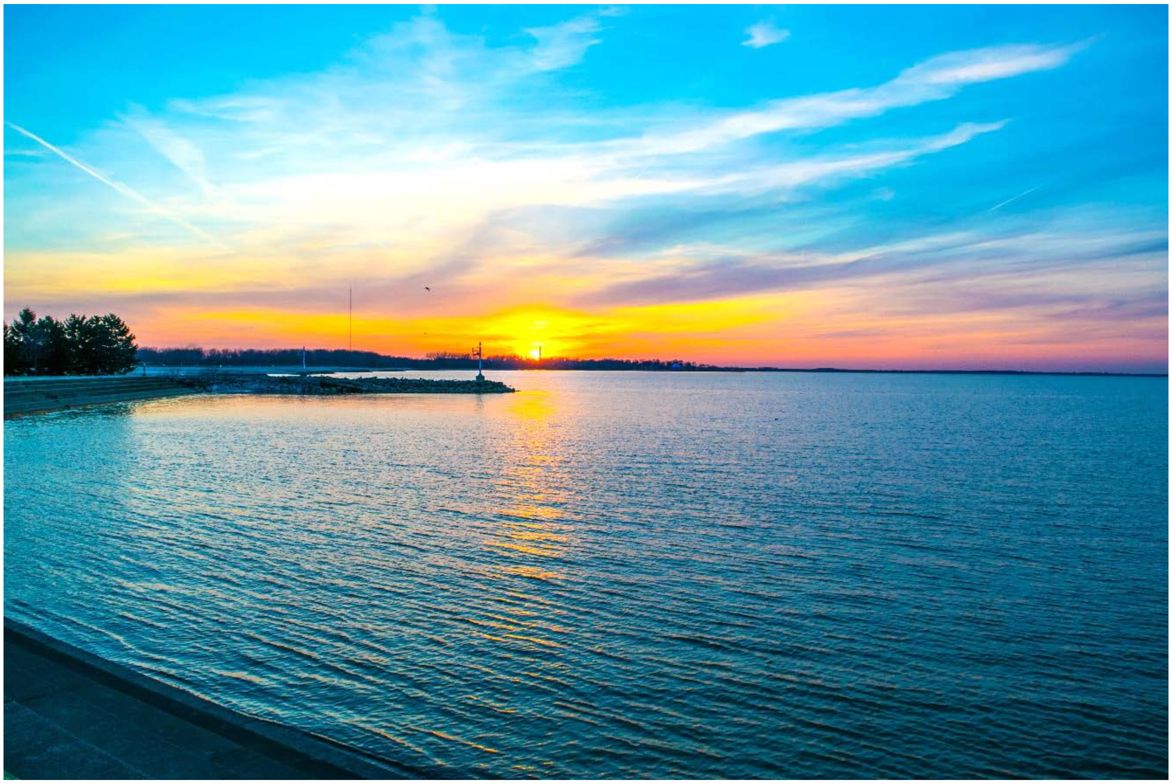
Ohio Environmental
Protection Agency

Maumee Watershed Nutrient

Total Maximum Daily Load



Ohio EPA Technical Report AMS/2020-MWN-5

Division of Surface Water

Assessment and Modeling Section

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TMDL Development | ●●●●●

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Acronyms

AOC – Area of Concern

AFG – allowance for future growth

ARS – Agricultural Research Service

BMP – best management practice

CAFF – concentrated animal feeding facility

CAFO – concentrated animal feeding operation

CDP – census-designated places

CEAP – Conservation Effects Assessment Project

CLM – certified livestock manager

CSA – critical source areas

CSO – combined sewer overflows

DAP – Domestic Action Plan

DLEP – Division of Livestock Environmental Permitting

DRP – dissolved reactive phosphorus

DSWC – Division of Soil and Water Conservation

ECBP – Eastern Corn Belt Plains

EWG – Environmental Working Group

FWMC – flow-weighted mean concentration

GIS – geographic information system

GLRI – Great Lakes Restoration Initiative

GLWQA – Great Lakes Water Quality Agreement

HAB – harmful algal bloom

HABRI – Harmful Algal Bloom Research Initiative

HB – House Bill

HELP – Huron – Erie Lake Plains

HSTS – home sewage treatment systems

HUC – hydrologic unit code

ICIS – Integrated Compliance Information System

IJC – International Joint Commission

LA – load allocation

MAP – monoammonium phosphate

MOS – margin of safety

MPCA – Minnesota Pollution Control Agency

MS4 – municipal separate storm sewer system

MSGP – Multi-Sector General Permit

NCWQR – National Center for Water Quality Research

NLCD – National Land Cover Database

NOAA – National Oceanic and Atmospheric Administration

NPDES – National Pollutant Discharge Elimination System

NPS – nonpoint source

NPS-IS – Nonpoint Source Pollution Implementation Strategy

NRCS – Natural Resources Conservation Service

NSE – Nash Sutcliffe Efficiency

OAC – Ohio Administrative Code

ODA – Ohio Department of Agriculture

ODH – Ohio Department of Health

ODNR – Ohio Department of Natural Resources

OLEC – Ohio Lake Erie Commission

ORC – Ohio Revised Code

OSU – Ohio State University

P – phosphorus

PMR – Preliminary Modeling Results

RCPP – Regional Conservation Partnership Program

SB – Senate Bill

SPARROW – SPAtially Referenced Regressions on Watershed attributes

SSO – sanitary sewer overflow

SWAT – Soil and Water Assessment Tool

SWCD – soil and water conservation district

TMACOG – Toledo Metropolitan Area Council of Governments

TMDL – total maximum daily load

TP – Total Phosphorus

USDA – United States Department of Agriculture

U.S. EPA – United States Environmental Protection Agency

USGS – United States Geological Survey

WLA – wasteload allocation

WLEB – Western Lake Erie Basin (the watersheds draining to the Western Basin of Lake Erie, this includes the Maumee watershed and others)

WQS – water quality standard

WWRF – water resource recovery facility

WWTP – wastewater treatment plant

Units of Measure

°C – degrees Celsius

°F – degrees Fahrenheit

µg/L – micrograms per liter

ft – feet

kg – kilogram

L – liter

lb – pound

m – meters

mg – milligram

MG – million gallons

MGD – million gallons per day

mi^2 – square miles

mm – millimeters

MT – metric ton

ppm – part per million

Executive Summary

The Clean Water Act and U.S. Environmental Protection Agency (U.S. EPA) regulations require that states develop total maximum daily loads (TMDLs) for waters that the states list as impaired on their section 303(d) lists. A TMDL is a water quality restoration planning process that involves several steps, including watershed characterization, target identification, source assessment, allocation of loads, and development of an implementation plan.

The Maumee Watershed Nutrient Total Maximum Daily Load (TMDL) Project has the goal to remove impairments to drinking water, aquatic life, and recreational uses in Ohio's western Lake Erie assessment units due to harmful algal blooms (HABs). To achieve this goal, this project focuses on planning reductions to the phosphorus load delivered from the Maumee watershed. The Maumee watershed extends into the neighboring states of Michigan and Indiana. Ohio's delegated Clean Water Act authority does not extend to sources in these states. Therefore, allocations do not include sources in these states; rather, a boundary condition load is set that can be used by those states in their water quality planning processes. Figure ES-1 shows Ohio's impaired Lake Erie Assessment Units and the Maumee watershed.

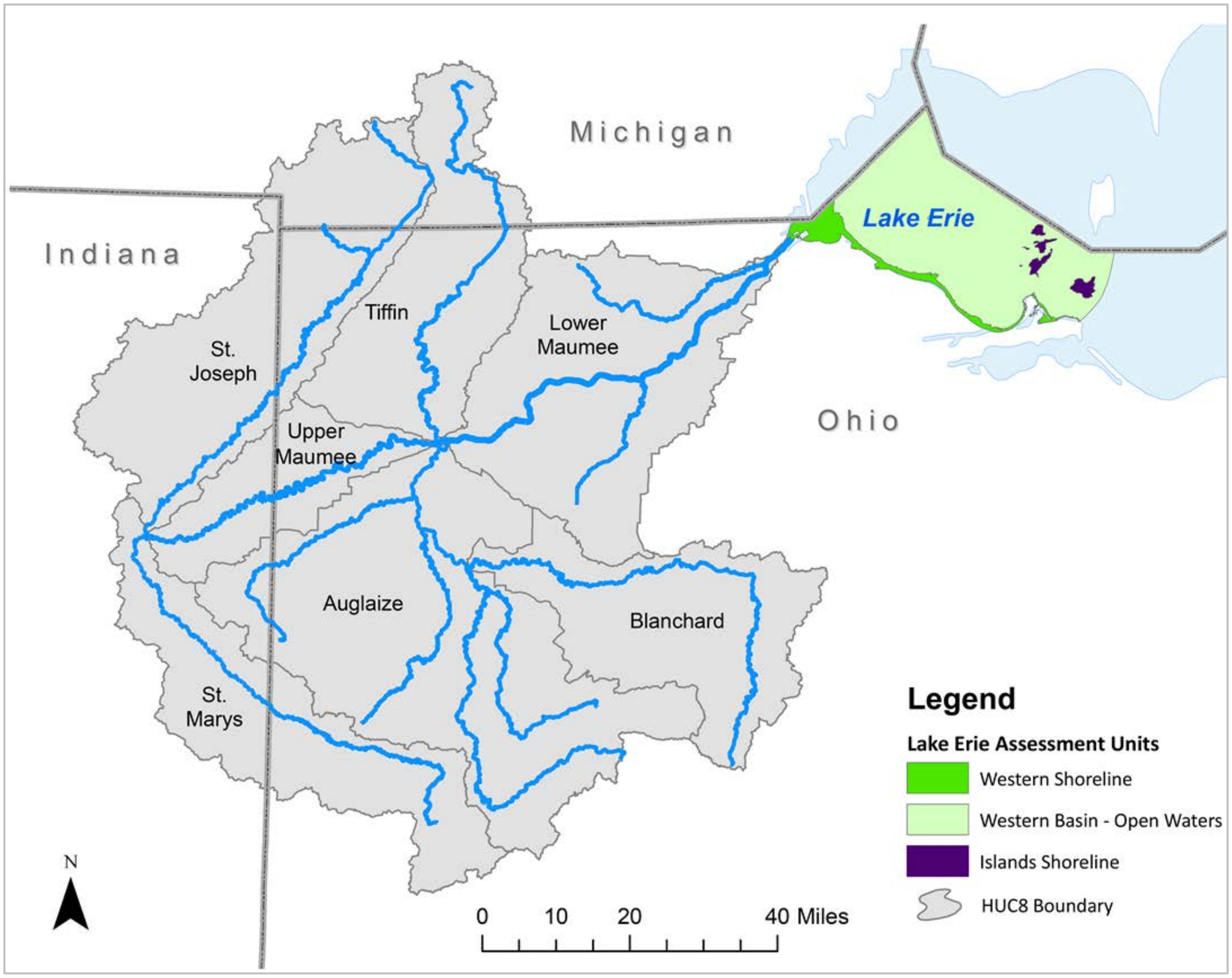


Figure ES-1. Map of Ohio's western Lake Erie assessment units and the Maumee Watershed.

Ohio EPA developed this TMDL report to have all the components required in Ohio Revised Code 6111.562 and Ohio Administrative Code 3745-2-12, in addition to the elements required by the Clean Water Act identified in the following guidance from U.S. EPA: epa.gov/sites/default/files/2015-10/documents/2002_06_04_tmdl_guidance_final52002.pdf.

This TMDL identifies the pollutant loads of phosphorus necessary to attain and maintain applicable water quality standards in the Lake Erie assessment units, specifically criteria of the recreational, public drinking water and aquatic life designated uses. The TMDL uses phosphorus reduction targets are based on the Great Lakes Water Quality Agreement's Annex 4 load reduction recommendations to achieve desired Lake Erie ecosystem objectives regarding impacts from HABs. This TMDL's allocations are enumerated for the total phosphorus parameter. The Annex 4 recommendations also specifically call for the dissolved reactive portion of total phosphorus to be reduced. Dissolved reactive phosphorus is part of the total phosphorus load. To address this, this portion of the total phosphorus is specifically considered throughout the report.

The TMDL report contains a comprehensive review of the sources of phosphorus in both the particulate and dissolved forms. This includes all point and nonpoint sources. Ohio EPA regulates point sources, and contributions are discussed relative to the agency's permitting programs. Nonpoint sources are diffuse in nature and have been the focus of much research in the Maumee watershed. An extensive review of research and analyses of available water quality data was completed to consider how the following factors affect nonpoint source phosphorus loads:

- Agricultural fertilizers, both commercial and manure
- Agricultural soil and legacy sources
- Unpermitted stormwater sources from developed areas
- Ditch and streamside sources
- Natural sources and atmospheric deposition
- Impacts from changes in hydrology

The TMDL employs a mass balance method to allocate phosphorus loads to different sources. This data-driven approach leverages the wealth of monitoring from the National Center for Water Quality Research at Heidelberg University's long-term monitoring station in Waterville, Ohio. This reduces calculation uncertainty because it is directly tied to this robust measurement of load.

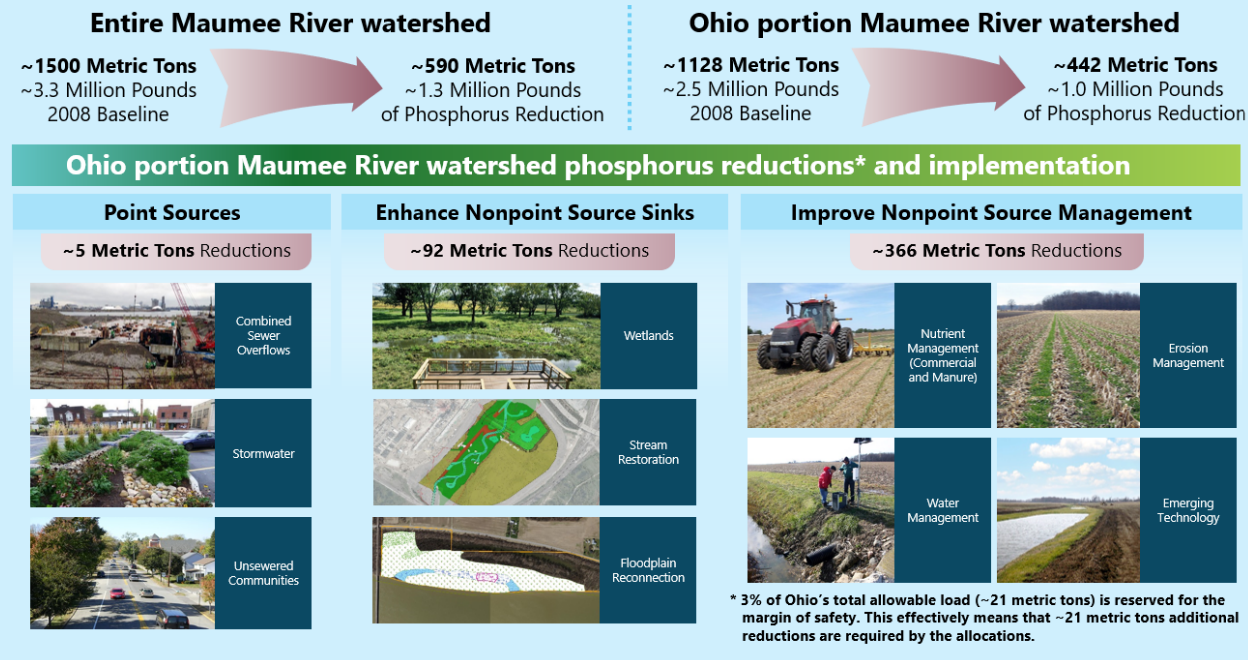
The TMDL allocates loads to different sources that will achieve needed load reductions to meet water quality standards. To do this, Ohio EPA considers the relative contribution of each source, the available technology for managing load reductions, the cost of implementing technology, and more. With these considerations in mind, the TMDL's allocations reflect the fact that nonpoint sources contribute the majority of the existing phosphorus load from the Maumee watershed. Nonpoint sources are captured in the load allocation in Table ES1. These allocations reflect an overall load reduction of approximately 40 percent from the 2008 baseline total phosphorus load. An additional 3 percent of the load is reserved for a margin of safety.

Most point source load is from the largest treatment facilities in the Maumee watershed. These facilities already use phosphorus-removal technologies, and achieving further reductions would involve expensive capital upgrades. These capital upgrades do not present a cost-effective action to reduce phosphorus. However, opportunities for point source reductions exist through ongoing efforts to continue reducing the discharge of combined sewer overflows and additional management of stormwater. The wasteload allocation on Table ES1 denotes the combined permitted source load allowed in this TMDL.

Table ES1. Allocations to meet the TMDL for the Maumee watershed to address western basin of Lake Erie impairments.

Allocation type	Spring season total phosphorus (metric tons)	Daily total phosphorus (kilograms)
Boundary condition: Michigan	180.7	1,180.9
Boundary condition: Indiana	48.0	313.6
Wasteload allocation	109.3	714.6
Load allocation	555.9	3,633.2
Explicit margin of safety (3%)	20.6	134.5
TOTAL	914.4	5,976.8

Nonpoint sources represent the largest portion of the load. Nonpoint sources can be managed through source-control efforts and by enhancing natural infrastructure (e.g., wetlands and floodplains) to trap and treat phosphorus. Figure ES2 shows how load will be achieved for point and nonpoint sources through implementation efforts. The trap and treat aspects of nonpoint source reductions are described as enhancing nonpoint source sinks on this figure.



* 3% of Ohio's total allowable load (~21 metric tons) is reserved for the margin of safety. This effectively means that ~21 metric tons additional reductions are required by the allocations.

Figure ES2. Implementation of the TMDL is accomplished by managing all reduction opportunities in the watershed, both by reducing sources and enhancing existing sinks.

The allocation for the largest treatment facilities reflects the existing level of control these plants have already demonstrated. An approach novel to Ohio is proposed to increase the flexibility for demonstrating compliance with wasteload allocations. Rather than using individual permits to implement the TMDL allocations, they will be implemented through a watershed-wide general permit. The general permit will increase flexibility by evaluating compliance against a grouped wasteload allocation. Facilities will be covered under this new general permit in addition to their individual NPDES permits. It would only include provisions to collectively demonstrate compliance with the seasonal total phosphorus wasteload allocation from this TMDL.

The Clean Water Act exempts agricultural stormwater from NPDES permitting requirements (40 C.F.R. § 122.23(e) and *Natl. Pork Producers Council v. U.S. EPA, 2011*). Therefore, the majority of nonpoint source reductions remain voluntary. TMDLs are planning tools that identify loads needed to attain and maintain water quality standards, which include the identification of pollutant reductions from point and nonpoint sources.

TMDLs are informational tools that identify the sources of pollutants and quantify the amount of a pollutant that can enter a waterbody so that the waterbody will attain and maintain the appropriate water quality standards. TMDLs cannot change existing regulations, nor are they self-implementing. TMDLs utilize existing definitions and approaches currently available in the Clean Water Act and associated regulations.

This TMDL's implementation plan shows how nonpoint source programs will be used to meet its goals. The nonpoint source implementation efforts include managing agricultural stormwater loads. Manure application that follows a manure management plan, including manure from confined animal feeding operations (CAFOs) that is applied in appropriate agronomic amounts and inadvertently enters streams due to precipitation, is considered agricultural stormwater and thus, not regulated as a point source (40 CFR 122.23). This source is incorporated within the TMDL's nonpoint source allocations.

While CAFOs are defined as point sources, unless they are designed to discharge non-agricultural stormwater, they are not compelled to seek NPDES permit coverage. No CAFOs in the Ohio portion of the Maumee watershed discharge wastes that require NPDES permit coverage. No CAFOs in the Ohio portion of the Maumee watershed have NPDES permits allowing discharges of treated wastewater. Therefore, the TMDL provides no CAFO point source allocations. Because TMDLs do not institute policy/regulatory change, existing requirements regarding the management of CAFOs continue.

Because this TMDL includes pollutant allocations to both point and nonpoint sources, it must also contain a consideration of reasonable assurances. This report's reasonable assurances demonstrate that the nonpoint source reductions to meet water quality standards are feasible. It explains that allocations in the TMDL are not based on excessive projections of nonpoint source pollutant reductions. Reasonable assurances are provided by detailing the commitments, planned and ongoing activities, and programmatic support to realize phosphorus reductions. These assurances are reinforced with accountability and oversight from Ohio EPA and federal and binational efforts.

1. Introduction

The goal of the Maumee Watershed Nutrient Total Maximum Daily Load (TMDL) Project is to remove drinking water, aquatic life, and recreational impairments due to Harmful Algal Blooms (HABs) to the Lake Erie Western Shoreline assessment unit, the Lake Erie Western Basin Open Water assessment unit, and Lake Erie Islands Shoreline assessment unit (see Table 1 below). The intention of the TMDL is to attain and maintain the criteria of drinking water, aquatic life and recreational designated uses for the Western Lake Erie assessment units. The phosphorus reduction targets described in the Great Lakes Water Quality Agreement's Annex 4 load reduction recommendations inform Ohio's consideration of how the TMDL may best ensure that the Western Lake Erie Basin can meet water quality standards, when the TMDL allocated loads (Table 26) are reached the designated uses for drinking water, aquatic life and recreational uses will be restored. This TMDL report was developed to include all of the components required in the Ohio Revised Code (ORC) 6111.562 and Ohio Administrative Code (OAC) 3745-2-12, in addition to the elements required by the Clean Water Act identified in the following guidance from the United States Environmental Protection Agency (U.S. EPA): epa.gov/sites/default/files/2015-10/documents/2002_06_04_tmdl_guidance_final52002.pdf.

The draft TMDL document was developed as the fifth step in Ohio's TMDL development process and required a public notice of at least 60 days. Following receipt of comments from interested stakeholders, comments were considered and improvements to the document were made. To document these considerations, a response to comments will be published along with the revised final TMDL document, which will be submitted to U.S. EPA Region 5 for review and approval.

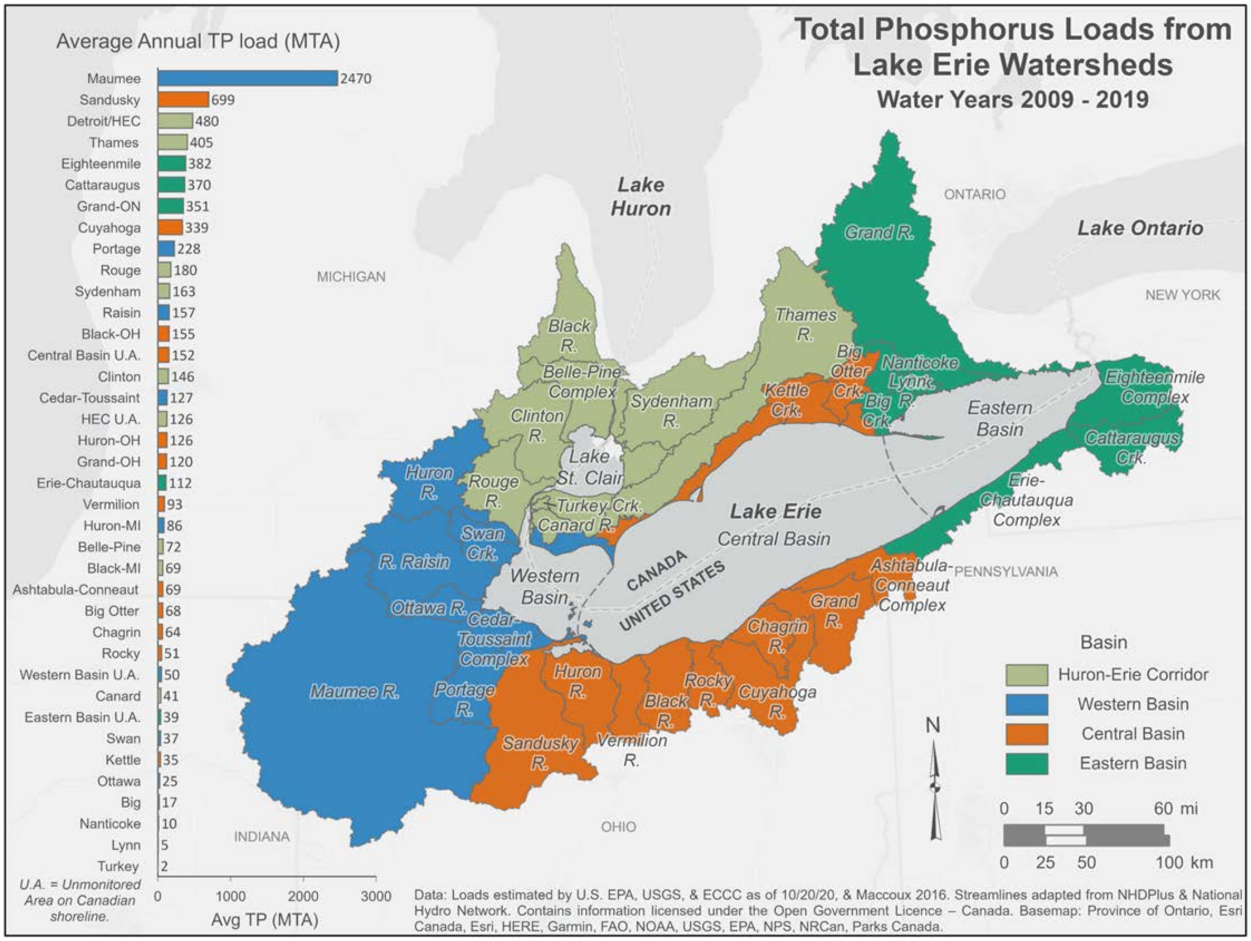
To fulfil the requirements of a TMDL, this document first presents a watershed characterization to describe the water body (Western Lake Erie Basin) and watershed (Maumee) involved in this study (Section 2). Then Ohio's water quality standards are explained, beneficial uses are evaluated, impairments are identified, targets are developed, and actions are proposed to develop a TMDL (Section 3). Section 4 then reviews the sources of phosphorus in the Maumee River watershed (Maumee watershed) to build a foundation for developing the model and allocations. Next, the modeling method and the methods to evaluate baseline conditions and target conditions are described (Section 5). The results of the modeling effort and allocations for major sources are then presented (Section 6). An implementation plan to meet the allocations is presented next (Section 7). The next section (Section 8) describes how achieving the reductions needed to meet the TMDLs allocations are reasonably expected. Finally, Section 9 details the public outreach efforts that were used to communicate the effort to regulated stakeholders and the public.

Several appendices are also included in the report to document some of the detailed technical analysis referenced in the project and to provide other supporting information. Of note, Appendix 7 highlights the efforts taken throughout the project that address the specific considerations required for TMDL development in ORC 6111.562 and OAC 3745-2-12. Works Cited are all included in Appendix 9.

2. Watershed Characterization

Lake Erie is the smallest, by volume, and the shallowest of the Great Lakes. Lake Erie is bordered by the states of New York, Pennsylvania, Ohio, and Michigan and the Canadian province of Ontario. It is the most populated of the Great Lakes basins, with about one-third of the total Great Lakes basin population (ECCC and U.S. EPA, 2021). Together, the Western, Central, and Eastern basins make up Lake Erie. Each Lake Erie basin is unique in geometry, depth, hydrology, and biological productivity. The Eastern Basin is the deepest, with an average depth of 24.4 meters (m), or 80 feet (ft), and a maximum depth of 64 m (210 ft). The Central Basin is the largest and has an average depth of 18.3 m (60 ft). The Western Basin is the smallest and shallowest, with an average depth of 7.3 m (24 ft). Although Lake Erie overall is considered mesotrophic (moderate biological productivity), some areas in the shallow Western Basin are eutrophic (high productivity) (ECCC and U.S. EPA, 2021). Unlike the Central and Eastern basins, the Western Basin does not thermally stratify (Lake Erie LaMP, 2011; Ohio EPA, 2010). Water flows in from the Detroit River and moves from the Western Basin to the Central Basin and then to the Eastern Basin, finally flowing out through the Niagara River. Water leaves the lake through consumptive uses, evaporation, and downstream flows. Twenty-one billion liters (5.55 billion gallons) of water exit through the Niagara River per hour and eventually flow into Lake Ontario. Because of Lake Erie's shallow depth and significant flow volume, the water entering the lake requires only 2.6 years on average to flow out of the lake (referred to as a 2.6-year "retention time").

Numerous direct tributaries and the Detroit River System feed Lake Erie. Around 90 percent of the water in the Western Basin of Lake Erie flows from the Detroit River (IJC, 2014), which drains the three upper Great Lakes. The Maumee River is the largest direct tributary to the Western Basin (and all of Lake Erie). The Maumee River drains parts of Michigan, Indiana, and Ohio, but the majority (approximately 73 percent) of its area is within Ohio. The Maumee River forms at the confluence of the St. Marys and St. Joseph rivers in Fort Wayne, Indiana. In Ohio, the Maumee River flows through portions of Paulding, Defiance, Henry, Wood, and Lucas counties before discharging to Lake Erie through Maumee Bay. The Tiffin and Auglaize rivers join the Maumee River within a short distance of each other in Defiance, Ohio. The Maumee River drains a total of 5,024 square miles in Ohio and is 140 river miles long (107.8 river miles in Ohio). Even as the largest direct tributary, the Maumee River only contributes around 5 percent of the water flowing into western Lake Erie, but it contributes nearly 50 percent of the phosphorus (Figure 1).


Total Phosphorus Loads from Lake Erie Watersheds

Water Years 2009 - 2019

Data: Loads estimated by U.S. EPA, USGS, & ECCC as of 10/20/20, & Maccoux 2016. Streamlines adapted from NHDPlus & National Hydro Network. Contains information licensed under the Open Government Licence – Canada. Basemap: Province of Ontario, Esri Canada, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS, NRCan, Parks Canada.

Figure 1. Lake Erie major watersheds divided into contributing basins by color. The bar chart on the left arranges watersheds by average annual total phosphorus export (2009–2019) (Annex 4, 2021).

2.1 History of eutrophication in Lake Erie

The Western Basin of Lake Erie has historically been impacted by HABs due to high phosphorus concentrations from the upland watershed that drains into the Western Basin; this watershed is often referred to as the Western Lake Erie Basin (WLEB).

Early 1900s to 1970

Starting from the industrialization around 1850 up through the early 1900s, inputs of phosphorus increased due to municipal and industrial sewage entering through direct discharges and via the Lake Erie tributaries. The phosphorus load continued to increase throughout the 1900s with a peak load in 1968 from sewage and detergents containing phosphates (Lake Erie LaMP, 2011). During this time, the fish community was extremely degraded, including the walleye whose commercial stock population reached a very low level, declining from 5.9 million pounds in 1956 to 140,000 pounds in 1969 (Koonce et al., 1996; Busch et al., 1975). Prior to 1954, the Western Basin of Lake Erie supported a large population of burrowing mayfly nymphs (Manny, 1991). By 1961, this population was extirpated due to a period of intermittent thermal stratification coupled with hypoxic hypolimnetic conditions (Carr and Hiltunen, 1965). In this era, many considered Lake Erie to be "dying."

1970s to 1980s

In 1972, the United States and Canada signed the Great Lakes Water Quality Agreement (GLWQA), which aimed to reduce phosphorus loads and implement programs to protect the Great Lakes. By the 1980s, the phosphorus load was cut by nearly half, largely through reductions at wastewater treatment facilities. In the mid to late 1980s, the invasive zebra and quagga mussels (known collectively as dreissenid mussels) were non-native species introduced from ocean-going vessels. The presence of these new species caused several years of improved water clarity and a shift in the food web; specifically, a shift in primary production from phytoplankton to bottom-dwelling algae and plants (Lake Erie LaMP, 2011).

1990s

In the early 1990s, burrowing mayfly nymphs started to recolonize the Western Basin of Lake Erie (Krieger et al., 1996). In the mid to late 1990s, large HABs started reappearing in the Western Basin (Lake Erie LaMP, 2011). During this time, the zebra mussel started dominating the benthic community (Berkman et al., 1998).

2000s to Present

HABs remerged in the early 2000s, with a particularly large bloom in 2003 and summertime HABs have been an annual occurrence ever since (Annex 4, 2015). In 2014, a HAB caused the city of Toledo to issue a drinking water advisory due to microcystins (cyanotoxin from the HAB) in the treated water from the Collins Road water treatment facility. Residents in over 20 communities were affected and advised to not drink the water from August 2 to 4, 2014. Over 300 Ohio National Guardsmen were activated to help distribute clean water and the Governor declared a state of emergency. Following this event, Ohio passed legislation in 2015 (Senate Bill 1) and now requires public drinking water systems (with surface water sources) to monitor for microcystins and HABs (see Ohio Administrative Code 3745-90). Some assessment units in Lake Erie are listed as impaired for beneficial uses (i.e., drinking water and recreation) associated with HABs (see details in Chapter 3 herein and the 2022 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2022a).

Some of the largest blooms occurred in 2015 and 2017, which were very wet years. Conversely, smaller blooms occurred in 2004 and 2012, which were very dry years. Research shows that the proportion of total phosphorus load that is in the dissolved form has significantly increased since the late 1990s (Rowland et al., 2021); this increase has been related to the modern proliferation of HABs. Dissolved reactive phosphorus (DRP) is the parameter most commonly used to monitor this dissolved form of phosphorus.

2.2. Land use and land cover

The Lake Erie watershed is predominantly rural and used for agricultural production, owing to highly fertile soils and moderate temperatures, but it also contains some highly urbanized areas and forested lands. Forests cover 19 percent of the Lake Erie basin area (ECCC and U.S. EPA, 2021) and are largely temperate deciduous and mixed forests, with small remnants of Carolinian forest. Agricultural lands, most of which are artificially drained, account for approximately 75 percent of the Lake Erie watershed. Coastal wetlands formerly occurred throughout Lake Erie, and they were especially abundant in the Western Basin; Lake St. Clair; and along the shores of the Detroit River, St. Clair River, and the upper Niagara River. In many of these areas, wetland losses have been significant, with losses as high as 95 percent (ECCC and U.S. EPA, 2021).

Historical land use and land cover of the Maumee River Watershed

Before European settlement, most of the area in the Maumee River Watershed was a large, hardwood, glacial swamp known as the Great Black Swamp. Wild rice was domesticated and sustainably cultivated by local tribes of Native Americans (Siman and Niewiarowski 2023). Following European settlement, the Great Black Swamp was drained for agricultural purposes, and agriculture became the dominant land use. A wide variety of crops were grown, including winter wheat, corn, hay, potatoes, rye, oats, and barley being the predominant crops. Though not dominant, these other crops were found to grow well, including flax, tobacco, sorghum, sugar beets, apples, peaches, pears, plums, and grapes (Slocum 1905:3). Wild rice only grew in abundance at the mouth of the Maumee River. By the 1950s, agriculture switched from a polyculture of crops to a monoculture of a few main crops, mainly wheat, corn, soybeans, and hay (Siman and Niewiarowski 2023).

Current land use and land cover of the Maumee River Watershed

Today, land use in the Maumee River watershed is 70 percent agriculture (Figure 2). The Auglaize, Tiffin, and St. Marys River watersheds are predominantly cultivated crops (87, 76, and 81 percent, respectively). The St. Joseph's River watershed has a majority of its land use in cultivated crops, but it has a higher percentage of land use in hay and pasture than the other Maumee River watersheds. The St. Joseph's watershed land use is 12 percent hay/pasture, while the other watersheds are less than 6 percent (NLCD, 2016). Corn and soybeans are the overwhelmingly dominant crop types.

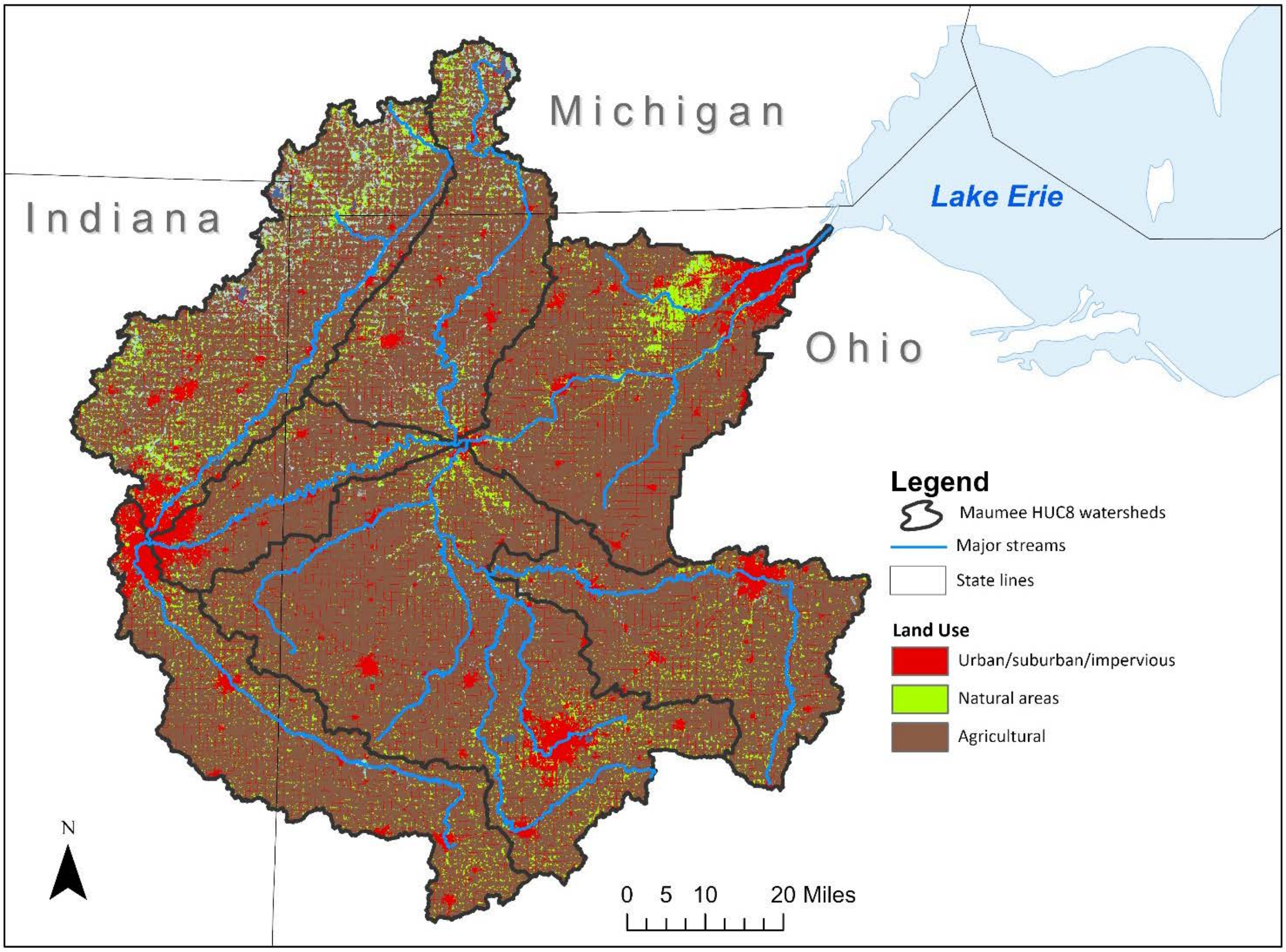


Figure 2. Maumee watershed map showing generalized land uses.

2.3. Geology and soils

2.3.1. Ecoregions

The WLEB drains three Level III ecoregions: the Eastern Corn Belt Plains (ECBP); the Huron-Erie Lake Plains (HELP) from Ohio, Michigan, and Indiana; and the Lake Erie Lowlands from Canada. The Maumee watershed encompasses two of those ecoregions: ECBP and HELP (Figure 3) (Omernik, 1987). “Ecoregions are areas where ecosystems (and the type, quality, and quantity of environmental resources) are generally similar… Designed to serve as a spatial framework for the research, assessment, and monitoring of ecosystems and ecosystem components, ecoregions denote areas of similarity in the mosaic of biotic, abiotic, terrestrial, and aquatic ecosystem components, with humans considered as part of the biota” (U.S. EPA, 2022).

The HELP (labels starting with number 57 in Figure 3) has poor natural soil drainage characterized by lakebed soils, often dominated by clays. This relates to historical land cover in the ecoregion, which was characterized by swamplands at the time of European settlement, known as the historic Great Black Swamp. It has less topographic variation than the neighboring ECBP, being almost flat except for beach ridges and end moraines. Important distinctions, however, are noted when looking at Level IV Ecoregion classifications across the HELP. Two notable areas, the “Paulding Plains,” characterized by very heavy clays, and the “Oak Openings,” comprised of sand dunes and ridges, are not considered “prime farmland,” though most of the HELP is characterized and used as such. The geomorphology of streams in the eastern portion of the HELP, the Marblehead Drift/Limestone Plain, has distinctly less clayey substrate and more carbonate bedrock exposed. Additionally, karst areas are present and are indicative of the area’s association with dolomitic bedrock. Streams in the HELP ecoregion and former Great Black Swamp are low gradient and high in organic material. Some of the richest soils in the state are found here, including Roselms, Paulding, Latty, Hoytville, Fulton, Pewamo, and Glynwood, (Omernik and Gallant, 1988). Once densely forested wetlands were drained with an extensive drainage ditch system to facilitate the establishment of cultivated row crop agriculture.

The ECBP (labels starting with number 55 on Figure 3) is characterized by flat to gently rolling topography, primarily represented by ground moraine, with areas of higher relief defined by dissected end moraine, kames, outwash terraces, and related landforms of glacial origin. Soils here are primarily derived from high lime glacial drift. Natural drainage can vary significantly, but soils are typically well to moderately well-drained and therefore have not had as much need for extensive hydrological manipulation.

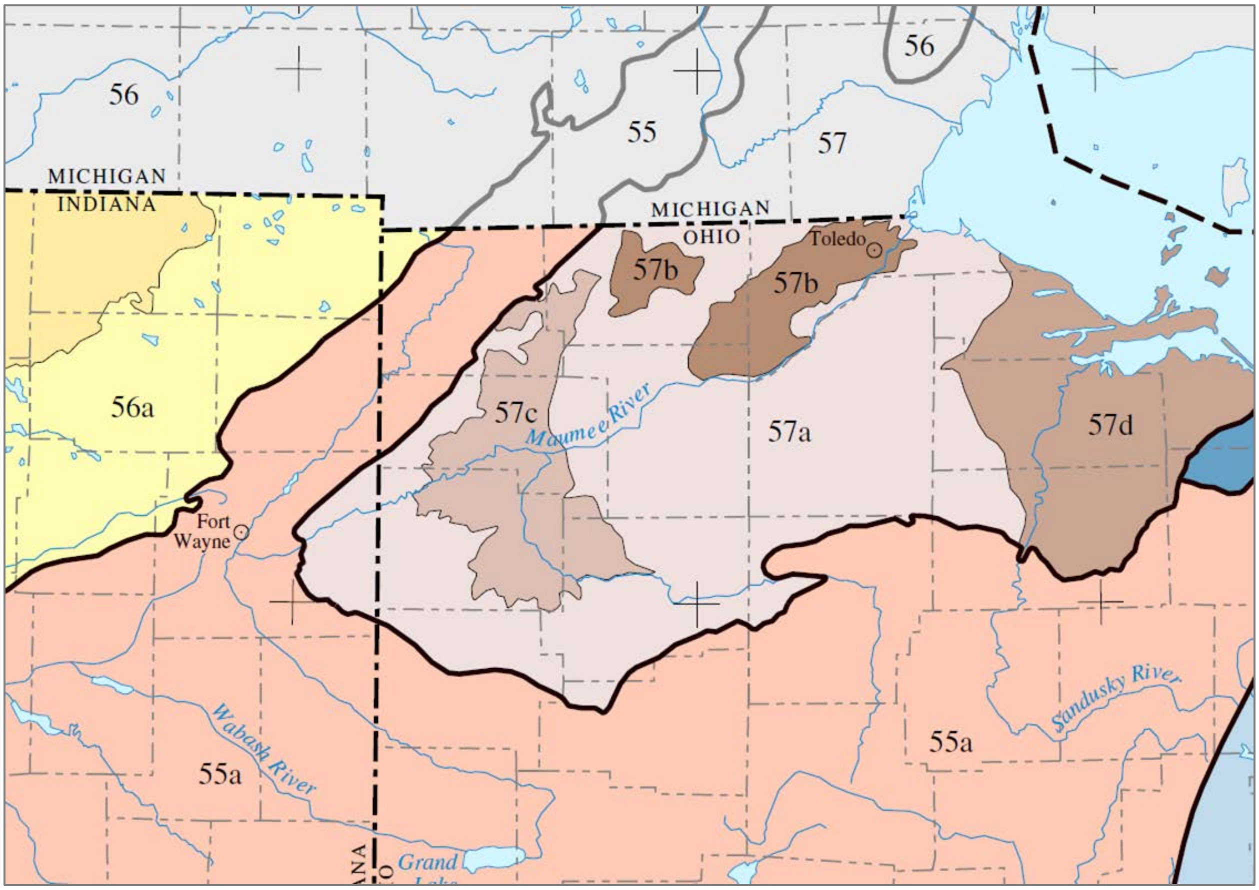


Figure 3. Ecoregions of the Maumee and adjacent watersheds.

2.3.2. Geology

The Lake Erie watershed's (including the Maumee watershed) drainage patterns, topography, soils, and water chemistry are influenced by their underlying geology. In general, the geology has been profoundly influenced by glacial advances and retreats, in which rocks and soils were eroded repeatedly. These materials were redeposited as sediments during several ice advance, melt, and retreat cycles. Of these, the later Wisconsin glacial epoch arguably has had the most profound influences on streams within this area (Trautman, 1981). As much of the inland ice retreated northward, only areas along the eastern portions of Lake Erie remained. This is due to the bedrock of the Western Basin being dominated by dolomite and limestone, which are more resistant to erosion (ODNR, 2018). This, along with the Ft. Wayne and Defiance end moraines, roughly defined the boundary of glacial Lake Maumee, the first and largest of the several glacial lakes that formed during this time period (Trautman, 1981). Due to the influence of the glacial advances and retreats, low, flat topography associated with the lake plain and glacial tills are characteristic of the Maumee watershed.

2.3.3. Soil

Soils in the Lake Erie watershed are comprised mostly of glacially deposited till materials and lakebed soils (ODNR, 2018). As with the Lake Erie watershed, the Maumee watershed soils are derived from glacial till material and lacustrine deposits, characteristic of the ECBP and HELP ecoregions, respectively (USDA, 2013). Due to its geologic history, the Maumee watershed soils are deep and somewhat poorly to very poorly drained. At the end of the last ice age, massive ice blocks broke off as the glaciers retreated. These dammed the flow of running water and created glacial lakes. The suspended sediments in the running water began to settle out as the velocity of the water diminished. Heavy sand particles fell out first, then silts, and finally, clays. Clay surface soils dominate in the Maumee watershed because clay was the last to be deposited in the lake. Eventually, the ice melted, and the lakes drained, leaving behind soils with 35–60 percent clay at the surface. The landscape is very flat, with many depressional areas and a seasonal water table near the surface. Even with these flat, ponding soils, the potential for water runoff and soil erosion is high due to the low permeability of these soils. Because of the high clay content of these soils, they are very fragile and prone to compaction. These soils are relatively high in soil organic matter but have very poor soil structure. Soils in the Maumee watershed are also prone to shrink/swell, forming large deep fissures and cracks. There is little, if any, water filtering capability when soils are compacted, and a high percentage of soils in northwest Ohio have compaction problems. Compaction destroys soil structure, which prevents water infiltration and matrix flow through the soil profile. Instead, surface water and dissolved nutrients travel through fissures, cracks, and macropores (preferential flow), and they flow out through subsurface drains or tiles. A healthy soil with good structure, porosity, and infiltration will promote matrix flow, giving nutrients a chance to bind to the soil. The dominant soil types in northwest Ohio are Hoytville, Paulding, Toledo and Latty, all of which have similar characteristics. The most common of these is Hoytville. All these soils are classified as soils with high runoff potential when thoroughly wet (Ohio EPA, 2010). The dominant soil type in the Maumee watershed is Hoytville and Blount, making up approximately 19 percent and 16 percent, respectively (Calhoun et al., 2002).

Artificial drainage is frequently used in the Maumee watershed due to the high seasonal water tables and poor natural soil drainage. This drainage includes extensive ditch systems dug in the 1850s to drain the Great Black Swamp, as well as surface and subsurface tiles installed in the agricultural areas. The Maumee watershed has more than 16,000 miles of drainage ditches in place (ODNR, 2018). Ohio drainage law provides a framework for these ditches to be maintained. In the Maumee watershed, smaller projects that do not cross county boundaries are often managed by county soil and water conservation districts (SWCDs) under ORC 6131. The Maumee watershed is also served by the Maumee Watershed Conservancy District, established under ORC 6101. The conservancy implements projects that consist of flood risk reduction and improved drainage. While it is clear much of the watershed is influenced by artificial drainage, the exact extent is not known due to the incomplete maps, distributed nature, and extended installation history of the drainage systems (Jaynes and James, 2007).

In addition to the extensive surface drainage network in the Maumee watershed, extensive subsurface tile drainage is also present. Sugg (2007) estimated that subsurface drains underlie more than 50–80 percent of agricultural lands in the Maumee watershed. Though artificial drainage has increased agricultural productivity, it also affects the ecology and hydrology of streams. Artificial drainage has been shown to impact the flow regime by intensifying different flow events. Sloan et al. (2017) saw an increase in low flows and a decrease in intermediate flows in streams impacted by subsurface drainage systems.

2.3.4. Climate

The climate of Lake Erie, being part of the Great Lakes basin, is affected by three factors: air masses from other regions, the location of the basin within a large continental landmass, and the moderating influence of the lake itself. The prevailing movement of air is from the west. The characteristically changeable weather of the Great Lakes region results from the alternating flows of warm, humid air from the Gulf of Mexico and cold, dry air from the Arctic. These factors tend to increase humidity and can create lake-effect precipitation during the cold fall and winter months. Despite that, the proximity to Lake Erie also moderates the local climate as the large water body acts as a heat sink or source, warming the air in cold months and cooling the air in the summer (U.S. EPA, 1995).

In winter, Arctic air from the northwest is very cold and dry when it enters the basin, but it is warmed and picks up moisture traveling over the comparatively warmer lake. When it reaches the land, the moisture condenses as snow, creating heavy snowfalls on the lee side of the lake in areas frequently referred to as snowbelts. For part of the winter, the region is affected by Pacific air masses that have lost much of their moisture crossing the western mountains. Less frequently, air masses enter the basin from the southwest, bringing in moisture from the Gulf of Mexico. This air is slightly warmer and more humid. During the winter, the lake's temperature continues to drop, and ice frequently covers Lake Erie (U.S. EPA, 1995). The Maumee watershed has a temperate, continental climate. There are no barriers to protect it from cold air of the polar region or warm, moist air from the south. Lake Erie has some moderating influence on the climate, preventing extreme swings in the weather (USDA, 1966).

Average annual temperature in the Maumee watershed is 11.3 degrees Celsius (°C), or 52.5 degrees Fahrenheit (°F), with February (−6 °C, 21 °F) and July (23.6 °C, 74.6 °F) as the coldest and warmest months, respectively (NOAA, 2021). The annual rainfall for 2021 was 1,062 millimeters (mm) (NOAA, 2021). A 2012–2015 study found the average annual rainfall in the Maumee watershed ranged from 833 mm to 1,135 mm (Pease et al., 2018).

2.3.5. Community profile

Lake Erie's watershed is the most densely populated watershed of the Great Lakes basin, with almost 12 million people living within the basin, of which 2 million live within Ohio (ODNR 2018). However, the Maumee watershed in northwest Ohio is largely rural; small cities, villages, and towns are dispersed across the landscape, with a population of more than 526,000 people (U.S. Census Bureau, 2010). The largest urban center is Toledo, Ohio, which, along with outlying metropolitan areas, occupies most of Lucas County and parts of adjacent Wood, Ottawa, and Fulton counties. It is a historic port city located at the mouth of the Maumee River. Other major municipalities include Lima, Defiance, Findlay, Van Wert, Napoleon, and Perrysburg. Across most of the basin, however, a dominance of agricultural production led to a proliferation of small villages and towns existing as administrative and supply centers, with associated populations dispersed across the surrounding rural landscape.

A moderate climate and fertile soils support a strong regional economy that includes water-based industries, commercial and recreational fishing, commercial shipping, a charter boat industry, agriculture, nature-based tourism and recreation, and natural gas and oil extraction. In addition to these major sectors, the basin supports a variety of other industries typical of the Great Lakes basin, including finance, services (health, education, and religion), transportation, communications, and manufacturing, including automotive and steel. (ECCC and U.S. EPA, 2021). Even though there is a strong regional economy, several areas within the Maumee Watershed are considered disadvantaged within urbanized areas of Toledo and Lima, as well as some rural areas.

Over 12.5 million people get their drinking water from Lake Erie (U.S. EPA, 2018), including 3 million within Ohio (ODNR, 2018). Over 500,000 Ohioans get their drinking water from the Western Basin of Lake Erie (Ohio EPA, 2022). In 2014, over half a million Toledo residents were impacted by a drinking water advisory due to microcystins associated with the HAB. In 2020, Ohio EPA's Division of Drinking and Groundwater conducted a survey of public water supply systems to assess the expenditures and financial impacts associated with HABs. The survey revealed that the average annual HAB-related costs of monitoring, treatment, and residual disposal varied greatly. The city of Toledo is in the process of completing several upgrades to the Collins Road Water Treatment Facility to improve treatment of algal toxins. These upgrades have a total estimated cost of over $100,000,000 and include the addition of powder activated carbon storage and feed systems, new ozonation facilities, and filter upgrades. While HABs remain an annual occurrence in the source water, treatment at Toledo's drinking water plant has been effective. HAB monitoring continues per rule requirements (OAC 3745-90-03). Many areas impacted by the drinking water advisories are already considered "disadvantaged" due to environmental and socioeconomic burdens. In addition to those burdens, they now bear more cost related to treatments for HABs at the drinking water plant.

3. Identifying Water Quality Impairments and Actions

The chapter is broken into five subsections: (3.1) the water quality standards section, which explains the applicable water quality standards in the Maumee Watershed Nutrient TMDL project area; (3.2) the beneficial use section, which outlines the applicable beneficial use designations; (3.3) the evaluation of criteria section, which assesses the applicable criteria and identifies impairments of the designated uses; (3.4) the linkage analysis and targets section, which contains details on the development, justification, and selection of targets for this TMDL; and (3.5) the proposed actions section, which discusses the action being taken to address the impairments and presents the rationale behind the selected model.

3.1. Water quality standards

TMDLs are required when a water body fails to meet the state's water quality standards. Every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. Water quality standards represent a level of water quality that will support the Clean Water Act goal of swimmable and fishable waters and other important goals. Ohio's water quality standards, set forth in Chapter 3745-1 of the Ohio Administrative Code (OAC), include three major components: beneficial use designations, numeric and narrative criteria, and antidegradation provisions. Where numeric criteria have not been developed, the State can develop project-specific targets.

Beneficial use designations describe the existing or potential uses of a water body, such as public water supply; protection and propagation of aquatic life; and recreation in and on the water. Ohio EPA assigns beneficial use designations to each water body in the state. Use designations are defined in paragraph (B) of rule 3745-1-07 of the OAC and are assigned in rules 3745-1-08 to 3745-1-32. Attainment of uses is based on specific numeric and narrative criteria.

Numeric criteria are estimations of the chemical concentrations, degree of aquatic life toxicity, and physical conditions allowable in a water body without adversely impacting its beneficial uses. Narrative criteria, located in rule 3745-1-04 of the OAC, describe general water quality goals that apply to all surface waters. These criteria state that all waters shall be free from sludge, floating debris, oil, and scum; color and odor-producing materials; substances that are harmful to human, animal or aquatic life; and nutrients in concentrations that create nuisance growths of aquatic weeds and algae.

3.2 Designated uses

Beneficial use designations describe existing or potential uses of water bodies. They take into consideration the use and value of water for public water supplies, protection and propagation of aquatic life, recreation in and on the water, agricultural, industrial, and other purposes. Beneficial use designations for Ohio are promulgated into rules.

In OAC rule 3745-1-31, Lake Erie is designated as exceptional warmwater habitat, superior high-quality water, public water supply, agricultural water supply, industrial water supply and bathing water.

This section reviews the attainment status and evaluation criteria of recreation use (algae), public water supply use, and aquatic life use for the Western Basin of Lake Erie assessment units (i.e., Western Basin shoreline, Western Basin open water, and Western Basin islands shoreline), depicted in Figure 4.

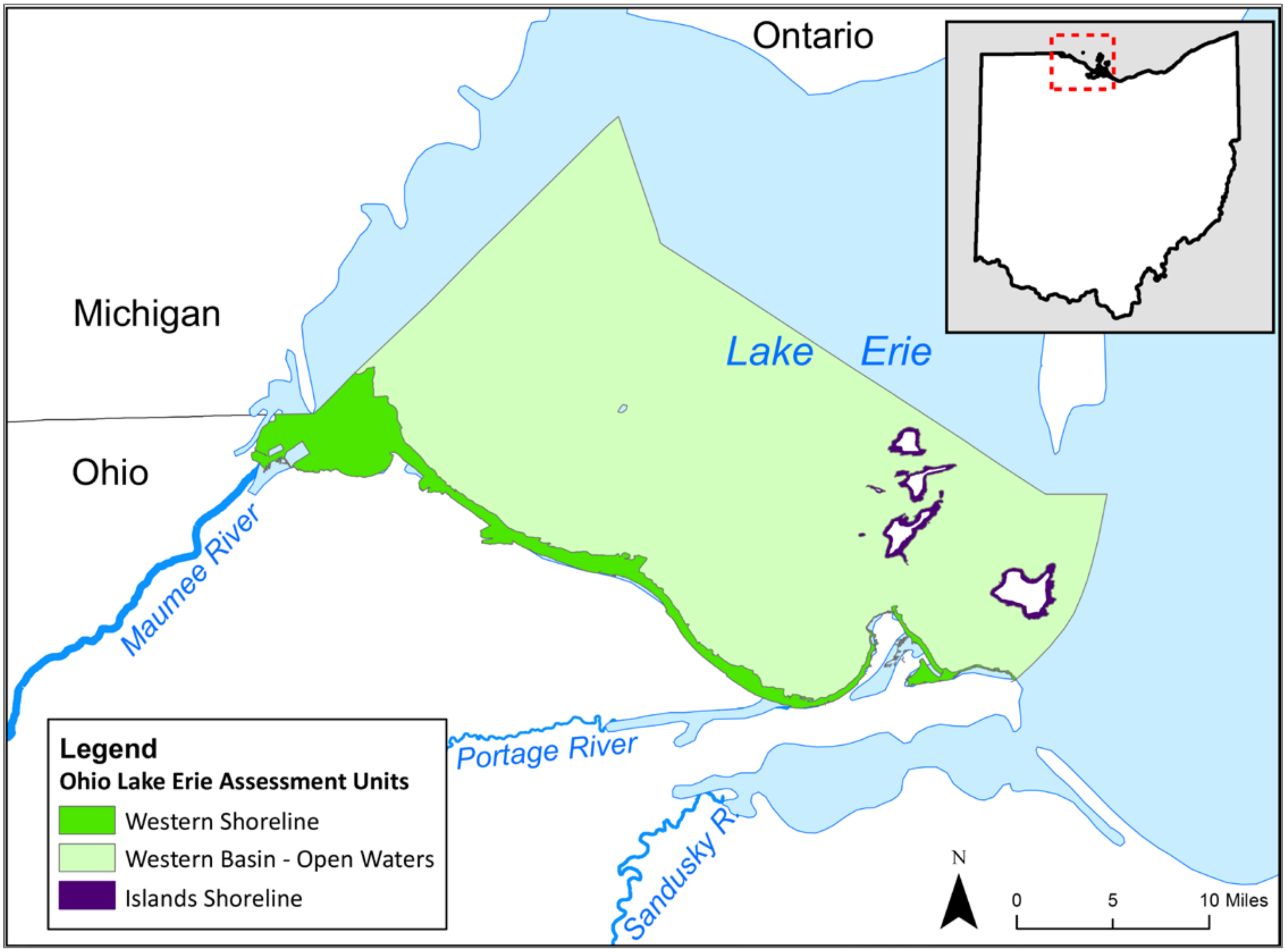


Figure 4. Map of Ohio's Western Basin of Lake Erie assessment units.

3.3. Evaluation of criteria

The following subsections evaluate the associated criteria for the Western Basin and describe the impairments being addressed by this TMDL. Table 1 summarizes the beneficial use impairments in the Western Basin.

Table 1. Summary of impairments addressed by the Maumee Watershed Nutrient TMDL.

Lake Erie assessment unit (OHLE)	Narrative description	Causes of impairment (Beneficial use in parentheses)
041202000201	Lake Erie Western Shoreline (≤3 meters depth)	Algae (Recreation use) Algae: Cyanotoxins (Public drinking water use) Nutrients (Aquatic life use)
041202000301	Lake Erie Western Basin Open Water (>3 meters depth)	Algae (Recreation use) Algae: Cyanotoxins (Public drinking water use)
041202000101	Lake Erie Islands Shoreline (≤3 meters depth)	Algae (Recreation use) Algae: Cyanotoxins (Public drinking water use) Nutrients (Aquatic life use)

3.3.1. Recreation use

Attainment of recreation use goals are evaluated based on the narrative criteria for nuisance algae. Ohio water quality standards (OAC rule 3745-1-04) require that all surface waters be:

> *"(D) Free from substances entering the waters as result of human activity in concentrations that are toxic or harmful to human, animal or aquatic life or are rapidly lethal in the mixing zone.*
>
> *(E) Free from nutrients entering the water as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae."*

Using these standards, Ohio EPA worked with the best available science and data collection methods available to quantify the algal bloom and assess attainment of the narrative water quality standards. See Section F4 of Ohio's 2022 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2022a) for additional information, a summary of which is provided below.

To assess Ohio's Western Basin of Lake Erie, satellite data from the National Oceanic and Atmospheric Administration are reviewed in 10-day frames during bloom season: July–October. If a year has three or more 10-day frames with an average cyanobacteria cell count of greater than 20,000 cells/milliliter (mL) in greater than 30 percent of the area in the Western Basin assessment units, then that year exceeds the target algal bloom goal for that year. Impaired status is triggered if any two or more years in a rolling six-year window exceed the target algal bloom goal. This method addresses the "patchy and temporally variable nature of blooms" described in an academic paper outlining Ohio's impairment metrics (Davis et al., 2019). This paper explains that this method was developed "to establish a threshold that was consistent with the GLWQA Annex 4 report" (Annex 4, 2015). Additionally, it provides a slightly more rigorous analysis of the duration and magnitude of each year's bloom.

Ohio's recreation use goals for the Western Basin of Lake Erie will be met (or delisted if previously determined to be impaired) when the algal blooms do not cover greater than 30 percent of the Western Basin assessment unit with a cell count greater than 20,000 cells/mL for more than 30 days (not contiguous) during a bloom season more than once out of six years. Algal blooms that do not exceed these assessments are considered mild and not impairing recreation use. They are also consistent with the Annex 4 target year blooms of 2004 and 2012.

Ohio's 2022 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2022a), explains that the algae (cyanobacteria) cell count level in the bloom, as observed via the satellite data sets, should be no greater than 20,000 cells/mL. The 20,000 cells/mL threshold corresponds to the nominal floor used by NOAA to analyze satellite imagery with a comfortable degree of certainty (Wynne and Stumpf, 2015). Additionally, Ohio has found that scum formation in the Western Basin of Lake Erie is likely to occur at the 20,000 cells/mL cell density. Therefore, Ohio set the 20,000 cell/mL threshold based on the elevated likelihood of scum formation at 20,000 cells/mL level and that scum formation has toxin concentrations of microcystin which impair human health recreational exposure.

Ohio's 2022 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2022a), also explains that the threshold of 30 percent coverage of the Western Basin assessment unit is based on an examination of the bloom coverage in Lake Erie's western basin since 2002. Bloom coverage was considered against an Annex 4 target severity index (Figure F-7 of Section F of the 2022 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2022a). Bloom severity met the Annex 4 target in 2004 and nearly met the target in 2012. In those years the bloom was not considered to significantly impede recreational use of the water and the extent of the coverage did not exceed 30 percent of the western basin open water assessment unit in three or more 10-day frames.

Table 2 shows the results of the analysis, using satellite data from 2016–2021, for the six-year window in the assessment. Some years do not include all 12 of the 10-day frames because of extended cloud cover or other interferences with the satellite images. The Western Basin open waters are considered impaired because all six years exceeded the thresholds outlined above (three or more 10-day frames have an exceedance in one year [July – October]).

The 2020 cyanobacterial bloom in the Western Lake Erie Basin experienced three 10-day frames exceeding 30 percent coverage of greater than 20,000 cells/mL during the May–October period. That year's bloom started in early July and ended in early October. The 2021 bloom had four 10-day frames exceeding the benchmark. The 2021 bloom started later in July but persisted until late October. The greatest aerial extent of the two new years presented in this report, with 76 percent of the assessment unit covered, occurred during two consecutive 10-day windows centered on September 3, 2021, and September 13, 2021.

Based on the current results, this assessment unit could not attain the recreation use until after the 2026 bloom season. For that to happen, there must be fewer than three 10-day frames exceeding the 30 percent area coverage of algae at the outlined density each year from 2022–2026.

Table 2. The number of 10-day time frames exceeding the 30 percent coverage threshold.

	≥30% coverage at ≥20,000 cell/mL	
Year	**10-day frames exceeding**	**Total frames**
2016	**5**	10
2017	**7**	11
2018	**6**	12
2019	**5**	12
2020	**3**	10
2021	**4**	10

Since the island shoreline assessment units are contained within the Western Basin open water unit satellite assessment zone that was used to conduct the analysis, the island shoreline unit is also considered impaired. As people are more likely to come into direct contact with the water and algae along the shoreline than in the open water, Ohio EPA is also including the Western Basin shoreline unit on the impaired waters list. This is based on proximity to the open waters that are clearly impaired, and the expectation that, reviewing the patterns of blooms over the past six years, the shoreline area would be just as impacted by the blooms as the open water.

3.3.2. Public drinking water supply

The public drinking water supply use is applied to surface waters from which water is sourced to be treated for public use as drinking water. Assessment methodology for algal toxins in drinking water sources is described in detail in Section H of the 2022 Integrated Report (Ohio EPA, 2022a). The summary of the drinking water thresholds is in Table 3 and a summary of data evaluated to identify the impaired conditions is presented in Table 4.

Table 3. Public drinking water supply use attainment determination for algal toxins (Ohio EPA, 2020a: Section H, Table H-1).

Indicator	**Impaired conditions**
Algae: Cyanotoxins[a]	Two or more excursions[b] above the state drinking water thresholds (microcystins = 1.6 µg/L) within the 5-year period
	Full attainment conditions

	No more than one excursion[b] above the state drinking water thresholds (microcystins = 1.6 µg/L, cylindrospermopsin = 3.0 µg/L, and saxitoxins = 1.6 µg/L) within the 5-year period
	“Watch list” conditions
	Maximum instantaneous value ≥ 50% of the state drinking water thresholds

Notes:

[a] Impaired conditions based on source water detections at inland public water supply systems and detections at public water system intakes for Lake Erie source waters. Cyanotoxins include microcystins, saxitoxins, anatoxin-a and cylindrospermopsin.

[b] Excursions must be at least 30 days apart to capture separate or extended source water quality events.

Table 4. Summary of public drinking water system intake samples identifying impaired conditions in Western Basin of Lake Erie assessment units.

Assessment unit	Cause of impairment	Summary of key water quality data
041202000201 Lake Erie Western Basin Shoreline (≤3m)	*Algae* Two public water systems had at least two raw water samples with microcystins concentrations above the threshold.	Carroll Township and Ottawa County had raw water samples that exceeded the microcystins threshold in 2010, 2011, 2013–2015, and 2017–2021. Maximum detection of microcystins was 22.4 µg/L in August 2019.
041202000301 Lake Erie Western Basin Open Water (>3m)	*Algae* Four public water systems had at least two raw water samples above the threshold for microcystins.	Oregon had raw water samples that exceeded the microcystins threshold in 2010, 2011, 2013–2019, and 2021. Toledo had raw water samples that exceeded the microcystins threshold in 2010, 2011, 2013–2015, 2017–2019, and 2021. Marblehead had raw water samples that exceed the microcystins threshold in 2015, 2017, and 2021. Kelleys Island had results above the threshold from 2015, 2017, 2018 and 2021.
041202000101 Lake Erie Islands Shoreline (≤3m)	*Algae* Three public water systems had at least two raw water samples above the threshold for microcystins.	Put-In-Bay had sample results above the threshold in 2010, 2013–2015, and 2017–2019. Camp Patmos had results above the threshold in 2010, 2013–2015, and 2017–2019. Lake Erie Utilities had results above the threshold in 2014, 2015, 2018 and 2019.

3.3.3. Aquatic life use

The Western Basin shoreline and islands shoreline assessment units are listed in the Integrated Report as impaired for aquatic life use due to nutrients. The Western Basin of Lake Erie open water assessment unit is currently not assessed for aquatic life use.

In Ohio’s 2022 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2022a), it explains that aquatic life use determinations are predicated on a narrative description of the aquatic community associated with the relevant use tier. In the absence of numeric criteria, the narrative description is used at the basis for the aquatic life use impairment determination. In the late 1990s, Ohio completed several different studies which developed biological indices based on fish and macroinvertebrate measurement. These documents provided the foundation for Ohio to refine its field sampling protocols and to develop assessment indices for numeric biological targets/expectations using the Index of Biotic Integrity (IBI) and the Modified Index of well-being (MIwb). IBI and Miwb scores for aquatic life were developed to measure aquatic life use in Lake Erie along the shoreline.

The status of Lake Erie shoreline and island shoreline assessment units were evaluated using fish community assessment targets for the Lake Erie IBI and Miwb based on sites in the Lake Erie Wester Basin Shoreline assessment unit and the Lake Erie Islands Shoreline assessment unit. These assessment units were determined to be impaired for aquatic life uses based on fish community data collected during night electrofishing events and the percentage of sites, within the individual assessment unit, which did not attain the biological IBI and Miwb targets where sufficient biosurvey data were available.

Ohio EPA is revising the Lake Erie aquatic life use assessment methodology (Section G of the 2022 Integrated Water Quality Monitoring and Assessment Report). As stated in the 2022 Integrated Report, The Ohio State University's (OSU's) Ohio Sea Grant College Program has been assisting Ohio EPA in leading a panel of experts to advise the state on the development of aquatic life use metrics for Lake Erie. This includes developing the state's first set of metrics to be applied to the three open water assessment units and redefining metrics for the four shoreline assessment units. Ohio EPA plans to include an update on this effort in the 2024 Integrated Report.

3.4. Linkage analysis and targets

The intention of the Maumee Watershed Nutrient TMDL is to attain and maintain the applicable water quality standards, for the criteria described in Section 3.3 (recreation use (algae), drinking water use (algae), and aquatic life use (nutrients)). The phosphorus reduction targets described in the Great Lakes Water Quality Agreement's Annex 4 load reduction recommendations were evaluated relative to these impairments. Ohio EPA has found that the designated uses described in Section 3.3 will be restored when the TMDL allocated loads (Table 26) are reached.

This section links water quality impairments to the TMDL pollutant. It contains details regarding the development, justification, and selection of targets for this TMDL—including targets to address recreation, public drinking water supply, and aquatic life use impairments.

The binational U.S. and Canadian GLWQA includes 10 issue-specific annexes, one of them being Annex 4: Nutrients (hereafter referred to as Annex 4). The GLWQA's 2012 amendment called for Annex 4 to convene an Objectives and Targets Task Team. In 2013, this task team was formed to determine how to meet Annex 4 Lake Erie objectives impacted by nutrients.

One goal of this Annex 4 task team was to consider the driving forces of the HABs that annually grow in the Western Basin of Lake Erie. The team assessed the various ecosystem drivers of these HABs. These included changes to the phytoplankton community and what conditions led to the dense growth of cyanobacteria. The task team scrutinized various scientific research resources. The key drivers identified were increasing water clarity due to dreissenid mussels and the changes to inorganic nutrients being delivered to the lake. The team determined that reducing the amount of phosphorus entering the lake was the most scientifically sound and practical approach to managing the HABs. The task team then synthesized various phosphorus-ecosystem response models to determine nutrient reduction recommendations. This effort included hydrodynamic lake models that considered the metrological, water current (including seiche impacts), and limnological factors Lake Erie experiences.

The group's ultimate recommendations were outlined in a report titled "Recommended Phosphorus Loading Targets for Lake Erie" (Annex 4, 2015). This called for reductions of all available forms of phosphorus to meet the task team's HAB ecosystem objective. Phosphorus targets to achieve the objective were expressed as both total phosphorus and DRP delivered to Lake Erie during the "spring loading period" of March 1 through July 31 each year. Once the target loads are achieved, the Annex 4 HABs ecosystem objective will be met. This objective was outlined as a bloom size expected to be less than or equal to size of the blooms observed in 2004 or 2012. Those are considered years with mild, acceptable-sized blooms. The phosphorus targets consider annual variability in streamflow and are expected to be met in nine out of 10 years. The Annex 4 (2015) recommended targets report is referred to hereafter as the Annex 4 targets document.

The Annex 4 targets document considered the impact of all loads to Lake Erie, including those from the Detroit River and other western basin tributaries. The task team came to the following conclusion about the large blooms in the western basin (emphasis added):

> "*To* ***achieve a bloom no greater than that observed in 2004 or 2012,*** *90% of the time, the Task Team recommends a total phosphorus (TP) spring load of 860 metric tons and a dissolved reactive phosphorus (DRP) load of 186 metric tons* ***from the Maumee River****.*"

The report goes on to state (emphasis added):

> "*The Task Team also found that* ***smaller cyanobacteria blooms*** *have been observed from satellite imagery at the mouths of the Thames River (the 2011 phosphorus load from the Thames was 835 metric tons), River Raisin, Toussaint Creek, Portage River, and near Leamington. As a result, the Task Team concluded that, a 40% load reduction for each of those tributaries is also warranted. The 40% reduction target applies to all Western Basin tributaries unless there is a tributary program in place, which includes, monitoring, modeling, and/or management plans that demonstrate that the tributary and rivermouth nutrient conditions do not pose a cyanobacteria threat to* ***adjacent nearshore water****.*"

Ohio EPA evaluated the Annex 4 targets in the context of the listed impairments for recreation, drinking water, and aquatic life. The subsections below explain how achieving a bloom consistent with the 2004 or 2012 bloom (by meeting the Maumee River targets) is expected to protect the beneficial uses and implement the associated narrative criteria. Since this bloom condition is expected to restore the beneficial uses, non-Maumee tributary loads to the western basin of Lake Erie were not included in this TMDL.

The Annex 4 targets document also includes annual phosphorus loading targets to reduce seasonal hypoxia in the Central Basin of Lake Erie. Ohio currently does not have beneficial use impairments attributed to seasonal hypoxia in the Central Basin. While nutrient reductions that occur in the Maumee watershed due to this TMDL will help work towards hypoxia targets, this TMDL is not explicitly addressing beneficial use impairments attributed to seasonal hypoxia or the related Annex 4 targets because no such impairment is present. Actions to address targets for the other tributaries are outlined in the Ohio Domestic Action Plan (OLEC, 2020a).

The subsections below explain that the TMDL targets used in this project are based on these Annex 4 targets and can be used to protect the beneficial uses and implement the associated narrative criteria.

3.4.1. Recreation use

The Annex 4 targets document outlines that the phosphorus load from the Maumee watershed "during the spring period of 1 March to 31 July each year was the best predictor of cyanobacteria bloom severity…". It explains total phosphorus and DRP load targets for the Maumee River to the Waterville, Ohio, monitoring point of 860 and 186 metric tons (MT), respectively, for this spring loading period. As noted above, these target loads are expected to result in acceptable bloom sizes. These loading targets were proposed to be met in nine out of 10 years.

Ohio's recreation use assessment methodology, summarized above, determines use attainment to be met when mild, acceptable blooms occur in five out of six years. This slightly differs from the nine out of 10 years called for in the Annex 4 targets. In effect, the only impact from Ohio's assessment methods having a different number of years than the Annex 4 HAB size objective is that it allows Ohio to potentially delist an impairment by considering more recent information, rather than having to wait for 10-years. From the academic paper outlining Ohio's methods (Davis at al., 2019):

> *"A six-year window was decided to maintain consistency with the GLWQA Annex 4 report as this interval allows for climatic fluctuations leading to variability in rainfall-driven nutrient loading, and resultant overall bloom size. In the Annex 4 context, a fluctuation driving a bloom is expected in one year out of ten; a longer time window than six years could result in western Lake Erie remaining in impairment status for nearly a decade before it could be removed from the 303(d) list. If any two years out of a rolling six-year window met the annual impairment criteria described above, the Ohio open waters of western Lake Erie would be*

> *designated as impaired and could only be delisted once five years out of the six-year window were considered unimpaired."*

Ohio EPA's assessment methodology was developed to be consistent with the Annex 4 western Lake Erie HAB objective, but it was written for listing/delisting purposes under Section 303(d) of the CWA. Annex 4 does not address this CWA mechanism. As a subcommittee of the GLWQA, it does not implement and is not expected to implement Clean Water Act provisions such as Section 303(d). Meeting the targets developed by the Annex 4 Objectives and Targets Task Team will lead to water quality conditions in the Western Lake Erie assessment units that result in the attainment of Ohio's recreation use. The determination of attainment will be made using the approach described in Ohio's Integrated Report, Section F.

Flow-weighted mean concentrations (FWMCs) that corresponded to these loading targets are also provided in the Annex 4 targets document for the Maumee River. These are 0.23 milligrams per liter (mg/L) and 0.05 mg/L for total phosphorus and DRP, respectively. These concentration targets provide a benchmark to track progress of load reduction. Flow-weighted means are used instead of standard concentrations because this statistic is less sensitive to stream flow fluctuations. This is a helpful addition to the load targets, especially during spring seasons that may be a wetter or dryer than the norm. TMDLs are inherently load-based planning tools; therefore, the concentrations outlined in the Annex 4 targets document will not be included in this TMDL project's allocations. The FWMC targets are, however, included in the Ohio Domestic Action Plan and are considered for monitoring progress at stream water quality gages.

This Maumee Watershed Nutrient TMDL is focused on addressing the three impaired western Lake Erie assessment units described in Table 1 of outlined above in this document. Annex 4 identified the springtime load from the Maumee River watershed as controlling the large western basin of Lake Erie HABs, and Ohio EPAs evaluation for identifying impaired conditions was consistent with the Annex 4 goals. Therefore, Ohio EPA expects meeting the Maumee River targets to restore the impaired uses of the three impaired western Lake Erie assessment units. Therefore, this project is focused on the phosphorus load exclusively from the Maumee River watershed and does not consider loading from other priority tributaries to the western basin of Lake Erie. The map in Figure 5 shows the assessment units and affected watershed. Table 5 lists the eight-digit hydrologic unit code (HUC), or HUC-8, subwatersheds that are included in this TMDL's allocations. As discussed above, these priority tributary targets are not tied to the larger western basin of Lake Erie HABs that are resulting in impaired conditions.

