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Harmful Algal Blooms in Western Lake Erie

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Background on harmful algal blooms (HABs) in Western Lake Erie

Lake Erie is the smallest and shallowest of the five Great Lakes, and it is divided into three parts, including the shallow western basin, the flatter central basin, and the deep eastern basin. The delineation of the watershed draining to the western basin differs among studies; here, I consider the tributaries that directly empty into the western basin, stretching from the River Raisin to the Maumee River (Figure 1). These lands that drain directly into the western basin are mostly agricultural, with corn and soybeans as dominant crops. They include major urban centers such as Toledo, Ohio; Monroe, Michigan; and Fort Wayne, Indiana. Rainfall and snowmelt carry nutrients like phosphorus and nitrogen from farm fields and cities into Lake Erie through these rivers (Reutter, 2019). These nutrients are considered nonpoint source pollution, meaning we cannot pinpoint precisely where the pollution comes from. While nutrients are essential for aquatic life, too much of them lead to excessive algae growth.

Algal blooms occur when algae grow rapidly and form thick, green scums on the water's surface. Some types of algae, especially cyanobacteria (commonly called blue-green algae), can release harmful toxins known as cyanotoxins. These toxins can harm fish and other aquatic animals and may cause liver, neurological, and respiratory problems in humans and other animals (Weigle, 2020; Michalak et al., 2013). Toxic algal blooms are also referred to as harmful algal blooms (HABs).

Protecting the health of Lake Erie requires keeping nutrients on the land and out of the water. Reducing nutrient runoff from

farms and cities not only helps control HABs but also supports clean, safe, and sustainable water for communities and ecosystems across the Great Lakes region for now and future generations.

History of water quality in Western Lake Erie

Concerns about water quality in Lake Erie date back to the 1960s, when the lake was so polluted it was often described as "dead" (Sweeney, 1993). During that time, large amounts of phosphorus, a nutrient that fuels algae growth, were washing into the lake from farms, cities, and wastewater plants. These nutrient loadings led to serious environmental problems, including HABs in the western basin and low oxygen levels (hypoxia) in the central basin (Johnson et al., 2024; Scavia et al., 2014). In response, the United States and Canada entered into the Great Lakes Water Quality Agreement in 1972, focusing on reducing phosphorus pollution from point sources, places where the source of pollution can be easily identified, such as municipal wastewater treatment facilities. These efforts brought significant improvements, and Lake Erie's water quality recovered through the 1980s.

However, over time, nonpoint source pollution, including phosphorus and other nutrients, washed off farm fields and urban landscapes by rain and snowmelt, and became the leading cause of nutrient enrichment in the lake. The Great Lakes Water Quality Agreement was later updated in 2012 to address this growing challenge. Despite these efforts, HABs continue to persist, especially in Western Lake Erie during spring and summer, which have been visible from space (Figure 1). The most notable event occurred in 2014, when a severe HAB near Toledo, Ohio, produced toxins that contaminated the city's drinking water supply. For three days, nearly 500,000 residents were left without safe tap water.

This history highlights both the progress made and the ongoing challenges of protecting water quality in Western Lake Erie. Continued collaboration between farmers, communities, and policymakers will play an important role in addressing these challenges and keep the lake healthy for people, wildlife, and future generations.

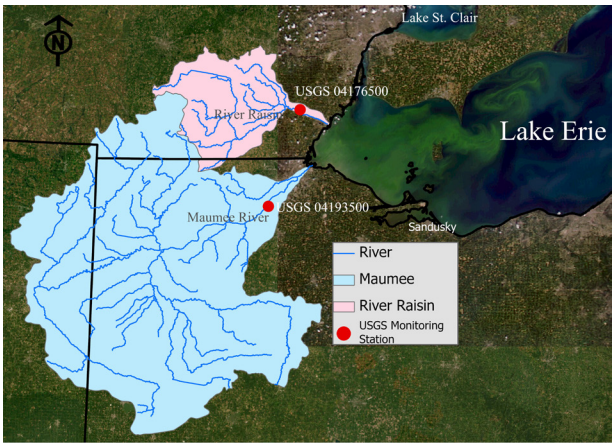


Figure 1. Satellite image (Source: NOAA) showing a large harmful algal bloom (HAB) in Western Lake Erie on September 3, 2011. The Maumee River and the River Raisin, two major rivers that drain into this portion of the lake, as well as USGS streamflow and water quality monitoring stations, are also shown.

Need for water quality analysis

Freshwater supports nearly every aspect of life. We rely on it for drinking, cooking, cleaning, and growing our food, and it provides critical habitat for fish and other aquatic life. The total amount of freshwater on Earth is limited, while demand continues to rise due to population growth, industrial development, and agricultural production. As these pressures increase, regularly testing and

monitoring water quality help determine whether water remains safe for people and the environment. Water quality analysis helps determine whether physical, chemical, and biological characteristics of water fall within safe limits for human use. When water quality declines, it can lead to serious health risks. For example, children developed muscular rash, fever, headache, vomiting, diarrhea following swimming, and other recreational activities in the cyanobacteria HAB affected water of the Maumee River and Maumee Bay (French et al., 2023).

