ATTACHMENT #2: EPA Review of Dissolved Reactive Phosphorus Information

INTRODUCTION:

During the development of the Maumee Watershed Nutrient (MWN) Total Maximum Daily Load (TMDL), the Ohio Environmental Protection Agency (Ohio EPA) devoted considerable time and effort into assessing the role that dissolved reactive phosphorus (DRP) has in the growth of harmful algal blooms (HABs) in the Western Basin of Lake Erie. As a result of this effort, Ohio EPA determined that at this time it is more feasible to develop allocations for total phosphorus (TP) as it moves through the watershed compared to DRP (MWN TMDL, Section 3.5.1 and Appendices 1 and 2). Ohio EPA explained that the MWN TMDL could be revised to include DRP allocations as new studies and modeling efforts are completed in the Maumee River Watershed (MRW). Ohio EPA also stated that, if needed, it can make future revisions to the MWN TMDL to specifically account for DRP contributions to the surface waters of the MRW, set DRP TMDL targets, and allocate point and nonpoint source loads.

ANALYSIS:

EPA reviewed the DRP sections in the MWN TMDL as well as information in *Appendix 1: Dissolved Reactive Phosphorus* and *Appendix 2: Soil and Water Assessment Tool Models and Publications* of the MWN TMDL. Appendix 1 explored several topics regarding DRP, including:

- Uncertainties in the delivery of DRP from landscape sources (i.e., agricultural loading) to stream environments in the MRW;
- Uncertainties of DRP fate and transport (i.e., in-stream DRP cycling) within stream environments; and
- Uncertainties in applying a mass balance methodology, used in the development of the total phosphorus MWN TMDL, to model DRP movement in the MRW.

EPA notes that Ohio EPA provided significant discussion in Appendix 1 of the MWN TMDL regarding the history of HABs and the linkage of those bloom events to DRP inputs to the Western Basin of Lake Erie. As noted in the *Recommended Phosphorus Loading Targets for Lake Erie (2015)* (hereafter, the Annex 4 targets document), DRP reductions will be important for addressing the algal problems in Lake Erie. However, the Annex 4 targets document also notes that there may be different combinations of particulate phosphorus (PP) and DRP that can achieve the same target load of total phosphorus and associated biologically available phosphorus to eliminate HABs in the Western Basin of Lake Erie. PP and DRP together form total phosphorus, which is the targeted parameter of the MWN TMDL (Baker, 2014; Osterholz, 2020, King et al, 2022).

EPA reviewed the modeling report, *Great Lakes Water Quality Agreement Nutrient Annex 4 Objectives and Targets Development Task Team Multi-Modeling Report – Final* (Annex 4, 2016), which serves as the foundation for the nutrient targets selected in the Annex 4 targets document. One of the conclusions of this report is that achieving cyanobacteria biomass reduction in the Western Basin of Lake Erie will require a focus on reducing total phosphorus loading from the Maumee River Watershed, especially total phosphorus loads transported during high-flow events. Also noted was that solely focusing on the reduction of DRP loading to the

Western Basin of Lake Erie will be insufficient for attaining the phosphorus targets of the Annex 4 targets document and therefore attaining the water quality standards.

DRP delivery uncertainties

In Appendices 1 and 2 of the MWN TMDL, Ohio EPA discussed the uncertainty in determining the sources of DRP in the MRW. As noted by Ohio EPA, the generation of DRP in the watershed is complex and fairly site-specific. DRP can be generated by precipitation mixing with fertilizers (e.g., chemical or manure) and mobilizing the phosphorus constituents of those fertilizers to surface waters. Chemical fertilizers are designed to be utilized by plants fairly quickly (MWN TMDL, Section 4.1.1.1). Most other forms of phosphorus must undergo various biochemical processes to transform into DRP. As noted in Ni et al, 2020, soil types can have an impact on the generation of DRP; either due to soil particle size or the amount of organic material in the soil, both of which can impact phosphorus retention time and thus the conversion of particulate phosphorus to DRP and vice versa.

