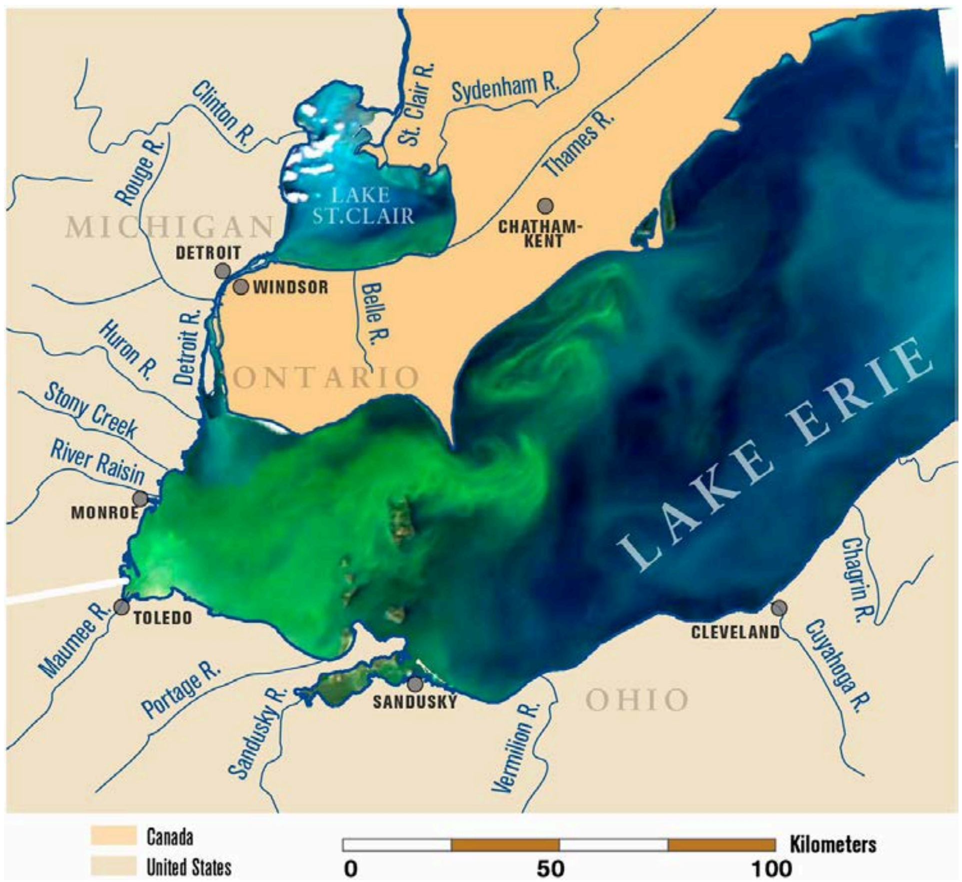
Loading Analysis Plan and Supporting Data Acquisition Needed for the

Maumee Watershed Nutrient

Total Maximum Daily Load Development



Anna M. Michalak et al. PNAS 2013;110:16:6448-6452

Ohio EPA Technical Report AMS/2020-MWN-3

Division of Surface Water
Assessment and Modeling Section
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TMDL DEVELOPMENT |

Table of Contents

Introduction

This document provides an overview of the information considered in proposing analytical method(s) to develop Total Maximum Daily Loads (TMDLs) for the Maumee River watershed to address shoreline and open water impairments in the Western Basin of Lake Erie caused by cyanobacteria harmful algal blooms (HABs) as identified in Table 1 below. Ohio EPA listed the Ohio shoreline and open water of Lake Erie's western basin and islands shoreline as impaired in the amended 2016, 2018, and 2020 Integrated Water Quality Monitoring and Assessment Reports (Ohio EPA 2018a, 2018b, 2020) for recreation use due to HABs. The proposed TMDL report discussed herein will address these impairments in addition to public drinking water supply impairments in these assessment units. Water quality impairments in the Maumee River mainstem and tributaries will be addressed through separate, subsequent near-field TMDL projects.

This Loading Analysis Plan (LAP) is the third step in the TMDL development process. The LAP explains the following three important aspects of a TMDL project.

1) **It lists assessment units found to be impaired for a beneficial use designation (e.g., aquatic life, recreation, and public water supply).**
2) **How water quality restoration targets are set to directly address the recreation and public water supply use impairments due to HABs, and are protective of aquatic life use impairments due to nutrients.**
3) **It proposes modeling method(s) for the TMDL loading calculations.**

The actual TMDL load calculations and allocations will be provided at the next step in the process, a document called the Preliminary Modeling Results (PMR).

This project is a change in scale for Ohio's TMDL program. In the past, local stream or river "near-field" impairments were the focus of TMDL projects. Nutrient loading targets required to achieve adequate reductions in the Western Basin of Lake Erie's algae have been outlined; however, existing TMDLs that cover much of the watershed draining to the Western Basin of Lake Erie do not require enough nutrient reductions to meet these targets. In a report, U.S. EPA (2018) found that that areal extent of impaired subwatersheds in the Maumee River basin with TMDLs developed using near-field TMDL targets (i.e., TMDLs that addressed nutrients impairments within the watershed's tributary rivers and streams) were too few to reach the Western Basin of Lake Erie Annex 4 targets. Further, these near-field TMDLs used targets and often hydrology that focused on stream low flow critical periods from June 15 – October 15. A period that does not align with the Annex 4 critical period (March to July) which is explained in this report.

This project is considered as a "far-field" TMDL. This term indicates that impairment in the Western Basin of Lake Erie is well downstream of the sources of pollutants causing the impairment. This far-field TMDL project is much broader in scale than a near-field TMDL and applies to the entire watershed drained by the Maumee River. Because of this, the portions of the Maumee River watershed in Indiana and Michigan will be included in this TMDL's calculations, as explained in the Proposed Actions to Address Algal Impairments of Recreation Waters section of this document. However, TMDL pollutant allocations will not be provided for the non-Ohio portion of the watershed. Total phosphorus is the TMDL pollutant, and measures will be taken to ensure dissolved reactive phosphorus (DRP) is specifically addressed as a proportion of total phosphorus. The reasons for focusing on the seven 8-digit hydrologic units of the Maumee River watershed and using these parameters are explained in the Proposed Targets section.

This project builds on numerous other pieces that serve as the previous steps 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. The following lists these documents and projects based on which step they service for this TMDL project. See Appendix A for more detail on how each item applies to this TMDL project.

Step 1 Study Plan Documents:

- ***Ohio Lake Erie Phosphorus Task Force Phase I (2010)***
- ***Ohio Lake Erie Phosphorus Task Force Phase II (2013)***
- ***State of Ohio Directors' Agricultural Nutrients and Water Quality Working Group (2011)***
- ***Point Source and Urban Runoff Nutrient Workgroup Final Report and Recommendations (2012)***
- ***Ohio's Nutrient Reduction Strategy (2013, 2015)***
- ***Annex 4 Objectives and Targets Task Team Final Report, Recommended Phosphorus Loading Targets for Lake Erie (2015)***
- ***Ohio EPA's Maumee River watershed Near-Field TMDLs***
- ***U.S. EPA's Methodology for Connecting Annex 4 Water Quality Targets with TMDLs in the Maumee River Basin project (2018)***
- Tributary nutrient monitoring, outlined in the report: ***Expanded Lake Erie Tributary Nutrient Load Monitoring Report***
- Ohio EPA's Nutrient Mass Balance Study for Ohio's Major Rivers (***2016, 2018, 2020***)
- ***Ohio Domestic Action Plan (2020)***

Step 2 Biological and Water Quality Report or Equivalent Documents:

- ***NOAA's Cyanobacteria Index and Harmful Algal Bloom Forecast***
- "Science meets policy: A framework for determining impairment designation criteria for large waterbodies affected by cyanobacteria harmful algal blooms." (Davis et al., 2019).
- ***Lake Erie HAB monitoring data and algae toxin results***
- "The Lake Erie HABs Grab: A binational collaboration to characterize the western basin cyanobacterial harmful algal blooms at an unprecedented high-resolution spatial scale." (Chaffin, 2021).
- Listing of the Ohio Lake Erie Western Basin shoreline and open water and islands shoreline on Ohio's 303(d) list for recreation impairment due to harmful algal blooms in Ohio's biennial Integrated Water Quality Monitoring and Assessment Reports (***2016 amended, 2018, 2020***)

Project Outreach

Ohio EPA hosts a webpage for this TMDL project that serves as a repository for all project information. This website's address is: ***epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/surface-water/reports-data/maumee-river-watershed.***

Outreach for this TMDL project began in early 2021 with the release of three outreach module videos. The first module explained Ohio's TMDL process and the far-field nature of this project. The second module provided an outline of all the TMDL step's 1 and 2 documents listed above. This module asked stakeholders to suggest any additional documents and/or projects they would like the Ohio EPA to include for consideration in the TMDL step's

1 and 2 stages of this TMDL. The second module also provided an overview of the required elements for this LAP document. A third module outlined information about the existing and ongoing actions to reduce nutrients in the Maumee watershed. Stakeholder feedback from these modules have been considered in this LAP document and will be used to inform subsequent TMDL development. The following documents were referenced in stakeholder comments:

- ODA Permits for CAFO's and livestock expansions
- USDA Census of Agriculture data
- Ohio's Concentrated Animal Feeding Facilities: A Review of Statewide Manure Management and Phosphorus Applications in the Western Lake Erie Watershed – Ohio Environmental Council
- Manure From Unregulated Factory Farms Fuels Lake Erie's Toxic Algae Blooms – Environmental Working Group and Environmental Law & Policy Center
- Summary of Findings and Strategies to Move Toward a 40% Phosphorus Reduction – Whitepaper Consortium led by Ohio Sea Grant
- Upper Maumee River Watershed Management Plan
- Toledo Harbor Sediment Use Plan prepared for the Toledo Harbor Dredge Task Force Great Lakes Restoration Initiative Project. U.S. EPA Grant # GL-E00523 Prepared for: Ohio Lake Erie Commission 111 Shoreline Drive, Sandusky, Ohio 44870, and the Toledo-Lucas County Port Authority One Maritime Plaza Toledo Ohio 43604, Prepared by: Hull & Associates, Inc. 3401 Glendale Avenue Suite 300 Toledo Ohio 43614. December 2012
- Ohio Sea Grant's recent "Understanding Algal Blooms: State of the Science" conference presentation on the role of in-stream processes in shaping p exports to Lake Erie during low and high flows
- NRCS 2017 CEAP Study indicated that meeting a 40 percent edge-of-field phosphorus reduction target would reduce the phosphorus load to Lake Erie up to a maximum of 23 percent due to legacy phosphorus in the delivery system. (USDA-NRCS. 2017. Conservation Practice Adoption on Cultivated Cropland Acres: Effects on Instream Nutrient and Sediment Dynamics and Delivery in Western Lake Erie Basin, 2003-06 and 2012. 77pp.)
- "Shifts in precipitation and agricultural intensity increase phosphorus concentrations and loads in an agricultural watershed" by Donald M. Waller, Andrew G. Meyer, Zach Raff, and Steven I. Apfelbaum – University of Wisconsin and Marquette
- "China requires region-specific manure treatment and recycling technologies" by Zhaohai Bai, Xuan Wang, Xiaofei Wu, Weishuai Wang, Ling Liu, Xiaohang Zhang, Xiangwen Fan, and Lin Ma Center for Agricultural Resources Research, Institute of Genetic and Developmental Biology, Chinese Academy of Science

Ohio EPA issued this LAP document as a draft for at least 30-days to collect stakeholder comments. Ohio EPA held a virtual outreach event on Oct. 5, 2021, to discuss this report during the public comment period. The comment period was extended from Oct. 8, 2021 to Oct. 22, 2021. A total of 14 sets of comments were received. A response to comments document has been prepared and changes have been made to the LAP prior to it being published as final.