Testing and monitoring water quality also help identify early warning signs of contamination and the spread of waterborne diseases. By tracking changes in water quality over time, scientists and communities can detect trends, assess risks, and take corrective actions to protect public health and ensure sustainability of water resources. To that end, high frequency and long-term monitoring plays a crucial role telling us what is happening right now as well as how water quality changes over time. For example, heavy rainfall or rapid snow melt can quickly wash sediment, nutrients into waterways, causing sudden decline in water quality. Similarly, slow changes in land use, including the gradual conversion of forest to agricultural land or urban areas, may lead to long-term quality issues. Therefore, monitoring water quality in a river is crucial during a storm event to capture what is happening right now as well as changes over time.

Water quality trends in Western Lake Erie

We analyzed water quality data from the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory to understand recent trends in HABs in Western Lake Erie. The study focused on chlorophyll-a levels, a key indicator of algae growth, at three monitoring stations: WE8 (near the mouth of the River Raisin) and WE9 and WE6 (both near the mouth of the Maumee River) (Figure 2). Chlorophyll-a is a natural pigment found in algae. Higher concentrations of chlorophyll-a indicate more algae in the water. When levels exceed 30 micrograms per liter (µg/L), it generally signals the presence of an algal bloom (Brehob et al., 2024; Michalak et al., 2013; USEPA, 2000).

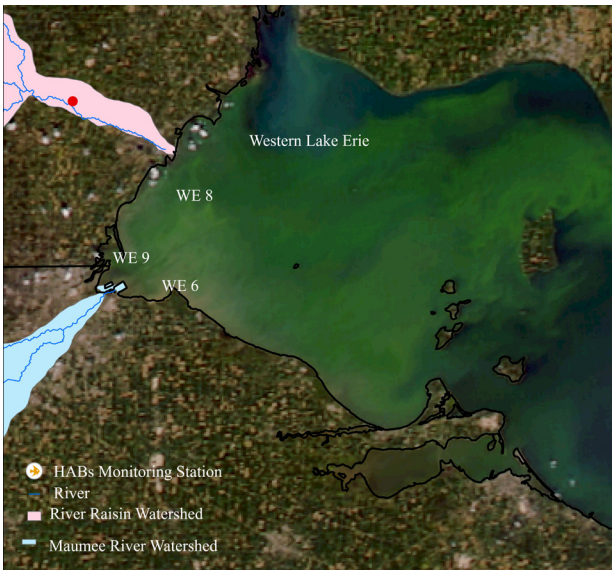
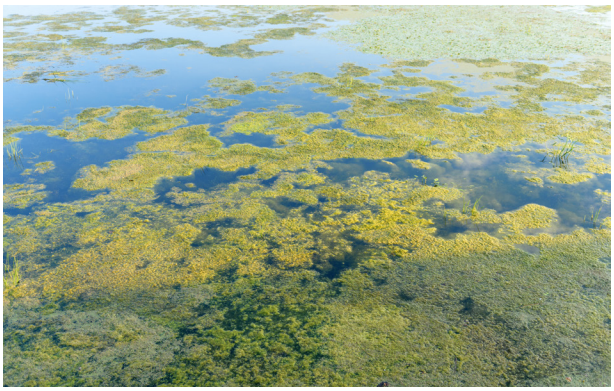


Figure 2. HABs monitoring stations in Western Lake Erie close to mouth of River Raisin and Maumee River.



(Photo credit: iStock Borislav)

Our analysis shows that chlorophyll-a concentrations at all three stations frequently rise above this threshold, suggesting persistent and widespread algal blooms in Western Lake Erie (Figures 3–5). One notable exception occurred in 2018, when bloom activity was relatively mild. This was likely due to a drier summer, which reduced storm runoff from surrounding farmland (DAP, 2025). With less runoff, fewer nutrients, especially phosphorus, were carried into the lake from the River Raisin and Maumee River.

