Northeast-Midwest Institute: The Lake Erie Nutrient Case Study

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U.S. Geological Survey

Great Lakes Water Quality Agreement Annex 4
Loading Calculations Technical Symposium
April 5-6, 2017
Ann Arbor, MI

“Toward Sustainable Water Information”

- Program objective:
  - Investigate and describe the ability of the NEMW region’s water monitoring programs to support decision making
- Primary Audience:
  - U.S. Congress and regional decision makers
- Case Studies:
  - Nutrient enrichment
  - Shale gas fracking development
- State of the Region Report

Sept.2011 bloom (Michalak et al, 2013)

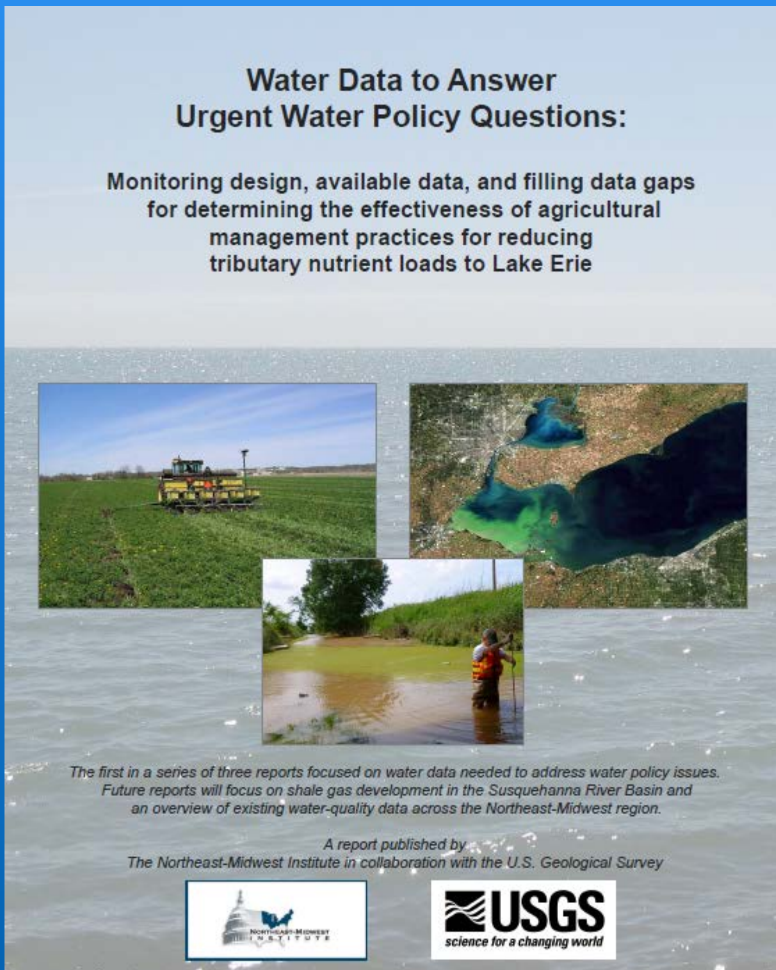
Case Study Objectives

- Describe the types and amounts of water data needed to answer a specific water policy question
- Assess the extent to which those data are available and usable
- Identify the additional data that would be needed to effectively answer the question

- Input from multi-agency panels: Steering Committee, and Technical Advisory Committees

Lake Erie Nutrient Case Study

"How effective are agricultural management practices at reducing nutrients at the watershed scale?"



Water Data to Answer Urgent Water Policy Questions:

Monitoring design, available data, and filling data gaps for determining the effectiveness of agricultural management practices for reducing tributary nutrient loads to Lake Erie

The first in a series of three reports focused on water data needed to address water policy issues. Future reports will focus on shale gas development in the Susquehanna River Basin and an overview of existing water-quality data across the Northeast-Midwest region.

A report published by
The Northeast-Midwest Institute in collaboration with the U.S. Geological Survey

Water Data to Answer Urgent Water Policy Questions:

Monitoring design, available data, and filling data gaps for determining the effectiveness of agricultural management practices for reducing tributary nutrient loads to Lake Erie

Addendum
describing new, expanded,
and planned monitoring sites

A report published by
The Northeast-Midwest Institute in collaboration with the U.S. Geological Survey

Northeast-Midwest institute reports at: http://www.nemw.org/lake-erie-report/

Contents: Case Study Reports

Case Study

[monitoring conditions as of late 2014]

- Framing the Policy Question
- Review of types of data needed
- Multi-agency data compilation
- Monitoring design options
- Review of available monitoring data
- Current data gaps
- Recommendations

Addendum

[monitoring conditions as of spring 2015]

- New, expanded, and planned monitoring in western Lake Erie basin
- Current and planned agricultural conservation and incentive programs
- Update of monitoring recommendations

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ADDENDUM Report: E. Betanzo, A. Choquette, and L. Hayes

Technical Advisory Committee

Member	Organization
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R. Peter Richards	Heidelberg University
Dale Robertson	U.S. Geological Survey
Paul Stacey	Great Bay National Estuarine Research Reserve, New Hampshire
Mark Tomer	Agricultural Research Service, USDA
Elizabeth Toot-Levy	Northeast Ohio Regional Sewer District

In addition: 18-member steering panel provided high-level direction for both Case Studies, and 20 water quality and agricultural researchers contributed data for the Addendum monitoring and incentive program updates.

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"How effective are agricultural management practices at reducing nutrients from nonpoint sources at the watershed scale?"

Study Approach

Tributary Water Data

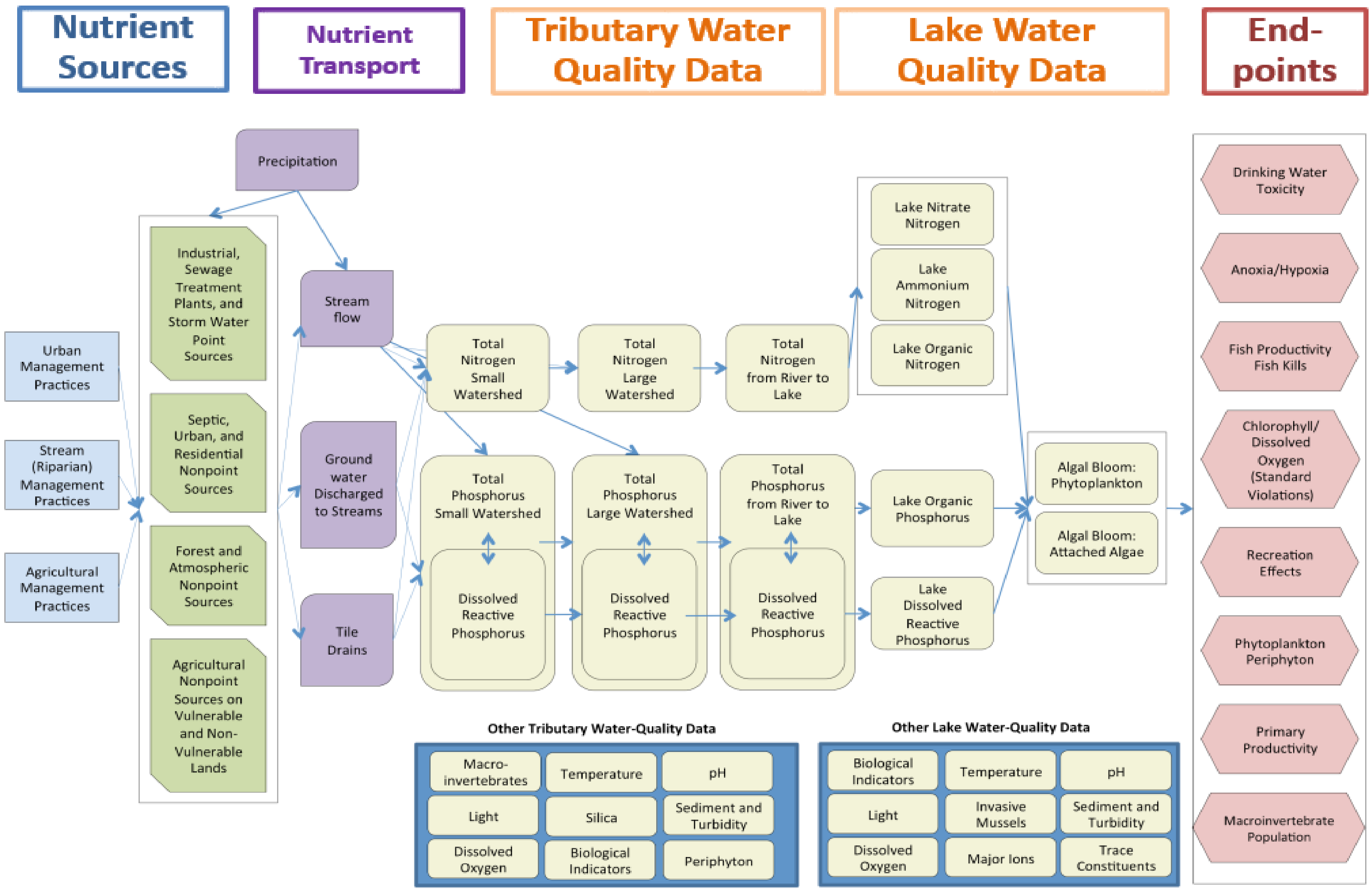
Appropriate Monitoring Sites

Supporting Data

Data requirements and monitoring design

- Selection of water quality parameters (constituents)
- Scale: size of basins
- Frequency of sampling
- Duration of monitoring

What Data are Needed to Understand the Effectiveness of AMPs in the Lake Erie Basin?