An additional 30-day outreach period will occur following the posting of the draft Preliminary Modeling Results report, the next step in this TMDL project. Finally, a 60-day public comment period will occur following the posting of the draft TMDL document. In addition to the public comment periods there will be monthly webinars, in-person outreach, and targeted workgroups occurring while the Preliminary Modeling Results report and draft TMDL report are developed.

Assessment Units

In Ohio EPA's 2018 and 2020 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2020a; herein referred to as Integrated Report), Ohio's Lake Erie waters were divided up into seven assessment units. There are three assessment units within Ohio's borders of the Western Basin of Lake Erie – western basin shoreline, western basin open water and islands shoreline (assessment units 041202000201, 041202000301, and 041202000101, respectively). Figure 1 shows these assessment units and the Maumee River watershed that are the focus of this TMDL project. Table 1 outlines the 8-digit hydrologic unit code (HUC) watersheds in the Maumee River watershed that are included in this project; there are seven of them.

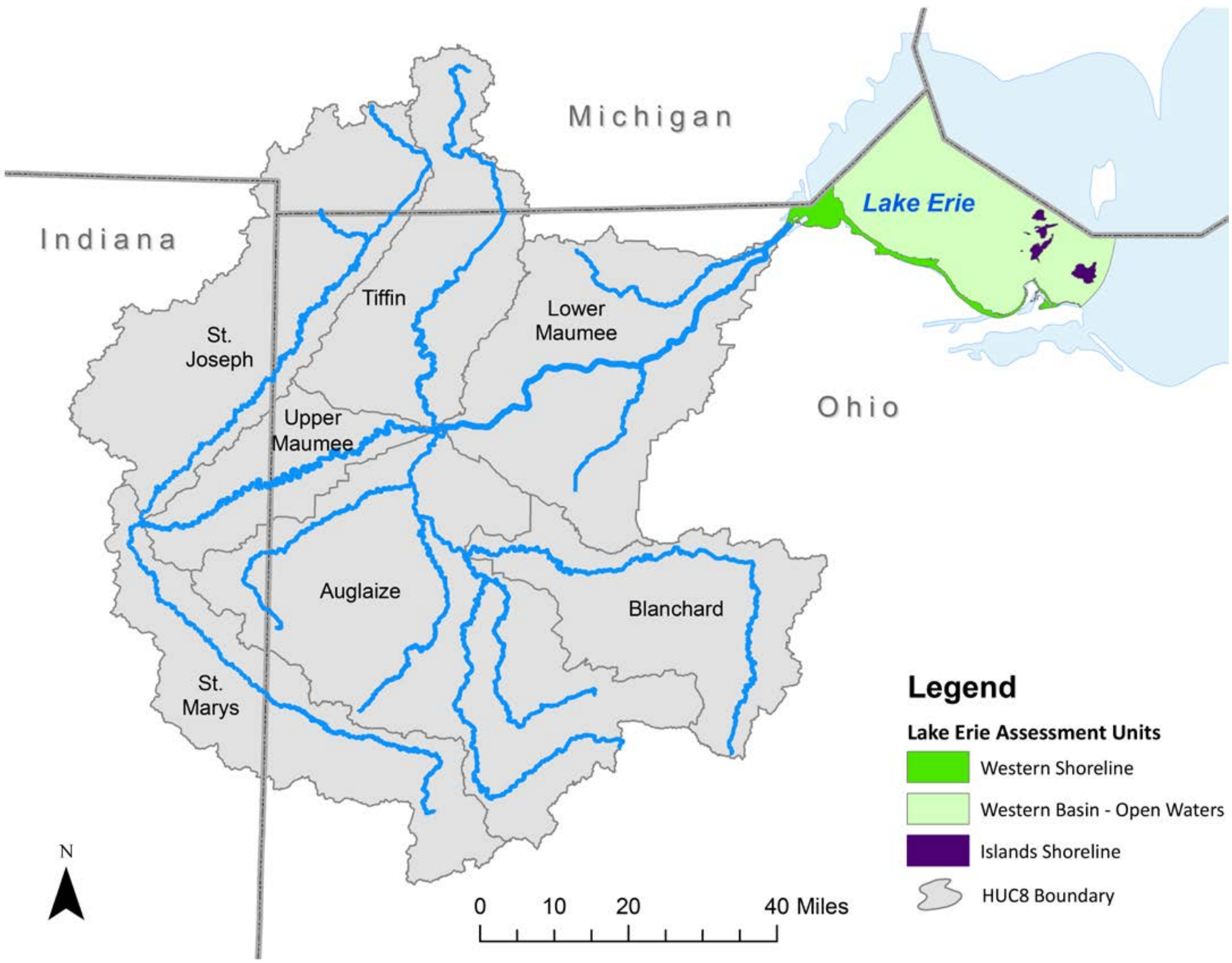

Figure 1: Map of Ohio's Western Basin of Lake Erie assessment units and the Maumee River watershed

Table 1 – Maumee River watershed HUC8s included in this TMDL.

HUC 8	Watershed Name	HUC 8	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		

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

Designated Uses

In Ohio Administrative Code (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.

The following sections review the attainment status 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 islands shoreline).

Recreation Use (algae)

Evaluation of Criteria

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 the 2020 Integrated Report (Ohio EPA, 2020a) 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 (NOAA) are reviewed in 10-day frames during bloom season, July through October. If more than three 10-day frames in a year have an average cyanobacteria cell count of greater than 20,000 cells/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 previous 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. Table 2 provides shows the impairment status for this use.

Table 2 – Recreation use attainment information for the Western Basin Lake Erie Open Waters and Shoreline assessment units, first identified as impaired in the amended 2016 Integrated Report.

Assessment Unit Code	Assessment Unit Name	Attainment Status	Cause
041202000201	Western Basin Shoreline	Non	Algae
041202000301	Western Basin Open Waters	Non	Algae
041202000101	Island Shorelines	Non	Algae

Proposed Actions to Address Algal Impairments of Recreation Waters

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 waterbody kinetics involved, will determine the complexity needed in a model. Additionally, Ohio EPA must take into consideration 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 targets section of this report explains Lake Erie nutrient reduction recommendations that that were developed to address HABs. These recommendations culminated several modeling efforts of various methods and scope. This included hydrodynamic lake models that considered metrological, current (including seiche impacts), and limnological factors Lake Erie experiences. With the nutrient reduction recommendations determined from that effort final and being used by this TMDL, lake modeling is not needed. Rather, modeling for this TMDL focuses on nutrient source allocation within the Maumee River watershed. A summary of Ohio EPA's preliminary modeling approach is presented in Table 3.

Table 3 – Summary of Recreation Use (algae) impairments and potential modeling approaches.

Assessment Unit	Cause of Impairment	Source(s) of Impairment	Integrated Report Category[a]	Action	Method	Parameter
041202000201	Algae	Nutrients from Maumee River	5	TMDL	Mass Balance	Total phosphorus
041202000301	Algae	Nutrients from Maumee River	5	TMDL	Mass Balance	Total phosphorus
041202000101	Algae	Nutrients from Maumee River	5	TMDL	Mass Balance	Total phosphorus

[a] The Integrated Report Category of 5 means the assessment unit is impaired by a pollutant and is not currently addressed by a TMDL.

Different modeling methods were evaluated 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 (Table 4). Due to the prevalence in prior studies in this watershed, model evaluation focused primarily on utilizing the data driven mass balance methods and process-based 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 unknowns (Table 4).

Table 4 – 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

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 1970's when efforts were initiated to reverse cultural eutrophication of the Great Lakes (Dolan, 2012). These initial mass balance modeling efforts were most recently extended to the period of 1967 – 2013 for Lake Erie as efforts to address the re-eutrophication and harmful algal blooms amplified (Maccoux, 2016). In 2015, the Ohio General Assembly added a statutory requirement [Ohio Revised Code 6111.03 (U)] stating that Ohio EPA will; "study, examine, and calculate nutrient loading from point and nonpoint sources in order to determine comparative contributions by those sources, and report every two years." The result of this statutory requirement were three iterations of a report titled "Nutrient Mass Balance Study for Ohio's Major Rivers"; most recently published in 2020. Ohio EPA's mass balance studies sought to refine the mass balance methods to include sources not addressed in the previous efforts, most notably household sewage treatment systems and combined sewer overflows (Ohio EPA, 2020b). The mass balance will be further refined for this project's TMDL calculations to attribute loads to municipal separate storm sewer systems that were lumped with the nonpoint sources in previous efforts.

Robust tributary and edge-of-field water quality monitoring in the region supports this effort by providing detailed information from loading sources, as well as loadings near the watershed outlet at the Waterville gaging station. This includes over twenty-five tributary monitoring stations throughout the Maumee River watershed, most of which have a period of record at least ten years long. With such an abundance of high-quality data available the need for a process-based watershed model to quantify watershed loading is minimized. 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 due to 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. The method Ohio uses considers that the point source (including CSOs) and calculated home sewage treatment system loads to be completely delivered to the downstream pour point. Explained below, TMDL allocations will be carried out for total phosphorus. For longer periods of time, such as the five-month loading period applicable to this TMDL, assuming conservation of the total phosphorus point source loads is consistent with the literature cited earlier in this section.

