Monitoring and Modeling of Nutrient & Sediment Loads for Varying Climate & Landscapes

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Champaign, IL

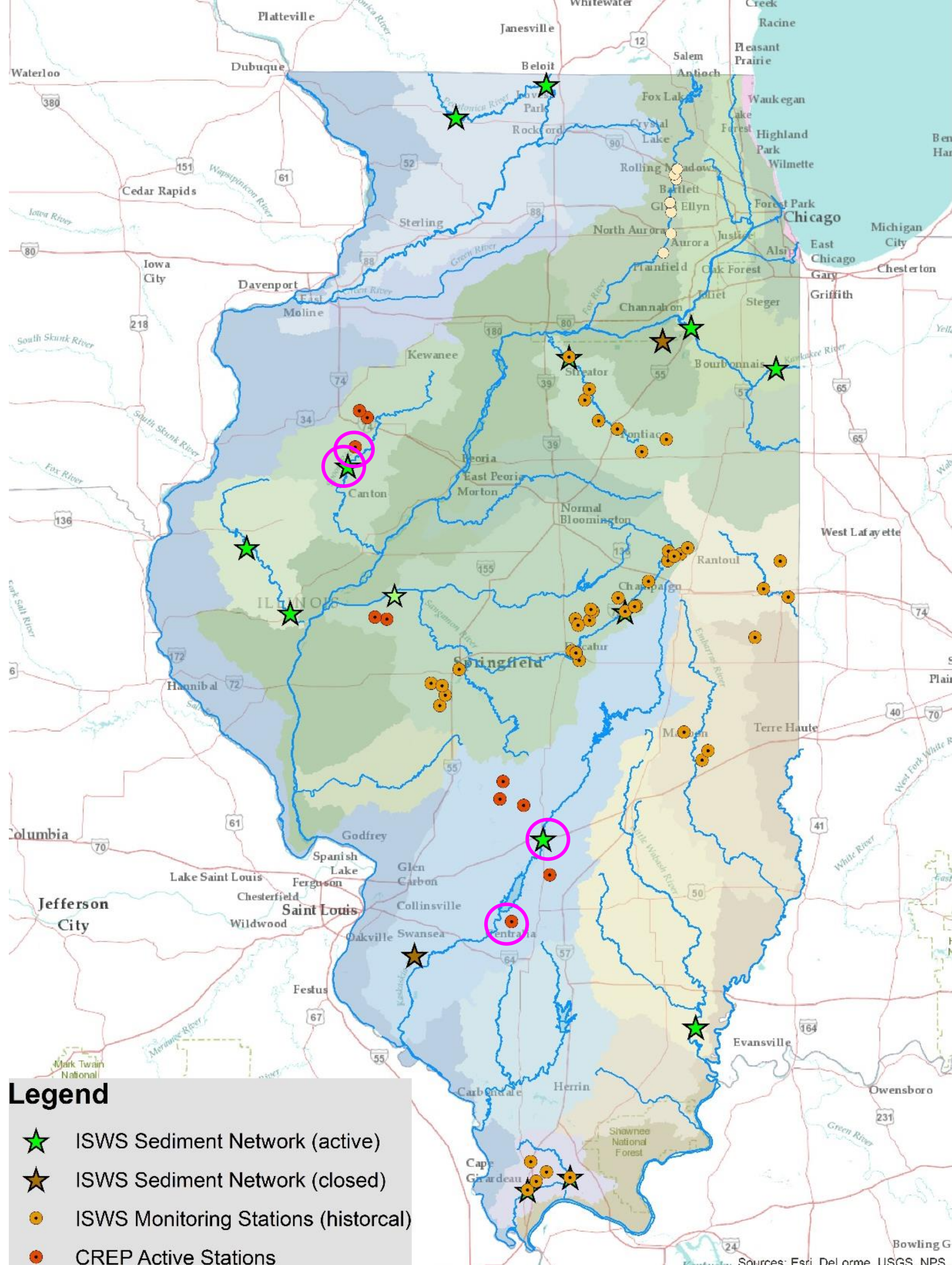
Overview

- ISWS Watershed Data Collection Activities – Laura Keefer
  - What, where and how data is collected
  - Not all watersheds are the same
    - Examples from Illinois River & Kaskaskia River Basins
  - Monitoring for long-term sediment trends
  - Data applied for better modeling…
- Watershed Management Tool (WMT) – Elias Getahun
- Statistical Modeling – Momcilo Markus
  - Development of short- and long-term nutrient predictions
  - How and why to calculate nutrient and sediment loadings

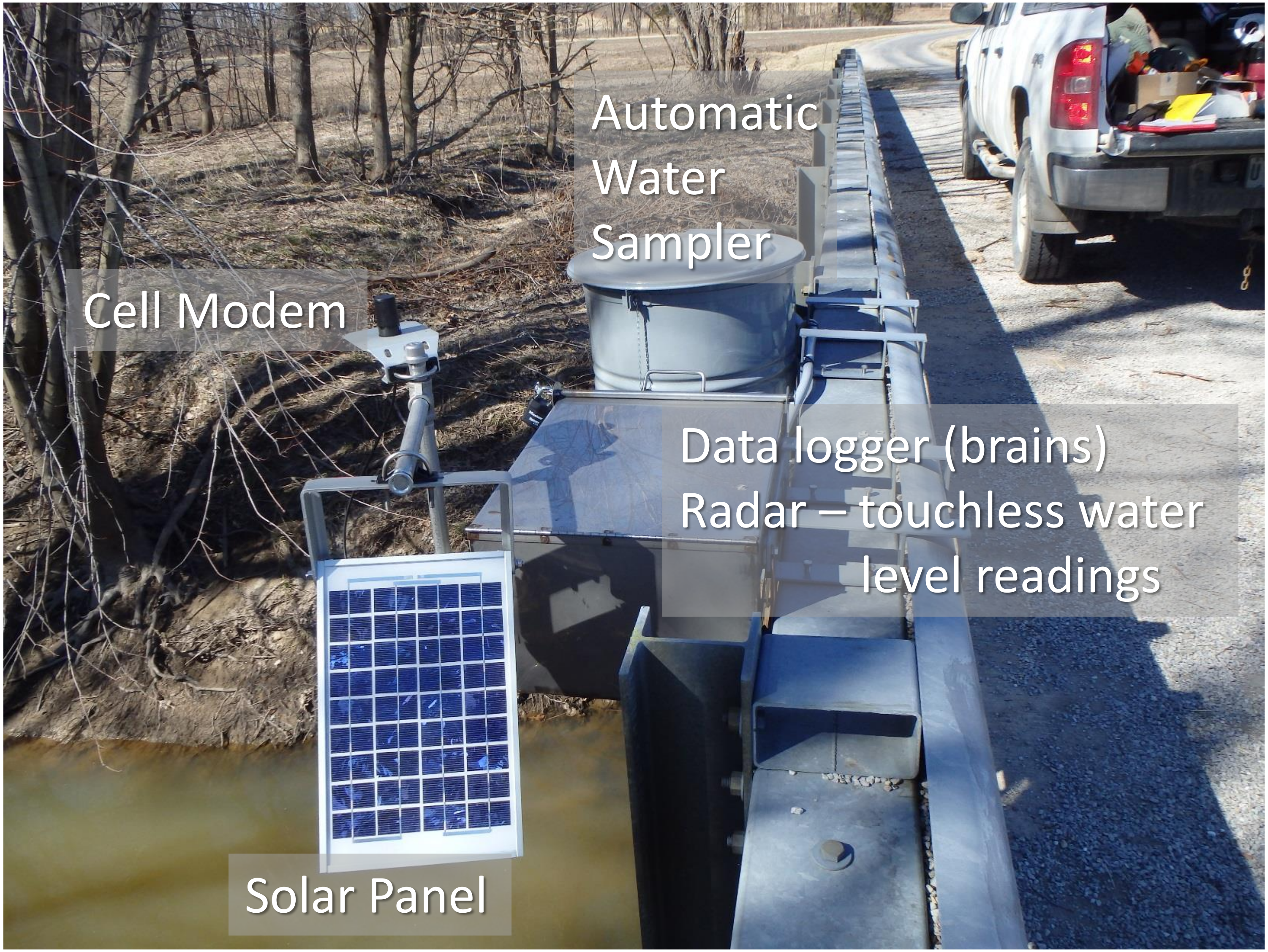
ISWS Monitoring Stations

-since 1980s

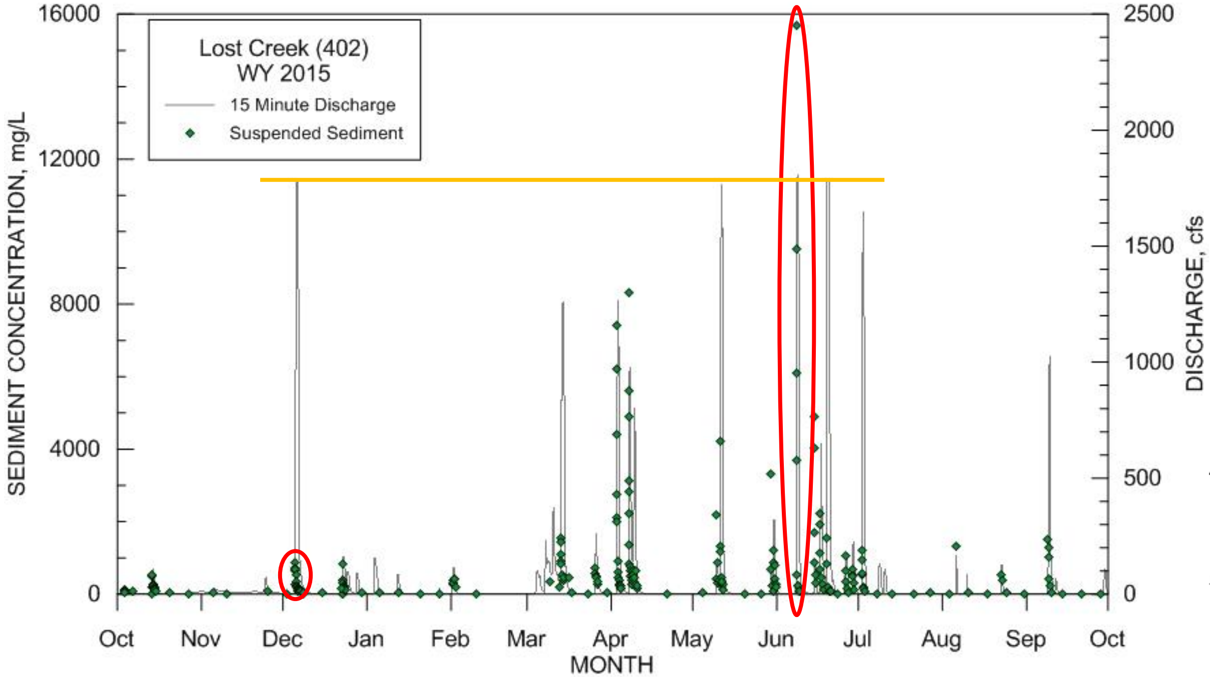
- Investigative:
    - Streamgaging
    - Sediment
    - Nutrient
- ISWS Sediment Network
    - 15 stations (1981-today)



