LAKE ERIE
LAKEWIDE
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PLAN

Lake Erie Binational

NUTRIENT MANAGEMENT STRATEGY

Protecting Lake Erie by Managing Phosphorus

Prepared by the Lake Erie Lakewide Management Plan Work Group for the Lake Erie Lakewide Management Plan Management Committee

Note to Reader

Purpose of the Strategy

The Lake Erie Binational Nutrient Management Strategy is a coordinated and strategic response from Canada and the United States that outlines nutrient management actions to reduce excessive phosphorus loading and the eutrophication of Lake Erie. The Strategy was created by the Lake Erie Lakewide Management Plan (LaMP) Work Group to inform the Lake Erie LaMP Management Committee and its respective agencies of management actions needed to mitigate nutrient threats to Lake Erie: it is a blueprint for action. The Strategy was developed based on the findings of the Status of Nutrients technical report (http://epa.gov/greatlakes/lakeerie/erie_nutrient_2010.pdf). Both documents are based on the best available science as of November 2008.

The Strategy outlines the goals, objectives, quantitative targets, and actions needed to improve current conditions and prevent further eutrophication. The success of this Strategy will depend on the commitment from various stakeholders to join forces and change how nutrients are currently used, applied, transported and discharged. Multiple jurisdictions, in both Canada and the United States, will be responsible for implementing actions.

As part of the LaMP's commitment to adaptive management, the LaMP will closely monitor advancements and recommend appropriate adjustments to nutrient management actions and targets, and will ensure that sound science continues to serve as the basis for responsible public policy.

Intended Audience

Achieving the goals of the Lake Erie Binational Nutrient Management Strategy is essential for the successful restoration of Lake Erie and depends on a renewed commitment from LaMP partners. Accordingly, partnerships will be critical to the achievement of results, and require the dedication and participation of those responsible for improving water quality in the Lake Erie basin. Partners that will play a key role in implementing nutrient management actions include:

- Canadian and U.S. federal, state and provincial governments
- Towns, cities and counties in the Lake Erie basin
- Conservation authorities as well as watershed and environmental organizations involved in lake-specific issues
- Industry, businesses, farmers, developers and landowners in the Lake Erie basin
- Academia

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Resources that supported the development of this Strategy include:

- Lake Erie Lakewide Management Plan Update (2008)
- Status of Nutrients in the Lake Erie Basin (2009)
- Literature Review on Beneficial (Best) Management Scenarios in Nutrient Management for the Lake Erie Basin (2008)
- Review and Evaluation of Lake Erie Nutrient Management Programs (2009)
- Lake Erie Lakewide Management Plan Nutrient Indicator Draft Report (2009)
- Ohio Lake Erie Phosphorus Task Force Final Report (2010)

Preface

Lake Erie water quality has taken a turn for the worse. Despite successful past efforts to reduce phosphorus loadings to the lake, evidence of phosphorus enrichment (eutrophication) is again before us and Lake Erie water quality continues to decline.

Algal blooms that threatened the Lake Erie ecosystem in the 1960s and 1970s have returned. In the 1970s and 1980s, collaborative efforts to reduce phosphorus in Lake Erie by treating point source discharges were successful and lake conditions improved (efforts to reduce non-point sources were also initiated; however, reductions have not achieved the same success and remain a critical issue to the health of the Lake).

Problems resurfaced in the mid-1990s but the reasons for the resurgence of the algal blooms are much more complex than in past decades. For example, the introduction of non-native invasive species such as zebra mussels and round gobies has significantly changed the cycling of nutrients and food web dynamics in the lake; there is evidence that the form of phosphorus entering the lake has changed to one that increases the growing ability of algae (called soluble reactive phosphorus); water temperatures have increased; and, there has been a reduction in the extent and duration of ice cover over the past 50 years. There are ongoing scientific investigations to determine how these changes are interacting and contributing to the re-emergence of algal blooms in locations throughout the Lake Erie basin.

There is an urgent need now for a coordinated and strategic response to the nutrient management issues on Lake Erie.

The algal blooms that began their return to the western basin in the mid-1990s are composed primarily of the cyanobacteria (commonly referred to as "blue green algae") *Microcystis aeruginosa*. This species is capable of producing high concentrations of the toxin microcystin which can impact human health through drinking water supplies, recreational use, and the aquatic community. Health Canada reports that some of the impacts associated with the ingestion of water, fish or blue-green algal products containing elevated levels of cyanobacterial toxins, include headaches, fever, abdominal pain, nausea and vomiting. Risks associated with swimming in contaminated water include itchy and irritated eyes and skin, as well as other hay fever-like allergic reactions.

At the mouth of the Maumee River, Sandusky Bay and in the eastern basin, benthic mat-forming blue-green algae float to the surface and wash ashore after storms; the fouled shorelines can have harmful impacts on people and the ecosystem. There are trends of increasing loads of soluble reactive phosphorus in the Maumee and Sandusky Rivers. Similar loads may be present in other tributaries, but monitoring data are limited for these areas.

We are now again faced with the challenge to reduce phosphorus inputs and help the lake become healthy again. We faced this challenge before, and succeeded; and with coordinated actions and the same commitment to working together, we can again succeed.

Water is the keystone resource upon which all life is dependent. Impacts associated with excessive nutrient loading include unstable fish and wildlife populations and degraded habitats, beach contamination and closures, declines in property values and tourism, and added costs to municipalities, industry and people for the provision of safe drinking water.

The Lake Erie Binational Nutrient Management Strategy is a coordinated and strategic response from Canada and the United States that outlines nutrient management actions to reduce phosphorus loading and the eutrophication of Lake Erie. It represents the consensus of Lake Erie resource managers. The Strategy provides quantitative targets and identifies nutrient management, research and monitoring actions that need to be considered and adopted by everyone (government agencies, non-government organizations, academia, local communities) in the watershed.

This approach, to make phosphorus reduction a priority and to engage and promote the actions of a wide range of people and agencies, will result in a significant reduction in phosphorus concentrations and ensure a healthy Lake Erie for everyone to enjoy.

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1.0 Introduction

1.1 About Lake Erie

The Lake Erie watershed, the most populated of all Great Lakes basins, is very diverse; it is largely agricultural, intensively industrialized, and highly urbanized. About one third of the total population of the Great Lakes basin resides within the Lake Erie watershed. This amounts to 11.6 million people (10 million U.S. and 1.6 million Canadian), including 17 metropolitan areas, each with more than 50,000 residents. Lake Erie provides important natural, economic and recreational values and provides drinking water to 11 million people.