Water quality constituents identified as important, and screened in the multi-agency data set

Parameter name	Fraction measured
Ammonia	dissolved
Ammonia	total
Chlorophyll a	NA
Discharge (streamflow)	NA
Dissolved oxygen	NA
Inorganic carbon	dissolved
Nitrate	dissolved
Nitrate	total
Nitrite	dissolved
Nitrite	total
Nitrite plus nitrate	dissolved
Nitrite plus nitrate	total
Organic carbon	dissolved
Organic carbon	total
Orthophosphate (DRP)	dissolved

Parameter name	Fraction measured
Orthophosphate	total
Particulate carbon	NA
Particulate nitrogen	NA
Periphyton, biomass	NA
pH	NA
Phytoplankton	total
Silica	dissolved
Specific conductance	NA
Stage (stream, water level)	NA
Suspended sediment (concentration)	NA
Total Kjeldahl nitrogen (TKN)	dissolved
Total Kjeldahl nitrogen (TKN)	total
Total dissolved nitrogen	dissolved
Total nitrogen	total
Total phosphorus	dissolved
Total phosphorus (TP)	total
Turbidity	NA
Velocity (stream)	NA
Water temperature	NA

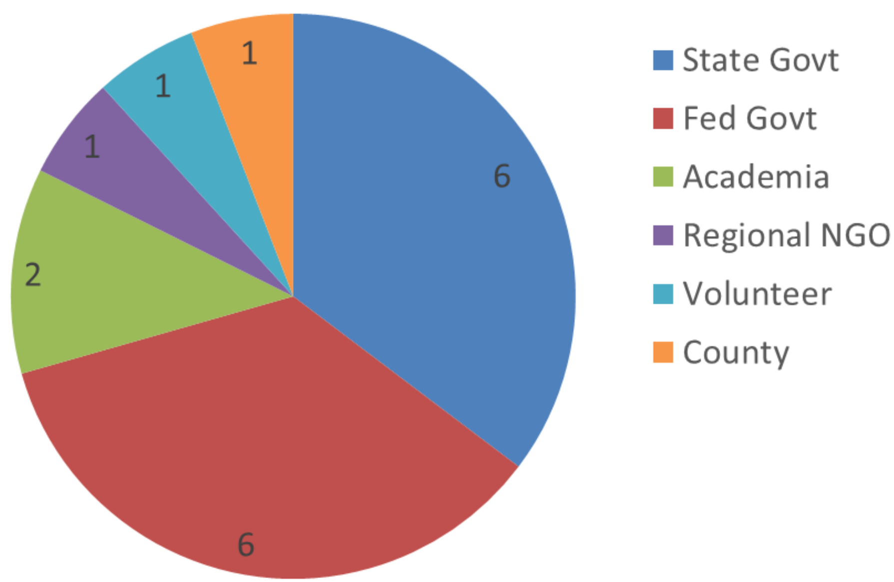
Stream Water Quality Data in the Lake Erie Drainage Basin

Screening water quality parameters identified as important to the policy question

Data from 1943-2013

17 organizations
3,005 monitoring sites
1.2 million records

Types of monitoring organizations collecting data, by number of sites



Values indicate number of organizations.

Database source: USGS National Data Aggregation

Challenges with secondary use of multi-source water-quality data in the United States

Lori A. Sprague [a,*], Gretchen P. Oelsner [b], Denise M. Argue [c]

Water Research, v. 110 (2017)

- Ambiguity in parameter names used, and missing metadata critical to interpretive analysis.
- Orthophosphate (includes dissolved reactive P) had the largest number of variations in reported parameter names: 147.

Types of critical missing metadata: fraction sampled (filtered, unfiltered), reported units as species (e.g. N, NO_3), censoring level

Note: In Lake Erie Basin data set ~11,500 nitrogen or phosphorus analyte records were missing data on fraction sampled (filtered or unfiltered).

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The Right Tributary Water-Quality Data

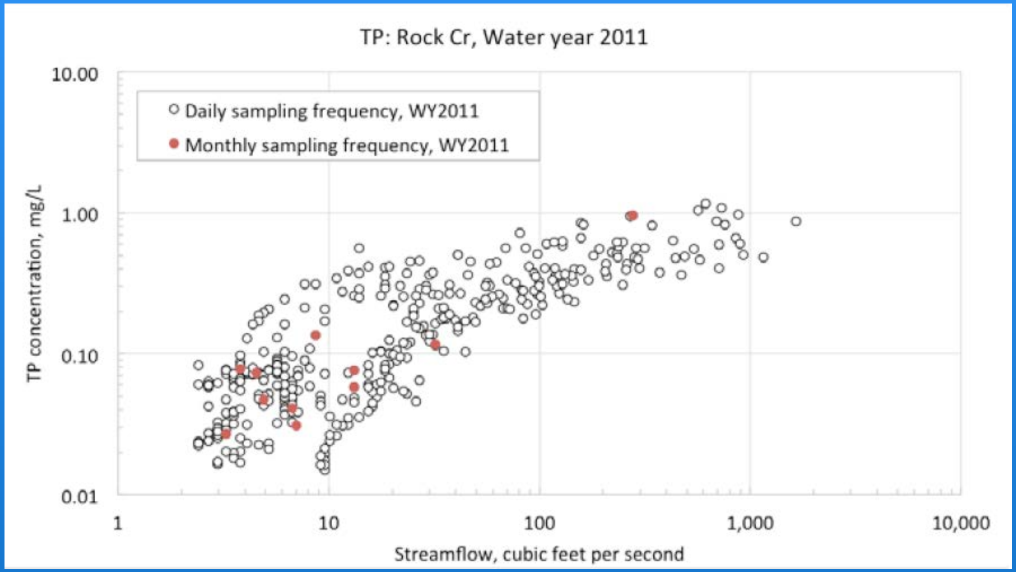
The most critical data:

Sites recently active, monitoring for total phosphorus and dissolved reactive phosphorus, located at or near an active streamgage

Large watersheds
Greater than or equal to 1,000 square miles
Drains directly to Lake Erie
Greater than or equal to 40-percent row-crop coverage
--
TP, DRP, and streamgage
Active as of 2014

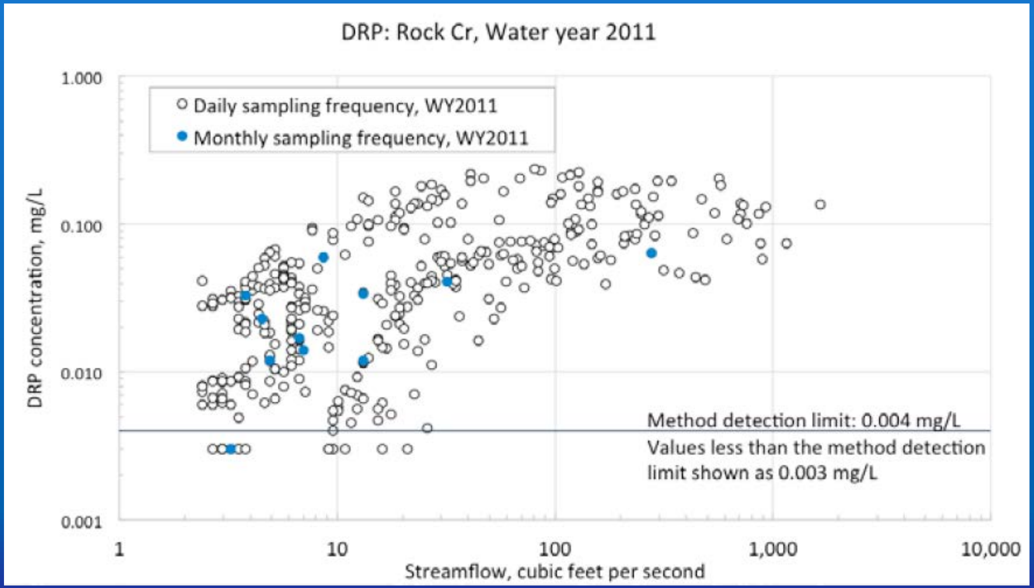
Small watersheds
Less than or equal to 50 square miles
--
Greater than or equal to 40-percent row-crop coverage
High phosphorus yield and high soil vulnerability
TP, DRP, and streamgage
Active as of 2014

Sampling-frequency design needs



Sampling frequency must capture the full range of flow conditions and seasonal changes for accurate load estimates

