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

Executive Summary

Throughout its history, the United States has made major investments in assessing natural resources, such as soils, timber, oil and gas, and water. These investments allow policy makers, the private sector and the American public to make informed decisions about cultivating, harvesting or conserving these resources to maximize their value for public welfare, environmental conservation and the economy. As policy issues evolve, new priorities and challenges arise for natural resource assessment, and new approaches to monitoring are needed. For example, informed conservation and use of the nation's finite fresh water resources in the context of increasingly intensive land development is a priority for today's policy decision-makers. There is a need to evaluate whether today's water monitoring programs are generating the information needed to answer questions surrounding these new policy priorities.

The Northeast-Midwest Institute (NEMWI), in cooperation with the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program, initiated this project to explore the types and amounts of water data needed to address water-quality related policy questions of critical concern to today's policy makers. The collaborating entities identified two urgent water policy questions and conducted case studies in the Northeast-Midwest region to determine the water data needed, water data available, and the best ways to fill the data gaps relative to those questions. This report details the output from one case study and focuses on the Lake Erie drainage basin, a data-rich area expected to be a best-case scenario in terms of water data availability.

1.1 Case Study Question

The policy question that frames this case study evaluating water monitoring capacity is: How effective are management practices at reducing nutrients from nonpoint sources at the watershed scale in the Lake Erie drainage basin? This question is of urgent importance to Great Lakes decision-makers. A harmful algal bloom (HAB) in Toledo, Ohio, contaminated the city's drinking water supply in August 2014, forcing local governments to prohibit home and commercial water use for 3 days. Phosphorus is a primary nutrient that influences HAB growth, and nonpoint-source runoff in the Lake Erie drainage basin contributes 61 percent of the total phosphorus (TP) load to the lake (Ohio Lake Erie Phosphorus Task Force, 2010). Tributaries in the western Lake Erie drainage basin, which is dominated by agricultural land use, contribute the greatest external nutrient loadings to Lake Erie[1]. Any approach to control HABs must include a means of reducing nonpoint-source contributions of phosphorus and other nutrients from agricultural lands.

Understanding the effectiveness of agricultural management practices is also a priority for the Northeast-Midwest region, generally, as evidenced in an informal project survey of Northeast-Midwest Congressional Coalition member offices where many asked whether implementation of agricultural management

[1] The Detroit River and Canadian tributaries were not evaluated in this case study; the watersheds draining to the Detroit River do not meet the large watershed and agricultural land-use criteria established for this case study, and data from Canadian tributaries were not compiled.

practices could reduce nonpoint-source nutrient loads that contribute to HABs. Moreover it is clear that quantifying the effectiveness of agricultural management practices for reducing nutrients from nonpoint sources is an enduring national concern. Nutrient loads are known to cause dead zones in the Gulf of Mexico, Lake Erie, and the Chesapeake Bay (Committee on Environment and Natural Resources, 2010).

Despite this ongoing interest, the question of whether management practices produce desired nutrient reductions remains largely unresolved at the watershed scale, but not for lack of trying. Over the last 25 years, several water-quality and conservation research programs were initiated to quantify relationships between agricultural activities and water quality at the watershed scale, including the U.S. Department of Agriculture (USDA) Water Quality Initiative (Womach J., 2005), USDA Conservation Effects Assessment Project (CEAP) (Mausbach and Dedrick, 2004), and most recently, in 2012, the USDA Natural Resources Conservation Service National Water Quality Initiative (Larsen, 2014). In summary, this case study topic represents an urgent environmental and public health priority for the Great Lakes region, a national agricultural policy priority, and an issue for which a comprehensive and analytical look at water-quality data needs and data availability has the potential to create the data needed to inform new policy solutions.

1.2 Case Study Approach

The case-study approach consisted of three main tasks:

1. Describe the types and amounts of water data needed to answer the policy question,
2. Assess the extent to which those data are available and usable, and
3. Identify the additional data that would be needed to more effectively answer the policy question and estimate the level of effort to collect the additional data.