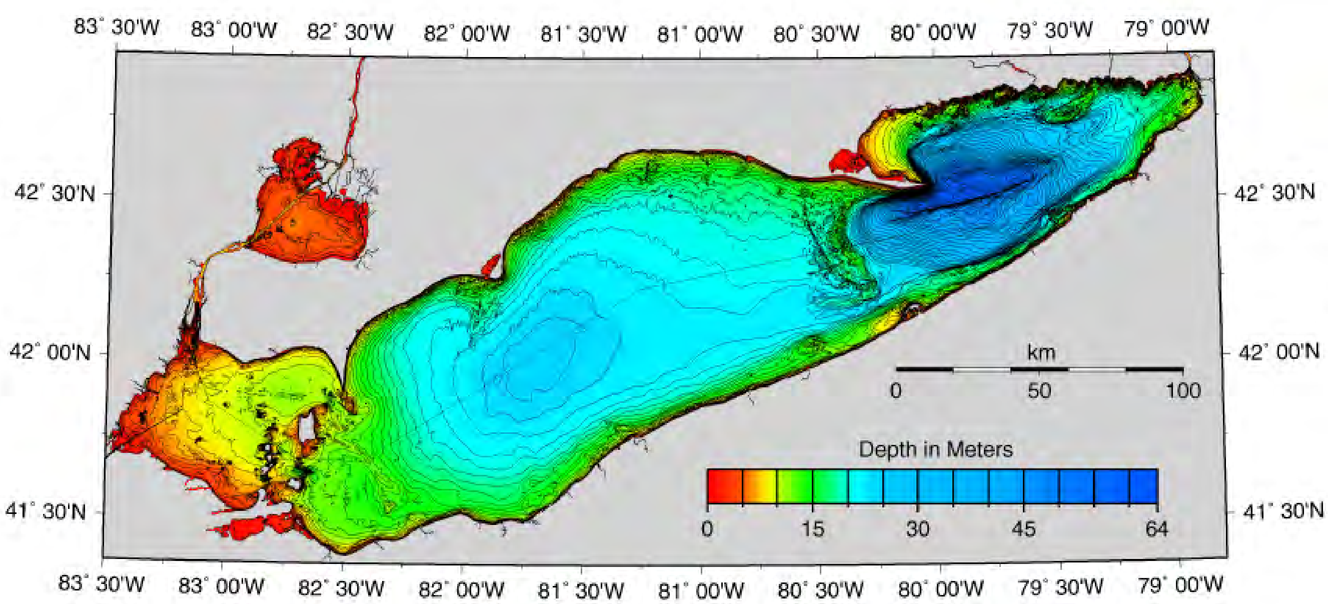
Of all the Great Lakes, Lake Erie is exposed to the greatest stress from urbanization, industrialization and agriculture. Lake Erie surpasses all the other Great Lakes in the amount of effluent received from sewage treatment plants and is also most subjected to sediment loading due to the nature of the underlying geology and land use. Exposed agricultural and urban lands, particularly in southwest Ontario and northwest Ohio, contribute immense sediment loads to the lake.

Lake Erie is the smallest of the Great Lakes by volume and also the shallowest. It warms quickly in the spring and summer and cools quickly in the fall. The shallowness of the basin and the warmer temperatures make it the most biologically productive of the Great Lakes. Eighty percent of Lake Erie's total inflow of water comes through the Detroit River. Eleven percent is from precipitation (rain and snow) and the remaining nine percent comes from the other tributaries.

The lake is naturally divided into three basins that virtually function as three separate lakes:

- The western basin is very shallow, with an average depth of 7.4 metres (24 ft) and a maximum depth of 19 metres (62 ft). It is the most turbid region of the lake as most of the lake bottom is covered with fine sediment particles that are easily disturbed by wind and wave action.
- The central basin is quite uniform in depth, with an average depth of 18.3 metres (60 ft) and a maximum depth of 25 metres (82 ft).
- The eastern basin is the deepest of the three basins, with an average depth of 24 metres (80 ft) and a maximum depth of 64 metres (210 ft).

The central and eastern basins thermally stratify every year. Stratification refers to the layering that occurs, particularly in the warmer months, where a warmer, less dense layer of water (the epilimnion) overlies a colder denser layer (the hypolimnion). Stratification can occur in the western basin but does not last very long. Stratification impacts the internal dynamics of the lake physically, biologically and chemically, and this in turn affects the amount of dissolved oxygen present at the bottom of the lake.



Bathymetry of Lake Erie and Lake St. Clair.
© National Oceanic and Atmospheric Administration National Geospatial Data Exchange.

1.2 Why is Water Quality in Lake Erie Important?

The Lake Erie basin ecosystem is important because of the many ecological services that it provides:

- **Drinking water:** Provides drinking water for 11 million people.
- **Biodiversity:** Provides important areas for food, forage, spawning and safe refuge for many species of fish and wildlife.
- **Recreation:** Provides many opportunities for swimming, fishing, boating and tourism.
- **Aesthetics:** Provides many opportunities to simply enjoy the aesthetic and natural environment.

Increased phosphorus loadings to Lake Erie and associated algal blooms are a concern for a number of reasons:

- **Risks to human health** from the threat of harmful algae toxins near drinking water intakes or through recreational contact;
- **Risks to water quality** for agricultural use (e.g., food safety);
- **Unstable fish communities** due to harmful algae blooms and low levels of dissolved oxygen;
- **Disruptions in food web and energy flow** that cause negative impacts on species and their habitat;
- **Degraded habitats** especially in nearshore, wetlands and tributaries due to increases in *Cladophora* and *Lyngbya* (algal) biomass;
- **Beach contamination and closures** and loss of tourism revenue;
- **Added costs** to municipalities, industry and the public to protect drinking water sources and restore recreational areas; and
- **Declines in property values** due to loss of recreational opportunities and aesthetics.

***Eutrophication** refers to the addition of nutrients in excessive amounts to a body of water and the effects of the added nutrients (e.g., increased plant and algal growth, reduced levels of dissolved oxygen). The nutrient of primary concern in Lake Erie is phosphorus.*

1.3 What is the Lake Erie Binational Nutrient Management Strategy?

The Lake Erie Binational Nutrient Management Strategy (the Strategy) is a coordinated and strategic response from Canada and the United States that outlines priority management actions to reduce excessive phosphorus loadings and the eutrophication of Lake Erie. The Strategy represents the consensus of key binational Lake Erie resource managers on the vision, goals, and targets for the protection, conservation and restoration of the Lake Erie ecosystem. The Strategy identifies the steps for managing nutrients, conducting research and monitoring, and reporting on current conditions, trends and progress.

Photos (top to bottom): © Jonathan S. Yoder, Centre for Disease Control (from SOGL Highlights 2009); © Jim Schmidt, provided by U.S. National Parks Service; Upper Thames River Conservation Authority (2 photos)

The Strategy is the result of research undertaken in collaboration with the agencies and organizations involved in the Lake Erie Lakewide Management Plan (LaMP). It is a mechanism for the LaMP to engage government and non-government groups to take action to reduce excessive phosphorus inputs to Lake Erie.