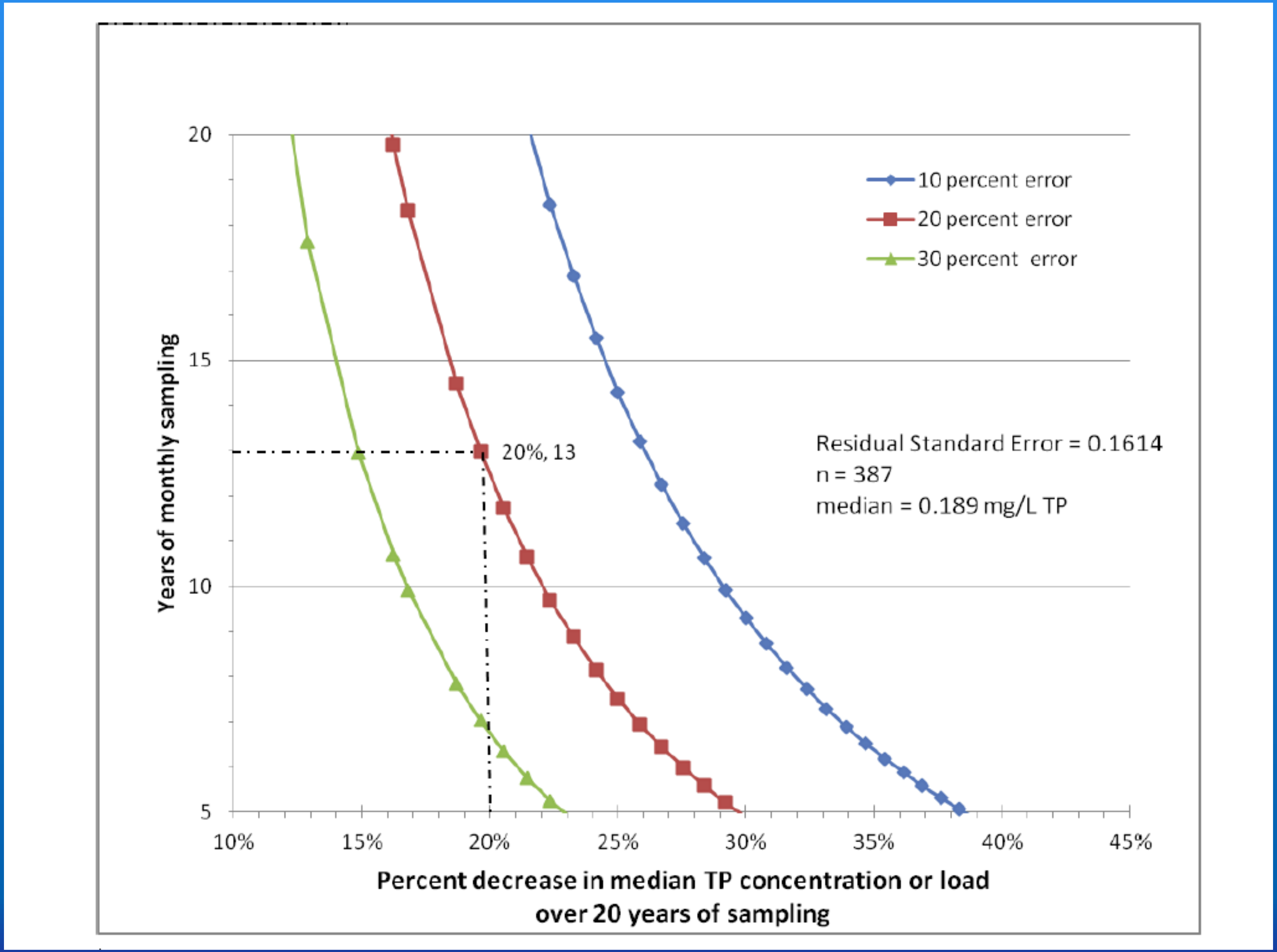
Minimum sampling = 12 monthly + 12 events per year



Sampling Frequency Options

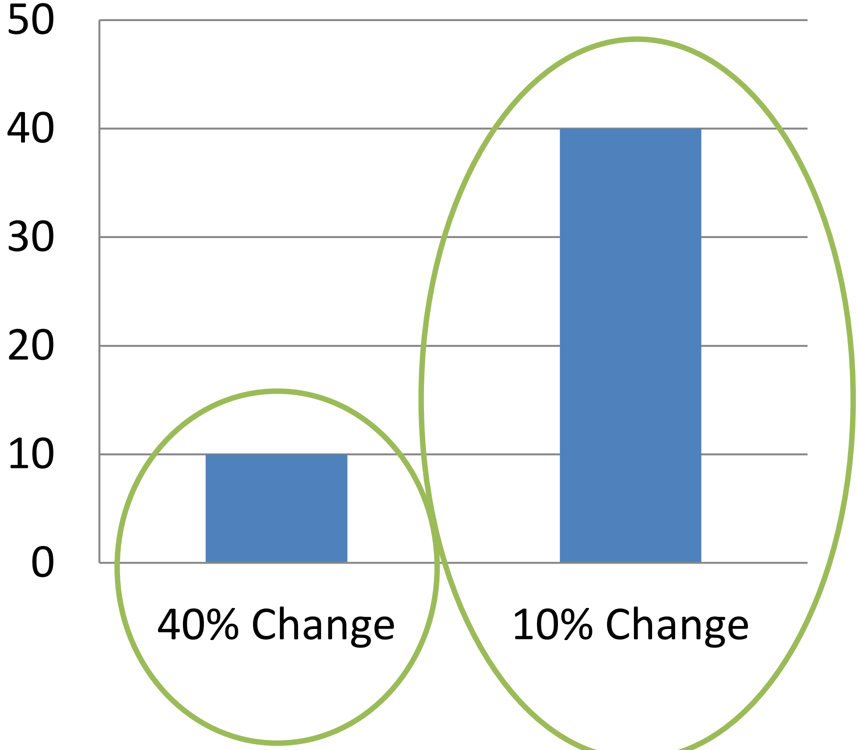
Option	Description
1	Monthly plus 12 samples targeting a range of high- and low-flows on the hydrograph
2	Two years of monthly sampling plus sampling during all storm events followed by adaptive management to identify long-term sampling plan.
3	Daily plus up to 3x daily during storms
4	Continuous monitoring (turbidity and/or dissolved phosphorus) plus supplemental discrete samples (2 per month 1st 2 years, then 1 per month).

Duration of monitoring:
Power analysis focused on
detection of trends of a given magnitude



The Right Monitoring Duration

Minimum years of monthly sampling to detect change in TP load based on power analysis of Lake Erie tributaries



AMP = Agricultural management practice

- Monitoring duration depends on magnitude of water-quality change and variability
- 40% phosphorus load reduction can be detected within 10 years
- 10% phosphorus load reductions projected using current AMP implementation rates

What does it mean?

- Plan for at least 10 years of monitoring
- Maximize AMPs within monitored watersheds to minimize time to detect change

Summary of monitoring recommendations

	Small Watersheds	Large Watersheds
Monitoring sites located in watersheds with these characteristics	• Less than or equal to 50 square miles, • Greater than or equal to 40% of row-crop coverage, • High phosphorus yield and high soil vulnerability	• Greater than or equal to 1,000 square miles • Drains directly to Lake Erie • Greater than or equal to 40% of row-crop coverage
Monitoring parameters	• TP, DRP, streamgage • Suite of parameters from Table 3	• TP, DRP, streamgage • Suite of parameters from Table 3
Sampling frequency (pick one)	• Monthly plus supplemental sampling (24/year) • Two-year intensive monitoring followed by adaptive management to modify sampling plan (100 per year then 24 per year), or • Daily plus storm sampling (approx. 500 per year) • Monthly plus continuous monitoring (turbidity and/or dissolved phosphorus)	• Monthly plus supplemental sampling (24/year) • Two-year intensive monitoring followed by adaptive management to modify sampling plan (100 per year then 24 per year), or • Daily plus storm sampling (approx. 500 per year) • Monthly plus continuous monitoring (turbidity and/or dissolved phosphorus)
Minimum duration of monitoring to detect change	>8 years[1] (assumes 40% reduction in TP and DRP over 20 years)[2]	>20 years (assumes 20% reduction in TP and DRP over 20 years)[2]

