U.S ACTION PLAN FOR LAKE ERIE

2025 MILESTONE REPORT

This document is an update and companion to the U.S. Action Plan for Lake Erie published in 2018. It was developed pursuant to the 2012 U.S.-Canada Great Lakes Water Quality Agreement.

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PREFACE

Excessive algal growth in Lake Erie poses significant threats to the environment, human health, and the economy of the region. Multiple state and federal government agencies are working together to reduce phosphorus inputs that fuel harmful algal blooms and protect this important source of drinking water for 11 million Americans.

The U.S. and Canada adopted phosphorus reduction targets for Lake Erie in 2016, per the U.S.-Canada Great Lakes Water Quality Agreement (GLWQA). This document serves as an update to the *"U.S. Action Plan for Lake Erie (2018),"* and was developed pursuant to the GLWQA, and in accordance with the *"Lake Erie Binational Phosphorus Reduction Strategy (2019)*."

The GLWQA does not require that the U.S. and Canada achieve, or commit to achieving, phosphorus reduction goals in a specific timeframe. However, to demonstrate their commitment to act swiftly, Ohio, Michigan and Ontario committed to achieve the 40% reduction by 2025, through what's known as the Western Lake Erie Basin Collaborative Agreement. While Indiana and the Federal governments were not parties to this agreement, all of the jurisdictions are reporting progress annually and agreed that 2025 would be an appropriate milestone date to assess progress.

The 2025 Milestone Report reflects the fact that significant progress is being made but more needs to be done. Federal and state agencies are actively implementing management actions to reduce phosphorus and are committed to continuing and accelerating progress on the ground and evaluating our progress regularly. Indications thus far are that the implementation efforts are directionally correct. Should future reviews find that the lake is not responding to phosphorus reduction, or that our management strategies are ineffective at reducing phosphorus, we will issue new or updated action plans, as appropriate.

ACKNOWLEDGEMENTS

This report was developed by the U.S. Environmental Protection Agency, Great Lakes National Program Office, with the assistance of multiple state and federal agency partners:

Indiana Department of Environmental Management
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New York State Department of Environmental Conservation
Ohio Department of Agriculture
Ohio Environmental Protection Agency
Ohio Lake Erie Commission
Pennsylvania Department of Environmental Protection
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United States Geological Survey Water Centers

EXECUTIVE SUMMARY

Excessive algal growth in Lake Erie is caused by high levels of nutrients, specifically phosphorus (P), from agricultural and municipal runoff. Federal and state governments are collectively taking action to reduce phosphorus inputs and improve water quality. The goal is to reduce phosphorus loads from the U.S. by approximately 7.3 million pounds per year. Since adopting this goal in 2016, the governments have worked with numerous partners and stakeholders to develop the Lake Erie Binational Phosphorus Reduction Strategy, multiple state and federal level "Domestic Action Plans" (DAPs), and a Binational Lake Erie Nutrient Adaptive Management Framework to track and evaluate progress.

This 2025 Milestone Report shows clear progress toward reducing phosphorus inputs to the lake, while underscoring the need to go further to meet the binational targets and minimize harmful algal blooms (HABs) and hypoxia. Phosphorus remains the primary and most manageable driver of Lake Erie HABs, and the Maumee River—Lake Erie's largest tributary, dominated by cropland and nonpoint sources—continues to be the top U.S. priority for P reduction.

In the 10 years since P targets were established under GLWQA in 2016, phosphorus loads from the U.S. have been curbed significantly. Still, major tributaries routinely exceed target P levels, and smaller tributaries can drive localized blooms. Water quality trends reflect both progress and persistent challenges. EPA analyses indicate mixed trends in the Maumee River: flow-normalized total P loads have increased, while soluble P has decreased relative to 2008. There are some indications of water quality improvement – specifically, the HABs of 2020-2024 were mild in comparison to the 2010s; and phosphorus loads from the Maumee River and Detroit Rivers have been lower in recent years. However, river discharge remains the strongest driver of tributary nutrient loading, and a single wet year or a few intense storms could deliver high loads and disrupt the downward trend we're seeing now.

Over the past decade, federal and state agencies in Ohio, Michigan, and Indiana have supplied over $400 million in financial incentives to accelerate adoption of conservation practices in the western Lake Erie basin watershed (WLEB). Farmers in the WLEB have worked with USDA NRCS assistance to voluntarily implement nearly 13,000 conservation practices since 2013, reducing phosphorus losses at edge-of-field by more than 4.3 million pounds. The Ohio Department of Agriculture's H2Ohio program launched in 2019 has enrolled 1.85 million acres under nutrient management plans, keeping an estimated 550,000 pounds of phosphorus out of waterways. If maintained, this would indicate that about half of the 5.3 million acres of cropland in the watershed are enrolled in a federal or state conservation program, which is an outstanding adoption level.

Trends in fertilizer use are showing positive signs. Ohio's Fertilizer Applicator Certification program has increased education on fertilizer use, and Ohio continues to expand outreach to farmers through training and technical assistance. Most farmers in the WLEB routinely test soils, and soil test P is declining. Acres serviced by 4R Certified providers grew from around 1 million in 2016 to more than 1.5 million by late 2022. In Ohio, use of commercial fertilizer is declining while crop yields steadily increase. Long-term mass balances indicate that, since 2003, crops have removed more phosphorus at harvest than has been applied.

Michigan has achieved substantial point-source reductions through operational improvements to Detroit's wastewater treatment. To date, Michigan estimates a 450 metric ton reduction in total P, meeting its 20% reduction by 2020 and projecting roughly two-thirds of the 40% target by 2025. The remaining ~200 metric tons will need to come from agricultural nonpoint sources, and the state is expanding field-by-field inventories, farm-specific conservation plans, and greater technical assistance to lower barriers to adoption.

Indiana has prioritized the St. Marys River—the state's highest source of phosphorus—by expanding monitoring with USGS and local partners and addressing key contributors such as unregulated livestock operations and failing septic systems. Major urban infrastructure upgrades in Fort Wayne are on track to reduce combined sewer overflows to the St. Marys and Maumee Rivers by about 90%. In agricultural areas, partners are scaling up farmer engagement efforts, and in 2023, adoption of conservation practices in Indiana's portion of the WLEB exceeded 150,000 acres, or about 26% of the available cropland.

Together, federal and state partners are taking coordinated action through programs like the Great Lakes Restoration Initiative and the WLEB Partnership to align management strategies with the best available science. NOAA delivers HAB forecasts and hypoxia early warning tools to drinking water utilities, resource managers, and the public; USGS monitors streamflow and water quality to track nutrient inputs from tributaries; and EPA sustains long-term in-lake monitoring to assess ecosystem conditions. USDA continues to document measurable improvements in water quality as a result of conservation efforts, and USACE researchers are evaluating ways to capture P in agricultural runoff before it reaches the lake. These programs underpin the states' efforts and provide the foundation for tracking progress.

Continued monitoring and research will be critical to detecting changes to HAB dynamics and toxicity and identifying the drivers of these changes. Recent years have seen blooms with early starts, longer durations at peak biomass, and persisting late into fall. EPA's long-term Great Lakes Water Quality Program data show that the western basin of Lake Erie remains strongly phosphorus limited, which is beneficial because nitrogen limitation would favor potentially more toxic algae. It is assumed that management actions to reduce phosphorus loads will also reduce nitrogen inputs. However, it is important to monitor nitrogen contributions, and our strategy may need to be refined in the future.

The current efforts to better manage nutrient runoff must continue to grow and be sustained over the long term to reduce HABs and hypoxia. This includes the ongoing challenge and expectation for agricultural producers to precisely and effectively manage crops and fertilizer use despite unpredictable weather, inconsistent resources, and competing demands of the market. There are many dynamic factors that pose risks to the success of this nutrient management strategy, and partners are taking action to actively monitor and respond to these risks.

For example, some stakeholders have voiced concerns over the recent growth of livestock operations in Ohio. It is important to keep an eye on this trend and continue to collect information to ensure that the introduction of more livestock to the watershed will not be detrimental to P reduction efforts. Transporting liquid manure from livestock farms to fields that need P is a challenge that partners are working to address through targeted programs. Ohio is collaborating with EPA and others to expand the use of manure instead of commercial fertilizer where it is available, and pilot soil amendments and manure treatment technologies that have potential to further prevent P losses from manure.

Federal and state partners believe that the comprehensive and adaptive approach laid out in the 2018 U.S. Action Plan and the individual state DAPs will continue progress towards the 40% reduction goals in the WLEB. It will take time to reduce phosphorus loads to a level that water quality improvements will become apparent. Achieving the 40% reduction goals will require sustained, widespread, and strategically targeted adoption of conservation practices in highest loss areas, with a particular focus on preventing soluble P losses during high flow events.

Federal, state and local leaders must continue to work in partnership to be successful in affecting change over such a large region. The accomplishments to date would not be possible without the broad support and engagement among multiple levels of government and numerous stakeholders – municipalities, local government, private industry, academia, and citizens. Success will require active participation and continued diligence among all stakeholders.

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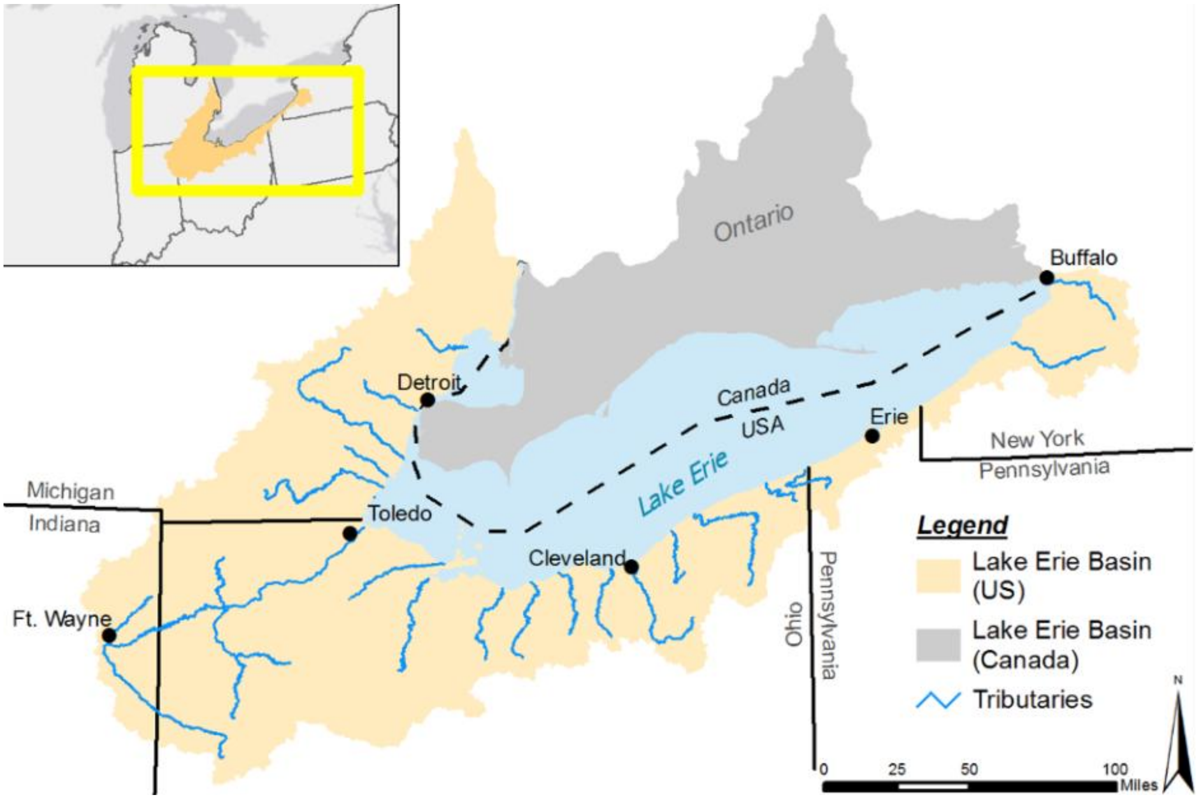
BACKGROUND



Map of the Lake Erie watershed.

Lake Erie is the shallowest of the Great Lakes and the smallest by volume, with a surface area just under 10,000 square miles. The average depth of Lake Erie is only about 62 feet (210 feet, maximum), so it warms rapidly in the spring and summer. The surrounding 30,000 square mile watershed is intensively farmed and the most densely populated of the five lake basins. These characteristics make Lake Erie susceptible to excessive algal growth, which poses significant threats to the environment, human health, and the economy of the region. Algal growth in the lake is caused by high levels of nutrients in the water, specifically from agricultural and municipal runoff. This process is called eutrophication, a common and widespread problem and one of the leading causes of water quality impairment globally.

The three key nutrient issues to be addressed in Lake Erie are:

- in the western basin, massive blue-green algae (cyanobacteria) blooms and associated toxins,
- in the central basin, seasonal hypoxia – areas of low oxygen, and
- in the eastern basin, excessive growth of non-toxic algae on the lake bottom, primarily *Cladophora,* that washes ashore and decays on beaches.

Phosphorus (P) is the growth-limiting nutrient in the Great Lakes and the primary driver of these issues. Lake Erie receives the highest P load of all the great lakes, varying from about 7,000–12,000 metric tons each year. While many other nutrients are present in water, such as nitrogen, silica, carbon, and even trace metals, these nutrients are considered to be only secondarily or seasonally limiting.

To address growing concerns about eutrophication impacts, in 2016, the U.S. and Canada revised the Great Lakes Water Quality Agreement phosphorus targets for Lake Erie, calling for reductions in phosphorus loads to the western and central basins of the lake by 40%. The governments then worked with numerous partners and stakeholders to develop the Lake Erie Binational Phosphorus Reduction Strategy, multiple state and federal level "Domestic Action Plans" (DAPs), and a Binational Lake Erie Nutrient Adaptive Management Framework to track and evaluate progress.

State and federal partners in the U.S. and Canada routinely report on progress in a number of venues.

Every three years, the governments issue a "Progress Report of the Parties (PRP)," and host a Great Lakes Public Forum, to provide Great Lakes stakeholders the opportunity to provide feedback on the implementation of the GLWQA.

EPA co-chairs the Annex 4 (Nutrients) subcommittee, which each year hosts a special webinar to keep stakeholders apprised of our progress implementing the Lake Erie domestic action plans. Phosphorus loads are calculated on an annual basis and reported via the webinar and online. Find more information at Blue Accounting – ErieStat or EPA's Lake Erie Water Quality Data.

More specific information is distributed by the states. For example, Ohio produces an annual Water Monitoring Summary report that tracks monitoring results against the Annex 4 targets. Ohio, Michigan, and Indiana hold DAP stakeholder meetings annually.

Examples of excess algae in the water and on the shore in Lake Erie. Source: NOAA, CWA.

GLWQA PHOSPHORUS REDUCTION GOALS

As formalized through an exchange of letters, Canada and the U.S. adopted the following phosphorus reduction targets in 2016. These numbers are relative to baseline conditions in 2008. EPA's external Science Advisory Board reviewed and supported this approach as an appropriate starting point and recommended ongoing adaptive management.

- **To minimize the extent of hypoxic zones in the waters of the central basin of Lake Erie:** a 40 percent reduction in total phosphorus (TP) entering the western and central basins of Lake Erie—from the United States and from Canada—to achieve an annual load of 6,000 metric tons to the central basin. This amounts to a reduction from the United States and Canada of 3,316 metric tons and 212 metric tons respectively.
- **To maintain algal species consistent with healthy aquatic ecosystems in the nearshore waters of the western and central basins of Lake Erie:** a 40 percent reduction in spring TP and soluble reactive phosphorus (SRP) loads from the following watersheds where algae is a localized problem: in Canada, Thames River and Leamington tributaries; and in the United States, Maumee River, River Raisin, Portage River, Toussaint Creek, Sandusky River and Huron River (Ohio).
- **To maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the waters of the western basin of Lake Erie:** a 40 percent reduction in spring TP and SRP loads from the Maumee River in the United States. Using 2008 as the baseline, this equates to a spring (March-July) load of 860 metric tons TP and 186 metric tons SRP.

The targets for reduction remain focused on phosphorus, though there is continued attention on the importance of nitrogen contributions. EPA committed to research and monitor the effects of nitrogen loads and concentrations so that management decisions and actions can be adapted as necessary. Both phosphorus and nitrogen loads are being tracked, even though there is not a specific nitrogen reduction target.

Note that while no phosphorus reduction targets have been proposed for the eastern basin of the lake, the reductions to the western and central basins are expected to help address *Cladophora* issues in the eastern basin and still supply enough nutrients to support the fisheries. The modeling performed in 2015 predicted that the 40% reductions would result in mesotrophic conditions in the open waters of the western and central basins of Lake Erie, and oligotrophic conditions would be maintained in the eastern basin of Lake Erie. A binational workgroup of technical experts reviewed the latest science in 2020 and concluded that phosphorus loading is not a good predictor of Cladophora growth at the basin scale, and therefore no reductions are recommended for the eastern basin at this time.

Key reference documents describing how targets were developed can be found here:

Annex 4 Objectives and Targets Task Team Final Report to the Nutrients Annex Subcommittee

Annex 4 Multi Modeling Report

EPA Science Advisory Board Final Report (EPA-SAB-17-006)

U.S. PRIORITY TRIBUTARIES

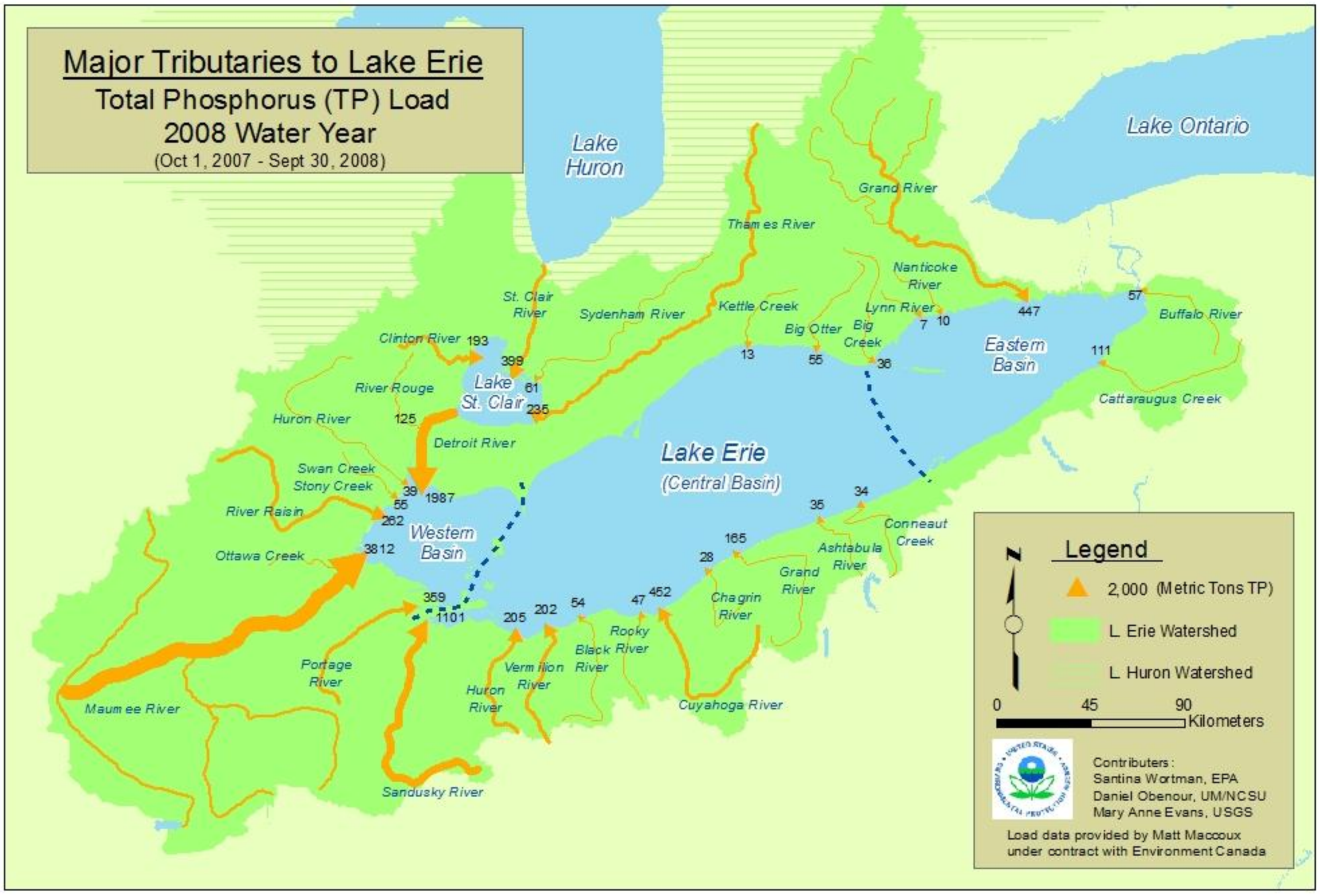
The U.S. originally identified 10 priority tributaries for nutrient reduction, and this list was further narrowed to 8 in 2024. The tributary targets can be specific to a form of phosphorus (TP vs SRP); timeframe (spring or annual); or measurement (load vs flow weighted mean concentration), depending on the issue to be addressed (HABs, hypoxia, or both). The specific numeric targets are summarized in the following table. Note the following updates since 2018:

- Removed Toussaint and Grand as these are no longer of priority in 2024 due to limitations in data and relative importance, consistent with Ohio's DAP.
- The River Raisin annual TP target load was updated from 157 to 131 MT reflecting a change in the method used to fill a monitoring gap in the 2008 baseline year for consistency with other tributaries and likely higher accuracy.
- The Portage River targets were updated to use 2017 as the baseline year to better approximate loads in 2008, as documented in Ohio's 2023 DAP.

Numeric targets for Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP), 2024.

