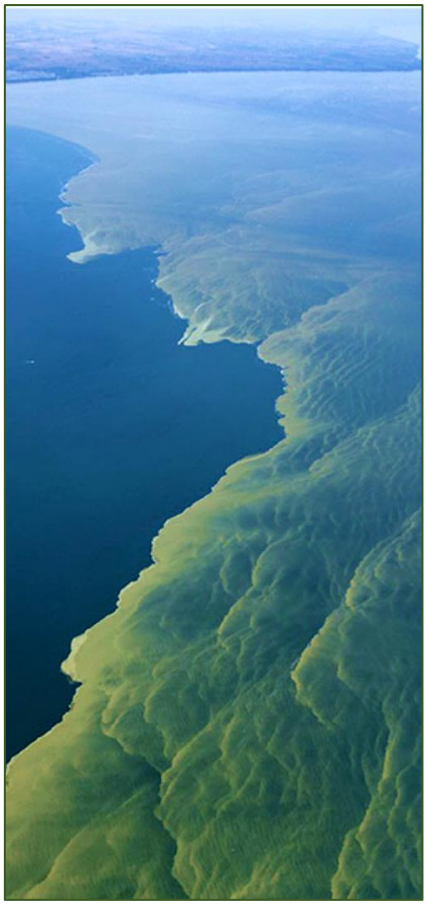
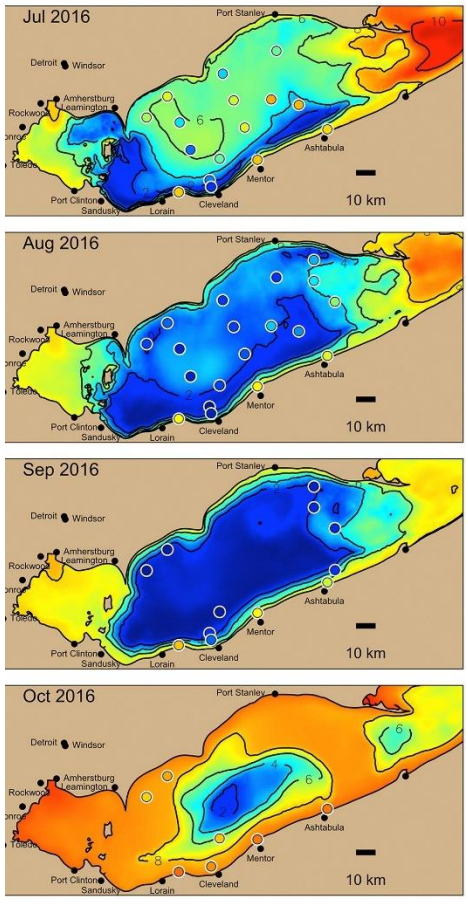
Synthesis of Recommendations and Assessment of Action to Reduce Great Lakes Nutrient Impacts

March 2022

Prepared for:
International Joint Commission
Great Lakes Science Advisory Board and Water Quality Board
Work Group on Nutrient Synthesis





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Cover images, clockwise from left: *Edge-of-field study site (U.S. Geological Survey), Lake Erie algal bloom (Aerial Associates Photography, Inc., photo by Zachary Haslick, Flickr), and simulated hypoxic areas in Lake Erie in 2016 (National Oceanic and Atmospheric Administration-Great Lakes Environmental Research Laboratory; Rowe et al., 2019).*

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Final Report

Prepared for:
The International Joint Commission

March 2022

Prepared by:
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Acknowledgments and Disclaimers

The consulting team gratefully acknowledges the time and energy of the Work Group members, workshop participants, and IJC staff who provided advice and guidance for this study and report. The views expressed in this report do not necessarily reflect the positions of Work Group members or their employers. The use of product or trade names is for descriptive purposes only and does not reflect endorsement by report contributors or their employers.

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1. Executive Summary

Lake Erie and Lake Ontario have been impacted by excess nutrient loading for many years. Under the commitments of the Great Lakes Water Quality Agreement (GLWQA) and its Annex 4 (Nutrients) Subcommittee, the Parties have been working to reduce nutrient loads and restore the lakes and their ecosystems. The goal of this project has been to assess federal, state, and provincial domestic action plans (DAPs) and progress toward 40 percent phosphorus (P) load reductions for Lake Erie, along with determining the state of scientific knowledge related to associated lake and watershed processes. The assessment was conducted in light of nutrient-related recommendations presented in recent International Joint Commission (IJC) advisory board and work group reports concerning actions needed to address impacts in Lake Erie. A secondary goal was to explore priority issues concerning nutrient-related impacts in Lake Ontario. Excess nutrients are a pervasive threat in several transboundary basins beyond the Great Lakes (e.g., Lake Champlain and Lake of the Woods), and although the focus of this project has been on Lake Erie and Lake Ontario, there are substantial opportunities to share the understanding of science and management approaches across basins. The findings, gaps, and recommendations listed here were the result of LimnoTech's overall assessment as well as incorporation of workshop feedback and Work Group comments received during multiple review cycles of draft report versions.

Key Findings

- Substantial progress has been made in advancing research priorities identified in IJC reports, but nonpoint nutrient reduction commitments are not on track in most Lake Erie jurisdictions.
- There has been major progress over the last 10 years in developing the monitoring, modeling, and data management infrastructure necessary to support future adaptive management.
- The combined effects of increased spring runoff, ongoing installation of tile drains in agricultural land, and less incorporation of applied fertilizer and manure into agricultural soil have led to increased loading of dissolved phosphorus (P) to Lake Erie over the last two decades.
- Scientific understanding and management of nutrient loading and impacts on Lake Ontario are substantially different from those in Lake Erie and require their own approaches.

Gaps

- Critical data gaps include a lack of high-resolution geospatial data at an annual scale on the implementation of agricultural best management practices (BMPs) in the lake watersheds, and an insufficient understanding of the distribution and dynamics of legacy P in soils across the basins that is necessary to target BMP implementation.
- Additional barriers to effective BMP implementation include a lack of clarity on the most effective and efficient ways to incentivize adoption by producers, and inadequate linkages between BMP adoption and water quality impacts in tributaries and lakes.
- High-resolution and comprehensive data showing annual hypoxic area and dynamics in Lake Erie, toxin concentrations across algal blooms, and *Cladophora* coverage in eastern Lake Erie and Lake Ontario are not available.

- Understanding of winter limnology and nutrient cycling in Lake Erie and Lake Ontario is a longstanding but important gap, especially in terms of influence on Lake Erie hypoxia formation.

Recommendations

Short-term, Lake Erie

- By 2024, support completion of coordinated studies (with partners) to assess costs and primary communication and adoption barriers to implementation of the top three BMPs (cover crops, riparian buffers, subsurface fertilizer placement) to achieve 8 percent nonpoint P load reductions by 2026 (= the first fifth of the 40 percent overall nonpoint goal).
- Support continued development and institutionalization within three years of the technical and governance elements of an effective Annex 4 Adaptive Management process including coordinated lake and watershed monitoring, modeling, data management, decision-support, convening of advisory groups, and annual communications products.
- Facilitate broad engagement in the 2023 DAP update and review process.

Long-Term, Lake Erie

- Support development and implementation by the Parties of policies and programs that accelerate nonpoint nutrient load reductions in tributaries of Lake Erie and increase accountability of jurisdictions and producers toward meeting 40 percent reduction goals.
- Identify annual BMP adoption targets and sources of the necessary investments and incentives to achieve annual nonpoint P load reductions of an additional 8 percent annually from 2027 through 2030 (= the remaining four-fifths of the 40 percent overall nonpoint goal).

Short-Term, Lake Ontario

- Support investment in Lake Ontario research, monitoring, and modeling to bring the state of knowledge of the unique watershed and lake system to a point where appropriate nutrient management action commitments can be made and implementation initiated by 2025.

Long-Term, Lake Ontario

- Support investment in additional Lake Ontario studies to reduce uncertainty about balancing impacts of improving nearshore eutrophic conditions and offshore oligotrophic conditions such that 2025 commitments can be refined by 2030.

2. Introduction

Nonpoint agricultural sources are broadly recognized as the major contributors of excess phosphorus to Lake Erie, with some estimates placing the nonpoint agricultural contribution to the western basin as high at 85 percent of the total load (Scavia et al., 2016; Baker et al., 2019; Ohio Lake Erie Task Force, 2013). The goal of this project was to synthesize nutrient-related information for Lake Erie and Lake Ontario based on a review of domestic action plans, IJC reports, and other recent literature concerning actions needed to address nutrient-related impacts in the lakes. Great Lakes advisory boards and their Work Groups provide input on water quality issues to inform the IJC's advice to governments. In executing the project the LimnoTech contractor team worked closely with the Nutrient Synthesis Work Group and IJC staff to execute project tasks and prepare interim and final report drafts. Project elements included the following:

a) Review and summarize key findings and recommendations in eight IJC reports related to nutrient impairments in Lake Erie (subject of GLWQA Annex 4).

b) Review and summarize other relevant peer-reviewed literature published since these reports were issued addressing Lake Erie nutrient impairment.

c) Assess federal, state, and provincial domestic action plans and their implementation considering their adequacy to meet their objectives.

d) Identify key issues from Lake Erie that should be part of efforts to address nutrient impacts in Lake Ontario.

The study also included a virtual two-day workshop on the afternoon of October 28 and the morning of October 29, 2021, that included approximately 40 multi-national subject matter experts. The workshop is described in more detail below, but its objectives were to review draft project findings and refine recommendations developed and summarized in an interim report. Workshop results were incorporated into the final project report.

The following sections provide results of the literature review, an analysis of data gaps and critical uncertainties that limit some management actions and decisions, summaries and comparisons of IJC report recommendations and domestic action plan commitments (with appendix tables), a workshop summary, a summary of results, and a list of references. This synthesis links disciplines, lakes, countries, jurisdictions, institutions, documents, and subject matter experts to determine the state of knowledge about nutrient impacts on two Great Lakes and uses that knowledge to propose a limited set of actions to improve understanding, management, and restoration of these valuable ecosystems.

3. Literature Review

A major part of this synthesis was a review of recent literature related to Great Lakes nutrients. The review included recent (post-2013) IJC reports and broader research concerning Lakes Erie and Ontario with an emphasis on 2016 to 2021 peer-reviewed and gray literature. A total of eight IJC reports, and 191 watershed and lake-related publications were reviewed, along with numerous websites. Not all are cited below, but all are listed alphabetically and classified according to a simple code in the references list (Section 9). Work Group members suggested additional papers and topics to consider beyond those initially identified by the contractor team.

Short summaries related to recent research on Lake Erie and Lake Ontario nutrient loading and impacts follow, along with related research from other parts of the Great Lakes basin or beyond. The research reviewed includes science, policy, and management elements, as well as specific consideration of factors such as the impacts of climate change, legacy phosphorus, aquatic invasive species, and watershed BMPs. Additional discussion of key data gaps and process understanding uncertainties is provided in Section 3. The Great Lakes HABs collaborative also released a HABs knowledge gaps fact sheet in April 2021.

Watershed Research

Rural Watersheds

As stated above, nonpoint phosphorus from agricultural sources contributes up to 85 percent of the total load to western Lake Erie (Scavia et al., 2016; Baker et al., 2019) and is the focus of much of the watershed-based research in the region. Kalcic et al. (2018) and King et al. (2018) related both in-field fertilizer management practices and beyond-field practices to P transport by surface runoff and tile drainage and showed a greater load from tile drainage than was previously recognized. In a lead-off article to a special issue of the *Journal of Soil and Water Conservation,* Daniels et al. (2018) summarized how edge-of-field monitoring experiments were being used in the Lake Erie watershed and elsewhere to quantify the details of nutrient loss at the field scale. Long et al. (2018) and Kast et al. (2019) published research on manure transportation from its sources to areas of application and found that existing guidelines and practices can result in the overapplication of manure near some farms where it is produced. Although these manure studies did not examine regulatory and management policies in detail, the IJC Water Quality Board is currently conducting a study to explore approaches to collaborative management of manure and other potential improvements to manure handling, application practices, and oversight associated with animal feeding operations. The LimnoTech (2017/2019) study found that P in manure generated in the western Lake Erie watershed in Ontario was approximately equal to commercial fertilizer P applied to fields, but that manure P was substantially less than fertilizer P in U.S. watersheds of the basin. Kast et al. (2021b) determined that manure sources of phosphorus contributed only 8 percent of the total phosphorus load and 12 percent of the dissolved reactive phosphorus load from the Maumee River Watershed to Lake Erie. Given the importance of

fertilizer management practices to load reductions, enhancing the implementation of 4R practices is a priority (see additional 4R discussion in the *Data Gaps* section below).

Wilson et al. (2018 and 2019) reported results of research on farmer behavior and incentives that influence the reduction of P loading to Lake Erie and associated policy development. An interesting finding of this study was the importance that farmers placed on believing that the conservation actions they take will actually have a substantial impact on nutrient losses before they were willing to implement them. This indicates that financial incentives alone are unlikely to lead to widespread adoption of BMPs unless producers are convinced that they make a difference. Akkari and Bryant (2017) drew similar conclusions. Data on BMP implementation are difficult to obtain at high spatial resolution and are rarely linked to water quality data from the same subwatersheds to quantify anticipated improvements as increased BMP adoption takes place.

Robertson et al. (2019) published watershed loading results based on the modeling of 2012 data for the entire Midwest U.S., including the Lake Erie basin. A research effort led by The Ohio State University brought together an ensemble of watershed SWAT models and the USGS SPARROW model to assess a suite of related watershed management questions and scenarios. The results of this work have been published in several recent articles (Kujawa et a., 2020; Martin et al., 2021; Kast et al., 2021a; Apostel et al., 2021; Evenson et al., 2021). In addition to changes in nutrient loads, shifting nutrient ratios have also been identified as potentially important drivers of ecosystem change in Lake Erie (Prater et al., 2017). Differential impacts on N and P loads from cover crops were measured by Hanrahan et al. (2021). Watershed research in the Lake Ontario basin has been less intense than in Lake Erie, but many of the same issues have been studied (Makarewicz et al., 2012 and 2015).

Urban Watersheds

Important new research has been published on urban stormwater and wastewater processes and impacts in Detroit (Hu et al., 2019) and Toronto (Howell and Benoit, 2020). Related monitoring work has also been done on the Niagara River (Hill and Dove, 2021). Urban wastewater load reductions from the Detroit area are among the largest reductions in the basin since the baseline year of 2008 (see Scavia et al., 2019c).

Lake Research

In-lake bloom processes were examined as they relate to remote sensing (Binding et al., 2019, Soontiens et al., 2019), algal bloom seed stock in sediment (Kitchens et al., 2018), and the influence of nitrogen and other factors on bloom growth and toxicity (Chaffin et al., 2018; Newell et al., 2019; Palagama et al., 2020; see also Bruulsema et al. [2022] for watershed nitrogen considerations). Choquette et al. (2019) reported on statistical methods for handling variability in streamflow for P loading calculations, and Scavia et al. (2016, 2019a, 2019b, 2019c, 2020), Bocaniov and Scavia (2018), Bocaniov et al. (2019), and Dagnew et al. (2019) published results of new modeling and monitoring studies that inform P loading from the St. Clair-Detroit River system to Lake Erie. A companion report to the Scavia et al. (2019a) paper was also released in 2019 (Scavia et al. 2019b). Arhonditsis et al. (2019a and 2019b) reviewed Lake Erie watershed and lake models and monitoring and made recommendations for their use in adaptive

management. Burniston et al. (2018) published results of a collaborative binational project to directly measure nutrient loads in the St. Clair-Detroit River connecting channel. Liu et al. (2020) synthesized weekly in-lake monitoring data and satellite data collected between 2008 and 2017 with a goal of moving toward HAB toxicity forecasting. Anderson (H. Anderson et al., 2021a and 2021b) made novel in situ time-series measurements of phosphorus (P) release from central basin sediments in association with the development of bottom-water hypoxia, and others have done studies on nutrient processing in river mouths including Sandusky Bay (Salk et al., 2018; Hampel et al., 2019). Recent research looked at P limitation related to lipid binding in Lake Erie (Musial et al., 2021).

Modeling and Monitoring

This section mostly concentrates on Lake Erie work, with a brief discussion of Lake Ontario at the end. Watershed models exist for the St. Clair-Detroit River system, Maumee River, Portage River, and Grand River, among others. Mechanistic lake models exist for the western Lake Erie basin (Verhamme et al., 2016), the central basin (Rowe et al., 2019; Bocaniov et al., 2020; Valipour et al., 2021), and the eastern basin (Valipour et al., 2016 and 2019). LimnoTech completed a new whole-lake model in early 2021. Kuczynski et al. (2020) recently published an improved *Cladophora* model that incorporates self-shading and other mechanistic enhancements.

Monitoring programs for water quality and flow are ongoing or have recently been conducted by the Ontario Ministry of Environment, Conservation, and Parks (MECP), U.S. Geological Survey (USGS), Heidelberg University's National Center for Water Quality Research (NCWQR), and others in tributaries including the Thames, Detroit, Huron (MI), Raisin, Maumee, Portage, Sandusky, Vermilion, Cuyahoga, Cattaraugus Creek, Grand, Nanticoke, Lynn, Big, and Big Otter. Phosphorus loads from smaller, unmonitored tributaries can be estimated using watershed areas, land use data, and precipitation data. The data from these programs could be consolidated and synthesized annually by water year by the Great Lakes Water Quality Agreement Nutrients Annex Subcommittee (Annex 4) and supporting groups to produce a basin-wide estimate of seasonal and total loads. Betanzo et al. (2015a and 2015b) reviewed watershed monitoring and found that it was inadequate to support many management decisions. The whole-lake modeling effort mentioned previously required load inputs and developed average loads from various data sources and estimations.

Lake monitoring has been most intensive in the western basin, where the focus has been on the areal extent and toxicity of HABs. Satellite monitoring and in-lake sampling for HABs are conducted by the U.S. National Oceanic and Atmospheric Administration (NOAA), with results released in twice-weekly bulletins as an operational product. NOAA also produces a pre-season ensemble model forecast and a post-season comparison of HAB model predictions to observed conditions. Other organizations that conduct in-lake HAB monitoring are the USGS, University of Windsor, MECP, University of Toledo, Ohio Sea Grant, Bowling Green State University, Ohio Environmental Protection Agency, and drinking water utilities such as the City of Toledo Division of Water Treatment and the Township of Pelee West Shore Water System. Coordinated whole-bloom sampling was done in the western basin in 2018 and 2019 to get two snapshots of the summer blooms (Chaffin et al., 2021).

Central basin hypoxia monitoring has been conducted most intensively since the 2014 Cooperative Science and Monitoring Initiative (CSMI) field year by the U.S. Environmental Protection Agency – Great Lakes National Program Office (USEPA-GLNPO; Xu et al., 2021), although earlier data also exist (Zhou et al., 2013). The City of Cleveland has also monitored hypoxia near their water intakes since 2014. These monitoring programs supported a modeling project by the Cooperative Institute for Great Lakes Research (CIGLR) and NOAA (Rowe et al., 2019), which built on prior research by Scavia et al. (2016) and Rucinski et al. (2016). The modeling program developed an experimental short-term forecast product but was not designed to produce a seasonal forecast. A seasonal forecast would likely require winter and early spring monitoring of diatom biomass in the western basin and central basin, which is not routinely performed (Twiss et al., 2012). Annual summaries of hypoxic area or volume are not produced at present, although an operational monitoring program, especially with sensors that report in real time rather than after physical recovery and downloading of data, could be used to create such summaries.

Eastern basin macroalgae spatial coverage and biomass are not consistently monitored or reported for the whole basin, although related research programs have been conducted or are underway by Environment and Climate Change Canada (ECCC; Valipour et al., 2016), MECP (Chomicki et al., 2016), Michigan Tech Research Institute (MTRI; Brooks et al., 2015), and USGS (Wimmer et al., 2019). The MTRI methodology using remote sensing has been applied retrospectively to create a macroalgae time series at select sites (e.g., Ajax, Ontario), and could be applied annually to produce a summary of the maximum extent of coverage.

Lake Ontario is less complex than Lake Erie and has been the subject of recent modeling of nutrient loading from the Niagara River plume (Pauer et al., 2021), as well as a new whole-lake model that simulates Niagara and tributary loading as well as upwelling and dreissenid mussel impacts (Hui et al., 2021a and 2021b). Dreissenid mussel impacts on Lake Ontario are discussed further below.

Climate Change

The Midwest Region chapter of the Fourth National Climate Assessment by the U.S. Global Change Research Program (USGCRP, 2018) highlighted several trends that have the potential to influence phosphorus loading to Lake Erie and ecological impacts in the lake. National analyses have shown or predicted increasing algal bloom intensity related to climate change (Chapra et al., 2017), although some analyses have suggested that the apparent increase in blooms, particularly in inland lakes, may be an artifact of more intensive sampling (Hallegraeff et al., 2021; Kraemer et al., 2021; Wilkinson, et al., 2021). Several researchers have identified statistical trends of increasing spring rainfall, runoff, and nutrient loading in Lake Erie watersheds (Stow et al., 2019; Williams and King, 2020). Warmer lake temperatures and longer summers with changing weather patterns are expected to produce more toxic algal blooms and more intense hypoxia in Lake Erie (Michalak et al., 2013; Perello et al., 2017; Jankowiak et al., 2019; Jabbari et al., 2021).

Some researchers have proposed that shifting baselines may necessitate adjustments to nutrient loading targets even before they are achieved (Baker et al., 2019). Others have pointed out that

under scenarios of longer growing seasons and more winter precipitation falling as rain rather than snow, agricultural nutrient losses in spring may decline, partially mitigating other negative climate change impacts on Lake Erie (Culbertson et al., 2016; Kalcic et al., 2019). More rainfall, especially in the spring, may hinder planting and fertilizing due to field conditions that do not allow equipment to access the fields, as was observed in 2019 (Guo et al., 2021). Changes in nutrient release from cover crops during the non-growing season and other impacts on BMP effectiveness of changing climate are not well understood (Cober et al., 2019).

Uncertainty related to net climate change impacts in the coming years is an important factor that is aligned with taking an adaptive approach in the management of the system. High ice cover in Lake Erie, which requires sustained low winter temperatures and low winds, has shown no trend over most of the lake from 1973 to 2013, and a slight downward trend along the Ontario shore over the same period (Mason et al., 2016). Anderson (E. Anderson et al., 2021) showed evidence of long-term warming in deep waters of Lake Michigan, which may also be taking place in other lakes but insufficient data are available to document it as completely.

Legacy Phosphorus

The role of legacy phosphorus (Sharpley et al., 2013; Muenich et al., 2016; Bruulsema et al., 2019) in overall loading to Lake Erie is an area of active research (LimnoTech, 2017/2019; Osterholz et al., 2020; Guo et al., 2021; Van Meter et al., 2021). Phosphorus that is already in fields and tributary sediments may delay ecosystem recovery, even after BMPs are widely adopted (Jarvie, et al., 2017; King et al., 2017). Analysis of 2019 loading data suggested that loads were lower than what would have been expected given the wet spring and high flows (Guo et al., 2021). Other recent field and stream sediment studies have produced results that seem inconsistent with these observations (e.g., Osterholz et al., 2020; Williamson et al., 2021). That is, stream studies show greater fractions of legacy P in some settings, particularly in upper watershed areas and small streams, than would be expected based on Guo et al. (2021) data and interpretations. Research to reconcile these results continues. Legacy P is one of the considerations in a more holistic approach to soil health and regenerative agriculture, as described by Zimnicki et al. (2020).

Aquatic Invasive Species

Where present in abundance, invasive dreissenid mussels have caused a nearshore shunting and benthification of phosphorus in multiple lakes (Hecky et al., 2004). This suggests that mussels trap and retain phosphorus in nearshore areas and especially around tributaries, thereby increasing benthic nutrient levels in nearshore areas. Over the long-term, mussel densities in the western and central basins have remained low due to unsuitable substrate and hypoxia, while densities in the eastern basin are much higher but peaked in 2002 (Karatayev et al., 2014; Karatayev et al., 2018). Selective feeding by mussels on diatoms versus cyanobacteria has been described by Vanderploeg et al. (2001), but modeling suggests that this is not a major factor in algal bloom intensity (Verhamme et al., 2016). In Lake Ontario, dreissenid density peaked at the 31-90 m depth interval in 2003, yet continues to increase at > 90 m based on 2013 data. It should also be noted that while

density has decreased, biomass has increased at 31-90 m in recent years (ECCC & USEPA 2017 ad 2020) and growth rate declines with depth (Elgin et al., 2021).

Other Topics and Locations

Additional related research has been done on agricultural BMP performance in cold regions outside of the Great Lakes (Liu et al., 2019a, 2019b, 2019c, 2021; Satchithanantham et al., 2019; Klaiber et al., 2020), and on land cover impacts on nutrients (Pearce and Yates, 2020; Fasching et al., 2019). Basin-wide impacts of dreissenid mussels were quantified by Li et al. (2021), and Larson et al. (2020) examined nutrient processing in river mouths around Green Bay. Binding et al. (2018) did similar satellite studies of Lake Winnipeg HABs to those they conducted in Lake Erie (Binding et al., 2019). Ghosh and Bakshi (2019) discussed how nutrient treatment wetlands can be incorporated into biofuel supply chains (e.g., corn for ethanol production) to mitigate eutrophication impacts.

Literature Review Summary

Several of the scientific discoveries and innovations described above have special significance to nutrient management in Lake Erie, Lake Ontario, and their watersheds. The results of the natural experiment that took place in 2019 where excess rainfall in the spring resulted in less fertilizer application indicated that legacy P may not be as important in the Maumee Watershed as previously hypothesized (Guo et al., 2021). New understanding of how dynamic hypoxia in the central basin of Lake Erie is, based on new modeling and monitoring (Rowe et al., 2019), suggests that progress toward the goal of reduced hypoxic area or volume based on nutrient reduction to may be difficult to measure and track. The integrated pattern of dreissenid mussel presence or absence in the basin may be a reasonable if unusual proxy (Karatayev et al., 2018).