The successful recovery of Lake Erie will require a strong multi-jurisdictional, multi-partner and multi-year commitment.

What is the LaMP?
The LaMP provides a binational management framework for planning, coordination and reporting in support of the Canada-United States Great Lakes Water Quality Agreement (GLWQA). The LaMP also provides the overall direction and scientific support for the restoration, protection and maintenance of the waters of the Lake Erie ecosystem, including nearshore and offshore waters, tributaries and coastal wetlands.

1.4 Why is Phosphorus the Focus of the Strategy?

In Lake Erie, phosphorus is the primary nutrient causing excessive algae and other water quality associated-impacts, such as beach closings and contamination of drinking water.

In most lakes and rivers, phosphorus is typically considered to be the primary limiting nutrient that stimulates algal growth. While many other nutrients are present in water, such as nitrogen, silica, carbon, and even trace metals, these nutrients are considered to be only secondarily or seasonally limiting in Lake Erie. Almost any nutrient can be shown to appear limiting to algae on a given day, but nitrogen or other nutrients present in Lake Erie do not cause the same algal response as phosphorus. This rationale is based on the best current scientific knowledge; however, it is important to continue to research and monitor the effects of nitrogen and other nutrients so that management decisions and actions can be adapted to appropriate concerns.

Phosphorus is the primary limiting nutrient causing excessive algae and other water quality associated impacts.

To communicate the nutrient status of water and predict the potential for algae problems, measures of total phosphorus concentration and load are used. Total phosphorus is the easiest and most reliable form of phosphorus to measure and this is why federal, provincial and state agencies regularly measure total phosphorus concentrations in water. Total phosphorus is comprised mostly of particulate and dissolved phosphorus. Typically, the higher the dissolved component the higher the bioavailability, which means that plants and algae can readily absorb or uptake this nutrient for growth. The dissolved component of total phosphorus is made up of a number of different forms, including soluble reactive phosphorus (SRP). SRP is the chemical method used to quantify orthophosphate, the most available form of phosphorus for algal growth. Orthophosphate is found in sewage and fertilizers, and when dissolved, is highly bioavailable.

While total phosphorus loads to Lake Erie have been stable or declining since 1981, studies from Heidelberg University indicate that the tributary loading of SRP to the lake is actually increasing. While there is evidence that SRP loadings may be increasing throughout the lake, the trend is particularly evident for the Maumee and Sandusky Rivers.

Monitoring SRP provides better information for resource managers to understand the conditions leading to an algal bloom and the impacts of management decisions. There is a strong need to develop and use consistent and reliable methods to collect and monitor SRP (in addition to total phosphorus) at the tributary, nearshore, and offshore scales.

While total phosphorus loads to the lake have been stable or declining, recent studies indicate that the loading of soluble reactive phosphorus to the lake from the Maumee and Sandusky rivers is actually increasing.

Photo: Upper Thames River Conservation Authority

2.0 A Vision for the Lake

In order to move forward, we must first envision what Lake Erie's future state will be. Achieving this vision will require the commitment and imagination of all people in the Lake Erie watershed.

Implementation of the Nutrient Management Strategy and achievement of the Vision will be based on the following key principles:

- **Adaptive Management** – Decisions must be flexible and be adjusted in the face of uncertainties, natural variability and new information.
- **Precautionary Principle and No Regrets Actions –** The lack of full scientific certainty shall not be used as a reason for postponing cost effective best management practices.
- **Prevent Pollution** – It is better for the environment and more cost effective to prevent nutrient enrichment than to clean it up after the fact.
- **Shared Responsibility –** The responsibility for policy and program development and implementation should be shared within the mandate of all jurisdictional levels.
- **Promote Awareness –** Connecting people with the watershed and nutrient issues facing the Great Lakes provides a key motivating force for actions.
- **Accountable and Clear Actions** – Actions must be coordinated and transparent and everyone must be accountable for their actions.
- **Work Together** – Integration and cooperation must occur across traditional environmental, social and economic boundaries to align our actions.

Lake Erie LaMP Vision

The Lake Erie LaMP envisions a future state of Lake Erie with a sustainable ecosystem that supports beneficial economic and social activities for society.

Lake Erie LaMP Nutrient Goals

Nutrient inputs from both point and non-point sources are managed to ensure that ambient nutrient concentrations are within the bounds of sustainable watershed management.

A substantial reduction in the current levels of algal biomass to levels below a nuisance condition in Lake Erie, including associated bays and other areas where nuisance algal blooms occur. (GLWQA, Annex 3-1).

Lake Erie LaMP Nutrient Objectives

Stop further degradation – Ensure no further human-induced eutrophication. Nutrient concentrations in waters are, at a minimum, to be maintained at current levels so eutrophication does not get worse.

Conserve and protect waters that meet nutrient targets – Maintain current nutrient concentrations and loadings in those waters that already meet nutrient targets and protect those waters from increases due to future land use practices.

Restore waters that do not meet nutrient targets – Work to reduce phosphorus concentrations and loadings in those waters that are not meeting water quality targets by using a focused nutrient management approach that considers both current and future land uses.

Regularly monitor and report on the status of nutrients in the tributary, coastal wetland, nearshore, and offshore waters of Lake Erie, as they relate to established LaMP targets and goals.

Conduct research to better understand nutrient cycling and the effect of human activities, to improve management decisions.

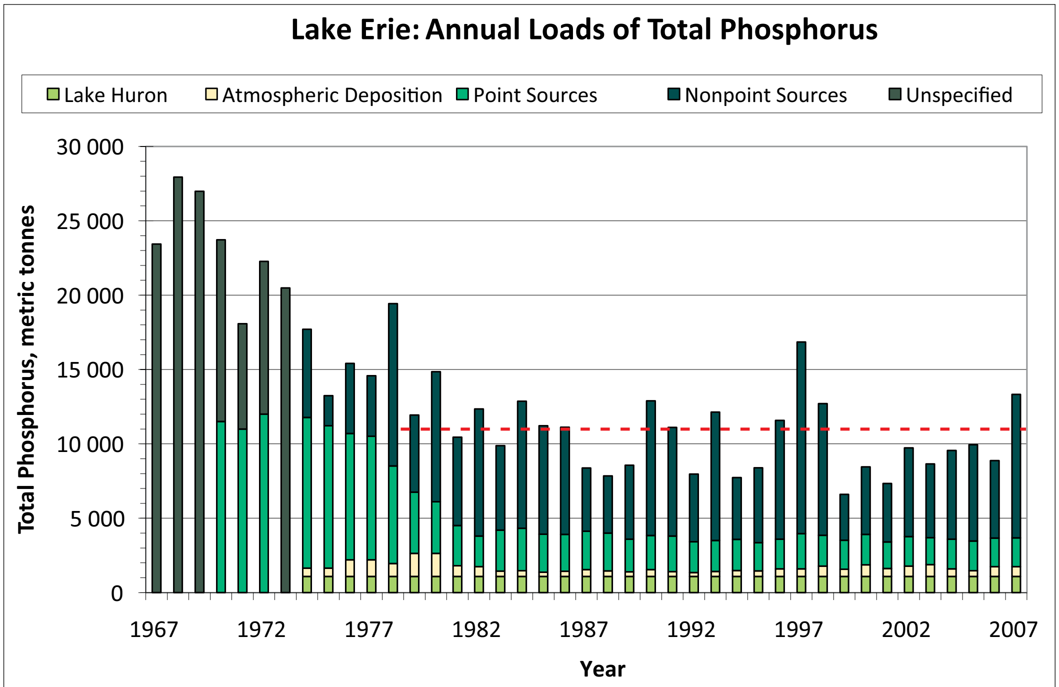
3.0 Lake Erie's Nutrient Status and Effects