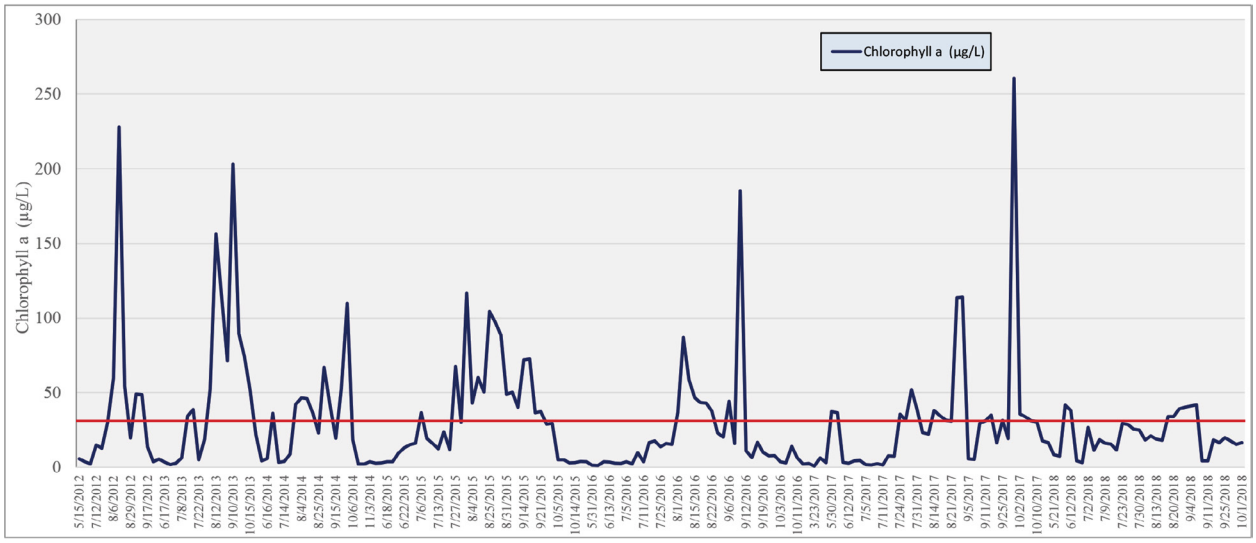


Figure 3. Chlorophyll-a levels at the WE8 monitoring station (see Figure 2), located near the mouth of the River Raisin where it flows into Lake Erie. The red line marks the threshold of 30 µg/L—the level above which algae growth is likely to become excessive and lead to harmful algal bloom.

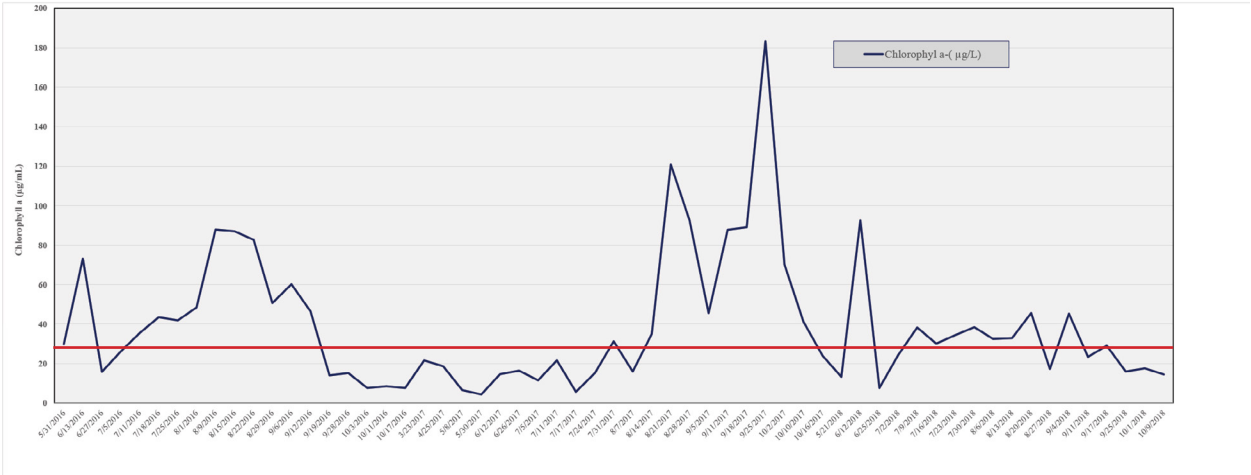


Figure 4. Chlorophyll-a levels at the WE9 monitoring station (see Figure 2), located near the mouth of the Maumee River where it flows into Lake Erie. The red line marks the threshold of 30 µg/L—the level above which algae growth is likely to become excessive and lead to harmful algal bloom.

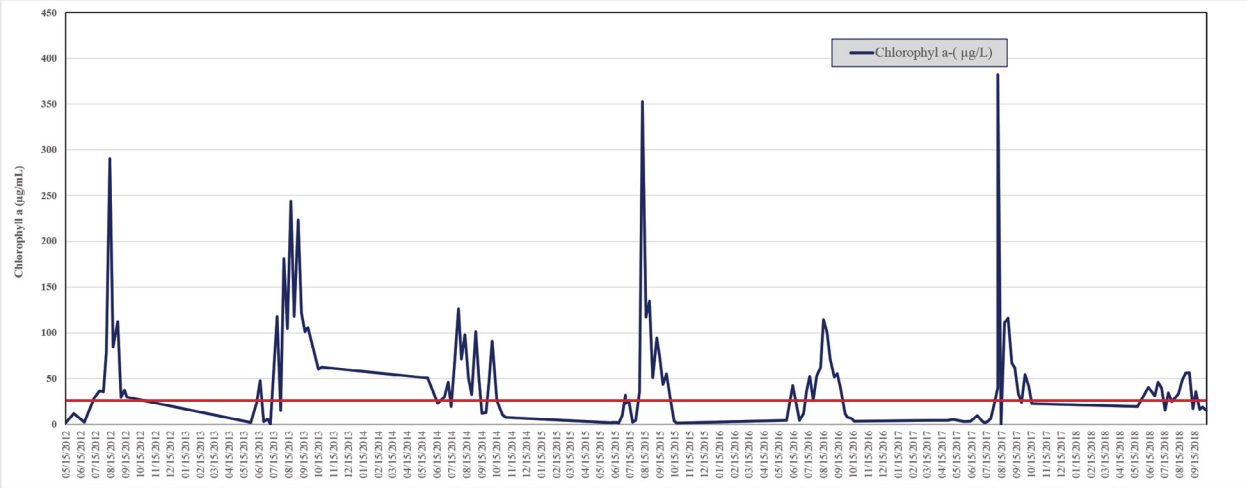


Figure 5. Chlorophyll-a levels at the WE6 monitoring station (see Figure 2), located near the mouth of the Maumee River where it flows into Lake Erie. The red line marks the threshold of 30 µg/L—the level above which algae growth is likely to become excessive and lead to harmful algal bloom.