Similarly, the dynamic nature of watershed nutrient delivery based on changing climate, farming practices, drainage modifications, and inadequate tracking make systematic monitoring of BMP implementation and assessment of positive impacts difficult. Despite this, innovative ensemble modeling of agricultural watersheds incorporating enhancements for simulating tile drainage and manure management impacts at high resolution is very promising (Martin et al., 2021). Better understanding of the drivers of BMP adoption by producers (Wilson et al. 2018) paired with BMP scenario modeling (Martin et al., 2021) also presents valuable insights on how to adjust nonpoint reduction programs to improve results. Three specific BMPs that seem to be effective and widely accepted are cover crops, riparian buffer or filter strips, and subsurface fertilizer placement (Wilson et al., 2018; Martin et al., 2021). Finally, new work on field measurements and modeling of benthic interactions among dreissenid mussels, macroalgae, river plumes, and upwelling (Wimmer et al., 2019; Kuczynski et al., 2020; Hui et al., 2021) is reducing uncertainty that will be critical in managing nutrients in eastern Lake Erie and in Lake Ontario, where offshore oligotrophication is also a concern.

4. Data Gaps and Process-Understanding Uncertainties

In 2015, the Annex 4 Objectives and Targets Task Team identified 17 priority research, monitoring, and modeling activities to support management decisions and listed critical overarching topics under a heading of "What we do not know". The list included questions about phosphorus speciation and bioavailability; the roles of nitrogen, dreissenids and other invasive species, and inter-annual variability in hydrometeorology; and whether a 40% load reduction will be adequate to reduce impacts at local scales for each priority tributary and receiving water area (e.g., Sandusky River/Sandusky Bay). Mohamed et al. (2019) also listed key uncertainties that impact the ability to make good management decisions about Lake Erie restoration. In addition to lake-wide uncertainties, management of subwatersheds and of each lake basin is also hindered by knowledge and data gaps, although substantial progress has been made since the 2015 report was released.

Uncertainties about the Effectiveness of Agricultural BMPs

Although a variety of agricultural BMPs have been formally approved for conservation funding by the U.S. Department of Agriculture under the Farm Bill and under similar Canadian programs, the particular effectiveness at reducing phosphorus loading associated with each practice is not routinely well quantified. Monitoring of effectiveness is rarely conducted, and region-specific performance data are often lacking. The Thames River Phosphorus Reduction Collaborative, U.S. Agricultural Research Service, and many other organizations are investigating this priority research area. Historical emphasis on erosion control and retention of particulate phosphorus on agricultural fields via practices like conservation tillage, cover crops, and buffer strips has been enhanced by new research on soluble phosphorus, which is more mobile and more bioavailable (Scavia et al., 2014).

Studies showing significant delivery of soluble phosphorus from drain tiles to waterways (King et al., 2015; Osterholz et al., 2020) have led to a new emphasis on conservation practices that make applied fertilizer and manure less mobile. Such practices include limited incorporation via tillage and an emphasis on subsurface injection to maintain erosion-control benefits of less soil disturbance while also reducing the inherent P losses that come from broadcast application of fertilizer on the soil surface without incorporation (Baker et al., 2017; Williams et al., 2018). This would be considered a "right place" element of the 4R nutrient management practices (4R nutrient management = right source, right rate, right time, right place; Vollmer-Sanders et al., 2016; King et al., 2018). Additional considerations of 4R principles, incorporating knowledge gained from over a decade of implementation, are described by Bruulsema et al. (2019) and Bruulsema (2022), including needs for further research. Wetland creation or restoration has been shown to be an effective means of removing P from agricultural runoff and from flowing waterways (Messer et al., 2021).

Western Basin Uncertainties

In the western basin of Lake Erie, several important areas of uncertainty impact nutrient reduction program implementation, particularly related to determining the most effective suite of agricultural practices and the right placement of those practices to effectively reduce P loading

(Scavia et al., 2017; Yuan et al., 2020). Despite recent research by the University of Michigan and others (Scavia et al., 2019), questions remain about P loading and processing in southern Lake Huron (i.e., sediment resuspension and advection into the St. Clair River), the Thames River (Ontario), and the St. Clair-Detroit River system. The interaction of P in the Detroit River plume with spring diatom production and summer cyanobacteria blooms in the central basin is still unclear, as that part of the basin is not well monitored and important interactions occur in early spring when ice is breaking up, and during summer when complex mixing between river plumes takes place. The transfer of biomass and nutrients from the western basin to the central basin is also not well understood or quantified, but this is important as a driver of central basin hypoxia. Additional questions remain about the nature and importance of the P stored in surface sediment in the western basin between spring loading from the Maumee River and summer bloom initiation and expansion. Cyanotoxin formation mechanisms and environmental controls are also poorly understood. Lastly, the diversity of cyanobacteria in river mouths, as opposed to monospecific blooms in open waters of the basin, is somewhat enigmatic. In particular, the drivers of the consistent and persistent *Planktothrix* bloom in Sandusky Bay have not been determined (Hampel et al., 2019).

Central Basin Uncertainties

Apart from small offshore blooms of *Dolichospermum* in July (Chaffin et al., 2019), the central basin of Lake Erie does not typically experience HABs, but it does host large areas of hypoxic bottom water in summer and early fall. As mentioned under discussion of the western basin, the Detroit River is believed to be the primary source of nutrients that fuel diatom and, to a lesser extent, cyanobacteria blooms that sink into the stratified basin and consume oxygen as they decay. Sediment oxygen demand is also believed to play a role, along with upward fluxes of nutrients from sediment and bottom waters during upwelling events. Direct tributary loads to the central basin are smaller than fluxes from the western basin but may be locally important. A full mechanistic understanding of these processes and movements of nutrients, biomass, and hypoxic water over the spring, summer, and fall has been elusive, but mechanistic and predictive models have recently been developed to simulate these processes, and the resolution of monitoring data has also improved (Rowe et al., 2019; Tellier et al., 2022).

Eastern Basin Uncertainties

The eastern basin of Lake Erie is the deepest, and also possibly the least well understood. Growth and sloughing of excess macroalgae such as *Cladophora* are widespread in nearshore areas of the eastern basin, but the interplay of river loading, shading by river plume turbidity, upwelling of nutrients, and macroalgae-mussel interactions are areas of active research (Kuczynski et al., 2020). Numerical models of macroalgae growth, satellite monitoring of occurrence, and studies by divers and others incorporating repeat surveys, bottom instrument packages and cameras, and experiments have improved understanding substantially in the last five years. Fluxes into the basin from the west and out of the basin to the Niagara River could be better monitored. Numerical models to simulate these processes are being developed. Effective ways to reduce nutrient loading to the basin, particularly from Ontario tributaries including the Grand River, suffer from many of the same challenges as the Maumee River watershed such as insufficient

understanding of BMP effectiveness and of legacy P cycling in the system (Hanief and Laursen, 2019; Van Meter et al., 2021). Current research on macroalgae-related processes, including extensive field elements, is underway by USGS at stations in Lake Erie and Lake Ontario, among other locations (Wimmer et al., 2019).

Lake Ontario Uncertainties

The Niagara River represents the largest tributary input of nutrients to Lake Ontario. As described in the *Lake Ontario – State of Nutrient Science* report prepared for the Lake Ontario Nutrient Task Team (LONTT; deBarros, 2016 and 2021), there is a significant discrepancy between estimates derived by Dolan and Chapra (2012) and recent assessments conducted by ECCC (Dove, 2017; Hill and Dove, 2021), with the latter suggesting that Niagara River total phosphorus (TP) loading to Lake Ontario is at least two times higher than previously estimated. Much of the discrepancy is related to whether TP concentrations from the eastern basin of Lake Erie, the upstream end of the river (Fort Erie or Buffalo), or the downstream end of the river (Niagara-on-the-Lake, NOTL) are used to compute TP loading (deBarros, 2016 and 2021). The scientific community has not yet reached a consensus on this subject. Apart from the measurement uncertainties, the situation is complex as the TP loads from the Niagara River could be carried by the eastward Niagara plume and flushed out of the lake in much less time than the average lake residence time, rather than staying in the nearshore or being transported to the offshore (Pauer et al., 2021). Additional uncertainties that impact future decisions about nutrient management include the abundance, distribution, and future impacts of dreissenid mussels on nutrient cycling in the lake; and important aspects of the role of stratification (Scofield et al., 2018) and upwelling versus river loading in nutrient cycling and delivery of phosphorus to macroalgae along the north shore, along with mussel impacts (Howell and Dove, 2017; Shen et al., 2020; Hui et al., 2021a and 2021b). The offshore oligotrophication of Lake Ontario waters induced by nearshore trapping of nutrients by invasive dreissenid mussels (Hecky et al., 2004) creates an extra challenge for nutrient management in the lake. Additional reductions in tributary loading can further impact food supplies for offshore fish communities (LimnoTech, 2018; Hui et al., 2021a).

5. IJC Report Recommendations and Status

Over 100 recommendations or sub-recommendations from eight previous IJC reports related to nutrients are summarized in Table 1 below and reproduced fully in a 23-page table in Appendix A, along with a brief assessment of the status of subsequent actions or research publications consistent with each recommendation. The columns on the right side of the summary table below include qualitative assessments of the degree of progress made to date on the overall set of recommendations from each report based on best professional judgment. The most significant recommendation topics, as listed in column 2 of Table 1, were weighted most heavily in assessing progress.

In general, as would be expected, more progress has been made on recommendations from some of the older reports, and especially under the general areas of research and monitoring. Since the 2014 "Balanced Diet" report, many of its recommendations regarding the setting of loading targets and other actions have been implemented under GLWQA Annex 4 and other agreements and programs. Many of the 2014 report's recommendations are also reflected in the 2018 DAP commitments. Efforts to develop more formalized adaptive management approaches at state/provincial and binational levels are underway and are aligned with many of the recommendations in these reports, including contributions by many members of prior workgroups who contributed to these reports and who are now involved in adaptive management planning and implementation. Of particular value are recommendations that supported research and monitoring to reduce uncertainty, modeling to integrate data and allow for scenario evaluation, and improvements in governance and mitigation program effectiveness. Improving the management process alone, however, is unlikely to translate into direct nonpoint load reduction benefits without modification of policies, incentives, and potentially of regulations.

The succession of IJC assessment projects has produced greater clarity on many related topics and has facilitated critical synthesis across disciplines and geographies. Among the older reports, there has been less progress on recommendations of the 2015 HABs economics report than the others. This is likely due to the smaller community of practice in the area of Great Lakes environmental economics than in other areas such as aquatic ecology, fishery science, agronomy, or biogeochemistry. The health and cyanotoxins report (2017) called for the development of health limits for a suite of cyanotoxins, but only a few have been released to date. The watershed management report (2016/2017) recommendations have only been partially realized for a variety of reasons including inadequate governance and insufficient incentives. The major shortcoming related to the fertilizer application study (2018/2019) is the continued lack of data on agricultural BMP placement and effectiveness in controlling nonpoint P.

It is difficult to evaluate the impact of some of the more general recommendations (e.g., "strengthen and increase the use of regulatory mechanisms"). It is clear, however, that many specific recommendations have been implemented in whole or in part. The IJC has no regulatory authority concerning water quality but advises the Parties on related policies that could be implemented by their agencies within their respective legislative and governance frameworks and

program missions. The IJC's reports, advisory boards, work groups, workshops, and communication products, including those reviewed in this project, have broad influence on research agendas, resource allocation, and policy development in Lake Erie, Lake Ontario, and the rest of the lakes, even if that influence is not always easy to assess directly or explicitly.

Several recommendations touch on the area of ecosystem services valuation, which is a growing area of quantitative decision support where choices that optimize a broad suite of services or co-benefits are favored over more narrow options (Steinman et al., 2017). Wang et al. (2019) performed a Lake Erie ecosystem services assessment for the City of Toledo. It estimated the benefits to recreational fishers and beach-goers of a 40 percent reduction in nutrient loading to Lake Erie (as high as 125 million USD). Arnillas et al. (2021) and Liu et al. (2020) applied integrated watershed and economic or ecosystem service models to assess best management practice efficiency in the Lake Erie watershed. Pyo et al. (2017) developed a spatially explicit model that optimized cost, effectiveness, and farmer familiarity for various BMPs in a typical Lake Erie watershed.

Nutrient trading programs mentioned in some recommendations are attractive ways to incentivize fertilizer or manure management practices, although there are substantial barriers to effective implementation, including quantitative monitoring. A complex trading scheme in Ohio's Great Miami River Watershed links five wastewater treatment plants with hundreds of non-point agricultural credit providers (Kieser and McCarthy, 2015). A study in Wisconsin found that recovery of value-added products from livestock waste was not economically viable unless it was combined with biomethane capture for energy generation (with renewable energy credits) and potentially phosphorus credits from nutrient capture (Sampat et al., 2018). An attempt to establish a trading program in the Lower Fox River in Wisconsin in 2013-2016 only reached a pilot scale. The Great Lakes Restoration Initiative funded five market-based nutrient reduction projects in 2020, including water quality trading, to further explore these concepts.

Beyond these approaches, an even broader suite of co-benefits beyond simple crop yields is being considered. The management of agricultural lands can incorporate certain practices that enhance soil health and ultimately reduce the need for fertilizer application, while also resulting in more carbon storage. This can potentially create carbon sequestration credits that can be purchased from agricultural producers as offsets via carbon trading programs (Zimnicki et al., 2020; Croft et al., 2021). Note, however, that additional nutrient inputs are required during the buildup phase of soil organic matter (Christopher and Lal, 2007; Giweta et al., 2014; van Groenigen et al., 2017; Spohn, 2020) so that long-term benefits may require negative impacts (e.g., increased nutrient application and more potential loss) in the short term.

Table 1. IJC Nutrient Report Summaries

IJC Report Topic, Year(s)	Focus of Recommendations	Progress		
		Little	Some	Much
1. Declining Offshore Productivity, 2018/2020	Improve connections between fisheries management and nutrient-related monitoring, modeling, and forecasting; link related efforts to Great Lakes Executive Committee (GLEC), annual Great Lakes Fishery Commission (GLFC) Lake Committee meetings, five-year CSMI cycles, and Lake Ontario Annex 4 efforts	●		
2. Manure Management, 2020	Increase tracking and regulation of animal feeding operations and manure application, promote manure reuse and treatment, and development of collaborative management efforts	●		
3. Nutrient Modeling Approaches, 2019	Maintain and improve ensemble modeling approaches, couple lake and watershed models, enhance monitoring and ground-truthing, improve model accuracy and predictive skill, improve coordination and governance, implement adaptive management approaches			●
4. Fertilizer Application, 2018/2019	Improve quantitative understanding and tracking of phosphorus application and cycling, tile drainage, BMP adoption and effectiveness, changes in eutrophication phenomena, and climate change		●	
5. Watershed Management, 2016/2017	Develop nutrient management plans for the Lake Erie watershed and elsewhere, improve governance, incentivize implementation, maintain and apply existing modeling tools to guide, standardize metrics for reporting progress, and improve communications		●	
6. Health and Cyanotoxins, 2017	Improve drinking water monitoring and treatment for cyanotoxin removal, increase standardization of approaches, improve toxin testing, enhance toxin monitoring and reporting for beaches, develop numerical health limits for a suite of cyanotoxins		●	
7. Economics of HAB Reduction, 2015	Develop and implement models and survey tools to link HAB occurrence to economic impacts on property values, tourism, recreational demand (beach use, fishing, boating), drinking water treatment and use, agriculture (irrigation water), and industry	●		
8. A Balanced Diet for Lake Erie, 2014	Adopt new targets for spring and annual phosphorus loading in Lake Erie (total and dissolved) and its basins, develop domestic action plans, list U.S. waters of the western basin as impaired and implement total maximum daily loads under the Clean Water Act, link crop insurance to farm conservation practices, enhance and maintain tributary monitoring, optimize load reductions with a suite of actions in rural and urban settings, protect and restore wetlands, consider climate change impacts on ecosystems and economic impacts of HABs			●

6. Domestic Action Plan Status

Actions specified in domestic action plans and related documents are presented in Appendix A and summarized in matrix form in Table 2. Although the granularity of items specified in the 10 documents reviewed differs, a total of 402 distinct actions, recommendations, commitments, or goals was identified in the documents. Progress to date in implementation has been primarily in refinement of state, provincial, and binational nutrient management program elements, including developing adaptive management approaches (Michigan and Ontario) and supporting technical elements such as enhanced monitoring networks and new numerical models. Point source reductions, including projects that were underway before the release of the DAPs in 2018 but still after the baseline year of 2008, have shown the most progress in consistent P loading reductions. Nonpoint P load reductions have been limited in all jurisdictions.

Updates and news about DAP-related activities and additional commitments or priorities are reported fairly frequently (e.g., Ohio 2021 update), along with P loads from large tributaries, but data about changes in loads by source, especially from different nonpoint sources at finer subwatershed resolution, are not available in many cases. Agricultural BMP implementation data seem especially difficult to obtain—they may not exist at the resolution needed for prioritizing management decisions and linking BMP implementation directly with water quality impacts in most cases. Jurisdictions tend not to highlight or even report challenges or obstacles to implementation. Measured loads from larger tributaries have been reported more consistently, including the creation and rollout of the Heidelberg Tributary Loading Program Data Portal in 2021, but variability in spring rainfall and runoff tend to obscure trends over short periods (although see Guo et al., 2021, for interesting low loading results from 2019; and Rowland et al., 2021 for load normalization approaches). It is anticipated that 2023 DAP updates will provide more detailed information on progress to date.

A comparison of IJC nutrient report content or recommendations (Table 1) and DAP actions (Table 2) is compiled in Table 3. The reports and DAPs were prepared for different purposes, so noted differences should not be considered as critiques—merely as observations. The crosswalk analysis shows that there is more focus on research and in-lake impacts of nutrients in IJC analyses than in DAPs. The research element has included synthesis, identification of data gaps, and specification of research priorities. The IJC studies and reports have demonstrated innovation in spanning disciplines (e.g., HAB science with human health and economics), geographies (e.g., cross-jurisdictional or watershed-lake), and scales (lake basin to regional to global, concerning climate change, for example). Some of the IJC reports contain policy recommendations that are more abundant and specific than are found in the DAPs, which is to be expected, as DAP-implementing agencies representing particular jurisdictions generally respond to legislative and mission mandates and authorities, rather than recommending changes to their authorities. Such changes are more properly initiated by those who develop policy and then advocate with the public and elected officials for changes and improvements to existing laws, regulations, programs, and resource allocation. That said, the two countries are signatories to the GLWQA, and so their

respective federal agencies and state or provincial agencies with delegated authority should be taking actions as needed to meet GLWQA objectives.

Table 2. DAP and Related Report Summaries

DAP or Report, Year	Actions/Recommendations									Comments
	Number of Actions/Recs/Goals	Wastewater/Septic Upgrades	Urban Nonpoint Reduction	Fertilizer Management	Manure Management	Cover Crops, Other BMPs	Wetland Restoration, Buffers	Monitoring, Research, Tools	Adaptive Management	
1. U.S. Action Plan, 2018	44		•	•		•	•	•	•	Progress under the Great Lakes Restoration Initiative (GLRI) and federal agency commitments highlighted
2. Indiana DAP, 2018	71	•	•	•	•	•	•	•		Small watershed area in Erie western basin (190 sq. miles, or 492 sq. kilometers)
3. Michigan DAP, 2018	43	•	•	•	•	•	•	•	•	Michigan Agriculture Environmental Assurance Program (MAEAP) is unique
4. Ohio DAP, 2017, 2020, 2021	41	•	•	•	•	•	•	•	•	Particular investments under H2Ohio program, state-funded research program
5. Great Lakes Commission (GLC) Joint Action Plan, 2015	17	•	•	•	•	•	•	•	•	The report anticipated later DAP commitments
6. Pennsylvania DAP, 2017	6	•				•		•		Small watershed area in Erie's eastern basin (511 sq. miles or 1,323 sq. kilometers)
7. Canada-Ontario DAP, 2018	128	•	•	•	•	•	•	•	•	Numerous actions are listed, but many lack metrics
8. Niagara River (New York) Watershed Mgmt. Plan, 2019	30	•	•	•		•	•	•	•	New York was not required to develop a DAP
9. Lake Erie LAMP, 2019-2023	6	•	•	•	•	•	•	•	•	Includes syntheses of DAPs
10. Lake Ontario LAMP, 2018-2022	16	•	•			•	•	•		Includes promotion and enforcement of wastewater and stormwater compliance

Table 3. IJC Report/DAP Comparison

IJC Report	DAP Actions or Recommendations								Comments
	Wastewater/Septic Upgrades	Urban Nonpoint Reduction	Fertilizer Management	Manure Management	Cover Crops, Other BMPs	Wetland Restoration, Buffers	Monitoring, Research, Tools	Adaptive Management	
1. Declining Offshore Productivity							•		DAPs do not incorporate linkages to fishery impacts or in-lake processes more generally
2. Manure Management				•			•	•	Report has specific policy recommendations; DAPs for Indiana, Michigan, Ohio, and Ontario mention manure but focus on guidelines and outreach; some regulation commitments in Ohio and Ontario
3. Nutrient Modeling Approaches	•	•	•	•	•		•	•	Modeling and research are incorporated in some DAPs, but with a watershed loading emphasis; little explicit linkage to in-lake processes
4. Fertilizer Application			•	•	•	•	•		Focus of report is on drivers and inadequacy of data and process understanding to manage effectively; such needs are not articulated clearly in DAPs; climate change only mentioned in Ontario DAP
5. Watershed Management	•	•	•	•	•	•	•	•	This IJC report is most closely aligned with the DAP content; communications elements could be especially valuable to incorporate in DAPs
6. Health and Cyanotoxins							•		HAB health impacts, including drinking water and swimming risks, are not considered in DAPs
7. Economics of HAB Reduction							•		DAPs do not focus on economic assessments or incorporate benefit-cost analyses
8. Balanced Diet for Lake Erie	•	•	•	•	•	•	•		Recommendations in this report influenced 2015 Great Lakes Commission report and later DAPs

7. Workshop Information

The IJC Nutrients Synthesis workshop took place virtually the afternoon of October 28 and the morning of October 29, 2021, and involved a mix of plenary and breakout sessions to address workshop objectives. The workshop involved approximately 40 subject matter experts from diverse disciplines addressing progress in implementing DAPs and related programs to manage nutrient-related problems in Lake Erie and Lake Ontario including harmful algal blooms, hypoxia, and nuisance macroalgae. The workshop's purpose was to review draft project findings and refine recommendations developed and summarized in the interim report (October 25, 2021) prepared by the contractor team, including three primary objectives:

- Review conclusions of the draft assessment concerning the adequacy of DAPs and their implementation for Lake Erie in light of recommendations from IJC reports and other recent literature, and identify any additional issues of concern;
- Identify priority findings and recommendations from the draft assessment that were thought to be most important in addressing nutrient problems in Lake Erie, including concerning any key management efforts as well as research and monitoring efforts needed; and
- Review and revise recommendations as appropriate concerning programs addressing nutrient-related problems in Lake Ontario.

Recommendations from the workshop were captured to inform the final contractor report as well as the subsequent Nutrients Synthesis Work Group report on recommendations for better implementation of DAPs and related programs by the Parties to the Great Lakes Water Quality Agreement.

Summary of Workshop Presentations

An opening workshop presentation on Day 1 oriented workshop participants to the draft report review tasks, with an initial focus on draft findings. At the beginning of Day 2, slides summarizing Day 1 results and Day 2 objectives (review of draft report recommendations) were presented by the co-chairs, followed by a short overview of the Binational Lake Erie Adaptive Management Framework for Phosphorus Load Reduction by a representative from USEPA. Day 2 concluded with a discussion of how to modify draft recommendations and the presentation of a set of slides covering the project's next steps and an estimated timeline for completion, with milestones.

Summary of Workshop Breakout Discussions

Four breakout groups were hosted in sessions on Day 1 and Day 2 with consistent membership in each group on the two days. Shared slide sets were used to gather input and to display notes during breakout discussions and recaps. Summary notes are included in Appendix D for each breakout group and session.