Both mass balance modeling and process-driven models (like SWAT) require generalizing assumptions to be 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 such that agricultural practices are applied uniformly across the watershed. In both cases, this limits detail captured about what specific landscape and management factors are driving loads higher on some fields than others. The data required to parameterize a process-based model to better represent these factors 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). Where 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 is 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.

While the mass balance method was selected to develop the TMDL, process-driven SWAT models have been widely employed in the Maumee River 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. Ohio EPA recognizes their usefulness in testing certain hypothesis about implementation and will continue to interact with institutions and researchers that utilize 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. While the mass balance model lacks predictive ability, results from research employing process-driven models will be utilized to inform implementation strategies.

Out-of-state loads

While this TMDL is a state of Ohio 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, and they participated in the third module of initial outreach noted earlier in this document. Efforts will continue to coordinate with all three states to maximize nutrient reduction implementation practices and projects.

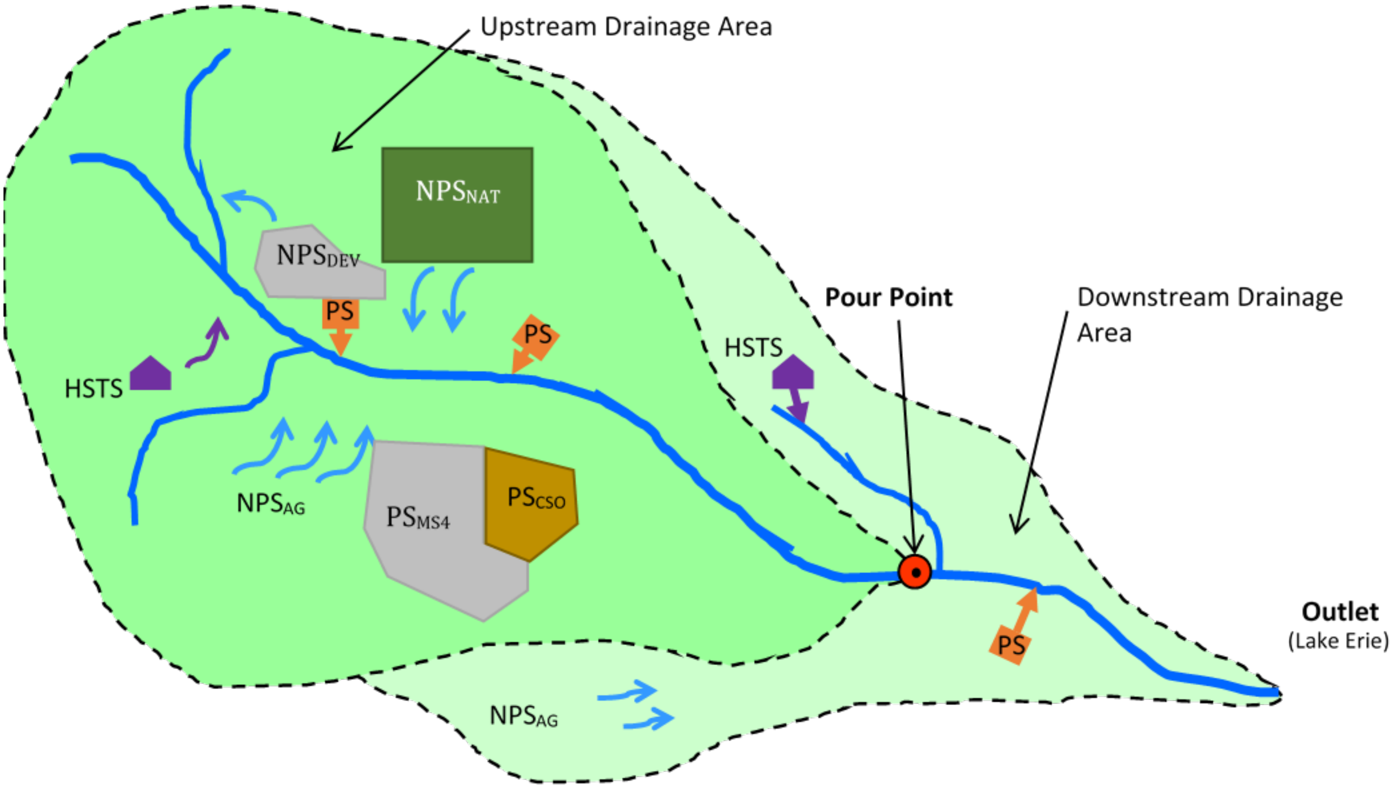

Figure 2: Graphic representation of different allocation categories that will be accounted for in the studies. Sources are identified if they are point sources (PS) that will be included in the wasteload allocation or nonpoint sources that will be included in the load allocation in the TMDL. Subcategories of point sources include municipal and industrial treatment facilities (PS), municipal separate storm sewer systems (PS_{MS4}), combined sewer overflows (PS_{CSO}), discharging household sewage treatment systems (HSTS). Subcategories of nonpoint sources (NPS) will include agricultural land (NPS_{AG}), on-site HSTS, unregulated developed land (NPS_{DEV}), and natural land (NPS_{NAT}).

Proposed Targets to Address Algal Impairments of Recreation Waters

The targets for this TMDL project are based on the Great Lakes Water Quality Agreement's Annex 4 Objectives and Targets Task Team Final Report, "Recommended Phosphorus Loading Targets for Lake Erie" (Annex 4, 2015). This document, referred to herein as the 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…." The Targets document explains total and dissolved reactive phosphorus load targets for the Maumee River to the Waterville, Ohio monitoring point of 860 and 186 metric tons, respectively, for this spring loading period. These target loads are expected to result in Western Basin of Lake Erie HAB blooms at or equal to the blooms observed in 2004 or 2012, which are considered years with mild, acceptable sized blooms, 90 percent of the time. With targets framed in this manner, they are translated to be met in nine out of ten 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. 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 in a more practical manner. 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 adhere to the Annex 4 western Lake Erie HAB objective but done so in a fashion that can be used for actual listing/delisting purposes. Annex 4 does not have to consider these demands. As a component of the Great Lakes Water Quality Agreement, it does not have authority or expectation to implement Clean Water Act provisions such as Section 303(d). Meeting the targets developed by the Annex 4 Targets and Objectives Task Team will result in conditions that result in attainment of Ohio's assessment of the recreation use.

Flow weighted mean concentrations that corresponded to these loading targets are also provided in the Targets document for the Maumee River. These are 0.23 and 0.05 mg/L for total phosphorus and dissolved reactive phosphorus, respectively. These concentration targets provide a benchmark to track progress of load reduction. Flow weighted means are used instead of standard concentrations as 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 great deal wetter or dryer than the norm. TMDLs are inherently load based planning tools, therefore the concentrations outlined in the Targets document will not be included in this TMDL project's allocations. The flow weighted mean concentration targets are, however, included in the Ohio Domestic Action Plan and will be evaluated to facilitate adaptive implementation.

The Targets document provides spring season load targets for other Western Basin of Lake Erie tributaries. The Targets document explains that these targets are to address the HABs in the mouths of these tributaries and, "adjacent nearshore water." This Maumee Watershed Nutrient TMDL is focused on addressing the three impaired Lake Erie assessment units outlined above in this document. Therefore, this project is focused on the phosphorus load exclusively from the Maumee River watershed and does not include other priority tributaries in Ohio. Actions to address targets for the other tributaries are outlined in the Ohio Domestic Action Plan (Ohio Lake Erie Commission, 2020a).

The 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 in working towards hypoxia targets, because there is no impairment present, this TMDL is not explicitly addressing these targets.

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 has been continuously collected at this location by the National Center for Water Quality Research (NCWQR). This monitoring includes water quality samples collected three times a 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 mi^2 of the 6,607 mi^2 total Maumee watershed area; greater 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, 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, in this TMDL.

Figure 3 highlights aspects of the Maumee watershed that are important for the TMDL. Generalized land use is presented on this map. The watershed divide for up and downstream of the Waterville monitoring location is outlined in yellow. Note that the watershed downstream of Waterville, which includes most of the greater Toledo metro area, is far denser in urban and natural land uses than upstream of Waterville. Not shown on Figure 3, but to be included in the next TMDL project document, a denser presence of large municipal wastewater treatment plants also exists downstream of Waterville. Because of these factors, Ohio EPA considers it very important to include this area in the Maumee Watershed Nutrient TMDL.