For the first task, the study team and technical advisory committee (TAC) identified the data types that were most critical for measuring the effectiveness of management practices at the watershed scale and analyzed available data to determine the quantity of data needed to detect statistically significant changes in water quality. The study team collected data available from agencies and organizations that monitor tributary water quality and USGS streamgages within the Lake Erie drainage basin, evaluated those data against the data needed, and reviewed the usability of those data to inform the policy question. Once data availability and usability were determined, the study team assessed data gaps and made recommendations for meeting data needs to inform the policy question. This report identifies the minimum amount of water data needed to detect statistically significant change in water quality due to agricultural management practice implementation within a 10-year time frame, given certain study design assumptions; identifies available water data; and makes recommendations for filling the information gaps.

1.3 Case Study Findings

The case study findings relative to water data needed, water data available and usable, and approaches to filling the data gaps are summarized below.

1.3.1 Water data needed to answer the policy question

- **Water data needs for addressing the case-study policy question are highly dependent on study design.**

It is not possible to identify water data needs for answering the case-study policy question without an initial discussion of an appropriate study design (Figure ES-1). For example, the selection of appropriate monitoring sites for answering the case-study policy question is critical. Monitoring sites must be located in watersheds dominated by agricultural land use, and where management practices can, and will, be widely implemented in optimal places for reducing nutrient loss. Monitoring sites in these types of watersheds allow for the detection of water-quality changes that these practices can generate. Further, tributary water-quality and streamflow data at these monitoring sites must be available to evaluate trends in concentration and load in these watersheds over time. Finally, data on management practice implementation and other changes in land use and nutrient sources throughout the watershed must be available to correlate water-quality change with alterations on the land. Without this information, the relationship between management practices and water quality cannot be evaluated, even if management practices are delivering detectable reductions in nutrient loads.

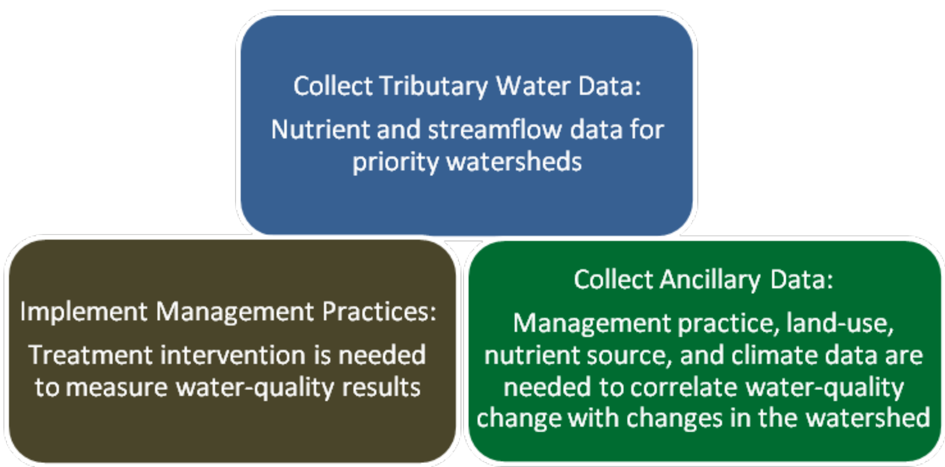


Figure ES-1. Study design needed to answer "How effective are management practices at reducing nutrients from nonpoint sources at the watershed scale?"

- **Water data are needed from two watershed scales to answer the case-study policy question.**

The time and effort required to establish the necessary study conditions described in Figure ES-1 will be most readily achievable in small (less than 50 square miles) agricultural watersheds. At the same time, large (more than 1,000 square miles) agricultural watersheds that drain directly to Lake Erie are largely responsible for the nutrient loads that lead to HABs; complex nutrient fate and transport mechanisms in these large tributaries preclude scaling results from small watersheds. Therefore, water data from large watersheds, specifically the Maumee River, Sandusky River, and the River Raisin in the Lake Erie drainage basin, are also critical to addressing the case-study policy question.