Two groups were formed to discuss Lake Erie Watershed issues (Group A and Group B). A summary of Day 1 feedback from Group A included:

- Not enough emphasis on the importance of NPS/agricultural nutrient sources
- Value in cross-walk of IJC recommendations and DAP actions, as well as a better synthesis of the information in the large DAP table
- Incomplete/dated information in some cases (Ohio DAP)
- BMPs – challenges with information on the type, location, duration, sustainability, effectiveness; aggressive implementation needed
- Need more accountability regarding DAPs
- More research on legacy P, soil test P, human health

The summary from Lake Erie Watershed Group B included:

- Provide context and sense of urgency, critique and prioritize unmet recommendations, perhaps with an added column in the summary table – communicate urgency in the executive summary
- Recommendations need to be clearer, specific, and measurable; as effective as Great Lakes Area of Concern objectives (removal of Beneficial Use Impairments)
- Prioritize data gaps and explain the consequences of leaving the gaps unfilled
- Organize recommendations by issue category and feature the most important ones in the final report; others in appendices
- Consider developing a matrix of IJC reports vs. DAP recommendations to better see linkages and progress

The breakout group to discuss Lake Erie-related issues (lake only) stated:

- Retrospective comments in the draft report are qualitative, but greater specificity, evaluation, and quantification of progress toward desired endpoints are missing and would be helpful
- The adaptive management approach for L. Erie or L. Ontario needs to include further modeling development as a fundamental aspect
- There is an overall need to better coordinate and resource a complete monitoring program
- Connections to human health are lacking; lack of data on impacts on economic and social benefits

The breakout group to discuss Lake Ontario (lake and watershed) stated:

- Many findings in the draft report are more specific to Lake Erie

- *Cladophora* problems in nearshore, and oligotrophication offshore
- Different problems from Lake Erie, though they can draw on the Lake Erie process
- Have many data gaps; there is an ongoing need for a P budget for Lake Ontario
- Still need to revisit P concentration and loading targets for Lake Ontario (underway under GLWQA Annex 4)

Workshop Conclusions

Original recommendations from the draft report that workshop participants reviewed included:

- Clarify the roles of IJC boards and Annex 10 in supporting Adaptive Management under Annex 4
- Support development and implementation of the enterprise architecture elements of an effective Annex 4 Adaptive Management process including monitoring, modeling, data management, decision-support, convening of technical and advisory groups, and communications
- Identify ways to accelerate progress and impact effectiveness at scale of nonpoint nutrient loading reduction programs in various jurisdictions in the Lake Erie and Lake Ontario watersheds, including elements of DAP updates in 2023

Guidance from the co-chairs on how to improve recommendations included:

- Aim for recommendations that are **S**pecific, **M**easurable, **A**chievable, **R**ealistic, and **T**ime-bound
- Tie recommendations to the maximum extent possible to previous IJC recommendations
- Recognize that ultimate IJC recommendations are advisory, but still carry weight
- Need to ultimately aim for the fewest recommendations that can address needs regarding nutrients in Lake Erie and Lake Ontario

Consolidated feedback from the breakout groups and plenary discussions on how to modify recommendations included the following:

- Recommendations can generally be made more specific, ambitious, and practical
- Recommendations should incorporate inclusion and equity elements, considering rural vs. urban cost burdens of nutrient reduction and ability to pay
- Consider ways that the IJC can influence the pace of progress on Annex 4 nutrient reduction including promoting more regulatory controls in the jurisdictions around Lake Erie and Lake Ontario, developing an accountability framework for when targets are not met, tracking BMP implementation and effectiveness more closely, providing better incentives for adoption, and reducing program siloing

- Include direct linkages to Annex 10 (Science) and the Cooperative Science and Monitoring Initiative (CSMI) in the recommendations; also Lakewide Action and Management Plans
- Consider linkages to other IJC projects such as the Great Lakes Decadal Science Plan effort
- Consider reframing metrics in terms of basin-wide Environmental Response Indicators (ERIs)
- Separate recommendations for Lake Erie and Lake Ontario—too Erie-centric as initially written, plus Lake Ontario only has an interim nutrient reduction target and no adaptive management framework
- Give greater consideration to motivation in formulating recommendations

A workshop summary document was circulated to Work Group members and other workshop participants for review and additional feedback in late December 2021, and comments were received, reviewed, and incorporated into a revised project report in January and early February of 2022.

8. Summary and Recommendations

This study looked closely at available scientific and policy-related information on Lake Erie and Lake Ontario and benefited from workshop and Work Group feedback from subject matter experts from Canada and the U.S. The assessment confirmed that little progress toward 40 percent reductions of nonpoint P loads to Lake Erie has been realized. Scientific knowledge of watershed and lake processes has advanced significantly over the last eight years, particularly as a result of intensified numerical modeling, monitoring, and experiments (lab, field, and natural). The IJC and its boards and Work Groups have provided valuable support to synthesizing and advancing the science and management enterprises related to reducing nutrient impacts in the lakes, as specified under GLWQA Annex 4. Prior IJC recommendations appear to have been impactful on many aspects of the problem, but substantial work remains. A major opportunity is presented by this body of work to transfer new knowledge and productive approaches from Lake Erie to Lake Ontario, recognizing that the lakes are very different in many aspects, even though they share excess nutrient problems.

Key findings, gaps, and recommendations are summarized below. Recommendations are intended to be Specific, Measurable, Achievable, Realistic, and Time-bound (SMART) and are organized in tiers by lake and timeframe (short versus long). Although one desired outcome of this effort has been to arrive at a handful of key findings, gaps, and recommendations, this should not be understood to imply that other relevant issues are unimportant or that recommendations in prior reports that have not yet been realized should be abandoned. For example, the technical review noted limited work to date related to recommendations in the 2015 IJC HABs and economics report, and a lack of renewed emphasis on these issues in this report's overall recommendations does not mean that such work is no longer needed.

Key Findings

- Substantial progress has been made in advancing research priorities identified in IJC reports, but nonpoint nutrient reduction commitments are not on track in most Lake Erie jurisdictions.
- There has been major progress over the last 10 years in developing the monitoring, modeling, and data management infrastructure necessary to support future adaptive management.
- The combined effects of increased spring runoff, ongoing installation of tile drains in agricultural land, and less incorporation of applied fertilizer and manure into agricultural soil have led to increased loading of dissolved P to Lake Erie over the last two decades.
- Scientific understanding and management of nutrient loading and impacts on Lake Ontario are substantially different from those in Lake Erie and require their own approaches.

Gaps

- Critical data gaps include a lack of high-resolution geospatial data at an annual scale on the implementation of agricultural best management practices (BMPs) in the lake watersheds, and an insufficient understanding of the distribution and dynamics of legacy P in soils across the basins that is necessary to target BMP implementation.

- Additional barriers to effective BMP implementation include a lack of clarity on the most effective and efficient ways to incentivize adoption by producers, and inadequate linkages between BMP adoption and water quality impacts in tributaries and lakes.
- High-resolution and comprehensive data showing annual hypoxic area and dynamics in Lake Erie, toxin concentrations across algal blooms, and *Cladophora* coverage in eastern Lake Erie and Lake Ontario are not available.
- Understanding of winter limnology and nutrient cycling in Lake Erie and Lake Ontario is a longstanding but important gap, especially in terms of influence on Lake Erie hypoxia formation.

Recommendations

Short-term, Lake Erie

- By 2024, support completion of coordinated studies (with partners) to assess costs and primary communication and adoption barriers to implementation of the top three BMPs (cover crops, riparian buffers, subsurface fertilizer placement) to achieve 8 percent nonpoint P load reductions by 2026 (= the first fifth of the 40 percent overall nonpoint goal).
- Support continued development and institutionalization within three years of the technical and governance elements of an effective Annex 4 Adaptive Management process including coordinated lake and watershed monitoring, modeling, data management, decision-support, convening of advisory groups, and annual communications products.
- Facilitate broad engagement in the 2023 DAP update and review process.

Long-Term, Lake Erie

- Support development and implementation by the Parties of policies and programs that accelerate nonpoint nutrient load reductions in tributaries of Lake Erie and increase accountability of jurisdictions and producers toward meeting 40 percent reduction goals.
- Identify annual BMP adoption targets and sources of the necessary investments and incentives to achieve annual nonpoint P load reductions of an additional 8 percent annually from 2027 through 2030 (= the remaining four-fifths of the 40 percent overall nonpoint goal).

Short-Term, Lake Ontario

- Support investment in Lake Ontario research, monitoring, and modeling to bring the state of knowledge of the unique watershed and lake system to a point where appropriate nutrient management action commitments can be made and implementation initiated by 2025.

Long-Term, Lake Ontario

- Support investment in additional Lake Ontario studies to reduce uncertainty about balancing impacts of improving nearshore eutrophic conditions and offshore oligotrophic conditions such that 2025 commitments can be refined by 2030.

9. References

Coding after reference entries:
L = Lake, W = Watershed, E = Erie, O = Ontario, N = different geography, topic, or mixed

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Appendix A -- Summary and Status of IJC Nutrient-Related Report Recommendations

Appendix A Table. Summary and Status of IJC Nutrient-Related Report Recommendations

IJC Report	Key Recommendations	Status of Recommendations
Understanding Declining Productivity in the Offshore Regions of the Great Lakes **Science Advisory Board-Science Priority Committee, 2020**	**The Great Lakes Executive Committee (GLEC) should** • **Explore and implement opportunities and capacities for cooperative application** of ecosystem forecasting science addressing nutrient and fisheries management in the Great Lakes. • **Engage and partner with state and provincial fisheries and environmental agencies** as well as other national and binational agencies involved with monitoring and managing Great Lakes aquatic resources.	New report—little action to date, although workgroup participants have made their organizations aware of results. Technical report was completed in 2018; Work Group report was released in June 2020.
	Form a multiagency Cooperative Ecosystem Monitoring and Modeling Advisory Committee ("Committee") that should be: • Established within two years • Use the Annex 4 assessment on Lake Ontario as a testbed for integrating and instituting coordinated data/information management	Annex 10 Ecosystem Indicators & Reporting Task Team covers some of this; draft Binational Lake Erie Adaptive Management Framework lays out additional elements; Lake Ontario Annex 4 team is meeting and watching Lake Erie approach; new whole-lake models exist for Erie and Ontario.
	Share progress on measures, analysis and outcomes at annual Lake Committee meetings hosted by the Great Lakes Fishery Commission.	This is done on an annual basis; information also shared at 2021 State of Lake Ontario meeting and CSMI planning workshop.
	Report success in connecting and adapting nutrient-related actions to fishery management through effective information flow and decision support, modeling and forecasting after the next two consecutive five-year Cooperative Science and Monitoring Initiative cycles	Such reporting is just beginning and will require full food-web models linked to monitoring programs to be quantitative.

IJC Report	Key Recommendations	Status of Recommendations
Oversight of Animal Feeding Operations for Manure Management in the Great Lakes Region	**Recommendation 1:** **Each Great Lakes state and Ontario** should conduct an in-depth assessment of permitting rules and requirements and the actual implementation of each state/province's respective manure management framework to identify successes and challenges in achieving reduced nutrient runoff goals.	New report—little action to date, although states and Ontario are updating domestic action plans and corresponding manure management actions (e.g., State of Michigan general CAFO permit and manure management guidance).
Water Quality Board, 2020	**Recommendation 1:** **Federal governments and/or state/provincial governments** should establish a set of guidelines and regulations for mid- and large-size animal feeding operations to be incorporated by all states/provinces to ensure an equivalent implementation framework, which includes the coordination and oversight of manure management among federal and provincial/state regulators. Such guidelines and regulations should include: **1.1 A manure management plan permitting framework** for mid- and large-size animal feeding operations (USEPA definition). Currently, most midsize operations have no permitting requirements. The framework should have consistent permitting requirements including comprehensive nutrient guidelines, consideration of management plans by a qualified professional that are consistent for all nutrient sources, and a framework that requires assessment and compliance with federal and provincial/state policies and recommendations. The Province of Ontario's manure management framework, which includes nutrient management plans, should be used as a model. **1.2 Require systematic testing of manure nutrient soil content** and **developing a template of best management practices** (BMPs) and recommended standards for optimal nutrient application which minimize nutrient runoff. This policy should consider testing results and costs. The Ontario template of BMPs should provide a process for evaluating the effectiveness of the Nutrient Management Plan and include an adaptive management component. Ontario's ban on the use of high trajectory irrigation guns to apply manure (unless containing more than 99 percent water) should be considered.	See manure-related research results published by Long et al., 2018, and Kast et al., 2019, but note that they do not address guidelines or regulations in detail. Specific action on points 1.1-1.4 has been limited, but the IJC is currently conducting a project for "determining an umbrella Great Lakes organization to create a diverse steering committee with key stakeholders to establish and advance a manure management framework, based on the WQB's 2019 report".

IJC Report	Key Recommendations	Status of Recommendations
	1.3 Eliminate allowing animal feeding operations to subdivide adjoining operations, physically located in the same area, to bypass the requirement for a permit and thus bypass permit requirements (a practice in US Great Lakes states). **1.4 Develop a binational, central Great Lakes information center** that shares new and evolving technology for manure treatment/reuse (potentially through the US Great Lakes Observing System Data Portal).	
	Recommendation 2 **Create rules and policies for manure applications** in the US Great Lakes states and Ontario, if not already doing so, that include: **2.1 A systematic approach that requires dedicated minimum acreage** for the amount of land needed per animal unit for manure application. This should include factors such as livestock types, soil phosphorous levels and a requirement for manure storage needed per animal unit. Ontario's Nutrient Management Act provides an example of how this can be accomplished. The minimum acreage requirement should apply to onsite and offsite manure applications in the region the facility is located in. Reduction of land needed should be given when the manure is transported outside the facility region with reporting of destination required. **2.2 A land base registry in each state and province that is reported to the national/federal government or equivalent tracking system** and includes the number of animals, manure application agreements, parcel identification where manure is applied, the manure application dates and the manure amounts. **2.3 An assessment of liquid and other manure applications and runoff** (including field tile) and requirements for the permissible timing and amount of manure applications (e.g., not on frozen ground and not when there are forecasts for heavy rains) that incorporates both onsite and offsite locations and to animal feeding operations that are both permitted and unpermitted. Bans on frozen ground can be date specific or on a definition of frozen ground. Determinations should also be made as to when manure is a waste and when it is a fertilizer. **2.4 A required system of public notification and public comment** by property owners and residents within a certain radius of a facility seeking a permit for a new or expanding animal feeding operation (may use Alberta's approach as a model)	Little progress here—see status under Recommendation 1 above.

IJC Report	Key Recommendations	Status of Recommendations
	2.5 A more established, standardized process by which Indigenous communities are notified, engaged and consulted on new or expanding animal feeding operations within a certain radius of their communities.	
	Recommendation 3 **Provide funding dedicated to assisting agriculture for manure management** including reuse and treatment technologies. Funding should come from the federal Canadian and U.S. governments, along with Great Lakes states and the province of Ontario. Funding should also assist existing animal feeding operations to make necessary changes to meet recommended standards and best management practices.	See examples from Wisconsin biodigester programs and point/nonpoint source nutrient trading: Wisconsin Biogas and Feedstock Survey Final Report, 2021
	Recommendation 4 **Establish federal funding from Canada and the United States to create a Canadian and US panel of experts** who will: • **Report on the international management policies, tools, technologies, reporting and recordkeeping practices of the Netherlands and Denmark**, who have a long history with manure management that can inform on lessons learned and may have application in the Great Lakes basin. Additionally, there should be a comprehensive assessment of manure management impacts on the Indigenous community.	No known progress.
Use of Modeling Approaches to Affect Nutrient Management Through Adaptive Management	**Technical Recommendations**	
	Focus on augmenting the existing models rather than building new models including: **Ensemble modeling**: • Maintain and improve the ensemble character of modeling and continue research to better coordinate the diversity of watershed and lake models in Lake Erie. • Use the diversity of models in the ensemble approach to better understand and quantify key processes in the lake and watershed. • In taking an ensemble approach, efforts should be made to quantify and reduce uncertainty in ecological forecasting in response to nutrient loading/concentration and other drivers.	Three whole-lake models were recently completed for Lake Erie; one was completed (Hui et al., 2021a) and one underway for Lake Ontario; both sets use existing models but some novel combinations and new data compilations.

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Science Advisory Board-Research Coordination Committee, 2019	**Couple lake and watershed models**: • Establish an integrated system of watershed and lake models with ecological response indicators. • Establish/maintain consistency between the temporal/spatial scales of the watershed models with that of the lake models to serve as boundary condition inputs to the lake models. • Incorporate sediment transport along with erosion and deposition in the watershed and lake models.	Lake Erie: SWAT output used in A2EM-FVCOM LEEM model, but not coupled in a strict sense. ELCOM-CAEDYM model also not coupled.
	Monitoring Program: Design a monitoring program based upon appropriate metrics and scales to measure changes in nutrient loading and the ecological response.	Monitoring program is undergoing continuous enhancements in instrumentation, resolution, standardization, data transmission, and data management and communications (e.g., LE-HABS EWS, Heidelberg University Data Portal)
	Improved evaluation of model performance: Identify a suite of appropriate skill metrics and evaluate model performance at multiple scales of resolution.	See Rowe et al. (2019) hypoxia model and associated data collection efforts.
	Ground-truthing: Further ground-truthing of the watershed models should include the following: • Model calibration and evaluation at finer temporal/spatial scales to better assess the role of episodic events (e.g., extreme precipitation/flow) and land use practices; • A directed evaluation of the management actions (BMPs) that will be necessary to achieve the new loading targets, including an assessment of associated uncertainties; • Increased attention to the role of legacy phosphorus bound to the soil in the watersheds and sediment in the lakes in driving algal blooms and toxicity levels of HABs; and	Enhanced BMP monitoring programs and tracking systems are being developed, including exploration of using remote sensing technologies.

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	• Consideration of additional watershed models that may better capture urban areas.	
	Predictive ability: To improve predictive ability, future lake modeling efforts should include an improved understanding of key phytoplankton growth processes, internal nutrient sources, the growth, role of nitrogen, interactions between phytoplankton and Cladophora role of dreissenids in nutrient cycling and availability, and zooplankton interactions and connection to upper food web.	See related references and discussions in literature review, especially including internal loading, nitrogen, *Cladophora*, and dreissenids.
	Institutional Recommendations	
	Define Lake Erie's eutrophication problem(s) aligning with a Gret Lakes Nutrient Adaptive Management (GLNAM) Framework to provide the rationale for institutionalizing a framework based on collaboration across government agencies and jurisdictional lines.	See 2019 Binational Nutrient Reduction Strategy and 2022 Annex 4 Adaptive Management Framework.
	Develop consensus-based goals in support of the GLNAM Framework as a long-term, sustainable institutional arrangement.	See 2022 Annex 4 Adaptive Management Framework and supporting technical elements, in development.
	Integrate watershed and lake modeling (discussed above under technical recommendations) as part of the GLNAM Framework • Frame the "correct" questions and testable hypotheses (linked to the aforementioned problem) in the development and implementation of models to better understand the ecological processes underlying eutrophication and to support nutrient reduction management. • Establish a common awareness and understanding among researchers, resource managers, and a broad spectrum of stakeholders of the linkages between adaptive management and watershed/lake modeling as part of the GLNAM Framework.	The 2022 Annex 4 Adaptive Management Framework and supporting technical elements focus on binational coordination of in-lake monitoring and modeling, with supporting role in watershed management and modeling, which is being led by states, Ontario, and a subset of the larger group of federal agencies that are working in the lake.

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	Use the GLNAM Framework to inform coordinated planning and implementation of Lake Erie's watershed/ecosystem modeling and nutrient reduction management; as part of this coordinated effort, address the following: • Identify key players currently participating in the GLNAM Framework in Lake Erie and use this information to identify gaps and unmet needs that must be addressed to further advance the GLNAM Framework. • Provide a status report on the progress achieved thus far in the development and implementation of a GLNAM Framework.	The binational framework was finalized in 2022.
	Establish/integrate a monitoring program as part of the GLNAM Framework on a long-term continuous basis and evaluate results to learn and adjust research, modeling, and management decisions.	Watershed and lake monitoring programs exist and are being improved over time.
	Update models regularly (characteristic of adaptive management approach) to reduce uncertainty and better represent an improved understanding of the ecological dynamics.	Operational use of models, and parallel research to enhance future models, is envisioned as an important part of the Adaptive Management Framework, but full scoping of the organizational frameworks and necessary budgets for such an enterprise have not yet been developed. Seasonal and biweekly forecast products for blooms and a research hypoxia model with provisional forecasts of upwelling are currently available.
	Diagnose models with "post-audit process" (research, test, sensitivity analysis, recalibrate) and reapply to determine how model performance and management decisions can be improved (e.g., reevaluate target loads).	Whole-lake models are currently being used in scenario development, but have not yet been used in management decisions except at the target level (i.e., binational 40% reduction target).

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	Raise awareness of the following principles underlying an adaptive management approach	
	Integration of testable questions/hypotheses that serve as key drivers to a GLNAM Framework.	This is incorporated in the 2022 Lake Erie Adaptive Management Framework under GLWQA Annex 4.
	Collaboration among stakeholders as a key element of adaptive management to ensure long-term sustainability guided by the GLWQA.	This is incorporated in the 2022 Adaptive Management Framework.
	Communication, outreach, and engagement with stakeholders as critical drivers in building and maintaining spheres of influence in support of a GLNAM Framework; stakeholder engagement plays a role in identifying research/management priorities under the GLNAM Framework.	This is incorporated in the 2022 Adaptive Management Framework.
	Consideration of the GLNAM approach as a learning process from which we should expect surprises (e.g., dreissenids, cyanobacteria, climate change).	This is incorporated in the 2022 Adaptive Management Framework.
	Management actions under the GLNAM Framework should be recognized as experiments that provide the opportunity for learning, given the inherent uncertainty associated with modeling and decision-making. It is also important to track such actions and make data available publicly to enhance iterative learning.	This is incorporated in the 2022 Adaptive Management Framework, although most management "experiments" will be conducted in the watersheds rather than directly in the lakes, so the federal and binational elements are secondary to hands-on actions by states, Ontario, municipalities, and producers.
	Identify institutional and governance considerations for the GLNAM Framework	
	Establish the GLWQA as the binational authority to institutionalize the GLNAM Framework through Nutrients Annex 4 to facilitate implementation.	An Adaptive Management Framework for implementing Annex 4 in Lake Erie was finalized in 2022.

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	Identify agency and institutional partners as well as programs responsible for the development and conduct of a GLNAM Framework: • Lead federal agencies: U.S. Environmental Protection Agency (EPA) and Environment Canada Climate Change (ECCC) • Supporting Canadian and US federal agencies: US Department of Agriculture Natural Resource Conservation Service (NRCS), US Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA); Canadian Department of Fisheries and Oceans • Supporting state and provincial agencies: Ohio EPA, Pennsylvania Department of Environmental Protection, New York Department of Environmental Conservation, Indiana Department of Natural Resources, Michigan Department of Natural Resources • Partner institutions: International Joint Commission (IJC), academia, private sector • Reporting programs: domestic action plans (DAPs), and GLWQA triennial reporting	These agencies were are all involved directly or indirectly in Lake Erie Adaptive Management Framework development.
	Identify experts, resources, and stakeholders needed to effectively meet identified adaptive management goals and objectives on a long-term basis.	Currently under development.
	Establish a cycle of adaptive management (annual modeling and assessment; annually or every 5-10 years (to be determined) to advance model improvement and to reduce uncertainty in the decision-making process on nutrient management.	Currently under development and linked to existing reporting cycles and outlets.
	Identify and establish funding streams to support the GLNAM Framework through existing and/or new authorizations and appropriations. Among the funding streams identified to date are the IJC-International Watershed Initiative, USGS monitoring programs, NOAA granting programs (ECOHAB, Sea Grant, etc.) and NOAA research and development laboratories' base funding, Harmful Algal Bloom Hypoxia and Control Act (HABHRCA), Great Lakes Restoration Initiative (GLRI), Lakewide Management Programs (LAMPs), and state natural resource and environmental protection programs of the Great Lakes region.	Currently under development. Several related research projects funded by NOAA, Sea Grant, GLRI, Ohio Department of Higher Education, and other sources are currently underway.

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	Establish justification for the GLNAM Framework: Quantify benefits of healthy ecosystem services, justifying investment in institutionalizing the GLNAM Framework. This is considered key in maintaining GLNAM Framework on a long-term, sustainable basis that is necessary to advance nutrient management on eutrophication-related problems. Case in point: the cost of nutrient loading reduction in Lake Erie should not be disconnected from the economic value of the ecosystem services provided by the lake.	See Steinman et al., 2017; and Stratos, 2021, Valuation of the Great Lakes Fisheries and Aquatic Ecosystem Services Virtual Workshop Summary Report.
Fertilizer Application Patterns and Trends and Their Implications for Water Quality in the Western Lake Erie Basin **IJC, 2018 and 2019 supplement (augments analysis for 2018 SAB report)**	Recommendations from the SAB-SPC's 2018 report, Fertilizer Application Patterns and Trends and Their Implications for Water Quality in the Western Lake Erie Basin	
	Recommendation 1: Continue emerging research on phosphorus source monitoring, including stable isotope and organic phosphorus fingerprinting research as part of source attribution efforts, and site-based monitoring of P loss by species from fields receiving differing amounts of commercial fertilizer and manure.	See related publications, including recent edge-of-field studies and Brooker et al., 2018, for fingerprinting.
	Recommendation 2a: Agencies should obtain (e.g., through surveys, available datasets, and any new data as appropriate) commercial fertilizer sales and application data at both higher temporal and spatial resolution to allow for improved understanding of this important source. In addition, agencies should evaluate approaches to making these data broadly available at the highest spatial resolution possible.	In the 2017/2019 LimnoTech reports to IJC on fertilizer and manure, these public data were reported at approximately the HUC-8 watershed scale, converting from county-level data to watersheds in the U.S. Higher resolution data are not generally available and are unlikely to become available soon. Industry-supported nutrient balance information at the HUC-8 level is available at https://nugis.tfi.org
	Recommendation 2b: Better quantify all major components of manure generation, management, field application, and associated P loss and impacts on local and regional surface water quality and ecosystems.	See prior manure-related references, edge-of-field studies, and management actions. Increasing density and temporal resolution of water quality monitoring stations in tributaries is including local understanding of P impacts.

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	Recommendation 3a: Agencies should collect and regularly update a statistically representative binational data set of phosphorus concentrations and vertical stratification in agricultural soils (including more consistent protocols for soil test phosphorus), whether through an existing program or a new (agency-led, or potentially multi-sector) program.	See recent Ohio publications and high-P fields research project by Martin et al.
	Recommendation 3b: Improve spatial resolution of data on legacy phosphorus (including reservoirs of legacy P in locations not actively farmed), as well as linkages between P fluxes from reservoirs and lake phenomena including algal blooms and hypoxia.	Recent and current research efforts have examined the presence and fluxes of legacy P in fields, tile drains, stream sediments, and lake sediments. Guo et al., 2021 suggest that legacy P may be less important as a driver of tributary loading than previously thought.
	Recommendation 4: Support research and monitoring to quantify and better understand the implications of no-till agriculture for P accumulation at the soil surface and P transport through drain tiles, and to explore potential new approaches to minimizing P losses associated with no-till practices.	Such studies are ongoing by King et al. at NRCS-ARS, Martin et al. at The Ohio State University, and others in Ontario (Univ. of Guelph, Univ. of Waterloo, OMAFRA, AAF-Canada).
	Recommendation 5: Agencies should obtain more current data on tile drainage networks and their impact on P form and mass transport, including interactions with tillage practices, commercial fertilizer and manure application, and the relative role and rates of tile discharge of P in comparison with surface runoff.	Ontario tile mapping data are better than for the U.S., but see Valayamkunnath et al., 2020 for 30-m resolution U.S. map developed by modeling. Research on all these topics is ongoing, but availability of data at high spatial resolution is an unresolved issue.
	Recommendation 6: Continue to evaluate climate change impacts on P loads from rivers as a potentially complicating factor influencing how target loads are determined, as well as implications for management actions needed to meet targets.	See climate change discussion above in literature review narrative.
	Recommendation 7a: Design and implement an optimized and integrated long-term monitoring network for water quality and agricultural practices to support decisions about the best approaches to nutrient load reductions.	Existing monitoring networks are being expanded (Heidelberg Univ., USGS, OMECP, RCAs), but linkages to BMP decision-making can be improved.

