitude information to identify facilities that were upstream of the monitoring locations. The sum of the point source discharges above a monitoring location was then subtracted from the load estimated at the monitoring site, and the result was assumed to be the non-point source load for the monitored area. This load was divided by the drainage area for the monitoring site to provide an estimate of non-point source yield, which was assumed to represent HUC as a whole. The non-point source load from the HUC as a whole was then estimated by multiplying the non-point source yield by the HUC area. The sum of the point source discharges within each HUC was then added to the estimated non-point source load to provide an estimate of total nitrate-N and TP loads from each HUC 8 for which there was monitoring data. Point source N loads were assumed to include all forms of N and these loads were multiplied by 0.90 to approximate point source nitrate-N loads.

Both methods of distinguishing between point and non-point source inputs implicitly assume that there is little or no denitrification or TP removal by plant uptake or deposition in the river between the point source discharge and the outlet of the monitoring location or the HUC. In settings where these processes are significant, the proportion of riverine load from point sources will be overestimated and non-point sources will be underestimated.

Results

Statewide Water, Nitrate and TP Loads

Nutrient loads tend to be highly correlated with water flow, which is highly variable, largely due to fluctuation in annual precipitation. Variations in annual and five year average nutrient loads are best interpreted in light of the corresponding water flows. The estimated statewide average water yield for the 2013-2017 was 14.7 in/yr, which was about 13% greater than the 1980-96 baseline average water yield of 13.0 in/yr (Figure 2). The five year moving average water yields have ranged from a low of 10.1 in/yr during 2003-7 to a high of 17.5 in/yr during 2007-11. These values are 23% lower and 36% greater, respectively, compared to the water yield during the baseline period.

Similarly, the estimated statewide average nitrate-N load during 2013-17 was 425 million lbs N/yr, which was approximately 7% greater than the 1980-96 baseline average of 397 million lb/yr. The similarity between variations in nitrate load and water yield is illustrated in Figure 3. As with water flow, the maximum five year average nitrate load (503 million lb N/yr) occurred during 2007-11, which was 27% greater than the baseline. The minimum five year average load (283 million lb N/yr, 29% less than baseline) occurred during 1985-89. Water yield during this period was 10.6 in/yr, only slightly greater than lowest value (10.1 in/yr) that occurred during 2003-07.

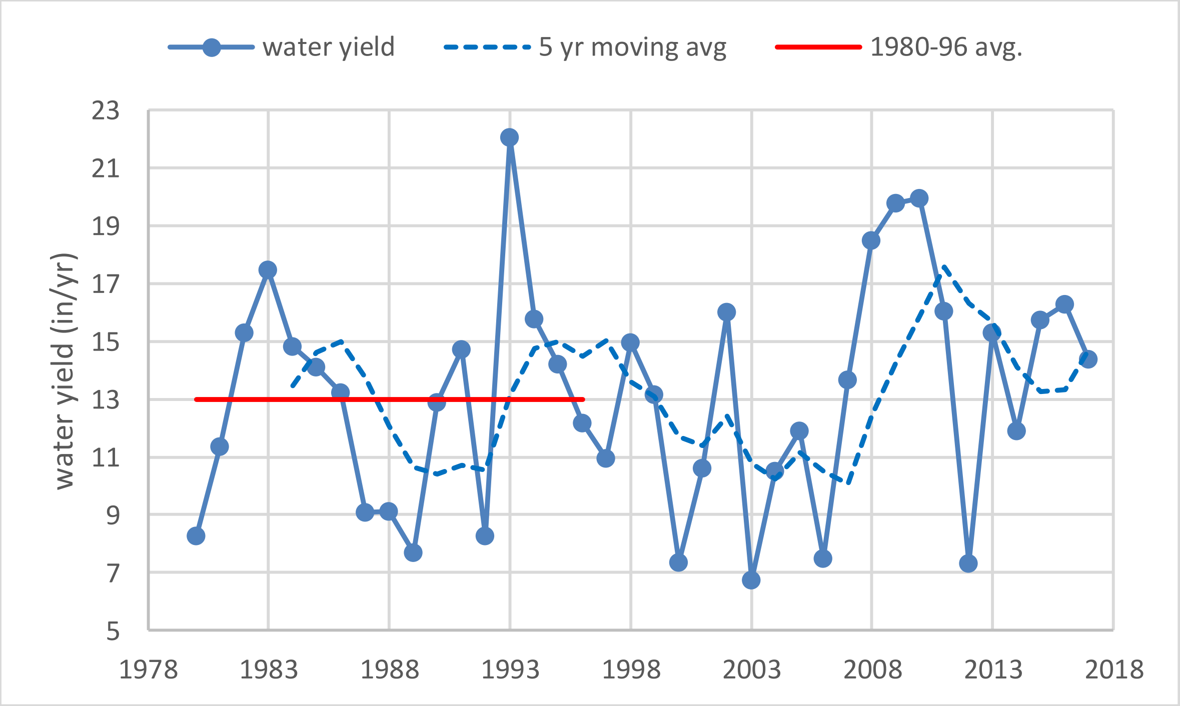

Figure 2. Statewide estimated annual water yields (blue circles), five year moving average (dashed line) and 1980-96 baseline average (red line).

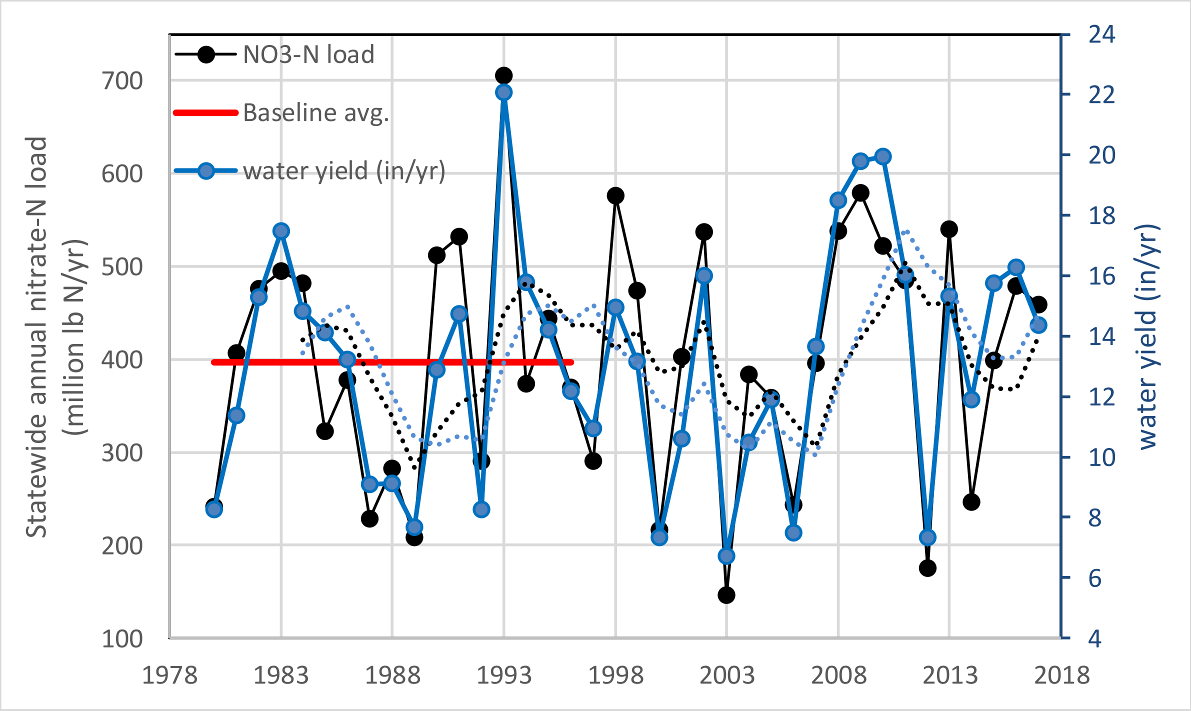

Figure 3. Statewide estimated nitrate loads (black circles), annual water yields (blue circles), five year moving averages (dashed lines) and 1980-96 baseline average (red line).

The estimated statewide average TP load during 2013-17 was 43.0 million lb P/yr, a 26% increase over the baseline load of 34 million lb P/yr. The greatest five year average TP load was

48.8 million lb P/yr (45% greater than baseline) which occurred during 2007-11 (Figure 4). The minimum five year average load was 26.5 million lb/yr (21% below baseline) which occurred during 1988-92. These variations are very similar to changes in five year average water flow.

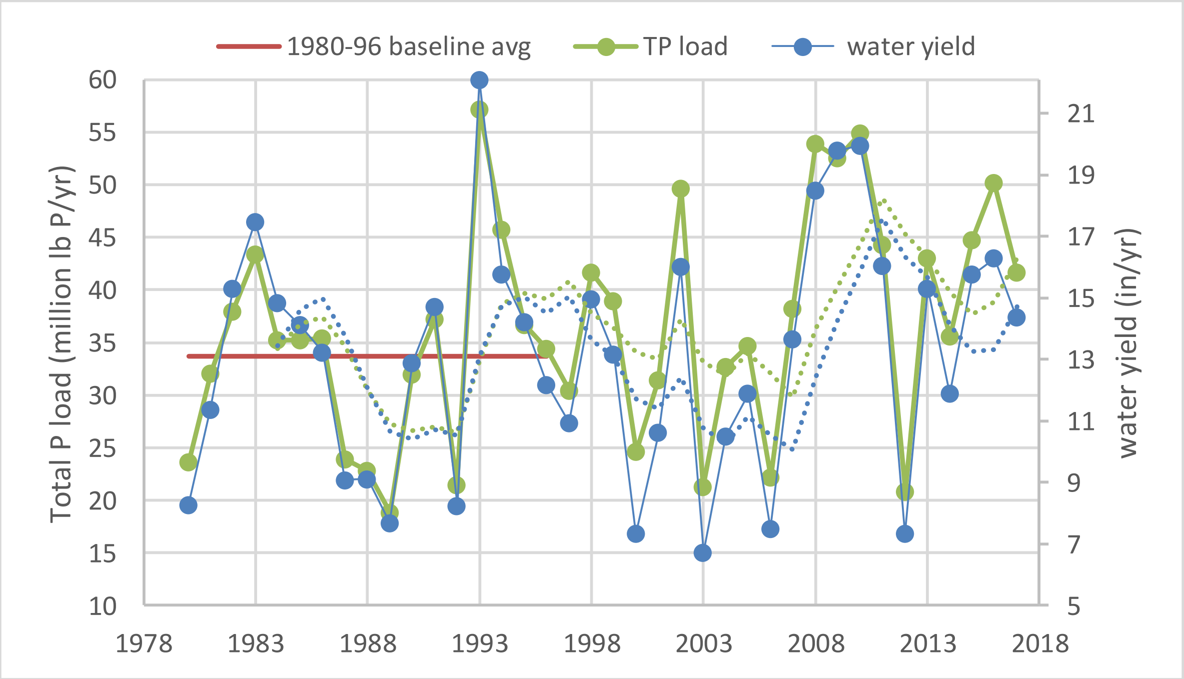

Figure 4. Statewide estimated TP loads (green circles), annual water yields (blue circles), five year moving averages (dashed lines) and 1980-96 baseline average (red line).

Changes in water yield and nutrient loads were not uniform across the state (Table 2). Average water yield increased in all eight major river basins during 2013-17 relative to the baseline period. The greatest absolute increase (3.8 in/yr) and percentage increase (34%) occurred in the Illinois portion of the Rock River Basin (difference between the Rock River at Joslin and the Rock River at Rockton). The Illinois portion of the Rock River Basin also had the greatest absolute nitrate-N load increase (18 million lb N/yr) and relative increase (104%) compared to the baseline period. Nitrate loads also increased for the Embarras, Little Wabash and Green River systems. Small reductions in nitrate-N load were calculated for the Big Muddy, Kaskaskia, Illinois and Vermilion river systems.

The greatest absolute increase in TP load (4.12 million lb/yr) occurred in the Illinois River, which increased 25.3% from the baseline period. There were greater percentage increases in TP load relative to the baseline period for the Little Wabash (51%) and Kaskaskia (68%) rivers, but because these loads are much smaller than for the Illinois River, the absolute load increases in the Illinois River was greater. It is notable that the Kaskaskia and the Little Wabash had the second and third greatest percentage increases in water yield after the Rock River system. For the Green River there was a relatively large percentage reduction in TP load (36%) but this represented a relatively small change in absolute load (0.22 million lb P/yr).

Table 2. Changes in average water yield, nitrate-N load and TP load from 1980-96 to 2013-17.

River Basins	Change in water yield		Change in Nitrate-N Load		Change in TP load	
	(in/yr)	(%)	(million lb N/yr)	(%)	(million lb P/yr)	(%)
Embarras (St. Marie)	0.7	5.5	4.1	27.7	0.03	2.7
Little Wabash	2.9	20.9	2.2	35.3	0.98	51.1
Big Muddy	1.6	11.8	-0.1	-7.2	0.27	28.3
Kaskaskia (Venedy Sta.)	2.7	22.3	-1.3	-12.9	1.64	68.0
Illinois	1.3	9.8	-4.7	-2.0	4.12	25.3
Rock (between Joslin and Rockton)	3.8	34.3	18.0	104	0.15	8.5
Green	0.7	7.0	1.1	14.1	-0.22	-36.0
Vermilion (Wabash)	0.5	4.0	-0.8	-4.0	0.03	2.6

<u>Load Estimates from Discrete Samples vs. Semi-Continuous Probe Concentrations</u>

The USGS has established semi-continuous monitoring stations (aka “supergages”) on the eight major rivers draining Illinois, where nitrate concentrations have been measured at 15 minute intervals using Hatch NITRATAX probes (USGS 2018). Water flow and nitrate-N loads were also calculated by the USGS at 15 minute intervals, except for periods when sensors were not functional. To estimate annual loads, these gaps were filled with average 15 minute loads for the water year. This approach to gap filling may introduce an upward bias in the annual load estimate if the probe tended to be nonfunctional during low flow periods; or introduce a downward bias if the probe was nonfunctional during high flow and high concentration periods.

For nearly all locations and years, loads estimated from the continuous probe concentrations were 10 to 20% greater than the loads estimated by linear interpolation between traditional sampling methods (Table 3). There appear to be three factors contributing to this: 1) monthly sampling often misses some high concentration values that the probes capture; 2) there is a tendency for the probe concentrations to be greater than corresponding point sample concentrations; and 3) disparities resulting from the two different methods used to estimate concentrations and loads during periods of missing data. For the Kaskaskia River, the difference between the two methods was also affected by an 18% larger drainage area at the USGS sampling location.

The ratios between sample and probe calculated loads were lowest for the Kaskaskia and Little Wabash Rivers, where sample estimated loads were about half as large as loads estimated from probe measured concentrations. Concentrations and loads are relatively small at these locations, and consequently small absolute differences may be large relative differences (as indicated by the ratio), but these load estimates contribute little to the overall state load.

Table 3. Annual nitrate-N loads for the 2016 and 2017 water years 1) estimated from linear interpolation between approximately monthly concentration samples; 2) estimated by USGS (2018) from semi-continuous probe measurements of nitrate concentration; and 3) the ratio of loads estimated by the two methods.

	--------------------2016-----------------				**------------------2017-------------------**		
Location	Load estimated from samples & linear interpolation (mil. lb N/yr)	Load estimated from continuous probe conc. (mil. lb N/yr)	Ratio of load from samples to load from cont. probe conc.		Load estimated from samples & linear interpolation (mil. lb N/yr	Load estimated from continuous probe conc. (mil. lb N/yr)	Ratio of load from samples to load from cont. probe conc.
Illinois River at Florence	265.2	292	0.91		237.6	263	0.90
Embarras River at Lawrenceville	15.7	20.3	0.78		21.9	15.8	1.38
Big Muddy River at Murphysboro	2.4	3.21	0.73		1.4	Incomplete	
Green River near Geneseo	13.2	14.4	0.92		10.2	11.5	0.89
Rock River near Joslin	92.8	92.7	1.00		114.0	128	0.89
Little Wabash River (Main St) at Carmi	6.8	14.1	0.48		6.9	11.9	0.58
Kaskaskia River at Venedy Station/ New Athens	10.8	16.6	0.65		5.8	11.6	0.50
Vermilion River near Danville	17.1	21.1	0.81		18.7	20.7	0.90

For the Illinois River at Florence, probe measured concentrations were on average 11% greater than concentrations measured in corresponding point samples (Figure 5). This appears to account for essentially all the difference in load estimates at Florence. This analysis was not conducted on data from the other locations.

One exception to the general pattern of lower load estimates from linear interpolation occurred in the Embarras River in 2017, when the load estimated by linear interpolation was about 40% greater than the load estimated from continuous probe concentrations. In the spring of 2017, a sample was collected at a time of unusually high flow and concentration, and this led to considerable overestimation of concentrations between previous and subsequent samples and thus overestimation of loads (Figures 6 and 7). The sample in question had the highest concentration of any sample analyzed for this location since October 2001. The continuous probe measured a similarly high concentration at about the same time. Since similarly high concentrations tend to persist for short periods, and discrete sampling is relatively infrequent, discrete sampling will often miss the highest concentrations and thus contribute to underestimation of load. But when discrete sampling catches an unusually high concentration, this contributes to an overestimation of load. Loads for any one year estimated with limited sampling can be significantly biased if the sample concentrations do not represent the varying river concentrations. Averaging loads over multiple years can reduce the influence of such bias.

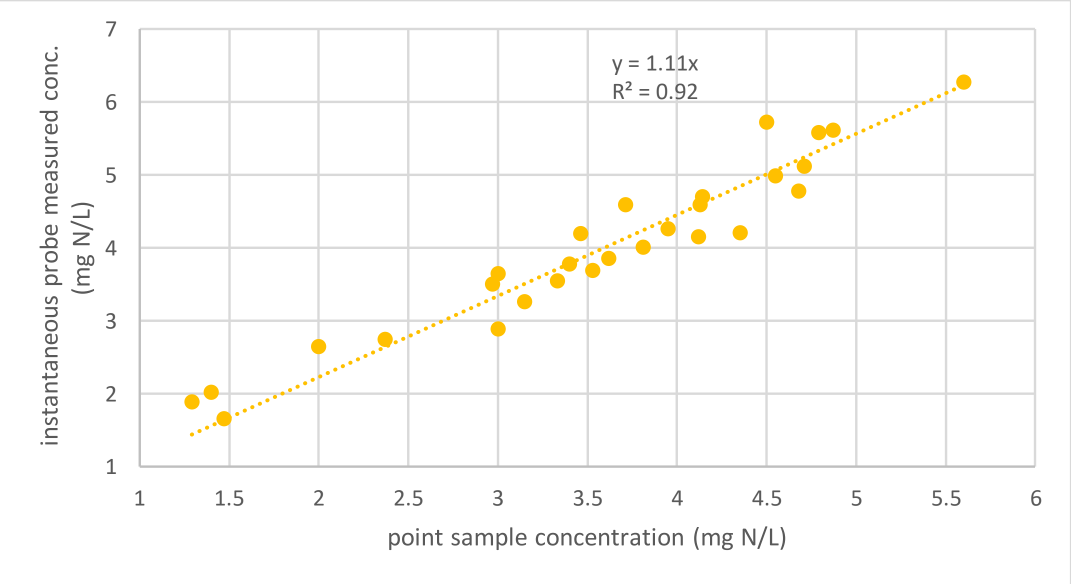

Figure 5. Instantaneous probe measured nitrate N concentrations and corresponding point sample concentrations for the Illinois River at Florence during the 2016 and 2017 water years.

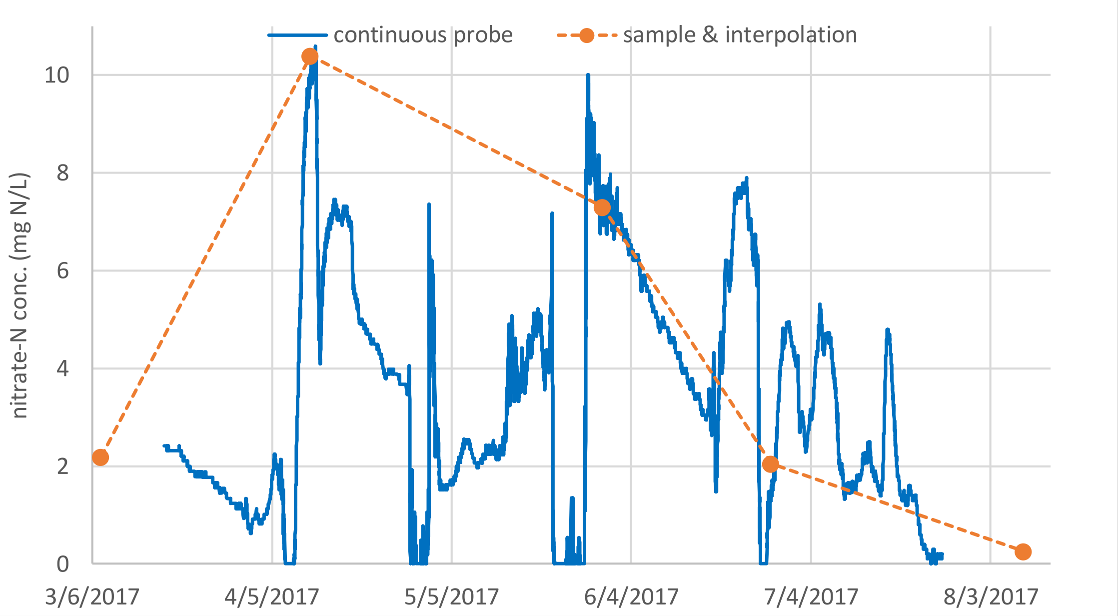

Figure 6. Nitrate-N concentrations measured in situ by a semi-continuous probe and by laboratory analysis of samples collected in the Embarras River at Lawrenceville.