3.1 History of Cultural Eutrophication

Prior to European settlement, the estimated phosphorus load to Lake Erie was 3,000 metric tonnes per year.

By 1900, the load had increased to about 9,000 metric tonnes per year as a result of land use changes that occurred after 1850. At that time the majority of the total annual loading was derived from spring runoff to the western basin and from continuous inputs from municipal and industrial sewage wherever rivers entered Lake Erie.

From about 1900, sewage and detergents containing phosphate increased the total phosphorus load to a peak of approximately 28,000 metric tonnes in 1968.



Annual Loads of Total Phosphorus in Lake Erie. The dashed red line represents the phosphorus target for Lake Erie, as set in the 1978 Canada-United States Great Lakes Water Quality Agreement. Graph provided by Agriculture and Agri-Food Canada.

In 1972, the Great Lakes Water Quality Agreement (GLWQA) was signed and programs were initiated to protect, maintain and restore the waters of the Great Lakes. As a result, by 1980 annual loadings to Lake Erie had declined to approximately 15,000 metric tonnes.

In 1981, the GLWQA target load of 11,000 metric tonnes per year was achieved as a result of a substantial drop in the point source total phosphorus load resulting largely from sewage treatment plants being improved and a reduction of phosphates in laundry soaps and detergents.

During the mid-to-late 1980s, dreissenid mussels (zebra and quagga) arrived in the Great Lakes. The mussels are filter feeders capable of removing large quantities of phytoplankton from the water. Colonization of Lake Erie by dreissenid mussels resulted in several years of improved water clarity and dramatic food web changes, especially a shift in algal production from phytoplankton to bottom-dwelling algae and plants.

By the early 1990s, the average annual load from tributaries had been reduced to about 10,000 metric tonnes. However, in the mid- to late-1990s, large late-summer algal blooms began to reappear sporadically in western Lake Erie and have been increasing in frequency ever since.

Algal blooms of varying magnitude occurred in the western basin each summer from 2003 to 2011. These blooms have been dominated by the blue-green alga (cyanobacteria) *Microcystis aeruginosa*. *Microcystis* had been a common species in Lake Erie for at least a century, but rarely grew to nuisance bloom proportions. Blooms of *Microcystis* become most evident during warm, calm periods when the cells float to the surface and form a layer of scum. Blooms from 2009 to 2011 extended into the central basin.

During the period from 1981 to 2007, the GLWQA total phosphorus loading target was achieved in 16 of the 27 years (see figure above). This variability in annual loading is the result of hydrological influences, with loads exceeding the target in years with higher precipitation and runoff.

Photo: NASA image courtesy Jeff Schmaltz, MODIS Rapid Response Team at NASA GSFC, October 2011.

3.2 What is the Status of Nutrients in the Lake Erie Basin?

3.2.1 Nutrient Status of Offshore Waters

The offshore waters of Lake Erie consist of three distinct basins – western, central, and eastern (see map, page 1) – and are generally found greater than 3-4 km (2 miles) from the shore at depths exceeding 15 m (49 ft).

From 1967 to 1981 the annual total phosphorus load to Lake Erie dropped substantially from approximately 28,000 metric tonnes to 11,000 metric tonnes. However, between 1982 and 2007, total phosphorus loading fluctuated annually, resulting in loads exceeding the GLWQA target in years with relatively high precipitation.

While estimates of phosphorus loading from point sources, atmospheric sources, and the interconnecting channel have remained relatively stable since 1982, non-point sources via the tributaries continue to contribute the largest portion of phosphorus loadings and are mostly responsible for the periodic exceedences of the Lake Erie loading target during high flow years.

Reductions in non-point source phosphorus, especially in high flow years, would reduce nutrient related impacts to the offshore waters, including hypoxia and algal blooms.

Effects of Excessive Nutrient Inputs to Offshore Waters

Hypoxia *– Hypoxia is the depletion of oxygen in the bottom waters (hypolimnion) of the lake. Prolonged events of hypoxia can have a devastating effect on fish and lake processes. Although hypoxia may be a natural characteristic of the central basin, research has now determined that increased phosphorus loading affects the magnitude and duration of oxygen depletion. Through the mid-1990s, there was a decrease from historic levels in the severity of hypoxia; however, there is evidence that seasonal hypoxia may again be intensifying in the central basin.*

Algal Blooms *– There are increasing reports of blue-green algae species concentrations in the central basin. These species can form blooms containing natural toxins that are dangerous to humans and wildlife. Increased phosphorus concentrations enhance the probability of blue-green algal growth. Increased algal productivity in the central basin is expected to exacerbate seasonal hypoxia as dead algae accumulate in the hypolimnion, resulting in increased biological oxygen demand throughout the growing season.*

3.2.2 Nutrient Status of Nearshore Waters

The nearshore nutrient situation is complex and dynamic and varies widely across Lake Erie. For definition purposes, the Lake Erie LaMP divides the nearshore into two areas: coastal margin and nearshore open-water. The coastal margin is defined as the shoreline, water column and substrate in embayments with water depths of 3 m (10 ft) or less. The nearshore open-water is defined as the water column and substrate with water depths between 3 m (10 ft) and 15 m (49 ft). The primary sources of nutrients to the nearshore waters include loads from tributaries (similar to offshore sources) and inputs from shoreline land uses, agricultural activities, and municipal wastewater treatment plant outflows.

Although the relative proportion of non-point source versus point source loadings has not been quantified on a whole lake basis, there is growing evidence that non-point sources are accounting for the majority of the loadings throughout much of the basin. A recent thorough assessment undertaken in Ohio found that non-point sources are the most important source of dissolved phosphorus in the Maumee and Sandusky watersheds, Ohio's largest agricultural watersheds. The Ohio Lake Erie Phosphorus Task Force also reported that peak SRP concentrations coincide with peak storm water runoff. In the Maumee and Sandusky Rivers over a 20 year period, 90% of the sediment and phosphorus load was delivered during storm events (Ohio EPA, 2010).