- **The sampling frequency and duration of monitoring must meet minimum requirements to adequately characterize and detect changes in nutrient concentrations and loads to be used to answer the case-study policy question.**

Assuming the necessary management practice intensity and ancillary data (Figure ES-1) are available, tributary water-quality and streamflow data requirements can be characterized as shown in Table ES-1. A minimum of six monitoring sites in six small watersheds are needed to provide spatial representation of the Lake Erie drainage basin, and one monitoring site is needed in each of the three large watersheds that meet the identified criteria.

The most critical parameters for assessing the effectiveness of management practices in the Lake Erie drainage basin are total phosphorus (TP), dissolved reactive phosphorus (DRP), and streamflow. The sampling frequency at each monitoring site must capture the full range of hydrological conditions within the watershed annually and over time. Several sampling frequency options are presented in Table ES-1. The increase in sampling frequency across these options reflects improved ability to characterize the relationship between streamflow and concentration.

Monitoring duration must be sufficient to detect the effects of new changes to the landscape and distinguish them from historical land management practices, climate effects, and other factors. If appropriate agricultural management practices are implemented and consistently maintained throughout a watershed such that annual TP loads are reduced by 40 percent, a load reduction goal recommended by the International Joint Commission (2014), a monthly sampling program would be able to detect that change for both small and large watersheds with statistical significance within 10 years. However, current or moderately increased rates of management practice implementation are expected to generate reductions in TP loads that are closer to 10 percent, particularly in large watersheds, according to available models (Bosch et al., 2013; Lund et al., 2011). This case study found that more than 40 years of monthly TP data would be needed to detect a 10-percent change at a given monitoring site with statistical significance because the natural variation that occurs in streamflow and water quality from year to year obscures this small magnitude of change.

Table ES-1. Summary of water data needed to detect water-quality change resulting from agricultural management practices in the Lake Erie drainage basin. Analysis supporting these findings is presented in Chapter 5.

[Abbreviations: %, percent; TP, Total Phosphorus; DRP, Dissolved Reactive Phosphorus]

	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
Number of watersheds and monitoring sites	Minimum of 6 active monitoring sites (1 per watershed) representing a variety of watershed characteristics and spatially distributed across the agricultural areas of the basin	3 active monitoring sites (1 per watershed)
Monitoring parameters	• TP, DRP, streamgage • Suite of parameters from Table 3	• TP, DRP, streamgage • Suite of parameters from Table 3
Sampling frequency options	• 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) • Daily plus storm sampling (approx. 500 per year), or • 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) • Daily plus storm sampling (approx. 500 per year), or • 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
[2]See Table 16 and Table 17

1.3.2 Availability and usability of existing water data to answer the policy question

This investigation found more than 300,000 TP and DRP records collected at nearly 2,000 monitoring sites over the last 70 years in the Lake Erie drainage basin (Figure ES-2). However, as indicated in Figure ES-3 only six of those monitoring sites use a sampling plan that meets the specifications summarized in Table ES-1 for addressing the case-study policy question. This study found the following specific results regarding currently available data:

- **The small watershed data needed for answering the case-study policy question are not currently being collected.**