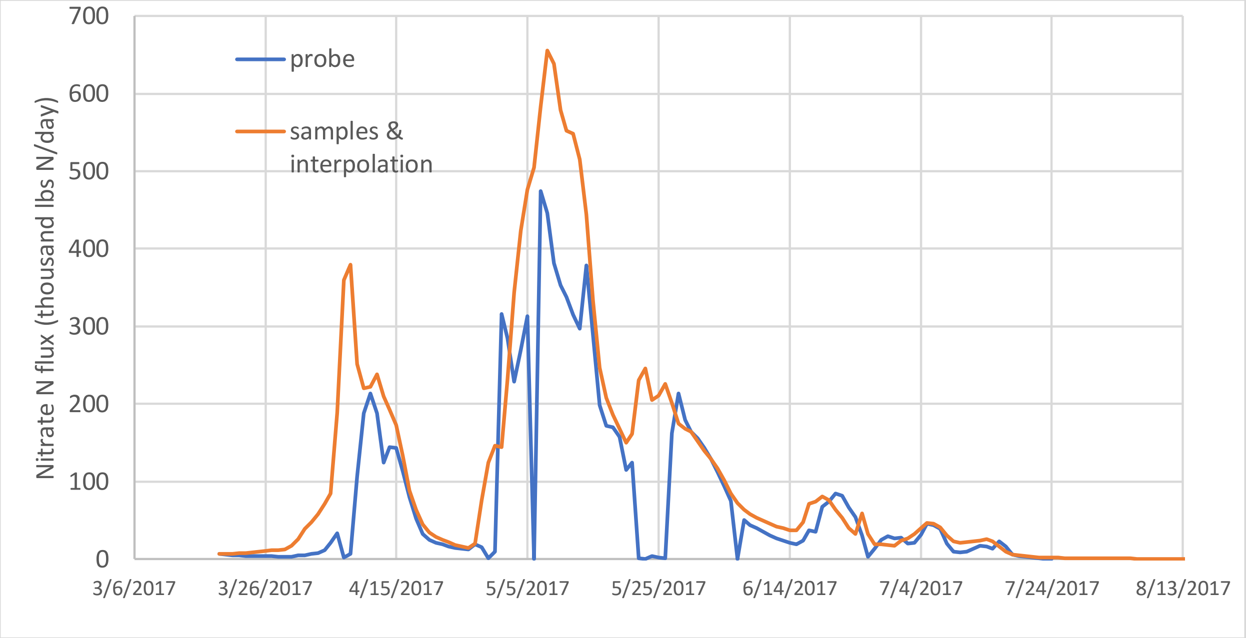

Figure 7. Daily Nitrate-N load estimates for the Embarras River at Lawrenceville calculated from the semi-continuous probe concentrations and from discrete sample collection and linear interpolation.

TP load estimates based on discrete samples and WRTDS tended to be similar to or greater than the USGS estimates based on semi-continuous monitoring of phosphate and turbidity (Table 4). For the Illinois, Rock, Little Wabash and Kaskaskia Rivers, load estimates by the two methods differed by less than 12% and as little as 2% for the Illinois River. The Illinois River was the only location for which data from the semi-continuous phosphate probe was used in developing the TP load estimates. For all other locations, the TP load estimates were based on relationships between TP sample concentrations and turbidity without additional data from the phosphate probe. Phosphate probe measurements were frequently interrupted by fouling with sediment and need for maintenance. Efforts to reduce the frequency of these interruptions have been ongoing and will allow for incorporation of phosphate probe data into future TP load estimates.

For the Kaskaskia River, the comparison between the two methods was also affected by an 18% greater drainage area at New Athens where the semi-continuous probes were located. If loads were directly proportional to drainage area, then the estimates from WRTDS would be about 8% greater than the estimate from the probe measurements in the Kaskaskia. For the Vermilion River, the 2016 TP load estimate from WRTDS was nearly three times the estimate from the probe method, probably because the probes were not operational during a high flow event during late 2015 and early 2016.

Table 4. Annual TP loads for the 2016 and 2017 water years for eight major rivers draining Illinois 1) estimated from discrete water samples and WRTDS; 2) loads estimated by USGS (2018) from semi-continuous probe measurements of phosphate and turbidity; and 3) the ratio of loads estimated by the two methods.

	--------------------2016-----------------				------------------2017-------------------		
Location	Load estimated from samples WRTDS (mil. lb P/yr)	Load estimated from continuous probe conc. (mil. lb P/yr)	Ratio of load from samples to load from cont. probe conc.		Load estimated from samples & WRTDS (mil. lb P/yr	Load estimated from continuous probe conc. (mil. lb P/yr)	Ratio of load from samples to load from cont. probe conc.
Illinois River at Florence	22.8	22.6	1.01		20.3	20.8	0.98
Embarras River at Lawrenceville	2.69	2.56	1.05		3.55	1.84	1.93
Big Muddy River at Murphysboro	1.78	1.54	1.15		0.94	incomplete	
Green River near Geneseo	0.57	0.44	1.30		0.43	0.35	1.23
Rock River near Joslin	4.24	4.30	0.99		6.43	5.80	1.11
Little Wabash River (Main St) at Carmi	3.42	3.26	1.05		2.10	2.26	0.93
Kaskaskia River at Venedy Station/ New Athens	4.84	5.32	0.91		3.25	3.52	0.92
Vermilion River near Danville	1.64	0.56	2.92		0.84	0.66	1.28

Statewide Point-source Discharges

Estimated TN discharge from point sources totaled 75 million lbs N/yr, with 70.1 million lb/yr coming from the 213 major POTWs. In the NLRS the statewide point source TN discharge was estimated to be 87.3 million lb N/yr. While some of the 14% reduction is probably due to reductions in actual discharge at some sites, some reduction may also be due to changes in estimation methods. For the NLRS, there was relatively little measured concentration data, so an average TN concentration of 16.8 mg N/L was assumed to apply to the discharge for many POTWs. More of the 2017 TN point source discharges are based on measured concentration values. However, some of the TN concentration values for minor POTW sites had TN values of 1.0 mg N/L or less, which are probably ammonia concentrations, not TN concentrations. IEPA did not provide nitrate or ammonia load values, or TN concentration values for the major POTWs in 2017, so it was not possible to assess whether low TN concentration values might also affect those estimates.

Estimated TP discharges from point sources totaled 14.1 million lb P/yr, which is a 22% reduction from the 18 million lb P/yr estimated in the NLRS. As with TN, the vast majority of the 2017 estimated TP discharge appears to come from major POTWs: 11.4 million lb P/yr or 81% of the 14.1 million lb P/yr. Approximately half of the 3.9 million lb P/yr statewide reduction in TP discharge was due to 1.9 million lb P/yr reductions across six facilities operated by the Metropolitan Water Reclamation District (MWRD) of Greater Chicago. Several smaller municipalities reported 2017 TP discharges that were 20 to 60 thousand lb P/yr lower than the 2011 values in the NLRS (e.g., Springfield, Champaign-Urbana and Quincy). Increases in TP discharge on the order of 200 thousand lb P/yr were estimated for the Sanitary District of Decatur and the City of Joliet.

HUC 8 Nitrate-N Yields

In general, the 2012-17 average nitrate-N yields estimated from monitoring station data were greatest in the northeast and east central regions of the state and lowest in the south (Figure 8). For larger watersheds with multiple monitoring locations, the incremental yields illustrated in Figure 8 are the nitrate yields from the drainage areas between monitoring locations. Using these values to estimate yields at the HUC 8 scale led to results that were mostly similar to the 1997-2011 values (Table 5 and Figure 9). The greatest nitrate-N yields occurred in the Des Plaines, Upper Illinois and Vermilion (IL) HUCs. The lowest yields occurred in the Lower Ohio-Bay, Lower Illinois Senachwine Lake and Middle Kaskaskia HUCs.

Table 5. Estimated average nitrate-N yields from HUC 8s for 1997-2011, 2012-2017 and the change between the two periods. Values are sorted from greatest to least yields for 2012-17.

HUC		**Estimated NO3-N Yield (lb N/ac-yr)**		
ID #	**Name**	**1997-2011**	**2012-17**	**change**
07120004	Des Plaines	48.6	45.9	-2.7
07120005	Upper Illinois	22.2	27.5	5.3
07130002	Vermilion (IL)	22.5	23.0	0.5
05120108	Middle Wabash-Little Vermilion	23.7	22.2	-1.5
07120002	Iroquois	22.8	21.9	-0.8
07080104	Flint-Henderson	28.4	21.2	-7.2
05120109	Vermilion (Wabash)	21.8	20.8	-1.1
07130004	Mackinaw	20.1	18.3	-1.8
07080101	Copperas-Duck	19.6	18.1	-1.5
07090005	Lower Rock	14.4	17.1	2.7
07090003	Pecatonica	15.3	16.2	0.9
07090004	Sugar	15.3	16.2	0.9
07060005	Apple-Plum	16.0	16.0	0.0
07120003	Chicago	15.1	15.4	0.3
07120001	Kankakee	11.9	15.1	3.2

Table 5 (continued). Estimated average nitrate-N yields from HUC 8s for 1997-2011, 2012-2017 and the change from the earlier to later period. Values are sorted from greatest to least yields for 2012-17.

HUC		Estimated NO3-N Yield (lb N/ac-yr)		
ID #	**Name**	**1997-2011**	**2012-17**	**change**
07120007	Lower Fox	13.2	15.0	1.8
07090006	Kishwaukee	14.2	14.4	0.2
07090001	Upper Rock	13.1	14.3	1.1
07130005	Spoon	17.8	13.5	-4.3
07130006	Upper Sangamon	15.6	13.3	-2.3
07090007	Green	12.6	12.4	-0.3
05120111	Middle Wabash-Busseron	11.4	12.3	0.9
05120112	Embarras (Lawrenceville)	11.4	12.3	0.9
07130009	Salt	15.7	12.0	-3.7
07130007	South Fork Sangamon	14.2	11.2	-3.0
07110004	The Sny	8.1	9.6	1.6
07140201	Upper Kaskaskia	11.7	9.2	-2.5
07130003	Lower Illinois-Lake Chautauqua	10.4	8.3	-2.2
07130012	Macoupin	7.2	8.2	1.0
07110001	Bear-Wyaconda	6.7	7.8	1.0
07130010	La Moine	9.6	7.7	-1.9
07140204	Lower Kaskaskia	6.4	6.6	0.1
07110009	Peruque-Piasa	4.8	5.6	0.8
07130011	Lower Illinois	N/A	5.2	N/A
07140203	Shoal	3.4	4.6	1.2
07130008	Lower Sangamon	5.0	4.5	-0.5
07120006	Upper Fox	4.5	4.4	0.1
05120114	Little Wabash	3.0	3.9	0.9
05120113	Lower Wabash	3.0	3.9	0.9
07140105	Upper Miss/Cape Girardeau	3.1	3.2	0.2
07140101	Cahokia-Joachim	2.5	3.1	0.6
05120115	Skillet	1.7	1.9	0.2
07140108	Cache	1.3	1.6	0.3
07140106	Big Muddy	1.4	1.5	0.1
05140202	Highland-Pigeon	1.0	1.4	0.4
05140204	Saline	1.0	1.4	0.4
05140206	Lower Ohio	1.4	1.3	0.6
05140203	Lower Ohio-Bay	0.7	0.8	0.1
07130001	Lower Illinois-Senachwine Lake	-0.3	0.4	0.8
07140202	Middle Kaskaskia	0.2	0.2	0.0

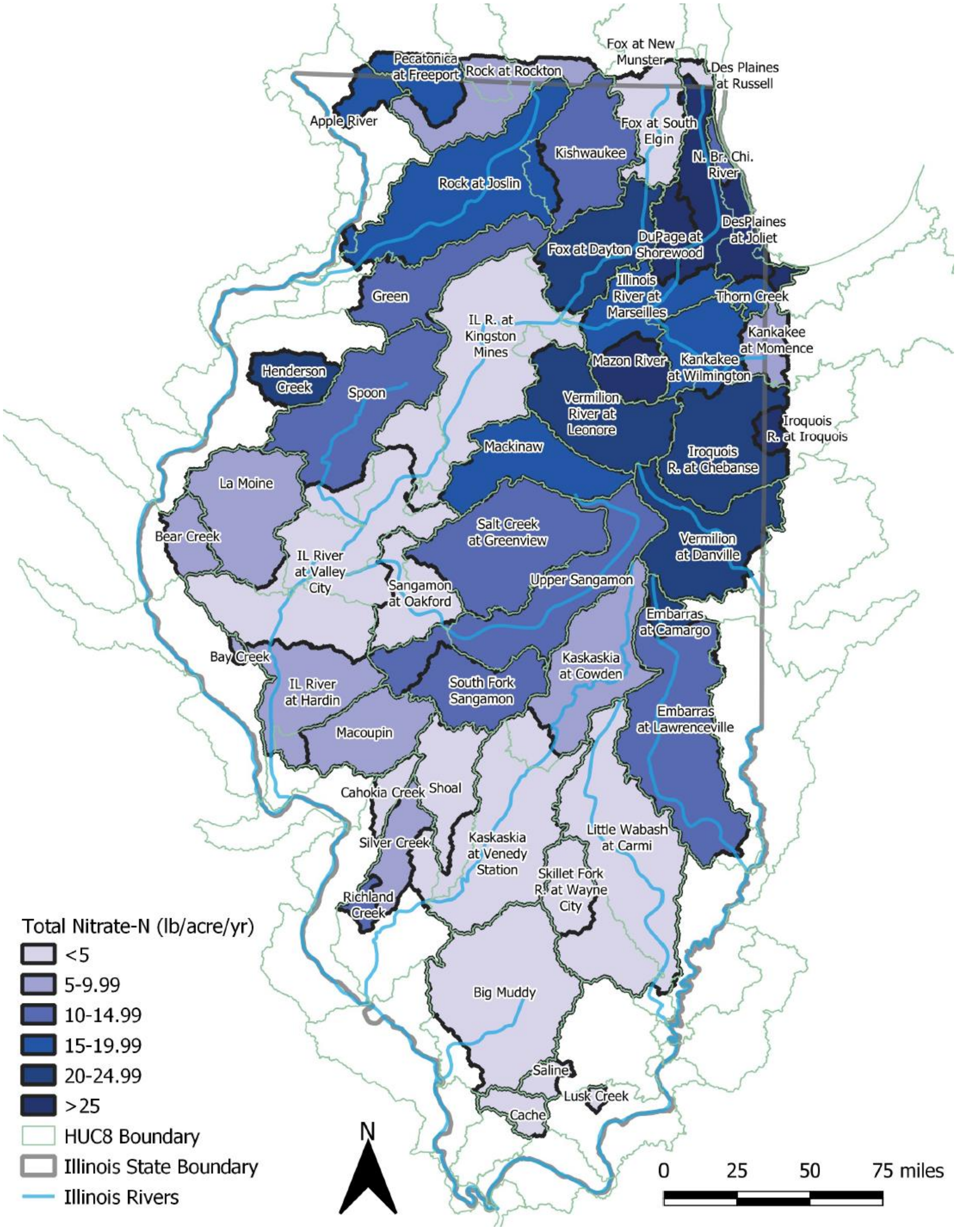

Figure 8. Average annual 2012-17 incremental nitrate-N yields at monitoring locations used to estimate HUC 8 yields and loads.

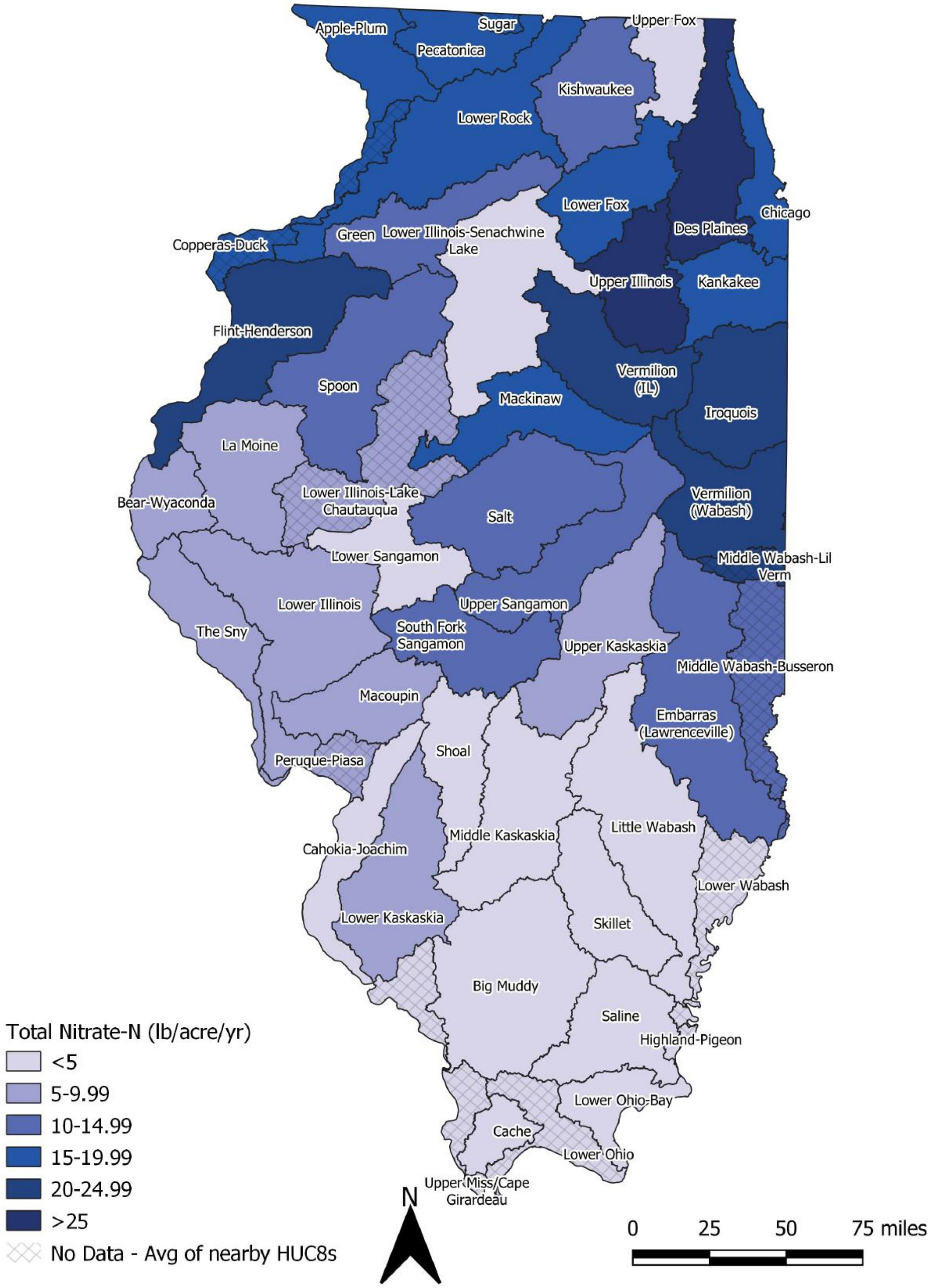

Figure 9. Estimated average annual nitrate-N yield by HUC during 2012-17.

Changes from 1997-2011 average nitrate yields to 2012-17 values were partly related to changes in water yield. Change in water yield as an independent variable accounted for 38% of the variation in change in nitrate-N yield in linear regression analysis for all HUCs except for four without monitoring data assumed to be equal to equal to a neighboring HUC. But for the

HUCs with 1997-2011 water yields greater than 11 lb N/ac-yr, linear regression with change in water yield accounted for 53% of the variation (Figure 10). For the HUCs with 1997-2011 nitrate-N yields less than 11 lb N/ac-yr, changes in nitrate yield were statistically unrelated to water yield.

The HUCs with nitrate yields less than an average of 11 lb N/ac-yr during 1997-2011 are largely in southern Illinois, except for the Upper Fox, Lower Sangamon and Bear-Wyaconda HUCs. The tendency for nitrate yield at these locations to be unrelated to water yield suggests either nitrate yields may be limited by low nitrate availability, and/or are controlled by relatively constant point sources, and/or affected by nitrate yield lag times longer than six to 10 years.

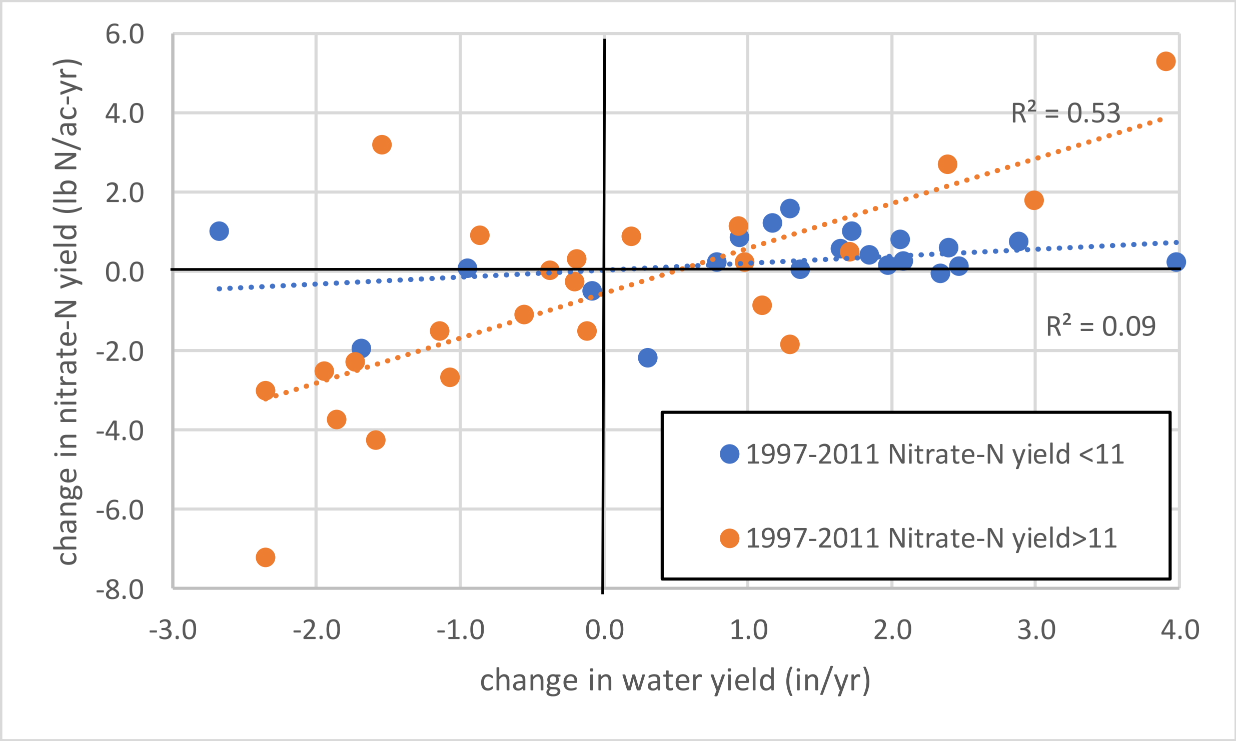

Figure 10. Change in average nitrate-N yield from 1997-2011 to 2012-17 potted against change in water yield for the same period for Illinois HUC-8s.