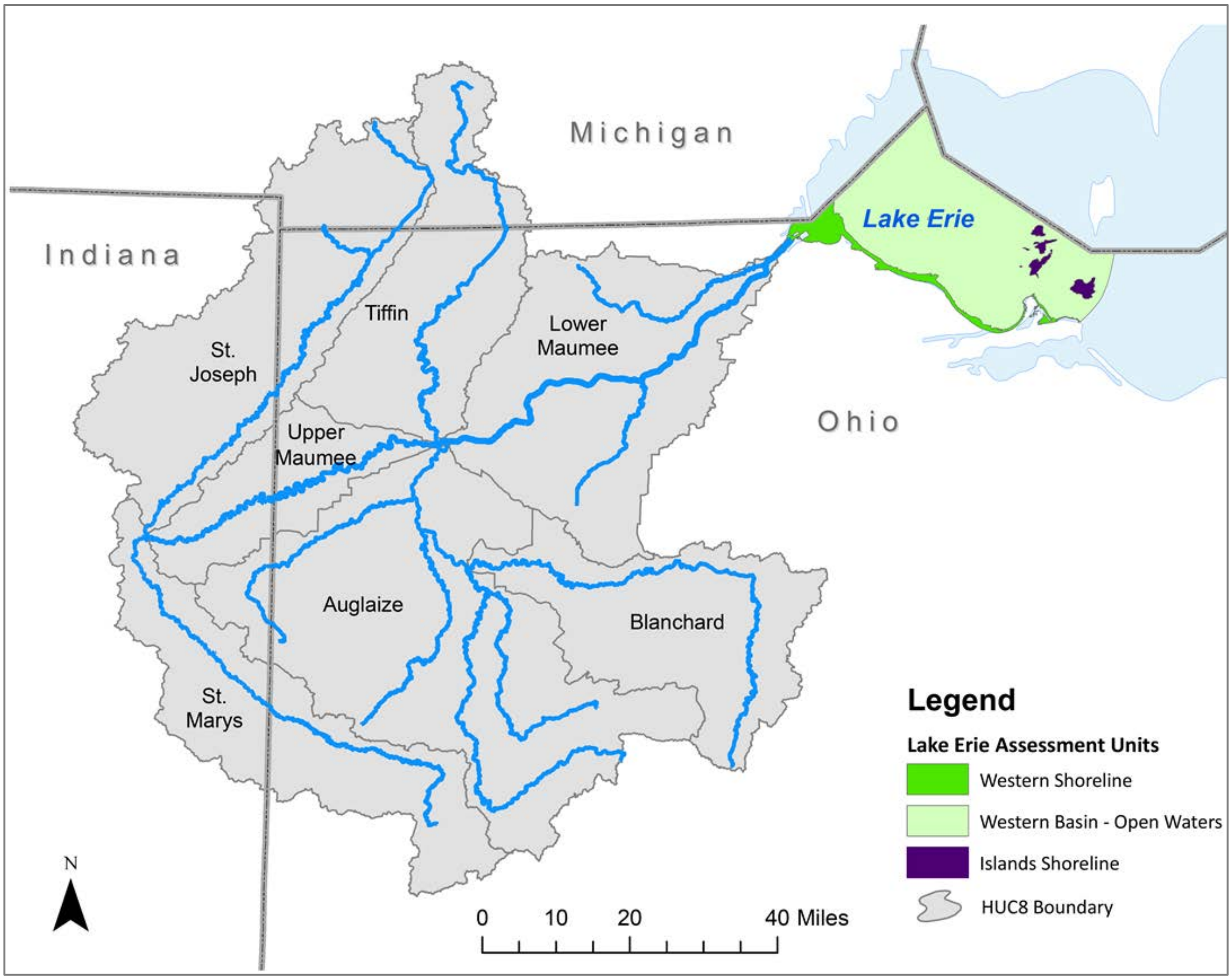


Figure 5. Map of Ohio's WLEB assessment units and the Maumee watershed.

Table 5. Maumee watershed HUC-8s included in this TMDL.

HUC-8 code	Watershed name	HUC-8 code	Watershed name
04100003*	St. Joseph River	04100007*	Auglaize River
04100004*	St. Marys River	04100008	Blanchard River
04100005*	Upper Maumee River	04100009	Lower Maumee River
04100006*	Tiffin River		

Note:

** Only the Ohio portions of these HUC 8s will be included in this TMDL's allocations*

Ohio EPA recognizes that the Maumee watershed targets to address Western Basin of Lake Erie HABs are developed for the Waterville, Ohio, monitoring location. Over 30 years of nutrient-loading data have been continuously collected at this location by the National Center for Water Quality Research at Heidelberg University (NCWQR). This monitoring includes water quality samples collected three times each day. If streamflow does not fluctuate during a given day, only one sample is analyzed for that day. The second and sometimes third samples are analyzed when the streamflow hydrograph indicates changes as determined by NCWQR staff. This monitoring location drains 6,306 square miles of the Maumee watershed's 6,607-square-mile area—more than 95 percent of the total. It is impractical to monitor continuous loads on the Maumee River further downstream of the Waterville location due to backwater conditions from Lake Erie's Maumee Bay. The measurements of load at Waterville will always be extremely important for tracking nutrients being delivered to Lake Erie from the Maumee River. It is also important, however, for this TMDL to account for the nutrient load being contributed to the Maumee River downstream of Waterville, to the mouth of the Maumee at the start of the Maumee Bay.

To include the area downstream of Waterville in this TMDL's target, the Annex 4's total phosphorus target must be extrapolated. The Annex 4 targets document noted that the 860 MT target for Waterville is "approximately a 40 percent reduction" from the 2008 baseline spring season used for target calculations. According to the NCWQR, the exact total phosphorus load at Waterville for the 2008 spring season is 1,414.1 MT. The 860 MT target is a 39.2 percent reduction from that baseline. Ohio EPA used nutrient mass balance methods, documented in Ohio's 2020 Domestic Action Plan (OLEC, 2020a; see Appendix A of that document), to determine that the load downstream of Waterville in the 2008 season contributed an additional 89.5 MT. This equates to a combined load of 1503.6 MT, including the area up and downstream of the Waterville pour point, in the 2008 spring season. Applying the 39.2 percent reduction from the Annex 4 targets document results in a full Maumee watershed total phosphorus target of 914.4 MT. To account for extreme weather years, loading targets are to be met in nine of 10 years.

Table 6 summarizes the targets that will be used for TMDL development. Only total phosphorus will be used to develop allocations; additional discussion on this TMDL management decision follows in Section 3.5.1. Allocations in the TMDL will be determined for the complete Maumee watershed using the 914.4 MT value. The target at the Waterville station will continue to be used as the primary tracking tool of TMDL implementation nutrient reduction success.

Table 6. Maumee watershed nutrient TMDL targets.

Location	Total phosphorus spring (March–July) target (in MT)
Maumee River at Waterville, Ohio 41.4998, -83.7140	860.0*
Maumee River at mouth/Maumee Bay 41.6937, -83.4682	914.4*

Note:
* To be met nine out of 10 years to account for interannual flow variability for the March–July period in extreme years.

3.4.2. Public drinking water supply use targets

The impairments to recreation use and public drinking water supply use in the Western Basin of Lake Erie are both linked to HABs, specifically those producing microcystin. Both impairments are addressed via the same TMDL. However, the metrics used to evaluate the two uses are different. The recreation use targets are derived from a biomass perspective and coverage across the wider lake. The drinking water use is based on toxin detections in the raw water intake of drinking water facilities. A recent publication (Chaffin et al., 2021) characterizes spatial and temporal dynamics of microcystins in the Western Basin of Lake Erie during HAB blooms. This research supports the concept that bloom toxicity (concentration of microcystins) correlates with metrics of bloom abundance. Thus, efforts to limit the extent, duration, and intensity of HAB blooms will correspond with smaller areas, periods, and concentrations of microcystin.

Based on past observations, when the bloom size meets the goals in Ohio's recreation use assessment methodology (the size of the HAB blooms in 2004 and 2012), the drinking water use was shown to be in attainment. Both the target years—2004 and 2012—occurred before routine compliance monitoring for total microcystin was undertaken by Ohio's public water systems per OAC 3745-90-03. However, in 2012 Ohio EPA staff sampled microcystin at public water system intakes and ambient locations (the data are accessible at epa.ohio.gov/wps/portal/gov/epa/monitor-pollution/pollution-issues/harmful-algae-blooms). Most (94 percent) of microcystin samples that year were below the detection limit. Although data showed that only three results near public water system intakes exceeded the water quality standard, all occurred within a one-week period. Were the current metrics in place at that time, the assessment unit would have been on Ohio EPA's watchlist (see Table 3), but it would not have been impaired.

Like the goals for recreation use, the assessment methodology for drinking water intakes allows for some excursions while not triggering an impaired status. The recreation targets are expected to be met in nine years out of 10, however the public drinking water supply use assessment is calculated over a five-year period. Therefore, achieving the recreation use goal would result in drinking water goals being met at least four out of five years. Based on this discussion, the same numeric TMDL targets outlined for recreation use in Section 3.4.1 are protective of public drinking water supply use.

3.4.3. Aquatic life use targets

To support the development of the Annex 4 targets, the Great Lakes Fisheries Commission–Lake Erie Committee (LEC) evaluated the impact of the targets on the lake's trophic status (Annex 4, 2015). The LEC promotes the maintenance of the mesotrophic status of the Western Basin to maintain the desired carrying capacity for a healthy and diverse fish community. The total phosphorus concentrations expected to maintain that status are in the 10–15 micrograms per liter (µg/L) range. The lake models used by the Annex 4 task team that developed the Annex 4 targets document found that the change in concentration in the Western Basin at the proposed 40 percent reduction would result in a reduction of the average concentration from 19 µg/L (2008 conditions) to 12–15 µg/L. While the target modeling was carried out to determined phosphorus reductions necessary to achieve HABs of acceptable sizes, reducing the lake's ambient phosphorus concentration is an ancillary benefit. These reductions move the lake from eutrophic to mesotrophic conditions and facilitate a healthy aquatic community.

Based on this discussion, the same numeric TMDL targets outlined for recreation use in Section 3.4.1 will be used to address aquatic life use impairments.

3.5. Proposed actions

Due to the nonattainment within these Lake Erie assessment units, this project will develop TMDLs as required by Section 303(d) of the Clean Water Act and U.S. EPA's Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations [CFR], Part 130). Specifically, total phosphorus TMDL allocations for the Maumee watershed are developed to address all applicable Lake Erie impairments. Table 7 summarizes the Lake Erie assessment units addressed by this project, showing their associated causes of impairment and the actions taken to address those impairments. Ohio EPA has assigned a high priority for TMDL development to these assessment units and impairments (Ohio EPA, 2020a).

The TMDLs for recreation use impairments due to algae will also directly address both the public drinking water and aquatic life use impairments. The same TMDL allocations will be applicable to address all three beneficial uses.

Table 7. Summary of impairments in Lake Erie and methods used to address impairments in the Maumee watershed.

Lake Erie assessment unit	Narrative description	Causes of impairment (Beneficial use in parentheses)	Action taken
041202000201	Western Basin Shoreline (≤3 meters depth)	Algae (Recreation use)	Maumee Watershed Nutrient TMDL: Total phosphorus allocations
		Algae: Cyanotoxins (Public drinking water use)	
		Nutrients (Aquatic life use)	
041202000301	Western Basin Open Water (>3 meters depth)	Algae (Recreation use)	
		Algae: Cyanotoxins (Public drinking water use)	
041202000101	Western Basin Islands Shoreline (≤3 meters depth)	Algae (Recreation use)	
		Algae: Cyanotoxins (Public drinking water use)	
		Nutrients (Aquatic life use)	

3.5.1 Total phosphorus as the modeled parameter

Only total phosphorus will be used to develop allocations. The science clearly shows that the total phosphorus and the DRP portion of total phosphorus need to be reduced, to meet the designated uses this TMDL addresses. Using total phosphorus for TMDL allocations is necessary at this time.

Part of this necessity is that it is more feasible to account for total phosphorus as it moves through the watershed compared to DRP (Appendix 1). Ohio EPA considered options to complete a DRP TMDL and found limitations to the current modeling science for determining allocations in all cases. Accounting for the nonconservative nature of DRP when modeling a watershed the size of the Maumee requires modeling of intricate kinetics. Many water quality models can represent these kinetics through complex equations that use many reaction rates. There is a wide range of acceptable values for these rates. Since several rates can work together to develop a satisfactory calibrated model, multiple ways of arriving at the same solution exist (Yuan and Koropeckyj-Cox, 2022). Given this and the fact that a TMDL must have finite allocations, DRP TMDL allocations would result in an unacceptable amount of uncertainty that could not be controlled. This influenced Ohio EPA's decision to use the approach of allocating only to total phosphorus. Using high-quality monitoring data in modeling the total phosphorus minimizes error. As noted in Appendix 1, numerous studies are underway to better refine DRP processes and impacts in the watershed. If a model with an acceptable level of error is identified in the future this new information could be used as justification for the TMDL to be revised.

Further, total phosphorus and DRP are related, as DRP represents a portion of total phosphorus. Various biological and chemical processes dynamically affect that proportion as DRP moves from its sources to Lake Erie. Those shifting processes result in DRP load reductions at times. At other times, particulate phosphorus releases DRP—adding to its load. These phenomena are being further explored through active research, as explained in Section 4.1.1.4 and Appendix 1.

While these factors make DRP untenable for allocations in the TMDL at this time, many actions are proposed so that DRP is adequately managed as a proportion of total phosphorus, including:

(1) Promoting the prioritization of management actions based on the impact on DRP losses at the source when developing planning documents.
(2) Evaluating ongoing research as part of the monitoring strategy. This research includes DRP and can inform adaptive management.
(3) Monitoring water quality throughout the watershed, including both total phosphorus and DRP; these data can inform adaptive management.

More details about the science considered to inform the management decision to allocate total phosphorus are outlined in Appendix 1.

3.5.2 Model selection

Ohio EPA considers many factors when deciding how to address impairments. The complexity of each impairment, including the primary origin of the pollutant, its delivery mechanisms, and the water body kinetics involved, will determine the complexity needed in a model. Additionally, Ohio EPA must take into consideration the ongoing efforts in the watershed, previous TMDL analyses, the questions to be answered by a model, and the amount of effort required to complete the model.

The linkage analysis and targets discussion (Section 3.3) of this report explains the Lake Erie nutrient-reduction recommendations that were developed by the Annex 4 Objectives and Targets Task Team to address HABs. These recommendations culminated in several modeling efforts of various methods and scope, which included complex limnological modeling. Because the nutrient-reduction recommendations determined by the Annex 4 Objectives and Targets Task team are final and as explained earlier, inform this TMDL for purposes of implementing applicable water quality standards, lake modeling is not needed. Instead, modeling for this TMDL focuses on nutrient source allocation within the Maumee watershed.

Ohio EPA evaluated different modeling methods for developing a TMDL for the Maumee River watershed to address impairments in the Western Basin of Lake Erie. Generally, watershed models fit into two broad categories: empirical (data-driven) and process models. Due to the prevalence in prior studies in this watershed, the model evaluation focused primarily on using the data-driven, mass balance modeling methods and process-based Soil and Water Assessment Tool (SWAT) modeling. Determining whether a data-driven or a process-based model is preferred in each situation requires weighing the pros and cons of the method with the available information and the unknowns (Table 8).

Table 8. TMDL modeling approach considerations.

Model Type	Pros	Cons
Data Driven (Mass Balance Method; Load Duration Curve; Sparrow)	- More easily understood - More reproducible - Based on observed data	- Static; cannot simulate future changes - Does not incorporate soil nutrient processes - Treats some pollutant sources conservatively
Process (SWAT; LSPC; WASP)	- Simulates on field nutrient processes - Dynamic; responds to changes in inputs (management, weather, etc.) - Many SWAT models already developed	- High cost/time investments - Multitude of variables - Higher degree of uncertainty with instream processes - Due to computational limitations and scale of the watershed parameterization is generalized

Notes:
LSPC= Loading Simulation Program in C++; WASP= Water Quality Analysis Simulation Program

Mass balance methods have long been used to support load-reduction strategies in the larger Great Lakes watershed. Mass balance methods were first used in the 1970s when efforts were initiated to reverse the cultural eutrophication of the Great Lakes (Dolan and Chapra, 2012). These initial mass balance modeling efforts were most recently extended to 1967–2013 for Lake Erie, as efforts to address the re-eutrophication and harmful algal blooms amplified (Maccoux et al., 2016). In 2015, the Ohio General Assembly added a statutory requirement (ORC 6111.03 [U]) stating that Ohio EPA will "study, examine, and calculate nutrient loading from point and nonpoint sources to determine comparative contributions by those sources, and report every two years." This statutory requirement resulted in a biennial report titled "Nutrient Mass Balance Study for Ohio's Major Rivers," published starting in 2016. Ohio EPA's mass balance studies sought to refine the mass balance methods to include sources that were not addressed in the previous efforts, most notably home sewage treatment systems (HSTS) and combined sewer overflows (CSOs) (Ohio EPA, 2020b).

Robust tributary and edge-of-field water quality monitoring in the region supports overall nutrient-reduction efforts by providing detailed information from loading sources and from loadings near the watershed outlet at the Waterville gaging station. This monitoring effort includes over 25 tributary monitoring stations throughout the Maumee watershed, most of which have a period of record of at least 10 years. With such abundant high-quality data available, the need for a process-based watershed model to quantify watershed loading is minimal. Mass balance methods are sufficiently effective at characterizing total phosphorus loading patterns and identifying needed source reductions.

Pollutants, including phosphorus, can experience losses or gains as water moves through the stream network because of settling, instream biogeochemical processes, and other factors. Mass balance methods consider these pollutant losses and gains because they are based on downstream monitoring data. The net change of loads is reflected at that downstream point. However, mass balance methods do treat loads from certain sources conservatively. Ohio's method considers that the point source (including CSOs) and calculated home sewage treatment system loads are completely delivered to the downstream pour point. As explained above, TMDL allocations will be carried out for total phosphorus in this project. For longer periods of time, such as the five-month loading period applicable to this TMDL, assuming the conservation of the total phosphorus point source loads is consistent with mass balance literature cited earlier in this section.

Both mass balance modeling and process-driven models (like SWAT) require that generalizing assumptions are made across the landscape to estimate nonpoint source loads. Mass balance methods aggregate loads from broad categories into one group. Complex mechanistic models require simplifying assumptions to be made so that agricultural practices are applied uniformly across the watershed. In both cases, this limits the detail captured about what specific landscape and management factors are driving loads higher on some fields than others. The data needed to parameterize a process-based model to represent these factors better are either unavailable (e.g., spatial soil test phosphorus) or too cumbersome to represent in the model framework (e.g., representing all fertilizer application windows). Whereas both methods share limitations from generalizing loads from the landscape, the mass balance model does not emphasize the link to a specific practice or location. This provides more flexibility for TMDL implementation at the local level, where facility-, farm-, and field-scale data can be considered.

Ultimately, Ohio EPA selected the mass balance model because high-quality data are available to inform such a data-driven approach model. Both efforts have issues with generalization due to the scale of the project area. However, the results of a data-driven model are more readily reproduced, and uncertainty is constrained by tying the loading estimates to measured data. The methods that Ohio uses for the Nutrient Mass Balance report are refined for this project's TMDL calculations to attribute loads to municipal separate storm sewer systems (MS4s) that were lumped with the nonpoint sources in previous efforts.

While the mass balance method was selected to develop the TMDL, process-driven SWAT models have been widely employed in the Maumee watershed and serve a valuable role in guiding implementation. For example, SWAT models have been used to evaluate the likely effectiveness of different best management practices (BMPs). Ohio EPA recognizes their usefulness in testing certain hypotheses about implementation and will continue to interact with institutions and researchers that use them to evaluate management practices and the impacts on watershed loading. Further, process-driven models that have been developed can offer additional perspective to verify that the mass balance methods are accurate representations of allocated sources. Although the mass balance model lacks predictive ability, results from research employing process-driven models will be used to inform implementation strategies.

3.5.3 Out-of-state loads

Although this TMDL is the state of Ohio's project, the mass balance method requires a calculation basis for the entire Maumee watershed. Seventy-three percent of the Maumee's watershed is within Ohio's borders. The remainder of the watershed is in Indiana (20 percent) and Michigan (7 percent). Ohio proposes to provide the TMDL allocations (i.e., load and wasteload) only for sources from within Ohio. Even though no allocations will be expressed for out-of-state loads, this project will provide a boundary condition load at the state line that reflects targets for Michigan and Indiana. Ohio is working with Indiana and Michigan on this project; these two states participated in the third module of initial outreach noted earlier in this document. Continued coordination between all three states will maximize nutrient reduction implementation practices and projects.

4. Phosphorus in the Maumee Watershed

This section explores the overall understanding of phosphorus in the Maumee watershed. It explains why phosphorus reductions are required to address the HAB impairments in the Western Basin. A comprehensive source assessment follows (section 4.1), which explains the overall phosphorus trends that facilitated the existing Western Basin of Lake Erie seasonal HABs. The source assessment is then broken down into four components: nonpoint source (section 4.1.1), point source (section 4.1.2), home sewage treatment (section 4.1.3), and instream processes (section 4.1.4). The nonpoint and point source components are further subdivided by detailed sources to adequately cover the breadth of information. These subsections document relevant research and available information regarding the nature of that source's phosphorus delivery mechanisms and its prevalence in the Maumee watershed. A discussion of critical source areas (CSAs) (section 4.2) looks at the heterogeneity of phosphorus delivered throughout the Maumee watershed. This is organized by examining efforts that study and/or manage phosphorus throughout the Maumee watershed. Finally, a summary of phosphorus sources in the Maumee watershed is provided (section 4.3).

4.1. Source assessment of phosphorus – in total and dissolved reactive forms

Source assessment is used in a TMDL project to identify and characterize pollutant sources by type, magnitude, and location (U.S. EPA, 1999a). This TMDL's source assessment leverages an extensive amount of water quality observations and studies that have taken place in the Maumee watershed. It is intended to be a very robust examination that provides a strong basis for pollutant-reduction implementation recommendations.

Active research, noted throughout this section, is expected to result in refinements to this understanding. Examining phosphorus movement processes and emerging science provides input for the TMDL's adaptive management cycle to inform modifications to implementation recommendations as needed.

Tributary water quality monitoring is a key component to understanding sources of phosphorus in the Maumee watershed. It is the foundation of most of the research discussed in this detailed assessment. Monitoring of the Maumee River near Waterville, Ohio, which has occurred since 1975 by the NCWQR, provides insight into what has changed over time. This location is 23 river miles upstream of the Maumee Bay (shown on Figure 6). This point is the farthest downstream regular monitoring location before the river becomes backwatered from Lake Erie.

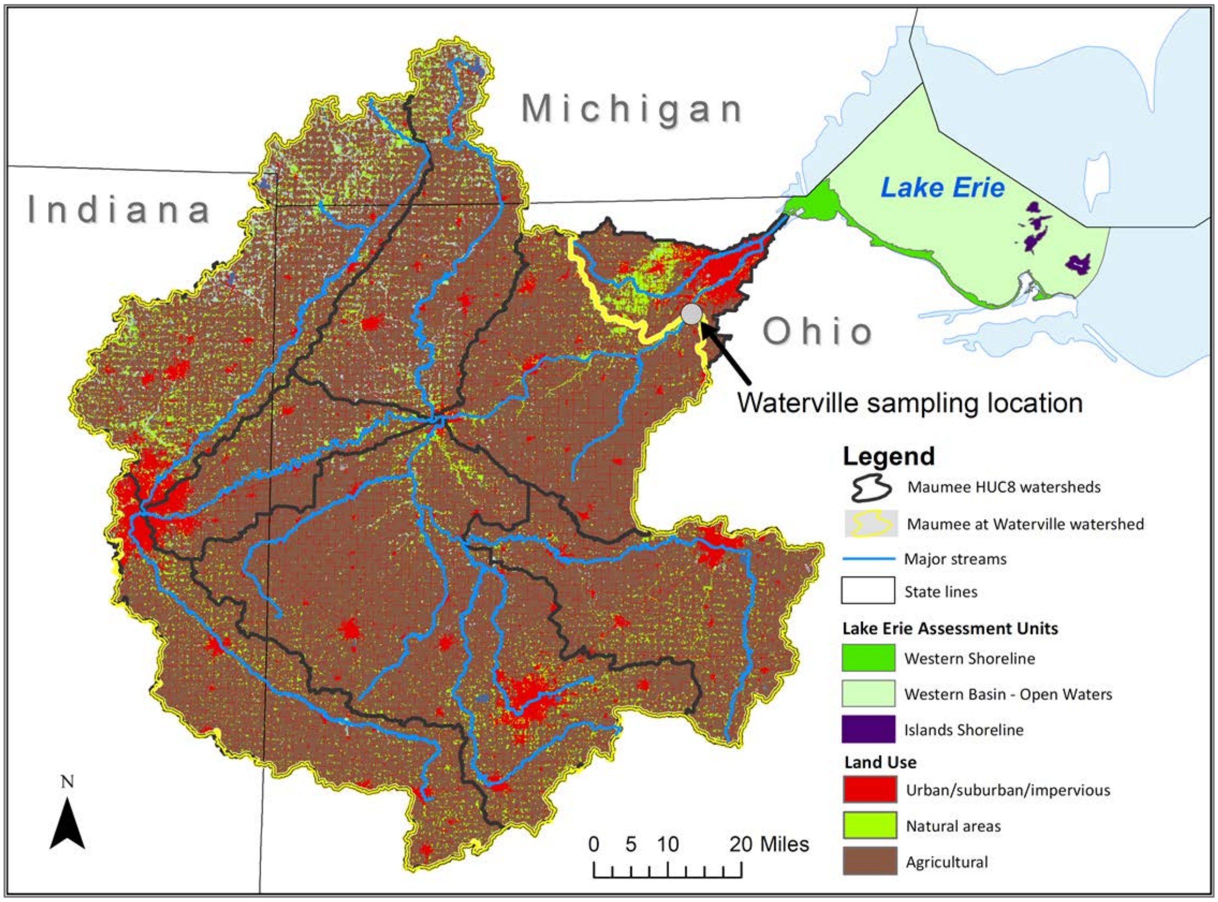


Figure 6. Maumee watershed map showing generalized land uses. The Waterville monitoring station is located with a gray dot. The part of the watershed draining to the Waterville monitoring station is highlighted as a yellow line.

Sample collection is automated at this location, with between one and three samples analyzed every day for several nutrient parameters and suspended sediments. These data are tied to the nearby United States Geological Survey (USGS) continuous streamflow gage at Waterville. With this wealth of sampling data, relatively straightforward analytical methods are carried out to calculate daily loads and FWMCs (NCWQR, 2022).

Of all the Lake Erie tributaries, the Maumee watershed contributes the greatest total phosphorus and related DRP load to the lake (Koltun, 2021; Maccoux et al., 2016). Figure 7 shows the Maumee watershed and its average total phosphorus load in relation to other Lake Erie watersheds. The Maumee delivers more than three and a half times as much phosphorus as the second greatest exporting watershed, the Sandusky River (Maccoux et al., 2016). Draining 6,570 square miles, the Maumee is the largest watershed to Lake Erie and is the largest river network drainage basin in all the Great Lakes (ODNR, 2018).

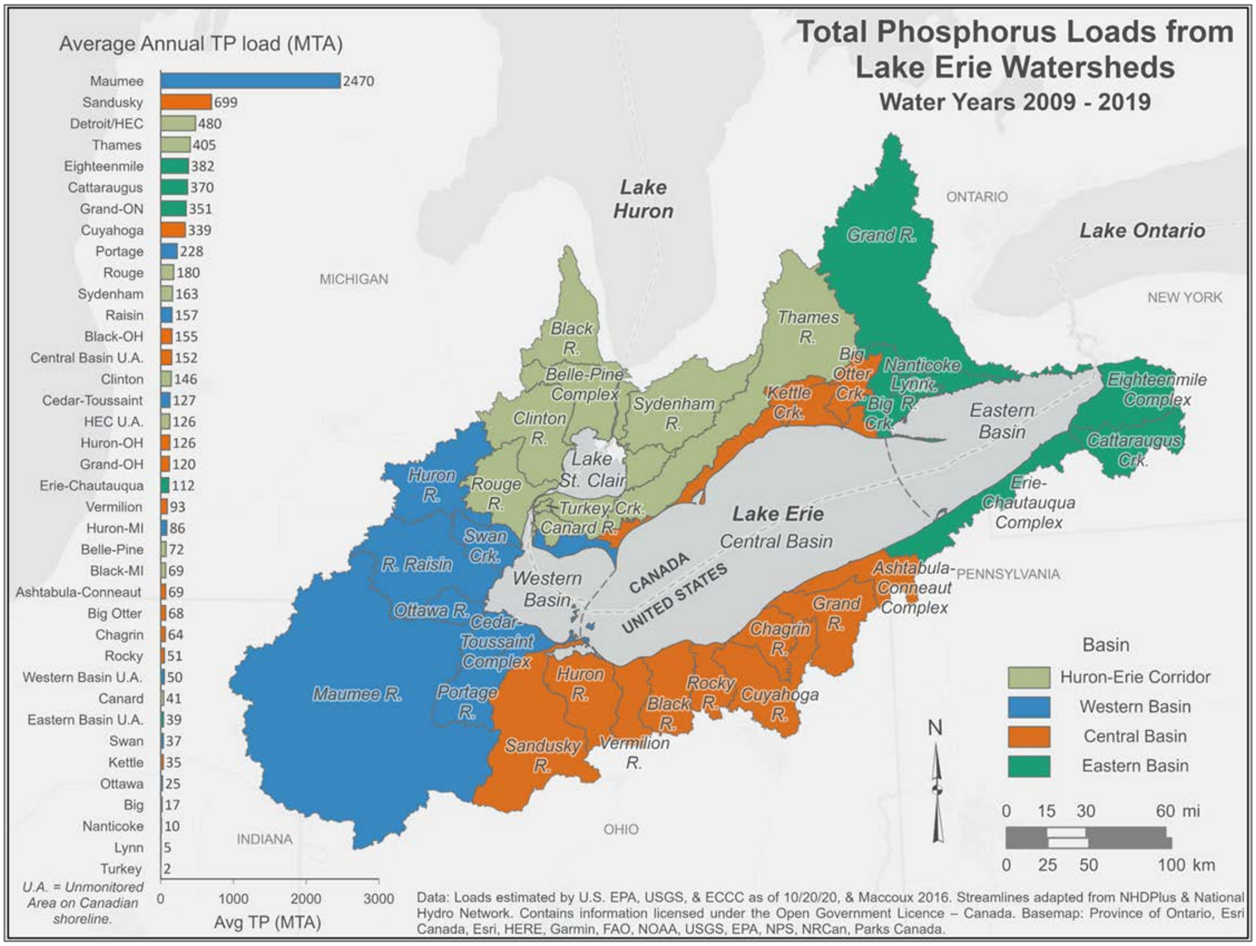


Figure 7. Lake Erie major watersheds are divided into contributing basins by color. The bar chart on the left arranges watersheds by average annual total phosphorus export (2009–2019) (Annex 4, 2021).

While its size certainly plays a role in the amount of exported load, elevated phosphorus concentrations show that the Maumee, and other WLEB tributaries, contribute more nutrients per unit area than other Lake Erie watersheds. For example, the Ohio Lake Erie Commission's (OLEC's) annual water monitoring fact sheet shows that phosphorus FWMCs of the Maumee, Portage, and Sandusky rivers are regularly greater than the Cuyahoga and Huron rivers (OLEC, 2020b).

The amount of streamflow in the Maumee River strongly influences the interannual variability in phosphorus loads and concentrations. A recent paper used flow-normalization techniques to evaluate nutrient trends over time at the Maumee River Waterville sampling location from 1982 through 2018 (Rowland et al., 2021). Flow normalization minimizes the effect of flow variability when interpreting trends in concentration and loads. Figure 8 shows the concentration and load annual results and trends for total phosphorus and DRP over the last several decades, with the flow-normalized trend overlaying the data. Note Rowland et al. (2021) uses soluble reactive phosphorus instead of DRP; however, these parameters are essentially equivalent, with only minor differences in analytical technique. The paper reports a steady and gradual decrease in total phosphorus over this time, whereas the DRP trend is more variable. The Maumee River initially showed a DRP reduction through the 1980s and then a stable, lower annual export through the early 1990s. DRP then increased for about a decade and has stabilized at an elevated level since 2006.

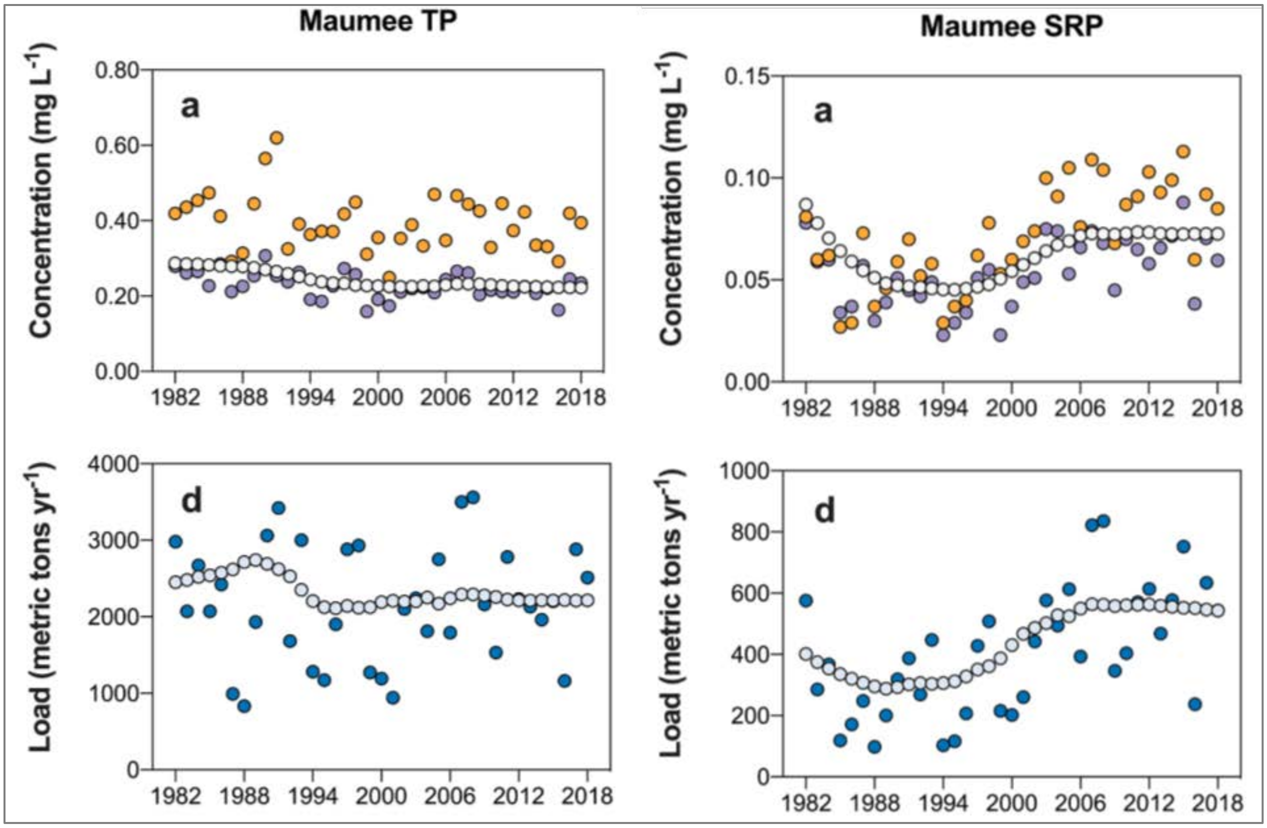


Figure 8. Total phosphorus (left) and DRP (right) water year annual concentrations (upper) and loads (lower) observed in the Maumee River at the Waterville monitoring station. In the concentration figures, the orange-filled circles are flow-weighted mean; the purple-filled circles are time-weighted. In the load figures, the blue-filled circles are actual observed loads. The circles with lighter colored fill in all figures are flow-normalized concentration or loads. Adapted from Rowland et al. (2021).

The timing of this DRP increases corresponds to the increase of the Western Basin of Lake Erie HABs discussed in the previous subsection. It is this elevated DRP export that the Maumee Watershed Nutrient TMDL project intends to remediate. This project utilizes total phosphorus as the TMDL parameter however implementation efforts are focused reducing the DRP portion. The remainder of this subsection will examine the sources of phosphorus within the Maumee watershed, with a focus on DRP.

Ohio EPA's Nutrient Mass Balance project provides a biennial nutrient analyses of the state's major tributaries (Ohio EPA, 2020b). The monitoring results from the NCWQR are used, with the Waterville sampling station employed for the Maumee's watershed assessment. In these analyses, the monitoring station locations are called "pour points." Various methods are used to calculate the loads from the watershed that are added between the pour point and the mouth of the river so that this area can be included in the analyses.

Ohio EPA's Nutrient Mass Balance study assigns total phosphorus loads to three coarse source categories:

- National Pollutant Discharge Elimination System (NPDES) – Discharging point sources that are covered by individual NPDES permits make up the NPDES load. This source consists mostly of effluent from public wastewater treatment plants. These loads are determined based on compiling the individual plants' self-monitoring of their effluent data. Loads from combined sewer overflows are also included in the NDPES category. Note that permitted stormwater is not included in the NPDES category of Ohio EPA's Nutrient Mass Balance work; instead, it is grouped with nonpoint sources. How permitted stormwater is characterized in this TMDL is further addressed in this source assessment.
- Home sewage treatment systems (HSTS) – Loads from HSTS are calculated based on unsewered population and various levels of treatment performance.

- Nonpoint sources (NPS) – The remaining load is attributed, or balanced, to nonpoint sources.

Ohio EPA's 2020 Nutrient Mass Balance report included an analysis of the spring loading season for Western Basin of Lake Erie tributaries. Figure 9 shows the Maumee's total phosphorus spring load broken down by the major source categories for the most recent seven years (Ohio EPA, 2020b). Nonpoint source loads contribute the vast majority of total phosphorus load to the Maumee—92 percent on average in the last five years. The NPDES and HSTS load contributed an average 6 percent and 2 percent of the spring total phosphorus load, respectively. The Nutrient Mass Balance determined that 79 percent of the land upstream of the Waterville pour point is used for agricultural production; this is evident on the map in Figure 6 above. Detailed analyses that links land uses to load contributions are presented in the next three subsections divided by the three major source categories: nonpoint sources, NPDES, and HSTS.

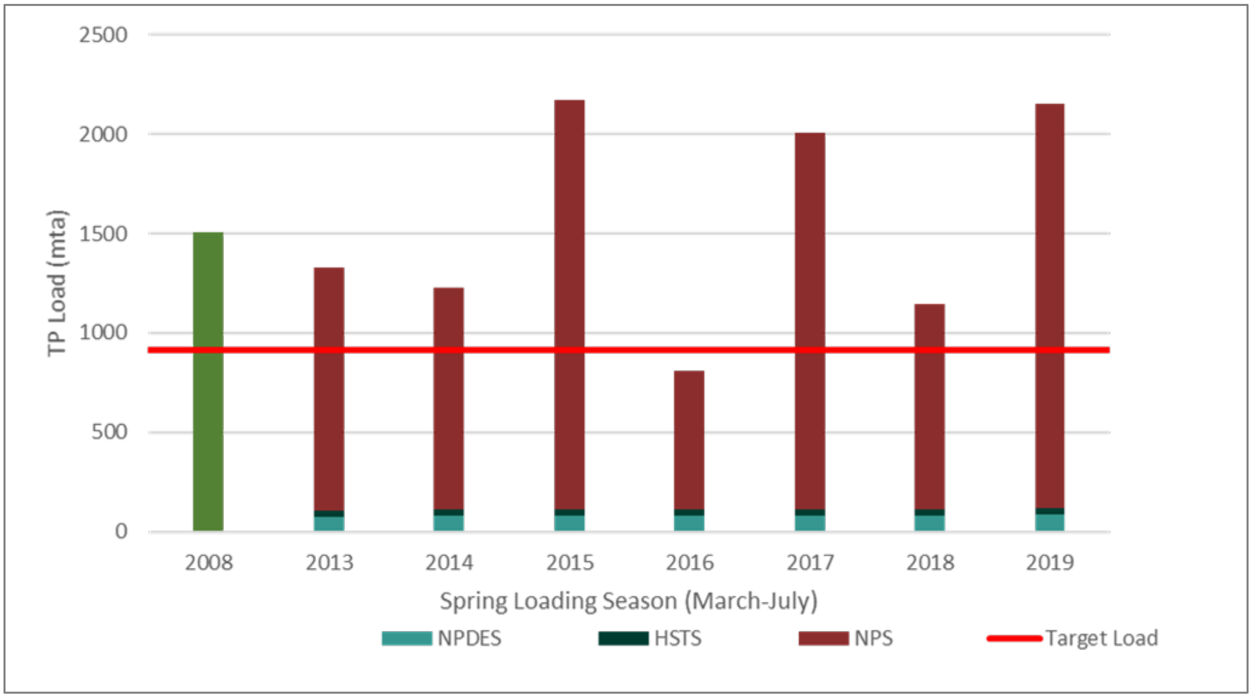


Figure 9. Maumee River total phosphorus loads for spring seasons in 2013–2019, broken out by Ohio EPA Nutrient Mass Balance major source categories. Note that the NPDES load in this work only includes the non-stormwater individual permitted load. For comparison with the Annex 4 reduction targets baseline, the 2008 spring season total load is also shown. (Ohio EPA, 2020b, Appendix A)

Process models, like SWAT provide an effective means to simulate pollutant movement in a watershed. SWAT is designed to simulate agricultural watersheds, allowing the model developers to incorporate detailed agronomic and conservation practices. Nutrients applied as fertilizers and existing in soils are accounted for in detail. They are removed with crops, discharged to waterways, or remain on fields for the next season. All additional nutrient exports in a watershed, including from point sources and HSTS, are incorporated in SWAT modeling. Precipitation input data drives the movement of water and pollutants, which includes a careful understanding of evapotranspiration, surface runoff, tile discharge, and ground water storage. Phosphorus is divided into inorganic and mineral pools, with several subdivisions throughout SWAT's modeled processes. These two major categories of phosphorus remain discrete at stream outlets (Neitsch et al., 2011). SWAT is, therefore, a useful tool in understanding the magnitude of existing sources of total phosphorus and DRP in a watershed.

SWAT models have been developed for the entire Maumee River watershed with high levels of detail (Kalcic et al., 2016; Scavia et al., 2017; Apostel et al., 2021). Academic efforts in the Maumee watershed have improved the baseline spatial resolution of SWAT models, even to the field scale. This work better represents tile drainage, nutrient soil stratification, and many other factors (Apostel et al., 2021). The sources of exported nutrients, including legacy soil phosphorus and manure as a fertilizer, have been described using SWAT outputs (Kast et al., 2019; Kast et al., 2021). SWAT has been used in addressing uncertainties in identifying pollutant CSAs (Evenson et al., 2021) and the time lag in legacy phosphorus reductions (Muenich, et al., 2016).

These improved models have been used to consider various BMPs to meet the Annex 4 targets discussed in this report. Some of these studies used multiple SWAT models (a method known as "ensemble modeling") to use the strength of various model parameterization choices in estimating the certainty of success for various BMP scenarios (Kalcic et al., 2016; Scavia et al., 2017; Martin et al., 2021).

The baseline, or existing conditions, results of SWAT modeling will be presented throughout this assessment evaluating existing sources of phosphorus. Content from all peer-reviewed research noted above will be included. However, the Kast et al. (2021) study is the most important to this analysis, as this work specifically focuses on source contributions of phosphorus loads from the Maumee watershed. Source contribution results from this study are summarized for the same March–July "spring loading period" applicable to this TMDL project. This work used a SWAT model calibrated to the data from 2005–2015 at the Waterville sampling location. A validation was carried out using data from 2000–2004. Calibration and validation statistics summarized by both monthly and daily time periods were found to be satisfactory.

SWAT modeling advancements are ongoing, concurrent with this TMDL's development. A project in the Maumee watershed is being carried out by OSU, University of Wisconsin, and University of Toledo to directly assess the state of Ohio's H2Ohio BMP programs (Harmful Algal Bloom Research Initiative [HABRI]/H2Ohio, 2020–2021). This project also intends to use remote sensing algorithms to improve model inputs of existing conservation practices for the baseline simulation. Additional ongoing studies are working to improve SWAT instream phosphorus cycling and how legacy phosphorus is modeled (HABRI, 2019; NRCS, 2021, respectively). The results of this work will be valuable to Ohio's adaptive implementation of this TMDL and help further refine this source assessment. In addition to discussions throughout this source assessment, Appendix 2 presents a detailed review of SWAT research in the Maumee.

4.1.1. Nonpoint sources of phosphorus

Recent research has contemplated why DRP increased from a low in the mid-1990s to causing the lake's current annual HABs. In 2015, researchers from the United States Department of Agriculture's (USDA's) Agricultural Research Service (ARS) outlined a list of 25 "theories" about the cause of this increase (Smith et al., 2015). These theories include a wide range of hypotheses, including changes to agricultural lands or management practices and invasive species. They note that multiple factors and their interactions are most likely driving the changes seen in the system. Nearly all these theories involve nonpoint sources of DRP. This section explores these nonpoint sources and considers how they many have contributed to the increase in DRP in the Maumee watershed.

Figure 9 shows that nonpoint source loads vary substantially from year to year. Guo et al. (2021) analyzed the magnitude of nutrient export during the spring loading season in the Maumee watershed. Figure 10 shows this relationship by plotting loading season Maumee DRP and particulate phosphorus loads against season streamflow discharge. (Particulate phosphorus is the portion of phosphorus attached to particles in the water; the sum of DRP and particulate phosphorus is total phosphorus.) This work shows that load-streamflow relationship measured in the Maumee River has been consistent since 2002. This reflects the fact that nonpoint sources are tightly linked to precipitation and the resulting streamflow.

Figure 11 also shows the relationship between discharge and spring season DRP load, illustrating how this trend differed between the 1983–1999 and 2000–2021 timeframes. The 2000–2021 timeframe shows both higher spring discharge events and higher DRP concentrations relative to the 1983–1999 timeframe.

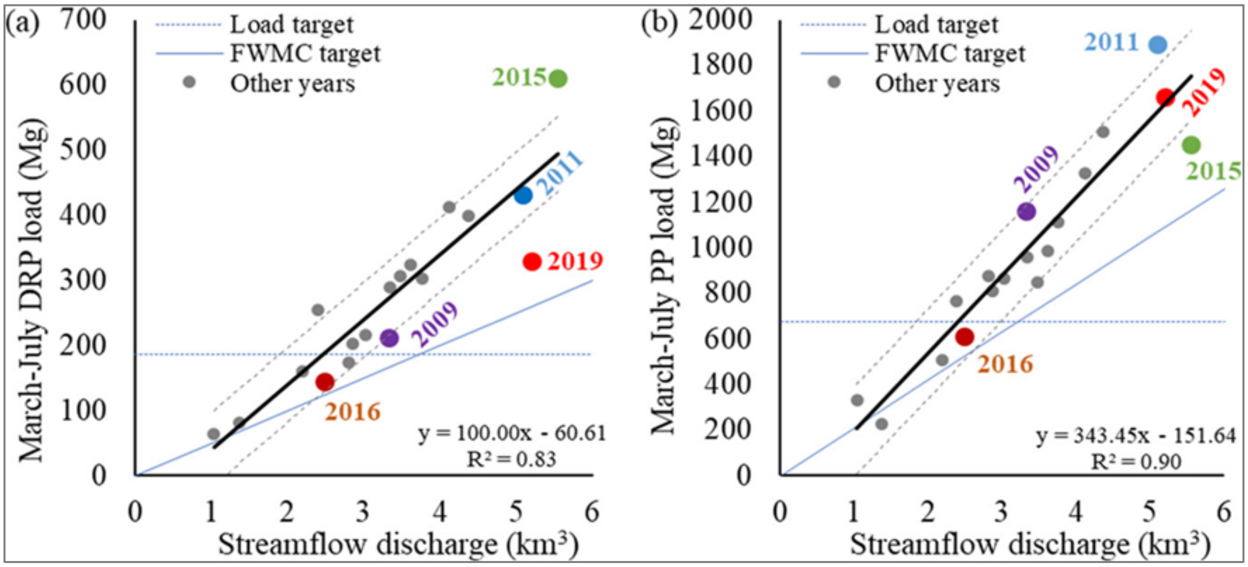


Figure 10. DRP load (a) and participate phosphorus (b) plotted against Maumee River "spring" loading season streamflow discharge showing results from 2002–2019, with several years labeled. The bold black lines show the linear relationship between load and discharge, with dashed gray lines showing 95th confidence intervals of that relationship. Other lines represent various target conditions (Guo et al., 2021).

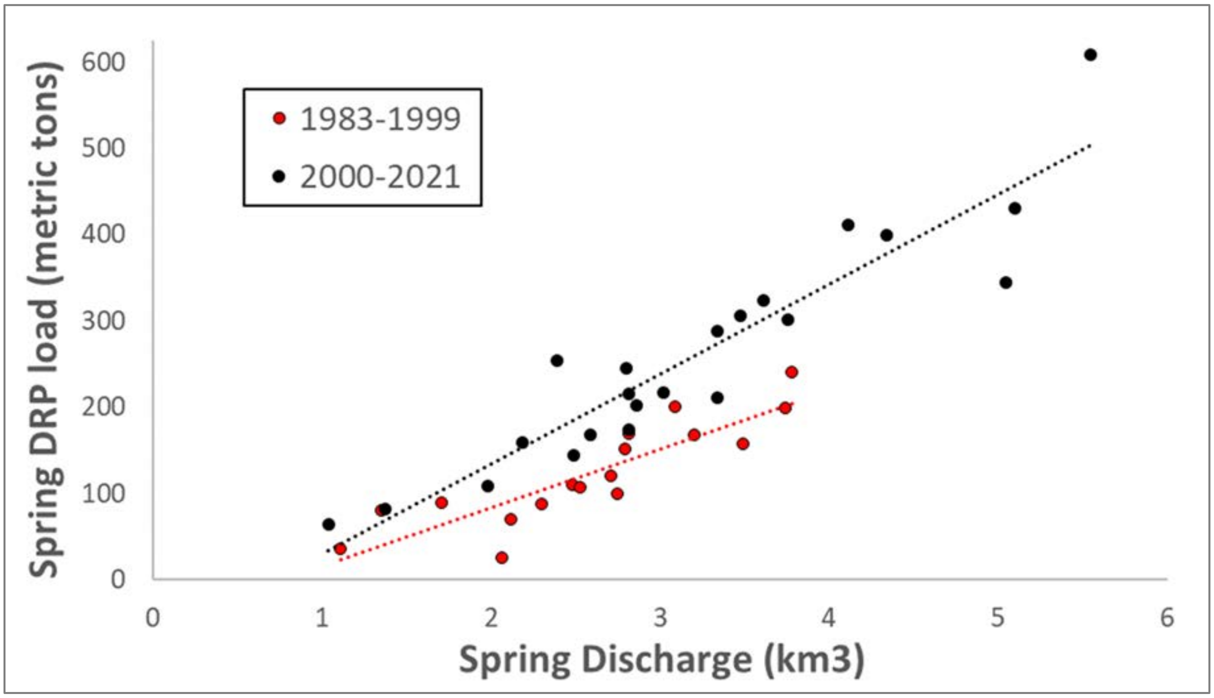


Figure 11. Spring (March–July) discharge plotted against the Maumee River spring loading season for two time periods, 1983–1999 (red dots) and 2000–2021 (black dots). Lines are a best fit of the linear relationship in the two time periods.

With the overall knowledge that the movement of water drives pollutants from nonpoint sources to the stream network, and ultimately to Lake Erie, the different types of nonpoint sources of phosphorus in the Maumee watershed are now discussed.

4.1.1.1. Row crop fertilizer sources: commercial and manure

Fertilizer use

Row crops predominate the land use in the Maumee watershed. Corn and soybean production, with some wheat rotations, occurs on 70 percent of the watershed's agricultural land area (Kalcic et al., 2016). Other crops, such as alfalfa, hay, and vegetables, are present but less common. Row crop agriculture requires certain phosphorus concentrations in the soil to achieve expected crop yields. Phosphorus fertilization, along with nitrogen and potassium, is often needed to maintain adequate soil concentrations. Many agronomic factors are considered when determining fertilization farm management decisions, such as the type and amount of fertilizer used. Many environmental factors come into play dictating if phosphorus used as fertilizer is exported off cropland to the Maumee watershed stream network and eventually to Lake Erie. This subsection explores these considerations and their implications for phosphorus export from fertilizer use.

There are two major categories of row crop phosphorus fertilizer: commercial (sometimes referred to as chemical or inorganic) and organic. Commercial phosphorus fertilizers are typically made by converting mineral rock phosphate to phosphoric acid, which then undergoes further chemical refinement. The resulting types of commercial fertilizers have varying concentrations of phosphate (the biologically available form of phosphorus) for crop uptake. The major categories are superphosphate, monoammonium phosphate, and diammonium phosphate.

Organic fertilizers consist of manure, composts, and biosolids. Manure is by far the leading organic fertilizer used in the Maumee watershed. Therefore, manure is the focus of organic fertilizer use in this source assessment. Chemical analyses are required to understand the available phosphorus content from different manure sources. The rate of decomposition of organic fertilizers in the field must also be understood. This allows producers to determine manure application rates that are equivalent to commercial fertilizers.

The rate of phosphorus fertilizer applied to fields in the Maumee watershed is generally determined by the Tri-State Recommendations (Culman et al., 2020). Figure 12 shows the conceptual framework for phosphorus fertilizer recommendations. These recommendations were revised in 2020 with the following updates:

- Critical levels were updated to reflect a shift to the new default Mehlich-3 extractant. Levels were practically unchanged, but the Mehlich-3 extractant typically yields a 35 percent higher soil test phosphorus than the Bray P1 extractant.
- The new standard identified that the build-up range is recommended, recognizing that economic or soil-specific factors may influence application decisions.
- The new standard removed the recommendation to apply phosphorus while excess soil phosphorus is drawn down to the maintenance limit.
- Updated the crop removal rates to reflect a decrease in the removal rates per bushel of grain.
- The critical level for phosphorus is 20 parts per million (ppm) with the maintenance limit of 40 ppm (30 ppm and 50 ppm, respectively, if wheat is in the rotation).

The timing of application for both manure and commercial fertilizer is dependent on cropping system and field conditions. Precipitation or poor drainage can result in soil moisture levels that prevent the farmer from operating equipment in the field. Proper timing of fertilizer application is also important to minimize risk of loss due to runoff or erosion.

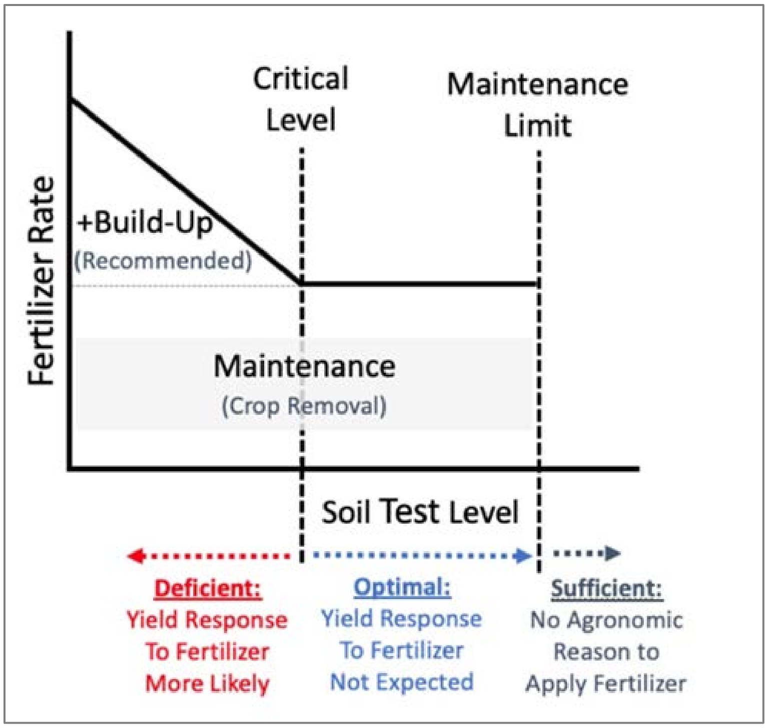


Figure 12. Figure shows the conceptual framework for fertilizer applications (Culman et al., 2020).

Commercial phosphorus fertilizer is typically applied in the fall after harvest or in the spring before planting. It is often applied in a formulation that includes nitrogen, such as monoammonium phosphate or diammonium phosphate. Fertilizer may be applied across a field at a flat rate or at a variable rate based on grid or zonal soil tests. Surface broadcasting fertilizer is common, but fertilizer on the soil surface is vulnerable to runoff. Incorporating fertilizer into the soil can reduce the risk of loss. Fertilizer incorporation can be done through tillage, which works the fertilizer into the soil, or by applying the fertilizer subsurface using specialized equipment.

Manure is often applied in the late summer or fall post-harvest, but it may be applied in the spring if field conditions allow or if needed for a growing crop. Injecting manure directly into the soil or incorporating it using tillage can reduce the runoff risk. Manure applications should follow the Ohio USDA Natural Resources Conservation Service (NRCS) Nutrient Management Practice Standard (Code 590) (USDA, 2020).

Oversight of manure application and commercial fertilizer is provided by the Ohio Department of Agriculture (ODA). This authority is divided between three ODA divisions:

- The ODA Division of Livestock Environmental Permitting (DLEP) has regulatory authority over Ohio's largest livestock and poultry operations, specifically the animal feeding facilities that are required to have a permit under ORC Chapter 903.

  DLEP is charged with regulating the construction and operation of Ohio's largest livestock and poultry facilities using science-based guidelines that protect the environment while allowing the facility to be productive. DLEP rules regulate how Ohio's largest livestock and poultry farms manage manure, wastewater, and nutrients, as well as control flies, rodents, and other pests. Permitted facilities, known as Concentrated Animal Feeding Facilities (CAFFs), are designed to have zero discharge of pollutants into the waters of the state from the production area.

  The Livestock Management Certification program ensures that managers and manure applicators receive training and are informed about using manure according to regulations and best practices.

- The ODA Division of Soil and Water Conservation (DSWC) has regulatory authority over manure application from most agricultural operations in Ohio, specifically those that do not possess a permit issued under ORC Chapter 903 or division (J) of Section 6111.03. The DSWC establishes a set of standards for management and conservation practices in farming and animal feeding operations to reduce pollution of waters of the state by soil sediment, animal manure, and residual farm products. This authority is granted through ORC Chapter 939.

  Enforcement of DSWC regulations is typically performed through a complaint process. If the DSWC receives a complaint alleging that an agricultural operation is not in compliance with these standards, then the DSWC will investigate. If the DSWC determines that the agricultural operation is in violation of the law, then the DSWC will seek to find a cooperative solution to return the operation to compliance. ODA may require corrective actions. If these corrective actions are not completed, ODA has the authority to issue a civil penalty of up to $10,000 per violation per day.

  ODA has entered into agreements with local SWCDs to implement these rules. These agreements give the SWCDs authority to investigate complaints, identify violations, and require corrective actions. SWCDs also assist ODA by providing landowners and farm operators with technical assistance, advice, expertise, and information about the level of conservation necessary to comply with the rules and standards.

- The ODA Division of Plant Health (DPH) has some regulatory authority over commercial fertilizer application. The DPH oversees the licensing program for the manufacture or distribution of commercial fertilizer in Ohio, including collecting annual tonnage reports for fertilizer sales. DPH also runs the Agricultural Fertilizer Applicator certification program. After Sept. 30, 2017, any individual in Ohio who applies or supervises the application of commercial fertilizer to more than 50 acres of agricultural production grown primarily for sale is required to be certified by ODA under the rules in OAC 901:5-4-02. Since 2017, more than 16,000 fertilizer applicators have received training through this program.

On Jan. 1, 2016, additional Ohio statutes came into effect restricting the application of manure and commercial fertilizer in the WLEB in Ohio. (The WLEB is defined by ORC 905.326 and comprises 11 HUC-8 watersheds. The Maumee watershed in Ohio is completely within the WLEB in Ohio.) These statutes, ORC 905.326 and 939.08, are colloquially referred to by their introduced legislation: Senate Bill 1. For applications of manure or fertilizer (defined as nitrogen or phosphorus) in the WLEB, a person may not apply:

- On snow-covered or frozen soil;
- When the top two inches of soil are saturated from precipitation; or,
- When the local weather forecast prediction for the application area contains a greater than 50 percent chance of precipitation exceeding one inch in a 12-hour period for granular commercial fertilizer or one-half inch in a 24-hour period for manure.

These requirements do not apply if the manure or commercial fertilizer is injected into the ground, incorporated within 24 hours of surface application, or applied to a growing crop. In the event of an emergency, manure can be applied in accordance with the Ohio USDA NRCS Nutrient Management Practice Standard (Code 590) with written consent from the director of ODA.

Commercial fertilizer sales can be used to determine the amount of commercial fertilizer applied to a given watershed. A study sponsored by the International Joint Commission (IJC) found commercial fertilizer to be responsible for 81 percent of fertilizer phosphorus applied to the United States portion of the WLEB's watersheds' croplands in 2006–2007 (IJC, 2018). That work noted commercial fertilizer use declining as more livestock operations concentrated their feeding operations. Moving livestock out of pastures results in more manure available for fertilization of cropland. This shift has brought attention to the number of livestock present in the Maumee watershed and the management of manure.

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 3. Figure 13 shows an estimated 88 percent increase of animal units from 2002 to 2017 in the Maumee watershed. However, this came after a decrease that bottomed out in the early 2000s, as shown in Figure 14. The analysis estimates that 5,100 MT of manure phosphorus were produced in the Maumee watershed in Ohio in 2017. Combining that estimate with an estimate of crop removal shows that manure phosphorus produced supplies approximately 23 percent of the crop need in the Maumee watershed in Ohio.

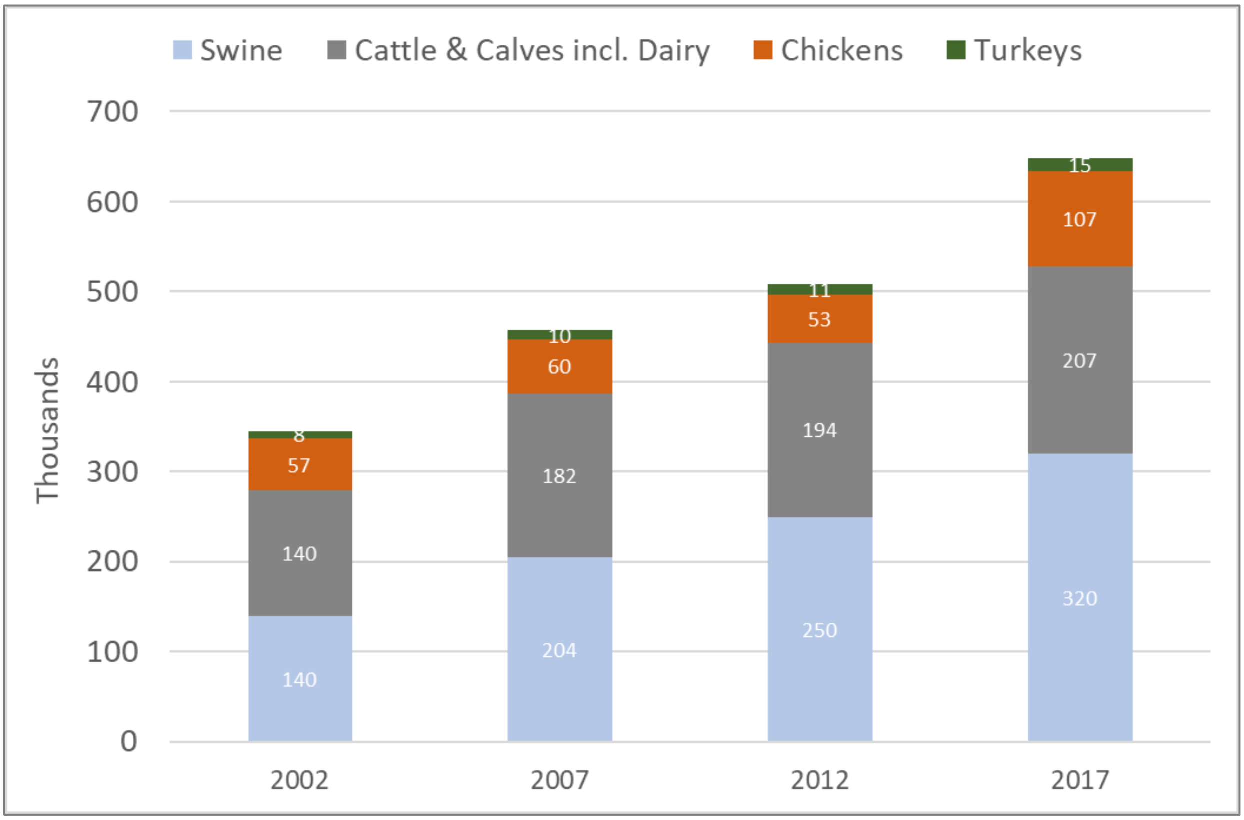


Figure 13. ODA estimate of animal unit capacity based on a combination of USDA's Census of Agriculture and ODA DLEP numbers.

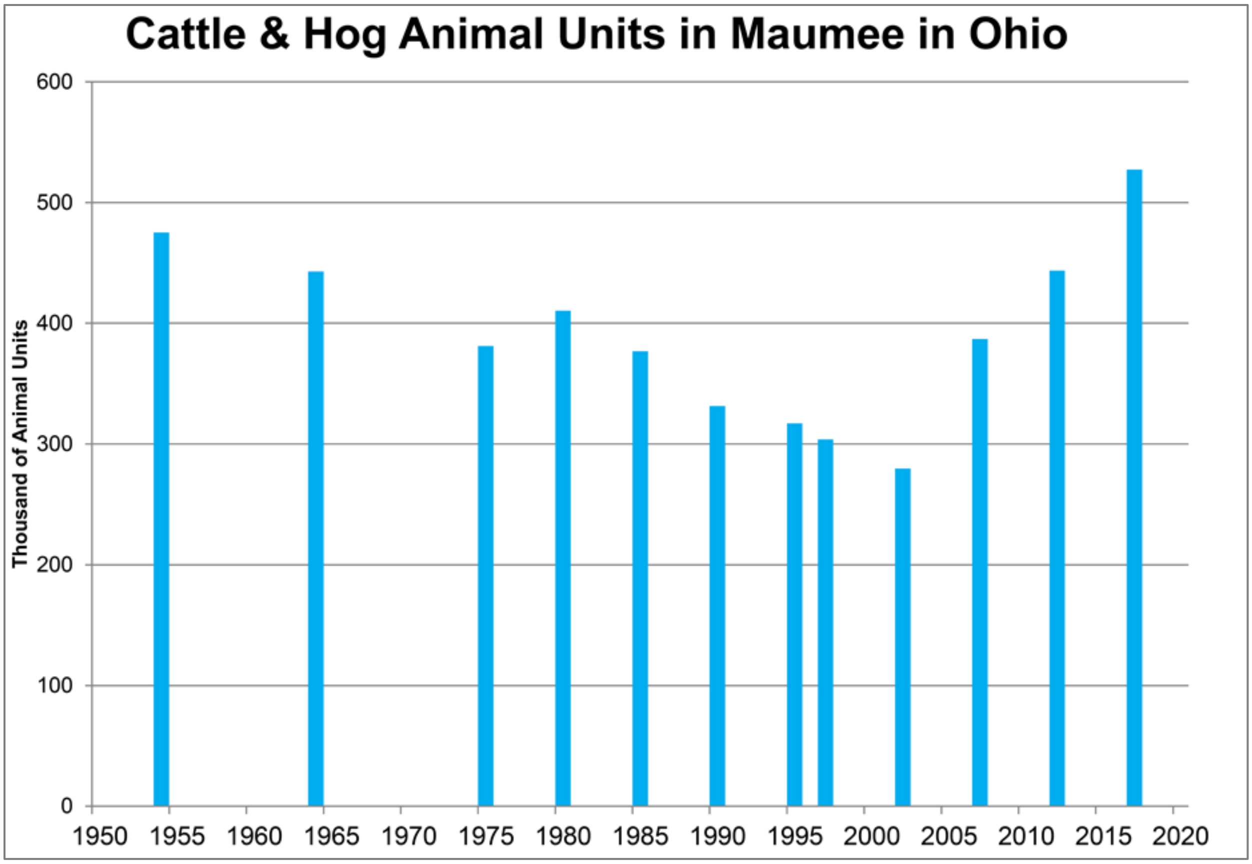


Figure 14. Capacity for cattle and hog animal units in the Maumee watershed have recently been trending upward based on ODA's analysis of the USDA Census of Agriculture.

As manure phosphorus production has increased in the watershed, commercial fertilizer use has decreased proportionally. This represents a shift in the relative contributions of fertilizer types rather than an increase in phosphorus application (EWG, 2019). Understanding the specific management of manure fertilizer is an important consideration for this source assessment.

Kast et al. (2019) examined concentrated animal feeding operation (CAFO)/CAFF manure management in the Maumee watershed. The authors found 79 percent of acres under the control of CAFO/CAFFs that receive manure had less than 50 ppm (using Bray-P1 procedures). However, that paper described the management of about 80 percent of the Maumee's manure phosphorus still represented a "knowledge gap" due to CAFO/CAFF manure transfers and non-permitted livestock operations. Work is underway to address this knowledge gap using publicly available data.

The Environmental Working Group (EWG) recently published a report on animal feeding operations in the WLEB (EWG, 2022). This work modifies NRCS' Agricultural Conservation Practice Framework toolbox to identify agricultural fields more likely to use manure as a nutrient source throughout the WLEB's 12-digit HUC (HUC-12) watersheds, which are small watershed management units. Farm-scale accounting of manure production is estimated throughout the watershed using this tool. This includes analyses of permitted CAFO/CAFF data, detailed review of aerial imagery to indicate locations and capacities of non-permitted facilities, and quality control activities such as comparisons with USDA Census of Agriculture. This work found that phosphorus from livestock manure produced in the WLEB supplies about 23 percent of the phosphorus removed by crops. Thus, the EWG estimate of manure phosphorus for crop need agrees with the ODA estimate described above for the Maumee watershed. Importantly, these independent studies used different methods and had similar findings.

An objective of the EWG (2022) research is to evaluate the spatial distribution of manure production and row crop fields throughout WLEB's watersheds and then identify fields at risk for overapplication of manure. This involves analyzing the proximity of manure application from each livestock operation following the methods of Porter and James (2020). The methods distribute manure to all available fields near livestock operations at agronomic rates. If more manure is available, the application continues to fields further away until it is completely used. EWG (2022) reported that some areas with the most livestock production require manure to be transported more than three miles away.

Several factors play a role in understanding manure distribution when assessing the risk of overapplication. These include the extent of manure being sold as a commodity, especially chicken litter, and the technology and practices used in cost-effective transportation of manure. At large poultry operations, chicken litter is often managed as a solid product that results in a high-nutrient-density product. Thus, chicken litter competes with commercial fertilizer as a marketed product that is economical to transport greater distances than liquid manure. In the Maumee watershed, CAFOs/CAFF house 8.7 million egg-laying hens and participate in the market-based manure utilization model. Thus, manure from these facilities competes with commercial fertilizer regionally and less directly with other nearby manure nutrients.

Fertilizer contribution to phosphorus pollution

Fertilizers, both commercial and manure, enter stream networks and contribute to phosphorus pollution. Fertilizer movement is generally precipitation-induced and inadvertent. These phosphorus losses are typically consistent with the definition of agricultural stormwater; thus, they are exempt from Clean Water Act regulation (CWA Section 502 (14): 40 CFR 122.23). A robust meta-analysis of research studies on this subject with authors from USDA's ARS found that generally less than 2 percent of applied phosphorus is lost from fields (Christianson et al., 2016). This environmental externality also impacts agricultural producers economically. It is, therefore, beneficial for all interests to mitigate phosphorus loss. Agricultural producers aim to minimize these costs while maintaining agronomic yield expectations. Many additional agricultural BMPs exist to address the risk of fertilizer phosphorus pollution. These are outlined in the implementation framework of this report.

Fertilizer, both commercial and manure, is at times lost from farms and fields in a way that is inconsistent with the definition of agricultural stormwater. These discharges are illicit according to federal and state regulations (see ORC Section 6111.04 and OAC 901:13-1, OAC 901:5, and OAC 901:10-1-10). When livestock operations are found to have a discharge of manure or other waste products, they are required to eliminate the discharge. They also may be required to pay a penalty and to obtain a permit from Ohio EPA and/or ODA to ensure that future discharges do not occur. When direct discharge events do occur, management actions are required to eliminate the source and mitigate the impact. Mitigation often results in much of the discharged material being removed from the surface water body. Overall, these discharges represent a small proportion of manure or commercial fertilizer applied in the watershed. For example, ODA DLEP has responded to five or fewer substantiated spills in each of the last five years (2017–2021). The ODA DLEP oversees manure application completed by CAFO/CAFF operations and certified livestock managers, representing a substantial amount of manure applied in the watershed.

Like all nonpoint source pollutants, fertilizer phosphorus loss from fields is driven by water movement. Large, infrequent precipitation events are known to drive most of the phosphorus exported from the Maumee watershed. Baker et al. (2014a) calculated 76 percent and 86 percent of the DRP and particulate phosphorus, respectively, is exported at high stream flows (i.e., during the 20 percent of the time with the highest flows). These high-precipitation, high-stream-flow events can overwhelm measures taken to avoid fertilizer phosphorus loss and make them less effective. Phosphorus from fertilizer is washed off fields and delivered to streams via runoff and subsurface tile drainage. Phosphorus can be attached to the soil, or other particles, in the particulate form or in the dissolved form most often monitored as DRP (Christianson et al., 2016). Phosphorus stored in soils that is naturally occurring and/or from prior crop fertilization (often referred to as legacy or soil phosphorus) is discussed in Section 4.1.1.2 below.

Manure overapplication near livestock operations may lead to phosphorus accumulation in soil, leading to greater export risk (see the discussion on agricultural soil and legacy phosphorus sources in Section 4.1.1.2). Studies have shown manure application occurs on soils with already-elevated available phosphorus and by overestimating crop yield/nutrient removal (Long et al., 2018). Kast et al. (2019) did not find evidence that this was widespread in fields under control by CAFOs/CAFFs in the Maumee watershed. These samples come from fields that use 66 percent of CAFO/CAFF swine and 37 percent of CAFO/CAFF cattle manure. CAFO/CAFF operations do not report soil test phosphorus data to Ohio state agencies for fields not under their control (including manure transferred from CAFO/CAFFs through distribution and utilization and smaller facilities).

Another process affecting nutrient movement from fertilizer applications is preferential flow, where soil cracks, earthworm burrows, and other soil fissures can lead to rapid transport to tile drains. This pathway exists for all applied nutrients. Incidences of manure discharges are more prevalent with liquid waste from swine and dairy operations (Hoorman and Shipitalo, 2006). Current nutrient management standards, state law, and state administrative codes have incorporated requirements aimed to reduce the risk of these discharge events. These requirements include many recommendations by Hoorman and Shipitalo (2006) and other studies. Practices exist to prevent the movement of manure or commercial fertilizer to tile lines, and include tillage to disrupt macropores, blocking tile lines to prevent discharge, limiting the volume of liquid waste that can be applied, prohibitions for snow covered/frozen ground, restrictions on soil water content, and more.

Consequently, when discharges of fertilizer—manure or commercial—are not consistent with the definition of agricultural stormwater, parties are often liable for civil penalties and damages. As discussed above, these discharges do sometimes occur and certainly cause local disturbances. However, these discharges are irregular and infrequent. They deliver a relatively small amount of the overall load compared to other sources.

Manure fertilizer form and application methods play a role in phosphorus loss. Surface broadcasting of liquid manure with no soil incorporation has been found to have higher total phosphorus and DRP export rates than other methods (Veith et al., 2011; Wang et al., 2022). Several studies have shown that the greater amount of water-soluble phosphorus content in manure fertilizer, the greater the amount of DRP export (summarized in LimnoTech, 2017 and Wang et al., 2022).

Using monitoring data collected at “irregular intervals” and for a different purpose, Waller et al. (2021) found small surface water total phosphorus concentration increases in two out of three Wisconsin watersheds downstream of large, confined livestock operations (a companion paper to this work included an economic analysis [Raff and Meyer, 2022]). The critical source analysis in Section 4.3 of this report examines phosphorus concentrations and loads from continuous monitoring throughout the Maumee watershed.

In other studies, manure as a fertilizer has been documented to increase soil organic matter, promoting infiltration, and thus reducing phosphorus loss (IJC, 2018). Another meta-analysis of research studies on phosphorus loss from agricultural fields found no significant difference in the range of total phosphorus and DRP export from commercial versus organic (manure) fertilizer applications, although the authors noted the sample size of comparable studies was not robust (Christianson et al., 2016).

A county-level study examined soil test phosphorus and farm soils phosphorus balance trends throughout Ohio (Dayton et al., 2020). This work found that from 1987 to 2014, 84 percent of Ohio counties had a negative phosphorus balance, which indicates that phosphorus outputs exceed inputs. All but two counties that drain to the Maumee watershed, Mercer and Lucas, were found to have a negative balance. This paper suggests that decreasing phosphorus inputs and managing soil phosphorus content sets the stage for reduced phosphorus export to streams.

A recent fertilizer study by ODA shows a decreasing trend in nitrogen and phosphorus fertilizer sales in the Maumee watershed since 2007 (for additional details see Appendix 3). The study evaluated fertilizer sales in the Maumee watershed, using annual statistics that are regularly tracked by ODA PHD. Those statistics show a 15–20 percent decrease in fertilizer sales from 2007 to 2020 (Figure 15). The relationship between fertilizer sales and crop removal was also examined. Crop removal estimates for corn, wheat, and soybeans in the Maumee watershed were calculated using National Agricultural Statistics Service data and crop removal rates from the Tri-State Fertilizer Recommendations. These data showed crop removal increasing while fertilizer application has decreased (Figure 15).

To further highlight the relationship, fertilizer application was examined as a ratio to crop removal (Figure 16). This ratio was consistently below 1.0 with a decreasing trend, which shows that nutrients applied through fertilizers were less than that removed through crop harvest. If crop removal exceeds fertilizer application, soil phosphorus levels will decrease over time.

Commercial fertilizer is the largest source of crop nutrients, but manure also contributes to crop needs. The combined phosphorus from commercial fertilizers and manure was graphed for 2007, 2012, and 2017 in Figure 17. The combined phosphorus values varied but were below crop removal.

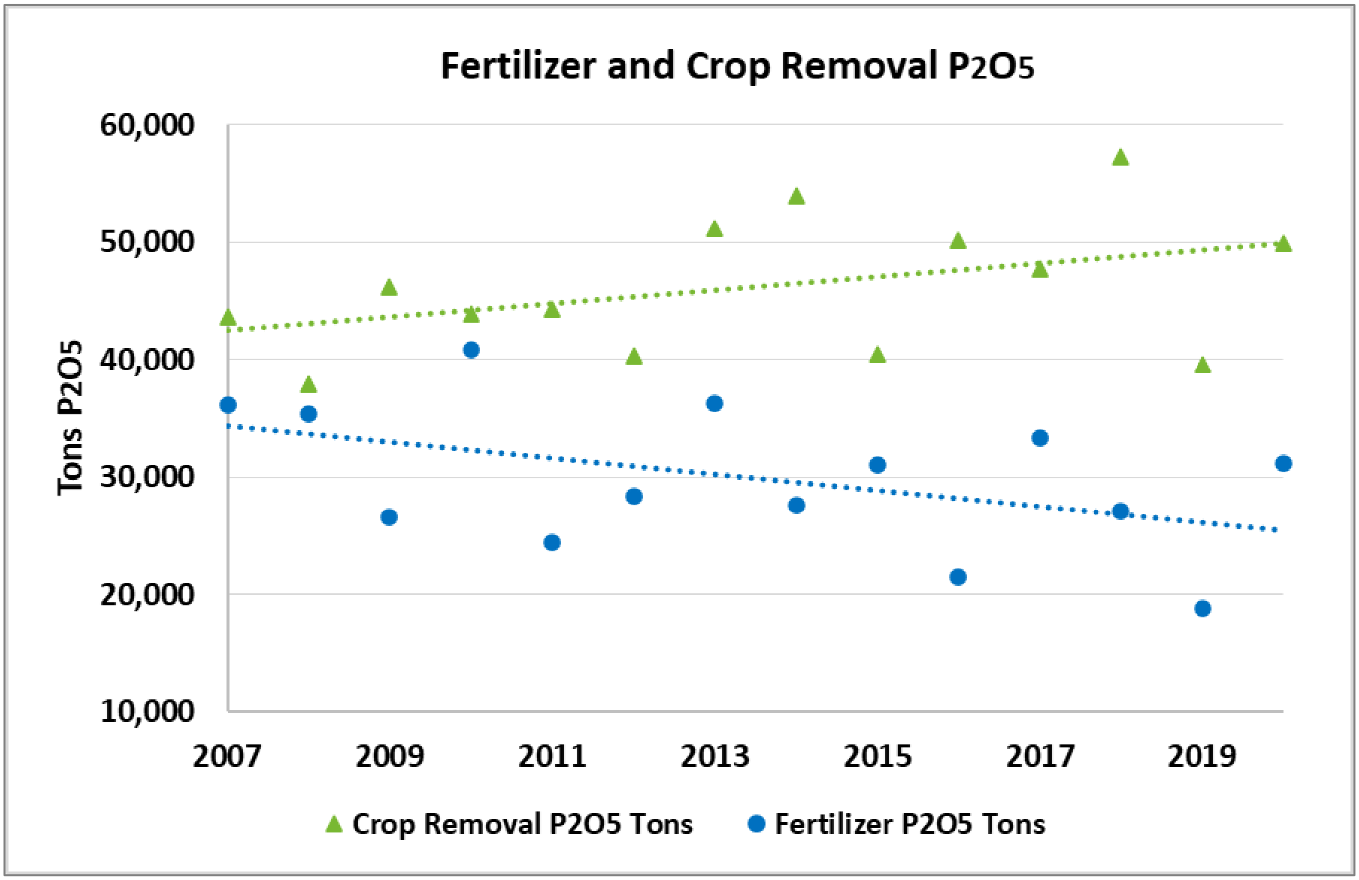


Figure 15. Tons of phosphorus pentoxide (P_2O_5) from fertilizer sales and corn, soybean, and wheat crop removal in the Maumee watershed from 2007 to 2020.