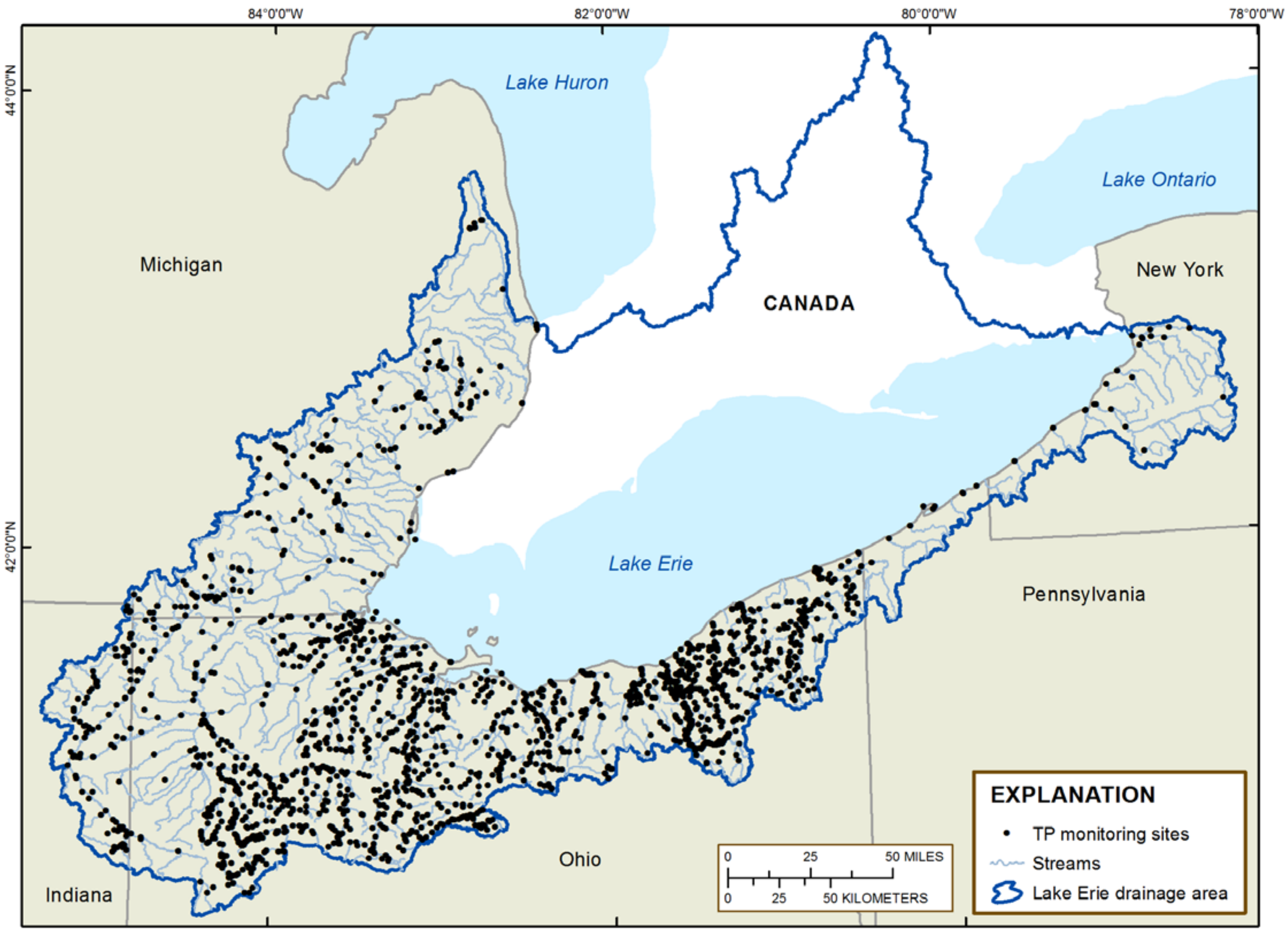
[1]If less than 10, review monitored years to verify a range of climatic conditions

Tributary data identified as important for answering the policy question

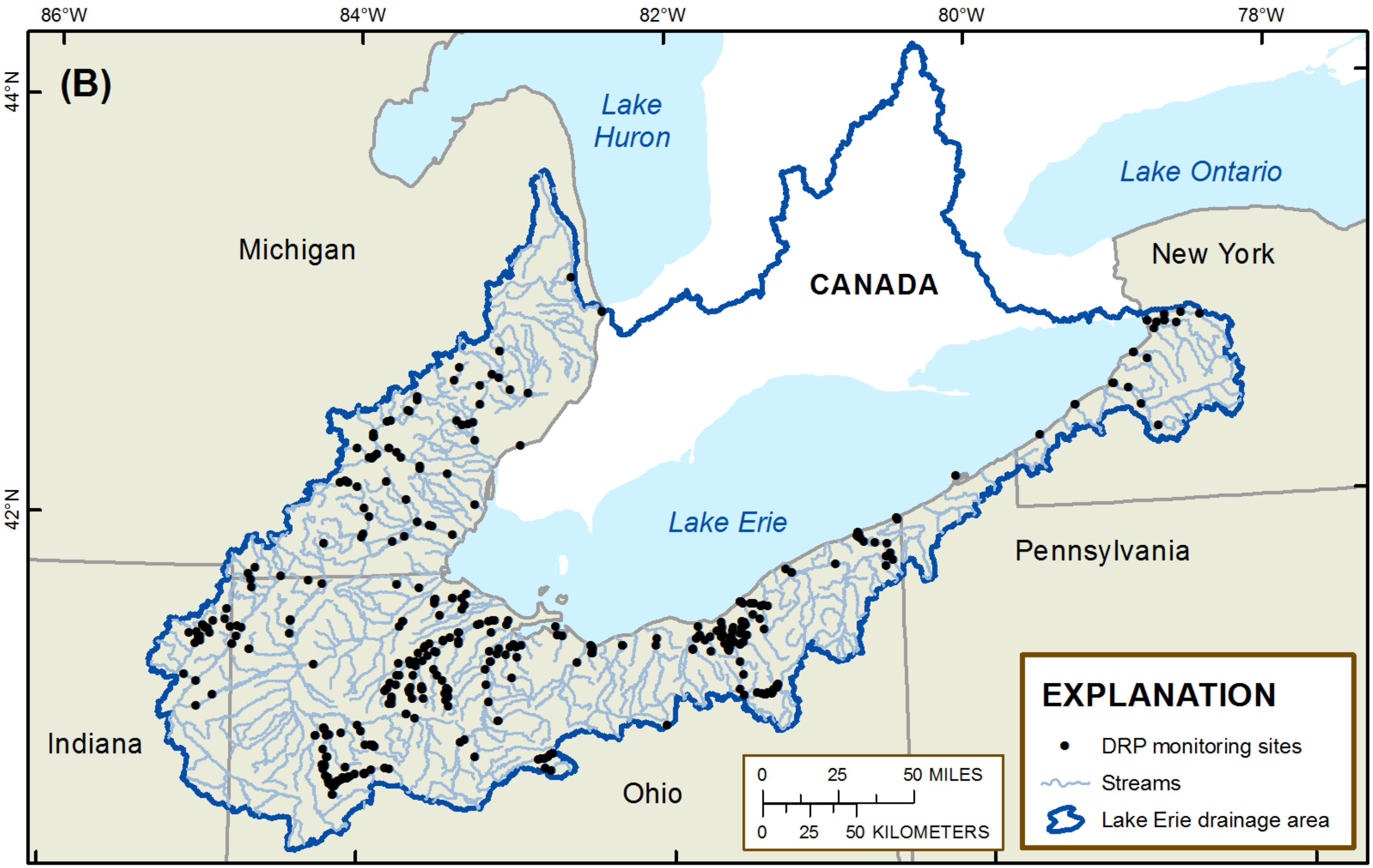
Parameter	Laboratory measurement	Field measurement	Bioindicators
Total phosphorus	x		
Dissolved reactive phosphorus	x		
Total nitrogen	x		
Silica	x		
Suspended sediment	x		
Water temperature		x	
Air temperature		x	
pH		x	
Dissolved oxygen		x	
Streamflow		x	
Macroinvertebrates		x	x
Periphyton (attached algae)		x	x