The HUCs with nitrate yields greater than an average of 11 lb N/ac-yr during 1997-2011 were in central and northern Illinois, where tile drainage is common. The correlation with water yield suggests that nitrate is readily available, and nitrate yields are limited by water yield which is largely driven by rainfall quantity and timing. Lower nitrate yields during low flow may be the result of storage of nitrate in soils or groundwater and/or greater denitrification of nitrate due to longer water residence times.

Deviations from either of these patterns may be indications of changes occurring within the HUC, possibly due to changes in agricultural practices, land use, and/or point source discharges. The greatest reduction in nitrate-N yield (7.4 lb N/ac-yr) was observed for the Flint Henderson HUC, which was accompanied by a 2.4 in/yr reduction in water yield. This nitrate yield reduction is greater than the average reduction for a 2.4 in/yr water yield reduction. Greater than average nitrate yield reductions also occurred in the Spoon (4.3 lb N/ac-yr) and the Mackinaw (1.8 lb N/ac-yr) HUCs. Although the reduction in the Mackinaw was not large, it occurred despite an increase in water yield of 1.3 in/yr. The fact that these three HUCs are located in the same region suggests that regional factors (e.g., soil or weather) may be involved. In contrast to these reductions, a relatively large increase in nitrate-N yield (3.2 lb N/ac-yr) was estimated for the Kankakee HUC despite a reduction in water yield of 1.5 in/yr.

For a few HUCs, there are large differences between the 1997-2011 nitrate-N yield values estimated for the NLRS and the values presented in this report because of changes in the methods of estimation. The largest of these changes is for the Lower Illinois River-Senachawine Lake (07130001). For the NLRS, the 1997-2011 nitrate yield was estimated to be 18 lb N/ac based on the average of the neighboring HUCs and the Big Bureau Creek near Princeton which is located within the HUC. The nitrate yield from Big Bureau Creek was 31 lb N/ac-yr, but it covers only 10% of this HUC area. The much lower yield estimate (-0.3 lb N/ac-yr) for the HUC results from subtracting upstream loads (Illinois at Marseilles, Fox at Dayton, Vermilion at Leonore) from the downstream load (Illinois River at Pekin with flow estimated from Illinois River at Kingston Mines minus the Mackinaw River). A nitrate-N yield below zero may be due to load estimation errors and/or this section of the Illinois River acting as a nitrate sink due to denitrification. For the NLRS it was assumed that load estimation errors were the primary reason for negative yield values, which is why an alternative estimation approach was used. However, the downstream portion of the Illinois River in this HUC is very flat, which leads to long water residence times and greater opportunities for denitrification in the River and associated lakes and wetlands. For instance, Big Bureau Creek flows into Goose Lake, which flows into Senachwine Lake, which flows into Lake Peoria, providing considerable opportunity of denitrification to reduce nitrate loads in this section of the river. The 2012-17 estimated nitrate yield near the outlet of this HUC (14 lb N/ac-yr at the Illinois River at Pekin) is less than the yield at the inlet (19 lb N/ac-yr at the Illinois at Marseilles), which suggests that the net contribution of the Lower Illinois-Lake Senachwhine HUC is small and sometimes less than zero.

A similar change in estimation method resulted in a large reduction in the nitrate yield estimate for the Lower Sangamon River (07130008). For the NRLS the nitrate-N yield estimate for this HUC was based only on the Spring Creek watershed at Springfield (17.9 lb N/ac-yr), which covers only 12% of the Lower Sangamon HUC area. The lower nitrate yield (5 lb N/ac-yr) was calculated for the Lower Sangamon by subtracting the upstream loads at Riverton and Greenview (Salt Creek) from the downstream load at Oakford. This approach results in annual nitrate-N yield values below zero in some years, which may be due to load estimation errors and/or the lower section of the Sangamon River periodically acting as a nitrate sink due to denitrification. Spring Creek yields were used in the NLRS because it was assumed that the low and negative yield values were due to estimation errors. However, nitrate-N concentrations in Spring Creek tend to be considerably greater than concentrations near the outlet of the Lower Sangamon HUC, the Sangamon River at Oakford (Figure 11). While the yield estimated by subtraction may be an underestimate, higher nitrate concentrations and yields from Spring Creek compared to Oakford indicates that Spring Creek nitrate-N yields are an overestimate. The yield estimated by subtraction was chosen to better represent the Lower Sangamon HUC as a whole.

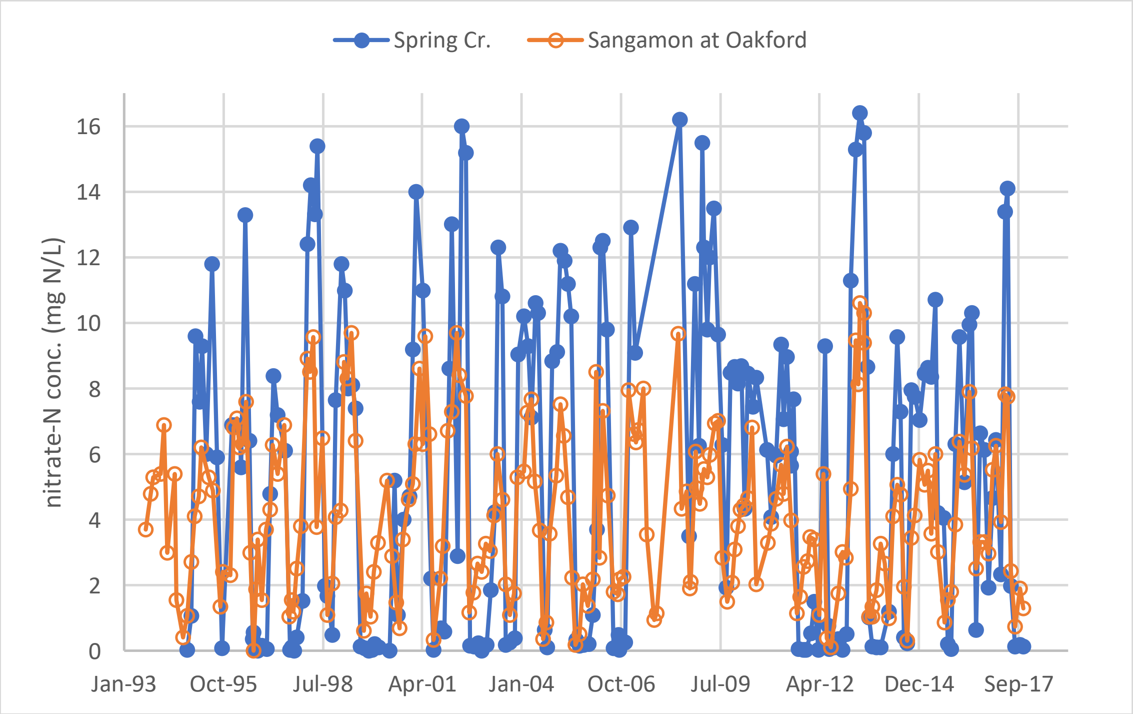

Figure 11. Nitrate N concentrations in Spring Creek at Springfield (blue solid circles) and Sangamon River at Oakford (orange open circles).

Another large nitrate yield change resulting from different estimation methods occurred for the Middle Wabash-Little Vermilion HUC (05120108). Although there is concentration data for this HUC (BO-07 at Georgetown), there is no streamflow data, so loads and yields could not be calculated directly. For the NLRS, yield was estimated to be 16.6 lb N/ac-yr based on the average of two neighboring HUCs: the Vermilion (Wabash) and the Embarras (Lawrenceville). The Little Vermilion River and the upper portion of the Embarras River watershed are extensively tile drained, but much of the lower portion of the Embarras is not. Nitrate yield at Lawrenceville (12.3 lb/ac-yr) is about half the yield upstream at Camargo (23.7 lb/ac-yr). Nitrate concentrations at Camargo (BE-14) tend to be slightly greater than concentrations in the Little Vermilion River near Georgetown (BO-07), which is in the Middle Wabash-Little Vermilion HUC, while concentrations in the Vermilion River below Danville tend to be slightly less than for the Little Vermilion (Figure 12). Concentrations at in the Embarras at Lawrenceville tend to be considerably lower than any of these sites. Based on these comparisons, the average of the Vermilion at Danville and Embarras at Camargo appears to be a better approximation for the Middle Wabash-Little Vermilion HUC. This change in method increased the 1997-2011 estimated nitrate yield from 16.6 lb N/ac-yr to 23.7 lb N/ac, which is among the five greatest HUC nitrate-N yields in the state.

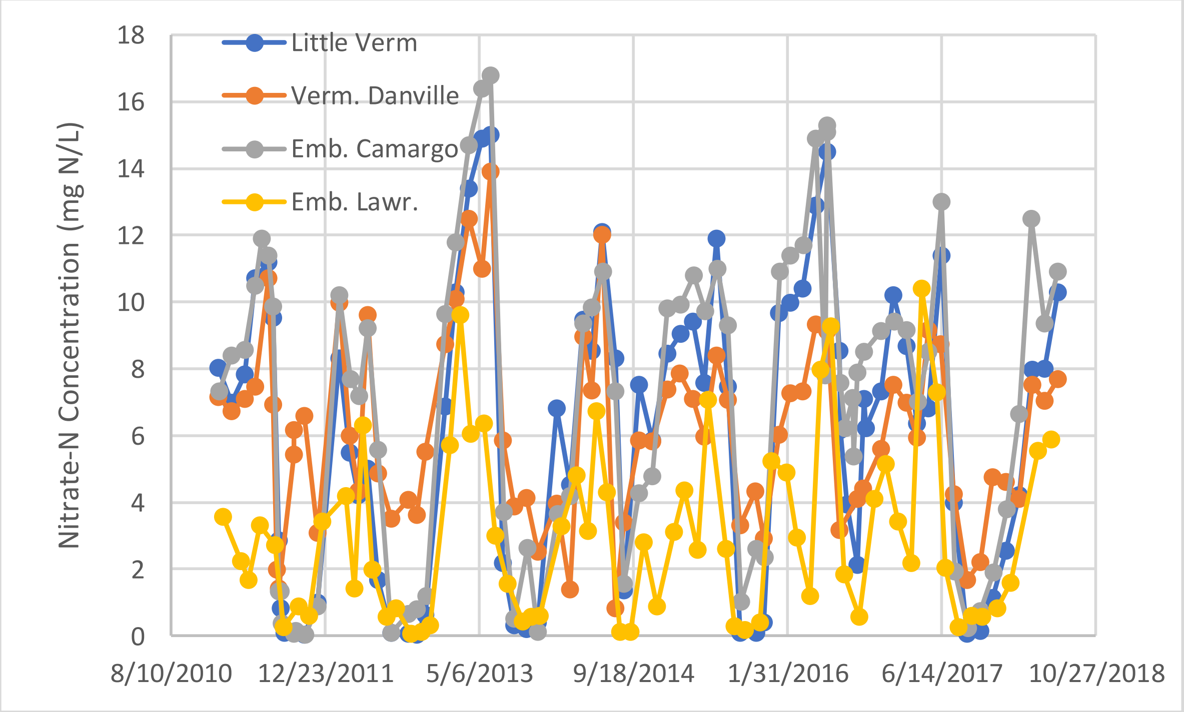

Figure 12. Nitrate concentrations for the Little Vermilion near Georgetown, the Vermilion River below Danville, the Embarras at Camargo and the Embarras at Lawrenceville.

HUC 8 TN Point Source Yields

Point source TN yields were greatest in northeastern Illinois (Figure 13). The 2017 estimates of point source TN yields for the HUC 8s were generally similar to the 2011 TN yields calculated for (but not reported in) the NLRS (Table 6). Of the 50 HUCs, point source TN yield had declined in 29, increased in 19 and remained the same in two. Most of the changes were small except for the HUCs with the Des Plaines, Chicago and the Upper Rock, where yields declined by more than 5 lb N/ac-yr, or more than 15%. The Upper Rock covers only seven square miles in Illinois, so this yield reduction represents a very small reduction in load. Modest increases (~ 1.5 lb N/ac-yr) in point source TN yield were calculated for the Peruque-Piasa, Lower Rock, the Upper and Lower Sangamon. To some extent these increases may be due to more comprehensive inclusion of facilities in the data. For the Preuque-Piasa HUC, the number of facilities included increased from one for the NLRS to three for this analysis. For the state as a whole, the number of facilities included in the point source TN analysis increased from approximately 400 for the NLRS to over 700 for this analysis.

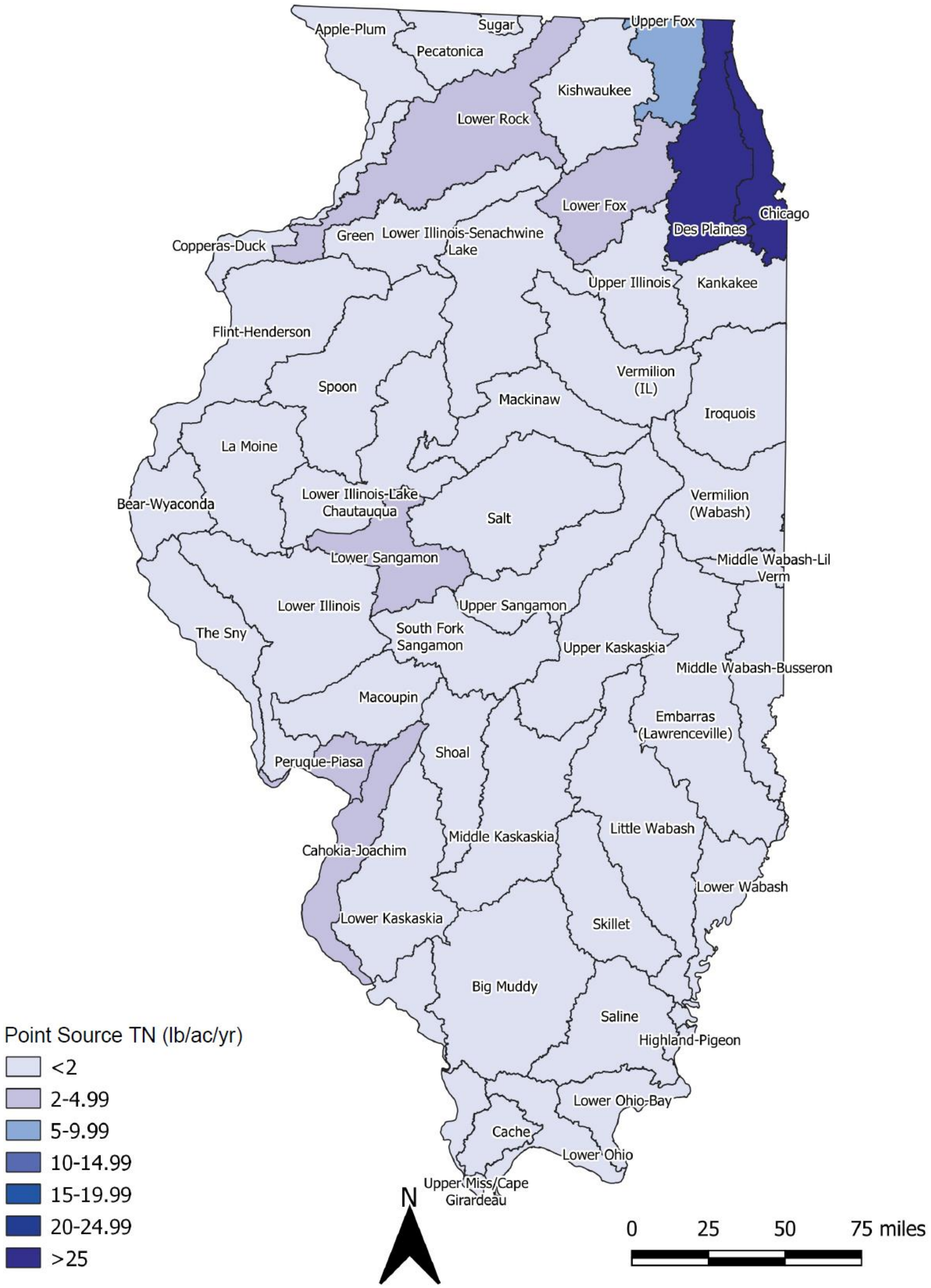

Figure 13. Estimated point source TN yields by HUC 8 based on 2017 discharge data except for some minor facilities for which 2017 data was not available and so 2011 data was used for those facilities.

Table 6. Estimated point source TN yields by HUC 8 for 2011, 2017 and the change from 2011 to 2017 sorted from greatest to least 2017 yield estimates.

IL HUC 8		Point source TN Yield (lb N/ac-yr)		
ID #	Name	2011	2017	change
07120004	Des Plaines	46.8	38.5	-8.4
07120003	Chicago	44.9	38.0	-6.9
07090001	Upper Rock	35.1	29.6	-5.5
07120006	Upper Fox	10.3	9.4	-0.9
07120007	Lower Fox	4.4	3.8	-0.5
07130008	Lower Sangamon	1.6	2.9	1.3
07140101	Cahokia-Joachim	3.3	2.5	-0.8
07090005	Lower Rock	0.6	2.4	1.8
07110009	Peruque-Piasa	0.1	2.0	1.9
07080101	Copperas-Duck	2.0	1.6	-0.3
05120109	Vermilion (Wabash)	1.9	1.6	-0.3
07120001	Kankakee	0.4	1.5	1.1
07090006	Kishwaukee	1.5	1.5	0.0
07130006	Upper Sangamon	0.1	1.4	1.3
07130009	Salt	1.1	1.0	-0.1
07140204	Lower Kaskaskia	1.3	0.8	-0.4
07130003	Lower Illinois-Lake Chautauqua	0.6	0.8	0.2
07090003	Pecatonica	0.9	0.8	-0.1
07130001	Lower Illinois-Senachwine Lake	0.6	0.7	0.2
07130007	South Fork Sangamon	0.9	0.7	-0.3
07060005	Apple-Plum	0.2	0.6	0.5
07110001	Bear-Wyaconda	0.0	0.5	0.5
07080104	Flint-Henderson	0.5	0.5	0.0
07120005	Upper Illinois	0.4	0.5	0.1
05140206	Lower Ohio	0.4	0.4	0.1
07130010	La Moine	0.5	0.4	0.0
07130002	Vermilion (IL)	0.5	0.4	0.0
05120108	Middle Wabash-Little Vermilion	0.4	0.4	0.0
07140201	Upper Kaskaskia	0.4	0.3	0.0
07140106	Big Muddy	0.8	0.3	-0.5
05120112	Embarras (Lawrenceville)	0.4	0.3	-0.1

Table 6 (continued). Estimated point source TN yields by HUC8 for 2011, 2017 and the change from 2011 to 2017, sorted from greatest to least 2017 yield estimates.

IL HUC 8		Point source TN Yield (lb N/ac-yr)		
ID #	Name	2011	2017	change
07140203	Shoal	0.4	0.3	-0.1
05120114	Little Wabash	0.4	0.2	-0.2
07130005	Spoon	0.3	0.2	-0.1
07130004	Mackinaw	0.2	0.2	0.0
07090007	Green	0.2	0.2	0.0
07130011	Lower Illinois	0.4	0.2	-0.2
07130012	Macoupin	0.3	0.2	-0.1
05120113	Lower Wabash	0.0	0.1	0.1
07140202	Middle Kaskaskia	0.3	0.1	-0.1
05140204	Saline	0.2	0.1	-0.1
05120111	Middle Wabash-Busseron	0.3	0.1	-0.2
07140105	Upper Miss/Cape Girardeau	0.2	0.1	-0.1
07120002	Iroquois	0.1	0.1	-0.1
07110004	The Sny	0.0	0.0	0.0
05120115	Skillet	0.0	0.0	0.0
05140203	Lower Ohio-Bay	0.0	0.0	0.0
07090004	Sugar	0.0	0.0	0.0
07140108	Cache	0.0	0.0	0.0
05140202	Highland-Pigeon	0.0	0.0	0.0

Estimated non-point source nitrate-N yields were greatest in northern and central Illinois (Figure 14). These values ranged from 27 lb N/ac-yr in the Upper Illinois River HUC (as approximated by the Mazon River) to -18.8 lb N/ac for the Chicago HUC (Table 7). Negative estimates of non-point nitrate-N yield were also calculated for the Upper Rock and Upper Fox HUCs. These values are likely influenced by mismatches between HUC drainage areas and monitored drainage areas. For the Chicago HUC, the drainage areas of the two monitored rivers used to represent the HUC (see Appendix 1) drain a combined area that is only 34% of the HUC area. The yield from the monitored area is considerably less than point source yield from the HUC as a whole, thereby producing an unrealistic negative non-point source yield. For the Upper Rock, there is no river monitoring data, so the total nitrate yield was estimated from neighboring HUCs. A relatively small point source (South Beloit, 0.13 million lb N/yr) discharges within the HUC, which leads to a high point source yield because of the very small size (seven square miles) of the HUC within Illinois. For the Upper Fox, the monitored area is about 23% greater than the HUC area in Illinois, with much of the extra monitored area outside the HUC occurring in Wisconsin. Additionally, lakes are a common feature in the Upper Fox and these provide conditions favorable for nitrate removal through denitrification. In a such a setting, a negative value of non-point source nitrate yield may indicate that the HUC is a nitrate sink rather than a source. Negative nitrate-N yields might also be a result of inaccurate estimates of total and point source nitrate yield estimates.