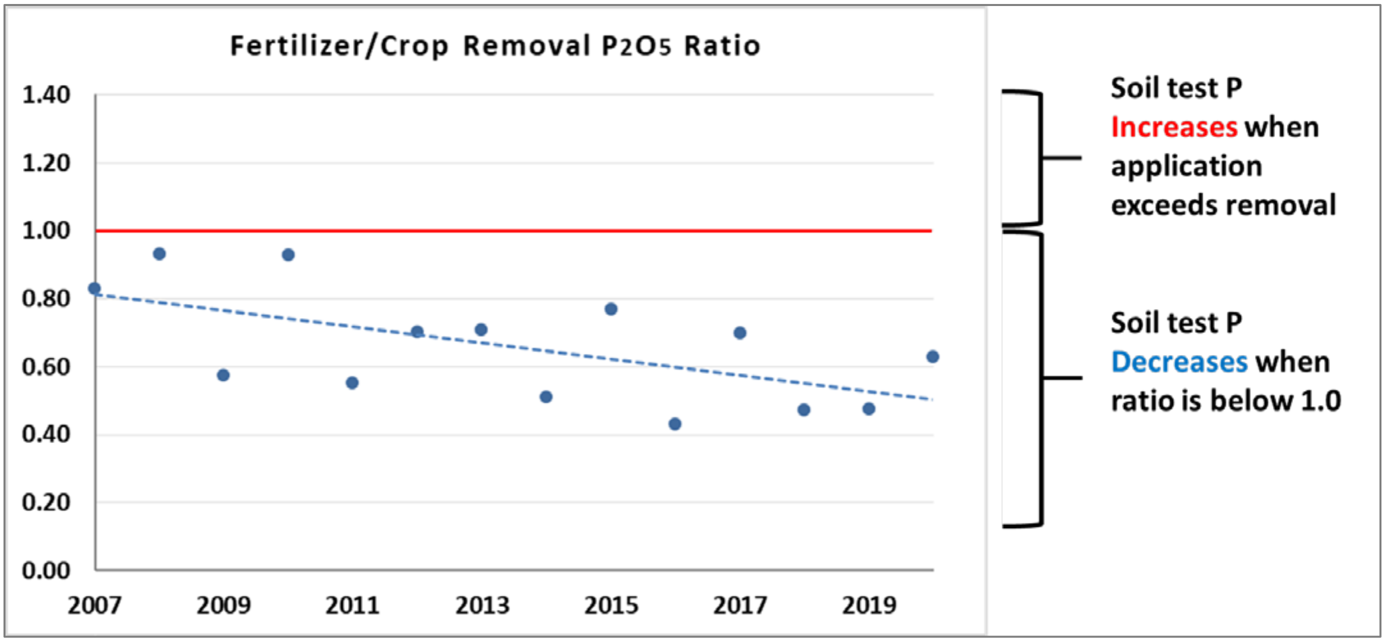


Figure 16. The ratio of P_2O_5 from fertilizer sales and crop removal from 2007 to 2020. A ratio below 1.0 indicates a net deficit of P_2O_5 in relation to crop needs.

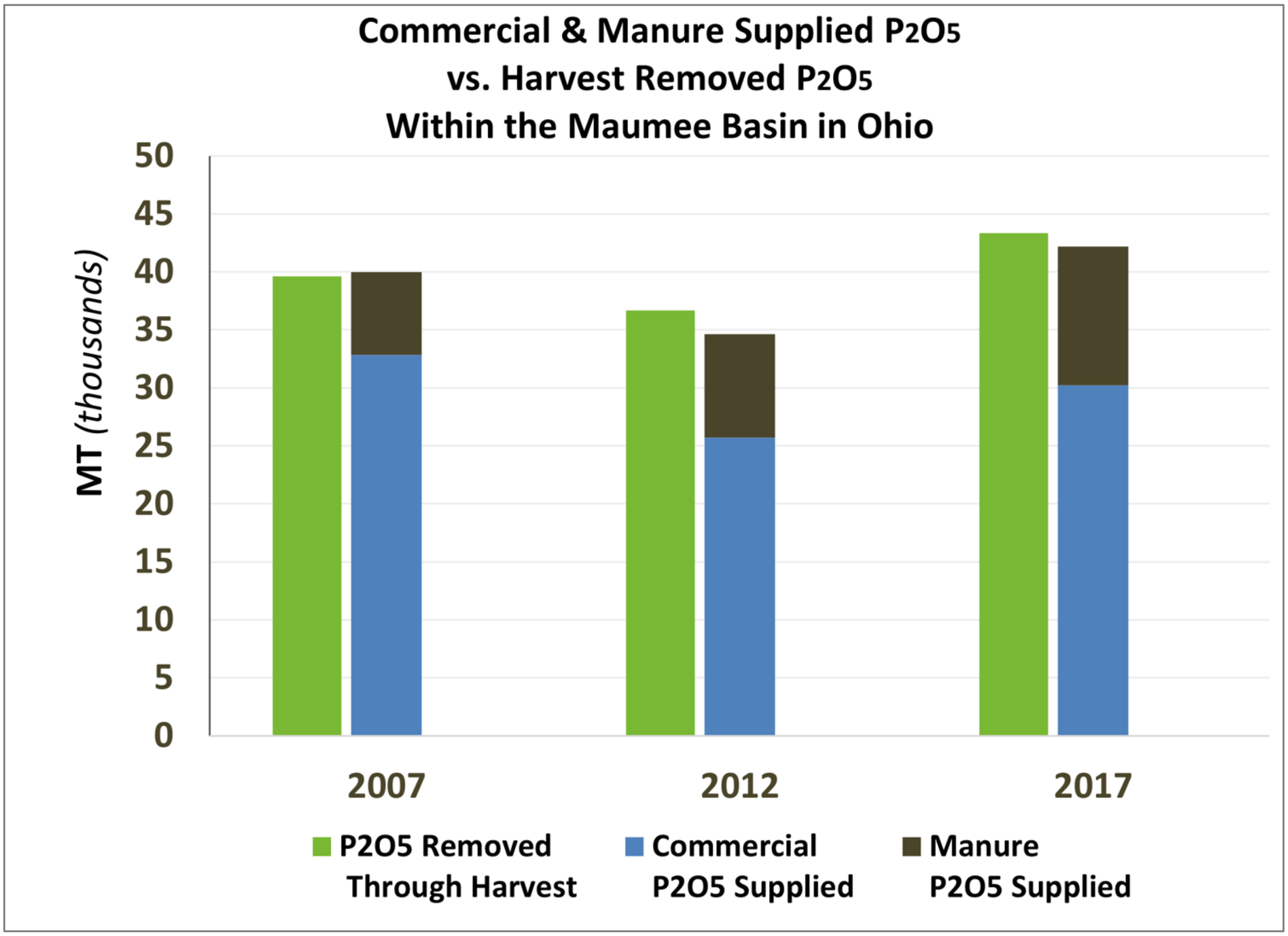


Figure 17. Harvest-removed P_2O_5 compared with combined P_2O_5 from commercial fertilizers and manure for 2007, 2012 and 2017.

In addition to evaluating research using empirically measured data, other modeling efforts offer additional insight into the role of different fertilizers in phosphorus export.

SWAT modeling was used to evaluate the impact of different sources of fertilizer. Commercial fertilizer contributes an average of 58 percent and 42 percent of the DRP and total phosphorus load, respectively, which is delivered to Maumee Bay during the spring loading months (Kast et al., 2021). That same study found manure fertilizer contributes 12 percent and 8 percent of DRP and total phosphorus load, respectively. Ensemble SWAT modeling presented by Martin et al. (2021) found eliminating manure resulted in 7.7 percent and 7.2 percent DRP and total phosphorus export reductions, respectively. According to Kast et al. (2021), commercial fertilizer contributed the greatest amount of DRP and the second-greatest amount of total phosphorus. The largest total phosphorus source contribution was from soil sources, which are discussed in the next subsection.

Kast et al. (2021) also used SWAT to evaluate the impact of liquid content in manure. SWAT does not include manure liquid content as an input; this potential model weakness is overcome by adding an irrigation event equivalent to the water content, a practice used in the Kast et al. (2021) model. To evaluate the impact of manure liquid content, Kast et al. (2021) performed a sensitivity analysis that eliminated the irrigation event and found little change to overall export.

In another example modeling scenario, Kast et al. (2021) cut the average initial soil phosphorus concentration by 75 percent, which reduced the export of DRP and total phosphorus by 29 percent and 24 percent, respectively. When they doubled the initial soil phosphorus concentration, the DRP and total phosphorus export increased by about 35 percent and 23 percent, respectively.

Kast et al. (2021) calculated delivery ratios that determine how much of the fertilizer applied to row crops is exported and delivered to the mouth of the Maumee River. Delivery ratios represent the amount applied compared to the amount transported to Lake Erie. Similar average delivery ratios were found for commercial and manure fertilizers: around 3 percent for total phosphorus and 1 percent for DRP. This is in line with the Christianson et al. (2016) meta-analysis that found no export difference between these fertilizer sources. Other statistical-based modeling in the overall Great Lakes region found no statistical difference between commercial and manure fertilizers' export to streams; both were around 2 percent (Robinson et al., 2019).

The assumptions used to determine the amount and location of manure application in the 2021 SWAT modeling paper are built upon work published by Kast et al. (2019), some of which is summarized above. Using assumptions similar to the EWG project outlined previously, this modeling work considered manure to be applied to about 18 percent of cropland at least once every six years (see Figure 18). The authors note that if fields receiving manure fertilizers have greater soil phosphorus than fields receiving commercial fertilizers, then the contribution of manure may be underestimated.

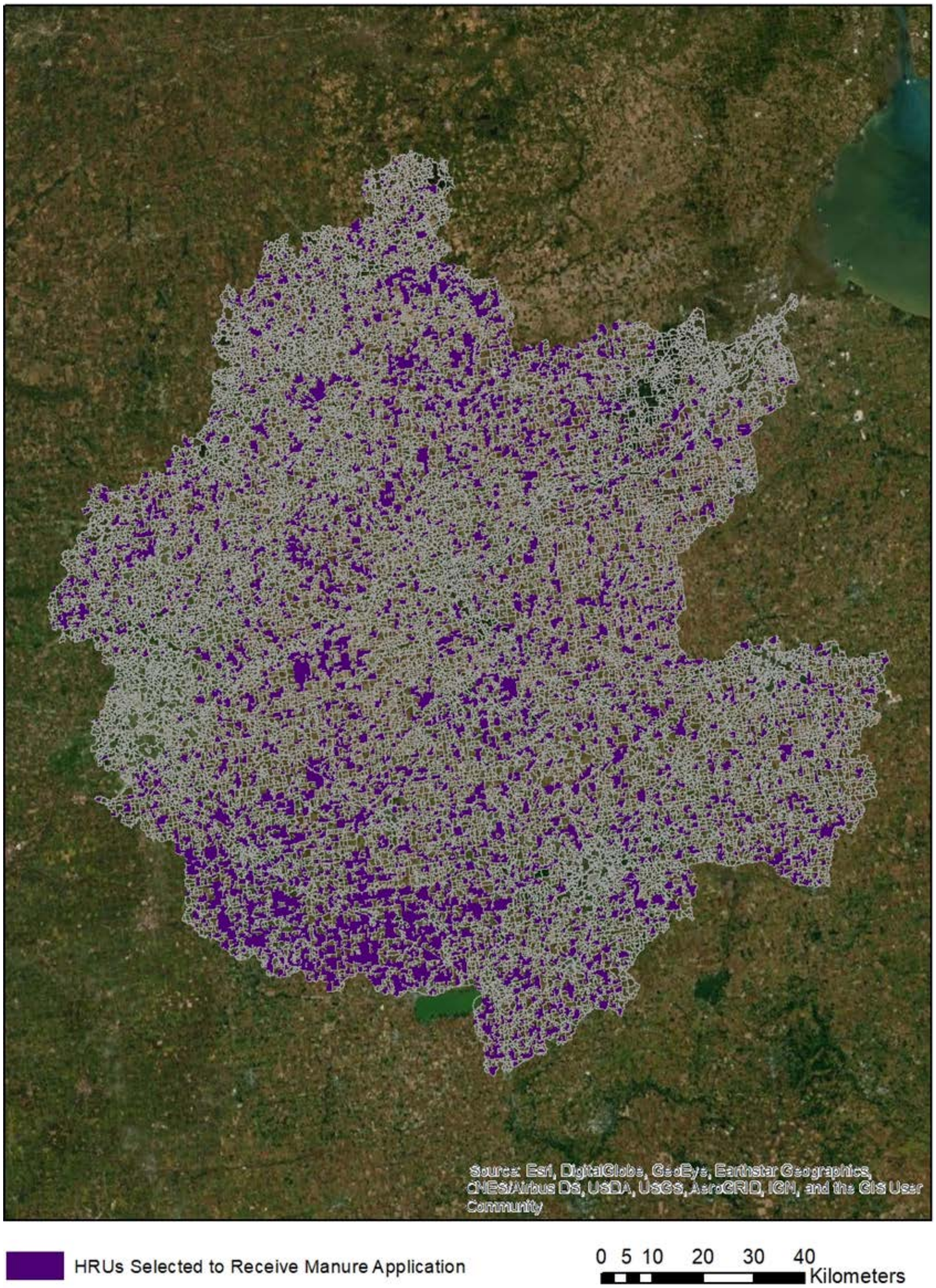

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 18. Locations of hydrologic response units (HRUs) chosen to receive manure applications within the watershed. Approximately 18 percent of the agricultural cropland was selected to receive manure applications at least once every six years (Kast et al., 2021: Supplemental Material).

A current SWAT modeling project examining H2Ohio practices will continue improving model performance. The model will incorporate more detailed existing conditions, including using actual soil test phosphorus concentrations as an input (most models us this as a calibration parameter), and existing BMPs (HABRI/H2Ohio, 2020–2021).

More information about SWAT modeling in the Maumee can be found in Appendix 2.

Fertilizer's role in increased DRP to Lake Erie

Examining fertilizer as a DRP source can help understand the increased levels of DRP the Maumee River has been delivering to Lake Erie, which began in the early 1990s and stabilized at an elevated level around 2006 (see discussion and Figure 8 above).

As explained earlier, the number of livestock and the amount of manure fertilizer used in the Maumee watershed has increased since the early 2000s. However, this increase occurred about a decade after the DRP increases started. In fact, it coincides more closely with when DRP loads stabilized, albeit at DRP levels considered unacceptably high. Also explained above, increased production and usage of manure as a fertilizer has co-occurred with reductions in commercial fertilizers and increases in crop removal. Given this information, factors other than the amount of fertilizer (commercial or manure) used must be explored to explain the observed DRP increases.

An IJC (2018) report on fertilizer found some type of conservation tillage has been employed in 63 percent of the WLEB watersheds' cropland, with adoption largely taking place in the early 1990s. The report notes that conservation tillage increases the accumulation of phosphorus in the uppermost layers of soil and promotes more soil macropores (worm holes). These factors make phosphorus more available for transport overland and via subsurface tile drains. This is exacerbated by increases in tile drainage in the Maumee watershed, which has grown to cover at least 86 percent of agricultural land in the Maumee watershed (LimnoTech, 2017). These changes coincide with the observed increase in DRP loads starting in the mid-1990s.

The DRP load in 2019 is highlighted in the Guo et al. (2021) study as it fell well below expectations given the amount of streamflow discharge that year (note the bright red dot on Figure 10 in panel A, several pages above). This load was 29 percent lower than predicted by flow alone and has been explained due to a 62 percent reduction in applied phosphorus fertilizer that year (the study considered both commercial and manure fertilizer sources). The reduction of application occurred in 2019 because the excessively wet conditions resulted in a record number of unplanted and unfertilized row crop fields. While a 62 percent reduction in fertilization is incompatible with sustaining crop yields, the quick, easily observable response to exported DRP loads in 2019 supports the idea that changing key agricultural management practices will, in fact, result in changes to nutrient export. It shows that improving fertilization rate, timing, and placement of phosphorus could quickly reduce DRP loads.

Row crop fertilizer (commercial or manure) applied in a given agronomic season is clearly a source of phosphorus exported to the Maumee watershed. The changes in agricultural field management noted above have increased the mobility of DRP from these fertilizers. However, these changes also increase mobility and export of phosphorus "left over" from previous fertilizations. These factors are considered next.

4.1.1.2. Agricultural soil and legacy sources

This discussion provides an overview of agricultural soil and legacy sources in the Maumee watershed. Phosphorus is naturally occurring in soils but also can accumulate in soil to higher-than-natural levels due to agricultural use. The term *legacy phosphorus* is used to describe different phenomena in soil and results in several definitions. However, they all share the concept of soil phosphorus from fertilizer or manure application in the past (legacy). Some definitions apply a threshold and discuss legacy phosphorus when the available soil phosphorus exceeds a certain level (e.g., 100 ppm-P Mehlich-3). Both perspectives are important when considering the impact of past fertilization on phosphorus loss.

Erosion of agricultural soils

Various human activities such as tilling cropland and clearing land for development can accelerate soil erosion. The loss of cropland soil negatively affects productivity. There are also several undesirable environmental impacts when soil enters stream networks. Physically, some of the soil settles out of suspension, smothers stream habitat, and fills pools. Some of it becomes suspended solids in the water column and makes the water murky, which can interfere with some organisms' ability to function. Chemically, phosphorus is attached to the soil particles and can become suspended in the water column as particulate phosphorus or be separated in the stream and dissolved into the water.

Over many decades, agricultural soil conservation efforts and construction stormwater standards have greatly reduced soil erosion and sediment delivered to streams. Agricultural tillage is performed to control weeds, prepare a seedbed, manage crop residue, and increase fertility (by providing a short-term stimulus to soil microbial activity). Tillage can increase the risk of erosion by breaking apart soil structure and reducing crop residue. "Conventional tillage" is soil inversion in the fall, winter, or spring that is typically performed with a moldboard plow, followed by a disc, harrow, or field cultivator. "Minimum tillage" replaces the moldboard plowing with chisel plowing, discing, or field cultivating. With "no-till," weed control is accomplished with herbicides, and the soil is not tilled. "Conservation tillage" is an umbrella term that refers to either minimum tillage or no-till.

This discussion provides an overview of these soil sources to the Maumee watershed from agricultural land uses.

Sediment exports to Lake Erie tripled from 1935 to the early 1970s. The IJC is a binational, independent institution formed to guide the United States and Canada in developing solutions to protecting the Great Lakes as outlined by the Boundary Waters Treaty. In 1972, the IJC facilitated the GLWQA, where both countries agreed to take actions to address eutrophication issues in Lake Erie. The export of phosphorus bound to soil loss was determined to be the largest source from agricultural lands, and soil conservation practices were prioritized (as summarized in NRCS, 2017). Additionally, through the late 1970s and early 1980s, the U.S. Army Corps of Engineers' Lake Erie Wastewater Management Study recommended a management program for agricultural sources of pollution (Logan and Adams, 1981). This study identified conservation tillage as the most cost-effective practice to reduce erosion risk and improve water quality.

As a result, conservation efforts in the 1980s were primarily focused on increasing the adoption of conservation tillage in northwest Ohio. This effort was considered successful, as the acreage of conservation tillage practices increased and the particulate phosphorus load to Lake Erie decreased. Conservation tillage was used on roughly 45 percent of cropland in the Maumee watershed by 1995 (NRCS, 2017).

NRCS (2017) documented that by 2012, existing conservation practices on the WLEB's cultivated croplands were responsible for an 80 percent decrease in sediment loss compared to if no practices were in place. Total phosphorus losses are 61 percent less, thanks to these practices. These pollutant reductions largely addressed excessive hypoxic and eutrophic conditions in Lake Erie (Michalak et al., 2013; Baker et al., 2014a; Kane et al., 2014).

The NRCS (2017) study also documented that soil conservation efforts led to a 65 percent reduction in sediment deposited in waterways throughout the watershed. This reduction in sediment has improved the ecological health of the waterways throughout the WLEB. Stream bed sedimentation and embeddedness is highly detrimental to instream (near-field) aquatic life (Henley et al., 2000). Ohio EPA historically documented sedimentation as the top cause of impairments to Ohio streams' aquatic life use. As conservation tillage acculturated, these issues progressively improved. Agricultural conservation has significantly improved stream impacts due to sedimentation in Ohio (Richards et al., 2009; Miltner, 2015).

Ohio EPA recently found the relative abundance of pollution-sensitive fish species in the Tiffin River (a Maumee tributary) has more than doubled since 1992 (Ohio EPA, 2015a). Most notable is the state-listed eastern sand darter (*Ammocrypta pellucida*), a species of concern in Ohio. The eastern sand darter is exceptionally sensitive to the excess silts and flocculent clays that can blanket the clean sandy substrates it requires for feeding and reproduction. These are the first Ohio EPA records of eastern sand darters in the Tiffin River basin. Historically, the eastern sand darter was widespread throughout the Maumee River and the lower portions of its tributaries. But the fish was nearly eliminated by the early 1900s due to habitat degradation and changes in land use practices that accelerated the delivery of silts and clays to river systems (Trautman, 1981). "Drastic improvements" of instream sediment impacts have also been documented in St. Joseph River tributary's watershed compared to the early 1990s (Ohio EPA, 2015b).

Although the reduced direct export of soils and attached phosphorus was largely considered a success, changes to row crop management brought unintentional consequences. It was noted in the early 1980s that "while no till can be expected to greatly decrease soil loss on land previously tilled, the main effect on phosphorus loads will be to significantly decrease the particulate phosphorus with no change or increase in soluble phosphorus" (Logan and Adams, 1981). This notable observation has important implications for today's DRP export delivered to Lake Erie.

Legacy sources

Sharpley, et al. (2013) describe legacy phosphorus as what has accumulated in soils because of prior nutrient applications and land management. That paper explains that water energy can mobilize particulate phosphorus in episodic waves to various accumulation points in a watershed. These points can occur on fields, at stream edges, in stream channels, and all the way to the downstream collection point, such as Lake Erie. Mobilization of dissolved phosphorus occurs from these accumulations. Various processes drive this mobilization, many of which include transformations of the form of phosphorus (often referred to as cycling). Details of these cycling processes are explained in Section 4.1.4. There are a great many factors that dictate the processes resulting in the movement of legacy phosphorus.

The texture of soils has been documented as an important factor regulating the movement of soil phosphorus. Sandy soils have a lower capacity to hold phosphorus chemically and can develop more flow pathways for dissolved phosphorus export than clay, silty, and loamy soils (Sharpley, 2006). Figure 19 shows the relationship between DRP overland runoff and soil phosphorus for two groups of soils from a central Pennsylvania study. Note the change points on this figure at certain soil phosphorus concentrations above which DRP runoff increases. Sharpley (2006) also documented similar change points for subsurface DRP loss; however, soil texture differences were not apparent.

Soil types vary throughout the Maumee watershed. The soil type and texture are important considerations in field-level nutrient management planning. This is discussed further in the Critical Source Assessment, Section 4.2.

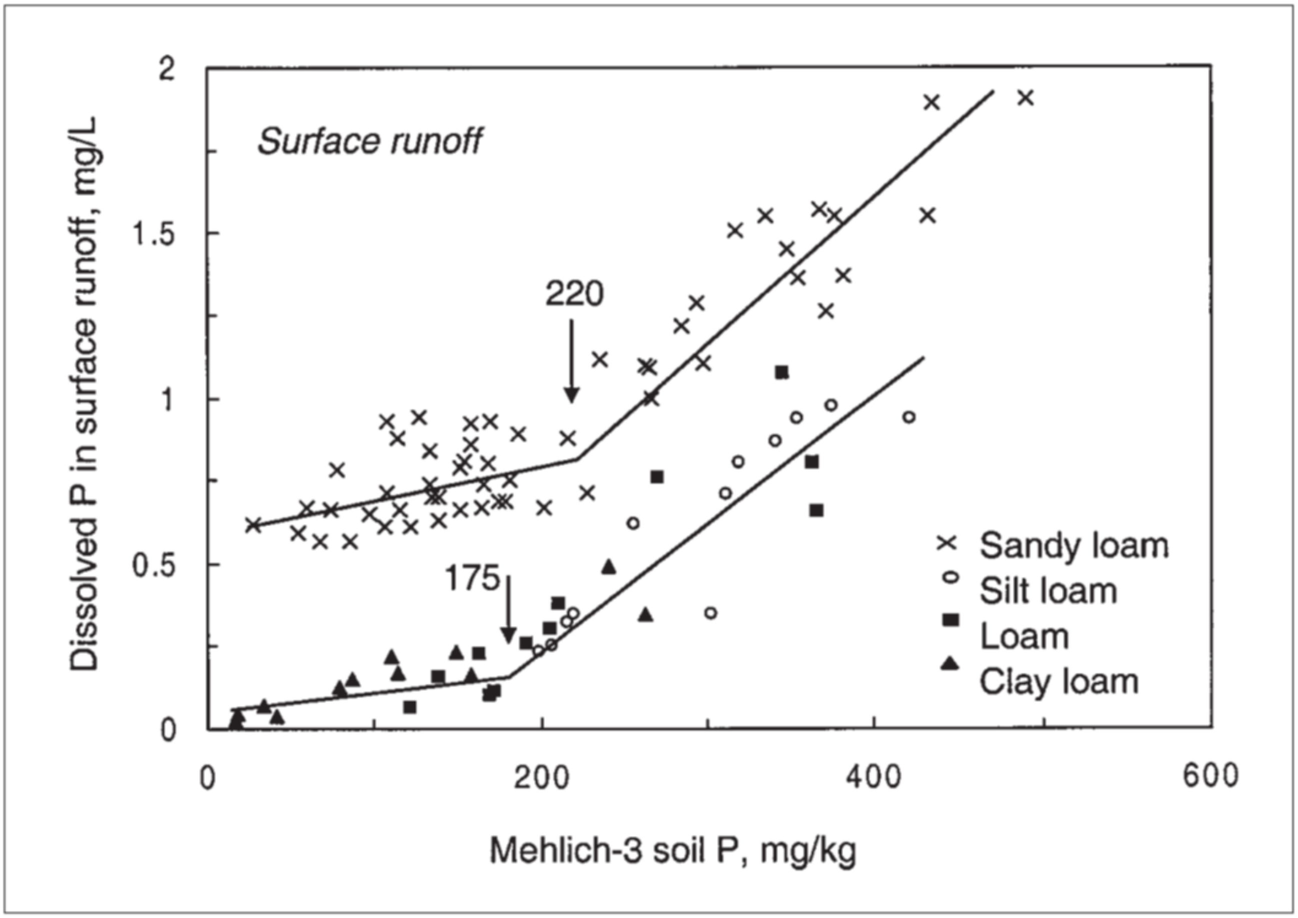


Figure 19. Relationship between DRP concentration in surface runoff and top layer soil phosphorus (P) (Sharpley 2006).

Legacy phosphorus is a persistent source of both total phosphorus and DRP to streams via tile and overland flow in the Maumee watershed, according to an ARS study published on the relationships of legacy phosphorus to various factors from 39 northwestern Ohio agricultural fields (Osterholz et al., 2020). Higher available soil phosphorus resulted in greater total phosphorus and DRP concentrations in tile and surface runoff. High-flow events were found to drive greater nutrient concentrations in nearly all tile flows studied. The concentration-to-flow relationship is more complex in surface runoff due to several factors, including dilution. However, the authors warn against extrapolating these results, partially because of limited surface runoff observations. Variation analyses found that tile flow concentrations are not as uniform as surface flow given similar flows. The authors suggest that this could be due to "activation" of macropores changing the flow pathways to the tiles before and during high-flow events. After considering all legacy phosphorus relationship factors, the study suggests there may be an available soil test phosphorus "threshold" above which DRP exports increase. This corresponds to the findings outlined in Sharpley (2006). Therefore, addressing elevated soil phosphorus in the most elevated fields will result in the greatest reduction of total phosphorus and DRP export concentrations. Osterholz et al. (2020) conclude by highlighting the "importance of identifying fields with enhanced risk of legacy phosphorus loss."

Ongoing research by the ARS in the WLEB to quantify the magnitude and mechanisms of legacy phosphorus movement is generating new findings (ARS, 2020). One of these areas of study is considering the magnitude of legacy phosphorus contributions to DRP loss through tile discharges. One recent study analyzed DRP loss from a well-drained row crop field in Indiana using hydrograph separation and other methods (Williams et al., 2022). The increased risk of phosphorus loss from fertilizer application decreases with time until it approaches the level of risk from the field before fertilization. The authors found greater than 50 percent of the tile flow's DRP loss was from phosphorus in the field/ground water system more than 30 days after the most recent fertilizer application, indicating the phosphorus already in the soil contributes much of the edge-of-field DRP loss. Using similar methods, this type of legacy phosphorus contribution has been estimated to contribute up to 70 percent of the tile DRP loss across Ohio's ARS edge-of-field assessment sites (King, 2022). Research continues to develop methods to differentiate legacy phosphorus from new fertilizer applications, including the use of stable isotopes (Bos et al., 2022). This research will continue improving the understanding how the contribution of phosphorus from contemporary fertilization compares to that of phosphorus already in agricultural soils. This is important for understanding of the impact of different management actions.

While the Sharpley/ARS research noted in the above paragraphs considers any phosphorus remaining in soils from previous fertilization as "legacy," other studies have narrowed this definition to those soils containing soil phosphorus levels above certain thresholds. Farm soil data are generally proprietary, making detailed analyses challenging. Research examining pooled soil data has found that over 5 percent of the soil samples in the WLEB have available phosphorus concentrations at levels greater than 100 milligrams (mg) per kilogram (kg) Mehlich-3 soil test phosphorus (Williams et al., 2015; Dayton et al., 2020). This is more than two times the level where additional phosphorus is not needed to achieve optimal yields.

OSU's Department of Food, Agricultural, and Biological Engineering has developed a public-private partnership with agricultural retailers to begin understanding the spatial extent of excessive accumulation of legacy soil phosphorus in a manner that protects the privacy of individual farm data. This effort has documented that elevated soil phosphorus often occurs in zones within fields rather than uniformly across fields (Brooker et al., 2021). This work also found that fields with sandy soils frequently have elevated soil phosphorus. This study documented elevated soil phosphorus in fields with a history of the application of manure or municipal biosolids, including one field with livestock operations and ongoing manure applications. One field with past vegetable production and one former orchard were also identified with elevated soil phosphorus. Sharpley et al. (2013) outline circumstances where elevated legacy phosphorus can result due to changes in agronomic phosphorus management.

Phosphorus from soils moves in waves downslope in a watershed to eventually be delivered to water bodies (Sharpley et al., 2013). Given advances in soil conservation practices, they often lead to the accumulated soil phosphorus arriving in waterways in the dissolved form (i.e., DRP). When legacy soil phosphorus is present at excessively high concentrations, phosphorus exports increase in tandem. Considering the threshold effect explained above, the phosphorus export that eventually occurs from elevated soil phosphorus may be much greater than from fields with soil phosphorus concentrations maintained in the typical agronomic range.

Soil and legacy sources contributing to phosphorus pollution

As explained in the fertilizer discussion above, the Guo et al. (2021) study highlighted a 29 percent lower-than-expected DRP exported load in 2019 (note the bright red dot on Figure 10 in panel A, several pages above). The 62 percent reduction in applied phosphorus fertilizer that year is postulated as the main reason for the observed DRP reductions. However, because DRP export reduction was less than half of the reduction of applied phosphorus, it suggests that legacy sources likely play an important role in export from fields. While 2019 was instructional, it remains uncertain exactly how to quantify the partition of DRP load between seasonally applied sources and legacy sources in a more-typical year.

Understanding legacy phosphorus as it moves through stream networks is a subject of active study. Streambank erosion, especially during high streamflow times, can be an important source of temporarily trapped legacy phosphorus (Williamson et al., 2021a). The cycling of phosphorus forms in stream channels plays a role in legacy phosphorus mobility and seems to have implications for the availability of the phosphorus exported to Lake Erie. These factors are considered in more detail in the 2.2.4 subsection below.

Recent Maumee watershed modeling suggests that soil sources of phosphorus (defined similarly as legacy phosphorus in studies above) contribute, on average, 18 percent of DRP and 45 percent of total phosphorus discharged from the watershed (Kast et al., 2021). This represents the greatest source of total phosphorus and second-greatest source of DRP from this study. Similar to active fertilizer sources, soil sources were found to contribute more in wet years and less in dry years.

Many assumptions are required for modeling nutrient movement through a watershed, especially in the case of legacy phosphorus. Elevated soil phosphorus concentrations throughout the watershed are managed at the field scale, and knowledge of their precise spatial extent is unavailable outside producer-level nutrient management planning. As noted in the fertilizer source discussion above, Kast et al. (2021) modeling used an assumed average soil phosphorus concentration based on soil samples throughout the watershed. Were an excessive number of fields to have much greater soil phosphorus, the modeled soil sources of exported phosphorus could be much greater. These uncertainties have been pointed out as one of the key challenges in nutrient-reduction efforts to control lake eutrophication (Jarvie et al., 2013).

Ongoing modeling is examining distributing differences of soil phosphorus throughout the watershed (HABRI/H2Ohio, 2020–2021). Following Arrueta Antequera (2020), this work will also consider simulating the effects of behavioral and landscape heterogeneity on nonpoint source pollution.

The Kast et al. (2021) modeling found soil sources increasing in the proportion of phosphorus delivered to Lake Erie when scenarios reduced the amount of fertilizer applied to row crops. These factors may prompt a necessary shift in nutrient-reduction implementation efforts or other measures to address a lag in nutrient export. Muenich et al. (2016) used SWAT to examine how long it would take for legacy phosphorus reductions to meet Annex 4 targets, given various modeling scenarios. This showed that the total phosphorus lag takes much longer than the DRP lag. The authors attributed this to the lower mobility of total phosphorus. This agrees with the Guo et al. (2021) observed findings of 2019’s DRP export below expectations given that year’s stream flow, while total phosphorus was correct on the relationship’s predicted export.

Hydrology greatly affected total phosphorus reductions in the Muenich et al. (2016) scenarios. In fact, total phosphorus targets were never met in modeling out 80 years into the future in extreme reduction scenarios, such as no new fertilizer applied, when stream flow and rainfall conditions were held at elevated levels.

More information about SWAT modeling in the Maumee watershed can be found in Appendix 2.

Soil and legacy source’s role in increased DRP to Lake Erie

Kast et al. (2021) SWAT modeling noted the severity of Lake Erie HABs was likely driven by precipitation changes, which were leading to increased soil contributions of phosphorus to the watershed. Note that the increase has occurred at a time when soil erosion and particulate phosphorus have declined. Therefore, the leaching of legacy phosphorus from soils is the most likely source of DRP increases.

Jarvie et al. (2017) documented changes in water quality from the Maumee, Sandusky, and River Raisin watersheds. All experienced similar DRP loading shifts as the Maumee. Net reductions of the particulate portion of total phosphorus and sediment were documented uniformly after 2002, while DRP increased. The authors attributed 65 percent of the DRP load increase to “increased source availability and/or increased transport efficiency of labile phosphorus fractions.” They link the DRP load increase to a combination of changes in agricultural land management that has shifted the type of phosphorus export from agricultural fields. The authors highlight the following as the leading management causes for this shift: “reduced tillage to minimize erosion and particulate phosphorus loss, and increased tile drainage to improve field operations and profitability.” Choquette et al. (2019) used different statistical approaches and also found that land management changes explained more of the increasing nutrient trends than hydrology increases.

Modern soil conservation has addressed a large proportion of direct soil erosion from agricultural areas. The environmental and agronomic benefits of soil conservation are well documented (Richards et al., 2009; Miltner, 2015). While unintentional consequences of these actions have been documented, reverting to farming practices that do not conserve soil is not an option.

However, the movement of phosphorus built up in soils via various pathways, often in the dissolved form, is clearly an important source requiring attention today. Areas where this legacy phosphorus is elevated are often described as CSAs. The Great Lakes Advisory Board provides advice and recommendations to U.S. EPA on implementing the Great Lake Restoration Initiative. In 2021, this board's nutrients workgroup recommended that resources be prioritized in identifying CSAs and reducing legacy phosphorus (GLAB, 2021). The IJC recommends that better soil phosphorus concentrations and vertical stratification databases be developed (IJC, 2018). The research outlined in this discussion (Osterholz et al., 2020; Kast et al., 2021; etc.) completely agrees with this priority. More is presented on the current state of identifying CSAs in Section 4.2 below.

The voluntary implementation of agricultural soil conservation practices has produced great environmental successes over the years. Tri-state fertilizer standards have been updated recently (Culman et al., 2020). Practices exist to reduce legacy phosphorus, such as targeted soil phosphorus draw-down and edge-of-field phosphorus filters. These actions are considered for TMDL implementation recommendations addressing both agricultural fertilizer and legacy sources of phosphorus export.

4.1.1.3. Non-agricultural stormwater sources

Non-agricultural (non-ag) stormwater sources of phosphorus exported to the Maumee watershed also contribute to total phosphorus and DRP loading. Non-ag stormwater contributions originate from 11 percent of Ohio's portion of the Maumee watershed. This is calculated by summing the four developed land use categories in the 2019 National Land Cover Database (NLCD) and dividing by Ohio's portion of the watershed (Dewitz, 2021). The natural and agricultural land use categories are therefore not included.

No matter the point of origin, non-ag stormwater pollution is diffuse, and precipitation drives its delivery. While the mechanisms delivering phosphorus from non-ag stormwater in permitted and non-permitted areas are the same, TMDLs require that non-ag stormwater be bifurcated based on if the stormwater's source area is regulated under the Clean Water Act or not. The stormwater discharges from areas within regulated MS4s and from NPDES-permitted stormwater facilities are considered a point source and receive a wasteload allocation in TMDLs. The remaining stormwater loads are considered nonpoint sources and are included in the TMDL's load allocation. Sixty percent of the developed land area in Ohio's portion of the Maumee watershed has been calculated as being part of the non-permitted nonpoint load in the load allocation in this TMDL.

Non-ag stormwater considered to be contributing to the nonpoint load in the Maumee watershed is much more spread out than the stormwater from permitted areas. Small communities, country homesteads, and roads dominate these areas. Phosphorus contributions from roads may be a significant non-ag stormwater source in areas without permitted stormwater. Williamson et al. (2020) found that roads contributed up to 24 percent of suspended sediment in a rural Maumee River tributary in Indiana. Analysis in that tributary watershed determined that, of the 6–11 percent of the developed land, 5–6 percent was roads. That work, however, notes that sediment from road dirt contained the lowest proportion of phosphorus of the sediments tested in the study. This, along with relatively high organic carbon content, could mean that sediment from roads may adsorb DRP within stream channels. More information about instream practices is presented in Section 4.1.4.

Stormwater from regulated MS4s and other NPDES-permitted facilities is regulated because of the amount of impervious area, artificial drainage systems, total population, and/or density of human-developed areas. This results in efficient pollutant delivery to receiving waters. These factors also allow for more effective implementation of pollutant-reduction activities. For this reason, non-ag stormwater sources are discussed in more detail in the point source section (Section 4.1.2).

4.1.1.4. Ditch and streamside sources

Agricultural and developed land uses often alter and augment the natural drainage of the landscape. Removing excess water and lowering the water table allow for more fields to be available for productive crop and livestock use. Flood control is also culturally desired for built landscapes. Open ditches or culverted streams are often used to facilitate these drainage needs. As described in the legacy phosphorus discussion, ditches and streams can be a temporary stopping point for phosphorus-enriched soils. Erosion from ditches and streams can contribute to phosphorus pollution downstream through the stream network. Other processes can mobilize DRP from this source as well.

When naturally occurring waterways or artificial channels are maintained to maximize drainage, they are often channelized lengthwise and sculpted into a trapezoidal cross-section. The resulting ditches are stabilized and maintained with the intent to neither aggrade nor degrade material (NRCS, 2015). While this most efficiently moves water, instream sediment trapping, and therefore the phosphorus reduction service provided by aggrading sections of streams, are reduced (Brooks, 1988). Channelization and ditch maintenance also can reduce instream processes that trap dissolved phosphorus (Smith and Pappas, 2007). More is presented on these instream processes in Section 4.1.4. Ditching also often hydrologically disconnects channels from their floodplains, restricting the phosphorus reduction services from that interaction (Hopkins et al., 2018).

When left unmaintained, ditched channels regress back to more natural conditions, with areas of both sediment accumulation and dispersal (Simon, 1989; Landwehr and Rhoads, 2003). This can also impact sediment mobility upstream and downstream of the ditched zoned, and deposits can locally change velocities that cause points of channel incision (Simon, 1989). These issues can occur more readily after channelization where channel dimensions are constructed too wide (Landwehr and Rhoads, 2003).

Unaltered "natural" channels contribute to phosphorus loads due to erosion and instream processes in the same manner as channelized ditches. The size and the amount of channel alteration certainly factor into the magnitude of this source, however. Regardless, the remainder of the discussion of this source will use the generic term "streambank sources."

Understanding the watershed scale impacts of streambank sources of phosphorus is challenging. Process-based models, like SWAT, do not fully represent floodplain and streambank erosion processes and the BMPs addressing sources from these areas (Kalcic et al., 2018). Modeling uncertainty is exacerbated when legacy phosphorus sources are contained within the stream channel in pooled areas or behind dams (Kalcic et al., 2018).

Fox et al. (2016) carried out a meta-analysis on streambanks as a source of sediment and phosphorus to streams. The various studies reviewed documented that streambank and gully erosion could be the source of a wide range of phosphorus found in streams, from 6–93 percent. A multitude of factors, many of them relating to stream velocity and channel dynamics (shape, degradation/stability, etc.), play into uncertainties that result in such a wide range. This work stresses the importance of understanding the form of streambank phosphorus. However, several studies in the review do not investigate dissolved phosphorus, or DRP.

Eroding streambanks were found to contribute the most suspended sediment during high flows in a study of agriculture-heavy watersheds in southern Minnesota (Williamson et al., 2014). However, that study found streambank material did not contribute the majority of channel sediments in streams where the edges of fields were removed from row crop use through the federal Conservation Reserve Program. This indicates that buffer areas along stream sides can reduce streambank sources of phosphorus export.

A recent paper calculated the contribution of streambanks to total phosphorus export throughout Iowa (Schilling et al., 2022). This work used a simple equation based on channel dimensions linked to erosion that was inferred with remotely collected light detection and ranging (LiDAR) data. By combining that analysis with previous streambank recession rate studies, the authors calculated the amount of sediment being eroded from channels statewide. The authors applied this mass of eroded sediment to the average streambank phosphorus content they found from a sampling to determine the mass of total phosphorus contributed to streams from streambanks for the state. Comparing this with a calculation of how much total phosphorus is exported through the state's streams allowed the authors to determine that 31 percent of river-exported total phosphorus in Iowa is from streambanks.

Calculating the proportion of phosphorus sourced from streambanks by analyzing the actual amount of phosphorus exported by streams is also being examined. Studies by USGS use sediment fingerprinting methods to understand the relative contribution of phosphorus in a stream's suspended sediments (Williamson et al., 2020). These methods have been applied to small streams in the Maumee watershed with the intent of understanding the phosphorus contribution from streambanks and other upland sources. Antecedent soil moisture and vegetation cover before storm events appear to make a difference in streambank erosion (Williamson et al., 2021a). That study, looking at a Maumee tributary watershed, found phosphorus export was mainly in the DRP form when conditions were dry, and crops were on the fields. However, streambank erosion was the main source of exported total phosphorus when storms occurred, and conditions were already wet.

Sediment fingerprinting research by the USGS in the Maumee watershed continues with the objective of improving estimates of the magnitude of streambanks as a phosphorus source. Preliminary indications show streambanks can contribute a high proportion of suspended sediment in one Maumee tributary over a two-month monitoring period (Williamson et al., 2019). This work also includes analysis of the short-lived beryllium-7 isotope with the hopes of understanding if eroding soils sourced from upland areas and streambanks are from the surface or buried deeper. Scaling results up to larger watersheds, even to the entire Maumee watershed, is a long-term goal of this work.

Streambanks as a source of phosphorus is considered nonpoint within the TMDL framework in that it is unregulated by the Clean Water Act. It is also nonpoint in the sense that it is connected to precipitation-driven hydrology. However, this is a source that is largely already existing in place, i.e., it is not dependent on ongoing activities such as regular fertilization. Contribution from upland legacy soil sources of phosphorus (largely described above) and instream processes interact with this streambank source. Once in the streambanks, slowing phosphorus export is the most reasonable approach to managing this source. As noted in the legacy and soil source section above, streambank sources will likely result in a lag in overall phosphorus export reduction even if upland phosphorus conservation efforts are greatly increased. The continued study by USGS and efforts described in Section 4.1.4 will help quantify this lag.

Channel alteration to improve drainage, i.e., ditching, disturbs stream systems' ability to store and process phosphorus. Practices such as two-stage ditches can provide a more stable structure to facilitate drainage needs (Kalcic et al., 2018). This stability allows for improved ecological functions, such as sediment trapping and instream processing, to contribute to overall net phosphorus reductions in a given time period. This practice, and others, will be considered in the implementation recommendations for this report.

Reducing and slowing the amount of water delivered to streams during storm events can also reduce the net export of streamside phosphorus sources. Practices such as wetlands, especially in agricultural systems, and even more novel activities, such as small detention basins used to irrigate crops during dry months, show promise in achieving suitable water management.

4.1.1.5. Natural sources

Natural sources of phosphorus, often considered the background, are known to contribute some load in most river systems. Weathering of soil and parent rock is described as the primary natural source of phosphorus (Holtan et al., 1988). The decomposition of aquatic life and washed-off upland vegetation (such as leaf litter) can also be categorized as a natural source (Wither and Jarvie, 2008). For any of these sources to be considered natural, they must be from undisturbed environments, such as eroded soil or leaf litter washed off from pristine land without human disturbances.

The amount of phosphorus delivered to streams from natural sources is considered very small compared to the human-caused sources in disturbed watersheds (Wither and Jarvie, 2008). Even with 9 percent of the Maumee watershed area within Ohio classified as having natural land cover (Dewitz, 2021), it is understood that only extremely small areas, if any, are completely undisturbed. Because of this, the natural sources of phosphorus in the Maumee watershed are considered negligible. It is not a documented source in modeling efforts such as Kast et al. (2021) or Martin et al. (2021) and will not be itemized in this TMDL project.

Certainly, phosphorus was present and moved through the Maumee watershed and the WLEB before European settlement. Human land use disturbances have, in essence, overrun most of these natural sources. Therefore, if a greater proportion of land is placed into a natural state, or nutrient reduction implementation efforts mimic natural conditions, the proportion of natural sources would be expected to increase. However, because human land uses produce so much more phosphorus, the net effect would be a phosphorus reduction. This concept is often discussed regarding installing or enhancing wetlands for nutrient reduction. A natural background of nutrients should be expected when examining all nutrient-reduction activities.

4.1.1.6. Atmospheric deposition

Unlike carbon and nitrogen, there is no stable gaseous phase of phosphorus in the Earth's atmosphere. The dominant source of atmospheric deposition of phosphorus globally is mineral aerosols. In general, this is soil phosphorus mobilized by winds, often characterized as dust. In non-desert, industrialized areas such as the Great Lakes region, biogenic aerosols and combustion deposits are primary sources (Mahowald et al., 2008). Based on monitoring data, Maccoux et al. (2016) calculated atmospheric deposition to Lake Erie's open water to contribute 6 percent of the total phosphorus load delivered to the whole lake. That study, and similar phosphorus accounting, incorporates atmospheric deposition of phosphorus to land masses among all the nonpoint sources. That is, atmospheric deposition is not itemized as a specific source when not over large bodies of water. While this source is clearly measurable, it is relatively uniform across the landscape on a regional scale, making this approach reasonable.

Atmospheric deposition is a source of phosphorus to Lake Erie, that contribution was considered by Annex 4 and is accounted for in Lake models that show meeting the targets described in Section 3.4 will attain water quality standards. The Annex 4 target document and several of the studies cited in this section note that continued investigation of the role atmospheric deposition plays in algal blooms in Lake Erie is needed. As new data becomes available, the TMDL could be revised to address changes in loads or allocations. Further quantifying the amount of atmospherically deposited phosphorus on land was not supported with available data. Quantifying any potential impacts of this source would need to consider the context which atmospheric deposition compares to other sources and delivery mechanisms. For example, application of commercial fertilizer and manure place 40,000 metric tons of P2O5 (17,500 metric tons of P), see Figure 17, on the land surface each year. Implementing practices to specifically target sources of atmospheric deposition can also be challenging as sources of terrestrial derived mineral aerosols can be local, interstate, or international in origin (Mahowald, et al, 2008; IJC, 2014; Weiss et al, 2018, Environment and Climate Change Canada, 2021).

However, several of the implementation actions discussed in Section 7 targeting larger sources of phosphorus loss, like soil erosion and fertilizer application, will likely reduce local sources of phosphorus available for atmospheric deposition. As noted in Weiss, et al., (2018), BMPs that focus on local dust/soil control will reduce mineral aerosols and dust that transport phosphorus into Lake Erie. BMPs included in the management strategy that reduce the potential for soil transport via air include cover crops and subsurface placement of fertilizer.

4.1.1.7. Changes in watershed hydrology

Changes in precipitation amount, timing and intensity present a complicating challenge to nonpoint source control of phosphorus. The earth's hydrologic cycle has been altered by human activities (Manabe and Stouffer, 1980; Milly et al., 2008; Abbott et al., 2019).

An ARS study by Williams and King (2020) examined hydrologic changes in the Maumee watershed. Twenty-three daily rainfall and 12 streamflow gages in and near the watershed were examined from 1975 through 2017. An overall increase in rainfall of 11–13 percent (Figure 20) and streamflow of 19–32 percent were documented for the Maumee watershed. Heavy and very-heavy rainfall events brought the majority of these increases, more often in the spring. The study noted that the greatest increases in rainfall were observed in the southern half of the Maumee. A different statistical analysis approach of the Maumee River at Waterville and St. Marys River near Ft. Wayne gages found highly likely increasing streamflow trends in the days with the greatest 20 percent of streamflow (Choquette et al., 2019). That study did not find similar increases at the St. Joseph River near Ft. Wayne gage. The heterogeneity of hydrology in the watershed is discussed more below in Section 4.2 in considering CSAs.

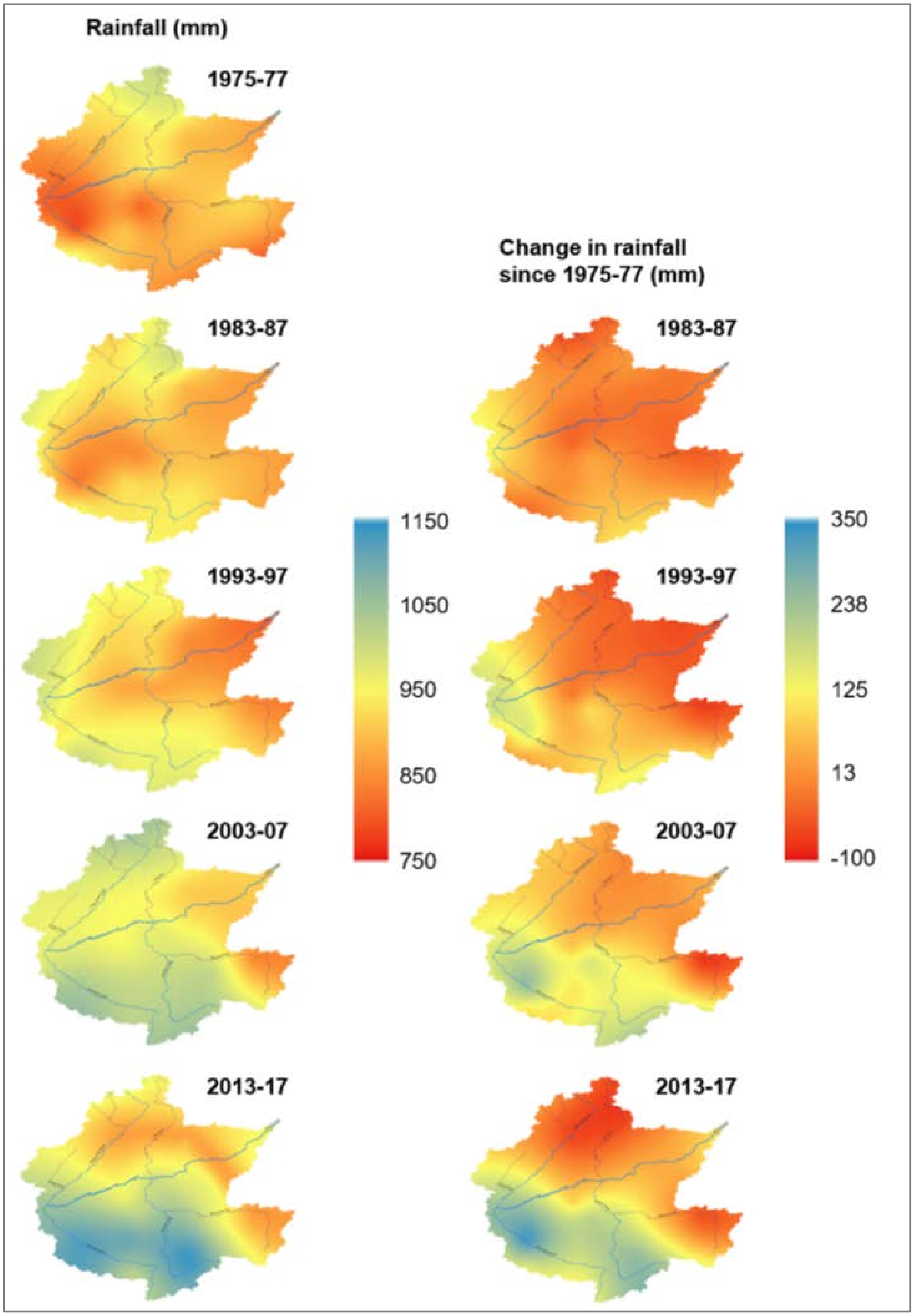


Figure 20. Rainfall trends for various time periods between 1975 and 2017. The right maps show the calculated differences from the 1975–1977 period (Williams and King, 2020).

The Williams and King (2020) paper included implications of changing hydrology on phosphorus export in the Maumee watershed. It notes that agricultural conservation practices, such as improving soil infiltration and water holding capacities, have provided some increased water resiliency to the watershed. However, increased rainfall occurring via more extreme events (in relatively shorter periods of time) overwhelms the overall watershed water storage capacity. The authors say this can directly increase DRP concentrations due to increased time with wet conditions. Therefore, many activities intended to address water management, especially subsurface tiling, play a role in facilitating increased DRP export.

Choquette et al. (2019) employ a different suite of statistical analyses to document trends on observed streamflow and nutrient exports. This work attributes about one-third of nutrient increase to increasing discharge trends. The remaining changes documented in this work occur due to greater nutrient concentrations in waters delivered throughout the Maumee watershed.

The Rowland et al. (2021) trend analysis explains that some, but less than half, of the DRP export is due to flow increases. Jarvie et al. (2017) attribute 35 percent of the historic DRP load increase to higher runoff volumes, likely exacerbated by tile drainage and precipitation increases.

Overall, this implies that land management plays as much or greater a role in increasing nutrients as changes in hydrology. However, the two factors have had an additive impact on increasing nutrient loads.

Hydrology directly plays a role in all nonpoint sources discussed in this section as well as permitted stormwater sources, described below. Increased rainfall in the Maumee watershed has, and most likely will continue to, exacerbate controlling these sources. Note that there have been some modeling findings showing that if temperatures increase it may offset some of these issues due to increased evapotranspiration and decreased snowfall in the Maumee watershed (Kalcic et al., 2019). Regardless, hydrology must be considered when recommending, planning, and designing nutrient controls.

Watershed hydrology may continue to change in the with warmer temperatures and more extreme precipitation events predicted in the Midwest. Climate models vary, but generally predict a 1-3 degree C increase in temperature by 2050 (Great Lakes Integrated Science and Assessments, 2014). Additionally, the amount of precipitation falling in extreme precipitation events (i.e., high magnitude events) has increased by 37 percent from 1958-2012 in the Maumee watershed. More extreme precipitation events can lead to increased nutrients in surface waters that contribute to the development of algal blooms. However, as noted in the previous paragraph warmer temperatures will also result in greater evapotranspiration which may reduce runoff.

There is uncertainty in how these predictions will impact the Maumee watershed and Lake Erie. Ohio will monitor water quality (Section 7.4) and track the progress of on-the-ground implementation actions. Ohio will also adjust implementation strategies as necessary, through an adaptive management approach (Section 7.6). If additional information on changes to temperature or precipitation patterns emerge sufficient enough to require action, Ohio will be able to adjust its implementation strategies to account for these changes. Water management practices (i.e., edge-of-field buffers, two stage ditches, blind inlets, wetlands, etc.) are one of main tenets of the implementation approach described in Section 7.3.3.1. Implementation efforts that target water management will provide resiliency to the expected more intense rainfall events.

4.1.2. NPDES-permitted point sources (including permitted stormwater) of phosphorus

This subsection describes permitted sources of phosphorus in the Maumee watershed. Ohio EPA regulates these sources via the state of Ohio's rules and in accordance with the NPDES framework. In TMDL budgeting, these sources fall within the wasteload allocations. The "major" municipal NPDES WWTPs, those treating sewage from the largest populated areas, contribute the greatest proportion of phosphorus in this category. Permitted stormwater from urbanized areas and some industrial sources are also included in this discussion. There are also many small sources of NPDES-permitted phosphorus. Table 9 shows a breakdown of the various categories of permitted sources of phosphorus. These are explained throughout the remainder of this subsection.

Table 9. Summary of types of NPDES-permitted sources. Detailed categories that are shaded in gray are not included in the phosphorus TMDL wasteload allocations.

Program	Permit type	Major category	Detailed category
Treatment Facilities: Point source pipe(s) directly contributing waste to surface waters	**Individual NPDES Permit**: Facility-specific permits issued for each facility	**Public**: Treats a majority of municipal/human waste, most often delivered from public sewer systems	Major: Plants that are permitted to treat about 1 MGD or more
			Minor: Plants that are permitted to treat less than 1 MGD
		Industrial: Facilities that treat waste from industrial processes	Phosphorus discharging: Mostly commercial plants treating phosphorus at concentrations requiring treatment (e.g., food processing facilities)
			Non-phosphorus discharging: Discharging plants that do not treat phosphorus at concentrations greater than background (e.g., most drinking water treatment plants)
		Concentrated Animal Feeding Operation (CAFO)	Livestock operations meeting certain criteria requiring an individual permit; none in the Maumee watershed
	General: Permits that cover facilities with similar operations and wastewater characteristics	Phosphorus discharging	Discharging general permits considered to contribute phosphorus at concentrations greater than background; these include home sewage treatment systems and small sanitary discharges
		Non-phosphorus discharging	The several discharging general permits not considered to contribute phosphorus at concentrations greater than background
Stormwater	**Individual**: Facility-specific permits	Facility-based	Stormwater controls measures and pollution prevention provisions, very often included within individual treatment facility permits
		Municipal-based	Phase I Individual MS4 Permits
	General: Permits that cover facilities or areas with similar operations	Facility-based	Construction and multi-sector industrial general stormwater permits (i.e., MSGP)
		Municipal-based	Phase II Small MS4 General Permit
Beneficial Use	**Beneficial Use of Materials**: Discharge of these materials is prohibited	Biosolids	Field application of biosolids generated by publicly owned treatment works in Ohio
		Land application	Wastewater treatment effluent irrigation
			Industrial waste used for agronomic benefit

Notes:
MGD= million gallons per day; MSGP= multi-sector general permit

4.1.2.1 Permits for treatment facilities

Defining treatment facility permitting and its source contribution

Facilities that discharge directly to streams or other waterways are considered first. These act as what is typically considered a traditional point source. Unlike permitted stormwater, which is primarily driven by precipitation, these sources are more directly driven by treatment plant influent flow rates associated with receiving municipal sewage or industrial flows. Municipal and some industrial wastes contain concentrations of phosphorus that require additional management.

As seen on Table 9 above, treatment facility permits are first divided between individual and general permits. General permits are developed when the waste type and technology used to manage it are consistent and permit conditions can cover a large number of discharges.

Individually permitted treatment facilities that process primarily municipal/human waste are considered public permits by Ohio EPA. Municipal waste contains phosphorus due to nutrient inputs from human food consumption (Metson et al., 2012), detergents, and other activities. Ohio EPA divides these public permits into major and minor categories, which is largely determined by the volume of wastewater the facility is designed to treat. Plants that are permitted to discharge 1 million gallons per day (MGD) or more of treated effluent are considered majors. There are 22 major, public, individual permits in the Maumee watershed, which are generally city-operated facilities. Minor permits cover facilities operated by smaller communities or semi-public organizations treating human waste and designed to discharge less than 1 MGD of treated effluent.

Twenty-four communities in the Maumee watershed have (or had) permitted CSOs (Table 10). Communities with combined sewers have pipes that were historically designed to intentionally capture stormwater within the same sewers as sanitary wastewater. During heavy rainfall events, when the carrying capacity of these pipes is exceeded, CSOs are designed to discharge a mixture of stormwater and sanitary sewage to streams. Constructing new combined sewers is no longer permitted.

Table 10. Combined sewer overflow communities in Ohio's portion of the Maumee watershed.

HUC-8 name – code	CSO community	HUC-8 name – code	CSO community
St. Joseph River – 04100003	Montpelier	Blanchard River – 04100008	Findlay
St. Marys River – 04100004	none		Dunkirk
Upper Maumee River – 04100005	Hicksville		Pandora
Tiffin River – 04100006	Fayette		Forest
Auglaize River – 04100007	Paulding	Lower Maumee River – 04100009	Defiance*
	Ohio City		Wauseon
	Payne		Delta
	Van Wert		Deshler
	Columbus Grove		Leipsic
	Delphos		Swanton
	Wapakoneta		Toledo†
	Lima		Perrysburg
			Napoleon

Notes:
* Some Defiance CSOs discharge to the Auglaize River near its mouth to the Maumee River.
† Some Toledo CSO outfalls are outside of the Maumee watershed and will not be included in this project.

Ohio EPA works to control CSOs through provisions in NPDES permits and by using orders and consent agreements when appropriate. The agreements and permits require CSO communities to implement nine minimum control measures. Requirements to develop and implement long-term control plans are also included where appropriate. A Long Term Control Plan (LTCP) is the description of how wet-weather discharges will conform to the Clean Water Act Section 402(q) (epa.gov/npdes/combined-sewer-overflows-csos). Within the Ohio portion of the Maumee River watershed, all CSO communities have approved CSO LTCP; either through Ohio EPA or U.S. EPA (U.S. EPA, 2016; Ohio EPA, 2020c). Half the CSO communities in the Maumee watershed are planning for complete separation and elimination of all CSOs; in fact, some of the communities listed in Table 10 have separated their sewers since the 2008 baseline year. Details about each community's CSO status are presented in Section 5.

Bypasses from public WWTPs occasionally occur due to various factors overwhelming the treatment capacity. These bypasses are prohibited unless certain conditions are met and a 'no feasible alternatives' analysis is completed. Steps are required to minimize the bypasses as part of this process, similar to CSO control plans.

Discharges from separate sewer systems occasionally occur due to various factors overwhelming sewer capacity. The Clean Water Act and all NPDES permits prohibit sanitary sewer overflows (SSOs). All communities with known SSOs must plan to eliminate these sources. All permittees are required to report SSO events, with various monitoring levels, as a condition of their NPDES permit.

Individual NPDES treatment facilities that treat industrial wastewater from a specific facility are considered "industrial." In Table 9, these permits are divided based on whether their discharge is considered to contain phosphorus or not. Most industrial phosphorus-discharging facilities in the Maumee watershed are related to the food processing category. Those considered as non-phosphorus discharging treat a variety of industrial wastes and include most drinking water treatment plants. This group of facilities has been determined to discharge phosphorus at levels that do not require additional oversight or control—often below background concentrations in the watershed.

There are no NPDES-permitted CAFO facilities within the Maumee watershed. Large livestock operations are permitted as CAFFs by ODA. CAFFs are regulated through state operating permits, but not NPDES permits. CAFOs/CAFFs are discussed above, with fertilizer nonpoint sources, in Section 4.1.1.1.

Ohio EPA issues several general permits that cover activities resulting in non-stormwater-related discharges of wastewater. Unlike individual NPDES permits, these permits cover a type of activity rather than a specific facility; the specific facilities that conduct that activity apply for coverage under the general permit. Therefore, many facilities are covered under each general permit—some permits cover thousands of facilities. The treatment technologies for these sources are consistent, and the eligibility criteria and/or appropriate limits within the general permit ensure individual evaluations are not needed to ensure water quality standards are met. Note that these facilities almost always contribute fewer pollutants than the minor public individual permits outlined above. General permits are divided into those considered to discharge wastes with phosphorus concentrations greater than the background and those at or below background concentrations. The general permits that include phosphorus-containing discharges cover discharging home sewage treatment systems and small sanitary discharges (i.e., very small package plants, such as restaurants or mobile home parks).

All individual NPDES permits require that effluent volume be monitored before being discharged to streams. Nearly all of these permits also require effluent total phosphorus monitoring. The required monitoring frequency is greater for major public permits than for minors. Monitoring of CSO discharges varies due to the different configurations of CSOs; however, permits for all CSO communities require some type of CSO monitoring.

Using these monitoring data, Ohio's Nutrient Mass Balance reports that NPDES permittees contribute a five-year spring loading season average of 6 percent of the Maumee watershed's total phosphorus load (Ohio EPA, 2020b). This proportion includes the calculated CSO loads and the load from the general permit for discharging home sewage treatment systems. The total phosphorus load from the other general permits were not included in Ohio's Nutrient Mass Balance methods; thus, they do not appear in the remaining figures in this section. However, they are accounted for in this TMDL (see Sections 5 and 6).

Figure 21 shows the breakdown of the 6 percent of total phosphorus spring load contributed by NPDES facilities by treatment facility category from Ohio EPA's Nutrient Mass Balance 2020 report (Ohio EPA, 2020b). This pie chart includes the combined NPDES facility loads from Michigan and Indiana. These "out of state" loads represent 28 percent of the total load from NPDES-permitted sources. The other slices of the pie are from the various categories described above from Ohio facilities. The major public wastewater treatment facilities from Ohio are the largest of these categories, at 48 percent of the total NPDES-permitted load, and approximately two-thirds of the load from treatment facilities in Ohio.

Figure 21 also includes the calculated loads from CSOs and other wet weather bypasses, except SSOs. These sources from Ohio make up 2 percent of the spring load from NPDES permittees, or around 0.12 percent of the total spring phosphorus load. In 2020, Ohio EPA learned that the city of Maumee had SSOs that had been unreported for several years. The city entered into orders with Ohio EPA in July 2021, agreeing to pay a penalty and to take immediate actions to eliminate these SSOs. Preliminary estimates of the unreported total phosphorus load contributed from the city of Maumee's SSOs were calculated by Heidelberg University's NCWQR, which determined that these loads would have added less than 0.02 percent of the annual phosphorus load. Eliminating these SSOs is currently being planned, with an evaluation study due in 2024.

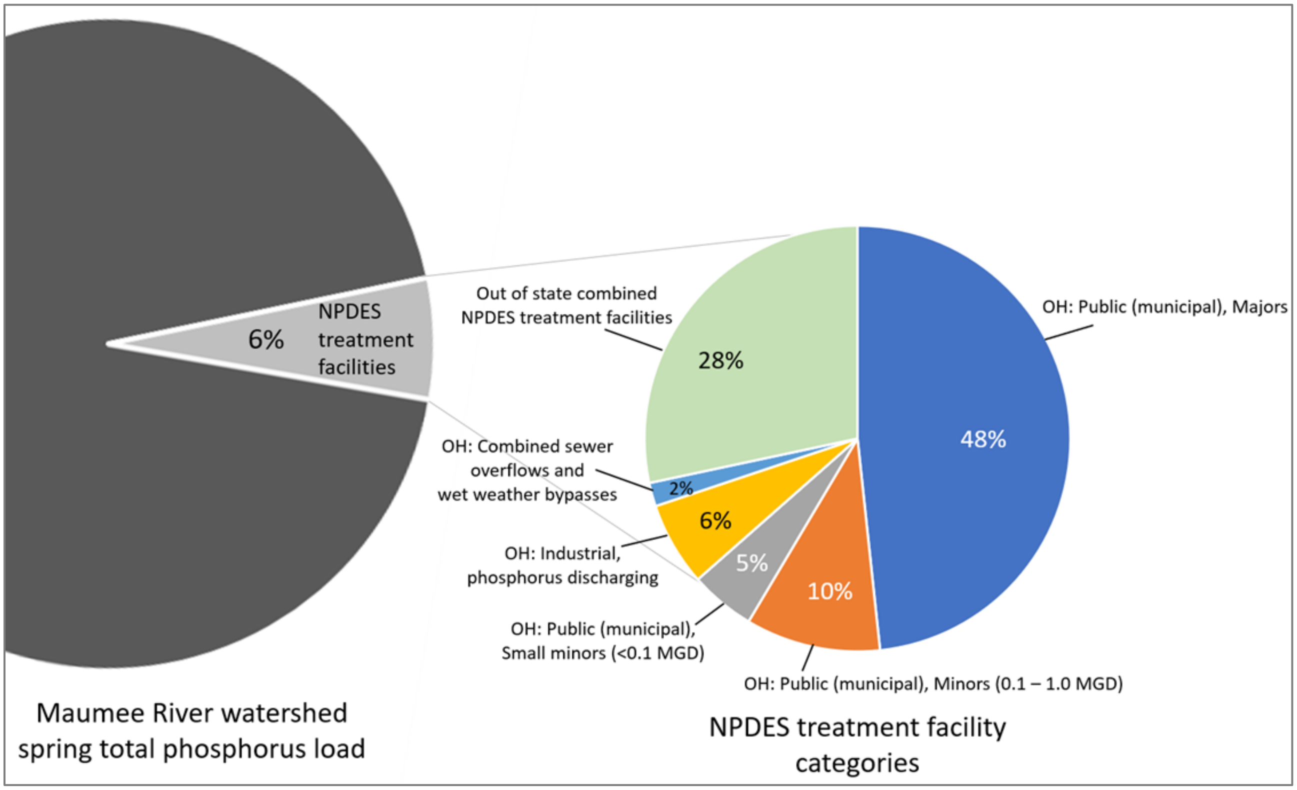


Figure 21. The left pie chart shows the five-year (2015–2019) average spring season total phosphorus Maumee watershed load proportion of NPDES treatment facilities. The right pie chart breaks that 6 percent down by treatment facility categories (Ohio EPA, 2020b).

There is a wide distribution in the amount of total phosphorus delivered from the 22 individual major public wastewater treatment facilities within Ohio's portion of the Maumee watershed. Figure 22 shows this distribution based on these sources' five-year (2016–2020) average annual total phosphorus load proportions. The five largest facilities contribute 83 percent of the total. The remaining 17 major Ohio public facilities contribute 17 percent of this load. Figure 23 shows a breakdown of all 22 of these facilities. This figure outlines the five-year (2016–2020) average total phosphorus load and concentration for each facility based on Ohio Nutrient Mass Balance calculation methods (Ohio EPA, 2020b). The figure also shows the proportion of each facility's discharged flow of their permitted design flow rate.

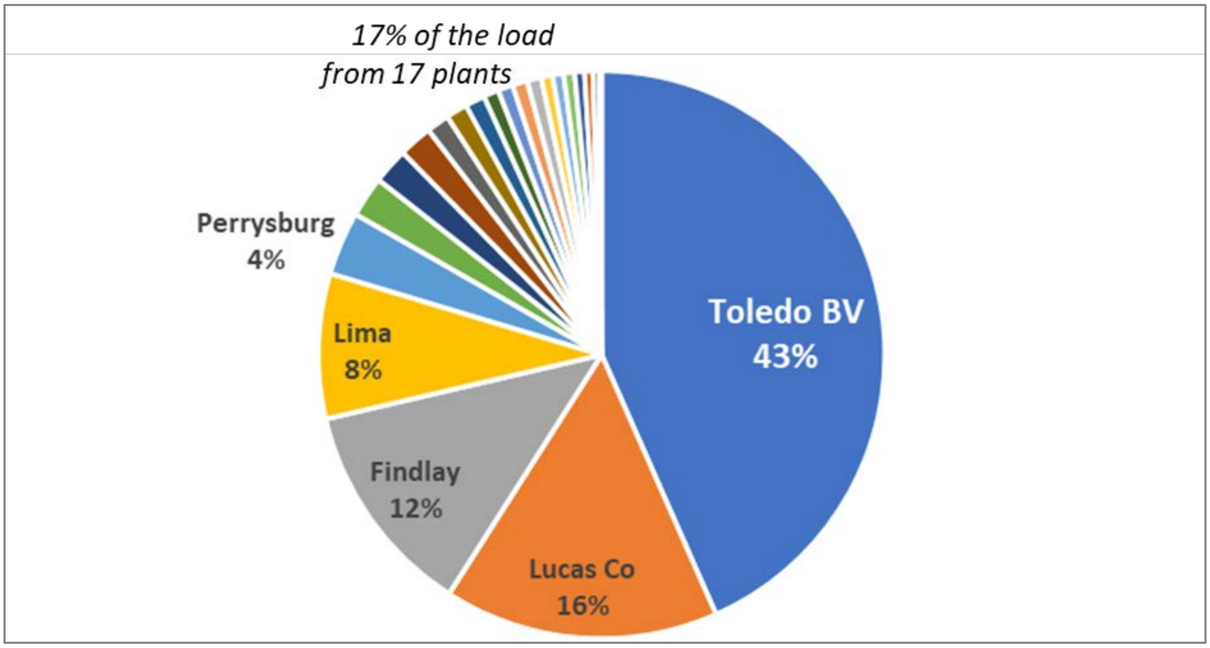


Figure 22. Pie chart showing the proportion of total phosphorus load from each individual public treatment facility within Ohio's portion of the Maumee watershed. Loads based on the five-year (2016–2020) annual average calculated using Ohio Nutrient Mass Balance methods (Ohio EPA, 2020b).

Discharged total phosphorus concentrations of the facilities shown on Figure 23 indicate that phosphorus treatment is occurring at all plants.

SWAT modeling described in Kast et al. (2021) examined NPDES-permitted facility phosphorus source contributions from the Maumee watershed to Lake Erie. This work found these point sources contribute an average of 5 percent of the total phosphorus and 12 percent of the DRP during the spring loading season. As with Ohio EPA's Nutrient Mass Balance work, this modeling found permitted facility loads to fluctuate very little compared to hydrology-driven nonpoint sources. Because of this, facility-based point sources contribute a greater proportion in drier years and a lesser proportion in the wettest years. The Kast et al. (2021) paper points out that, on average, point sources contribute a similar proportion of phosphorus as manure fertilizer sources.

Phosphorus discharged from wastewater treatment facilities is often assumed to be largely in the dissolved form because wastewater treatment facilities are designed to remove solids through settling and filtration. However, treatment technologies vary between facilities, including the means of managing phosphorus. Because of this, Baker et al. (2014a) reported that the bioavailability of the phosphorus discharged from municipal plants is variable. That study reports a range of DRP from 42–81 percent of the total phosphorus discharged from three northeast Ohio plants with different phosphorus-removal technologies.

Plants often use chemical additions to reduce phosphorus in their final effluent. These additions, such as aluminum salts, preferentially remove the bioavailable portion of the plant's total phosphorus effluent. Baker et al. (2014a) noted that realizing higher removal rates with chemical precipitation results in a lower proportion of DRP to total phosphorus in the effluent. Other factors that might play a role in the variability of DRP in wastewater effluent include the settling efficiency, whether the facility has tertiary filtration capacity, or the type of phosphorus removal technology (i.e., biological versus chemical).

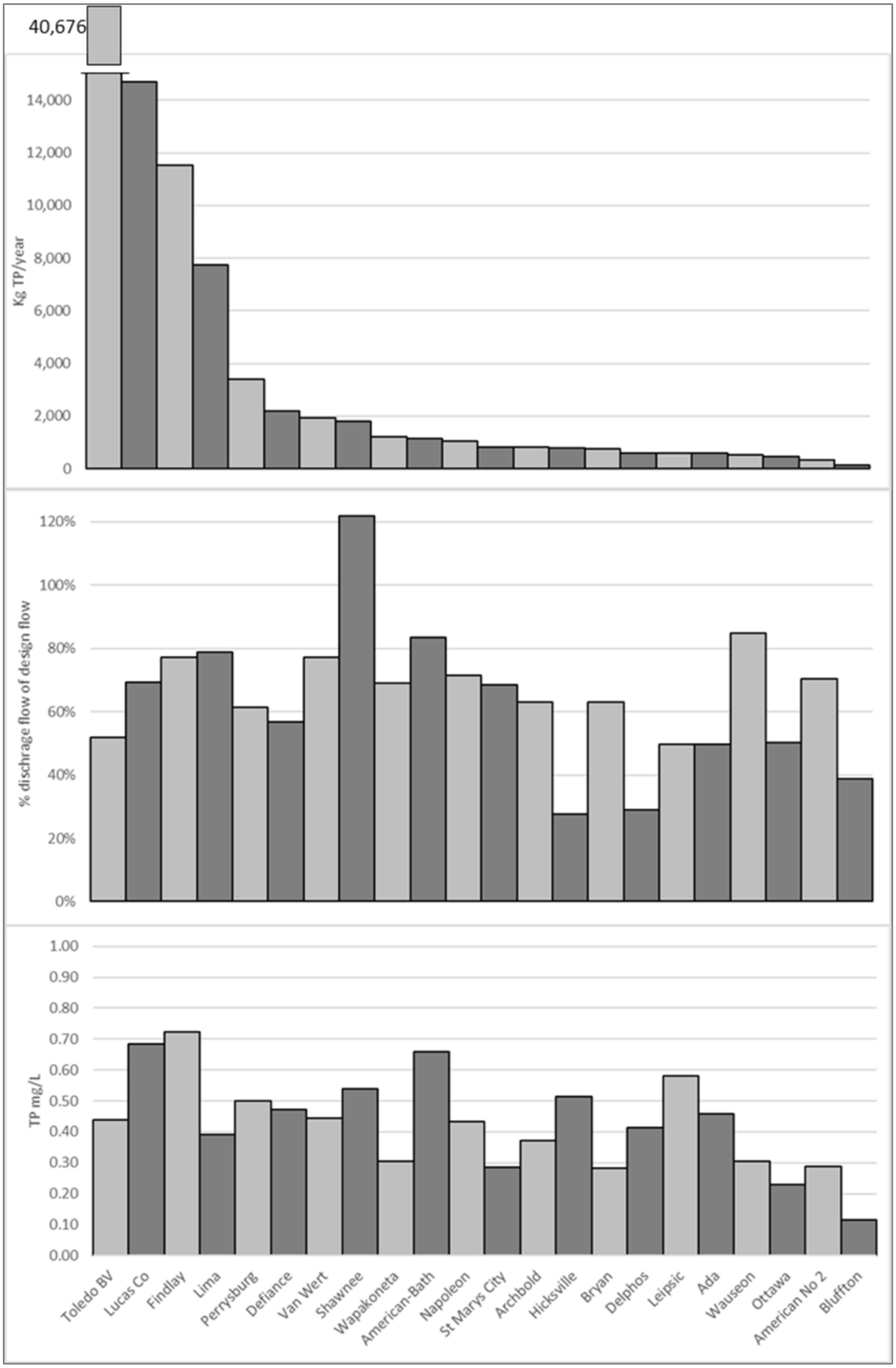


Figure 23. Three bar charts showing all major individual public treatment facilities within Ohio's portion of the Maumee watershed. The top chart shows total phosphorus load. The middle chart shows the proportion of discharged flow of each facility's permitted designed flow rate. The bottom charge shows total phosphorus concentrations. All statistics show the five-year (2016–2020) annual average calculated based on Ohio Nutrient Mass Balance methods (Ohio EPA, 2020b).