Analyzing the two primary tributaries to Western Lake Erie

The River Raisin and Maumee River are the two major tributaries that flow into Western Lake Erie, carrying water and nutrients from large surrounding watersheds. A watershed is an area of land where all rainfall and snowmelt eventually drain into a common river, lake, or stream.

The River Raisin watershed covers just over 1,000 square miles, spanning six counties in southeastern Michigan and a small portion of northwest Ohio before entering Lake Erie near Monroe, Michigan. Most of the land is agricultural, with corn and soybeans as the dominant crops. The watershed also includes urban areas such as Adrian, Tecumseh, and Monroe, along with forests, wetlands, and riparian buffers that help filter runoff and support wildlife.

The Maumee River watershed is the largest in the Great Lakes region, covering about 6,600 square miles across Indiana, Ohio, and Michigan before entering Lake Erie at Toledo, Ohio. Like the River Raisin Watershed, the Maumee River Watershed is dominated by row-crop agriculture, primarily corn and soybeans, along with urban centers, forests, and wetlands.

Both watersheds rely heavily on subsurface tile drainage systems, which help remove excess water from poorly drained soils and improve crop productivity. However, these same systems can also speed up the movement of dissolved phosphorus from farm fields into rivers and eventually into Lake Erie. The added phosphorus can fuel HABs in the Western Lake Erie, contributing to water quality degradation that affects ecosystems, communities, and recreation throughout the region.

Extreme precipitation events on nutrient transport into Western Lake Erie

To assess how extreme precipitation events influence nutrient transport, we calculated the frequency of such events in both the River Raisin and Maumee River watersheds. We analyzed long-term precipitation records from NOAA weather stations, identifying four stations in or near the River Raisin Watershed and

15 stations in or near the Maumee River Watershed (Figure 6) with continuous data from 1980 to 2019. The period from 1980 to 1999 was used as a baseline and compared with the period 2000 to 2019. Extreme precipitation events were identified using the 95th percentile threshold method (Alexander et al., 2006), a widely used approach for detecting unusually high rainfall.

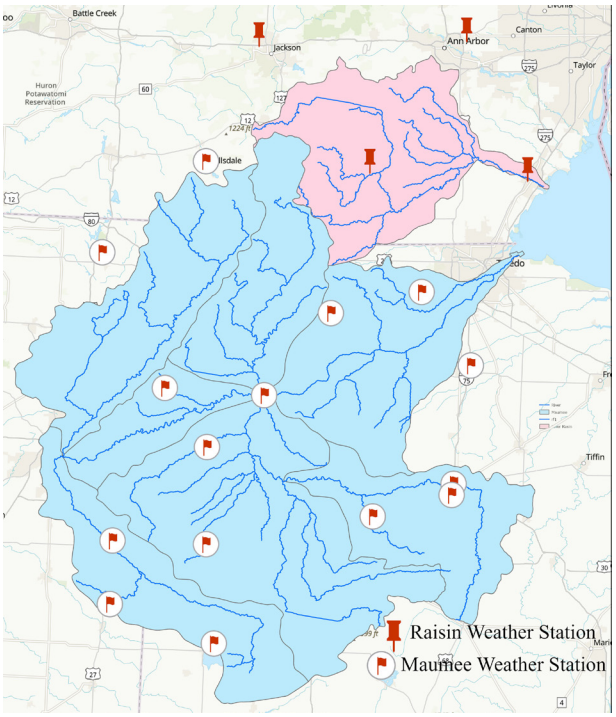


Figure 6. Locations of weather stations with long-term data records (1980–2019) within the River Raisin and Maumee River Watersheds.

Maumee River Watershed: Figure 7 shows the increase in seasonal rainfall over recent decades in the Maumee River Watershed, with the largest rise occurring in winter (18%), followed by spring (12%), fall (4%), and summer (3%). Using rainfall data from 1980–1999 as the baseline, the 95th percentile threshold for extreme precipitation was determined to be 0.58 inches. During the baseline period, 354 extreme rainfall events were recorded, compared with 396 events from 2000 to 2019 (Figure 8), representing a 12% increase in extreme precipitation events in the Maumee River Watershed. If this upward trend in extreme rainfall continues, it would be expected to accelerate nutrient transport from agricultural fields to the Maumee River, ultimately reaching Western Lake Erie and contributing to the development of HABs.