Evaluating available data

How Many Monitoring Sites Have Data for Total Phosphorus?
Answer: 1,890 sites

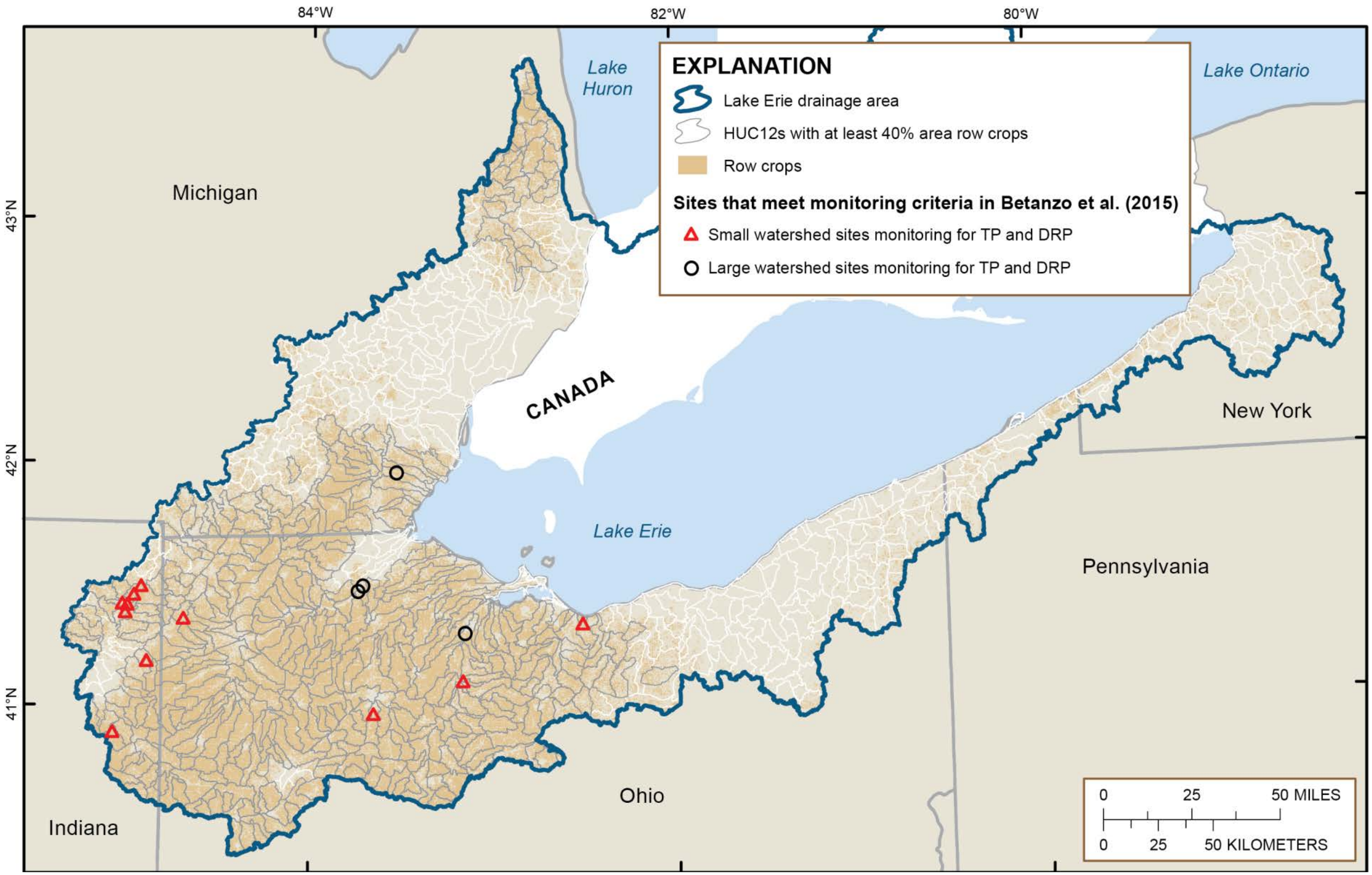


Dissolved Reactive Phosphorus Monitoring: 411 sites

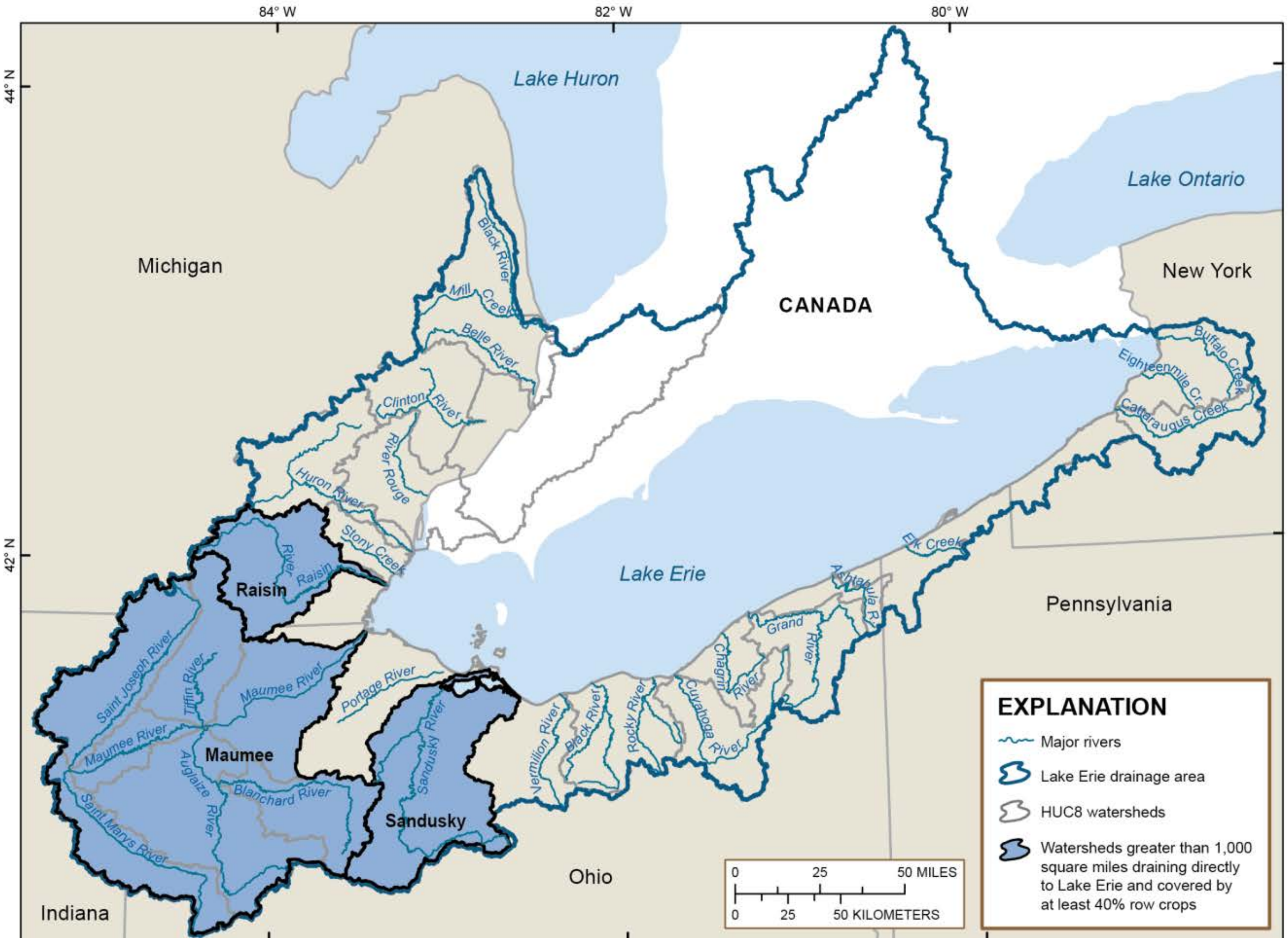


State lines from U.S. Geological Survey, 2005, 1:2,000,000-scale digital data
Streams from U.S. Geological Survey, 2012, 1:1,000,000-scale digital data
Albers projection, NAD 1983

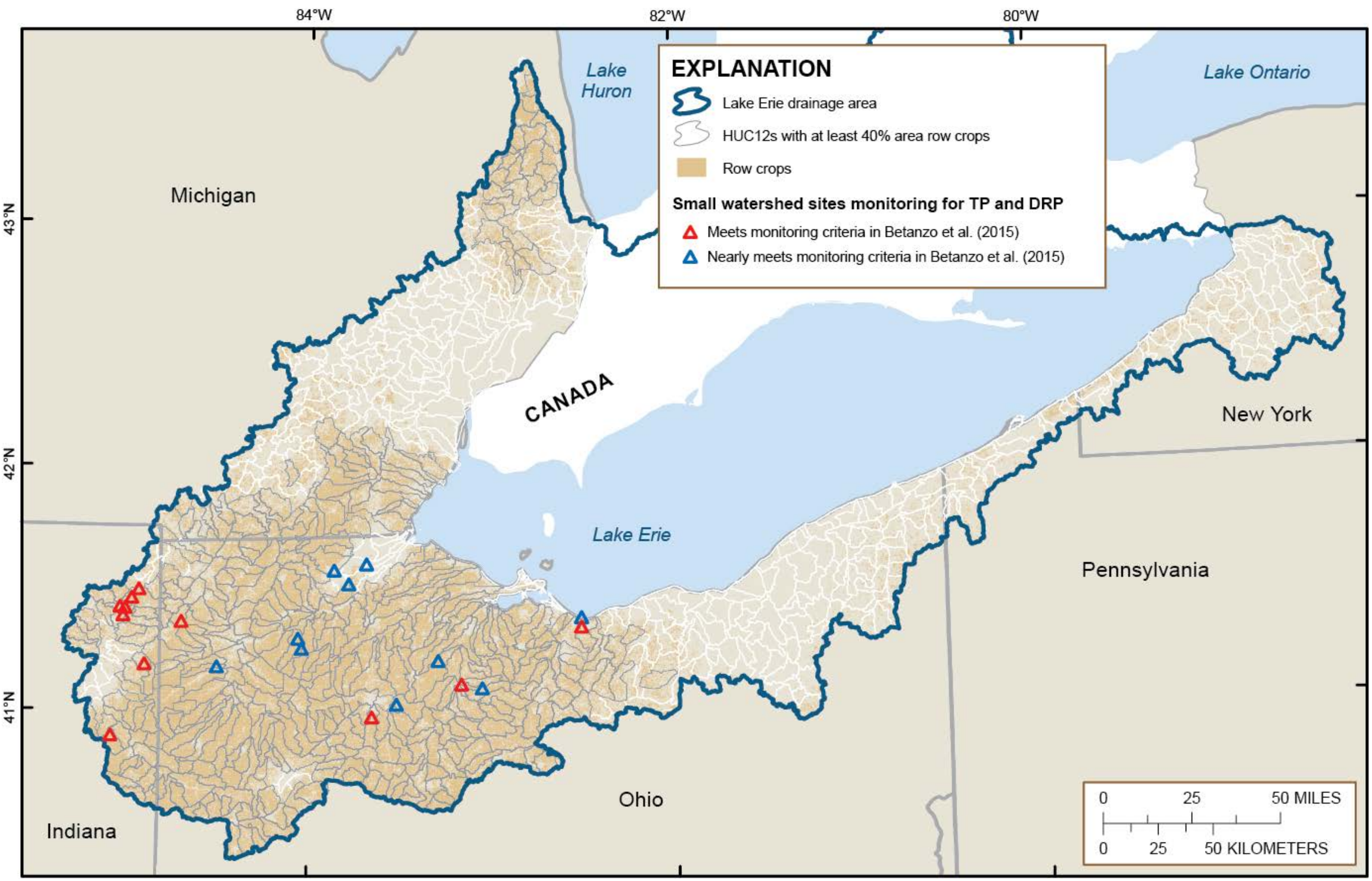
How many of the 1,890 monitoring sites meet the study criteria? Answer: 15 sites