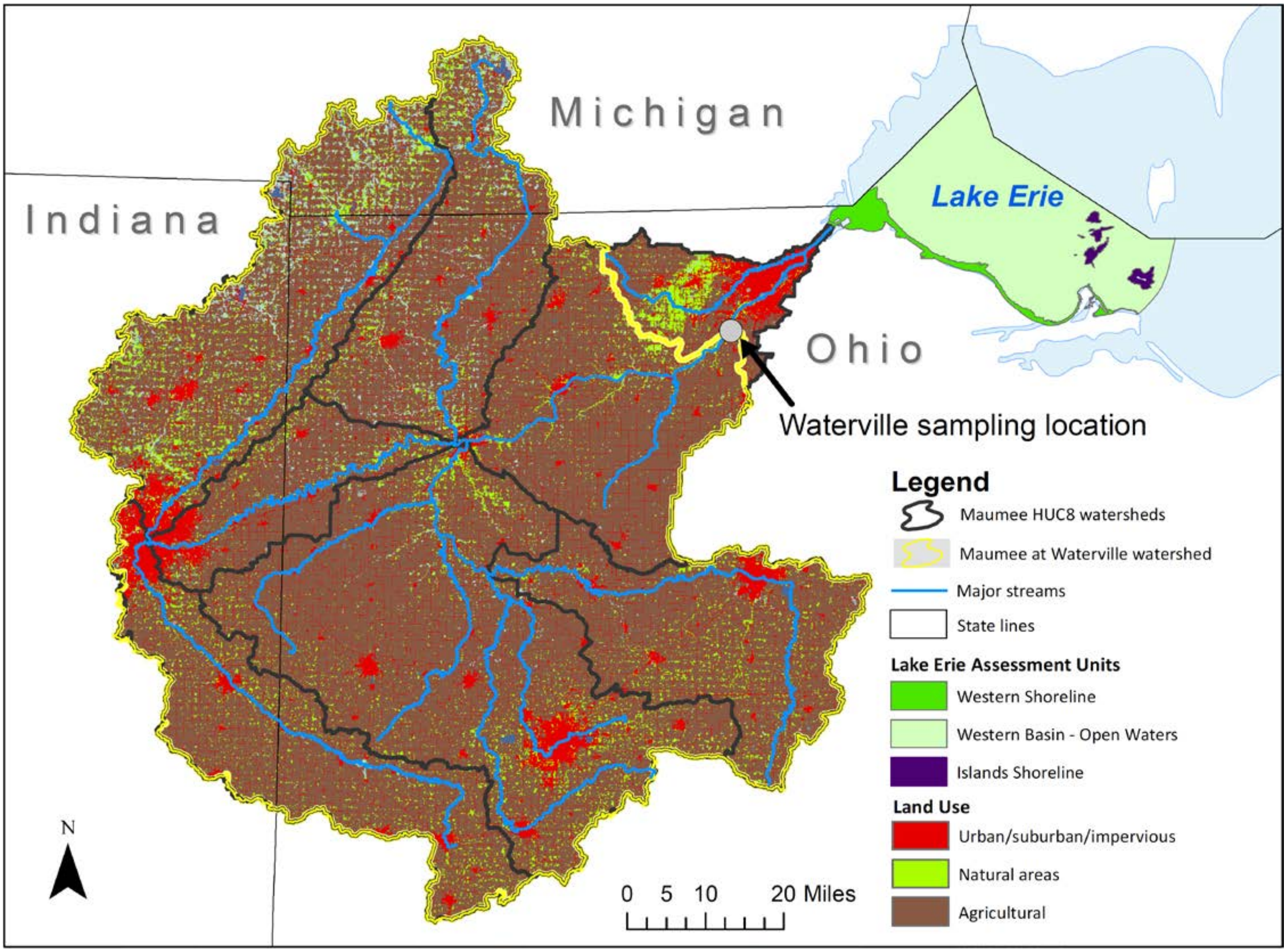

Figure 3: Maumee River watershed map showing generalized land uses. The Waterville monitoring point is located with a gray dot and that locations watershed is highlighted as a yellow line.

To include the area downstream of Waterville in this TMDL's target, the Annex 4's total phosphorus target must be extrapolated. The Targets document noted that the 860 metric tons target for Waterville is "approximately a 40 percent reduction" from the 2008 baseline spring season used for target calculations. The exact load at Waterville for the 2008 spring season is 1,414.1 metric tons (National Center for Water Quality Research, personal communication, 2020). The 860 metric tons target is a 39.2 percent reduction from that baseline. Ohio EPA utilized nutrient mass balance methods, discussed in the section above and documented in Ohio Lake Erie Commission, 2020a (see Appendix A), to determine that the load downstream of Waterville in the 2008 season contributed an additional 89.5 metric tons. This equates to a combined full Maumee 2008 spring season load of 1503.6 metric tons. Applying the 39.2 percent reduction from the Targets document results in a full Maumee watershed total phosphorus target of 914.4 metric tons. To account for extreme weather years loading targets are to be met in 9-of-10 years.

Table 5 summarizes the targets that will be used for TMDL development. Allocations in the TMDL will be provided for the Waterville monitoring location and the complete Maumee watershed. The former will allow for the Waterville station to be used as the primary tracking tool of TMDL implementation nutrient reduction success.

Table 5: Maumee Watershed Nutrient TMDL Targets

Maumee River at Waterville, Ohio 41.4998, -83.7140	**Spring (March – July)**
Total Phosphorus load	860.0 metric tons#
Maumee River at mouth/Maumee Bay 41.6937, -83.4682	
Total Phosphorus load	914.4 metric tons#

#to be met 9-of-10 years to account for inter-annual flow variability for the March-July period in extreme years.

Only total phosphorus will be used to develop allocations. However, in recognition of its importance, dissolved reactive phosphorus (DRP) will be incorporated into this TMDL and specifically addressed in several ways.

Dissolved reactive phosphorus (DRP) is a subset of total phosphorus; it is the part that is directly available for algal growth. In 2015, the governors of Michigan and Ohio and the premier of Ontario committed to both TP and DRP reductions (Conference of Great Lakes and St. Lawrence Governors and Premiers, 2015). Ohio recommitted to this agreement in 2019. The Maumee River at the Waterville monitoring station's DRP springtime loading target is 186 metric tons with a flow weighted mean concentration of 0.05 mg/L.

The non-conservative nature of DRP means DRP loads cannot be allocated to specific sources with an acceptable level of certainty using available modeling techniques (see Appendix B). Available data about DRP at source locations and pour point monitoring sites will be used to inform implementation. For example, an analysis of the DRP proportion of total phosphorus at various existing flow conditions will be included in the TMDL Preliminary Modeling Results report. This will provide information to inform where reductions are necessary based on relative contribution during different flow conditions. DRP targets will be plotted at the pour point location to show the impact of reductions at various flow intervals required to achieve loading and FWMC targets.

Many pollutant reduction practices (or best management practices) used to reduce total phosphorus can equally or even more effectively reduce DRP. However, emerging research shows that some practices reduce the particulate portion of total phosphorus, but inadvertently allow for the release of more DRP. This TMDL project will promote implementation of practices that that will maximize DRP reductions. Ohio is coordinating with researchers and implementation experts to this end.

Development of this TMDL is informed by high quality monitoring data. As implementation progresses, this data will serve as a basis to make adaptive management decisions during TMDL implementation. Adaptive implementation will be included in the Preliminary Modeling Results stage of this project and more explanation of this plan can be found in Appendix B of this report.

Public Drinking Water Supply Use

Evaluation of Criteria

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 the 2020 Integrated Report. The summary of the drinking water thresholds is in Table 6. A summary of attainment status and associated data is presented in Table 7.

Table 6 – Public drinking water supply use attainment determination for algal toxins (Ohio EPA, 2020a Section H, Table H-1).

Indicator	Impaired Conditions
Algae: Cyanotoxins[b]	Two or more excursions[a] above the state drinking water thresholds (microcystins = 1.6 µg/L) within the 5-year period
	Full Attainment Conditions
	No more than one excursion[a] 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

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

[b] 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.

Table 7 – Public drinking water supply information for impaired sampling locations in the Western Basin Lake Erie Open Waters and Shoreline assessment units.

Assessment Unit	Cause of Impairment	Summary of Key Water Quality Data	Possible Source(s)
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 2017-2019.	Nutrients from Direct Tributaries
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, 2014, and 2015-2019. Toledo had raw water samples that exceeded the microcystins threshold in 2010, 2011, 2013-2015, and 2017-2019. Marblehead had raw water samples that exceed the microcystins threshold in 2015 and	Nutrients from Maumee River

		2017. Kelley's Island had results above the threshold from 2015, 2017, and 2018.	
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.	Nutrients from Maumee River

Proposed Actions and Targets to Address Public Drinking Water Supply Impairments

The impairments to recreation use and to public drinking water supplies in the Western Basin of Lake Erie are both linked to HABs, specifically those producing microcystin, and will be 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 for drinking water facilities. A recent publication (Chaffin et al., 2021) characterizes spatial and temporal dynamics of microcystins in western Lake Erie during HAB blooms and supports 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.

When 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 target years, 2004 and 2012, occurred prior to routine compliance monitoring for total microcystin 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 (data accessible at ***epa.ohio.gov/wps/portal/gov/epa/monitor-pollution/pollution-issues/harmful-algae-blooms***). The majority (94 percent) of microcystin samples that year were below the detection limit. While only three results near public water system intakes exceeded the water quality standard, all occurred within a one-week period. Were the current metrics established at that time, the assessment unit would have been on the watchlist (Table 6) but it would not have been impaired. Similar to 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, which would result in drinking water targets (met in the goal year of 2012) to be met at the assessment target of four out of five years.

The TMDLs for recreation use impairments due to algae, explained in the prior section, will directly address the public drinking water use impairments. The same TMDL allocations will be applicable to address both beneficial uses.

Aquatic Life Use

The Western Basin of Lake Erie shoreline and islands shoreline assessment units are listed in the Integrated Report as impaired for aquatic life use due to nutrients (Table 8). The Western Basin of Lake Erie open water assessment unit is currently not assessed for aquatic life use.

Table 8 – Aquatic life use attainment information for the Western Basin Lake Erie Shoreline assessment units.

Assessment Unit Code	Assessment Unit Name	Attainment Status	Cause
041202000201	Western Basin Shoreline	Non	Nutrients
041202000301	Western Basin Open Waters	Not Assessed	N/A
041202000101	Island Shorelines	Non	Nutrients

To support the development of the Annex 4 Recommended Phosphorus Loading Targets for Lake Erie the Great Lakes Fisheries Commission-Lake Erie Committee (LEC) evaluated the impact of the targets on the lake's trophic status. 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 concentrations expected to maintain that status are in the 10-15 µg/L range. The lake models utilized by the Annex 4 task team that developed the Targets document found the change in concentration in the Western Basin at the proposed 40 percent reduction would result in reduction of the average concentration from 19 µg/L (2008 conditions) to 12-15 µg/L. These reductions move the lake from eutrophic to mesotrophic conditions and facilitate a healthy aquatic community.

The TMDLs for recreation use impairments due to algae, explained in the recreation use section, will also directly address the aquatic life use impairments associated with nutrients. The same TMDL allocations will be applicable to address both beneficial uses.

Ohio EPA is developing revisions to the Lake Erie aquatic life use assessment methodology. As stated in the 2020 IR, The Ohio State University'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 2022 Integrated Report.

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Appendix A: Explanation of Step 1 and 2 TMDL Process Documents

This appendix provides a brief outline on each of the TMDL process step 1 and 2 documents and/or projects for this effort. A weblink is provided for each item in order to provide readers with details of the work.

Step 1 Study Plan Documents ●○○○○

In a near-field Ohio TMDL project the study plan document is a straightforward Quality Assurance Project Plan. This document outlines the data quality objectives for an assessment of beneficial uses for a particular watershed. The assessment sites and methods are shown. Methods normally include biocriteria and supporting data collected at about 50-100 stream sites to assess aquatic life use. Indicator pathogen data (i.e., *E. coli*) is collected at most of those sites to assess recreation use. Public drinking and human health fish consumption are normally assessed based on other project plans.