Nearshore waters tend to flow parallel to the shore and, if there are specific local inputs, certain portions or reaches of the nearshore can develop their own chemical, physical and biological properties. This can be the result of local water currents, depth and weather conditions. Under calm conditions the effects of offshore currents are lessened; however, under storm events or windy weather, the nearshore is subsequently mixed with the offshore water.

Water quality studies in the nearshore area are plagued by extreme variability. It is important to gain a better understanding of how nutrient sources (such as tributaries, urban runoff, ground water, and sewage effluents) dissipate in lakes, and how nutrient concentrations affect the nearshore ecosystem, especially the nearshore phosphorus shunt and algae blooms. Our short-term challenge is to gain a better understanding of the nearshore processes through more research and consistent approaches to water quality monitoring.

Effects of Excessive Nutrient Inputs to Nearshore Waters

Nearshore Phosphorus Shunt and Dreissenid Mussels *– Variations in total phosphorus loading to nearshore areas may be affected, or exacerbated, by the "nearshore phosphorus shunt". This hypothetical model seeks to describe a change in nutrient movement and quantity caused by the presence of dreissenid mussels (e.g., zebra and quagga mussels).*

The bedrock areas in the eastern basin are prime habitat for both dreissenid mussels and Cladophora. Dreissenid mussels are thought to filter the nearshore waters and concentrate their energy and nutrients locally within their population and waste products. While this may result in clear water due to reduced nutrient concentrations surrounding the dreissenids, the accumulating shells of the mussels provide a physical refuge for many species and a place where their decomposing waste can concentrate. The mussels are thought to stimulate Cladophora growth by the excretion of concentrated soluble nutrients in their waste bi-products. Further, as the mussels increase water clarity during filter feeding, sunlight is able to penetrate to ever greater depths thereby expanding the amount of habitat available for Cladophora colonization.

Algal Blooms *– Algal populations vary widely throughout the three basins of the lake. One of the most visible responses to excess phosphorus inputs in the nearshore is the filamentous algae Cladophora. Nuisance growths of Cladophora are again being reported in the eastern basin. Accumulations of Cladophora on the shoreline decompose and cause obnoxious smells and visual impairments of the waterfront, impacting recreational enjoyment and property values.*

However, the growth of Cladophora is limited by the availability of soluble reactive phosphorus. This is good news, because it means that the reduction of phosphorus through better phosphorus controls could be effective at controlling Cladophora blooms. Dealing with localized phosphorus inputs from tributary streams, groundwater discharge, and non-point agricultural runoff will play an important role in reducing these nearshore Cladophora blooms.

Blue-green algae, such as Microcystis, are being reported in the western basin and fouling shorelines and embayments in areas where, historically, they did not proliferate. These species can form blooms containing natural toxins that are dangerous to humans and wildlife.

3.2.3 Nutrient Status of Tributaries

The majority of total phosphorus loading to Lake Erie is the result of inputs from a few major tributaries, including the Detroit River (especially the Trenton Channel, Michigan); Maumee River, Ohio; Sandusky River, Ohio; Grand River, Ontario; and Thames River, Ontario. These larger rivers contain a mix of non-point source pollution, including agricultural and urban runoff, and point source pollution, such as treated municipal sewage. While phosphorus inputs from these tributaries may be the key driver of intensifying central basin hypoxia and eutrophication on a lakewide basis, localized inputs from smaller tributaries and other sources play a primary role in exacerbating nuisance *Cladophora* growth in the nearshore waters. As well, the nearshore phosphorus shunt, and changes in the timing, frequency and intensity of storm events (possibly related to changes in global climate patterns) may be exacerbating total phosphorus inputs, resulting in accelerated eutrophication.

Most tributary watersheds in the Lake Erie basin urgently need reductions in total phosphorus concentration. The following priority watersheds are very far above target and require focused total phosphorus concentration reductions: Clinton River, Trenton Channel-Detroit River, River Raisin, Maumee River, Sandusky River, Vermilion River, Cuyahoga River, Grand River (Ohio), Grand River (Ontario), Big Otter Creek, Kettle Creek, Thames River, Essex Region watersheds and Sydenham River.

Although there have been significant reductions in total phosphorus loading, recent research indicates that SRP, the most biologically available form of phosphorus, is increasing in watersheds where data are available. The Ohio EPA's recent Ohio Lake Erie Phosphorus Task Force Final Report reported that the majority of annual phosphorus loading to Lake Erie is associated with the storm pulsed runoff from the landscape into the tributaries that drain to Lake Erie (Ohio EPA, 2010). These findings suggest a particular emphasis must be placed on the timing and delivery of nutrients from non-point sources throughout the agricultural portions of the Lake Erie basin and that the focus of any phosphorus management efforts must target actions in the watershed to reduce phosphorus sources and loads (Ohio EPA, 2010).

Major Tributaries Contributing Phosphorus to Lake Erie

Detroit River/Interconnecting Channel – The Detroit River, which carries the inflowing waters from all the upper Great Lakes, contributes roughly 80% of the total inflow to Lake Erie. All other Lake Erie tributary rivers and streams combined provide 9%, with the remaining 11% coming from precipitation falling on the lake's surface. Despite being the principle source of inflow to Lake Erie, the waters of the Detroit River contain relatively low concentrations of total phosphorus, estimated to contribute 16% of the annual total phosphorus load to Lake Erie (1,800 metric tonnes).

Total phosphorus concentrations in the Trenton Channel, which is the outflow of the Detroit wastewater treatment plant, were found to be significantly higher than at other sampling sites in the Detroit River and have the potential to exacerbate the phosphorus overload effects in the Maumee River area.

Maumee River – The Maumee River is estimated to contribute the same annual total phosphorus load to Lake Erie as the Detroit River (1,800 metric tonnes).

While total phosphorus concentrations in the Maumee River have decreased due to municipal sewage plant upgrades and agricultural cultivation techniques designed to reduce soil erosion, the fraction of total phosphorus that is soluble reactive has increased. These concentrations are of great biological concern and are believed to be feeding the blue-green algal blooms in the western basin.

Sandusky River – Although the Sandusky River has a much smaller discharge than the Maumee River, the total phosphorus properties of these two rivers are very similar. The total phosphorus and soluble reactive phosphorus concentrations measured in the river between 2001 and 2009 were more than enough to stimulate algal blooms and the establishment of *Cylindrospermopsis*, an invading cyanobacterium which is capable of generating dangerous toxins, in Sandusky Bay.

Ontario Tributaries – Less information about phosphorus loading exists for the Ontario tributaries. Increased research and monitoring is needed, especially to confirm loading estimates and to determine the status of SRP. Total phosphorus concentrations in most Ontario Lake Erie streams and rivers exceed the Provincial Water Quality Objective (PWQO) of 30 micrograms per litre (µg/L) which is thought to be a threshold for deleterious in-stream effects.