Basin	**Tributary**	**State**	**Spring Target Load (metric tons)**	**Spring Target FWMC (mg/L)**	**Annual Target Load (metric tons)**
Western	Detroit River	Michigan	N/A	N/A	756 MT TP
Western	River Raisin	Michigan	50 TP	0.09 TP	131 MT TP
Western	Maumee River	Ohio	860 TP 186 SRP	0.23 TP 0.05 SRP	2,287 MT TP
Western	Portage River	Ohio	69 TP 18 SRP	0.24 TP 0.05 SRP	138 MT TP
Central	Sandusky River	Ohio	230 TP 43 SRP	0.23 TP 0.05 SRP	660 MT TP
Central	Huron River	Ohio	N/A	N/A	123 MT TP
Central	Vermillion River	Ohio	N/A	N/A	121 MT TP
Central	Cuyahoga River	Ohio	N/A	N/A	271 MT TP

SOURCES OF PHOSPHORUS

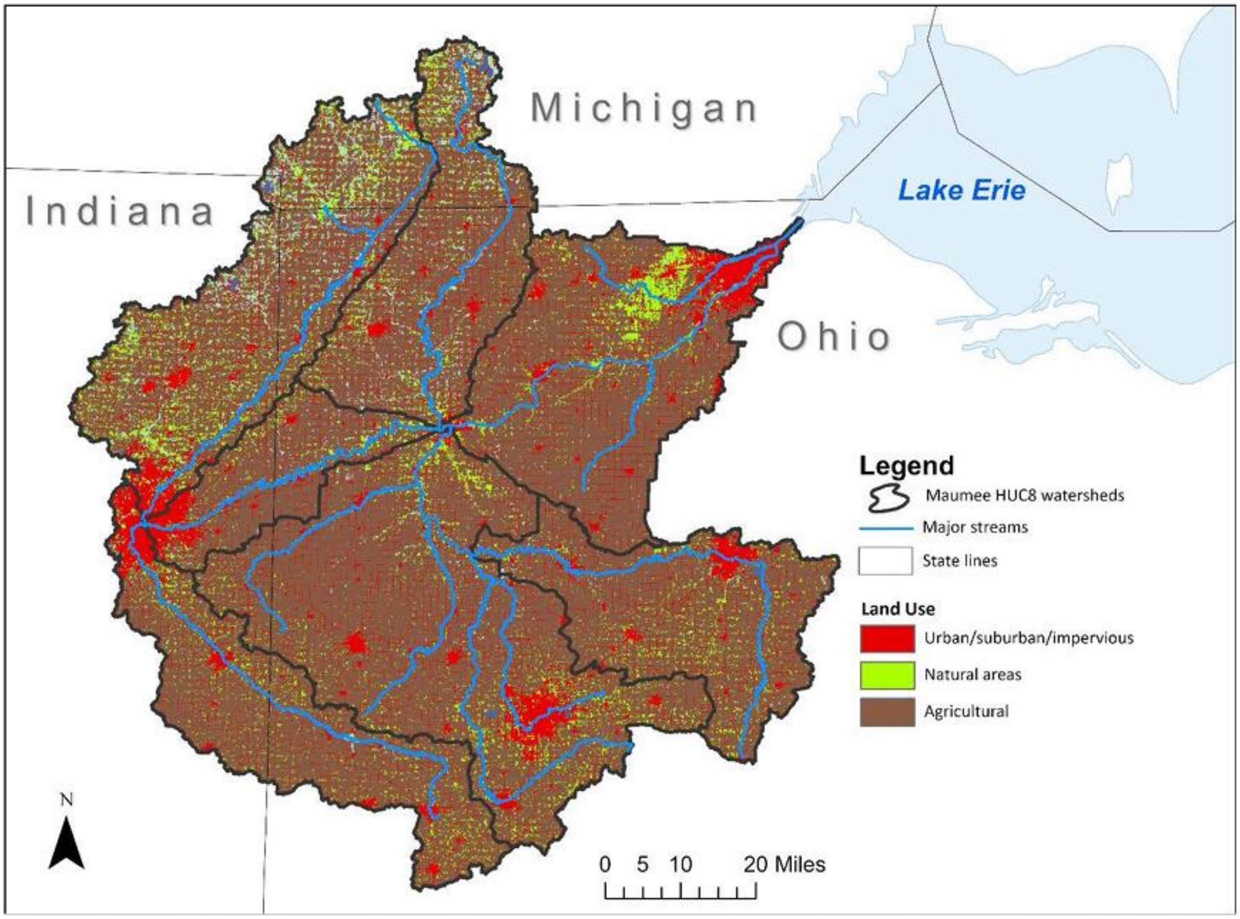


Map of Lake Erie drainage basin showing baseline phosphorus loads from major tributaries in 2008. Note the thickness of the orange tributary lines correspond to the relative magnitude of their loads. Source: EPA.

The biggest source of phosphorus and highest priority for reduction in the U.S. is the Maumee River. Of all the Lake Erie tributaries, the Maumee watershed contributes the greatest phosphorus load to the lake (Maccoux et al., 2016), and to all of the Great Lakes. The Maumee contributes nearly 50% of the total load to the lake and its watershed makes up 64% of the drainage area to western Lake Erie. The Maumee has the largest watershed of any Great Lakes river, spanning 6,571 square miles in Michigan, Indiana, and Ohio. While its size plays a role in the amount of its load, elevated phosphorus concentrations show that the Maumee, and other WLEB tributaries, contribute more nutrients per unit area than other Lake Erie watersheds. Ohio EPA estimated nonpoint source yields of total P ranged from 0.53 to 1.9 pounds per acre in the Maumee from 2013-2023.

Nonpoint sources contribute 90 percent of the phosphorus load in the Maumee watershed. These are diffuse sources carried by wind or rain, such as runoff carried over land during heavy storms. The bulk of this load originates from agricultural fertilizers being applied to cropland each year and building up over time in the soil and streambeds. Streambank erosion, atmospheric deposition, and residential fertilizers also contribute to the nonpoint source load.

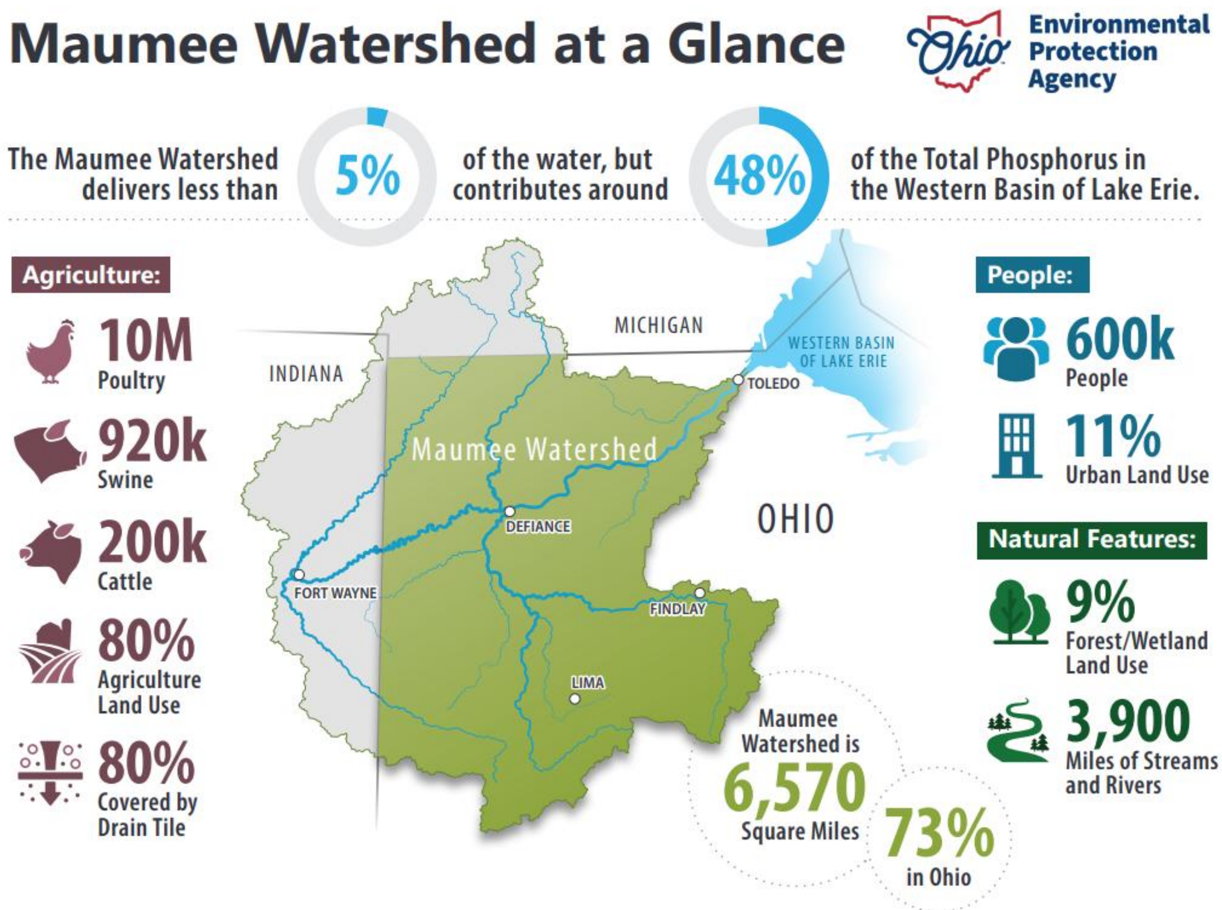
According to Ohio EPA's 2024 Nutrient Mass Balance Study, the highest nutrient yields (lbs/acre) occur in northwest Ohio, where about 80% of the land is used for agriculture. Given the intensity of agricultural land use, it's not surprising that runoff of fertilizer, both inorganic (manufactured chemical fertilizers) and organic (animal manure) is the primary source of phosphorus in the Maumee and the WLEB. A study sponsored by the International Joint Commission (IJC) found that commercial fertilizer made up 81 percent of fertilizer phosphorus applied to the U.S. portion of the WLEB's croplands in 2006–2007 (IJC, 2018). More recent studies have shown that manufactured chemical fertilizers applied to cropland continue to represent the largest overall source of nutrients in the river. While livestock expansion has risen, manure application remains a significantly smaller portion compared to commercial fertilizers.



Map of the Maumee River Watershed showing generalized land uses. Approximately 70% of the Maumee watershed is used to grow crops, primarily corn and soybeans. Source: Ohio EPA.

In 2021, ODA inventoried livestock in the Maumee watershed in Ohio and evaluated the population trends for recent years. Details of this analysis are included in Appendix 1 of Ohio EPA's Maumee Watershed Nutrient TMDL (2023). The ODA analysis showed an estimated 88 percent increase of animal units from 2002 to 2017 in the Maumee watershed. As manure phosphorus production has increased in the watershed, commercial fertilizer use has decreased, indicating a shift in relative contributions of fertilizer types. However, more information is needed on the management of manure fertilizer. About 80 percent of the Maumee's manure phosphorus is not tracked, due to manure transfers and non-permitted livestock operations (Kast et al., 2019). It is also important to understand where increasing concentrations of livestock pose a risk because of their location relative to the amount of nearby cropland land available to apply it. Transport of liquid manure from livestock farms to fields needing P is a challenge in some regions of the WLEB.

Ohio EPA produced a helpful Maumee watershed infographic. Readers are also encouraged to review Ohio EPA's Maumee Watershed Nutrient TMDL for more details on loading allocations.



Maumee Watershed "at a Glance" graphic. Source: Ohio EPA.

IMPLEMENTATION STRATEGY

FRAMEWORK FOR ACTION

Consistent with the Lake Erie Binational Phosphorus Reduction Strategy, federal and state agencies are implementing actions within these broad areas of focus.

- Reduce phosphorus loading from agricultural sources
- Reduce phosphorus loadings from municipal sources
- Support watershed-based planning and restoration efforts
- Coordinate science, research, and monitoring
- Enhance communication and outreach

A main thrust of the U.S. Action Plan has been to leverage partnerships and resources to accelerate implementation of conservation practices in the WLEB. The level of cooperation and involvement among so many partners in the WLEB is astounding. Watershed-based groups, like the Maumee Watershed Alliance, bring together rural and urban perspectives to address local water quality concerns. The WLEB benefits from long term, high quality and expansive water quality monitoring programs. State management programs are supported by robust, targeted scientific research by the NRCS, NOAA, USGS, EPA, and USACE. There are too many partners to name, but some of the major partners involved in the domestic action plans include:

- WLEB Partnership
- Ohio Lake Erie Commission
- H2Ohio | An Ohio Partnership for better water statewide
- Taking Action on Lake Erie (michigan.gov)
- Indiana State Department of Agriculture | Western Lake Erie Basin
- Great Lakes Restoration Initiative (GLRI) | EPA
- Western Lake Erie Basin Project - Ohio | Natural Resources Conservation Service
- Ohio Department of Higher Education (ODHE) Harmful Algal Bloom Research Initiative | Ohio Sea Grant
- NOAA GLERL HABs and Hypoxia
- Heidelberg University National Center for Water Quality Research
- USDA Agricultural Research Service EOF Monitoring
- USDA Conservation Effects Assessment Project
- USGS HABs Science and Monitoring

GENERAL APPROACH

Reducing phosphorus loads to the western and central basins by 40% requires that both nutrient sources or inputs (such as fertilizer) and the transport and delivery of nutrients to waterbodies be managed better. The following are key components of the U.S. implementation strategy to reduce phosphorus:

1. **Geographic focus**: Focus resources on the WLEB, particularly the Maumee River watershed.

2. **Enhanced coordination**: Strengthen coordination and collaboration among federal, state, and local partners in the WLEB.

3. **Fertilizer use**: Maintain and expand adoption of effective nutrient management through increased education, outreach, and financial incentives to farmers.

4. **Water management**: Increase the capacity of riparian areas, floodplains, and wetlands to infiltrate runoff and reduce peak flows.

5. **Optimize municipal wastewater treatment**: Many wastewater treatment plants present opportunities to reduce discharges in the absence of significant investments in new treatment technologies or infrastructure.

6. **Track progress**: Regularly report and track progress using environmental and programmatic indicators.

7. **Adaptive management**: Intentional testing of assumptions that allows us to take action despite uncertainty and adjust priorities and tactics with our federal and state partners as scientific knowledge improves.

*Our strategy is focused not only on traditional means of reducing loads through **source reductions,** but also on phosphorus **transport, timing and delivery** downstream.*

AGRICULTURAL SOURCES

Multiple studies have shown that widespread adoption of conservation practices will be necessary to meet phosphorus reduction targets, and targeted placement of practices (e.g., to areas of greatest estimated phosphorus loss) is most effective (NIFA-CEAP Publication, 2012, CEAP Cropland Report, 2016, Scavia et al., 2016, Scavia et al., 2017, Martin et al., 2021). Government partners are working with non-governmental organizations and industry to implement an agricultural strategy in the WLEB that takes into account both the effectiveness of practices and the willingness to voluntarily adopt them.

NRCS is the lead federal agency to assist farmers to adopt voluntary conservation, partnering with researchers, universities, soil and water conservation districts, and agricultural businesses and associations. As a result of these partnerships, more farmers are being engaged in conservation and being exposed to newer technologies like variable rate fertilizer application and manure transformation techniques. In addition, several techniques to capture nutrients from agricultural runoff are being promoted such as: runoff retention for reuse as irrigation, automated drainage water management, rerouting drainage tiles to buffers, phosphorus removal beds or structures, adding floodplains to drainage ditches, and using wetland-like features in series to form a treatment train.

Prevention of soluble phosphorus losses during high flow events is a key area of focus to prevent HABs in Lake Erie. According to USDA researchers, soluble phosphorus loss is the greatest treatment need for agricultural land in the WLEB, and the majority of soluble phosphorus losses occur through subsurface tile drains (King et al., 2014, USDA NRCS 2016). However, as phosphorus builds up over time in soils and streambanks, commonly referred to as "legacy P," erosion can transport the particulate phosphorus bound to sediments. Kreiling et al. (2023) sampled sites across the Maumee River network and found that streambed sediment is currently a net P sink during summer, but sites in headwater streams may become a P source if stream water SRP concentrations decrease. There is no one solution or conservation practice that can address all of these pathways.

The effectiveness of conservation practices is site-specific and can result in trade-offs such as the form of P (sediment-bound vs. soluble P) and mode of delivery (surface vs. subsurface, acute versus chronic). A national modeling analysis by the World Resources Institute examined the trade-offs of prioritizing P over other environmental benefits, such as N reduction, sediment reduction and soil carbon sequestration. This analysis found that, if only one environmental benefit could be optimized, then a conservation program designed to maximize P reductions is likely to yield the greatest overall environmental benefits.

There are numerous resources on BMP effectiveness (see, for example, the Ohio State University Extension program), and a body of literature that shows the need for a variety of management practices to effectively reduce agricultural phosphorus runoff. USDA edge-of-field monitoring data indicate that soil testing and following recommended application rates, avoiding fertilizer application during wet periods of the year (e.g., winter and early spring) and prior to large precipitation events, and placing fertilizer below the surface are all practices that result in decreased P loss. In addition to these in-field practices, water management practices are needed to minimize offsite transport, especially in artificially drained landscapes (King et al., 2018).

The H2Ohio program prioritizes smart nutrient farming practices to reduce nutrient runoff from commercial fertilizer and manure, in combination with wetlands, forested buffers, and conservation ditches to slow runoff and filter nutrients (see H2Ohio Managing Nutrients). Ongoing modeling efforts led by Ohio Lake Erie Commission in collaboration with researchers at The Ohio State University and the University of Toledo have reinforced that nutrient management techniques (specifically, subsurface placement, manure incorporation, and fertilizer rate reduction) in combination with headwater wetlands have the greatest potential to reduce loss of dissolved P at the field scale.

Ohio State is leading a multi-million dollar project backed by numerous partners to measure changes in water quality in response to conservation. The Shallow Run Pilot Watershed Project, in combination with the USDA Conservation Effects Assessment Project – Blanchard River Watershed Assessment Study, aims to show that concentrating proven farm practices and robust monitoring in a small area can produce measurable improvements in water quality. Early results from the 5,200-acre watershed show that dissolved phosphorus exports fell 38% after just two years of increased adoption of conservation practices. Success is tied to unusually high adoption of stacked practices—especially subsurface phosphorus placement—along with cover crops, nutrient management, soil testing, buffers, wetlands, drainage water management, and phosphorus filters—supported by clear incentives and close farmer engagement.

At the regional, tri-state level, WLEB partners are implementing an overarching strategy for agriculture sources that considers these factors and ways the partners can maximize the impact of broader conservation efforts on nutrient load reductions. The strategy for agriculture is for the most part, unchanged from the 2018 plan, with some refinement. It is comprised of four elements: 1) Outreach and collaboration, 2) Technical and financial assistance, 3) Placement and selection of practices, and 4) Applied research.

AGRICULTURAL STRATEGY

1. Outreach and collaboration

- Enhance collaboration and communications among agricultural partners (government agencies, land grant universities, certified crop advisors, farm bureaus, commodity groups) to significantly ramp up farmer education and outreach in WLEB.
- Partner with non-traditional "trusted advisors" such as agricultural retailers to broaden reach and impact.
- Increase outreach to those individuals who are currently willing to consider and adopt the practice, and those who are community leaders and can help to extend the practice to others.
- Provide opportunities for peer-to-peer learning and farmer-led demonstration networks. Where possible, incorporate field monitoring to quantify efficacy of practices.

Participants of Blanchard River Demonstration Farms Network. Source: Blanchard River Demonstration Farms Network.

2. Technical and financial assistance

- Build capacity and expertise available within soil and water conservation districts to provide greater technical assistance.
- Utilize financial incentives to help farmers overcome short term risks and barriers to adoption of conservation practices. Focus efforts on building farmer's confidence in their ability to implement a set of cost-effective solutions.
- Apply whole-farm comprehensive conservation planning and a systems approach to maximize both environmental and economic benefits to the farmer.

3. Placement and selection of practices

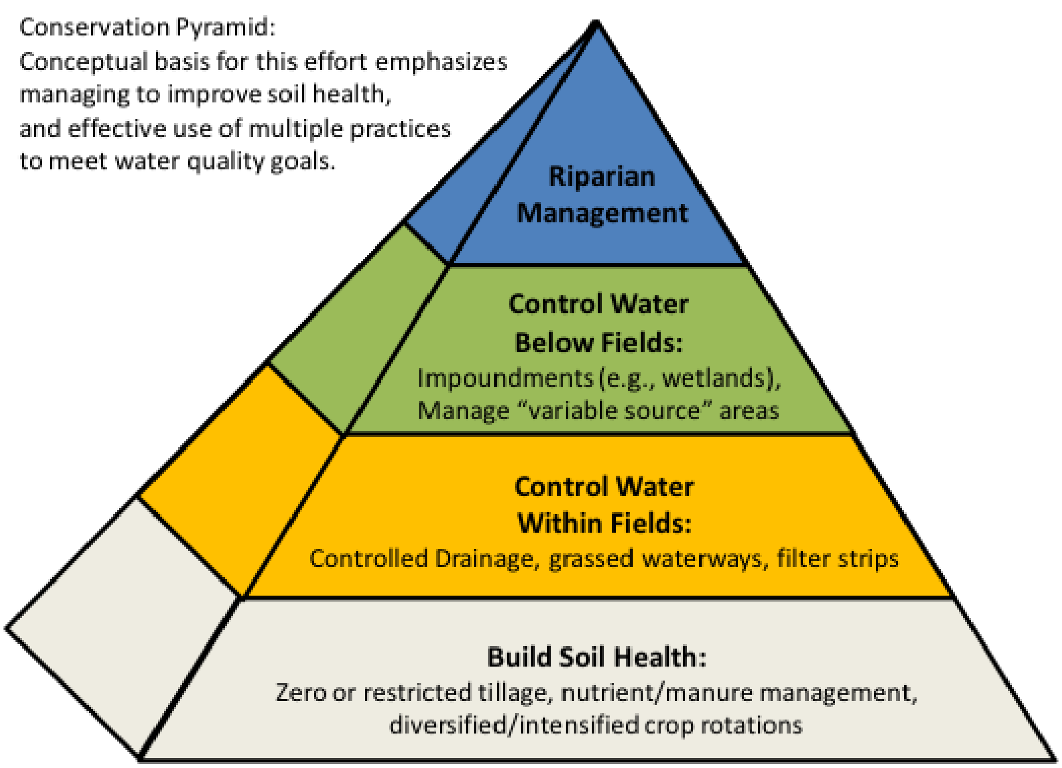
- Prioritize implementation of the following best management practices (BMPs):
    - Soil-test informed fertilizer application rates.

  - Subsurface placement of fertilizer.
  - Water management – this includes in field, edge of field, and in-stream practices to reduce surface and subsurface runoff and filter P to prevent it from moving downstream.

- Target situations where nutrient management is needed most, e.g. fields with the greatest P losses, or management practices that would lower the risk of P losses for the farmer.
- Encourage phosphorus filtering practices to treat runoff from fields (or areas within fields) exhibiting high soil test P (>150 ppm).

4. Applied research

- Continue to support research to fill key information gaps, such as:
  - Alternative strategies and programs to aid farmers who are dealing with manure application and distribution challenges.
  - Cost-benefit of specific management practices, e.g. a fertilizer placement tool bar.
  - How soil health impacts water holding capacity, P loss, and water infiltration as well as how soil health is impacted by tillage.
  - What combination of practices will effectively retain water to reduce load delivery at the watershed scale.
- Leverage edge of field monitoring and conservation effects assessments to demonstrate and communicate efficacy of practices.



The agricultural conservation planning framework is based on the concept that multiple conservation practices working together make up a "Conservation Pyramid." Source: Tomer et al., 2013.