Ohio EPA began requiring major municipal wastewater treatment to monitor orthophosphate, a parameter analogous to DRP, in 2016. Most facilities monitor orthophosphate (reported as a concentration of phosphorus) in their final effluent monthly. This is much less frequent than total phosphorus sampling, which is required twice a week for most plants.

An analysis of these monitoring data is presented here to consider the proportion of available phosphorus in treatment plant effluent. In addition to the sampling frequency differences noted above, another sampling detail also impacts the analysis. Total phosphorus is required to be sampled as a 24-hour composite, but orthophosphate samples are collected via grab sample because the testing procedures require immediate filtration for orthophosphate samples. Therefore, pairing individual orthophosphate with total phosphorus samples is not appropriate.

A more approximate analysis to evaluate this proportion considers the average effluent concentrations of the two parameters for each plant. This analysis examined the period of record starting in 2016 through the most recently submitted sampling data to Ohio EPA as of December 6, 2022. One plant was excluded, due to multiple outfalls affecting sample pairing. All municipal plants in Ohio EPA's northwest district were included in this analysis, including plants outside of the Maumee watershed. This allowed for a sample of 52 WWTPs. The ratio of average orthophosphate to average total phosphorus was determined for each plant. Figure 24 shows the distribution of the plant's ratios. The median of this distribution found 69 percent of the effluent being orthophosphate. The 25th and 75th percentiles are 57 percent and 87 percent, respectively. These results are similar to the range reported by Baker et al. (2014a). This analysis found seven plants with ratios greater than 100 percent, and three others with ratios of 90–100 percent. Since orthophosphate is a portion of total phosphorus, results greater than 100 percent are not possible. This is likely a result of the sampling differences noted above, or other sampling bias not accounted for in this analysis (e.g., changing frequency of sampling).

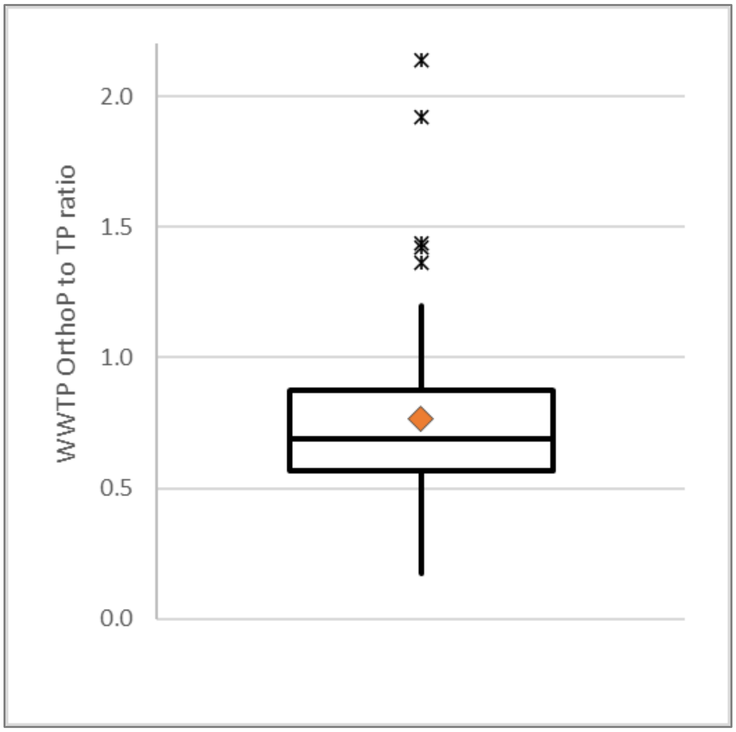


Figure 24. Boxplot showing the distribution of Ohio EPA Northwest District municipal WWTPs' effluent orthophosphate to total phosphorus ratio. The average is indicated with an orange diamond. The calculation is based on an average of each plants' concentration data from January 2016–November 2022. Only plants that monitor orthophosphate are included (n=52). Outliers are determined if they are greater than 1.5 times the inner quartile range plus the 75th percentile.

Existing facility-based (discharging) point source reduction efforts

Reducing phosphorus from municipal sewage wastewater treatment facilities and applicable industrial facilities has been ongoing in the state. Beginning with the GLWQA in 1972, municipal point source discharges were acknowledged as contributors to the nutrient loadings to the lake. The early versions of the GLWQA recommended that all major WWTPs discharging within the Lake Erie basin meet a 1.0 mg/L total phosphorus effluent concentration. By 1980, the affected WWTPs reduced phosphorus effluent levels to the point that nonpoint sources became the major contributor of phosphorus loading to the lake. A majority of the WWTPs began treating for phosphorus by adding metal salts to precipitate the phosphorus and then incorporating the precipitate into the solids waste stream.

Coupled with the treatment at the major WWTPs were reductions in the phosphorus content in laundry detergents. Beginning in the late 1980s, Ohio began limiting the amount of phosphorus allowed in home and commercial laundry detergents. In 2010, Ohio became one of 16 states that also included a requirement that dishwasher detergent could not contain more than 0.5 percent phosphorus. Not only did these measures reduce the influent phosphorus concentration to the WWTPs, but they also reduced contributions from uncontrolled point sources such as CSOs and bypasses. In collaboration with the Ohio Lake Erie Phosphorus Task Force, the Scotts Company, LLC has removed phosphorus as a component of residential lawn fertilizers used for lawn maintenance. This effort has further reduced inputs from CSOs and MS4-permitted stormwater communities considered in Section 4.1.2.2.

For historical perspective, springtime total phosphorus from major public NPDES permittees dating back to 1995 are provided in Figure 25. This period was chosen to develop an understanding of total phosphorus loads from major facilities during the period of re-eutrophication of Lake Erie from the mid-1990s to the mid-2000s. The largest dischargers are the city of Toledo Bayview WWTP, Lucas County Water Resource Recovery Facility (WRRF), city of Lima WWTP, city of Findlay WWTP, and city of Perrysburg WWTP. These facilities are presented individually in the figure, with the 18 remaining major municipal wastewater treatment facilities grouped together.

Major municipal facility loading remained relatively flat during the period of re-eutrophication of the Western Basin of Lake Erie (1995–2005), followed by a period where springtime total phosphorus loads show a downward trend (2005–2018). Total phosphorus load from major municipal facilities averaged 53 MTs per spring from 2004–2008 and 42 MTs per spring from 2014–2018. This was a net decrease of 22 percent for major municipal facilities in the Maumee watershed from the period leading up to the 2008 base year and the most recent conditions. The downward trend is attributed to voluntary load reductions, mainly driven by the Toledo Bayview WWTP. In the five springs from 2004–2008, the Toledo Bayview WWTP discharged an average of 29 MT/spring but averaged 18 MT/spring for 2014–2018.

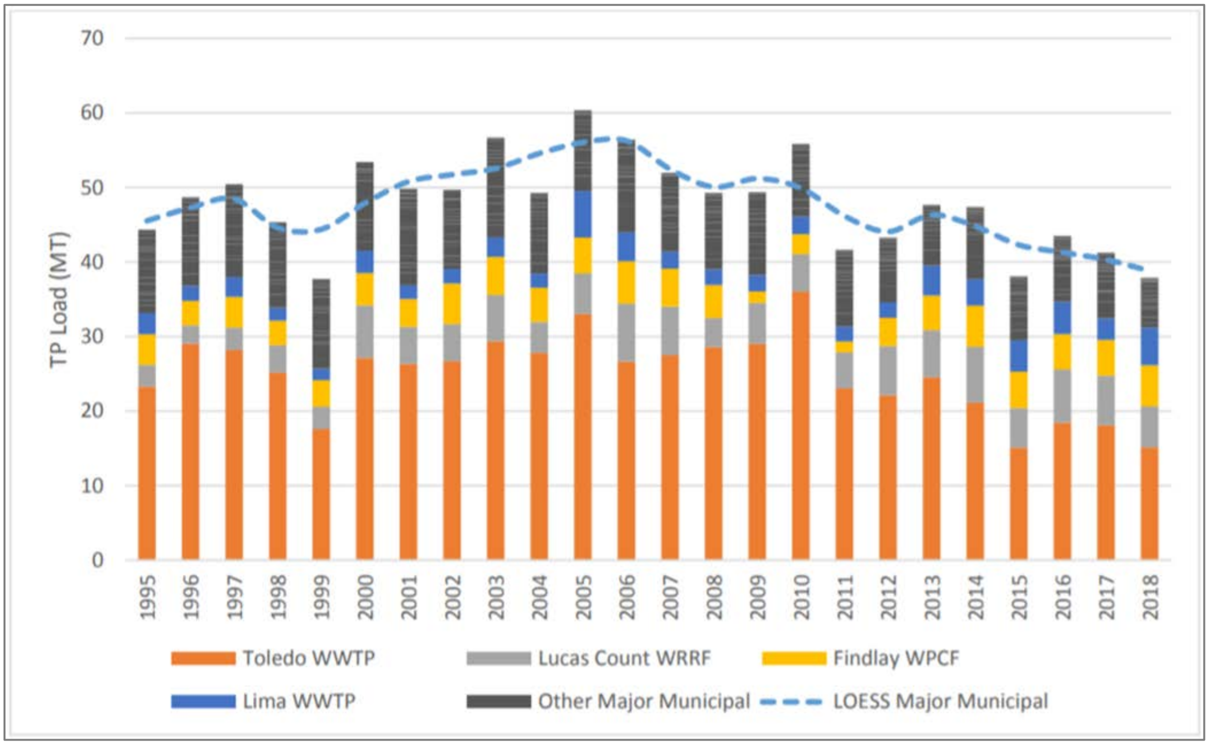


Figure 25. Springtime total phosphorus loads from major public facilities in the Maumee watershed in Ohio's portion of the Maumee watershed in 1995–2018. The LOESS line presents a locally weighted smoothing trend line.

The state of Ohio has invested in nutrient reduction efforts by offering financial assistance to communities with NPDES permits for WWTP upgrades and CSO-control projects. Through the Water Pollution Control Loan Fund, Ohio EPA has provided WLEB communities with over $1 billion in wastewater resource infrastructure project loan funds between 2009 and 2022 (to date). Nearly $88 million of these funds have been provided as principal forgiveness (OLEC, 2020a).

While major municipal WWTPs are required to achieve an effluent concentration of 1.0 mg/L to comply with their NPDES permits, many treatment plants consistently perform well below this level. One reason for this is to remain in compliance throughout varying flow rates, operating conditions, and process upsets. A facility would need to achieve a long-term average concentration of 0.73 mg/L in order to remain in compliance 99 percent of the time (U.S. EPA, 1991). Long-term averages lower than this value indicate that performance is better than what is needed to maintain minimum compliance.

Figure 26 shows the spring total phosphorus loads from phosphorus-discharging facilities with individual permits in Ohio's portion of the Maumee watershed from 2008 to 2018. Note that the "authorized load" shown in this figure is the total loads of all facilities if they were to discharge at their permitted design flow and total phosphorus concentration limit (or existing concentration for facilities without limits). This indicates that, as a whole, these facilities are discharging less than half the phosphorus load allowable under their permits. The bottom chart in Figure 23, above, shows that treating to concentrations below the 1.0 mg/L permit limit explains much of this performance. The middle chart of that figure shows that the actual average volume being discharged below the facility's permitted design is also a factor.

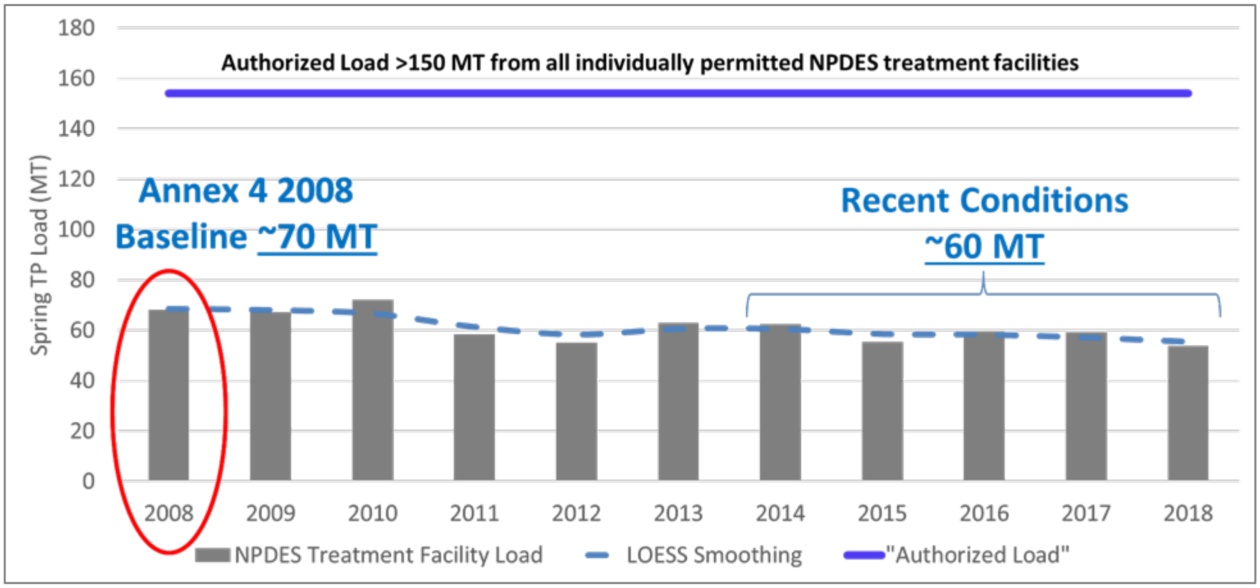


Figure 26. Spring loading season total phosphorus loads from phosphorus-discharging public facilities with individual permits in Ohio's portion of the Maumee watershed from 2008 to 2018. The authorized load bar shows the total loads of all facilities considering they were to discharge at their permitted design flow and total phosphorus concentration limit.

Permitted facilities have invested heavily in phosphorus reductions over the last several decades. Today, they contribute a relatively minor source contribution to the Maumee watershed's overall load. Incremental gains continue to be made through optimization.

4.1.2.2. Permitted stormwater

Stormwater discharges are generated by runoff from land and impervious areas such as paved streets, parking lots, and building rooftops during rainfall and snow events. Stormwater often contains pollutants in quantities that could adversely affect water quality. The primary method to control stormwater discharges is through the use of BMPs. Many of the watershed's stormwater discharges are regulated, considered point sources, and require coverage by an NPDES permit. Table 9, above, outlines the individual and general NPDES permits authorizing stormwater discharges.

Industrial facilities must apply to be covered by Ohio's Multi-Sector General Permit (MSGP) if they have the potential to discharge stormwater to a surface water of the state and participate in one or more of the 29 industrial sectors outlined in the permit. Facilities in these categories that do not have industrial materials or activities exposed to stormwater may file a No Exposure Certification form to Ohio EPA in lieu of obtaining NPDES permit coverage and submitting an NPDES permit application. Facilities covered by the general permit must implement stormwater controls and develop a stormwater pollution prevention plan.

Many facilities with individual public or industrial treatment facility permits (described in section 4.1.2.1) meet the requirements for the MSGP. In most of these cases, stormwater control measures outlined in the general permit are incorporated into the facility's individual permit for their treatment facility's discharge(s). This allows the facility to not need to apply for the general permit. Ohio EPA also has the discretion to require a facility to apply for an individual NPDES permit for stormwater controls. This most often happens for facilities with a history of known stormwater control issues. Stormwater controls outlined in an individual facility NPDES permit are similar to the MSGP; however, additional regulatory scrutiny occurs at individually permitted facilities.

Ohio EPA also maintains a general permit to limit the impacts of stormwater from construction sites. Projects that disturb one or more acres of ground must apply for this general permit. Projects that disturb less than one acre but are part of a larger development plan or sale also need to be permitted to discharge stormwater. Conditions of the Construction General Permit require BMPs to control sediment export during soil disturbances and to implement non-sediment pollutant controls for other activities related to construction (e.g., fuel storage, concrete rinse, fertilizer storage/application). Post-construction practices that provide extended water detention and enhanced infiltration are intended to reduce and slow water and pollutant movement away from the developed area.

U.S. EPA and Ohio EPA's stormwater programs addressed municipal-based stormwater runoff in two phases. Phase I of the stormwater regulations required NPDES permits for discharges from MS4s serving large and medium municipalities. The size of the population that the MS4 services dictates if it is considered a large or medium municipality. These Phase I MS4s are required to obtain an individual NPDES permit. Toledo is the only Phase I MS4 community in the Maumee watershed.

The Phase II MS4 regulations address stormwater runoff from areas serving populations less than 100,000, which are termed small MS4s. More particularly, Ohio EPA designates small MS4s in areas that are partially or fully within urbanized areas—as determined by the U.S. Census Bureau—and on a case-by-case basis if they are outside of urbanized areas. Small MS4s are permitted in Ohio via a general permit. Several communities within the Maumee watershed are covered by the MS4 General Permit (e.g., suburban Toledo communities, Findlay, Lima, Defiance, and Bowling Green).

All MS4 permits require the development of a stormwater management program. These permits encourage green infrastructure BMPs such as bioretention areas, vegetated swales, and permeable pavements. The Phase I Toledo MS4 permit requires additional measures such as inspecting industrial and commercial stormwater discharges and monitoring outfalls from various land uses to assess BMP performance. Monitored parameters have included phosphorus and DRP.

Traditionally, stormwater controls have focused on the abatement of exporting solids. As most soils are rich in phosphorus, these efforts address phosphorus export, mostly in the particulate form. Some U.S. states have more directly included nutrient export considerations in their stormwater permitting programs. For instance, several states require that nutrient removal rates be calculated for practices outlined in stormwater plans. Ohio EPA is studying how such a framework could fit into Ohio's stormwater permitting program in a manner that is scientifically sound.

Stormwater is driven by precipitation in the same manner as nonpoint source pollution. In Ohio EPA's Nutrient Mass Balance reports, all stormwater is grouped within the coarse nonpoint source category (Ohio EPA, 2020b). However, TMDLs require that permitted stormwater be included within the point source wasteload allocation. Because of this, the land area covered by stormwater permits has been estimated for this project. Section 5.9 below outlines the details of this accounting. It finds that Ohio stormwater permits cover 4.3 percent of the watershed's total area within Ohio.

With the Maumee being an agriculturally dominated watershed, much less direct study of nutrient export from developed land stormwater has occurred within the watershed. Like unregulated nonpoint sources, hydrology drives stormwater runoff and is an important factor when considering this source.

A study of various residential communities in Florida found that DRP dominated the phosphorus runoff in more than 90 percent of storm events monitored (Yang and Torr, 2018). This was attributed to the decomposition of plant material such as leaf litter, grass clippings, and eroded soils when conditions were wet. The study also found that after prolonged dry periods, more soil-bound particulate phosphorus was found to runoff. Trees, especially when streetside, were found to contribute the majority of phosphorus load from residential areas in a St. Paul, Minnesota, study (Janke et al., 2017). USGS examined the impact of both leaf litter and the delivery of phosphorus via streets in a study of urban areas in Wisconsin (Selbig et al., 2020). This work found that frequent municipal street cleaning/sweeping can reduce total phosphorus and DRP load export by up to two-thirds compared to controls without street cleaning.

A study (Hobbie et al., 2017) examining nutrient budgets, also in St. Paul's urban areas, found pet waste dominated the phosphorus inputs to the system. While this brings up a different residential source, the study found the greater overall phosphorus export was due to the high density of streets facilitating the stormwater runoff.

Older research, such as a detailed study of residential areas in Madison, Wisconsin, in the 1990s, found lawns and streets contributed the majority of total phosphorus and DRP (Waschbusch et al., 1999). The actual role of lawn fertilizer is often discussed as an urban stormwater source. In collaboration with the Ohio Lake Erie Phosphorus Task Force, since 2012 the Scotts Miracle-Gro Company has removed phosphorus as a component of residential lawn maintenance fertilizers in Ohio. This follows a similar trend of not including phosphorus in lawn fertilizers across the country. An expert panel convened to look at urban stormwater for the Chesapeake Bay Partnership (Aveni et al., 2013) documented various studies examining lawn fertilizer phosphorus bans. These studies found phosphorus concentration reductions in both total phosphorus and DRP by about a quarter compared to before the phosphorus lawn fertilizer bans.

Residential areas are generally considered to contribute fewer pollutants to stormwater overall than more intensive urban land uses based on a meta-analysis of urban stormwater studies (Simpson et al., 2022). That study found land use types predict stormwater quality better than the density of impervious surfaces. It also determined that dissolved nutrients, such as DRP, are less associated with the solids and other pollutants most often examined from stormwater sources.

Modeling non-ag stormwater runoff has not been a priority in the Maumee watershed. Kast et al. (2021) modeled the watershed with a simulation considering agricultural fertilizers (both manure and commercial) were not applied and point sources were not discharging. Results from this simulation found over 55 percent total phosphorus and over 75 percent DRP reductions from the baseline spring loads. The authors note that soil sources, including legacy phosphorus, are very likely contributing much of the remainder of phosphorus export. Combined with the information presented above and the overall small proportion of developed land, stormwater from developed land is expected to be a minor source of phosphorus to the Maumee.

The Maumee watershed has a dense network of continuous water quality monitoring stations at streamflow gages (further explained in Section 4.1.5). One of these stations, Wolf Creek at Holland, a Toledo suburb, drains an area of much greater density of developed area than the rest of the monitoring stations. As explained in Section 4.1.5, the available data for the Wolf Creek station shows reduced total phosphorus and DRP FWMCs compared to the more agricultural-land-use-dominated stations. This substantiates the general understanding of the overall magnitude of phosphorus export from urban lands versus agriculture-dominated watersheds. These factors were considerations used in Ohio's 2020 Domestic Action Plan's far-field total phosphorus targets developed for small watershed management units (OLEC, 2020a). In that work, the state considered all developed land runoff to contribute load total phosphorus at a rate half that from agricultural lands. This concept is expanded upon in the baseline condition load calculations for this TMDL effort (Section 5).

The information presented in this section supports the continuation of stormwater BMPs. Water detention and retention can slow flow and potentially settle out pollutants that are being carried in runoff. Practices to increase ground water recharge and evapotranspiration show some promise in minimizing urbanization disturbances (Winston et al., 2016).

4.1.2.3. Permitted beneficial use

Biosolids

Ohio EPA's biosolids program regulates the beneficial use of biosolids generated by publicly owned treatment works in Ohio (OAC 3745-40). The biosolids program goals are to protect public health and the environment, encourage the beneficial reuse of biosolids, and minimize the creation of nuisance odors. Beneficial use requires that biosolids be used for an agronomic benefit, displacing other agricultural fertilizers discussed above in Section 4.1.1.1. Table 11 outlines the amount of biosolids applied and the number of acres they were applied to in Ohio's portion of the Maumee over the last several years.

Table 11. Summary of annual beneficial use of biosolids in the Maumee watershed.

Land application of Class B biosolids		
Year	**Dry tons**	**Acres**
2016	10,659	3,080
2017	7,634	2,957
2018	7,797	2,730
2019	9,851	3,118
2020	8,275	2,353
Average	8,843	2,847

Overall, biosolids are a small source of agricultural nutrients in the Maumee watershed. On average, biosolids were beneficially used as a source of agricultural nutrients on less than 3,000 acres per year in the Maumee watershed from 2016 to 2020.

Land application

Ohio EPA issues state permits that allow facilities to beneficially reuse liquid industrial wastes or land apply treated wastewater. These systems must be designed so discharges to waters of the state do not occur. Industrial liquid wastes must provide an agronomic benefit while protecting human health and the environment, and treated wastewater must meet effluent limits in accordance with OAC 3745-42-13. These facilities are issued individual permits that contain different conditions specific to the treated wastewater or liquid industrial waste. Three facilities are authorized to land apply treated effluent, and five facilities are beneficially reusing liquid industrial waste with Ohio EPA state permits.

4.1.3. Home sewage treatment systems

Residential homes not serviced by a municipal sewage treatment system maintain individual home sewage treatment systems (HSTS). HSTS fall into one of two main treatment types:

On-site (non-discharging) or leach field systems percolate septic tank effluent through the soil. Soil microbes treat the effluent, and there is no point source discharge from these systems.

Discharging systems provide enhanced treatment by creating an aerobic environment where microorganisms digest organic carbon and nitrogen is oxidized to nontoxic inorganic forms (i.e., nitrates). Effluent is then discharged to surface waters. Phosphorus treatment is minimal in discharging HSTSs.

Ohio Department of Health (ODH) rules for sewage treatment systems require that all new and existing systems are issued an operation permit with an identified maintenance schedule; discharging systems are issued a sampling schedule to ensure the system is meeting discharge standards. As of January 1, 2015, all new and modified discharging systems are required to be covered by Ohio's general NPDES permit (OHK000004).

Both non-discharging and discharging HSTS systems can fail to treat waste as designed. Soils receiving septic tank effluent from non-discharging systems can become overloaded; sometimes, this causes effluent to surface or short circuit, reducing treatment and resulting in discharges to surface water. A common failure of discharging systems occurs due to malfunctions of the mechanical components. In these cases, waste is minimally treated, and exported pollutants are elevated.

Upon identification of a failing system, local health departments establish specific action plans and timeframes for correction of the nuisance conditions. These plans may include repair, alteration, or replacement of the sewage treatment system or connection to public sewers, where available.

To account for the HSTS source contributions, the population using HSTSs, the partitioning of the two major system types, and the failure rates for these systems must be calculated. Ohio's Nutrient Mass Balance Report finds that HSTS contributes the smallest total phosphorus load to the Maumee watershed among its three coarse source categories. This is 2 percent for the average spring loading season (Ohio EPA, 2020b; also see Figure 9 above).

The Toledo Metropolitan Area Council of Governments (TMACOG) member-driven planning partnership has estimated critical areas with high densities of HSTSs in the Maumee watershed in Ohio (TMACOG, 2018). This work includes a detailed survey of HSTS locations. Dense areas of residences serviced by HSTS, most often in unincorporated communities, have been identified as these critical sewage areas. These are important as they identify the densest and, therefore, most cost-effective areas where HSTS pollution abatement can be targeted.

ODH will continue to work with local health departments to ensure implementation of their Operation and Maintenance Tracking Programs for sewage treatment systems as required in the OAC. ODH will provide options and resources for implementing operations and maintenance tracking, including identification of failing sewage treatment systems within targeted watersheds. The number of discharging HSTS covered by Ohio EPA's HSTS General Permit will continue to grow as existing systems are upgraded and new ones are installed.

4.1.4. Instream processes

Instream processes such as biological activity or sedimentation can capture and release phosphorus. They also can change the chemical form of phosphorus, which may have important implications for Lake Erie HABs. Which process dominates can vary in space and time, with season and streamflow levels playing key roles. Understanding these processes advances knowledge of phosphorus sources but can also provide insight into ways to store and slow the export of phosphorus. These processes are subject to active research, and many unknowns still exist.

Soil particles eroded from fields and stream banks become sediments that are carried by swiftly moving water. Particulate phosphorus attached to suspended sediment settles at spots with slower moving water, such as natural pools and behind dams. Once deposited in stream channels, especially in pools, this sediment can be resuspended when higher stream flows create the necessary forces (Sharpley et al., 2013).

During times of low streamflow and in warmer months, soluble phosphorus (most often represented by DRP) is sunk in the stream network due to incorporation by biological growth, predominantly by benthic algae (Dodds, 2006). This phenomenon has been observed by Ohio EPA. DRP concentrations in the Maumee River near the Waterville monitoring station are often near or below detectable levels during warm, low-flow conditions, with excessive benthic algae mats covering the streambed. Most of this captured DRP is released back into the stream as the algae die or are washed off in high flows and via other processes (Withers and Jarvie, 2008). This process is important in the near-field setting as excessive benthic algae can be deleterious to a stream's local ecological health.

DRP can also adsorb into or desorb out of stream bed sediments due to biogeochemical reactions. This generally depends on the nature of the sediment and DRP water concentration (Taylor and Kunishi, 1971; Kunishi et al., 1972). Stream bed sediment is known to have a certain phosphorus equilibrium concentration. When DRP concentrations in waters overlying bed sediments are greater than the sediments' equilibrium concentration, DRP can be adsorbed. Conversely, DRP can desorb from bed sediments into overlying waters when the water's DRP concentration is below the equilibrium; this is often described as "internal" loading. Stream bed equilibrium concentrations vary and largely depend on the sediment's chemical and geological nature. Certain conditions are more favorable for this type of exchange to occur (Sharpley et al., 2007), and rates can vary greatly based on these conditions (Froelich, 1988).

ARS studies of ditches in the Maumee watershed have found that adsorption of DRP in ditches does occur. Fine sediments trapped by aggrading ditches remove relatively more DRP than recently dredged or "dipped" ditches (Smith and Pappas, 2007). The implications of these findings support the above implementation suggestion that more stable ditching practices be installed (i.e., two-stage ditches) rather than the traditional trapezoidal channels.

A review of the delivery and cycling of phosphorus in rivers (Withers and Jarvie, 2008) noted that phosphorus transformations are expected to be the greatest under low-flow conditions during the spring and summer, especially driven by instream algal activity and other eutrophication processes. That work notes, "most phosphorus inputs delivered under very high flows will be flushed through without entering the stream biogeochemical pathways." Most of the phosphorus exported from the Maumee watershed occurs during high-flow periods (Baker et al., 2014a), which may indicate that instream processes are not of prime concern for this project.

However, it has been shown that during high flows, it is possible for suspended sediment to adsorb soluble phosphorus in the flowing water. DRP has been found to transform to the particulate form through adsorption to instream suspended solids during high-flow conditions at several Maumee watershed tributaries in King et al. (2022). This work showed this novel process in 77 out of 78 samples in the flowing water. Another study examining a small Maumee watershed tributary also found sediment carried by high flows may be adsorbing dissolved phosphorus (Williamson et al., 2021a).

Williamson et al. (2021b) focused on the anomalous stream flows, land management, and pollutant delivery that occurred in 2019. Several tributary monitoring stations throughout the Maumee watershed were examined. This work found that the 2019 reduction of DRP, but not total phosphorus, observed at Waterville (discussed above and shown in Figure 10 from Guo et al. [2021]) did not occur at many of the smaller watershed monitoring stations. Williamson et al. (2021b) explained that this could have occurred due to the desorption of sediment-bound phosphorus in those stream channels due to that year's reduced DRP ambient water concentrations. This provides more evidence that the instream cycling of phosphorus may have important implications. It also provides insight into the time lag for phosphorus export to reduce after phosphorus watershed imports are abated (as discussed by Muenich et al., 2016; Jarvie et al., 2013).

The King et al. (2022) study explains that the implications of the stream-water suspended sediment adsorbing DRP means the process can potentially be providing an environmental service. The paper suggests that transforming DRP to a less-available particulate form during higher flows may account for reducing DRP exports to Lake Erie by 24 percent, thus decreasing HABs by 61 percent. As explained above, long-term reductions in sediment delivery to the Maumee watershed may mean that this ecosystem service has likewise declined. This possibly plays a role in the DRP increase in western Lake Erie tributaries since the mid-1990s (as shown by Rowland et al. [2021]).

Instream cycling and even trapping of DRP is an area of very active study in the Maumee watershed and similar watershed systems.

A USGS research project measured sediment nutrient processes throughout the Maumee watershed in 2019 and 2021. This work, led by Dr. Becky Kreiling, involves measuring phosphorus source/sink dynamics at approximately 80 sites throughout the basin. To understand the capacity of phosphorus that sediment can store, the phosphorus saturation ratio will also be determined at each site. Instream flux rates of nitrogen are also included in this work. Models of sediment nutrient dynamics based on land use and sediment physiochemical variables are now being developed, and various publications are expected within the next year (Kreiling, 2021).

A project led by Dr. James Hood at OSU (HABRI, 2019) will evaluate when and where rivers within the Maumee watershed are sources or sinks of phosphorus. Separate methods for assessing low- and high-flow conditions will be incorporated. The high-flow methods will expand upon the King et al. (2022) work, which was performed by the same lab. Detailed field studies will be used to understand spatial patterns in sediment stocks, phosphorus content, and aspects of phosphorus cycling. This will allow for the sources and sinks of phosphorus to be mapped throughout the Maumee River's watershed stream network. The results from this work will be used to develop and parameterize instream phosphorus cycling into OSU's existing SWAT model for the Maumee (more on the modeling below). With the coupling of instream processes to upland BMP modeling, the overall results of this project will improve what is known about BMPs that best address DRP reductions. This project's completion date is scheduled to be December 31, 2022.

Another project out of Dr. Hood's lab (HABRI, 2020/2021) is evaluating the sources and chemistry of sediment moving through the Maumee stream network. Methods will be employed to understand how long sediment from various sources takes to move through the watershed. Then, an examination of the phosphorus cycling will occur, with a focus on phosphorus sorption to and desorption from these sediments. Incorporating this work with the findings from the study noted in the paragraph above, the King et al. (2022) work, and the Williamson et al. (2021a) study will facilitate an improved understanding of how sediment source influences the sediment-DRP exchange during stream transport in high-flow events. This project's completion date is scheduled to be December 31, 2023.

A large, paired watershed study currently occurring within the Maumee watershed (ARS, 2019) will provide additional insight into nexus agricultural BMPs, nutrient and sediment runoff, and instream processes. Monitoring for this study is being organized by the USDA ARS/NRCS Conservation Effects Assessment Project (CEAP) program with Heidelberg University's Dr. Laura Johnson as the lead. It focuses on two small watersheds within the Blanchard River subwatershed. Water quality and hydrology measurements are taking place in both watersheds to quantify loads. One will be held as a control, while the other will be treated with a dense suite of BMPs. The BMPs selected will focus most on those promising to reduce DRP runoff (e.g., nutrient management, phosphorus removal structures) and those that retain water (e.g., drainage water management, blind inlets). OSU's Dr. Jay Martin has obtained a USDA Regional Conservation Partnership Program (RCPP) grant to augment funding for BMP initiatives and provide additional research and monitoring as part of this project. This project's original completion date was scheduled to be October 2022. However, the RCPP grant funding BMPs is expected to continue through at least 2027. Therefore, research findings from this work should continue for several years.

USGS is undertaking a study to examine most of the factors outlined in the two Hood studies noted above in Wisconsin's Fox River that feeds the Green Bay of Lake Michigan (Kreiling, 2021). This work will characterize the sources of sediment nutrients in streams, study the instream interactions (sources and sinks), and incorporate its findings into watershed models. This work intends to improve sediment and nutrient export reductions to Green Bay management decisions. This has yet to begin, with a project completion date expected in two to three years.

NRCS and ARS are just starting a multiphase CEAP project examining various aspects of legacy phosphorus (NRCS, 2021). This project covers study areas all across the country, including the WLEB. This work will develop a database that quantifies the contribution of legacy phosphorus at the edge-of-field and watershed scale across the large study area. Watershed management recommendations will be made based on this work. What is learned of phosphorus cycling/movement will then be incorporated into an array of watershed models. This is a multimillion-dollar project with a completion date of 2026.

Recommendations to the IJC in 1980 on Great Lakes bioavailable phosphorus management strategies noted that phosphorus discharge to streams "have a markedly different effect on a downstream lake…compared to the effect that would result if phosphorus were discharged directly to the lake" (Lee et al., 1980). The location of the phosphorus discharge plays a role as less cycling is expected, or at least less time of streambed contact is expected. Dr. James Larson with USGS is researching how nutrients (nitrogen, phosphorus, and carbon) are transformed in the Maumee River mouth in Toledo. For this project, samples were collected at numerous sites in the river mouth three times in 2021 (May, July, and August). The study continues with plans for repeat sampling in 2022 (Kreiling, 2021).

Estuary and lake dynamics using monitoring that moves with pollutant masses (i.e., Lagrangian sampling) have been studied in the lower Maumee River and throughout Maumee Bay. Employing these methods, Baker et al. (2014b) found rapid deposition of suspended sediment and particulate phosphorus as the river water enters the bay during high/storm flow periods. These findings support the emphasis on the DRP portion of total phosphorus because it is the main driver of the Western Basin of Lake Erie HABs.

Taken as a whole, these complex processes can be important to the export of phosphorus from the Maumee watershed. This TMDL project focuses on nutrients delivered to Lake Erie during the spring loading season (March through July). The DRP captured in the stream channel's primary production, especially in the later part of this season, may provide a measurable service. However, the magnitude of this service is assumed to be minimal, mainly impacting concentrations during lower-flow periods. Alterations to headwater streams and ditches have implications for erosion and movement of sediment. They also play a role in capturing or releasing DRP. The DRP transformed to particulate form by suspended solids throughout the watershed may play a larger role in understanding the changes of DRP loads to the Western Basin over time. This process seems to occur during higher-flow periods. Loads of suspended solids have changed, as has the rate and magnitude of streamflow.

How to best use the understanding of instream processes to achieve phosphorus export reductions is a work in progress. Ongoing studies may provide more evidence of the overall implications of these processes. In addition to promoting stream channel stability, other implementation actions that maximize instream processing, or "sinking," of DRP may prove useful in the portfolio of recommendations.

4.2. Critical source areas and overall heterogeneity of sources in the Maumee watershed

The Maumee watershed is approximately 5.3 million acres. While its land use is dominated by agricultural row crop production, the landscape is heterogenous. Land management activities (such as row crop drainage practices) change in response to that geographic heterogeneity. These factors result in disproportionate pollutant loads being delivered from different parts of the watershed. Areas with higher relative pollutant losses are often termed CSAs. Analysis of modeling and water quality monitoring provides evidence for CSAs of various spatial scales throughout the Maumee watershed. This section will present the current state of knowledge of Maumee watershed CSAs.

First, a review of the watershed's major ecological and geographical zones is presented.

Ecoregions denote areas of general similarity in ecosystems and the type, quality, and quantity of environmental resources; they are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. Ecoregions are directly applicable to the immediate needs of state agencies, including developing biological criteria and water quality standards and establishing management goals for nonpoint source pollution. They are also relevant to integrated ecosystem management, an ultimate goal of most federal and state resource management agencies. The following factors are considered when determining ecoregions: geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (U.S. EPA, 2012). The Maumee watershed drains two ecoregions at the level III resolution as defined by U.S. EPA (2012): the HELP and the ECBP (Figure 27).

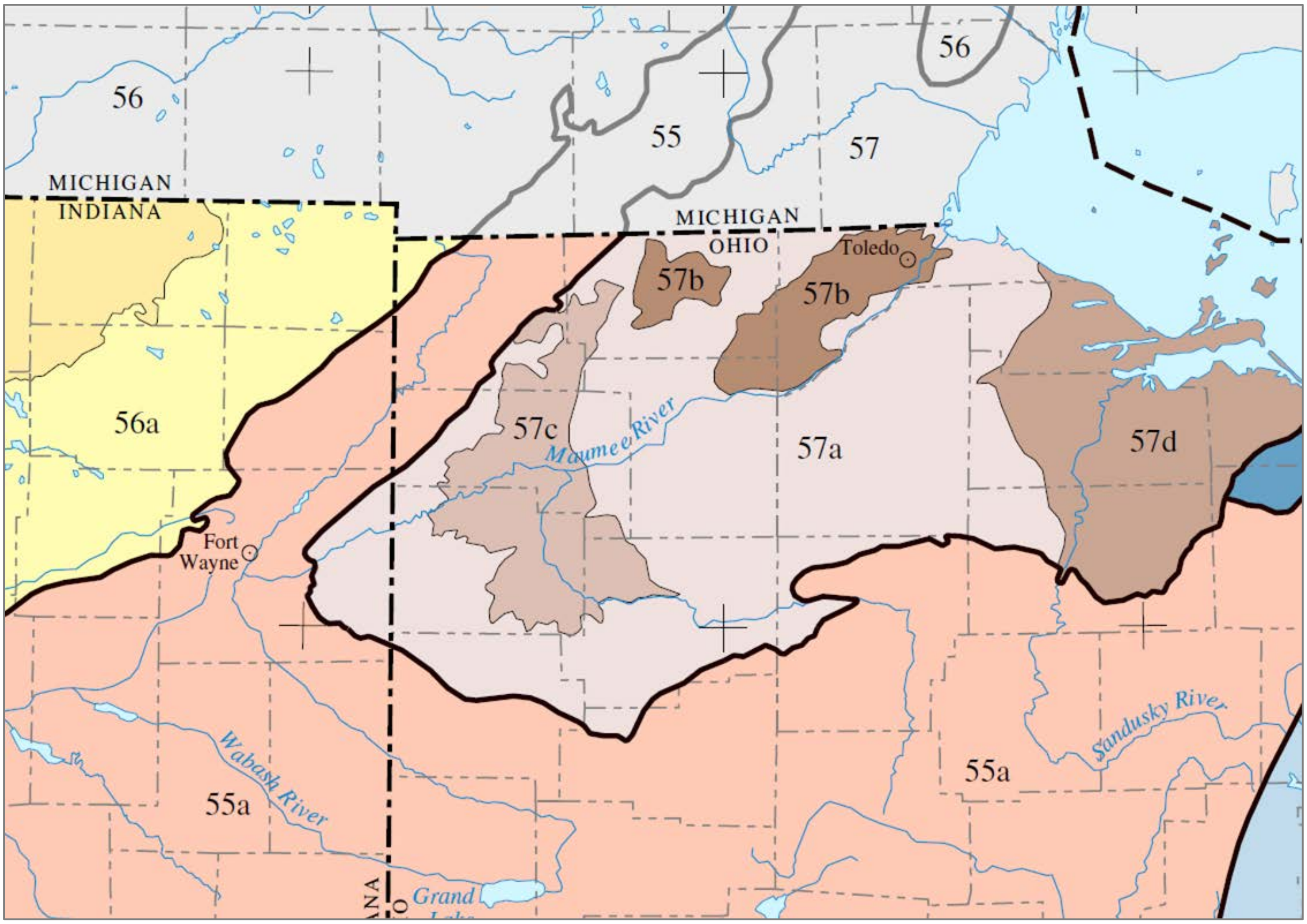


Figure 27. Ecoregions of the Maumee River and adjacent watersheds.

Labels starting with the number 57 on Figure 23 show the HELP ecoregion. This area covers broad, fertile, nearly flat plains punctuated by relict sand dunes, beach ridges, and end moraines. The soils in this ecoregion were the most poorly drained of all ecoregions in Ohio. Today, most of the area has been cleared and artificially drained. It now contains highly productive farms producing corn, soybeans, livestock, and vegetables. Three subcategories (level IV) of this ecoregion exist in the Maumee watershed (U.S. EPA, 2012).

Much of the Maumee watershed in Ohio is drained by the HELP, Maumee Lake Plains level IV ecoregion (labeled 57a on Figure 23). This area is naturally poorly drained and contains clayey lake deposits, water-worked glacial till, and fertile soils. Elm-ash swamp forests and beech forests that once existed have been replaced by productive, drained farmland (U.S. EPA, 2012).

A portion of the HELP in the Maumee watershed is classified as being in the Paulding Plains level IV ecoregion (labeled 57c on Figure 23). This area drains much of the Auglaize and Tiffin rivers' watersheds. This lake plain area is characterized by clayey lacustrine sediment and extensive, very poorly drained, illitic (clay) soils. The near-level to level and depressional topography supported mostly elm-ash swamp forest but now has been cleared and drained for soybean, small grain, corn, and hay farming. Surface drains are much more common in this zone than in the Maumee Lake Plains, presenting different nutrient management challenges. Very sluggish, low-gradient streams and many ditches are typically turbid and have very high loads of suspended clay (U.S. EPA, 2012).

The final level IV ecoregion within the Maumee watershed's HELP is the Oak Openings (labeled 57b on Figure 23). This is a belt of low, often-wooded sand dunes and paleobeach ridges situated among the broad, nearly flat agricultural plains of the Maumee Lake Plains. This area drains small tributaries north of the Maumee River in its downstream reaches, central Fulton County and much of Lucas County. Well-drained, sandy soils are common and originally supported mixed oak forests and oak savanna; poorly drained depressions with wet prairies were also found. Today, general farms, residential development, oak woodland, and sand quarries occur in the Oak Openings region (U.S. EPA, 2012).

The ECBP level III ecoregion is primarily a rolling till plain with local end moraines. Corn, soybean, wheat, and livestock farms are dominant and have replaced the original beech forests and scattered elm-ash swamp forests. The Maumee portion of this ecoregion is noted as having less-productive soils and more tile drainage compared to other areas of the ECBP across the Midwest. This ecoregion generally rings the upper portions of the Maumee watershed to the west and south (labeled 55a on Figure 23). It primarily drains the two tributaries that form the Maumee River (the St. Joseph and St. Marys rivers), the headwaters of some of the upper Auglaize River tributaries, and the upstream portion of the Blanchard River watershed (U.S. EPA, 2012).

Watershed models have been used to identify CSAs of nonpoint sources in watersheds. An advantage of using the SWAT model is that pollutant loads can be determined while finding CSAs. For instance, a study of several agriculturally dominated watersheds in Oklahoma found 22 percent of sediment and phosphorus export loads were from only 5 percent of the area (White et al., 2009). Various methods have been used to structure SWAT and other models to determine CSAs in the Maumee watershed. These will be discussed throughout the remainder of this section.

The use of tributary water quality monitoring stations also provides evidence to compare portions of the Maumee watershed. This is water quality monitoring at USGS streamflow gages in a fashion similar to the station on the Maumee River at Waterville, described above. Combined, Heidelberg's NCWQR and USGS currently maintain 29 of these stations in the Maumee watershed in addition to Waterville (Figure 28). More detail on these stations and results data have been compiled in OLEC (2020b). Monitoring at the majority of these stations did not start until after 2014. Many of them only now have enough results to begin detailed analyses. This section will present some of these new analyses in considering CSAs. These sites will also be used for tracking the progress of nutrient reductions as outlined in the implementation section of this TMDL.

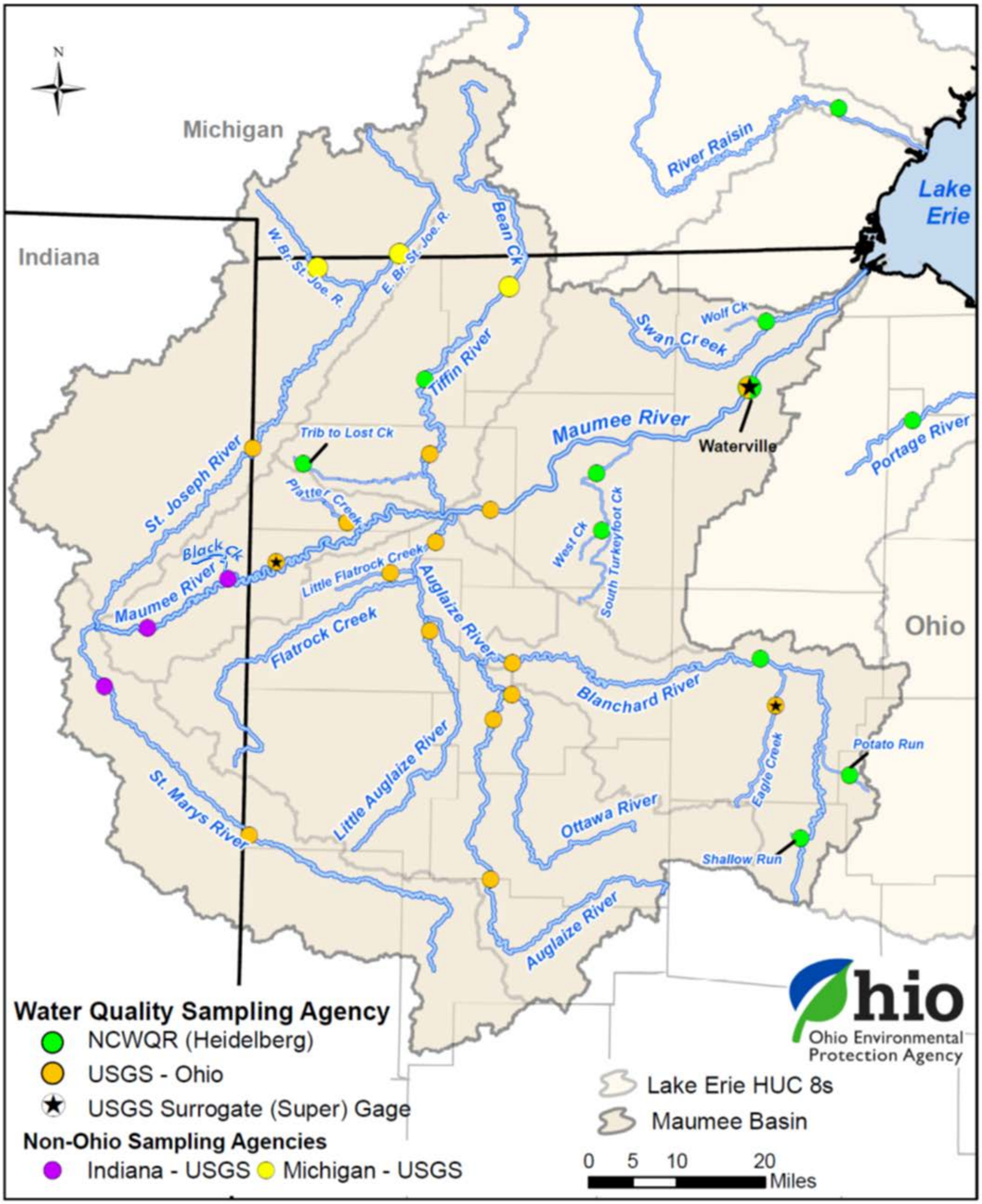


Figure 28. Network of continuous water quality monitoring stations throughout the Maumee watershed at USGS streamflow gages. The various water quality sampling agencies are noted.

4.2.1. Ohio's 2017 WLEB Collaborative Implementation Framework

A detailed effort by Scavia et al. (2016) uses ensemble modeling to examine nutrient export in the Maumee watershed's HUC-12s. This report considers the results from modeling analyses carried out by its coauthors, a wide range of resource experts from the University of Michigan, OSU, ARS, LimnoTech (a consultancy), Heidelberg University, USGS, The Nature Conservancy, and Texas A&M. Five SWAT models and one SPAtially Referenced Regressions on Watershed attributes (SPARROW) model are examined and aggregated. One product of this report is the identification of "hotspot" subwatersheds. These hotspots are determined by agreement among the various models on the top 20 percent of nutrient export (Figure 29). Note that the work that went into the Scavia et al. (2016) report was later published in an academic journal by Scavia et al. (2017).

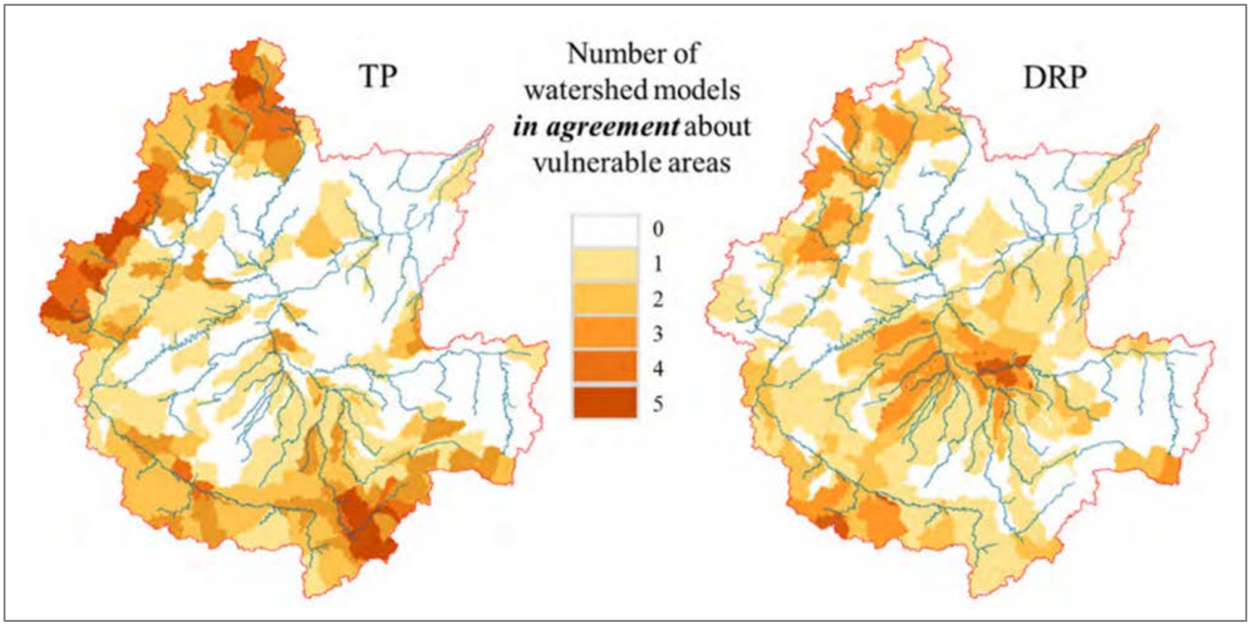


Figure 29. Potential "hotspots" of nutrient export to WLEB in the Maumee watershed identified by comparing multiple models. Scale is 0–5 based on models in agreement. There were six models used in the total phosphorus map; however, all six models did not agree on any area. Only five models are used in the DRP map (Scavia et al., 2016).

In early 2017, the state of Ohio released a collaborative implementation framework report intended to serve as a pathway for developing the state's first Domestic Action Plan (OLEC, 2017). Using results from the Scavia et al. (2016) report and various other data sources, this report divided the Ohio Maumee watershed HUC-12s into three priority levels for phosphorus loss. Twenty-four HUC-12s were identified as the top priority. These top-priority HUC-12s were each assigned to one of four primary phosphorus-loss source mechanism categories. The following briefly summarizes these categories as outlined in the OLEC (2017) report:

- **Soils in hydrologic group D**. Fourteen of the 24 top priority HUC-12s were identified due to a high density of soils in the hydrologic group D. These soils were characterized by very low infiltration rates even when drained. Most of these HUC-12s are in the Paulding Plains portion of the HELP ecoregion. The low infiltration rates may result in reduced effectiveness of subsurface drainage systems, so drainage practices could include surface enhancements that may promote surface runoff. The SWAT models generally identify these regions as high DRP loading sources. The models predict the potential for elevated DRP loading when subsurface drainage intensity is high. Twelve of these 14 HUC-12s are south of the mainstem Maumee River.
- **High sloped lands.** Five of the top priority HUC-12s were identified with the primary source of phosphorus bound to sediment eroded from agricultural fields. These areas, within the ECBP ecoregion, have some of the highest overall land slopes due to being crossed by glacial end moraines. The greater energy generated by these slopes increases the potential for soil erosion and, thus, particulate phosphorus. Four of these five HUC-12s are south of the mainstem Maumee River.
- **High Livestock density**. Two HUC-12s were identified as being top priorities due to high livestock density. Rather than basing this on modeling results, the collaborative report used results from water quality monitoring and other available sources of data to determine these watersheds. One of these two HUC-12s is south of the mainstem Maumee River.

- **Various hotspots characteristics**. Finally, three HUC-12s fell into the top priority list due to various landscape characteristics. These watersheds were identified by the Scavia et al. (2016) ensemble modeling report as hotspots, but they do not fall into any of the three previous categories listed above. All three of these HUC-12s are south of the mainstem Maumee River.

It is important to understand that all pollutant modeling has resolution limitations. These start with the inputs and are carried through modeling computations into the outputs. One limitation with regards to the SWAT models examined in Scavia et al. (2016) is that existing row crop agricultural practices (e.g., planting, tilling, fertilizing) and pollutant reduction BMPs are not input with geographic detail at the HUC-12 level. Since that effort, SWAT modeling advances have been made in the Maumee models. Many of those studies have been discussed above. Next, before explaining the modeling studies regarding CSAs, the more recent Ohio efforts toward nutrient reduction are outlined.

4.2.2. Ohio's 2018 and 2020 Domestic Action Plans

In 2018, the state of Ohio progressed past the priority subwatershed concept used in the 2017 collaborative implementation framework report with the release of the Ohio Domestic Action Plan 1.0 and subsequent 1.1 update (OLEC, 2018). While the ensemble modeling from Scavia et al. (2016) was still discussed in these documents, emphasis was put on the need for phosphorus reductions throughout the entire Maumee watershed. These documents also stressed the continued support for the water quality monitoring network, described in the section above, which was maturing to close to its current, i.e., 2022, state.

The Ohio Domestic Action Plan was updated in 2020 (hereafter referred to as "Ohio DAP 2020") with new material relevant to identifying CSAs in the Maumee watershed (OLEC, 2020a). In this report, the emphasis on phosphorus reductions throughout the entire Maumee watershed was combined with new analyses of the geographic variations of phosphorus delivery. At the basin scale, Ohio's nutrient mass balance methods were augmented with a relevant literature review of phosphorus sources to distribute nonpoint sources of total phosphorus to three land use/cover categories: agricultural, developed, and natural. The Ohio DAP 2020 calculations were carried out for the Annex 4 targets base spring season of 2008. This resulted in determining that 85 percent of Ohio's contribution of total phosphorus load was sourced from agricultural lands. Developed land contributed about 6 percent, comparable to the 7 percent total load from wastewater treatment facilities. Note that developed land in the Ohio DAP 2020 analysis did not divide non-ag stormwater from permitted or unpermitted areas as described in this TMDL. The Ohio DAP 2020 work found that HSTS and natural lands contribute around 2 percent and 1 percent of the watershed's total phosphorus spring 2008 base load, respectively.

The Ohio DAP 2020 analysis also looked at the spring 2008 base load distribution throughout the Maumee watershed's HUC-12s. To determine this, a hydrology analysis was carried out on stream gages throughout the watershed. Similar to results documented by Williams et al. (2020), this work determined that the southern, and particularly southwestern, part of the watershed delivers relatively more water. This analysis was used to determine a hydrologic weighting factor for each HUC-12. This, combined with the land use/cover distribution carried out at the basin scale, results in calculated total phosphorus yields for each HUC-12. Figure 30 shows the spring 2008 baseline total phosphorus yield (mass per area) results for Ohio's Maumee watershed HUC-12s.

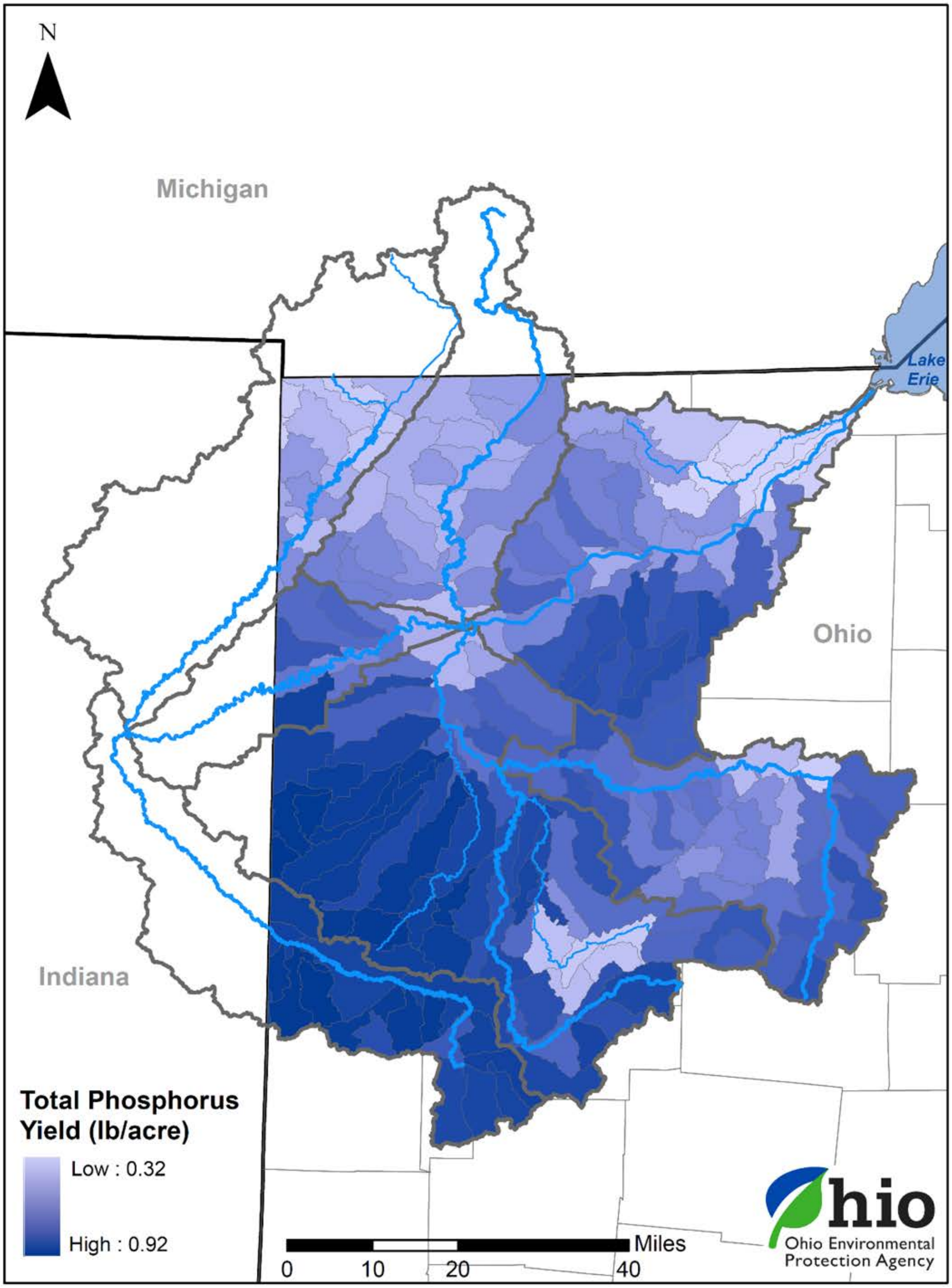


Figure 30. Total phosphorus yield from the landscape by HUC-12 in the Maumee watershed for the spring 2008 base condition from the Ohio DAP 2020 (OLEC, 2020a).

Based on this work, the part of the watershed south of the mainstem river contributes a greater proportion of total phosphorus. While higher stream discharge in the south factors into this, land use is also important. On Figure 30, the lighter-shaded HUC-12s around the Lima, Findlay, and Defiance denote developed areas. This reflects the fact that the Ohio DAP 2020 method calculated developed land to contribute half the total phosphorus compared to agricultural lands before accounting for the hydrologic weighting factor.

The Ohio DAP 2020 provided the spring 2008 baseline total phosphorus loads for the three land use categories and HSTS for each Maumee watershed HUC-12 within Ohio. It also calculated a “landscape target” by taking a 40 percent cut from the total of those four sources. The intent of this work was to provide watershed managers with quantifiable targets that could be used for implementation planning.

4.2.3. Ohio EPA’s 2020 Nutrient Mass Balance Report

Another Ohio-led effort to discuss Maumee CSAs is Ohio EPA’s 2020 Nutrient Mass Balance Report (Ohio EPA, 2020b). This report included an analysis of several Maumee watershed subwatersheds, including major portions of seven tributaries in the Maumee: the St. Joseph and St. Marys rivers to the Ohio/Indiana state line; most of the Tiffin, Ottawa, and Blanchard rivers; and the upper portion of the Auglaize River (Figure 31). The area included in this analysis covers 52 percent of the total Maumee watershed.

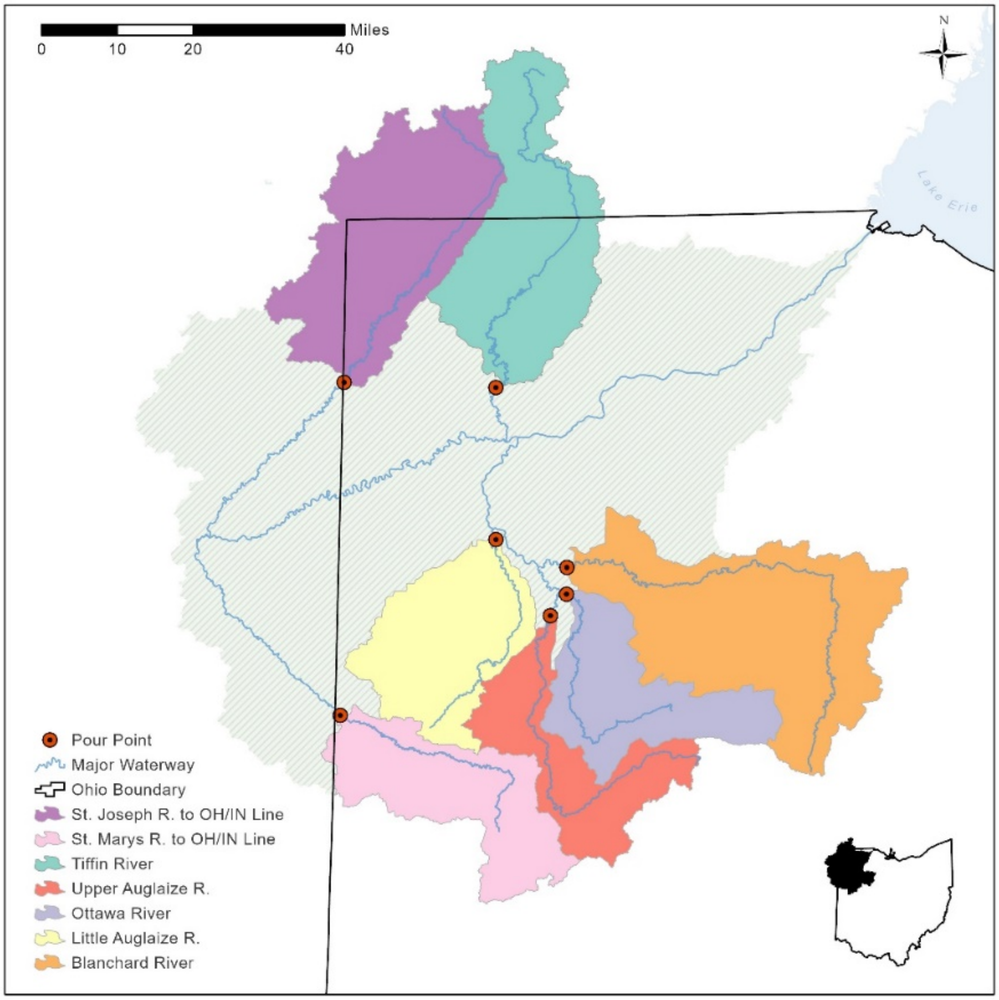


Figure 31. Maumee River subwatershed areas included in the Nutrient Mass Balance 2020 analysis (Ohio EPA, 2020b).

In general, the Maumee watershed is dominated by agricultural production, which occupies 77 percent of the total watershed. However, as noted on Figure 6 (Section 4.1), there is a higher proportion of natural areas north of the Maumee River mainstem. Figure 32 shows land use for the seven tributaries included in the Nutrient Mass Balance 2020 subwatershed analysis. The land use in this figure only characterizes the area upstream of the pour point on each tributary (the same area as the map in Figure 31). Of these subwatersheds, the two northern tributaries, the St. Joseph and Tiffin rivers’ watersheds, drain the highest percentage of natural lands. The Ottawa River watershed has the greatest percentage of developed land due to it draining the greater Lima area. The Blanchard River watershed drains the developed Findlay area; however, because it is an overall larger watershed, developed land does not take up as much of a proportion. The St. Marys and Little Auglaize rivers' watersheds drain the greatest percentage of agricultural land among these seven tributaries.

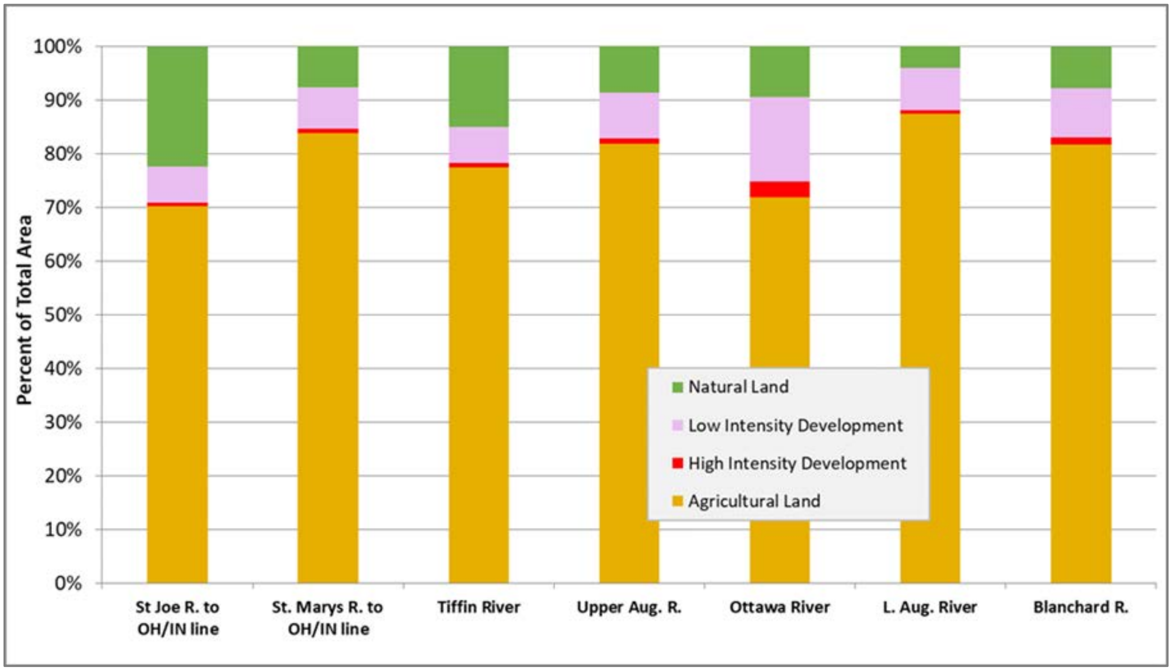


Figure 32. Distribution of major land use and land cover categories in Maumee River subwatersheds. Shown as percent of total watershed area. Stacked bars represent the area indicated by the map in Figure 31 (Ohio EPA, 2020b).

Figure 33 shows the nonpoint source total phosphorus yield of the Maumee subwatersheds for water year 2018, as presented in the 2020 Nutrient Mass Balance. This represents the amount of nonpoint source normalized by the land area in each tributary's watershed, presented in pounds per acre (lbs./acre). The stacked bars in Figure 34 show the total phosphorus loading sources. It is important to note that because nutrient loading is primarily driven by high streamflow events, comparing different watersheds by only looking at one year of data can be influenced by localized weather. That is, some watersheds may have had more runoff-producing rain events than others in water year 2018.

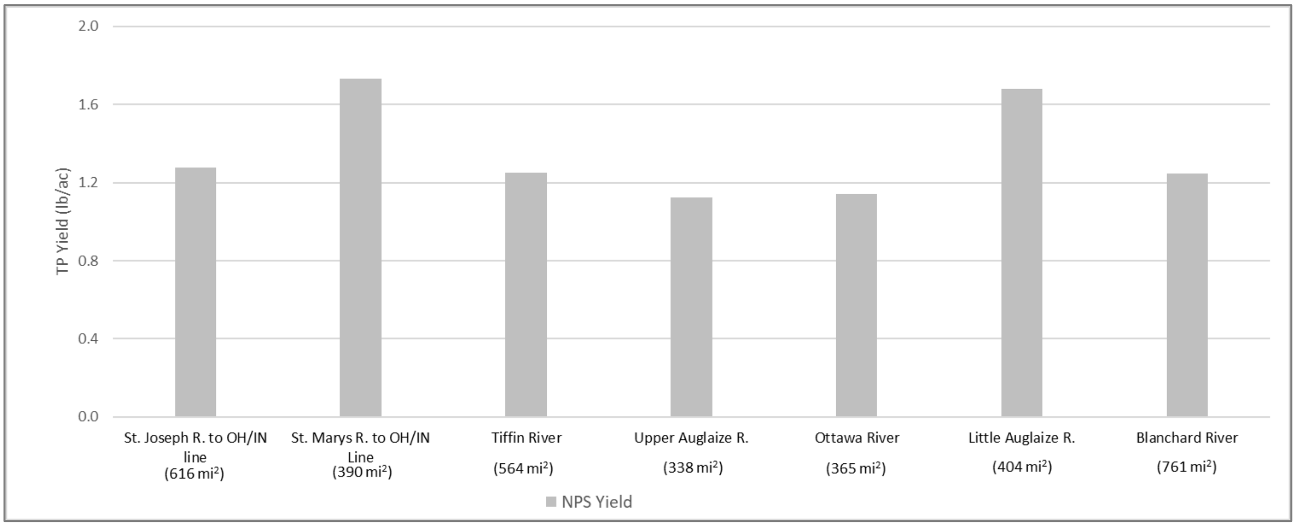


Figure 33. Total phosphorus nonpoint source yields for subwatersheds of the Maumee River shown on Figure 31 for water year 2018 (Ohio EPA, 2020b).

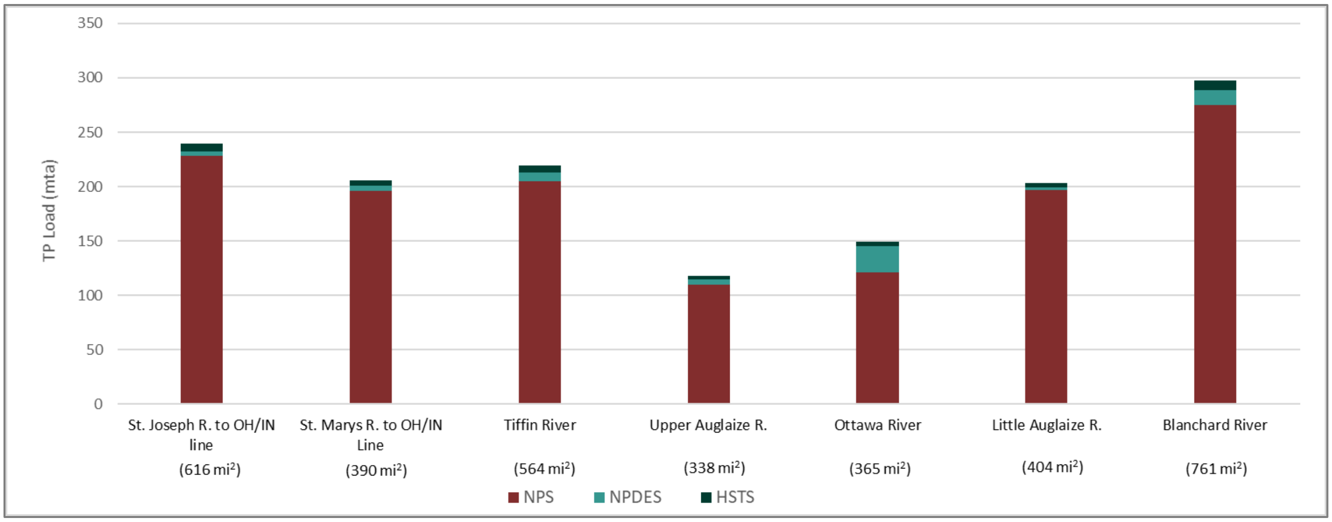


Figure 34. Total phosphorus loads, in metric tons, for subwatersheds of the Maumee River shown on Figure 31 for water year 2018 (Ohio EPA, 2020b).

Like the greater Maumee River watershed, nonpoint sources dominated the total phosphorus loading in all tributaries. Even considering this caveat, on Figure 34 the order of greatest to least total loads for each tributary is roughly the same as the largest to smallest watershed areas (areas are noted below each tributary's name in Figure 33 and Figure 34). However, differences among the watersheds are apparent.

On Figure 34, the tributary with the greatest permitted wastewater NPDES load is the Ottawa River. This reflects the population and industry in the greater Lima area.

On Figure 33, the Little Auglaize and St. Marys watersheds have the greatest nonpoint source yield for total phosphorus of all the tributaries examined. As noted above, these two subwatersheds drain the largest amount of agricultural area.

Reduced loading in the watersheds of the St. Joseph and Tiffin rivers is likely due to the greater amount of natural area. The 2020 Nutrient Mass Balance points out that the upper Auglaize River watershed stands out as having a lower water year 2018 FWMC and nonpoint source yield. This subwatershed also drains a higher relative proportion of natural lands. However, the upper Auglaize River watershed had a relatively higher FWMC in the water year 2017, when it received a greater streamflow yield than in water year 2018.

Overall, this analysis uses real monitoring data and Nutrient Mass Balance methods to provide supporting evidence to the results of the Maumee HUC-12 far-field total phosphorus targets work in the Ohio DAP 2020 (OLEC, 2020a). Both analyses indicate that the southern section parts of the Maumee watershed contribute greater amounts of total phosphorus relative to the other tributaries.

4.2.4. Published modeling on Maumee watershed critical source areas

USGS maintains a modeling program called SPARROW. This uses a hybrid mass balance and statistical approach to simulate pollutant transport. "SPARROW models simulate long-term mean-annual transport given source inputs and management practices similar to a given base year" Robertson et al. (2019). The 2019 publication outlined phosphorus and nitrogen transport for the complete Great Lakes Basin using 2002 as its base year.

Figure 35 shows the total phosphorus load broken down by sources for the seven Maumee HUC-8 watersheds based on this modeling approach. Data used to develop this figure were provided as supporting information from the Robertson et al. (2019) publication. It is important to note the loads on this figure are calculated as what the entire HUC-8 contributes; this includes parts of the watersheds in Michigan and Indiana. The two Maumee and one

Auglaize HUC-8s results do not include upstream loads delivered to those watersheds, i.e., only the loads "produced" within each HUC-8 are shown. Also note that these figures were produced using statistical models; this differs from the Nutrient Mass Balance reports shown above and new analysis provided below, which are based on water quality monitoring.

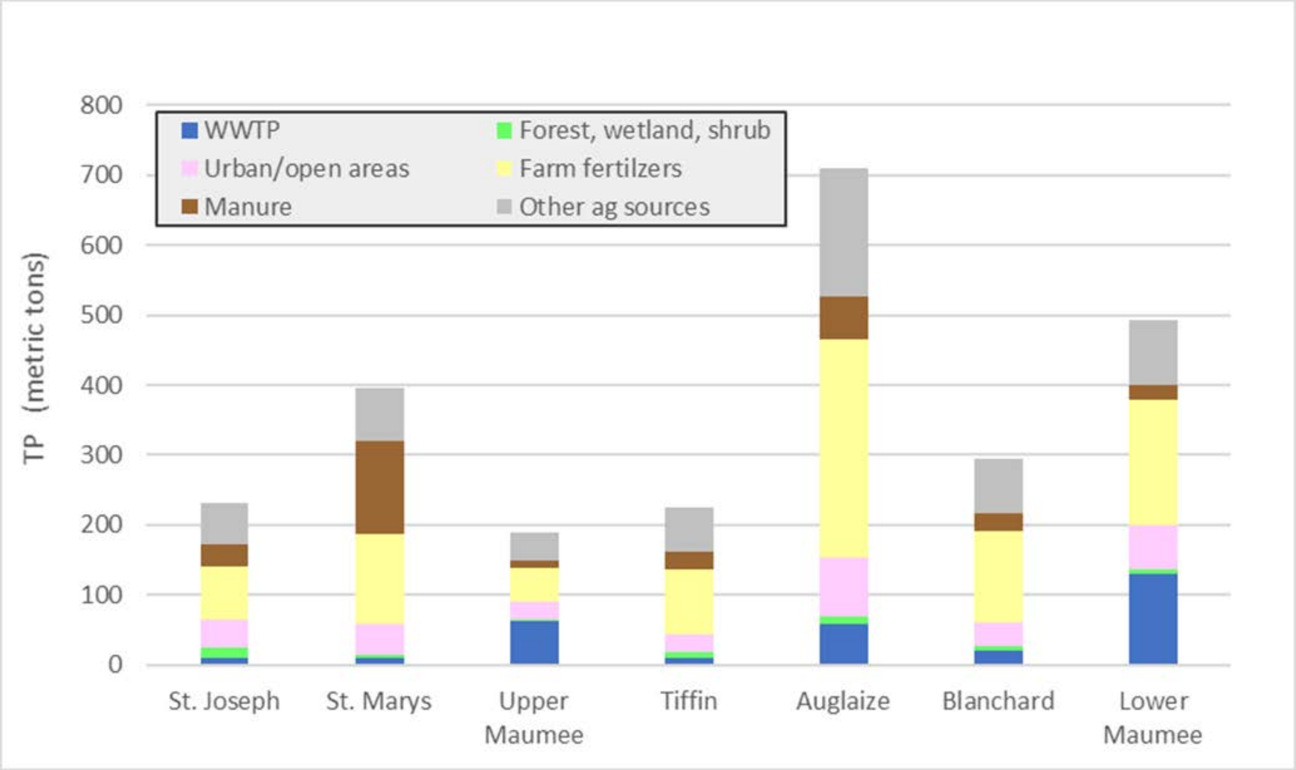


Figure 35. Total phosphorus loads in the Maumee River watershed HUC-8s with sources shown based on SPARROW modeling of the 2002 base year (Robertson et al., 2019; figure developed from supporting information).