The total phosphorus loads from Ontario tributaries are not known. The* Grand River *sediment plume can be detected up and down the coast for a distance of 12 km (7 miles) and up to 3 km (2 miles) offshore depending on weather, and the* Thames River *sediment plume can be detected as far away as the western basin.

Photo: Upper Thames River Conservation Authority

Effects of Excessive Nutrient Inputs from Tributaries to the Lake

All tributaries contribute to the net nutrient load to Lake Erie which exacerbates problems (algal and hypoxia growth) in the offshore and nearshore waters. Major tributaries may be the principal driver of open lake processes, but research is showing that smaller tributaries and other localized nutrient sources may be equally important in the nearshore environment and play a primary role in local nuisance algal growths, such as Cladophora.

Urgent action must be taken to reduce nutrient loadings from large and small tributaries that are not meeting nutrient targets, and more research and monitoring is needed to understand the relationship between smaller tributaries, nearshore nutrient conditions and nuisance algal growth.

3.2.4 Nutrient Status of Coastal Wetlands

Coastal wetlands play a significant role in the mitigation and release of phosphorus into the nearshore. Similar to the nearshore waters, the nutrient cycles around coastal wetlands are complex and dynamic and vary depending on local conditions.

Although a significant amount of information exists about the location of coastal wetlands, very little is known about the complex relationship between these environmentally sensitive areas and nutrient loading. More research is needed to understand the status and function of these wetlands and how they interact with the nearshore nutrient cycle.

3.2.5 Summary of Lake Erie Phosphorus Status

Between 1981 and 2007 the total phosphorus annual target load of 11,000 metric tonnes was met in 16 of 27 years. The variation in annual loads is due to the positive correlation between non-point source loads and precipitation amounts. The ongoing effects of excessive nutrient loading include:

- Seasonal hypoxia (depleted oxygen conditions) appears to be intensifying in the central basin.
- Blue-green algal blooms are occurring regularly in the western basin and fouling shorelines and embayments in areas where they never used to proliferate.
- Fouling of nearshore areas of the eastern basin by *Cladophora* is reminiscent of the early 1970s. Additionally, new species of cyanobacteria are appearing.
- Loading of soluble reactive phosphorus, the most biologically available form of phosphorus, is increasing in the Sandusky and Maumee rivers and may be increasing in other Lake Erie tributaries. Research is needed to develop and implement a consistent approach to reliably measure SRP.

In addition, climate change-related increases in water temperatures, reduced winter ice extent and duration, and colonizing invasive species are exacerbating the nutrient problems of Lake Erie.

While the mechanisms behind these changes are areas of active scientific investigation, there is a clear need for immediate phosphorus reduction actions coupled with ongoing research and monitoring.

4.0 Nutrient Targets for Lake Erie

In order to sustain a healthy lake ecosystem, total phosphorus targets have been established for the four different habitat types in the Lake Erie basin: offshore, nearshore, tributaries and coastal wetlands.

Targets for Total Phosphorus Concentrations Lake Erie and Watershed

Habitat Type	Total Phosphorus Concentration (μg/L)
Offshore*	
West Basin	15
Central Basin	10
East Basin	10
Nearshore**	20
Tributaries***	32
Coastal Wetlands	one recording of <30 μg/L/year

* Mean spring total phosphorus concentration
** Mean total phosphorus concentration during ice free period
*** Mean annual total phosphorus concentration

Photo: © David Poulson, Great Lake Echo

These water quality targets are based on the desired ideal biotic response in the environment that should result in negligible risks to all living things, including the ecosystem features that they depend on for survival.

The comparison of lake total phosphorus concentrations to these targets over long- and short-term periods will inform us of new trends and provides a means for assessing the results of our management efforts and adapting to the natural variability of the ecosystem.

Research and monitoring will continue to refine these targets to ensure they are ecologically credible and appropriately sustainable to meet the vision, goals and objectives of the Lake Erie Binational Nutrient Management Strategy.

4.1 Offshore Nutrient Targets

The offshore spring total phosphorus concentration target is 15 micrograms per litre (μg/L) for the western basin and 10 μg/L for the eastern and central basins. These targets are based on achieving the GLWQA total phosphorus loading target for Lake Erie of 11,000 metric tonnes/year, and complement the Great Lakes Fisheries Commission's Lake Erie Environmental Objectives (2005) to support a desirable sustainable fish community by maintaining mesotrophic conditions (10-20 μg/L) in the west and central basins.

4.2 Nearshore Nutrient Target

The nearshore total phosphorus concentration target is 20 μg/L. This target applies to both the coastal margin and the nearshore open-water. The nearshore total phosphorus target is based on the Ontario Provincial Water Quality Objective (OMOE, 1999) of 20 μg/L for lake water during the ice-free period, and complements the Great Lakes Fisheries Commission Lake Erie Environmental Objectives (2005) to support a desirable sustainable fish community by maintaining mesotrophic conditions (10-20 μg/L) in the nearshore waters of the eastern basin.

Due to the extreme variability of the nearshore environment and the unknowns about nutrient sources, dissipation and the distribution of total phosphorus concentrations, it is very difficult to take measurements and generate conclusions that can be consistently applied across the lake. Therefore, it is extremely important that research and monitoring efforts continue to develop scientifically credible and ecologically-based targets for the nearshore areas and that the targets are adapted as better science becomes available.

4.3 Tributary Nutrient Target

The tributary total phosphorus concentration target is 32 μg/L. The tributary target applies to tributary waters immediately above the lake effect zone of the tributary, which is the zone of water near the mouth of the tributary that contains a mix of Lake Erie water and tributary water. The size and shape of the lake effect zone will differ with each tributary.

The tributary nutrient target is based on research by Environment Canada that established a total phosphorus concentration target of 32 μg/L for smaller, agriculturally-dominated watersheds (Chambers et al., 2008). Further research and monitoring is required to assess the applicability of this approach in both larger and more urban-influenced watersheds. Other existing tributary total phosphorus concentration targets established by various agencies such as the Ontario Provincial Water Quality Objective (OMOE,

1999) (30 µg/L), the New York State Guidance (2008) (20 ug/L) and the 2000 US EPA Recommendation (33 µg/L), were also considered.

4.4 Coastal Wetlands Nutrient Target

The total phosphorus concentration target for coastal wetlands is based on the State of the Lakes Ecosystem Conference indicator “Nitrate and Total Phosphorus for Coastal Wetlands (Indicator ID: 4860)” which recommends a target of at least one instance per year of less than 30 µg/L.

Although a significant amount of information exists about the location of coastal wetlands, more research is needed to understand the complex relationship between these environmentally sensitive areas and their role in nutrient loading and management.