MUNICIPAL SOURCES

Given the Maumee River is the highest priority for source reduction of phosphorus, much of the current focus is on management of agricultural lands, but it is important not to lose sight of other contributing sources. P reductions are needed from urban, suburban, and rural non-farm areas of the WLEB too. Within individual watersheds the proportion of nonpoint and point sources varies. For example, nonpoint sources make up most of the Maumee River load, but in the Detroit River, which has the second highest load after the Maumee, the bulk of the P load comes from point sources, specifically the GLWA (Great Lakes Water Authority). The GLWA serves a population of more than three million people and is the largest municipal wastewater treatment plant in all of North America.

Wastewater discharges from cities may not always be a large contributor in terms of the loading magnitude, but an important one to manage because it is constant and, in many cases, has room to grow. Lowering discharge permit levels helps ensure that wastewater contributions will not increase in the future.

Most U.S. wastewater treatment facilities in the basin are currently permitted to discharge 1.0 mg/L of Total Phosphorus for a given volume of daily discharge (often in million gallons per day, or MGD). While many are actually discharging at lower rates, there is potential for those discharges to increase and still be in compliance with their permits. Many WWTPs have opportunities to reduce discharges within their existing treatment processes. Possibly the best example of this is the GLWA, which through optimization methods is discharging at 0.3-0.6 mg/L. This was accomplished without significant capital investments, and is being applied at smaller facilities in the WLEB. EGLE published Phosphorus Removal Guidance for Wastewater Utilities in Michigan's Western Lake Erie Basin, a document that describes low-cost, practical methods to optimize phosphorus removal, in October 2024.

View of secondary clarifiers at the Great Lakes Water Authority’s Water Resource Recovery Facility. Source: Michigan EGLE.

IMPLEMENTATION EFFORTS SUMMARIZED BY AGENCY AND STATE

Here we summarize the DAP implementation efforts for five lead federal agencies (NRCS, EPA, USACE, NOAA and USGS) and the three WLEB states (Ohio, Michigan and Indiana). Some key programs and projects are highlighted below.

Note: Individual summaries were not provided for Pennsylvania and New York, because they are not part of the WLEB area of focus and have no phosphorus reduction targets to meet. They are, however, actively involved in Annex 4, and contributing to nutrient and HABs reduction efforts in their portions of Lake Erie. See the 2018-2023 U.S. Action Plan for more information on efforts in Pennsylvania and New York.

MAJOR ACTIONS TO-DATE

Widespread farmer engagement. Federal and state agencies in the U.S. have significantly increased conservation assistance to farmers over the past several years, with new and enhanced programs focused on improving nutrient management practices in priority watersheds. As of 2025, about 2 million acres of cropland in the western Lake Erie watershed is or was recently enrolled in a federal or state conservation program. This is an outstanding adoption level, that if maintained will significantly reduce phosphorus contributions from agricultural sources to Lake Erie.

USDA Conservation Programs. Since 2018, NRCS has invested over $112 million in financial assistance to farmers in the Lake Erie watershed through multiple Farm Bill programs and the GLRI. More than half of the over 3,000 landowner contracts between 2018-2023 focused specifically on fertilizer and manure management practices. USDA's Agricultural Research Service and Conservation Effects Assessment Project continue to demonstrate measurable improvements in water quality as a result of conservation efforts. Findings from an extensive edge-of-field monitoring network, from two small watershed studies and from basin scale modeling analysis have been used by NRCS, EPA and states to inform effective conservation strategies and document the outcomes of farmer's voluntary conservation actions. USDA and partners developed an informational video that shows how researchers, farmers, government agencies and nonprofit organizations are collaborating to develop science-based solutions and strategically place them where they can deliver the greatest conservation benefits in the WLEB.

H2Ohio Initiative. H2Ohio has been incredibly successful to date in expanding the implementation of agricultural best management practices, wetland restoration, and improvements to wastewater infrastructure. Since the program's inception in 2019, more than 2,600 farmers have adopted voluntary nutrient management 1.85 million acres of farmland across the 24 counties that make up the WLEB watershed. Farmers enrolled in H2Ohio kept 420,000 pounds of phosphorus out of Ohio's waterways in 2024. Additionally, H2Ohio funds are being used to construct and enhance 183 wetland projects in the Lake Erie watershed and established a long-term monitoring program to evaluate the effectiveness of the wetlands at retaining nutrients. These programs are producing measurable environmental and economic benefits to Ohio residents. See the H2Ohio and the Value of Restoring Watersheds report for more information.

EPA GLRI Grants. Since 2018, EPA has offered three new competitive grant funding opportunities totaling over $10 million in new programming for local watershed organizations, conservation districts, and non-government entities in the WLEB. These grants are strategic investments to accelerate phosphorus reduction efforts in the watershed through locally-led, voluntary efforts to better manage agricultural runoff. EPA also provides direct grants to state agencies, to expand the impact of state-led priorities and programs. For example, in 2022 EPA allocated $1.5 M in GLRI funding to OEPA's H2Ohio Technology Assessment Program to establish GLRI Pilot Projects to test innovative technologies including slow-release fertilizers, treating manure lagoons with electricity, and automated drainage water management systems.

Major reductions from Detroit wastewater and combined sewer overflows (CSOs). Michigan has continued making significant reductions in phosphorus loading to Lake Erie as the result of major improvements in facility operations and stricter permit requirements. These reductions are especially attributable to the Great Lakes Water Authority (GLWA), the Detroit region's primary municipal wastewater service provider, where annual total phosphorus (TP) loads have been reduced by over 55 percent. Building on this success, EGLE established a framework for achieving a 0.5 mg/L TP effluent limit (i.e., a growing season average) at all 25 major publicly owned wastewater treatment facilities located within Michigan's portion of the WLEB. To help facilities meet the lower TP effluent limits, EGLE published Phosphorus Removal Guidance for Wastewater Utilities in Michigan's Western Lake Erie Basin, a document that describes low-cost, practical methods to optimize phosphorus removal, in October 2024.

Fort Wayne Deep Tunnel. In Indiana, five miles of the Fort Wayne Deep Tunnel project, an essential part of its CSO long-term control plan, became operational in 2023 (two years ahead of schedule). The Deep Tunnel project will reduce CSOs into the St. Marys and Maumee rivers from 72 per year to four per year or fewer.

Maumee River Total Maximum Daily Load (TMDL). In 2023, Ohio EPA completed a TMDL for the Maumee River watershed to address impairments in western Lake Erie due to HABs. The TMDL includes phosphorus load allocations for point source and nonpoint source pollution occurring throughout Ohio's portion of the Maumee drainage basin to meet the reduction goals established under Annex 4.

NY State Watershed Management Initiatives. New York State Department of Environmental Conservation (NYSDEC) has been working with the USGS, the Lake Erie Watershed Protection Alliance (LEWPA), and other partners to better characterize water quality in NY's portion of the Lake Erie watershed and assess where protective actions may be needed. Robust water quality monitoring, modeling and stream visual assessments over the past few years are currently being synthesized to develop a watershed-based plan for the Niagara River/Lake Erie watershed. Since 2018, NYSDEC has launched two web-based reporting tools the public can use to report occurrences of harmful and nuisance algae: The New York Harmful Algal Bloom System (NYHABS) and a *Cladophora* reporting tool. More information on NY's efforts to manage HABs, including priorities for research, can be found at NYSDEC's webpage on HABs.

Pennsylvania Nonpoint Source Control Efforts. Pennsylvania Department of Environmental Protection (PADEP) continues to implement several water quality and grant programs that reduce nutrient pollution through cooperative work with partners. From 2019 to 2025, Pennsylvania invested over $5.5 million in the Lake Erie Watershed through Coastal Resources Management Coastal Zone, Agriculture Conservation Assistance Program, and Growing Greener Plus Program funding. In 2026, PADEP and Pennsylvania Sea Grant will begin a ten-year update of the Pennsylvania Lake Erie Watershed Integrated Water Resources Management Plan.

USACE "Phosphorus-Optimal" Wetland. In 2020, the U.S. Army Corps of Engineers constructed a 10-acre demonstration wetland in Defiance, Ohio, to serve as a model for optimizing phosphorus retention and nonpoint source reduction in agricultural settings. Monitoring data at the site shows phosphorus losses are being reduced by ~50%. The innovative project coordinates with federal partners, including USEPA, NRCS, and USGS, as well as partners at the state and local level, to share lessons learned and inform other wetland restoration project designs to maximize efficiency. USACE is partnering with City of St. Marys to build a second wetland in 2027.

NOAA HABs Forecasting. Since 2018, NOAA has continued to refine and expand the capabilities of the Lake Erie Harmful Algal Bloom forecast system using the latest technologies available. In 2023 and 2024, the NOAA Great Lakes Environmental Research Laboratory deployed a network of sophisticated instruments in Lake Erie that can collect and analyze water samples in situ to provide near-real time measurements of the dangerous toxin often present in these blooms, microcystin. NOAA is planning to expand their bloom forecasts to include a prediction on the probability of exceeding toxin threshold levels in 2026.

USGS Tributary Nutrient Monitoring. Under the GLRI, USGS is monitoring nutrient inputs to all of the Great Lakes from 26 of the tributaries with the largest nutrient contributions to the lakes. Ten of the 26 monitoring sites are on rivers flowing into Lake Erie. A recent analysis found that flow-normalized total phosphorus loads have decreased or remained steady in most (21 of the 24) of the monitored tributaries, indicating widespread progress toward the nutrient reduction goals of the GLRI and the GLWQA. All of the results of this analysis are published on an interactive, web-based dashboard that is updated every two years.

NRCS UPDATE

USDA's Natural Resources Conservation Service (NRCS) provides voluntary, incentive-based conservation technical and financial assistance to landowners through local field offices in nearly every county of the nation. Key conservation programs include: Conservation Technical Assistance Program (CTA), the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP), the Agricultural Conservation Easement Program (ACEP), and the Regional Conservation Partnership Program (RCPP). In addition, NRCS launched a new program in 2016 called the WLEB Initiative, and through an inter-agency agreement with EPA, NRCS directs Great Lakes Restoration Initiative (GLRI) funding to smaller priority watersheds for nutrient reduction.

Through the combination of these programs, from 2013 through 2025, nearly 13,000 conservation practices have been implemented by farmers in the WLEB and certified complete by NRCS. A majority of the practices were nutrient management, cover crops, and animal waste storage and management. On average, this substantial effort by farmers reduced phosphorus losses by over 330,000 lbs annually. NRCS conservation practices prevented more than 4.3 million cumulative pounds of phosphorus (2013-2025) from entering the waterways of the western Lake Erie watershed, an amount that would fill 35 train cars.

There are multiple voluntary conservation programs available to help landowners restore and protect marginal, frequently flooded, or degraded agricultural lands through long-term conservation easements. Under the GLRI, NRCS efforts recently expanded to include wetland and floodplain easements. Through 2029, NRCS estimates that 30 acres of restored wetland easements and 500 acres of floodplain easements will be secured in the western Lake Erie watershed with NRCS GLRI funding. In addition, USDA's Farm Services Agency (FSA) and the State of Ohio entered into a new agreement with a goal of enrolling 67,000 acres of land in permanent vegetative cover adjacent to rivers and streams in the Lake Erie watershed through the Conservation Reserve Enhancement Program (CREP).

NRCS partners with the USDA Agricultural Research Service (ARS) to conduct leading edge assessments and research of the effects of conservation practices and programs through the Conservation Effects Assessment Project (CEAP). The ARS Soil Drainage Research Unit located in Columbus, Ohio, operates an extensive edge-of-field water quality monitoring network with farmers under CEAP, consisting of 20 paired sites across 40 monitored fields. A majority of those sites are located within the intensively drained WLEB.

USDA will continue collaborating with universities, other agencies, and organizations on science-based assessments and implementation of conservation on-the-ground to meet the challenges in Lake Erie. Particular areas of focus include:

- Evaluating and demonstrating innovative practices
- Conservation Effects Assessment Project
- Agricultural Conservation Planning Framework
- Extension and education

EVALUATING AND DEMONSTRATING INNOVATIVE PRACTICES

The USDA-ARS National Soil Erosion Laboratory out of West Lafayette, Indiana leads a research and extension program on Phosphorus Removal Structures, an innovative practice designed to treat soluble phosphorus by collecting untreated tile drainage water and filtering it through various filter media. Since 2020, ARS has developed several resources to help non-engineers build and design P filters including the P - TRAP software and free training videos. More P removal structures are being built as this information is disseminated. As of 2024, 16 Phosphorus Removal Structures have been installed under the design of USDA ARS in farm fields across Ohio and Indiana. ODA recently expanded their investments in P removal structures, and plans to build an additional eight P removal structures in 2027. ARS continues evaluation, education and outreach on this practice, and it was officially established as an NRCS national conservation practice standard (Code 624) in 2025.

Installation of a P removal structure. Source: Chad Penn, USDA-ARS.

CONSERVATION EFFECTS ASSESSMENTS

USDA's Conservation Effects Assessment Project continues to document measurable improvements in water quality as a result of conservation efforts. Findings from an extensive edge-of-field monitoring network, on-going small watershed studies in the St. Joseph River and the Blanchard River watersheds, and from basin scale modeling analysis are being used by NRCS, EPA and states to inform effective conservation strategies and document the outcomes of farmer's voluntary conservation actions in the WLEB.

Recent special projects under CEAP by NRCS, ARS and university partners are assessing the influence of factors such as lag time and legacy P on conservation outcomes. For example, a new assessment of legacy P focusing on the WLEB was funded by NRCS in 2020. In addition, in 2021 a new national CEAP assessment of legacy phosphorus was initiated, including additional work in the WLEB. These new projects will give us new techniques to measure phosphorus and analyze water quality trends, and have provided new insights on effective conservation options to treat legacy phosphorus sources (Osterholz et al., 2023; Simpson et al., 2025; Mott et al., 2025).

In 2022, USDA CEAP and partners developed an informational video that shows how researchers, farmers, government agencies, and nonprofit organizations are collaborating to develop science-based solutions and strategically place them where they can deliver the greatest conservation benefits in the WLEB.

NRCS hosts one-hour virtual webinars featuring scientists and other subject matter experts in voluntary conservation efforts on working lands. The Conservation Outcomes Webinar Series often features key findings, data, and tools that are highly relevant to WLEB nutrient reduction efforts.

AGRICULTURAL CONSERVATION PLANNING FRAMEWORK

A USDA-led partnership founded on CEAP Watershed Assessments led to development of the Agricultural Conservation Planning Framework (ACPF), a tool that maps out locations for effective placement of numerous types of conservation practices, including controlled drainage, grassed waterways, water and sediment control basins, and nutrient removal wetlands. This tool is being used by watershed planners in Ohio, Indiana and Michigan, and is being expanded into new geographic areas. NRCS purchased updated LiDAR for the WLEB to support use of this tool and the ACPF HUB recently built new databases for the Ontario portion of the WLEB, in partnership with a Canadian researcher.

In 2024, tools were added for an enhanced pixel-based evaluation of soil vulnerability risk assessment, a ManureMap tool was developed and published to evaluate manure nutrient distribution, and tools for citing two stage ditches were developed, evaluated and published. In 2025, a new version of the ACPF was released that includes assessment tools for citing phosphorus removal systems including blind inlets. Future work will focus on critical source area identification and tools for legacy phosphorus conservation planning.

Example of edge-of-field surface (left) and subsurface (right) control volumes at data collection points. Source: Williams et al., 2016.

EXTENSION AND EDUCATION

Ohio NRCS continued to fund five Water Quality Extension Specialist positions through The Ohio State University Extension. The Water Quality Specialists conduct outreach and follow up with NRCS program participants, to improve long-term implementation of conservation practices.

USDA continues to support extension and education efforts, such as that of the Southern Extension and Research Activity (SERA) – 17. SERA-17 is an information exchange group administered through the Southern Region Land Grant Universities, focused on agricultural nutrient management, particularly phosphorus. In 2019, this group published Phosphorus and Soil Health Management - a discussion of the existing literature regarding trade-offs in water quality outcomes following the implementation of core soil health practices, and the need to combine soil health practices with other BMPs (e.g., nutrient placement, drainage management) to manage these trade-offs. Additionally, the SERA-17 Phosphorus Best Management Practice Fact Sheets were revised and updated in 2023. Updates included five new fact sheets on the following practices:

- Blind Inlets
- Nutrient Management
- Management for Snowmelt
- Treating Biosolids
- Controlled Drainage

View these fact sheets and other resources at the NCSU SERA 17 Publications website.

EPA UPDATE

As the lead agency coordinating the implementation of the GLWQA and the GLRI, EPA has an important role in assisting Great Lakes States and partners working collaboratively to minimize and prevent HABs. To meet the GLWQA commitments for nutrients (Annex 4), EPA co-chairs the Nutrients Annex Subcommittee with CWA, which has representation from more than 20 Federal, State, and regional organizations. EPA implements Annex 4 commitments in large part using GLRI funding, which supports many nutrient reduction projects in the Lake Erie watershed. Current areas of focus include:

- Strategic use of GLRI resources
- Expanded role in WLEB Partnership
- Long term water quality monitoring
- Analysis of water quality data and trends

STRATEGIC USE OF GLRI RESOURCES

EPA collaborates with federal and state partners to leverage GLRI resources with other programs available to support nutrient reduction efforts. Through these partnerships, EPA looks for ways to fill gaps and avoid duplication of efforts.

The primary way EPA does this is through grant funding assistance to state agencies, local watershed organizations, conservation districts, and non-government entities. Since 2018, EPA has offered three new competitive grant funding opportunities in the WLEB totaling over $10 million to enhance technical assistance and outreach to farmers. For example, an EPA GLRI grant to The Nature Conservancy supported a pilot project that successfully recruited 26 farmers to train and mentor other farmers on conservation practices. From 2020-2024, the mentors, who manage more than 20,000 acres themselves, directly engaged over 8,000 farmers in the Maumee River watershed through workshops, field days, and one-on-one interactions. The goal is to expand the program across Ohio to train one-to-three farmers in each county and continue building a culture of conservation in the region.

EPA collaborates with multiple Ohio state agencies to further the impact of many H2Ohio Initiative projects. For example, EPA partnered with OEPA to conduct field trials of innovative technologies being evaluated under the state's Technology Assessment Program (TAP). The GLRI Pilot Projects currently include slow-release fertilizers, treating manure lagoons with electricity, and automated drainage water management systems. In addition, EPA is collaborating with USACE, ODNR and other partners to conduct field trials to assess nutrient removal of wetlands through the H2Ohio Wetland Monitoring Program and the P Optimal Wetland Demonstration Project.

From 2020-2024, EPA and partners invested approximately $20 million in GLRI funds each year towards nutrient reduction efforts in Lake Erie. EPA will continue coordinating on strategies to maximize the impacts of available resources.

Agricultural Runoff Treatment System project at The Ohio State University's Lima Branch Campus. Source: Allen County Soil and Water Conservation District.

EXPANDED ROLE IN WLEB PARTNERSHIP

Since 2006, the multi-agency Western Lake Erie Basin Partnership has provided a platform for collaboration between federal partners and the states of Ohio, Indiana and Michigan. The initial focus was on watershed planning and implementation, along with collaboration and consensus building to coordinate public and private resources across political boundaries. In 2023, EPA signed on as a tri-chair with NRCS and USACE, and the agencies together initiated an effort to re-invigorate the Partnership and resume pre-COVID level engagement. More frequent meetings and field tours are improving public communication of the work the Partnership does to accelerate achievement of phosphorus reduction goals. A celebration commemorating the 20th anniversary of the Partnership is planned for 2026.

LONG TERM WATER QUALITY MONITORING

EPA's Great Lakes National Program Office (GLNPO) has been annually monitoring the Great Lakes since 1983. Twenty sites in Lake Erie are sampled for nutrients each spring and summer. These sites are also sampled for phytoplankton, zooplankton, and benthic invertebrates, which can serve as indicators of changing nutrient conditions and hypoxia. In addition, the 10 sites in the central basin are sampled more intensely for hypoxia annually. Between 2018 and 2023, GLNPO conducted approximately eight dissolved oxygen surveys annually at 10 stations within Lake Erie's Central Basin. During this time period, every station, except one during 2018, experienced hypoxic conditions (2 mg/L), and most reached anoxic conditions (<1.0 mg/L), between August and October of each year. These data support ongoing analyses to quantify the duration, spatial extent, and thickness of the hypoxic layer.

EPA's research vessel Lake Guardian is the largest research vessel operating on the Great Lakes. Source: EPA.

ANALYSIS OF WATER QUALITY DATA AND TRENDS

EPA's GLNPO leads load calculations and other data analyses to track progress against the GLWQA P reduction goals. In the U.S., these calculations integrate data from EPA, USGS, state agencies, and Heidelberg University's National Center for Water Quality Research, and in combination with Canada's load calculations provide consistently estimated loads for priority tributaries and the entire Lake Erie basin each year.

EPA also computes "flow-normalized" loads to assess trends. Flow-normalization is a statistical tool that reduces variability in load estimates and is implemented in the EGRET software developed by the USGS (Hirsch et al., 2023) which integrates daily Weighted Regressions on Time, Discharge, and Season (WRTDS) of nutrient concentrations over the probability distribution of discharge (Choquette et al., 2019). The resulting flow-normalized loads remove most of the daily, annual, and seasonal variability due to flow and are less variable than actual loads, which makes detecting and interpreting trends and changes due to other effects easier. Using WRTDS, EPA found that for the Maumee River, flow-normalized TP load has increased, and flow-normalized SRP has decreased in recent years relative to 2008. These trends are not apparent from the loading data alone, and can help determine whether P reduction efforts are having an impact.