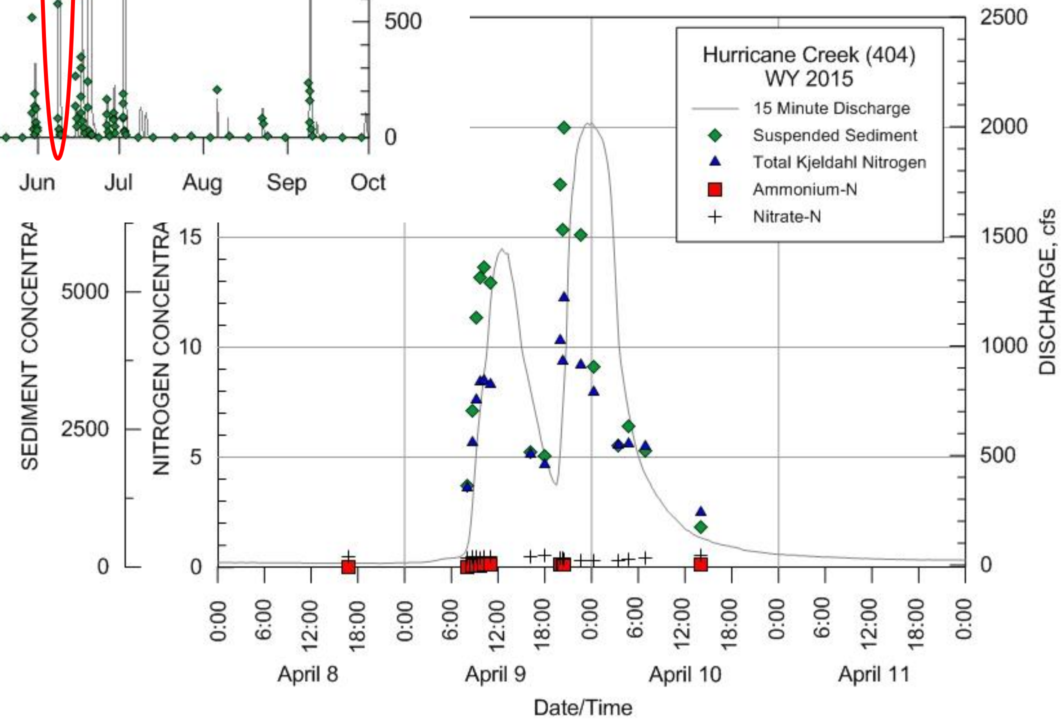
Current ISWS Stations



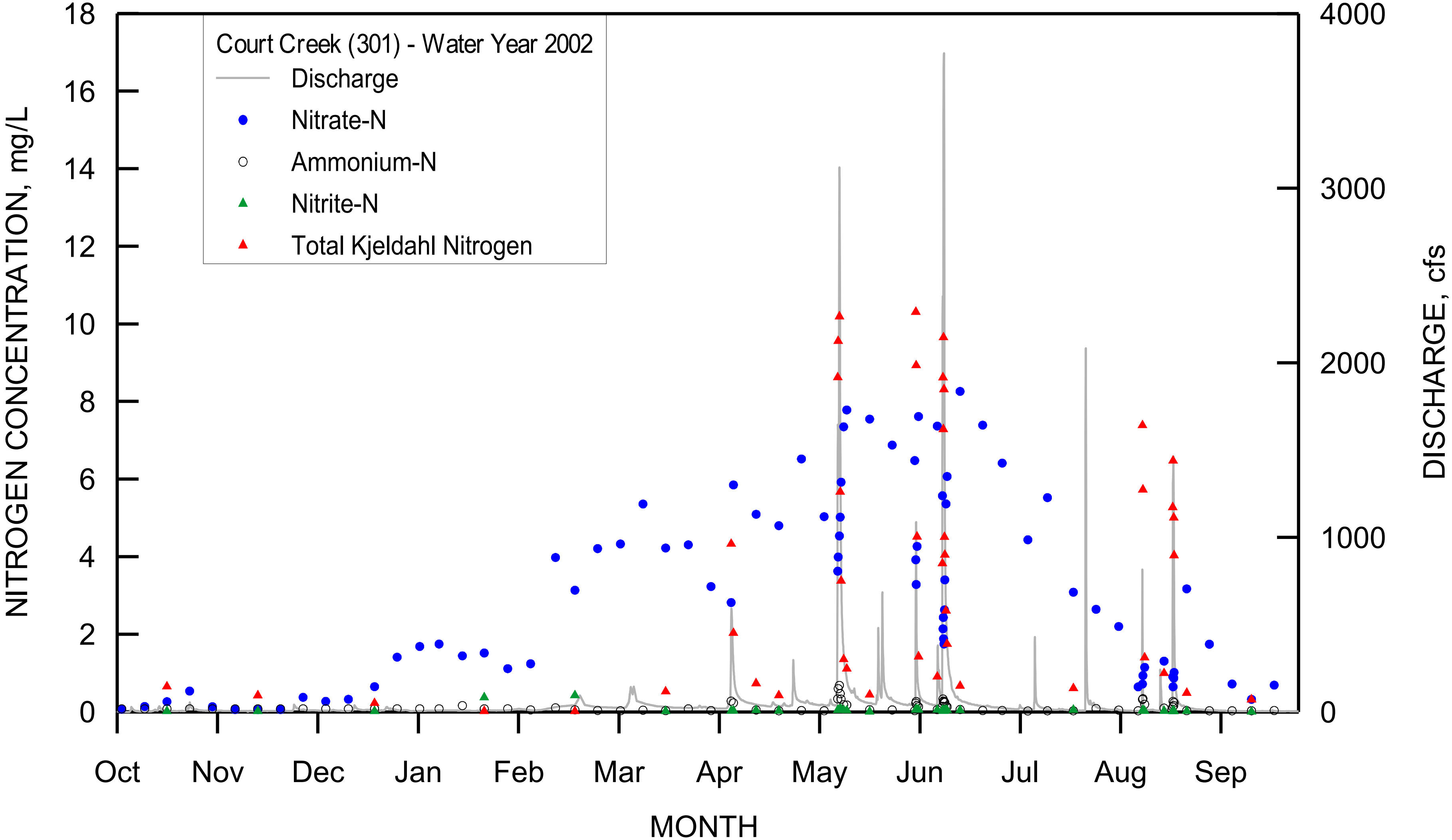
Kaskaskia – nitrogen & sediment sampling



- Weekly samples
- High frequency during flow events



Spoon - Nitrogen



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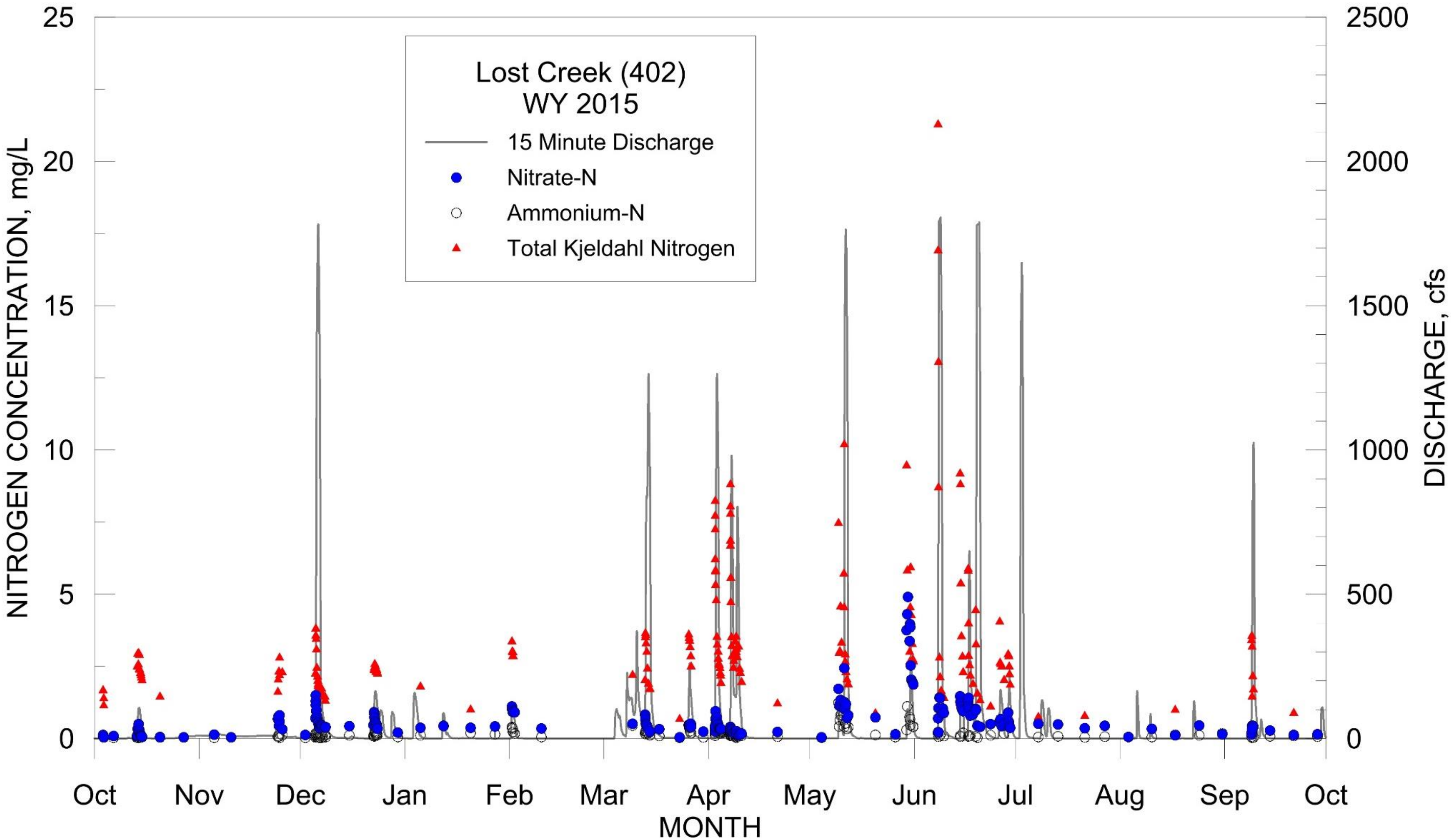
Court Creek (301) - Water Year 2003