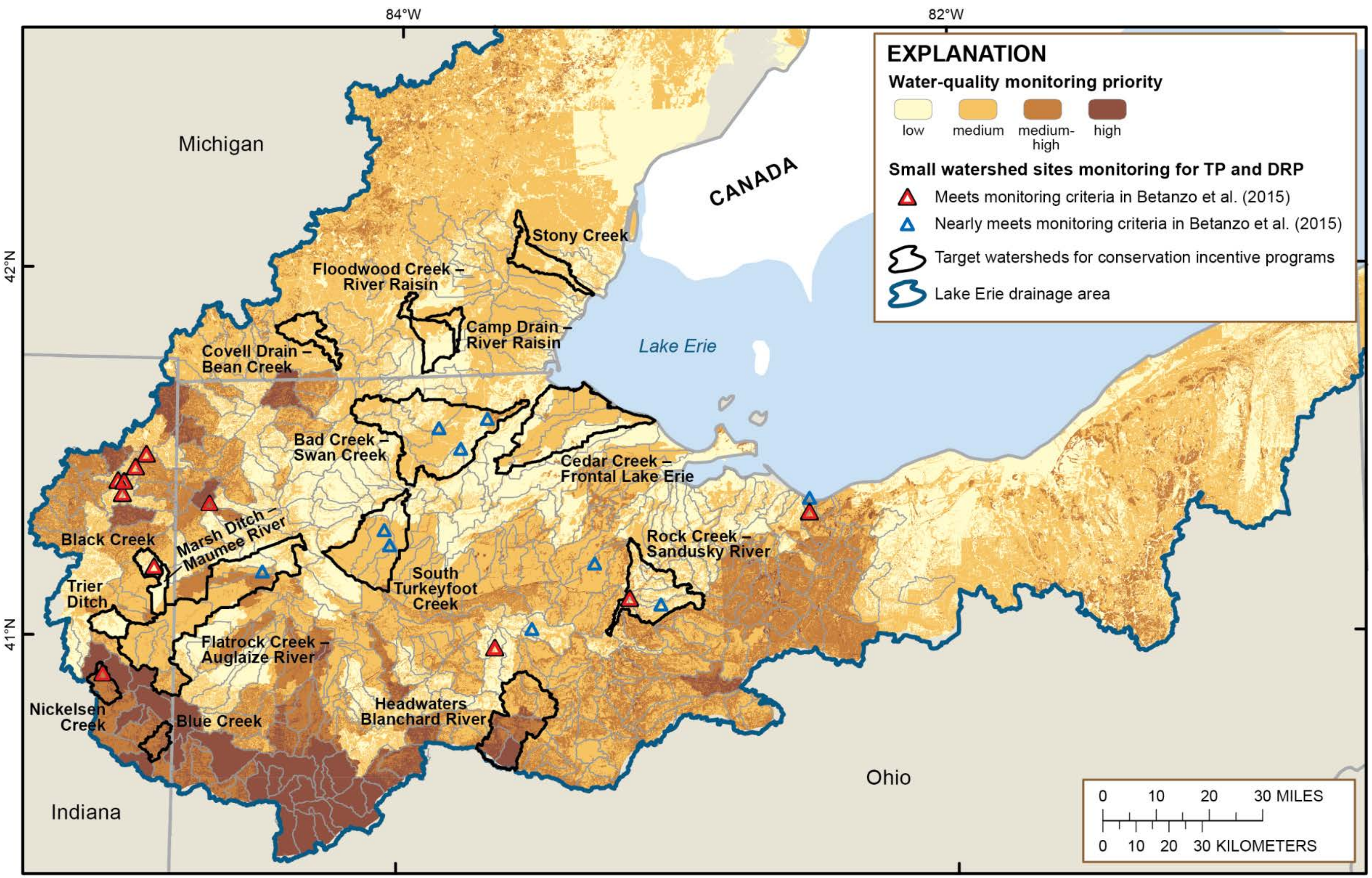
Needed data are being collected for large watersheds, near point of discharge to Lake Erie



Existing, New, and Planned Small Watershed Monitoring Sites (<=50 mi²) as of Feb. 2015



Lack of overlap between small watershed monitoring sites and conservation incentive areas, priority areas for water quality monitoring



Water Data Usability Recommendations

- Establish a coordinating entity for ensuring compatible data collection, sharing, and analysis.
- Adopt common data-management standards, data-entry protocols, and consistent naming and coding conventions.
- Additional monitoring agencies should submit data annually to the USEPA STORET Data Warehouse (WQX) and additional partners should participate in continued enhancements of the National Water Quality Portal.

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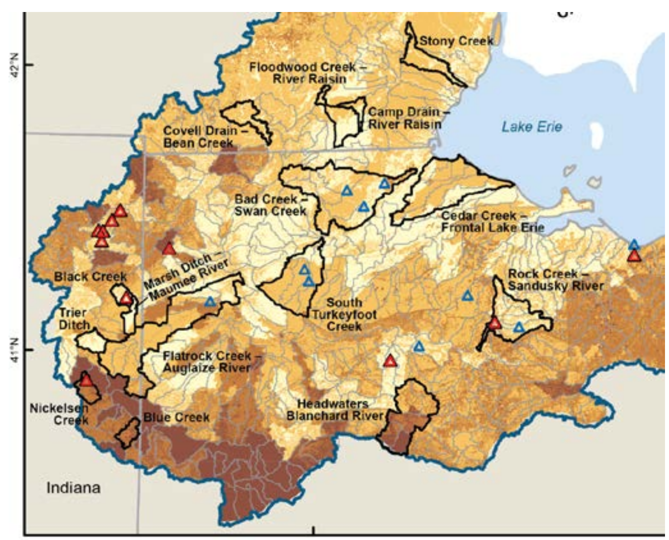
Recommendations: Right Water Data in the Right Places

- Add small watershed monitoring sites and conservation incentive areas in high priority watersheds.

- Identify modifications to water monitoring and conservation incentive programs that provide the most efficient use of small watershed monitoring resources.

- Sample for a minimum of ten years after new practices are installed.



Recommendations: Right Supporting Information

- Increase the use of agricultural management practices to generate reductions that can be detected through monitoring

- Ensure access to management practice implementation and land use data

- A coordinating entity should lead a collaborative planning process enlisting both water monitoring and agriculture organizations

Study Recommendations

Collaboration and Coordination

Increase and maintain water monitoring

Maximize management practice implementation

Collect and share implementation and land use data

Supplemental slides

Trends in concentration and load: Weighted Regressions on Time, Discharge and Season (WRTDS)

Site name and number	Monitoring period	Number of years	Total change in concentration over monitoring period (percent)	Total change in load over monitoring period (percent)
		Dissolved reactive phosphorus		
Rock Creek (ohUSGS:04197170)	1992-2012	20	+74	+159
Maumee River (ohUSGS:04193500)	1992-2012	20	+100	+118

Power analysis estimates of the number of years of monthly sampling to detect reductions in median TP concentration or load at the 20-percent error level

	Years of monthly sampling to detect reductions in median TP concentration or load at the 20-percent error level		
	10% reduction	20% reduction	40% reduction
Large: **>1,000 square miles**	>40	13 to 26	5-10[1]
Medium: **> 50 to 1,000 square miles**	>40	9 to >40	5-11[1]
Small: **50 square miles and smaller**	>40	27 to >40	5-10[1]

[1]If less than 10 years, verify the climatic conditions span a range representative of long-term climatic variability

TP: Power analysis estimates for duration of monthly sampling to detect trends (at the 20 percent error level)

	Years of monthly sampling to detect reductions in median TP concentration or load at the 20-percent error level		
Watershed size	**10% reduction** Estimated decrease in TP load with current or slightly increased rates of management practice implementation	**20% reduction** Estimated decrease in TP load with mandatory appropriate high-density management practice implementation	**40% reduction** International Joint Commission (2014) TP load reduction goal; likely requires multiple TP source reductions
Large: >1,000 square miles	>40	13 to 26	5-10[1]
Medium: > 50 to 1,000 square miles	>40	9 to >40	5-11[1]
Small: 50 square miles and smaller	>40	27 to >40	5-10[1]