Ohio EPA also discussed the role of legacy phosphorus in the generation of DRP. Legacy phosphorus is typically the excess phosphorus built up in soils over time that is unavailable for immediate plant use. As noted by Ohio EPA in the MWN TMDL, Appendix 1, and in Kast et al, 2021, legacy phosphorus is a significant source of phosphorus to the Western Basin of Lake Erie. Ni et al, 2020 noted that phosphorus enriched soils may leach DRP as a response to precipitation events. However, the amount of available DRP varies depending upon the original soil phosphorus levels (Ni et al, 2020). Therefore, as discussed in Appendices 1 and 2 of the MWN TMDL, and in several of the studies cited both in the Appendices and reviewed by EPA, quantifying the source contributions of DRP can be dependent on the existing phosphorus concentrations of individual fields and is uncertain at this time.

EPA notes that new research on phosphorus source contributions from the MRW and HAB related studies are ongoing. Ohio EPA cited a grouping of research efforts in Section 7.5.3 of the MWN TMDL. A recent study by Speise et al, 2023, notes that the causes of DRP increases are not well known and suggests that glyphosate, a phosphonate based herbicide applied to glyphosate-resistant crops (i.e., corn and soybeans) has been used in agricultural areas in the MRW over the previous 30 plus years. Glyphosate, commercially known as Roundup, has been applied to agricultural areas in the MRW and could be an additional source of phosphorus to the watershed. Glyphosate can degrade into DRP, thus, potentially increasing DRP loading from agricultural fields. The authors of the study highlight that glyphosate and its potential contributions to DRP loading from agricultural areas requires further research. EPA notes that glyphosate is another potential DRP source contributing to MRW. Also, EPA recognizes that the science and understanding of phosphorus sources in the MRW is still evolving.

DRP uncertainties related to fate and transport

In Appendices 1 and 2 of the MWN TMDL, Ohio EPA discussed the uncertainty of DRP fate and transport in the MRW, especially regarding DRP transformations that occur in stream environments as a result of in-stream DRP cycling. EPA reviewed the same scientific studies cited by Ohio EPA in its examination of DRP fate and transport (including Jarvie, et. al, 2017; Kast et al., 2021, Guo et al. 2021 and Osterholz et al, 2020). EPA, after consideration of the scientific studies and information included in the MWN TMDL, agrees with the determination made by Ohio EPA on DRP; namely, that quantifying DRP sources in the MRW at this time is not possible with existing data and analyses with an acceptable level of confidence, and that additional data are needed to better understand DRP sources and behavior in the Maumee River Watershed.

Studies have also demonstrated that movement of phosphorus through stream environments in the Maumee River Watershed is not yet fully understood. King, et. al, 2022, cited the complex interactions between particulate phosphorus, DRP and total phosphorus in stream environments and how these interactions affect bioavailability of phosphorus. The authors note that phosphorus sorption (i.e., the removal of a compound by solid phase constituents) under high flow conditions is particularly poorly known. The MWN TMDL and the Annex 4 targets document recognize high streamflow conditions, particularly high streamflow conditions in the spring season (March 1 to July 31), as the critical time period for phosphorus contributions to the Western Basin of Lake Erie. The minimizing phosphorus loading from high stream flow events in the spring season is one of the central objectives of the MWN TMDL and Annex 4 targets document. Similar results were noted by Withers et al. 2008, who found numerous hydrogeochemical mechanisms in stream environments that can affect phosphorus cycling, such as: mineralization, interactions with suspended sediment, nutrient uptake by instream algae and/or macrophytes, and several other biochemical processes.

DRP uncertainty in the mass balance model (i.e., DRP requires greater modeling capabilities)
Ohio EPA explained that there was uncertainty in applying the mass balance methodology to model DRP. The most common watershed model that has been applied in the MRW is the Soil and Water Assessment Tool (SWAT). SWAT has been used in many different studies in the MRW as well as around the world (King et. al, 2022; Yuan and Koropeckyj-Cox, 2022), and one study recognized SWAT as the most suitable watershed model for use in the MRW (Gebremarium et al., 2014).