USACE UPDATE

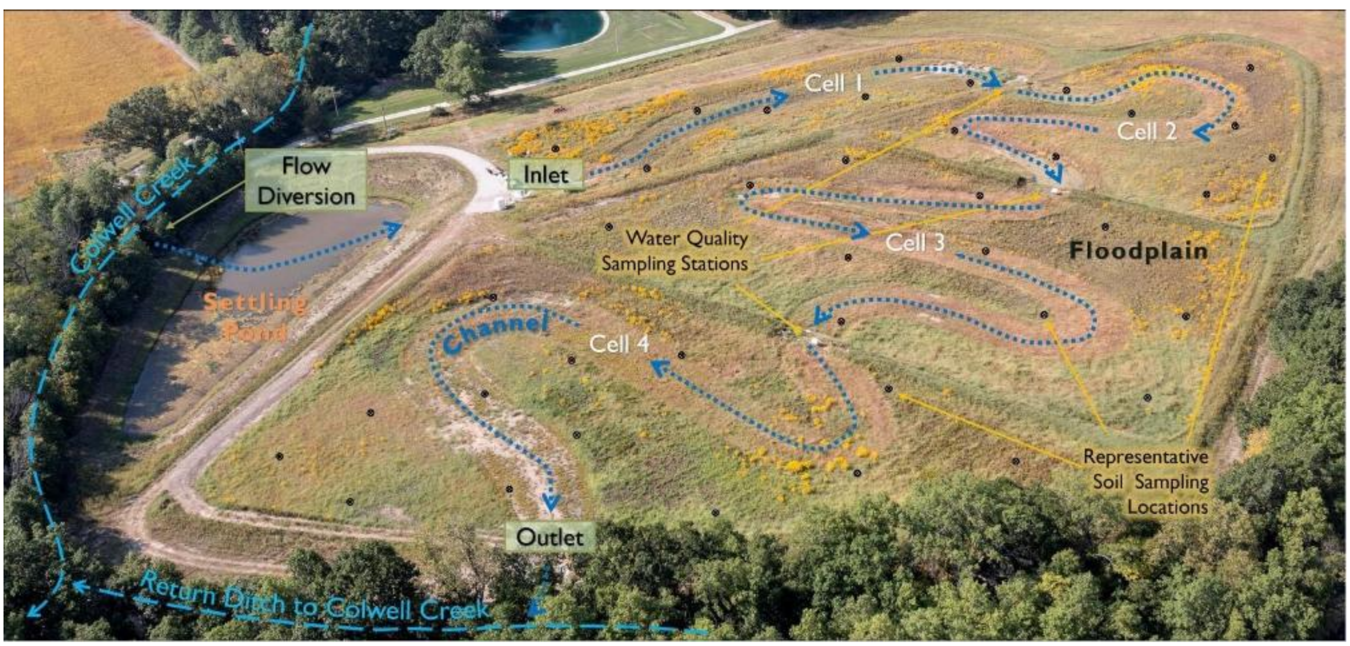
USACE is committed to utilizing the full range of authorities and expertise to partner with other agencies and stakeholders to help solve the HABs problem. USACE programs that can address HABs (either directly or indirectly) include, but are not limited to: the Ecosystem Management and Restoration Research Program (EMRRP), the Aquatic Nuisance Species Research Program (ANSRP), the Great Lakes Fishery and Ecosystem Restoration Program (GLFER), Planning Assistance to States, Environmental Infrastructure Programs, and the WLEB Partnership. See U.S. Action Plan 2018-2023 for a more detailed description of the USACE's programs and authorities.

USACE's Engineer Research and Development Center (ERDC), along with the Buffalo, Chicago, and Detroit Districts are working with stakeholders to evaluate targeted wetlands restoration and creation as a potentially long-term and effective means for P removal. USACE is also working with USEPA to enhance and expand current WLEB ecosystem model capabilities so that decision makers can evaluate loading scenarios and eutrophication response indicators in the lake. Areas of focus include:

- P-Optimal Wetlands
- Lakewide ecosystem models
- Targeted research on P sorbents
- Scaling up P optimization

P OPTIMAL WETLANDS

Building on several years of research on soil phosphorus storage capacity, in 2021, USACE completed construction of the first "P Optimal Wetland" GLRI demonstration project. The 10-acre demonstration project is located in the Maumee River watershed, in Defiance, Ohio, on a former cropland site specifically identified as having high potential to capture and retain phosphorus. The P optimal wetland is designed to capture high tributary flows and associated legacy phosphorus loads and filter them through a series of treatment cells. An inter-agency project team from the USACE's Engineer Research and Development Center and the US Geological Survey secured GLRI funding to operate, research, and monitor the demonstration wetland through 2030.



Aerial image of a phosphorus optimal wetland that shows the direction of water being diverted through the constructed wetland. Source: USACE.

Wetland performance has been promising with data from 2023 showing dissolved P concentration reductions by over 50% with the trend continuing in 2025. Recurrent soil sampling indicates P retention is occurring and that there is additional capacity for P storage remaining. Beginning in 2026, USACE will begin Phase II of the project. Structural modifications will be made to enhance wetland areas and improve existing P-removal & retention capacities. The

Defiance demonstration site also serves as a “learning endeavor” for the community. USACE and partners annually hold a Conservation Field Day, hosting over 300 sixth graders to the site. The tour provides an opportunity to learn about why water quality in the Great Lakes and its tributaries are important.

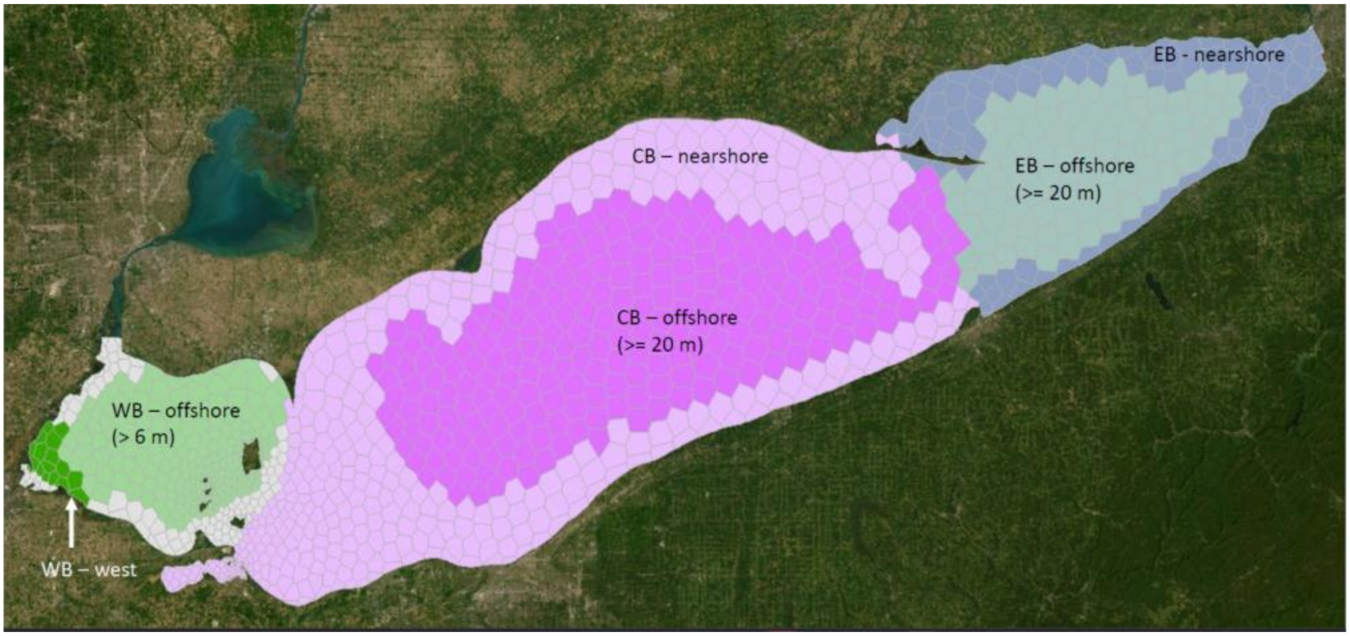
Over 300 sixth graders from four schools near Defiance, Ohio experience a hands-on tour of the [GLRI Phosphorus Optimal Wetland Demonstration] Project. Source: USACE.

Design strategies and other lessons learned from the Defiance P-optimal demonstration site are already being applied elsewhere in Ohio. USACE Buffalo District recently partnered with the State of Ohio H2O Program, City of St. Marys, and the Auglaize Soil and Water Conservation District to construct a second P-optimal wetland in the St. Marys River watershed.

LAKEWIDE ECOSYSTEM MODELS

Another major effort in Lake Erie that USACE supports is ecosystem modeling. USACE contracted with LimnoTech to develop the Western Lake Erie Ecosystem Model (WLEEM) in 2010, and in partnership with EPA under the GLRI, made subsequent applications and enhancements to the model since. This model was instrumental in development of the P reduction goals for Lake Erie in 2016. In 2019, as recommended by EPA’s Science Advisory Board, the model was expanded to include all of Lake Erie (now called LEEM). Additional work completed in 2023 further extended the model to simulate and evaluate Lake Erie hydrodynamics, wind/wave resuspension of sediments, and advanced eutrophication processes.

Now in its third phase of operation, the model is being used to assess sensitivity to Detroit River loads and changes to load timing, run continuous long-term simulations, and explore the impact of mussels. Applications of the model in 2024 found that because the Detroit River TP and SRP concentrations are roughly an order of magnitude (10x) lower than that of Maumee, Portage, and Sandusky Rivers, HABs and hypoxia are not as responsive to Detroit River loading changes as compared to other tributaries. Findings such as this are shared among scientists on the Annex 4 Adaptive Management Data and Modeling Workgroup as modeling efforts progress.



Representation of the LEEM model showing varying size grid cells in the western basin, central basin, and eastern basin nearshore and offshore zones. The model can be run for different zones and at various grid sizes. Source: LimnoTech.

TARGETED RESEARCH ON P SORBENTS

USACE ERDC is conducting targeted research on potential HAB mitigation and P removal technologies. USACE ERDC is studying novel technologies to reduce P loading within floodplain and in-stream environments. While a variety of BMPs reduce phosphorus losses from the edge of fields, few technologies exist to reduce and sequester P long term once it is transported into receiving waterbodies. A variety of natural and engineered sorbents are known to effectively retain P in aquatic systems and a subset of these materials have been used for decades in lentic systems such as lakes and ponds. However, these products have not been widely applied to flowing waters.

USACE will undertake research to test performance of multiple sorbents including (but not limited to) aluminum sulfate, Phoslock®, biochar, metal (iron and manganese) (hydr)oxides, and several aluminosilicate minerals (i.e. imogolite, allophane, gibbsite). The goal will be to identify a sorbent, or a combination of sorbents, that will enable optimized P immobilization under dynamic flow conditions. If laboratory experiments are successful, a field deployment will follow to demonstrate the technology.

SCALING UP P OPTIMIZATION

The USACE is collaborating with partners across the region to move the concept of Phosphorus Optimization to the watershed scale. The primary goal is to develop practical tools that identify the best locations for new wetlands and optimize their management for nutrient removal, with a specific emphasis on their potential to remove phosphorus. USACE is developing predictive models for common soil types to determine how much phosphorus different soils across the region can absorb and retain. These models can be used to project P storage capacities and help target investments for maximum efficiency and impact. Stakeholder engagement provides a pathway to expand the Ohio based methods across the Great Lakes basin and beyond.

NOAA UPDATE

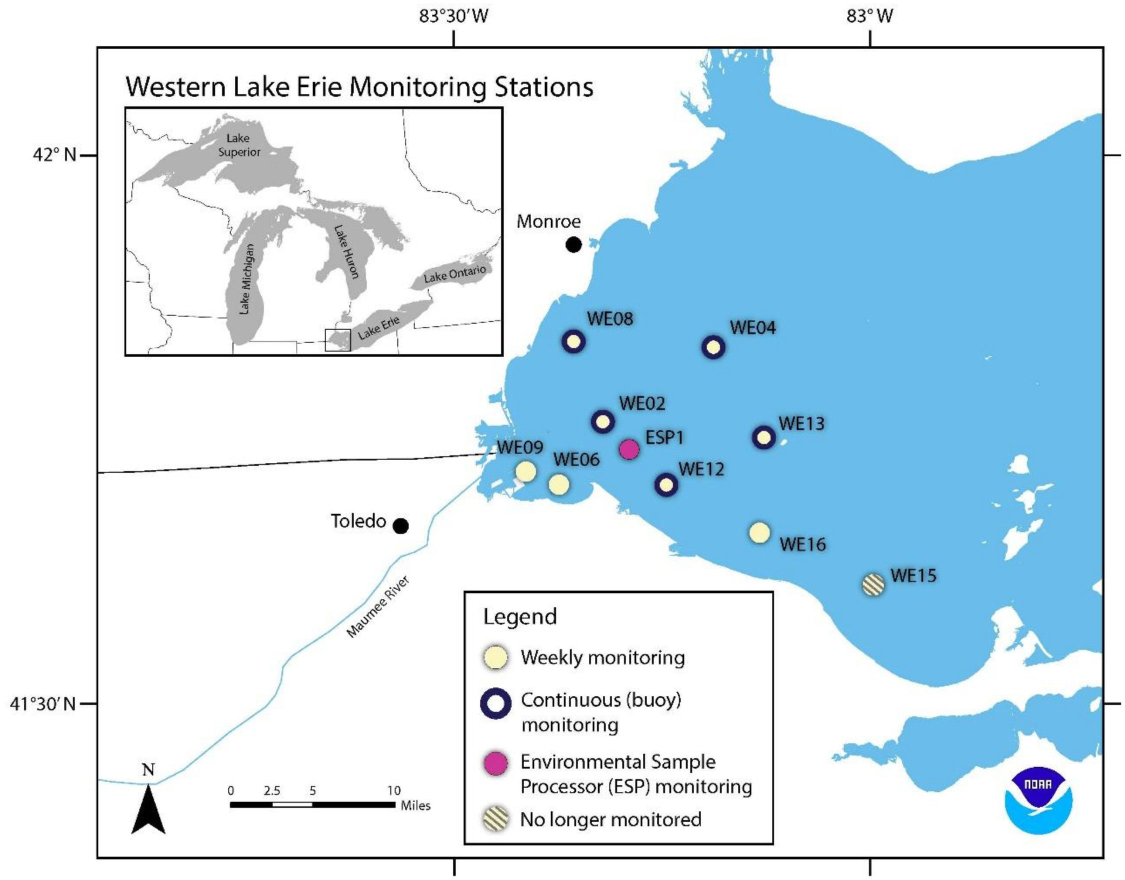
NOAA's dedicated scientists use cutting-edge research and high-tech instrumentation to provide citizens, planners, managers, and other decision makers with reliable information they need when they need it. NOAA's Great Lakes Environmental Research Laboratory, in concert with academic, agency, and private sector partners, has been actively monitoring Lake Erie and issuing forecasts on cyanobacteria location and concentration since 2008. In addition to leading a number of HABs and Hypoxia research efforts in the Great Lakes, NOAA works in partnership with Great Lakes states and EPA to address nonpoint source pollution through coastal zone management programs, and supports vital education and outreach through the Sea Grant Program. See U.S. Action Plan 2018-2023 for a more comprehensive description of NOAA's activities. Major areas of focus include:

- Monitoring HABs and hypoxia in Lake Erie
- Forecasting HABs
- Hypoxia Early Warning System

Scientists aboard a small aircraft obtain hyperspectral imagery of a Lake Erie algal bloom. Source: NOAA.

MONITORING HABS AND HYPOXIA IN LAKE ERIE

From April – October, NOAA and CIGLR conduct in-lake monitoring at eight sites in the western basin while deploying continuous near-real time water quality monitoring buoys at four of those sites (see below map). NOAA-GLERL also produces a yearly report on HAB areal extent derived from NASA MODIS imagery and weekly hyperspectral overflights. Hyperspectral flyovers detect and map HABs near water intakes and under clouds where satellite coverage is ineffective. These hyperspectral data are being used to differentiate HABs from other phytoplankton for more accurate toxin prediction. Additionally, buoys and sensors collect observations of water quality characteristics in real time. To support the hypoxia forecasts, sensors deployed around the central basin provide near-continuous temperature and dissolved oxygen measurements at various depths (2017 dataset). NOAA reports observations of water quality characteristics including water temperature, phosphorus, nitrogen, chlorophyll and phycocyanin on the GLERL Real-time Buoys website and the Great Lakes Observing System (GLOS) HAB Data Portal.



NOAA GLERL western basin Lake Erie weekly monitoring sampling sites. Source: NOAA GLERL.

The first Environmental Sample Processor (ESP) to be deployed in a freshwater setting was in 2016 near the Toledo, Ohio water intake. Since then, NOAA GLERL has expanded their use of ESPs to support near real-time detection of HABs and their toxins. In just a few hours, the third generation ESP can collect and analyze water samples from the bloom with the same methods that scientists use to analyze samples back at the lab. In 2023, NOAA GLERL began providing continuous monitoring over the bloom season at two sites in western Lake Erie using ESPs to provide local and municipal managers with early warnings of blooms and toxicity. View the Lake Erie ESP data for more information.

During the 2023 HAB season, NOAA also successfully field-tested a new platform that improves access to shallow areas where humans may encounter algal toxins. The SeaTrac uncrewed surface vehicle is a solar electric powered vessel capable of accessing water depths less than 1.5 meters. The autonomous system can stay on the lake continuously and in conditions that are not safe for human crews. Samples collected by uncrewed platforms expand the ability to get the samples needed to understand how harmful algal blooms start and stop.

An uncrewed surface vehicle monitoring for algal toxins (left). An environmental sample processor (ESP) sits inside a custom underwater stationary mooring during deployment in Lake Erie (right). Source: NOAA.

FORECASTING HABS

Since 2018, NOAA has continued to improve Lake Erie HABs forecasting tools in a number of ways. The Lake Erie Harmful Algal Bloom forecast system, which predicts 3D movement of blooms, was upgraded in 2021. The forecast system provides analysis of the location of blooms, most recent accurate estimate of size (area), as well as five-day forecasts of transport, mixing, scum formation, and bloom decline. The forecast, operated by NOAA's National Centers for Coastal Ocean Science, is available on a website with automated daily updates and weekly bulletins. The bulletin subscriber list is now >8,000 subscribers.

NOAA collaborates with other researchers to produce a seasonal projection of bloom severity in the May-June timeframe each year. This forecast is meant to provide stakeholders with a general sense of how potentially disruptive the upcoming bloom season might be, by giving a likely range on a scale from 1 to 10. Currently, the forecast utilizes an ensemble of models, and is based largely on total bioavailable phosphorus load from the Maumee River. Additional improvements to the forecast are currently ongoing, and will include biological parameters, such as cyanobacteria growth rate and toxin probability, to provide a better forecast of the bloom dynamics.

As explained above, the NOAA Great Lakes Environmental Research Laboratory deploys a network of sophisticated instruments in Lake Erie that can collect and analyze water samples in situ to provide near-real time measurements of the dangerous toxin often present in these blooms, microcystin. NOAA is planning to expand their bloom forecasts to include a prediction on the probability of exceeding toxin threshold levels in 2026.

The forecast is communicated to stakeholders and the media via an online and in person live event hosted by Ohio Sea Grant and the Stone Laboratory each summer. Following the 2024 bloom, NOAA reprocessed the HABs Severity Index time series record with new calibrations and improved algorithms, incorporating data from three satellite sensors going back to 2002. These updates resulted in the most consistent satellite imagery time series for Lake Erie to better capture historical bloom patterns.

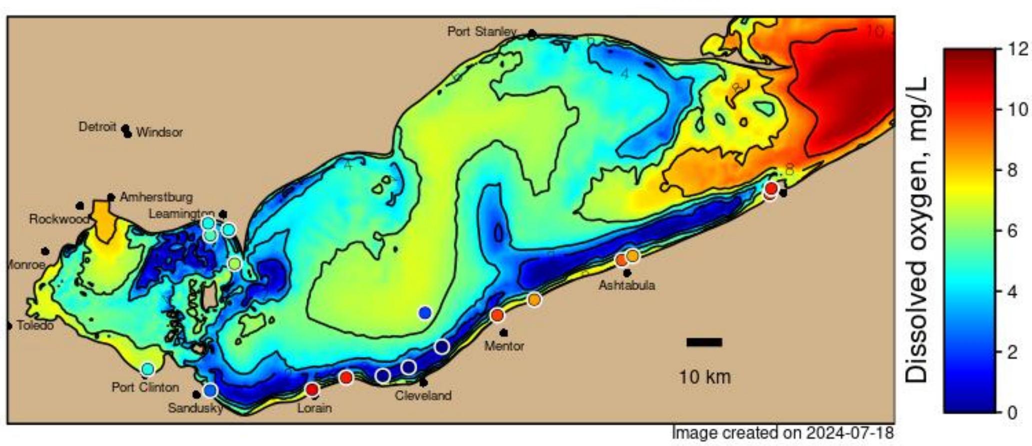
HYPOXIA EARLY WARNING SYSTEM

In 2018 GLERL and the Cooperative Institute for Great Lakes Research began producing an Experimental Lake Erie Hypoxia Forecast to predict the movement of hypoxic water in Lake Erie's central basin. This model provides an early warning to Lake Erie drinking water managers when hypoxic water approaches intake pipes. Hypoxic water requires additional treatment to remove metals and other contaminants prior to distribution in the public supply system. The forecast is produced daily from July through October using weather forecast information and a hydrodynamic model that predicts currents and temperatures in the lake.

NOAA's model predicted a notable upwelling event along the Ohio shoreline of central Lake Erie on September 1, 2021, which impacted Cleveland and surrounding coastal communities. The forecast helped drinking water plants be prepared to adjust treatment processes at their intakes and helped communities and resource managers respond to public inquiries regarding fish kills and noxious odors.

In October 2021, the Cooperative Institute for Great Lakes Research (CIGLR) hosted a virtual summit on hypoxia in the central basin of Lake Erie. Forty-one attendees representing U.S. and Canadian federal, state and provincial agencies, academic partners, and other stakeholder groups reviewed the state of the science, assessed approaches for tracking the future progress of hypoxia extent, and identified data gaps. NOAA continues to enhance their monitoring programs in response to the needs identified at the summit.

Since 2022, NOAA (GLERL with CIGLR and state/utility partners) has expanded and upgraded moored platforms and increased autonomous glider surveys in Lake Erie's central basin to map the hypoxic boundary between cruises, producing high-frequency, vertically resolved dissolved oxygen and temperature observations that better capture the onset and progression of hypoxia. Through 2024, NOAA refined experimental hypoxia early warning and forecast tools and sustained coordination with drinking-water utilities. Tracking at a finer vertical and temporal resolution is improving detection of hypoxic intrusions and providing earlier, more actionable warnings for operations. In 2025 the model was transferred within NOAA from experimental to operational status and will continue to provide early warnings of hypoxia intrusions to the user community into the foreseeable future.



Lake Erie Hypoxia Forecast on July 9, 2024, showing low oxygen levels predicted along the southern shore. Source: NOAA.