The Robertson et al. (2019) paper does not provide a detailed explanation of what it categorizes as other agricultural sources. It describes these as loads in addition to fertilizer and manure, "which represents general losses from agricultural areas, such as natural sources and increased losses caused by agricultural activity." Soil-stored/legacy sources of phosphorus, which are described several subsections above, likely contribute to this category.

Figure 36 shows the total phosphorus load for each HUC-8 watershed plotted against its drainage area. Note that the drainage area of contributing watersheds to the lower Maumee and Auglaize HUC-8s are not included in this calculation. The St. Marys, Blanchard, and Tiffin HUC-8s all drain similar-sized areas, which allowed for an interesting comparison. As previously noted, the northern Tiffin watershed contributes only about half as much as the southern St Marys watershed. The yield for the Tiffin watershed from this analysis is 0.29 MT per square mile (MT/mi^2), while the yield for St. Marys is 0.50 MT/mi^2. Additionally, the lower Maumee and St. Joseph HUC-8s have similar-sized drainage areas. Again, the northern watershed, St. Joseph, contributes markedly less than the lower Maumee. The St. Joseph's yield is 0.21 MT/mi^2, and the lower Maumee's is 0.46 MT/mi^2. The Auglaize and Blanchard watersheds' yields are in between the four HUC-8s already noted, at 0.43 MT/mi^2 and 0.38 MT/mi^2, respectively.

A different statistical examination of stream flows and nutrient monitoring reported similar heterogeneity in the Maumee watershed. Choquette et al. (2019) documented increasing higher stream flows in the St. Marys near Ft. Wayne gage while reporting nearly flat trends in the St. Joseph River near Ft. Wayne gage. This work also found increasing total phosphorus annual yields at two St. Marys sites but reduced yields at the lower St. Joseph gage. The study calls out greater flow regulation and less extensive row crops in St. Joseph watershed compared to the St.

Marys watershed as a potential explanation for these findings. Certainly, spatial differences in stream discharge, as documented by Williams and King (2020), play a role as well.

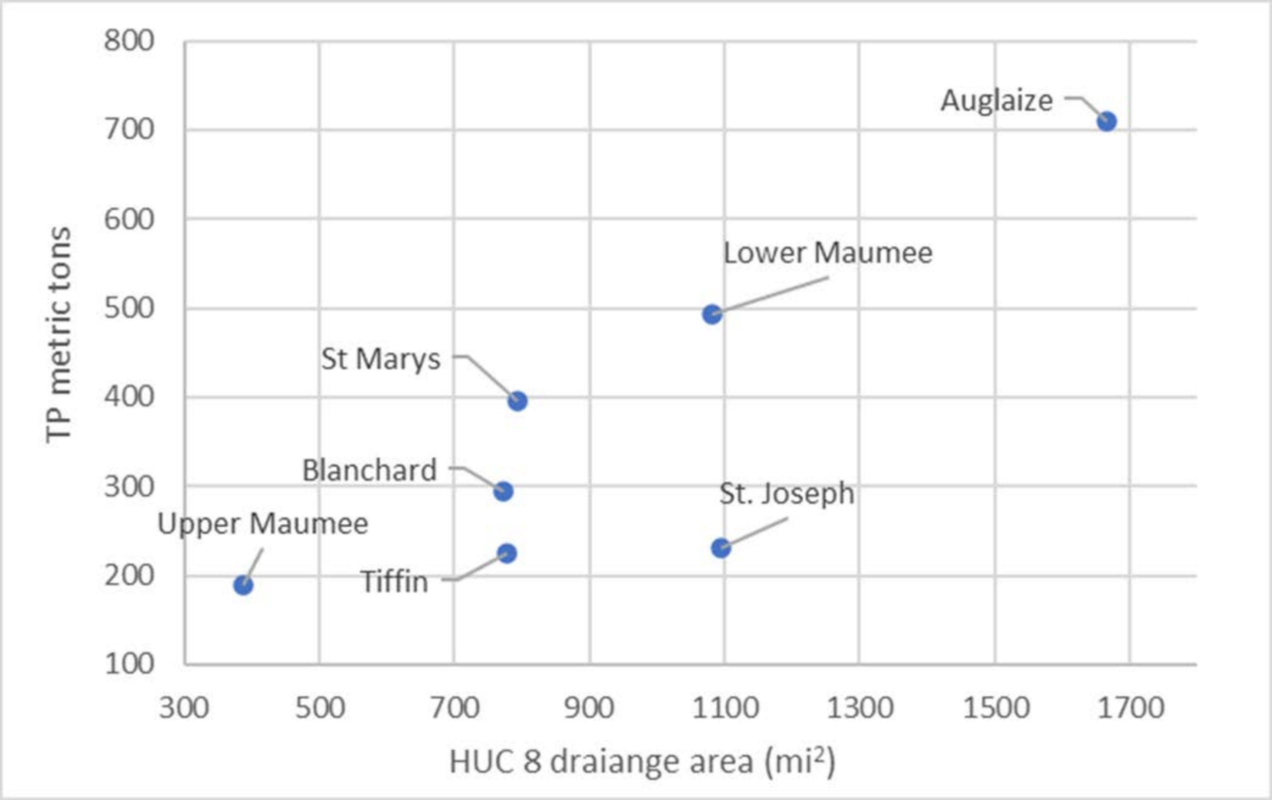


Figure 36. Total phosphorus loads in the Maumee River watershed HUC-8s plotted against the HUC-8s drainage area from SPARROW modeling of the 2002 base year (Robertson et al., 2019; figure developed from supporting information).

CSAs were evaluated through a multi-SWAT model evaluation by Evenson et al. (2021). For each model, the 20 percent of HUC-12 subwatersheds (of the 252 HUC-12 subwatersheds in the Maumee watershed) with the highest export of flow, total phosphorus, DRP, total nitrogen, and total suspended solids were identified as CSAs. The CSAs between models were then evaluated statistically and graphically to determine patterns.

Generally, the multi-modeling did not agree on the location of CSAs: "the overwhelming majority of HUC-12s identified as CSAs were identified as such by a minority of models" (Evenson et al., 2021). This observation suggests that the models are not as accurate at the HUC-12 scale, probably due to calibration mostly at the large-basin scale, but also perhaps reflecting underlying weaknesses in SWAT.

The quantity of fertilizer application per HUC-12 subwatershed was evaluated within the CSAs to determine if the quantity of fertilizer applied was correlated to CSA identification. The authors generally found that CSAs were more likely to be identified in areas with higher fertilizer application; however, the fertilizer application did not explain much of the variation in model outputs (Evenson et al., 2021). They concluded that "fertilizer application rates were only weakly related to nutrient export and thus CSA location for most [of the SWAT] models" (Evenson et al., 2021).

In the statewide soil phosphorus balance study by Dayton et al. (2020) noted above, all but two counties that drain the Maumee watershed were found to have a negative phosphorus balance trend by 2014. Only Mercer and Lucas counties were found to have phosphorus inputs that exceeded outputs. The increase in Mercer County is most likely due to an increase in livestock farms around the Grand Lake St. Marys watershed, outside of the Maumee watershed. Negative phosphorus balances were found in the two counties neighboring Mercer within the Maumee watershed:

Van Wert County to the north and Auglaize County to the east. This study also found Paulding and Hancock counties were among the four counties with the greatest statewide decrease in soil phosphorus balance.

4.2.5. Ohio EPA analysis of Maumee watershed phosphorus monitoring data

The following presents a new analysis of the results from the tributary water quality monitoring stations presented above and shown in Figure 28. The total phosphorus and DRP spring season FWMCs and loads used have been calculated by whichever organization monitors each site, either Heidelberg's NCWQR or USGS. Daily loads and concentrations are also examined for several stations monitored by USGS. These results are calculated based on extremely robust sampling programs; all stations are at USGS streamflow gages with continuous discharge monitoring in place.

Ohio EPA also collects water quality monitoring data from stream sites throughout the state, including the Maumee watershed. An extensive number of samples, well over 10,000, have been collected at hundreds of sites throughout the watershed over several decades. These samples intend to reflect conditions impacting near-field beneficial uses, mostly aquatic life use. The vast majority of these samples have been collected during summertime low-flow conditions. These conditions make pollutant sources that continuously discharge, such as WWTPs, appear more prominent. Runoff-driven sources, such as most nonpoint sources, are conversely less apparent due to this sampling bias. These samples differ from the NCWQR and USGS samples because Ohio EPA collects relatively few samples at many locations. While Ohio EPA's data collection is useful to understand near-field impacts to streams throughout the watershed, they are of much less value in understanding nutrient delivery relevant to this TMDL. The NCWQR and USGS samples are collected expressly to understand seasonal and annual loads. Thousands of samples are collected at a small number of key locations with continuous streamflow gaging. Every single high-flow event and either a daily or weekly steady-flow condition is sampled at these sites. Because extremely high-quality data for understanding loads are available from NCWQR and USGS, Ohio EPA's water quality samples will not be used for this analysis.

Figure 37 shows the total phosphorus and DRP spring loads for three years, 2018 through 2020, plotted against each station's drainage area. Stations that are north and south of the Maumee River mainstem, as well as the mainstem river stations, are each noted with different symbols on this figure. Note that unlike the results from the SPARROW modeling shown above, these are the measured loads at each station. Therefore, all the load that passes each monitoring station, including loads captured upstream by "nested" monitoring stations, are included in these results. As expected, the magnitude of loads generally increases with increasing drainage area. However, there are some visible differences between the southern and northern sites, especially in 2019 and 2020 for both parameters. The southern tributary sites appear to have a higher load-to-drainage-area trend than the northern sites in this analysis.

Loads are calculated as the product of streamflow and concentration with applicable unit conversion factors. An examination of streamflow and concentrations helps to understand the difference between the northern and southern tributaries, as well as some of the loads labeled on Figure 37. Figure 38 shows the normalized spring stream discharge for all Maumee watershed monitoring stations from 2014 to 2020, again with the same symbols for the stations' geography. In some years, most of the southern sites appear to have greater streamflow than most of the northern sites; however, this is not always the case (see 2018). This indicates that the northern sites overall experienced more precipitation in the 2018 spring—an apparent anomaly compared to the other years examined on this figure.

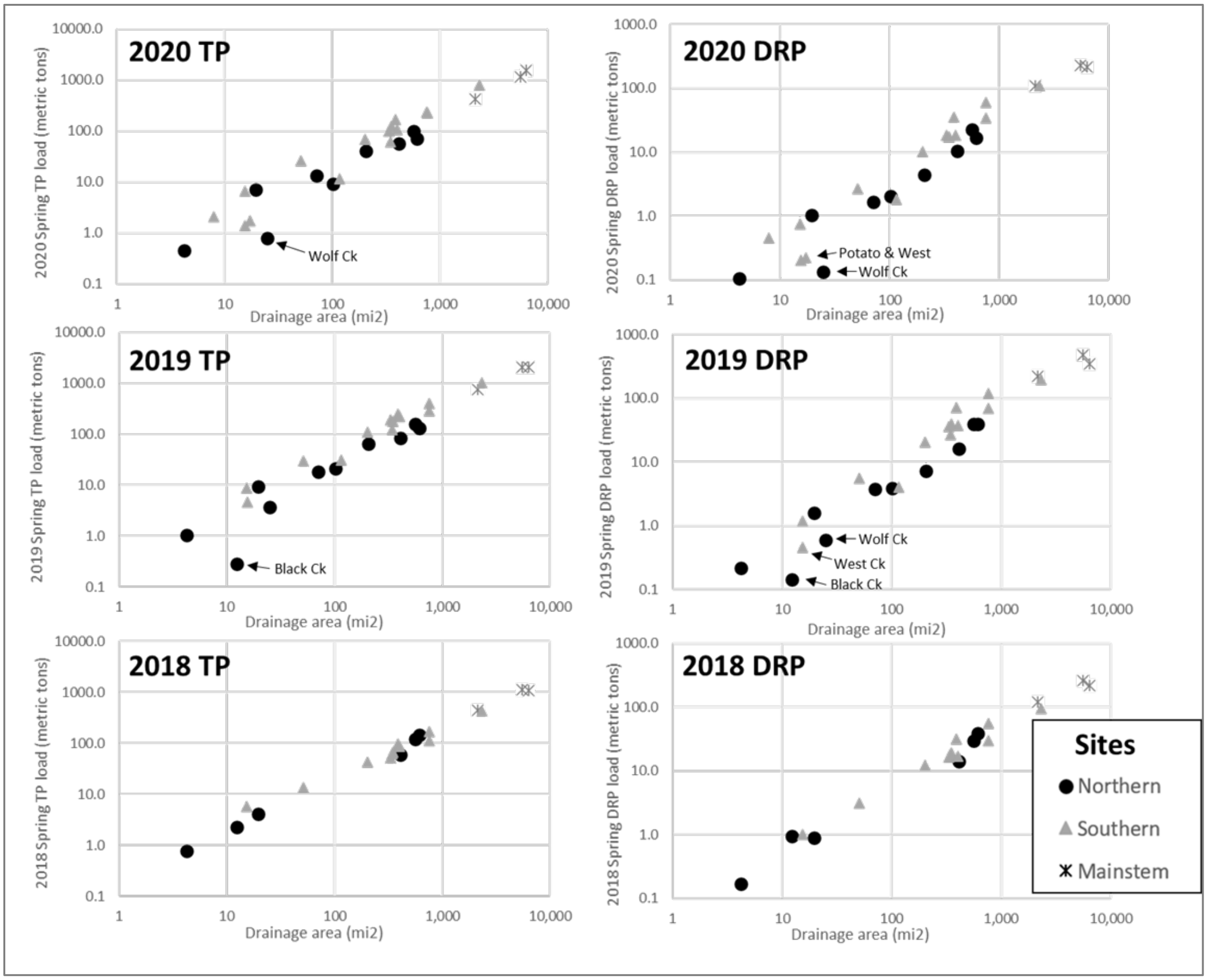


Figure 37. Total phosphorus (left) and dissolved reactive phosphorus (right) loads for three different years plotted against monitoring station drainage area. Stations north and south of the Maumee River mainstem and stations on the mainstem are shown with different symbols. Not all stations have available data for each year.

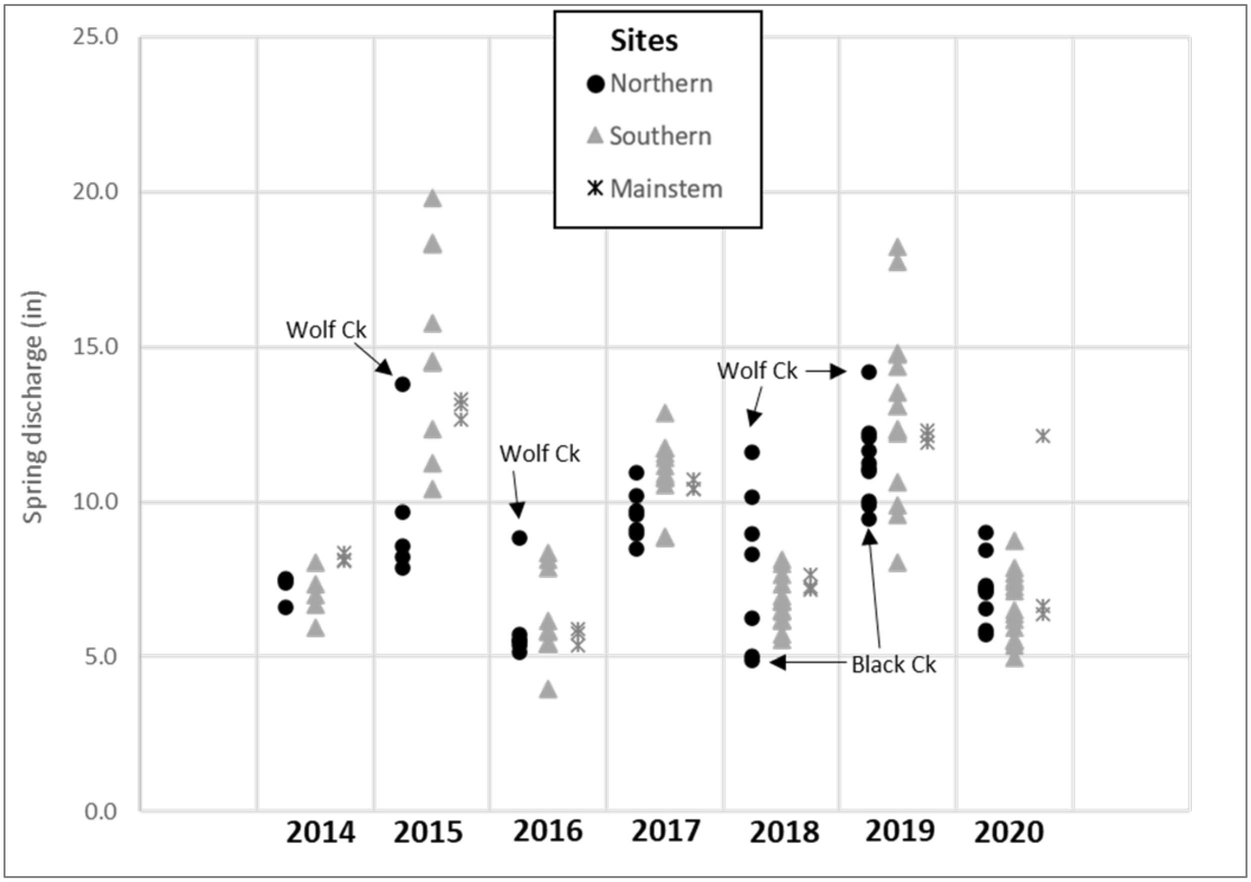


Figure 38. Spring stream discharge water yield for all Maumee watershed monitoring stations with available water quality data for 2014–2020. Stations north and south of the Maumee River mainstem and stations on the mainstem are shown with different symbols. Not all stations have available data for each year.

Figure 39 shows the flow-weighted mean total phosphorus and DRP concentrations of all stations for the spring seasons of 2018 through 2020. Notably, the southern sites generally have more elevated FWMCs than the northern sites. Figure 40 shows the FWMCs for all years available for each station from 2014 through 2020. Again, the southern sites' more elevated total phosphorus and DRP FWMCs overall is noticeable.

Figure 41 shows the distribution of daily spring season DRP concentrations for the key tributaries included in Ohio's 2020 Nutrient Mass Balance study; the map is shown above in Figure 31. This analysis includes all daily DRP concentrations available for each assessment site (the period of record for each site is listed on Table 12). The interquartile range (the half of the distribution within the boxes—between the 75th and 25th percentiles) of these distributions continue to show similar trends as noted above with FWMCs. Most notable is the difference between the northern St. Joseph River and the southern St. Marys River. The Ottawa and Auglaize rivers, both draining southern watersheds, are also noticeably higher than the northern Tiffin River. The Little Auglaize River, draining a southern watershed, however, appears to be closer to the lower-concentration northern sites. That station experiences backwater when the mainstem Auglaize River is elevated. Days when backwater conditions occurred at the Little Auglaize station were removed from this analysis.

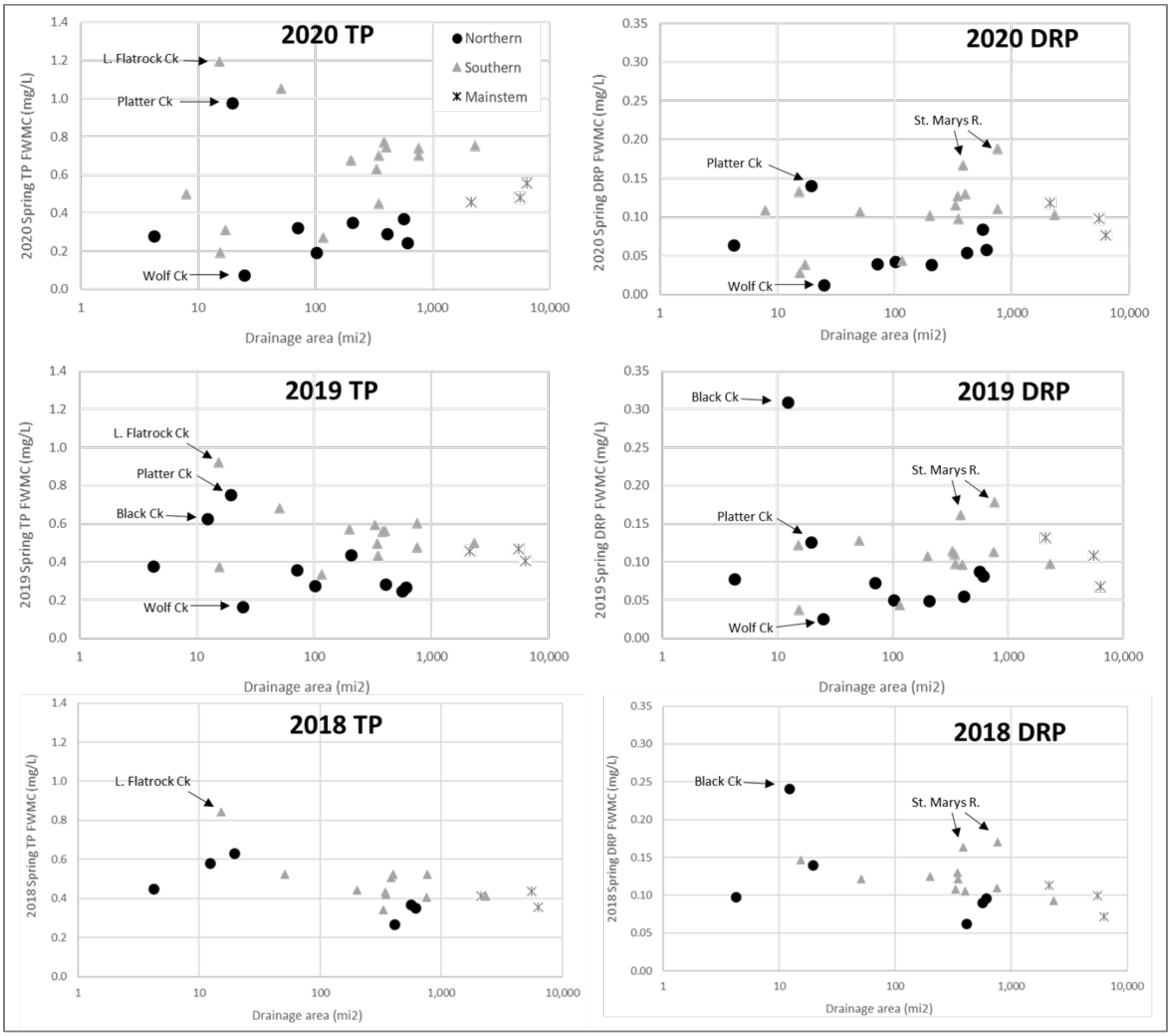


Figure 39. Total phosphorus (left) and dissolved reactive phosphorus (right) FWMCs for three different years plotted against monitoring station drainage area. Stations north and south of the Maumee River mainstem and stations on the mainstem are shown with different symbols. Not all stations have available data for each year.

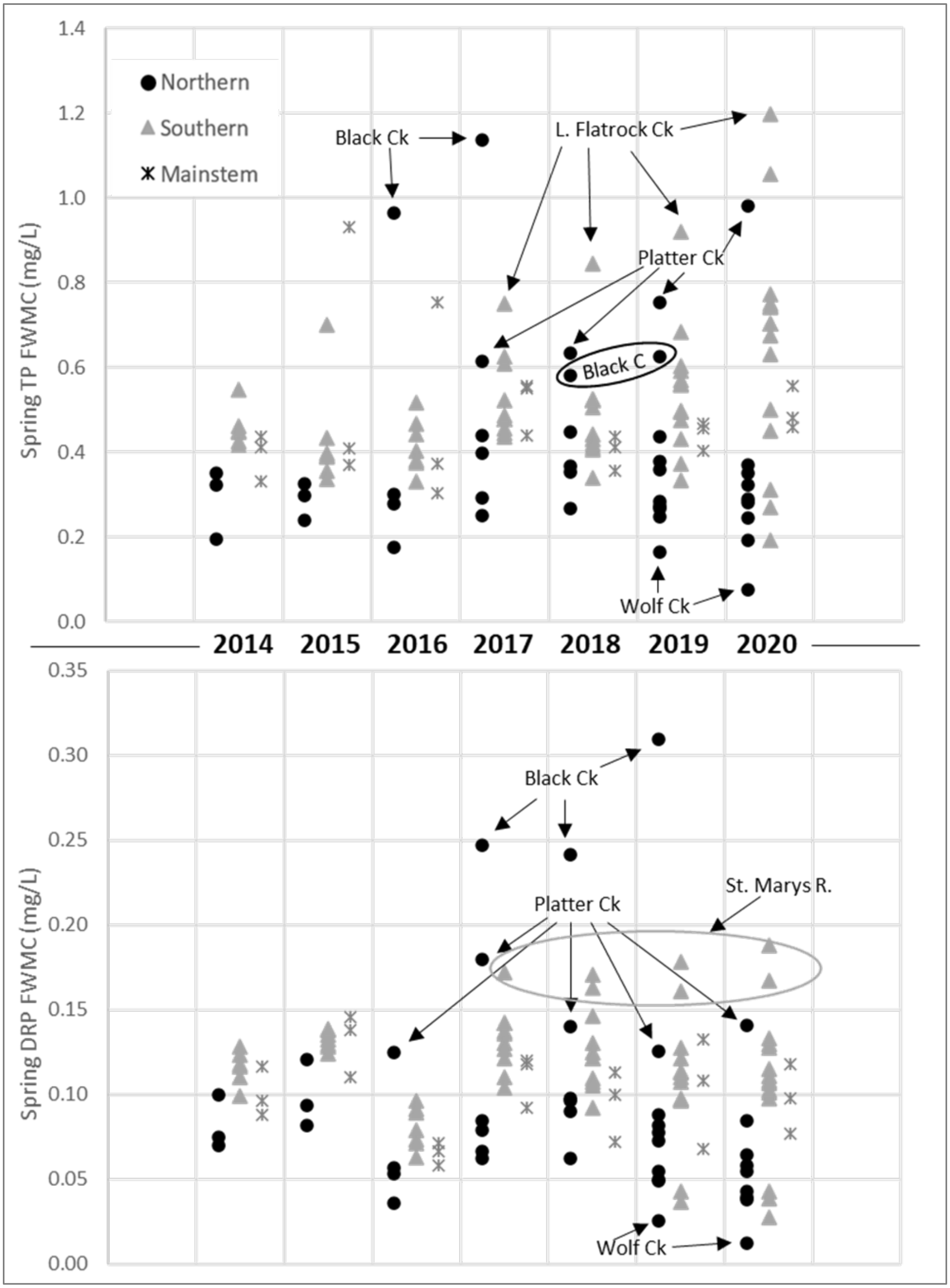


Figure 40. Total phosphorus (top) and dissolved reactive phosphorus (bottom) spring FWMCs for all Maumee watershed monitoring stations with available water quality data for 2014–2020. Stations north and south of the Maumee River mainstem and stations on the mainstem are shown with different symbols. Not all stations have available data for each year.

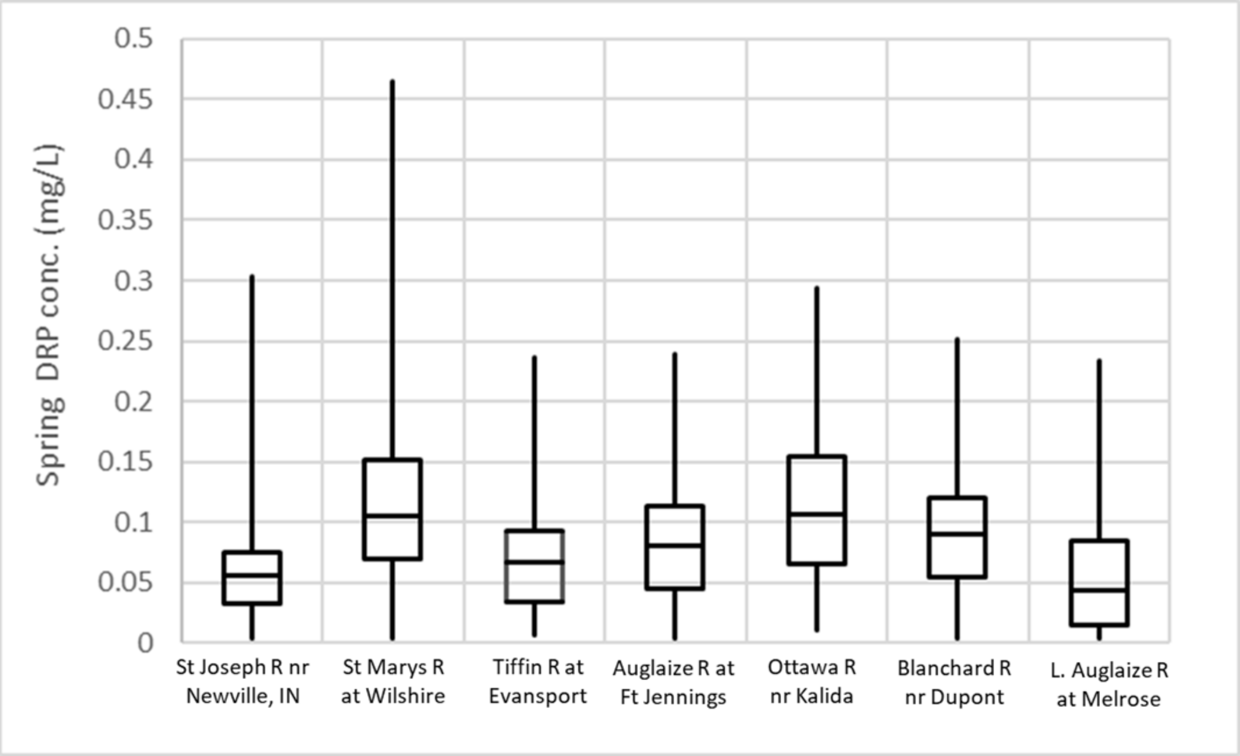


Figure 41. Distribution boxplots of spring DRP daily concentrations for select Maumee watershed tributary monitoring stations. A map of these stations' watersheds is shown above in Figure 27.

Table 12. Median daily spring DRP concentration broken down by flow regime for select water quality monitoring stations. Values over the Annex 4 FWMC DRP target of 0.05 mg/L are bolded, and those 0.15 mg/L or greater are underlined.

	Median spring DRP concentration (mg/L) at various flow regimes*					Period of record: Spring seasons
Site	**High**	**Moist**	**Mid**	**Dry**	**Low**	
04178000 St Joseph R nr Newville, IN	**0.09**	0.04	0.04	**0.06**	NA	2017–2020
04181049 St. Marys R at Wilshire	**0.18**	**0.14**	**0.06**	**0.08**	**0.15**	2017–2020
04183038 Black Ck nr Harlan, IN	**0.20**	**0.06**	**0.06**	**0.09**	**0.18**	2016–2019
04183979 Platter Ck nr Sherwood	**0.12**	0.05	0.01	0.01	NA	2017–2020
04185318 Tiffin R nr Evansport	**0.10**	**0.06**	**0.05**	**0.08**	**0.10**	2014–2020
04186500 Auglaize R nr Fort Jennings	**0.12**	**0.08**	**0.05**	**0.08**	**0.18**	2014–2020
04188100 Ottawa River near Kalida	**0.12**	**0.08**	**0.08**	**0.17**	**0.24**	2014–2020
04190000 Blanchard R near Dupont	**0.13**	**0.08**	**0.07**	**0.11**	**0.12**	2014–2020
04191058 L. Auglaize R at Melrose[†]	**0.11**	**0.06**	0.02	0.01	NA	2015–2020
04191444 L Flatrock Ck nr Junction	**0.14**	**0.10**	**0.07**	**0.16**	NA	2017–2020

Notes:

* Flow regimes exceedance percentile range: High 0–10, moist 10–40, mid 40–60, dry 60–90, low 90–100.

[†] Little Auglaize River results not included in this analysis when river was in backwater conditions.

To analyze variable flow regimes for daily DRP concentrations, several stations were plotted with a concentration exceedance curve. Figure 42 shows an example. Note that the daily concentrations are plotted based on that day's streamflow exceedance percentile. The curve is broken up into five flow regimes that Ohio EPA regularly uses to assess pollutants. In this St. Marys River example, more elevated DRP concentrations are observed in the higher flow regimens compared to the mid-range flows. Concentrations are slightly higher in the mid-range flows compared to the dry conditions. There are very few concentrations in the low-flow regime mainly because these are concentrations only from the spring season, and lower flows generally occur outside of March through July.

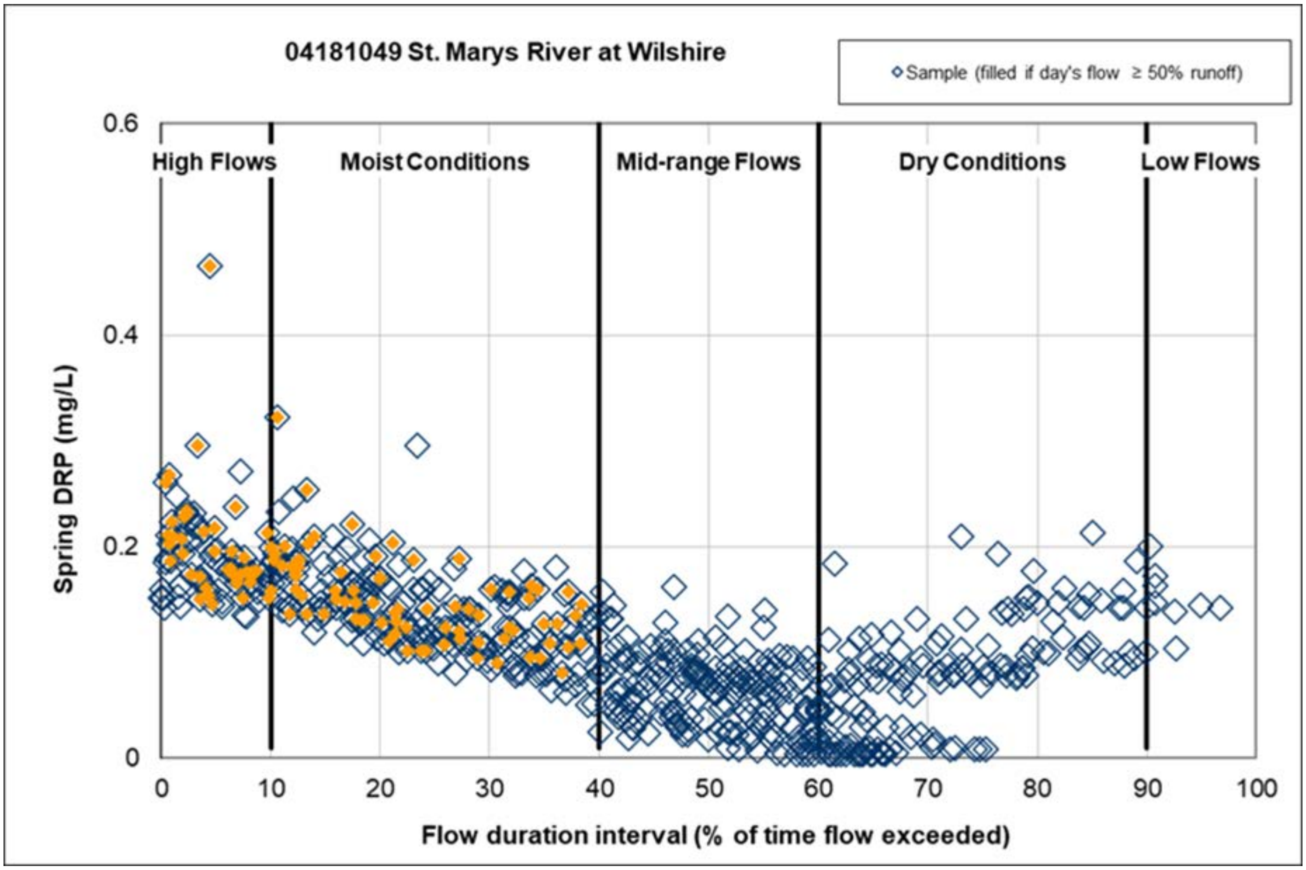


Figure 42. Concentration exceedance curve of spring DRP daily concentrations of the St. Marys at Wilshire sampling location. Diamonds represent daily concentrations throughout the 2017–2020 spring seasons. Filled diamonds indicate days where streamflow had greater than or equal to 50 percent runoff based on baseflow separation methods.

Table 12 and Table 13 show the median and 75th percentile spring season daily DRP concentration in the same subset of sites examined in Figure 41, with a few additional stations, broken down by flow regime. The majority of the phosphorus export occurs during higher flows, as explained above in this source assessment; therefore, a focus should be on the high and moist flow regimes in these tables. The same general trends observed in the St. Marys River example, Figure 42, are present for most sites. The middle flow condition has the lowest DRP concentrations. The concentration increases from the mid-flow condition with greater streamflow. And a somewhat less steep increase occurs as stream flows reduce to the dry and low conditions. However, the Ottawa and Blanchard rivers stations have a steeper increase in the lower flow conditions than the other sites. This is expected due to the major WWTPs upstream of these stations. As stream flow decreases, the plants continue to discharge at steady rates, and the influence of their concentrated effluents becomes observable.

The St. Joseph and Tiffin rivers' sites, both representing a sizable portion of the northern drainage area, are reduced compared to the southern tributaries, best examined by the St. Marys, Auglaize, Ottawa, and Blanchard rivers sites on the tables. As the modeling data reported earlier in this CSA section suggests, the southern tributaries contribute more phosphorus loads than the northern tributaries. The results presented here confirm with observed water quality data that this occurs.

Table 13. 75th percentile daily spring DRP concentration broken down by flow regime for select water quality monitoring stations. Values over the Annex 4 FWMC DRP target of 0.05 mg/L are bolded, and those 0.15 mg/L or greater are underlined.

Site	**75th percentile spring DRP concentration (mg/L) at various flow regimes***					**Period of record: Spring seasons**
	High	**Moist**	**Mid**	**Dry**	**Low**	
04178000 St Joseph R nr Newville, IN	**0.11**	**0.07**	**0.06**	**0.07**	NA	2017–2020
04181049 St. Marys R at Wilshire	**0.21**	**0.16**	**0.09**	**0.10**	**0.16**	2017–2020
04183038 Black Ck nr Harlan, IN	**0.27**	**0.10**	**0.09**	**0.09**	**0.20**	2016–2019
04183979 Platter Ck nr Sherwood	**0.15**	**0.07**	0.02	0.01	NA	2017–2020
04185318 Tiffin R nr Evansport	**0.14**	**0.08**	**0.07**	**0.09**	**0.10**	2014–2020
04186500 Auglaize R nr Fort Jennings	**0.16**	**0.11**	**0.08**	**0.11**	**0.20**	2014–2020
04188100 Ottawa River near Kalida	**0.15**	**0.14**	**0.15**	**0.21**	**0.28**	2014–2020
04190000 Blanchard R near Dupont	**0.15**	**0.11**	**0.11**	**0.12**	**0.16**	2014–2020
04191058 L. Auglaize R at Melrose[†]	**0.14**	**0.09**	0.04	0.03	NA	2015–2020
04191444 L Flatrock Ck nr Junction	**0.17**	**0.15**	**0.13**	**0.37**	NA	2017–2020

Notes:

* Flow regimes exceedance percentile range: High 0–10, moist 10–40, mid 40–60, dry 60–90, low 90–100.

[†] Little Auglaize River results not included in this analysis when river was in backwater conditions.

Figure 43 summarizes by HUC-8 the distributions of Ohio HUC-12's nonpoint source total phosphorus yield (mass per area, in lbs./acre) for the 2008 spring baseline year following the methods used in the Ohio DAP 2020 (OLEC, 2020a). This work is summarized above with a map showing these results in Figure 30. This new conceptualization is presented here to summarize the differences between the northern and southern parts of the Maumee watershed. The interquartile range of HUC-12 total phosphorus yields for the northern St. Joseph and Tiffin HUC-8s is completely below the St. Marys, Auglaize, and Blanchard HUC-8s in the south. The upper and lower Maumee HUC-8s are transitionary between the northern and southern HUC-8s.

The figures and tables described here show that concentrations delivered from all monitored stations are greater than the Annex 4 target for the Maumee River at Waterville. Therefore, while evidence points to the fact that the southern watersheds deliver a greater amount of phosphorus load to the Maumee River and should be considered CSAs, phosphorus reductions are still required throughout the greater Maumee watershed.

The following paragraphs examine some specific watersheds based on results from individual monitoring stations.

The St. Marys River at Wilshire site monitors the St. Marys River close to where it flows out of Ohio and into Indiana. This assessment site has consistently elevated DRP concentrations compared to most other sites. On Figure 40, this and the other St. Marys assessment site further downstream in Indiana are noted to have the highest concentrations of DRP for every year monitoring occurred, except for Black and Platter creeks' 2017 results. The St. Marys River watershed is the most southwestern HUC-8 of the greater Maumee watershed. It has experienced among the greatest increases in rainfall (Figure 20) and has some of the densest agricultural land use (Figure 32).

Platter Creek stands out as having relatively elevated phosphorus concentrations based on its drainage area (Figure 39) and compared to other "northern" sites (Figure 40). This small, direct-to-the-Maumee-River watershed is only just north of the mainstem in western Defiance County. DRP concentrations are more elevated in higher flows (Table 12 and Table 13). Dense agricultural use and being geographically close to the elevated hydrology zone makes this watershed's phosphorus exports appear more like a typical "southern" watershed.

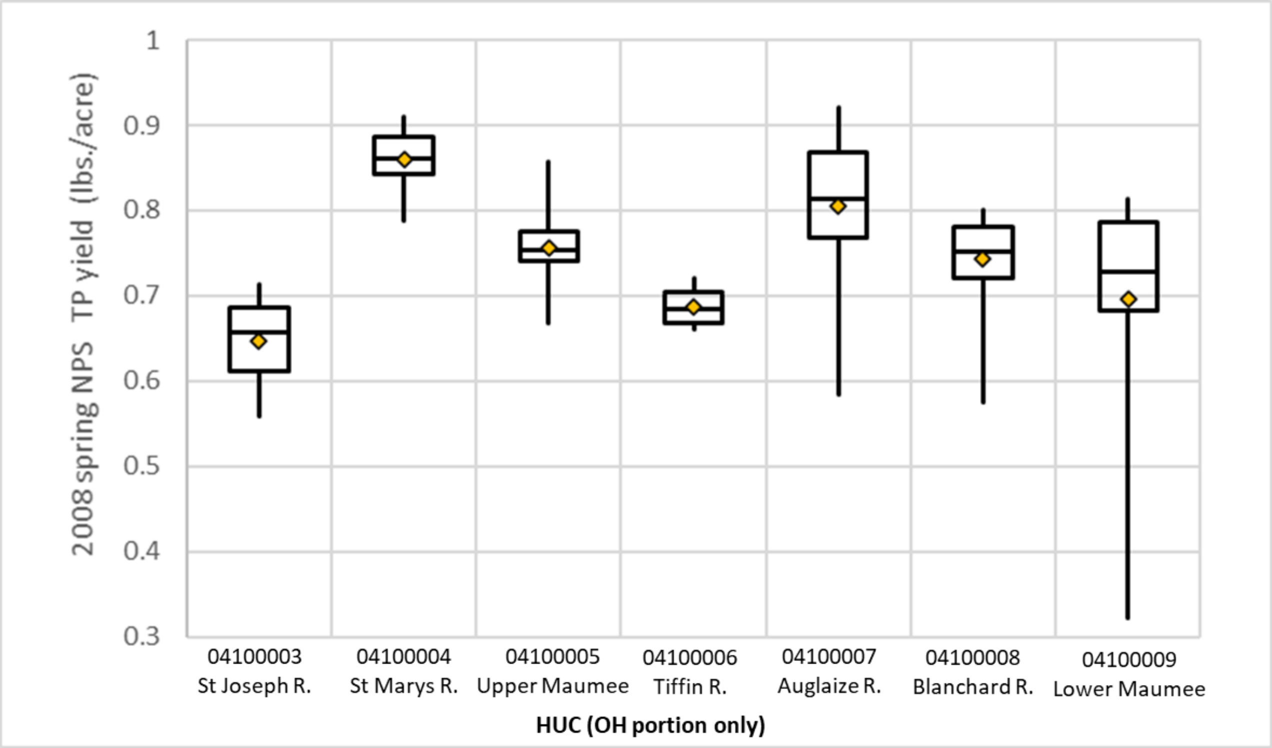


Figure 43. Distribution boxplots of spring 2008 HUC-12 total phosphorus daily nonpoint source yields, in lbs./acre, summarized by HUC-8s. Average HUC-12 yield for each HUC-8 shown with a diamond. From far-field target analysis explained above and documented in the Ohio DAP 2020 (OLEC, 2020a).

Black Creek stands out on several of the figures and tables presented in this section. This is a small direct-to-the-Maumee-River tributary in Indiana. Its drainage area is close to the Maumee River north of the mainstem. Because of this geography, this assessment site has been plotted as a northern site in many of the figures shown below. However, both total phosphorus and DRP concentrations for Black Creek are very elevated compared to all other assessment sites (see Figure 40). The exported phosphorus load from Black Creek is not elevated in relation to its drainage area size, however, as noted for 2019 in Figure 37. This is because of the relatively lower stream discharge measured (see Figure 38). This is a densely row-cropped watershed with some unique management practices. However, being in Indiana, this watershed will not be discussed further. Much published research is available regarding Black Creek (see Williamson et al., 2019, 2020, 2021a, and 2021b).

Little Flatrock Creek is another small, monitored tributary in Paulding County. This Auglaize River tributary drains part of the Paulding Plains described above as having very poorly drained, high-clay soils. This watershed is within the area of the watershed with greater precipitation and denser agriculture. Elevated phosphorus concentrations are expected. Monitoring results for the Little Flatrock station show very elevated total phosphorus concentrations but not among the top DRP concentrations relative to all assessed stations (Figure 39 and Figure 40). When examining Little Flatrock's DRP concentrations broken down by flow regimes, however, they are among the highest in the dry-flow condition, suggesting a more continuous source is present (Table 12 and Table 13). Table 14 and Table 15 show the median and 75th percentile, respectively, of the daily DRP to total phosphorus load ratio for select stations broken down by flow regimes. Little Flatrock has the lowest ratio of sites assessed on both tables for the high flow regime. These observations suggest that the increased clay sediment material suspended may be adsorbing DRP in higher flows relative to other monitoring stations. This phenomenon is described in the instream processes discussion above in Section 4.1.4.

Table 14. Median daily spring DRP to total phosphorus (TP) load ratios broken down by flow regime for select water quality monitoring stations. Values over 50 percent are bolded.

	Median spring DRP:TP load at various flow regimes*					Period of record: Spring seasons
Site	**High %**	**Moist %**	**Mid %**	**Dry %**	**Low %**	
04178000 St Joseph R nr Newville, IN	28	25	30	36	NA	2017–2020
04181049 St. Marys R at Wilshire	30	36	28	29	38	2017–2020
04183038 Black Ck nr Harlan, IN	38	**57**	**59**	**66**	**80**	2016–2019
04183979 Platter Ck nr Sherwood	22	34	18	12	NA	2017–2020
04185318 Tiffin R nr Evansport	28	27	31	43	45	2014–2020
04186500 Auglaize R nr Fort Jennings	26	33	39	**53**	**75**	2014–2020
04188100 Ottawa River near Kalida	25	41	**53**	**68**	**71**	2014–2020
04190000 Blanchard R near Dupont	24	28	42	**58**	**60**	2014–2020
04191058 L. Auglaize R at Melrose[†]	18	27	19	15	NA	2015–2020
04191444 L Flatrock Ck nr Junction	16	30	28	17	NA	2017–2020

Notes:

* Flow regimes exceedance percentile range: High 0–10, moist 10–40, mid 40–60, dry 60–90, low 90–100.

[†] Little Auglaize River results not included in this analysis when river was in backwater conditions.

Table 15. 75th percentile daily spring DRP to total phosphorus (TP) load ratios broken down by flow regime for select water quality monitoring stations. Values over 50 percent are bolded.

	75th percentile spring DRP:TP load at various flow regimes*					Period of record: Spring seasons
Site	**High %**	**Moist %**	**Mid %**	**Dry %**	**Low %**	
4178000 St Joseph R nr Newville, IN	34	32	35	42	NA	2017–2020
04181049 St. Marys R at Wilshire	35	41	35	38	40	2017–2020
04183038 Black Ck nr Harlan, IN	47	**62**	**63**	**73**	**83**	2016–2019
04183979 Platter Ck nr Sherwood	31	45	32	18	31	2017–2020
04185318 Tiffin R nr Evansport	36	35	42	**51**	**51**	2014–2020
04186500 Auglaize R nr Fort Jennings	35	45	**60**	**72**	**82**	2014–2020
04188100 Ottawa River near Kalida	32	**51**	**63**	**74**	**75**	2014–2020
04190000 Blanchard R near Dupont	35	38	**55**	**66**	**65**	2014–2020
04191058 L. Auglaize R at Melrose[†]	30	42	34	25	NA	2015–2020
04191444 L Flatrock Ck nr Junction	24	40	39	18	NA	2017–2020

Notes:

* Flow regimes exceedance percentile range: High 0–10, moist 10–40, mid 40–60, dry 60–90, low 90–100.

[†] Little Auglaize River results not included in this analysis when river was in backwater conditions.

Wolf Creek stands out as the only monitoring site in the Maumee watershed with more developed land. The Wolf Creek monitoring station drains over 28 percent developed land within the western suburbs of the greater Toledo area (compare this developed land to the land cover of the major tributaries monitored in the 2020 Nutrient Mass Balance; see Figure 32). The Wolf Creek monitoring station is notable for having relatively elevated stream discharge (see Figure 38) among all stations. This makes sense as a more developed watershed is expected to have reduced ground water seepage and evapotranspiration compared with more agriculturally dense watersheds. Wolf Creek also stands out as having the lowest total phosphorus and DRP concentrations of all assessed watersheds (Figure 39 and Figure 40). The reduced concentrations are low enough to offset the elevated stream flows in Wolf

Creek, resulting in lower phosphorus loads. In Figure 37, the Wolf Creek load is labeled for the two years of its results as being well below watersheds of similar drainage area.

4.3. Summary of phosphorus sources

This section provides a summary of the many sources of phosphorus that the Maumee watershed exports to the Maumee Bay/western Lake Erie system. Table 16 provides a list of the types of sources outlined in this assessment.

Table 16. Summary of various phosphorus sources in the Maumee watershed.

	Sources	**Subcategory**	**Primarily driven by hydrology?**
Nonpoint sources	Agricultural fertilizer	Commercial	Yes
		Manure	Yes
	Sediment sources	Soil erosion	Yes
		Legacy	Yes
	Streambank erosion		Yes
	Instream (stored phosphorus export)		Sometimes
	Nonpoint stormwater		Yes
	Nonpoint (on-site) HSTS		No
	Natural lands		Yes
Point sources	Wastewater treatment plants	Individual NPDES	No
		General NPDES	No
	Permitted stormwater	MS4 NPDES	Yes
		General facility- based NPDES	Yes
		General construction NPDES	Yes
	Discharging HSTS		No
	Agricultural fertilizer	Biosolids	Yes

Several studies have confirmed that a large majority of the phosphorus loads result from nonpoint sources. While various analyses share this finding, this TMDL does not rely on a single, definitive accounting for the proportions of detailed sources. For instance, the Ohio DAP 2020 calculated that 84 percent of the spring total phosphorus load from Ohio's portion of the Maumee watershed is from agricultural lands (OLEC, 2020a). A SWAT modeling source assessment (Kast et al., 2021) calculated agricultural fertilizers and soil sources to contribute around 95 percent of the total watershed's spring total phosphorus load. And the statistical SPARROW modeling (Robertson et al., 2019) determined that agricultural sources contribute about 73 percent of the entire watershed's annual load, using an older (2002) base year.

Rather than selecting a particular study to represent source contributions definitively, this assessment intends to take a weight-of-evidence approach toward phosphorus sources. Many sources contribute to the phosphorus load. Nonpoint sources, particularly nonpoint sources from agriculture, dominate this load. However, there are some areas of greater uncertainty. For instance, the contribution of streambanks has not been studied or modeled as intensively as many other sources. And an understanding of the extent of elevated soil phosphorus that can contribute to export via legacy phosphorus is only just beginning to be understood.

This source assessment also examines the late 1990s–early 2000s increasing DRP export trend. Earlier reductions in phosphorus export from excessive sediment loss and poorly operating WWTPs have largely addressed historical water quality issues in Lake Erie and its tributaries. However, some land use changes that addressed sediment erosion may have helped set the stage for the DRP increases. Hydrological changes, largely due to changes in precipitation, also contribute to the DRP increase. Understanding these issues provides context for addressing elevated DRP with the intent of reducing the annual Western Basin of Lake Erie HABs.

The overall intent of this section is to provide scientific rigor to assist in decisions for the TMDL's implementation recommendations. Addressing DRP movement with source management, in addition to traditional soil conservation, has great promise for targeting DRP export. Practices that manage and slow water movement through the watershed also appear to be poised to address this problem. Phosphorus reduction is required throughout the Maumee watershed, as evidenced by elevated concentrations at all monitoring stations; however, there are more opportunities for reduction in some parts of the watershed.

This assessment should serve as part of the backbone of this TMDL project. As the science of understanding phosphorus movement and remediation actions progresses, this assessment will incrementally become outdated. The adaptive management approach of developing and implementing a TMDL, explained in detail in Section 7, allows for new science to be incorporated as time progresses.

5. Analysis Methods

This section explains the details of the numeric TMDL development. Descriptions of the modeling methods used to determine baseline sources and initial TMDL allocations of total phosphorus makes up most of this section. Model verification methods and discussions of other required TMDL considerations complete the section.

5.1. Sources of data

Table 17 outlines the data used to determine baseline conditions and reduction allocations for this TMDL. Further details of data used are explained throughout Section 5.

Table 17. Sources of data used to develop this TMDL project with data processing details noted.

Data	Source	Details
Watershed pour point loads	NCWQR at Heidelberg	Results are calculated by NCWQR with water quality monitoring concentrations and stream flow data. Available at ncwqr.org (NCWQR, 2022).
Water quality concentrations	NCWQR at Heidelberg	One to three samples collected daily with refrigerated samplers. Samples are lab-analyzed weekly.
Stream flows	USGS Ohio-Kentucky-Indiana Water Science Center	Continuous stream flow stage monitoring converted into stream flow following detailed protocols. Available at waterdata.usgs.gov/nwis.
Land use	NLCD – USGS' Earth Resource Observation and Science Center	Definitive land cover database for the United States. Both 2011 and 2019 datasets used (USGS, 2014; Dewitz, 2021).
NPDES effluent data	Discharge monitoring records	Facility submitted monitoring effluent concentration and flow rate data as required by NPDES permits. Publicly available from Ohio EPA upon request.
HSTS-served population	Ohio EPA GIS analysis	Analysis combining population data and unsewered areas.
Population	U.S. Census	2010 Census GIS data. Available at census.gov.
Unsewered areas	TMACOG Nutrient Source Inventory	Analysis and GIS data of unsewered areas (TMACOG, 2018).
Permitted stormwater areas (MS4)	Based on U.S. Census population densities	MS4 areas within the Maumee watershed were determined by Ohio EPA staff via GIS analysis.

Data	Source	Details
Permitted stormwater areas (facility based)	Ohio EPA GIS analysis	Used various aerial imagery and property parcel geospatial data to delineate permitted stormwater areas.

5.2. Methods to assess baseline loads

The baseline condition for the Annex 4 2015 targets that this TMDL uses is the spring season (March 1 through July 31) of 2008. Because of this, the baseline condition loads developed for this TMDL will be based on an accounting of this five-month period of that year.

In the Ohio DAP 2020, Ohio EPA augmented the state's Nutrient Mass Balance method to differentiate nonpoint source loads (see Appendix A in OLEC [2020a]). This involved determining the total phosphorus loads delivered from agricultural, developed, and natural areas. This TMDL employs a similar method that was used in the Ohio DAP 2020 to calculate baseline loads for this TMDL. Changes from the Ohio DAP 2020 method for this TMDL mostly consider the details regarding point sources. This includes careful accounting for discharging and stormwater NPDES-permitted facilities and communities. Refer to Table 9 in the earlier source assessment section to see the various point source categories included in this TMDL. The source assessment also includes details about the various point source types that are accounted for in this part of the report.

The remainder of this subsection walks through the baseline condition calculation methods for this TMDL.

5.2.1. Pour point load estimation

Central to this modified Nutrient Mass Balance method is a monitoring point, hereafter called the pour point, where the NCWQR collects near-continuous data. The pour point on the Maumee River is at Waterville, Ohio (USGS Gage No.: 04193490). Data are collected one to three times daily, resulting in the ability to calculate an accurate annual load at that location.

The load calculated at this point is the sum of daily loads based on the product of USGS daily flow and NCWQR daily nutrient concentrations (NCWQR, 2022).

5.2.2. Baseline overall loading calculation

Equation 1 shows the overall loading calculation. The load discharged by wastewater treatment facilities is within the regulatory authority of Ohio EPA and represented as WT in equation 1. In addition to waste treatment facilities, loads from CSOs are also regulated by Ohio EPA. HSTS contributions are estimated separately. The landscape-derived loads are separated into two categories: load calculated upstream (UPST) from the pour point and load calculated downstream (DST) of the pour point. The landscape loading terms include loads from agricultural, developed, and natural lands. These components of loading are presented schematically in Figure 44. Details of how all these sources were determined are explained in the following sections of this report.

$$Total\ Load = WT + CSO + HSTS + Landscape_{UPST} + Landscape_{DST}\ (1)$$

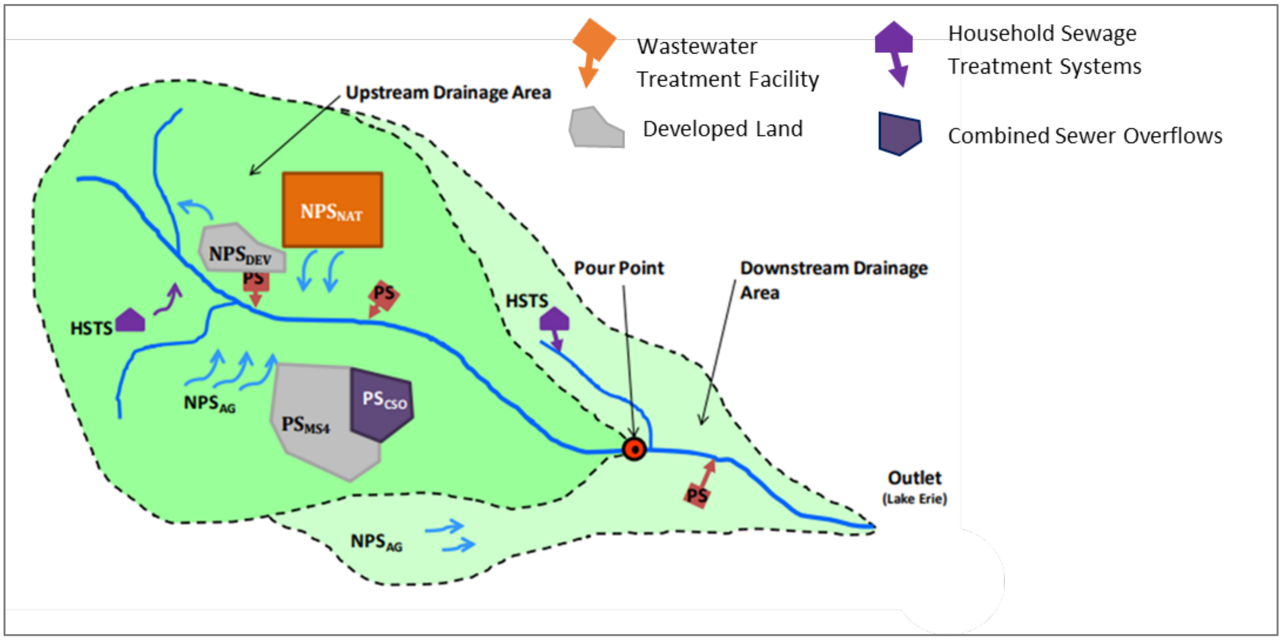


Figure 44. Schematic of sources represented in the modified Nutrient Mass Balance.

5.2.3. Baseline loads from wastewater treatment facilities

Wastewater treatment facilities report operational data to Ohio EPA. All facilities are required to report flow volume. Phosphorus is reported at each facility and depends on factors such as the potential for elevated concentrations and facility size. The varied reporting from different facilities requires that loads be estimated using a method that is flexible and can account for missing data. Equation 2 estimates the generic loading from a wastewater treatment facility.

$$Annual\ Load = Q(in\ MG) * [TP] * cf\ (2)$$

In Equation 2, Q represents a facility's flow volume in million gallons (MG). The cf term, equal to 3.78451, is a conversion factor used to convert the product of MG and mg/L into kilograms.

The total phosphorus concentration denoted [TP] in Equation 2 must be estimated from either reported data or assumptions based on similar facilities. Within the Maumee watershed, wastewater treatment facilities are generally accounted for in two categories: public facilities and industrial facilities. The public facilities are further broken down into subcategories: major (≥1.0 MGD facility design flow), significant minor (≥0.5 MGD and <1.0 MGD), minor (≥0.1 MGD and <0.5 MGD), package plant (<0.1 MGD), and controlled discharge lagoons (any size).

To estimate the phosphorus concentration, each facility is placed into one of four groups depending on the type of plant and available phosphorus monitoring data. The groups and approaches for calculating phosphorus concentrations are: (1) industrial facilities reporting phosphorus concentrations, which use the median concentration of phosphorus reported during the calculation period; (2) industrial facilities not reporting phosphorus concentrations, which use similar facilities or other means to estimate phosphorus concentrations; (3) sewage treatment facilities reporting phosphorus concentrations, which use the median phosphorus concentration from the calculation period; and (4) sewage treatment facilities not reporting phosphorus concentrations, which use the median phosphorus concentration from similar facilities. Nutrient concentrations estimated for five classes of municipal effluent are presented in Table 18.

Table 18. Facility classes by design flow.

Group	Type	Design flow (MGD)	Median concentration of group (mg/L)
Industrials	All industrial permits	--	N/A
Major Municipal	Sewage treatment	≥ 1.0	0.54
Significant Minor Municipal	Sewage treatment	0.5 to 1.0	1.72
Minor Municipal	Sewage treatment	0.1 to 0.5	2.07
Controlled Discharge	Sewage treatment	Varies	1.92
Package Plant	Sewage treatment	< 0.1	3.54

Wet-weather events often result in increased wastewater flows within collection networks, either by design in combined sewer communities or inflow and infiltration. The result of increased flows is reduced treatment at the plant (usually a bypass of secondary treatment), wastewater bypasses at the plant headworks (raw bypasses), CSOs, and SSOs. SSOs typically report occurrences but not volume. Therefore, SSOs are excluded from the analysis unless flow volumes are reported. This report uses a wet-weather loading nutrient concentration of 0.75 mg/L for total phosphorus, which is the median concentration of 131 samples reported from September 2014 to August 2017 by two Ohio sewer districts that are required to monitor total phosphorus at select CSO outfalls in their NPDES permit. When bypasses go through primary treatment, a 15 percent removal is assumed by Ohio EPA to account for settling and sludge removal. This value is set to be greater than the 6 percent removal from septic tanks but not as high as the removal rates observed when fine solids are eliminated via extended settling and/or anaerobic digestion.

The Maumee watershed includes wastewater treatment facilities that are outside the state of Ohio. Data on monthly loads were available from the Integrated Compliance Information System (ICIS) maintained by U.S. EPA. These monthly loads were summed for each facility within the watershed and are reported in the lumped out-of-state load. Facilities identified as controlled dischargers were excluded from the out-of-state analysis because using the data maintained in ICIS results is a gross overestimation of discharge volume. This is because ICIS averages the discharge for only the days a discharge occurred. No associated count of days that a discharge occurred is reported. Due to this being a very small fraction of the out-of-state wastewater load, it is more practical not to include this source. This load contains a CSO load estimate where the overflow volumes are reported, and combined sewer systems were assumed to have the same concentration as those within Ohio.

5.2.4. Baseline home sewage treatment system loads

The population served by HSTS is estimated using a spatial analysis of census data (U.S. Census Bureau, 2010), combined with an assessment of populations that are likely served by sewer systems of NPDES-permitted facilities. The populations served by NPDES-permitted wastewater treatment facilities are estimated using two methods. The first method is that census-designated places (CDPs) are assessed as sewered or not. The second method is applied to NPDES-permitted sewage treatment facilities that are not associated with a CDP. In this case, the population served by the facilities is estimated by determining the average flow for facilities associated primarily with homes and then dividing by 70.1 gallons/day/person (Lowe et al., 2009). Facilities serving mobile home parks and subdivisions were included in the latter approach, while facilities serving highway rest stops and recreation facilities were excluded. The HSTS population is then estimated to be the remaining population when the NPDES-served CDP population and the non-CDP NPDES-served population are subtracted from the total population of the watershed.

Equation 3 outlines this overall method.

$$Load_{HSTS} = Pop_{HSTS} * Nut_{Yield} * \left[percentPop_{\text{on-site, working}} * DR_{\text{on-site, working}} + percentPop_{\text{on-site, failed}} * DR_{\text{on-site, failed}} + percentPop_{discharge} * DR_{discharge} \right] \quad (3)$$

where,

Pop_{HSTS} = Total population served by HSTS in watershed (persons)

$\text{Nut}_{\text{Yield}}$ = Annual yield of nutrient per person $\left(\frac{\frac{\text{lb}}{\text{year}}}{\text{person}}\right)$

$\text{percentPop}_{\text{on-site, working}}$ = percent of population served by on − site working HSTS

$\text{DR}_{\text{on-site, working}}$ = nutrient delivery ratio for on − site working systems

$\text{percentPop}_{\text{on-site, failed}}$ = percent of population served by on − site failing HSTS

$\text{DR}_{\text{on-site, failing}}$ = nutrient delivery ratio for on − site failing systems

$\text{percentPop}_{\text{discharge}}$ = percent of population served by discharging HSTS

$\text{DR}_{\text{discharge}}$ = nutrient delivery ratio for discharging systems

A literature review was used to determine the per capita nutrient yield in home wastewater. A study by Lowe et al. (2009) reported a median nutrient yield of 0.511 kg-P/capita/year. In a similar effort to this mass balance study, the Minnesota Pollution Control Agency (MPCA) estimated the annual per capita nutrient yield to be 0.8845 kg-P/capita/year (Wilson and Anderson, 2004). The MPCA study used estimated values based on different home water use activities, while the Lowe study reported statistics on data measured on actual systems. The Lowe study's median concentrations were used because the methodology uses actual sampling data of septic tank effluents.

A literature review was also used to estimate phosphorus delivery ratios for three different system types. In the first system type—properly operating soil adsorption systems—wastewater percolates through the soil matrix, where physical, chemical, and biological processes treat pollutants. Phosphorus is usually considered to be effectively removed in these systems. Beal et al. (2005) reviewed several studies and reported findings that included a greater than 99 percent phosphorus removal, an 83 percent phosphorus removal, and slow phosphorus movement to ground water. In a nutrient-balance study, MPCA assumed that HSTS with soil adsorption systems removed phosphorus at an 80 percent efficiency (Wilson and Anderson, 2004). For this study, an 80 percent efficiency will be used for these systems. This is because the studies reviewed by Beal used fresh soil columns that did not consider a reduction in efficiency with system age.

Another category of systems included in the mass balance study is soil adsorption systems that are failing to function as designed. Myriad problems cause systems to fail, so literature values are not available for phosphorus removal. For this method, the assumption is made that failing systems still involve some soil contact; therefore, total phosphorus removal will be between the value of a direct discharge and a soil adsorption system. The value used for this study is a 40 percent total phosphorus removal for failing soil adsorption systems, or half of which is assumed for properly working systems.

The third group of HSTS is systems that are designed to discharge directly to a receiving stream. These systems use mechanical treatment trains to treat wastewater before discharging directly to streams. Like septic tanks, they are designed to remove suspended solids, but sludge removal is limited to periodic pumping. Lowe et al. (2009) studied septic tank influent and effluent and found a 6 percent reduction in total phosphorus. This study will use the same 6 percent reduction that Lowe et al. (2009) observed.

The final component needed to estimate HSTS loading is the relative proportion of system types, split into three categories: (1) working soil adsorption systems; (2) failing soil adsorption systems; and (3) systems designed to discharge. ODH is tasked with regulating the treatment of home sewage. In 2013, ODH published the results of a 2012 survey of county health departments as an inventory of existing HSTS in the state (listed by Ohio EPA district) (Table 19). The Maumee River watershed is in the northwest district.

TMACOG refined the Ohio portion of the HSTS estimate from Ohio EPA's Nutrient Mass Balance Study (TMACOG, 2018). Study improvements included refined sewershed areas for NPDES facilities and completing HSTS loading estimates at the HUC-12 subwatershed scale. The improvements for the Ohio portion of the HSTS load are incorporated into this study.

Table 19. Proportions of total HSTS systems grouped into categories for Ohio's Nutrient Mass Balance Study. From the 2012 ODH statewide inventory (ODH, 2013).

Ohio EPA district	Working soil adsorption (%)	Failing soil adsorption (%)	Discharging (%)
Northwest	41.5	26.5	32
Northeast	44.0	27.0	29
Central	42.8	25.2	32
Southwest	64.0	14.0	22
Southeast	61.2	10.8	28

5.2.5. Baseline loading from the landscape

Central to calculating the load from the landscape is the pour point load described in Section 5.2.1 above. The calculation of the load from the landscape upstream of the pour point is the total load at the pour point minus the wastewater treatment facilities and HSTS loads upstream of the pour point. The landscape load calculated at this point includes loads from all land uses. This subsection explains how the lumped landscape load is empirically broken down into different land use types.

Note that the permitted stormwater is determined after this landscape load is calculated and explained in Section 5.3.6.

Using land use to break down total loading from the landscape is based on the concept that there are unique and important differences in loads from different parts of the landscape. To do this in the context of an empirical mass balance, a ratio of the loads from different parts of the landscape is defined. Field-scale data from different land uses are needed to define the contributions of each land use type. A review of the literature was completed to summarize field-scale data for different land uses. Land use was lumped into three broad categories discussed below: (1) agricultural land, (2) developed land, and (3) natural lands. These uses were aggregated from the 2011 NLCD (USGS, 2014), as shown in Table 20.

The purpose of the literature review was to index yields from the three broad landscape categories to each other, as described below in Section 5.3.5.4 by Equations 4–6. The range of values from each category within the landscape will vary; however, the emphasis here is on the average. Variation within these categories is complex, and the data may not be available at an appropriate spatial scale. For example, soil test phosphorus and tillage practices vary across small areas but are summarized at the county or zip code level.

Table 20. Land use recategorization from NLCD land use types to broader landscape mass balance groups.

NLCD land use type	Mass balance group
Cultivated Crops	Agriculture
Hay/Pasture	Agriculture
Developed, High Intensity	Developed
Developed, Low Intensity	Developed
Developed, Medium Intensity	Developed
Developed, Open Space	Developed
Emergent Herbaceous Wetlands	Natural
Evergreen Forest	Natural
Deciduous Forest	Natural
Herbaceous	Natural
Open Water	Natural
Shrub/Scrub	Natural
Woody Wetlands	Natural
Mixed Forest	Natural

5.2.5.1. Baseline agricultural lands loads

Agriculture comprises nearly 78 percent of the landscape in the Maumee watershed, with approximately 93 percent of that area represented by cultivated crops. The abundance of the agricultural land means that its contribution weighs heavily into the average load conveyed to the pour point near the Maumee River outlet. Edge-of-field monitoring networks and modeling efforts have been employed to improve knowledge of nutrient loss from agricultural fields in Ohio. Much of this research is led by the USDA Soil Drainage Research Unit at OSU. A recent study spanning water years 2012–2015 summarized the edge-of-field phosphorus loading from 38 field sites throughout the corn belt region of Ohio. The study reports an average annual total phosphorus yield for this period of 1.1 lbs./acre (Peace et al., 2018). USDA's NRCS-CEAP estimated an annual average of 1.9 lbs./acre of total phosphorus loss at the edge of agricultural fields based on the 2012 conservation condition (NRCS, 2017). The NRCS-CEAP effort used modeling results to describe phosphorus losses across the landscapes broader than the monitoring network. The results for the annual loss observed by the Soil Drainage Research Unit edge-of-field data collection ranged from ~0.1–4 lbs./acre (Peace et al., 2018), and were within the distribution of the NRCS-CEAP modeling effort. An earlier report by the Ohio Lake Erie Phosphorus Task Force II (Ohio Phosphorus Task Force II, 2013) had estimated an average annual loss of total phosphorus yield of 2.05 lbs./acre from cultivated cropland after reviewing the literature.

5.2.5.2. Baseline developed lands loads

Developed lands are defined by the amount of impervious surface they represent (Table 21). Within the Maumee watershed, approximately 11 percent of the landscape is classified as developed land. The Maumee watershed's developed land was estimated at 27 percent impervious cover. This was determined by using the percent imperviousness in the center of each class and weighting that value to each classes' relative proportions in the watershed. The runoff volume and nutrient concentrations from pervious versus impervious landscape areas differ significantly.

Research pertinent to Ohio has been carried out on developed land in the upper Midwest and the Northeast. Some of the studies were executed to quantify the impact of removing phosphorus from lawn fertilizers, an action that has since been largely implemented in Ohio. In a Wisconsin study, total phosphorus loss from turf grass plots were 0.05–0.61 lbs./acre/year over three monitoring years: 2005–2007 (Bierman et al., 2010).

Table 21. NLCD land use classes for developed land (adapted from USGS, 2014) and the percentage of each class within the Maumee River watershed's developed land.

Class	Description	% of Maumee
21	Developed, Open Space: Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	55
22	Developed, Low Intensity: Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20%–49% of total cover. These areas most commonly include single-family housing units.	30
23	Developed, Medium Intensity: Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50%–79% of the total cover. These areas most commonly include single-family housing units.	10
24	Developed, High Intensity: Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial areas. Impervious surfaces account for 80%–100% of the total cover.	5

The primary impact of impervious areas within the developed landscape is increased runoff. Data from U.S. EPA's Nationwide Urban Runoff Program showed the lowest event mean total phosphorus concentrations on commercial land compared to other developed land uses, except for open spaces (U.S. EPA, 1999b). However, this is compounded by increases in runoff as the amount of impervious area increases. As imperviousness increases in commercial and industrial areas, runoff volumes exceed 50 percent of observed rainfall compared to less than 10 percent for lawns (Bannerman et al., 1993; U.S. EPA, 1999b). The same studies reported mean total phosphorus concentrations that were approximately 2.5 times greater for lawns when compared to streets and 5–10 times greater when compared to parking lots. Annual loads across the developed landscape start to balance across the landscape as concentrations are elevated in low-runoff areas and lower in high-runoff areas.

5.2.5.3. Baseline natural lands loads

Natural lands are grouped as areas within the watershed that are generally not managed with nutrient inputs (Table 20). Most of the research on the natural landscape has focused on enhancing the capacity of natural lands to serve as nutrient and sediment sinks. However, across the broader landscape, natural lands represent a wide variety of landforms that serve as sources and sinks (Hornbeck et al., 1987; Swank and Waide, 1988). While the distribution of loads from agricultural and developed lands was always reported as positive loads, natural lands are represented by both positive and negative loads. Without adequate monitoring data to compare with other land uses, a small positive bias of 0.1 lbs./acre/year is assumed for natural lands.

5.2.5.4. Baseline landscape loading summary

The literature supports the assumption that agricultural lands yield the highest loads of the three defined categories. Annual agricultural loads reported in the region ranged from 1.1–2.05 lbs./acre/year on average. Developed land had results that were less than 0.1–0.6 lbs./acre/year on turfgrass and similar values from the impervious landscape, albeit due to increased runoff at lower concentrations. The natural landscape is not well described with field-scale monitoring data across the diverse natural landscape, but a small positive load of

0.1 lbs./acre/year is assumed. The ratio that is used to define the relative contributions at the pour point is that agricultural land yields twice as much per acre as developed land (2:1), and agricultural land yields 10 times as much per acre as natural lands (10:1). Small changes in these ratios will not result in large changes in the breakdown of the total load because the equations are constrained by the large proportion of the landscape represented by agricultural production.

Equations 4–6 define the relative contribution of the landscape load at the pour point.

$$\frac{Landscape_{up}}{Area_{up}} = \frac{Landscape_{AG}}{Area_{AG}} + \frac{Landscape_{DEV}}{Area_{DEV}} + \frac{Landscape_{NAT}}{Area_{NAT}} \quad (4)$$

$$Landscape_{DEV} = Landscape_{AG} * 0.5 \quad (5)$$

$$Landscape_{NAT} = Landscape_{AG} * 0.1 \quad (6)$$

Note that each component in Equation 4 is normalized by area, signifying that these are yields, not total loads. $\text{Landscape}_{\text{up}}$ and Area_{up} indicate the landscape load and area upstream of the pour point, respectively. Agricultural, developed, and natural land areas are denoted as AG, DEV and NAT, respectively.

The series of equations gives the relative load from each sector at the pour point that can then be used to estimate the load downstream of the pour point from the nonpoint source. To do this, the upstream loads are converted into yields for each land use. The yield is then used to determine the nonpoint source downstream by assuming the same yield from the upstream area applies to the downstream area for each landscape component. This calculation is necessary because it is not possible to measure load directly due to the lake's influence on the river downstream of the pour point.

5.2.6. Baseline permitted stormwater

Several groups of permitted stormwater must be broken out from the baseline condition basinwide load calculation. These are described in detail above in the source assessment within Section 4.1.2.

The area covered by MS4 permitting is based on existing U.S. Census geospatial data. The MS4 coverage area was cut out to the Maumee watershed via a geographic information system (GIS) analysis. The individually permitted city of Toledo MS4 area was further broken out of the MS4 area within the Maumee using GIS analysis. This resulted in an amount of area within the Maumee watershed for the Toledo MS4 area and the remainder of MS4 areas covered by Ohio EPA's MS4 General Permit (OHQ000004).

Stormwater is also permitted through facility-based NPDES permits. These may be included in individual NPDES permits or by the MSGP (OHR000007). Ohio EPA staff have used GIS to delineate all the facilities permitted in both categories. Areas for 41 individual NPDES permits with stormwater controls and over 250 facilities covered by the MSGP, were determined. Facility-based permitted stormwater areas within the Toledo and general MS4 areas are removed from the MS4 areas for the TMDL calculations.

Figure 45 shows example results for part of the Maumee watershed, indicating the delineation of various types of permitted stormwater.

Construction activities covered by Ohio EPA's general permit (OHC000005) are accounted for differently due to the transient nature of these operations. When filing for coverage of this permit, permittees must state the construction site location and the number of acres impacted. Ohio EPA analyzed the number of acres within the Maumee watershed covered by this permit for the most recent five years of available data (2017–2021). Assuming most operations do not span more than a year, the average annual area coverage by this permit was determined to be used for TMDL calculations.