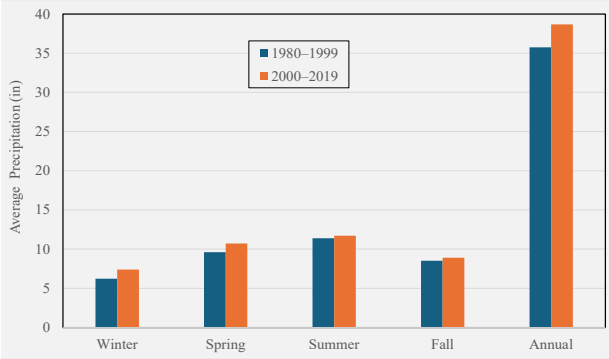


Figure 7. Comparison of seasonal and annual precipitation totals for 1980–1999 and 2000–2019 in the Maumee River Watershed.

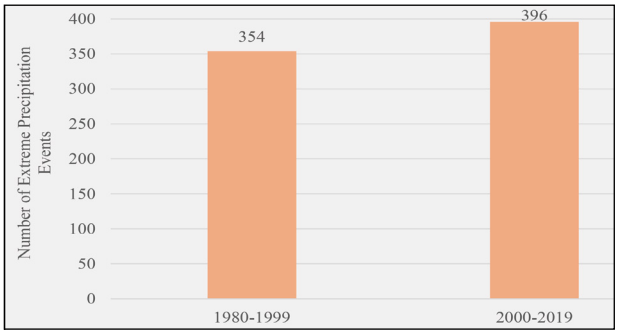


Figure 8. Comparison of number of extreme precipitation events (over 0.58 inches) for 1980–1999 and 2000–2019 in the Maumee River Watershed.

River Raisin Watershed: Figure 9 highlights changes in seasonal and annual rainfall across the River Raisin Watershed. Spring rainfall increased the most (13%), followed by winter (6%) and summer (1%). Fall rainfall decreased by 6%. Overall, annual rainfall rose by 3%, which can increase the transport of sediment and nutrients from agricultural and urban areas

into the river system and eventually into Western Lake Erie, where they can fuel HABs. Using rainfall data from 1980–1999 as the baseline, the 95th percentile threshold for extreme precipitation was determined to be 0.56 inches. Extreme rainfall events became slightly more frequent: 357 events occurred during 1980–1999 compared with 370 events from 2000–2019 (Figure 10), representing a 4% increase.

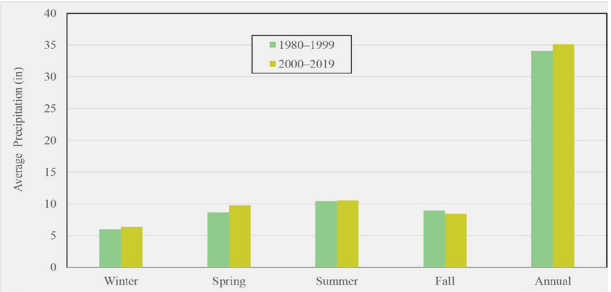


Figure 9. Comparison of seasonal and annual precipitation totals for 1980–1999 and 2000–2019 in the River Raisin Watershed.

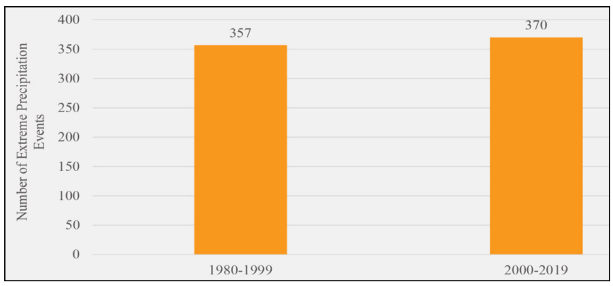


Figure 10. Comparison of number of extreme precipitation events (0.56 inches) for 1980–1999 and 2000–2019 in the River Raisin Watershed.

Streamflow and phosphorus transport into Western Lake Erie

***Maumee River Watershed*:** Rainfall in the Maumee River Watershed has increased in recent decades. Between 2000 and 2018, the watershed received more annual rainfall than during 1981–1999 (Figure 7), which caused higher average streamflow in the rivers and streams (Figure 11). The streamflow and water quality data for Maumee River and River Raisin were obtained from the United States Geological Survey (USGS) monitoring stations located closer to Western Lake Erie (Figure 1). Higher flows move more water across the landscape, carrying nutrients from farm fields, lawns, and urban areas into the river. As a result, total phosphorus (TP) level has increased in the Maumee River (Figure 12). TP is the combination of dissolved phosphorus (P) and phosphorus attached to particles like soils and organic matters, all of which can be transported during high flow conditions.

The impact is most pronounced during the winter and spring, when rainfall and snowmelt are highest. During these seasons soil stores more moisture before a rainfall event known as antecedent soil moisture, plays an important role not only generating runoff but also washing up nutrients from the soil, making the soil more vulnerable. One form of phosphorus is of particular concern: dissolved P. This form of phosphorus is immediately available for plants and algae. Dissolved P loads increased by roughly 50% annually between 2000–2018 compared with 1981–1999 (Figure 13). This increased dissolved P is partly due to increased streamflow. This extra phosphorus fuels the growth of HABs in Western Lake Erie, which can affect drinking water, recreation, and aquatic ecosystems.