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	Recommendation 7b: Develop stable funding mechanisms and institutional stewards for sustained, long-term binational monitoring and data management.	Long-term funding is always a challenge, but data management and communications systems are improving (e.g., https://ncwqr-data.org/).
	Recommendation 8a: Develop operational models linked to optimized monitoring networks, and high-resolution surveys of changing agricultural practices and watershed characteristics to support forecasting of evolving conditions, and to inform inter-annual and within-season adaptive management decisions.	Such linked operational systems are in development and recognized in the Adaptive Management Framework, but the associated funding, infrastructure, and governance systems are not yet in place.
	Recommendation 8b: Continue financial and policy support for the development and application of research models at various scales to improve process understanding of phenomena and dynamics (including improving soil phosphorus routines and addressing other processes noted above), as well as to simulate alternate management scenarios.	See modeling and monitoring section of literature review.
	Recommendation 9a: Continue to promote 4R guidelines for fertilizer application through outreach, education, and technology to enhance the adoption and effectiveness of 4R practices. Expand efforts to evaluate the effectiveness of 4R and other best management practices at the field and watershed scales, and identify areas for improvement.	Promotion of adoption of 4R practices is ongoing through a variety of programs. See Vollmer-Sanders et al., 2016, and subsequent SWAT modeling work.
	Recommendation 9b: Support research and monitoring (watershed and lake) to improve process understanding and identify management options best able to reduce the export of all forms of P so that P remains onsite and available for crop uptake.	See results of recent multi-model projects led by D. Scavia and J, Martin to assess P load reduction impacts of various BMP adoption scenarios.

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Watershed Management of Nutrients in Lake Erie **Water Quality Board, 2016 and 2017**	**Recommendations from the WQB's 2016 report, Evaluating Watershed Management Plans – Nutrient Management Approaches in the Lake Erie Basin and Key Locations Outside the Lake Erie Basin**	
	Recommendation 1: The Canadian and United States federal governments, as well as the provincial and state governments, should ensure that lakewide basin, sub-basin, watershed and subwatershed management plans (including plans to manage bays, islands, and the nearshore) are developed for nutrient management in Lake Erie.	Progress will reported by each jurisdiction in 2023 DAP updates. Some jurisdictions (e.g., Michigan and Ohio) have provided more frequent updates via websites and other reports and the ErieStat website provides related data and documents. Elements of this recommendation are also incorporated in IJC's Triennial Assessment of Progress reports, GLWQA Progress Reports of the Parties, Annex 4 reports to the Great Lakes Executive Committee, USEPA reports to Congress on GLRI progress, Lakewide Area Management Plan updates and annual reports, and other related documents and presentations, although progress at finer resolution (e.g., subwatershed plans) is often difficult to determine.
	Recommendation 2: There are several key success factors that the Canadian and United States federal governments, as well as the provincial and state governments, should ensure are included in the lakewide basin, sub-basin, watershed, and subwatershed management plans for nutrient management. These factors include science-based watershed characterization, clear goals and milestones, adaptive management, consistent watershed-wide approach, partnerships for implementation, public awareness strategy, and a monitoring program.	These elements are all incorporated in the 2022 Lake Erie Adaptive Management Plan and associated DAPs. Macrae et al. (2021) argue for approaches optimized to individual subregions that consider geomorphology, hydroclimate, and other factors.
	Recommendation 3: The Canadian and United States federal governments as well as the provincial and state governments around Lake Erie should ensure that funding is available to support planning activities and implementation of watershed management plans for nutrients.	Funding has been uneven based on priorities of particular jurisdictions, but progress is generally being made in all areas.

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	The following 2017 recommendations supplement those made in 2016 (noted above)	
	Recommendation 1: Building upon the work of Annex 4, the federal governments, in partnership with Great Lakes States, Province of Ontario, First Nations, Tribes, and Métis, should use existing monitoring data and identify a preferred model(s)/tool for determining nutrient loading to the lake that integrates both tributary nutrient loading as well as in lake nutrient processes. This can be used to assist in identifying and prioritizing those watersheds and subwatersheds where implementation of management efforts would garner a significant reduction in loadings in relation to the effort applied.	This has already been completed by U.S. and Canadian watershed modeling efforts mentioned above (see also Kast et al., 2021a and 2021b). The spatial resolution of targeting of BMP implementation is continuing to increase.
	Recommendation 2: A lakewide plan should include basin-by-basin plans for the western, central, and eastern basins, which coordinates all plans to avoid any duplication of service. The primary purposes of the lakewide plan should be to translate the binational targets upstream to the watersheds and subwatersheds and to assist in identifying subwatersheds that are of the highest priority for nutrient/phosphorus reduction. The governments must then ensure that each priority subwatershed has a sufficiently-empowered watershed planning authority.	U.S. watershed planning authorities have less power to implement nutrient reduction policies than would be ideal. There has been some work with county drain commissioners in place of this. Basin-specific considerations are captured in DAPs and whole-lake models.
	Recommendation 3: The federal, provincial, and state governments should provide half of the long-term funding support, with the other half to be matched by funding at the local level by municipalities, local agencies, water users, and landowners. There should also be a funding source dedicated specifically for managed and coordinated monitoring.	Funding arrangements, including consideration of matching, vary across the basin, which is likely to persist.
	Recommendation 4: Drawing from the work undertaken by the Annex 4 subcommittee, the federal governments, in partnership with Great Lakes States, Province of Ontario, First Nations, Tribes, and Métis, should identify a few key common parameters to be measured in all watersheds to assess progress towards the larger Lake Erie targets. At a minimum, total phosphorus, nitrogen, dissolved reactive phosphorus, and dissolved oxygen should be monitored; however, a more comprehensive program is desirable including atmospheric loading of phosphorus and the impacts of climate change on the entire basin.	Data collection across jurisdictions is improving but is not yet harmonized.

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	Recommendation 5: Through an existing agency, a communications plan should be drafted that outlines how continuous information on nutrient management/reduction efforts should be distributed to the Great Lakes implementation agencies. This plan should identify the type of information to be shared, including Traditional Ecological Knowledge, message distribution timelines, and tools to be used, such as newsletters, social media, webinars, workshops, etc. A media relations plan should be incorporated into the communications plan.	The need for a coordinated communications plan and team has been identified in the draft Binational Adaptive Management Framework, but such a plan and team do not yet exist. Some annual and multi-annual reporting mechanisms for regional, national, and binational audiences are in place.
Human Health Effects of Cyanobacterial Toxins in the Great Lakes Region: A Science and Monitoring Assessment. **Health Professionals Advisory Board, 2017**	**Strategic improvements to support public health protection**	
	1) Improvements in drinking water treatment technologies or management of existing modern technologies to ensure cyanotoxins are efficiently removed without the production of toxic byproducts. There are multiple cyanotoxins and different treatment strategies affect them differently.	See Ohio DHE research and related upgrades at Toledo and Cleveland drinking water plants, including advanced early warning instrument networks.
	2) Drinking water treatment plant (DWTP) operations should include robust monitoring of prevalent cyanotoxins and optimization for different source conditions and treatment systems. Monitoring data suggests that current treatment strategies are not always effective at removing or destroying all types of cyanotoxins and occasionally fail to reduce concentrations to below the World Health Organization's safe drinking water level of 1 microgram per liter of microcystin per day. While the recent (August 2014) drinking water ban in Toledo, OH focused public and government attention, more activity is needed.	Monitoring requirements are managed by state or provincial authorities under federal guidance (e.g., Safe Drinking Water Act in U.S.).; monitoring is adaptive in the sense that frequency is increased as detections and concentrations increase.
	3) Further research on optimal drinking water treatment approaches for Great Lakes cyanotoxins should be developed. DWTPs currently practice a range of treatment regimes, but typical treatment processes may not be effective for cyanotoxins. Many uncertainties on the effective removal of cyanotoxins from DWTPs remain.	See Ohio DHE research and related upgrades at Toledo and Cleveland drinking water plants, including advanced early warning instrument networks. USEPA has also developed related research and training programs—see: https://www.epa.gov/cyanohabs

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	4) Improvements are needed in cyanotoxins laboratory testing, and to establish uniform methods and practices across laboratories, including standards and quality assurance. Promising technologies include methods for multiple toxins and toxin congeners along with methods to measure cyanotoxins directly or indirectly.	Existing programs are optimized for distinct operational (ELISA) vs. research analytical methods. This difference in approaches is likely to persist, although a growing number of commercial labs are now able to perform more complex cyanotoxin analyses (see: https://www.epa.gov/cyanohabs/laboratories-analyze-cyanobacteria-and-cyanotoxins).
	5) An examination of drinking, source water, and beach monitoring strategies should include provisions for regular and improved monitoring of cyanotoxins, reporting of such results to the public in a timely fashion, and continued development of predictive models for forecasting cyanoHABs and their toxins given predictions of increasingly warm waters for longer periods of the year.	See recent federal guidance documents: https://www.epa.gov/sites/production/files/2019-09/documents/recommend-cyano-rec-water-2019-update.pdf; https://www.epa.gov/ground-water-and-drinking-water/managing-cyanotoxins-public-drinking-water-systems. Similar state or provincial guidance documents also exist (e.g., https://epa.ohio.gov/ddagw/HAB)

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	6) Additional toxicity studies are needed to improve the development of strong numerical limits for a broader range of cyanotoxins beyond microcystins. These include using purified cyanotoxins in animal studies, additional work examining exposure from inhaled aerosols (e.g. from shower bathing), and skin irritation, and additional data on chronic effects from cyanotoxin exposure such as tumor promotion and cancer.	Dozens of such studies are underway. Over 1,000 research articles per year on cyanotoxins have been published over the last few years.
Economic Benefits of Reducing Harmful Algal Blooms in Lake Erie. **Science Advisory Board-Science Priority Committee, 2015**	**Develop an econometric model that links data on the presence and severity of HABs with sales data on the properties at risk** to scientifically quantify the relationship between the presence and severity of HABs and property value losses. Such a study would replace the transfer and scenario-based evaluations conducted for this analysis with a parametrized evaluation of the property value effects of HABs.	See Toledo-specific and broader recent studies (Palm-Forster et al., 2016; Smith et al., 2019; Zhang, W. and Sohngen, 2018; Lupi et al., 2020), including U.S. consideration of criteria for HABs of national significance (like oil spills). See also the recent National Wildlife Federation report on business impacts of HABs.
	Identify if property effects of HABs, which differ in their impact every year, more closely resemble short-term disasters or events with effects spanning several years.	See Wolf and Klaiber, 2017.
	Future work could also involve a more detailed study that accesses tax assessor data and more fully describes all the property values along the shore and in the nearshore areas where HABs are a risk.	No such study has been conducted.
	A related line of research could also incorporate homeowner preference data from surveys. Since shoreline and nearshore property owners are important stakeholders, a viable option for addressing the impacts of HABs on property values is to combine survey-based research approaches with formal property value models, as was done for contaminated sediment remediation in Waukegan Harbor (Braden et al, 2004).	No such study has been conducted, although Robyn Wilson et al. (2018 and 2019) surveyed various Lake Erie stakeholder groups about preferences for HABs Early Warning Systems.

IJC Report	Key Recommendations	Status of Recommendations
	There are numerous parameters relating the presence and severity of HABs to changes in tourist activity that are not well understood and were specified as defined scenarios for this analysis. A key next step would be to develop scientifically-based evaluations of the following: • The proportion of late summer and early fall trips to counties that border western Lake Erie and are Lake Erie related. • Develop a scientific evaluation of the relationship between the presence of HABs and diverted tourist trips. • The relationship between the types of trips that are diverted because of the severity of HABs, where those trips are diverted to, and the amount of spending on those diverted trips.	No such study has been conducted, although Robyn Wilson surveyed various Lake Erie stakeholder groups about preferences for HABs Early Warning Systems. A study of diverted tourist trips in the event of a large oil spill in the Straits of Mackinac has been conducted: https://mipetroleumpipelines.org/document/risk-analysis-straits-pipelines.
	There is currently no study that links the presence and severity of HABs with changes in recreation demand. The analysis conducted for this report transfers results from other relationships to parameterize the effect that HABs have on beach use, fishing, and boating. However, a key next step would be to undertake a recreation demand study to quantify the effect that changes in the presence and severity of HABs has on recreational beach use, fishing, and boating demand. The study would also better quantify the baseline level of beach use, fishing, and boating trips to western Lake Erie.	See fishing and beach studies cited above as well as Wolf et al., 2017
	If current averting and treatment costs do not adequately protect against HAB interruptions to potable water supply or do not change individual, consumer behavior, further documentation on and research into losses of such events are highly warranted.	See studies cited above.
	Lastly, a key next step may also involve gathering behavior-specific and cost data on what residents of Pelee Island did to mitigate the 2014 HAB, how much they spent on their mitigation efforts, and identifying whether they have made any capital investments or behavioral changes to avoid having to undertake those mitigation activities under future HAB events.	See studies cited above and this website: https://www.pelee.org/community-2/blue-green-algae/
	While an estimated approach has been employed, the appropriate impact to apply to shoreline and near-shore properties has not been studied scientifically, and doing so is a recommended next step.	See studies cited above.

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	Scant evidence of much impact on direct water users, such as agricultural and industrial production. Although there is anecdotal evidence of increased filtering for some agricultural uses and some power production, a review of the evidence does not suggest this service warrants further research.	See studies cited above and Lee et al., 2017.
	It is unknown if any changes have occurred in how households use publicly-supplied or private water in response to HAB events. For example, households may switch to filtered or bottled water for some uses	There is anecdotal evidence to support this idea, including periodic "runs" on bottled water in the Toledo area based on rumors. See: https://www.michiganradio.org/post/toledo-works-restore-trust-its-water-after-2014-microcystin-scare
	Understanding how households responded to the HAB events of 2011 and 2014 would require more in-depth analyses and likely benefit from primary data collection, such as a household survey, which, in turn, would be able to identify any persisting and as yet unquantified economic losses for HABs due to changes in potable water supply use.	No such study has been completed. See studies cited above.
	Combine survey-based research approaches with formal property value models, as was done for contaminated sediment remediation in Waukegan Harbor (Braden et al, 2004).	No such study has been completed. See studies cited above.

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A Balanced Diet for Lake Erie: Reducing Phosphorus Loadings and Harmful Algal Blooms
 	
IJC, 2014
	Adopt new targets for maximum acceptable phosphorus loadings in Lake Erie
	• Total phosphorus load target for the Maumee River for the spring (March-June) period should be established as 800 MT
	• Dissolved reactive phosphorus target for the spring period should be 150 MT
	• Total phosphorus target should be 1,600 MT when the rest of the watersheds in the western Lake Erie Basin are included:
	  ○ Total phosphorus load target for the spring should be 1,600 MT
	  ○ Total phosphorus target should be 3,200 MT when extended over a full year,
	  ○ Dissolved reactive phosphorus target should be 300 MT
	• The target total phosphorus load for the western basin and central basin should be 4,300 MT to decrease the central Lake Erie Basin hypoxic area by 50% to about 2,000 km^2 (772 mi^2) and 10 hypoxic days a year
	• The target for achieving the same hypoxic area (2,000 km^2) and number of hypoxic days (10) in the central Lake Erie Basin should be 550 MT when expressed as annual dissolved reactive phosphorus load
	• The total phosphorus and dissolved reactive phosphorus targets should be phased in over nine years (2014-2022) by setting transitional targets on a three-year basis to coincide with the triennial cycle and assessment of progress outlined in the 2012 Agreement
		See Annex 4 progress and 2020 IJC offshore productivity report above. Some researchers prefer to quantify spring loads of "bioavailable phosphorus" or BAP instead of just annual TP and DRP loads as a better way of linking loads to blooms.

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	To establish and implement new targets of phosphorus loadings: • The governments of the **United States and Canada** should develop domestic action plans including both regulatory and non-regulatory measures to reduce nutrient pollution of Lake Erie sooner than the 2018 goal set in the 2012 Agreement • The governments of **Michigan, New York, Ohio, Pennsylvania and Ontario** should apply a public trust framework consisting of a set of important common law legal principles shared by both countries, as an added measure of protection for Lake Erie water quality; governments should apply this framework as an added decision-making tool in policies, permitting and other proceedings • The governments of **Michigan and Ohio** should, under the United States Clean Water Act, list the waters of the western basin of Lake Erie as impaired because of nutrient pollution; this would trigger the development of a tri-state phosphorus total maximum daily load (TMDL) involving those states and Indiana, with U.S. Environmental Protection Agency oversight.	State and provincial/national DAPs were released in 2018 and DAP updates are planned for 2023. Michigan waters of the Western Lake Erie Basin were listed as impaired in 2016. Ohio listed its Lake Erie waters as impaired in 2018.
	The Governments of the United States and Canada should:	
	Develop federal policies that link the cost and availability of crop insurance purchases or premiums to farm conservation planning and implementation of nutrient management practices.	National studies have looked at this issue such as Weber et al., 2016.

IJC Report	Key Recommendations	Status of Recommendations
	Commit sustained funding to enhance and maintain monitoring networks in the Lake Erie Basin, focusing on: • Tributaries throughout the Lake Erie Basin, including key sub-basins and wet weather events to capture seasonal differences from a wider range of basin tributaries • Dissolved reactive phosphorus, in addition to total phosphorus and other parameters, will need to be regularly monitored at all appropriate sites • establishment of water quality monitoring stations to quantify the nutrient dynamics of Lake Huron, the St. Clair River and Lake St. Clair • Establishment of a continuous, long-term water quality monitoring system at the outlet of the Detroit River that measures critical nutrient parameters • An evaluation of the cumulative effectiveness of urban and rural best management practices.	Tributary and lake monitoring has received substantial enhanced investment since the 2014 Toledo water crisis.
	Support research to strengthen understanding of: • The dynamics of harmful algal blooms through a comprehensive limnological approach to studying entire bloom communities; • How open-lake disposal of dredged sediments from the Toledo navigational channel affects phosphorus loadings in Lake Erie; • Environmentally sustainable methods of sediment disposal; • How various factors, such as the interaction of lake water with land-based runoff and tributary discharges, can be used to predict the conditions associated with nuisance blooms under current and future climate change scenarios; • How Lake Erie's diverse and productive fish communities could respond under the warming trends and altered precipitation patterns associated with continued climate change; and, • The economic effects of Lake Erie algal blooms throughout the entire lake basin.	Substantial research has been conducted in all of these areas. See synthesis discussion.

IJC Report	Key Recommendations	Status of Recommendations
	Improve data management through greater coordination and sharing.	Better data management and coordination have been achieved within and across agencies, including via online portals (Heidelberg Univ., GLOS).
	The Governments of the United States, Canada, Ontario, Michigan, Indiana, Ohio, Pennsylvania, and New York should:	
	Immediately expand the focus of existing and planned incentive-based agri-environmental programs beyond particulate phosphorus to include an emphasis on best management practices that are most likely to reduce dissolved reactive phosphorus, such as reducing the amount of phosphorus applied to fields, slowing the movement of water to the field drainage system, and detaining flows at field drainage outlets.	Besides reducing application rates, subsurface placement with conservation tillage is among the most effective BMPs to reduce dissolved reactive phosphorus (DRP) loss (e.g., Martin et al., 2021).
	Future phosphorus management efforts should focus on: • Avoiding agricultural applications of phosphorus in autumn; • Reducing the load delivered during the spring period (March 1 to June 30) • Directing focus to sub-watersheds that are delivering the most phosphorus into the lake, including the Maumee River.	BMP practices that address dissolved phosphorus include subsurface placement of fertilizer and manure in particular.
	Increase the scale and intensity of agricultural best management practices programs that have been shown to reduce phosphorus runoff.	This is underway in all jurisdictions under the DAPs.
	Strengthen and increase the use of regulatory mechanisms of conservation farm planning to reduce nutrient loadings.	There is widespread opposition to regulatory mechanisms over voluntary actions within the agricultural community.
	Accelerate 4Rs (right source, right rate, right time and right place) outreach/ extension programs, and phase in mandatory certification standards for agrology advisors, retailers and applicators to ensure fertilizer is applied based on the 4Rs.	Adoption of 4R practices is being incentivized, but certification standards are generally not mandatory.

IJC Report	Key Recommendations	Status of Recommendations
	Work with municipalities to promote and accelerate the use of green infrastructure (such as filter strips, rain gardens, bio-swales, and engineered wetlands) in urban stormwater management in the Lake Erie Basin by: • Providing funding, regulatory direction and technical support to municipalities and, where feasible and appropriate as an alternative to more expensive stormwater controls, authorize green infrastructure in United States municipal water discharge permits and Ontario environmental compliance approvals • Encouraging the adoption of local ordinances/bylaws promoting green infrastructure	Most communities are adopting green infrastructure to some extent, with some cities (e.g., Detroit) instituting stormwater utility fees with offsets for green infrastructure to incentivize installations.
	The Governments of the United States, Canada, Ontario, Michigan and Ohio should:	
	Commit to the goal of a 10% increase by 2030 beyond current levels of coastal wetland areas in the western basin of Lake Erie to reduce nutrient pollution and promote biodiversity (an increase of about 1,053 ha or 2,600 acres)	>25 wetland restoration or creation projects are currently underway in Ohio and Michigan parts of the basin—total area and impact are unclear.
	Allocate adequate funding to support this significant first step in coastal wetland restoration, in concert with non-governmental funders	Substantial coastal wetland restoration is underway in the U.S. under GLRI and H2Ohio programs. See Berkowitz et al., 2020.
	Set a science-based goal for protection and restoration of wetlands inland from the Lake Erie coastal zone and develop appropriate strategies to meet the goal	No such goal has been set at this time, but monitoring of new wetlands is underway to determine their effectiveness at P removal and retention.

IJC Report	Key Recommendations	Status of Recommendations
	The Governments of Ontario, Michigan, Indiana, Ohio, Pennsylvania and New York should:	
	Ban the application of manure, biosolids, and commercial fertilizers containing phosphorus from agricultural operations on frozen ground or ground covered by snow for lands that drain to Lake Erie.	Ohio has banned this practice.
	The Governments of Ontario and Michigan should:	
	Enact legislation requiring inspection of septic systems at regular intervals, and at the time of property sale or land severance, to identify and assure upgrade/replacement of failing and potentially failing systems	Legislation varies across the Lake Erie and Ontario basins. No such statewide sanitary code legislation exists in Michigan.
	Expand state/provincial and community education initiatives promoting homeowner awareness of the need for septic system maintenance, including regular pump-out, and upgrade/replacement.	Such activities are currently being conducted by health departments, extension agents, watershed districts, and conservation authorities.
	The Governments of Ontario, Ohio, and Pennsylvania should:	
	Prohibit the sale and use of phosphorus fertilizers for lawn care, except for the establishment of new lawns during the first growing season or in cases where soil testing indicates a need for phosphorus.	Even without state bans, manufacturers are taking this action. In 2013, Scotts Miracle-Gro removed phosphorus from its popular Turf Builder line of lawn fertilizer.

Appendix B -- DAP and Related Report Summaries (under separate cover)

Document and Link	Recommendations/Actions	Progress/Milestones
U.S. Action Plan for Lake Erie (2018)	Source Reductions	
	WLEB Initiative: Coordinated strategy using funding from multiple Farm Bill programs and GLRI to double the number of acres under conservation in WLEB.	Programs have combined goals of 870,000 acres of conservation systems to reduce edge of field losses by 640,000 lbs TP (290 metric tons) and 175,000 lbs SRP.
	RCPP Tri-State Western Lake Erie Basin Phosphorus Reduction Initiative: A diverse team of partners using a targeted approach to identify high-priority sub- watersheds for phosphorus reduction and implement conservation practices on the 855,000 acres that have been identified as the most critical areas to treat.	RCPP will accomplish 180 acres of wetland restorations; 500 conservation plans; 60,000 acres of nutrient management; and 1000 environmental risk assessments.
	GLRI Ag Nonpoint Source Projects: Implementation of watershed management and domestic action plans to reduce nutrient loading from agricultural lands. Projects will target best management practices to critical source areas	Anticipate over 100,000 pounds phosphorus reduction in Lake Erie watersheds
	Great Lakes Sediment and Nutrient Reduction Program: Great Lakes Commission provides grants to local governments and nonprofit organizations to control nutrient & sediment losses to reduce the nutrient loading into the Great Lakes.	14,000 pounds of phosphorus annually across the Great Lakes Basin.
	Conservation Partners Program: National Fish & Wildlife Foundation (NFWF) is managing two USDA grants awarded through this program to Ohio State University Extension and Ohio Soybean Council to develop resources to help improve nutrient management and farmer outreach in the Western Basin of Lake Erie.	Deliverables include Nutrient Management Plans and the development of a Best Management Practice manual.
	Runoff and drainage management	
	Conservation Technical Assistance and Financial Assistance: Implement whole-farm conservation plans to improve water quality, reduce nutrients loss, and slow runoff from agricultural operations. Promote adoption of drainage water management, phosphorus filters, and other innovative techniques to reduce and treat runoff from agricultural land. Optimize siting of wetland restorations, creations and enhancements to treat agricultural runoff.	Acres treated and associated phosphorus reductions are reported annually under GLRI Action Plan II and Action Plan III.
	Transforming Drainage project: Expand extension education materials and programming on enhancing the management of drainage water to address water security and nutrient use. Understanding of potential benefits of these practices on yield, water budget, and water quality.	Deliver extension-based programming across the Great Lakes region, with several field sites in the Lake Erie basin. Provide innovative drainage water treatment or recycling options for producers based on the costs and benefits of implementing the drainage water storage practices at field sites.