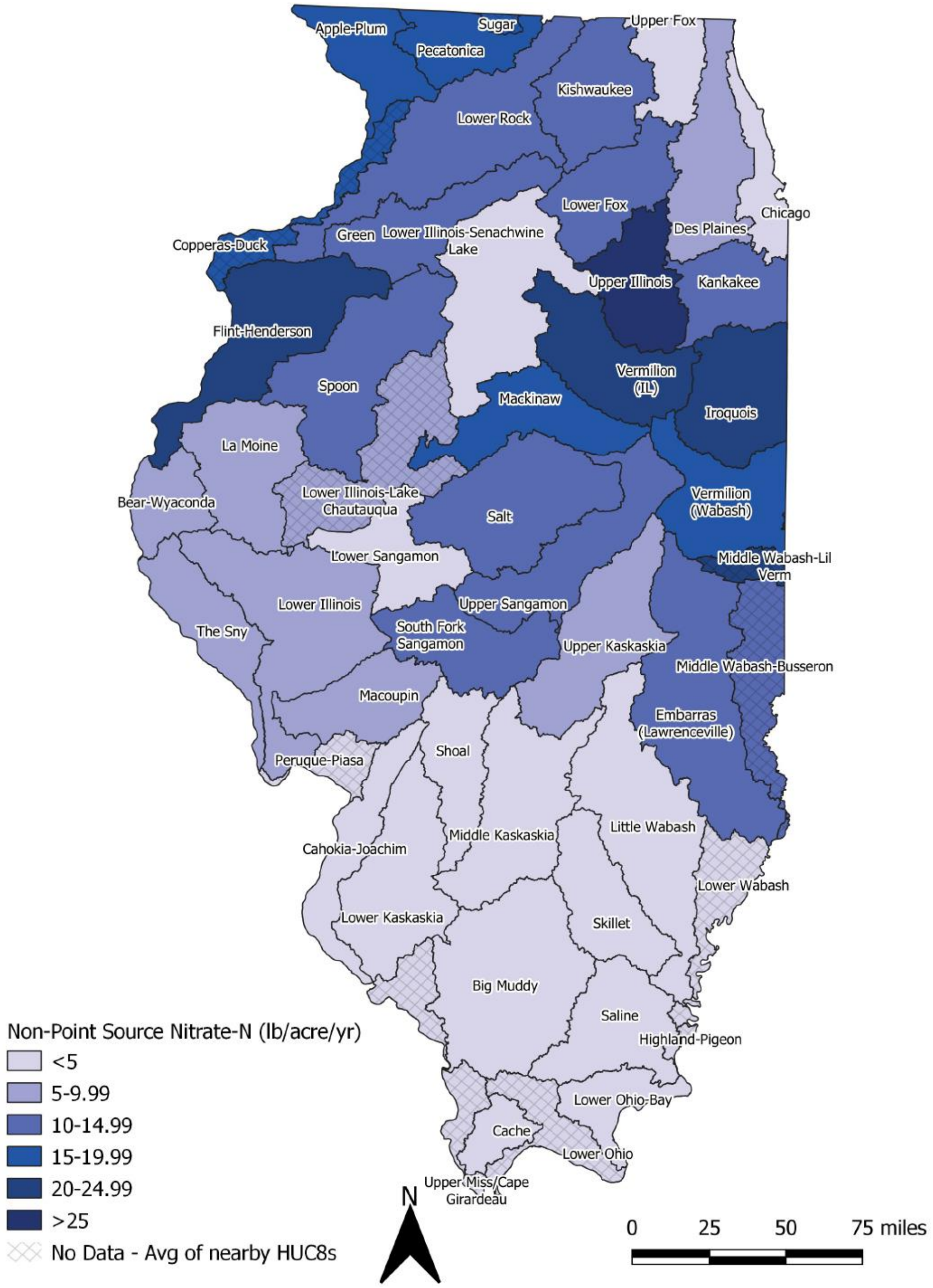

Figure 14. Estimated non-point source nitrate-N yields 2012-17, based on approach used in the NLRS.

Table 7. Estimated average non-point source nitrate-N yield from HUC8s, based on the approach used in the NLRS, for 1997-2011, 2012-17 and the difference between the two time periods. Values are sorted from the greatest to least yield for the 2012-17 period.

IL HUC 8		**Estimated NPS Nitrate-N yield (lb N/ac-yr)**		
ID #	**Name**	**1997-2011**	**2012-2017**	**change**
07120005	Upper Illinois	23.5	27.0	3.5
07130002	Vermilion (IL)	22.2	22.6	0.4
05120108	Middle Wabash-Little Vermilion	15.7	21.9	6.1
07120002	Iroquois	22.0	21.9	-0.1
07080104	Flint-Henderson	23.6	20.7	-2.9
05120109	Vermilion (Wabash)	20.3	19.2	-1.1
07130004	Mackinaw	19.9	18.1	-1.7
07080101	Copperas-Duck	16.9	16.5	-0.5
07090004	Sugar	14.6	16.2	1.6
07060005	Apple-Plum	13.2	15.4	2.1
07090003	Pecatonica	14.6	15.4	0.8
07090005	Lower Rock	14.0	14.7	0.7
07120001	Kankakee	12.3	13.6	1.3
07130005	Spoon	17.6	13.3	-4.2
07090006	Kishwaukee	12.9	12.9	0.0
05120111	Middle Wabash-Busseron	11.2	12.2	1.0
07090007	Green	12.5	12.2	-0.3
05120112	Embarras (Lawrenceville)	11.2	12.0	0.8
07130006	Upper Sangamon	13.5	12.0	-1.5
07120007	Lower Fox	10.2	11.2	1.0
07130009	Salt	14.8	11.0	-3.7
07130007	South Fork Sangamon	13.4	10.6	-2.8
07110004	The Sny	6.8	9.6	2.8
07140201	Upper Kaskaskia	11.4	8.9	-2.5
07130012	Macoupin	6.9	8.0	1.1
07130003	Lower Illinois-Lake Chautauqua	14.0	7.5	-6.6
07120004	Des Plaines	1.8	7.4	5.6
07130010	La Moine	9.2	7.3	-2.0
07110001	Bear-Wyaconda	5.9	7.2	1.4
07140204	Lower Kaskaskia	5.3	5.8	0.5
07130011	Lower Illinois	7.8	5.0	-2.8
07140203	Shoal	3.0	4.3	1.3

Table 7 (continued). Estimated average non-point source nitrate-N yield from HUC8s, based on the approach used in the NLRS, for 1997-2011, 2012-17 and the difference between the two time periods. Values are sorted from the greatest to least yield for the 2012-17 period.

IL HUC 8		Estimated non-point source Nitrate-N yield (lb N/ac-yr)		
ID #	**Name**	**1997-2011**	**2012-2017**	**change**
05120113	Lower Wabash	6.5	3.8	-2.7
05120114	Little Wabash	3.2	3.7	0.6
07110009	Peruque-Piasa	5.2	3.6	-1.6
05140206	Lower Ohio	1.0	3.1	2.1
07140105	Upper Miss/Cape Girardeau	2.0	3.1	1.1
05120115	Skillet	1.7	1.9	0.2
07140108	Cache	1.3	1.6	0.3
07130008	Lower Sangamon	16.7	1.5	-15.2
05140202	Highland-Pigeon	2.7	1.4	-1.2
05140204	Saline	0.9	1.3	0.5
07140106	Big Muddy	0.7	1.1	0.4
05140203	Lower Ohio-Bay	0.7	0.8	0.1
07140101	Cahokia-Joachim	0.9	0.5	-0.3
07140202	Middle Kaskaskia	3.3	0.1	-3.3
07130001	Lower Illinois-Senachwine Lake	18.3	-0.3	-18.6
07120006	Upper Fox	0.0	-7.1	-7.1
07090001	Upper Rock	14.3	-15.3	-29.6
07120003	Chicago	3.4	-22.6	-26.0

When estimating non-point source nutrient yields for the NLRS, similar negative yields occurred, but it was assumed that these results were based on mismatches between HUC areas and monitored drainage areas and/or load estimation errors. Rather than report negative values, alternative, ad hoc methods were used to develop non-negative yield estimates for particular HUCs. For this report, the negative values are reported to facilitate future identification and correction of inappropriate assumptions or errors in calculating point and non-point source yields. The results of an alternative approach to distinguishing between point and non-point sources is presented in the next section of this report.

Large changes in estimated non-point source nitrate-N yield from 1997-2011 to 2012-17 occurred for the Lower Illinois Senachwine Lake, Lower Sangamon, Lower Illinois Lake Chautauqua, and Middle Wabash-Little Vermilion. All these changes were largely the result of changes in estimation methods as described in a previous section.

Total and Non-Point Source Nitrate-N Loads, and Point Source TN Loads Estimated by the Alternative Method

As described in the methods section, alternative estimates of point, non-point and total nitrate-N loads were developed based on the location of point sources relative to river monitoring stations. Using this approach, estimated non-point source nitrate-N load for the Chicago HUC is a small positive value (Table 8) rather than an unrealistically large negative value (Table 7). Negative non-point source loads were nonetheless estimated for the Upper Fox, Lower Illinois Senachwine, and the Middle Kaskaskia HUCs, all of which contain significant area of lakes that provide opportunities for denitrification. It is possible that denitrification in lakes and streams between the point of discharge and the monitoring location reduced the riverine loads to be less than the sum of the point source inputs. By ignoring the role of denitrification, both methods of estimating point and non-point source contributions are prone to overestimating the point source contributions to HUC loads and yields. Negative non-point source load values may be due to this overestimation and/or to riverine nitrate load estimation errors.

A negative non-point source load was also estimated for the Upper Rock HUC. This HUC covers only seven square miles in Illinois and there is no river monitoring data for it. Riverine nitrate-N load was estimated from the average of neighboring HUCs, which could easily underestimate the total riverine load, which would contribute to an underestimate of non-point source load and also contribute to the point source load being greater than the riverine load.

For the HUCs with point source load estimates greater than riverine load estimates, the percentage of load from point sources would appear to be greater than 100%, which is unrealistic. For these HUCs, the percentage of the estimated load from point sources is presented in Table 8 as >100%. It should also be noted that the percentages of nitrate loads from point sources for the other HUCS may also be overestimated by ignoring the role of denitrification between the location of point source discharge and the location of river monitoring. Moreover, a substantial portion of point source discharge occurs during summer and autumn low flow periods when denitrification rates tend to be high because of high temperatures.

Comparisons of nitrate-N loads across HUCs (Table 8 and Figures 15, 16 and 17) should recognize the role of HUC area on load. Nitrate loads generally increase as HUC area increases, so that smaller HUCs with high nitrate yields (e.g. Middle Wabash-Little Vermilion) can have relatively low nitrate-N loads simply because they are small. Conversely, the largest HUC (Embarras) has the 5th largest estimated nitrate N load in the state despite having only the 23rd highest nitrate-N yield (Table 5). Conservation efforts are often most effective when deployed to reduce high nutrient concentrations and yields. Using HUC loads alone to set conservation priorities without considering yields might contribute to reduced effectiveness of conservation investments.

Table 8. **Estimates** of 2012-17 average annual riverine nitrate-N load, non-point source (NPS) nitrate-N load, and 2017 point source TN load in million lbs N/yr and as a percent of the HUC 8 riverine nitrate-N load assuming point source nitrate-N is 90% of point source TN discharges. Values are sorted from greatest to least estimated riverine nitrate-N load. NPS loads were estimated by subtracting point sources within the monitored drainage area from the monitored load.

HUC 8		Riverine nitrate-N load 2012-17	NPS Nitrate-N Load 2012-17	Point source TN 2017 only	Point source nitrate-N 2017 only
ID #	Name	Million lb N/yr			% of HUC nitrate-N load
07120004	Des Plaines	42.14	9.95	32.19	76%
07080104	Flint-Henderson	24.55	24.05	0.56	2%
07090005	Lower Rock	23.20	20.22	3.31	13%
07130002	Vermilion (IL)	19.62	19.29	0.36	2%
05120112	Embarras (Lawrenceville)	19.20	18.76	0.49	2%
07120005	Upper Illinois	17.87	17.59	0.31	2%
07120002	Iroquois	17.87	17.83	0.05	0%
05120109	Vermilion (Wabash)	17.11	15.93	1.31	7%
07130005	Spoon	16.12	15.92	0.22	1%
07120003	Chicago	15.00	2.03	14.41	86%
07130009	Salt	14.32	13.25	1.19	7%
07130004	Mackinaw	13.47	13.35	0.13	1%
07130006	Upper Sangamon	12.12	10.98	1.27	9%
07090006	Kishwaukee	11.06	10.02	1.16	9%
07120007	Lower Fox	10.58	8.15	2.70	23%
07140201	Upper Kaskaskia	9.22	8.92	0.32	3%
07090007	Green	9.05	8.94	0.13	1%
07060005	Apple-Plum	8.80	8.50	0.33	3%
07130007	South Fork Sangamon	8.60	8.16	0.49	5%
07130003	Lower Illinois-Lake Chautauqua	8.50	7.74	0.85	9%
07120001	Kankakee	8.41	7.65	0.85	9%
07090003	Pecatonica	7.81	7.50	0.35	4%
07130011	Lower Illinois	7.70	7.48	0.24	3%
05120111	Middle Wabash-Busseron	6.99	6.93	0.06	1%
07130010	La Moine	6.62	6.29	0.37	5%
07110004	The Sny	6.18	6.16	0.03	0%
07080101	Copperas-Duck	5.85	5.37	0.53	8%
07140204	Lower Kaskaskia	5.82	5.06	0.85	13%
05120114	Little Wabash	5.42	5.19	0.26	4%

Table 8. **Estimates** of 2012-17 average annual riverine nitrate-N load, non-point source (NPS) nitrate-N load, and 2017 point source TN load in million lbs N/yr and as a percent of the HUC 8 riverine nitrate-N load assuming point source nitrate-N is 90% of point source TN discharges. Values are sorted from greatest to least estimated riverine nitrate-N load. NPS loads were estimated by subtracting point sources within the monitored drainage area from the monitored load.

HUC 8		**Riverine nitrate-N load 2012-17**	**NPS Nitrate-N Load 2012-17**	**Point source TN 2017 only**	**Point source nitrate-N 2017 only**
ID #	**Name**	**Million lb N/yr**			**% of HUC nitrate-N load**
07130012	Macoupin	5.09	5.00	0.10	2%
07110001	Bear-Wyaconda	3.23	3.05	0.20	6%
05120108	Middle Wabash-Lil Verm	2.91	2.87	0.05	1%
07140101	Cahokia-Joachim	2.80	1.57	1.37	44%
07130008	Lower Sangamon	2.80	1.29	1.67	54%
07140203	Shoal	2.72	2.56	0.18	6%
07140106	Big Muddy	2.17	1.73	0.48	20%
07120006	Upper Fox	2.07	-1.21	3.64	>100%*
05120113	Lower Wabash	1.69	1.63	0.06	3%
07140105	Upper Miss/Cape Girardeau	1.49	1.45	0.05	3%
05120115	Skillet	1.31	1.30	0.01	0%
07110009	Peruque-Piasa	1.19	0.80	0.42	32%
05140204	Saline	1.17	1.09	0.09	7%
07090004	Sugar	0.65	0.65	0.00	0%
05140206	Lower Ohio	0.51	0.36	0.17	30%
07140108	Cache	0.31	0.31	0.00	0%
05140203	Lower Ohio-Bay	0.31	0.31	0.00	1%
07140202	Middle Kaskaskia	0.11	-0.01	0.14	>100%*
07090001	Upper Rock	0.05	-0.07	0.13	>100%*
05140202	Highland-Pigeon	0.03	0.03	0.00	0%
07130001	Lower Illinois-Senachwine Lake	-0.93	-1.77	0.93	>100%*

*total of point source N load within the HUC was greater than the estimated nitrate-N load at the HUC outlet possibly due to denitrification occurring within the HUC

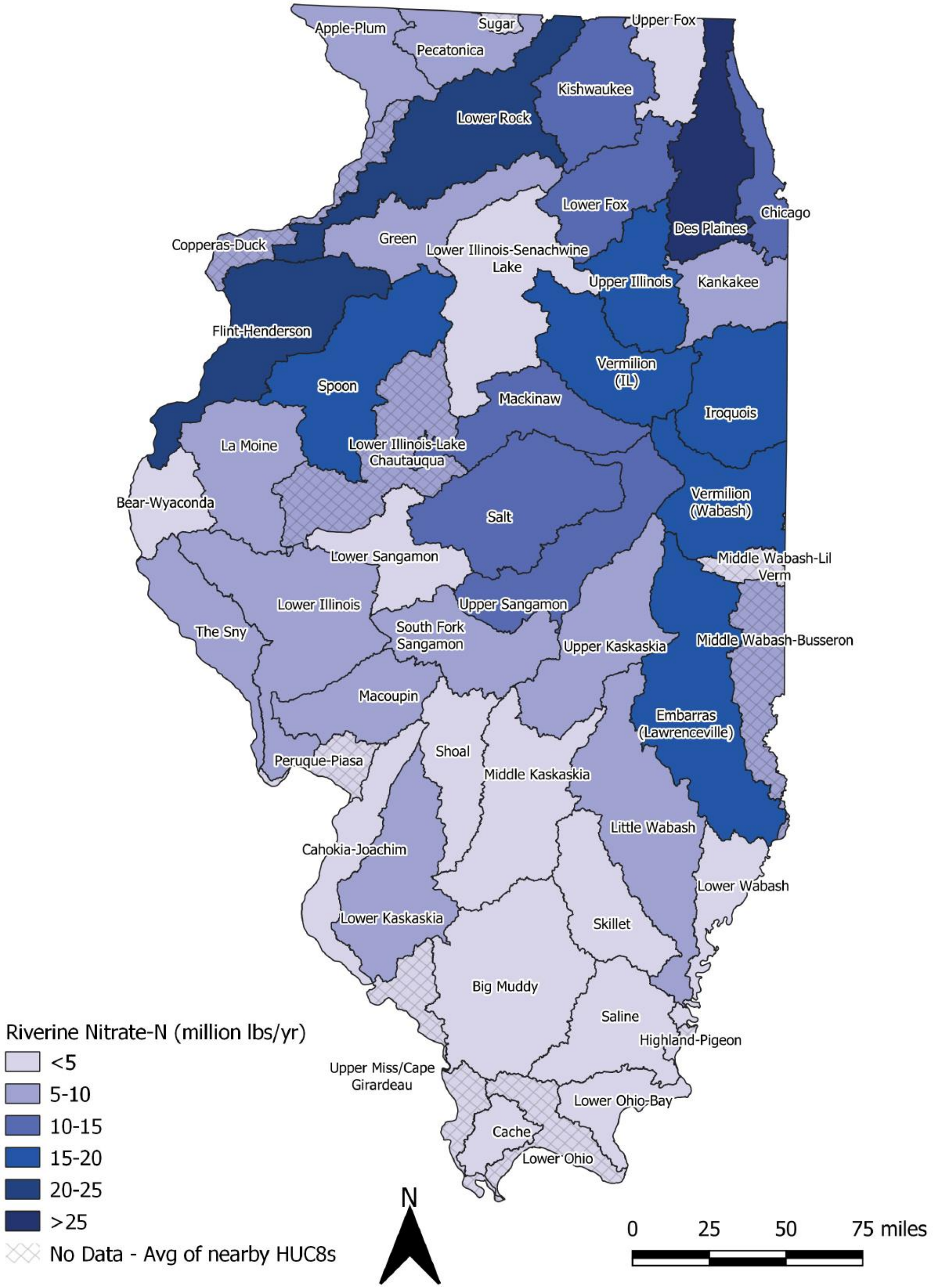

Figure 15. Estimated annual average 2012-17 riverine nitrate-N loads for HUC-8s based on the alternative method.

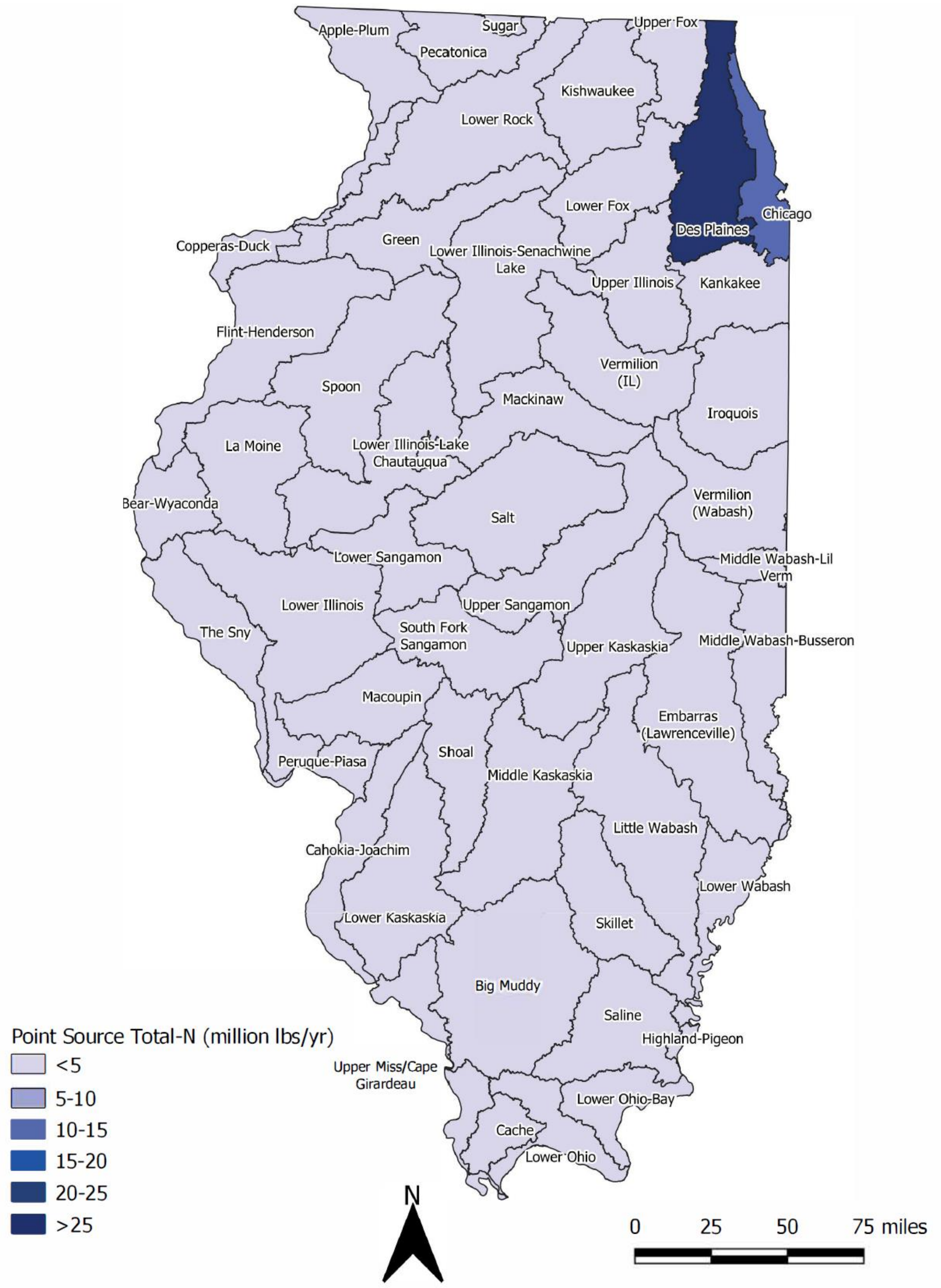

Figure 16. Estimated 2017 point source TN loads by HUC based on 2017 discharge data except for some minor facilities for which 2017 data was not available, but 2011 data from the NLRS was available and used as an estimate of 2017 loads from those facilities.