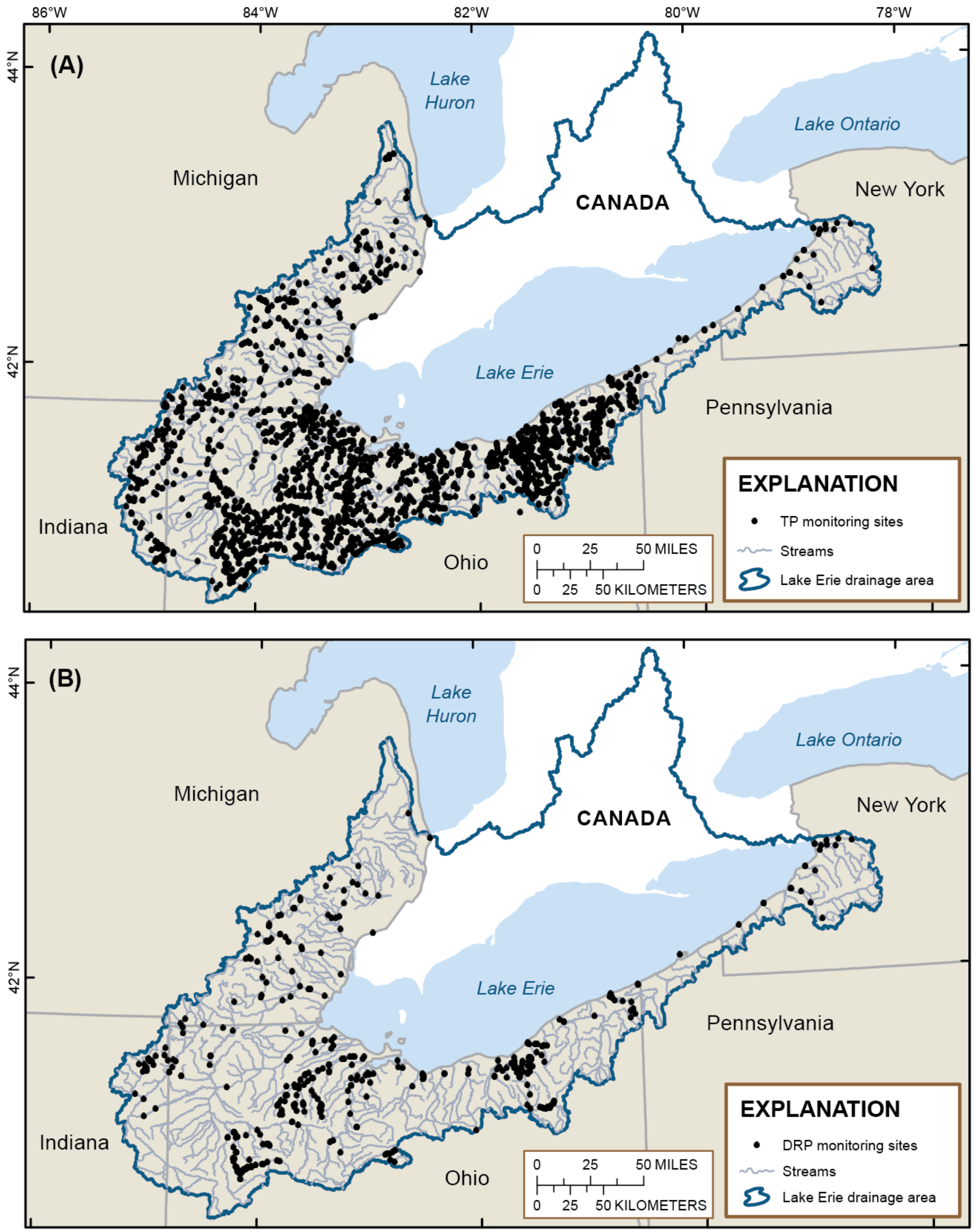
The water data collected at only two existing small watershed monitoring sites meet the requirements described in Table ES-1. The two sites (site E, unnamed Tributary to Lost Creek, and site F, Rock Creek, in Figure ES-3) are monitored by Heidelberg University at USGS streamgages. Water data collected at two other sites maintained by the USDA and the National Oceanic and Atmospheric Administration (NOAA) National Estuarine Research Reserve System (NERRS) could, with increased sampling frequency, provide the needed data for two additional monitoring sites. Nonetheless, a minimum of two entirely new small watershed monitoring sites also would be needed to meet the data needs for answering the case-study policy question.

- **The needed water-quality data are being collected for the three large watersheds; data collection at these sites should continue uninterrupted into the future to be useful in answering the policy question.**

Water-quality and streamflow data are being collected by Heidelberg University and the USGS for the three large agricultural watersheds that drain directly to Lake Erie, at monitoring sites on the Raisin, Maumee, and Sandusky Rivers where they discharge into the western basin of Lake Erie. These monitoring sites (A-D in Figure ES-3) measure the needed parameters with daily or continuous sampling frequency, and over 30 years of data records are available for these monitoring sites. Data collection should continue at these sites to measure changes in nutrient concentrations and loadings to Lake Erie over time as management practices continue to be implemented throughout the watersheds.

