Geographic and Annual Variations in Riverine Nitrate and Total Phosphorus Loads in Illinois

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IL Nutrient Loss Reduction Strategy
Multi-agency collaboration
Long term goal: reduce nitrate and total phosphorus loads by 45%
2025 goals: reduce nitrate by 15% and total phosphorus loads by 25%

https://www2.illinois.gov/epa/topics/water-quality/watershed-management/excess-nutrients/Pages/nutrient-loss-reduction-strategy.aspx
My role: Quantifying Nitrate and TP loads statewide and for HUC 8s

Statewide loads based on 8 major river systems

~40 HUC 8s with sufficient flow and concentration data for load estimation

Point source discharges also reported by HUC 8

HUC 8 Nitrate-N yields 1997-2011 (NLRS 2015)
River Load Calculation Methods

Load \( (\text{lb/yr}) = \text{water flow (volume/time)} \times \text{concentration (mass/volume)} \)

Yield \( (\text{lb/ac-yr}) = \frac{\text{Load}}{\text{drainage area}} \)

USGS provides daily water flow
IEPA and USGS provide sample concentrations approximately monthly

Daily Load = daily water flow \( \times \) _estimated_ daily concentration

Daily concentrations estimation methods
Nitrate: Linear Interpolation over time between measured samples
Phosphorus: Weighted Regressions on Time, Discharge and Seasonality (WRTDS)
## Statewide Results: Riverine Flow and Loads

<table>
<thead>
<tr>
<th></th>
<th>1980-96 baseline</th>
<th>2013-17</th>
<th>% change from 1980-96</th>
<th>2014-18</th>
<th>% change from 1980-96</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Yield (in/yr)</td>
<td>13.0</td>
<td>14.7</td>
<td>+13%</td>
<td>14.1</td>
<td>+9%</td>
</tr>
<tr>
<td>Nitrate-N Load (Million lb N/yr)</td>
<td>397</td>
<td>425</td>
<td>+7%</td>
<td>378</td>
<td>-5%</td>
</tr>
<tr>
<td>Total P Load (Million lb P/yr)</td>
<td>34</td>
<td>43</td>
<td>+26%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Statewide Point Source Discharges

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2017*</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total N</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Million lb N/yr)</td>
<td>87.3</td>
<td>75.0</td>
<td>-14%</td>
</tr>
<tr>
<td># of facilities incl.</td>
<td>392</td>
<td>898</td>
<td></td>
</tr>
<tr>
<td><strong>Total P</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Million lb P/yr)</td>
<td>18.0</td>
<td>14.1</td>
<td>-22%</td>
</tr>
<tr>
<td># of facilities incl.</td>
<td>1660</td>
<td>1371</td>
<td></td>
</tr>
</tbody>
</table>

*2011 discharge data was used for facilities included in the NLRS estimate, for which 2017 data was unavailable.

Cooling water discharge not included in 2017

Note that we do not have point source discharge data during the 1980-96 baseline period. Riverine load increases in the previous slide were relative to the baseline period and are not directly comparable to these decreases. Statewide riverine NO3-N loads in 2017 were 5% lower than in 2011 and 2017 TP loads were 6% lower than in 2011.
Statewide annual water yield
annual, 5 year moving average, and 1980-96 average

water yield (in/yr)
water yield 1980-96 avg. 5 per. Mov. Avg. (water yield)
Statewide average precipitation and water yield 1980-2019

Water yield (in/yr)

Precipitation (in/yr)

5 yr avg water yield

5 yr avg precip
Statewide estimates of annual nitrate loads (black), water yield (blue), 1980-96 baseline average (solid red line), and five year moving average values (dashed lines). Point sources quantified in 2011 and 2017.
% Changes in water flow from 1980-96 for major rivers in Illinois
Rock River between Rockton and Joslin
HUC-8 Challenges
Drainage areas of the monitoring locations do not match HUC boundaries.

Extrapolating from monitored area to HUC area introduces uncertainty and probability of inaccurate estimates

For 16 HUCs, monitored drainage area is between 85% and 115% of HUC area.

For another 9 HUCs, monitored drainage area is between 65% and 135% of HUC area.

For 15 HUCs, monitored drainage area differs from HUC area by more than 35%.

For 9 HUCS there is no monitoring data

2 HUCs draining to Lake Michigan are ignored
Estimated Average Annual Nitrate-N Yields by HUC (lb N/ac-yr)

1997-2011, NLRS

HUC8 total nitrate-N yield

2012-17 update

Figure 3.12. Total nitrate-nitrogen yields by HUC8 in Illinois.