USGS UPDATE

USGS provides a key science support role in HABs and hypoxia prevention and management. USGS staff across the region are performing monitoring and scientific support activities to help managers track and understand the development of HABs and hypoxia in the Great Lakes. USGS evaluates trends in water-quality loads at several spatial scales within the Great Lakes Basin. USGS will continue collaborating with federal and state partners to conduct tributary monitoring and load computations to support tracking of nutrient inputs to Lake Erie. Areas of focus include:

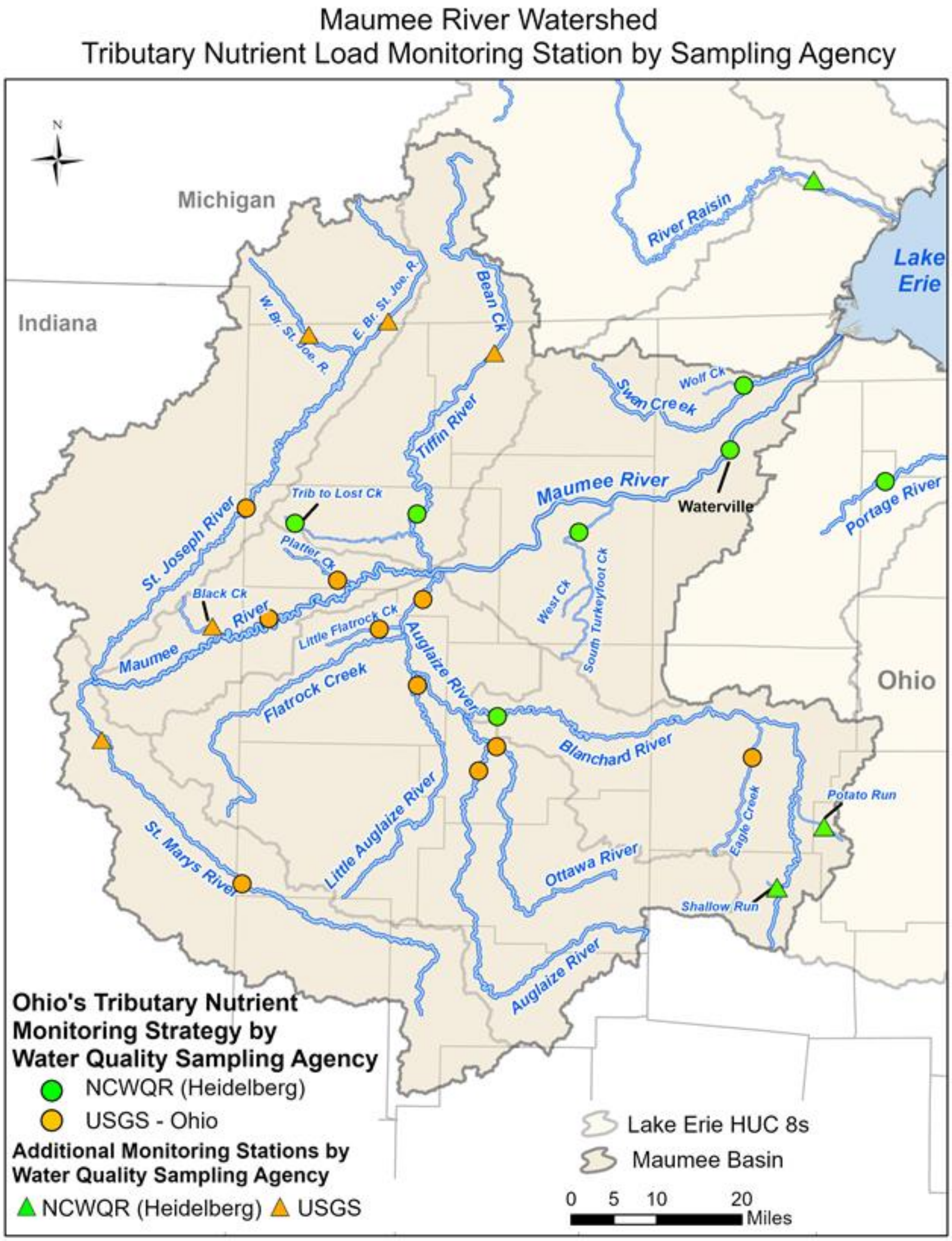
- WLEB Tributary Monitoring Network
- Evaluating trends in tributary water quality loads
- Research on nutrient and sediment dynamics in streams
- Cladophora monitoring and research
- Hypoxia monitoring

WLEB TRIBUTARY MONITORING NETWORK

USGS scientists compute daily and annual loads of phosphorus, nitrogen, and suspended sediment for several monitoring sites in the western Lake Erie basin watershed (WLEB). For sites with sufficient data, trends in loads are computed to assess potential connections to variations in weather, management activities, or other changes within the basins. This information provides valuable, data-driven metrics for cooperators to evaluate the potential impact of restoration and/or conservation efforts.

USGS also works cooperatively with several of the State governments to monitor various locations in the watersheds to track changes on a smaller scale. USGS has monitored streamflow, nutrients, and sediment at 20 sites in the Maumee River basin since 2014. These data are used to track P concentrations and compute P loads from major tributaries to the Maumee (Auglaize, Blanchard, St. Marys, St. Joseph, Tiffin, and Ottawa Rivers) and are used by Ohio to track compliance with defined targets.

In late 2025, adjustments were made to the Maumee River basin sampling network due to changes in Ohio’s available funding for its portion of the monitoring effort. As a result, GLRI assumed funding for water quality monitoring at four sites previously supported by Ohio, discontinued water quality funding support for two sites on tributaries with overlapping Ohio-funded monitoring (through another monitoring entity), ended funding to monitor water quality at one site deemed unnecessary based on data analysis, and stopped funding streamflow monitoring at four sites that Ohio now supports. Ohio DAP’s updated monitoring plan (Appendix E) outlines the updated monitoring plan and includes continued monitoring of five “sentinel sites” – smaller watersheds that provide critical insight into specific landscape features.



Map of the WLEB Tributary Monitoring Network in 2025. Source: Ohio EPA.

EVALUATING TRENDS IN TRIBUTARY WATER QUALITY LOADS

USGS will continue evaluating trends in water quality at multiple spatial scales across the Great Lakes basin. Pertinent to Lake Erie, this includes monitoring water quality at 10 tributary sites that flow directly into Lake Erie or indirectly through the Detroit River. Additionally, USGS is monitoring water quality at four edge-of-field (EOF) sites and 16 stream sites nested within the Maumee River basin above the most downriver site at Waterville. Because these sites span a range of spatial and temporal scales, USGS is using and evaluating multiple methods for trend evaluation and making results available to the public through open-source resources (data releases, web applications, journal articles). These resources are being combined with other USGS – GLRI products in public-facing web pages to synthesize information as it relates to understanding of spatial patterns and trends of nutrient loads as well as potential impacts of eutrophication including HABs across the Great Lakes. Additionally, these resources facilitate exploration of and access to definitive water quality datasets. Within this project, USGS is providing consistent methods for water-quality loads and trends evaluations to understand how hydrologic patterns and other landscape drivers are influencing the loads of nutrients delivered to downstream waterbodies, including Lake Erie.

Under the GLRI, USGS is working jointly with USDA-NRCS, EPA, and local partners to quantify the effects of agricultural management practices by monitoring nutrient and sediment loss across spatial scales in states throughout the Great Lakes basin. An installed bioreactor in Ohio was monitored from 2023 to 2025 to evaluate the efficiency and potential duration of this innovative conservation strategy. From 2018 to 2025, monitoring efforts occurred at multiple EOF locations and downstream watershed (HUC12) outlets. This monitoring regime was designed to effectively evaluate the influence of management actions on water quality and provide critical information to managers about the direct or measured effect of specific practices on individual fields as well as the expected effect of these practices at the watershed scale. Monitoring locations within the Lake Erie basin include the Black Creek watershed in Indiana and the Eagle Creek watershed in Ohio. Results from these locations have been mixed and confirm that cover crops must be well established on the field in order to effectively reduce nutrient runoff.

RESEARCHING NUTRIENT AND SEDIMENT DYNAMICS IN STREAMS

USGS is evaluating how aquatic nutrient processing and sediment storage in the tributaries and river mouths contribute to nutrient export to Lake Erie. Algal blooms and nearshore productivity have been linked with nutrient and sediment loads, the timing of nutrient delivery, and the form of the nutrients upon delivery. Results from earlier studies have indicated that in-stream storage of sediment might be a significant source of phosphorus contributing to the phosphorus loads to Lake Erie.

Research projects for this effort include evaluating the erosion and storage of fine-grained streambed sediment in two HUC-12 streams in the WLEB (Black Creek in IN and Little Flatrock Creek in OH); measuring the retention and transformation of P and nitrogen in streambed sediment throughout the Maumee River basin; and providing detailed estimates of nitrogen, P, and carbon processing in the Maumee River mouth. Key findings from these research efforts are: 1) streambanks are a significant source of sediment to the stream and the eroded sediment may bind and release dissolved P as it moves downstream; 2) the streambed is currently retaining P that may be released to the water column if stream water dissolved P concentrations decrease; and 3) sediment in the Maumee River mouth is largely a source of P and ammonium-bound nitrogen and a sink of nitrate-nitrogen.

A new study initiated by USGS in 2023 is estimating the pool of legacy nutrients being stored throughout the Maumee River basin. USGS will continue to assess how streambank erosion and accumulation of fine-grained material in the streambed contributes to long-term phosphorus storage in the basin and how in-stream and rivermouth nutrient cycling contributes to nutrient loads. Information from these efforts can be used to locate and actively manage areas throughout the basin where nutrients are being stored and where increased nutrient cycling may help mitigate nutrient loads.

CLADOPHORA MONITORING AND RESEARCH

Since 2018, USGS has expanded monitoring and research to better understand *Cladophora* growth in the Great Lakes. Sentinel site assessments of algal biomass and potential growth limiting factors (i.e., nutrients, light, substrate) compared transects in Lake Erie to other Great Lakes.

Cladophora biomass data collected by USGS each year continues to inform the Adaptive Management process under Annex 4 and has been incorporated into State of the Great Lakes reporting. Sentinel site sampling has also been leveraged to document high levels of microplastics associated with benthic algae (Peller et al., 2021). Innovative computer visions methods have been developed to expand the spatial coverage of Cladophora assessment using imagery from autonomous underwater vehicles (AUVs).

USGS intends to continue to monitor *Cladophora* growth at sentinel sites in Lake Erie near Erie, PA and Dunkirk, NY, to better understand distribution, algal community dynamics, and drivers of growth. Satellite and AUV based remote sensing will be used to expand the spatial and temporal scale of assessments. A geo-statistical model will integrate data across these scales to maximize information for management and optimize efficiency of sampling efforts.

A diver collects benthic samples of Cladophora. Source: USGS.

HYPOXIA MONITORING

The USGS provides near-bottom measurements of temperature and dissolved oxygen for the central basin of Lake Erie using self-contained environmental data loggers. Since 2023, 75 data loggers are deployed between April and November to better understand how hypoxia develops and how that influences fish habitat quality during lake stratification. The loggers are deployed on acoustic telemetry receivers in a network designed to record tagged fish movements (Great Lakes Acoustic Telemetry Observation System, GLATOS). Data collection is ongoing, and the data release is updated annually.

STATE PROGRAMS: OHIO

Ohio has a variety of programs at play that are accomplishing significant load reductions. These efforts are being led through collaboration among the Ohio Department of Natural Resources (ODNR), Ohio Environmental Protection Agency (Ohio EPA), Ohio Department of Agriculture (ODA), and Ohio Lake Erie Commission (OLEC).

Ohio's DAP is focused on four overarching strategies: 1) agricultural nutrient, land, and water management; 2) restoring wetlands to recover their function in removing nutrients from the waterways; 3) addressing community sources including HSTS and wastewater treatment infrastructure; and 4) the use of watershed planning at the county and local level to assist with placing nutrient reduction practices on farm fields and in-stream to maximize nutrient reduction potential.

Since 2015, Ohio has enacted a ban on the placement of manure on frozen or saturated ground, restricted fertilizer application around the time of intense rain events, banned the disposal of dredge material in the open waters of Lake Erie, enrolled 1.85 million acres of farmland in voluntary nutrient management plans, and constructed or begun the process toward constructing 4,386 acres of wetlands in the WLEB.

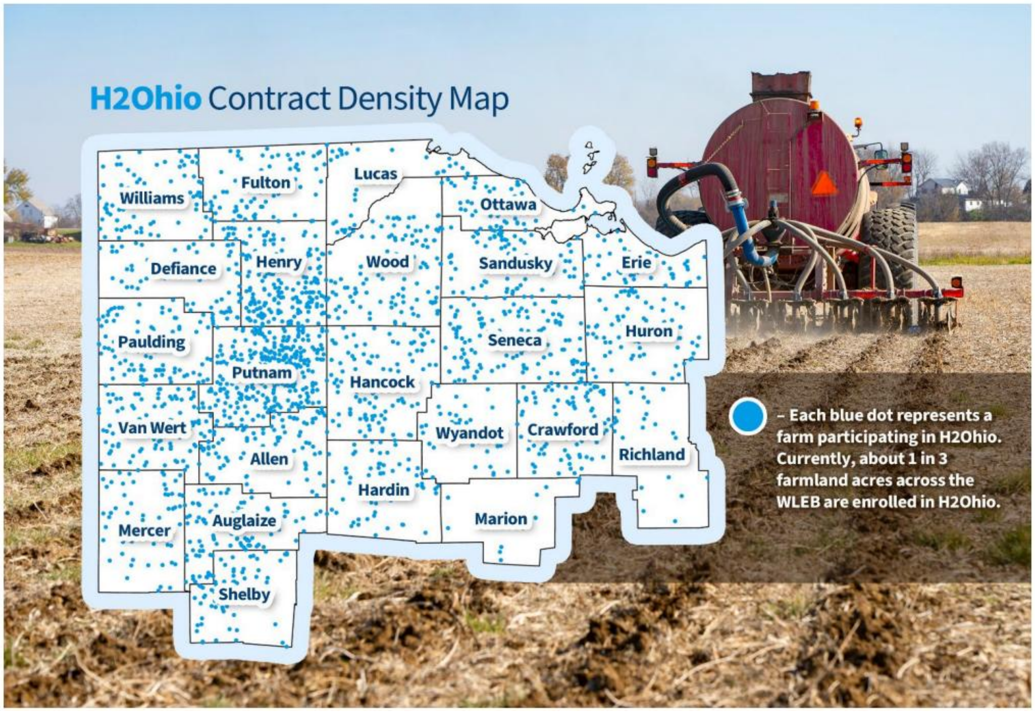
Ohio's Fertilizer Applicator Certification program launched in 2014 has increased education on fertilizer use. Also in 2014, the agriculture community proactively launched a voluntary, third-party auditor verified nutrient certification program to provide a consistent, recognized standard for agricultural retailers and nutrient service providers. Since the 4R Stewardship Certification Program was established in the WLEB (Indiana, Michigan and Ohio), the number of 4R Certified facilities in the WLEB grew from 25 to 45 in 2023. The total acreage serviced by 4R Certified nutrient service providers has steadily increased from over 1 million acres in 2016 to over 1.5 million in late 2022.

In March 2019, Governor DeWine introduced H2Ohio, a water quality initiative to invest in targeted, long-term solutions to ensure clean and safe water in Lake Erie and throughout Ohio. The state has appropriated over $600 million for H2Ohio through state fiscal year 2025.

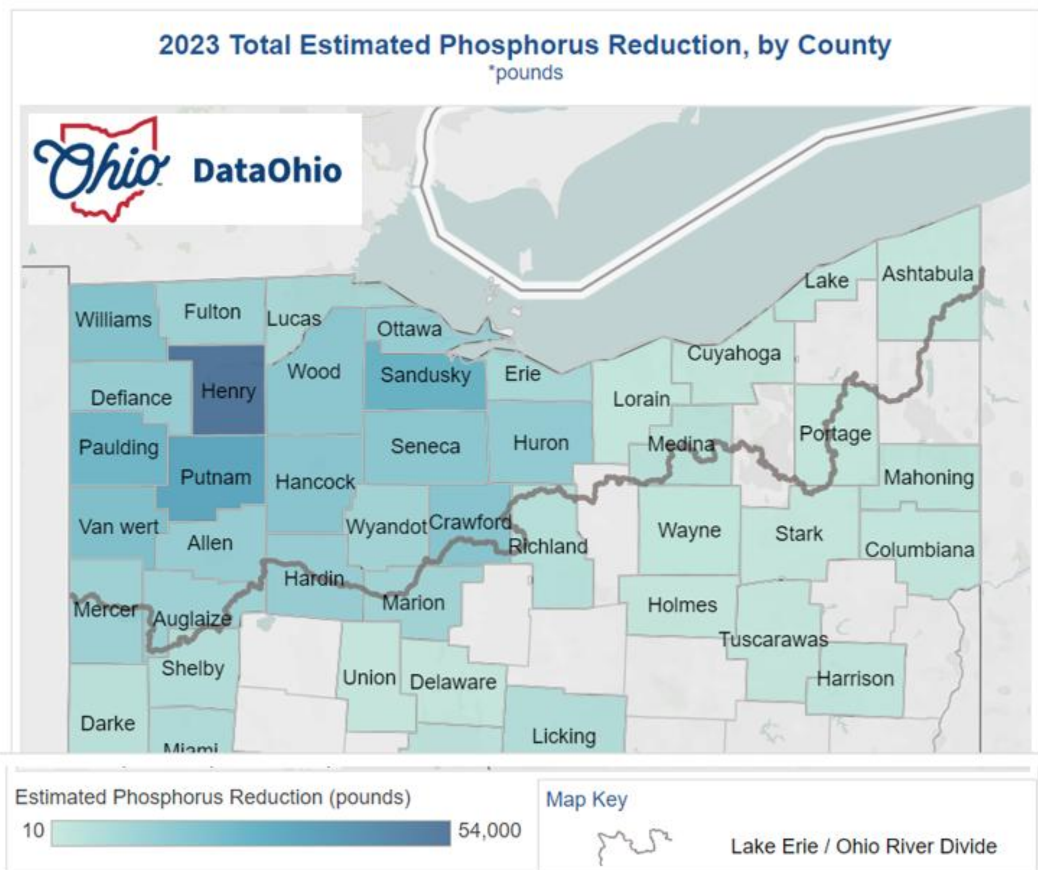
Though H2Ohio is a statewide initiative, it has been designed, in part, to address the specific needs of Lake Erie. Approximately half of H2Ohio funds are spent in the WLEB. The primary focus of H2Ohio in the WLEB is on the implementation of agricultural best management practices and wetland restoration.

Through the H2Ohio program, more than 2,600 farmers have enrolled 1.85 million acres of farmland across the 24 counties that make up the WLEB watershed. Additionally, H2Ohio has provided funding to construct and enhance more than 100 wetland projects in the WLEB.

Nearly $250 million in H2Ohio funding has been allocated by ODA to support cropland nutrient management activities, as well as drainage water management structures and conservation ditches in the WLEB. All 1.85 million acres enrolled in H2Ohio have Voluntary Nutrient Management Plans (VNMPs), which is the first step and a precondition for further participation in the program. Producers are also encouraged to implement other best management practices, which increase the effectiveness of the VNMP and load reduction impact. ODA's goal is to enroll 2 million acres across the H2Ohio area by the end of 2025, which would be approximately 50 percent of the cropland in the WLEB.



H2Ohio Contract Density Map. About one in three farmlands in the WLEB were enrolled in H2Ohio in 2023. Source: H2Ohio.



[H2Ohio contract density and estimated phosphorus reductions](), as of October 8, 2024. Source: H2Ohio.

The joint agencies (ODA, ODNR, and OEPA) estimated phosphorus reduction is 573,708 lbs from fully implemented practices as of 2024. While the amount of phosphorus loading being reduced from sources is significant, the primary indicator of progress will be actual water quality monitoring data. Ohio water resource agencies, Heidelberg University and USGS are all involved in tributary nutrient monitoring throughout the Lake Erie watershed. There are more than 20 monitoring stations in the Maumee River watershed alone.

Starting in 2016, every two years Ohio EPA issues a Nutrient Mass Balance Study, which uses the extensive water quality monitoring network and other data to allocate sources of P loads in watersheds.

Ohio EPA finalized and submitted the Maumee Watershed Nutrient TMDL to U.S. EPA in June 2023. The TMDL allocated P loads at the watershed outlet, and to facilitate nonpoint source planning efforts at a local scale, the load allocation was extrapolated to the HUC12s within. The Maumee Watershed Nutrient TMDL includes an implementation strategy which identifies several mechanisms and funding programs that state and local entities can utilize to achieve the reduction goals. Biennial reports on progress will be issued every two years starting in 2024.

In addition to tracking implementation at the watershed scale, the Ohio Agriculture Conservation Initiative (OACI) conducts statistical surveys to better understand current on-farm conservation and nutrient management efforts. The OACI is a partnership of the agriculture, conservation, environmental, and research communities. Producers register confidentially with OACI to assess their current conservation adoption level, to promote continuous improvement, and highlight positive changes associated with H2Ohio participation. Thus far, these surveys indicate enrollment in cost-sharing programs is high, the majority of farmers routinely test their soils, and more advanced precision agriculture is widely used.

Implementation of wetland projects under H2Ohio is being supported by a multi-million-dollar monitoring program led by a team of scientists from six Ohio universities through the Lake Erie and Aquatic Research Network (LEARN). Its mission is to independently assess the ability of wetland restoration projects to reduce nutrients and improve water quality. Researchers collected data from 45 H2Ohio wetland projects in 2022.

For more information, see:

Ohio Domestic Action Plan 2023

H2Ohio Annual Reports

H2Ohio tracking tool for BMP data by county

H2Ohio tracking tool for load reductions by county

OEPA Nutrient Pollution – Finding Solutions

OEPA Maumee Watershed

Ohio Agriculture Conservation Initiative

Ohio 4R Nutrient Stewardship Certification

LEARN H2Ohio Wetland Monitoring Project

STATE PROGRAMS: MICHIGAN

Implementation of Michigan's DAP is being led by the Michigan Departments of Agriculture and Rural Development (MDARD); Environment, Great Lakes, and Energy (EGLE, formerly MDEQ); and Natural Resources (MDNR). The Michigan portion of the Lake Erie watershed, including areas that drain to the St. Clair River, Lake St. Clair, and the Detroit River before reaching Lake Erie, covers 5,808 square miles. Michigan's DAP is focused on achieving P reduction goals for the mouth of the Detroit River, the River Raisin Watershed, and Michigan's portion of the Upper Maumee River Watershed.

Michigan has the unique situation where one regulated entity comprises the bulk of the State's phosphorus load to Lake Erie: the Great Lakes Water Authority (GLWA). The GLWA Water Resource Recovery Facility (formerly the Detroit Water and Sewerage Department WWTP) is the largest single site wastewater treatment facility in the U.S. The GLWA services 35% of the state's population contained within Detroit and 76 other communities in a service area of more than 946 square miles. Detroit's treated wastewater and stormwater runoff was estimated to make up over 60% of the U.S. load to the Detroit River in 2008.

In the 2018 DAP, Michigan made several commitments to reduce the largest point source contributions to western Lake Erie: 1) maintaining more stringent TP effluent limits for the three key WWTPs that discharge to the Detroit River and one key WWTP that discharges to the River Raisin, 2) that the communities in the WWTPs service areas maintain compliance with Municipal Separate Storm Sewer System (MS4 and biosolid permits), and 3) for the GLWA to achieve their Long-term CSO Control Program. To date, all of these objectives have been met. For the four key WWTPs, the current TP effluent limits are 0.7 mg/l monthly average, and 0.6 mg/l growing season average (April – Sept.). Implementation of the LTCSOCP has reduced the untreated CSO discharge from around 25 billion gallons per year (BGY) in 1993 to 1-2 BGY today.