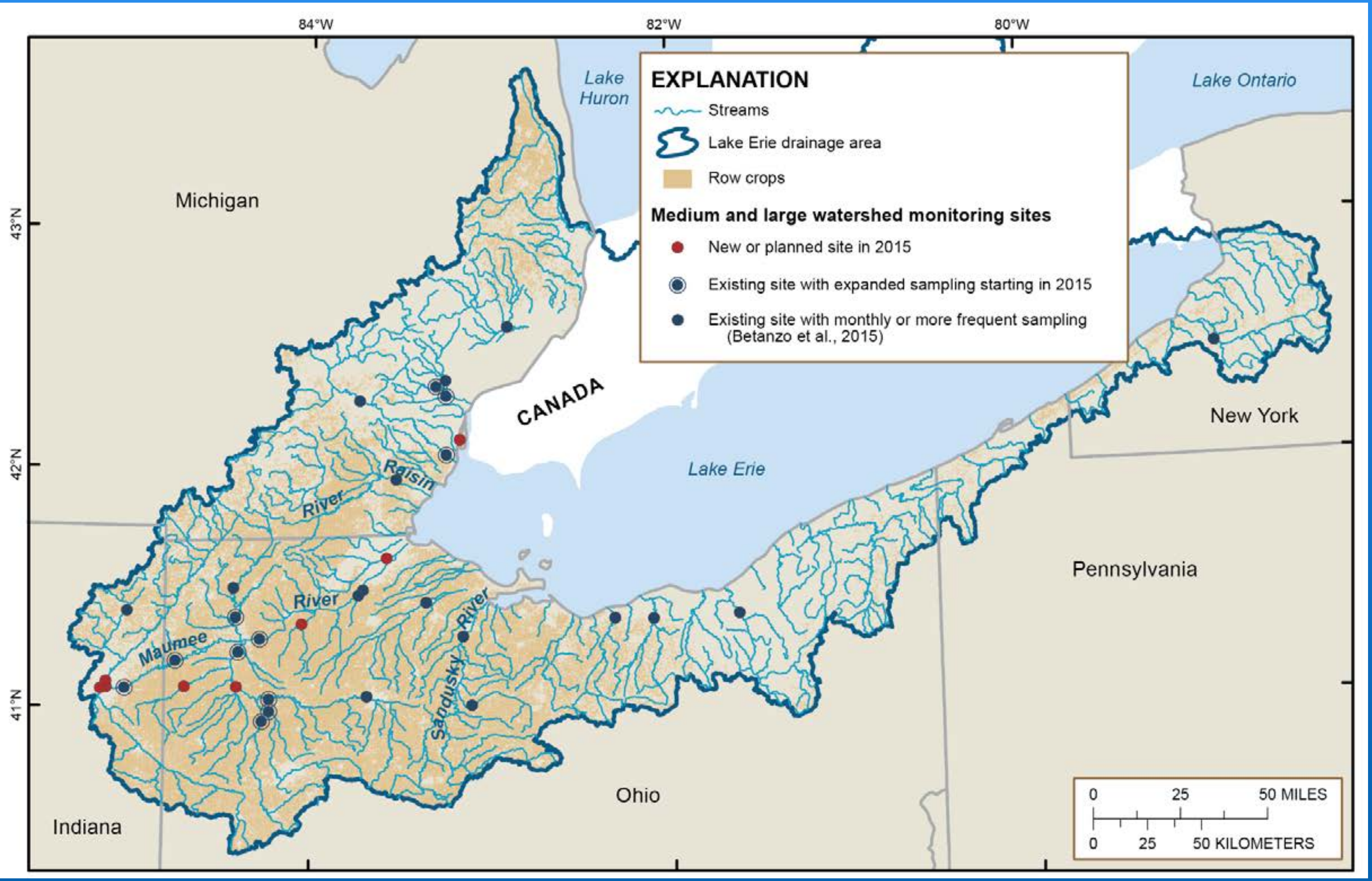
[1]If less than 10 years, verify the climatic conditions span a range representative of long-term climatic variability

DRP: Power analysis estimates for duration of monthly sampling to detect trends (at the 20 percent error level)

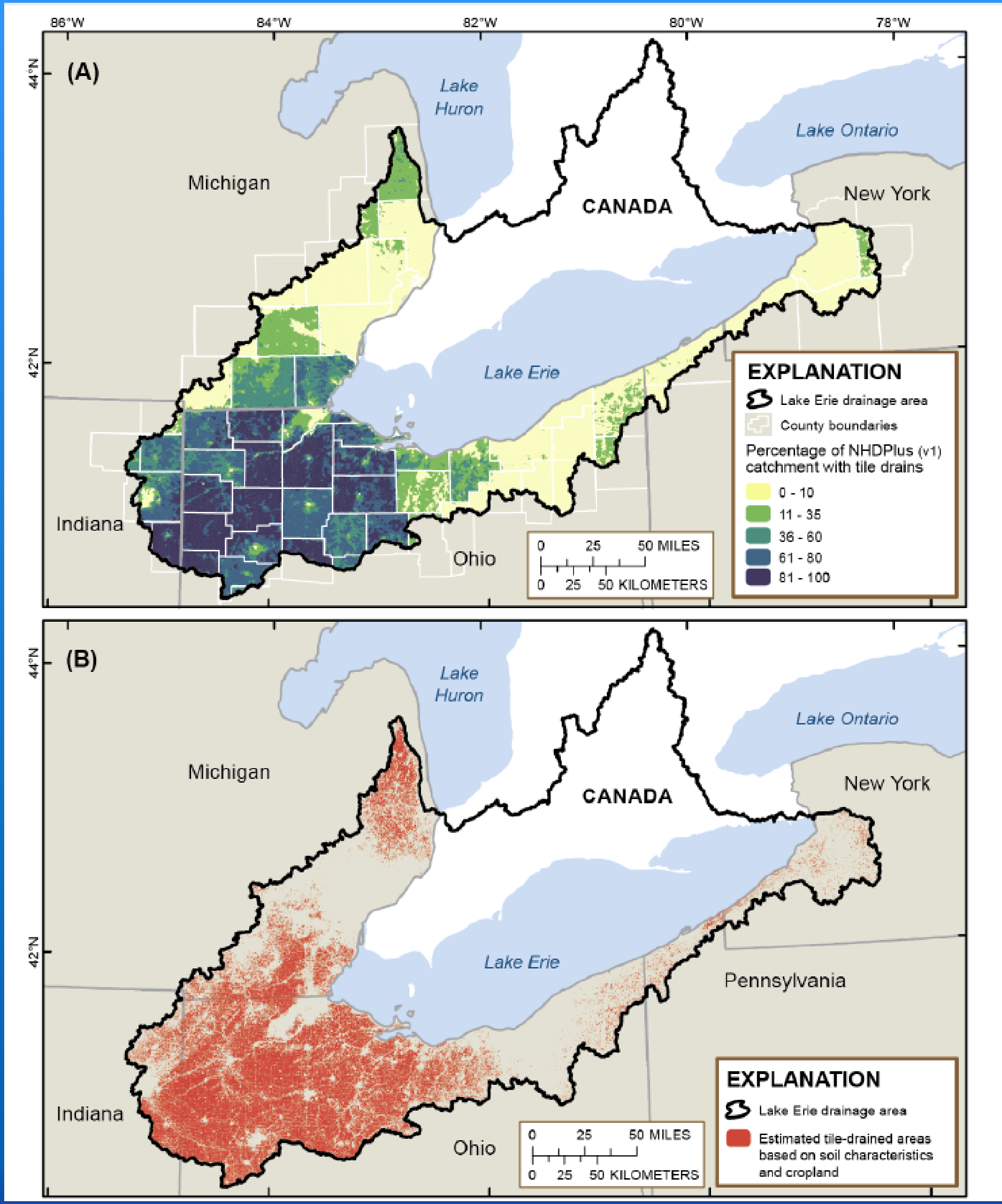
	Years of monthly sampling to detect reductions in median DRP concentration or load at the 20-percent error level		
Watershed size	**10% reduction** Estimated decrease in DRP load with current or slightly increased rates of management practice implementation	**20% reduction** Estimated decrease in DRP load with mandatory appropriate high-density management practice implementation	**40% reduction** International Joint Commission (2014) DRP load reduction goal; likely requires multiple DRP source reductions
Large: >1,000 square miles	>40	>40	24-35
Medium: > 50 to 1,000 square miles	>40	>40	8-15[1]
Small: 50 square miles and smaller	>40	>40	8-23[1]

[1]If less than 10 years, verify the climatic conditions span a range representative of long-term climatic variability

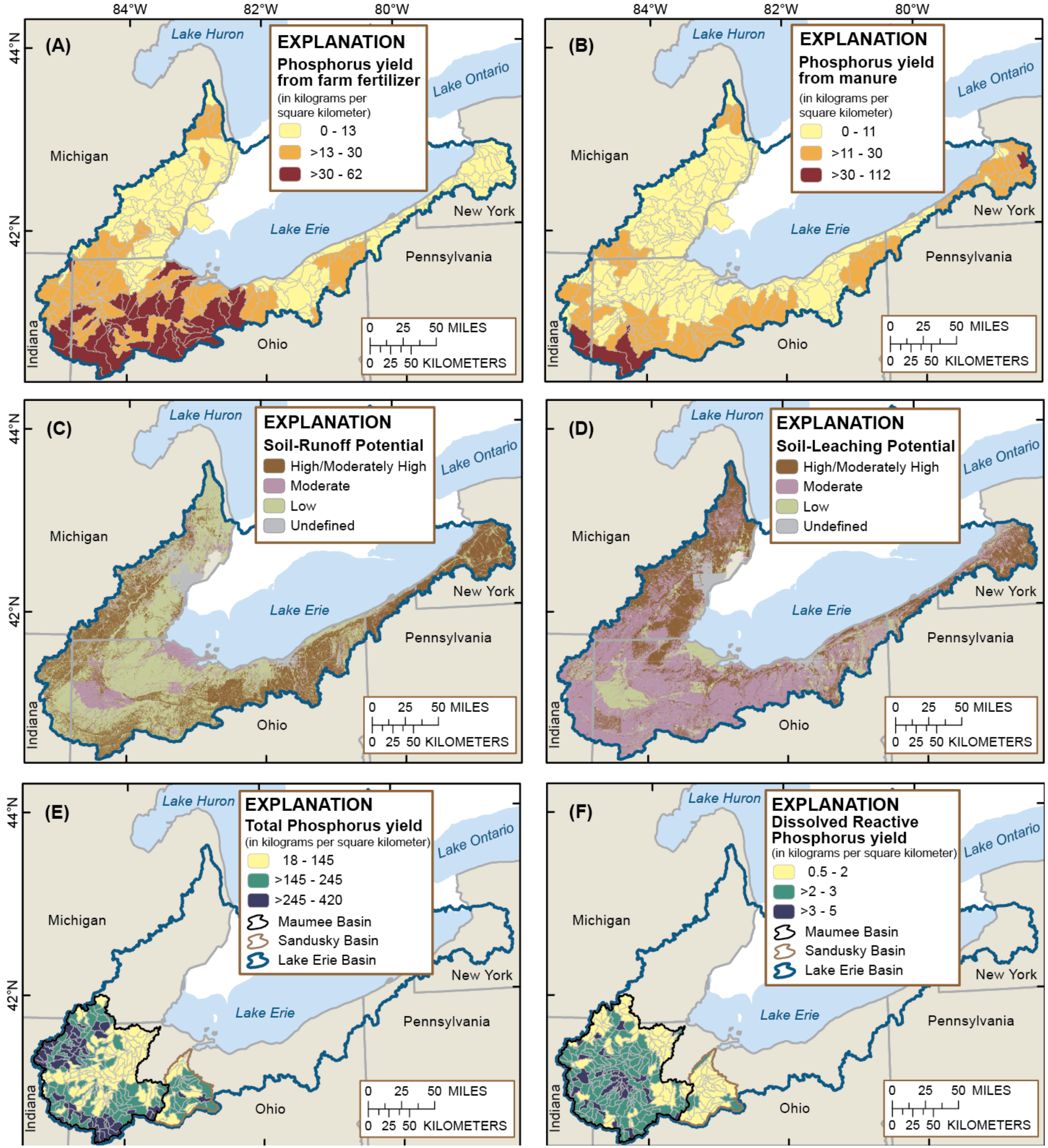
Monitoring sites in watersheds larger than 50 square miles with streamflow and at least monthly monitoring for TP and DRP, as of spring 2015