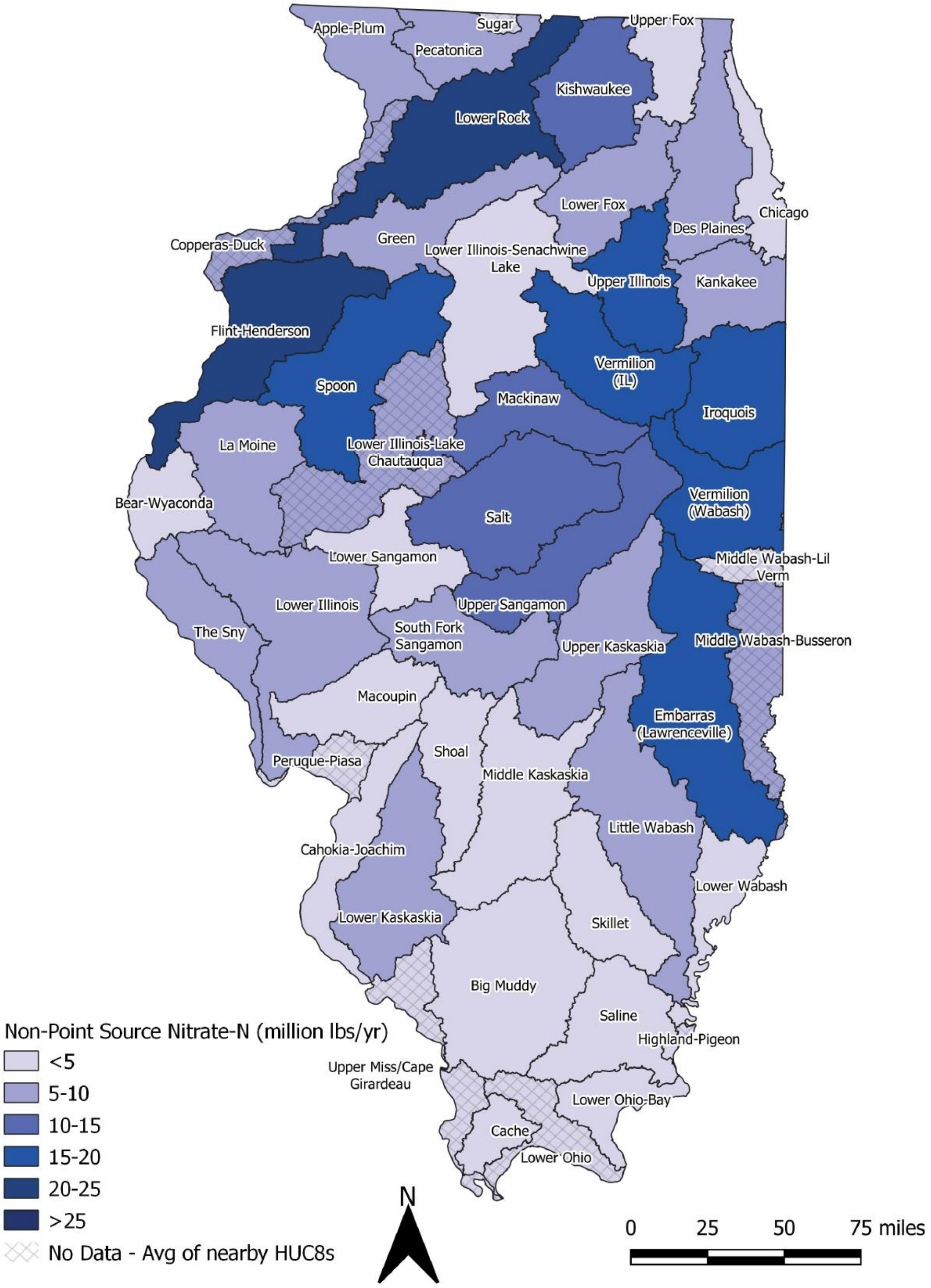

Figure 17. Estimated annual average 2012-17 non-point source nitrate-N loads for HUC-8s using the alternative method.

HUC 8 TP Yields

Estimated TP yields for 2012-17 at monitoring locations (Figure 18) and at the HUC 8 scale were greatest in HUCs with large point source inputs (e.g., Des Plaines, Chicago, Upper Sangamon HUCs), and in southern Illinois (e.g., Macoupin and Skillet) where rainfall and surface runoff are high relative to other regions in the state (Figure 19 and Table 9). High TP yields for some HUCs are based on relatively small monitoring areas, such as 4% of the HUC area for The Sny and 25% of the HUC area for the Cahokia-Joachim (Appendix 1). It is not known whether the TP yield from these small monitored areas are representative of the HUCs as a whole. A high TP yield for the Peruque-Piasa is not based on direct monitoring within that HUC, but based on an average of the Cahokia-Joachim and the Macoupin HUCs.

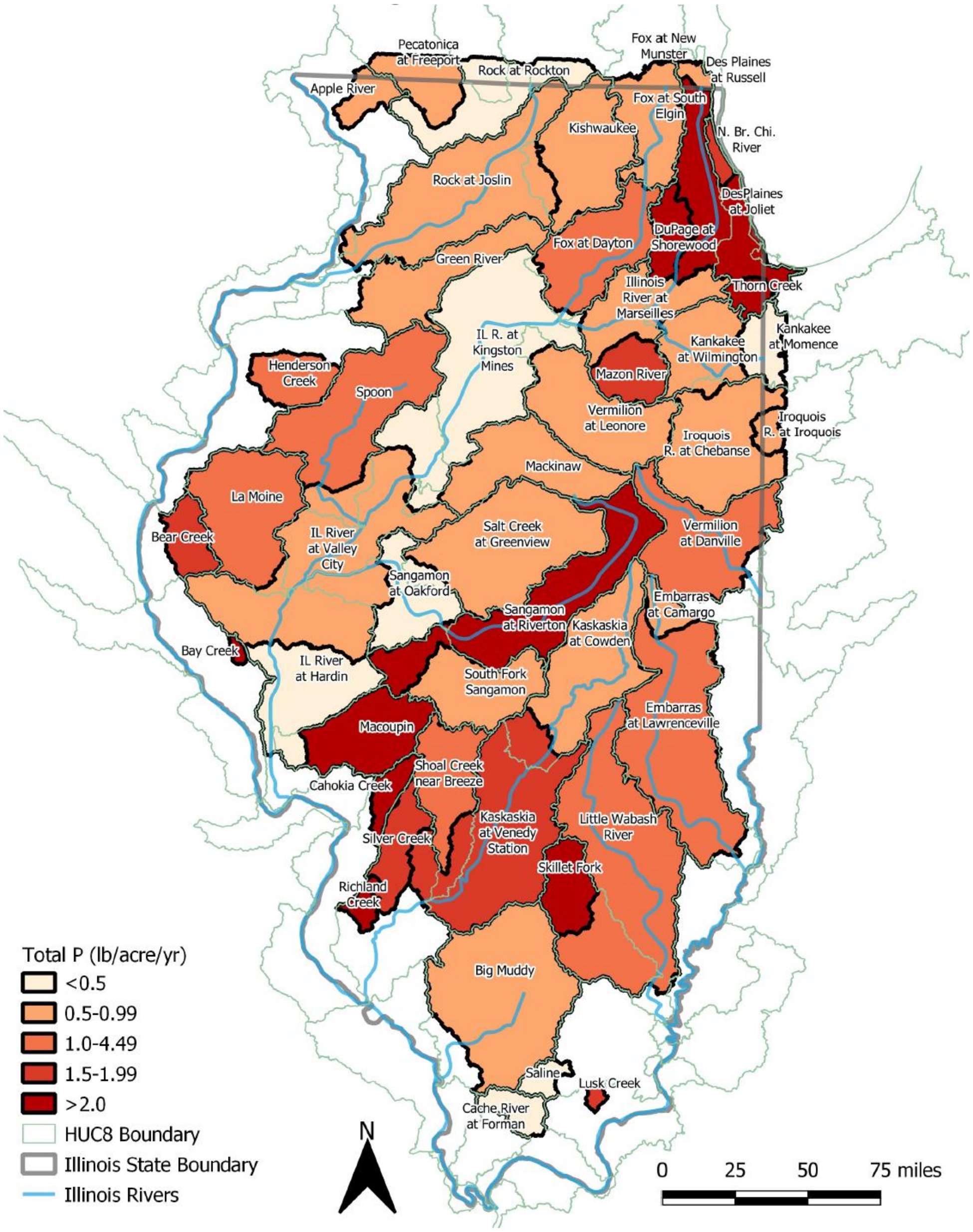

Figure 18. Annual average 2012-17 estimated incremental TP yield at monitoring locations.

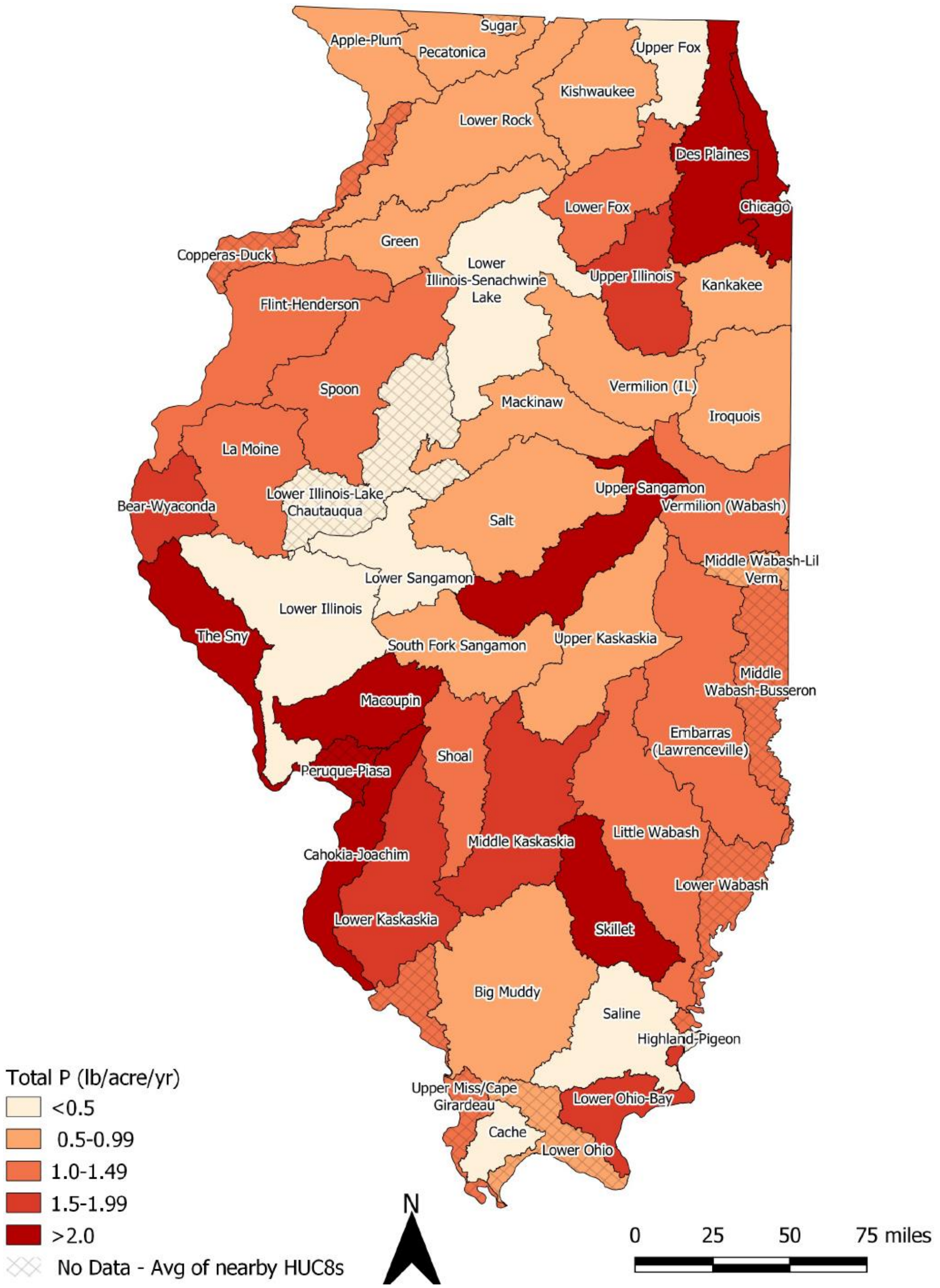

Figure 19. Estimated annual average 2012-17 TP yields by HUC 8 (NLRS approach to estimation).

Table 9. Estimated average TP yields from HUC 8s for 1997-2011, 2012-2017 and the change from the earlier to later period. Values are sorted from greatest to least yields for 2012-17.

IL HUC 8		**TP yield (lb P/ac-yr)**		
ID #	**Name**	**1997-2011**	**2012-17**	**Change**
07120004	Des Plaines	9.42	8.00	-1.42
07110004	The Sny	2.75	4.20	1.45
07140101	Cahokia-Joachim	2.17	3.01	0.84
07110009	Peruque-Piasa	2.00	2.84	0.85
07130012	Macoupin	1.82	2.67	0.85
05120115	Skillet	1.37	2.31	0.93
07120003	Chicago	3.15	2.29	-0.86
07130006	Upper Sangamon	1.32	2.12	0.80
07140204	Lower Kaskaskia	1.93	1.97	0.04
07110001	Bear-Wyaconda	2.00	1.92	-0.08
07140202	Middle Kaskaskia	1.14	1.62	0.48
05140203	Lower Ohio-Bay	1.08	1.52	0.45
07120005	Upper Illinois	1.02	1.52	0.50
07140203	Shoal	1.25	1.34	0.10
07080104	Flint-Henderson	1.77	1.32	-0.46
05120111	Middle Wabash-Busseron	1.29	1.31	0.02
05120112	Embarras (Lawrenceville)	1.29	1.31	0.02
05120113	Lower Wabash	1.22	1.19	-0.02
05120114	Little Wabash	1.22	1.19	-0.02
07130010	La Moine	0.86	1.14	0.27
07130005	Spoon	1.01	1.13	0.11
05120109	Vermilion (Wabash)	1.14	1.07	-0.07
07140105	Upper Miss/Cape Girardeau	1.03	1.06	0.03
07120007	Lower Fox	0.86	1.03	0.17
07080101	Copperas-Duck	1.20	1.01	-0.20
07130002	Vermilion (IL)	0.94	0.96	0.02
07090005	Lower Rock	0.83	0.94	0.11
07120002	Iroquois	0.91	0.92	0.01
05120108	Middle Wabash-Little Vermilion	1.03	0.90	-0.13
07130004	Mackinaw	0.69	0.88	0.19
07120006	Upper Fox	0.99	0.87	-0.12

Table 9 (continued). Estimated average TP yields from HUC 8s for 1997-2011, 2012-2017 and the change from the earlier to later period. Values are sorted from greatest to least yields for 2012-17.

IL HUC 8		TP yield (lb P/ac-yr)		
ID #	**Name**	**1997-2011**	**2012-17**	**change**
07140106	Big Muddy	0.72	0.84	0.12
05140206	Lower Ohio	0.70	0.79	0.09
07060005	Apple-Plum	1.01	0.77	-0.24
07130007	South Fork Sangamon	0.97	0.76	-0.21
07120001	Kankakee	0.38	0.72	0.34
07130009	Salt	0.75	0.72	-0.03
07090006	Kishwaukee	0.97	0.69	-0.28
07090001	Upper Rock	0.69	0.68	-0.01
07090003	Pecatonica	0.68	0.61	-0.07
07090004	Sugar	0.68	0.61	-0.07
07090007	Green	0.52	0.54	0.02
07140201	Upper Kaskaskia	0.57	0.52	-0.05
05140202	Highland-Pigeon	0.56	0.42	-0.14
05140204	Saline	0.56	0.42	-0.14
07140108	Cache	0.44	0.38	-0.06
07130008	Lower Sangamon	2.01	0.25	-1.76
07130003	Lower Illinois-Lake Chautauqua	0.94	0.24	-0.70
07130001	Lower Illinois-Senachwine Lake	0.11	0.04	-0.07
07130011	Lower Illinois	N/A	-2.00	N/A

For most HUCs, the average estimated TP yields during the 1997-2011 period were similar to yields during the 2012-17 period, except for the Lower Sangamon, Des Plaines and Chicago HUCs where there were relatively large reductions. Conversely, relatively large increases in yields were estimated for the Sny, Skillet, Upper Sangamon, Macoupin, Cahokia-Joachim, and Preuque-Piasa.

The reductions in riverine TP yield from the Chicago and Des Plaines HUCs and the increase in TP yield from the Upper Sangamon HUC were associated with changes in point source TP discharges discussed in the next section. The reduction in TP yield from the Lower Sangamon HUC may be partly due to a reduction in point source inputs, reduced water yield, and an increased TP load coming from the Upper Sangamon with little or no change in the TP load downstream at Oakford. From this, it appears that much of the increased TP load from the Upper Sangamon is being deposited in the Lower Sangamon. It is not known why this may be occurring, but it is probably facilitated by reduced water yield, and this stored TP may become mobilized and transported downstream at some time in the future. The increased TP yields for the Macoupin, Skillet, and Cahokia-Joachim HUCs were associated with increased water yields.

The lowest TP yield of -2 lb P/ac-yr was calculated for the Lower Illinois HUC (07130011). The negative value may be the result of this HUC being a sink rather than a source of P and/or load estimation errors. This segment of the Illinois River between Valley City and Hardin has a very low gradient and is often affected by backwater from the Mississippi River, creating conditions favoring sediment deposition within the river reach. Since much phosphorus is transported attached to sediment, this may also lead to a reduction of P transport downstream. Additionally, the estimates of riverine load at Valley City and Hardin are very large and the differences between them are relatively small. Consequently, even small percentage errors in either load estimate can produce large variations in the difference between them, and thus lead to large variations in the estimate for this HUC. Moreover, water flow is not measured at Hardin, but estimated from the additional flow from Macoupin Creek. While there is considerable uncertainty about the TP yield from the Lower Illinois HUC, a small or negative yield seems plausible given the large quantity of TP coming from upstream and the generally sluggish nature of Illinois River flow in this HUC.

HUC 8 Point Source TP Yields

Estimated point source TP yields were greatest in northeastern IL (Chicago and Des Plaines HUCs) and in the Upper Sangamon HUC (Figure 20 and Table 10). For most other HUCs, TP yield from point sources was less than 0.2 lb P/ac-yr. Point source TP yields from the Chicago and Des Plaines HUCs declined nearly 2 lb/ac-yr from 2011 to 2017. This is probably the major reason for the decline in riverine TP yields from these HUCs (Table 9). The fact that the riverine TP reduction was less than the point source TP reduction may be due to mobilization of legacy P in river sediments and/or due to mismatches between time periods of monitoring point sources and river loads and/or mismatches of river monitoring locations and the HUC outlets.

The combined discharge of P from the Calumet and Stickney wastewater treatment facilities managed by the Metropolitan Water Reclamation District of Greater Chicago (MWRD) was 1.7 million lb TP less in 2017 than in 2011. In 2017, the Sanitary District of Decatur discharged the greatest quantity of TP of any facility in the state (1.77 million lb TP), followed closely by the MWRD Calumet facility (1.70 million lb TP). Decatur has a population of approximately 90,000, but much of the wastewater treated by and discharged from the Sanitary District of Decatur comes from large grain processing facilities.

Despite the reductions in point source TP yields from the Chicago and Des Plaines HUCs, these HUCs had the first and third highest TP yields in the state in 2017. The Upper Rock TP yield was second greatest at 7 lb P/ac-yr, but this in an artifact of the Illinois portion of this HUC being only seven square miles with South Beloit discharging 31,000 lb P/yr into it. The South Beloit discharge is less than 5% of the 670,000 lb/yr of point source P discharged into the Lower Rock HUC, where the point source TP yield is 0.48 lb P/ac-yr. When ranked by point source **loads**, Des Plaines (4.07 million lb P/yr) and Chicago (2.94 million lb P/yr) are first and second greatest, respectively (Table 12), while the Upper Rock is 35th (0.03 million lb/yr).

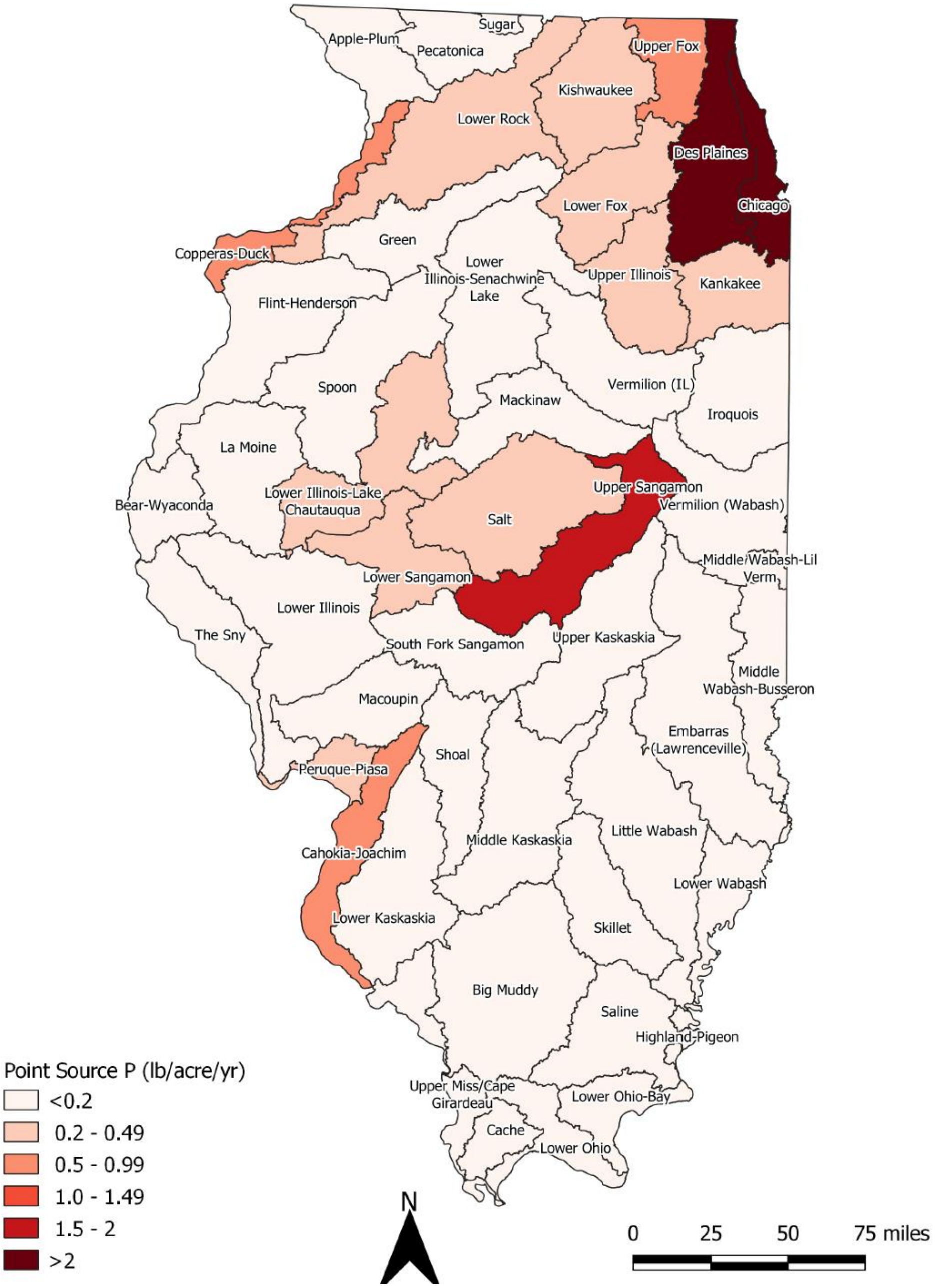

Figure 20. Estimated TP yields from point sources based on 2017 discharge data except for some minor facilities for which 2017 data was not available and so 2011 data was used as an estimate of 2017 loads from those facilities.