Document and Link	Recommendations/Actions	Progress/Milestones
	Agricultural Conservation Planning Framework (ACPF) pilot in WLEB: Apply assessment tools, framework and geospatial analysis, to small watershed assessment and comprehensive precision comprehensive conservation planning. Supports agricultural watershed planning process.	Produce effective watershed-scale conservation options for land owners in up to 6 small watersheds in OH and IN, including the new CEAP Watershed in the Blanchard River. Explore using output as part of locally-led conservation planning process.
	Runoff Risk Decision Support Tools for Nutrient Application Timing: In partnership with Great Lake States, develop real-time decision support tools based on National Weather Service modeling and forecasts that provide producers guidance on the risk that runoff could occur, so that nutrient application preceding runoff events can be avoided.	On-going work includes modeling improvements and expanding collaboration. Planned work includes analysis to estimate the ability of Runoff Risk to reduce nutrient losses by analyzing edge of field data and investigating the factors affecting likelihood of adoption by producers.
	GLRI Urban Nonpoint Source Projects: Implementation of green infrastructure practices to reduce stormwater runoff from urban areas	Over 250 million gallons of untreated urban runoff captured or treated by GLRI-funded projects (broader than Lake Erie)
	Ottawa River Wetland Restoration Toledo, OH: This Great Lakes Fisheries & Ecosystem Restoration (GLFER) project will convert 16 acres of urban/industrial land into high-quality flood plain wetlands and associated riparian habitat.	The restored wetlands will be designed to maintain a hydrologic connection with the river and result in the capture and treatment of roughly 24 million gallons of overland flow each year
	P Optimal Wetlands - Demo site: Construct and actively monitor one or more permanent demonstration wetlands that are sited and designed for maximum P uptake to evaluate as a priority action that may occur systemically throughout the basin	Construction of one or more demonstration sites in Western Lake Erie basin in 2019
	Hydrologic Health Initiative: Demonstrate potential for nutrient reduction from conversion of marginal cropland to riparian habitat	Identify partners to secure riparian easement for pilot project
	Monitoring, Assessment and applied research: BMP Effectiveness	
	ARS Edge of Field Water Quality Research: Determine the effectiveness of various conservation practices by monitoring changes in nutrient losses from fields over time (an extension of CEAP Watersheds)	Peer-reviewed papers published regularly; conservation practice standards evaluated in conjunction with field scale assessment.
	Conservation Effects Assessment Project (CEAP) - National Cropland Assessment: CEAP Cropland was established to develop a methodology for estimating the environmental benefits and effects of conservation practices on cultivated cropland at regional scales. The assessment has been on a 5-year cycle in the WLEB, but future timing is TBD.	Next report assessing 2016 conservation condition is expected to be released in 2019. Prior reports were released by USDA NRCS in 2011 (Great Lakes), 2016 and 2017 (WLEB).

Document and Link	Recommendations/Actions	Progress/Milestones
	Conservation Effects Assessment Project (CEAP) - Watersheds - Stacked Practices Study: A new and innovative project initiated in 2016 in the WLEB aimed at measuring reductions from implementing a series of conservation practices in a treatment train. Practices will be implemented as a system and reductions assessed in the field, at the edge of field and instream.	Initial results in 2019. Data on the sequential and cumulative effects of "stacked" conservation practices in 3 small watersheds in northwestern Ohio.
	Edge of Field BMP Monitoring in GLRI Priority Watersheds: Determine the effectiveness of various GLRI-funded BMPs by monitoring changes in nutrient loads leaving fields over time and tracking changes in soil health characteristics of the impacted fields	Initial results by Fall 2018
	Blanchard River Demonstration Farms Network, Ohio: A GLRI-supported project designed to showcase and demonstrate leading-edge conservation practices to improve Great Lakes water quality.	Edge of Field monitoring, economic analysis, and outreach to farmers and landowners.
	P-Optimal Wetlands - Soil research: Research to understand the role of legacy phosphorus in areas being considered for wetland creation.	Development of standard soil phosphorus sorption capacity (SPSC) data collection is needed to identify potential constructed wetlands
	Monitoring, Assessment and applied research: Tributary/watershed	
	Conservation Effects Assessment Project (CEAP) - Watershed Assessment Studies: Long-term watershed-scale assessment of conservation practice effects on water quality, water management and soils in selected watersheds in the WLEB.	Peer-reviewed papers published regularly; new conservation practice standards being developed and evaluated in conjunction with field and watershed-scale assessment.
	Great Lakes Tributary Monitoring Program: Track changes and identify long-term trends in nutrient and sediment loads to the Great Lakes.	Early results (2011-2013 annual loading estimates) were published in early 2018. The next round of results thru 2016 is expected by 2019.
	Enhanced State Watershed Monitoring: Track changes in nutrient and sediment loads at specific locations in Lake Erie watersheds with high-frequency monitoring (including dissolved phosphorus spring loads)	Annual reporting
	Investigation of Nutrient Cycling in Rivermouths: Evaluate the magnitude of river mouth effects on the delivery of nutrients to the nearshore zone	Final report expected in spring 2019
	P-Optimal Wetlands - Watershed modeling: Using existing models and partnerships prioritize, evaluate, & monitor permanent wetland restoration projects designed to maximize phosphorus removal	Identification of one or more optimal sites in WLEB to construct and conduct long term efficacy monitoring
	Load allocations: Develop a methodology for allocating in-lake targets for subwatersheds to the Maumee River.	Methodology and initial findings for St. Joseph and Tiffin Rivers are expected in 2018.
	Pilot integrated water management strategies: Spatial analysis and landscape modeling conducted in 2014-2017 identified opportunities to implement drainage management in selected Lake Erie & Saginaw Bay watersheds.	Disseminate tools and information to assist local watershed planners in Ohio and Michigan. Seek partners to develop pilot projects to demonstrate the

Document and Link	Recommendations/Actions	Progress/Milestones
		potential nutrient reduction impacts of implementing a system of drainage management practices.
	Tools for estimating nutrient reductions: Update the pollutant removal rates and improve functionality in two tools used by nonpoint source program managers: The Spreadsheet Tool for Estimating Pollutant Loads (STEPL) and "the Region 5 Model" (R5 Model)	Updates to STEPL and the R5 Model were released in 2017.A web-based version is anticipated by 2019.
	Monitoring, Assessment and applied research: In Lake	
	Cladophora research: GLRI will support a concerted monitoring and modeling effort at several sentinel sites to better understand nuisance Cladophora growth and allow for future development of phosphorus targets in Lake Erie's eastern basin and the other Great Lakes.	Data collected over 2018 and 2019 field seasons will be used to update and enhance Cladophora growth models
	Remote sensing of benthic algae: Analysis of satellite data to survey the extent of submerged aquatic vegetation (including Cladophora) in the lower Great Lakes	Maps and summary statistics of benthic algae
	Nearshore assessment Offshore monitoring: An enhancement to the NCCA, 34 sites were added to the 201 5 survey of Lake Erie coastal condition in USEPA's Great Lakes National Program Office long term monitoring programs	Assessments of nearshore condition for western, central and eastern basins Spring and summer surveys of water quality and annual hypoxia monitoring
	HAB Forecasting: Now operational, NOAA's HABs Bulletin provides short and long-term projections of Microcystis blooms in western Lake Erie. These forecasts help water managers identify which blooms are potentially harmful, where they are, how big they are, and where they're likely headed.	Early season forecast based on tributary loads. Twice weekly publication of the HAB Bulletin. Daily bloom movement observations using the HAB Tracker.
	Hypoxia Forecasting: Develop a low oxygen warning system for drinking water managers in central Lake Erie basin.	Development of a model for fine-scale hypoxia forecasting to drinking water intakes.
	Environmental Sample Processor: Provide water intake managers early warning of HAB toxicity.	Daily HAB toxicity detection during 2017 season
	HABs and Hypoxia Monitoring: Weekly and real-time monitoring of relevant water quality parameters to support HABs and hypoxia forecasts. In addition to analysis of water samples, monitoring techniques also include airborne observations, satellite imagery, buoys and sensors.	Yearly satellite remote sensing estimates of average HAB extent. In 201 7, weekly data sharing including toxicity; weekly cyanobacteria mapping of areas near shore, over water intakes, and under clouds not visible to satellites.
	"Nowcast" for drinking-water and recreational sites: Develop models for determining, in real-time, the quality of Great Lakes waters near beaches and water intakes.	Implementation of new sites and enhancements to existing sites by 2019
	Lake Ecosystem Modeling: Expand and enhance current model and link to watershed model for evaluation of nutrient loading scenarios and eutrophication response.	Development of a whole lake integrated watershed-lake ecosystem model

Document and Link	Recommendations/Actions	Progress/Milestones
	Program assessment & improvement activities	
	Science Advisory Board: USEPA sought Science Advisory Board external peer review of the phosphorus reduction targets and supporting science. The review was conducted in two phases during 2015 - 2017.	Implementation of SAB recommendations as part of an adaptive management approach
	Tracking system: Efforts underway to improve methods for computing loads and report to the public through the GLC's ErieStat Pilot & Blue Accounting Initiative	Annual tracking and reporting of phosphorus loads
	Socio-economic analysis of agriculture incentive programs: A GLRI grant was awarded to the Great Lakes Commission to lead this project in FY l 7. The goal of the project is to understand whether GLRI investments in ag priority watersheds to date are being successful in changing farmer attitudes and willingness to adopt conservation practices.	Analysis and rankings of ag incentive projects funded under GLRI and recommendations to improve program implementation
	GLRI Adaptive Management: A pilot study is examining GLRI work in the WLEB to inform science based adaptive management and implementation of GLRI	Report from Pilot study in early FY 18 will include recommendations to the GLRI Regional Working Group to consider in development of GLRI Action Plan III
	GLRI Action Plan III: The next GLRI Action Plan (2020-2024) will improve the integration of GLRI and U.S. domestic responsibilities under the GLWQA.	Major Milestones: November 2018 - Public Comment September 2019 - Final
	Agricultural nutrient reduction strategy: A diverse group of partners in Ohio, Michigan, and Indiana developed the agricultural nutrient reduction strategy component of the U.S. Action Plan for Lake Erie.	Semi-annual meetings and coordination to develop and implement the strategy.
	Western Lake Erie Basin Partnership (WLEB) Partnership: The WLEB Partnership is a federal and non-federal interagency tri-state effort chaired by USDA-NRCS OH and USACE Buffalo District. The partnership is dedicated to improving land and water resource management in the basin and promoting a healthy, productive watershed	Semi-annual meetings and outreach to identify, prioritize and enhance projects
	Great Lakes HABHRCA: Federal action strategy for HABs and Hypoxia research in the Great Lakes	Biannual progress reports
Indiana's Great Lakes Water Quality Agreement (GLWQA) Domestic Action Plan (DAP) for the Western Lake Erie Basin (WLEB) (2018)	Programs/Projects.	
	Draft OAP public noticed. 1. Develop draft OAP, as well as Milestone and Action Table 2. Develop PN with questions for comment period (60 days) 3. Post-draft OAP and Milestone and Action Table for PN and comment period.	Complete
	Determine priority areas. Use monitoring data map, WMP critical areas, NRCS phosphorus export spreadsheet, and all ambient WQM data	Complete
	Restore Natural Hydrology and Ecological Functions.	

Document and Link	Recommendations/Actions	Progress/Milestones
	Rethinking Drainage for the 21st Century workshop. 1. Workshop with county surveyors and drainage professionals to learn about activities and barriers 2. The goal is to establish an innovative drainage pilot project	First workshop held, additional workshops will follow
	Ecological maintenance of regulated & unregulated drains to reduce hydrological modification & maintenance needs. Convene a drainage work group with county surveyors, members of the drainage boards, stream ecology/watershed restoration professionals, and concerned citizens	
	Point Source, Urban.	
	City of Fort Wayne LTCP	Tunnel Works Project began in 2017 and will be complete in 2025
	Stormwater NPDES MS4 Permit.	In progress
	Municipal NPDES permit.	In progress
	Adams County RSD sewer extension.	Extension began in 2017 and is ongoing
	Nonpoint Source, Urban.	
	Local ordinances and technical design standards.	In progress
	Revegetate urban stream banks with native plants in the Upper Maumee River.	In progress
	Install 2,800 linear feet of riparian buffers with woody vegetation in three Upper Maumee critical subwatersheds; Trier ditch (04100005010010), Bullerman (04100005010040), and Six-mile Creek (04100005010060).	
	Nonpoint Source, Rural.	
	Adams County emergency manure lagoons, one located north and one located south in Adams County. 1. One northern lagoon holding ten million gallons of manure 2. One southern lagoon holding 996,000 gallons of manure	In progress
	Phosphorus-Risk Reduction Pilot, 319(h) grant project, reimbursing for the reduction of phosphorus-risk potential by implementing conservation practices, including Black Creek (0410050104), Marsh Ditch (0410050106), Sixmile Creek (0410050103), Trier Ditch (0410050102), and Bottern Ditch (0410050105). 1. Develop the phosphorus risk reduction reimbursement program 2. Implement the phosphorus risk reduction reimbursement program	In progress

Document and Link	Recommendations/Actions	Progress/Milestones
	Upper Maumee River Implementation, GLRI grant project, reducing nutrient and sediment loading through the implementation of conservation practices, including Black Creek (0410050104), Marsh Ditch (0410050106), Sixmile Creek (0410050103), and Trier Ditch (0410050102) 1. Develop a cost-share program targeting conservation practices addressing nutrient loss 2. Implement the cost-share program reimbursing the full cost of conservation practices 3. Conduct an education and outreach program to bring about behavioral change	In progress
	St. Marys River Watershed Initiative, 319(h) grant project, implementing a paired watershed monitoring project, including the Weber Ditch (041000040502) and the Nickelsen Creek (041000040503) sub-watersheds. 1. Develop and implement a watershed-wide coordination program 2. Develop and implement a targeted education and outreach program 3. Develop and implement targeted social indicator surveyors 4. Perform and complete paired watershed monitoring and modeling 5. Perform and complete soil health monitoring	In progress
	Reduce sediment and nutrient loading through installation and adoption of watershed land treatment practices. Administer grant and allocate funds for producers	In progress
	Reduce streambank erosion, repair streambank damage, and improve wildlife habitat through the City of Auburn. Complete feasibility study on Cedar Creek from Morning Star Road to Eckhart Park	In progress
	Reduce sediment and nutrient runoff through adoption and installation of conservation practices. Cover crops, gypsum application, blind inlets, and streambank stabilization	In progress
	Reduce nutrient loading from failed septic systems. Lead septic issues, update ordinance, and provide cost-share funds for assisting with pair/replacement of septic systems	Ordinance passed 7/31/2017
	Support Infield Advantage program by working with participants on data collection and nutrient stewardship. Help landowners/producers participating in the program to understand their nitrogen management plan Groups participating include: 1. INWL - WLEB group 2. INWA - Adams/Wells group 3. INST - Steuben/LaGrange group	In progress
	Support rigorous enforcement of environmental rules & regulations. Determine legitimacy of claims of inconsistent implementation, identify barriers to execution, and establish a process for full implementation	

Document and Link	Recommendations/Actions	Progress/Milestones
	4R Nutrient Stewardship Certification program. Identify willing landowners, apply for grants, install BMPs, and engage universities in on-farm research	Indiana has one certified facility and is in dialogue to start a 4R program
	Establish woody plants for long-term erosion control and improvement of water quality, enhancing aesthetics, and wildlife habitat. Fourteen acres of trees planted within the West Branch, Fish Creek subwatershed	Completed 2016 and 2017
	Develop a response process for reports of manure mishandling & runoff from unregulated livestock operations or land application. Determine agency resources required	
	Sustainable,functional septic systems throughout the WLEB via ordinances identifying best practices installation, maintenance & repair. Convene a WLEB septic system workgroup	
	Soil Health Partnership. Identify willing landowners, attend field days, and share results, as well as five to ten years of tillage, nutrient management, and cover crops	In progress (five to ten years of tillage, nutrient management, and cover crops)
	Cover crop discount program. Assist local small farmers with cover crops and education on benefits of cover crops	Complete
	Monitoring	
	Secure GLRI grant for auto-sampler on the St. Marys River. Submit application	Complete
	Add capacity to sample for DRP laboratory analysis. Secure laboratory equipment for the ISDH	100% Funds secured and MOU executed
	Collect DRP at IDEM fixed stations in the WLEB. Investigate necessary resources for collecting and analyzing for DRP	DRP sample collection and analysis began on 1/18
	Collect TP, DRP, and nitrate-nitrite samples at 27 sites during recreational season. Tri-State Watershed Weekly Water Quality Monitoring program	In progress
	In-stream water quality. Monthly and storm grab samples at locations within Fish Creek watershed	Complete
	Ecology of two-stage ditches. Macroinvertebrate sampling at constructed two-stage ditch sites in St. Joseph watershed	In progress
	Education and Outreach	
	In-stream water quality. Weekly sampling during recreation season and monthly sampling during non-recreation season at ten locations	In progress
	Use the WLEB GIS Story Map to showcase the conservation and monitoring activities going on in the Indiana WLEB watershed. Update Story Map annually, as necessary	In progress
	Continue to conduct the spring and fall cover crop and tillage transect survey in the counties in the WLEB. Partnership staff in Adams, Allen, DeKalb, Noble, Steuben, and	In progress

Document and Link	Recommendations/Actions	Progress/Milestones
	Wells counties will conduct this transect in the spring following planting on an annual or bi-annual basis	
	Report the nutrient load reductions for all ICP assisted conservation practices within the WLEB on an annual basis. ISDA staff will use the Region 5 Model to analyze practices and show sediment and nutrient load reductions	In progress
	Provide soil health education to 100+ farmers, retailers, and CCAs. Seeing Green: Fields and Profits conservation day	Complete
	Educate producers on production practices related to water quality issues in the WLEB. Annual agronomy field day, held in conjunction with The Andersons, Purdue Extension, and surrounding SWCDs	On going
	Educate the public on the WLEB issues. Planned and implemented the Watershed-n-Spread event. Dr. Chad Penn presented "WLEB: the perfect storm"	Complete
	Educate producers/landowners on production/urban practices related to water quality issues in the WLEB. Annual meeting, presentations, various district workshops, booth at 4H Fair, and educational materials	In progress, hundreds impacted
	Youth education. Educational materials provided on pollinators, soil health, trees, water quality, and summer conservation camps	In progress, an average of 1,450 students, annually
	Youth education for 32 years, hands-on educational event for 4th-grade students of the Metropolitan School District of Steuben County to teach soil health water quality, and other conservation-related subjects. 4th grade youth conservation field day	In progress, an average of 300 students, annually
	Educate homeowners/landowners on urban practices related to water quality issues in the Maumee WLEB. Promote urban BMPs for storm water management from streets, parking lots, and other impervious pavement surfaces to community members and homeowners in the city	In progress
	Partner with local non-profits to harvest and collect native seeds. Seed harvest event in wetland, preserve, or natural habitat	In progress
	Work with local non-profits to organize community urban stream bank restoration projects within the upper Maumee watershed. Collect/purchase 100 lbs native seeds to be planted on the stream and riverbanks and collect/ purchase 1,100 native trees to be planted on severely eroded riverbanks and streams; secure GLRI funding	In progress
	Sponsor and present at soil health, 4R, and farmer working group field days and events in IN. Two to three events/year, serve on Tri-State Watershed Alliance Board, and sponsor and help host annual expo	In progress (direct contact with 1,000 WLEB stakeholders)
	Youth education. River Camp	Complete

Document and Link	Recommendations/Actions	Progress/Milestones
	Youth and adult education. Johnny Appleseed Festival	Complete
	Youth education. Izaak Walton League Conservation Camp	Complete
	Youth education. Envirothon/aq uatics	Complete
	Youth education. Canterbury Day of Service	Complete
	Provide education on cover crops, wet lands, filter strips, and wildlife habitat and water quality issues. Land management field day	Complete
	Adult and youth education. Various pasture walks at farms, including the Amish	In progress
	Public education on BMPs, soil health, watersheds, water quality, and pollinators. Booth at Adams County 4H Fair	In progress, thousands impacted
	Youth education. Earthworms, investigating soil health, frogs, owls, butterflies, and trees	In progress, thousands impacted
	For 22 years, all 5th graders from public, parochial, and homeschool attend to learn lessons in conservation. Splash event: watershed, common water, trees, pollinators, earthworms, nematodes, and soil health	In progress, thousands impacted
	Adult education. Various field days focused on water quality and soil health topics	In progress, hundreds impacted
	Provide education materials explaining the WLEB and how actions affect others (promotes BMPs), how watersheds are connected and affect one another, and proper management of manure and how it affects phosphorus in the soil. Adams County Watershed, Adams County Watershed Maps, and Manure Management Practices booklets	Complete, hundreds dispersed
	Education on cover crops and how it helps phosphorous levels on farms. Cover Crop PARP meeting	Complete, over a hundred impacted
	Public promotion of soil health and water quality (combined annual meeting of SWCD, Farm Bureau, and Pork Producers). Ag extravaganza	In progress, hundreds impacted
	Education on proper management of manure and reducing our phosphorous and education on value of manure and the IN State Chemist standards. Winter ag meeting	Complete
	Designed and disbursed nutrient management packets to encourage manure management and to ease record-keeping for our producers. Nutrient management packets	Complete
	Education on importance of soil testing and the levels of phosphorous, soil health and best management practices are encouraged, as well as follow-up meetings to interpret tests and provide aerial maps of farms. Soil testing	Complete, over a hundred tests
	Education on the importance of manure and its value and a follow-up farm visit. Manure tests	Complete

Document and Link	Recommendations/Actions	Progress/Milestones
	Provide education on WLEB, phosphorous levels in our area, and water and marine life testing. OSU Stone Lab tour on Lake Erie	Complete
	Two meetings (am and pm) regarding education on WLEB, effects on phosphorous, water quality, and benefits and use of gypsum. Connect the Dots water quality meeting	Complete
	Promote use and benefits of cover crops and no-till practices, specifically drill being modified to be pulled by horses or tractors. Purchase of new Land Pride 7' no-till drill	Complete
	Educate on a variety of stormwater and water quality-related topics to neighborhood groups and other organizations. Speakers available to discuss stormwater and water quality-related topics	In progress
	Hands-on rain garden workshops and incentives for City of Fort Wayne residents to install a rain garden. Hands-on rain garden workshop held locally in Fort Wayne to provide rain garden and stormwater education	In progress

Document and Link	Recommendations/Actions	Progress/Milestones
State of Michigan Domestic Action Plan for Lake Erie (2018)	1. Maintain the reductions achieved in the Great Lakes Water Authority (GLWA) Wastewater Resource Recovery Facility (WRRF) discharge as a result of the tightened permit limits.	
	TP limits of 0.7 mg/l monthly average, and 0.6 mg/l growing season average (April - Sept.), are required at the main secondary treated outfall at the WWTP.	Completed through NPDES Program Discharge Monitoring Reports (DMRs).
	TP limits of 1.5 mg/l monthly average are required at the two wet weather outfalls at the WWTP.	Completed through NPDES Program DMRs.
	Monthly calls/meetings between MDEQ and GLWA to ensure compliance with effluent limits and to discuss any issues.	Ongoing, monthly but reassessed annually for call frequency.
	2. Achieve reductions in P discharged from the Wayne County Downriver Wastewater Treatment Facility (DWTF) and continue reductions at Ypsilanti Community Utility Authority Wastewater Treatment Plant (YCUA WWTP).	
	Reissue NPDES permit with TP limits of 0.7 mg/l monthly average, and 0.6 mg/l growing season average (April - Sept.), at the secondary treated outfall at the WWTP.	Draft permit under negotiation, expect to reissue NPDES permit by 9/30/2017.
	More stringent TP limits are required by permit schedule by 2020.	More stringent TP limits required by 2020 through NPDES Program.
	Continue to achieve the TP 0.6 mg/l growing season average permit effluent limit at the tertiary treated outfall at the YCUA WWTP, as required in its NPDES permit.	Completed through NPDES Program.

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	3. Identify priority areas in Michigan's portion of the Maumee River Watershed for P reductions. Identify and implement priority actions to reduce P loads from Michigan's portion of the Maumee River Watershed.	
	Develop and implement 2016 monitoring plans.	Completed.
	Develop and implement 2017 monitoring plan, including SRP, in coordination with Indiana and Ohio.	Monitoring began April 2017 and will conclude in spring 2018.
	Conduct additional monitoring as appropriate to evaluate P reduction success and identify additional target areas for reduction.	MDEQ is working with USEPA, USGS, OH and IN to develop a coordinated, appropriate monitoring plan for the
	Develop WMPs for the Tiffin and Bean Watersheds. The Tiffin/Bean are the last Maumee River subwatersheds in Michigan without a USEPA approved 319-approved WMP.	Ongoing. Grant awarded to Hillsdale County CD to develop 319-approved WMP. Target completion date is January 2019.
	4. Support and invest in research to better understand the causes of HABs, including invasive mussels and SRP (urban and rural sources), and how these factors increase/decrease HAB events.	
	Assess annually to understand information gained, and opportunities for additional HAB research support through the Great Lakes HAB Collaboratory and other coordination networks. A better understanding is critical to refine the state's implementation programs under the adaptive management approach and Annex 4 process.	Ongoing.
	Implement two HAS-related research grants: Detection of toxin-producing cyanobacteria (Grand Valley State University); development of HAB hazard maps using land use and toxin data, and development of smartphone app to detect HABs (Oakland University with Wayne State University, Lake Superior State University and Northern Kentucky).	MDEQ awarded grants in 2016.
	Conduct Zequanox pilots as needed.	Pilot completed in 2014.
	Participate in the Invasive Mussel Collaborative and support research to better understand the role of invasive mussels in nutrient cycling and potential contribution to cyanobacteria blooms.	Ongoing.
	To further understand SRP, including agreement on appropriate sampling and analytical methods, participate in Annex 4, develop relationships, attend regional conferences, and partner with federal, state, and local monitoring efforts.	Ongoing.
	Design and fund a study to evaluate SRP discharge quality as a function of level of municipal treatment, including: secondary treated, primary treated, CSO Retention Treatment Basins, and untreated CSOs.	2017, ongoing.