Photo: Ontario Parks

5.0 Nutrient Management, Research and Monitoring Goals

Photo: Upper Thames River Conservation Authority

Lake Erie is a complex watershed with a diversity of characteristics, uses and threats. As a result, a one-size-fits-all approach will not be successful in achieving a sustainable nutrient cycle. The following provides nutrient management, research and monitoring goals to be considered for action by all levels of government (federal, provincial, state and municipal), non-government organizations, industry, academia, community groups, and landowners.

5.1 Phosphorus Management Goals

Halting further degradation and restoring Lake Erie waters requires a commitment to reducing anthropogenic phosphorus loadings to the lake and its tributaries. Focusing immediate attention on priority watersheds where targets are being exceeded and on sources that are locally dominant will produce short- and long-term benefits.

Phosphorus Management Goal 1: Focus on Priority Watersheds and Dominant Sources – Identify and focus efforts in priority watersheds where targets are being exceeded, and on dominant sources of phosphorus in these watersheds.

Phosphorus Management Goal 2: Establish Policies and Practices to Reduce Phosphorus Loading – Put in place appropriate policies, controls and practices to mitigate the form and timing of dominant phosphorus sources across the Lake Erie basin.

Phosphorus Management Goal 3: Take Action to Reduce Phosphorus Loadings from Existing Sources – Implement specific actions to reduce phosphorus loading in priority watersheds and from existing dominant sources.

5.2 Research Goals

Scientific research provides essential information that will help us to better understand nutrient and ecosystem processes, anthropogenic sources and impacts, and to direct management decisions and actions to priority areas.

There are many knowledge gaps regarding the type of phosphorus entering the lake and how the lake ecosystem responds. These gaps need to be addressed in order to consider the adequacy of phosphorus management practices and to adopt necessary future changes.

Research Goal 1: Conduct Research to Understand Nutrients and Ecosystem Processes – Improve our understanding of how nutrients affect Lake Erie's water quality and ecosystem processes.

Research Goal 2: Conduct Research to Understand Human Impacts – Improve our understanding of how human activities change over time and how they impact nutrient conditions in Lake Erie in order to develop effective phosphorus management options.

Research Goal 3: Conduct Research to Predict Outcomes – Develop new, and improve existing, models to better predict the effects of stressors and alternative nutrient mitigation actions.

Research Goal 4: Develop Beneficial (Best) Management Practices – Continue to research and develop new technologies and best management practices for reducing phosphorus losses from land, reservoirs, rivers and lakes.

Research Goal 5: Communicate Science Findings – Promote awareness and understanding about the linkage between individual and communal actions and nutrient issues in Lake Erie to develop a strong sense of responsibility and motivation from everyone to participate in the reduction of phosphorous loadings.

5.3 Monitoring Goals

Consistent monitoring allows for a better understanding of how Lake Erie responds to natural and anthropogenic influences and is an essential component in adaptive management. Monitoring is already ongoing through the LaMP partnership and a regular review of these programs will ensure there are resources to meet current and future needs. Currently, there are spatial and temporal gaps in the monitoring data that must be addressed to understand the effectiveness of management programs and practices, and to determine our progress towards meeting the nutrient targets.

Monitoring Goal 1: Monitor Nutrient Status – Monitor the status of total phosphorus and soluble reactive phosphorus in open waters, nearshore and tributaries to identify trends and measure progress towards meeting nutrient targets. Regular monitoring of nutrient status is a key component of adaptive management, and will ensure that targets are being met, actions are anticipatory and that plans put in place are making a difference.

Monitoring Goal 2: Monitor Ecosystem Response – Monitor how the ecosystem responds to natural lake cycles, invasive species and the implementation of management programs and beneficial (best) management practices.

Monitoring Goal 3: Monitor Human Health/Socio-Economic Implications – Monitor the occurrence and impacts of harmful algae blooms on drinking water sources and recreational activities.

Monitoring Goal 4: Monitor Progress of Implementation – Measure the progress of implementation efforts to ensure we are headed in a sustainable direction.

Monitoring is an essential component of adaptive management and the implementation of the Nutrient Strategy. Photo: National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory.

6.0 Moving Forward and Making a Commitment

6.1 Who Is Involved and What Can Be Done?

Everyone is responsible for reducing phosphorus loads to Lake Erie. By joining forces we can better achieve a sustainable ecosystem.

Achieving the goals of the Strategy will depend on a renewed commitment from throughout the watershed. Partnerships will be critical to achieving results. A commitment to work together and take action is required from federal, state, provincial and local governments, academia, non-government organizations, businesses, landowners and local citizens, in both Canada and the United States.

- **Federal, State and Provincial Governments** can provide leadership and coordination, set basin-wide targets, work across jurisdictional boundaries and watersheds, provide technical advice and funding, enact and enforce legislation and establish policy direction, conduct research and monitoring, and report the findings to everyone.
- **Towns, Cities and Counties** can provide direction in their land use plans and make wise development decisions that mitigate the impacts of phosphorus loadings. Municipal governments are responsible for sewage treatment plants, stormwater management and the protection of environmentally sensitive areas. They can create by-laws and introduce stewardship initiatives to promote beneficial management practices for nutrients.
- **Academics and Schools** can lead research programs, conduct restoration projects and provide educational programs to improve our understanding and appreciation of the Lake Erie ecosystem.
- **Conservation Authorities** and other watershed-based organizations can refine and/or design and implement watershed based phosphorus reduction programs in consultation with local communities to achieve LaMP targets. They can provide leadership and guidance for watershed and sub-watershed based projects such as water budgets for rivers and streams, restoration projects, and monitoring. They can provide advice to municipalities on environmental management and they can work with community members and property owners through stewardship programs.
- **Non-Government Organizations** can be environmental leaders and encourage others through education and communication programs, research and monitoring, restoration projects and the preservation of environmentally sensitive areas such as coastal wetlands, streams and rivers.
- **Community Groups** can take on-the-ground action and raise local awareness about the importance of living sustainably in the Lake Erie Basin.
- **Industry, business, farmers, developers and land owners** can lead their peers by demonstrating strong environmental values and adopting Beneficial Management Practices that lessen their impacts on the Lake Erie ecosystem.
- **All people** including politicians, planners, engineers, scientists, residents, cottagers and land owners can practice phosphorus reduction activities in their everyday work and lives.

Photo: Upper Thames River Conservation Authority

By working together we can take appropriate actions to protect the waters of Lake Erie and achieve a sustainable ecosystem that supports fish and wildlife populations while providing economic and social benefits for society.

The LaMP's Commitment and Path Forward

Lake Erie LaMP members are committed to improving the health of the Lake and will continue to facilitate the implementation of management actions and to promote focused research and monitoring efforts. The LaMP will work with partners to identify specific actions to be undertaken in support of the Strategy. Progress on actions will be reviewed annually and will be integrated into the five-year Lake Erie LaMP management, work planning and reporting cycle.