Table 10. Estimated point source TP yields by HUC for 2011, 2017 and the change between the two time periods, sorted by the 2017 yields.

HUC 8		Point Source TP Yield (lb P/ac-yr)		
ID #	**Name**	**2011**	**2017**	**change**
07120003	Chicago	9.74	7.77	-1.97
07090001	Upper Rock	6.70	7.00	0.30
07120004	Des Plaines	6.65	4.86	-1.79
07130006	Upper Sangamon	1.72	1.95	0.22
07120006	Upper Fox	1.52	0.89	-0.63
07080101	Copperas-Duck	1.05	0.81	-0.24
07140101	Cahokia-Joachim	0.74	0.56	-0.18
07120007	Lower Fox	0.69	0.48	-0.20
07090005	Lower Rock	0.48	0.48	0.01
07130003	Lower Illinois-Lake Chautauqua	0.42	0.42	0.00
07120005	Upper Illinois	0.44	0.34	-0.11
07110009	Peruque-Piasa	1.10	0.29	-0.82
07120001	Kankakee	0.35	0.25	-0.10
07130009	Salt	0.26	0.25	-0.02
07130008	Lower Sangamon	0.36	0.23	-0.13
07090006	Kishwaukee	0.30	0.21	-0.08
07140203	Shoal	0.22	0.18	-0.04
07130001	Lower Illinois-Senachwine Lake	0.19	0.16	-0.03
07110001	Bear-Wyaconda	0.32	0.15	-0.17
05120109	Vermilion (Wabash)	0.27	0.14	-0.13
07090003	Pecatonica	0.20	0.14	-0.06
07140204	Lower Kaskaskia	0.27	0.12	-0.15
07130007	South Fork Sangamon	0.13	0.11	-0.02
07140105	Upper Miss/Cape Girardeau	0.13	0.11	-0.02
05120114	Little Wabash	0.12	0.11	0.00
07080104	Flint-Henderson	0.12	0.10	-0.02
07140106	Big Muddy	0.14	0.08	-0.07
05120113	Lower Wabash	0.03	0.08	0.04
07130005	Spoon	0.09	0.06	-0.03
07130011	Lower Illinois	0.09	0.06	-0.03
05120111	Middle Wabash-Busseron	0.08	0.06	-0.02

Table 10 (continued) Estimated point source TP yields by HUC for 2011, 2017 and the change between the two time periods.

HUC 8		Point Source TP Yield (lb P/ac-yr)		
ID #	**Name**	**2011**	**2017**	**Change**
05140204	Saline	0.08	0.06	-0.02
05140206	Lower Ohio	0.07	0.06	0.00
05120112	Embarras (Lawrenceville)	0.06	0.06	-0.01
07130010	La Moine	0.06	0.06	0.00
07130002	Vermilion (IL)	0.07	0.05	-0.02
07140202	Middle Kaskaskia	0.06	0.05	-0.01
05120108	Middle Wabash-Little Vermilion	0.05	0.05	0.00
07130004	Mackinaw	0.05	0.05	0.00
07090007	Green	0.04	0.04	-0.01
07140201	Upper Kaskaskia	0.04	0.04	0.00
07060005	Apple-Plum	0.03	0.04	0.00
07130012	Macoupin	0.04	0.03	-0.01
07120002	Iroquois	0.03	0.03	0.00
07090004	Sugar	0.00	0.03	0.03
07140108	Cache	0.02	0.02	0.00
07110004	The Sny	0.00	0.02	0.02
05120115	Skillet	0.01	0.01	0.00
05140203	Lower Ohio-Bay	0.01	0.01	-0.01
05140202	Highland-Pigeon	0.00	0.00	0.00

HUC 8 Non-Point Source TP Yields

The greatest estimated non-point source TP yields for 2012-17 were located in southern and western Illinois (Figure 21.) The HUCs with the top five greatest estimated TP yields also appear to have undergone large increases from the 1997-2011 estimate (Table 11). Among these top five, however, there is considerable uncertainty about the estimates for all but the Macoupin HUC, because the other four are either based on averages of neighboring HUCs (Peruque-Piasa) or based on monitoring areas that are less than half of the HUC area (the Sny, Skillet and Cahokia-Joachim). Increased non-point TP yield for the Macoupin, Skillet and Cahokia-Joachim are associated with increased water yield. The non-point TP yield estimates for the Sny are probably the most uncertain for a variety of reasons. The monitored drainage area covers only 4% of the HUC for water flow and 16% for water quality and thus may not represent the HUC as a whole. Using WRTDS to estimate TP loads in the Sny resulted in a high flux bias statistic, and an ad hoc regression method was used to estimate load rather than WRTDS. These non-point source yields are estimated by subtracting the point source yields (Table 10) from the monitored riverine nutrient yields (Table 9). Underestimation of point source inputs will contribute to overestimation on non-point source yields.

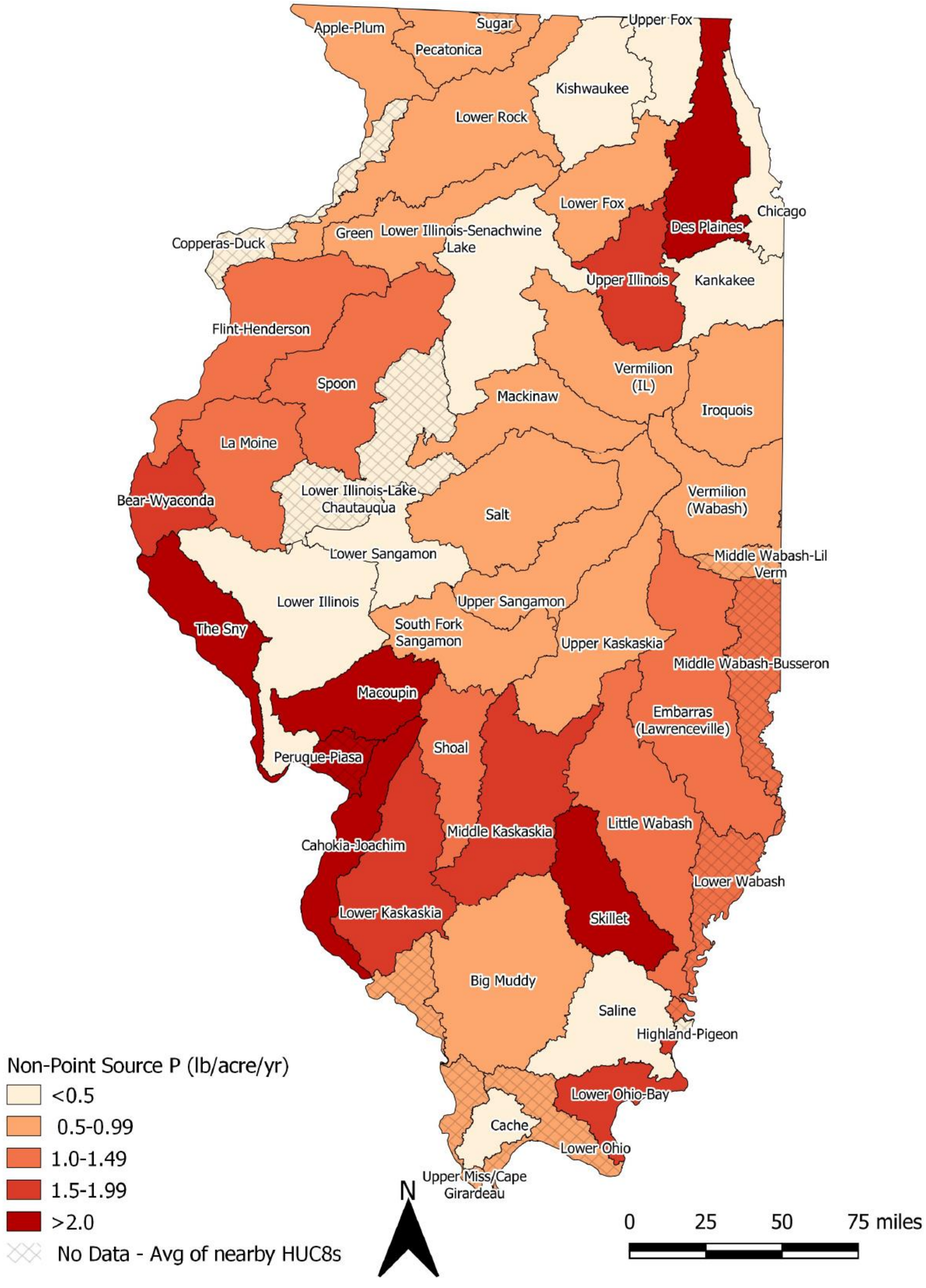

Figure 21. Estimated non-point source TP yield for 2012-17 (NLRS method).

Table 11. Estimated average annual non-point source TP yields using the NLRS method for each HUC for 1997-2011, 2012-17 and the change between the two time periods sorted by yields for the 2012-17 period.

IL HUC 8		**Non-point Source TP yield (lb P/ac-yr)**		
ID #	**Name**	**1997-2011**	**2012-17**	**Change**
07110004	The Sny	2.75	4.18	1.44
07120004	Des Plaines	2.77	3.14	0.37
07130012	Macoupin	1.79	2.64	0.86
07110009	Peruque-Piasa	0.89	2.56	1.66
07140101	Cahokia-Joachim	1.43	2.45	1.03
05120115	Skillet	1.37	2.30	0.93
07140204	Lower Kaskaskia	1.66	1.85	0.19
07110001	Bear-Wyaconda	1.68	1.77	0.09
07140202	Middle Kaskaskia	1.08	1.57	0.49
05140203	Lower Ohio-Bay	1.06	1.51	0.45
05120111	Middle Wabash-Busseron	1.22	1.26	0.04
05120112	Embarras (Lawrenceville)	1.23	1.26	0.03
07080104	Flint-Henderson	1.65	1.21	-0.44
07120005	Upper Illinois	0.57	1.18	0.61
07140203	Shoal	1.03	1.16	0.13
05120113	Lower Wabash	1.18	1.12	-0.06
05120114	Little Wabash	1.10	1.08	-0.02
07130010	La Moine	0.80	1.07	0.28
07130005	Spoon	0.93	1.07	0.14
07140105	Upper Miss/Cape Girardeau	0.90	0.96	0.05
05120109	Vermilion (Wabash)	0.87	0.92	0.05
07130002	Vermilion (IL)	0.87	0.91	0.04
07120002	Iroquois	0.88	0.89	0.01
05120108	Middle Wabash-Lil Verm	0.98	0.85	-0.13
07130004	Mackinaw	0.63	0.83	0.19
07140106	Big Muddy	0.58	0.77	0.19
05140206	Lower Ohio	0.63	0.73	0.10
07060005	Apple-Plum	0.97	0.73	-0.24
07130007	South Fork Sangamon	0.84	0.65	-0.18
07090004	Sugar	0.68	0.58	-0.10
07120007	Lower Fox	0.18	0.55	0.38
07090007	Green	0.48	0.50	0.02

Table 11 (continued). Estimated average annual non-point source TP yields using the NLRS method for each HUC for 1997-2011, 2012-17 and the change between the two time periods sorted by yields for the 2012-17 period.

IL HUC 8		**Non-point Source TP yield (lb P/ac-yr)**		
ID #	**Name**	**1997-2011**	**2012-17**	**Change**
07140201	Upper Kaskaskia	0.53	0.49	-0.04
07090006	Kishwaukee	0.68	0.48	-0.20
07120001	Kankakee	0.03	0.48	0.44
07130009	Salt	0.48	0.47	-0.01
07090003	Pecatonica	0.47	0.47	-0.01
07090005	Lower Rock	0.36	0.45	0.10
05140202	Highland-Pigeon	0.56	0.42	-0.14
07140108	Cache	0.42	0.36	-0.06
05140204	Saline	0.48	0.36	-0.12
07080101	Copperas-Duck	0.16	0.20	0.04
07130006	Upper Sangamon	-0.40	0.17	0.57
07130008	Lower Sangamon	1.65	0.03	-1.63
07130001	Lower Illinois-Senachwine Lake	-0.08	-0.12	-0.04
07130003	Lower Illinois-Lake Chautauqua	0.51	-0.18	-0.70
07120006	Upper Fox	-1.00	-0.42	0.58
07130011	Lower Illinois	N/A	-2.05	N/A
07120003	Chicago	-6.59	-5.48	1.11
07090001	Upper Rock	-2.11	-6.32	-4.21

Non-point source TP yields less than -0.4 lb P/ac-yr were estimated for the Upper Rock, Chicago, Lower Illinois and Upper Fox. For all these HUCs the mismatch between the HUC area and the monitored drainage area was at least 22%. For the Chicago HUC the monitored area was only 34% of the HUC area and did not include many of the point source facilities. These mismatches were addressed by using GIS to identify the facilities that were upstream of the monitoring locations to recalculate loads as described in the next section.

From 1997-2011 to 2012-2017 a relatively large reduction in non-point TP yield (-1.63 lb P/ac-yr) was estimated for the Lower Sangamon HUC, which was associated with a reduction in water yield of about 10%; reduced flow may be facilitating accumulation of P in the lower reaches of the Sangamon River. Increases were estimated for the Upper Illinois, Upper Fox and the Upper Sangamon. These were associated water yield increases for the Upper Illinois and the Upper Fox, but not for the Upper Sangamon.

Total, Non-Point Source, and Point Source TP Loads Estimated by the Alternative Method

When GIS was used to distinguish between point sources that were upstream and downstream of monitoring locations (rather than aggregating all point sources by HUC), estimated non-point source TP loads were less than zero only in the Lower Illinois HUCs, where low gradients and backwaters plausibly cause net deposition of TP with sediment (Table 12). The estimated non-point source load from the Chicago HUC was a small positive value as opposed to a large negative value estimated by aggregating point sources to the HUC level.

Table 12. **Estimates** of HUC average annual riverine TP load 2012-17, average annual non-point source (NPS) TP load 2012-17, and annual point source TP load 2017 in million lb P/yr and as a percent of the HUC 8 riverine TP load. Values are sorted from greatest to least estimated riverine TP load. NPS loads were estimated by subtracting point sources within the monitored drainage area from the monitored load and extrapolating the yield to the HUC area.

HUC		Riverine TP 2012-17	NPS TP 2012-17	Point Source Load 2017 only	
ID #	Name	Million lb P/yr			% of riverine TP
07120004	Des Plaines	7.58	3.51	4.07	54%
07120003	Chicago	3.10	0.16	2.94	95%
07110004	The Sny	2.69	2.68	0.01	0%
07130006	Upper Sangamon	2.27	0.48	1.80	79%
05120112	Embarras (Lawrenceville)	2.06	1.97	0.09	4%
07140204	Lower Kaskaskia	1.93	1.81	0.12	6%
07140101	Cahokia-Joachim	1.93	1.63	0.31	16%
07140202	Middle Kaskaskia	1.80	1.74	0.06	3%
05120114	Little Wabash	1.75	1.60	0.16	9%
07130012	Macoupin	1.67	1.65	0.02	1%
07080104	Flint-Henderson	1.61	1.49	0.12	7%
05120115	Skillet	1.57	1.57	0.00	0%
07090005	Lower Rock	1.48	0.82	0.67	45%
07130005	Spoon	1.38	1.31	0.07	5%
07140106	Big Muddy	1.32	1.20	0.11	9%
07120005	Upper Illinois	1.19	0.97	0.22	18%
07130010	La Moine	1.01	0.95	0.05	5%
07130009	Salt	0.96	0.67	0.29	30%
05120109	Vermilion (Wabash)	0.88	0.76	0.12	13%
07140203	Shoal	0.87	0.76	0.11	12%
07130002	Vermilion (IL)	0.83	0.78	0.04	5%
07110001	Bear-Wyaconda	0.82	0.76	0.06	7%

Table 12 (continued). **Estimates** of HUC average annual riverine TP load, non-point source (NPS) TP load, point source TP load, and point source TP load as a percent of the HUC 8 riverine TP load. Values are sorted from greatest to least estimated riverine TP load. NPS loads were estimated by subtracting point sources within the monitored drainage area from the monitored load.

HUC		Riverine TP 2012-17	NPS TP 2012-17	Point Source 2017 only	
ID #	name	Million lb P/yr			% of riverine TP
07120002	Iroquois	0.75	0.73	0.02	3%
05120111	Middle Wabash-Busseron	0.75	0.72	0.03	4%
07120007	Lower Fox	0.73	0.39	0.34	46%
07130004	Mackinaw	0.66	0.62	0.04	6%
07130007	South Fork Sangamon	0.64	0.56	0.08	12%
07110009	Peruque-Piasa	0.60	0.54	0.06	10%
05140203	Lower Ohio-Bay	0.60	0.59	0.00	1%
07140201	Upper Kaskaskia	0.55	0.51	0.04	7%
05120113	Lower Wabash	0.53	0.50	0.03	6%
07090006	Kishwaukee	0.52	0.36	0.17	32%
07140105	Upper Miss/Cape Girardeau	0.50	0.44	0.05	10%
07090007	Green	0.42	0.39	0.03	6%
07060005	Apple-Plum	0.41	0.39	0.02	5%
07120006	Upper Fox	0.40	0.05	0.34	87%
07120001	Kankakee	0.39	0.25	0.14	36%
05140204	Saline	0.36	0.32	0.05	13%
07090003	Pecatonica	0.33	0.27	0.06	20%
07080101	Copperas-Duck	0.33	0.07	0.26	80%
05140206	Lower Ohio	0.32	0.29	0.02	8%
07130003	Lower Illinois-Lake Chautauqua	0.25	-0.19	0.44	>100%*
07130008	Lower Sangamon	0.20	0.07	0.13	64%
05120108	Middle Wabash-Lil Verm	0.12	0.11	0.01	6%
07140108	Cache	0.09	0.08	0.00	5%
07090004	Sugar	0.02	0.02	0.00	4%
05140202	Highland-Pigeon	0.01	0.01	0.00	0%
07090001	Upper Rock	0.03	0.00	0.03	100%
07130001	Lower Illinois-Senachwine Lake	-0.05	-0.25	0.20	>100%*
07130011	Lower Illinois	-2.82	-2.91	0.09	>100%*

*total of point source TP load within the HUC was greater than the estimated load at the HUC outlet possibly due to deposition of TP within the HUC

Among the HUCs with the greatest estimated riverine TP loads, The Sny, Cahokia-Joachim, Flint-Henderson and Skillet are most uncertain because these estimates are based on river monitoring that drained less than half of the HUC area and point sources accounted for less than 20% of the HUC loads. Estimates for the Chicago HUC are also based on river monitoring that drains less than half the HUC area, but there is less uncertainty about these estimates because 95% of the HUC load came from point sources that were intensively monitored by MWRD. Comparisons of TP loads across HUCs (Table 12 and Figures 22, 23 and 24) should recognize the influence of HUC area on load. TP loads generally increase as HUC area increases, so that larger HUCs (e.g., Embarras) may have relatively high TP loads because they drain larger areas than other HUCs.