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	5. Utilize research and field demonstrations to identify the suite of best management practices (BMP) that work collectively to reduce both TP and SRP at the field-scale implementation level.	
	Implement new MAEAP reporting and planning database to better track the cumulative impact of conservation practices across the watershed and county scale. Environmental and conservation practice information will also be used to estimate sediment and nutrient loading reductions.	Started October 1, 2016, ongoing.
	Expand MAEAP database through the addition of a spatial mapping decision-based tool to enable MAEAP technicians to demonstrate to farmers sensitive areas that are conducive to BMP installation.	FY 2018 creation of spatial mapping decision-based tool, ongoing.
	Implement spatial mapping decision-based tool upgrades to database with MAEAP technicians.	FY 2019 roll-out to MAEAP technicians.
	Continue to seek new data and information about BMPs, and monitoring strategies through ongoing communications with research universities and federal agencies such as the USEPA, USDA - NRCS, USGS, U.S. Army Corps of Engineers, and USDA Agricultural Research Service.	MDARD Environmental Stewardship Division staff annually identify and review research and conference opportunities. Discuss at MAEAP staff meetings.
	Work with partners to design and implement a study to evaluate the effectiveness of DWM control practices installed to reduce tile line discharges of SRP.	Ongoing.
	Use pass-through grants to reduce sediment and nutrient loads from the WLEB by implementing priority BMPs from approved WMPs.	The NPS Program's pass-through grant request for proposals is issued annually.
	6. Implement P control actions in the River Raisin Watershed to achieve the target load reductions.	
	Conduct forensic analysis to determine likely sources resulting in reductions.	Completed February 2016.
	Reissue the Monroe Metro WWTF permit with more stringent TP limits of 0.7 mg/l monthly average, and 0.6 mg/l growing season average (April - Sep), at the main secondary treated outfall at the WWTF.	Completed April 2016; revised TP limits required by 2019.
	Continue to use pass-through grants to emphasize a targeted and comprehensive approach to farm conservation planning, livestock management strategies, and drainage water management strategies.	The MDEQ NPS Program will release a request for proposals annually.
	7. Maintain and expand partnerships to provide valuable technical and financial assistance to farmers. Specifically, maintain an increased level of Conservation District (CD) Michigan Agriculture Environmental Assurance Program (MAEAP) technical assistance levels through 2018 and beyond.	
	Seek additional funding to assure the ongoing expanded levels of local MAEAP technicians in the WLEB.	For 2017 and each subsequent year, maintain technicians in the WLEB. Annually review the

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		technical assistance need to expand, reduce, or target efforts.
	Strengthen partnerships with the agricultural community, including farming input providers and CCAs through the 4R Nutrient Stewardship Program, to encourage more farmers to take action to protect water quality.	FY 2017-2019 Partner on the Farmer- Led Conservation effort to encourage grassroots farmer involvement in education, cost-share and decision-making. FY 2017 Promote CCA incentive program to strengthen partnerships.
	Partner with USDA - NRCS, MSUE, and other partners to offer training to MAEAP technicians.	Annually train staff in risk assessment tools, nutrient management, manure management system plans, knowledge of BMPs, communications, and landowner outreach.
	Coordinate partnerships through quarterly WLEB Team meetings to review technical assistance and resources available to farmers.	Host four per year. Debrief on local efforts to review who is doing what, success stories, and obstacles.
	Partner to identify and secure additional funding and cost share to provide opportunities to farmers.	Seek additional partnership opportunities to provide technical and financial conservation assistance.
	Continue to use pass-through grants that place an emphasis on a targeted and comprehensive approach to farm conservation planning; livestock management strategies; and DWM strategies.	The NPS Program will release a request for proposals annually.
	8. Increase and maintain MAEAP practice implementation and verification for long-term water quality improvement.	
	Identify and implement more incentives to expand participation in MAEAP through the MAEAP Advisory Council (AC).	Evaluate incentives and pilot projects annually. Incentive survey completed in 2016 with four recommendations submitted to MAEAP Advisory Committee and MDARD. FY 201S-19, MDARD will pursue incentives identified and approved by the MAEAP AC incentives workgroup to increase program participation.
	Increase MAEAP cropland acres managed under NMPs	In FY 201S, increase total MAEAP NMP acreage on farms by 35,000 annually.
	Identify number of farms eligible for re-verification and discuss during local MAEAP goal-setting meetings.	Maintain a minimum of S5 percent re-verification rate for farms in the WLEB.
	MAEAP technicians work one-on-one with farmers to provide technical assistance and identify environmental risks and recommend and prioritize BMP installation.	Track number of risk assessments, BMPS installed, and acreage impacted.

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	Increase farmers participating in MAEAP and track the environmental gains on both verified and non-verified farms.	Increase number of program participants to 120 percent of FY 2017 level. Track pounds of sediment, N, and P reduced.
	9. Improve and increase outreach to the public and farmers to promote understanding of the WLEB and good conservation practices by initiating new targeted outreach campaigns, workshops, field demonstrations and information sharing.	
	Work with the MAEAP Communications work group committee and partners to conduct targeted outreach to public and farmers to raise awareness of the benefits of MAEAP.	MAEAP Communications work-group meets six times a year and will annually review short and long-term communication goals. FY 2017-2019 MDARD partner with Farmer-led conservation effort on targeted outreach analysis and campaign in WLEB.
	Host six conservation sails in FY 2017 to help farmers experience the impact of land management decisions on the waters of Lake Erie firsthand through water sampling and educational presentations.	Annually review attendance and impact of education to determine ongoing efforts.
	Coordinate with partners to host on-farm field days, MAEAP Phase 1 educational events.	Annually review attendance and impact of education to determine ongoing efforts.
	10. Promote wetland restoration and other land management initiatives to reduce P loading.	
	Develop innovative strategies to enhance wetland restoration, and green infrastructure, and other land management planning and implementation efforts in Southeast Michigan.	Ongoing.
	Work with agency staff to review BMPs implemented on state-managed lands in the WLEB.	Ongoing.
	Work with partners to pursue strategic conservation easements in coastal wetlands, riparian zones, and key wetland areas to improve groundwater infiltration, reduce runoff, and support diverse aquatic and terrestrial biota.	Ongoing. External and internal funding opportunities will be shared with interested partners.
	Issue requests for proposals that place a priority on purchasing conservation easements to limit land-use activities that are detrimental to water quality.	The NPS Program's pass-through grant request for proposals is issued annually.

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Promoting Clean and Safe Water in Lake Erie: Ohio's Domestic Action Plan 2020 to Address Nutrients (2020) and State of Ohio's Western Lake Erie Basin Collaborative Implementation Framework - A Pathway for Transitioning Ohio to a Great Lakes Water Quality Agreement Domestic Action Plan (2017)	**Ohio DAP 2020 Actions (Current)**	
	Actions to Further Develop Targets	
	Ohio EPA will publish a nutrient reduction target for each priority watershed and major western Lake Erie basin tributaries. These targets will be used in assessing nutrient reduction progress toward the Annex 4 targets.	The Ohio DAP 2020 includes a listing of targets for each HUC12 watershed in the Maumee River basin (Table 4 and Table 5 of the Ohio DAP 2020). This information has been supplemented with additional targets for additional watersheds in the Maumee AOC. Also see the Ohio DAP 2020 Appendix A and supplemental materials at lakeerie.ohio.gov. Ohio EPA is continuing to refine the targeting process under the Maumee Watershed Nutrient TMDL which is being developed based on the 303(d) listing.
	Strategy 1: Actions to Address Nutrient Loss from Agriculture	
	Develop a robust list of agricultural BMPs that very specifically address nutrient loss, with an emphasis on total phosphorus reduction.	ODA, Ohio EPA, and other experts developed a list of over 100 suitable agricultural BMPs. This list was narrowed down to ten cost-effective practices to focus the H2Ohio effort. Cost-effectiveness was developed using a marginal abatement cost curve approach. Data on the cost-effectiveness of the practices continue to be collected. Most notably, the H2Ohio program includes the LEARN wetland research project which will detail the cost-effectiveness of wetlands created using H2Ohio funding.
	Implement H2Ohio programs funding agricultural BMPs in the Maumee River watershed	Programs were rolled out by ODA in 2019 and 2020 for 14 priority counties in the Maumee River watershed and funding has been secured through state fiscal year 2023.

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	Implement H2Ohio agricultural BMPs in the remaining Annex 4 priority tributaries of the Lake Erie watershed in Ohio	In 2021, ODA expanded from the original 14 counties to include 10 additional counties including areas within the Sandusky and Huron River watersheds.
	Support and work closely with the SWCD conservationists to provide resources to producers to implement conservation practices across the western Lake Erie basin.	ODA has established staff resources to coordinate with the SWCD conservationists. This effort has been expanded with the addition of the HB 7 watershed coordinators.
	Implement SB 299 programs. SB 299 provides roughly $36 million in funding toward a variety of programs, including $3.5 million to support county SWCDs in the western Lake Erie basin for staffing and to assist in soil testing, nutrient management plan development, enhanced filter strips, and water management and other conservation support and up to $20 million for ODA programs.	These programs are being implemented as part of H2Ohio.
	ODA will coordinate with the United States Department of Agriculture Commodity Credit Corporation to strengthen and stimulate the Ohio Lake Erie Conservation Reserve Enhancement Program (LE-CREP) to achieve its 2004 goal of voluntarily establishing 67,000 acres of filter strips, riparian buffers, hardwood tree plantings, wildlife habitat, and field windbreaks	Beginning in 2019, the state of Ohio is providing a $200 bonus for all newly enrolled filter strip and riparian area practices. For current CREP participants with expiring contracts, re-enrolling and expanding the width of filter strips or riparian areas will earn bonus dollars on additional acres. This program is being supplemented through H2Ohio.
	ODA will educate producers on the importance of following the fertilizer and manure application restrictions and fertilizer certification requirements in the WLEB. Implementation and enforcement of these restrictions will be a top priority for ODA and Ohio's SWCDs.	OAC 905.326 Establishes additional manure application rules related to weather conditions for operations within the Western Basin of Lake Erie while ORC 939 establishes rules and complaint-based enforcement to prevent sediment and manure runoff from non-permitted agricultural operations. State Agricultural Programs for Voluntary Nutrient Management Plan Development & Implementation; Variable Rate Phosphorus Application; and Subsurface Phosphorus Replacement are available in the 2020 DAP. The training program for nutrient

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		applicators was completed by September 30, 2017, with over 18,000 participants receiving certification.
	The Ohio Agriculture Conservation Initiative is an innovative, collaborative effort of the agricultural, conservation, environmental, and research communities. OACI will assess farm practices in Ohio to better understand current on-farm conservation and nutrient management efforts; and create a new, voluntary certification program for farmers to promote continuous improvement and increase adoption of BMPs to improve water quality in the western Lake Erie basin. OLEC and ODA will coordinate activities and communication with OACI as needed.	OACI continues to roll out its certification program. State agency staff meet with OACI as needed.
	Strategy 2: Actions to Restore Wetlands	
	ODNR has developed a strategic approach focused on investing in natural infrastructure to provide nutrient reduction and water quality benefits to Lake Erie. This includes implementing the tenth H2Ohio BMP: wetlands.	ODNR is committed to creating and restoring thousands of wetland acres over the next decade in the Lake Erie watershed. ODNR's initial wetland efforts are focused in northwest Ohio. These areas include 1) the mouth of the Maumee River; 2) the Lake Erie coastal region between the Maumee River and the Toussaint River; 3) the Sandusky Bay region; and 4) the Maumee and Sandusky River watersheds. Projects are listed in Appendix F of the Ohio DAP. Also see H2Ohio updates at h2.ohio.gov and the H2Ohio Annual Reports for up-to-date project listings.
	ODNR, in cooperation with Ohio EPA, will continue to fund and complete engineering and design work for potential in-water coastal wetland restoration projects in the western basin that beneficially use dredged material and can help assimilate in-lake nutrients.	ODNR will complete two coastal wetland pilot projects recommended for Great Lakes Restoration Initiative funding by the U.S. Fish & Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), and U.S. Environmental Protection Agency (U.S. EPA) Great Lakes Coastal Conservation Working Group. These pilot projects will reconnect existing degraded tributary and diked wetlands with Sandusky Bay resulting in restored nutrient processing functions and enhancing habitat connectivity with Sandusky Bay.

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	ODNR will continue to coordinate with and assist the USFWS/NOAA Upper Midwest and Great Lakes Landscape Conservation Cooperative (LCC) coastal conservation workgroup to develop a tool to identify potentially restorable wetlands for the western basin that incorporates landscape conservation design principles and goals, with a focus on restoring and conserving functional coastal wetlands that maximize coastal habitat, water retention, sediment trapping and nutrient processing/reduction benefits and in cooperation with Ohio Sea Grant shall jointly fund projects to investigate and quantify nutrient processing and reduction benefits of coastal wetlands	This work is ongoing. See Appendix F of the Ohio DAP 2020 for a list of several different project types that will provide direct nutrient and sediment-reduction benefits to the Maumee River Watershed, Western Lake Erie Basin, Sandusky Bay and other watersheds throughout the state. Also see H2Ohio updates at h2.ohio.gov and the H2Ohio Annual Reports for up-to-date project listings.
	Strategy 3: Actions to Reduce Community Sources	
	ODH will continue to work with local health districts to ensure the implementation of their Operation and Maintenance Tracking programs for sewage treatment systems as required in the Ohio Administrative Code, by prioritizing identification of failing sewage treatment systems within targeted watersheds. Upon identification of a failing system, local health districts will establish specific action plans and timeframes for correction of the nuisance conditions which may include repair, alteration or replacement of the sewage treatment system, or connection to public sewers, including an analysis of those areas of concentrated failing HSTS and their proximity to public sewer as well as existing capacity of the most likely provider of public sewer.	This work is ongoing. Since 2016, Ohio EPA has awarded almost $50 million to Ohio local health departments to direct to eligible homeowners. Ohio EPA provides additional funding through the H2Ohio initiative for infrastructure projects that improve water quality. The initial project announced in the Lake Erie watershed entails the construction of a new wastewater collection and treatment system in the unincorporated area of Kunkle, Ohio, Williams County (Maumee River watershed). H2Ohio funds will be combined with a U.S. Army Corps of Engineers grant and Ohio EPA funding for this project covering the overall cost of $3.5 million. About 90 homes with failing HSTSs will be taken offline reducing phosphorus by 168 pounds per year. See h2.ohio.gov and the H2Ohio Annual Reports for more information and updates on these projects.
	Ohio continues to include phosphorus optimization language in NPDES permits issued to major dischargers within the lake basin. This language requires the permittees to investigate source reduction, operational improvements, and minor facility modifications to reduce current effluent concentrations cost-effectively.	This work is ongoing. See Appendix E of the Ohio DAP 2020 for examples and discussion.
	Ohio EPA has identified top 30 facilities in the Maumee basin with an NPDES permit. Ohio EPA will evaluate those facilities that currently do not have a permit limit for total phosphorus and that are discharging less than 1 MGD to determine options on a facility by facility basis for reducing the phosphorus discharge level	Since 2017, Ohio EPA had reviewed at least 28 optimization plans. These plans have periodically identified potential optimization opportunities and permittees have submitted schedules to implement changes when appropriate. Additional explanation

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		and some project examples are provided in Appendix E of the Ohio DAP 2020.
	Ohio EPA will continue to focus State Revolving Loan Fund dollars and coordinate with other infrastructure funding programs to direct funding at priority CSO separation projects, wastewater treatment plant upgrades, stormwater management and home sewage treatment systems.	This work is ongoing. The state of Ohio has invested in these nutrient reduction efforts by offering financial assistance to communities with NPDES permits for wastewater treatment plant upgrades and combined sewer separation projects. Through its Water Pollution Control Loan Fund, Ohio EPA has provided Lake Erie communities with over $2.6 billion in wastewater resource infrastructure project loan funds between 2009 and 2018.
	Strategy 4: Using Watershed Planning for Practice Placement	
	Ohio will continue to encourage the development of watershed plans for the most effective placement of structural practices. Ohio EPA and ODA will coordinate with local entities in the development of 9-Element Watershed Plans (Ohio NPS-IS) with a focus on priority watersheds. The intent is to focus on completing the southern portion of the Maumee River watershed, and then include the remainder of the Maumee, Portage, Sandusky and Cuyahoga River watersheds as time and funding become available.	GLRI funds and CWA §319 funds are being passed through to local jurisdictions to encourage this effort to create NPS-IS plans. Ohio EPA provides a list of watersheds with approved 9-element NPS implementation strategies. The initial 26 plans using the far-field targets were completed in 2020. Over 120 watersheds are currently listed with approval dates as recent as August of 2020. This effort continues and will be further supported by the HB 7 ODA watershed coordinators program.
	Ohio EPA will continue to develop a process to identify and recommend priority watersheds at the HUC 12 level.	The Ohio DAP 2020 Appendix A includes a finer-scale geographic distribution of the TP load from various sources within the Maumee River watershed and further division by landscape source. The method is a modified form of the Ohio EPA Nutrient Mass Balance Study methodology. It breaks the 4 million+ acre watershed into approximately 26-square-mile (17,000-acre) geographic units corresponding to the U.S. Geological Survey HUC12s. This information was used to inform the monitoring network locations at HUC12 sentinel watersheds.

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	Provide a suite of recommended practices based on best available knowledge about the nutrient reduction benefits of these tools.	These are provided in Appendix B of the Ohio DAP 2020.
	The Agricultural Conservation Planning Framework uses a watershed approach to locate practices within a HUC12 using GIS tools designed to find conservation opportunities across different agricultural landscapes. While not a comprehensive tool for siting all possible practices, it will be useful in this context because of its focus on water retention in agricultural landscapes.	The ACPF has been piloted in a few watersheds in the western Lake Erie basin and efforts are underway at NRCS and Ohio universities to expand its coverage. State agencies are actively working with academic and NGO partners to develop this tool in Ohio and share it with the local jurisdictions developing NPS-IS.
	Monitoring, Tracking, and Reporting	
	To track reduction progress, the primary indicator will be water quality monitoring and associated load calculations at the key downstream station on each of the Annex 4 priority watersheds in Ohio. OLEC and member agencies will provide an annual update to the Ohio House and Senate Agriculture, Agriculture and Rural Development, Energy & Natural Resources Committee as well as the Lake Erie Caucus on the state of the water quality in the WLEB. These updates and status reports will be made available to the public on the OLEC website.	Ohio has produced an annual Water Monitoring Summary and an associated Expanded Lake Erie Tributary Nutrient Load Monitoring Report that tracks monitoring results against the Annex 4 targets. These are available for download on the OLEC website: https://lakeerie.ohio.gov/planning-and-priorities/03-wms/wms
	Ohio EPA will take a leadership role with member entities on the Annex 4 Monitoring Task Team (Ohio, Indiana, Michigan and Ontario) to ensure a consistent sampling and lab testing protocol is in place and being followed.	Review and coordination of lab protocols have been occurring in conjunction with the Annex 4 Subcommittee and its working groups. A round of lab duplicates and protocol comparisons between Ohio EPA, Heidelberg University, and USGS was completed in 2014-2015 as part of the Water Monitoring Summary effort led by OLEC.
	Ohio EPA will establish a comprehensive water quality monitoring network specific to tracking progress toward meeting the requirements of Annex 4. Monitoring locations will be established at key subwatersheds and at the most practical location near the mouth of all the direct, primary tributaries to the western Lake Erie basin.	The state of Ohio and its federal and institutional partners have restructured the pre-existing river monitoring network to better inform tracking towards the Annex 4 nutrient reduction targets. Review and coordination of this network continue in conjunction with the Annex 4 Subcommittee and its working groups. See Appendix G of the Ohio DAP 2020 for a list and map of the monitoring sites.

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	Ohio EPA is required by state law to develop a nutrient mass balance report every two years. The next nutrient mass balance study will be published in 2020 and will include all Annex 4 priority tributaries.	Completed, with 2022 report underway. See: https://epa.ohio.gov/static/Portals/35/documents/Nutrient-Mass-Balance-Study-2020.pdf
	ODNR will support extensive wetland monitoring work, especially in the WLEB and Sandusky Bay.	ODNR is working cooperatively with partners (Cleveland Water Alliance, City of Sandusky, Bowling Green State University, and others) to develop a low-cost sensor network to monitor water quality within Sandusky Bay and at the Old Woman Creek National Estuarine Research Reserves. This network has been deployed and is being tested.
	Through the NPDES permit program, discharging entities monitor and report nutrient concentrations and flow volume via a dedicated database.	Ohio EPA maintains this database and utilizes it for permit compliance.
	Ohio EPA will oversee monitoring and tracking of microcystins at drinking water plants and HABs at public recreational beaches.	The Division of Drinking and Ground Waters tracks all HAB monitoring data from public water systems via a database and maintains an interactive map where the public can assess these data. Surface water data for beaches and other water bodies are available via BeachGuard.
	Ohio EPA will coordinate with local authorities to conduct monitoring of nutrient discharge levels from priority combined sewer overflows to evaluate the total nutrient load resulting from these periodic discharges and to assist in determining priorities for separation projects.	Ohio's Domestic Action Plan 2020 reports on the median concentration of 131 samples reported from September 2014 to August 2017 by two Ohio sewer districts that are required to monitor TP at select CSO outfalls in their NPDES permit. This work continues.
	Agricultural BMP funding will be tracked.	As a part of the H2Ohio initiative, agricultural BMP projects routed through Soil and Water Conservation Districts will be tracked via a digital platform already in use (Beehive). Metrics reported from data posted to this platform are under further development and could include extent of adoption of agricultural BMPs (number of acres enrolled, number of acres completed, funds committed, funds disbursed). H2Ohio tracking systems will also be able to track and report on number and type of completed wetlands projects, number and type of OEPA infrastructure projects completed. The ODA Division of Soil and Water Conservation will track the extent

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		and location of practices and will report relevant SB 299 metrics (ex: dollars spent, number of practices installed, acreage, location of practices by HUC12) to OLEC. This information is included in the H2Ohio Annual Reports to the legislature which are available at h2.ohio.gov.
	Watershed planning projects will be tracked.	The state of Ohio has implemented a tracking mechanism to summarize project lists from multiple HUC12 watersheds' NPS-IS in one spreadsheet to streamline project and conservation practice implementation. The development of the spreadsheet was completed via a technical assistance grant from USEPA.
	Ohio is committed to working with U.S. EPA to coordinate and provide progress tracking information in a consistent and timely manner.	Ohio has participated in the ErieStat online platform, annual webinars, and other public forums such as the Great Lakes Public Forum which is held every three years. Ohio also provides information used in the GLWQA Triennial Progress Report of the Parties which is published every three years. The current Triennial Progress Report was issued in June 2019 and the next report will be issued in 2022.
	As a part of the H2Ohio initiative, progress will be reported to the public at regular intervals via a dashboard, which may be either static (periodic reports or infographics) or online interactive (aspirational).	Development of this portal is underway.
	The state agencies will continue to highlight key phases and successful projects through news releases.	See h2.ohio.gov and the OLEC YouTube channel for examples.
	OLEC will develop a strategy for public involvement.	The Western Basin of Lake Erie Collaborative Framework and the initial Ohio DAP 2018 were developed with input through meetings and conversations with various stakeholder groups and state agencies, individually and collectively. The Ohio DAP 2020 indicates several potential options for public involvement with the Ohio DAP: an advisory board, an annual conference, and ad-hoc meetings with stakeholders. A technical workshop for stakeholders was held in April 2021, and the

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		presentations from that workshop are available on the OLEC YouTube channel. OLEC has been facilitating individual meetings with stakeholders on request. A formal advisory board is not being pursued at this time.
	Research Actions	
	ODA will monitor the progress of the USDA Agricultural Research Service to finalize and present initial results from edge-of-field monitoring and research	It is the goal of the overall water quality monitoring strategy in Ohio to include monitoring data from edge-of-field, sub-watershed, Annex 4 priority watersheds, and Lake Erie to provide a total picture of nutrient sources and the nutrient delivery system. The Ohio DAP 2020 includes a review of some available edge-of-field results in section A2.5.1 Agricultural Lands. This task is continuing.
	ODA will monitor the progress of OSU and other state and federal agencies to complete potential revisions to the Tri-State Fertility Guide and the Phosphorus Risk Index	The research for the Ohio Phosphorus Risk Index is complete. The online tool is under development: https://nutrientmanagement.osu.edu/field-ohio-tool The updated Tri-State Fertility Guide is available at https://agcrops.osu.edu/FertilityResources/tri-state_info And as an interactive spreadsheet at: https://agcrops.osu.edu/file/osufertilitycalculatorver2021xls
	ODHE Harmful Algal Bloom Research Initiative (HABRI) for applied research at Ohio universities.	This program continues to be funded by the Ohio Legislature. An RFP is available currently with a preproposal due date of March 31, 2022. Project funding will begin on 1 August 2022 and will end on 31 December 2024.
	OLEC, in cooperation with Heidelberg National Center for Water Quality Research and USGS, will continue to develop and implement a program to track and verify water quality improvements resulting from nutrient reduction practices and BMPs at the HUC 12 level	As a part of the H2Ohio initiative, the existing SWAT model for the Maumee River will be adapted to represent the practices available under H2Ohio and various scenarios will be modeled to refine predictions of the effectiveness of the H2Ohio

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		program in meeting water quality goals. This effort uses the NCWQR and USGS data for model calibration.
	Other Actions	
	Maumee Watershed Nutrient TMDL	This activity is now underway. See: https://epa.ohio.gov/divisions-and-offices/surface-water/reports-data/maumee-river-watershed
	Ohio EPA will establish a contractual arrangement with Battelle to evaluate process and product effectiveness for addressing nutrient and/or microcystin management, treatment and control with a focus on drinking and wastewater treatment systems, products and processes.	The contract with Battelle was implemented in 2017-2018 and has ended. Follow-up on this task has been through the Technology Assessment Program within H2Ohio. The final report of the TAP is being developed. See H2Ohio Annual Reports for more information.
	Ohio EPA in coordination with ODA will evaluate the nutrient and manure management plans and the Biosolid Land Application and Management Plans (LAMPS) to evaluate the need for more consistency.	Ohio EPA biosolids rules were revised as of 12-1-2018 with coordination between ODA and Ohio EPA.
	OLEC will take the lead to ensure there is annual coordination between state and federal agencies for identifying priority programs, priority areas and timelines related to Lake Erie and the Lake Erie Basin. Each OLEC members' state agency will coordinate with OLEC staff.	OLEC will continue planning and implementation oversight including coordination between the agencies and the governor's office as needed. As part of this effort, the OLEC Executive Director is leading the coordination of the H2Ohio program.
	OLEC will seek cooperation, request coordination, and may review funding requests made to federal or state agencies from state agencies, government subdivisions, and organizations for funding related to Lake Erie or Lake Erie Basin projects.	This work is continuing as needed. In particular, we are coordinating closely with USEPA on GLRI Focus Area 3 (nonpoint source pollution) priorities and projects.
	Completed or Retired Actions from the Collaborative Framework and Ohio DAP 2018	
	Ohio EPA will implement the requirement of SB1 that all facilities discharging more than 1 MGD will include monitoring of both total phosphorus and ortho-phosphorus by Dec. 1, 2016.	This task is complete.
	Ohio EPA and ODA will cooperate in the development and anticipated implementation of a pilot Lake Erie Basin nutrient trading and stewardship credit program being developed by the Great Lakes Commission.	The development of this program is now complete. See https://www.glc.org/work/enviromarkets.