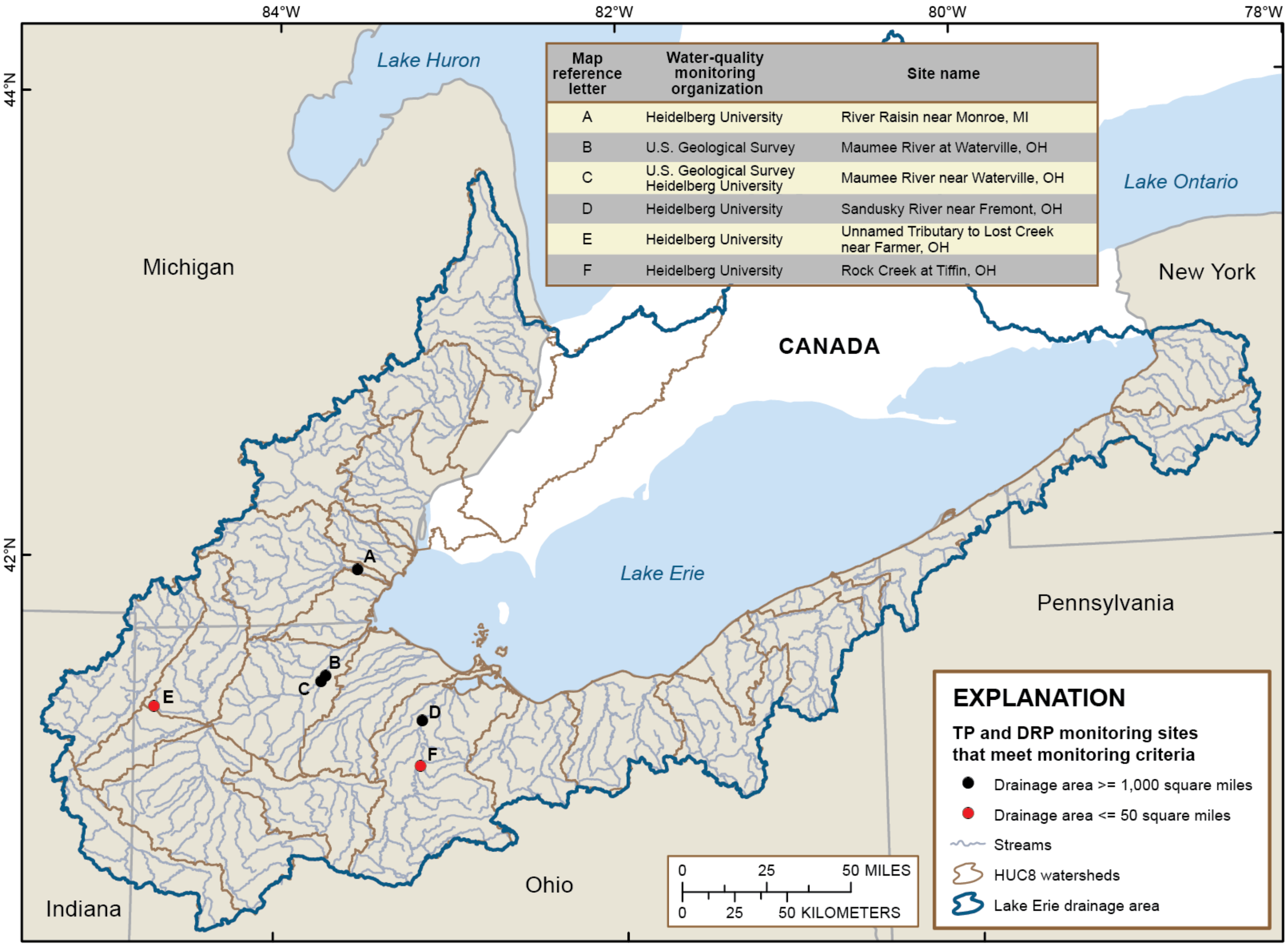
- **Current water data usability for answering the policy question is limited by insufficient or inconsistent data documentation and sharing.**

Water-quality monitoring programs are usually designed to meet a stated objective or follow a historical precedent. Data collected for one monitoring objective may not be directly applicable to another objective, due to the location of monitoring sites, frequency of monitoring, parameters measured, and analytical methods used. The water-quality records identified through this case study were generated by 17 organizations that collect nutrient-related data in the Lake Erie drainage basin. Insufficient and inconsistent documentation of available data limited the utility of these existing data sets. Substantial project time and effort over the course of this multi-year project were required to locate, obtain, and consistently format data.