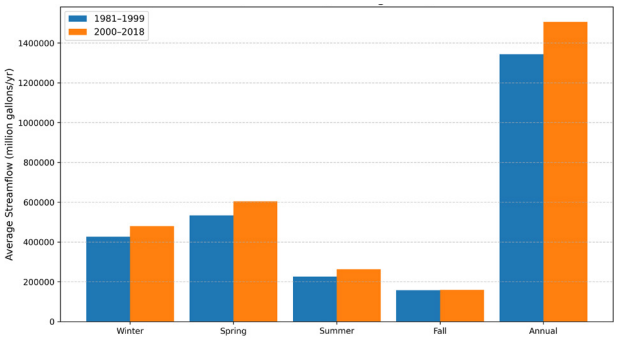


Figure 11. Comparison of average streamflow for 1981–1999 and 2000–2018 in the Maumee River at USGS 04193500 (Waterville, Ohio).

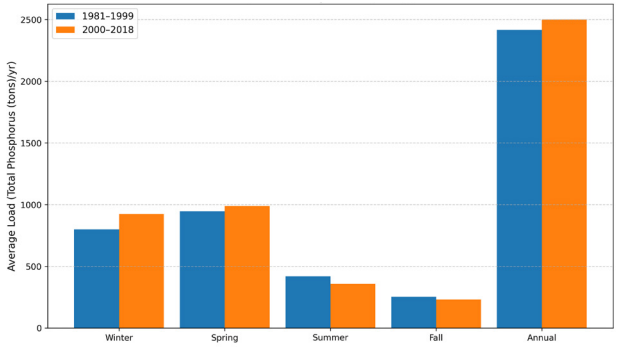


Figure 12. Comparison of average total phosphorus load for 1981–1999 and 2000–2018 in the Maumee River at USGS 04193500 (Waterville, Ohio).

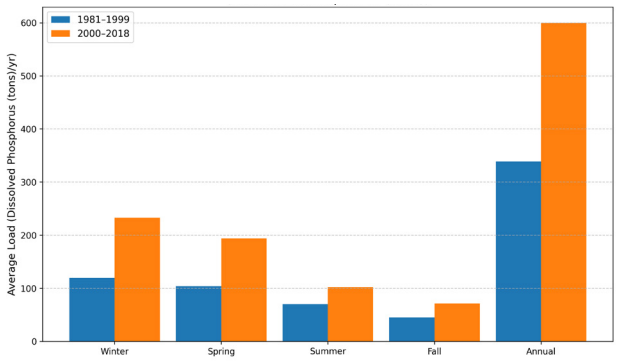


Figure 13. Comparison of average dissolved phosphorus load for 1981–1999 and 2000–2018 in the Maumee River at USGS 04193500 (Waterville, Ohio).

***River Raisin Watershed**:* Rainfall patterns in the River Raisin Watershed have shifted in recent years, with the region receiving more precipitation than in past decades. This increase in rainfall has led to higher streamflow throughout the watershed (Figure 14), especially during the spring and summer months when storms are more frequent. Higher flows generally have the potential to carry more nutrients and sediment into rivers, but the River Raisin tells a more complex story.

Despite the upward trend in streamflow, TP loads in the River Raisin have actually decreased compared with the 1981–1999 period (Figure 15). This improvement is largely linked to reductions in point-source pollution, especially upgrades to wastewater treatment facilities and tighter discharge regulations as well as reduction of soil erosion from agricultural farms (DAP, 2012). These investments have significantly lowered the amount of phosphorus released directly into the river.

However, not all forms of phosphorus are following the same pattern. Dissolved P, the form most readily taken up by algae, has increased by more than 40% annually in recent years (Figure 16). Even though TP is declining, the rise in dissolved P is still contributing to HABs in Western Lake Erie. Dissolved P is highly mobile, moves easily with runoff during storm events, and originate from recent applications as well as “legacy” phosphorus stored in soils, which may take decades to change.

These trends show that while progress has been made in reducing point-source pollution, nonpoint source phosphorus—particularly dissolved P—remains a challenge. Continued efforts in conservation practices, nutrient management, and soil health are essential to further reduce runoff and safeguard Western Lake Erie’s water quality.

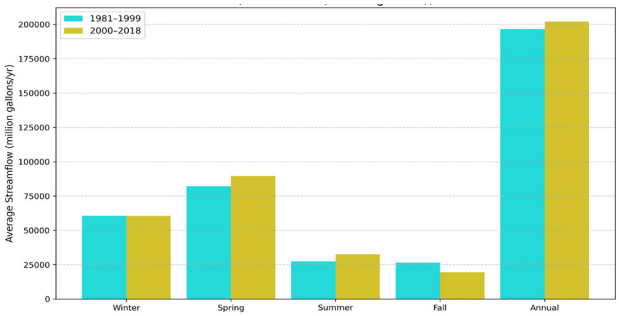


Figure 14. Comparison of average streamflow for 1981–1999 and 2000–2018 in the River Raisin at USGS 04176500 (Monroe, Michigan).