Tile drainage is extensive in the western basin



Prioritizing Locations for Water Quality Monitoring



Water data can be difficult to access

- The Water Quality Portal provides access to water-quality data in federal databases
- Of the data collected for this case study, the Water Quality Portal includes only
  - 26 percent of the monitoring sites
  - 8 percent of the water-quality data records

Right Supporting Information

Types of agricultural practices information needed to compare to water quality data

Conservation practices

- Installation dates
- Design and locations
- Maintenance plan and dates

Agricultural practices

- Crop, tillage, and management practices
- Artificial drainage changes and enhancements

Critical Supporting Information for Answering the Policy Question

Annual data on installation of agricultural management practices, and maintenance

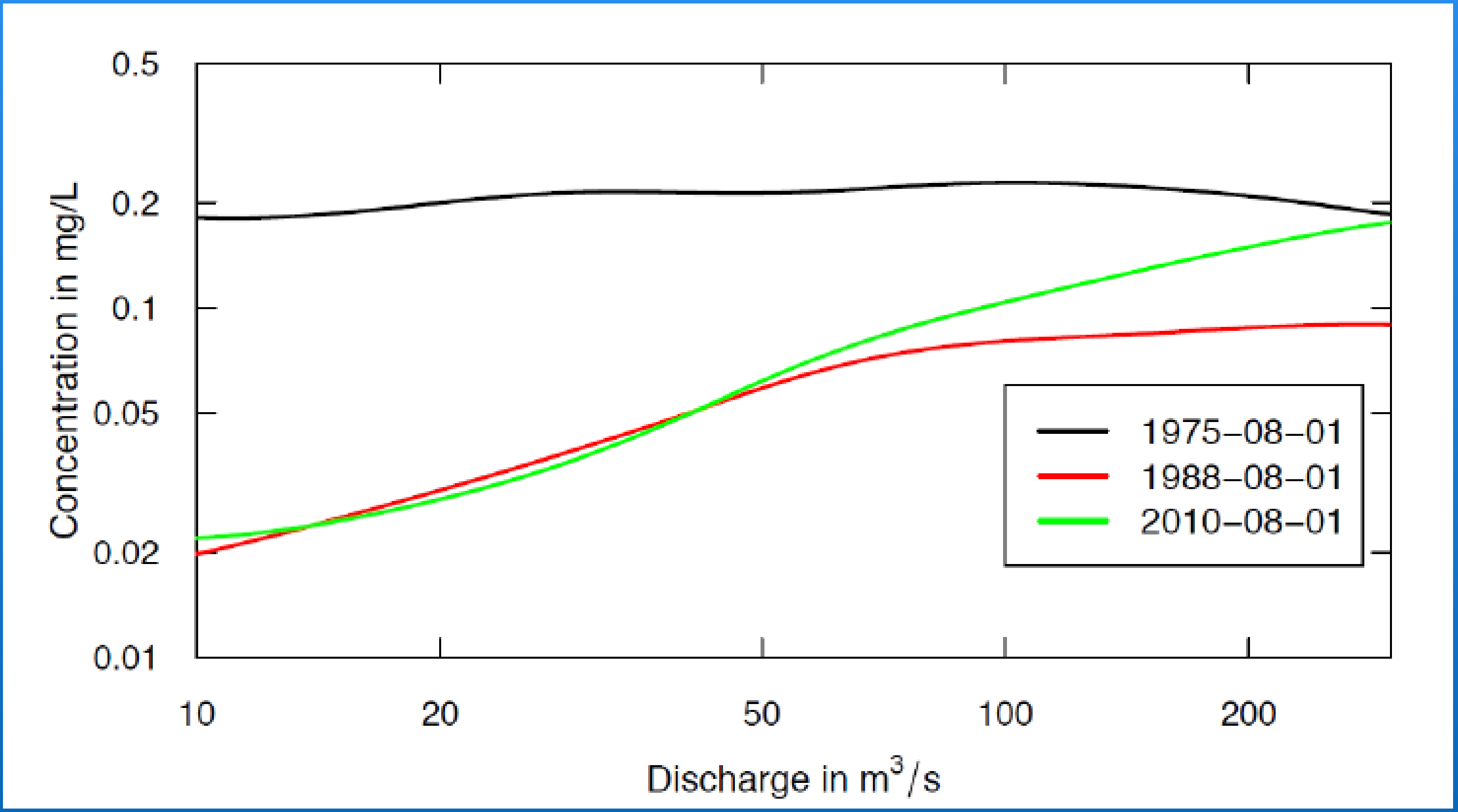
Data on changes in:
-- land use and in agricultural practices (e.g. market-driven)

-- urban and point source nutrient loading

-- climate conditions

-- artificial drainage, and hydrologic response

Changes in concentration-flow relationships over time and implications for trend detection



Dissolved reactive phosphorus, Maumee River at Waterville:
(from Hirsch and DeCicco, 2015)

Contributors to the Case Study Addendum

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Who is monitoring the small watersheds?

- Heidelberg University
- U.S. Geological Survey
- USDA, Agricultural Research Service
- NOAA, National Estuarine Research Reserve
- Ohio Environmental Protection Agency

Estimates of TP and DRP reductions for AMP scenarios in watersheds

Description of Management Practice Implementation	Estimated Percent Reduction	Reference
Large Watershed "Feasible" scenarios with voluntary management practice implementation		
Random application of no-till, cover crop, and filter strips to 20-25% of cropland in the Maumee, Sandusky, and Raisin River Basins.	-10% from baseline TP and DRP average annual yield	Bosch et al. (2013)
Management practice application to priority cropland in Lake Erie drainage basin.	-4% TP annual load	Lund et al. (2011)
Large Watershed High-Implementation Scenarios with mandated management practice implementation requirements		
No-till, cover crop, and filter strips implemented together applied to 100% of cropland in the Maumee River Basin.	-30% from baseline TP average-annual yield -26% from baseline DRP average-annual yield	Bosch et al. (2013)
Management practice application to 50% of cropland in Maumee River Basin.	-20% TP or DRP annual load	Scavia et al. (2014)
Management practice application to all "under-treated" cropland areas in the Lake Erie drainage basin.	-32% TP annual load	Lund et al. (2011)

Power analysis estimates of the number of years of monthly sampling to detect reductions in median DRP concentration or load at the 20-percent error level

	Years of monthly sampling to detect reductions in median DRP concentration or load at the 20-percent error level		
Watershed size	**10% reduction** Estimated decrease in DRP load with current or slightly increased rates of management practice implementation	**20% reduction** Estimated decrease in DRP load with mandatory appropriate high-density management practice implementation	**40% reduction** International Joint Commission (2014) DRP load reduction goal; likely requires multiple DRP source reductions
Large: >1,000 square miles	>40	>40	24-35
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Small: 50 square miles and smaller	>40	>40	8-23[1]

[1]If less than 10 years, verify the climatic conditions span a range representative of long-term climatic variability

Water Data Usability is limited by insufficient or inconsistent data sharing and documentation

- Water data sharing is limited; of the water data identified through this case study, the Water Quality Portal includes only
  - 26 percent of the monitoring sites
  - 8 percent of the water-quality data records
- Data from multiple agencies must be collected and analyzed using compatible sampling plans and protocols to compare trends in concentration and load over time
- Small watershed data are collected by USGS, Heidelberg University, USDA, NOAA NERRS, and Ohio EPA; each agency uses different monitoring designs reflecting different study objectives

Tributary phosphorus monitoring in the U.S. portion of the Laurentian Great Lake Basin: Drivers and challenges

Meredith Ballard LaBeau [a,1], Hugh Gorman [b,2], Alex Mayer [a,*], David Dempsey [c,3], Alicia Sherrin [a,4]

* Provide states with incentives to support the monitoring of phosphorus for the purpose of estimating loads to the Great Lakes.

* Identify phosphorus monitoring protocols that include enough samples to identify trends and quantify loads at a level of certainty necessary for use in statistical models and load control programs.

* Develop funding mechanisms consistent with long-term policy goals.