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

Figure ES-2. Monitoring sites in the Lake Erie drainage basin with one or more water-quality records for (A) total phosphorus (TP) or (B) dissolved reactive phosphorus (DRP).



Map reference letter	Water-quality monitoring organization	Site name
A	Heidelberg University	River Raisin near Monroe, MI
B	U.S. Geological Survey	Maumee River at Waterville, OH
C	U.S. Geological Survey Heidelberg University	Maumee River near Waterville, OH
D	Heidelberg University	Sandusky River near Fremont, OH
E	Heidelberg University	Unnamed Tributary to Lost Creek near Farmer, OH
F	Heidelberg University	Rock Creek at Tiffin, OH

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

HUC8 watersheds from U.S. Department of Agriculture, February 2012, ftp://ftp.ftw.nrcs.usda.gov/wbd/

Figure ES-3. Active water-monitoring sites in the Lake Erie drainage basin in priority watersheds that collect water data needed for detecting changes in water quality resulting from agricultural management practices. These sites collect TP, DRP, and streamflow daily or have continuous monitors, and have 5 to over 30 years of data records. The U.S. Geological Survey operates the streamgages at each of these monitoring sites. [**Abbreviations**: TP, total phosphorus; DRP, dissolved reactive phosphorus; HUC, hydrologic unit code]

Data sharing and data accessibility were also limiting factors in data availability in this case study. It is possible that despite the work completed for this case study, additional relevant data that are not being shared or are not available in electronic format may exist. The Water Quality Portal (National Water Quality Monitoring Council, 2014a), a cooperative service that provides publicly available water-quality data from federal databases, including data collected by more than 400 state, federal, tribal, and local organizations, was established to facilitate water data sharing. Yet data collected at only 26 percent of the monitoring sites identified through this case study in the Lake Erie drainage basin were available through the Water Quality Portal, and only 8 percent of the water-quality data records are available through the Portal.

Finally, for water data to be useful for addressing the policy question, they must be compatible in terms of sampling plans and protocols, analysis, and interpretation. Several agencies and organizations collect small watershed data that meet or nearly meet the data needs identified in section 1.3.1, including USGS, Heidelberg University, USDA, NOAA NERRS, and additional agencies described in the addendum to this report (Betanzo et al., 2015). However, these agencies all use different sampling plans that limit the ability to compare trends in concentration and load over time at these monitoring sites.

1.3.3 Approaches for filling data gaps to answer the policy question

This section presents the study findings regarding approaches for filling the data gaps to address the case-study policy question in the Lake Erie drainage basin.

- **Add at least two new small watershed monitoring sites in watersheds with priority characteristics.**

As noted in Table ES-1, six monitoring sites for each of six small watersheds are needed to address the policy question. Given data available in the Lake Erie drainage basin, two additional monitoring sites, one per each of two small watersheds, will be needed. Table ES-2 presents a strategy for identifying and prioritizing candidate small watersheds for additional monitoring to answer the case-study policy question. This report identifies several small watersheds with both high phosphorus yield and high vulnerability to soil loss and no current monitoring sites. At least one of the two new monitoring sites should be located in this area. The second site should be a watershed with high phosphorus yield or high vulnerability to soil loss but also provide spatial representation of the drainage basin. New monitoring sites may require new streamgages in addition to new water-quality data. New water monitoring sites and management practice incentive programs are already under development in the Lake Erie drainage basin and are described in an addendum to this report (Betanzo et al., 2015). The recommendations of this report, site selection process (Table ES-2), and data needed (Table ES-1) should be considered and incorporated as plans for new small watershed monitoring sites are finalized if the new sites are to be instrumental in answering the case-study policy question.