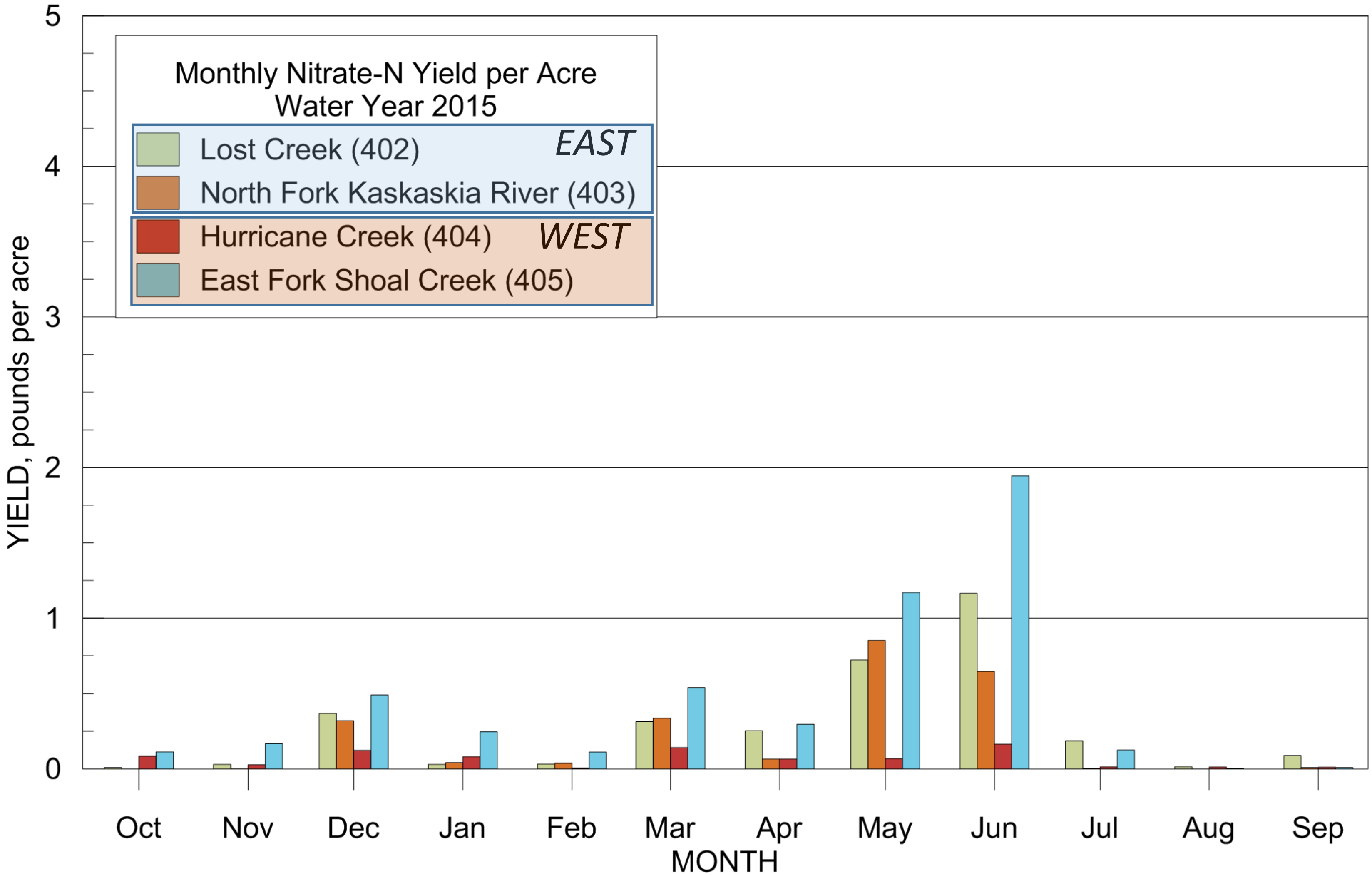
Kaskaskia - Nitrogen



Nutrient & Sediment Summary Statistics

	NO3-N	*NH4-N*	*TKN*	*t-P*	*t-P-dissolved*	*oPO4-P*	*SSC*
Court Creek -ILL							
Count	1250	1250	747	747	747	1250	6201
Mean	2.9	0.1	2.5	0.8	0.1	0.1	617
Median	2.7	0.1	1.4	0.4	0.1	0.1	111
Min	< 0.04	< 0.03	0.23	0.03	< 0.03	< 0.003	2
Max	11.4	1.7	18.7	6.6	1.0	0.9	13632
25th Percentile	0.9	0.1	0.7	0.1	0.1	0.0	48
75th Percentile	4.6	0.2	3.2	1.1	0.1	0.1	485
Lost Creek - KSK							
Count	496	460	389	411	348	413	490
Mean	0.7	0.4	2.9	1.0	0.5	0.2	604
Median	0.5	0.4	2.4	0.9	0.5	0.1	249
Minimum	0.0	0.0	0.2	0.0	0.0	0.0	4
Maximum	4.9	1.3	21.3	6.2	1.4	1.2	15704
25th Percentile	0.3	0.3	1.7	0.7	0.3	0.0	92
75th Percentile	0.9	0.6	3.3	1.2	0.6	0.2	589

Kaskaskia – N loads



Benchmark Sediment Monitoring Program

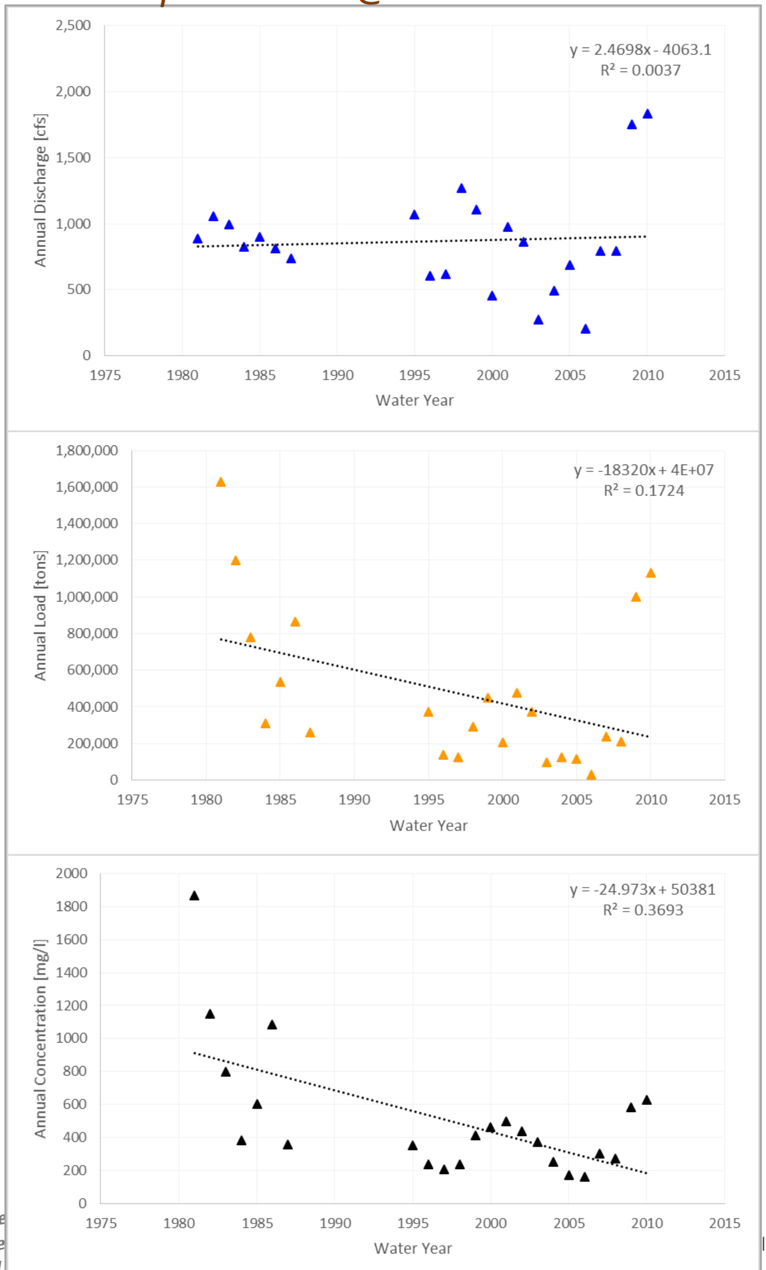
Develop comprehensive, long-term database of suspended sediment transport to provide a means for investigating and quantifying long-term trends that may be occurring in Illinois watersheds.

Has 35+ years of suspended sediment data.