Based on a 40% reduction from 2008, Michigan's target TP load reduction is 705 MT. So far, Michigan estimates 450 MT TP has been reduced, largely through optimization at the GLWA to reduce TP concentrations in effluent. Michigan met its goal to achieve a 20% reduction by 2020. With additional point source controls planned, Michigan estimates that nearly 2/3 of the 40% target will be achieved by 2025, leaving the remaining 200 MT to be addressed primarily by agricultural nonpoint sources.

Agriculture is the dominant land use in the River Raisin and Michigan's portion of the Upper Maumee River Basin. The predominant crops are corn, soybeans and wheat. Planning, implementation, and monitoring has been further prioritized to five agricultural subwatersheds (HUC-12 scale). There are 76 HUC-12 subwatersheds in Michigan's portion of the WLEB.

EGLE's Nonpoint Source Program and MDARD are using desktop tools (specifically, the ACPF) coupled with field-by-field inventories to better understand current conditions and identify fields with a greater potential of contributing sediment and nutrients to surface waters. The Agricultural Inventory data are made available to the Conservation Districts via web-based applications designed to be user-focused and do not require GIS expertise. To date, this process has been fully completed in 11 HUC-12 watersheds, with field inventory data for 58 HUC-12's and the ACPF component completed on 74 HUC-12's. The goal is to complete the process in all 75 HUC-12s by late 2026.

Implementation of conservation practices has largely been driven by the Michigan Agriculture Environmental Assurance Program (MAEAP) and the tri-state Regional Conservation Partnership Program (RCPP). Over 71,428 acres were enrolled in RCPP in Michigan. This included more than 28,034 acres of cover crops and 11,393 acres of nutrient management. Additionally, as of November 2025, there were 256 sites (i.e., farms or properties) within the WLEB enrolled in the MAEAP verification process. The newly verified conservation practices in Fiscal Year 2025 included: 861 acres under nutrient management plans (i.e., cropland, pasture, etc.); 575 acres under conservation tillage, including multiple forms of conservation tillage and grass cover; 108 acres under cover crops; and six stabilized gullies.

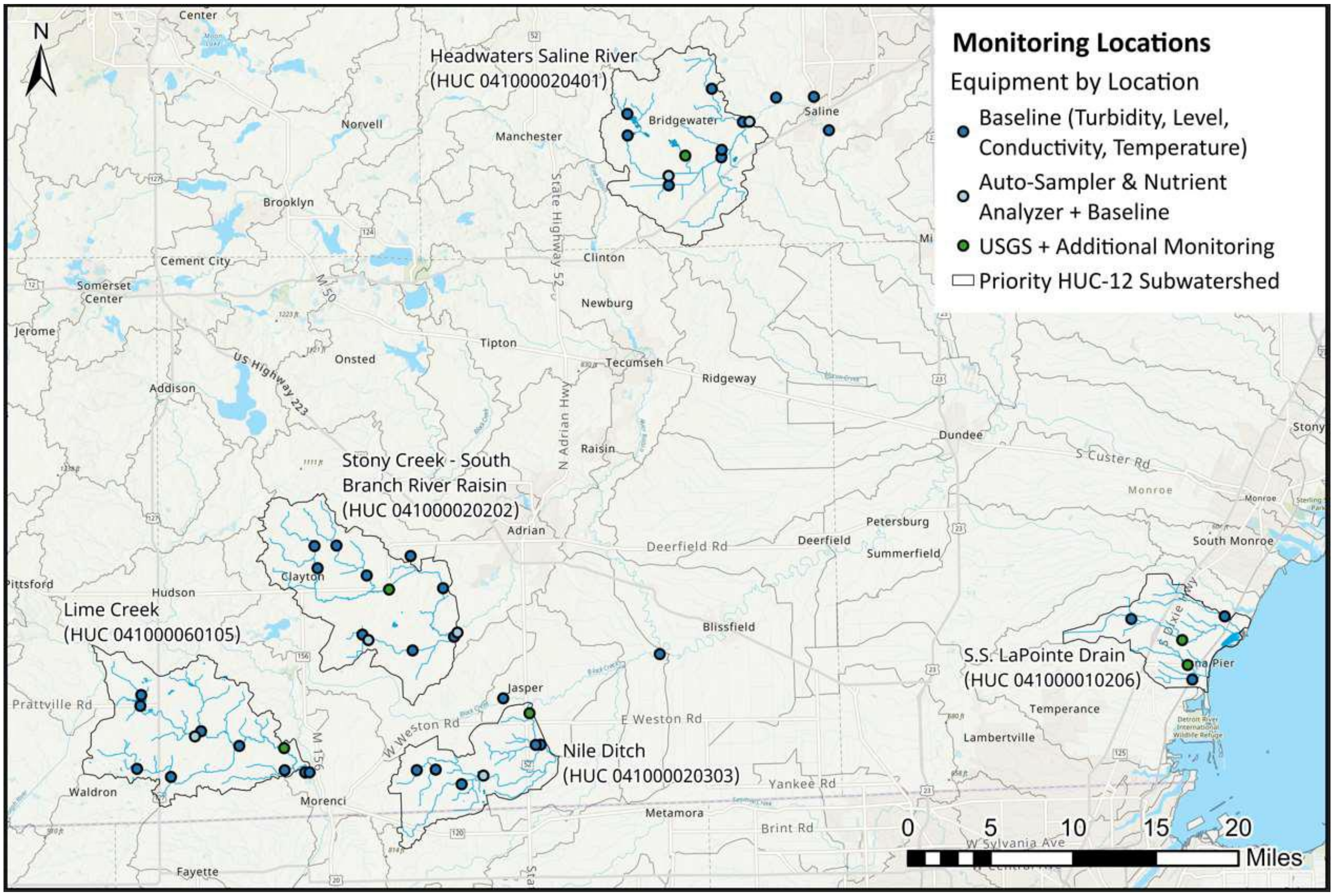
With funding from the GLRI, Michigan's EGLE – NPS Program created the Soil Health Investment Program (SHIP) to boost financial and technical assistance to WLEB farmers for a range of conservation practices. The EGLE – NPS Program launched SHIP in early 2025 in collaboration with Lenawee, Washtenaw, Monroe, and Hillsdale County conservation districts. SHIP helps farmers employ a variety of actions to reduce erosion and keep nutrients on fields and out of Lake Erie. The leading conservation practices implemented so far are cover crops, grassed waterways, equipment purchases, upgrades for precision nutrient management, and drainage water management systems. SHIP saw early success in its first year (58 farmers enrolled by October 1, 2025); their actions will account for over 50 percent of the available funds over the next three years.

Michigan developed an Adaptive Management Plan (AMP) in 2021, a companion document for the DAP’s implementation. The AMP formalizes the strategic approach to accelerating progress under the DAP by monitoring and evaluation to learn about the impacts of management actions and then using the results to update knowledge and adjust management approaches.

MDARD established the Office of Agricultural Science and Research (OASR) in 2024 to strengthen the department’s ability to respond to emerging challenges in agriculture through a science-driven, adaptive management approach. OASR strengthens Michigan’s DAP approach by interpreting scientific findings, improving clarity of technical information, and guiding continuous learning. OASR’s adaptive management focus is helping the state reduce uncertainty about how farm-level practices affect Lake Erie, improving the efficiency and impact of nutrient-reduction DAP-related programs over time.

Michigan partners have established new research and monitoring projects to evaluate impacts to nutrient losses from fields and water quality in streams. MDARD recently partnered with the Alliance for the Great Lakes to expand the water quality monitoring network in the WLEB in and around the five priority subwatersheds. This program will be implemented over a five-year period (2024-2029) and will deploy higher spatial density monitoring instrumentation with a particular focus on understanding phosphorus trends. The system includes 50 new monitoring locations throughout the River Raisin and Bean Creek watersheds and direct tributaries to western Lake Erie in the Ottawa-Stony watershed area (see map below). This higher spatial density monitoring instrumentation will enable state, partners, and practitioners to implement better conservation and land management practices to meet phosphorus reduction goals.

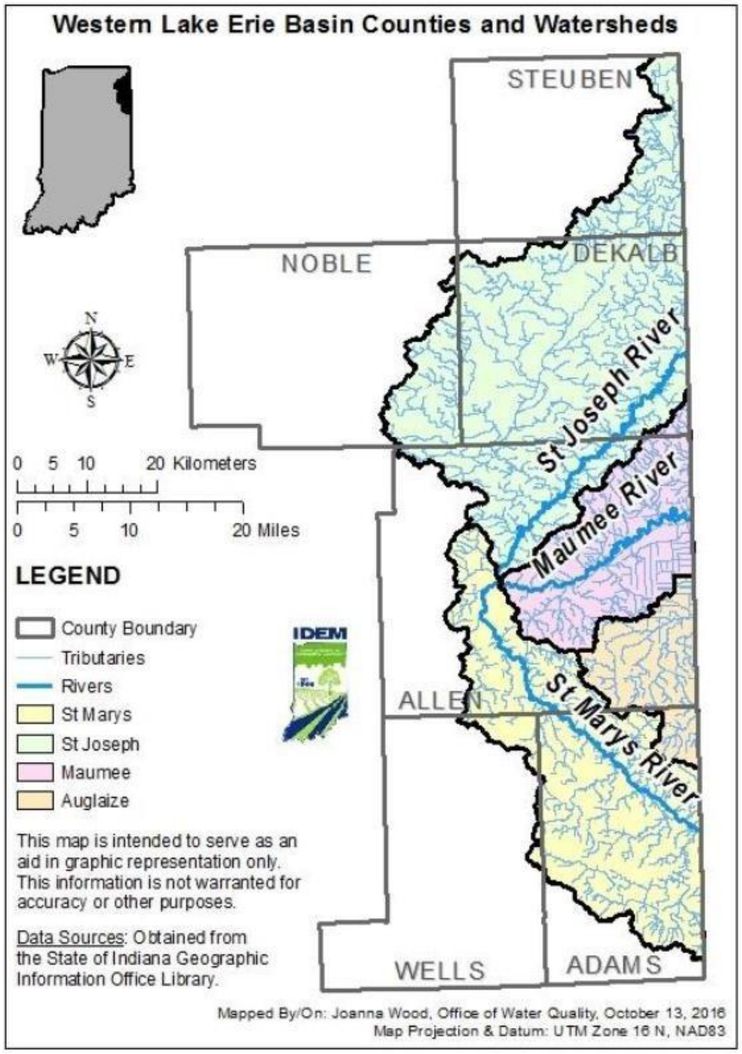
Increased outreach and engagement to stakeholders in the WLEB is a key priority objective in the Michigan DAP. Michigan created the WLEB Community Advisory Group as a formal way for the state agencies to hear from community leaders that represent different constituencies in the watershed. This diverse group of 65 partners brings together science, policy, and local perspectives to inform the development and implementation of the 2025 DAP and plays a critical role in moving Michigan’s phosphorus reduction goals for Lake Erie forward. Since forming in 2023, the advisory group has provided opportunities for education and networking, including an annual conference facilitated by the University of Michigan Water Center.



Approximately 50 monitoring stations in southeastern Michigan are being outfitted with monitors to gauge water quality and flow in five priority sub-watersheds. Source: Michigan 2025 DAP.

For more details on Michigan's DAP, visit: Taking Action on Lake Erie.

STATE PROGRAMS: INDIANA



Map of Western Lake Erie Basin counties and watersheds in Indiana. Source: State of Indiana Geographic Information Office Library.

Founded on the principle of adaptive management, Indiana's Domestic Action Plan to reduce phosphorus to Lake Erie is the product of a dedicated Advisory Committee comprised of representatives from different stakeholder sectors and led by the Indiana Department of Environmental Management (IDEM). Emphasis is on using existing regulatory instruments and implementing voluntary best management practices to achieve phosphorus reduction goals.

Indiana drains roughly 12 percent of the western Lake Erie basin watershed (WLEB) and is comprised of 821,300 acres across 5 counties. This portion of the WLEB is home to nearly a half million people. The largest city is Ft. Wayne with a population of approximately 260,000. More than 70 percent of the land is used for agriculture, 16 percent is developed, and the remaining 14 percent is comprised of forests, wetlands, and open water.

Indiana's DAP seeks to address these sources by:

- affecting the most change with the least cost;
- prioritizing resources to areas with the most phosphorus reduction potential;
- seeking to engage citizens who are not participating in conservation efforts;

- using social indicators; and
- employing adaptive management.

Indiana's goal is to meet the spring-time flow weighted mean concentration (FWMC) targets of 0.23 mg/L and 0.05 mg/L for TP and SRP respectively in the Maumee River as it flows across the border into Ohio. Using different models, analysis of water quality monitoring data from IDEM, Allen County Soil and Water Conservation District (SWCD), Maumee Watershed Alliance (MWA), and the City of Fort Wayne indicates the highest TP concentrations and loads come from the St. Marys watershed. Nutrient loading from unregulated livestock operations and community septic system failures are of concern. IDEM will continue to support USGS gages and additional monitoring by the local water monitoring entities to better characterize nutrient loading in the St. Marys.

Since the development of the initial DAP in 2018, Indiana has had several successes to report in both urban and rural landscapes. A noteworthy project is the Ft. Wayne Deep Rock Tunnel, or The Three Rivers Protection & Overflow Reduction Tunnel (3RPORT) and the Tunnel Works program which will collect and transport sewage and stormwater to the sewage treatment plant that would have otherwise been directed to Fort Wayne's combined sewer overflow system. Tunnel Works will reduce the amount of sanitary sewage and stormwater that is discharged into Ft. Wayne's rivers. Completion of 3RPORT and Tunnel Works will result in a 90% reduction of combined sewage overflows to the St. Marys and Maumee Rivers. Combined sewer overflows will be reduced from 72 to four occurrences during a typical year. Tunnel Works will be completed and operational by the end of 2025. Further upstream in the St. Marys watershed, Adams County Regional Sewer District is working to connect homes to sewers. Project 5 is in the beginning phase of construction. At completion, the Adams County RSD will service 1078 residences.

Active agricultural programs in Indiana include:

- The Regional Conservation Partnership Program (RCPP) in the tri-state WLEB area. Partners have hosted hundreds of farmers and landowners on Lake Erie and at Stone Lab so they can see the algae bloom problems firsthand in the lake.

- The TNC Farmer Advocacy Program developed a program with other WLEB partners to elevate the voices of conservation farmers in a water quality and soil health advocacy program.

- The Indiana Conservation Partnership continues to complete spring and fall cover crop and tillage transect surveys.

- The Conservation Reserve Enhancement Program (CREP) will be expanded in 2024 to include the entire state of Indiana, so the western Lake Erie basin watershed in Indiana will be a part of this expansion. Conservation Buffers, Riparian Buffers, Bottomland Timber Establishments, and Wetland Restorations will be the conservation practices that will be eligible to landowners through the Indiana CREP.

Indiana estimates a source reduction of 343,621 lbs/yr total phosphorus from 153,400 acres between 2018-2023 for practices funded by federal cost share programs. In addition, the Indiana Nutrient Research and Education Program (INREP) is being created to continue and expand upon work of the Indiana Science Assessment in support of the Indiana State Nutrient Reduction Strategy. This program will be housed at Purdue University and will include conservation organizations and agency personnel as well as researchers and experts from five academic institutions and well as research agencies such as USGS and USDA, ARS.

For more details on Indiana's DAP, visit: ISDA: Indiana's Great Lakes Water Quality Agreement (GLWQA) Domestic Action Plan (DAP) for the Western Lake Erie Basin (WLEB).

TRACKING PROGRESS

A wealth of information must be collected over several years to determine whether these actions will be effective in reducing phosphorus loads to the Lake. Federal and state agencies are using multiple indicators and metrics for measuring progress "on the ground" and in the water. Various data and information currently being used to assess progress is summarized in this section. Based on this information, we are not proposing major changes to our implementation strategies at this time. There has been significant work on the ground to reduce phosphorus, and we are starting to see some indications of progress. Existing efforts need to be sustained and expanded to further reduce phosphorus loads to the Lake.

Example of the multiple tiers of information being used to evaluate progress in Ohio. Source: Ohio EPA.

WATER QUALITY INDICATORS

EPA in coordination with state, federal, and Canadian partners, annually track changes in phosphorus loads to Lake Erie and the in-lake response of HABs and hypoxia. The Annex 4 Adaptive Management Task Team published its first binational evaluation of progress in 2024, to be repeated every five years. This first evaluation serves an initial assessment of progress and a baseline against which to track future progress towards our binational goals. The purpose of the 5-yr binational evaluation is to:

- Track changes in phosphorus loads to Lake Erie.
- Assess in-lake response of harmful algal blooms (HABs), hypoxia, and Cladophora to changes in nutrient loads and measure progress towards achieving lake ecosystem objectives for Lake Erie.
- Provide evidence-based recommendations to the Annex 4 Subcommittee regarding research, modeling, and monitoring activities that would improve our ability to assess progress over time.

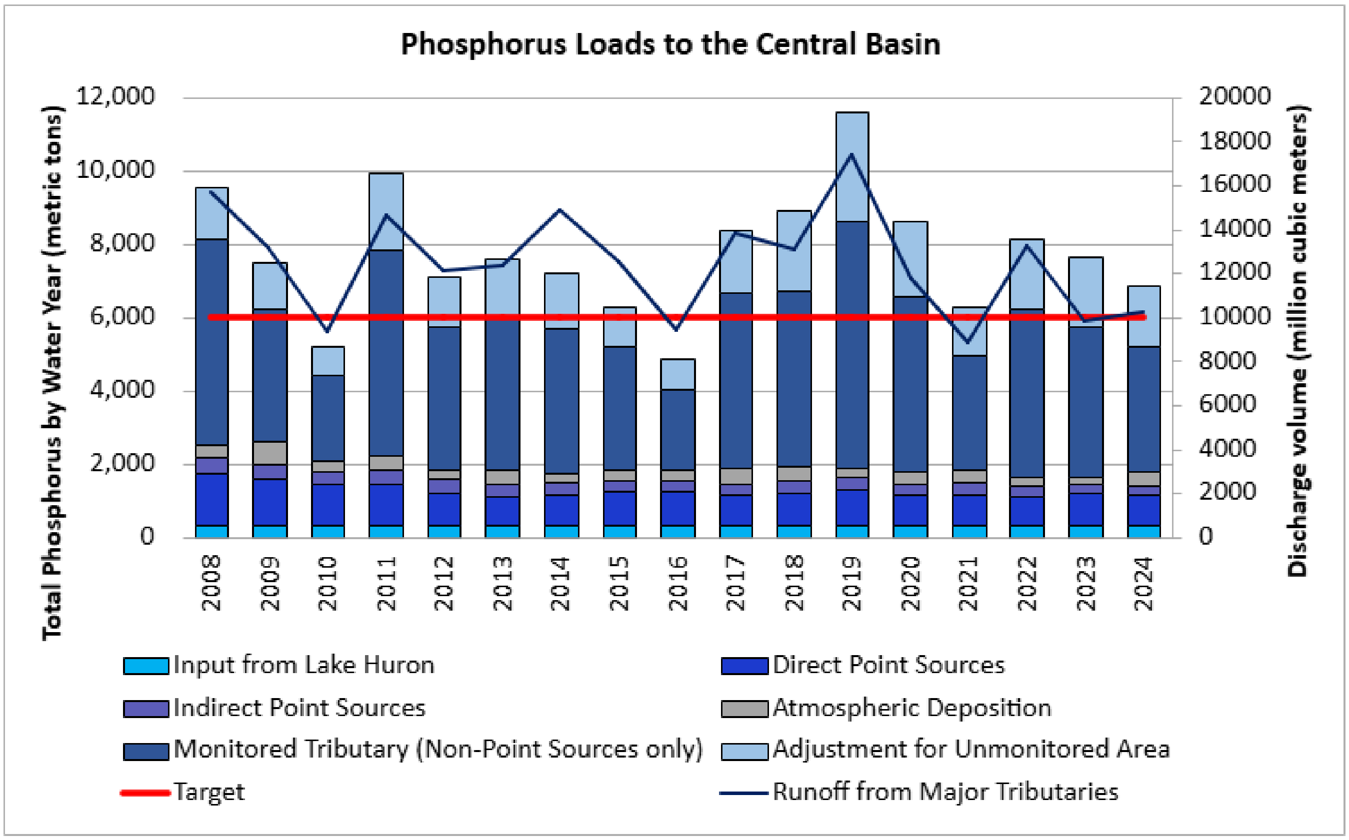
According to the 2017-2021 assessment, the western basin remains highly eutrophic, as indicated by high phosphorus and chlorophyll concentrations as well as recurring HABs that limit recreational opportunities. Phosphorus and chlorophyll concentrations in the central and eastern basins are relatively stable and consistent with the desired ranges.

However, hypoxia remains a concern in the central basin and shoreline wash-up of nuisance benthic algae is an issue in the eastern basin.

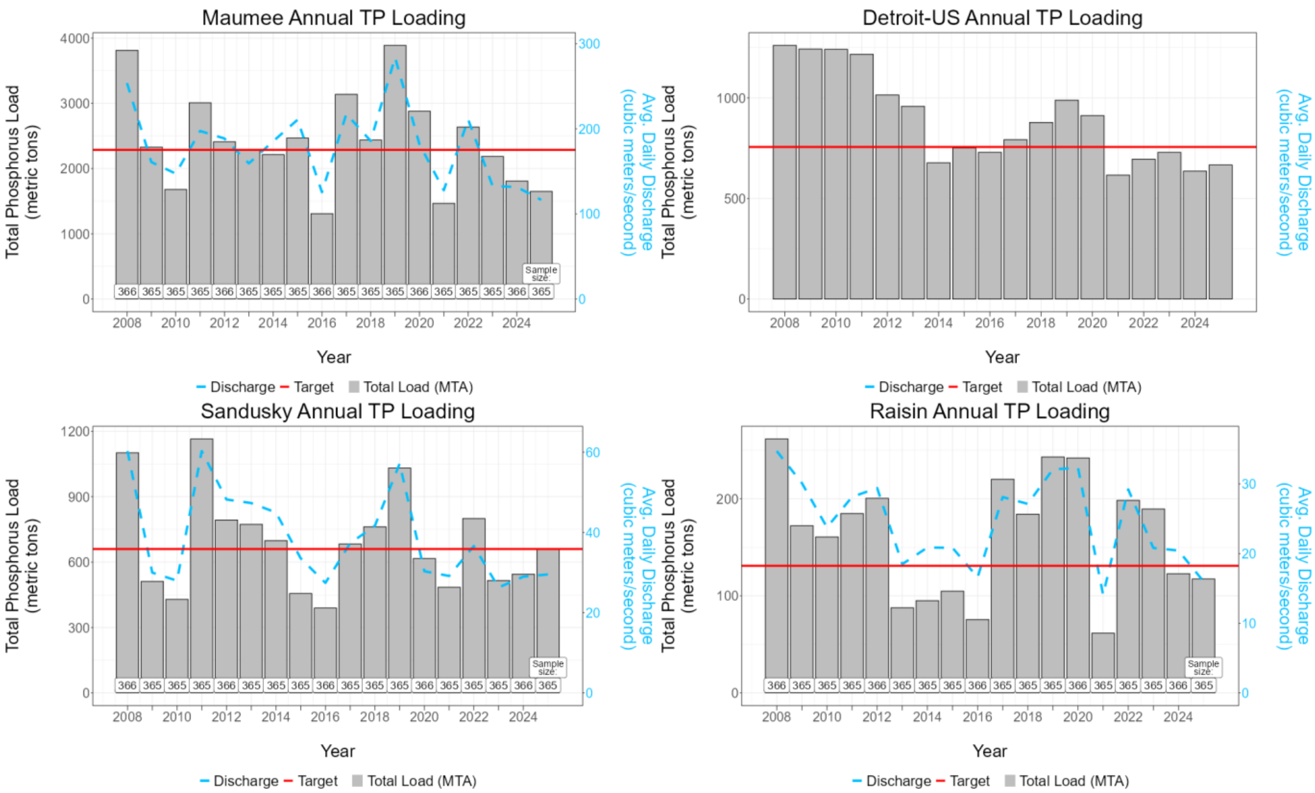
The largest sources of phosphorus to the lake, the major tributaries, routinely exceed target levels. In addition, smaller tributaries still contribute, at times, high concentrations of phosphorus leading to smaller, but still significant, localized algal blooms. Phosphorus reduction trends were difficult to discern, and loads continue to be largely driven by precipitation (e.g., rain events) and discharge from rivers, which is highly variable from year-to-year.