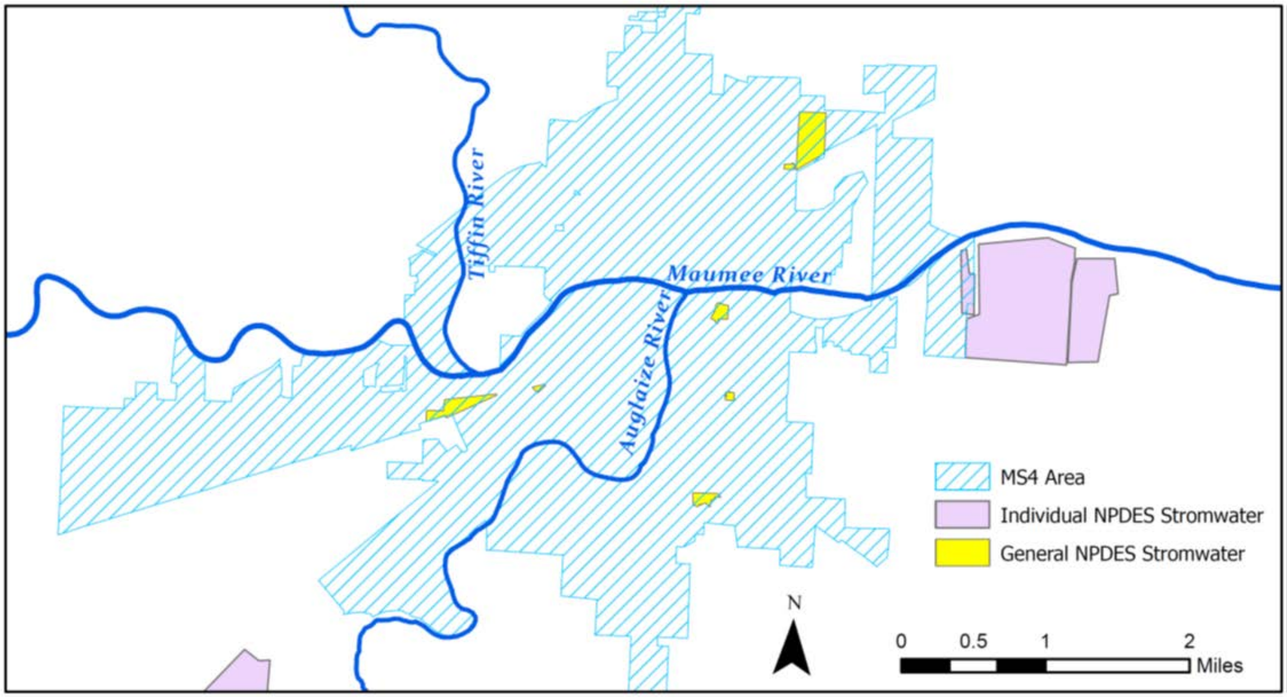


Figure 45. Map showing the permitted stormwater area delineated around the Defiance, Ohio, area.

To calculate the baseline total phosphorus loads for the MS4, facility-based, and construction-permitted stormwater areas, the percent of area that falls into each category is taken out of the total landscape load from the developed load portion. The remainder of the developed land is combined with the agriculture and natural lands in order to calculate the final nonpoint source load.

5.3. Modeling the target condition – proposed allocations

The following outlines the proposed total phosphorus allocation methods for meeting the TMDL. Like the baseline conditions, these allocations apply to the spring loading season of March through July. Also, like the baseline conditions calculations, reductions will be calculated through empirical means rather than using scenario(s) outputs from a process-based model. Additional discussion on this modeling will be included in the implementation recommendations section of this report to guide those recommendations.

This is the Preliminary Modeling Results (PMR) step in this TMDL project. This step is designed to provide stakeholders with detailed results prior to when the actual proposed TMDL allocations are presented. There is an expectation that these methods, and subsequent results, will be altered after careful consideration by stakeholders and further discussions with Ohio EPA.

The potential that phosphorus reductions can be met in the fashion outlined by these methods has been carefully considered. This is explained in detail in the Reasonable Assurances part of this report, Section 8. The allocations must sum to the seasonal target load of overall 914.4 MT of total phosphorus. The following subsections first present the allocation method for each type of source. Then the subsections show how the wasteload and load allocations are summarized. These reduction methods will only be carried out for loading to the Maumee watershed from the state of Ohio. An explanation of out-of-state boundary conditions is provided at the end of this subsection.

5.3.1. Allocations for permitted wastewater treatment facilities

This subsection outlines the details of proposed permitted treatment facilities' total phosphorus allocations.[1] As explained above in Section 4.1.2.1, wastewater treatment facilities currently discharge well below their permitted allowance. The allocations for the wastewater treatment facilities are based on the objective of preserving the baseline total phosphorus reductions already realized by this source. While this does not result in new reductions from what is currently being discharged, it effectively eliminates capacity between the currently authorized and actual loads shown above on Figure 26.

The concept of grouping most of the facility-based load is proposed to provide the most flexibility to permitted facilities. Implementing grouped permitted loads could be achieved via a watershed general permit.

There are also over 100 facilities that contribute an extremely small amount of total phosphorus load to the Maumee watershed. These facilities are not being proposed to join the grouped load that would be included in the general permit. Rather, individual wasteload allocations are calculated with the expectation that baseline conditions will be maintained.

Calculation methods for CSO-specific wasteload allocations are also presented in this subsection. These allocations represent a level of control that each CSO community has either completely enacted or is in the process of enacting.

5.3.1.1. Proposed allocation methods for grouped wastewater treatment facilities

Facilities that are proposed to be part of the grouped load, which may result in a special TMDL general permit, are generally what are currently considered "majors" (see Section 4.1.2). These are municipal WWTPs with an average design flow of 1 MGD or greater. Significant minors with an average design flow greater than 0.5 MGD are also included. Several industrial facilities that have been previously identified as contributing significant amounts of total phosphorus are also included. The facilities included in the grouped load are shown below in this subsection.

The sum of the load that all facilities within this group contributed during the 2008 spring season is used to determine the total allowable load for the group. This reflects the objective of not exceeding the baseline load from these sources.

While each facility's baseline, the 2008 spring season load, is used to determine the grouped load allocation, this load is not what is used to determine each individual facility's wasteload allocation. If that were done, it would reward the facilities that were not maximizing total phosphorus reductions in 2008 and penalize facilities that were optimizing controls the most. Rather, a tiered system of determining the grouped facilities' individual wasteload allocations is proposed. This system is intended to reflect: (1) the magnitude of facilities' loading contributions, (2) each facility's existing ability to treat total phosphorus, (3) the objective that the cumulative facility-based load does not increase from the 2008 baseline. This calculation method also allows for a certain amount of allowance for future growth (AFG) to be reserved for new or expanding facilities.

It is important to note that having an individual wasteload allocation for each permitted facility is a required component of any TMDL. This applies to these facilities that are being proposed to be grouped and implemented via a general permit or similar action. Additional discussion on the general permit is in Section 7.

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[1] Total phosphorus wasteload allocations for facilities included in near-field TMDL reports (see Table A5.1 of Appendix 5) in the Maumee River watershed are not impacted by this TMDL and are still applicable and must be considered during the development and/or revision of a NPDES permit. In those instances where there is a WLA calculated as part of this TMDL (see Tables in Appendix 4) ***and*** an earlier calculated WLA from a near-field TMDL report (see Table A5.1 of Appendix 5), both WLAs are applicable and must be considered during the development and/or revision of a NPDES permit. Please see Appendix 5 for additional information.

Table 22 shows the tiered approach for determining the individual wasteload allocation for each facility proposed to be in the grouped load limit.

Table 22. Different tiers for calculating wasteload allocations for the facilities in the proposed grouped load.

Grouped permit WLA tier	Description	Wasteload allocation calculation method
GP1	Municipal WWTPs with average daily design flows greater 10 MGD	Average daily design flow at a total phosphorus concentration of 0.37 mg/L (the expected long-term average total phosphorus discharge concentration where a 0.50 mg/L monthly limit exist) for the 153 days of the spring season.
GP2	Municipal WWTPs with average daily design flows between 1 and 10 MGD	Calculated for each facility as their average design flow divided by the sum of all the GP2 design flows and then multiplied by the remainder of load available after accounting for the other grouped permit tiers. This results in a concentration of 0.43 mg/L (~0.59 mg/L monthly limit) over the 153 days of the spring season.
GP3	Minor municipal WWTPs with average daily design flows of 0.5–1 MGD; several industrial facilities	Average daily design flow at a total phosphorus concentration of 0.73 mg/L (the expected long-term average total phosphorus discharge concentration where a 1.0 mg/L monthly limit exist) for the 153 days of the spring season.
GPX	Industrial facilities included in grouped WLA	Calculation methods are specific to each facility and described below.
Grouped permit AFG	1.4 MT of total phosphorus reserved for future growth	This amount of load can accommodate new effluent treating about 6.5 MGD at the 0.37 mg/L (GP1) level.

Notes:
AFG = allowance for future growth; MGD = million gallons per day; MT = metric tons; WLA = wasteload allocation.

The following paragraphs provide more details on these wasteload allocation tiered groups. Table 23 lists the facilities proposed to be included in the grouped load and what tiered group they fall into.

GP1 – Four facilities have an average daily design flow greater than 10 MGD. These are all municipal WWTPs that currently have a monthly total phosphorus limit of 1.0 mg/L. Setting an individual wasteload allocation based on average design flows and a total phosphorus concentration of 0.37 mg/L is reflective of a long-term discharge concentration average if the facilities were to have monthly limits of 0.5 mg/L. This average monthly limit is derived using Table 5-2 from the U.S. EPA *Technical Support Document for Toxics Control* (U.S. EPA, 1991). To calculate the monthly limit from the long-term average value of 0.37 mg/L, a coefficient of variation of 0.6 and 10 samples collected monthly are assumed. Due to the large size of these facilities, the marginal cost of optimizing for phosphorus treatment is more inexpensive than facilities in the other tiers.

GP3 – Most of these facilities currently do not have total phosphorus limits in their individual permits. These eight municipal WWTPs are designed to operate with a daily average discharge of 0.5–1 MGD. Individual wasteload allocations for these facilities consider a total phosphorus concentration that would be discharged were they to have a monthly limit of 1.0 mg/L, which is 0.73 mg/L (following the guidance mentioned in U.S. EPA [1991]). The permitted average design flow is used to calculate the wasteload.

GPX – This tier includes eight industrial facilities that have all demonstrated discharging effluent with total phosphorus loads that require additional considerations and are included in the grouped wasteload allocation.

There are a variety of different methods used for calculating each facility's wasteload allocation. These differences are necessary based on the unique nature of the facilities. The following explains these differences:

> 2ID00018 – Toledo HBI Facility: This facility contributes total phosphorus via its cooling water additives. Other sources of phosphorus at the facility include the make-up water for the cooling system, which includes filter backwash water from the Collins Road Water Treatment Plant and potable water from the city of Toledo. The total phosphorus concentration used to calculate the individual wasteload allocation was 0.73 mg/L as a long-term average value, and the flow was 1.03 MGD. This is the total phosphorus concentration assumed to be consistent with optimizing cooling water additive used to meet a monthly limit of 1.0 mg/L (following the guidance mentioned in U.S. EPA [1991]). The flow is the 95th percentile monthly average discharged by the facility since its operations began in 2021.
>
> This facility was identified as contributing to the project area since the PMR was published during the evaluation for the permit renewal.
>
> 2IF00004 – PCS Nitrogen Ohio LP: This facility has a total phosphorus load limit due to a near-field TMDL. The total phosphorus concentration used to calculate the individual wasteload allocation for this TMDL was 0.73 mg/L as a long-term average value, and the flow was 4.33 MGD. This is the total phosphorus concentration assumed to be consistent with the optimizing cooling water additive used to meet a monthly limit of 1.0 mg/L (following the guidance mentioned in U.S. EPA, [1991]). The flow is the 95th percentile monthly average discharged by the facility. PCS Nitrogen does not use biological treatment and is evaluating per its permit if cooling water system chemical use could be further optimized to lower phosphorus concentrations.
>
> 2IG00001 – Lima Refinery: This facility has a total phosphorus load limit due to the implementation of a near-field TMDL. Due to the nature of this facility's operations, it has been discharging very low concentrations of total phosphorus in recent years (spring season medians ranging from 0.16 to 0.22 mg/L in the five seasons ending 2021) and during that period did not discharge on a daily or continuous basis. The facility has also recently implemented a water conservation project that reduced total discharge substantially. The individual allocation for this TMDL accounts for the lower flow values achieved from the water conservation project and meets a limit consistent with 0.37 mg/L as a long-term average (assumed to be equivalent to a monthly average concentration of 0.5 mg/L). Because the facility is currently discharging effluent consistent with these considerations, additional technology has not been considered.
>
> 2IH0021 – Campbell Soup Supply Company: This facility has had a total phosphorus concentration limit for several permit cycles. The permit's average design flow used for permitting wasteload calculations is 10 MGD, and the actual average daily flows have averaged 5.5 MGD for the spring seasons 2017–2021. The facility uses biological treatment and has been evaluated with the GP2 subcategory of municipal wastewater treatment facilities.
>
> 2IH00110 – Cooper Farms Cooked Meats Van Wert: With no existing total phosphorus permit limit, this facility has voluntarily reduced the total phosphorus concentration of their effluent discharges. Current discharge concentrations are approximately 1.0 mg/L, whereas spring median concentrations from 2008 to 2011 ranged from 18.7 to 23.85 mg/L. Because of this, the individual wasteload allocation for this facility is set at the second greatest load calculated for the last five spring seasons, 2017–2021. Note that this is similar to how the wasteload allocations are calculated for minor WWTPs (see Section 5.4.1.2).
>
> 2IK00002 – G.A. Wintzer and Son Co: This facility has no existing total phosphorus limits in its permit; it uses biological treatment and discharges at elevated concentrations compared to similar-sized municipal wastewater treatment facilities. Median spring season total phosphorus concentrations have ranged from 4.7

to 13.1 mg/L in the last five seasons, 2017–2021. Because no total phosphorus controls currently exist at this plant, their wasteload allocation is calculated in the same fashion as facilities in the GP3 tier.

2IW00010, 2IW00070, 2IW00190 – McDowell/Bowling Green, Delta, and Napoleon water treatment plants: These three drinking water treatment plants use reverse osmosis treatment that uses phosphorus-containing additives to clean membranes. The wasteload allocation for these facilities assumes they will meet a long-term average concentration of 0.73 mg/L, consistent with optimizing the use of treatment additives to meet a monthly average limit of 1.0 mg/L (following the guidance mentioned in U.S. EPA [1991]).

Grouped permit AFG – An AFG for the grouped permit is set at 1.4 MT. This provides a load available for new or expanding major treatment facilities. An additional 0.1 MT of total phosphorus AFG is reserved for loads that will not be included in the grouped permit. In order to not increase the baseline load, this extra 0.1 MT of load is added to the 1.4 MT allowance explained here for calculating the GP2 loads (see the paragraph below).

GP2 – This tier has 18 major municipal WWTPs with average design flows of less than 10 MGD. All these facilities have an existing monthly total phosphorus limit of 1.0 mg/L in their permits. The total wasteload allocation for all facilities in this group is set as the remainder of the grouped wasteload allocation after the other individual wasteloads for the other tiers (GP1, GP3, GPX, and the grouped permit AFG) have been assigned. Within this tier, that load is distributed to each facility based on their average design flow (i.e., each facility gets the percent of the total GP2 tier wasteload allocation equal to their design flow divided by the sum of all GP2 facilities' design flows). Employing this method has two advantages. First, it completely allocates the remaining group wasteload. Second, it essentially calculates the wasteload allocations for the facilities in this group at a concentration between what is used for the GP1 and GP3 groups. This concentration is a long-term average of 0.43 mg/L, or what would be expected with a monthly concentration limit of about 0.59 mg/L (following the guidance mentioned in U.S. EPA [1991]).

Table 23. Different tiers for calculating wasteload allocations for the facilities in the proposed grouped load.

Tier	Permit number	Facility name
GP1	2PF00000	Toledo Bay View Park WWTP
GP1	2PK00000	Lucas Co WRRF
GP1	2PE00000	Lima WWTP*
GP1	2PD00008	Findlay WPCF*
GP2	2PD00002	Perrysburg WWTP
GP2	2PD00013	Defiance WWTP
GP2	2PD00006	Van Wert WWTP
GP2	2PD00019	Wapakoneta WWTP
GP2	2PD00029	Delphos WWTP
GP2	2PD00018	Bryan WWTP
GP2	2PD00026	St Marys City WWTP
GP2	2PD00028	Ottawa WWTP*
GP2	2PD00000	Napoleon WWTP
GP2	2PD00017	Archbold WWTP
GP2	2PB00050	Ada WWTP*
GP2	2PK00002	Shawnee No 2 WWTP*
GP2	2PC00005	Bluffton WWTP*
GP2	2PH00006	American No 2 WWTP
GP2	2PD00003	Montpelier WWTP
GP3	2PB00025	Swanton WRRF*
GP3	2PB00042	Hicksville WWTP
GP3	2PB00034	New Bremen WWTP
GP3	2PC00004	Columbus Grove WWTP
GP3	2PB00048	Cridersville WWTP
GP3	2PB00003	Delta WWTP
GP3	2PB00046	Elida WWTP
GP3	2PD00027	Paulding WWTP
GPX	2ID00018	Toledo HBI Facility
GPX	2IF00004	PCS Nitrogen Ohio LP*
GPX	2IG00001	Lima Refinery*
GPX	2IH00021	Campbell Soup Supply Company
GPX	2IH00110	Cooper Farms Cooked Meats Van Wert
GPX	2IK00002	G.A. Wintzer and Son Co
GPX	2IW00010	McDowell/Bowling Green WTP

Tier	Permit number	Facility name
GP2	2PB00040	Leipsic WWTP
GP2	2PD00016	Wauseon WWTP
GP2	2PH00007	American-Bath WWTP

Tier	Permit number	Facility name
GPX	2IW00070	Delta WTP
GPX	2IW00190	Napoleon WTP

Notes:
WWTPs and WRRFs are wastewater treatment plants of municipal sewage; WTPs are drinking water treatment plants.
* These facilities also have WLAs in TMDLs approved by the U.S. EPA (See Appendix 5 for complete list)

5.3.1.2 Proposed allocation methods for minor and general wastewater treatment facilities

The remaining wastewater facilities receiving a wasteload allocation in this TMDL contribute a relatively small portion of the total facility-based wasteload allocation.

Over 110 municipal and semi-public individual permitted wastewater plants and 10 industrial facilities are considered within the wasteload allocation. With only a few exceptions, the individual wasteload allocation for each of these facilities is set based on the second-greatest spring season load that each facility has discharged in the last five spring seasons (2017–2021). Many of these facilities do not monitor the total phosphorus in their effluent. Similar assumptions to those used to calculate the 2008 baseline loads were used to determine these facilities' total phosphorus concentrations (see Section 5.3.3).

The exceptions to this calculation method are for wastewater plants that have not reported any effluent flow during this time period. In those cases, assumptions are made to determine an appropriate discharge from which to calculate the facility's individual wasteload allocation. These facilities' names and permit numbers are reported in Appendix 4 of this report, along with the actual wasteload allocation results (see Section 6.1).

A small AFG is explicitly reserved for these small, individually permitted facilities. This load, 0.1 MT of total phosphorus per spring season, is being set aside for the use of new or expanding small facilities that may discharge phosphorus to the Maumee watershed in the future. This action is considered part of the AFG and is explained further in Section 5.7.

A single wasteload allocation is calculated for the load contributed from Ohio's Small Sanitary General Permit (OHS000005). Currently, 11 facilities in the Maumee watershed are covered by this permit. Facilities covered by this permit must have an average design flow of less than 25,000 gallons per day; however, Ohio EPA is aware that most discharge significantly less than this amount. To allocate adequate load for the facilities covered by this general permit, a daily discharge flow rate of 12,500 gallons per day is used to calculate the wasteload allocation. This calculation assumes a total phosphorus effluent concentration of 2.5 mg/L for these plants. Ohio EPA is aware that many small sanitary treatment systems across the state are currently unpermitted. Ohio EPA is steadfast in its efforts to bring these facilities into compliance either by permitting them under this general permit or by tying their influent to existing, individually permitted WWTPs. Because of the potential for additional plants being covered by this general permit, the existing number of 11 plants is increased to 25 for the wasteload allocation calculation of this general permit. This action is considered part of the AFG and is explained further in Section 5.7.

5.3.1.3. Proposed allocation methods for CSOs and other wet weather events

Section 402(q) of the Clean Water Act requires that each permit, order, or decree associated with CSO discharges must conform to U.S. EPA's 1994 CSO Policy. Included in the CSO Policy are expectations that CSO permittees will implement the Nine Minimum Controls to mitigate environmental impact if CSOs occur and will develop and implement Long Term Control Plans (LTCPs) to control CSO discharges and ultimately meet water quality standards.

In 2015, U.S. EPA modified their goal for the Water Safe for Swimming Measure, which seeks to address the water quality and human health impacts of CSOs. The goal includes incorporating an implementation schedule of approved projects into an appropriate enforceable mechanism, including a permit or enforcement order, with specific dates and milestones for 92% of the nation's CSO communities by the end of September 2016.

Ohio EPA implements CSO requirements through provisions included in NPDES permits and using orders and consent agreements when appropriate. The NPDES permits for CSO communities require them to implement the Nine Minimum Control measures. Requirements to develop and implement LTCPs are also included where appropriate.

All 24 CSO communities within the Ohio portion of the Maumee watershed have approved LTCPs in place to address their systems. The following describes how these plans are used to set CSO-specific total phosphorus wasteload allocations.

Half of these communities have planned for complete separation of their storm and sanitary sewers. The CSO wasteload allocation for these communities is zero load (WLA = 0).

For the other 12 communities, some CSO discharge events are expected once the control plans are completed. Six of these communities have developed hydraulic models to estimate the amount of CSO discharge during a typical year at their completed plans' level of control. The wasteload allocation for these facilities is calculated by determining the product of that typical year's flow rate, an assumed total phosphorus concentration of 0.75 mg/L, five-twelfths to calculate the spring season period, and a conversion factor. The 0.75 mg/L assumption is based on an assessment of CSO data documented in Ohio EPA (2020b).

The method described above uses five-twelfths of the planned annual control plan discharges for the TMDL's spring season wasteload allocation. This assumes the discharge occurrences average out evenly throughout the year. Mathematically this assumption means that 42 percent, or five-twelfths, of the level-of-control discharges will occur from March 1 through July 31. Because all the communities' controls are not yet finished (and, therefore, the level of control is not yet realized) and considering that every system is different, assumptions with which to estimate the timing of future occurrences are very imprecise. Ohio EPA has observed that 38–62 percent of discharge events for the eight most active CSO communities occurred during this TMDL's spring season for 2017–2021. The 42 percent assumption is within this range, and Ohio EPA considers using 42 percent an acceptable approach rather than estimating a different proportion, considering the challenges noted above.

A different wasteload allocation calculation method is required for the six remaining CSO communities that expect some discharges upon completion of their control plans but have not developed a hydraulic model for their control plan. This is because the flow rate is unknown for the releases that may occur once control work is complete. The wasteload allocation is calculated by reducing the 2008 baseline CSO load by 80 percent based on Ohio EPA's expectations from communities with hydraulic models and similar levels of implementation.

The sanitary sewer overflows (SSOs) are prohibited by the Clean Water Act. All communities with known SSOs must plan to eliminate these sources. Because of this, there are no wasteload allocations given for SSOs (WLA=0).

CSO provisions are tied to a community's NPDES permit. Table 24 summarizes the wasteload allocation being used for each of the 24 CSO communities.

Table 24. Wasteload allocation method for CSO communities.

Community/permittee	Permit number	Wasteload allocation method
Toledo Bay View Park WWTP	2PF00000	Level-of-control hydraulic model flow and a 0.75 mg/L total phosphorus concentration are used to calculate WLA.
Lima WWTP	2PE00000	
Findlay WPCF	2PD00008	
Wapakoneta WWTP	2PD00019	
Napoleon WWTP	2PD00000	
Defiance WWTP*	2PD00013	
Hicksville WWTP	2PB00042	WLA is set at an 80 percent reduction of the calculated 2008 baseline CSO load.
Van Wert WWTP	2PD00006	
Wauseon WWTP	2PD00016	
Delta WWTP	2PB00003	
Delphos WWTP	2PD00029	
Payne WWTP	2PA00019	
Perrysburg WWTP	2PD00002	WLA is set to zero to reflect complete sanitary and storm sewer separation upon completion of CSO control plans.
Montpelier WWTP	2PD00003	
Fayette WWTP	2PB00045	
Paulding WWTP	2PD00027	
Ohio City WWTP	2PB00030	
Columbus Grove WWTP	2PC00004	
Dunkirk WWTP	2PB00061	
Pandora WWTP	2PB00029	
Forest WWTP	2PB00044	
Deshler WWTP	2PC00002	
Leipsic WWTP	2PB00040	
Swanton WRRF	2PB00025	

Note:
* Ohio EPA is expecting Defiance to provide the results of their level of control hydraulic modeling in August 2022. Prior to that point, the WLA for this facility is temporarily calculated based on an 80 percent reduction of their calculated baseline spring 2008 CSO load.

5.3.2. Allocations for permitted stormwater

Permitted stormwater shares a close relationship with nonpoint source loads, as they are primarily driven by precipitation events. Allocations need to match implementable solutions, which requires consideration of how and where these loads are best managed on the landscape. Implementing source control and green infrastructure (e.g., permeable pavement, rain gardens) can be completed within the area managed by stormwater utilities through their permits. Additionally, natural infrastructure projects, such as wetlands or two-stage ditches, are also an effective means of managing stormwater. The load that runs off from regulated stormwater areas includes nonpoint sources from adjacent lands, such as riparian corridors. These adjacent areas are most likely where natural infrastructure practices will be sited. Because of this, allocating all the pollutant reductions in these areas completely to the permitted stormwater would result in reduced flexibility. Therefore, these allocations reflect a mix of the required nonpoint and point source reductions.

This TMDL's allocations for MS4s are set based on a 20 percent reduction from their baseline condition. This is approximately half the reduction set for the nonpoint source load allocation. Splitting the reductions between the wasteload and load allocations is justified because implementing natural infrastructure projects in communities involves diverse partnerships, including the regulated community. They have been a component of nonpoint source planning efforts throughout the basin. The existing development of Nonpoint Source Implementation Strategies (NPS-IS), explained in Section 7.2, are a testament to the value of collaboration from these communities. To encourage these partnerships to continue, its reasonable that the reductions targeting natural infrastructure are allocated to the nonpoint sources.

The non-MS4-regulated stormwater sources have been calculated to contribute only 7.8 percent of the total baseline regulated stormwater load and less than 0.2 percent of the total watershed baseline load. These permits have conditions that require management actions that improve pollutant source control compared to other stormwater areas. Because of the small contribution and existing measures to control phosphorus, additional reductions are not included in these sources' wasteload allocations. The wasteload allocations for non-MS4-regulated stormwater sources are set equal to their baseline load.

5.3.3. Allocations for home sewage treatment system loads

As described in the baseline conditions methods, soil adsorption on-site and discharging HSTSs are accounted for using specific calculations. For a TMDL, these types of systems are allocated differently. Discharging systems are expected to be covered under Ohio EPA's general permit (OHK000004). Being a permitted source, this pollutant allocation is considered part of the wasteload allocation. The on-site HSTSs are not point sources and are, therefore, part of the load allocation.

No extra load reduction is expected from discharging systems. Therefore, the wasteload allocation for this source is set at the calculated baseline load.

The calculation for baseline soil adsorption on-site HSTSs explains that many of these systems are failing. The load allocation for this source sets an expectation that progress is made addressing these failed on-site systems. Specifically, this allocation method proposes that half the failing systems are addressed. For the allocation, the load produced by these repaired systems is reduced to have them contribute the same amount that is discharged from properly working on-site systems. Therefore, the total load allocation for on-site HSTS is the sum of (1) the load from the 2008 baseline for properly working systems, (2) half of the baseline for failing on-site systems considered repaired, and (3) the other half of the baseline for failing on-site systems still considered discharging at the failing rate.

5.3.4. Allocations for CAFOs/CAFFs

There are 73 CAFO/CAFFs in the watershed that have PTIs and PTOs through ODA-DLEP (see Table A.3.2 for a list of facilities). The requirements for these facilities to obtain NPDES permits have changed with time. The obligations for CAFOs to obtain NPDES permits coverage are primarily defined by two federal court rulings. These two decisions followed the 2003 CAFO regulations that expanded the number of operations covered by the CAFO regulations by an estimated 15,500 facilities nationwide (epa.gov/npdes/pubs/summary_court_decision.pdf). Following the implementation of that rule, in Waterkeeper Alliance, Inc. v. U.S. EPA, 399 F.3d 486, 506 (2d Cir. 2005), the Court held that "we believe that the Clean Water Act, on its face, prevents the EPA from imposing, upon CAFOs, the obligation to seek an NPDES permit or otherwise demonstrate that they have no potential to discharge." In other words, while they were a point source by definition, that does not itself trigger the obligation to get a permit. CAFOs actually need to discharge pollutants to trigger the obligation of a permit.

Following that ruling, U.S. EPA revised the rule in 2008 to say CAFOs need to get a permit if they discharge or "propose" to discharge. The rule defined "proposed" to mean that CAFOs were designed, constructed, operated and maintained in a manner such that the CAFO will discharge". This rule was again challenged in the case of National Pork Producers Council v. U.S. EPA, 635 F.3d 738 (5th Cir. 2011), the Court explained:

> "the EPA's definition of a CAFO that "proposes" to discharge is a CAFO designed, constructed, operated, and maintained in a manner such that the CAFO will discharge. Pursuant to this definition, CAFOs propose to discharge regardless of whether the operator wants to discharge or is presently discharging. This definition thus requires CAFO operators whose facilities are not discharging to apply for a permit and, as such, runs afoul of Waterkeeper. . ."
>
> Id. at 750.
>
> The Court invalidated the 2008 CAFO rule, stating:
>
> "These cases leave no doubt that there must be an actual discharge into navigable waters to trigger the CWA's requirements and the EPA's authority. Accordingly, the EPA's authority is limited to the regulation of CAFOs that discharge. Any attempt to do otherwise exceeds the EPA's statutory authority. Accordingly, we conclude that the EPA's requirement that CAFOs that "propose" to discharge apply for an NPDES permit is ultra vires and cannot be upheld."
>
> Id. at 751.

The clean water act specifically exempts agricultural stormwater from NPDES permitting requirements (CWA Section 502 (14): 40 CFR 122.23). Agricultural stormwater includes stormwater from fields where manure from CAFOs is applied consistent with a nutrient management plan. There are currently no CAFOs in the watershed that discharge or propose to discharge non-agricultural stormwater under an NPDES permit. CAFOs do contribute to the nonpoint source phosphorus load via agricultural stormwater from the land application of manure. This load is considered part of the load allocation for nonpoint sources discussed in Section 5.3.6. Therefore, while the Clean Water Act defines CAFOs as point sources, this TMDL provides no wasteload allocations to CAFO livestock operations (this can be interpreted as WLA=0).

5.3.5. Wasteload allocation summary

The various wasteload allocation methods appliable to the point sources of total phosphorus in this TMDL are summarized on Table 25. The sum of the allocations for all categories is the total wasteload allocation.

Table 25. Wasteload allocations method summary.

Program	Permit type	Major category	Wasteload allocation method summary
Treatment Facilities: Point source pipe(s) directly contributing waste to surface waters	**Individual NPDES Permit**: Unique permits issued for each facility	**Public**: Treats a majority of municipal/human waste; most often delivered from public sewer systems	Major: WLA included in the grouped wasteload that could be implemented via a general permit. Grouped WLA determined by these facilities' 2008 effluent. Individual WLAs re-distributed; see **Section 5.4.1.1**
			Minor: WLAs set at the 2nd greatest load in the last five spring seasons; see **Section 5.4.1.2**
			CSO: Separate WLAs calculated for each CSO community based on their long-term control plan; see **Section 5.4.1.3**
		Phosphorus Discharging Industrial: Facilities that treat waste from industrial processes	Facilities with current total phosphorus limit and other special cases included in grouped WLA; see **Section 5.4.1.1**
			Facilities with minimal total phosphorus discharges. WLAs set at the 2nd greatest load in the last five spring seasons; see **Section 5.4.1.2**
	General: Permits that cover smaller facilities	Small sanitary general permit	WLA set based on assumptions; see **Section 5.4.1.2**
		Discharging HSTS general permit	WLA set at the baseline condition total load; **see Section 5.4.3**
Stormwater: Regulated nonpoint sources	**Individual**: Unique permits	Facility-based	MS4 stormwater sources' WLA set based on a 20% reduction from baseline conditions. All other permitted stormwater receives WLAs consistent with the estimated baseline conditions; see **Section 5.4.2**
		Municipal-based (Phase I MS4s)	
	General: Generic permits	Facility-based (i.e., MSGP)	
		Municipal-based (Phase II Small MS4 general permit)	
		Construction general permit	
Beneficial Use	Beneficial use of materials	Biosolids	Discharge of materials to surface water is prohibited; agricultural stormwater from land application fields is captured in the TMDL's load allocation.
		Land application	

5.3.6. Allocations for nonpoint sources

The allocations for all nonpoint source load, except for the on-site HSTS load, are grouped together and termed the "nonpoint source landscape load" in this method. This reflects the allocation calculated for the land area grouped in the agricultural and natural lands uses, plus the developed land that is not accounted for by the permitted stormwater (as noted above in Section 3.4.2). This load allocation is determined by giving this source the remaining total phosphorus load available of the target after all other allocations, noted in the subsections above and including an explicit margin of safety (MOS) described below in Section 5.6, have been taken.

Due to the nature of this allocation calculation method and how nonpoint source implementation actions are proposed to be carried out, the nonpoint source landscape load allocation is not itemized by land use or any other means. Just one total allocation value is provided. This is similar to the specific land use far-field targets for each HUC-12 watershed management unit in Ohio's part of the watershed that have been published in the Ohio DAP 2020 (OLEC, 2020a). Like this TMDL, the Ohio DAP 2020 HUC-12 targets are also based on the Annex 4 overall watershed target.

A separate load allocation for the on-site HSTS is provided in the results section. The sum of the nonpoint source landscape and on-site HSTS allocations is the total load allocation.

5.3.7. Out-of-state boundary condition and resulting Ohio targets

The baseline conditions of phosphorus load were calculated for the entire watershed draining to the Maumee River, including the areas within Michigan and Indiana. This results in 1,503.6 MT of total phosphorus, as noted in Section 3.4.1. However, the allocations calculated in this TMDL are only for the load delivered from within Ohio's borders. This includes reductions for streams that flow into Indiana.

The baseline conditions assessment method, described above, finds the out-of-state 2008 baseline load of 374.2 MT of total phosphorus: 295.7 MT and 78.5 MT from Indiana and Michigan, respectively. The remaining 75.1 percent of the baseline total phosphorus load delivered to the Maumee watershed is from Ohio. Note that Ohio makes up 73.3 percent of the area in the watershed, which is very close to the load proportion.

In order to meet the complete watershed target load of 914.4 MT of total phosphorus (as noted in Section 3.4.1), proportional reductions are applied to the baseline agricultural and developed area loads from both Ohio and out-of-state. This recognizes that it is infeasible to expect load reductions from natural land areas whose prevalence varies between states. Once the needed reductions are calculated, the unreduced natural land baseline condition loads added back into the Ohio and out-of-state targets. Because the proportion of natural areas is not the same everywhere, this results in a reduction rate for Ohio's load of 39.3 percent and 38.9 percent for the out-of-state load. The targets are 685.7 MT for Ohio and 228.7 MT for the out-of-state loads. Comparing these targets summed (914.4 MT) to the full watershed baseline load (1,503.6 MT) results in a 39.2 percent reduction rate, as explained in Section 3.4.1.

All streams that flow into Ohio from Indiana and Michigan are assumed to be at a boundary condition that meets the 228.7 MT out-of-state target. The proportion of the total out-of-state baseline load determined for each state is applied to the target to calculate each state's boundary condition. This is 79-percent, or 180.7 MT, of total phosphorus per spring season is assigned to Indiana. Michigan is assigned 21-percent of the boundary condition, with 48.0 MT of total phosphorus.

In summary, considering only the part of the total watershed target that Ohio is responsible for, the 914.4 MT complete watershed total phosphorus target becomes 685.8 MT. This is the value that the Ohio allocations will sum to in this TMDL.

5.4. Model verification methods

Because a mass balance method is being employed to develop TMDL baseline sources and allocations, statistical model calibration and validation tests used for mechanistic or process-based models are not applicable. The uncertainty of the components that go into the mass balance method are discussed in this report's MOS section (Section 5.5).

A verification of the mass balance method's ability to predict loads is carried out for this project. As explained in Section 5.3.5.4, the total phosphorus loads were estimated throughout the watershed by using land use and regional stream discharge patterns. This was initially done to support the development of the Ohio DAP 2020 to set planning targets for HUC-12 subwatersheds. Using these adjustment factors, the load was balanced for the area upstream of Waterville based on the 2008 observed load at the Waterville pour point. The land use and hydrology downstream of Waterville were then used to estimate that part of the watershed's total load (along with the discharging permitted WWTPs). This model verification tests the model's predictive ability for this unmonitored area downstream of Waterville.

Stream water quality monitoring stations upstream of Waterville exist throughout the Maumee watershed, as explained in Section 5.3 of this report (also see Figure 28). For this verification, the loads for several of these upstream monitoring stations are calculated by the same approach used to determine the HUC-12 landscape target in the Ohio DAP 2020 (OLEC, 2020a).

To do this, first, the load of the entire Maumee watershed upstream of Waterville is “balanced” using the spring season load at the Waterville monitoring station for 2017–2021. After accounting for NPDES-permitted facilities and HSTS loads, the nonpoint source load is determined. The method considers the different loading by area yields for agricultural, developed, and natural land use, as described in Section 5.3 of this report. A hydrologic weighting factor was applied to each HUC-12. This weighting factor is discussed in Section 4.3.2 of this report and in Appendix A of OLEC (2020a).

To determine the load for each upstream monitoring station for these five spring seasons, a subset of the load from the total watershed draining to the Waterville monitoring station is determined. This is carried out in two steps. First, the landscape load for all complete HUC-12s upstream of each monitoring station is summed. For the HUC-12 that each monitoring station resides in, the total landscape load for that HUC-12 is cut to include the proportion of load that equals the proportion of area within the HUC-12 that drains to the monitoring station. The second step is adding the load from the discharging NPDES-permitted facilities and HSTSs upstream of each monitoring station. This results in the total modeled load at each monitoring station. These steps were carried out for each of 10 upstream monitoring stations for the five spring seasons in 2017–2021.

For this verification, the loads for the upstream stations are also calculated in the same spring seasons using a simple drainage area ratio of the Waterville loads. The drainage area ratio loads are determined by multiplying the Waterville load, for a given season, by the proportion of drainage area of the upstream station’s watershed compared to the entire Waterville drainage area. For instance, the Ottawa River’s monitoring station drains 350 square miles, and the Waterville station drains 6,330 square miles. Therefore, for the drainage area ratio method, the Ottawa River’s station load is 5.5 percent of Waterville’s spring load for each season being examined.

This results in two modeled loads: the mass balance method and the drainage area ratio method. These two types of modeled loads have been calculated for 10 upstream stations for five seasons (2017–2021) each. Note that the actual observed loads at the upstream stations were not used in the calculations for these two methods of modeled loads.

The mass balance method is verified by comparing the two methods of modeled loads with the observed loads at each upstream station. Section 6.3 presents the results of this work. Graphical examination, dimensionless, and error performance measures are reported to present an overall qualitative rating of this model verification.

5.5. Margin of safety

The Clean Water Act requires that a TMDL include a MOS to account for any lack of knowledge concerning the relationship between load allocations, wasteload allocations, and water quality. U.S. EPA guidance (U.S. EPA, 1999a) explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

For this TMDL, both implicit and explicit MOSs are used. Overall, conservative assumptions are made through TMDL development and implementation. Most importantly, this is a data-driven process using continuously collected monitoring data to calculate the TMDL.

The following bullets explain the conservative assumptions that provide an implicit MOS for this project:

- Ohio used a conservative value for associating bloom density with toxicity in its method of assessing Lake Erie's recreation use impairment due to HABs. The value of 20,000 cells/mL used for the impairment assessment would not be expected to exceed toxicity thresholds for bathing waters; maintaining cyanobacteria density below this level also limits the formation of scums where toxins can be concentrated. (Ohio EPA, 2020a; Davis et al., 2019)

- The following two sub-bullets explain that the water quality targets were developed using detailed modeling and have been tested empirically. These can be considered part of the implicit MOS because they provide a high degree of confidence that the targets will lead to the desired ecosystem response.

    - Multiple models were used to derive the phosphorus target that will manage Lake Erie's HAB size (Annex 4, 2015). This work was carried out and published by a binational group of experts. It was also reviewed and determined to be appropriate by an extramural science advisory board to the United States federal government (U.S. EPA SAB, 2017).
    - In recent low-flow years (2004 and 2012), the loads were consistent with the phosphorus targets and resulted in HABs of an acceptable size. This empirical evidence adds certainty to the modeled targets.

- The mass balance model is based on loads calculated from high-quality sampling data.

    - The USGS streamflow data that goes into the loading calculations involves continuous stream stage monitoring, streamflow discharge measurements, and the development of a rating curve connecting the two measurements. McMillian et al. (2012) report that uncertainty in measuring stream stage is relatively small. That report notes that measuring discharge is more complicated than stage measurements which introduces more uncertainty in the overall measurement. In general, however, the greatest potential for streamflow gaging uncertainty is in the stage-to-discharge relationships. And these errors increase when streamflow is extrapolated beyond the observed stage-to-discharge relationship. Typical confidence bounds for overall streamflow gaging uncertainties range from +/- 10–20 percent for in-bank medium or high flows and +/- 40 percent for out-of-bank high flows (McMillian et al., 2017). Those values include streamflow measurements worldwide. In the United States, USGS employs robust quality-control measures that reduce the inherent uncertainties in streamflow gaging and continues to improve their methods (Holtschlag, 2022). Only nonprovisional, fully approved USGS daily streamflow data are used for the load calculations in this TMDL. Therefore, a small amount of uncertainty is expected in this TMDL's calculations due to the streamflow measurements component.

    - The total phosphorus sample concentrations and load calculations are monitored and calculated by Heidelberg's NCWQR. This program collects three samples every day of the year from the Maumee River at the Waterville sampling station. Depending on if the stream discharge is stable or changing, one, two, or all three of the samples collected will be analyzed. More samples are analyzed if stream discharge is changing. With this large number of samples collected, straightforward numeric integration is employed to calculate the daily total phosphorus loads. This results in low bias and high precision (Richards, 1998).

- WWTPs are monitored at a high frequency. Large facilities, representing the majority of the load in this category, are sampled several times per week. These plants are required by their permits to have high standards for their water quality and flow volume monitoring.

- The mass balance model is intrinsically conservative because it is indexed to monitored data and is not using watershed characteristics to predict loads.

- Wet weather and home sewage treatment loads are estimated using robust methods that Ohio EPA has published in several iterations of the Nutrient Mass Balance Report (Ohio EPA, 2020b).

- The phosphorus data used to calculate the TMDL will continue to be tracked and will ensure the environmental response is not overstated based on BMP implementation.

- The DRP fraction of total phosphorus is also directly monitored in the watershed. While it is not directly allocated, the response is monitored and can inform adaptive management and BMP selection.

The information above shows that this project employs scientific rigor and conservative assumptions throughout that are considered above for implicit MOS. However, quantifying these measures is challenging. Dilks and Freedman (2004) note that if a TMDL only uses implicit MOS, there exists no guidance as to what is appropriately conservative, which renders the magnitude of MOS unknown.

As explained above, however, uncertainty is still present and justifies additional consideration for an explicit MOS. The oft-stated goal for setting explicit TMDL MOS is to somehow base it on quantified uncertainties in estimating pollutant loadings and water quality responses (U.S. EPA, 1999). However, a scholarly review of over 100 TMDL projects with explicit MOSs found all but one of them selected safety factors arbitrarily (as reported in Dilks and Freedman [2004]). Due to this, a National Research Council report on TMDLs made a renewed call for uncertainty analyses to be used as the basis for MOS setting (NRC, 2001).

Turning a model's uncertainty analysis into an explicit TMDL MOS is not a straightforward task. Zhang and Yu (2004) point out that no uniform guidance has been distributed by U.S. EPA or others to TMDL developers for MOS calculations. That paper also notes that model uncertainty alone does not account for all unknowns that could warrant load being reserved.

The mass balance modeling employed for this TMDL is not amenable to formal uncertainty analysis for the majority of the watershed upstream of the monitoring pour point. However, the model verification results, as presented in Section 6.2 below, demonstrates that the error in calculating the unmonitored load downstream of the pour point could be as great as 19.2 percent for that area. Section 6.2 explains when that error is applied to the load allocation downstream of the pour point, it could underestimate the load by 3.4 MT of total phosphorus for the spring loading season.

To account for the much less quantifiable uncertainties spelled out in this section, more than 3.4 MT must be reserved. The 3.4 MT is the maximum error resulting from a very small portion, less than 5 percent, of the watershed. The remainder of the watershed represents a much larger load, but the error is mitigated by the implicit considerations discussed above (though this mitigation is not quantifiable). Considering these factors and using 3.4 MT as an anchor point, a reasonable value was determined to be greater than five times this amount of load and less than 10 times. The load that results from an explicit MOS of 3 percent, or 20.6 MT, meets these criteria.

An overall explicit MOS of 3 percent accounts for the unknown factors in both calculating baseline conditions and uncertainty in the relationship between sources receiving a load allocation and a wasteload allocation. This load is reserved as a proportion of the total loading capacity. Therefore, it reduces the loading capacity available for allocations. Unless an approved TMDL is officially reevaluated, the load reserved for MOS will remain unallocated in perpetuity.

5.6. Allowance for future growth

An AFG in a TMDL can be used to "account for reasonably foreseeable increases in pollutant loads" (U.S. EPA, 1999a). Some TMDL projects provide an explicit amount of load, often calculated as a proportion of the target (e.g., 2 percent). The AFG used in a TMDL is often tied to observed and expected human population growth and shifts in industrial activities that may impact the production and delivery of pollutants. Having an AFG set aside in a TMDL can be useful for permitted point sources, especially when new facilities are proposed after a TMDL is developed and accepted by U.S. EPA.

Population growth throughout Ohio's portion of the Maumee watershed has been essentially flat for the past 10 years, with only very small ups and downs locally. The most populated county, Lucas County, lost 2.4 percent of its population between the 2010 and 2020 U.S. Census. Wood County, the second most populous county, with more than three times fewer people than Lucas County, gained 5.4 percent. However, Allen County's population, which is close behind Wood's, lost 3.9 percent (U.S. Census, 2021). The remainder of the counties in the watershed experienced either population loss or a very small increase during the same decade. Additionally, population projections do not predict a large influx of people in the Maumee watershed (Mehri et al., 2020).

As explained in Section 5.4.1 above, 1.5 MT of total phosphorus is reserved as AFG for the discharging permitted point sources. The majority of this AFG, 1.4 MT, is reserved for the discharging point sources that are within the proposed general permit. This AFG will be available to new and expanding facilities that meet the conditions outlined in this TMDL's implementation recommendations. The remaining 0.1 MT of total phosphorus is reserved to account for unforeseen circumstances that would not be authorized through the proposed general permit. This could include a smaller treatment facility or unforeseen changes to a community's plan to address wet weather contributions.

The explicit AFG discussed above ensures that capacity is available for new or expanding point sources. However, additional consideration is needed to continue building capacity to ensure that growth capacity is maintained. The goal is to build this capacity through future actions rather than seeking short-term reductions from existing sources to anticipate the extent of future growth.

One measure is to use better technology when new facilities are proposed or existing facilities expand. To facilitate the adoption of this technology, any new or expanding major WWTPs will be required to meet an individual monthly total phosphorus concentration limit of 0.5 mg/L. For major facilities in the GP2 category, defined in Section 5.3.1.1, implementing a 0.5 mg/L concentration limit would result in a 16 percent reduction from the individual allocations in the TMDL. This difference in loading capacity can then be support a portion of the allocation needed for growth.

Another opportunity to facilitate the adoption of better technology is to work with planned facility upgrades at existing facilities that are not increasing capacity. For major facilities in the GP2 category, defined in Section 5.3.1.1, implementing a 0.5 mg/L concentration limit would result in a 16 percent reduction from the individual allocations in the TMDL. This would be available for future expansions or new facilities. Ohio EPA will consider the circumstances of upgrades at existing facilities on a case-by-case basis. The circumstances may vary from a complete replacement to a community updating the aeration components within the existing tankage. The complete replacement presents an opportunity to implement better technology at a marginal cost consistent with the evaluation in Appendix 6. The community replacing aeration components would not be able to implement new technology at the same marginal cost.

The use of a general permit for the largest wastewater treatment facilities could also be a vehicle to implement a trading program to offset growth. Regionalization and sewer extensions can also bring better technology to communities with authorized loads in the TMDL. If small treatment facilities or HSTS are captured by facilities that have permit limits, the load reduction would represent loading capacity that could be used for future growth.

As noted in Section 5.4.1.2, additional load from what is currently being discharged was added to the existing small sanitary general permit wasteload allocation. This measure is taken to anticipate more facilities that will be covered by this existing general permit.

Reserve capacity is not required for new or expanding permitted MS4s. For new or expanding permitted MS4s, the mass associated with the load allocation for the nonpermitted area will be transferred to the permitted MS4. This will increase the wasteload allocation for the MS4 area but will result in a reduced load allocation. Pollutant load reductions will then be assigned to the new or expanding permitted MS4 area consistent with the reductions needed for the TMDL.

This TMDL provides no wasteload allocations to CAFO/CAFF livestock operations. No livestock operations in the watershed are currently discharging non-agricultural stormwater under NPDES permits. In most circumstances, they are prohibited from discharges that would receive a wasteload allocation, and industry trends do not indicate interest in using the Alternative Management Standards that could allow some load to be authorized with a wasteload allocation. Because of these factors, no CAFO/CAFF operations are expected to need a wasteload allocation in the future.

Livestock operations contribute to the nonpoint source phosphorus load via agricultural stormwater from the land application of manure. The TMDL does not divide nonpoint sources but instead groups them into a single load allocation. The cumulative load of all contributing nonpoint sources must meet the TMDL's load allocation. For example, consider the impact of increasing CAFO/CAFF and other livestock operations on the load allocation. Livestock operations contribute to the nonpoint source phosphorus load via agricultural stormwater from the land application of manure. Section 4.1.1.1 discusses increases in livestock populations in the Maumee watershed since 2002. These increases occurred alongside other trends including decreasing manure phosphorus concentrations (largely due to swine diets), increasing crop yields, and declining commercial fertilizer sales. Each of these trends has played a role in changing the proportional contribution of sources or demand for phosphorus to promote optimal plant growth. Figure 17 shows that together these factors have had a negative balance given the crop removal in 2012 and 2017. SWAT modeling and edge-of-field research reviewed in Section 4.1.1.1 has also shown that manure and commercial fertilizers have similar effects on phosphorus loads exported to streams from agricultural land. Therefore, growth of CAFO/CAFF or other livestock operations will increase the proportional role of manure fertilizer as a nonpoint source but not the overall load allocation. The TMDL does not include a plan to offset livestock population growth with additional reductions to other sources from the outset. The agricultural phosphorus mass balance (manure plus commercial fertilizer vs. crop removal) will be tracked (see Section 7.5).

5.7. Seasonality and critical conditions

Federal regulations (40 CFR 130.7I(1)) require that TMDLs take into consideration seasonal variation in watershed conditions and pollutant loading.

5.7.1. Seasonality

The impairments this TMDL project addresses are a result of HABs that occur annually in the Western Basin during the summer and fall seasons. Several aspects of this project directly consider seasonal variation in loading and lake response.

The assessment method for Ohio's recreation use applicable to Lake Erie HABs impairment is based on the summer/fall HAB seasons (see section F in Ohio EPA [2020a]). In July through October, the aerial extent of the Western Basin of Lake Erie open water assessment unit is evaluated via satellite imagery for HABs during twelve

10-day windows. If three or more 10-day frames indicate excessive HAB conditions that exceed the assessment goals in any given year, then that year is counted as an exceedance year. If any two or more years in a rolling six-year window are in exceedance, then the unit is determined to be impaired. These factors were developed to take into consideration the spatial and temporal variation of Lake Erie's HABs to adequately determine the significance of the annual summer/fall bloom in making the impairment determination. They also provide a thorough assessment of seasonal changes that may occur during blooms.

Phosphorus pollutant-reduction targets are correlated with the HABs to serve as actionable acceptable levels related to Ohio's impairment metrics. These targets were developed by the binational Annex 4 subcommittee of the GLWQA (Annex 4, 2015). The phosphorus that directly contributes to the growth of the HABs was determined by the subcommittee to be primarily delivered with springtime snowmelt and rain. This resulted in targets limited to the phosphorus delivered to Lake Erie from the Maumee River in the "spring" March 1 through July 31 period each year. The TMDL allocations are, therefore, only applicable during this spring season.

This report's source assessment (Section 4) has taken into consideration the wide range of research pertaining to phosphorus export. A key point noted throughout is the links to hydrology, particularly large storm events in the spring, which drive a majority of phosphorus export through the stream networks in advance of the HAB summer and fall season. The comprehensiveness of the source assessment is intended to provide guidance on pollutant-reduction implementation recommendations. This includes those that are seasonal and explicitly address the spring runoff and its relationship to relevant seasonal agricultural practices such as fertilizer application.

5.7.2. Critical conditions

Ohio EPA considers this a "far-field" TMDL because the pollutants of concern are causing impairment to waters "far" downstream from their source. Phosphorus delivered by the stream network that makes up the Maumee watershed is the cause of the HAB impairments in the Western Basin of Lake Erie.

Impairments to designated uses within the Maumee watershed stream network are considered "near-field." This project does not address near-field impairments due to phosphorus pollution. Near-field impairments are addressed by near-field TMDLs. Where no existing TMDL addresses a near-field impairment, a future TMDL is still required. For a list of areas with existing near-field phosphorus TMDLs in the Maumee watershed, see Appendix 5.

The U.S. EPA's regulations in 40 CFR 130.7(c)(1) requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. For this TMDL, the critical condition is the spring season, March 1 through July 31, consistent with the targets developed by Annex 4, as explained in Section 3.4 of this report. When considering options for target conditions Annex 4 identified that the spring loads of phosphorus were the best predictor of algal bloom severity in the lake. Various studies in the western basin of Lake Erie have confirmed that spring runoff due to snowmelt or spring storms is correlated with algal blooms later in the summer (Stumpf et al., 2012; Obenour et al., 2014). While the blooms can (and do) occur in mid to late summer, the phosphorus loadings and related flows are most critical during the spring. As noted in the Annex 4 Target setting report, controlling spring loads will directly impact algal blooms in the lake.

However, it is important to note that the management actions in Section 7 will be implemented throughout the year to meet spring loading targets. For example, cover crops are planted in the fall to establish growing cover in the spring season and fertilizer incorporation is promoted regardless of when the fertilizer is applied. These practices with serve to reduce phosphorus loadings during the entire year.

While this far-field approach provides some flexibility in implementing pollution controls, the reality is that a substantial reduction from nonpoint sources is required. For success, certain recommended implementation actions, such as agricultural nutrient management planning, will need to cover a significant amount of additional acreage throughout the watershed. Additional, more-targeted improvements to nutrient-reduction practices are also needed where critical sources areas are identified. The reasonable assurances section (Section 8) discusses this further.

6. Results

This section presents the results of the TMDL allocations, the allocation calculation to the Waterville monitoring gage, and the results of the mass balance model verification.

6.1. Allocations

All allocations are for total phosphorus, as explained in Section 3.5.1. Reducing the DRP portion of total phosphorus as much as possible is an explicit goal of implementation for this TMDL.

Spring season allocations are presented in metric tons and daily allocations as kilograms. To express the seasonal allocations as a daily load, they are divided by 153, or the number of days in the March-July period. In each of those units, all allocations are rounded to the nearest tenth when greater than one. Allocations of less than one are rounded to two significant figures. Results less than 0.0010 are given in scientific notation.

Table 26 shows the total allocations for the nonpoint source load, point source wasteload, and margin of safety. This table also includes the out-of-state boundary conditions (refer to Section 5.4.6). Table 27 presents the summary of wasteload allocation totals by permit category. Allocations for individual NPDES permits are included in Appendix 4. The end of Appendix 4 includes an analysis of the loads for five recent spring seasons from permitted discharging facilities that are recommended to be grouped and managed by a general permit. This analysis finds that the general permit cap would not have been exceeded if the general permit had been in place during those spring seasons. The load allocation breakdown is shown in Table 28.

Table 29 shows the areas determined for permitted stormwater sources based on the accounting methods described above. The area for the individual NPDES facility permits is a sum of the areas for all 41 facilities with stormwater provisions. These facilities are itemized in Appendix 4. The Ohio portion of the developed land area in the watershed is also presented on this table. These areas sum to 40 percent. The stormwater from the remaining 60 percent of Ohio's developed land is considered part of the nonpoint source load allocation.

Table 26. TMDL allocation totals.

Allocation type	**Spring season total phosphorus (MT)**	**Daily total phosphorus (kg)**
Boundary condition: Michigan	48.0	313.6
Boundary condition: Indiana	180.7	1,180.9
Wasteload allocation	107.8	704.8
Load allocation	555.9	3,633.2
Explicit margin of safety (3%)	20.6	134.5
Allowance for Future Growth (AFG)	1.5	9.8
TOTAL	914.4	5,976.8

Table 27. A summary of the wasteload allocation totals.

Wasteload allocation	Spring season total phosphorus (MT)	Daily total phosphorus (kg)
Wasteload allocation, total	**107.8**	**714.8**
Individual permitted discharging NPDES facilities*	72.2	471.3
Combined sewage overflows*	0.37	2.4
Permitted industrial stormwater facilities**	1.45	9.5
Discharging small sanitary general permit (OHS000005)	0.45	3.0
Discharging HSTS general permit (OHK000004)	14.2	92.9
Construction general permit (OHC000005)	0.39	2.5
Individual MS4 permit – Toledo (2PI00003)	2.7	17.8
General MS4 general permit (OHQ000004)	16.1	105.3

Note:

*Itemized wasteload allocation for these facilities are listed in Appendix 4.

** The facilities in this wasteload allocation include industrial and municipal facilities subject to the multi-sector stormwater general permit (OHR000007) and equivalent stormwater permit provisions in individual permits.

Table 28. Load allocation breakdown.

Load allocation	Spring season total phosphorus (MT)	Daily total phosphorus (kg)
Load allocation, total	**555.9**	**3,633.2**
Grouped landscape nonpoint source load	547.0	3,575.4
On-site HSTS	8.8	57.8

Table 29. Areas within permitted stormwater.

Wasteload allocation	Area		% of developed land within Ohio
	Mile^2	Acres	
Multi-sector stormwater general permit (OHR000007)	7.21	4,612	1.4
Individual NPDES permits with stormwater (multiple permits)	4.71	3,016	0.9
Construction general permit (OHC000005)	3.17	2,031	0.6
General MS4 general permit (OHQ000004)	165.41	105,863	31.8
Individual MS4 permit – Toledo (2PI00003)	27.96	17,895	5.4

6.2. Model verification

Section 5.5 explains the model verification methods. The overall objective of this verification is to assess the mass balance method's predictive ability for loads downstream of the Waterville monitoring station. To do this, the mass balance method is projected to 10 upstream monitoring stations to determine the spring season's total phosphorus load for five spring seasons (2017–2021). The spring load for these station-years is also calculated using a drainage area ratio approach. Table 30 shows the average results for each upstream station assessed with these two methods compared to the observed load at each station. Figure 46 presents these results graphically.

Table 30. Model verification results. Modeled loads using the mass balance and drainage area ratio methods compared to observed spring loads with summary statics. All load results are shown in metric tons, averaged for the 2017–2021 spring seasons (except where footnoted).

Monitoring station gage	Drainage area (mi^2)	Average spring TP load (MT) 2017–2021		
		Observed	Mass balance method	Drainage area weighted method
04178000 St. Joseph R. near Newville	610	98.3	118.5	147.5
04181049 St. Marys R. at Wilshire	386	149.2	108.7	93.3
04185000 Tiffin R. at Stryker	410	59.9	89.9	99.1
04185318 Tiffin R. near Evansport	563	113.7	123.9	136.1
04185935 Auglaize R. near Kossuth	201	62.5	53.3	48.6
04186500 Auglaize R. near Ft. Jennings	332	112.1	88.7	80.3
04188100 Ottawa R. near Kalida	350	119.5	90.6	84.6
04189000 Blanchard R. near Findlay*	346	89.0	82.0	90.1
04190000 Blanchard R. near Dupont	756	199.1	185.0	182.8
04191058 L. Auglaize R. near Melrose	401	134.4	110.9	96.9

Note:
* The 2021 observed spring season load was not available for this station at the time of this analysis. Therefore, for appropriate comparison, 2021 is also not included in the two modeled averages for this station.

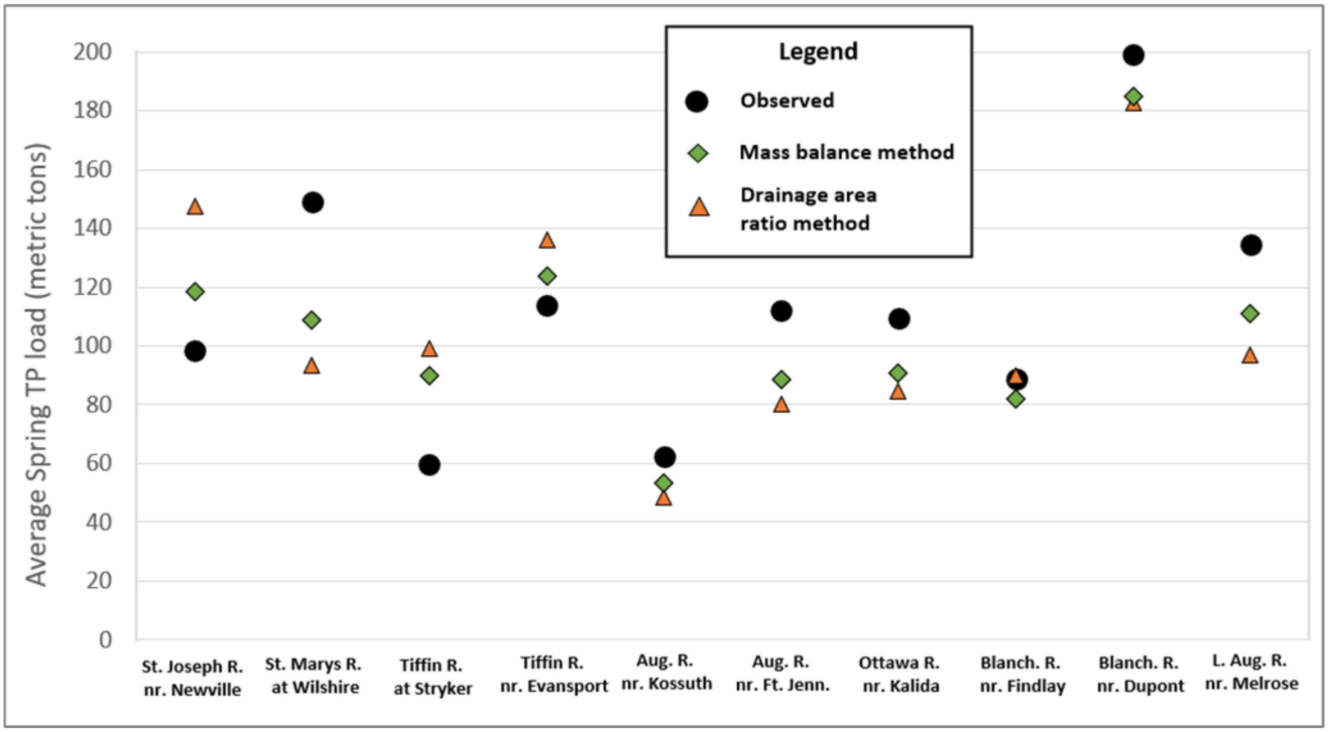


Figure 46. Model verification exercise results. For each monitoring station, the average 2017–2021 spring season total phosphorus load is shown. Symbols indicate load for observed and both modeling methods. The Blanchard River near Findlay station does not include the 2021 spring season load in any analysis.

As explained throughout Section 4.3, watershed size generally predicts the magnitude of load delivered, with larger watershed areas producing more load. Two pairs of the stations included in this verification, the Tiffin and

Blanchard rivers stations, are “nested” sites. In each of these pairs, one station is upstream of the other. Therefore, the greater load at the downstream station in each of these nested pairs is expected.

Moriasi et al. (2015) recommend a variety of performance measures when evaluating water quality models. These recommendations are intended to be used when comparing process-based models (such as SWAT and Hydrologic Simulation Program – FORTRAN [HSPF]). However, grouping the results of the 10 stations modeled for the two types of modeling employed in this verification allows for some of these statistical tests to be carried out.

The dimensionless Nash Sutcliffe efficiency (NSE) test determines the relative magnitude of the modeled to observed variance. This essentially provides a rating of the noise compared to information of the fit. Moriasi et al. (2015) suggest an NSE greater than 0.65 indicates a “very good” fit for phosphorus modeling. When examining the grouped averages of the two types of modeling to the observed loads, the mass balance method has an NSE of 0.96; the NSE for the drainage area ratio method is similar at 0.91.

The percent bias (PBIAS) test examines the average tendency of simulated data and provides a statistic for the overall estimation of bias. Values greater than zero suggest an overall underestimate, whereas values less than zero indicate an overestimate. The average of the 10 stations’ observed load is compared to both modeling methods results’ average load. This analysis finds a PBIAS of 6.8 percent for the mass balance method and 6.1 percent for the drainage area ratio method. It indicates a slight underestimation in both methods (mass balance method underestimates slightly more than the drainage area ratio method). However, both results are considered a “good” fit for nutrient modeling by Moriasi et al. (2015).

The standard regression analysis again averages the observed or predicted (modeled) loads for each station and provides several summary statistics that can be used to compare the performance of modeling methods. The coefficient of determination (R^2) is considered a benchmark performance evaluation. The closer this R^2 value is to one, the better the fit of the modeled dataset to the observations. Moriasi et al. (2015) recommend using such scatter plot analysis when the datasets do not contain extremely high values that may skew such assessments. To best quantify this fit, the regression’s gradient, or slope, along with its y-intercept, are recommended to also be presented with R^2. A slope of 1.0 and a y-intercept of 0 are optimal.

Summary statistics from the regression analysis show different performance for the two modeling approaches. The R^2 for the mass balance method is 0.72 with a slope of 0.72 and y-intercept of 24 MT. Compared to the drainage area ratio method’s R^2 of 0.40 with a slope of 0.59 and y-intercept of 39, the mass balance method has a higher (better) R^2, closer slope to 1.0, and closer y-intercept to 0. These metrics provide evidence that the mass balance method results in a tighter (better) relationship with the observed loads compared to the drainage area ratio. This analysis is quite evident when graphically observing these two regressions results in Figure 47.

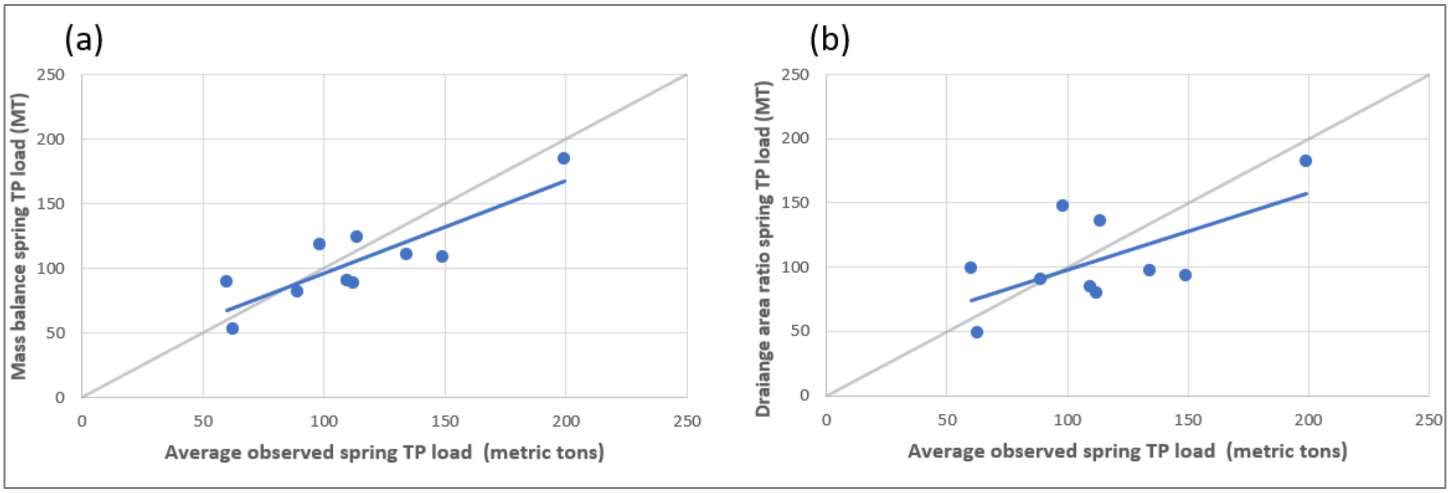


Figure 47. Model verification standard regression analysis. Panel (a) shows spring total phosphorus load from the mass balance model plotted against the average observed load (dots indicate five-year average load for each assessment unit). The blue line represents a linear regression of this relationship. The gray line shows a 1:1 relationship for comparison. Panel (b) contains the same information for the drainage area ratio modeling method.

This regression analysis shows that the mass balance method is superior to the drainage area ratio model. Therefore, it is reasonable to use the mass balance method to calculate TMDL loadings downstream of the Waterville monitoring station.

The verification also helps quantify some of the uncertainty in the mass balance method. The standard error for each monitoring station is the percent difference of the average modeled/predicted load compared to the average observed load. Some stations have a positive average standard error, indicating a model overestimation, and some have a negative average standard error. The average of the absolute value of all 10 stations' average standard error is 19.2 percent. This can be considered the mass balance method's model verification overall standard error. The TMDL's load allocation (prior to reserving a MOS) for the area downstream of the Waterville monitoring station is 17.8 MT of total phosphorus. Applying the 19.2 percent verification standard error to this 17.8 MT results in 3.4 MT of load that could be considered required to be reserved as a MOS accounting for modeling uncertainty. The reason this only applies to the area downstream of the Waterville monitoring station is because the load calculated for the area upstream of Waterville is based directly on observations. The explicit MOS reserved in this TMDL is greater than 3.4 MT, however, due to additional reasons further explained in Section 5.6.

7. Implementation Plan

The TMDL process was started based on assessments identifying impairments in the WLEB. The development of this TMDL includes the following implementation strategy to meet the load and wasteload allocations needed to restore the impaired conditions of the WLEB. A component of this strategy is a process of adaptive management. This is especially important due to the known information gaps for achieving the goals of the TMDL, such as instream cycling of phosphorus and improving knowledge of BMP effectiveness. Figure 48 presents a conceptual model of this project's adaptive management implementation planning process.

Adaptive management starts with setting goals or establishing milestones to provide clear targets for implementation measures. While implementing the strategy is given equal weight in the graphic, it is the most resource-intensive part of the process. It involves many local, state, and federal agencies; nonprofit organizations; and individuals. Monitoring the Maumee watershed and Lake Erie informs adaptive management. It also provides the link from implementation to the desired environmental response. Evaluating these monitoring data with defined metrics amplifies the data into information. Then, this information can be used to adjust the strategy if necessary.

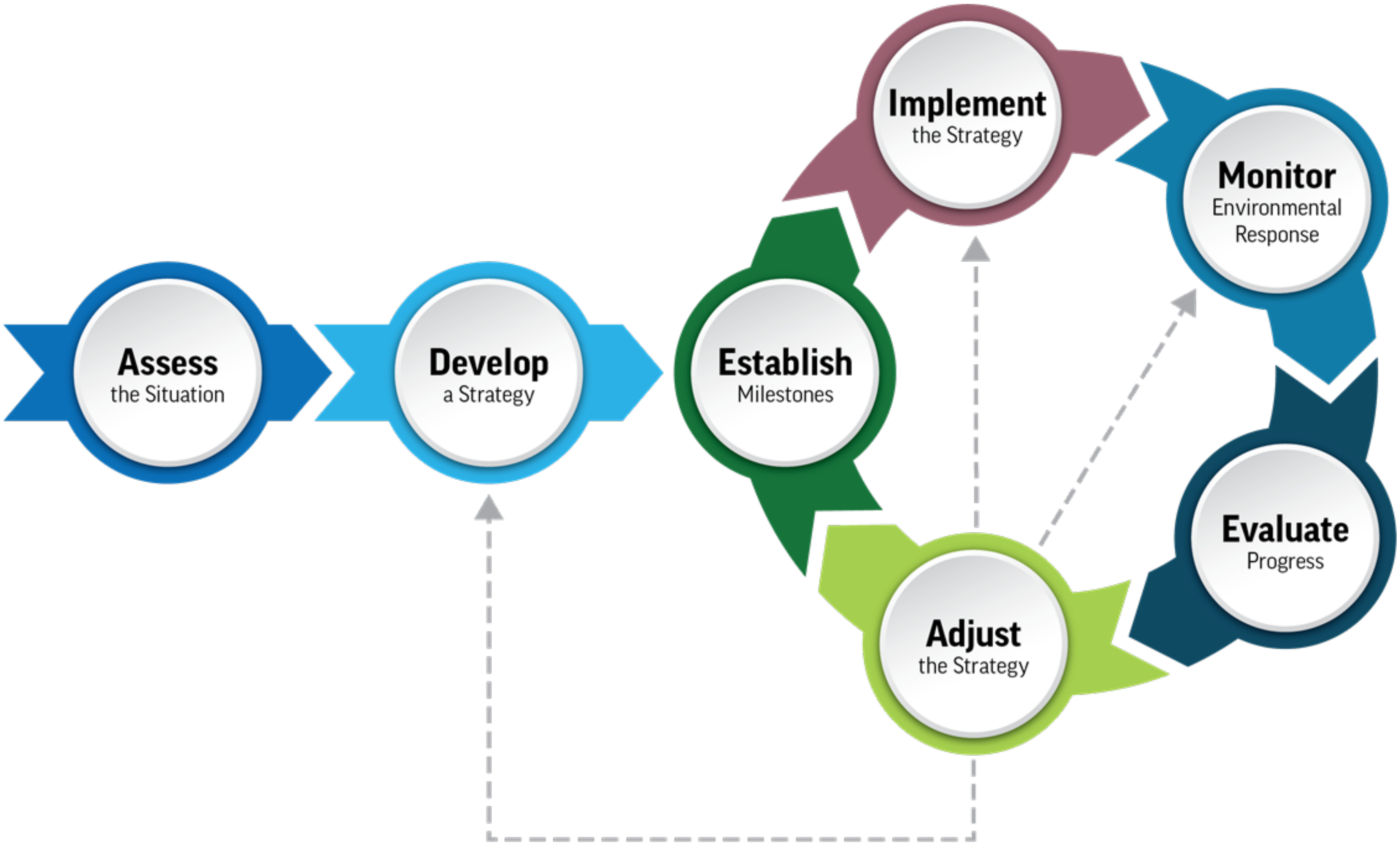


Figure 48. Conceptualization of TMDL implementation with adaptive management.

7.1. Develop the strategy

This section outlines considerations for developing this TMDL's implementation strategy. The TMDL provides allocations to point sources and nonpoint sources (load allocations). The wasteload allocations developed for this TMDL will be directly implemented through Ohio EPA's Clean Water Act permitting programs. The load allocation will be used to improve the ongoing implementation efforts targeted at managing nonpoint sources.

Overall, the strategy needs to identify where the best available science indicates that implementation efforts can achieve the needed phosphorus reductions. These reductions must meet the TMDL allocations—and in a cost-effective manner. Implementation opportunities were considered that would address the source categories discussed in Section 2 of this report. These opportunities include actions that provide phosphorus reductions through additional management of point sources and nonpoint sources, as well as through improving nonpoint source sinks. Nonpoint source sinks include natural infrastructure like floodplains, wetlands, and stream channels. Figure 49 shows how the three categories of actions were conceptually linked to implementation opportunities. The potential impact (i.e., effectiveness at reducing phosphorus) and relative costs of specific management actions inform the actions identified to implement the strategy. Figure 50 shows how these actions are planned to result in reductions from point sources and nonpoint sources, with nonpoint source reductions coming from additional source management and by enhancing nonpoint source sinks.

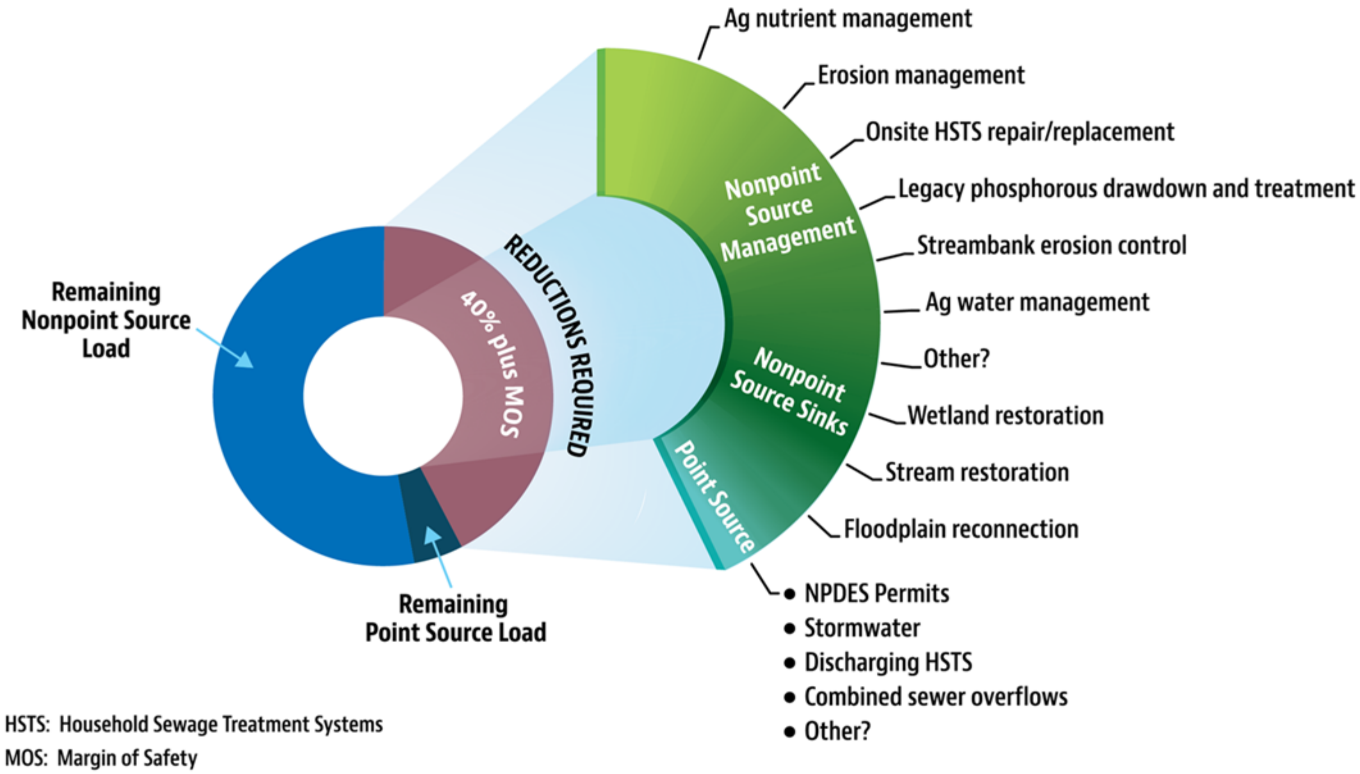


Figure 49. Implementation opportunities were considered for sources management and improving nonpoint source sinks of phosphorus in the watershed.