This is a far-field TMDL project which means the pollutants causing impairments are geographically disparate from where the impairment occurs. Excessive nutrient delivered to a waterbody can bring about the growth of harmful algal blooms. HABs are harmful because they often produce cyanotoxins. Impairment due to HABs and their toxins has been an emerging concern over the past decade. It took a great deal of effort and projects for Ohio to come to the point where impairment due to HABs in western Lake Erie could be determined. The documents listed below summarize this effort.

- Ohio Lake Erie Phosphorus Task Force Phase I (2010)
  epa.ohio.gov/static/Portals/35/lakeerie/ptaskforce/Task_Force_Final_Report_April_2010.pdf
  Ohio EPA, in consultation with Heidelberg University, convened the Ohio Lake Erie Phosphorus Task Force to review and evaluate the increasing dissolved reactive phosphorus (DRP) loading trends and a potential connection to deteriorating conditions in Lake Erie. This workgroup was made up of numerous stakeholders, including the Farm Bureau Federation, university partners, Ohio Department of Agriculture, Ohio Department of Natural Resources, US Environmental Protection Agency, US Geological Survey, US Department of Agriculture, and other interested parties. A final report of the task force was completed in 2010.

- Ohio Lake Erie Phosphorus Task Force Phase II (2013)
  epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/surface-water/reports-data/nutrient-pollution-finding-solutions
  In 2012, the Phosphorus Task Force was reconvened a second time with the purpose of developing recommendations for reduction targets for total phosphorus & DRP, as well as policy and management recommendations based upon new and emerging data. A final report of the Phase II task force was completed in 2013.

- State of Ohio Directors' Agricultural Nutrients and Water Quality Working Group (2011)
  epa.ohio.gov/static/Portals/35/wqs/nutrient_tag/Dir_Ag_WQ_final_report.pdf
  Around the same time as the first Lake Erie Phosphorus Task Force wrapped up, Ohio started drafting a statewide framework for nutrient reduction strategies. Ohio EPA developed the framework with Ohio Department of Natural Resources and the Ohio Department of Agriculture. This draft framework then became Ohio's Nutrient Reduction Strategy, a statewide nutrient reduction plan that is updated on a regular basis.

- Point Source and Urban Runoff Nutrient Workgroup Final Report and Recommendations (2012)
  epa.ohio.gov/static/Portals/35/documents/point_source_workgroup_report.pdf
  Two work groups – the State of Ohio Directors' Agricultural Nutrient and Water Quality Working group and the Point Source and Urban Runoff Nutrient Workgroup provided recommendations for the state Nutrient Reduction strategy. The recommendation for the Ohio Nutrient Mass Balance Study came out of this effort.

- Ohio's Nutrient Reduction Strategy (2013, 2015)
  epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/surface-water/reports-data/nutrient-pollution-finding-solutions
  As noted above, the Ohio's Nutrient Reduction Strategy was developed out of the State of Ohio Directors' Agricultural Nutrients and Water Quality Working Group. This strategy provides the overall framework for the state's efforts to reduce nutrient pollution. It is maintained by Ohio EPA.

- Annex 4 Objectives and Targets Task Team Final Report, *Recommended Phosphorus Loading Targets for Lake Erie* (2015)
  epa.gov/sites/production/files/2015-06/documents/report-recommended-phosphorus-loading-targets-lake-erie-201505.pdf
  This document was developed by a task team for the Great Lakes Water Quality Agreement's Nutrients Annex (or Annex 4). It was a product of U.S. and Canadian experts and outlines that the size of the western Lake Erie HAB bloom is primarily driven by the amount (or load) of phosphorus delivered by the Maumee watershed. The results in the Final Report are extensively discussed in the Proposed Targets section of this LAP document.

- Ohio EPA's Near-Field TMDLs
  epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/surface-water/reports-data/total-maximum-daily-load-tmdl-program
  All of the Maumee subwatersheds that make up the whole Maumee watershed have near-field TMDL projects either completed or in development. These historic (and ongoing) assessments and TMDLs provide crucial information about how the local environment is functioning. Near-field TMDLs also inform whether nutrient enrichment causes any local impairments. Phosphorus reduction efforts to address near-field TMDLs also reduce nutrients delivered to Lake Erie. Implementation plans and projects to address these near field impacts will continue to be prioritized concurrently with the Maumee Watershed Nutrient TMDL.

- U.S. EPA's Methodology for Connecting Annex 4 Water Quality Targets with TMDLs in the Maumee River Basin project (2018)
  epa.gov/tmdl/methodology-connecting-annex-4-water-quality-targets-tmdls-maumee-river-basin
  U.S. EPA commissioned this study which examined whether implementation of near-field TMDLs alone could meet the Annex 4 nutrient reduction targets for western Lake Erie. This work concluded that there are too few near-field nutrient impairments with TMDLs to reach the Annex 4 load targets for the Maumee watershed. Based on this document, it was apparent that establishing far-field phosphorus load targets was needed and hence this far-field TMDL.

- Tributary nutrient monitoring, outlined in the report: Expanded Lake Erie Tributary Nutrient Load Monitoring Report
  lakeerie.ohio.gov/wps/portal/gov/lec/planning-and-priorities/03-WMS
  In addition to the long-term water quality monitoring of the Maumee River at Waterville, there are over 25 other sites throughout the Maumee watershed where continuous water quality is measured. All of these monitoring locations are at U.S. Geological Survey (USGS) streamflow gages. Heidelberg's National Center for Water Quality Research and the U.S. Geological Survey share the effort of water quality monitoring and load calculations at various locations. The data collected by these organizations are certified as level 3 credible data which means they can be used by Ohio in regulatory decision making. The most recent Ohio Lake Erie Commission's Expanded Lake Erie Tributary Nutrient Load Monitoring Report can be downloaded at the link provided. This report includes: the locations of all these monitoring stations, details about who and how the stations are monitored, summary concentration and loads for all stations, and instructions on how to download the detailed (non-summarized) data. As noted in the Proposed Targets section of this LAP, the loading data from the Waterville station was used in developing the Annex 4 targets that will be used for this TMDL. As noted in the Proposed Actions of this LAP, data for other sites will be used to confirm the mass balance methods carried out for TMDL calculations.

- Ohio EPA's Nutrient Mass Balance Study for Ohio's Major Rivers (2016, 2018, 2020)
  epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/surface-water/reports-data/nutrient-pollution-finding-solutions
  As noted in the Proposed Actions section of this LAP, Ohio EPA's Nutrient Mass Balance Study reports have shown that nutrients delivered from the Maumee to Lake Erie are dominated by nonpoint sources. An adaptation of the methods delineated in the mass balance work will also be the foundation for this TMDL's allocation calculations.

- Ohio Domestic Action Plan (2020)
  lakeerie.ohio.gov/wps/portal/gov/lec/planning-and-priorities/02-domestic-action-plan/02-domestic-action-plan
  The Ohio Domestic Action Plan (DAP) coordinates how Ohio state agencies and other parties will address the Great Lakes Water Quality Agreement's Annex 4 nutrient reduction targets. The DAP is regularly updated to reflect nutrient reduction implementation planning and actions in the Ohio's Lake Erie watersheds. This document provides far-field loading targets for nonpoint sources of total phosphorus in the Maumee watershed in Appendix A. These targets are intended to be used by local stakeholders in developing nonpoint source implementation plans (also known as 9-Element Plans). This TMDL project will expand upon those targets by allocating all source of total phosphorus to meet the Annex 4 targets.

Step 2 Biological and Water Quality Report or Equivalent Documents ●●○○○

Step 2 in the TMDL process for near-field TMDLs is most often a document specific to the watershed titled the Biological and Water Quality Report. This document outlines beneficial use impairments and explains the pollutants and/or other stressors causing the impairment. The documents described below provide the equivalent of this material for this far-field TMDL. These are the water quality results documents. Overall, this material makes the case that two beneficial uses in the assessment units of Ohio's portion of the Western Basin Lake Erie are impaired due to HABs and that a TMDL will be developed to address this impairment under the Section 303(d) of the Clean Water Act.

- NOAA's Cyanobacteria Index and Harmful Algal Bloom Forecast
  coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-forecasts/lake-erie/
  The National Oceanographic and Atmospheric Administration (NOAA), along with US EPA, have developed a cyanobacteria index allowing them to interpret satellite data of Lake Erie and determine the extent of HABs. These data are used to inform the frequent NOAA Lake Erie bulletin that is published throughout the Lake Erie HAB bloom season. These level 3 credible data results are utilized by Ohio in our evaluation and impairment listing of the lake.

- Science meets policy: A framework for determining impairment designation criteria for large waterbodies affected by cyanobacteria harmful algal blooms. Davis, Timothy W., Richard Stumpf, George S. Bullerjahn, Robert Michael L. McKay, Justin D. Chaffin, Thomas B. Bridgeman, and Christopher Winslow. (2019) Harmful Algae, 81: 59-64 Published at: ***sciencedirect.com/science/article/pii/S1568988318301860***
  This is a peer-reviewed, scientific article by several Ohio academics and NOAA published in the Harmful Algae journal and is the basis for Ohio's western Lake Erie recreation use impairment designation. The metric for impairment utilizes NOAA's satellite data that evaluates the magnitude or extent of HABs over various time windows.

- Lake Erie HAB monitoring data and algae toxin results
  epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/drinking-ground-and-waters/public-water-systems/harmful-algal-blooms
  These data are used in determining the public drinking water use impairment status of Lake Erie.

- The Lake Erie HABs Grab: A binational collaboration to characterize the western basin cyanobacterial harmful algal blooms at an unprecedented high-resolution spatial scale. Chaffin, Justin D., John F. Bratton, Edward M. Verhamme, Halli B. Bair, Amber A. Beecher, Caren E. Binding, Johnna A. Birbeck, Thomas B. Bridgeman, Xuexiu Chang, Jill Crossman, Warren J.S. Currie, Timothy W. Davis, Gregory J. Dick, Kenneth G. Drouillard, Reagan M. Errera, Thijs Frenken, Hugh J. MacIsaac, Andrew McClure, R. Michael McKay, Laura A. Reitz, Jorge W. Santo Domingo, Keara Stanislawczyk, Richard P. Stumpf, Zachary D. Swan, Brenda K. Snyder, Judy A. Westrick, Pengfei Xue, Colleen E. Yancey, Arthur Zastepa, Xing Zhou. (2021) Harmful Algae, 108: 1568-9883 Published at: ***doi.org/10.1016/j.hal.2021.102080***
  This paper outlines the results of a binational effort to characterize the Western Basin bloom using high resolution satellite imagery and intense grab sampling results. The study quantified the bloom size and variability as well as relationships between bloom biomass and microcystin concentrations.