PHOSPHORUS LOADS

EPA and Canada jointly track phosphorus loads from major sources including runoff from tributaries, direct point sources (municipal wastewater, for example), and atmospheric deposition. At this time, there is no overall clear change in annual phosphorus loading at a lakewide scale. Annual loads to the lake are highly correlated to streamflow/discharge patterns. The objective is not to exceed 6,000 MT total phosphorus load to the central basin of Lake Erie, which includes inputs to the western basin and the St. Clair-Detroit River system.



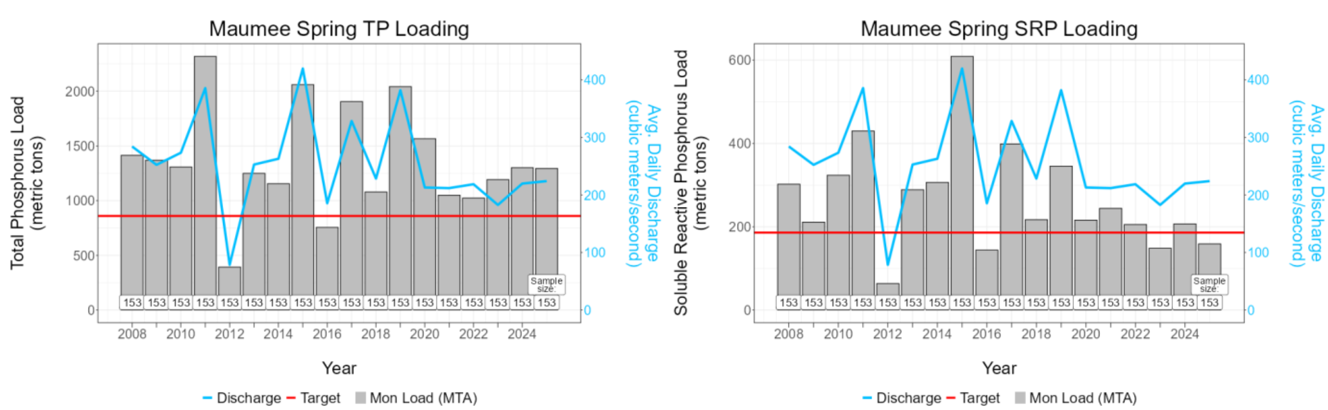
Annual Total Phosphorus Loads to the central basin of Lake Erie, from the U.S. and Canada, 2008-2024. Source: EPA.



Annual (Water year: October – September) Total Phosphorus loads for four priority tributary watersheds: Maumee, Detroit River (U.S. watershed and direct point source loads only), Sandusky, and River Raisin. Horizontal red lines are the loading targets representing a 40% decline from 2008. Blue lines show average daily discharge at the most downstream stream gage. Source: EPA.

MAUMEE RIVER TRENDS

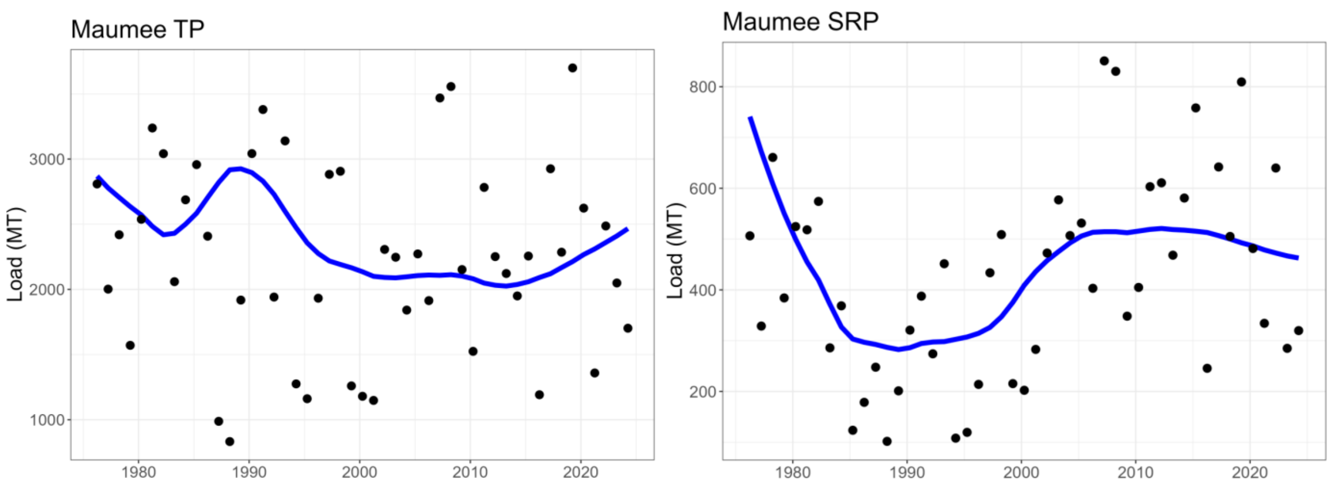
The Maumee River has the highest phosphorus load of all the Great Lakes tributaries and phosphorus loads from the Maumee River during the spring (March-July) is a reliable predictor of summer algal bloom severity each year. TP and SRP spring loads from the Maumee River have been relatively lower since 2019 but are still above targets. Loads generally track changes in discharge; the years in which targets were met had the lowest discharge over this time period.



Spring (March – July) Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP) loads measured at Waterville, OH. Horizontal red lines are the loading targets representing a 40% decline from 2008. Blue lines show average daily discharge. Source: EPA.

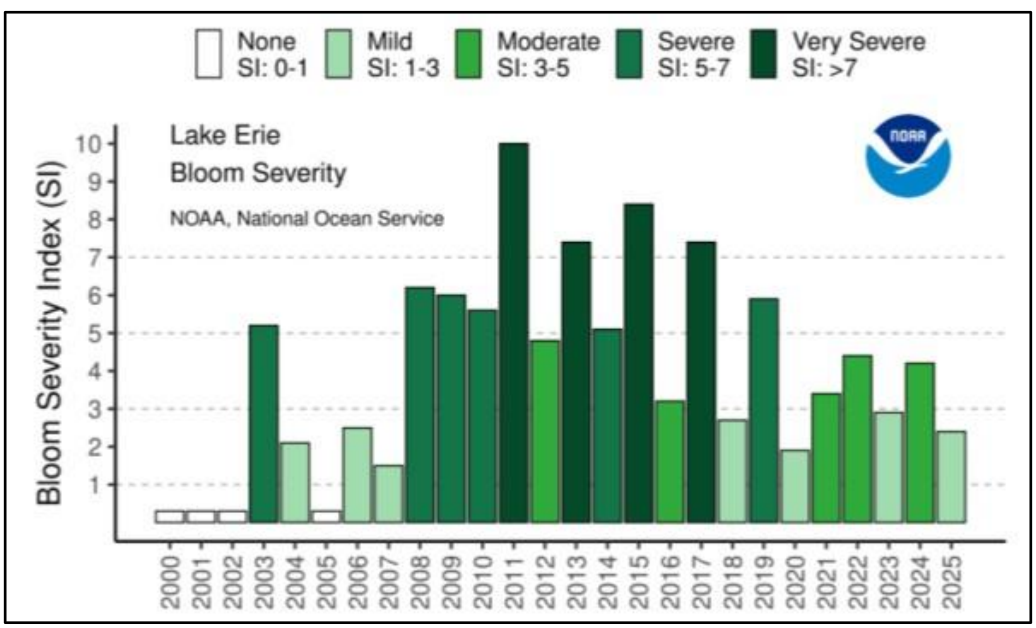
Because tributary discharge drives most of the variability in spring and annual phosphorus loads and changes from year-to-year with precipitation patterns, detecting changes in loads due to other factors such as land-use change or management actions is challenging. Flow-normalization is a statistical tool that reduces variability in load estimates and is implemented in the EGRET software developed by the USGS ([Hirsch et al., 2023]). The resulting flow-normalized loads remove most of the daily, annual, and seasonal variability due to flow and are less variable than actual loads, which makes detecting and interpreting trends and changes due to other effects easier.

As part of the Binational Adaptive Management Evaluation for Lake Erie (2017-2021), the Adaptive Management Team extended an analysis by [Rowland et al. (2021)] using EGRET to examine long term trends in the Maumee River since 1982. This analysis indicates that while flow-normalized TP loads appear to be increasing since 2013, the flow-normalized SRP loads have declined since peaking in 2012. Subsequent analyses through 2025 confirm these trends. The decrease in SRP is encouraging as this form of phosphorus is highly available to algae and increases in SRP loading have been tied to the resurgence of HABs. However, SRP remains nearly two times higher than the minimum in 1989.



Flow-Normalized (blue lines) and Actual (black points) Phosphorus Loads in the Maumee River. Source: EPA.

HABS AND HYPOXIA



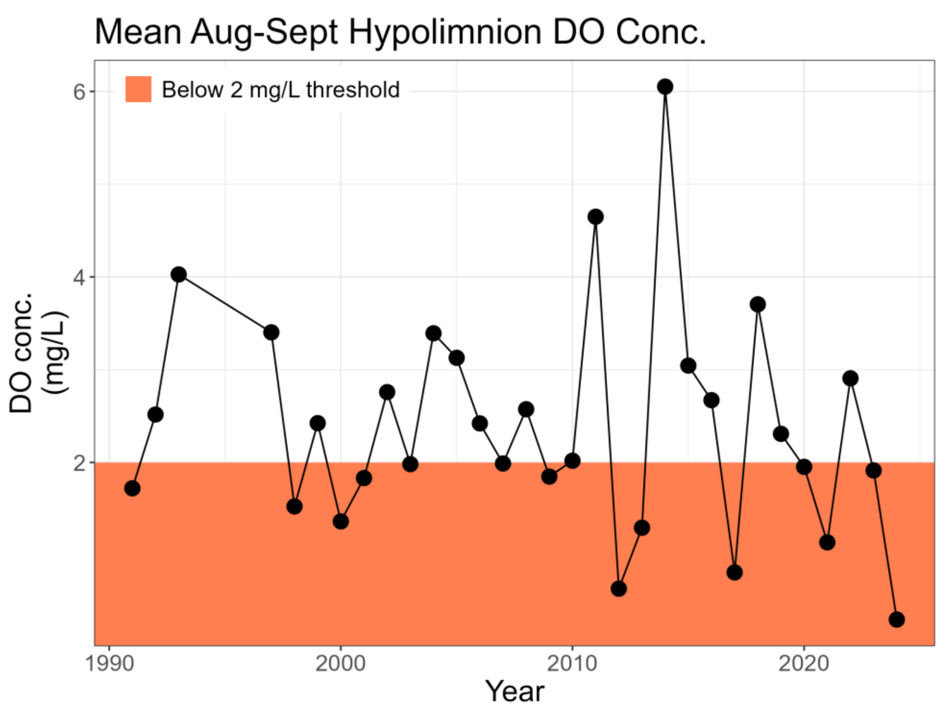
Lake Erie Bloom Severity Index, 2000-2025. Source: NOAA.

The U.S. and Canada rely on NOAA's National Centers for Coastal Ocean Science HAB Monitoring Program to forecast and track HABs over the growing season each year. The bloom severity is expressed on a scale of 1 to 10 based on measurements of cyanobacteria biomass using remote sensing validated with water samples taken in the field. The desired threshold is not to exceed 2.9 on the Lake Erie Severity Index (SI). An SI above 5 is considered a "severe" bloom, while blooms over 7 are "very severe."

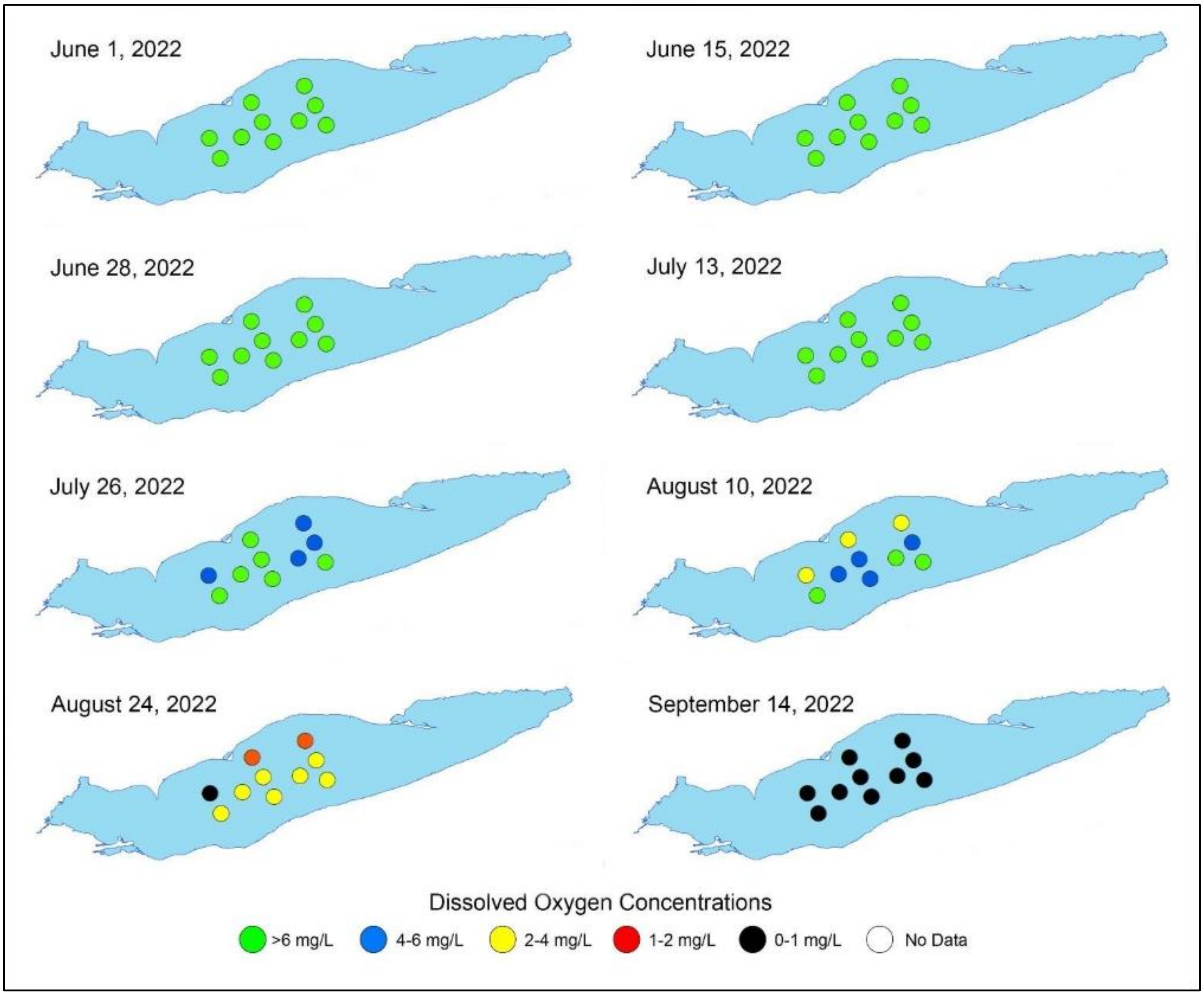
Overall, there is high interannual variability in the severity of the bloom. The largest blooms to date have occurred in 2011 and 2015. Blooms from 2020-2025 were generally perceived as less intense with fewer "scum" events as compared to the 2010s. From 2020 to 2025, harmful algal blooms mild to moderate in severity, compared with the numerous severe or very severe blooms recorded between 2013 and 2019. Much of the annual variability we see in harmful algal bloom extent and severity is driven by changing phosphorus loads influenced by precipitation and runoff, as well as other factors such as temperature and winds. For example, the mild to moderate severity of blooms from 2020 to 2025 are in part attributed to relatively lower streamflow discharge and corresponding lower phosphorus loads from the Maumee River.

The lake ecosystem objective for hypoxia is an average dissolved oxygen concentration of at least 2 mg/L in the bottom waters during the summer stratification season. Long term monitoring by EPA GLNPO indicates that this objective is rarely met. Between 2011 and 2024, EPA's measurements show the objective to remain above 2 mg/L was achieved in seven of 14 years.

These findings are largely expected at this early stage of expanded phosphorus reduction efforts and considering the influence of recent discharge amounts and patterns. Continued blooms should not be interpreted as a lack of progress, because an observable response in water quality will require significant and sustained reductions in phosphorus loads. Phosphorus remains the primary and most manageable driver of HABs and hypoxia in Lake Erie. A challenge moving forward will be to reduce and maintain phosphorus loads during periods of more frequent and intense storms.



Mean August-September hypolimnion dissolved oxygen concentrations in the central basin of Lake Erie. Source: EPA.



Dissolved oxygen (DO) concentrations in Lake Erie's Central Basin observed during the 2022 field surveys. Source: EPA.

PROGRESS ON THE GROUND

It will take time for work on the ground to show a water quality response. Improvements to water quality are the ultimate goal and the true measure of success. We are also tracking other intermediate indicators of progress so that we can adjust management programs in real time. The programs and projects described above have significantly reduced the amount of phosphorus entering the waterways from both agricultural and municipal sources to date. Adoption of conservation practices and voluntary nutrient management plans is high in the WLEB watershed. Trends in fertilizer use are showing positive signs: in Ohio, use of commercial fertilizer use is declining while crop yields steadily increase. The mass balance indicates that since 2003, P removal through crop harvest has exceeded applied nutrients, and soil test P levels are declining. Reductions in P use are being attributed to increased farmer knowledge, technical assistance programs, and economic returns to farmers (LaBarge, 2023). These are important indicators that implementation actions are on the right track.

SOURCE REDUCTIONS

By simply tallying the P load reductions being reported by the state and federal programs, one would anticipate that phosphorus sources have been reduced by over 2.5 million lbs since 2015. If implementation of the nonpoint source programs were to continue to increase at the current pace, coupled with the additional wastewater reductions anticipated from Michigan, one would expect an additional 1 million lbs will be reduced by 2030.

Note these are anticipated results based on modeling and several assumptions. One major assumption is that structural or engineered conservation practices are maintained, and changes to cropland and nutrient management, such as timing and application of fertilizer, continue in subsequent years. Load reductions from nonpoint sources are modeled at the edge of field scale, for long term average conditions. Actual BMP performance can be site specific, and P losses tend to be highly dependent on storm events. Also, there are many interacting in-stream dynamics that impact load deliveries between sources upstream and Lake Erie. This makes it difficult to compare source reductions to the 7.3 million lbs/yr reduction goal for what is ultimately delivered to the lake.

Despite these sources of uncertainty, this exercise provides a useful barometer to put the programmatic accomplishments into context. The estimates are intended to illustrate what may be possible from the federal and state actions, what more will be needed outside of government efforts, and how long it may take to reach P reduction goals.

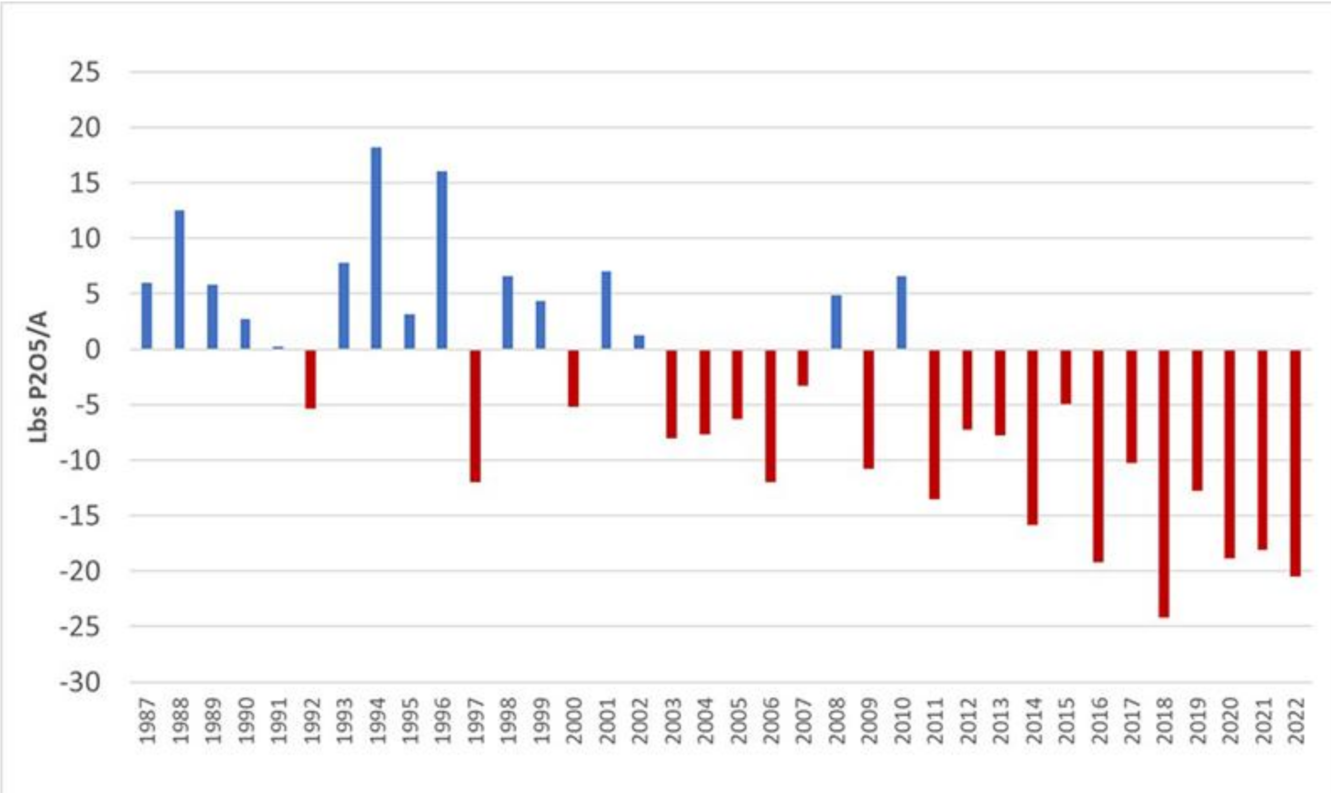
TRENDS IN FERTILIZER USE

Only a fraction of the fertilizers applied to the landscape make its way into Lake Erie. Most of the nutrients in fertilizer applied is taken up by crops, some remains in the soil, and a small fraction is lost via surface runoff or subsurface drainage. Nutrient mass balance is determined by taking the fertilizer and manure applied and subtracting the calculated value of P removed in the harvested grain and biomass.