EPA has reviewed the discussion in Appendix 2 of the MWN TMDL as well as additional studies in the watershed. To accurately represent the MRW via a comprehensive SWAT model, numerous assumptions would need to be made. Some of those assumptions involve: estimating soil phosphorus concentrations, estimating phosphorus uptake from plants, employing phosphorus ratios from multiple forms of phosphorus, estimating surface runoff, mapping tile drainage, estimating phosphorus levels in various manure types, etc. Determining the appropriate assumptions to use in SWAT can vary between different SWAT modelers (Yuan and Koropeckyj-Cox, 2022).

In the MRW, there are a number of different SWAT modeling efforts that have been completed and the results of those modeling efforts have been published. Some scientific studies have even compiled and reviewed different SWAT modeling efforts in the MRW. One such study, Yuan and Koropeckyj-Cox, 2022, reviewed 28 different SWAT model studies, and noted the ranges of different approaches employed to make phosphorus assumptions across all 28 of the different SWAT models. The authors noted that variations in assumptions by different SWAT modelers are expected due to the complexity and heterogeneity of the MRW. As a result, the SWAT modeling outputs also were quite variable, and while the authors found that flow and sediment SWAT modeling efforts were deemed satisfactory, the authors found that over one third of the

SWAT models considered performed unsatisfactorily for total phosphorus and soluble reactive phosphorus (SRP)[1]. The authors also noted that the routing of dissolved nutrients through subsurface drainage infrastructure (i.e., tile drainage lines) needed improvement to better reflect nutrient transport and potential biochemical transformation processes. Improving the model's ability to capture these processes would ultimately improve the model's ability to simulate nutrient transport within the watershed.

Another study by Apostel et al., 2021, reviewed several SWAT models, with similar results. The authors noted that SWAT tile drainage simulation has limitations, and outputs can be skewed depending upon how the DRP and total phosphorus proportions are estimated in tile flow. As noted by the authors, "*If a model is unable to capture key watershed transport processes, then we may not be able to reliably use the model to assess dynamics and management scenarios related to those processes. In this study we find that the simulation of field level dynamics of phosphorus transport through tile drains and surface run off were fairly uncertain, and so processes and scenarios based on phosphorus transport pathway may also be uncertain.*"

IMPLEMENTATION IMPACTS:

EPA notes that despite the fact that the dynamics of DRP are complex and incompletely understood, the TMDL implementation actions identified by Ohio EPA are consistent with the recommendations of many studies to address DRP. In Section 8 of the MWN TMDL, Ohio EPA presents numerous implementation actions to address phosphorus reductions in the MRW. In Section 7.3.3.1 of the MWN TMDL, Ohio EPA recognized 10 key implementation practices to be deployed in the Ohio portion of the MRW to reduce phosphorus inputs to the watershed.

Several of the SWAT modeling efforts also included model scenarios involving various best management practices (BMPs) in the MRW. These studies included:

- Yuan and Koropeckyj-Cox, 2022: The authors considered various agricultural conservation practices (ACPs) were considered including: cover crops, conservation tillage, filter strips, and nutrient management (varying fertilizer applications). Their analysis of the multiple SWAT models for both DRP and total phosphorus noted that the models utilized similar BMPs to address both forms of phosphorus but the use of specific BMPs was specialized to the landscape conditions of the subwatershed.
- Ni et. al, 2020: The authors noted that ACPs varied considerably in amount and type of phosphrous reduced. However, the ACPs reviewed were similar to those noted in the Section 7.3.3.1 of the MWN TMDL. The ACPs considered included: varying fertilizer application rates, crop rotation, drainage water management, tillage, and cover crop.
- Kast et. al, 2021: The authors considered twenty-one different SWAT scenarios for DRP and total phosphorus. This study did not investigate the use of specific BMPs, but instead considered reductions to major sources and those impacts on water quality. Three main scenarios were explored: 1) baseline removal of a source type (i.e., no manure; no point sources); 2) reducing manure/fertilizer to 75%; and 3) increasing manure to 300%.