- Listing of the Ohio Lake Erie Western Basin shoreline and open water and islands shoreline on Ohio's 303(d) list for recreation impairment due to harmful algal blooms (2016 amended, 2018, 2020)
  epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/surface-water/reports-data/ohio-integrated-water-quality-monitoring-and-assessment-report
  The Ohio Integrated Water Quality Monitoring and Assessment Report is published every two years and includes the state's 303(d) list prioritizing impaired waters. This report details the methods used to assess the impaired beneficial uses to Lake Erie due to HABs and the results of those methods. The 2020 report prioritized Ohio's development of this TMDL project.

Appendix B: Dissolved Reactive Phosphorus

It is understood that dissolved reactive phosphorus (DRP) is a significant driver of the Lake Erie harmful algal bloom (HAB) impairments this TMDL addresses. Ohio EPA received stakeholder comments concerned about DRP's role in this project. State agency staff have been working with experts, research institutions, and funding sources to develop and support recommended research to better understand DRP. This appendix provides an overview of DRP and how we are addressing it in the TMDL. First, we summarize the background and importance of DRP's influence on the occurrence of western Lake Erie harmful algal blooms (HABs). Then the uncertainties surrounding DRP export, instream processing (or cycling), and the ability to model DRP movement are described. Finally, actions taken to ensure this important parameter is addressed in this TMDL are discussed.

The importance of DRP

Modern conservation efforts throughout the later third of the twentieth century significantly reduced pollutants delivered to Lake Erie. Load reductions of sediment and total phosphorus exported from the lake's tributaries were considered successful thanks to decades of improvement in wastewater treatment and agricultural soil conservation practices. These loading reductions largely addressed eutrophication and hypoxic conditions that occurred in the lake by the late 1980s/early 1990s (Michalak et al., 2013; Baker et al., 2014a; Kane et al., 2014).

Large summer algal blooms started increasing again in the mid-1990s/early 2000s (Conroy & Culver, 2005). The biomass of these blooms is dominated by toxin producing cyanobacterial (Brittain et al., 2000; Budd et al., 2002) and form what is now referred to as HABs. This phenomenon was termed Lake Erie's "*re*-eutrophication" in Baker et al., 2014a and Kane et al., 2014. Those studies examined correlations between tributary nutrient loads and phytoplankton biomass. They found that increased DRP from nonpoint sources had the strongest correlation to increasing prevalence of HABs. In 2012, scientists warned that if the pulses of DRP continue to be delivered to the lake at magnitudes seen in 2011, then that record setting sized HAB in Lake Erie, would be "a harbinger of future blooms" (Michalak et al., 2013). Studies since (e.g., Rowland et al., 2021) have definitively confirmed increases in DRP during this time, especially as delivered by the Maumee River system. And subsequent Lake Erie summer HABs have indeed grown with the 2011 record bloom being surpassed in 2015, see Figure B1 (Ohio EPA, 2020a; Wayne et al., 2015).

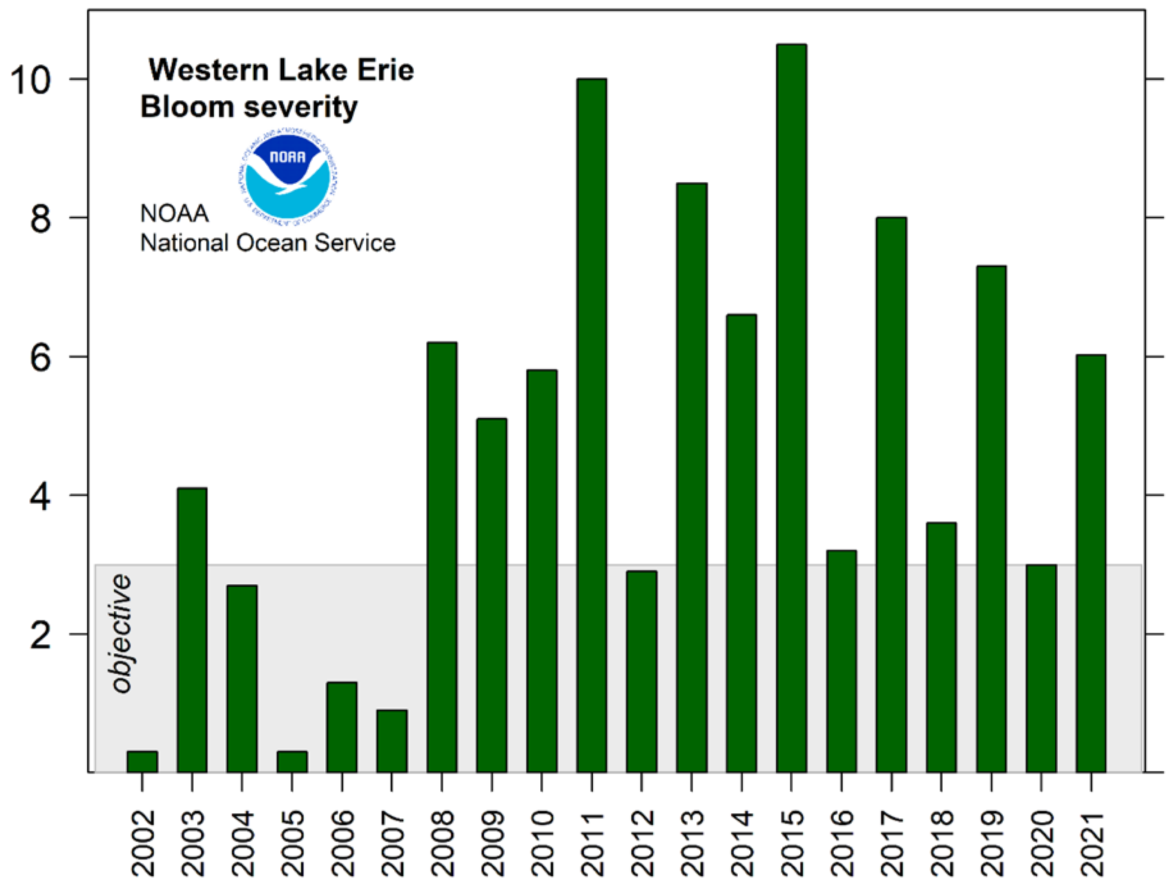

Figure B1: Western Lake Erie HAB severity observed since 2002. Adapted from figure by Dr. Rick Stumpf, NOAA National Centers for Coastal Ocean Science

DRP has long been considered completely bioavailable for rapid assimilation and growth by algae (IJC, 1980), and focusing on bioavailable forms of P for eutrophication control has long been recommended (Sonzogni et al., 1982). Other fractions of total phosphorus are known to also have some, albeit reduced, level of availability for algal growth. Figure B2, from Baker et al., 2014a, provides an overview of which phosphorus species are considered bioavailable. To adequately address all available forms of phosphorus, the Annex 4 Subcommittee Objectives and Targets Task Team developed phosphorus reduction targets to meet Lake Erie HAB ecosystem objectives that include both total phosphorus and DRP (Annex 4, 2015). Since the development of those targets, Baker et al., 2019, suggested a single target of "total bioavailable phosphorus" to include the biologically available forms of particulate phosphorus. This metric counts 100 percent of DRP and 25 percent of particulate phosphorus. The annual seasonal prediction of the western Lake Erie HAB size is primarily based on this measure of total bioavailable phosphorus delivered to Lake Erie from the Maumee River (Stumpf et al., 2016). A bioavailable phosphorus metric has not been fully adopted due to programmatic organization constraints and sampling considerations (Kalkhajeh et al., 2019).

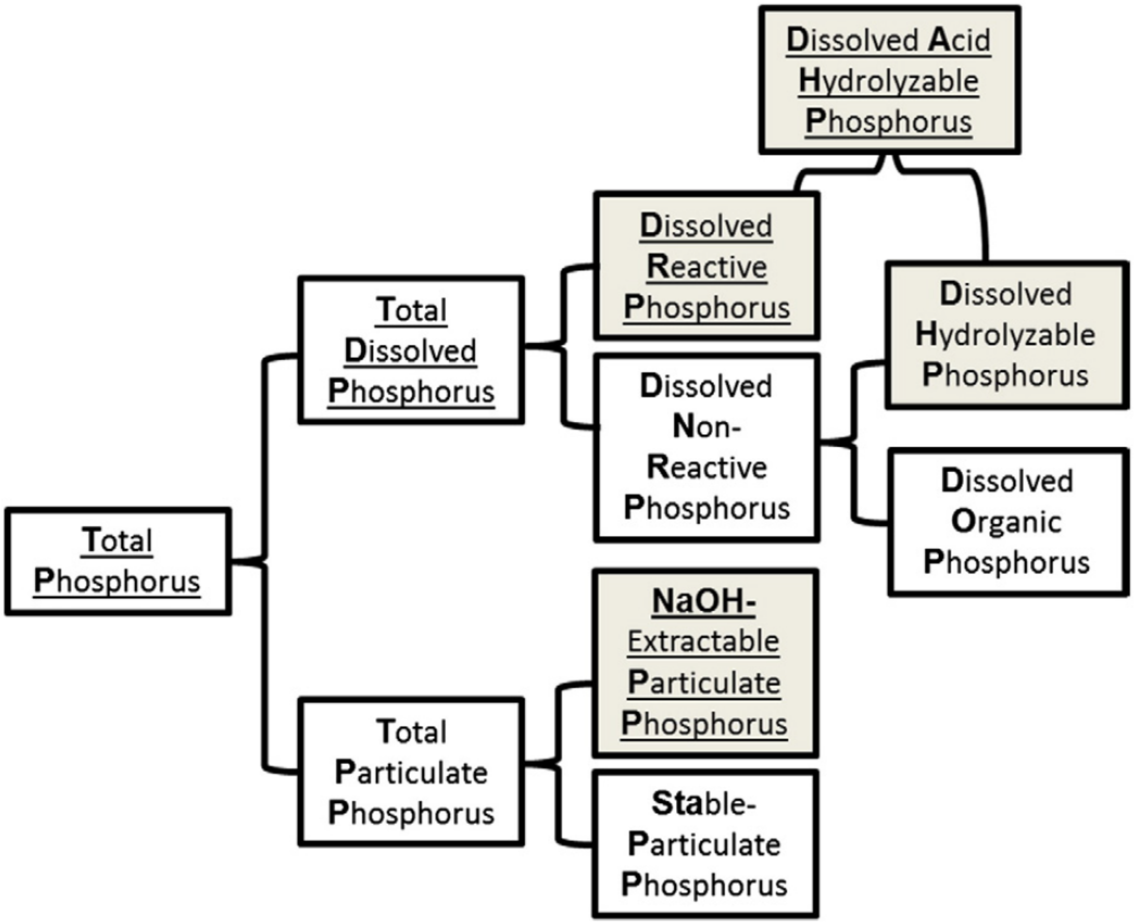

Figure B2: Phosphorus speciation showing analyzed forms (underlined) and calculated forms (not underlined) for surface water applications. Shaded boxes represent forms considered more bioavailable to algae. From Baker, 2013a, used with permission.