Ohio State University researchers (LaBarge, 2023) have analyzed data from USDA's National Agriculture Statistics Service, Nutrient Use Geographic Information System, and Ohio Department of Agriculture Fertilizer Tonnage data to summarize phosphorus use in Ohio, with a focus on soil test trends, fertilizer sources, and P nutrient balances. These data show a declining rate of commercial fertilizer use in the state, while corn yields have steadily increased. Corn yields increased from around 100 bushels per acre in 1987 to about 200 bushels per acre in 2022. Through improved nutrient stewardship, farms have increased yields with less added phosphorus.

In the WLEB counties specifically, commercial fertilizer use data shows a 48% decline in this region when compared to the most recent five years (2018–2022). At the same time, animal unit numbers and the corresponding amount of manure they produce have increased. Trendlines indicate manure excreted has risen from about 5,000 tons in 1987 to 8,000 in 2023. Overall, the mass balance indicates that since 2003, P removal through crop harvest has exceeded applied nutrients, resulting in a net annual removal of 11 pounds of P per acre.

A negative mass balance trend would result in lower soil test phosphorus (STP) values over time. Evidence that this is occurring can be found in previous studies that found 65% of Ohio counties had decreasing trends in mean STP levels between 1993 and 2015 (LaBarge, 2023). While soil test phosphorus is an important indicator of effective nutrient management, targeted upland (e.g., nutrient management) and edge-of-field (e.g., P removal structures) conservation practices are needed across the broad spectrum of STP concentrations to meet loading goals (Byers et al., 2025).



Balance of P2O5 applied from commercial fertilizer and manure after subtracting crop removal (1987–2022). Graphic by Greg LaBarge. Source: Ohio State University.

LEVEL OF ADOPTION OF CONSERVATION PRACTICES

The USDA Natural Resources Conservation Service began accelerating conservation planning and farmers began adopting more conservation practices around 2013, first with the Great Lakes Restoration Initiative and later with significant added resources under the NRCS WLEB Initiative in 2016 and on. Following that, since its inception in 2019, the H2Ohio program has achieved impressive results with outreach and enrollment with agricultural producers. Ohio reports that 35% of the cropland in the WLEB has enrolled in the H2Ohio program, with 1.85 million acres enrolled to complete Voluntary Nutrient Management Plans (a key tool to identify specific on-field practices) and 2.2 million acres enrolled in overwintering cover, manure incorporation and placement practices.

The Ohio Agriculture Conservation Initiative (OACI) has conducted a series of statistical surveys across the state to determine what practices Ohio farmers are implementing for water quality and nutrient management. In 2025, the OACI conducted a randomized sampling of 464 crop production fields within the WLEB to determine what practices were used by farmers in the crop year 2024. The report confirms that adoption of conservation practices and nutrient management in the WLEB is high. According to the assessment, 68% of surveyed fields are enrolled in cost-share conservation programs, including 62% in H2Ohio. In addition:

- 97% of fields are soil-tested at the recommended frequency of every 3-4 years;

- 85% were soil-tested using grid or zone sampling methods to better capture spatial variability;
- 51% of fields surveyed had phosphorus applied using variable-rate technology (VRT); and
- Nearly 64% of the fields were either no-tilled or minimally tilled.

OACI will continue to assess more watersheds in Ohio and revisit previously assessed watersheds to determine levels of change. View their Watershed Assessment Reports for additional information.

AREAS OF RISK

There are many challenges and issues that pose risks to the success of our nutrient management strategy. The primary ones we are watching closely are:

- Variability of precipitation and storms
- Legacy phosphorus
- Increasing livestock population
- Bloom toxicity and duration
- Nitrogen contributions

Partners are taking actions to actively monitor and respond to these risks. These highlighted risks, and others as they arise, will continue to be monitored so that management strategies for nutrient control can be adjusted if needed.

VARIABILITY OF PRECIPITATION AND STORMS

Most of the phosphorus that feeds the blooms each summer is delivered through a handful of storm events during the spring months. An analysis over 4 decades from 1975-2017 showed that both total and heavy rainfall events increased across the Maumee River Basin, with the largest increase occurring during the spring (Williams and King, 2020).

Increasing rainfall and, as a result, discharge pose a substantial risk to Lake Erie as phosphorus loads from the Maumee River are often proportional to water flux. Increasing rainfall amount and intensity may not only affect discharge and load, but also SRP concentration due to an increased number of days with high flows and potentially greater probability of overland flow.

Since 2020, Lake Erie has benefitted from lower discharge volumes from the Maumee River and relatively smaller blooms. Responding and adapting to this variability in wet and dry conditions is becoming increasingly difficult. This emphasizes the need for innovative and flexible ways to manage agricultural tile drainage.

Research and extension efforts, notably the Transforming Drainage project, have significantly expanded the tools and resources available for farmers in the Midwest. Demonstration projects like the OSU Lima Campus Drainage Water Recycling Project are garnering attention as they show potential of these systems to significantly reduce phosphorus losses while increasing yields for farmers. According to OSU, farmers in Northwest Ohio can expect a 19% higher corn yield and a 12% higher soy yield in dry years with the help of drainage water recycling and irrigation.

LEGACY PHOSPHORUS

It is well understood that there is a lag time between adoption of nonpoint source management controls and the detection of measurable improvement in water quality. The magnitude of lag time is highly site and pollutant specific – it can range from months to years for relatively short-lived contaminants such as bacteria, years to decades for excessive P levels in agricultural soils, and decades or more for sediment accumulated in river systems (Meals et al., 2010).

There is a tremendous amount of “legacy” phosphorus already in the system, bound to sediments in the soils and the streambeds, and on the lake bottom, that will need time to work its way through the system (Simpson et al., 2025). The impact of legacy phosphorus is a dynamic and complex process that could significantly delay when the benefits of upstream source reductions are apparent. Add to this, the fact that farmers trying new practices often need to maintain them for several years before they see improvements to the soil and measurable declines in runoff. It can take decades with no fertilizer application to draw down elevated nutrient levels in soil (Zhang et al., 2004, Sharpley et al., 2013). To prevent trade-offs in phosphorus losses, it is important to couple drawdown practices with good soil conservation practices (Mott et al., 2025).

This will continue to be a challenge and is one of the reasons why our management strategy is not focused solely on source reduction but also on controlling the transport, timing and delivery of phosphorus runoff. The only way to reduce legacy loads is to: 1) Decrease the amount replenishing the hydrologic system at the upper end by reducing edge-of-field losses (Osterholz et al., 2024) and, 2) Remediate its impact through passive restoration or other mechanisms to bind the in-stream legacy P so it doesn’t remobilize (Field et al., 2023). How phosphorus transforms as it is transported through ditches and streams is an area of active research (Casillas-Ituarte et. al, 2020).

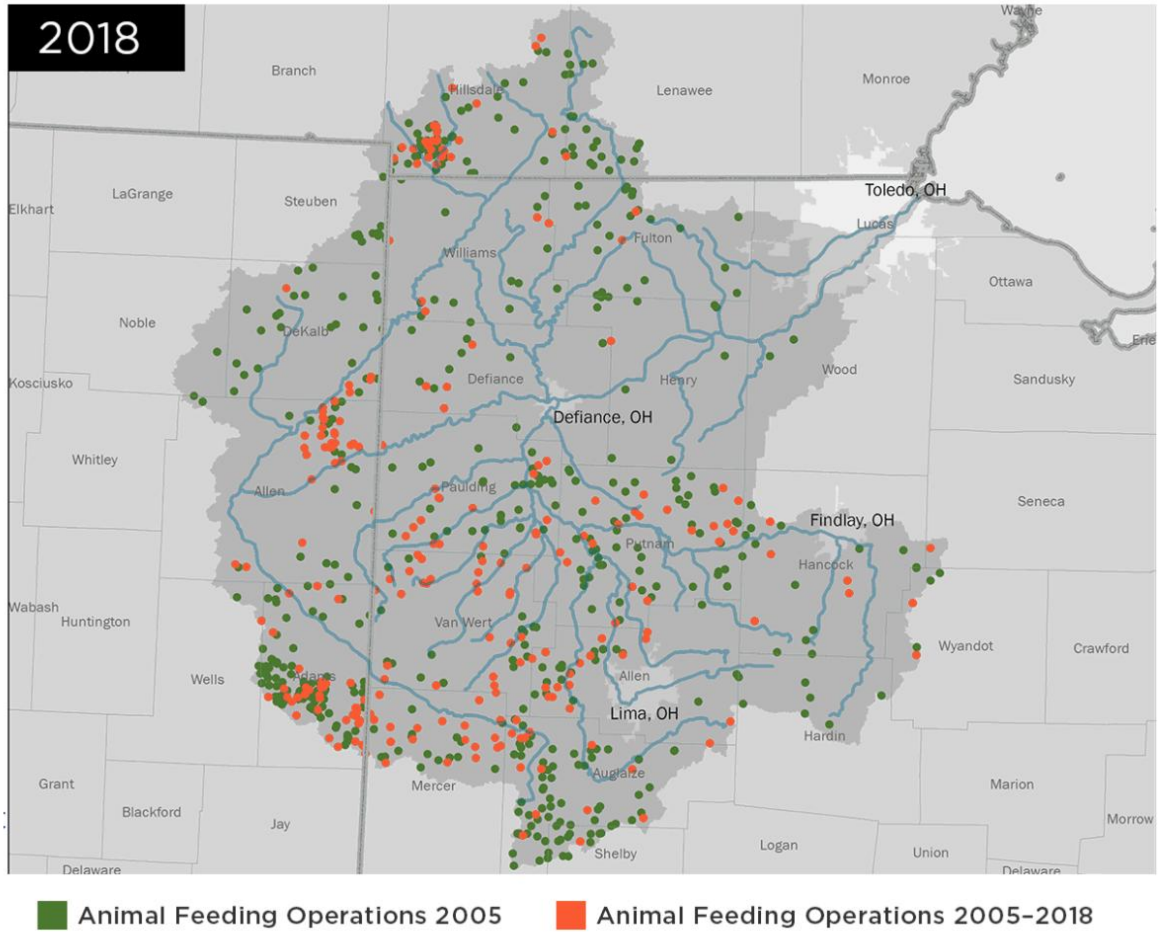
INCREASING LIVESTOCK POPULATION

Expansion of livestock operations in the WLEB is a concern because additional manure introduced to the watershed could serve to offset phosphorus reductions from other sources. As explained earlier (see Trends in Fertilizer Use above), in Ohio the purchase of commercial fertilizer has been trending down since the highest use period in the early to mid-1990s (OSU Factsheet). At the same time, the amount of available manure in NW Ohio has increased. Presumably, there is less need for commercial fertilizer when more manure is available. This is consistent with OSU’s assessment that overall, the P mass balance is declining, as are P levels in soil. It is important to keep an eye on this trend and continue to collect information to ensure that the introduction of more livestock to the watershed will not be detrimental to P reduction efforts.

It is also important to understand where increasing concentrations of livestock pose a risk because of their location relative to the amount of nearby cropland land available to apply it. A new USDA-produced tool can help with analyzing placement options for manure nutrients. A limitation in some regions of the WLEB is the transport of liquid manure from livestock farms to fields needing P.

The amount of manure that is land applied and the amount of nutrients in that land-applied manure can be variable and is difficult to quantify. Part of that challenge is that there is no available data on how much of stored manure is land applied annually. Ohio’s Department of Livestock Environmental Permitting tracks this information for the largest livestock facilities, but facilities that fall under the threshold are not part of that reporting process. While there are rules in place governing manure management plans and manure handlers, the lack of available data on land application of manure from unpermitted facilities is a known data gap.

Ohio law restricts the surface application of manure and fertilizers in the WLEB under certain soil and weather conditions (OSU Factsheet), and has robust voluntary programs that complement these regulations (see Ohio Update). Ohio’s Fertilizer Applicator Certification program has increased education on fertilizer use, and a growing number of facilities are participating in the 4R Stewardship program. The number of cropland acres enrolled in voluntary nutrient management planning through H2Ohio also continues to grow. ODA and OSU Extension continue to expand outreach to farmers through training and technical assistance, and ODA has targeted funding for specific projects focused on expanding the use of manure instead of commercial fertilizer where it is available. OEPA is piloting soil amendments and manure treatment technologies that have potential to further prevent P losses from manure.



Expansion of Animal Feeding Operations 2005-2018. Source: Ohio Environmental Council.

BLOOM TOXICITY AND DURATION

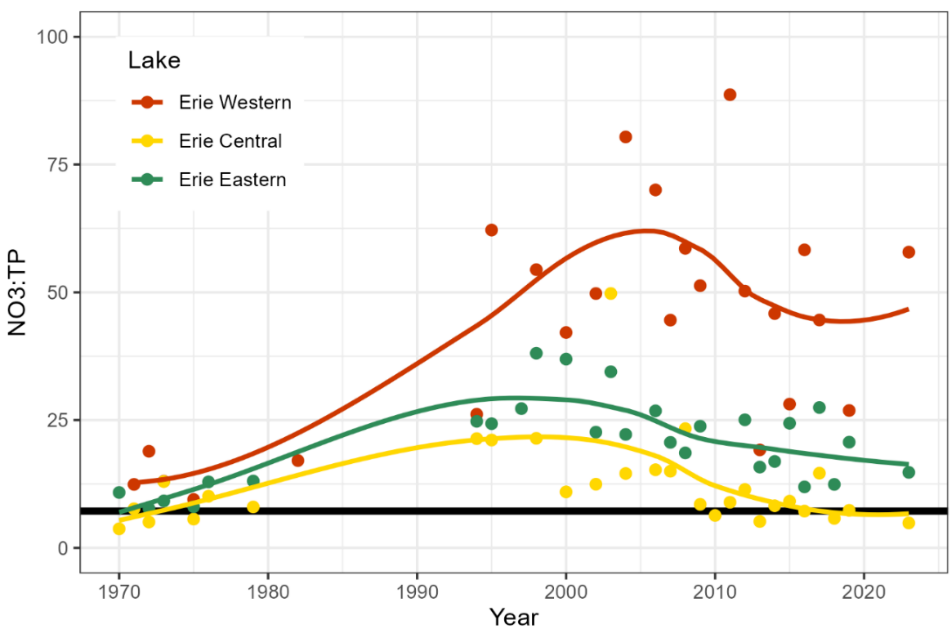
Multiple studies published after large blooms in the early-mid 2010s indicated bloom severity was increasing in western Lake Erie (Michalak et al., 2013, Ho et al., 2017, Sayers et al., 2019). However, a more recent study covering 2002–2022 found no significant trend in bloom extent (Bosse et al., 2024). While this suggests that bloom size has stabilized, or at least has not increased in recent years, recurring blooms are still a concern and subject to other changes that could impact human and ecosystem health. Even if anticipated P load reductions lead to smaller blooms, toxicity will likely remain an issue for areas within the bloom. The commonly used 30-day, basin-wide, peak biomass index may also miss important bloom aspects. A recent study (Maquire et al., 2024) documented location-specific differences in the start, peak, and end of bloom biomass and toxicity, and satellite remote sensing has also been used to map areas with frequent bloom conditions (Wynne and Stumpf, 2015). Recent years have seen blooms with early starts, long durations at peak biomass, and persisting late into fall (NOAA HAB Assessments 2022, 2023, and 2024).

NOAA's Great Lakes Environmental Research Laboratory, in concert with academic, agency, and private sector partners, has been actively monitoring HABs and hypoxia in Lake Erie and refining real time forecasting systems, using the latest technologies available. One of the most recent developments is the ability to predict the risk that a bloom is toxic (see NOAA Update for more explanation). Continued monitoring and research will be critical to detecting changes to bloom dynamics and toxicity and identifying the drivers of these changes.

NITROGEN CONTRIBUTIONS

As noted previously, the U.S.-Canada nutrient reduction strategy for Lake Erie remains focused on phosphorus reduction and assumes that management actions to reduce phosphorus will also reduce nitrogen. Nutrient management efforts have traditionally focused on controlling a single limiting nutrient (i.e., N or P) based on a paradigm that assumes primary production is N-limited in marine waters and P-limited in freshwaters (Wurtsbaugh et al., 2019). Conceptually, the assumption is that if the key limiting nutrient is controlled, primary production is limited and the cascading effects of eutrophication do not occur. In practice, however, this may be an overly simplistic model for management of nutrient pollution (see EPA's factsheet on scientific support for dual nutrient criteria).

It is important to monitor nitrogen contributions, and our strategy may need to be more refined in the future considering how nitrogen impacts the types of algal species present and the toxicity of algal blooms. There is scientific evidence that certain harmful algal taxa thrive, and are even potentially more toxic, in conditions where N is disproportionately available relative to P. For this reason, EPA and partners track nitrogen loads and concentrations in addition to phosphorus and evaluate both nutrients as part of the Adaptive Management Framework. EPA's long term in-lake monitoring programs measure TP, SRP, ammonia, nitrates and nitrites, silica, and total Kjeldahl nitrogen. The U.S. and Canada track multiple nutrient indicators including nitrogen-phosphorus ratios as part of the State of the Great Lakes Report, issued every three years under GLWQA.



Trends of open lake, spring ratios of median NO3:TP for the western (red line), central (yellow), and eastern (green line) basins of Lake Erie. The Redfield ratio of 7.2 mg N/mg P (black line) is superimposed as an estimate of the level above which lakes would tend to be phosphorus limited (Dove and Chapra, 2015). Phosphorus limitation is beneficial because nitrogen limitation would favor potentially toxic cyanobacteria. The western basin of Lake Erie remains strongly phosphorus limited in recent years. Source: EPA and ECCC.

As of the 2017–2021 AM Evaluation report, flow normalized loads for different forms of nitrogen in the Maumee River had been steady or declined over the past 10–20 years (Appendix 7.2.4), and "declines in flow-normalized SRP and nitrogen loads suggest that some progress is being made in the Maumee watershed." Updated analyses with data through water year 2025 indicate the decline in flow-normalized SRP loading has continued since 2021, though it appears flow-normalized nitrate/nitrite and total Kjeldahl nitrogen loading have increased in recent years. EPA and partners will continue monitoring and tracking nitrogen loading in addition to phosphorus.

CONCLUSIONS

This 2025 Milestone Report demonstrates that significant progress is being made but we still have a long way to go to meet water quality goals for Lake Erie. The current efforts to better manage nutrient runoff must continue to grow and be sustained over the long term to reduce HABs and hypoxia.

Significant work across the basin is curbing nutrient losses, and there are some indications of water quality improvement – specifically, the blooms of 2020-2024 were mild in comparison to the 2010s; and phosphorus loads from the Maumee River and Detroit Rivers have been lower in recent years. However, discharge remains the strongest driver of tributary nutrient loading, and a single wet year or a few intense storms could deliver high loads and disrupt the downward trend we're seeing now.

The rate of adoption of key management practices on agricultural lands such as nutrient management, drainage water management, and soil health initiatives has increased substantially over the past decade. Optimization of wastewater treatment has significantly reduced phosphorus loads to the Detroit River, and more opportunities exist to improve municipal stormwater management in the WLEB. Additionally, increased monitoring, application of new technology, and systematic approaches to evaluation have improved our ability to gauge progress and informed our decision making.

Federal and state partners believe that the comprehensive and adaptive approach laid out in the 2018 U.S. Action Plan and the individual state DAPs will continue progress towards the 40% reduction goals in the WLEB. It will take time to address the many challenges associated with meeting the nutrient reduction goals and subsequently reduce phosphorus loads to a level that water quality improvements will become apparent.

Agricultural nonpoint source pollution is a complex and difficult problem to address, and progress can be slow because of factors such as lag time and legacy sources. Stakeholder engagement in the WLEB watershed is high, and numerous federal, state and local leaders are demonstrating their commitment to action. However, many of the actions being taken to reduce P rely on discretionary funding and voluntary, incentive-based programs that lack regulatory drivers or enforcement measures. Government resources must be coordinated and targeted to be most effective.

Over the past decade, federal and state agencies have supplied over $400 million in financial assistance to accelerate adoption of conservation practices. Farmers in the WLEB have worked with USDA NRCS assistance to implement nearly 13,000 conservation practices since 2013, reducing phosphorus losses at edge-of-field by more than 4.3 million pounds. Ohio Department of Agriculture's H2Ohio program launched in 2019 has enrolled 1.85 million acres under nutrient management plans. If maintained, this would indicate that about half of the cropland in the watershed is enrolled in a federal or state conservation program, which is an outstanding adoption level. However, there is a limit to how many farmers are able or willing to participate in these types of programs.

A 2023 report by the Ohio Environmental Council and the Alliance for the Great Lakes found that Michigan and Ohio would need to both increase adoption of conservation practices and increase spending on those practices by $40-65 million and $170-250 million annually, respectively, to meet water quality objectives in the western basin of Lake Erie. The report states that meeting the 40% phosphorus reduction goal is possible but will require significant, sustained additional funding, along with major increases in voluntary adoption outside of government financing. There is a sizeable gap between current spending and the projected funding needed to achieve the reduction targets.

The current and ongoing efforts to limit excess phosphorus loading to the lake—through municipal sewage treatment, managing stormwater, and implementing best management practices on agricultural lands—must continue and be accelerated. Advancing toward a 40% reduction will require that best management practices be appropriately placed in the landscape, adequately funded, and promoted through multiple policy mechanisms and incentives. Given the dynamic nature of the ecosystem and evolving economic and social drivers, the path to success is not linear and our management approach will have to adapt in response to many factors.

Federal, state and local leaders must continue to work in partnership to be successful in affecting change over such a large region. The accomplishments to date would not be possible without the broad support and engagement among multiple levels of government and numerous stakeholders – municipalities, local government, private industry, academia, and citizens. Success will require active participation and continued diligence among all stakeholders.

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