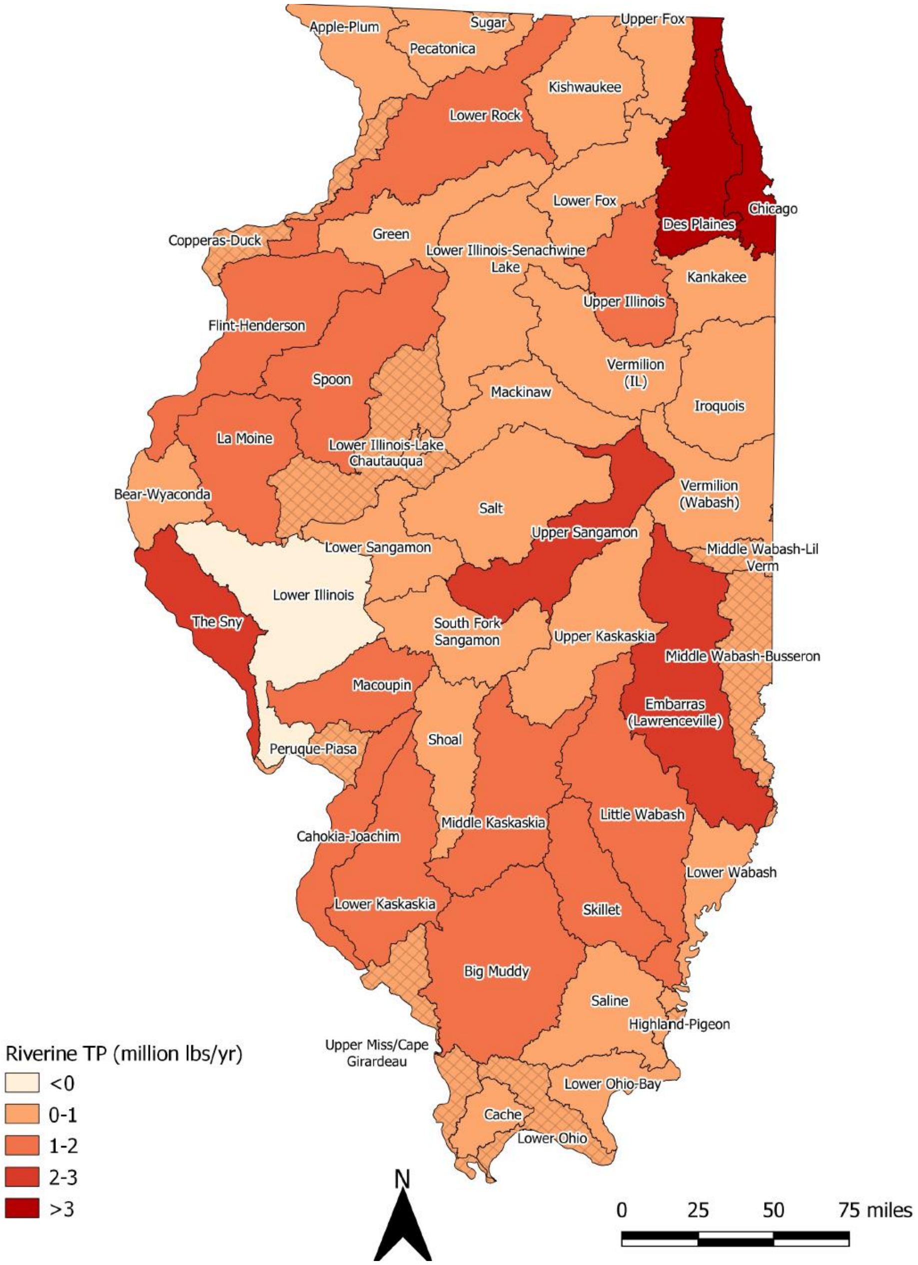

Figure 22. Estimated annual average 2012-17 riverine TP loads by HUC 8 (alternative method).

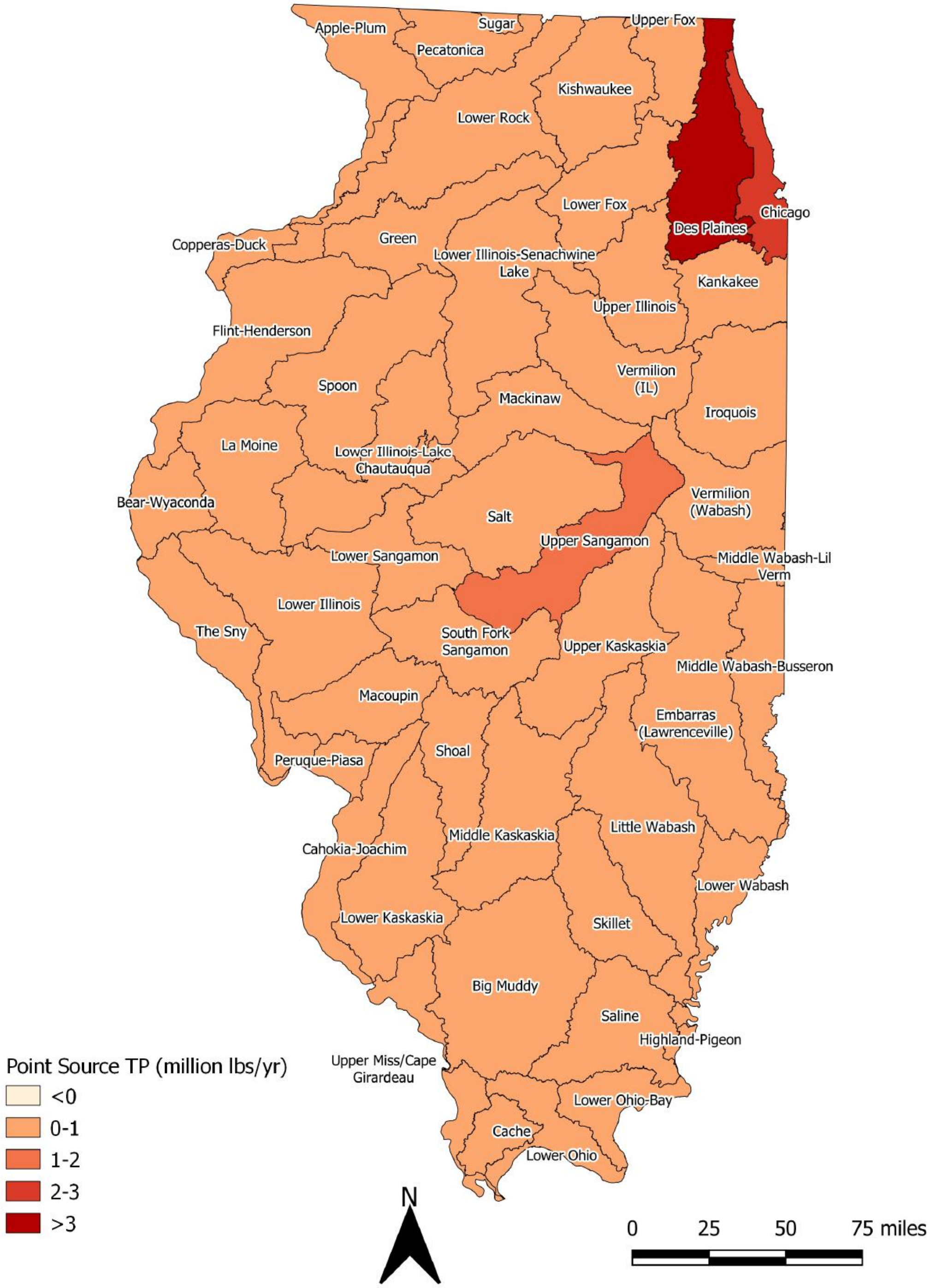

Figure 23. Point source TP loads by HUC 8 based on 2017 discharge data except for some minor facilities for which 2017 data was not available and so 2011 data from the NLRS was used as a 2017 estimate for those facilities.

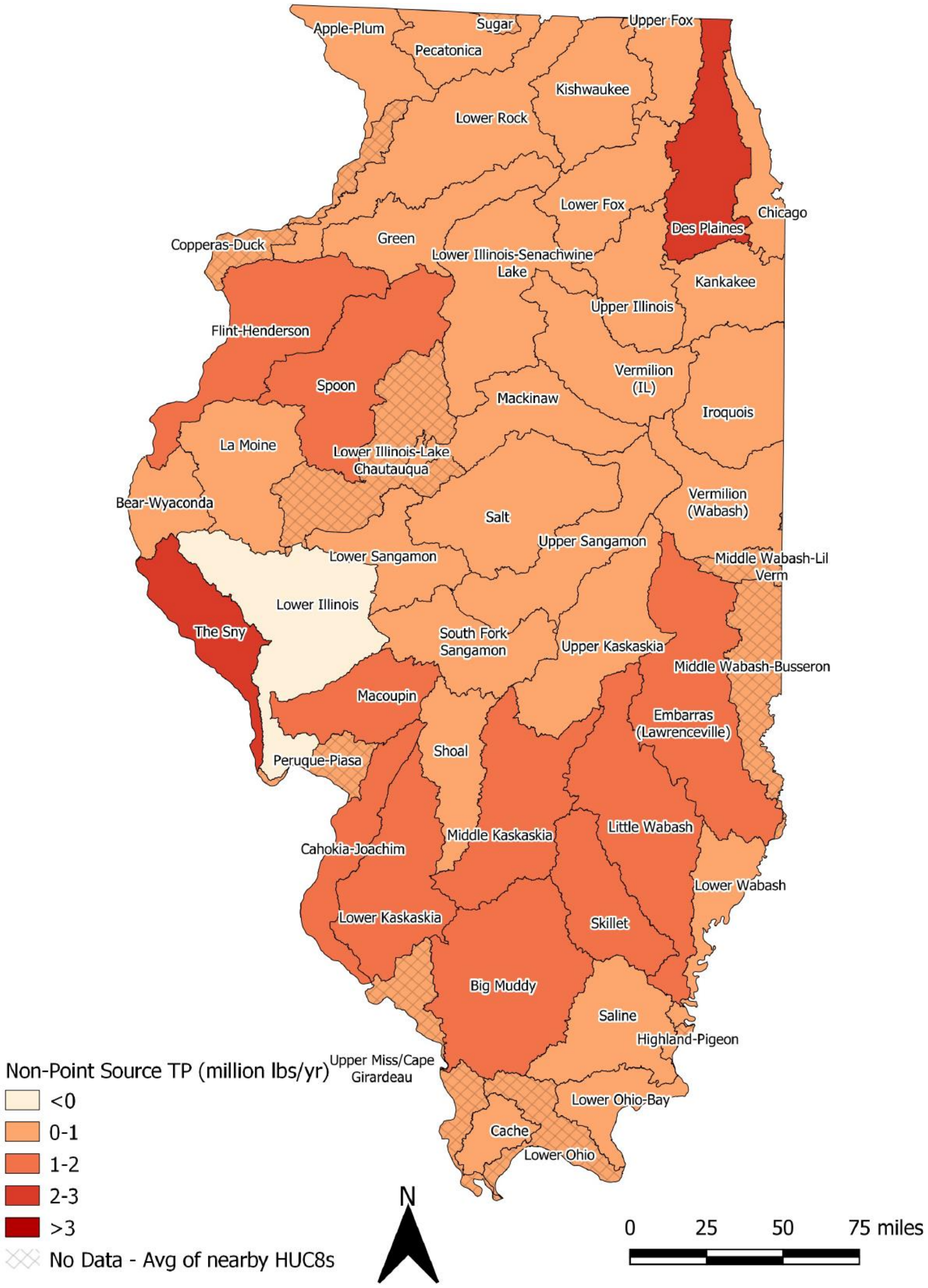

Figure 24. Estimated annual average 2012-17 non-point source TP loads for HUC-8s using the alternative method.

Recommendations for Improving Future Nutrient Loss Assessments

Improved estimation of nitrate and TP losses at the HUC 8 scale seems to be hampered by 1) relatively low frequency of concentration observations, especially for phosphorus at high flows, 2) lack of concentration and/or flow data for some HUCs; 3) mismatches between HUC areas and monitored drainage areas for some HUCs; and 4) mismatches between location of USGS flow monitoring and IEPA concentration sampling for a few HUCs.

A potential response to the second and third issue would be to expand collection of concentration and flow data at more locations closer to HUC outlets. While such an expansion would provide a more complete picture of nutrient losses at the HUC 8 scale in the future, the lack of historical data would not allow an assessment of changes since the baseline period at the new monitoring locations.

An additional strategy for improving and spatially expanding estimates of nutrient loss would be to make greater use of geographic information systems (GIS) to identify and quantify relationships between nutrient loads in monitored drainage areas to land use, soils and other watershed characteristics, and then use these relationships to estimate nutrient loads from unmonitored areas. Watershed models such as SWAT and SPARROW may be useful in this regard. Accurate implementation of this approach will require some improvements in the accuracy of the point source discharges and outfall locations.

Riverine concentration and flow data from the 1980s and 1990s at specific locations are highly valuable for assessing changes in nutrient losses over time. Significantly changing locations of monitoring stations would compromise our ability the quantify changes over time. Increasing the frequency of sampling at existing monitoring locations would seem to more quickly produce greater value at lower cost than relocating or expanding the number of monitoring locations.

Load estimates are most reliable when concentration and flow are measured at the same river location. Expanding or relocating sampling to coincide with USGS flow monitoring would likely be beneficial for estimating loads for the South Fork of the Sangamon River, the Illinois River at Kingston Mines, and Bay Creek at Pittsfield.

Focusing on HUC-8s may obscure conservation priorities and opportunities at smaller scales. For instance, nitrate-N yields for Big Bureau Creek, Spring Creek and the Embarras River at Camargo are among the highest in the state, but they are located within HUCs with relatively low yields. Small watersheds with high quality monitoring data may provide better opportunities to demonstrate reductions in nutrient loads resulting from changes in management practices than do larger HUCs where estimation of loads involves greater uncertainty due to approximations and extrapolations from monitoring data.

At the Ambient Water Quality Monitoring Network locations, IEPA collects water samples approximately 9 times per year. Estimating TP yields with this data often led to large flux bias estimates in WRTDS because limited and erratic concentration observations at high flow. Concentrations at high flow are highly influential in load estimation, but a small number of samples at high flow creates a high degree of uncertainty in the overall load estimate. This is illustrated below using relatively high frequency sampling (~50 samples per year) by the University of Illinois (Lowell Gentry lab) in the Embarras at Camargo.

Fifty samples per year provides a very good understanding of variation in concentrations over time, and the inclusion of 12 additional river concentration values from USGS, MWRD, FRSG at specific sites also helped improve riverine load estimates at several locations. To improve future assessments of river load, perhaps concentration data from additional organizations (e.g., federal, state, local, NGO) with adequate sampling and laboratory capabilities conforming to standard quality assurance and control procedures might also be included. Capability to collect samples at high flow at USGS flow monitoring locations would be particularly valuable.

Embarras River at Camargo: comparison of two data sets

The Embarras River at Camargo has been sampled approximately 9 times per year by the IEPA since the 1980s as part of its Ambient Water Quality Monitoring Network. It has also been sampled approximately 50 times per year since 1993, with the highest frequency sampling during high flow events, by a UIUC team led by Mark David and Lowell Gentry.

When both IEPA and UICU labs sampled on the same day, similar concentration values were obtained, but it is clear that the UIUC lab captured more variability in TP concentration especially for high concentration events (Figure 16).

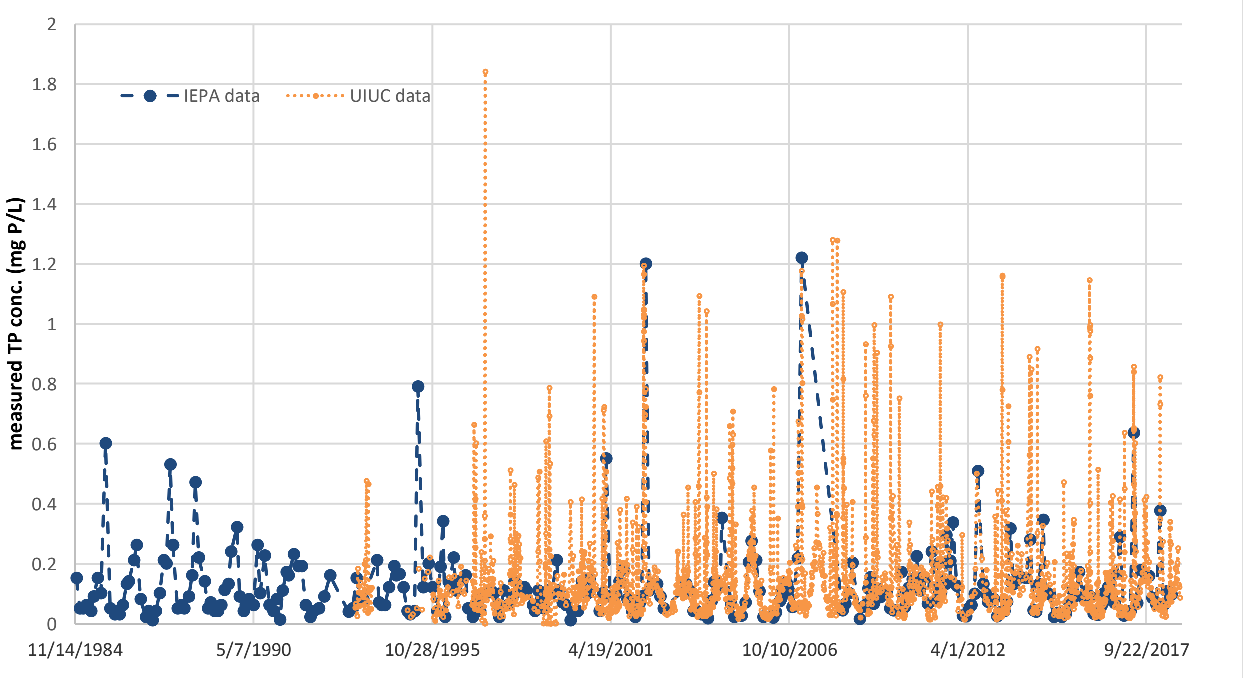

Figure 16. IEPA and UIUC measured TP concentration values at Camargo.

When plotted as a function of the log of daily stream flow (Figure 17), both data sets produce a similar pattern. Polynomial regression produces nearly identical best fit lines. Because the UIUC data captured more high concentration events, it might be expected that using the UIUC concentration data would result in greater estimates of riverine TP load than using the IEPA data, but this was not the case when WRTDS was used to calculate loads. Estimated TP loads from the two data sets were similar from 1994 to 2004 (Figure 18), but after 2004, the IEPA data tended to exceed the load values from the UIUC data. The most extreme divergence in load estimates occurred for 2016, where the load value estimated from the IEPA data was more than twice as large as from the UIUC data. There was little difference in load estimates during years with low flow. WRTDS load estimates can be evaluated with a Flux Bias Statistic, with values between 0.05 and -0.05 considered more reliable than values more divergent from zero. The Flux Bias Statistic for the IEPA data was 0.23, while the value for the UIUC data was 0.0455.

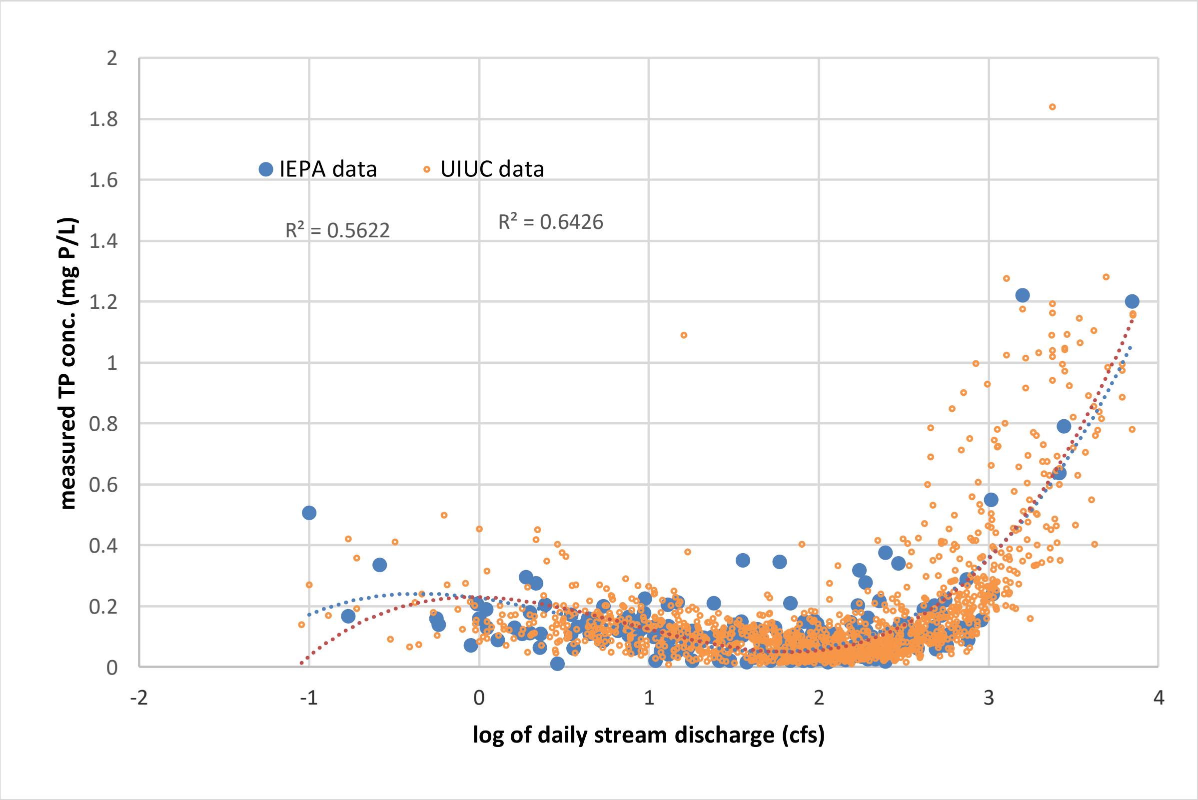

Figure 17. IEPA and UIUC measured TP concentrations at Camargo plotted as a function of the log of daily stream discharge.

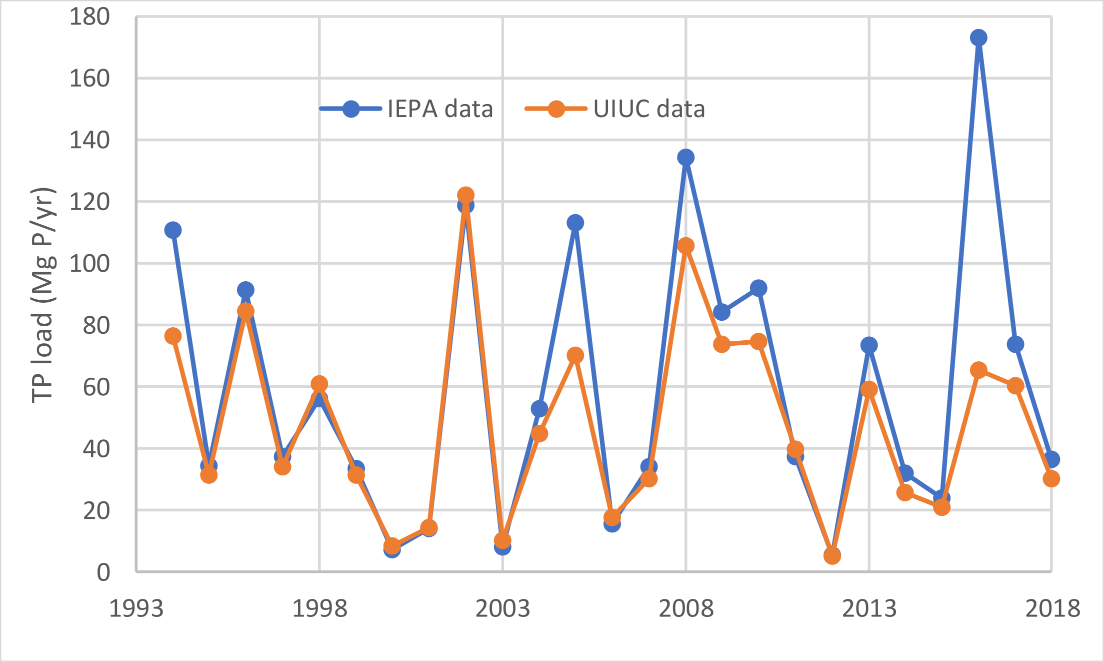

Figure 18. TP Load in the Embarras River at Camargo, estimated with WRDTS with concentration data from IEPA and UIUC.