The uncertainties surrounding DRP transport

This summary of the uncertainties of DRP transport is divided up into three subsections. First, DRP delivery from the landscape to the stream network is considered. Next explained are the knowns and unknowns of DRP transformations within the stream network as it travels to downstream endpoints, like Lake Erie. Finally, the challenges with various DRP modeling methods are outlined.

DRP Land Based Sources

Much recent research has been conducted on the question of why DRP increased from a low in the mid-1990s bringing about the lake's current annual HABs. In 2015 researchers from USDA's Agricultural Research Service provided a list of 25 "theories" about the cause, however they note that multiple factors and their interactions are most likely driving the changes seen in the system (Smith et al., 2015). These theories include a wide range of hypotheses including changes to agricultural lands or management practices, the climate, and invasive species.

Jarvie et al., 2017 found that the Maumee, Sandusky and River Raisin, watersheds of very different sizes, all experienced similar DRP loading shifts since the early 2000s. Net reductions of the particulate portion of total phosphorus and sediment were documented uniformly after 2002 while DRP increased. This study examined many factors outlined as "theories" in the Smith et al., 2015 work. It attributed 65 percent of the DRP load increase to "increased source availability and/or increased transport efficiency of labile phosphorus [P] fractions." The authors link that 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 P loss, and increased tile drainage to improve field operations and profitability." The remaining 35 percent of DRP load increase is attributed to higher runoff volumes with which increased tile drainage may also exacerbate.

Additional research led by the United State Department of Agriculture's Agricultural Research Service has highlighted these unintended consequences (Smith et al., 2018). The authors note that most farmers apply phosphorus at or below current recommendations. However, "wholesale agronomic changes (e.g., no-tillage adoption, crop cultivar advances, and fertilizer application and formation)" have been adopted while fertilizer recommendations have largely not changed. This points out the continued need for improvements in understanding the nexus of nutrient movement in relation to overall farming practices *and* new recommendations/communication to producers.

The amount of legacy soil phosphorus, or soils with phosphorus content far greater than agronomic needs, presents another uncertainty of DRP delivery to Lake Erie. This build up on fields and in the edge of fields is often the result of prior nutrient applications and land management (Sharpley et al., 2013). Legacy phosphorus is certainly contributing to loads being delivered to the Maumee River watershed with the amount of tile flow or overland runoff seemingly playing into the proportion of DRP (Osterholz et al., 2020). Edge-of-field studies by the Unites States Department of Agriculture - Agricultural Research Service continues in the Maumee watershed to quantify the magnitude and mechanisms of legacy phosphorus movement (ARS, 2020).

Recent Maumee Watershed modeling has suggested that legacy "soil sources" of phosphorus are contributing between 19 and 27 percent of DRP discharged from the watershed (Kast et al., 2021). Many assumptions are required for this modeling, especially in the case of legacy phosphorus. Elevated soil P 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. These uncertainties have been pointed out as one of the key challenges in nutrient reduction efforts to control lake eutrophication (Jarvie et al., 2013).

In addition to these land management factors, during this current era of elevated DRP export, there has also been large year-to-year variability. This variability has been tightly linked to precipitation of a given spring loading season which is defined as 1 March through 31 July. Figure B3 shows this relationship by plotting loading season Maumee DRP and total phosphorus loads against season streamflow discharge (Guo et al., 2021). While the year-to-year loads vary considerably, the load-streamflow relationship measured in the Maumee River has been remarkably consistent since 2002.

The 2019 DRP exported load 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 B3 in panel a). This load reduction, 29 percent lower than predicted by flow alone, has been explained due to a 62 percent reduction in applied phosphorous fertilizer that year (the study considered both inorganic and manure sources of fertilizer). The reduction of application occurred in 2019 because the excessively wet conditions resulted in a great many row crop fields left unplanted and thus unfertilized. The fact that such a quick, observable response to exported DRP loads due to an extensive land management change is considered a positive outcome as it shows more careful fertilization rate, timing and placement of phosphorus can quickly reduce loads. Additionally, since DRP export reduction was less than half of the reduction of applied phosphorus, it shows that legacy and/or edge-of-field/instream source-sinks processes play an important role in export. However, it remains uncertain exactly how to quantify the partition of DRP load between recently applied sources and legacy sources in a more typical year.

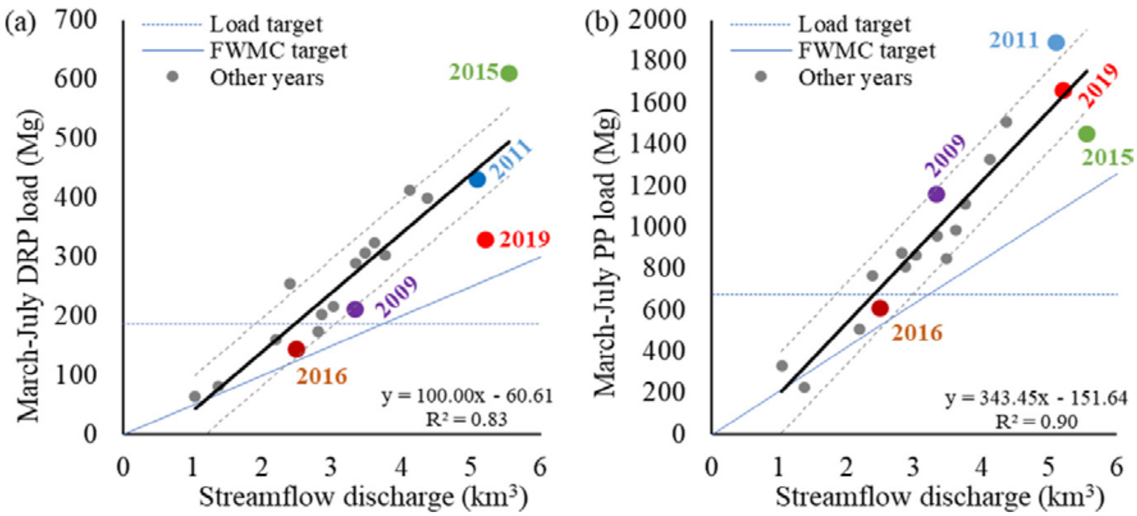

Figure B3: DRP load (a) and participate phosphorus (b) plotted against Maumee River "loading season" streamflow discharge showing results from 2002-2019; with several years labeled. The bold black lines show the linear relationship between load and discharge, with dashed gray lines showing 95th confidence intervals of that relationship. Other lines represent various target conditions. From Guo et al., 2021, used with permission.

DRP in the Stream Network

Compounding uncertainties related to the source of DRP loads exported *to* the stream network, additional unknowns exist as to the fate and transport of DRP as it moves *through* the stream network (Ohio EPA, 2020b). These uncertainties are more relevant to this TMDL when considering if DRP reductions needed at the watershed outlet can be directly allocated to upstream sources.

Recommendations to the International Joint Commission 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 P were discharged directly to the lake" (Lee et al., 1980). This work recommends focusing on direct lake discharges as further research was required to understand the "environmental chemistry of phosphorus" changes throughout stream networks.

Phosphorus retention and cycling throughout a stream network involves many complex physical and biogeochemical processes that have been the subject of study since the early 1980s. Withers and Jarive, 2008 published a review paper examining these processes and their interactions in river systems. This work outlined that the range of settling, biochemical transformation, and other cycling rates are considerable. Local factors appear to be very important for understanding phosphorus cycling with stream flow condition, seasonality, size (i.e., stream order), and oxygen concentration being key factors.

The Withers and Jarive, 2008 review 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. However, that work notes, "most P inputs delivered under very high flows will be flushed through without entering the stream biogeochemical pathways." Most of phosphorus exported from the

Maumee watershed network occurs during high flow periods. Baker et al., 2014a calculated 76 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). Therefore, it could be argued that during high flows DRP could be treated as a conservative parameter and conservative mass balance means of accounting for the parameter in this TMDL may be acceptable. New and ongoing research, however, suggests that there are more complicating factors at play.

Research on instream phosphorus transformations has been very active since the resurgence of the large Lake Erie algal blooms in the 2000s. In recent research, DRP has been found to transform through adsorption to instream suspended solids during high flow conditions at several Maumee River tributaries in a soon to be published study (King et al., in preparation). This work showed a novel mechanism where in 77 out of 78 samples DRP sorption to suspended sediments occurred in the flowing water. The study explains that the implications of these processes mean that suspended sediment provides a service in a way of transforming DRP to a less available particulate form during higher flows. It estimates that this type of sorption may account for reducing DRP exports to Lake Erie by 24 percent, thus decreasing HABs by 61 percent. Long term reductions in sediment delivery to the Maumee River may mean that this ecosystem service has likewise declined. This very possibly plays a role in the DRP increase in western Lake Erie tributaries since the mid-1990s.

A recent study by USGS that examined a small Maumee River watershed tributary also found sediment carried by high flows may be adsorbing dissolved phosphorus (Williamson et al., 2021a). This work determined the greatest amount of sediment to be from legacy sources, especially from stream bank erosion, during the highest flow event months. Another USGS study focused the anomalous stream flows, land management, and pollutant delivery that occurred in 2019 (Williamson et al., 2021b). In this study several tributary monitoring stations throughout the Maumee River watershed were examined. This work found that the 2019 reduction of DRP but not TP observed at Waterville (discussed above and shown in Figure B3 from Guo et al. 2021) did not occur at many of the smaller watershed monitoring stations. Williamson et al., 2021b explains that this very well could have occurred due to desorption of sediment-bound P in those stream channels due to that year's reduced DRP ambient water concentrations.