- **Increase sampling frequency at two existing small watershed monitoring sites.**

Increased and consistent sampling frequency of both TP and DRP at two existing monitoring sites maintained by USDA and NOAA NERRS would qualify these sites to become a part of the set of six monitoring sites needed to address the case-study policy question. Specifically, monthly year-round data collection, in addition to the current sampling frequency, would be necessary to meet the monitoring needs identified in Table ES-1.

Table ES-2. Process for identifying the most effective small watershed monitoring sites.

Process for identifying new small watershed monitoring sites
1. Identify candidate watersheds: • Watersheds with priority characteristics (high phosphorus yield and/or high vulnerability to soil loss) • Watersheds with existing streamgages and/or water-quality data.
2. Examine location of candidate watersheds relative to other monitoring sites that might allow for nested monitoring designs, such as edge-of-field, mid-size, and large watershed monitoring sites.
3. Examine candidate watersheds on a case-by-case basis for local information: • Representation of tile drainage in the watershed, • Untreated areas with potential for high implementation rates of new management practices • Willingness of agricultural community to implement and maintain new management practices throughout candidate watershed, and • Willingness of agricultural community to share management practice and land-management data with monitoring agency.
4. There may be situations in which monitoring sites in watersheds without priority characteristics are the most feasible study locations.

- **Maintain water-quality and streamflow monitoring at the two small watershed sites monitored by Heidelberg University and the USGS.**

The remaining two small watershed monitoring sites needed to compose the set of six sites are currently in place (sites E and F, Figure ES-3). However, monitoring would need to continue unchanged over time at these sites as new agricultural management practices are implemented within these watersheds.

- **Maintain data collection and analysis at all small watershed monitoring sites for a minimum of 10 years during implementation of new management practices.**

Water-quality and streamflow data should be collected in the six small watersheds for at least 10 years after new practices are implemented. New monitoring and new management practice implementation should begin as soon as possible to minimize the time to detect water-quality change and produce policy-relevant information regarding the case-study policy question. The new data should be evaluated and loads calculated annually so the sampling plans can be adjusted as necessary to adapt to an evolving understanding of management practice effectiveness and water quality.

- **Maintain monitoring at large watershed monitoring sites.**

Data collection at the large watershed monitoring sites (A-D in Figure ES-3) should continue to capture changes in TP and DRP concentrations and loadings to Lake Erie. In addition to supporting evaluation of agricultural management practices, monitoring these large watersheds provides critical information to estimate the total nutrient loads to the western basin of Lake Erie; to measure long-term water-quality change that may result from agriculture, urban development, or climate change; and to support additional river, lake, and ecosystem research and resource management applications.

Filling the data gaps to answer the case-study policy question:

- A minimum of two additional small watershed monitoring sites are needed. Effective monitoring sites should be identified using the process described in Table ES-2. New small watershed monitoring sites should collect the water data identified in Table ES-1.
- Increased sampling frequency at the USDA and NERRS small watershed monitoring sites to include monthly year-round data collection, in addition to the current sampling frequency, is needed for these monitoring sites to fill the need for two small watershed monitoring sites. Both TP and DRP should be sampled at the same frequency at these sites.
- Continued water-quality and streamflow monitoring are needed at the two small watershed sites monitored by Heidelberg University and the USGS who collect the needed water data.
- All small watershed monitoring sites need a minimum of 10 years of monitoring during implementation of new management practices and sharing of management practice implementation data.
- Continued long-term water-quality and streamflow monitoring are needed at the Raisin, Maumee, and Sandusky River sites monitored by Heidelberg University and the USGS.

- **Improve water data coordination and sharing across monitoring agencies and organizations in the Lake Erie drainage basin.**

For water data to be used to answer the case-study policy question, monitoring agencies and organizations should coordinate sampling plans among new and existing monitoring sites so data collection, analysis, and interpretation can be compatible and comparable. Data coordination across agencies can be achieved through a coordinating entity that facilitates collaboration on sampling plans, data sharing, and data analysis in the Lake Erie drainage basin. Improved data documentation and data sharing will facilitate the use of water data for answering the case-study policy question. Tools such as the Water Quality Exchange (WQX) (U.S. Environmental Protection Agency, 2015) and the Water Quality Portal provide the infrastructure for organizations to format and share their data, but greater participation is needed. Consistent, thorough data documentation and wider availability of data sources through services such as the Water Quality Portal will increase the value of water-quality data from all monitoring agencies and reduce the amount of time needed to access and prepare data for new applications. A continued commitment to water-quality data-sharing systems is essential for maximizing use of existing water-quality data.