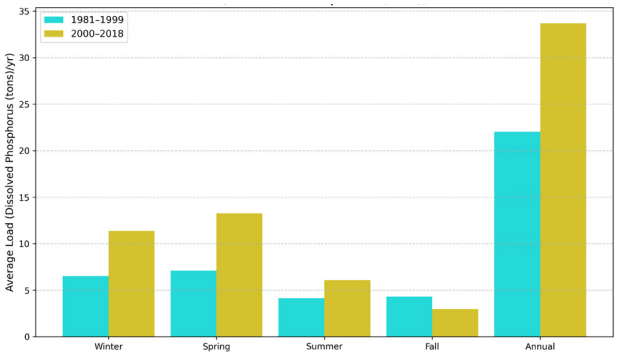


Figure 16. Comparison of average dissolved phosphorus load for 1981–1999 and 2000–2018 in the River Raisin at USGS 04176500 (Monroe, Michigan).

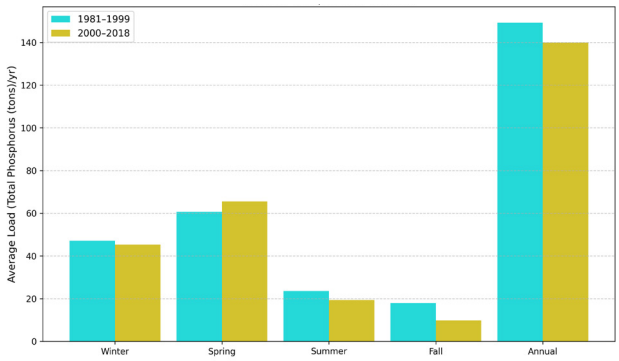


Figure 15. Comparison of average total phosphorus load for 1981–1999 and 2000–2018 in the River Raisin at USGS 04176500 (Monroe, Michigan).

(Photo credit: iStock Dmitrii Bykanov)

Land use land cover

Land use strongly influences water quality in rivers, streams, and lakes. In agricultural regions, such as the Maumee River and River Raisin Watersheds, land use directly influences the amount of sediment and nutrients that make their way into Western Lake Erie.