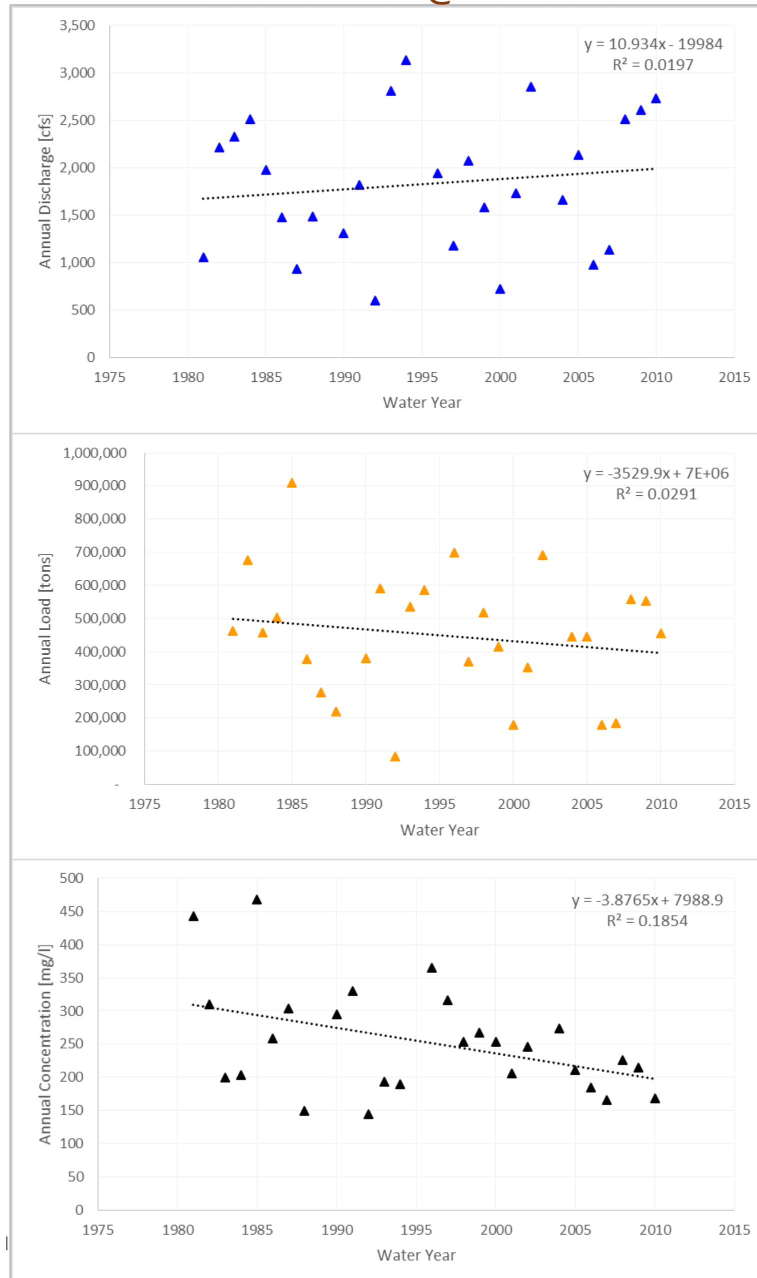
- *Identify watersheds with high erosion rates*
- *Evaluate effectiveness of erosion control programs*
- *Identify areas of potential degradation of surface water supplies*
- *Estimate sediment loads in nearby unmeasured streams*
- ***Determine long-term trends in sediment transport***

Long-term trends in Sediment Loading

Spoon River @ London Mills



Kaskaskia River @ Vandalia



Watershed Management Tool for Improving Water Quality in Streams and Rivers

- 75% of nutrient fluxes to the Gulf of Mexico originates from only 9 midwestern states including Illinois (Alexander et. al, 2008), mainly from agricultural sources
- Nutrient Loss Reduction Strategies

- Agricultural **w**atershed **m**anagement **t**ools can be used to identify critical source areas of nutrient loss and BMP selection and placement
- ISWS developed WMT to:
  - evaluate water quality impacts of user-specified BMP scenarios and unit costs
  - provide comparison of selected BMP implementations between
    - user specified and
    - optimal scenario

FRAMEWORK OF THE WATERSHED MANAGEMENT TOOL

MODEL INPUTS

- Topography (DEM), land uses, soils, management operations (e.g., crop rotations, tillage fertilization), climate data including precipitation, temperature, etc ...

BMP INPUTS

- Information specific to BMPs (e.g., fertilizer rate and timing)
- Unit cost of BMP implementation

WMT

SWAT

- Simulates hydrologic and **water quality** processes, plant growth, impacts of management practices

COST FUNCTION

- Computes cost of BMP implementation

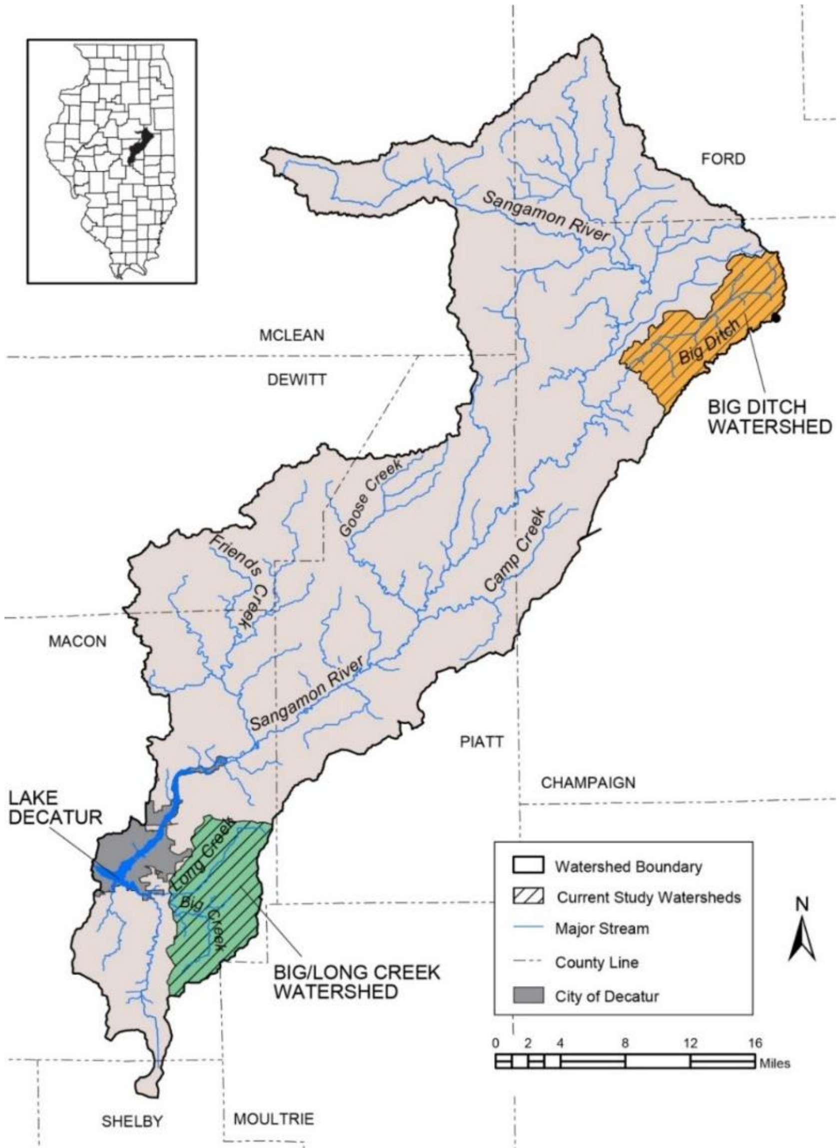
OPTIMAL BMP SCENARIOS

- Optimal BMP placements and tradeoffs b/n WQ reduction and cost

WMT OUTPUTS

- Percentage of sediment & nutrient reductions
- Optimal BMP placement based on user-specified costs of implementation

WMT EXAMPLE: LAKE DECATUR WATERSHED



WATERSHED MANAGEMENT TOOL

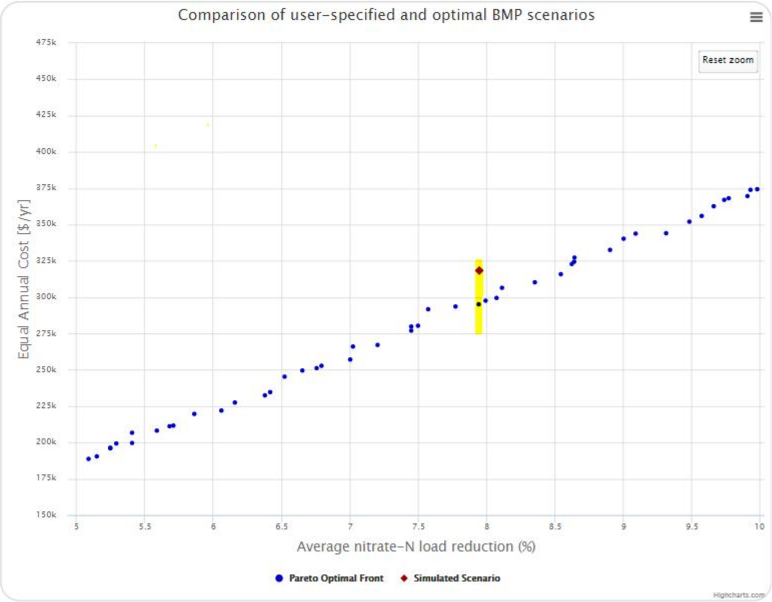
Decision Support Tool for Evaluating Watershed Best Management Practices

Big/Long Creek Watershed | 34 | Cover Crop (CC) | Enter User Information | Download User Guide | HRU/Landuse/Soil Chart | Download HRU/Landuse/Soil Report