Ongoing research

Several ongoing studies are examining DRP and phosphorus cycling in the Maumee River watershed and similar watershed systems. The following summarizes this work:

A USGS research project has measured sediment nutrient processes throughout the Maumee River watershed in 2019 and 2021. This work, being 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 from this effort (Kreiling, 2021).

A project being led by Dr. James Hood at the Ohio State University (OSU) (HABRI, 2019) will evaluate when and where rivers within the Maumee River 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. work (in preparation) which was performed by the same lab. Detailed field studies will be utilized 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 modeling below). With the coupling of instream processes to upland best management practices (BMP) modeling, the overall results of this project will greatly improve what is known about best management practices that best address dissolved reactive phosphorus reductions. This project's completion date is scheduled for Dec. 31, 2022.

Another project out of Dr. Hood's lab (HABRI, 2020/2021) includes an evaluation of the sources and chemistry of sediment moving through the Maumee River stream network. Methods will be employed to understand how long sediment of various sources takes to move though the watershed. Then an examination of the phosphorus cycling will occur with a focus on P 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. (in preparation) work, and the Williamson et al., 2021a study will facilitate an improved understanding of how sediment source influences the sediment - dissolved reactive phosphorus exchange during stream transport in high flow events. This project's completion date is scheduled for Dec. 31, 2023.

A large, paired watershed study currently occurring within the Maumee River watershed (ARS, 2019) will provide additional insight to the nexus between agricultural BMPs, nutrient and sediment runoff, and instream processes. Monitoring for this study is being organized by the USDA ARS/NRSC CEAP program with Heidelberg University's Dr. Laura Johnson as the lead. It focuses on two small watersheds within the Blanchard River sub-watershed. 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, prosperous removal structures) and those that retain water (e.g., drainage water management, blind inlets). Ohio State University's Dr. Jay Martin has obtained a USDA 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. The intent of this work is 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 (NRSC, 2021). This project covers study areas across the country including the western Lake Erie basin. This work will develop a database that quantifies the contribution of legacy phosphorous at the edge-of-field and watershed scale from 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 the completion date of 2026.

Dr. James Larson with USGS is researching how nutrients (N, P and C) 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).

Modeling DRP

This section explains that Ohio EPA plans to use a mass balance method to develop TMDL allocations on total phosphorus. This method is inappropriate for DRP. Process models like SWAT model DRP, however several limitations are present.

Ohio EPA (2020b) and others (Dolan & McGunnagle, 2005; Maccoux, et al., 2016) have employed mass balance methods for source attribution. The net change of loads due stream network to retention and export is captured because it is based on observed data at a downstream point. However, mass balance methods do treat loads from certain sources conservatively. The method Ohio uses considers that the point source (including CSOs) and calculated home sewage treatment system loads to be completely delivered to the downstream pour point. TMDL allocations will be carried out for total phosphorus. For longer periods of time, such as the five-month loading period applicable to this TMDL, assuming conservation of the total phosphorus point source loads is acceptable and consistent with the literature cited.

As noted in the preceding section, there are numerous factors and much greater uncertainty to consider when attributing sources of DRP. Ohio has not completed empirically based mass balance calculations on dissolved portions of nutrients for this reason (Ohio EPA, 2020b). Other modeling efforts, however, do include DRP export source attributions in stream networks.

Process models, like the Soil and Water Assessment Tool (SWAT), provide 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 as they are removed with crops, discharged to waterways, or remain on fields for the next season. Precipitation input data drives the movement of water and pollutants which includes careful understanding of evapotranspiration, surface runoff, tile discharge, and groundwater 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 in SWAT (Neitsch et al., 2011). SWAT, therefore, models the processes that govern DRP and particulate phosphorus 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 SWAT model spatial details, 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 (Kast et al., 2019; Kast et al., 2021). Addressing uncertainties in pollutant sources has also been examined (Evenson et al., 2021). Progressive model improvements have been used to consider various best management practices to the Annex 4 targets discussed in this report (Scavia et al., 2017; Martin et al., 2021). These last two studies use multiple SWAT models (a method known as "ensemble modeling") to utilize the strength of various model parameterization choices in determining the certainty of success for various BMP scenarios.

Refinement of SWAT work continues in the Maumee watershed with a current project being carried out by OSU and the University of Toledo to directly assess the state of Ohio's H2Ohio best management practice programs (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. This project's completion date is scheduled for Dec. 31, 2023. Additional improvements to SWAT in-stream phosphorus cycling and the manner in which legacy phosphorus is modeled are expected from the second CEAP study discussed in the previous section.

Improvements to SWAT modeling noted in the preceding paragraphs show that progress is being made to address uncertainties in DRP export, especially from land practices. Existing SWAT models' ability to simulate cycling of phosphorus species within stream channels is rather limited, however. SWAT's phosphorus transformations due to in-stream primary production, mostly a low flow condition consideration, is rudimentary considering the state of science on this subject (Pyo et al., 2019). Updates to SWAT to account for the impact of benthic algae and stream bed phosphorus equilibrium dynamics have been proposed based on work in Oklahoma (White et al., 2014; Mittelstet, et al., 2016), but have not been incorporated in the publicly available source code for SWAT. These improvements do not capture the emerging understanding of suspended sediment adsorbing DRP at high flows (i.e., from King, in preparation). Ongoing research, described above (HABRI, 2019), plans to incorporate into a Maumee River watershed SWAT model both the Oklahoma routines and high flow suspended sediment mechanics. The results of this work will be valuable in Ohio's implementation of this TMDL.

Actions the TMDL Will Take to Address DRP

Taken as a whole, there are numerous knowledge gaps in DRP sources, in-stream cycling, and the ability of existing models to simulate these factors. Uncertainty surrounding DRP sources and transport is large. TMDL allocations cannot capture this uncertainty while remaining meaningful for watershed planning efforts. This is especially so as new research matures and the collective understanding of DRP sources and transport is refined. The TMDL project will take several measures to account for DRP.

Detailed source assessment of DRP

While unknowns of DRP fate and transport throughout the Maumee River watershed stream network preclude TMDL allocation, much is known about the *amount* of DRP being contributed throughout the watershed as observations in streams. This is thanks to a robust tributary nutrient monitoring network in the Maumee that includes DRP. Figure B4 shows the locations of twenty-eight monitoring stations where water quality and streamflow is monitored on a continuous basis. Daily nutrient loadings are calculated at each of these stations with a high degree of accuracy. These stations capture a wide range of drainage areas and predominate land use types. They also cover the regional geographic and climatic variations in the watershed. While the Maumee River at Waterville station, discussed in the main report of this document, has been monitored since the 1970s, the remainder of stations all have, or are close to having, a ten-year period of record.

These monitoring data will be used to evaluate temporal and spatial relationships between TP and DRP. For example, this may include examining this relationship at various stream flow conditions. These analyses will be coupled with a thorough review of edge-of-field and SWAT modeling research to present the best understanding of detailed source assessments of TP and DRP throughout the watershed. With this work based on observed DRP concentration and loads it allows for the best assessments possible while avoiding the many aspects of uncertainty outlined in this appendix.

The analyses will also support tracking of DRP alongside TP as source reductions and other management actions are implemented. They will guide management decisions to inform whether the implementation strategy is effective or if changes need to be considered through adaptive implementation.

Tracking of nutrients

The TMDL will recommend nutrient tracking utilizing the stream monitoring network shown in Figure B4. The level of water quality monitoring ensures that adaptive implementation can be informed by measured environmental response data for both TP and DRP.

This tracking will continue to examine the loads and flow weighted mean concentrations, consistent with Ohio's Domestic Action Plan (Ohio Lake Erie Commission, 2020). In addition to these direct measures, monitoring data can be used to answer questions regarding TMDL implementation. These monitoring data can be used to decrease uncertainty in process models that can then be used with higher confidence to predict outcomes of different proposed management approaches. It will also outline how to assess nutrient trends over time. Recent efforts have utilized normalization methods to diminish trend variability largely from streamflow fluctuations (Rowland, 2021).

Implementation tracking metrics such as how many acres or linear feet to which certain BMPs are applied, and even how many dollars are spent, will also continue to ensure programs are effectively placing practices on the landscape. However, monitoring data-based tracking methods will definitively show if nutrient reduction is occurring and inform adaptive implementation.

Figure B4: Map of the Maumee River watershed showing the location of the existing continuous water quality monitoring stations.

Focus implementation actions on DRP reductions

Much of the information presented in this appendix support hypotheses of "unintended consequences" of soil conservation practices, which potentially result in increases of DRP export (Jarvie, 2017; Baker, 2014a). However, it is known that some agricultural BMPs reduce DRP export by reducing the total amount of phosphorus applied (e.g., nutrient management plans) and retaining/slowing runoff (e.g., in-field wetlands). For many practices, sufficient evidence of the impact on DRP is not yet available.

A vital role of this TMDL project is to steer nutrient reduction efforts towards identification of DRP sources and implementing practices that reduce DRP. When the TMDL implementation plan is published, Ohio EPA will coordinate with other agencies and stakeholders to prioritize implementation practices known at this time to specifically reduce DRP loadings. The stream nutrient monitoring network, continued edge-of-field studies, and modeling studies will allow Ohio to respond to changing conditions in the streams and adapt to practices that show more effective reductions of DRP.

TMDL implementation recommendations will follow an adaptive management process. The framework for adaptive management will be developed in with the preliminary modeling results. As DRP research and science evolves so will recommendations, funding opportunities, and actions.

Ohio's Commitment to Meet Both TP and DRP Loading Targets

In 2015, the governors of Michigan and Ohio and the premier of Ontario committed to both TP and DRP reductions (Conference of Great Lakes and St. Lawrence Governors and Premiers, 2015). Ohio recommitted to this agreement in 2019. While this TMDL will not have DRP allocations developed, Ohio has clearly committed to meeting both TP and DRP reduction targets. This TMDL project is considered part of Ohio's overall Domestic Action Plan to meet Great Lakes Water Quality Agreement objectives. **DRP loading reductions are of great importance to the State of Ohio and the Ohio EPA takes these commitments seriously.**

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