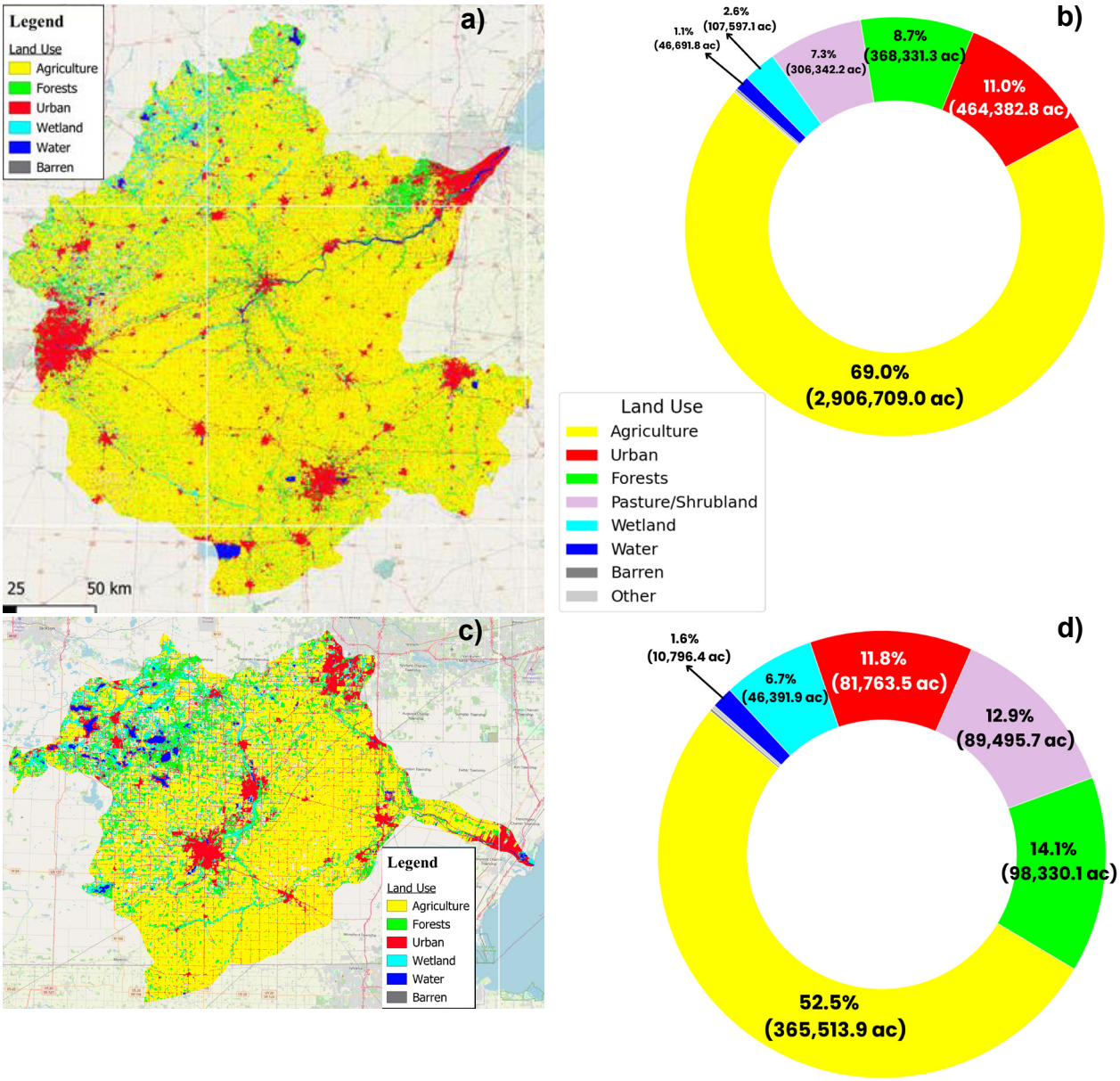


Figure 17. Land use distribution in the Maumee River Watershed and the River Raisin Watershed: a) Spatial land use map for the Maumee River Watershed; b) Land use composition shown as a pie chart for the Maumee River Watershed; c) Spatial land use map for the River Raisin Watershed; d) Land use composition shown as a pie chart for the River Raisin Watershed.

Maumee River Watershed:

The Maumee River Watershed is heavily dominated by agricultural land, which covers nearly 70% of the total watershed area (Figure 17a–b). Most of these acres are planted with row crops, particularly corn and soybeans, which require regular application of fertilizer and manure to maintain high yield. Often times manure is applied in amounts that exceed crop needs. The unused nutrients, especially phosphorus, remain in the soil and can be washed into nearby drainage ditches, streams, and ultimately the Maumee River. From there, they continue downstream into Western Lake Erie, where they contribute to HABs.

Another important factor is the extensive use of subsurface (tile) drainage systems throughout the watershed. These systems are designed to remove excess water from poorly drained soils, improving field conditions and supporting higher crop yields. Tile drains also provide a direct pathway for dissolved nutrients—particularly dissolved P and nitrate—to move quickly from fields into waterways. Because dissolved P is readily available for algal growth, the rapid transport of this form of phosphorus plays a significant role in fueling HAB development. However, several mitigation practices, including nutrient management, saturated buffers, control drainage, cover crops, reduced tillage, and diverse crop rotation, can be incorporated to trap nutrients during storm events and improve water quality.

River Raisin Watershed:

A similar pattern exists in the River Raisin Watershed (Figure 17c–d). Agriculture remains the dominant land use, covering about 53% of the watershed, with most production focused on corn and soybeans. Forested lands make up roughly 14% of the watershed, primarily in the western region, while urban areas account for about 12%. Like the Maumee, much of the agricultural land in the River Raisin is also equipped with subsurface tile drainage systems to improve field conditions. These drainage networks enhance crop production, but they also accelerate the movement of dissolved P and nitrates into the River Raisin, ultimately contributing to nutrient loads entering Western Lake Erie.

Overall, the extensive row-crop agriculture, reliance on fertilizer and manure inputs, and widespread tile drainage systems create conditions that favor nutrient transport. Understanding these land use patterns is essential for identifying effective management practices that can reduce nutrient losses and help improve water quality in Western Lake Erie.

Conclusions

HABs have continued to affect Western Lake Erie in recent years, with 2018 being a notable exception due to a dry summer that produced less runoff from agricultural lands. Long-term climate patterns show that precipitation has increased in both the Maumee River and River Raisin Watersheds during 2000–2019 compared to the 1980–1999 period. This increase is especially strong during the winter and spring seasons, when soils are more vulnerable to runoff. The number of extreme precipitation events has also risen, adding to the challenge.

Higher precipitation has led to increased streamflow in both rivers. However, trends in TP loads differ between the two

watersheds. The Maumee River shows an overall increase in TP loading, while the River Raisin has experienced a decline. The reduction in the River Raisin is likely linked to improvements in wastewater treatment plants, resulting in lower point-source phosphorus discharges, as well as a possible reduction in soil erosion.

Despite these differences in TP trends, both watersheds show a substantial rise in dissolved P loads in recent years. Dissolved P increases were most pronounced during winter and spring seasons that also saw the greatest increase in rainfall. Because dissolved P is the form of phosphorus most readily used by algae, these trends continue to drive HAB development in Western Lake Erie. Land use analysis further shows that agriculture is the dominant land use in both watersheds, contributing nonpoint source phosphorus loads to the rivers and ultimately to Western Lake Erie.

Several actions may be taken to improve water quality and reduce HABs in Lake Erie:

1. Evaluate conservation practices in combination to understand how stacked practices perform across different landscapes and climate conditions.
2. Promote strategies that integrate soil health, water quality, and crop productivity, ensuring solutions work for both farmers and the environment.
3. Strengthen outreach and education, making sure new and existing knowledge reaches farmers, landowners, and local communities.

Improvements in water quality take time. There is often a delay between implementing conservation practices and noticing measurable reductions in nutrient loads. Continued collaboration, long-term commitment, and adaptive management will be needed to protect Western Lake Erie into the future. To support this effort, the Michigan Department of Agriculture and Rural Development (MDARD), working in partnership with Michigan Environment, Great Lakes, and Energy, and Department of Natural Resources, is developing Michigan's Lake Erie Domestic Action Plan and supporting new initiatives to accelerate conservation planning and implementation across Michigan portion of the watersheds.

(Credit: Image generated by ChatGPT)

Expert Reviewed

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