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	Ohio EPA will track the installation of point source nutrient reduction BMPs installed since 2008.	Superseded by H2Ohio modeling effort which will estimate this based on remote sensing.
	Tracking will include all NPDES permits with discharge limits, those required to complete a technical and feasibility study (SB1), CSO outfalls, identified failed home sewage system locations and state or federal funded stormwater management practices.	Included in Ohio EPA Nutrient Mass Balance work.
	OLEC will work with the Ohio Public Works Commission and local Green Space Conservation Program's Natural Resource Assistance Councils (Clean Ohio) in the WLEB to evaluate the use of Clean Ohio funds toward projects that also result in nutrient reduction practices. Grant applications should reflect the preference toward this goal. Priority points should be awarded to those projects that include water quality improvements components.	This task is not part of the current Ohio DAP 2020.
	OLEC will establish the DAP Advisory Committee involving similar stakeholders as those involved in the Phosphorus Task Force initiatives. This Committee would provide input to the Commission on the progress of implementation toward achieving the stated nutrient reduction goals. Representatives from Michigan, Indiana and Ontario would be invited to participate periodically to evaluate the overall progress toward DAP goals, targets, project implementation and monitoring data.	Superseded by public involvement discussion in Ohio DAP 2020. Ohio will not be establishing a formal DAP Advisory Committee at this time although OLEC has been facilitating meetings with stakeholders on request.
	OLEC will coordinate with the member agencies and federal partners on the establishment of a WLEB fiscal operations plan. This plan will serve as guide for identifying short-term and long-term funding needs and potential funding sources including the re-allocation as well as new local, state and federal funding opportunities for the WLEB. Priority should be given to a consistent and possibly a dedicated funding source for water quality monitoring.	Superseded by the H2Ohio program at the state level. OLEC continues to coordinate funding priorities for Ohio DAP 2020 implementation with the federal agencies.
	Ohio EPA, in conjunction with ODA and ODH, will coordinate in the development of a nutrient reduction BMP Implementation, Verification and Evaluation process in watersheds to be administered by the appropriate agency. This would involve developing a record of federal or state cost-shared nonpoint BMPs being implemented, their location, documenting the proper installation and life-cycle monitoring to ensure functionality at the county and HUC 12 level.	This task from the Collaborative has been superseded by H2Ohio tracking.
	ODA will work with NRCS to establish a Western Lake Erie Basin Technical Advisory committee as a sub-committee to the State Technical Committee to provide technical assistance specific to nutrient management issues and agricultural practices in the basin	Superseded by H2Ohio and the HB 7 watershed coordinators program.

Document and Link	Recommendations/Actions	Progress/Milestones
	Ohio EPA, in cooperation with OLEC and ODA, will institute a tracking program by county within the western Lake Erie basin with a focus on priority watersheds showing the total public dollars allocated for point source and when possible nonpoint source nutrient management/reduction practices	This task from the Collaborative was superseded by the H2Ohio program. The H2Ohio Annual Reports have the data for the expenditures from that program.
	OLEC, in conjunction with the Department of Taxation, will evaluate the establishment of a pilot State-wide Conservation Land Tax which would serve as an incentive to landowners to place land which would also provide water quality benefits into long-term conservation programs	This task is not part of the current Ohio DAP 2020.
	OLEC with its member agencies will coordinate the development of an Adaptive Management Process "trigger mechanism" which would cause a change of program, practice or policy if the Milestones are not reached or do not indicate measurable progress toward achieving the goals	The Ohio DAP is subject to change following the adaptive management philosophy. The primary indicator of progress will be water quality monitoring and associated load calculations at the key downstream station on each of the Annex 4 priority watersheds in Ohio.
	OLEC, Ohio EPA, ODA and ODNR will meet with the Maumee Conservancy District to evaluate their role related to the design, construction, funding and management of stormwater management including water retention/detention options	Information has been exchanged, but this task is not part of the current Ohio DAP 2020.
	ODA will develop a Farm Stewardship Certification for farmers who protect farmland and natural resources by voluntarily implementing best management practices (BMPs) on their farms	A certification program for farmers in northwestern Ohio is up and running at ODA. H.B. 7 confirms that the legislature intends to collaborate with organizations representing agriculture, conservation, and the environment and institutions of higher education engaged in water quality research to establish a certification program for farmers who utilize practices designed to minimize impacts on water quality. H.B. 7 requires the Director of Agriculture to undertake all necessary actions to ensure that assistance and funding are provided to farmers who participate in the certification program
	ODA will identify existing programs and consider development of new programs to install practices that reduce or eliminate water quality impacts from agricultural drainage	Drainage water management is considered a water management priority practice for state H2Ohio funding as are saturated buffers (as part of the edge-of-field buffer practice).

Document and Link	Recommendations/Actions	Progress/Milestones
	ODA will work with NRCS to encourage the establishment of stream-line processes, sign-up periods, and application requirements for various federal and state funding and technical assistance programs	The NRCS 590 standard was recently revised and updated with participation in the process by ODA among other stakeholders.
	ODA will work with NRCS and encourage an assessment of the scoring criteria for Farm Bill program eligibility to ensure that those farmers in most need of technical and financial assistance are receiving higher consideration for assistance	Discussions were held after the Collaborative Framework. This task is not part of the Ohio DAP 2020.
	ODA will continue the Ohio Clean Lake Initiative - Impaired Watershed Restoration Program through the Ohio Department of Agriculture Division of Soil and Water Conservation	The focus currently is on running H2Ohio rather than updating this program to include the Western Basin of Lake Erie. The program remains in effect for the Grand Lake St. Mary's watershed.
	ODNR through the Division of Wildlife will evaluate opportunities through their Private Lands program and joint state-federal programs to develop projects within subwatersheds with a focus on the identified priority watersheds in the basin that provide a combination of long-term wildlife habitat along with water quality benefits such as riparian buffers and wetlands	The following two projects are examples of a wider array of wetland restoration projects under development through various partnerships between the ODNR Division of Wildlife Private Lands program, nongovernmental organizations, and state and federal partners: Carstensen/Herman Wetlands/Lake Erie CREP/GLFWRA and Smith Wetlands/Lake Erie CREP/GLFWRA

Document and Link	Recommendations/Actions
Great Lakes Commission **A Joint Action Plan for Lake Erie: A Report of the Great Lakes Commission Lake Erie Nutrient Targets Working Group (2015)** This joint Action Plan will be used to help drive additional actions including the 2018 DAPs.	**Overarching**
	1. Reduce phosphorus loads into western and central Lake Erie by 40% (from 2008 levels) by 2025
	2. Interim phosphorus reduction target of 20% by 2020
	3. Use an adaptive management approach – targets and timelines will be revised based on regular monitoring, new information, discussions/knowledge of the system
	Federal
	4. US and Canadian DAPs will apportion load allocations by country and identify priority management actions that will meet these targets
	5. US and Canada are required to report on progress toward meeting the targets every three years
	Local/State/Provincial
	6. Reduce nutrient applications on frozen or snow-covered ground: managing or restricting manure, fertilizer and biosolids applications on frozen or snow-covered ground, on saturated soil, or when the weather forecast calls for a severe rain event.
	7. Agricultural producers are encouraged to develop and follow plans that include BMPs that will help prevent excess manure and fertilizer nutrient loss and properly manage nutrients. BMPs should include using crop-specific agronomic rates for nutrient applications and soil testing to ensure proper implementation.
	8. Adopt 4Rs Nutrient Stewardship Certification program or other comprehensive nutrient management programs: voluntary retailer certification program for those who assist producers with implementing BMPs that optimize fertilizer use including right fertilizer, right rate, right time, right place.

Document and Link	Recommendations/Actions
	9. Reduce total phosphorus from seven key municipal discharges in the western and central Lake Erie basins by phasing in growing season (April-September) average effluent limits of 0.6 mg total phosphorus per liter by 2020 (or during the next permit renewal).
	10. Conduct optimization and upgrade studies to evaluate costs and compliance options for reducing point source discharge of nutrients.
	11. Encourage and accelerate investments in green infrastructure for urban stormwater and agricultural runoff, including ecological buffers for rivers, streams, and wetlands.
	12. Work with federal partners to develop plans to reduce the open-water disposal of dredged material and to advance beneficial re-use of dredge material as an alternative.
	13. Pilot innovative performance-based and/or market-based nutrient reduction projects.
	14. Phase out residential phosphorus fertilizer application within five years.
	15. Target conservation at the watershed scale.
	16. Within five years, validate or refine the reduction targets and timelines using an adaptive management approach.
	17. Collaborate toward an integrated monitoring, modeling, tracking, and reporting network for the Lake Erie basin by 2020.

Document and Link	Recommendations/Actions
Pennsylvania Department of Environmental Protection **Pennsylvania Lake Erie Phosphorus Reduction Domestic Action Plan – Final (2017)**	**See "Tactics" on page 14 – these include the multiple regulatory programs that have been required (MS4s, industry, AG, construction)**
	TRACKING MECHANISMS
	1. PADEP will be responsible for compiling and evaluating NPDES discharge monitoring reports for facilities in the Pennsylvania Central Basin tributaries for average monthly phosphorus discharge concentrations and total discharge volumes.
	2. PADEP will work with all existing nonpoint source pollution reduction PADEP grant recipients within the Pennsylvania Lake Erie Central Basin to assure that nutrient reductions from constructed best management practices are quantified and reported during the remainder of the period of performance of the grant agreements.
	3. PADEP will assure that all new nonpoint source pollution reduction PADEP grant recipients within the Pennsylvania Lake Erie Central Basin will be required to report nutrient reductions from all constructed best management practices on an annual basis during the period of performance of the grant agreements.
	4. PADEP intends to participate in ErieStat, a web-based information system being developed by the Great Lakes Commission to provide a common reporting platform for states and provinces to consistently track progress toward Lake Erie phosphorus reduction goals. ErieStat will determine standardized measurements to track progress toward the adopted reduction targets, while also considering the effects of strategies and investments intended to reduce phosphorus loading. The website is being developed with an initial focus on the western Lake Erie basin, with the intent to include central and eastern basins as consistent with the Annex 4 process.
	Phosphorus Contribution and Reduction Reporting
	5. PADEP will produce a report quantifying known phosphorus contributions and reductions on a frequency to be mutually determined between PADEP and U.S. EPA.
	6. PADEP will participate in the submission of phosphorus contribution and reduction data to U.S. EPA or a designated third-party entity on a frequency to be mutually determined for tracking and accounting for total lake-wide phosphorus reductions.

Environmental and Climate Change Canada; Ontario Ministry of the Environment and Climate Change Canada-Ontario Lake Erie Action Plan: Partnering on Achieving Phosphorus Loading Reductions to Lake Erie from Canadian Sources (2018)	
Goals & Objectives; Recommendations & Actions	
Goal: Reduce phosphorus loadings:	
Objective: Support watershed and nearshore-based strategies and community-based planning for reducing phosphorus loadings	1. Canada and Ontario will continue to collaborate with landowners, municipalities, conservation authorities, Indigenous communities, and others on a coordinated approach to watershed planning for reducing phosphorus loadings.
	2. Canada and Ontario will continue to work with conservation authorities, municipalities and other partners to promote implementation of existing watershed plans focused on reducing phosphorus loadings in the Lake Erie basin and develop new ones as required.
	3. Canada, with Ontario's support, will continue to work with conservation authorities and other partners to identify phosphorus sources and develop phosphorus reduction management strategies and plans for selected tributaries/regions in the Lake Erie watershed, including the Sydenham River, Thames River, Kettle Creek, Catfish Creek and the Grand River.
	4. Canada and Ontario will continue working with Indigenous communities in the Lake Erie watershed to support efforts to identify phosphorus sources and develop appropriate phosphorus reduction strategies for these communities.
	5. Canada, with Ontario's support, is leading the implementation of the binational nearshore assessment and management framework for Lake Erie.
	6. Canada and Ontario will focus phosphorus reduction efforts within Lake Erie's eastern basin on the Grand River watershed.
	7. Canada and Ontario will explore the development of initiatives that support the implementation of local actions within high-risk areas for phosphorus loadings in the western and central basins of Lake Erie, including the Thames River watershed and Leamington tributaries.

Goals & Objectives; Recommendations & Actions	
	8. Canada and Ontario will continue to support the conservation and restoration of Ontario's wetlands through programs such as the Ontario Eastern Habitat Joint Venture, the Habitat Stewardship Program and the National Wetland Conservation Fund.
	9. Nature Conservancy of Canada will conduct a review of Lake Erie planning documents to guide its conservation efforts in the Lake Erie watershed.
Objective: Reduce phosphorus loadings from urban areas	10. Canada and Ontario will continue to promote eligible investments for the reduction of excess phosphorus from sources, such as municipal wastewater treatment systems or municipal stormwater effluent, under applicable infrastructure and other funding programs.
	11. Ontario will work with municipal partners to establish by 2020 a legal effluent discharge limit (in Environmental Compliance Approvals) of 0.5 milligrams per litre of total phosphorus for all municipal wastewater treatment plants (WWTPs) in the Lake Erie basin that have an average daily flow capacity of 3.78 million litres or more (see Action B1.8).
	12. Ontario will, where feasible, work with municipal partners toward reducing loadings through: a) upgrades, including incorporation of innovative technologies and other modifications, to secondary WWTPs that have an average daily flow capacity of 3.78 million litres or more in the Lake Erie basin, to approach the phosphorus effluent concentrations achievable through a tertiary level of treatment b) improvements to wastewater treatment and collection infrastructure to reduce combined sewer overflows and bypasses c) improvements to stormwater management systems (including facility rehabilitation and incorporation of green infrastructure and innovative treatment technologies)
	13. Ontario will continue to collaborate with municipal partners to promote and encourage optimization of wastewater treatment as a way for municipalities to improve treatment plant performance (including lower phosphorus discharges) and achieve operational efficiencies.
	14. Ontario will continue to support area-wide optimization programs for municipal WWTPs to reduce phosphorus loads, with Lake Erie as the priority geography for this effort.

Goals & Objectives; Recommendations & Actions	
	15. Ontario will work with developers, municipalities, conservation authorities and others to promote and support the use of green infrastructure and LID systems for stormwater management, including clarifying and enhancing policies as well as developing green standards. Ontario's draft stormwater LID guidance manual is aimed at helping proponents implement LID and green infrastructure and is expected to be available in 2018.
	16. The Municipality of Leamington, located in the priority area of the Leamington tributaries, will work with partners to explore opportunities to reduce phosphorus loadings through upgrades to their wastewater collection system to service commercial facilities (including greenhouse operations) and residential properties currently serviced by septic systems.
	17. The City of London will undertake a pilot project using new technologies as an alternative to conventional tertiary treatment with the objective of achieving effluent quality of 0.1 milligrams per liter. Upon successful completion of the pilot project, the City of London will then develop a plan to rollout phosphorus reduction technologies to their five major treatment plants.
	18. The City of London will accelerate plans to separate combined sewers, including the design and construction of necessary stormwater outlets, with the target of separating 80 percent (17 kilometers) of its combined sewer system by 2025.
	19. The City of London will circulate for agency and public review by the end of June 2018 an implementation plan that provides the scope and timing for managing the highest priority sanitary sewer overflows as identified in its pollution prevention and control plan. To support implementation, the City will facilitate a proof-of-concept, in-field pilot project of high-rate treatment technologies with the support of industry (Trojan Technologies) and academic (Western University) partners and will continue its private property weeping tile disconnection program.
	20. The City of London will incorporate LID and adaptive environmental management principles into the Ministry of the Environment and Climate Change's Dingman Creek subwatershed area-wide Environmental Compliance Approval pilot project. The City will also implement a program to maximize the treatment and infiltration of stormwater using LID technologies in built-out areas in coordination with its linear infrastructure renewal program.
	21. The City of London will expand its current monitoring program to prioritize the retrofitting of stormwater ponds and will develop a stormwater pond retrofit program to improve operational performance and legacy phosphorus removal. To support this program, the City will evaluate the need to develop a stormwater sediment handling facility to repurpose stormwater pond sediment and appropriately manage the legacy phosphorus contained within it.

Goals & Objectives; Recommendations & Actions	
Objective: Reduce phosphorus loadings from agricultural and rural areas	22. Canada and Ontario will continue to leverage existing funding initiatives (e.g., Species at Risk Farm Incentive Program) to support the implementation of agricultural BMPs and environmental investments in targeted regions of the Lake Erie basin.
	23. Canada will create an application-based funding program in 2018 that provides $4.1 million over four years in financial support for projects demonstrating effectiveness of BMPs and/or innovative approaches to reducing phosphorus loads to Lake Erie.
	24. Canada and Ontario will pursue, under the next federal-provincial Canadian Agricultural Partnership, initiatives that support a multi-BMP, whole-farm approach to achieve phosphorus runoff reduction from farmland in the western and central basins.
	25. Canada and Ontario will ensure public land is managed to minimize phosphorus losses
	26. Canada and Ontario will encourage dam owners to explore managing dams to reduce phosphorus outputs (without compromising aquatic invasive species management or hydroelectric power generation).
	27. Ontario will continue to work with greenhouse growers to encourage nutrient recycling and reduce phosphorus levels in discharges to watercourses that flow into Lake Erie and Lake St. Clair, with a priority on the Leamington area and Thames River. Actions include education and awareness, innovation, monitoring, cost-shared investments, and regulatory compliance and enforcement.
	28. Ontario will work with the Lake Erie community to carry out measures to restore native habitats (including wetlands and riparian habitat), focusing efforts in priority watersheds where phosphorus loadings are high and natural cover is low.
	29. Ontario will encourage stewardship activities on private lands that support phosphorus reduction in Lake Erie by providing incentives for landowners through programs such as the Conservation Land Tax Incentive Program and the 50 Million Tree Program.
	30. Ontario, with Canada's support, will work with the agriculture sector to harmonize and streamline planning tools (e.g., Environmental Farm Plans, Farmland Health Check-Up, nutrient management planning, soil management BMPs, evaluation and monitoring tools) to support an integrated, whole-farm approach to environmental sustainability.

Goals & Objectives; Recommendations & Actions	
	31. 4R Ontario8 will lead the implementation of a voluntary 4R Nutrient Stewardship program based on the internationally recognized 4R Nutrient Stewardship system. The program will promote the adoption of nutrient management in Ontario to help farmers reduce nutrient losses into the environment and improve productivity through efficient nutrient application.
	32. The Ontario Greenhouse Vegetable Growers will continue its work through the Ontario Greenhouse Environmental Strategy working group to support compliance efforts by providing educational material and templates to assist the greenhouse sector in adhering to regulatory requirements and to explore options for monitoring, research and remediation of priority sub-watersheds.
	33. The Ontario Cover Crops Steering Committee, led by Grain Farmers of Ontario, will implement the Ontario Cover Crops Strategy to encourage widespread adoption of cover crops on farms in Ontario.
	34. The Ontario Federation of Agriculture will work within the Thames River Phosphorus Reduction Collaborative partnership and with Grow Ontario Together — a coalition of vested commodity organizations — to promote a suite of effective land management and drainage solutions for agriculture to reduce phosphorus loss and improve water quality in the Thames River. The federation will continue to support other relevant initiatives such as the Ontario Cover Crops Strategy, the Timing Matters initiative and 4R Nutrient Stewardship.
	35. ALUS (Alternative Land Use Services) Elgin will use marginal, environmentally sensitive and inaccessible parcels of land to mitigate and reduce phosphorus loading into Lake Erie and the Thames River by prioritizing sites with active erosion occurring and that are situated along a watercourse or wetland.
	36. Conservation authorities, as the second-largest land-owner next to the Province, will manage their lands to minimize phosphorus losses.
	37. Conservation authorities will continue to provide on-farm technical assistance and administer and deliver financial assistance programs for landowners to implement soil erosion control and best management practices related to the reduction of soil and nutrient loss.

Goals & Objectives; Recommendations & Actions	
	38. Ducks Unlimited Canada, in partnership with the Ministry of Natural Resources and Forestry, will implement a wetland restoration initiative in the Lake Erie basin to support conservation efforts with landowners and local organizations that help reduce phosphorus loads entering Lake Erie.
	39. Nature Conservancy of Canada will continue to strategically conserve and restore lands in the Essex Forests and Wetlands, Southern Norfolk Sand Plain and Western Lake Erie Island natural areas that will contribute to reducing non-point sources of phosphorus.
	40. Nature Conservancy of Canada will participate with and support partners to undertake initiatives that are actively seeking solutions to Lake Erie's water problems.
	41. Nature Conservancy of Canada will continue to work with partners to conserve and restore significant Lake Erie coastal wetlands to improve ecosystem health and resiliency.
Goal: Ensure effective policies, programs, and legislation:	
Objective: Support and strengthen policies, programs, and legislation	42. Canada and Ontario will, in collaboration with the United States, reassess in 2020 the viability of setting science-based numeric targets for the eastern basin.
	43. Canada will continue to work on revisions to the *Feeds Regulations* that would remove minimum nutrient levels for livestock feeds (including phosphorus). These revisions are anticipated to be enacted in 2018 and will enable the industry to be more flexible and decrease levels of phosphorus in feeds where it makes sense to do so. The revised regulations will likely result in a corresponding reduction in phosphorus content of manure.
	44. Ontario will engage with key sectors as it considers further restrictions on the application of nutrients during the non-growing season with a focus on conditions when there is higher risk of nutrient loss, such as when the ground is frozen or snow covered.

Goals & Objectives; Recommendations & Actions	
	45. *Ontario's General Regulation under the Nutrient Management Act* requires farms to have an approved nutrient management strategy when they submit applications for building permits for any buildings or structures that are used to house farm animals or to store manure on the land of the farm. Between January 1, 2005 and January 1, 2018 approximately 5000 nutrient management strategies were approved where an application for a building permit was made.
	46. Ontario will, in 2018, release and begin the implementation of a long-term *Agricultural Soil Health and Conservation Strategy*, developed in collaboration with stakeholders, to support agricultural soil management practices that provide economic, environmental and social benefits to Ontario.
	47. Ontario will, in 2018, begin a review of the Province's approach to rural stormwater and agricultural drainage management using an integrated watershed approach. This will include an examination of the interactions between runoff from rural lands and roads, outlet drainage from agricultural lands, and municipal drains with the objective of identifying opportunities to improve the sustainable management of water.
	48. Ontario will, as part of the hauled sewage policy and program review, develop and post for public comment a draft policy framework for managing hauled sewage in the province.
	49. Ontario will work with partners to update provincial policies for Lake Erie by 2019 to provide the basis for establishing a legal effluent discharge limit (in Environmental Compliance Approvals) of 0.5 milligrams per litre of total phosphorus for all municipal WWTPs in the Lake Erie basin that have an average daily flow capacity of 3.78 million litres or more.
	50. Ontario will update existing wastewater policies (i.e., F-series guidelines and procedures) and develop stormwater management policies and supporting guidance (e.g., LID and green infrastructure) by 2021 to enhance environmental protection, including reduction of nutrient loadings.
	51. Ontario will provide updated guidance related to stormwater management and planning, to support the implementation of policies in the *Provincial Policy Statement* (2014).

Goals & Objectives; Recommendations & Actions	
	52. Ontario will, through the implementation of a *Wetland Conservation Strategy* for Ontario, improve wetland conservation to achieve a net gain in wetland area and function to sustain biodiversity and to provide ecosystem services, including improved water quality.
	53. Ontario will, where feasible, streamline processes for environmental assessment and approvals related to wastewater and stormwater projects with a phosphorus reduction component within the Lake Erie basin.
Objective: Strengthen decision-making tools	54. Ontario will, with Canada's support, make publicly available in 2018 a digital elevation model of the Lake Erie watershed (based on LiDAR technology) to assist all members of the Lake Erie community in making evidence-based decisions (e.g., flood mapping, areas of soil erosion risk identification, precision agriculture) to ensure healthy lands and waters.
	55. Ontario will work with municipalities to encourage the use (e.g., LID guidance) and development (e.g., bylaws) of decision-making tools that help reduce phosphorus through management of urban stormwater at the source.
	56. Conservation authorities will continue to support analysis and reporting of information and data for decision making, including optimizing rural BMPs to improve water quality and using advanced GIS technologies and approaches to target locations for improved soil and nutrient management.
Goal: Improve the knowledge base:	
Objective: Conduct monitoring and modeling	57. Canada, with support from Ontario and conservation authorities, will use monitoring and modeling to provide annual assessments of phosphorus loads entering Lake Erie from Canadian sources.
	58. Conservation authorities will continue to work with other stakeholders and Canada and Ontario at the watershed, subwatershed and catchment levels to conduct research, monitoring and modeling activities on an annual basis to improve scientific efforts toward phosphorus reduction.
	59. Canada, starting in 2016 and in collaboration with partners, will develop a decision-making tool to improve and standardize the calculation of phosphorus loads to Lake Erie and the other Great Lakes to inform decision making.
	60. Canada, Ontario and conservation authorities began in 2017 to implement a nested watershed monitoring approach in the Thames River to model and track nutrient dynamics and changes over time.