An examination of the WRTDS daily load estimates indicated that much of the difference between the two estimates for the 2016 water year occurred during a high flow event in late December 2015. IEPA did not collect any samples during this event while the UIUC team collected nine samples, with concentrations ranging from 0.17 to 1.145 mg P/L. With the UIUC data set, the peak WRTDS estimate of daily TP concentration during this event was 1.13 mg P/L.

For the IEPA data set, the WRTDS estimated daily concentrations for this event as high as 4.1 mg P/L, nearly four times greater than the measured values and more than double the greatest concentration measured by either lab in more than 25 years of sampling. This estimate was largely influenced by a concentration of 1.22 mg P/L measured by IEPA on February 26, 2007 when the daily discharge was 1590 cfs. This was an unusually high concentration at this discharge, but not necessarily inaccurate because the UIUC team had measured a few greater concentrations in this discharge range (Figure 16). The IEPA concentration represented only one point in a wide range of concentration values at high flow. Within the IEPA data set, this observation became highly influential at high flows because it was one of only five concentrations recorded at flows greater than 1000 cfs, while the UIUC team recorded 133 concentrations at flows greater than 1000 cfs. Daily stream flows greater than 1000 cfs at Camargo are disproportionately influential in annual loads, and more than 10% of the samples analyzed for TP in the UIUC data set were collected at flows greater than 1000 cfs, while fewer than 2% of the samples in the IEPA data set were collected at flows greater than 1000 cfs.

Removing the Feb 26, 2007 concentration value from the IEPA data set results in considerable convergence in WRTDS load estimates (Figure 19) from the two datasets as well as a large reduction in the Flux Bias Statistic for the IEPA data to 0.023.

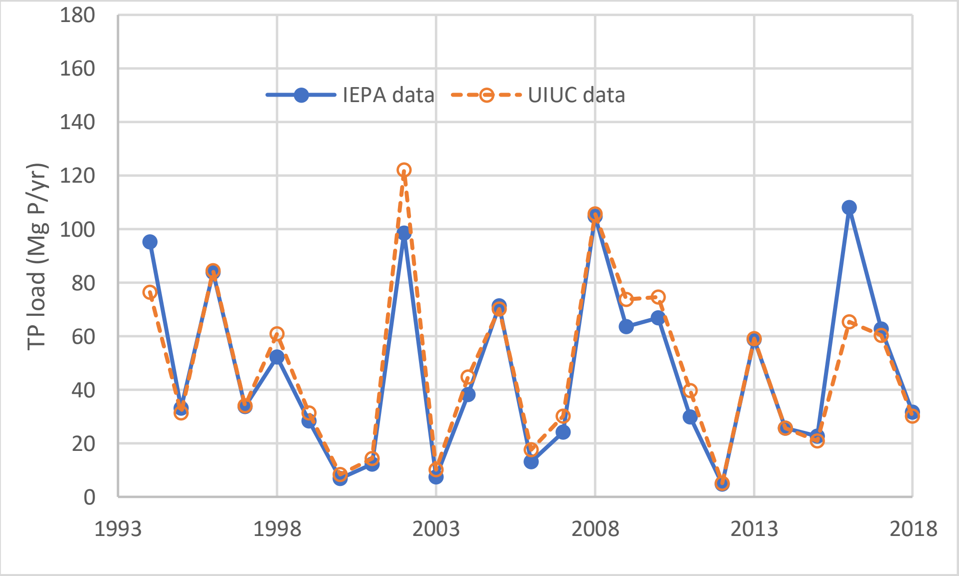

Figure 19. Riverine TP loads in the Embarras River at Camargo estimated using the WRTDS and concentration data from IEPA and UIUC after removing the February 26, 2007 concentration value from the IEPA data.

Even though WRTDS provides some capability of estimating loads with infrequent concentration values, more frequent sampling, especially at high flows, contributes to more reliable estimates of P load. Alternative methods for calculating loads, especially for smaller watersheds, may provide more accurate estimates, although this requires further investigation.

Background Literature

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Appendix 1. USGS and IEPA monitoring locations used for estimating nitrate-N and TP yields for HUC8s.

IL HUC 8			USGS Stations			IEPA Stations		Other conc. data source
		Area in IL		Drainage Area			Drainage Area	
ID #	Name	(sq. mi.)	ID #	(sq. mi)	% of IL HUC	ID	(sq. mi.)	
05120109	Vermilion (Wabash)	1292	03339000	1290	93	BP-01	1188	USGS
05120112	Embarras (Lawrenceville)	2436	03346500	2333	96	BE-01	2,403	
05120113	Lower Wabash	652	03378000	228	35	BC-02	228	
05120115	Skillet	1062	03380500	464	44	CA-05	464	
07110004	The Sny	997	05512500	39.4	4	KCA-01	161	
05140204	Saline	1177	03382100	147	12	ATH-05	147	
07060005	Apple-Plum	850	05419000	246	29	MN-03	181	
07080104	Flint-Henderson	1771	05469000	432	24	LD-02	430	
07090003	Pecatonica	724	05435500	1326	183	PW-08	226	
07090006	Kishwaukee	1215	05440000	1099	90	PQ-12	1062	
07090007	Green	1129	05447500	1003	89	PB-04	989	USGS
07110001	Bear-Wyaconda	614	05495500	349	57	KI-02	349	
05140203	Lower Ohio-Bay	609	03384450	42.9	7	AK-02	42.9	
07120005	Upper Illinois	1006	05542000	455	45	DV-04	455	
07130002	Vermilion (IL)	1333	05555300	1251	94	DS-07	1251	
07130004	Mackinaw	1149	05568000	1073	93	DK-12	1092	
07130005	Spoon	1865	05570000	1636	88	DJ-08	1636	
07130007	South Fork Sangamon	1170	05576000	867	74	EO-01 & EO-02 & EO-03	870 & 562	
07130009	Salt	1867	05582000	1804	97	EI-02	1804	
07130010	La Moine	1349	05585000	1293	96	DG-01	1293	
07130012	Macoupin	975	05587000	868	89	DA-06	868	
07140101	Cahokia-Joachim	854	05587900	212	25	JQ-05	212	
07140106	Big Muddy	2385	05599490	2159	91	N-12	2169	USGS
07140108	Cache	365	03612000	244	67	AD-02	244	
07140201	Upper Kaskaskia	1569	05592100	1330	85	O-10	1330	
07140203	Shoal	916	05594000	735	80	OI-08	735	

Appendix 1 (continued). USGS and IEPA monitoring locations used to estimate nitrate-N and TP yields for HUC 8s with multiple monitoring locations.

IL HUC 8			USGS Stations			IEPA Stations		Other conc. data sources
		Area in IL		Drainage Area			Drain. Area	
ID #	Name	(sq. mi.)	ID #	(sq. mi)	% of IL HUC	ID #	(sq. mi.)	
05120108	**Middle Wabash-Little Vermilion**	**205**	**Average of Vermilion (Wabash) and Embarras at Camargo**					
05120109	Vermilion (Wabash)	1292	03339000	1290	100	BP-01	1188	USGS
	Embarras at Camargo	183	03343400	183	100	BE-14	183	U of IL.
05120114	**Little Wabash**	**2142**	**Little Wabash River minus Skillet Fork**					
05120114	Little Wabash River at Carmi		03381500	3102		C-23	3088	USGS
05120115	Skillet Fork R. at Wayne City		03380500	464		CA-05	464	
	net area			**2638**	**123**			
07090005	**Lower Rock**	**2149**	**Rock at Joslin minus Rock at Rockton and Kishwaukee**					
	Rock at Joslin		05446500	9549		P-04	3934	USGS
	Rock at Rockton		05437500	6363		P-15	806	
	Kishwaukee		05440000	1099		PQ-12	1062	
	Difference			**2087**	**97**			
07120001	**Kankakee**	**881**	**Kankakee at Wilmington minus Kankakee at Momence and Iroquois at Chebanse**					
	Kankakee at Wilmington		05527500	5150		F-01 & F-16	5150	
	Kankakee at Momence		05520500	2294		F-02	2294	
	Iroquois at Chebanse		05526000	2091		FL-02	2091	
	difference			**765**	**87**			
07120002	**Iroquois**	**1272**	**Iroquois at Chebanse minus Iroquois at Iroquois**					
	Iroquois at Chebanse		05526000	2091		FL-02	2091	
	Iroquois at Iroquois		05525000	686		FL-04	686	
	Difference			**1405**	**110**			

Appendix 1 (continued). USGS and IEPA monitoring locations used to estimate nitrate N and TP yields for HUC 8s.

IL HUC 8			**USGS Stations**			**IEPA Stations**		**Other conc. data sources**
		Area in IL		**Drainage Area**			**Drain. Area**	
ID #	**Name**	**(sq. mi.)**	**ID #**	**(sq. mi)**	**% of IL HUC**	**ID #**	**(sq. mi.)**	
07120003	**Chicago**	592	**Weighted Average of North Branch Chicago R and Thorn Creek**					
	N. Br. Chi. River		05536000	100		HCC-07	100	MWRD
	Thorn Creek		05536275	104		HBD-04	104	MWRD
	Total			**204**	**34%**			
07120004	**Des Plaines**	**1308**	**DesPlaines at Joliet minus DesPlaines at Russell plus DuPage at Shorewood minus the Chicago HUC.**					
	Des Plaines at Joliet		05537980	1502		G-23	1502	
	Des Plaines at Russell		05527800	123		G-08	123	
	DuPage at Shorewood		05540500	324		GB-11	324	
	Chicago HUC	592		**673**			**673**	
	Net			**1030**	**79%**		**1030**	
07120006	**Upper Fox**	**606**	**Fox at South Elgin minus Fox at Channel Lake (IEPA) and New Munster WI (USGS)**					
	Fox at South Elgin		05551000	1556		DT-09	1556	FRSG
	Fox at New Munster, WI and Channel Lake		05545750	811		DT-35	871	
	Difference			**745**	**123%**		**685**	
07120007	**Lower Fox**	**1103**	**Fox at Dayton minus Fox at South Elgin**					
	Fox R at Dayton (USGS) Ottawa (IEPA)		05552500	2642		DT-01	2642	
	Fox at South Elgin		05551000	1556		DT-09	1556	FRSG
	Difference			**1086**	**98%**			

Appendix 1 (continued). USGS and IEPA monitoring locations used to estimate nitrate N and TP yields for HUC 8s.

IL HUC 8			USGS Stations			IEPA Stations	
		Area in IL		Drainage Area			Drainage Area
ID #	Name	(sq. mi.)	ID #	(sq. mi)	% of IL HUC	ID #	(sq. mi.)
07130001	**Lower Illinois-Senachwine Lake**	**1960**	**Downstream conc. at Pekin x (IL R. flow at Kingston Mines minus Mackinaw River flow at Greenview); minus IL R. at Marseilles, Fox River at Dayton and Vermilion River at Leonore**				
	IL R. at Kingston Mines minus Mackinaw R (USGS) and conc at Pekin (IEPA)		5568500	14745		D-05	14585
	Illinois River at Marseilles		05543500	8259		D-23	8259
	Fox R at Dayton (USGS) Ottawa (IEPA)		05552500	2642		DT-01	2642
	Vermilion River at Leonore		05555300	1251		DS-07	1251
	Net			**2593**	**132%**		
07130006	**Upper Sangamon**	**1441**	**Sangamon at Riverton minus South Fork of Sangamon**				
	Sangamon at Riverton		05576500	2618		E-26	
	South Fork Sangamon		05576000	867		EO-01 & EO-02 & EO-03	870 & 562
				1751	**122%**		
07130008	**Lower Sangamon**	**892**	**Sangamon at Oakford minus Sangamon at Riverton and Salt Creek at Greenview**				
	Sangamon at Oakford		05583000	5093		E-25	5093
	Sangamon at Riverton		05576500	2618		E-26	2618
	Salt Creek at Greenview		05582000	1804		EI-02	1804
	net area			**671**	**75%**		

Appendix 1 (concluded). USGS and IEPA monitoring locations used for estimating nitrate and TP yields for HUC 8s.

IL HUC 8			**USGS Stations**			**IEPA Stations**		**Other conc. data sources**
		Area in IL		**Drainage Area**			**Drainage Area**	
ID #	**Name**	**(sq. mi.)**	**ID #**	**(sq. mi)**	**% of IL HUC**	**ID**	**(sq. mi.)**	
07130011	**Lower Illinois**	**2273**	**IL River at Hardin minus IL River at Valley City minus Macoupin Creek**					
	IL River at Hardin		05587060	28690		D-01	28690	
	IL River at Valley City		05586100	26743		D-32	26743	
	Macoupin Creek		05587000	868		DA-06	868	USGS
	net area			**1079**	**47%**			
07140202	**Middle Kaskaskia**	**1718**	**Kaskaskia at Venedy Station minus Kaskaskia at Cowden**					
	Kaskaskia at Venedy Station		05594100	4393		O-20	4393	
	Kaskaskia at Cowden		05592100	1330		O-10	1330	
	Net			**3063**	**178%**			
07140204	**Lower Kaskaskia**	**1606**	**Weighted average of Richland Creek and Silver Creek**					
	Richland Creek		05595200	129		OC-04	129	
	Silver Creek		05594800	464		OD-07	464	
	total			**593**	**37%**			

Appendix 2. HUC 8s for which water and nutrient yields were estimated from neighboring HUCS due to lack of adequate monitoring data within the HUC.

IL HUC 8		**Area in IL**	**Basis of water and nutrient yield estimates**
ID #	**Name**	**(sq. mi.)**	
04040002	Pike-Root		None (Lake Michigan drainage)
04940001	Little Calumet-Galien		None (Lake Michigan drainage)
05120108	Middle Wabash-Little Verm	205	Avg. of Embarras (Camargo) and Vermilion (Wabash)
05120111	Middle Wabash-Busseron	888	Equal to Embarras (Lawrenceville)
05140202	Highland-Pigeon	27.5	Equal to Saline
05140206	Lower Ohio	622	Avg. of Cache, Saline, Big Muddy and Lower Ohio-Bay
07080101	Copperas-Duck	509	Avg. of Flint-Henderson, Lower Rock and Apple-Plum
07090001	Upper Rock	7	Rock at Rockton minus Pecatonica
07090004	Sugar	63	Equal to Pecatonica
07110009	Peruque-Piasa	329	Avg. of Macoupin and Cahokia-Joachim
07130003	Lower Illinois-Lake Chautauqua	1623	Avg. of Lamoine, Spoon, Lower Sangamon, Mackinaw, Lower IL Senachwine, Lower Illinois
07140105	Upper Miss/Cape Girardeau	727	Avg. of Big Muddy, Cache and Lower Kaskaskia

Appendix 3. Treatment of unusual concentration values.

Big Muddy River at Murphysboro station N-12

04/12/1988 two nitrate concentrations were recorded: 0.13 and 12 mg N/L. The value of 12 would be at least 5 times greater than any other sample concentration at this site. The value of 0.13 mg N/L was used. Most values at this site are less than 1.0 mg N/L.

05/02/1984 two nitrate concentration samples were recorded: 2.3 and 0.32 mg N/L. Flow was relatively high (6420 cfs). If the 12 mg N/L sample on 4/12/1988 is discarded as an error, the concentration of 2.3 would be the highest sample concentration sample recorded at this site. The value of 0.32 mg N/L was initially used for calculating the baseline load for the NLRS. However, in reconsidering this, there were four other samples in the range from 1.67 to 1.88 mg N/L and all occurred during May and June. Three of the four occurred at flows greater than 1000 cfs. Since 2015, the continuous nitrate probes have detected nitrate concentrations greater than 2.0 on three occasions including one event where concentrations exceeded 4.5 mg N/L. Thus, the value of 2.3 mg N/L now seems more plausible, and the value of 0.32 might be in error. Using the value of 2.3 mg N/L increases the 1984 annual load by a factor of 2, and increases the 1980-96 baseline load from the Big Muddy by 9%.

The Big Muddy contributes only about 0.5% of nitrate in the statewide nitrate load, so a 9% increase in the Big Muddy baseline load would represent about a 0.05% increase in the state baseline load, which would be lost in the rounding error.

Shoal Creek near Breeze station OI-08

05/23/2017 nitrate concentration recorded as 4.78 mg N/L, which is the highest on record for this site. The previous high was 3.3 mg N/L and the vast majority of concentrations at this site are less than 2.0 mg N/L. However, the 4.78 mg N/L sample and the 3.3 mg N/L value were collected at moderately high flows (1520 cfs and 1260 cfs, respectively). The value was included in the load calculations and 2017 has the highest flow weighted concentration in the record.

Little Wabash at Carmi

05/17/2016 nitrate concentration of 10.4 reported by the USGS is more than two times greater than any sample concentration reported at this station since 1977. On 5/16/2016 USGS reported a concentration of 1.15 mg N/L. On 5/18/2016 IEPA reported a concentration of 1.26 mg N/L. The USGS value of 10.4 on 5/17/2016 was discarded.

Rock River at Joslin

02/07/2006 nitrate concentration of 9.78 mg N/L is the highest value on record going back to 1974. The second highest value is 7.8. Most values are below 6.0. When plotted as a function of flow, it still appears to be an outlier. It is included in the current load calculations.

South Fork of Saline River

6/16/2011 nitrate concentration of 2.31 mg N/L was recorded. This is nearly twice as large as the next highest value (1.31). Most values were less than 0.5. In October and December of 2011 values of approximately 1.30 mg N/L were recorded. This led to unusually high nitrate N yields in 2011 and 2012: 4 and 3 kg N/ha-yr. All other years were less than 2 kg N/ha.

Pecatonica River at Freeport

1/25/2006 nitrate concentration of 9.74 was recorded at 405 cfs. The next highest concentration was 8.02, but this occurred at 1400 cfs. At 400 cfs the next highest concentration was less than 7 mg N/L.

Mazon River at Coal City

5/23/2012 nitrate concentration of 28 mg N/L was reported at 600 cfs. When plotted as a function of discharge, it appears in the same range where the higher concentrations are observed. The next highest concentration at this location is 19 mg N/L.

Kankakee River at Momence

Most nitrate concentrations at this site are less than 3 mg N/L and all IEPA concentrations are less than 6 mg N/L except for three:
6/27/2016 8.77 mg N/L

1/15/2013 15.3 mg N/L

05/24/1999 11.0 mg N/L

All other IEPA concentrations at this site are highly correlated with the log of discharge (r-square = 0.46), but these three outliers are much larger than the expected concentrations at the sampled discharge. The outliers may be decimal point errors. If the decimal point is moved one place to the left, the resulting concentrations are within the range of expected concentrations for the discharge at the time of sampling.

USGS reported a concentration of 7.48 mg N/L on 6/1/2000, which is also considerably greater than sample concentrations observed at similar flow values. This may be an erroneous value, or all of these values may be an indication that there are occasionally erratically high nitrate concentrations in this river. A compromise position would be to accept two lower values, but scale the two higher values back by a factor of 10, which is the approach I used.

DesPlaines River at Joliet

A value of 12.9 mg N/L was reported on 04/09/2013. The next highest value since 1995 is 10.0. Most values are less than 8. When plotted as a function of discharge, the 12.9 value appears to be more that twice as large as the average value for the daily discharge.

DesPlaines River at Russell

A value of 23.1 mg N/L was reported for 02/01/2006. All other values were less than 10 and most were less than 5. An annual load for the 2006 water year was not calculated because there were only 6 sample values for that year.

DuPage River at Shorewood

The highest concentration reported at this site was 15.6 mg N/L on 01/23/2006. The second highest concentration was 12.6 but the vast majority of concentrations are less than 10. Concentrations are highly correlated with flow and most concentrations at the measured flow on 01/23/2006 were about half of the observed concentration.

The lowest concentration reported at this site was 0.47 mg N/L on 07/18/2008. The second lowest concentration was 1.24. Concentrations at the flow observed on 07/18/2008 mostly ranged from 4 to 10 mg N/L. There were only two sample concentrations reported in the 2008 water year and consequently an annual load for 2008 was not calculated.

Bear Creek near Marcelline

The two highest nitrate concentration reported at this site were 16.1 mg N/L on 4/3/2017 and 12.2 on 5/12/2016. All other concentrations were less than 7.1. The two highest values occurred on days with 220 and 206 cfs flow. The next four highest concentrations, ranging from 7.04 to 6.27 mg N/L, occurred in a similar range of flows (69 to 374 cfs).

The greatest TP concentration (2.28 mg P/L) at this site occurred on July 8, 2014. The value was flagged with a QA/QC code of J3 (The reported value failed to meet the established quality control criteria for either precision or accuracy possibly due to matrix effects). Removing this value substantially reduced the Flux Bias Statistic, so this value was not included in the analysis.

Illinois River at Valley City

The three lowest TP concentration values are suspect.

Date	DRP	TP	Agency
1/4/1984	ND	0.02	USGSILWC
4/4/2005	0.215	0.063	IL-EPA
6/10/1997	0.17	0.11	USGSILWC

The TP concentrations reported on 4/4/2005 and 6/10/1997 are less than the DRP values which is not physically possible. The value of 0.02 mg P/L reported on 1/4/1984 is less than one fifth of the next lowest reliable reported concentration (0.12 mg P/L). When these three concentrations were removed, the flux bias statistic of the WRTDS model was considerably reduced. Consequently, these values were not used in TP load estimates.

Green River near Geneseo

Total P concentrations

4/24/1985	3.09
2/4/1986	2.34
1/20/1988	1.88

These values were removed from the analysis to estimate TP loads for the baseline period. But subsequent monitoring suggests that this watershed may be prone to produce erratically high TP concentrations.

Mackinaw River at Green Valley

On 6/17/1999 a TP value of 0.25 mg P/L was recorded at a flow of 198 cms. This was an unusually low concentration at relatively high flow. When this observation was removed, the flux bias statistic declined from 0.0705 to -0.0105. The average TP yield for 1997-2011 increased from 0.69 to 0.74 lb P/ac, and there was little change in the TP yields for 2009-17. Because there was relatively little change in TP yield, the value was included in the analysis.