Cover crop type: Cereal Rye | Cost per acre ($): 45

Select HRUs ... | 94

Assign BMP to HRUs | Reset | Evaluate | Check Selection

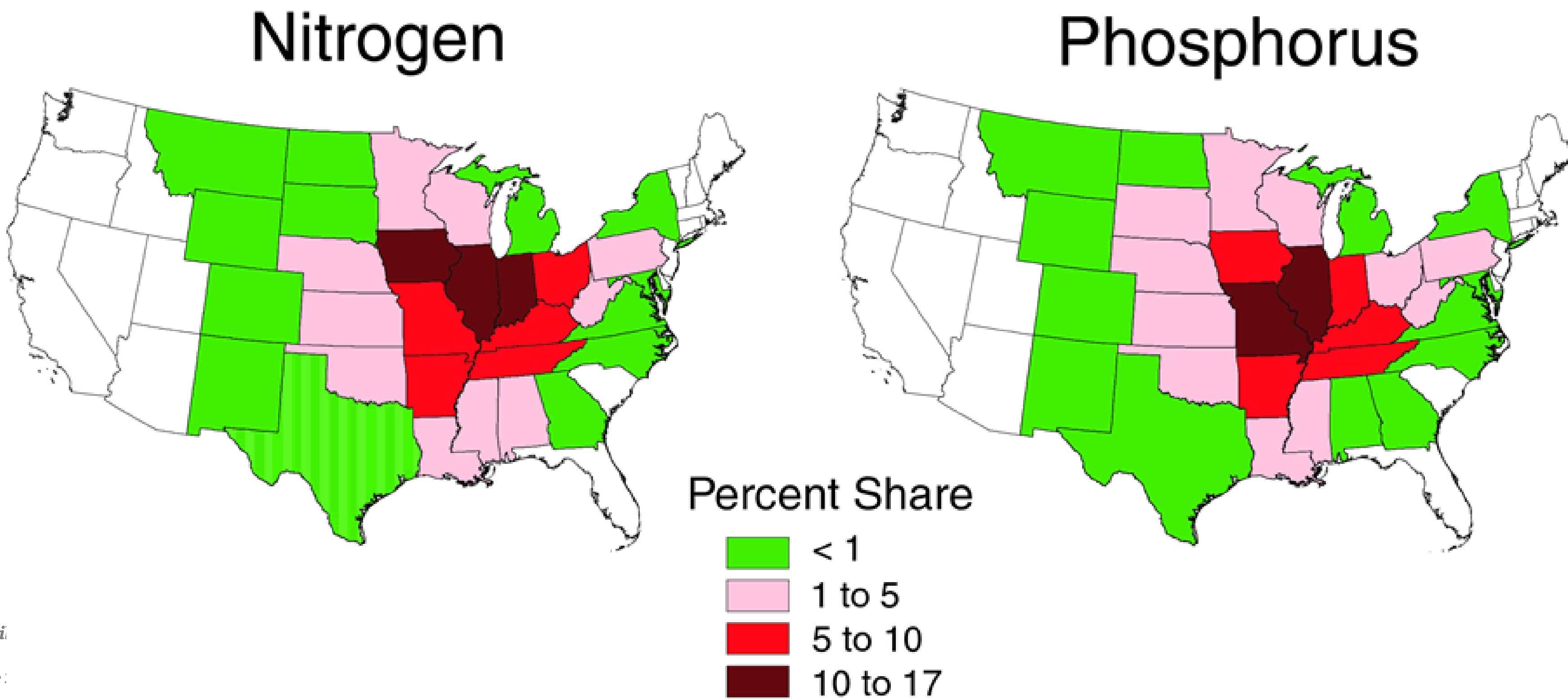


BMP scenario ID	BMP treatment area [%]	Pollutant load reduction						Equal Annual Cost (EAC) [$/yr]
		Nitrate-N		Total phosphorus		Sediment		
		[kg/ha/yr]	[%]	[kg/ha/yr]	[%]	[t/ha/yr]	[%]	
Scenario Simulated	22.2544	2.7239	7.9443	0.0455	4.3331	0.0259	3.0385	318319.5544
CR2396	20.7900	2.7224	7.9400	0.0370	3.5300	0.0197	2.3100	295127.6596

Statistical methods used in nutrient and sediment load calculation, trend analysis and prediction

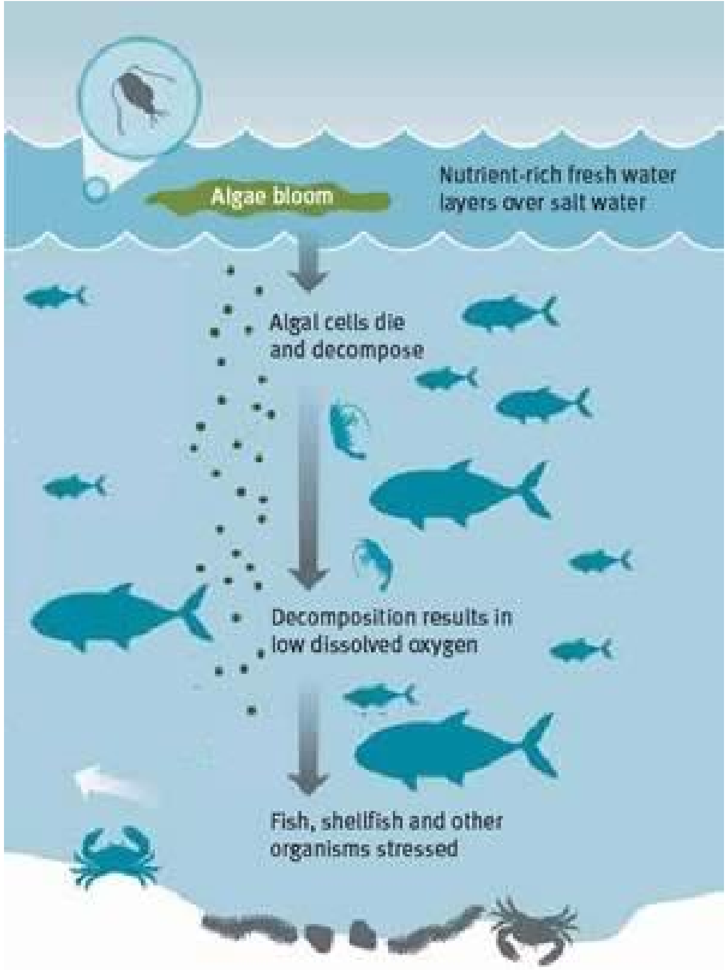
State Contributions to Nitrogen and Phosphorus loads delivered by the Mississippi River to the Gulf of Mexico

Total Nitrogen				Total Phosphorus			
State	Percent of Total Flux	Cumulative Percent of Total Flux	Delivered Yield (kg km^{-2} yr^{-1})	State	Percent of Total Flux	Cumulative Percent of Total Flux	Delivered Yield (kg km^{-2} yr^{-1})
Illinois	16.8	16.8	1734.9	Illinois	12.9	12.9	117.4
Iowa	11.3	28.1	1167.2	Missouri	12.1	25.0	89.4
Indiana	10.1	38.2	1806.6	Iowa	9.8	34.8	89.2
Missouri	9.6	47.8	800.5	Arkansas	9.6	44.4	94.6
Arkansas	6.9	54.7	750.1	Kentucky	9.0	53.4	113.4



Excessive Nutrient Loadings

- The hypoxic (low oxygen) zone in the Gulf of Mexico is a result of excessive nutrient loadings (primarily N and P) from the Mississippi River.



Mother Nature Network http://www.mnn.com/earth-matters/translating-uncle-sam/stories/what-is-the-gulf-of-mexico-dead-zone

EPA Science Advisory Board. (2008). "Hypoxia in the Northern Gulf of Mexico: An update by the EPA Science Advisory Board." EPA SAB-08-003, EPA Science Advisory Board, Washington DC.

Why do we calculate nutrient loadings?

- To detect watersheds with highest and lowest contributions.
- To determine if the management practices are efficient.
- To predict future trends (short-term, annual, and long-term)
- To design nutrient reduction strategies.

How do we calculate nutrient loadings?

Nutrient loading (Tons)

River discharge (m^3/s)

$$L = c \times Q$$

Nutrient concentration (mg/L)

How do we calculate nutrient loadings?

Regression-Based Estimator

$$\ln(C) = \beta_0 + \beta_1 \ln(Q/\tilde{Q}) + \beta_2[\ln(Q/\tilde{Q})]^2 + \beta_3(T-\tilde{T}) + \beta_4(T-\tilde{T})^2 + \beta_5 \sin(2\pi T) + \beta_6 \cos(2\pi T) + \varepsilon$$

Rating Curve Estimator:

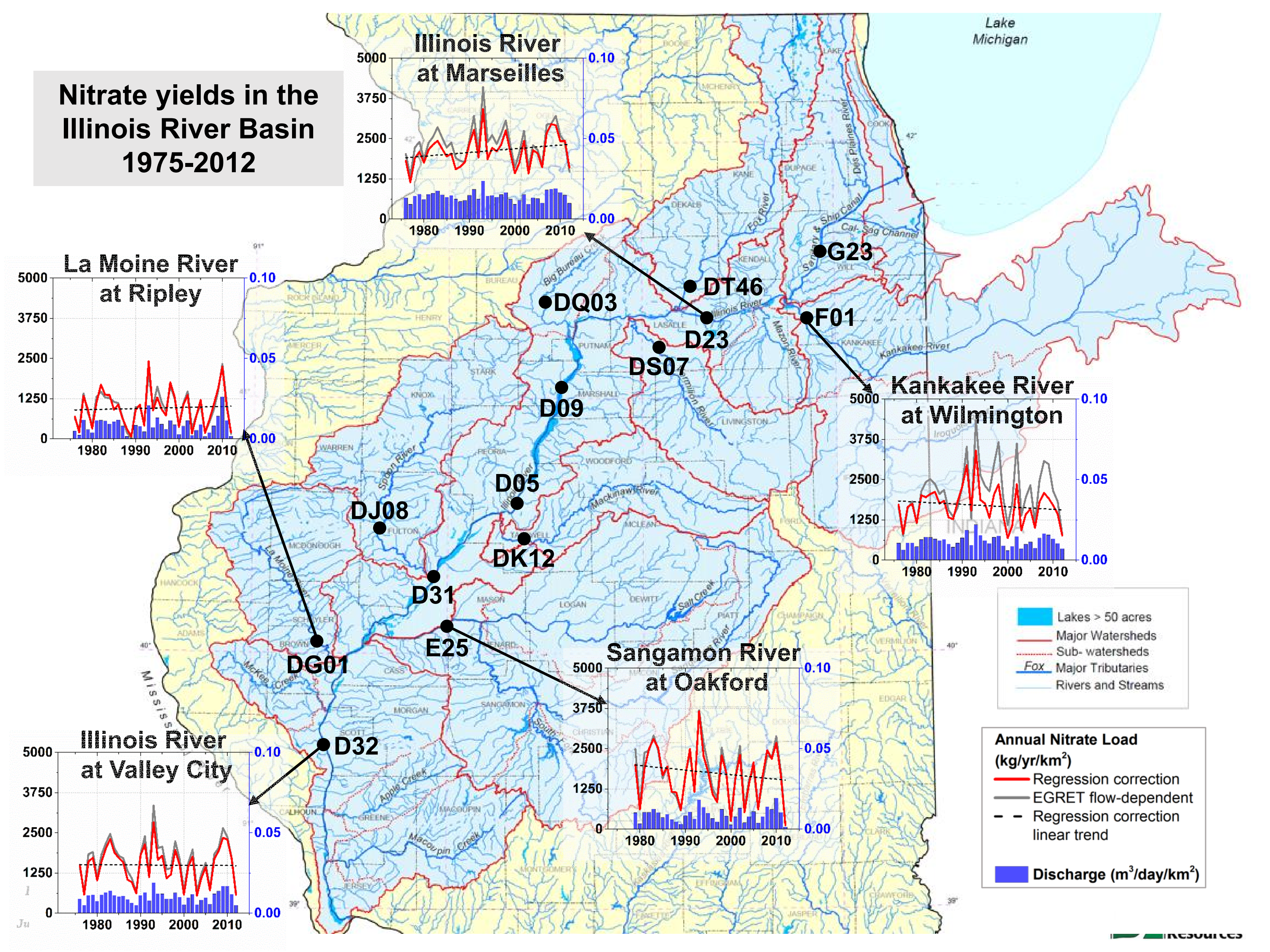
$$L_{RC} = \sum_{j=1}^{N} C_j Q_j \Delta t$$

MVUE:

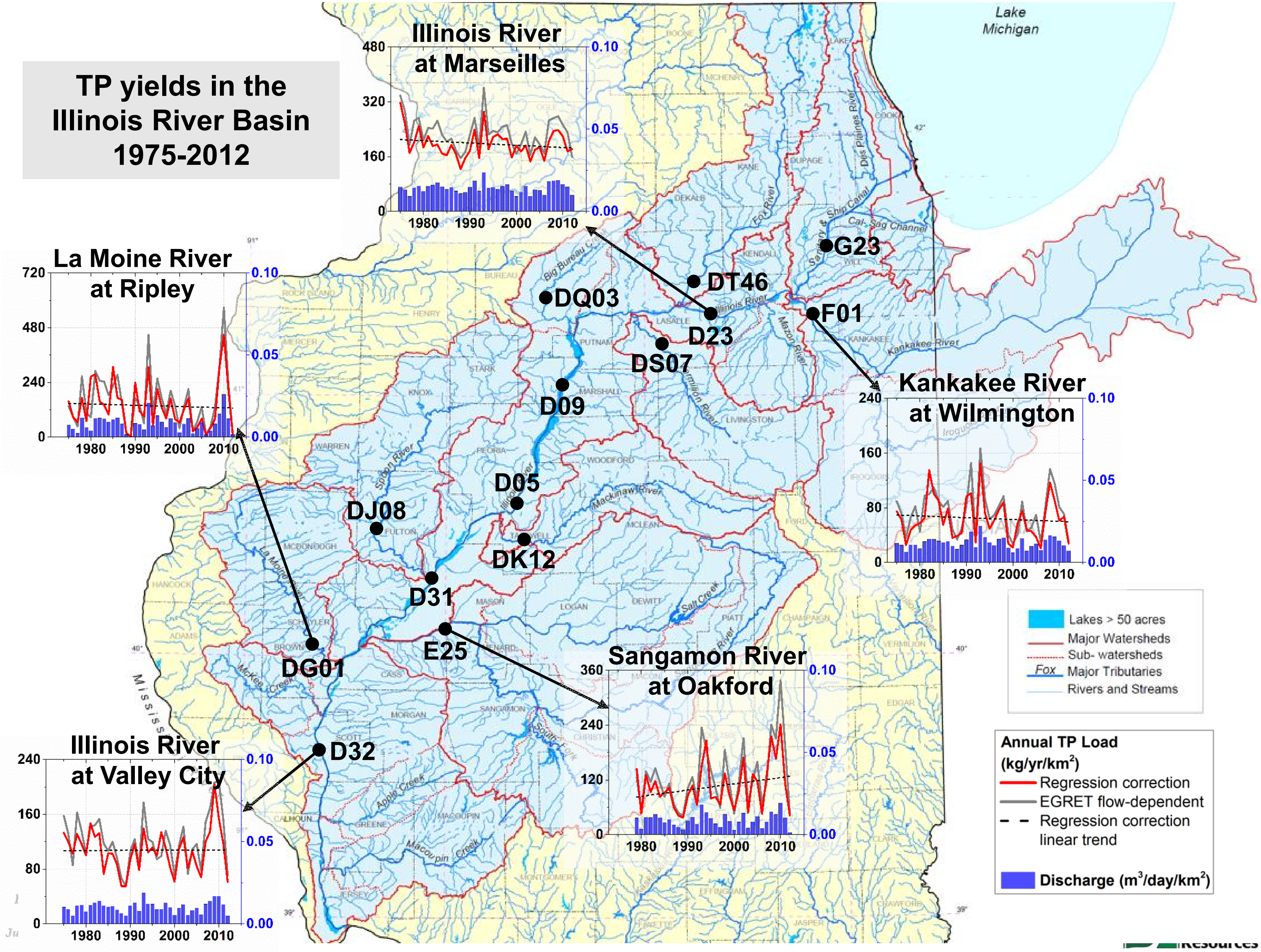
$$L_{MVUE} = L_{RC} g_m \left[\frac{m+1}{2m} (1-v) s^2 \right]$$

Smearing Estimator:

$$L_{SM} = L_{RC} \frac{1}{M} \sum_{i=1}^{M} \exp[e(i)]$$

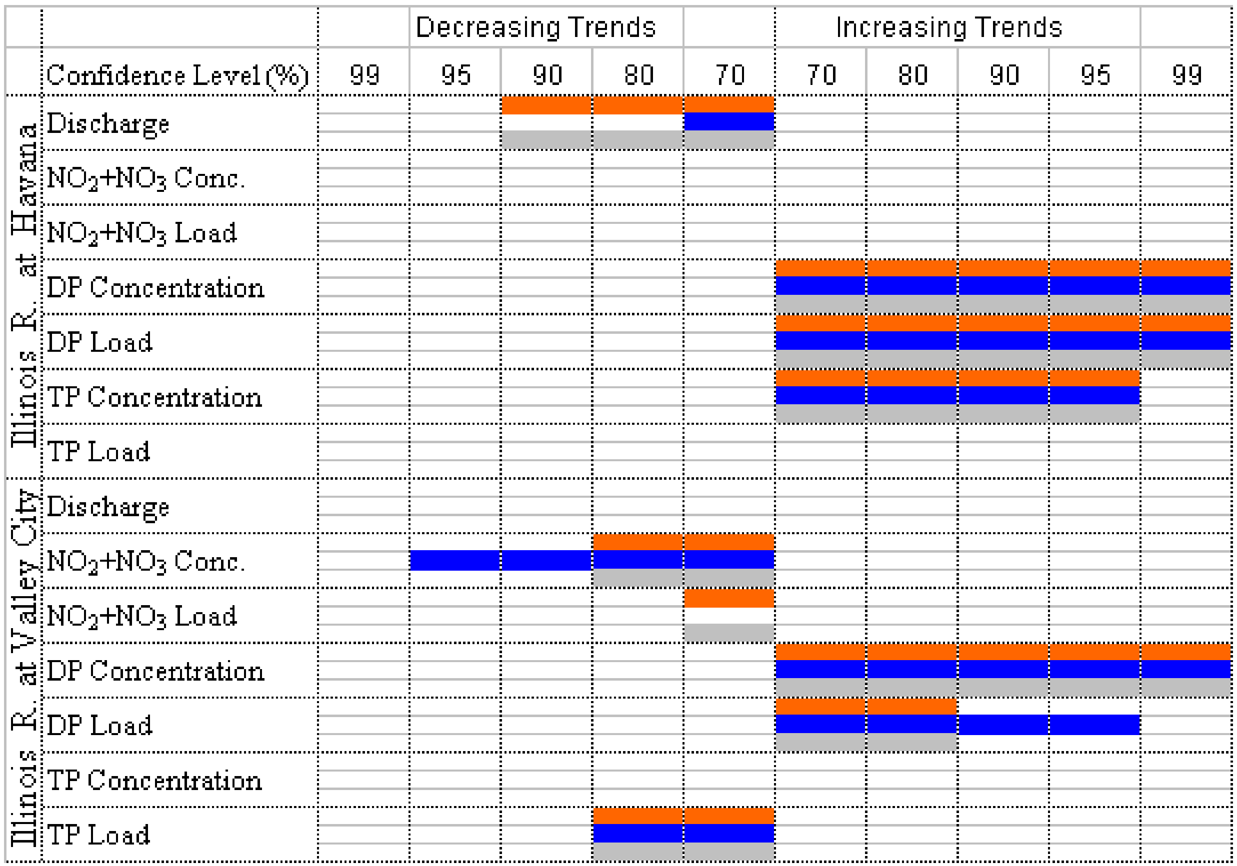


Nitrate yields in the Illinois River Basin 1975-2012
Illinois River at Marseilles
La Moine River at Ripley
Kankakee River at Wilmington
Sangamon River at Oakford
Illinois River at Valley City
5000
3750
2500
1250
0
0.10
0.05
0.00
1980
1990
2000
2010
G23
DT46
DQ03
D23
F01
DS07
D09
D05
DJ08
DK12
D31
E25
DG01
D32
Lake Michigan
Lakes > 50 acres
Major Watersheds
Sub- watersheds
Fox
Major Tributaries
Rivers and Streams
Annual Nitrate Load (kg/yr/km²)
Regression correction
EGRET flow-dependent
Regression correction linear trend
Discharge (m³/day/km²)

