LAKE HURON LAKEWIDE ACTION AND MANAGEMENT PLAN

2017-2021

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Lake Huron Partnership Agencies, 2017

Bay Mills Indian Community (BMIC)
Chippewa Ottawa Resource Authority (CORA)
Environment and Climate Change Canada (ECCC)
Fisheries and Oceans Canada (DFO)
Little Traverse Bay Bands of Odawa Indians (LTBB)
Maitland Valley Conservation Authority (MVCA)
Michigan Department of Environmental Quality (MDEQ)
Michigan Department of Natural Resources (MDNR)
National Oceanic and Atmospheric Administration (NOAA)
Nottawasaga Valley Conservation Authority (NVCA)
Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)
Ontario Ministry of the Environment and Climate Change (OMOECC)
Ontario Ministry of Natural Resources and Forestry (OMNRF)
Parks Canada (PC)
Saginaw Chippewa Indian Tribe of Michigan (SCIT)
Sault Ste. Marie Tribe of Chippewa Indians
St. Clair Region Conservation Authority (SCRCA)
U.S. Army Corps of Engineers (USACE)
U.S. Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS)
U.S. Environmental Protection Agency (USEPA)
U.S. Fish and Wildlife Service (USFWS)
U.S. Forest Service (USFS)
U.S. Geological Survey (USGS)

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ACRONYMS AND ABBREVIATIONS

AIS – Aquatic Invasive Species
AOC – Area of Concern
AOCiR – Area of Concern in Recovery
BMP – Best Management Practice
BUI – Beneficial Use Impairment
CCME – Canadian Council of Ministers of the Environment
CMC – Chemicals of Mutual Concern
CSMI – Cooperative Science and Monitoring Initiative
Σ_2DDC-CO – Dechlorane plus expressed as the sum of *syn-* and *anti-* isomer
DDT – Dichlorodiphenyltrichloroethane
Dioxins and furans – polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran; PCDD/PCDF
E. coli – Escherichia coli
EGBSC – Eastern Georgian Bay Stewardship Council
FEQG – Federal Environmental Quality Guidelines
GLEI – Great Lakes Environmental Indicator Program (1&2)
GLWQA – Great Lakes Water Quality Agreement or 'The Agreement'
GOs – General Objectives
HABs – Harmful algal blooms
HBCD – Hexabromocyclododecane
LAMP – Lakewide Action and Management Plan
LEOs – Lake Ecosystem Objectives
LC-PFCAs – Long-chain perfluorinated carboxylic acids
PBDEs – Polybrominated diphenyl ethers
PCBs – Polychlorinated biphenyls
PFOA – Perfluorooctanoic acid
PFOS – Perfluorooctane sulfonate
Phragmites – Phragmites australis subsp. australis
SAV – Submerged aquatic vegetation
SCCPs – Short-Chain Chlorinated Paraffins
SRP – soluble reactive phosphorus
TCDD – Tetrachlorodibenzo-*p*-dioxin (usually in reference to congener 2,3,7,8-)
TEQs – Toxic Equivalents
TP – Total phosphorus
Ww – wet weight

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EXECUTIVE SUMMARY

Lake Huron is the third largest Great Lake by volume and consists of four distinct, but interacting water bodies (Main Basin, North Channel, Georgian Bay, and Saginaw Bay). Its watershed, the largest of the Great Lakes, contains rich boreal and mixed hardwood forests, productive agricultural lands, extensive recreational areas, and more than thirty thousand islands. The lake is large enough to moderate local climate, powerful enough to shape shorelines and provides vital natural resources. It is a source of inspiration, rejuvenation, and discovery to its visitors and residents.

In keeping with the Great Lakes Water Quality Agreement (the Agreement), the governments of Canada and the United States have committed to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes. This 2017-2021 Lake Huron Lakewide Action and Management Plan (LAMP) fulfills a United States and Canadian commitment of the Agreement to assess ecosystem condition, identify environmental threats, set priorities for research and monitoring, and identify further actions to be taken by governments and the public that address the key threats to the waters of Lake Huron and the St. Marys River.

The LAMP was developed by members of the Lake Huron Partnership, a collaborative team of natural resource managers led by the governments of Canada and the U.S., in cooperation and consultation with State and Provincial Governments, Tribal Governments, First Nations, Metis, Municipal Governments, and watershed management agencies.

STATE OF LAKE HURON

Overall, Lake Huron is in "fair" condition, based on a synthesis of science and monitoring results that measure the achievement of nine General Objectives under the Agreement (Table i).

The waters of Lake Huron continue to provide high-quality drinking water, and its extensive beaches and nearshore areas provide excellent opportunities for swimming and recreation.