6.1.1 Implementing Actions

As a next step, the LaMP will work with partners to develop domestic action plans targeted at priority areas. Action plans in support of the Strategy will be reflective of the institutional and legislative differences between Canada and the United States. These work plans will focus on the needs of the Lake and will create the domestic decision frameworks necessary to lead to actions on the ground.

6.1.2 Research and Monitoring

The Lake Erie LaMP and Lake Erie research networks depend on comprehensive and timely research and monitoring information to adapt policies and actions to restore and protect the lake. In 2009, scientists and researchers conducted intensive fieldwork and data collection on the status of nutrients in Lake Erie. Initial results are scheduled to be available in 2011 and will be formally released in the LaMP's Five-Year Report in 2013.

6.1.3 Collaborating

Lake Erie LaMP managers are committed to working with partners to learn how priority actions can be adopted and implemented. The LaMP will continue to work with partners to enhance and build on ongoing initiatives. These include:

- The Ohio Task Force Phosphorus Report
  www.epa.ohio.gov/dsw/lakeerie/ptaskforce/index.aspx
- The US EPA National Nutrient Strategy
  www.epa.gov/waterscience/criteria/nutrient/strategy/nutstra3.pdf
- Lake Erie Millennium Network
  http://web2.uwindsor.ca/lemn/
- SOLEC Nearshore Areas of the Great Lakes (2009)
  http://binational.net/solec/sogl2009/SOGL_2009_nearshore_en.pdf
- Water Quality in Ontario Report (2008)
  www.ene.gov.on.ca/publications/6926e.pdf
- Proceedings of the Great Lakes Phosphorus Forum
  www.sera17.ext.vt.edu/Meetings/greatlakespforum/index.html
- An Urgent Call to Action: Report of the State-EPA Nutrients Innovations Task Force (US EPA 2009)
  www.epa.gov/waterscience/criteria/nutrient/nitgreport.pdf
- Essex Region Conservation Authority 2009 WQ Status Report
  www.erca.org/downloads/watershed_water_quality_report_09.pdf
- Lake Simcoe Phosphorus Reduction Strategy
  www.ene.gov.on.ca/publications/7633e.pdf
- Great Lakes Fishery Commission
  www.glfc.org/lakecom/lec/lechome.php

6.1.4 Public Reporting

Lake Erie LaMP managers are committed to regularly reporting on research and monitoring results and on the effectiveness of nutrient management activities to ensure the Lake Erie community has up-to-date information on the status of nutrients. This reporting will be integrated into the regular public reporting cycle required by the LaMP. Reporting on nutrient status, ecosystem response and management outcomes will incorporate the monitoring and research data acquired over the five-year LaMP cycle and compare progress towards achieving the phosphorus targets. The next LaMP Report will be released in 2013 and will include the most up-to-date information on the status of nutrients in Lake Erie.

6.1.5 Education and Awareness

Lake Erie LaMP managers are committed to continuing education and awareness activities that help connect the Lake Erie community to their watershed and to the lake. The LaMP will work with partners to increase awareness of how communities can help to manage nutrients in their watershed and improve the health of Lake Erie. Outreach and educational actions to reduce nutrients in Lake Erie will be identified within the LaMP five-year Work Plan.

Photo: Upper Thames River Conservation Authority

Acronyms

BMP - Beneficial (Best) Management Practice

CA - Conservation Authority (Canada)

DFO - Fisheries and Oceans Canada

EC - Environment Canada

GLFC - Great Lakes Fishery Commission

GLWQA - Great Lakes Water Quality Agreement

HAB - Harmful Algal Blooms

LaMP - Lakewide Management Plan

MDEQ - Michigan Department of Environmental Quality

MDNR - Michigan Department of Natural Resources

NGO - Non-Government Organization

NWRI - National Water Research Institute (Canada)

NYSDEC - New York State Department of Environmental Conservation

NYSDOH - New York State Department of Health

ODNR - Ohio Department of Natural Resources

ODH - Ohio Department of Health

OEPA - Ohio Environmental Protection Agency

OMNR - Ontario Ministry of Natural Resources

OMOE - Ontario Ministry of the Environment

SRP - Soluble Reactive Phosphorus

U.S. EPA - United States Environmental Protection Agency

µg - Microgram

Glossary

anoxia - a condition where dissolved oxygen in the water column is totally depleted.

anthropogenic - of man-made origin, not occurring naturally.

benthos - bottom-dwelling organisms.

bioaccumulation - the process whereby a contaminant increases in an organism over time in relation to the amount consumed in food or absorbed from the surrounding environment.

biomass - the total mass (weight) of all living organisms in an area

biotic - of or relating to living organisms.

chlorophyll a - the pigment that makes plants and algae green. Measurement of chlorophyll a is used to determine the quantity of algae in the water.

Cladophora - a long filamentous type of green algae that attaches to hard surfaces, particularly near the shoreline. Abundant growth is an indicator of phosphorous enrichment.

dissolved oxygen - the amount of oxygen measured in the water.

ecosystem - the complex of a living community and its physical and chemical environment, functioning together as a unit in nature, with some inherent stability.

eutrophication - the process by which a lake becomes rich in dissolved nutrients and deficient in oxygen, occurring either as a natural stage in lake maturation or artificially induced by human activities such as the addition of fertilizers and organic wastes from runoff.

Great Lakes Water Quality Agreement - an agreement signed by the United States and Canada to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin ecosystem.

hypolimnion – the cooler, lower most layer of water in a thermally stratified lake.

hypoxia – the reduction of oxygen levels.

lake effect zone - the area within the tributary where the water of Lake Erie and the river are mixed. This is typically the point at which the tributary reaches lake level. The size of the lake effect zone for every river is different and also varies with rising and falling lake levels.

loadings - the amount of pollutants being discharged or deposited into the lake.

limiting nutrient - A chemical nutrient, such as phosphorus, which is necessary for growth but is currently insufficient relative to other required nutrients and so controls potential plant growth.

microcystin - a naturally-occurring, potent liver toxin produced by species of blue-green algae

Microcystis - a blue-green algae that causes algae blooms under eutrophic, high phosphorus conditions. It can be toxic to aquatic life and humans if ingested in sufficient quantities due to the presence of microcystin.

phytoplankton - planktonic algae.

soluble reactive phosphorus - The fraction of phosphorus (defined by methodology) consisting largely of the inorganic orthophosphate (PO4) form of phosphorus. Orthophosphate is directly taken up by algae, and the concentration of this fraction constitutes an index of the amount of phosphorus immediately available for algal growth.

stratification - water stratification occurs when water of high and low oxygenation, density and temperature forms layers that act as barriers to water mixing.

total phosphorus - the total concentration of phosphorus found in the water.

turbid - sediment or foreign particles stirred up or suspended in the water column that can inhibit growth of submerged aquatic plants and affect other species' behaviour.

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