[1] Soluble reactive phosphorus (SRP) is a measure of orthophosphate, a soluble inorganic fraction of phosphorus which can be directly taken up by plant cells.

- Martin et. al, 2021: The authors investigated twelve BMPs (both source contributions and management effects) and 6 “bundled scenarios” representing a mix of BMPs. The BMPs include the same (or similar) BMPs as noted in Section 7.3.3.1 of the MWN TMDL.

Review of the studies noted by Ohio EPA in Appendices 1 and 2 of the MWN TMDL, as well as those identified by EPA, identify several common themes. First, there is no single BMP action that will result in attainment of the MWN TMDL target. For example, elimination of all point sources will result in a 5%-10% reduction in total phosphorus or DRP. Elimination of all manure loads will likely result in a reduction of 8%-12% in total phosphorus or DRP loads (Kast et. al, 2021; Martin et. al, 2021). The one conclusion that is consistent across the modeling studies is that multiple BMPs will need to be deployed at critical locations throughout the MRW. Other studies have noted the difficulties in quantifying the impacts of BMPs specifically on DRP. In Ni et. al, 2020, the authors noted that the effectiveness of BMPs on DRP reduction are still under investigation. Martin et. al, 2021, also reviewed modeling results from several SWAT models, and found similar variations in model outputs and BMP effectiveness.

The studies were also fairly consistent in noting that targeted application of BMPs to critical areas will achieve greater improvements to water quality in the watershed. Several studies noted that a “blanket” change in BMPs, such as eliminating no-till in the watershed (which will have limited impact on DRP loads but dramatically increase sediment loads to Lake Erie) will have a limited impact on water quality improvement. Also, many studies concluded that random placement of BMPs in the watershed will also have negligible impact to water quality improvement. In several of the SWAT studies, the models looked at applying BMPs in locations with the highest soil phosphorus levels, which tend to have relatively higher DRP runoff loads. This was identified by Ohio EPA in Section 4.2 of the MWN TMDL (Critical source areas and overall heterogeneity of sources in the Maumee watershed) and Figure 3 of the Ohio EPA Domestic Action Plan (DAP). As discussed by Ohio EPA in Sections 7.2 and 8.3.2 of the MWN TMDL, the identification of critical areas is a fundamental part of Nonpoint Source Implementation Strategy (NPS-IS) development efforts, and will be a key component of the overall nutrient reduction efforts in the Ohio portion of the MRW.

CONCLUSION:
EPA has carefully reviewed the MWN TMDL and appendices, as well as many of the studies cited by Ohio EPA. In addition, EPA examined numerous other studies and technical papers regarding total phosphorus and DRP. EPA has determined that it is reasonable that Ohio EPA has decided to develop a total phosphorus TMDL for the MRW and is not developing separate DRP allocations in the MRW TMDL **at this time.**

Ohio EPA will continue to utilize ongoing monitoring efforts to track phosphorus loads (both total phosphorus and DRP) and continue phosphorus reduction efforts that target both total phosphorus and DRP. The MRW has a relatively robust monitoring network that is obtaining more TP and DRP data every year. The USGS and Heidelberg University’s NCWQR collect water quality monitoring data at twenty-nine different tributary stations in the MRW (Figure 28 of the MWN TMDL). Some of these locations are newer (i.e., installed in 2014) while other stations in the NCWQR’s network have been operational for over 40 years. The data, the biennial reports, and the numerous independent studies that utilize that data will be used to track results in the watershed. Ohio EPA will develop a MWN Biennial Report every two years to document progress made via implementation activities, to report on water quality conditions and, if necessary, to revise its implementation strategy (MWN TMDL, Section 7.2).

EPA highlights the phrase “at this time”, as nothing in this explanation or in the Decision Document precludes Ohio EPA from revising the MWN TMDL to directly account for DRP in the MRW in the future if, using its best professional judgement, Ohio EPA determines the data and modeling have advanced to the point that revising the TMDL to allocate loads for DRP is feasible and necessary to meet the designated uses and WQSs.

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