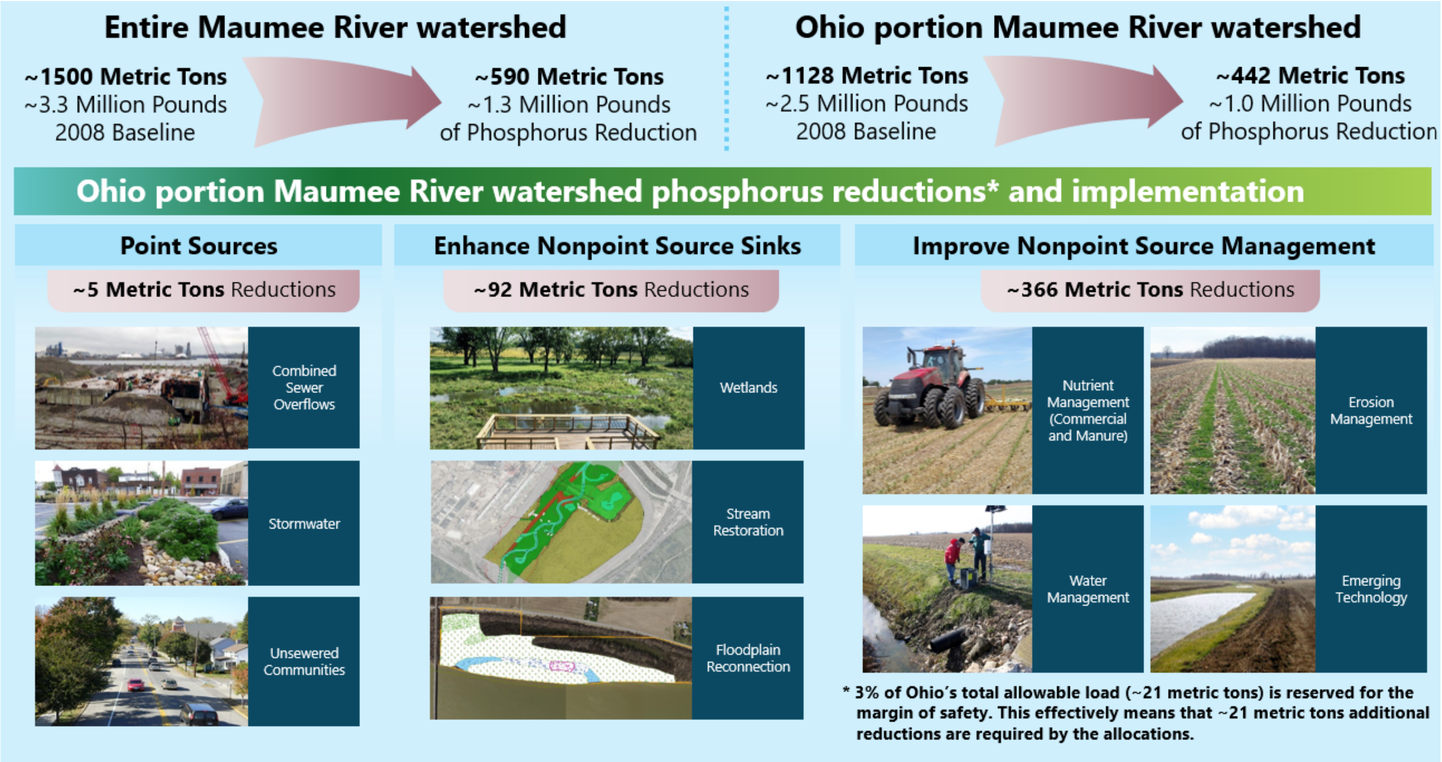


Figure 50. Implementation of the TMDL is accomplished by managing all reduction opportunities in the watershed, both by reducing sources and enhancing existing sinks.

Implementation efforts to address modern Lake Erie HABs have been underway for over a decade. Research, funding, and policy changes have made progress. International cooperation has set the goalposts for phosphorus management to address HABs. The Great Lakes Restoration Initiative (GLRI) at the federal level and Governor DeWine's H2Ohio initiative, among others, have specifically focused resources on addressing HABs in Lake Erie. Farmers are being tasked with changing the ways they farm and how they think about their link to water quality.

Historically, nonpoint source phosphorus management focused on managing soil loss. This resulted in observable success within the Maumee watershed, as detailed in Section 4.1 of this report. Fish species sensitive to sediment, such as the big-eyed chub and sand darters, have been expanding their presence throughout their historic range. That success, in part, is thought to have contributed to today's challenges by shifting the form of phosphorus delivered to streams. It is now known that phosphorus management extends beyond the soil surface. At the same time, these challenges are exacerbated by increasing precipitation in the Great Lakes region, with recent years' precipitation ranking among the wettest years on record. This additional rainfall transports more phosphorus into our waterways.

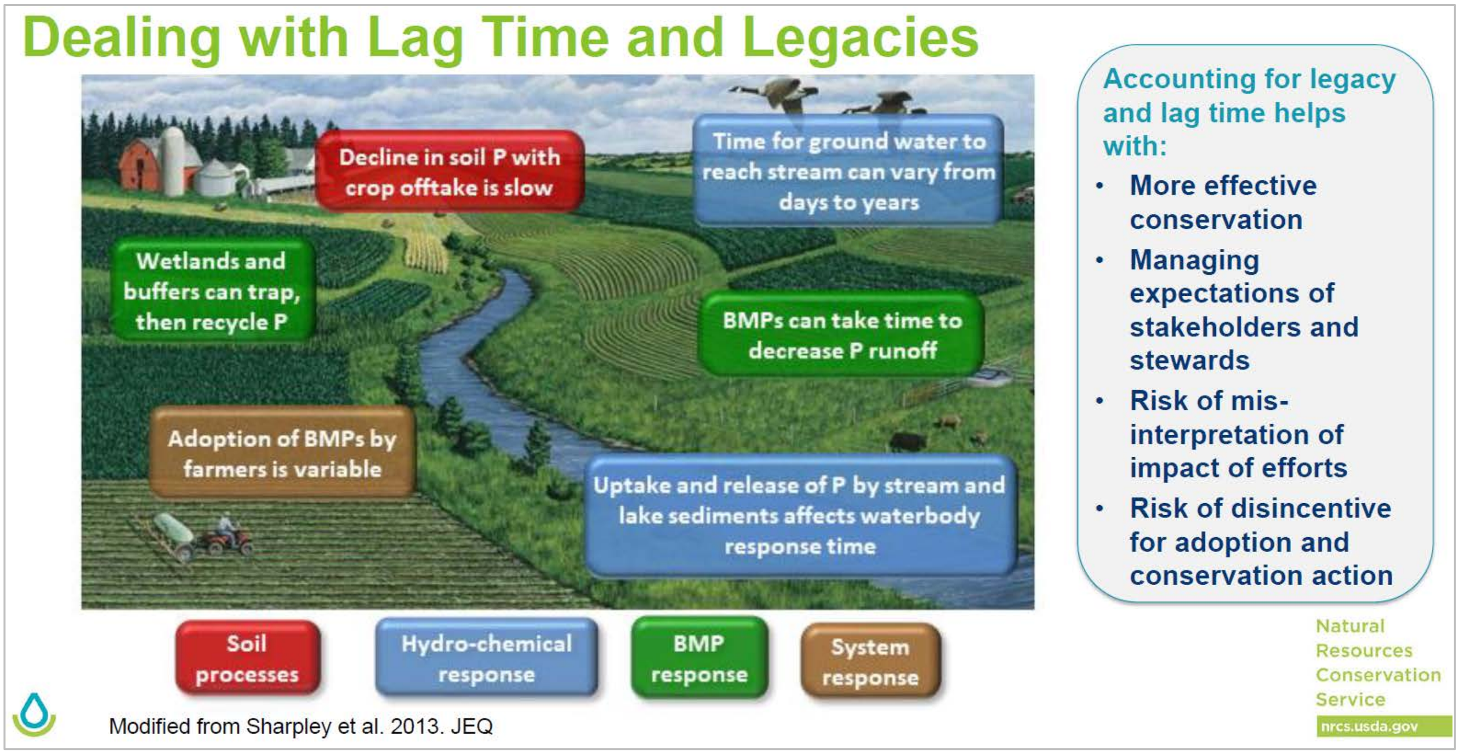
Nonpoint sources are the largest component of the total load. Consequently, they have been and will continue to be the focal point of management efforts. Tackling the nonpoint source challenge requires addressing key resource concerns for nutrient management, erosion management, and water management. It also calls for the need to support emerging technologies. Section 7.3 details specific ways agencies and partners can work together to implement these actions.

Actions for managing how water moves across the landscape are included in the strategy. Efforts to slow and hold water within the watershed have focused on restoring wetlands, stream channels, and floodplain connectivity, thereby enhancing or restoring the nutrient sink functions once provided by these landscape areas. These functions of retaining water and nutrients complement source management in achieving load reduction targets.

While point source contributors have substantially reduced phosphorus from historical levels, ongoing efforts to manage combined sewer overflows, stormwater, and failing household sewage treatment systems in unsewered communities will continue this trend. Management actions are also needed to ensure that existing facilities maintain the level of performance currently achieved through ongoing optimization, designing new infrastructure to perform to higher standards, and considering new technologies that cost-effectively manage phosphorus while promoting sustainability.

7.2. Establish milestones

Milestones need to be considered within the context of a timeline to establish accountability. Creating a timeline for pollution-reduction implementation leading to water quality improvements is not a simple process. Logistical challenges in BMP implementation and uncertainty about ecosystem response lag time complicate this effort. This is especially true for managing nonpoint source loads, which is central to success in the Maumee watershed. The NRCS developed an infographic that helps communicate why improvements in water quality may lag behind BMP implementation (Figure 51). This challenge means that implementation actions do not immediately translate to water quality improvements.


Dealing with Lag Time and Legacies

Decline in soil P with crop offtake is slow

Time for ground water to reach stream can vary from days to years

Wetlands and buffers can trap, then recycle P

BMPs can take time to decrease P runoff

Adoption of BMPs by farmers is variable

Uptake and release of P by stream and lake sediments affects waterbody response time

Soil processes

Hydro-chemical response

BMP response

System response

Accounting for legacy and lag time helps with:

- More effective conservation
- Managing expectations of stakeholders and stewards
- Risk of mis-interpretation of impact of efforts
- Risk of disincentive for adoption and conservation action

Natural Resources Conservation Service

nrcs.usda.gov

Modified from Sharpley et al. 2013. JEQ

Figure 51. Considering lag time is an important part of setting expectations for performance of BMP implementation.

Establishing milestones for future water quality restoration must recognize that historical actions have built the foundation for this implementation plan. This TMDL is not the beginning of focusing efforts on managing phosphorus in the Maumee watershed. Figure 52 shows actions that have occurred since HABs re-emerged in the early 2000s in the Western Basin of Lake Erie. Additional discussion about how these actions have built a foundation for ongoing implementation is included below.

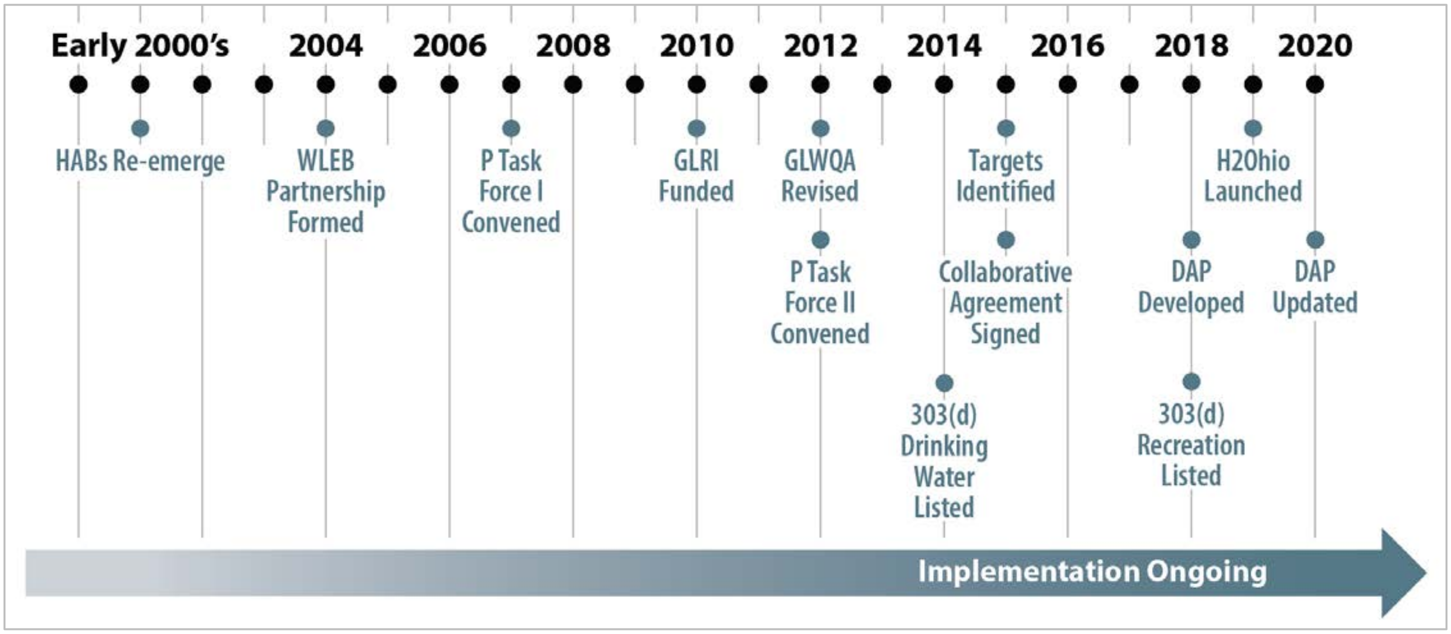


Figure 52. Historical actions that build a foundation for future implementation actions in the Maumee watershed.

Western Lake Erie Basin Partnership (2004): Recognizing the unique resource challenges of the Western Basin of Lake Erie, this partnership formed soon after HABs re-emerged in the watershed. This partnership, led at the U.S. federal level, brings together the USDA-NRCS and five other federal agencies; state agencies; and nongovernment, industry, and academic partners. These groups are dedicated to accelerating Lake Erie's rehabilitation by reducing phosphorus loading through a number of collaborative projects and initiatives. The partnership continues today as a venue that brings implementing partners together.

Phosphorus Task Force I (2007): For this 2007 state-led effort, Ohio EPA convened the Ohio Lake Erie Phosphorus Task Force. This group's intent was to review and evaluate the increasing DRP loading trends and the connection to the deteriorating conditions in Lake Erie. The Task Force was charged with identifying and evaluating potential point and nonpoint sources of DRP and related activities that might contribute to the increasing trends in DRP.

GLRI (2010): GLRI provides funding throughout the United States' Great Lakes region to strategically target the biggest threats to its ecosystem. It is administered by the U.S. EPA's Great Lakes National Program Office. Priorities and goals for this funding are established in the GLRI Action Plan. GLRI funding and action plans have served as a foundation for action in the Western Basin of Lake Erie.

Phosphorus Task Force II (2012): Recognizing the new information becoming available, Ohio EPA, in partnership with the OLEC, ODA, and the Ohio Department of Natural Resources (ODNR), reconvened the Ohio Lake Erie Phosphorus Task Force as a Phase II effort. The purpose of Phosphorus Task Force Phase II was to (1) develop reduction targets for total phosphorus and DRP that can be used to track future progress, and (2) develop policy and management recommendations based upon new and emerging data and information.

GLWQA (2012): With signatories of the Canadian and United States' governments, this agreement was first established in 1972 and has been updated several times. Its overall goal is to enhance water quality programs that ensure the "chemical, physical, and biological integrity" of the Great Lakes. The 2012 update called for actions to address HABs in the Western Basin of Lake Erie.

Annex 4 Targets (2015): One of the actions of the 2012 GLWQA was to convene a binational task team to develop new phosphorus targets for Lake Erie. The Objectives and Targets Task Team report established the approximately 40 percent reduction targets that have been a foundation for phosphorus reductions since then.

Western Basin of Lake Erie Collaborative Agreement (2015): Following the release of the Annex 4 2015 targets, the governors of Ohio and Michigan, along with the premier of the providence of Ontario, Canada, signed the collaborative agreement to affirm a commitment to meeting the phosphorus reduction goals for the Western basin of Lake Erie. Ohio's Western Basin of Lake Erie Collaborative Framework was written in 2016 to establish actions Ohio would take to implement the agreement. In 2019, Governor DeWine reaffirmed Ohio's commitment to the Collaborative Agreement.

Clean Water Act section 303(d) listings for HABs in Western Basin of Lake Erie (2014, 2016, and 2018): The reemergence of HABs in the Western Basin of Lake Erie drove a substantive effort to collect more data and better understand the HABs. While efforts were already underway to start managing phosphorus, Ohio EPA had not yet defined metrics that would allow the agency to list the impairments due to these HABs based on a sound scientific foundation. Drinking water was first prioritized, and sufficient data were available by the 2014 Integrated Report cycle for the initial listing of the shoreline of Lake Erie beneficial use impairment. In the 2016 Integrated Report, another assessment unit, Lake Erie Islands Shoreline, was listed as impaired for drinking water beneficial use. These drinking water listings were revised in the 2018 Integrated Report when Ohio EPA developed the Lake Erie assessment units currently in use. In 2018, the first recreation and aquatic life use impairments due to HABs were included in the 303(d) list. This occurred because an appropriate metric was identified to serve as a foundation for delisting the impaired uses once the HABs are mitigated.

Ohio's DAP (2018): As part of the 2012 GLWQA Annex 4 directive for the federal parties to develop DAPs to address nutrient reductions, Ohio developed a state plan to sit under the umbrella of the U.S. federal DAP developed by U.S. EPA. The Western Basin of Lake Erie Collaborative Framework (2016) was revised to fulfill Ohio's commitment to developing a DAP for nutrients in Lake Erie. The first version of Ohio's DAP was published in 2018.

H2Ohio Launched (2019): The H2Ohio initiative brought substantial new state funding to managing phosphorus in the WLEB. The program was funded and rolled out in 2020 and continues to the present. Additional information about the role of H2Ohio for nonpoint source implementation is provided in sections 7.2.2 and 7.3.3.

Ohio's DAP (2020): Following the funding of H2Ohio, the state undertook substantial revisions to the Ohio DAP, reflecting these new resources. This plan is currently being used by Ohio's state agencies to guide phosphorus-reduction activities in the Maumee watershed and throughout Ohio's Lake Erie watersheds.

The future of implementation of pollutant reduction in the watershed is anchored in continuing these efforts. The timeline in Figure 53 establishes milestones for the future based on this report's framework of implementation for the Maumee watershed. It ties these actions to biennial reports that will be completed by Ohio EPA in even years, corresponding to when the Integrated Report is published. These milestones are broken down into planning and development milestones (characterized in red) and implementation milestones (characterized in blue).

The milestones developed for this project reflect Ohio EPA's role in a much broader implementation effort that involves collaboration with local, state, and federal partners. Ohio EPA does not administer all the programs directed to implementing the goals of this TMDL project. This report sets implementation milestones to evaluate the progress towards achieving the goals of the TMDL through actions taken by Ohio EPA in partnership with and by collaborating agencies.

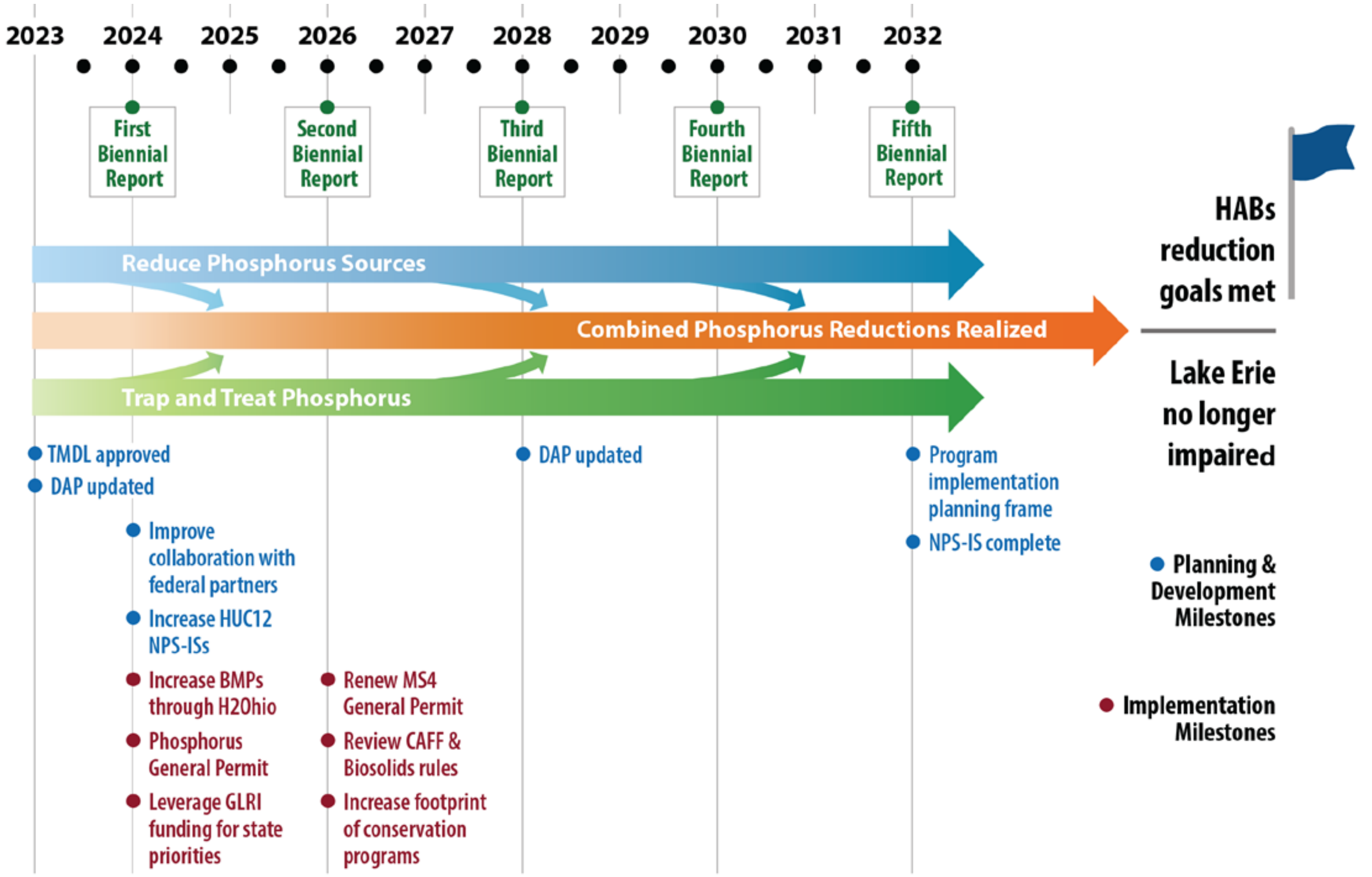


Figure 53. Establishing milestones gives implementation programs opportunities review effectiveness and make adjustments where progress is not meeting expectations.

7.2.1 Milestones for the first biennial progress report (2024)

Updates to Ohio's DAP based on TMDL: Through commitments to the GLWQA, Ohio's DAP addresses nutrients for several priority tributaries in the larger Lake Erie watershed. Because of the magnitude of the load coming from the Maumee River and its proximity to the Western Basin of Lake Erie, the current Ohio DAP has focused on efforts in the Maumee watershed. Ohio's 2020 DAP includes far-field landscape loading targets for HUC-12s in Ohio's portion of the Maumee watershed. These targets capture loads from the landscape's developed, agricultural, and natural portions to serve as loading targets for developing NPS-ISs for these HUC-12s. The TMDL uses a similar approach, but requirements for TMDLs (e.g., differentiating regulated versus unregulated stormwater) and management decisions made in the TMDL process (e.g., MOS) mean these targets, when summed together, are slightly different from the allocations in the TMDL. The DAP's local goals serve as useful planning tools but were not revised in this TMDL.

In 2023, Ohio's DAP will be updated as part of the overall Annex 4 DAP updated milestone. Revisions to Ohio's DAP will provide an opportunity to consider new information and the outcomes of ongoing research for adaptive management. To ensure DAP-facilitated planning is consistent with the goals of the TMDL, the HUC-12 far-field targets will be updated to match the TMDL. These changes will not be large shifts in load; the effort will merely align the analysis in the Ohio DAP with the TMDL. These revisions will be discussed in the first biennial progress report.

Improve collaboration with federal partners (planning milestone): Ohio EPA, along with ODA and ODNR, will continue to work with federal partners to accomplish nonpoint source load reductions in the Maumee watershed. This milestone will be ongoing in order to continue expanding collaboration. One example of how state and federal programs can be complementary is the Water Quality Incentive Program through H2Ohio. This program uses state funding to increase incentives for high-priority wetland and wooded riparian buffer restoration practices funded by federal sources.

Increase BMPs through H2Ohio (implementation milestone): Ohio EPA works with OLEC and sister agencies ODA and ODNR to implement the H2Ohio program. Funding programs directed towards nonpoint source management are implemented through ODA and ODNR. Projects to realize phosphorus reductions for the Western Basin of Lake Erie, and more specifically, the Maumee watershed, have been prioritized through these efforts.

Since H2Ohio launched in 2019, ODNR has allocated funding to 37 natural infrastructure projects that restore wetlands and reconnect floodplains within the Maumee watershed. To date, 14 of these projects are completed, treating water from 18,000 acres (H2Ohio Map (updated March 21, 2022) - h2.ohio.gov/wp-content/uploads/2022/04/H2Ohio_Statewide_Projectsstatus_wWQIP_03212022-scaled.jpg). Once complete, the remaining projects will treat water from at least another 25,000 acres in the watershed. The 2024 progress report will provide an update on these projects and identify additional projects that have been allocated funding.

ODA's portion of H2Ohio was initially made available in the 14 counties in the Maumee watershed. Producers showed remarkable interest, enrolling over 1 million acres in science-based and cost-effective BMPs proven to improve water quality (specific practices are discussed in detail in Section 7.3.3.1). The program has since expanded into 10 additional counties in the Western Basin of Lake Erie. However, the commitment to the Maumee watershed continues; in January 2022, enrollment in the original 14 counties was reopened. This gives producers an opportunity to sign up more acres for conservation practices. The 2024 progress report will evaluate the impact of H2Ohio BMPs implemented through ODA's programs on BMPs implemented in the Maumee watershed.

Phosphorus General Permit (implementation milestone): Ohio EPA anticipates using a watershed general permit to implement the wasteload allocation for the largest permitted phosphorus discharges in the Maumee watershed. This permit will be consistent with the wasteload allocations and assumptions in the Maumee watershed TMDL. Using this watershed-based permitting approach is new for Ohio. Ohio EPA expects to issue the permit in 2023 following approval of the TMDL by U.S. EPA and will report on the status of the general permit in the 2024 biennial progress report.

Leverage GLRI to implement state priorities (implementation milestone): Since 2010, GLRI has brought substantial funding to the Great Lakes region. The funding is directed via the GLRI Action Plan in five focus areas; Focus Area 3 accelerates progress to manage nonpoint source pollution, including nutrient reduction. OLEC coordinates with Ohio's state agencies to propose projects for GLRI funding that fit agency priorities within the GLRI Action Plan Focus Areas. The 2024 report will provide a summary of funded projects under the GLRI and how they contribute to meeting the phosphorus goals in the Maumee watershed.

Increase HUC-12 NPS-ISs (planning milestone): NPS-ISs are developed at the small watershed, or HUC-12, scale (typically <30 square miles). There are 194 HUC-12s in the Maumee watershed that are all or partly within Ohio. Planning based on HUC-12s allows for finer-scale inventories of critical areas and identification of specifically located and sponsored projects to achieve water quality goals. Projects are required to be identified in an NPS-IS to be eligible for Section 319 nonpoint source funding or GLRI funding directed through Ohio EPA.

Before the recurrence of algae blooms in the early 2000s, watershed planning in the agricultural areas of the Maumee watershed was extremely rare, with only a handful of plans completed that were usually near population centers. Once far-field targets were published in the Ohio DAP, Ohio EPA worked with contractors and many local partners to develop or update NPS-ISs in the Maumee watershed to include projects that address far-field phosphorus loading to Lake Erie. To date, 58 NPS-ISs have been approved in the Maumee watershed; 52 of those have included or are being updated to include far-field loading objectives. Ohio EPA has secured funding to facilitate the development of an additional 26 plans that will be completed in the next two years. Figure 54 shows the location of NPS-ISs in the Maumee watershed and whether they included far-field phosphorus targets. The 2024 progress report will consider progress on developing NPS-IS strategies.

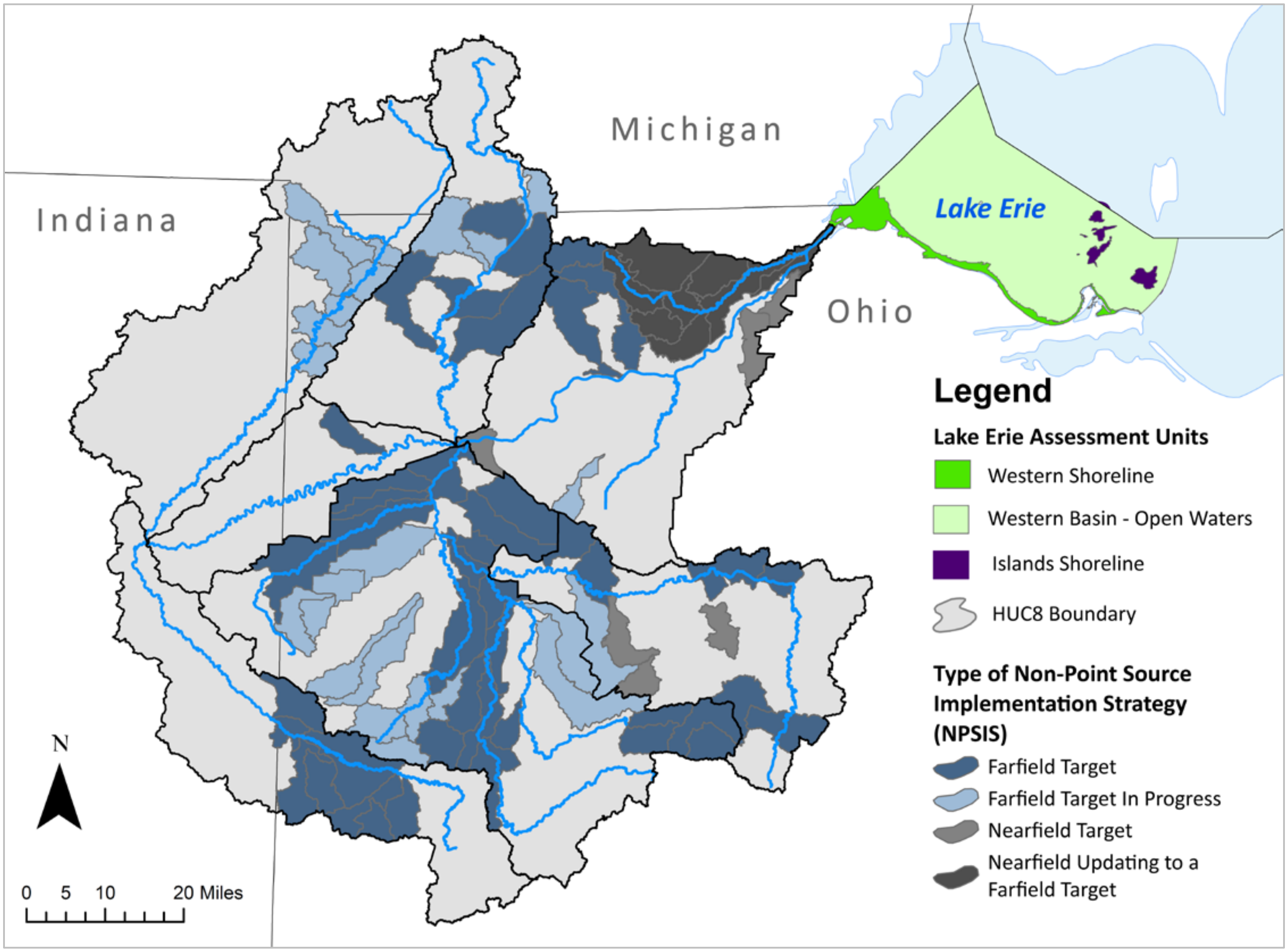


Figure 54. Status of Ohio's NPS-ISs in the Maumee watershed.

7.2.2. Milestones for second biennial progress report (2026):

At this time, there are fewer planning and implementation milestones identified for the 2026 biennial progress report. The 2026 milestones will be reevaluated in the 2024 progress report based on the progress identified at the time. Some implementation actions, however, are identified for the 2026 report because they are linked to scheduled actions for programs.

Increase footprint of conservation programs: The 2024-25 biennium budget has not been approved by Ohio's legislature, however, the proposed budget continues funding for the H2Ohio program. ODA plans to maintain priorities for the Maumee watershed and western basin of Lake Erie through the next biennium. Future efforts with the program will be contingent on the final approved budget. With the current budget proposal in mind ODA has identified an aspirational goal to increase the footprint of the H2Ohio program, and similar federally funded programs, from approximately one-third of row crop acres to one-half of Maumee watershed acres.

Renew MS4 general permit (implementation milestone): The MS4 general permit will be renewed in 2026. The permit prescribes stormwater pollution-reduction actions for communities that are within areas with phosphorus wasteload allocations in this TMDL. Many communities in the Maumee watershed already implement additional actions to manage phosphorus due to near-field TMDLs. However, this permit renewal will include additional regulated entities that are not already implementing additional practices. This permit and these conditions are discussed further in Section 7.3.1.1.

Review CAFF and Biosolids Rules (implementation milestone): Ohio EPA and ODA have a history of coordinating nutrient management requirements for manure management in ODA's CAFF rules and Ohio EPA's biosolids rules. Ohio state law requires agencies to review administrative rules every five years for their continued need and relevance. These rules are, or will soon be, up for this five-year review. The rule review process requires extensive outreach and coordination with interested parties. The 2026 biennial progress report will report on the outcomes of this rule review process and any impacts on the Maumee watershed.

7.2.3. Milestones for third biennial progress report (2028)

Looking further into the future, specific implementation milestones become less clear and more dependent upon progress to date. However, Ohio's DAP will continue to be revised following a five-year cycle. These revisions are planned to ensure that DAPs reflect changes in the understanding of nutrient-borne problems and actions being taken to address these problems. These updates are included as planning milestones because they present opportunities to consider adaptive management actions.

7.2.4 Long-term milestones (2030 and beyond)

Longer-term milestones focus on planning and development actions outlining when implementation strategies and planning documents need to be revisited. As implementation progresses and programs are revisited, additional implementation milestones will be considered for future evaluations. These will consider progress to date and any emerging research.

The goal of TMDL implementation is to restore the beneficial uses of Lake Erie and delist the impairments. Achieving that goal will take time and are likely to lag behind the time when implementation actions have reached the apparent threshold for phosphorus management in the watershed. SWAT modeling work evaluating the impact of implementing BMPs in the Maumee watershed has shown that effective BMPs on more than 70 percent of agricultural acres are likely needed to meet these goals. Effective practices include ones that are not yet widely deployed across the watershed. It will take time to make these large shifts. Figure 53 establishes a milestone for 2032 (approximately 10 years) for implementing the practices that are expected to meet phosphorus reduction goals. These include both source control efforts and practices that trap and treat phosphorus. Section 7.3.3.1 discusses specific practices that are being promoted to meet these goals. However, specific practices are not identified as a long-term milestone since ongoing research is expected to improve knowledge of practice effectiveness and enable greater refinement of the strategy before then.

7.3. Implement the strategy

7.3.1. Point source management

Point sources are broadly managed as stormwater and WWTPs. These are discussed in separate sections below because they are monitored and managed differently.

7.3.1.1. Stormwater

Stormwater is managed separately from wastewater treatment facilities because stormwater discharges are managed through a diffuse network of pipes and conveyances rather than a single discrete outfall. The discharges are not continuous and are irregular in nature. Because of this, monitoring stormwater discharges is more challenging than monitoring the discharges from treatment facilities. This challenge drives the expression of limits for managing stormwater through implementing BMPs.

Several permits have conditions related to the discharge of stormwater:

- Individual permits for Phase I MS4 communities
- General permits for Phase II small MS4 communities
- Individual permits for facilities that have stormwater requirements
- Facilities covered by MSGPs for industrial stormwater discharges
- Construction general permits for construction activities disturbing more than1 acre

The management activities for meeting the wasteload allocation in the Maumee watershed nutrient TMDL varies for each of these permits. Phosphorus is typically managed in stormwater in different ways that affect permitting:

- Manage sources of phosphorus (e.g., lawn fertilizers, lawn debris, pet waste).
- Manage the volume of stormwater discharged from a site (e.g., infiltration and retention practices).
- Manage concentrations of phosphorus with filtration practices.

NPDES permits are one way that these practices are required. Other local, state, and federal efforts influence phosphorus sources and management in the watershed's most urbanized landscapes. For instance, the use of phosphorus for lawn maintenance is very low due to voluntary actions by fertilizer producers. This results in phosphorus reductions statewide outside of the stormwater permitting program. Other initiatives have promoted water retention and filtration to promote wildlife habitat and water retention. Local park districts have worked to expand their footprint and enhance land preservation and water retention. The largest urbanized area in the watershed (Toledo) is within the Maumee Area of Concern (AOC), which has a specific objective of improving wildlife habitat. The H2Ohio initiative has increased the funding for natural infrastructure, and communities have been critical partners for getting projects implemented. These efforts contribute to ongoing nutrient reductions from stormwater accounted for in the load allocation that are not accomplished through the NPDES permits for these facilities and communities.

CSOs

CSOs are regulated under the NPDES program. All CSO communities in the Maumee watershed have approved LTCPs, and are in the process of implementing the plans through their NPDES permits (U.S. EPA, 2016; Ohio EPA, 2020c). Communities have made significant progress to date in implementing CSO controls. The city of Toledo has reached a major milestone in program implementation finishing the construction phase of the approved LTCP. Several communities have also already separated the sewer systems since 2008 including Fayette, Ohio City, Dunkirk, Pandora, Forest, and Leipsic.

General Permit for Small MS4 Communities

Small MS4s are required to comply with requirements contained in the NPDES Small MS4s General Permit. Small MS4s are required by the NPDES permit to develop a Stormwater Management Program that contains six minimum control measures. The NPDES Small MS4 General Permit (OHQ000004) contains more specific requirements for small MS4s in TMDL watersheds. The requirements apply to small MS4s identified in Appendix A of the General Permit (the listing includes small MS4s with wasteload allocations in current, approved TMDL reports). The fact sheet that accompanies the General Permit contains more-specific information on the requirements for the identified small MS4s in TMDL watersheds (epa.ohio.gov/divisions-and-offices/surface-water/permitting/small-municipal-separate-storm-sewer-systems-ms4s--general-permit).

Due to the timing of the NPDES Small MS4 General Permit renewal and the drafting of this TMDL, only the small MS4 communities listed in Appendix A of the permit will be required to follow the near-field phosphorus TMDL-related requirements during the term of the renewed general permit. The additional phosphorus allocation to small MS4 communities identified in the TMDL report will be incorporated into the next renewal of the NPDES

Small MS4 General Permit (renewal in 2026). The renewal will include communities affected by the allocations and will consider if alternative BMPs may provide better opportunities to improve the management of DRP.

The cost will vary for each small MS4 depending upon the number of pollutants causing water quality issues within a watershed, the types of pollutants and size of small MS4 (number of watersheds the MS4 is in), and the current level of BMP implementation. The cost may include the extra time in developing materials, distributing materials, performing additional construction site inspections of sites in noncompliance, educating contractors on green infrastructure practices, conducting additional street sweeping and catch basin cleanouts, etc. A new requirement for post-construction stormwater management will likely be an additional cost to the small MS4 communities with applicable TMDLs.

The small MS4 requirements are contained in the existing permit and listed below. Twenty-one of 34 permittees in the watershed are already required to implement these actions because they are included in near-field TMDLs.

- Retrofit one existing stormwater practice that solely provides a peak discharge function to meet the performance standard for an extended detention post-construction practice; or
- Restore at least 300 linear feet of channelized stream where natural channel stability and floodplain restoration will reduce stream erosion; or
- Update an ordinance or other regulatory mechanism to require OHC000005 Table 4b practices and/or other green infrastructure practices where feasible; or
- Install one or more Table 4b practices to treat a minimum of one acre of existing impervious area developed prior to 2003.

Individual MS4 Permit for Toledo

Similar to the Small MS4 General Permit, Toledo's individual NPDES permit (2PI00003) requires the development of a Stormwater Management Program and the implementation of BMPs that target the six minimum control measures. In addition, Toledo's permit contains conditions for inspecting industrial and commercial stormwater dischargers, BMP performance monitoring, and representative seasonal outfall monitoring. The outfall monitoring has included total phosphorus and DRP. While Toledo's MS4 permit is currently being renewed, a draft permit has not yet been public noticed. Toledo, and other individual permits, typically include the same performance standards as the Small MS4 General Permit discussed above. Due to the timing of the NPDES permit renewal and the drafting of this TMDL, Toledo's draft permit will likely contain many of the near-field phosphorus TMDL-related requirements listed in the discussion about the current Small MS4 General Permit. The phosphorus allocation to the city of Toledo identified in this (far-field) TMDL will be considered in the next renewal of the City's NPDES MS4 Permit.

Multi-sector General Permit and Individual Permits for Industrial Stormwater

Facilities that have coverage under the general permit (OHR000007) have discharges of stormwater exposed to industrial activities. Some facilities elect to have the conditions of the general permit incorporated into an individual permit for the facility. When this is done, the conditions from the active MSGP are used to incorporate the necessary conditions into the individual permit. The permits require installation of the BMPs that minimize the discharge of pollutants from the site. Industrial activities must also meet all local government construction stormwater requirements. Many of the required BMPs result in improved management of phosphorus leaving the site, including:

- Good housekeeping practices
- Spill prevention and response procedures
- Erosion and sediment controls
- Management of runoff

- Employee training
- Dust generation and vehicle tracking of industrial materials

If an industrial facility owner/operator obtains coverage under the NPDES Multi-sector Stormwater General Permit or has equivalent coverage under an individual NPDES permit and properly selects, installs, and maintains all BMPs required under the permit, the stormwater discharges are expected to be consistent with the wasteload allocation in this TMDL.

Construction General Permit

The wasteload allocation for construction activity stormwater discharges covers all construction sites greater than one acre that are expected to be active in the watershed at any time. The wasteload allocation reflects BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in Ohio's NPDES Construction Stormwater General Permit (OHC000005). Construction activity must also meet all local government construction stormwater requirements. BMP requirements that will result in compliance with the wasteload allocation include:

- Preservation methods
- Erosion control practices
- Runoff control practices
- Sediment barriers and diversions
- Post-construction stormwater controls

If a construction site owner/operator obtains coverage under the NPDES Construction Stormwater General Permit and properly selects, installs, and maintains all BMPs required under the permit, the stormwater discharges are expected to be consistent with the wasteload allocation in this TMDL.

7.3.1.2. Wastewater treatment facilities

The TMDL analysis showed that 20 percent of NPDES-permitted treatment facilities account for more than 85 percent of the point source wasteload allocation. These discharges are 30 municipal wastewater treatment facilities with nine industrial facilities that contribute phosphorus at similar magnitudes. The wasteload allocation was set based on the level of control demonstrated in 2008. Through optimization and other actions, this wasteload has been maintained when evaluated collectively. However, when the total wasteload allocation is distributed equitably to individual facilities, not all facilities would meet the individual allocation every season. To implement the wasteload allocation, a general permit is proposed to facilitate flexibility for permitted facilities. If a facility receives coverage under the general permit and the grouped wasteload allocation is achieved, Ohio EPA will consider the phosphorus discharge to be consistent with the assumptions and requirements of the wasteload allocation for the permittee. The following highlights the general permit concept:

- Implementing the individual wasteload allocations in this TMDL would trigger compliance schedules for capital upgrades at many facilities. This would occur even though the level of control among the entire wastewater treatment community is at an appropriate level when considering far-field impacts.
- A general permit gives the option to manage compliance as a seasonal load averaged across the community. This is consistent with how ongoing implementation efforts have considered the impact of treatment facilities on phosphorus loading.
- A general permit provides de facto trading by allowing loads across the community to be grouped. This option may be appealing because existing technology can be optimized to comply with the wasteload allocation. Therefore, it avoids the need for capital expenditures because the cumulative load limit is met. New and expanding facilities would be expected to use and optimize newer technology.

- A general permit is a good framework to facilitate formal pollutant trading as well. Trading could promote collaboration that allows for implementation where it is cost-effective, either through point-to-point or point-to-nonpoint source trading.

Following this flexible permitting proposal, existing facilities should be able to continue to optimize and operate to maintain the wasteload allocation without incurring additional costs. See Appendix 4 for an analysis of theoretical compliance with the grouped wasteload allocation from the entire group of facilities. In each of the last five years, the grouped wasteload allocation was met, which included a very wet 2019. However, to maintain the loading capacity and ensure compliance is maintained, opportunities to optimize treatment should continue to be evaluated. Opportunities include:

- Continuing the optimization of new and existing treatment processes
- Including phosphorus in pretreatment evaluations
- Using side-stream treatment
- Adding nutrient recovery
- Including spray irrigation of treated effluent

As individual facilities grow or new facilities are proposed, an opportunity is presented to use more advanced technology at a marginal cost compared to an unplanned upgrade triggered by a compliance schedule. To maintain capacity in the wasteload allocation and manage growth, the new, expanding, or upgrading biological treatment facilities with an average daily design flow equal to or greater than 1 MGD will receive a monthly average concentration limit of 0.5 mg/L. A 2021 study on the life-cycle cost of nutrient treatment technologies completed by U.S. EPA (2021) calculated the cost of facilities capable of meeting a 0.5 mg/L limit compared to the technology that would meet a 1.0 mg/L limit. It found this scenario would increase capital costs by 10–30 percent and annual operating costs by approximately 10 percent. Project costs will involve many factors specific to an individual facility design, including but not limited to:

- Space available for facility construction
- Existing infrastructure that can be repurposed in a new design
- Influent characteristics

Ohio EPA further evaluated the marginal costs associated with wastewater treatment upgrades through a contract with Tetra Tech. These marginal costs were considered to implement new technologies in the following scenarios:

- New, expanding, or upgrading major municipal wastewater treatment facilities (greater than or equal to 10.0 MGD of design flow) to meet a monthly average limit of 0.5 mg/L.
- New, expanding, or upgrading major municipal wastewater treatment facilities (greater than or equal to 1.0 MGD and less than 10.0 MGD of design flow) to meet a monthly average limit of 0.5 mg/L.
- New, expanding, or upgrading significant minor wastewater treatment facilities (greater than or equal to 0.5 MGD and less than 1.0 MGD of design flow) to meet a monthly average limit of 1.0 mg/L.

The cost associated with reducing total phosphorus varies on a case-by-case basis for each WWTP. Factors contributing to the variation include total phosphorus concentration of the raw wastewater influent, type of treatment system, design flow of treatment system, layout/location of the treatment system (e.g., available space for additional treatment components), and other miscellaneous plant details. This implementation strategy is proposed so these costs are realized on a marginal basis, rather than as unplanned capital upgrades. Depending on facility size and baseline technologies, the marginal costs to improve treatment vary substantially. The largest potential for cost increases would be for facilities that require tertiary filtration where it is not currently utilized.

Should an NPDES permit holder determine that compliance with the TMDL is technically and/or economically unattainable and that permittee is eligible for a variance, the permittee may apply for a variance to the underlying water quality standards (e.g., the narrative criteria for algae) used to develop the proposed effluent limitation in accordance with the terms and conditions set forth in OAC 3745-1-38(D).

The remaining 80 percent of facilities not proposed to join the group general permit together contribute less than 15 percent of the load from permitted facilities. These facilities may not have phosphorus-specific controls, and the wasteload allocation in the TMDL is consistent with the existing loads. Additional phosphorus reductions are not proposed for these facilities. Existing efforts to promote optimization, regionalization, and onsite discharge will continue but have not been accounted for as reductions needed to meet the wasteload allocation.

7.3.2. Modifications of point sources implementation

The final approved TMDL reports may be modified. In the future, Ohio EPA may make changes to the load and/or wasteload allocations in the Maumee Watershed Nutrient TMDL report when new information becomes available, or circumstances arise during the implementation of the TMDL report that suggests such modifications are appropriate. Ohio EPA will notify U.S. EPA Region 5 and the public regarding any shifts in loading it makes within the sum of the load allocations or within the sum of the wasteload allocations. Any changes or re-allocation between the wasteload allocation and load allocations or changes in the TMDL's loading capacity will be made available for draft public review and comment following the same procedures as a draft TMDL report and submitted to U.S. EPA Region 5 for review and approval as a revised TMDL.

New information generated during TMDL implementation may include monitoring data, BMP effectiveness information, and land use information. For shifts in loading within the sum of the wasteload allocations, Ohio EPA will provide public notice as part of the NPDES permitting process. Ohio EPA will make such shifts only if the shifts will not change the sum of the wasteload allocations, the sum of the load allocations, and the total loading capacity. In addition, any adjusted wasteload allocations or load allocations will be set at a level necessary to implement the applicable water quality standards. Additional reasonable assurance will be provided where appropriate. Ohio EPA will notify U.S. EPA Region 5 of any anticipated changes to this TMDL 30 days prior to proposing those changes.

7.3.3. Load allocation (nonpoint source) implementation plan

Achieving the reductions so nonpoint sources meet the load allocation can be accomplished through source reduction and enhancing sinks within the landscape. The Maumee watershed has been the focal point for nutrient management in the WLEB watershed since HABs reemerged in the mid-2000s. In this timeframe, a major shift in conservation planning for phosphorus management has also occurred. Historically, phosphorus management focused on surface losses driven by runoff and erosion because subsurface losses were perceived as negligible (King et al., 2015). That perception has changed, and phosphorus management now encompasses subsurface transport with the understanding that dissolved forms of phosphorus are a critical fraction to total losses. The groundwork has been laid to facilitate implementation through planning, funding, policy, voluntary actions, and ongoing research.

7.3.3.1. Water quality planning

The state of Ohio has been at the forefront of developing a response to algal blooms in Lake Erie. Building on the work of the Ohio Phosphorus Task Force (2007–2010), Ohio participated in efforts at the federal level through the GLWQA of 2012 to link the HABs to specific amounts of nutrients measured in the tributary rivers, especially the Maumee River.

The governors of Ohio and Michigan and the premier of Ontario committed to a goal of reducing phosphorus loadings to Lake Erie by 40 percent through the signing of the Western Basin of Lake Erie Collaborative Agreement, first in 2015 and again in 2019. The Collaborative Agreement was intended to serve as the precursor to the Ohio DAP, allowing Ohio to take action on nutrient reduction ahead of GLWQA milestones. Ohio's DAP has advanced efforts toward the proposed nutrient reduction targets put forth in the GLWQA under Annex 4 (Nutrients).

To facilitate implementation, the state of Ohio has cooperated with the development of many other modeling efforts in the watershed. Results from prior SWAT modeling efforts in the Maumee watershed and similar landscapes are summarized in Appendix 2. Ultimately, Scavia et al. (2017), used an ensemble of SWAT models to understand that it would take a suite of BMPs targeted at high-yielding areas to meet loading targets on average in the Maumee watershed. These BMPs included the subsurface application of phosphorus fertilizer, adding cereal rye cover crop in years without wheat, and installing medium-quality buffers. In a follow-up effort, Martin et al. (2021) concluded that only some models showed meeting the DRP targets under the highest levels of implementation considered using the more stringent 9-of-10 years metric for meeting the targets. The model review makes the following conclusions about implementation needs in the watershed:

- Implementation will need to be widespread.
- Accomplishing DRP reductions will be more difficult than meeting total phosphorus targets.
- No single BMP will meet loading targets, and a suite of BMPs is necessary.
- BMPs targeted to higher-yielding landscapes were more effective than random placement.
- It will take common and less common (even emerging) BMPs to meet the targets.

This work continues as a state priority, and Ohio is funding a current project through the HABRI and via H2Ohio (HABRI/H2Ohio, 2020–2021). The current evaluation of H2Ohio is based on edge-of-field effectiveness estimates per practice and is not tied to overall watershed performance. This project uses a SWAT model of the Maumee watershed as a separate tool to evaluate the impact of ongoing implementation, including specific actions and scenarios based on H2Ohio programs. These efforts continue to improve the capability of the SWAT models to evaluate DRP, incorporate additional BMPs (including instream processes for DRP), and refine the baseline inputs to make results more meaningful. Together these efforts have improved our understanding of nutrient dynamics throughout the watershed and identified a path forward that requires extensive implementation.

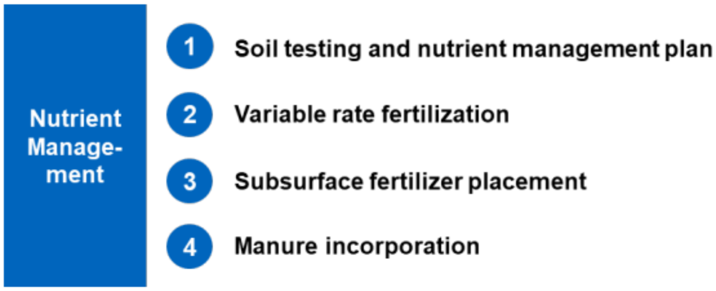
Several agricultural BMPs, including nutrient management plans, are broadly applicable, and county conservationists can promote these directly with growers. However, consistent with the modeling research summarized above (Martin et al., 2021; Scavia et al., 2017), the targeted implementation of other practices, particularly structural practices, could likely address the load reduction target more efficiently. Ohio is pursuing more efficient practice implementation through the development of watershed plans with far-field targets. The plans include local analysis such as, but not limited to, the Agricultural Conservation Planning Framework information to improve siting of structural practices.

Nine-element watershed plans (also known as NPS-IS) identify critical areas, organize stakeholders, set local goals and objectives for conservation practice implementation, identify implementers and funding sources, and most importantly, develop ready-to-go projects and conservation practice adoption and activity. These also establish project eligibility for federal funding (Ohio EPA, 2020c). These are written for HUC-12 watersheds, which are typically less than 30 square miles in area and are a key mechanism for identifying load reduction opportunities.

As part of the strategy outlined in the Ohio DAP, state agencies began including HUC-12 far-field load reduction recommendations in watershed planning efforts. Specific emphasis was placed on developing plans that include these recommendations in the southern portion of the Maumee watershed. This is because elevated loading is observed in the region due to relatively higher stream discharge and a higher percentage of the landscape being committed to agricultural production (Section 4.2 above). As discussed in Section 7.2, these far-field load reduction targets will be revised in the 2023 DAP revision so they are consistent with the allocations in the TMDL.

The Ohio DAP identified 10 key practices for the focus of state efforts to streamline funding through the H2Ohio Initiative. These practices showed the greatest potential for accomplishing phosphorus reductions due to the impact, both as the amount of the practice that could be used and the practice efficacy, and cost of the practices. These practices were divided into nutrient management, erosion management, and water management based on how they are used to manage phosphorus loads.

Nutrient Management is a generalized term for planning nutrient application events on the agricultural landscape. These characteristics are generally related to the 4R's of Nutrient Management: using the **right** nutrient source at the **right** rate and **right** time in the **right** place. Four selected practices are in this category:



Nutrient Manage-ment

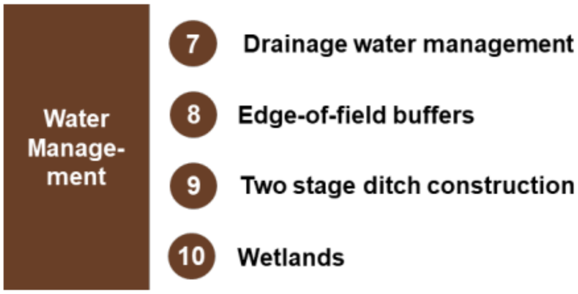
1. Soil testing and nutrient management plan
2. Variable rate fertilization
3. Subsurface fertilizer placement
4. Manure incorporation

Erosion Management seeks to slow or stop the loss of soil-attached nutrients by reducing soil disturbance and improving soil health. Two selected practices are in this category:

Erosion Manage-ment

5. Conservation crop rotation
6. Cover Crops

Water Management includes practices that slow water flow, settle sediments, and absorb nutrients. Four selected practices are in this category:



Water Manage-ment

7. Drainage water management
8. Edge-of-field buffers
9. Two stage ditch construction
10. Wetlands

Identifying appropriate key BMPs is vital to effective water quality planning. Section 4.2 of this report describes the existing science regarding the contributions of phosphorus from nonpoint sources in the watershed. These sources are organized into five major categories: agricultural row crop fertilizers (commercial and manure), agricultural soils and legacy sources, non-ag stormwater, ditch and streamside sources, and changes in watershed hydrology. However, BMPs do not cleanly manage just one source category. Therefore, sources must be linked to practices for planning purposes.

Agricultural Row Crop Fertilizers (commercial and manure): Nutrient management BMPs are directly linked to improving fertilization management. The fundamental tenet of managing fertilizers is soil testing and developing a nutrient management plan. This practice establishes a baseline for understanding nutrient needs on a farm. It also establishes a plan for how the 4R's can be successfully implemented for an individual field and producer. Within each farm's management plan, additional resource concerns can be identified and addressed. One of the most effective ways to manage agricultural fertilizers is through improved incorporation into the soil profile. This practice is central to the SWAT modeling scenarios research that has shown DRP targets being met.

Agricultural Soils and 'Legacy' Phosphorus: All soils contribute phosphorus to streams. Historically, management practices targeted at reducing erosion have reduced the loss of phosphorus attached to soils. These practices should continue. Increasing cropping diversity through conservation crop rotations and cover crops both provide further opportunities to manage soil loss by promoting wintertime cover on agricultural fields.

Applying phosphorus-containing fertilizers at historically recommended higher levels, buildup from historic manure sources, and other factors have increased phosphorus levels in some agricultural soils above what is needed to sustain agricultural crops. This is sometimes referred to as legacy phosphorus. Increased soil phosphorus means that soil loss and water runoff from these agricultural fields contribute relatively more total phosphorus and DRP to streams. These soils require additional consideration. The first step to managing these soils is identifying where they exist in agricultural fields. This is a critical function of nutrient management planning and soil testing. All or part of a field could have soil phosphorus that exceeds the recommended threshold. In each of these cases, there is an opportunity to reduce phosphorus application while maintaining crop yield. Where whole fields have elevated phosphorus levels, the application of phosphorus fertilizers can be avoided while crops mine phosphorus from the soil as a component of a nutrient management plan. When phosphorus is elevated in portions of a field, variable rate application affords the opportunity to avoid applying phosphate fertilizer where phosphorus is not needed agronomically to support optimal crop yield.

In some cases, the legacy phosphorus in agricultural soils can reach sufficiently high levels that make them critical to manage for environmental losses of DRP. Ongoing research discussed in Section 7.2.5 details continuing efforts to understand where these areas are and how to manage them. Edge-of-field management through practices like phosphorus treatment wetlands or other emerging technologies target this source.

Ditch and Streamside Sources: Streams and drainage ditches can contribute phosphorus through erosion and remobilization of phosphorus previously assimilated in their bank and bed sediments. Many streams in the Maumee watershed are maintained to promote drainage and facilitate agricultural production. Traditionally, these ditches were maintained as trapezoidal channels that were effective at providing drainage.

Two-stage ditches were identified as an opportunity to promote natural stream functions in these maintained channels. This design allows for the deposition of sediments on established benches and reduces shear stresses from high stream flows by lowering the elevation of peak flows. Other water management practices like controlled drainage and natural infrastructure practices also help mitigate erosive forces from peak flows, reducing this type of erosion.

Changes in Watershed Hydrology: As described in Section 4.1.1.7, precipitation, especially in large storm events, has increased in the last two decades. These changes have contributed to as much as a 30 percent increase in DRP loads in the Maumee watershed (Choquette et al., 2019). Addressing nutrients in the watershed necessarily includes considerations of managing the water volume and not just the concentrations of nutrients. Natural infrastructure and controlled drainage have been identified as cost-effective management practices directed at water management. These practices help store water on the landscape so it can infiltrate or be lost through evapotranspiration. With 319 and GLRI funding, Ohio EPA has worked with landowners to install new and emerging water management technologies, including cascading waterways, water reuse projects (storage and irrigation), and saturated buffers.

Watershed Planning Summary: The Ohio DAP and nine-element NPS-ISs are living documents that continue to develop and be revised as new information becomes available. Ongoing research continues to improve the understanding of practice efficacy, especially regarding the management of DRP. Some key research projects are evaluating practices for managing elevated soil test phosphorus, watershed-scale implementation efficacy for paired watersheds, the efficacy of water management practices (saturated buffers and water reuse), edge-of-field research on BMP efficacy, and more. As these planning efforts continue, Ohio will consider and integrate new information resulting from these projects into implementation planning.

7.3.3.2. Policies

Establishing a TMDL does not change laws, regulations, or policies. Nonetheless, when laws, regulations, and policies do change, Ohio's state agencies are required to implement them. Several existing regulatory and policy updates have been a part of Ohio's management of phosphorus in the WLEB as algal blooms have reemerged, including:

- Senate Bill (SB) 141 (2001) – Formed the Division of Livestock Environmental Permitting at ODA
    - ODA starts reviewing permits to install for CAFFs.
    - Established a Certified Livestock Manager (CLM) program.
- NRCS 633 Waste Utilization practice standard update (2003) – Put additional restrictions on liquid manure applications on tile-drained lands, including liquid application rates, macropore disruption, tile management, and winter application requirements.
- NRCS 590 Nutrient Management practice standard update (2012) – Added manure into the nutrient management standard and incorporated a phosphorus index.
- SB 1 (2015) – Expanded manure application restrictions to smaller operations, required distribution and use of CAFF manure to use CLMs or have an agricultural fertilizer applicator certification, and established agricultural fertilizer applicator certification.
- SB 299(2018) – Provided funding to support staff at soil and water districts in the WLEB.
- NRCS 590 Nutrient Management practice standard update (2020) – Incorporated updated Tri-state Standards, eliminated the phosphorus index, and emphasized drawdown for fields with elevated soil phosphorus.
- House Bill (HB) 7 (2021): Required the development of the Statewide Watershed Planning and Management Program, which ODA's DSWC administers. This program includes categorizing watersheds throughout the state and appointing regional watershed managers. Watershed managers will develop and implement new conservation plans in the region and support existing conservation activities.

These new laws have enabled state initiatives and prioritized funding opportunities in the WLEB, especially the Maumee watershed. The results of these efforts are discussed in the next section.

7.3.3.3. Initiatives and funding to facilitate implementation

Additional resources have been allocated through legislation and implementation initiatives. These efforts have spanned all levels of government in response to one of the most substantial water quality challenges facing Ohioans.

State initiatives

- **H2Ohio** – Launched by Governor Mike DeWine, this initiative was first funded by the General Assembly for the 2020–2021 biennium with an investment of $172 million. A targeted priority of the initiative is reducing phosphorus with a geographic focus on the WLEB and Maumee watershed. Initiatives include promoting agricultural management practices, natural infrastructure (mainly through wetlands), and addressing failing home septic systems.
- **Ohio EPA 319 Program** – The federal Clean Water Act amendments in 1987 created the national program to control nonpoint source pollution. Since 1990, Ohio EPA has annually applied for, received, and

distributed Section 319 grant funds to address nonpoint source-caused water quality impairment to Ohio's surface water resources. Section 319(h) implementation grant funding is targeted to Ohio waters where nonpoint source pollution is a significant cause of aquatic life use impairments. The cornerstone of Ohio's 319 program is working with watershed groups, ODA, ODNR, OLEC, local SWCDs, county engineers, and others who are implementing locally developed watershed management plans and restoring surface waters impaired by nonpoint source pollution.

- **Ohio Lake Erie Protection Fund** – OLEC administers Ohio's Lake Erie Protection Fund, which was established to finance research and on-the-ground projects aimed at protecting, preserving, and restoring Lake Erie and its watershed. The projects focus on critical issues facing Lake Erie, including nutrient reduction, beneficial use of dredged material, water quality protection, fisheries management, wetlands restoration, watershed planning, invasive species, algal bloom research, Lake Erie ecological shifts, and environmental measurements. More than $12 million has been distributed to over 365 projects since 1993. These projects have also been used as a match to help secure significant funding from various federal agencies.
- **Clean Lake 2020 Plan (SB 299)** – This bill provided funding for various programs to support Lake Erie and reduce HABs. This included additional funding for SWCDs in targeted WLEB counties to bolster staff needed for project coordination and implementation.
- **OSU Extension** – OSU Extension's mission is to "create opportunities for people to explore how science-based knowledge can improve social, economic, and environmental conditions." OSU Extension prioritizes programs to help people make informed choices and lead local efforts aimed at maintaining or improving environmental quality for future generations. OSU Extension has field specialists in agronomic and manure nutrient management systems. Their actions promote better nutrient management through outreach and applied research.
- **Ohio Sea Grant and Stone Lab** – Ohio Sea Grant works with the Lake Erie community to solve the region's most important environmental and economic issues. They use a strong combination of research, education, and outreach, as well as partnerships with academia, governmental agencies, and the private sector. Ohio Sea Grant administers the HABRI on behalf of the Chancellor of the Ohio Department of Higher Education.

Federal initiatives

- **USDA-NRCS**
    - EQIP – EQIP provides financial and technical assistance to agricultural producers and non-industrial forest managers to address natural resource concerns. The program delivers environmental benefits such as improved water and air quality, conserved ground and surface water, increased soil health and reduced soil erosion and sedimentation, improved or created wildlife habitat, and mitigation against drought and increasing weather volatility.
    - GLRI – Funding from GLRI supplements NRCS Farm Bill projects. GLRI funding is directed to priority watersheds in the Great Lakes region, including the Maumee watershed. Funding initiatives have emphasized farm research through a network of demonstration farms and edge-of-field research; building partnerships with other federal, state, and nonprofit organizations; and implementing practices to reduce phosphorus loads from agricultural fields.
    - RCPP – The Tri-State Western Lake Erie Basin Phosphorus Reduction Initiative is a multi-state RCPP project that brings together more than 40 partnering organizations from Michigan, Ohio, and Indiana to reduce the runoff of phosphorus into the WLEB. RCPP promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners.
- **USDA Farm Service Agency (FSA) Conservation Reserve Enhancement Program (CREP)**
    - CREP is part of the Conservation Reserve Program (CRP), the country's largest private-land conservation program. Administered by the FSA, CREP leverages federal and nonfederal funds to

    target specific state, regional, or nationally significant conservation concerns. The Lake Erie CREP was initiated in 2000 with the goal of establishing 67,000 acres of riparian and upland conservation practices through voluntary enrollment, including in the counties within the Maumee watershed.

- **U.S. EPA GLRI** funding is allocated through five focus areas. All focus areas are geared toward improving water quality in the Great Lakes. The following two focus areas include targeted actions that improve phosphorus management in the Maumee watershed:
    - Focus area 1 is for toxic substances and AOCs. The GLRI has a goal to delist the AOCs, which include the Maumee AOC. The AOCs include a beneficial use for habitat loss and wildlife. Though the focus of these initiatives is not phosphorus management, much of the lost habitat in the AOC is wetland or riparian in nature. Addressing these impacts places emphasis on restoring these ecosystems. These restoration efforts will restore crucial phosphorus sinks and slow water as it moves across the landscape.
    - Focus Area 3 is specifically for nonpoint source pollution impacts on nearshore health. This includes targeted investments to reduce nutrient loads from agricultural watersheds (like the Maumee), reduce untreated stormwater runoff, improve the effectiveness of nonpoint source control, and refine management efforts.

Local initiatives

Local communities have embraced the challenges of managing phosphorus contributions to Lake Erie with a vision shared by local governments and park districts. Many counties, communities, and other local organizations serve as partners for implementing projects in the Maumee watershed. Below, two initiatives are highlighted that have specific water quality goals in their mission statements. These examples show how communities can engage with water quality improvement while promoting projects that provide ancillary benefits to the community through enhanced green spaces.

- **Metroparks Toledo:** Metroparks Toledo includes water quality in its mission statement with an emphasis on increasing land holdings since 2003. Metroparks has more than 12,000 acres throughout the region, and much is in the Maumee watershed. Metroparks has also partnered with H2Ohio implementation efforts to implement wetland restoration activities.
- **Defiance Land to Lake:** The Land to Lake initiative in Defiance promotes getting involved in protecting the water resources of the Maumee River through Defiance County. Projects promoted by the initiative include education, research (Upper Maumee Smart Watershed Pilot), and facilitating wetland restoration through the H2Ohio Program.

Nonprofit organizations

Nonprofit organizations invest staff and resources in overseeing project development and providing opportunities for the public to contribute to implementation efforts. Several also facilitate land acquisition and provide continued maintenance for projects.

- **Black Swamp Conservancy:** The Black Swamp Conservancy is a land trust dedicated to preserving and protecting natural habitats and family farms in northwest Ohio for the benefit of future generations. The conservancy has permanently protected nearly 20,000 acres of land since its founding in 1993. Much of that land retains private ownership, but the conservancy owns several properties. The conservancy has partnered with H2Ohio on wetland projects that facilitate natural infrastructure implementation in the Maumee watershed.
- **The Nature Conservancy:** The Nature Conservancy has been a valuable partner for implementing projects in the Maumee watershed. This includes oversight of GLRI funds targeting natural infrastructure and nutrient management projects. They have also used GLRI funding to develop a peer learning network called

Farmer Advocates for Conservation. This program creates a space where farmers can learn about soil health and water quality from one another.

- **Pheasants Forever:** Pheasants Forever works with farmers and landowners to complete conservation and wildlife habitat projects that complement working farm operations. Staff include the "Farm Bill biologists" program, supported by diverse partnerships with USDA-NRCS, USDA-FSA, state wildlife agencies, and others. The program collaborates with local farmers and landowners to educate and assist with enrollment in various voluntary incentive-based conservation programs.
- **Ducks Unlimited:** Ducks Unlimited conservation efforts feature a Lake Erie Priority Area for Ohio conservation projects. This has led to restoring and protecting wetlands in the WLEB, including the Maumee watershed. The organization has partnered with ODNR's H2Ohio initiative.
- **Partners for Clean Streams:** This organization is dedicated to the health of the streams and rivers of the greater Toledo region and the people who use them. They partner directly with citizens, businesses, governmental agencies, and other nonprofit organizations to provide local stewardship of rivers, streams, and lakes. The group connects volunteers to opportunities for resource protection actions, such as stream litter cleanups. They have also served as a local partner for developing NPS-IS in the Maumee watershed.
- **Blanchard River Watershed Partnership:** The partnership began as an informal group in 2003. Since its inception, the partnership has formed many working relationships with federal, state, and local agencies in the watershed. The group's mission is to "encourage water quality improvements to our geologically unique, northwestern Ohio watershed, through sustainable land use, collaboration, conservation, and enhancement of natural and man-made resources." The partnership has been active in developing watershed action plans and facilitating projects in the Blanchard River watershed.
- **Ohio Agricultural Conservation Initiative:** This is a partnership between agriculture, conservation, environmental, and research communities. OACI is a partner for certifying farmers participating in the H2Ohio program. It also conducts farmer surveys to document farmers' current practices and how they use conservation programs.
- **Other environmental organizations:** Several other environmental advocacy groups in Ohio promote improving water quality in Lake Erie. These include the Lake Erie Waterkeeper program, Alliance for the Great Lakes, Ohio Environmental Council, Lake Erie Foundation, Lake Erie Charter Boat Association, and others. These groups promote various actions and provide opportunities for citizens to be involved in solutions.
- **Other agricultural organizations:** Ohio has a diverse group of agricultural organizations representing interests across the industry. These include the Ohio Farm Bureau Federation, Ohio Corn and Wheat Growers Association, Ohio Soybean Council, Ohio Dairy Producers Association, Ohio Pork Council, Ohio Poultry Association, Ohio Agribusiness Association, and others. These organizations participate in and support initiatives promoting nutrient management in Ohio, including the Blanchard River Demonstration Farms Network and the Ohio Agricultural Conservation Initiative.

Pilot programs to develop market-based approaches

These pilot programs and ongoing initiatives promote novel approaches that could facilitate additional implementation in the Maumee watershed.

- **Great Lakes Commission Erie P Market:** From 2016 to 2018, the Great Lakes Commission developed and piloted the Erie P Market. Its primary goal was to address the excessive phosphorus runoff from agricultural land that contributes to the formation of algal blooms and dead zones in the Great Lakes. The project was designed to test water quality trading and stewardship crediting as nutrient-reduction tools capable of crossing state and provincial boundaries in the WLEB.
- **Great Lakes Commission Conservation Kick:** The Great Lakes Commission launched Conservation Kick in March 2020 to create a water quality marketplace for the Great Lakes Basin. This program was built on

the foundation of the Great Lakes Basin Compact. It intends to develop, use, and conserve the water resources of the WLEB efficiently and responsibly. Conservation Kick aims to keep soil and nutrients out of the Great Lakes and protect drinking water by allowing utilities, industries, businesses, nonprofit organizations, and concerned citizens to invest in water quality credits.

- **Conservation Technology Information Center's Phosphorus Load-Reduction Stimulation Program (PLUS-UP):** This pilot program was offered in 2022 and developed a market mechanism where companies are encouraged to purchase phosphorus credits. It was funded by a purchase of credits from Bayer Crop Science. The NCWQR ran a model called the Nutrient Tracking Tool (NTT) to calculate load reductions. NTT was developed by the Texas Institute for Applied Environmental Research at Tarleton State University in cooperation with USDA's Office of Environmental Markets, NRCS, and ARS for the last nine years. This pilot is a "pay for performance" program, where farmers are then paid for practice implementation based on the mass of phosphorus reduced.

Additional voluntary actions

Improving water quality requires all available resources to be used. This includes actions led by individuals and/or industries. Just as is the case with other funding initiatives, these actions may not be solely intended for environmental management but nonetheless play an important role in nutrient management. The following outlines two industry-led actions:

- **4R Nutrient Stewardship:** This initiative is a collaboration between the Fertilizer Institute, the International Plant Nutrition Institute, the International Fertilizer Industry Association, and the Canadian Fertilizer Institute. The 4Rs promote using fertilizer with the right source, at the right rate, at the right time, and in the right place. The initiative encourages considering nutrient management's economic, social, and environmental dimensions to promote sustainable agriculture.
- **Phytase in Livestock Feeds:** Supplemental phosphorus is required in livestock diets, especially poultry and swine. Using dietary phytase to release phosphorus from the forms in plants typically unavailable to livestock allows less dietary phosphorus to be added. This can decrease the amount of phosphorus in manure by 15–30 percent (Applegate et al., 2008). This practice has become more common as phytase has become more available and economical.

Demonstrating efficacy emboldens communities and agricultural producers to embrace change. Land management has changed over the years as technology has evolved. For example, many agricultural producers have embraced gridded soil sampling and variable rate nutrient management. This is a win-win because it saves costs for producers and provides environmental benefits. While cost-share programs can facilitate initial exposure to these practices, long-term success depends on the value being recognized by an agricultural producer and continued voluntary implementation.

7.4. Monitor environmental outcomes

The goal of the TMDL project is to restore the beneficial uses of Lake Erie through phosphorus reductions. The ultimate measure of success is measuring the environmental outcomes that show that goal is met. That outcome is only expected to be realized when a high level of implementation is achieved. Therefore, intermediate measures are important to track interim progress and inform adaptive management. Figure 55 shows how monitoring occurs at different levels across the landscape and how data are collected at those levels.

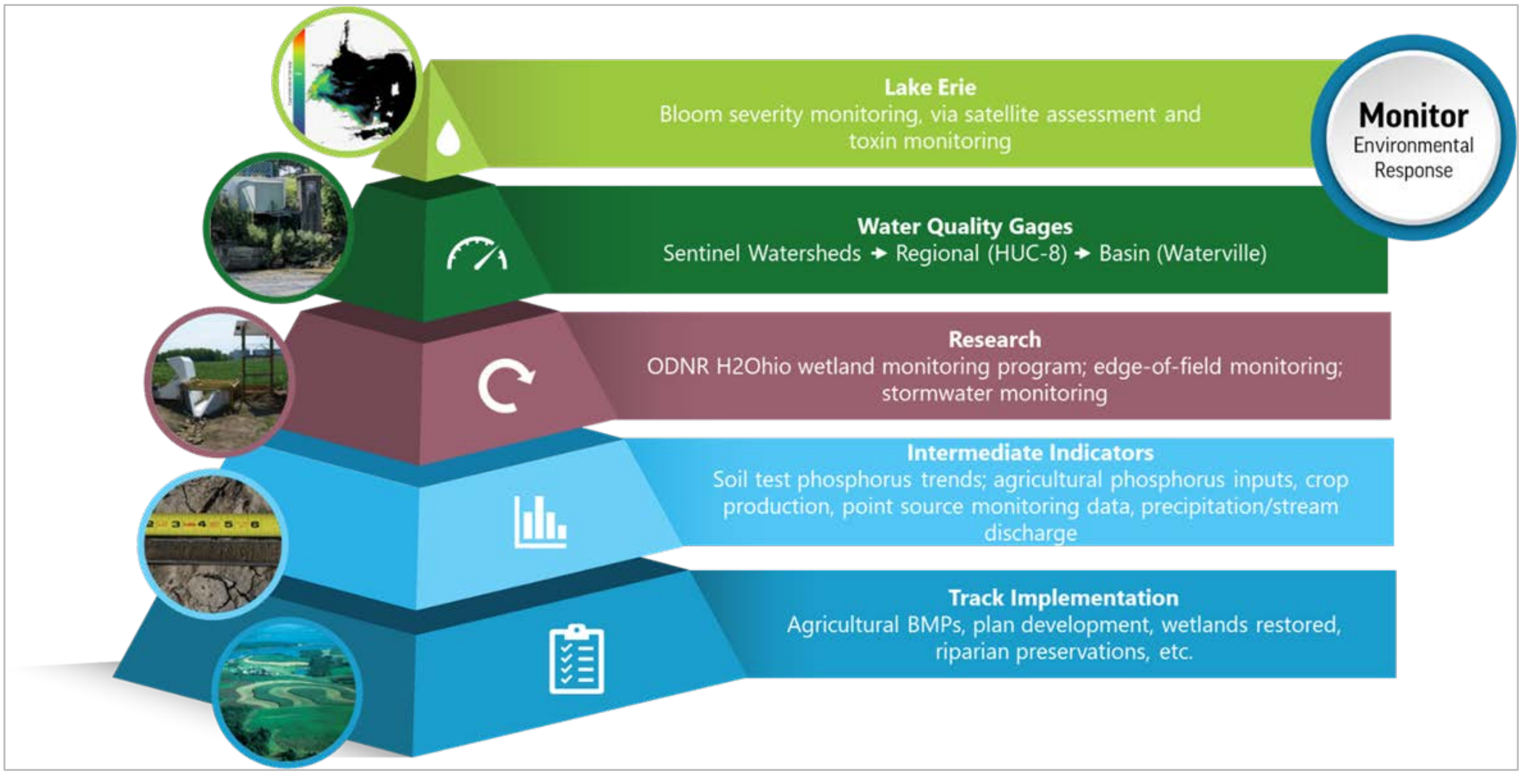


Figure 55. Pyramid demonstrating the various levels of monitoring TMDL implementation and the resulting environmental outcomes and TMDL project success. Actions monitored at the base of the pyramid drive environmental responses monitored at the higher levels.

Starting at the base of the pyramid, implementation measures are tracked to serve as programmatic indicators. This is the most fundamental level to track if programs are resulting in landscape changes. This level of monitoring includes tracking management practices, like agricultural BMPs and natural infrastructure projects, and planning activities like nine-element NPS-ISs.

Moving up the pyramid, data are collected to monitor intermediate indicators. These show if management practices are having real impacts on the landscape. This includes aggregated soil test phosphorus data (extent of legacy phosphorus), monitoring the inputs of agricultural fertilizers (commercial fertilizer and manure), crop production (crop removal of nutrients), monitoring data from point sources, and measures of watershed hydrology.

The next level up includes direct measures of water quality at the field or project scale. Due to the intensive nature of collecting data at this scale and the large number of projects to occur, research projects are best suited for this measurement level. This allows for various sampling methods to be used to inform water quality changes. Here, BMPs are monitored to ensure they are having the desired real-world impacts. Representative edge-of-field data for agricultural fields are collected largely by USDA-ARS researchers in the watershed through partnerships with many implementing agencies and private organizations. Implementing agencies have also included monitoring components for natural infrastructure projects, including the H2Ohio wetland monitoring program. Stormwater monitoring has been facilitated in Ohio through NPDES permits, research priorities, and partnerships between planning agencies and communities. Where practice evaluations have focused on total phosphorus, ongoing research has emphasized understanding practice efficacy for DRP management. Ensuring these data are collected provides a basis for adapting to practices that ensure DRP management improves moving forward.