Improve water data usability:

- Establish a coordinating entity for ensuring compatible data collection, sharing, and analysis across the Lake Erie drainage basin.
- Adopt common data-management standards, data-entry protocols, and consistent naming and coding conventions across monitoring agencies.
- Additional monitoring agencies should submit data annually to the U.S. Environmental Protection Agency (USEPA) Storage and Retrieval (STORET) Data Warehouse and additional partners should participate in the Water Quality Portal.

- **Maximize management practice impact in monitored watersheds.**

As noted in section 1.3.1, appropriate agricultural management practices must reduce TP loads in a watershed by 40 percent for a monthly sampling program to detect that change with statistical significance within 10 years. To achieve this goal, appropriate management practices should be strategically and extensively installed in areas most likely to result in nutrient reductions. Due to complexities of nutrient transport, agricultural specialists are in the best position to identify the most effective agricultural management practices for specific applications. Substantial treatment intervention will be needed to produce a 40-percent reduction in TP load. Generating this coverage in large watersheds almost certainly would require policy interventions, such as incentive programs. Smaller watersheds, though more practical to work with due to their size and the smaller number of producers, may also require incentives within specified watersheds.

- **Collect consistent, detailed data on implementation of agricultural management practices and other changes to the land and other nutrient sources within monitored watersheds.**

As noted earlier, in addition to water-quality data, consistent, detailed documentation of changes on the land and other nutrient sources within a watershed are needed to interpret water-quality data to answer the case-study policy question. Agricultural management practice implementation data are generally not available due to data sharing restrictions and lack of documentation at the level of detail needed for water-quality analysis (Jackson-Smith et al., 2010). Moreover, Section 1619 of the Farm Bill[2] restricts access to conservation practice data that have been provided to the USDA; water-quality researchers must depend on farmers' willingness to share their land management data. Protected data collection and data sharing systems for these types of ancillary data are needed to efficiently collect, store, and share these data at the level of detail needed for water-quality data analysis. Annual land management data are needed to

[2] Section 1619 7 U.S.C. § 8791

correlate water-quality change with annual changes on the land. The detailed ancillary data needed to interpret the water-quality data are either unavailable or difficult to obtain.

1.4 Conclusion

Additional water data are needed at both small and large watershed scales to answer the case-study policy question in the Lake Erie drainage basin. The recommendations in this report present the additional water data that will allow the question to be answered in a policy-relevant time frame. Key steps to generating the needed information include strategically selecting watersheds for monitoring, maximizing management practice impact in monitored watersheds, and collecting ancillary data necessary for water-quality data analysis. However, with cooperation and coordination of producers, local conservation staff, and water monitoring agencies, data collection and analysis can answer this long-standing policy question of critical importance to the Northeast-Midwest region. The sooner the region gets started, the better.

Summary of information needs to answer "How effective are management practices at reducing nutrients from nonpoint sources at the watershed scale?"

Collect tributary water data

- Increase small watershed monitoring capacity: Additional monitoring sites, additional sampling frequency at existing sites, and continued monitoring at selected small watershed monitoring sites are needed.
- Continue to invest in large watershed monitoring: Continued long-term water-quality and streamflow monitoring are needed at monitoring sites on the Raisin, Maumee, and Sandusky Rivers where they drain to Lake Erie.
- Improve usability of new and existing water data: Establish an entity for coordinating water monitoring and management practice implementation; encourage use of data-management standards and data-entry protocols, and increase participation in data sharing programs.

Implement agricultural management practices

- Maximize management practice impact in monitored watersheds to reduce time to detect changes in water quality.

Collect ancillary data

- Collect detailed management practice implementation and other ancillary data in both large and small monitored watersheds and make available for water-quality data analysis.