Goals & Objectives; Recommendations & Actions	
	61. Canada will monitor and assess the temporal trends and spatial distributions of nutrient concentrations in the offshore waters of Lake Erie and Lake St. Clair.
	62. Canada will monitor and assess the temporal trends and spatial distributions of nutrient concentrations and nuisance algae (*Cladophora*) biomass in the nearshore areas of Lake Erie's eastern basin.
	63. Canada will develop and apply remote sensing tools to detect and forecast harmful algal blooms in Lake Erie.
	64. Canada will collect and co-ordinate hydraulic and hydrologic data, including maintaining Canada's role on the Canada–U.S. Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data, to ensure accurate flow information is available to calculate seasonal and annual phosphorus loads.
	65. Conservation authorities will collect, maintain, compile and share hydraulic and hydrologic data in partnership with Canada and Ontario, for example, through the Water Survey of Canada Hydrometric Monitoring Network Agreement.
	66. Ontario, with support from Conservation Ontario and conservation authorities, will continue long-term monitoring programs in the watershed including the Provincial Water Quality Monitoring Network and the Provincial Groundwater Monitoring Network.
	67. Ontario will continue to implement the long-term Great Lakes water intake and nearshore monitoring programs.
	68. Canada and Ontario will deploy real-time monitoring systems in Lake Erie to monitor temperature, dissolved oxygen and algal pigments to enable tracking of hypoxia and lake stratification.
	69. Canada will continue to produce an annual national field-scale crop inventory map using remotely-sensed imagery.
	70. Canada, with support from its partners, will continue to develop, improve and apply Soil and Water Assessment Tool models for the Grand and Thames rivers to identify and provide advice to partners on strategies for optimizing BMPs.
	71. Canada, with support from Ontario and other partners, will continue to improve models and tools at two scales for risk of phosphorus loss: the soil-landscape scale (Indicator of Risk of Water Contamination by Phosphorus [IROWC-P]) and the field scale (P-Index).

Goals & Objectives; Recommendations & Actions	
	72. Nature Conservancy of Canada will investigate opportunities to measure and model the water quality and quantity benefits of its land acquisition and restoration work.
	73. The City of London will coordinate its water quality monitoring with the Upper Thames River Conservation Authority to aid river improvement efforts and studies.
Objective: Conduct research to better understand nutrient dynamics in the Lake Erie basin	74. Ontario will continue a multi-watershed nutrient study to assess the interaction between agricultural land use and nutrient loadings in streams in the Great Lakes basin.
	75. Ontario will support and conduct research on the use of sensor-based technology for monitoring phosphorus and associated parameters.
	76. Canada and Ontario will conduct research to improve the understanding of factors contributing to toxic and nuisance algae growth and their impacts on water quality and ecosystem health.
	77. Ontario, with support from Canada, will undertake a monitoring and research project to better understand the sources and types of phosphorus that are contributing to nearshore algal blooms in Lake St. Clair.
	78. Canada, with Ontario's support, will lead research and monitoring to improve understanding of invasive mussels and their influence on phosphorus dynamics and *Cladophora* growth in the eastern basin of Lake Erie.
	79. Ontario will work with the Lake Erie community to conserve and manage aquatic habitat and the fish community to maintain fish population health and resiliency.
	80. Ontario will lead research on the bioaccumulation of the algal toxin microcystin in fish tissue to better understand its impact on human health.
	81. Canada will investigate how land use changes in small Lake Erie tributaries are affecting instream water quality conditions, including the role of episodic wastewater releases and factors that have an impact on the effectiveness of agricultural BMPs.
	82. Canada, in collaboration with partners, will investigate how nutrients other than phosphorus, particularly nitrogen, may contribute to harmful algal bloom development and toxicity.

Goals & Objectives; Recommendations & Actions	
	83. Canada, in collaboration with partners, will investigate the potential role that internal loading and nutrient exchanges may have on the recovery of Lake Erie as external loads are reduced.
	84. Canada will develop and apply next-generation physical limnology and ecological models, including integrated watershed-lake models, for Lake Erie and Lake St. Clair to improve understanding of the causal factors affecting the development of algal blooms and hypoxia, and how phosphorus reductions from tributaries will affect those factors.
	85. Canada will improve and apply the *Cladophora* growth model to determine the relationship between *Cladophora* growth and phosphorus loadings.
Objective: Conduct research to better understand and predict the impact of climate change on the Lake Erie ecosystem	86. Canada, starting in 2017 and with support from conservation authorities, will run watershed simulation models under different climate change scenarios to understand how phosphorus loss from the land may change.
	87. Canada will deploy long-term climate buoys in the Great Lakes to determine the influence of climate change on the Great Lakes, including nutrient loading and in-lake conditions. Data sets will be made publicly available.
	88. Canada, starting in 2017, will investigate the exchange of nutrients between groundwater and surface water in the Thames River watershed to better understand the relationship between seasonal and year-to-year nutrient fluxes, land use and climate variations.
	89. Ontario will take climate change into account in all of its research and monitoring efforts relating to Lake Erie. Ontario will also encourage municipalities to apply to the *Municipal GHG Challenge Fund* to support eligible projects that make significant contributions to reducing greenhouse gas (GHG) emissions and phosphorus loads.
	90. Ontario will develop and implement initiatives that encourage soil health management practices that reduce net greenhouse gas emissions and reduce agricultural soil erosion.
	91. Ontario will continue to leverage government research programs and initiatives (e.g., *New Directions*; Ontario Ministry of Agriculture, Food and Rural Affairs–University of Guelph partnership) to fund needed research and new technologies to test and improve agricultural BMPs for phosphorus reduction.

Goals & Objectives; Recommendations & Actions	
Objective: Conduct research to improve existing practices and develop new innovative practices and technologies to reduce phosphorus loadings	92. Canada and Ontario, in partnership with others, will continue to research the effectiveness of BMPs in reducing phosphorus losses from agricultural land during typical and extreme weather events.
	93. Canada will continue to identify the capacity and progress of different agricultural production systems in implementing activities that reduce the risk of nutrient loss.
	94. Canada will continue to develop and assess methods for evaluating sustainable phosphorus levels in soils.
	95. Canada and Ontario, in partnership with others, will continue to conduct research to improve modeling capability to quantify phosphorus reductions from BMPs at a landscape scale.
	96. Canada and Ontario, in partnership with others, will investigate current (baseline) and future adoption of BMPs within the Lake Erie basin and selected subwatersheds to inform monitoring efforts and action plan progress.
	97. Ontario will investigate the social, economic and environmental determinants affecting BMP adoption.
	98. Ontario will support studies that improve understanding of the correlation between phosphorus load reduction and high uptake of LID/green infrastructure.
	99. Canada and Ontario will work with partners to measure the effectiveness of wetlands and other natural heritage features in reducing phosphorus through overland flow into watercourses.
	100. Canada and Ontario will evaluate the feasibility of using economic instruments to achieve phosphorus reductions.
	101. Canada and Ontario will work with partners to explore opportunities to adopt innovative technologies that encourage phosphorus recovery and reuse.
	102. Conservation authorities will continue to leverage their expertise and initiatives at the watershed, subwatershed and local levels to research, innovate and evaluate technologies for improved agricultural BMPs, LIDs and natural green infrastructure. This is in addition to research that aims to understand the social, economic and environmental determinants affecting BMP adoption.
Goal: Educate and build awareness:	

Goals & Objectives; Recommendations & Actions	
Objective: Enhance communication and outreach to build awareness, improve understanding and influence change	103. Canada and Ontario will develop a digital marketing campaign that includes social media to build awareness of the need for actions to reduce phosphorus in the Lake Erie basin.
	104. Canada and Ontario, in partnership with others, will support the development and implementation of tools, techniques and programming to enhance communication, education and awareness of the phosphorus issue in the Lake Erie watershed, and the practices available for effective management.
	105. Ontario will continue to work with partners to connect teachers, students and school boards with opportunities to use Lake Erie and its watersheds as a context for teaching and learning.
	106. Ontario will work with the agriculture sector and partners to communicate best practices through educational materials, events, technology demonstrations, peer-to-peer learning opportunities and demonstration farms that foster the adoption of BMPs (such as responsible nutrient management including soil testing, crop rotation, erosion control structures, and natural and built green infrastructure) and lead to a reduction of phosphorus loss to the environment.
	107. Ontario, in partnership with the agriculture industry, will continue to develop and deliver information and tools to increase cover crop use in the non-growing season to improve soil health and reduce field runoff.
	108. Ontario's livestock and poultry sector will lead the establishment of a peer-to-peer advisory committee to provide education and awareness to producers about the risks of nutrient application on frozen or snow-covered ground, with the goal being to effect behavioral change and reduce risk of nutrient loss to the environment.
	109. Ontario will, by 2018, deliver enhanced drainage and erosion control education and training to increase awareness of causes of nutrient loading in runoff and how to manage drainage to reduce phosphorus loads.
	110. Land Improvement Contractors of Ontario will continue to focus on proper drain installation to minimize phosphorus movement to the watercourse through its annual convention, newsletter articles and continuous training of those involved in drain installation to ensure phosphorus movement impacts remain a high priority.
	111. Conservation authorities will continue to communicate best practices and engage Lake Erie residents through the delivery of school-based programs, conferences, workshops and tours, development of media posts and publications, and face-to-face interactions.

Goals & Objectives; Recommendations & Actions	
	112. Ontario, through the *Premier's Award for Agri-Food Innovation Excellence*, will continue to encourage the recognition of excellence, innovation and leadership in demonstrating environmental action at the farm level in the Lake Erie basin.
	113. Ontario will facilitate an event, in 2018, that showcases the adoption of leading municipal approaches to integrated stormwater management.
Objective: Share data and information	114. Canada and Ontario, along with their partners, will make relevant long-term data and information on Lake Erie public as it becomes available.
	115. Ontario will report on Lake Erie every three years under the *Great Lakes Protection Act, 2015* and work with its partners to provide an annual update through its website.
	116. Ontario will encourage partners to make relevant information on Lake Erie accessible through various online platforms.
	117. Conservation Ontario will continue to undertake a partnership with the Great Lakes Observing System to help enable conservation authorities to make their data discoverable and accessible.
	118. Conservation authorities will continue to develop, maintain and share data management systems and services for use in various aspects of hydrologic, water budget and water quality analyses, groundwater monitoring, and climate change and other watershed studies.
Goal: Strengthen leadership and co-ordination:	
Objective: Improve communication and co-ordination	119. Canada and Ontario will continue to engage Indigenous communities to facilitate their participation and input in the development and implementation of this action plan. This will include consideration of traditional ecological knowledge from First Nations and Métis if offered. Youth engagement will be encouraged in particular.
	120. Canada and Ontario will continue to engage youth to seek their participation and input on the implementation of the action plan.
	121. Canada and Ontario will update the Great Lakes community on the progress of implementing the action plan through webinars, forums, meetings and other opportunities.

Goals & Objectives; Recommendations & Actions	
	122. Canada and Ontario will work with partners to co-ordinate research, monitoring and modeling activities to improve scientific efforts towards phosphorus reduction.
	123. Canada, with Ontario's support, will co-ordinate with the United States the implementation of nutrient-related commitments under the GLWQA.
	124. Conservation authorities will continue to provide local watershed-level leadership in partnership with Canada, Ontario, municipalities and all stakeholders to address the phosphorus challenge in Lake Erie.
Objective: Establish an adaptive management framework and governance structure for implementation	125. Canada and Ontario will build on existing governance structures to ensure partner participation in the implementation of the action plan. Parties identified in the plan will work together to develop a workplan by February 2019 that establishes timelines for actions and expected phosphorus reductions (as applicable), identifies lead agencies and determines the investment required.
	126. Canada and Ontario will assess and report on progress toward achieving phosphorus reduction targets and actions in 2023 and every five years thereafter.
	127. Canada and Ontario will establish metrics to support a suite of performance measures to track the impacts of actions over time, including changes to phosphorus loadings. Actions will be adjusted as necessary based on an adaptive management framework.
	128. Canada and Ontario will work with U.S. federal and state agencies and other partners (e.g., through the GLWQA "Nutrients Annex" and the Great Lakes Commission's *Blue Accounting ErieStat* pilot project) to develop a binational information platform to track progress toward meeting the phosphorus reduction targets.

P128 - New York State is not required to develop a Domestic Action Plan for phosphorus at this point, however, nutrient monitoring is underway. They go on to say that the 2018 Lake Erie LAMP Annual Report includes updates on cleaning AOCs that include the Buffalo River AOC and Niagara River AOC.

	Recommendations/Actions
Erie County Department of Environment and Planning; LEWPA; NY Department of State; Buffalo Niagara Waterkeeper **Regional Niagara River Lake Erie Watershed Management Plan – Phase 2 (2019)**	1. Municipalities should consider creating an additional layer of regulation at the local level to ensure septic systems are operating properly, such as requiring regular inspections or additional requirements for old systems.
	2. Municipalities should protect existing riparian buffers from vegetative clearing and development and re-establish riparian buffers where they have been lost.
	3. Model ordinances for riparian and shoreline protection
	4. Environmental overlay districts are one of the best ways to protect wetlands and riparian buffers at the local level. However, municipalities can also add provisions to their zoning setback requirements, subdivision regulations, sediment and erosion control laws, and site plan review process to protect these areas.
	5. WNY Stormwater Coalition is a group comprised of 40 MS4 municipalities in Erie and Niagara Counties that share resources and work together to ensure compliance with SPDES Phase II stormwater requirements.
	6. Improving system construction, operation, and maintenance can be done by ensuring that highway/public works departments are trained in and use BMPs, such as promptly seeding newly cleaned ditches. The key is ensuring consistent use of BMPs. The Highway Superintendent Road and Water Quality Handbook is a good information resource for departmental operations, as is the Stormwater Management Gap Analysis Workbook for Local Officials. Municipalities should appropriate adequate resources for staff training on BMPs, as well as staff time towards consistent and effective enforcement.
	7. To assist with the financial costs associated with stormwater infrastructure, municipalities can create special drainage taxing districts. Drainage districts can provide stable funding sources for the improvement, construction, operation, and maintenance of drainage structures, retention ponds, ditches and culverts. Drainage infrastructure often requires regular specialized maintenance.

	Recommendations/Actions
	8. Municipalities should limit the impact of development activities through effective erosion and sediment control laws and proper enforcement of Stormwater Pollution Prevention Plans (SWPPPs) during and following construction activities.
	9. Local zoning regulations addressing boating facilities or water-dependent uses should have specific provisions to address siting issues, and appropriately manage pollution from vessel waste and maintenance practices. Two model ordinances regarding marinas and docks are provided in Appendix Q.
	10. ???
	11. Non-MS4 communities should also consider integrating the Phase II Stormwater requirements into their stormwater management laws in order to more comprehensively address stormwater issues. Model stormwater management laws are also available from the NYSDEC.
	12. Municipalities should also consider limiting development in areas prone to erosion, such as steep slopes (with grades higher than 15%) and highly erodible soils. These areas can be protected via special provisions in ordinances for subdivision, site plan review, or a special overlay.
	13. Local awareness and encouragement of agricultural Best Management Practices is also helpful to address water quality issues stemming from smaller farming operations. Municipalities should encourage farmers to access the multitude of resources and voluntary programs offered by the Natural Resources Conservation Service, County Soil and Water Conservation Districts, and Cornell Small Farms Program aimed at reducing the environmental impacts of agriculture.
	14. Landowners can take simple measures to reduce erosion of their property and sedimentation runoff, such as maintaining riparian buffers along waterways, and using water bars (or similar strategies such as rubber razors or open-top culverts) on steep driveways with concentrated flows to divert water to stable vegetated areas.

In addition to the recommendations noted above, the Watershed Management Plan included specific suggested actions for 18 localities within the watershed. In summary, recommendations included:

1. Develop zoning provisions that maintain and restore vegetative buffers in riparian areas, including shorelines, wetlands, floodplains, and special habitats, with preferences for native vegetation.
2. Incorporate principles of Low Impact Design into zoning regulations and train municipal boards and staff on conducting site plan review with a lens towards water quality.
3. Incorporate performance standards or stricter regulations into zoning and site plan review ordinances to encourage low-impact design, green infrastructure, and reduction of impervious cover in private development.
4. Encourage highway maintenance staff to participate in Cornell Local Roads training.
5. Adopt specific ordinances to codify BMPs for marina design and ongoing maintenance or remove marinas as a permitted development within city zoning ordinances.
6. Train local boards and officials on low-impact development and other green methods of development that protect water quality.
7. Document green initiatives and practices initiated by municipal staff into formal program documents and policies to retain this departmental knowledge and efforts as staff change-over occurs.
8. Develop outreach and educational materials for waterfront landowners that address better yard management practices, riparian buffer design, and how best to mitigate shoreline erosion.
9. Educate officials and the public about BMPs and wetland protection programs.
10. Develop public education materials about proper maintenance of onsite sanitary waste disposal and distribute with town mailings.
11. Strengthen zoning regulations that protect wetlands from development encroachment.
12. Train local staff and board members on reviewing developments from a water quality and habitat protection lens.
13. Conduct regular inventories of culverts and stormwater infrastructure to identify issues earlier when they may still be functional but still impact water quality and habitat.
14. Ensure proper maintenance and upkeep of private stormwater management systems by adopting codes that strengthen enforcement authority (i.e., establishing fines for violations).
15. Create zoning provisions that limit the creation of impervious surfaces and encourage the use of green stormwater infrastructure (i.e., lot coverage, porous materials).
16. Educate pet/animal owners on the impacts of letting pet waste (e.g., from dogs) and other animal wastes (such as cow and horse) enter water bodies or drinking water sources.

The Lake Erie 2019-2023 Lakewide Action & Management Plan, developed by Environment and Climate Change Canada and the U.S. Environmental Protection Agency, includes a number of objectives, several of which are nutrient-related including:

General Objectives

- Support healthy and productive wetlands and other habitats to sustain resilient populations of native species;
- Be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health or human use of the ecosystem; and
- Allow for swimming and other recreational use, unrestricted by environmental quality concerns.

This document includes "priority strategies and examples of categories of action [that] are a synthesis of what can be found in the Domestic Action Plans…" from Canada-Ontario, United States, Ohio, Michigan, Indiana, and Pennsylvania. Included within the document is information associated with:

- Federal and state environmental regulations and associated programs that address these objectives,
- Article 4 and the Nutrients Annex of the 2012 Agreement
- Lake Erie Partnership Actions that address nutrient and bacterial pollution

A synthesis of the Domestic Action Plans (DAPs) and priority strategies, including the following, and examples of categories of action are also included:

- Strategies to reduce phosphorus loadings from agricultural sources
- Strategies to reduce phosphorus loadings from municipal sources
- Watershed-based planning and restoration efforts
- Science, surveillance, and monitoring
- Outreach and education

Lake Erie 2019 Lakewide Action and Management Plan Annual Report

This document provides a brief synopsis of the activities associated with and the progress made under the Lake Erie Lakewide Action and Management Plan. Specifically, this includes the current status of Lake Erie nutrients and algal blooms based on monitoring data. It also summarizes accomplishments regarding actions to reduce nuisance and harmful algal blooms including:

- Lower Thames Valley Conservation Authority – McGregor and Jeannette's Creek Phosphorus Reduction program initiated in 2019 (will be available from 2019-2022)
- New York State – tributary monitoring program and Soil and Water Assessment Tool (SWAT) model – the USGS began the monitoring and modeling effort in late 2017 and is scheduled for completion in 2021
- (Ontario) Water Management Plans in place for the two largest Canadian sub-watersheds in the Lake Erie Basin

    - Thames River Shared Waters Approach to Water Quality and Quantity – 20-year plan including key actions to improve the Thames and reduce its impact on Lake St. Clair and Lake Erie
    - Grand River Water Management Plan – completed in 2014 and is being implemented
- 2019 Cooperative Science and Monitoring Initiative (https://www.epa.gov/great-lakes-monitoring/cooperative-science-and-monitoring-initiative-csmi)
- NYSDEC launched an online reporting tool for the public can submit observations of nuisance algae along the NY shorelines of Lake Erie, Lake Ontario, and the Niagara and Saint Lawrence Rivers. https://www.dec.ny.gov/lands/117838.html
- (Ontario) Partnership between Swim Drink Fish Canada, Niagara College, and the Niagara Coastal Community Collaborative – provides recreational water quality data collected by citizen scientists https://www.theswimguide.org/

Lake Ontario Lakewide Action and Management Plan (2018-2022)

This document, developed by member agencies of the Lake Ontario Partnership, addresses management actions necessary to reduce nutrient levels entering the Niagara River from Lake Erie. These actions are to be considered in the Lake Erie Lakewide Action and Management Plan, discussed above. While Lake Ontario's nutrient issues are distinctly different from Lake Erie's, which has large in-basin agricultural nutrient sources, more than half of Lake Ontario's total nutrient load are received from Lake Erie via the Niagara River. This document addresses nutrient and bacteria-related impacts on the lake. Three nutrient-related objectives were identified:

- Allow for swimming and other recreational use, unrestricted by environmental quality concerns;
- Support healthy and productive wetlands and other habitats to sustain resilient populations of native species; and
- Be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote the growth of algae and Cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem.

Several actions are identified to address these objectives (see table below).

Lake Ontario Partnership Actions (2018-2022)	Agencies Involved
Point Source and Non-point Source Pollution	
Wastewater and Stormwater Management System/Facilities: Compliance promotion and enforcement of regulations to control end-of pipe sources of pollution. Implement water quality improvement projects, including upgrades/optimization of wastewater and stormwater facilities and infrastructure. Implement best management practices for the treatment of urban stormwater runoff to the Great Lakes, using green infrastructure and low impact development where feasible.	USDA-NRCS, NYSDEC, MECP, Conservation Authorities
Nutrient and Bacteria Control: Build on existing integrated and systematic efforts within targeted watersheds to improve soil health and reduce the overland runoff of nutrients, sediments, and bacteria to the Lake or tributaries. Where needed and as resources allow, conduct relevant research, source identification/track down, and identify potential actions to address sources.	USDA-NRCS, NYSDEC, MECP, Conservation Authorities, USACE
Watershed: Implement site-specific projects within coastal wetlands, beaches, and shorelines that will reduce impacts to the lake from nutrient and bacteria inputs.	
Remedial Action Plans: Continue to implement remedial actions in the Bay of Quinte, Hamilton Harbour, Toronto and Region and St. Lawrence Areas of Concern to address excess nutrient and bacterial contamination.	ECCC, MECP, MNRF
Watershed Management Planning and Implementation: Renew and/or develop integrated watershed management plans and link to coastal and nearshore management and other nutrient reduction/management actions as required at a community level.	NYSDEC, MECP, Conservation Authorities
Science, Surveillance, and Monitoring	
Nutrients: Conduct research and monitoring to better understand nutrient dynamics in Lake Ontario and its watershed including spring and summer open water nutrient and lower food web surveys, and tributary monitoring. Monitor *Cladophora* growth in nearshore areas and loads of phosphorus to Lake Ontario from tributaries. Assessment of nearshore waters of Lake Ontario, Niagara and St. Lawrence Rivers under the Nearshore Framework.	ECCC, USEPA, USGS, TRCA, MECP, NOAA, NYSDEC

Lake Ontario Partnership Actions (2018-2022)	Agencies Involved
Agricultural Areas: Continue to conduct Environmental Farm Plan risk assessments and edge-of-field monitoring to assess effectiveness of best management practices.	USGS, USDA-NRCS Conservation Authorities
Outreach and Education	
Communication: Improve engagement, communication and coordination to build awareness and improve understanding of Lake Ontario & connecting rivers issues	MECP, ECCC, USEPA, NYSDEC, Conservation Authorities
Aquatic Habitat Protection and Restoration: Development techniques and improved stormwater management to reduce the impacts (e.g., sediment and nutrients) of urban development on in-stream and nearshore fish and wildlife habitat.	ECCC, MECP, MNRF, Conservation Authorities, NYSDEC, USFWS, USACE, USFS

Additional LAMP science priorities for nutrient and bacteria-related impacts include:

Characterize nutrient concentrations and loadings	Characterize nutrient concentrations in nearshore and in open waters with a focus on nutrient loadings from tributaries, point and non-point sources as well as inputs from the Niagara River. This will support development and use of hydrodynamic/ ecological models to improve understanding of nutrient cycling and transport in the nearshore and offshore, as well as the nature of food web issues, Cladophora growth and phosphorus sources and sinks.
Improve understanding of nearshore nutrient-related problems	Characterize the degree and extent of nearshore nutrient-related impairments to help understand triggers of HAB, blue-green algal blooms and develop a standardized binational methodology to monitor Cladophora. This supports the continuation of nearshore monitoring efforts to maintain long-term nearshore and tributary water quality data set to inform focused water quality improvement efforts in areas of relatively higher need and to track success of management and conservation activities.

Finally, a priority action related to nutrients includes: Supporting nutrient reduction efforts and enhancing our understanding of nutrient dynamics – to better reduce the negative impacts of nutrients and bacteria, through programs focused on point-source and nonpoint source pollution, watershed planning, studying nearshore nutrient-related problems, monitoring, and increased awareness and engagement.