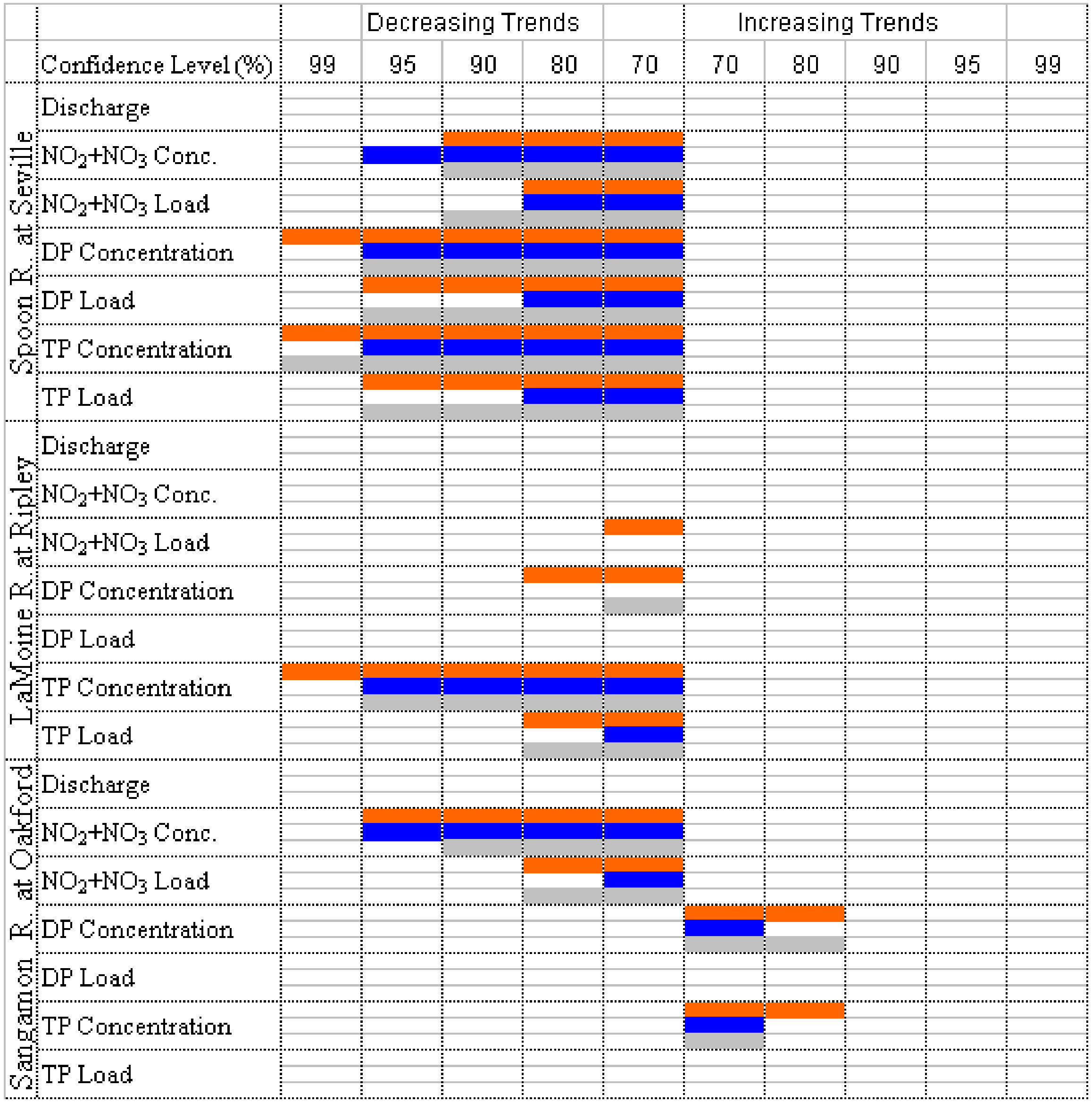


TP yields in the Illinois River Basin 1975-2012
Lake Michigan
Illinois River at Marseilles
La Moine River at Ripley
Kankakee River at Wilmington
Sangamon River at Oakford
Illinois River at Valley City
G23
DT46
DQ03
D23
F01
DS07
D09
D05
DJ08
DK12
D31
DG01
E25
D32
Lakes > 50 acres
Major Watersheds
Sub- watersheds
Fox Major Tributaries
Rivers and Streams
Annual TP Load (kg/yr/km^2)
Regression correction
EGRET flow-dependent
Regression correction linear trend
Discharge (m^3/day/km^2)
1980
1990
2000
2010

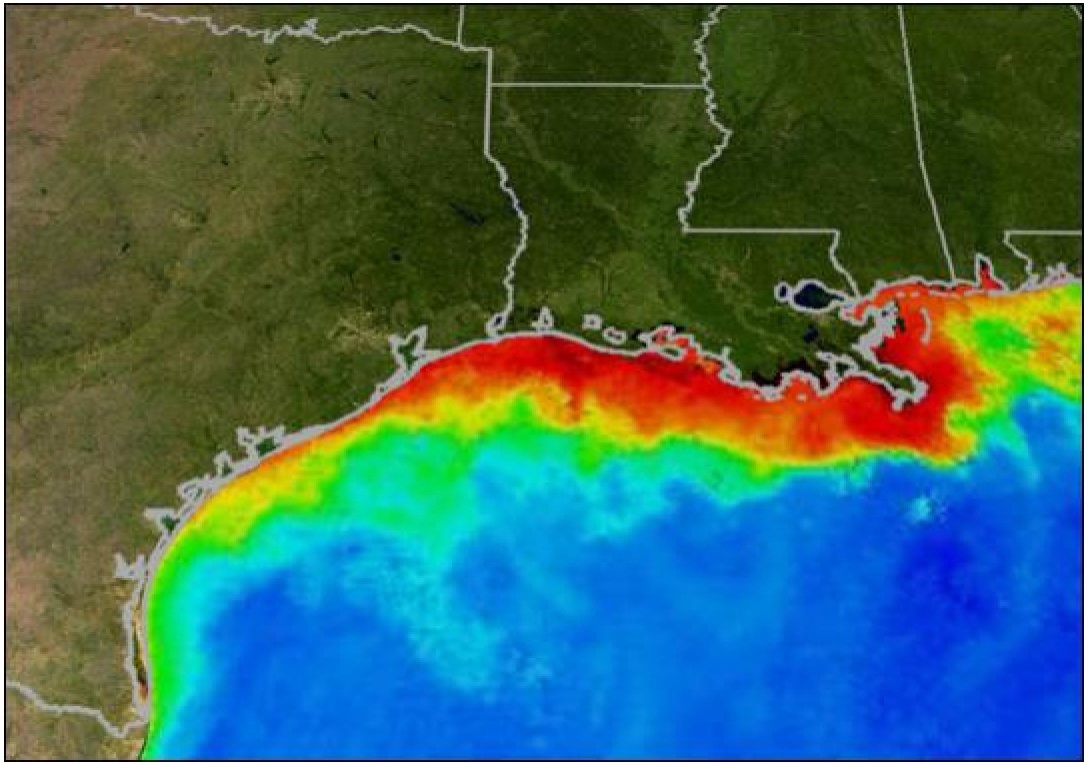
Trend Analysis



Trend Analysis (continued)



Nutrient Reduction Goals

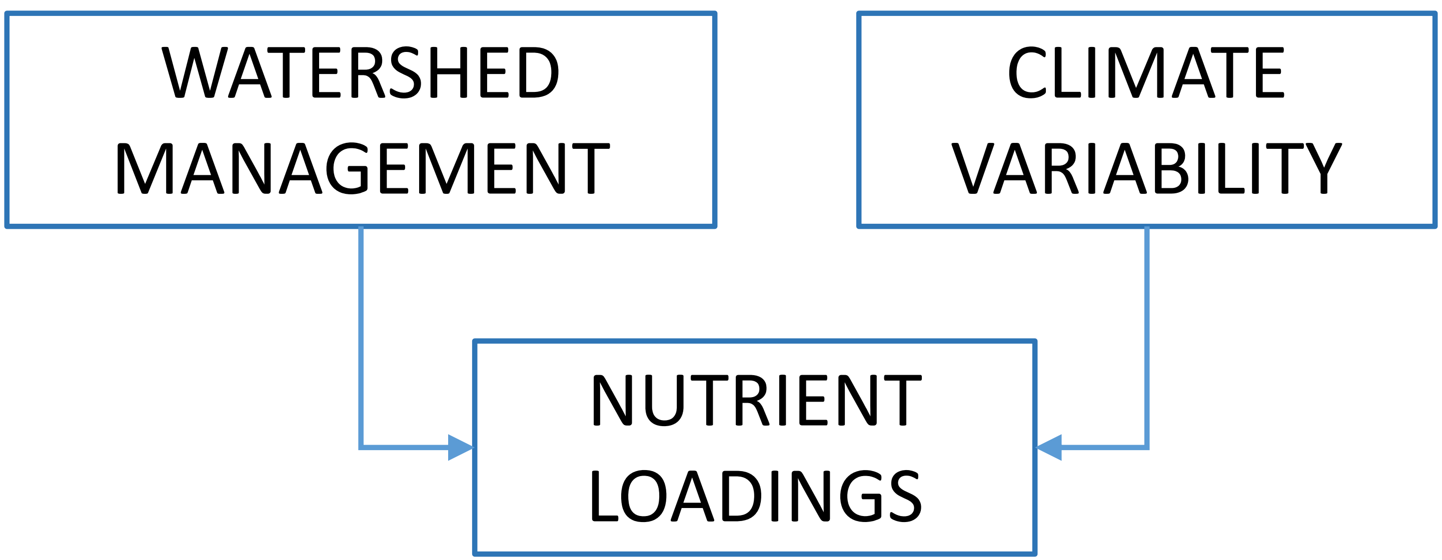


- To reduce the size of the hypoxic zone in the Gulf of Mexico, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force set a nutrient reduction goal of 45% for nitrogen and phosphorus by 2050 to reduce the size of the hypoxic zone from 8000 to 5000 square miles (MRGMWNTF, 2008).