Aaron Hoyle-Katz, NCSA
Changes in HUC 8 estimation methods for the Lower Sangamon and Lower Illinois-Senachewine Lake

• For NLRS (2015), small tributaries were used as proxies
  • Lower Sangamon: Spring Creek (12% of HUC area)
  • LI-SL: Big Bureau Creek (10% of HUC area)

• For 2012-17 Update
  • Upstream loads were subtracted from downstream load
  • Negative load estimates occurred in some years possibly due to denitrification
  • Comparison of upstream and downstream concentrations is consistent with denitrification losses
Changes in average annual Nitrate-N Yield vs Change in Water Yield from 1997-2011 to 2012-17

R² = 0.1081
R² = 0.7529

-8.0
-6.0
-4.0
-2.0
0.0
2.0
4.0
6.0

change in Nitrate-N yield (lb/ac-yr)

-3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0

change in average water yield from 1997-2011 to 2012-17 (in/yr)

1997-2011 Nitrate-N yield <13.6
1997-2011 Nitrate-N yield > 13.6

Henderson Creek Oquawka
Des Plaines
Russell
Mackinaw
Thorn Cr. Chicago
Richland Cr. Heckler
Mackinaw River at Green Valley (05568000) and South Pekin (DK-12)
Annual nitrate yield vs annual water yield 1996-2006 vs 2009-2017 water years

1996-2006
\[ y = 2.738x - 3.0812 \]
\[ R^2 = 0.9673 \]

2009-2017
\[ y = -0.1124x^2 + 4.0106x - 10.472 \]
\[ R^2 = 0.7551 \]

Similar patterns occurred for the Spoon River and Henderson Creek
Statewide total point source discharge: 75 million lb N/yr
(~18% of statewide riverine nitrate-N load)

Des Plaines HUC: 32.2 Million lb N/yr
Chicago HUC: 14.4 Million lb N/yr
Total = 46.6 Million lb N/yr
(62% of state total point source N)
Total Phosphorus (TP) Loads
Statewide estimates of annual TP loads (green), water yield (blue), 1980-96 baseline average (solid red line), five year moving average values (dashed lines) point-source loads were quantified in 2011 and 2017.
Changes in Riverine TP Loads from 1980-96 to 2013-17 for major rivers draining Illinois
Total P yield by monitored drainage area 2012-17

Total P yield by HUC 8 2012-17

Aaron Hoyle-Katz NCSA
Changes in TP yield from 1997-2011 to 2012-17 plotted against change in water yield from 1997-2011 to 2012-17. Chicago, Des Plaines, Sangamon Basins are excluded due to high point source inputs. The Sny is excluded due to high uncertainty in yield estimate.

Work in progress.
2017 Estimated **Point Source** Total P Discharge by HUC 8

Statewide 2013-17 TP riverine load: 43 million lb P/yr  
Statewide TP point source load 14.1 million lb P/yr (33%)

**Top 3 HUCs**
- Des Plaines HUC: 4.1 million lb P/yr
- Chicago HUC: 2.9 million lb P/yr
- Upper Sangamon HUC 1.8 million lb P/yr
  
  total 8.8 million lb P/yr  
  62% of statewide point source P
Riverine TP Load for the **Des Plaines River at Joliet** minus Des Plaines at Russell plus DuPage River at Shorewood (Approximately Des Plaines plus Chicago HUCs; Point source load reduction of ~2.3 million lb P/yr from 2011 to 2017)

![Graph showing TP load (Million lb P/yr) from 1997-2011 and 2012-17 with a reduction of 1.3 Million lb P/yr.](image-url)
Summary

• Statewide average riverine nitrate-N and TP load estimates 2013-2017 were 7%, and 26% greater than the 1980-96 baseline period.

• The 2014-18 nitrate-N load estimate was 5% less than the baseline period.

• Loads were generally correlated with water flow.

• 2017 Point-source TP and TN discharge estimates declined 22% and 14% relative to 2011 estimates.

• At the HUC 8 scale, nitrate and TP yields 2012-17 were generally similar to 1997-2011 values, with some exceptions:
  • TP load reductions in Chicago and Des Plaines
  • TP increases in the Upper Sangamon, Macoupin Creek and elsewhere
  • Changes in nitrate-N and TP load were correlated with changes in water flow for HUCs with high nitrate and TP yields
  • Nitrate-N reductions per unit of water yield in the Mackinaw, Spoon and Kaskaskia Rivers and Henderson Creek
Further Study and Action Needed

• Investigate and quantify factors causing and influencing changes in nutrient loads in monitored watersheds
• Evaluate uncertainty, lag times and Climate Change impacts
• Retire HUCs; transition to drainage areas above river monitoring sites
• Extensive conservation measures are needed to achieve the nutrient loss reduction goals
• Increased precipitation and river flow will likely increase the need for conservation
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Thank you!

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Full Science Assessment Update