The next level is load monitoring in streams throughout the watershed. These gaging stations are tiered, starting with sentinel watersheds representing the varied characteristics throughout the watershed at small-scale drainages. Then HUC-8 scale gages exist to understand the loadings from subregions in the watershed. These gages culminate near the Maumee watershed mouth at Waterville, where chemistry and hydrology have been paired for more than 40 years. This dataset is adequate to show long-term loading trends at the basin scale and is directly tied to the target phosphorus load used to develop this TMDL. Monitoring locations are detailed in Section 4 of this report.

Monitoring data within Lake Erie are measures of ultimate success. Lake Erie's ecological response is the top of the monitoring for environmental outcomes pyramid. Data collected includes algal toxins at drinking water intakes and satellite monitoring for the extent and duration of HABs. This data is collected by communities using Lake Erie as a public water supply and by the National Oceanic and Atmospheric Administration (NOAA) to capture routine satellite imagery of Lake Erie.

7.5. Evaluate progress

Monitoring data are important, but a systematic analysis and interpretive effort must be in place for it to be properly used to evaluate progress. Metrics allow for an objective way to evaluate success or lead to change. Figure 56 identifies metrics associated with the same monitoring levels identified in the previous subsection. In addition to the existing programs that collect data and present metrics, the biennial progress reports proposed in Section 7.2 will include monitoring data summarized to appropriate metrics. The subsections below detail the information Ohio EPA expects to include in the biennial reports.

7.5.1. Lake Erie

Ohio EPA assessments rely on three primary measures to track the conditions of Lake Erie that have identified impairments that led to the development of this TMDL. Those measures are the evaluation using NOAAs satellite imagery data in Ohio's integrated report, data from drinking water intakes collected by drinking water utilities and Ohio EPA, and electrofishing samples for Ohio's shoreline fish communities. Each of these sampling efforts continues and new data is reevaluated every two years in Ohio's Integrated report.

7.5.2. Stream Water Quality Gages

Robust water quality data needed to evaluate phosphorus loads is collected at more than 20 locations throughout the watershed, from small HUC12 watersheds to the Maumee River near its mouth at Waterville, OH. Monitoring at the Waterville gaging station has served as a foundation of evaluating water quality for more than 40 years, thanks to the foresight of the staff at the NCWQR at Heidelberg University and Ohio's leaders. Trends have been evaluated using flow-weighted mean concentrations and other flow normalization methods, both measures are utilized in the TMDL report to evaluate the baseline and target conditions. These metrics will serve as important measures of progress at the watershed outlet.

As algae challenges were being evaluated, monitoring at several key upstream pour points on major tributaries was initiated in 2013, and these stations now have ten years of data. Ten years is typically a minimum timeframe for establishing a record that can be analyzed to provide meaningful information on loading trends due to the strong influence of flow variability. In 2017, through support of GLRI another substantial expansion of the monitoring program took place and focused on sentinel watersheds (HUC12s) that represent the diverse agricultural landscape throughout the Maumee watershed. This information was used in Section 4.2.5.

Ohio EPA has previously worked with the OLEC to develop the annual monitoring summary for tributary loadings, the most recent report from 2021 is available here: lakeerie.ohio.gov/static/Water_Monitoring_Summary/Water%20Monitoring%20Fact%20Sheet%202021%20Final.pdf and a summary of all gaging station was included as an appendix to the 2020 summary here: lakeerie.ohio.gov/static/Water_Monitoring_Summary/Expanded_load_monitoring_report_2020_FINAL.pdf.

The state of Ohio continues to prioritize these monitoring stations, and the NCWQR received an Ohio Department of Higher Education grant through the Harmful Algal Blooms Research Initiative to evaluate the expanding information. This project will work to identify better ways to evaluate this data for identifying trends and communicating progress. The inaugural biennial report will utilize total load, FWMC, and other means identified as good measures to evaluate the stream water quality gage data.

7.5.3. Research

Research has been integral to developing the current implementation strategy and refining it. Research in the Maumee watershed has been cutting edge for evaluating agricultural BMPs for their ability to manage both total and dissolved reactive phosphorus. The following list may not be comprehensive but identifies specific research projects that the inaugural biennial report will evaluate for findings as they become available:

1) H2Ohio Wetland Monitoring Program: h2.ohio.gov/wp-content/uploads/2022/10/LEARN-Wetlands-sheet_2022-v5_Page_1-scaled.jpg
2) P-Optimal Wetland Demonstration Project: glri.us/node/458#:~:text=The%20project%2C%20known%20as%20the,health%2C%20especially%20in%20Lake%20Erie.
3) Conservation Effects Assessment Project – Paired watershed study: nrcs.usda.gov/publications/ceap-watershed-2021-summary-Blanchard.pdf
4) SWAT model being developed to evaluate H2Ohio practices, summary on page 7 of the October 2022 summary Ohio DAP 2020 of Actions: lakeerie.ohio.gov/static/DAP_SupportDocs/Ohio+DAP+Actions+Underway+and+Completed+2022-10-14.pdf
5) Outcomes from numerous projects supported by monitoring by the USDA-Agricultural Research Service Soil Drainage Research Units edge-of-field monitoring network: www.ars.usda.gov/people-locations/projects/?person-id=3013
6) Dr. Jay Martin’s legacy phosphorus project: portal.nifa.usda.gov/web/crisprojectpages/1016101-developing-public-private-partnerships-ppps-to-target-legacy-phosphorus-fields-to-increase-water-quality-and-availability.html
7) The Ohio Department of Higher Educations Harmful Algal Bloom Research Initiative projects: https://ohioseagrant.osu.edu/research/collaborations/habs

These research projects are integrated into the ongoing implementation efforts in the watershed. The biennial report will focus on lessons learned and programmatic responses based on the evolving state of the science.

7.5.4. Intermediate Indicators

Intermediate indicators can serve as opportunities to evaluate information that shows BMPs are having desired effects. Ohio EPA has identified the following information as intermediate indicators:

1) A calculated agricultural phosphorus mass balance. An agricultural phosphorus mass balance serves to evaluate watershed fertilizer inputs (commercial + manure) and outputs crop harvest. Appendix 3 details the method used to estimate the agricultural phosphorus mass balance in Section 4.1.1.1 of the TMDL report. As new data becomes available this agricultural phosphorus mass balance will be updated in biennial reports. Availability of the USDA’s Census of Agriculture which occurs every five years will drive future efforts to revise this evaluation.
2) Soil test phosphorus trends. In the TMDL report Ohio EPA relied on sharing information from Dayton et al. 2020 to interpret the pooled data that is available for soil test phosphorus at a regional and county level. New evaluations from the academic community will be used in future reports and other options considered for summarizing this dataset.

7.5.5. Tracking Implementation

Implementation relative to point sources will take place through these mechanisms: The implementation of the Maumee Watershed Nutrient General Permit, the implementation of stormwater controls through permits for municipal separate stormwater systems, sewer extensions to unsewered communities, and ongoing implementation of long-term control plans for combined sewer communities. As these permits are issued and projects implemented to comply with them the relevant information will be communicated in the Biennial Report.

Agricultural BMP implementation is accomplished through voluntary actions and facilitated through numerous incentive-based programs (e.g. H2Ohio and NRCS-EQIP). The incentive-based programs are an important component of the implementation strategy because they help agricultural producers adopt new practices while reducing the financial risks. Incentive-based programs are implemented by numerous agencies and organizations who track projects to fulfill a specific mission. Many of these agencies and organizations have prioritized nutrient management efforts in the Maumee watershed but not all efforts are targeted at phosphorus management. Ohio EPA enlisted the assistance of a contractor to evaluate how data is tracked for individual programs and how that data can be gathered. This memorandum summarizing the outcomes of this evaluation is included as Appendix 8. This project focused on three programs that facilitate the vast majority of incentive programs. These were the Conservation Reserve Enhancement Program (Farm Service Agency), the Environmental Quality Incentives Program (NRCS), and H2Ohio (ODA, ODNR, and Ohio EPA). These programs have data available at least at the county scale and information can be obtained to summarize ongoing programmatic efforts. These programs will be the focus of the inaugural biennial report.

Many other programs were identified that facilitate implementation in the watershed. However, the Tetra Tech evaluation identified broader objectives for the programs and less precise project information. For example, GLRI has provided funding for many phosphorus related projects in the watershed but also funds a wide variety of projects like contaminated sediment remediation. GLRI projects are tracked, but individual awards will require additional evaluation to determine if they are pertinent to implementation tracking for the Maumee Watershed Nutrient TMDL. Tetra Tech ultimately recommended that Ohio EPA may need to supplement other programmatic tracking efforts like GLRI with its own project database. Ohio EPA will strive to include as much information as possible in the biennial reports but other programs may take additional effort.

While these programs facilitate implementation, they will not outright generate outputs of what BMPs are on the landscape. Other tools are needed to evaluate what is actually on the landscape and how it is changing. Ohio EPA has identified several potential tools that capture this information. Those include:

1) Tools that utilize aerial imagery to track the extent of agricultural practices. Some agricultural practices are readily evaluated utilizing aerial imagery. This is especially true for overwintering cover crops and conservation crop rotations that include wheat. These products have the ability to track implementation that extends beyond program facilitated efforts and link contemporary trends to longer term records. These technologies are evolving rapidly. Two recent efforts are an OLEC led effort to use remote sensing to inform a SWAT model evaluating H2Ohio and the Operational Tillage Information System (OpTIS). These efforts will be evaluated for inclusion in biennial reports.
2) Survey tools to collect information from agricultural producers provide additional insight to the actual management practices utilized. Because not all management is incentivized tools that identify voluntary actions are needed to provide additional information. For example, variable rate phosphorus application and associated nutrient management planning are utilized outside of incentive programs. Survey tools that provide this type of information include the Ohio Agricultural Conservation Initiative, NRCS Conservation Effects Assessment Projects, and the USDA census of agriculture. As these products are developed they will be utilized to evaluate progress in the biennial reports.

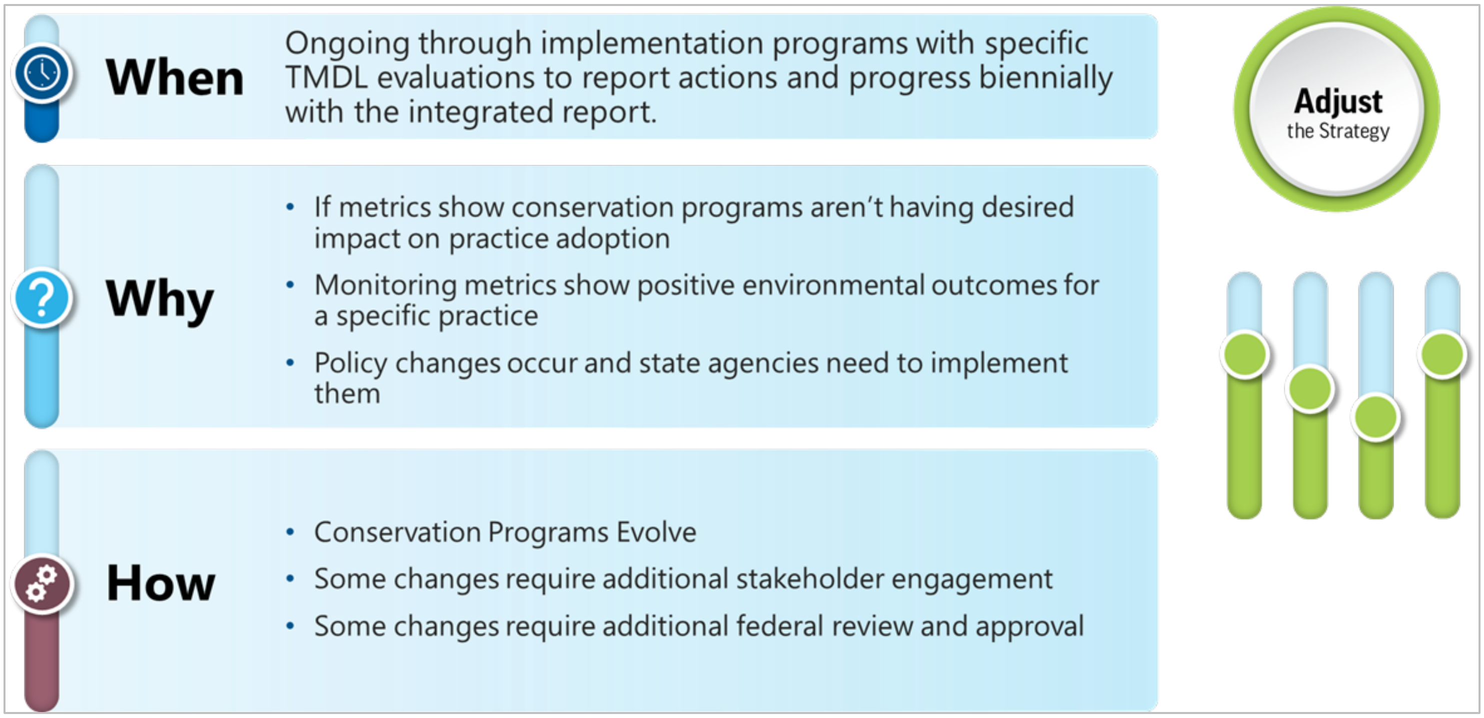
Figure 56. Pyramid showing metrics that can be used to evaluate monitoring data collected to represent various levels of implementation and environmental response.

7.6. Adjust the strategy

To complete the adaptive management circle, information needs to be used to adjust the strategy, if necessary. Figure 57 shows when, why, and how adjustments would occur.

Adjustments can occur at any time as implementation programs develop. Individual programs work on specific planning timeframes to get feedback on program effectiveness. Improving implementation is intrinsic to that process; although the TMDL provides useful information to the program, it does not change how the implementing agencies operate. TMDL-focused implementation evaluations are proposed to occur every two years to complement the related evaluations made in Ohio EPA’s Integrated Report. These evaluations will update metrics as data and analyses become available, incorporate updates from research that has been published, and identify updates to programs that have occurred in the preceding years. The reports will also provide an opportunity to update milestones and generally report on progress.

The goal of adaptive management is to accelerate programs that do work while looking for ways to improve or move away from ones that are not having the intended response. Therefore, changes in implementation actions could be driven by a metric that shows a program is not having the desired outcome or a metric that shows a practice is having positive outcomes. State agencies might also adapt to policy changes that require additional planning or implementation.



When Ongoing through implementation programs with specific TMDL evaluations to report actions and progress biennially with the integrated report.

Why

- If metrics show conservation programs aren't having desired impact on practice adoption
- Monitoring metrics show positive environmental outcomes for a specific practice
- Policy changes occur and state agencies need to implement them

How

- Conservation Programs Evolve
- Some changes require additional stakeholder engagement
- Some changes require additional federal review and approval

Figure 57. Adjustments made through adaptive management can occur at different times, for different reasons, and in different ways as implementation moves forward.

Not all adaptations to the implementation strategy happen the same way. Conservation programs evolving is "part of the plan," and these do not require special considerations to improve programs. New research findings or updated analyses of monitoring results might affect the assumptions made to develop the TMDL. This would require additional stakeholder outreach by Ohio EPA. An example is if a change is proposed that affects the technology considered for compliance with NPDES permit limits. If new information suggests changes to the allocations or reasonable assurances, additional federal review and approval may be necessary. Another example is if Annex 4 identifies different load reduction recommendations. Since this TMDL's targets are based on those recommendations, changes to them would likely cause the whole TMDL to be revisited. This, too, would require federal review and approval.

8. Reasonable Assurances

When U.S. EPA approves a TMDL that allocates pollutant loads to both point and nonpoint sources, it determines whether there is reasonable assurance that the point source wasteload and nonpoint source load allocations will be achieved, and water quality standards will be attained. This ensures that the allocations in the TMDL are not based on overly ambitious assumptions regarding the amount of nonpoint source pollutant reductions that will occur. This is necessary because excessive projections of nonpoint source reductions could be used to offset pollutant reductions from point source allocations. Since point source allocations are required to be implemented through existing NPDES permitting programs, an unrealistic elevated nonpoint source load reduction could be considered evading more strict permitting regulations. Such a situation would also result in a failure to achieve water quality standards.

This section demonstrates that there is reasonable assurance that the nonpoint source allocations in this TMDL can be met. It is organized by first explaining the background of Lake Erie's HAB problem. It next explains the commitments and planning efforts that have occurred to address this problem. A detailed review of the actions to implement phosphorus reduction is presented, with several specific examples of successful efforts. The section concludes by explaining the framework for accountability.

8.1. Background

8.1.1. Historical efforts to address nutrients, lake recovery, and reemergence of blooms

HABs are not a new phenomenon in Lake Erie. They were a common occurrence in the Western Basin of Lake Erie until they abated in the 1980s. The lake's recovery was due to modernizing WWTPs, including limiting phosphorus loadings to the lake from these plants, and changes to land management practices that reduced soil erosion and loss of nutrients from agriculture. These efforts resulted in a reduction of total phosphorus loading that met the lake's then-target load of 11,000 MTs, and the lake recovered accordingly.

However, in the mid-1990s, toxin-producing cyanobacterial blooms began reappearing in the Western Basin of Lake Erie. A particularly severe bloom occurred in 2003, and blooms of varying intensity have recurred most years since then. While the linkage between nutrients and algae is generally understood, why these blooms began to reappear was the subject of much scientific debate.

8.1.2. Understanding the problem

In an effort to understand this new trend, the State of Ohio convened the Ohio Lake Erie Phosphorus Task Force I in January 2007. This effort was led by Ohio EPA, and the task force included representatives from state and federal agencies, Lake Erie researchers, soil scientists, agricultural program representatives, and WWTP personnel. It also drew on the expertise of many other experts in a variety of disciplines. The task force developed a variety of recommendations to address nutrient reductions, particularly in the Western Basin of Lake Erie. Recommendations were made for all the sources examined, with a major focus on upland measures that influence agricultural practices. The report included a research agenda, which has served as a basis for directing millions of dollars of state and federal research funds.

In response to the findings of the task force, the State of Ohio directors of ODA, ODNR, and Ohio EPA convened the Directors' Agricultural Nutrients and Water Quality Working Group on August 25, 2011. The purpose of this group was to identify and implement agricultural practice initiatives that would ultimately result in the reduction of HABs developing in Ohio's inland lakes and Lake Erie. As a guiding principle, the final report encouraged farmers to adopt nutrient application guidelines known as 4R Nutrient Stewardship (4R). This approach was intended to, at least in part, be effective at reducing phosphorus and nitrogen from impacting waterways across the state.

Starting in 2012, Ohio EPA, coordinating with ODA and ODNR, developed Ohio's Nutrient Reduction Strategy. This comprehensive framework's intent was to manage point and nonpoint sources of nutrients and reduce their impact on Ohio's surface waters. It was an outgrowth of Ohio's participation on the Mississippi River/Gulf of Mexico Watershed Nutrient (Hypoxia) Task Force. The strategy was submitted to U.S. EPA Region 5 in 2013 and updated in 2015. The strategy and more information about the effort are available at epa.ohio.gov/divisions-and-offices/surface-water/reports-data/nutrient-pollution-finding-solutions.

The Point Source and Urban Runoff Work Group of the Hypoxia Task Force recommended that Ohio develop a statewide nutrient mass balance that examines both point and nonpoint sources of nutrients to Ohio's watersheds. This recommendation was eventually adopted in state law with a biennial requirement for Ohio EPA to produce a Nutrient Mass Balance report. This analysis determines the relative contribution of nutrient sources. Its results can be inferred to enable cost-benefit assessments to determine the most environmentally effective and economically feasible mechanism for the state to reduce nutrient loadings. The first round of this study was completed in December 2016 and has been repeated every two years since then. The findings of this report show that the predominant source of nutrients in Ohio's waters is nonpoint source runoff. The reports are available at epa.ohio.gov/divisions-and-offices/surface-water/reports-data/nutrient-pollution-finding-solutions.

Simultaneously with those efforts, Ohio EPA, OLEC, ODA and ODNR reconvened the Ohio Lake Erie Phosphorus Task Force as a Phase II effort. The Task Force II final report was completed in November 2013 and includes a detailed review of state and federal efforts, including research results from some of the initial studies recommended by Task Force I. After hearing from numerous experts at several meetings, Task Force II worked to develop a phosphorus target for Lake Erie's Western Basin. At this time, targets began to focus on springtime total phosphorus and DRP loads as the driving factor for HABs, and Task Force II recommended the need to reduce loads by approximately 40 percent.

Following recommendations of the binational GLWQA, Annex 4 convened an Objectives and Targets Task Team that continued to refine loading targets with a binational team of experts. Modeling showed that spring loading of phosphorus from the Maumee River dictates the size of the Western Basin of Lake Erie's annual HABs. The task team recommended that there should be a reduction of approximately 40 percent (with the baseline year of 2008) in spring loads of both total and dissolved phosphorus from the Maumee River. This reduction to the Maumee's load equates to a target spring load of 860 MTs per year of total phosphorus and 186 MTs per year of DRP under high spring discharge conditions. This goal is intended to limit the formation of HABs in nine years out of 10, which allows for an occasional very wet year in which the goal would not be achievable.

Listing impairments in Ohio's Integrated Report was another critical step that led to the development of this TMDL. Briefly, the initial impairment listing occurred in the 2014 cycle of the IR for public drinking water use due to detections of microcystins at several drinking water intakes located in the Western Basin of Lake Erie. The following cycle, the 2016 Integrated Report, identified the Lake Erie islands shoreline unit as impaired for public drinking water use. In 2018, an amendment to the 2016 Integrated Report included the impairment for recreational use based on the narrative criteria for nuisance algae. In subsequent biennial cycles of the Integrated Report , the status of these waters and designated uses have been updated with current data, but the listed waters have remained impaired.

8.2. Commitments

Section 8.1 shows that there is a long history of managing phosphorus in the Maumee watershed. Much of that history is linked to the commitments made by the GLWQA and via collaborative efforts among states and federal agencies.

8.2.1. Great Lakes Water Quality Agreement

The GLWQA is a commitment between the United States and Canada to restore and protect the waters of the Great Lakes; it was first signed in 1972 and has been updated several times, most recently in 2012. The GLWQA provides a framework for identifying binational priorities and implementing actions that improve water quality. There are 10 Annexes to the agreement, each focusing on a specific issue. Nutrients, including phosphorus to manage HABs, are managed under Annex 4. As Ohio's Task Force II was completing its final report, the GLWQA's Annex 4 Subcommittee was beginning the process of revising the prior GLWQA nutrient loading goal for Lake Erie.

8.2.2. Lake Erie Collaborative Agreement

The Lake Erie Collaborative Agreement was another state/province-led initiative that was signed in June 2015 by Ohio, Michigan, and Ontario. The agreement was intended to spur immediate actions that could be implemented at the state and provincial levels to make progress toward meeting the Annex 4 target load reductions. Ohio released a draft Collaborative Implementation Plan in June 2016. One of the goals spelled out in the Collaborative Agreement was to reduce nutrient levels going into Lake Erie. Governor DeWine and leaders from Michigan and Ontario reaffirmed their commitment to this agreement at the Great Lakes St. Lawrence Governors and Premiers 2019 Leadership Summit.

8.3 Planning efforts

As noted in Section 7, successful implementation and the realization of phosphorus reductions in the Maumee watershed require multiple scales of planning. These planning efforts are aligned with policy at the state and regional scales. They include collaborations and identify leadership to coordinate those efforts. Further, these planning documents are not intended to be static. Instead, they evolve with adaptive management iterations to incorporate new information and align with current programmatic objectives.

8.3.1. Ohio's Domestic Action Plan for Lake Erie

The State of Ohio's DAP was submitted to U.S. EPA on February 7, 2018. The management objectives in the Ohio DAP were defined through interagency collaboration under Annex 4 (Nutrients) of the GLWQA. The plan is also revised following the adaptive management philosophy. It was most recently updated in 2020 to support the H2Ohio initiative (released in 2019 and detailed below in Section 8.4.1). OLEC coordinates the Ohio DAP. Ohio EPA, ODA, ODH, and ODNR each share responsibility for implementing the plan. Each agency is accountable for implementing its respective areas of authority included in the state plan to meet the overall nutrient reduction goal.

New action items included in the 2020 Ohio DAP focus on:

- Establishing science-based priorities for agricultural BMPs and state programs to support H2Ohio efforts to encourage farmers to implement them;
- Calling out the importance of wetland restoration and outlining ODNR efforts to create, restore, and enhance wetlands for nutrient reduction as part of H2Ohio;
- Updated actions for communities, including H2Ohio support, for HSTS remediation;
- Integrating the role of watershed planning at the local level for siting projects to reduce nutrients efficiently, including a distribution of the load reduction throughout the Maumee watershed based on Ohio EPA's Nutrient Mass Balance method.

The 2020 Ohio DAP and supporting documents are available at lakeerie.ohio.gov/planning-and-priorities/02-domestic-action-plan/02-domestic-action-plan.

Since this planning document is intended to evolve and include new information, an update to the Ohio DAP is planned for 2023 upon completion and federal approval of this TMDL (noted in Section 7.2.2). Regular updates to the DAP allow the document to align with goals and targets of this TMDL. It incorporates outcomes of ongoing research for adaptive management. Information from the Ohio DAP is also aggregated for efforts of broader geographic scope, such as the U.S. Action Plan for Lake Erie, Lake Erie Lakewide Action and Management Plan (LAMP), and ultimately for progress reports for the GLWQA.

8.3.2. Ohio EPA nonpoint source management plan

Ohio EPA's update to its Nonpoint Source Management Plan was approved by the U.S. EPA in August 2020 (the full report is available at epa.ohio.gov/static/Portals/35/nps/2019-NPS_Mgmt_Plan.pdf). This plan provides direction and strategic focus to Ohio EPA's programs. It outlines activities geared toward reducing the impacts of nonpoint source pollution such as hydromodification, habitat alteration, and polluted runoff. The report also includes other activities like invasive species management and innovative storm water management demonstrations. Management practices listed in the update make them eligible for federal Section 319 grant funding and grants awarded from other sources.

Ohio's approved Nonpoint Source Management Plan incorporates extensive content from Ohio's Nutrient Reduction Strategy. This information was derived following collaboration and input from many agricultural and urban stakeholders. Moving forward, Ohio's Nonpoint Source Management Plan will implement several provisions of the Nutrient Reduction Strategy. This includes objectives for Ohio EPA's Lake Erie Program such as Remedial Action Plans for AOCs and monitoring efforts in the lake. The plan also includes strategies for dealing with nonpoint source issues in urban waters and activities critical to protecting high quality waters.

Nine-Element NPS-IS: These are strategic plans that outline nonpoint source pollution actions that can occur within a given HUC-12 watershed to address impairments. These plans are fine-scale and detailed to identify and assist with directing funding towards effective implementation projects; thus, they are a key component of the overall implementation plans for this TMDL (see details in Section 7.2). These plans provide assurance to nonpoint source grant programs and institutions that proposed water quality projects meet the nine essential elements per U.S. EPA Section 319 Program Guidance. NPS-IS plans ensures that potentially funded projects are "rooted in the best science available; located in areas that will address the worst problems; and that have the administrative, evaluation, and educational components needed to ensure that the water resource will maximize long-term benefits."

Each NPS-IS is a strategic planning document that summarizes causes and sources of impairment. They delineate critical areas contributing to impairment. The plans identify quantifiable objectives to address causes and sources of impairment and describe projects designed to meet those objectives. NPS-IS plans are designed to evolve as projects come and go. Every updated plan version (which could contain new projects; new data; and/or changes to critical areas, goals, and objectives) must be reviewed and approved by Ohio EPA.

For an implementation project to be eligible for Ohio EPA Section 319 funding, it must be described in an approved nine-element NPS-IS for the HUC-12 watershed in which the project is located. Ohio will continue to encourage the development of NPS-IS plans for the most effective placement of structural practices. Ohio EPA and ODA will coordinate with local entities in the development of nine-element NPS-IS plans with a focus on priority watersheds. This means completing plans for the southern portion of the Maumee watershed and then the remainder of the Maumee, Portage, Sandusky and Cuyahoga watersheds as time and funding become available.

GLRI funds and Clean Water Act Section 319 funds are being passed through to local jurisdictions to encourage development of nine-element NPS-IS plans. Ohio EPA maintains an interactive map of watersheds with approved NPS-IS. There are now 45 plans complete using the far-field phosphorus targets in the Maumee watershed. Sixteen new plans are underway, and 22 existing plans are being updated to include the far-field targets. When this work is completed, these plans will cover approximately half the total Maumee watershed. With continued efforts, Ohio EPA's nonpoint source program expects that the entire Maumee watershed will have approved NPS-IS plans in approximately 10 years. This effort will be further supported by the ODA Watershed Program (see details in Section 8.3.4). Links to the watershed plans and to the interactive map are available at epa.ohio.gov/divisions-and-offices/surface-water/reports-data/approved-nine-element-nonpoint-source-implementation-strategies-in-ohio.

8.3.3. Agricultural Conservation Planning Framework

A new planning toolbox interface that is becoming available in Ohio for planning in agricultural landscapes is USDA's Agricultural Conservation Planning Framework (ACPF). The ACPF employs a watershed approach to locate practices within a HUC-12 watershed. It uses GIS tools designed to find conservation opportunities across the watershed's agricultural landscapes. While not a comprehensive tool for siting all possible practices, it will be particularly useful in the context of this TMDL because of its focus on water retention in agricultural landscapes.

ACPF has been utilized in the Maumee River watershed and efforts are underway at NRCS and Ohio universities to expand its coverage. To date, ACPF modeling outputs have been developed for 24 HUC-12 watersheds (and 20 more ACPFs are in progress) in the Maumee watershed. The map and analyses are intended to facilitate landowner involvement in planning for conservation practice implementation. This is done by providing a menu of possible options to meet goals set for the watershed. Watershed coordinators and on-the-ground staff can show the maps and tools to a landowner in the field as they discuss potential projects. Additionally, the references, maps and analysis have been included in draft submissions of 9-Element NPS-IS plans for HUC-12 watersheds to assist in strategically locating BMPs on the agricultural landscape.

8.3.4. TMDLs for Lake Erie Watershed

TMDLs are Clean Water Act plans developed by various jurisdictions for waters that have been formally identified as impaired. TMDLs use monitoring and modeling to identify where load reductions and restoration actions are needed. Ohio EPA plans to continue using this tool to target implementation of CWA water quality standards in Ohio's Lake Erie watersheds as it works to meet the Annex 4 phosphorus targets and allocations.

A TMDL document provides guidance on where to focus implementation and recommends BMPs. The TMDL process does not provide additional authority to either Ohio or U.S. EPA to regulate nonpoint sources of pollution. Ohio's regulatory tools are limited to permits and enforcement actions against point sources of pollution. TMDLs help Ohio EPA work collaboratively with state partners, like ODA, to ensure that their authorities are best used to address nonpoint source pollution. Ohio has completed TMDLs for 22 of 32 project areas (watersheds) feeding into Lake Erie. TMDL development for the remaining 10 watersheds is underway by Ohio EPA. These TMDLs employ the state's narrative water quality criteria for nutrients and algae. They have established phosphorus targets and methods to address near-field impacts to rivers and streams. The list of areas in the Maumee watershed with existing near-field phosphorus TMDLs is provided in Appendix 4. Ongoing watershed surveys continue to identify local areas with elevated nutrients and focus future implementation activities to those sites.

8.3.5. Ohio Watershed Planning and Management Program

Ohio HB 7, which was passed by the Ohio General Assembly in April 2021, created a statewide watershed planning and management program to be administered by ODA. The intent of this program was to improve and protect the state's watersheds. ODA's DSWC oversees the watershed program, which provides watershed planning across the entire state with a dedicated manager for each of seven regions. Watershed managers engage in watershed planning and management through a collaborative network of stakeholders, supporting local efforts, and developing a watershed planning framework for implementing regional-scale conservation programs.

The program provides regional-scale watershed planning, supports local watershed activities, and provides the groundwork for new conservation efforts. The program considers all water quality issues within each region, with special attention given to nutrient loss from both agricultural and non-ag activities. Thus, the new watershed program has the same focus as this TMDL for the Maumee watershed.

ODA's Watershed Planning and Management Program objectives (from HB 7) are as follows:

- Appoint a watershed manager for each of the seven regions.
- Identify sources and areas of water quality impairment, with attention to nutrients.
- Engage in watershed planning, restoration, protection, and management activities.
- Support a certification program for producers.
- Collaborate and engage with all stakeholders involved in water quality work.
- Produce an annual water quality report.

Several objectives of the ODA's new watershed program align with Ohio EPA TMDL process and nonpoint source programs. Both identify sources and areas of water quality impairment. The watershed program's focus on nutrient impairments with efforts to engage in watershed planning, restoration, and management activities are pertinent to this TMDL project in particular. Watershed managers are assisting SWCDs and Ohio EPA with local watershed modeling, planning, and implementation actions. They are participating in partner-led regional watershed planning efforts, which include grant program proposal review and evaluation. While this program's annual water quality reports are statewide, they will contribute informative details to the biennial progress report for this TMDL.

8.3.6. Lake Erie Protection and Restoration (LEPR) Plan

This program is administered by OLEC, as authorized by ORC 1506.21: *The commission shall publish a Lake Erie protection and restoration strategy that describes the goals of the commission and prioritizes the uses of the Lake Erie protection fund and other funds for the following state fiscal year*. The 2020 LEPR plan reflected Ohio's two-year strategic priorities to protect, preserve, and restore Lake Erie and its watershed, as well as to promote economic development associated with Lake Erie. Additionally, the plan serves as the framework for administering the Lake Erie Protection Fund and securing federal funding to implement projects in Lake Erie. The LEPR plan is intended to be a comprehensive effort of the state agencies for the development of Lake Erie priorities and strategies. It ensures coordination of actions, progress reporting, and communication to stakeholders of these priorities.

8.4. Activities to meet the goal

8.4.1. H2Ohio

One key initiative that deserves special mention is Governor DeWine's H2Ohio Plan. H2Ohio was unveiled on November 13, 2019, by Ohio Governor Mike DeWine. It is a comprehensive, data-driven water quality plan to reduce HABs, improve wastewater infrastructure, and prevent lead contamination. H2Ohio is focused on targeted solutions to help reduce phosphorus runoff and prevent algal blooms through:

- increasing implementation of agricultural best practices;
- creating wetlands;
- improving wastewater infrastructure; and
- replacing failing home septic systems.

H2Ohio was first funded by the Ohio General Assembly with an investment of $172 million in the 2020–2021 biennium. This funding has allowed H2Ohio to begin the long-term process to reduce phosphorus runoff from farms through the use of proven, science-based nutrient management best practices and the creation of phosphorus-filtering wetlands. H2Ohio also passes funding on to local communities that need help paying for important water infrastructure upgrades and aids in the development of other innovative water quality solutions.

The H2Ohio plan was developed with input from a broad coalition of agriculture, education, research, conservation, and environmental partners. H2Ohio is implemented by the ODA, ODNR, Ohio EPA, and Lake Erie Commission with support from the Ohio Agricultural Conservation Initiative, Ohio Farm Bureau, USDA, and others. H2Ohio will serve as a major program implementing the efforts to address nonpoint sources of pollution for this TMDL.

8.4.1.1 ODA coordinated H2Ohio activities

ODA worked with a wide array of stakeholders to identify the most impactful and cost-effective practices for achieving phosphorus reductions in runoff. The H2Ohio plan invests substantially in those practices to help farmers reduce phosphorus runoff from commercial fertilizer and manure to prevent harmful algal blooms. The Maumee watershed was the initial focus H2Ohio investments for agricultural BMPs; this included 14 priority counties that comprise the majority of the Maumee watershed. After the initial roll out in state fiscal years 2020 and 2021, a second signup was provided in January 2022 for funding secured through state fiscal year 2023.

Producers work with their local SWCD to determine which practices will be most effective on their farm while still producing a high yield of crop. A Voluntary Nutrient Management Plan (VNMP) is required for all cropland enrolled in H2Ohio. The VNMP shows the amount of nutrients in the soil and helps determine which BMPs will be most effective. When ODA made the signup available for the initial 14 counties, producers showed remarkable interest. Over 1 million acres were enrolled into science-based and cost-effective BMPs proven to improve water quality. The overall progress of the H2Ohio phosphorus reduction plan is regularly assessed. Aggregate data is publicly available through annual reports and an online dashboard tool available at data.ohio.gov/wps/portal/gov/data/view/h2ohio-oda-overview.

ODA H2Ohio Success Stories

Through the Blanchard River Demo Farms and ODA outreach efforts, producers share their firsthand experience with these practices. A farmer in Henry and Fulton counties credits H2Ohio funding for helping to purchase equipment to apply phosphorus fertilizers subsurface (youtu.be/efMZXnl94xA). At another site, spanning Henry and Wood counties, a farmer details his experience implementing technology for better placement of phosphorus, noting the cost savings and that it is in the farmer's interest to have a clean environment (youtu.be/NGCou3Yos2M).

In March 2023, ODA announced $4.2 million in grant awards through H2Ohio for two-stage ditch projects. Nine of the 12 projects are located in the Maumee watershed with construction planned to begin summer 2023 and be completed by fall 2024. The two-stage ditch is one of the best management practices offered through ODA's portion of H2Ohio. A two-stage ditch is a conservation practice that modifies the shape of a drainage ditch to create vegetation benches on each side. Two-stage ditches provide benefits such as slowing water flow, reducing maintenance costs, and improving water quality. For more information on the award please see the following link: h2.ohio.gov/oda-awards-funding-for-h2ohio-two-stage-ditch-program/.

8.4.1.2. ODNR coordinated H2Ohio activities

ODNR's H2Ohio efforts focus on wetland systems and other natural infrastructure designed to naturally filter and trap nutrients. Using established and emerging technologies, wetland creation and preservation is the central feature of this program. The ODNR internal team of wetland specialists—along with other governmental agencies, individuals from academia, and nongovernmental agencies—have developed criteria and guidelines for targeted phosphorus-reducing wetland projects. Although a statewide program, ODNR focused its initial H2Ohio wetland efforts in the watershed of western Lake Erie. Projects that presented the best opportunities for preventing sediments and nutrients from reaching Lake Erie were prioritized.

In the H2Ohio Annual Report for Fiscal Year 2022, there were 23 wetland projects, of which 11 are complete, that include over 1,400 acres in the Maumee watershed (including Blanchard watershed; a detailed map of projects and location is available at h2.ohio.gov/wp-content/uploads/2022/04/H2Ohio_Statewide_Projectsstatus_wWQIP_03212022-scaled.jpg).

ODNR H2Ohio Success Stories

St. Joseph Confluence Wetland Reconnection (Williams County): This project is in partnership with the Black Swamp Conservancy. It covers 140 acres, filtering water from more than 8,000 upstream acres. A combination of nutrient-reduction practices is included in this project site, of which 20 acres had previously been in agricultural use. These practices include decommissioning subsurface drainage tiles, expanding existing wetlands, and creating new wetlands. Native vegetation, including shrubs and sedges, will be planted to trap nutrients on the land and prevent them from entering nearby waterways. Restoring a deciduous forest of native trees, which will develop nutrient and sediment-trapping vernal pools, is also part of this project.

Oakwoods Nature Preserve Wetland Restoration Projects East and West (Hancock County): These projects are in partnership with Hancock Park District and cover a combined 142 acres. The east project site is in a former agricultural field. The area has been primarily converted into wetlands, with the remaining portion to be planted as a native prairie. The project includes restoring natural water flow to the landscape and capturing excess nutrients and sediment from nearby farmland. The larger west project both creates and restores wetlands, woodlands, and prairie in a previously farmed floodplain. Aurand Run crosses the project area and will be reconnected to its floodplain. This will allow nutrient-rich water to be treated through 3 acres of forested wetlands. Other efforts include removing underground drain tiles, enhancing wooded habitat along Aurand Run, and restoring wooded streamside habitat. These actions expand and protect 15 acres of an existing high-quality forested wetland.

Blanchard River Floodplain Restoration (Putnam County): This project is in partnership with Village of Ottawa and Maumee Watershed Conservancy District. It will restore wetlands along the meanders of the Blanchard River, west of village of Ottawa. Low earth berms will create a series of terraced wetlands that will form water depths of 0–18 inches. Native plant communities will be restored, and additional vegetation will be planted to add onto a narrow riparian wooded corridor.

8.4.1.3. Ohio EPA coordinated H2Ohio activities

Infrastructure improvements: Under the H2Ohio plan, Ohio EPA funds infrastructure projects in communities to help ensure access to safe drinking water and quality sewer infrastructure. H2Ohio also helps fund replacing hundreds of failing HSTS in low-income households to prevent the release of raw sewage onto property or into waterways.

Ohio EPA H2Ohio Success Stories

Kunkle Sanitary Sewer and WWTP Project (Williams County): $500,000 in funding was announced in 2019 for this project. It will construct a new wastewater collection and treatment system that will serve approximately 90 homes (260 people) in the unincorporated area of Kunkle in northwest Ohio.

Findlay (Hancock County): $600,000 in funding was announced in 2021 for this project. Residents in more than 100 homes (231 people) in Findlay's Eagle Creek subdivision are currently being served by a failing WWTP. This H2Ohio funding awarded to Findlay will be used to extend the city's sewer system to include the Eagle Creek subdivision and allow for the old plant to be retired.

8.4.2. Great Lakes Restoration Initiative (GLRI)

The U.S. EPA's Great Lakes National Program Office coordinates U.S. efforts under the binational GLWQA to restore and maintain the chemical, physical, and biological integrity of the Great Lakes Basin ecosystem. The Great Lakes National Program Office brings together federal, state, tribal, local, and industry partners under the strategic framework of the GLRI to accomplish the objectives of the initiative's action plan. GLRI was launched in 2010 as a nonregulatory program to accelerate efforts to protect and restore the waters of the Great Lakes and to provide additional resources to make progress toward the most critical long-term goals for this important ecosystem. The GLRI program operates within five-year action plans; the plan currently in place, Action Plan III, covers federal fiscal years 2020–2024. GLRI Action Plan III outlines the current phase of work toward ameliorating environmental problems in the Great Lakes. It also outlines the necessary steps to achieve the long-term goals and commitments under the GLWQA. Key principles guiding GLRI planning and implementation under Action Plan III include accountability and reporting, communication and outreach, partnership and engagement, project sustainability, and science-based adaptive management.

GLRI contains five focus areas. Focus area three, nonpoint source pollution impacts, aligns with the objectives of this TMDL. Specific commitments and associated metrics for tracking results from GLRI funding projects within focus area three include:

- Implement systems of conservation practices on farms and instreams to reduce and treat nutrient runoff.

- Increase adoption of enhanced nutrient management practices to reduce risk of nutrient losses from farmland.
- Assess achievement of GLWQA Annex 4 nutrient targets.
- Evaluate effectiveness of nonpoint source projects.
- Develop new or improved approaches for reducing or preventing HABs.

Because implementing measures to prevent erosion and runoff from farmlands is often voluntary, the bulk of GLRI efforts to date has been to provide farmers with financial and technical resources to adopt conservation practices. Outreach and funding are targeted to where they have the greatest impact on improving water quality. GLRI federal agencies have used GLRI support to promote better nutrient management, which has more than doubled the number of farmland acres enrolled in agricultural conservation programs in four priority watersheds. The Maumee watershed is one of these priority watersheds. To date, these programs have helped producers reduce phosphorus in runoff—preventing more than one million pounds of phosphorus from washing off agricultural lands. Continued GLRI support for technical assistance and comprehensive conservation planning will be vital to sustaining and accelerating nutrient reductions. A comprehensive list of GLRI funded projects is available at glri.us/projects.

GLRI success stories

Decision-support tools improve nonpoint source management: Under Action Plan II, GLRI federal agencies partnered with states to develop weather-based forecasts to help farmers avoid nutrient application when the chance of runoff is high. Tools known as Runoff Risk Advisory Forecasts were developed for several states, including Ohio. Under Action Plan III, GLRI federal agencies and partners will promote adoption of these tools and assess how effective they are at reducing phosphorus loads. This tool in Ohio is called the Ohio Applicator Forecast and is designed to help nutrient applicators identify times when the weather risk for applying nutrients is low. The risk forecast is maintained by the National Weather Service and considers snow accumulation and melt, soil moisture content, and the forecasted precipitation and temperatures.

Edge-of-field monitoring sites: The duration of a typical agricultural edge-of-field study requires at least eight years. These studies measure water quality data downstream of fields and at the outlet of the local watershed. The data are assessed to detect improvements in water quality associated with agricultural conservation activities. Under the GLRI Action Plan II, six edge-of-field monitoring sites were established to evaluate the impact of nutrient-reduction activities in the priority agricultural watersheds. Two of these sites are in the Maumee watershed, including Eagle Creek in the Blanchard River watershed (a detailed Eagle Creek report is available at pubs.usgs.gov/fs/2015/3066/fs20153066.pdf). The information garnered from these studies will be used to improve future project designs so that water quality benefits can be maximized.

Ohio Lake Erie Tributary Grant: The 2017 GLRI grant awarded nearly $2 million during 2017–2020 to fund local projects that reduce nutrients and improve water quality in tributaries leading to Lake Erie. These projects included restoring stream channels, planting acres of cover crops, and improving drainage water management. One example project is the Maumee River floodplain restoration at Forrest Woods Nature Preserve in Paulding County. The Black Swamp Conservancy led this effort and restored 4,000 linear feet of floodplain, reducing nonpoint source nutrient pollution to Sixmile Cutoff-Maumee River. In addition, wetland and riparian restoration efforts increased terrestrial wildlife habitat and improved aquatic habitat in the watershed.

8.4.3. Environmental Quality Incentives Program

EQIP is the flagship conservation program offered through USDA-NRCS to assist producers in integrating conservation practices into working land. Through EQIP, NRCS provides agricultural producers with one-on-one help and financial assistance to plan and implement conservation practices. EQIP's objective is for NRCS and producers to invest in solutions that conserve natural resources for the future while improving agricultural operations. NRCS can help producers develop a conservation plan that becomes their roadmap for selecting effective conservation practices. NRCS offers about 200 unique practices designed for working farms, ranches, and forests.

Benefits of EQIP include:

- Reduced contamination from agricultural sources, such as animal feeding operations.
- More efficient use of nutrients, which reduces input costs and nonpoint source pollution.
- Improved soil health, which mitigates against increasing weather volatility and improves drought resiliency.
- Implementation of practices that improve carbon sequestration and reduce greenhouse gas emissions while building resilient landscapes.

Through EQIP, technical service providers carry out planning, design, implementation, and monitoring tasks for NRCS conservation program purposes (previously known as Conservation Activity Plans). NRCS has reorganized and renamed these plans into three new categories: Conservation Planning Activities, Design and Implementation Activities, and Conservation Evaluation and Monitoring Activities. These new categories are more clearly aligned with specific phases of the NRCS conservation planning process.

EQIP assistance was used to expand and accelerate conservation opportunities in the Western Lake Erie Basin Initiative (details in Section 8.4.4).

8.4.4. Western Lake Erie Basin project

The WLEB project is a multiagency partnership lead by NRCS to direct strategic resources to improve water quality. Specifically, the partners are dedicated to accelerating Lake Erie's rehabilitation by reducing phosphorus loading through a number of collaborative projects and initiatives. By providing technical and financial assistance to farmers to implement conservation practices, NRCS works improve water quality, enhance soil health, and sustain the region's economic viability. Under the partnership, numerous successful programs have been developed. Project details are available at nrcs.usda.gov/conservation-basics/conservation-by-state/ohio/western-lake-erie-basin-project-ohio.

NRCS partners with farmers and organizations ranging from local SWCDs, state and federal agencies, nongovernmental groups, and others to address natural resource management and agricultural production goals. Through this collaboration, NRCS developed the WLEB Initiative after soliciting recommendations from numerous agricultural, conservation, environmental, research, and government agency partners during a series of meetings held in the fall of 2015. Based on these recommendations, NRCS created the WLEB Initiative—a 3-year, $41 million investment to target, expand, and accelerate conservation solutions in the watershed of western Lake Erie. The WLEB Initiative focuses on comprehensive conservation planning first and foremost. These plans assess the current conditions of an agricultural operation, outline the actions that will have the greatest impact on nutrient and sediment reduction, and estimate the expected environmental benefits. The numerous agencies and organizations that contributed to shaping this initiative will be instrumental in disseminating the information gained from the effort.

Western Lake Erie Basin project success story

The Blanchard River Demonstration Farms Network is a partnership between NRCS and the Ohio Farm Bureau Federation and is also supported through GLRI. The network was launched in 2015 and continues today, showing the importance of collaborative efforts of Ohio's producers, researchers, and government partners to improve water quality.

The Blanchard River is a 103-mile-long tributary of the Auglaize River, located within the Maumee watershed in Ohio. The Blanchard River Demonstration Farms showcase conservation practices that improve agriculture's impact on downstream water quality. Three demonstration sites within the network have collectively evaluated 18 conservation practices, managed over 6,500 acres, and involved more than 25 supporting partners. Specific management practices implemented at the farms include using cover crops and nutrient management with subsurface placement, variable application rate, and soil testing. Structural practices installed on these farms include grassed waterways, wetland creation, and water control structures.

Research at Blanchard River Demonstration Farms and other related sites around the state help researchers determine what practices work best for reducing nutrient and sediment loss. Since the inception of the Blanchard River Demonstration Farms Network in 2015, on-farm research has shown that three practices in particular help reduce nutrient and sediment loss: following 4R approach, reducing soil erosion, and developing a water management plan.

The key initiatives of the Blanchard River Demonstration Farms Network include:

- Establishing sites within the watershed to test new and standard conservation systems in reducing phosphorus and sediment loss.
- Creating opportunities for industry partners to test their research, provide technical assistance, and develop program implementation.
- Establishing an efficient mechanism to share management approaches and information with farmers, agribusiness, conservation agencies, and the public.
- Sharing information and lessons learned from the Blanchard River Watershed throughout the WLEB.

Indeed, the ability to share the work, specifically to showcase conservation practices at different scales and to communicate to varied audiences, is a special component of the Blanchard River Demonstration Farms Network. The demonstration farms have hosted over 50 tours and welcomed thousands of visitors of policy makers, the non-farming public, other farmers, and related groups. The project and farmers have been featured in media interviews and presentations to local and regional technical groups.

One of the demonstration sites, Stateler Family Farms, includes a 7,200-head swine operation that uses innovative manure management practices, including variable rate technology and side-dressing application. This producer actively shares his expertise through the Blanchard River Demonstration Farms Network, including interviews shared through a streaming channel. He recently served on a panel for organic nutrient management coordinated through OSU Extension.

A searchable resources library is hosted on the Blanchard River Demonstration Farms project website (blancharddemofarms.org/). This shares information related to conservation practices that help to reduce nutrient loss and improve the agricultural impact on downstream water quality.

8.4.3. Lake Erie Conservation Reserve Enhancement Program (CREP)

CREP is a part of the CRP, the country's largest private-land conservation program. Administered by USDA-FSA, CREP leverages federal and nonfederal funds to target specific state, regional, or nationally significant conservation concerns. The program is developed through FSA agreements with state and local partners. These agreements are designed to address conservation goals on agricultural lands in specific geographic areas. Conservation practices that can be implemented in this program include riparian buffers, filter strips, wetlands, and pollinator plantings. In return for establishing permanent resource-conserving plant species, farmers are paid an annual rental rate along with other federal and state incentives as applicable within each CREP agreement.

The Lake Erie CREP was initiated in 2000 with a goal to establish 67,000 acres of riparian and upland conservation practices through voluntarily enrollment. The program is available in 27 Ohio counties within WLEB including Allen, Ashland, Auglaize, Crawford, Defiance, Erie, Fulton, Hancock, Hardin, Henry, Huron, Lucas, Lorain, Marion, Medina, Mercer, Ottawa, Paulding, Putnam, Richland, Sandusky, Seneca, Shelby, Van Wert, Williams, Wood, and Wyandot counties. FSA partners with ODA and local SWCDs in administering the Lake Erie CREP. It targets high-priority conservation areas by removing environmentally sensitive land from agricultural production.

8.4.5 Other state legislative actions and policies

While a TMDL is a planning tool, much of the implementation work discussed in this report has been enabled by existing legislative action and policy efforts. In addition to those already mentioned, the following outlines other relevant legislative actions and policy updates:

Ohio SB 1: The provisions of this bill, which became effective July 3, 2015, require major public-owned treatment works (POTWs) to conduct technical and financial capability studies to achieve 1.0 mg/L total phosphorus effluent. It establishes regulations for fertilizer or manure application for persons in the Western Basin of Lake Erie. SB 1 designates the director of Ohio EPA as the coordinator of harmful algae management and response. It requires the director to implement actions that protect against cyanobacteria in the Western Basin of Lake Erie and public water supplies. SB 1 also prohibits the director of Ohio EPA from issuing permits for sludge management that allow placement of sewage sludge on frozen ground, and it prohibits the deposit of dredged material in Lake Erie on or after July 1, 2020, with some exceptions.

Ohio SB 150: The provisions of this bill, which became effective August 21, 2014, require, among other things, that beginning September 31, 2017, fertilizer applicators must be certified and educated on the handling and application of fertilizer. SB 150 also authorizes a person who owns or operates agricultural land to develop a voluntary nutrient management plan or request that one be developed for him or her.

Ohio HB 64: The provisions of this bill, which became effective June 30, 2015, required the development of a biennial report by spring 2016 on mass loading of nutrients delivered to Lake Erie and the Ohio River from Ohio's point and nonpoint sources.

Ohio HB 7: The provisions of this bill, which became effective August 17, 2021, required the development of the Statewide Watershed Planning and Management Program administered by ODA's DSWC. This program includes categorizing watersheds throughout the state and appointing regional watershed coordinators. Watershed management is divided into seven regions based on USGS six-digit HUCs. Each region will have a watershed manager to lead watershed planning and management efforts. Watershed managers will also develop and implement new conservation efforts in the region and support existing conservation activities.

Ohio Clean Lakes Initiative: The Ohio Clean Lakes Initiative was created by the directors of Ohio EPA, ODNR, and ODA in 2012 to implement recommendations from the Directors' Agricultural Nutrients and Water Quality Working Group. To support the initiative, the Ohio General Assembly established the Healthy Lake Erie Fund and provided more than $3.5 million for projects to reduce nutrient runoff in the Western Lake Erie Basin. The fund also provided for installing additional water quality monitoring stations to measure the effectiveness of practices funded through the initiative.

Healthy Lake Erie Initiative: In 2014, the Ohio General Assembly provided $10 million to the Healthy Lake Erie Fund to reduce the open-lake placement of dredge material into Lake Erie. These sediments often contain high levels of nutrients or other contaminants. Therefore, this initiative prioritized finding alternative use or disposal options.

Clean Lake 2020 Plan – SB 299: The bill provides roughly $36 million in funding toward a variety of programs aimed at supporting Lake Erie and reducing toxic algae. This includes $3.5 million of funding to support county SWCDs in the WLEB for staffing and to assist in soil testing, nutrient management plan development, enhanced filter strips, and water management and other conservation support. It also includes funding of up to $20 million for ODA to establish programs to reduce total phosphorus and DRP in subwatersheds of Western Basin of Lake Erie. These programs are being implemented as part of H2Ohio.

Updates to Ohio's NRCS 590 Nutrient Management Standard: Ohio's Nutrient Management Standard (Code 590) is used to manage the rate, source, placement, and timing of fertilizers and soil amendments while reducing environmental impacts. Conservation planners can use this practice on all fields where nutrients, commercial fertilizer and/or manures are applied. These standards are periodically updated. The standard was updated in 2012 to include manure and a phosphorus index. The standard was recently revised in 2020. Highlights of the most recent update are available here, and the complete practice standard can be found at this link: efotg.sc.egov.usda.gov/api/CPSFile/28548/590_OH_CPS_Nutrient_Management_2020.

8.4.6. Targeted research activities

In addition to the significant nutrient reduction implementation efforts in this watershed, targeted research activities provide further reasonable assurances of nonpoint source reduction feasibility. Much of this research demonstrates environmental outcomes of implementation. In addition to helping account for pollution reduction, this information will be used to make implementation adaptive management adjustments. Some research programs and specific projects are outlined below:

HABRI: This program is funded by Ohio Department of Higher Education and is managed by Ohio Sea Grant. HABRI funds applied research at Ohio universities. Research aims to address HAB critical needs and knowledge gaps as identified by Ohio state agencies. The initial round of research funding occurred in 2015, and the program has since distributed $14.5 million. Now in its eighth year of funding, this program continues to provide valuable research insight toward solving the HAB problem in Ohio. In addition to contributing to scientific scholarship, findings and outcomes are shared directly with the agency programs. Several reports detailing projects and outcomes are available at ohioseagrant-test.org.ohio-state.edu/research/collaborations/habs.

H2Ohio Wetlands Study: In addition to constructing wetlands, ODNR's H2Ohio program includes a research effort to document the wetlands' impact on water quality and detail their cost effectiveness. The overall goal of the program is to is to assess nutrient removal of wetland restoration and management strategies. A consortium of researchers, known as the Lake Erie and Aquatic Research Network (LEARN), is leading this effort for ODNR. The H2Ohio Wetland Monitoring Program assesses how wetland restoration can improve water quality. Focus is placed on phosphorus and nitrogen, the key nutrients that fuel eutrophication and HABs. ODNR's wetland projects represent a wide range of wetland types, restoration and construction approaches, and complexity. To improve wetland design and management into the future, the monitoring program helps to understand wetland processes. This comprehensive approach not only determines whether a wetland is effective but also advances the understanding of how wetland systems work. More information is available at lakeerieandaquaticresearch.org.

SWAT modeling revisions: Efforts to improve water quality models and evaluate implementation efforts are ongoing. During 2021–2022 Ohio invested $250,000 as a part of the H2Ohio initiative into enhancements to the Maumee River SWAT models. The existing SWAT model for the Maumee watershed will be adapted to represent the BMP practices available from H2Ohio (as described in Section 7.2.1). Various modeling scenarios will then be examined to refine projections of the H2Ohio program's effectiveness in meeting water quality goals. This effort uses the NCWQR and USGS data for model development.

Conservation Effects Assessment Project (CEAP) Watershed Assessment, Paired Watershed Study: CEAP Watershed Assessment Studies are a partnership between NRCS, ARS, and other federal and university partners. They quantify the effects of conservation practices on water quality, water availability, and soil health within small watersheds. These types of studies also help build understanding of the processes that are influenced by, or that drive, conservation practices.

For this study, the water quality of two subwatersheds (<19 mi^2) within the Blanchard River watershed have been intensely monitored at USGS stream gages beginning in 2018. The treatment phase of the study began in 2020 with prioritized BMPs from the NRCS EQIP and CRP practices in one of the watersheds. For this study, the most promising practices include those that reduce the risk of dissolved phosphorus runoff (e.g., nutrient management/4R nutrient stewardship, phosphorus-removal structures) and those that will retain water on fields to reduce watershed flashiness (e.g., drainage water management, cover crops, blind inlets, gypsum application, and two-stage ditches). This study is ongoing with results expected to start being disseminated in 2023.

Phosphorus Optimal Wetland: The Phosphorous Optimal Wetland demonstration project is a 25-acre wetland test site in Defiance, Ohio. This project will attempt to optimize absorption of phosphorous in runoff by constructing a test bed demonstration wetland. Project objectives include developing wetland management standard operating procedures that result in improvements to downstream water quality. The project seeks to prove the concept that phosphorous trap-and-treat practices can be optimized as an alternative to additional nonpoint source reduction actions. If successful, this project will show ways to increase nonpoint source control effectiveness. Such an innovative solution would ease the burden of reducing nutrient loads from agricultural watersheds.

The project is being led by the Army Corps of Engineers' Buffalo District and its Engineer Research and Development Center, in collaboration with the cities of Defiance and St. Marys, Ohio; U.S. EPA; and other nonfederal partners. The project is funded by GLRI with a budget of $2,325,000. Construction of the demonstration wetland was completed in June 2021. A five-year monitoring program is ongoing, with research completion and technology transfer planned for 2026. More details about this project are available at glri.us/node/458.

8.4.7. Permitting and Enforcement Actions

Ohio EPA NPDES permits program

Ohio EPA's National Pollutant Discharge Elimination System (NPDES) program requires a permit for all facilities discharging pollutants from a point source to a water of the state. Ohio EPA administers the following NPDES permits and programs:

- Individual: An individual NPDES permit is unique to a specific facility.
- General: A general NPDES permit covers facilities with similar operations and wastewater. A general permit is a potential alternative to an individual permit for facilities meeting certain eligibility criteria.
- CSOs: Ohio EPA continues to implement CSO controls through provisions included in NPDES permits and using orders and consent agreements when appropriate. The NPDES permits for Ohio's CSO communities require them to implement the nine minimum control measures. Requirements to develop and implement Long-Term Control Plans are also included where appropriate.
- Pretreatment: The pretreatment program regulates industrial facilities discharging wastewater to publicly owned treatment works.
- Stormwater: Stormwater discharge is generated by runoff from impervious areas such as paved streets, parking lots and building rooftops. Some stormwater discharges are considered point sources and require coverage by an NPDES permit.

- Biosolids: Biosolids are the nutrients-rich organic materials resulting from the treatment of sewage. Proper disposal of biosolids may require a permit.
- CAFOs: There are currently no NPDES regulated CAFOs in the Maumee watershed and the WLA=0 for existing CAFOs because they are not authorized to have point source discharges. While no CAFOs are currently discharging as point sources in the Maumee watershed, Ohio EPA has the authority to issue NPDES permits to facilities that require coverage. The TMDL may need to be modified if there are NPDES regulated CAFOs in the future.

Ohio EPA will use its authority to implement these permit programs to ensure that the permits are issued consistent with the WLAs and assumptions within the TMDL.

ODA-DLEP permit and certification programs

The Division of Livestock Environmental Permitting (DLEP) is charged with regulating the construction and operation of Ohio's largest livestock and poultry facilities, known as CAFFs, using science-based guidelines that protect the environment while allowing the facility to be productive. Ohio has a strong permitting program, and state permit requirements exceed federal rules by requiring siting criteria, as-built construction certification for manure storage structures, yearly ground water monitoring, routine facility inspections, an insect and rodent control plan, and detailed operating records. ODA's routine inspection program is designed to identify potential problems before they become violations so that permitted facilities remain in compliance. DLEP regulates the facilities though the following permits and certifications:

- Permits to install (PTI): The Director of ODA issues PTIs to producers who are in the planning stages of developing or modifying a CAFF. Its purpose is to help assure the proposed facility, its manure storage structures, and location will adequately support such an operation.
- Permits to Operate (PTO): The Director of ODA issues PTOs to producers who operate a CAFF in Ohio. Its purpose is to help assure any proposed or existing facility has developed appropriate best management plans in the areas of manure management, insect and rodent control, animal mortality and emergency response. A PTO also requires specific operating records to be maintained.
- Certified Livestock Manager (CLM) certification: This certification is required of farmers and custom applicators at CAFFs exceeding 10,000 animal units and manure brokers or applicators who buy/sell, land apply or transport more than 4,500 dry tons of solid manure or 25 million gallons of liquid manure.

In addition to permitting and certification requirements, ODA-DLEP investigates complaints related to CAFF operations or CLM to ensure compliance with state law. When CAFFs or CLMs are not in compliance, ODA-DLEP has the authority to pursue enforcement actions.

ODA-DSWC Ag Pollution Abatement Program

Ohio's Agricultural Pollution Abatement Program (APAP) is administered by ODA-Division of Soil and Water Conservation (DSWC) and implemented locally by all 88 SWCDs. OAC 901:13-1 establishes state standards for a level of management and conservation practices in farming and animal feeding operations to abate pollution to waters of the state from soil sediment, animal manure and residual farm products from their farms. OAC 901:13-1 also defines Ohio's pollution abatement grant program for landowners and operators to voluntarily install best management practices and conservation practices.

The Chief of ODA-DSWC has entered into cooperative agreements with all 88 SWCDs to implement the APAP. SWCDs assist ODA-DSWC in implementing the APAP by providing landowners and farm operators' technical assistance, advice and expertise and informing them of the level of management and conservation necessary to comply with the rules and standards. SWCD Board of Supervisors or their designees perform the following tasks:

- Approve or disapprove nutrient management plans;
- Approve or disapprove operation and management plans;
- Investigate agricultural pollution complaints; and
- Record and document all complaints regarding agricultural pollution, and provide those documents to ODA-DSWC (Beehive management software)

When violations of the rules and standards under the APAP cannot be resolved voluntarily, ODA-DSWC may pursue further enforcement that may include civil penalties, administrative penalties and corrective actions. For additional information on APAP, see resources available at: agri.ohio.gov/divisions/soil-and-water-conservation/local-swcd-resources/chapter8_apap.

Enforcement for Clean Water Act prohibited discharges

The TMDL acknowledges several types of discharges that do occur but are prohibited by the Clean Water Act and associated federal requirements or other state requirements. The TMDL does not include a WLA for these sources (WLA=0) because the plan is to eliminate these sources. Discharge prohibitions apply to both SSOs (Section 5.3.1.3) and CAFOs/CAFFs (Section 5.3.4).

When discharges to regulated waters occur Ohio EPA is typically notified through the spill hotline (epa.ohio.gov/help-center/spill-hotline), initiating a response from Ohio EPA emergency response staff. During a response immediate remedial actions are taken to first stop the release and then to remediate the environmental impacts. Following the emergency response and remediation Ohio EPA may pursue further enforcement actions under ORC 6111.04(A). When evaluating whether further actions are required Ohio EPA considers the conditions which led to the discharge, the magnitude of the impact of the unauthorized discharge, the effect of the remedial actions, and other relevant facts. If enforcement is warranted Ohio EPA will issue Director's Findings and Orders or refer the case to the Ohio Attorney General.

8.5. Accountability framework

This section's extensive explanation of programmatic activities demonstrate that implementation is well underway in the Maumee watershed. However, it will take time for these efforts to be realized before they ultimately achieve the nutrient reductions necessary to restore the beneficial uses in Western Basin of Lake Erie impaired by HAB events. As noted in the implementation plan of this TMDL, assessing environmental outcomes and progress toward the delisting goal requires commitments to monitoring and reporting. For this reasonable assurances discussion, the following explains the extensive commitments of accountability in place.

Nearly every project, initiative, program, and/or funding sources has its own requirements for tracking and reporting. For example, progress through the H2Ohio initiative is reported to the public at regular intervals via website updates, periodic reports and infographics, and interactive data dashboards. H2Ohio programmatic metrics reported may include the extent of adoption of agricultural BMPs (number of acres, number of adopters), the number and type of completed wetlands projects, the number and type of Ohio EPA infrastructure projects completed, as well as the progress toward the actual phosphorus load targets. As implementation activities are being put in place, there is a concentrated effort to study the environmental response and to evaluate the outcomes of those activities to, in turn, inform the next phase of efforts.

Monitoring and evaluation efforts extend beyond implementation activities. This occurs in the watershed with water quality monitoring in the tributaries and in nearshore areas, beaches, and drinking water intakes. These efforts inform various advisories, treatment, and ultimately impairment listings. Additionally, the overall extent, intensity, and duration of HAB events in Western Basin of Lake Erie is continuously monitored from space via satellites. Those data are assessed through NOAA's operational forecast products. All this information is readily shared with regulators, water/beach managers, recreation and drinking water users, stakeholders, and the research community through state and federal agency websites.

Monitoring data are evaluated to determine if the beneficial uses are being met. Ohio EPA is responsible for publishing a biennial Integrated (Water Quality Monitoring and Assessment) Report, which fulfills the state's reporting obligations under Section 305(b) (33 U.S.C. 1315) and Section 303(d) (33 U.S.C. 1313) of the federal Clean Water Act. It indicates the general condition of Ohio's waters and lists waters that are currently impaired for specific beneficial uses. The next Integrated Report will be released in 2024. As detailed in Section 7.2.1, an additional report will summarize actions and other monitoring information within the Maumee watershed on the same biennial cycle of the IR (during even years). This ensures an additional level of oversight and timely reporting to document outcomes and ongoing efforts.

Further coordination and oversight of the efforts are detailed in this TDML to reduce nutrient pollution and ultimately limit HABs in Western Basin of Lake Erie. The GLWQA's Annex 4 has an established reporting and coordination structure. The highest priority under this annex is reducing excess phosphorus inputs to Lake Erie, as noted in the recent 2022 Progress Report of the Parties. At the state level, OLEC coordinates state efforts and reports on activities through the Ohio DAP and supporting documents. This information is expected to be incorporated into future updates to the U.S. Action Plan for Lake Erie. The United States and Canada have committed to reviewing and revising the domestic action plans under the GLWQA at least every five years beginning in 2023. Ohio also provides information used in the GLWQA Triennial Progress Report of the Parties which is published every three years. The current Triennial Progress Report was issued in 2022, and the next report will be issued in 2025.

Under the GLWQA, oversight at the federal level is coordinated through the Great Lakes National Program Office (within U.S. EPA) as well as binationally through the IJC. Since the 2012 update of the GLWQA, reporting by the IJC occurs on a triennial cycle and includes public involvement. The progress report was last completed in 2020, and efforts are underway to prepare the 2023 report, including the Great Lakes Public Forum 2022 (detailed reports and information on events are available at binational.net).

9. Public Outreach

U.S. EPA requires that there should be full and meaningful public participation in the TMDL development process. TMDL regulations require that each state/tribe must provide opportunities for public review consistent with its own continuing planning process (40 CFR §130.7[c][1][ii]).

9.1 Required stakeholder and public involvement

Ohio EPA is required to provide the following stakeholder involvement during the TMDL development process in accordance with section 6111.562 of the ORC. Ohio EPA must provide notice of and opportunity for input during the development of a TMDL at each of the following stages:

- The project assessment study plan, including portions of the plan that seek to determine the causes and sources of impairments or threats.
- The biological and water quality study report or an equivalent report.
- The loading analysis plan (LAP), including, but not limited to, the proposed modeling approach and the water quality restoration targets, goals, or criteria.
- The PMR, including any management choices; load allocations for nonpoint sources of pollutants; wasteload allocations for point sources of pollutants; allowances for MOS and future growth; permit limits necessary to achieve the wasteload allocations; and the preliminary TMDL implementation plan establishing specific actions, schedules, and monitoring proposed to effectuate a TMDL.

At each of these steps, Ohio EPA must provide notice to the following stakeholders:

- Potentially affected dischargers.
- County SWCDs.
- Other interested stakeholders, such as a watershed-specific stakeholder distribution list or listserv.

The remaining information in this subsection discusses the reports that were published along with the opportunities for comment.

2018 Integrated Report and Webinar: Ohio EPA's 2018 Integrated Report details the methodology and criteria for listing assessment units in Western Basin of Lake Erie as impaired for recreation beneficial use due to algal biomass and for public drinking water beneficial use due to exceedances of microcystins. A webinar highlighting the main findings of the 2018 Integrated Report was held on April 25, 2018. This report, along with previous and current Integrated Report documents, are available at: epa.ohio.gov/divisions-and-offices/surface-water/reports-data/ohio-integrated-water-quality-monitoring-and-assessment-report; the webinar recording can be found online at: youtube.com/watch?v=nlKoBZSQwYU.

Loading Analysis Plan Public Review and Comments: The Maumee Watershed Nutrient TMDL builds on numerous other pieces that serve as the initial two steps (Study Plan and Biological and Water Quality Report) in the TMDL development process, enabling this project to start on the third step. The Maumee Watershed Nutrient TMDL represents a culmination of efforts from previous workgroups consisting of federal and state agencies, universities, interested stakeholders, and other local partners.

Ohio EPA held a comment period from August 31, 2021, to October 22, 2021, regarding the Maumee Watershed Nutrient TMDL LAP. Ohio EPA received 97 comments during that time. Revisions were made to the LAP based on the comments received during the public review and comment period. More details on the scope of the project were added, including more clearly defining the Maumee watershed and how loads from Michigan and Indiana would be addressed. More details regarding DRP were included, such as DRP targets as a component of total phosphorus, and a new appendix detailing DRP's importance (now included as Appendix 1 of the TMDL report), issues, and the TMDL's plan. More information regarding the model selection process was also included in the final LAP. The final LAP can be found online at: epa.ohio.gov/static/Portals/35/tmdl/LAPs/MaumeeWatershedNutrientTMDL_LAP_Jan2022.pdf. The Response to Comments and agency responses are available at: epa.ohio.gov/static/Portals/35/tmdl/LAPs/MaumeeWatershedNutrientTMDL_LAP_RtoC.pdf.

Preliminary Modeling Results Public Review and Comment: Ohio EPA held a comment period from June 30, 2022, to August 17, 2022, regarding the Maumee Watershed Nutrient TMDL PMR. Ohio EPA received 160 pages of comments from a diverse group of stakeholders including citizens, environmental groups, community organizations, agricultural organizations, and point source facilities and their representative organizations. U.S. EPA also offered comments on the draft report for Ohio EPA's consideration. Substantive revisions to the report were made to Appendix 1 of the PMR (now included as Appendix 3 of the TMDL report), point source allocations, considerations for future growth, MOS considerations, and the model verification. Additional clarifications and minor edits were made as needed. The final PMR can be found online at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/MaumeePMR_Final.pdf. The Response to Comments and agency responses available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/MWN_TMDL_PMR%20RtoC.pdf.

TMDL Public Review and Comments: The draft TMDL was published for public review and comment on December 30, 2022. Ohio EPA provided public notice of the official draft TMDL in accordance with rule 3745-49-07 of the OAC. In addition to the information required by rule 3745-49-08 of the OAC, the public notice specified the water of the state to which the official draft TMDL relates and the time, date, and location of the public hearing, if applicable. Ohio EPA sent the public notice to the following stakeholders:

- All individual NPDES permit holders that discharge into the water of the state to which the official draft TMDL relates.
- All significant industrial users listed in the permit holders' annual report.
- Other stakeholders that provided input during the development of the TMDL.
- Ohio EPA listservs or watershed-specific stakeholder distribution list, if available.
- Ohio EPA shall allow not less than 60 days for comment on the official draft.

9.2 Additional stakeholder and public involvement

In addition to the minimum requirements for public participation, Ohio EPA provided more information to stakeholders through three overview module webinars, project update webinars, and development of a Frequently Asked Questions (FAQ) document. This outreach provided opportunities for the stakeholders and public to ask questions outside of the regular comment periods for specific documents.

Maumee Watershed Nutrient TMDL Overview Modules: To kickoff this TMDL process, Ohio EPA published three overview modules to provide information about the state’s TMDL process and background information regarding the Maumee Watershed Nutrient TMDL. These modules cover an extensive amount of material. All three were posted on the internet as videos and range in duration from 13–80 minutes.

- Module 1: This module is an overview of Ohio’s TMDL process and discussed near-field versus far-field TMDL targets. This module can be found online at: youtu.be/sysR7nq9xkw. The module presentation slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/Outreach-Event-Mod1.pdf.
- Module 2: This module is an overview of the study plans, technical support documents, and other bodies of research that have gone into the development of the Maumee Watershed Nutrient TMDL. This module can be found online at: youtu.be/mPM16l6RFr0. The module presentation slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/Outreach-Event-Mod2.pdf.
- Module 3: This module is an overview of ongoing nutrient reduction efforts across the Maumee watershed. It features highlights from many subject areas within several resource protection agencies within Ohio state government. It also features material presented from Indiana and Michigan state government pollution abatement experts. This module can be found online at: youtu.be/DmuGg7vlSSg. The module presentation slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/Outreach-Event-Mod3.pdf.

Maumee Watershed Nutrient TMDL FAQ: The FAQ document is a tool to help answer questions that stakeholders often ask Ohio EPA about the Maumee Watershed Nutrient TMDL. As the project progressed, the FAQ document was updated with new questions and answers, as well as refined answers to existing questions as new information became available and new management decisions were made. The FAQ document can be found online at: epa.ohio.gov/static/Portals/35/tmdl/Maumee-Watershed-Nutrient-TMDL-FAQ.pdf.

Maumee Watershed Nutrient TMDL Project Update Webinars: Routine webinars were hosted by Ohio EPA to share project updates as TMDL documents were developed. Summaries of these webinars are presented below.

- Outreach webinar – October 5, 2021. This webinar is an overview of the Maumee Watershed Nutrient TMDL LAP. The webinar was held during the LAP public comment period and covered the “where, what, when, and how” of the TMDL. The webinar recording can be found online at: youtu.be/Npw4GuhjTVM.

- Outreach webinar – December 14, 2021. This webinar discussed revisions to the LAP. It discussed the next steps and what to expect from the PMR. The webinar recording can be found online at: youtu.be/Virc6l6u4bo.
- Outreach webinar – January 20, 2022. This webinar discussed the outline for the PMR, the schedule for the project, and the outreach plan. This webinar recording can be found online at: youtu.be/PmJeJZiMd54. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/20220120-MaumeeWatershedTMDL.pdf.
- Outreach webinar – March 1, 2022. This webinar discussed the sources of phosphorus. The discussion included sources from agriculture fertilizer, legacy phosphorus, ditch and streamside sources, natural sources and atmospheric deposition, stormwater, and HSTS. This webinar also discussed the critical source areas in the Maumee watershed. The webinar recording can be found online at: youtu.be/tOEChNz2_18. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeWatershedTMDL-Slides-20220301.pdf.
- Outreach webinar – March 29, 2022. This webinar discussed management choices for achieving phosphorus reductions, an appropriate MOS, a plan for future growth, and how to appropriately allocate load between point and nonpoint sources. The discussion included loading trends in the Maumee watershed, evaluating implementation opportunities to find cost-effective solutions, ODA's authority over agricultural nutrient applications, climate impacts and accounting for climate in the TMDL, and ODNR implementation opportunities. The webinar recording can be found online at: youtu.be/SOHJLQynWZw. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/20220329_MaumeeWatershedTMDL_OutreachMeeting.pdf.
- Outreach webinar – April 28, 2022. This webinar discussed the role of nonpoint source sinks in TMDL allocations and NPDES wasteload allocations. The discussion included the use of natural infrastructure in the implementation plan, point source contributions of phosphorus and work they have done to reduce phosphorus, and the proposal of NPDES watershed general permit. The webinar recording can be found online at: youtu.be/UDKGMQWl3a4. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeWatershedTMDL-webinar-20220428.pdf.
- Outreach webinar – June 1, 2022. This webinar discussed the implementation plan for the Maumee Watershed Nutrient TMDL. This included BMPs for different sources of phosphorus, implementation milestones to track the success of the implementation plan, and ways to adjust the implementation plan. The new NPDES watershed general permit was discussed in further detail. The webinar recording can be found online at: youtube.com/watch?v=jAptG3BjmCU. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/Maumee-Nutrient-TMDL-062022.pdf.
- Outreach webinar – June 29, 2022. This webinar reviewed Lake Erie impairments and how they would be addressed in the PMR. This included discussing sources of phosphorus in the Maumee watershed, discussion of the model used to determine TMDLs, overall TMDL allocations, and the preliminary implementation plan. The webinar recording can be found online at: youtube.com/watch?v=pE6EI_SuOac. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/20220629_MaumeeTMDL_webinar.pdf.
- Outreach webinar – July 14, 2022. This webinar discussed the content of the PMR report. This included source assessment and critical source areas, methods and results, and the preliminary implementation plan. The meeting allowed time between each section for questions from the public. The webinar recording can be found online at: youtu.be/8Sf3Z-rnkCM. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/20220714_MaumeeTMDL_presentation.pdf.
- Outreach webinar – September 21, 2022. This webinar updated the public on the PMR comments, schedule, and new outreach efforts to target underserved communities. The webinar recording can be found online

at: youtu.be/JdfpqmFsoXk. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/20220921_MaumeeWatershedTMDL_webinar.pdf.

- Outreach webinar – December 20, 2022. This webinar updated the public on the response to comments received on the PMR report and details on new content and timeline for the draft TMDL report. The webinar recording can be found online at: youtu.be/H5sO_pUvRTY. The meeting slides are available at: epa.ohio.gov/static/Portals/35/tmdl/MaumeeNutrient/20221220_MaumeeTMDL_webinar.pdf.
- Outreach webinar – February 8, 2023. This webinar updated the public on the content of the draft TMDL report during the stakeholder outreach comment period. The webinar recording can be found online at youtu.be/NCkuXd5bomU.