MRGMWNTF (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force). 2008. Gulf Hypoxia Action Plan 2008 for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin. Washington, DC: Mississippi River/Gulf of Mexico Watershed Nutrient Task Force http://water.epa.gov/type/watersheds/named/msbasin/actionplan.cfm

Nutrient Loadings: Contributing factors

- A wet year in terms of nutrient loading is defined by large storm events.
- More precipitation, on average, in a given year doesn't necessarily lead to an increase in pollution.
- The increase is tied to heavy precipitation.



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Evaluating the Impact of Legacy P and Agricultural Conservation Practices on Nutrient Loads from the Maumee River Watershed

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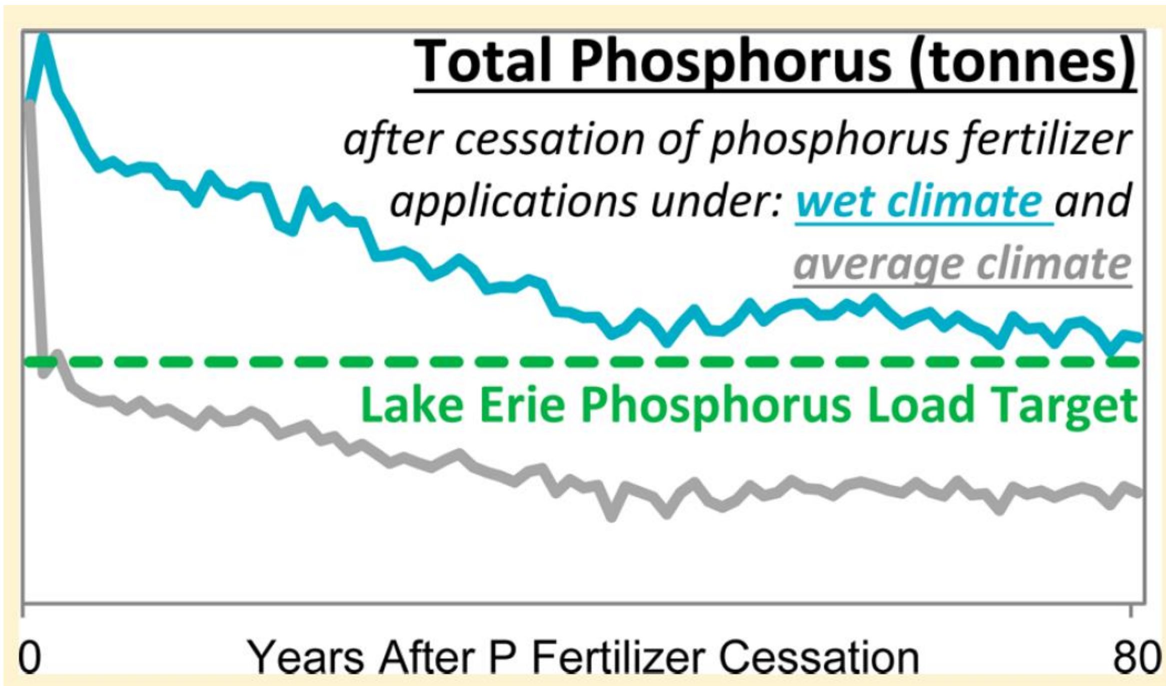
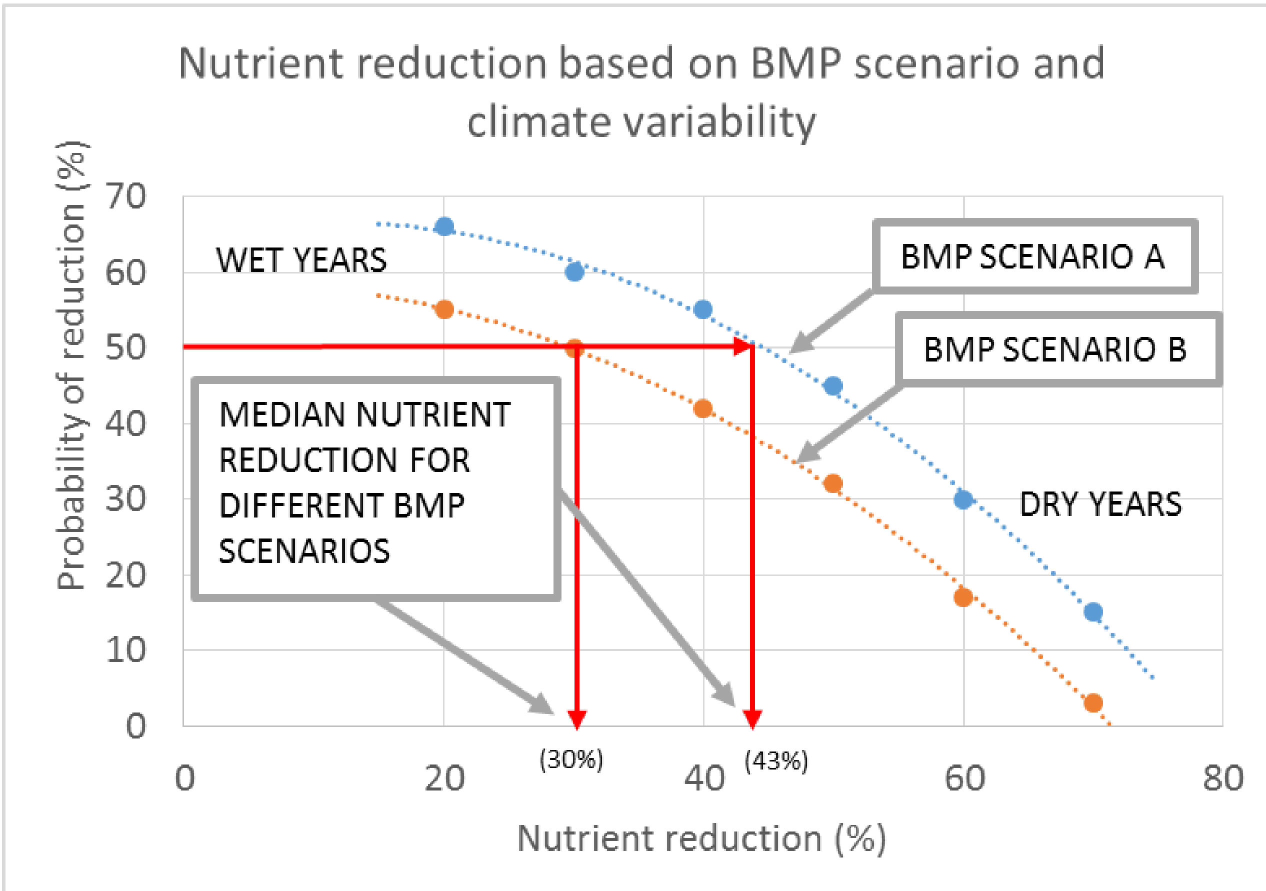


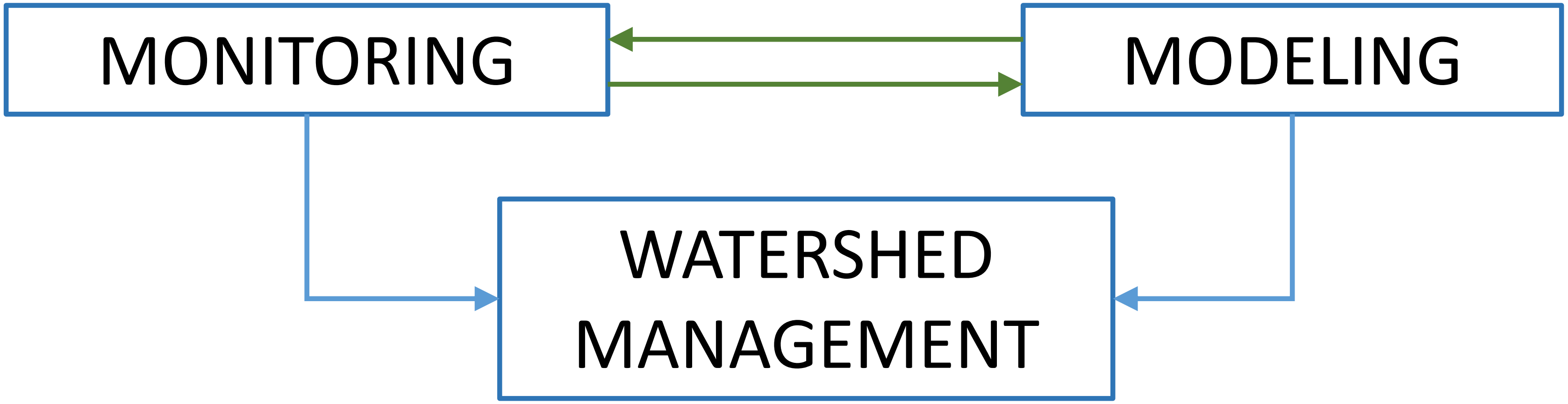
Probabilistic assessment and validation of nutrient reduction goals



Goals:

- To design a new probabilistic framework for *setting the nutrient reduction goals*, which would also show the uncertainty distribution based on past observed climates
- To evaluate the potential *effects of climate variability* on achieving the nutrient reduction goals.
- To design a tool to *verify if the goals have been achieved.*

Summary



- Importance of modeling
  - Watershed models/Statistical models
- Monitoring, monitoring, monitoring
  - Frequency/Spatial distribution