Chemical pollutants have declined significantly since the 1970s; however, fish and wildlife consumption advisories remain to protect human health. The majority of nearshore waters are of high quality, but areas of the southeast shore, Saginaw Bay, and eastern Georgian Bay experience episodic algal blooms. Nutrient and algae levels in the off shore are variable but largely below targets. Non-native, invasive Zebra and Quagga Mussels are associated with the decline in nutrient levels and nutrient availability to other organisms, increased water clarity, and nuisance algae growth and are suspected to facilitate episodic botulism outbreaks in parts of the basin. *Diporeia*, a major food source for prey fish, are declining, resulting in negative consequences for recreational and commercial fisheries. However, Walleye have largely recovered in Michigan waters of Lake Huron, and in the absence of the invasive Alewife, Lake Trout populations are approaching reproduction targets. The fragmentation of habitat continues; however, many high-quality areas are being protected or enhanced to support ecosystem services and resiliency to climate change impacts.

Table i. Status of Lake Huron in relation to the 2012 *GLWQA* General Objectives.

	GENERAL OBJECTIVE	STATUS
1.	Be a source of safe, high-quality drinking water.	GOOD
2.	Allow for unrestricted swimming and other recreational use.	GOOD
3.	Allow for unrestricted human consumption of the fish and wildlife.	FAIR
4.	Be free from pollutants that could harm people, wildlife or organisms.	GOOD
5.	Support healthy and productive habitats to sustain our native species.	FAIR
6.	Be free from nutrients that promote unsightly algae or toxic blooms.	FAIR
7.	Be free from aquatic and terrestrial invasive species.	POOR
8.	Be free from the harmful impacts of contaminated groundwater.	GOOD
9.	Be free from other substances, materials or conditions that may negatively affect the Great Lakes.	FAIR

Based on these findings, the Lake Huron Partnership has identified five priority threats to the waters of Lake Huron and the St. Marys River, including:

- Chemical contaminants;
- Nutrients and bacterial pollution;
- Loss of habitat and native species;
- Invasive species; and
- Climate change impacts.

The active threats identified above are the focus of this plan, while recognizing that there are also risks to water quality from possible spills or accidents. Other new or emerging threats may also impact the basin beyond the timeframe of this LAMP, 2017-2021. Assessing and managing those risks fall under the regulatory purview of the various jurisdictions around the lake, and are thus subject to their consulting and permitting processes.

PRIORITY SCIENCE AND MONITORING ACTIVITIES

Management priorities that would benefit from additional scientific study are identified by the Lake Huron Partnership with input from stakeholders and the public. Partnership agencies undertake routine research and monitoring on the Great Lakes, and through a Cooperative Science and Monitoring Initiative (CSMI), conduct a focused binational effort for each lake on a five-year rotational basis.

The CSMI is a joint United States and Canadian effort implemented under the Great Lakes Water Quality Agreement. CSMI provides environmental and fishery managers with the science and monitoring information necessary to make management decisions on each Great Lake. The intensive CSMI field year follows a five-year rotating cycle in which the lakes are visited one per year. The emphasis on a single lake per year allows for coordination of science and monitoring activities focused on information needs not addressed through routine agency programs, and cooperation on specific science assessments.

Lakewide priorities for 2017 include the following:

- Improved understanding of nutrients (sources, sinks, pathways and loadings) and nutrient-related issues (nuisance and harmful algal blooms);
- An evaluation of food web status, lake productivity, invasive species abundance, and fish production; and
- Characterization of chemical contaminants.

The Lake Huron CSMI field year is 2017, with data interpretation, analysis and reporting occurring in subsequent years.

LAKEWIDE ACTION AND MANAGEMENT

Over the next five years, members of the Lake Huron Partnership will undertake 43 actions to address priority environmental threats to water quality and the ecosystem health of Lake Huron and the St. Marys River. Management actions are organized by environmental threat in Table ii along with the responsible agencies.

IMPLEMENTATION AND ACCOUNTABILITY

Members of the Lake Huron Partnership look forward to advancing the binational protection and restoration of the Lake Huron and St. Marys River ecosystem through the implementation of this five-year plan. Members of the Partnership will work with watershed management agencies, local public agencies and the public, and indigenous people to implement the management actions. Coordination of efforts will be assisted through regular communication among the Lake Huron Partnership agencies. Tracking and reporting by the Partnership agencies will help in the assessment of progress and support accountability.

The Lake Huron LAMP is intended for anyone interested in the Lake Huron ecosystem and its water quality.

Table ii: Lake Huron Partnership actions that address key environmental threats.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
	CHAPTER 5.1: CHEMICAL CONTAMINANTS	
	ADDRESSING POINT SOURCE CHEMICAL CONTAMINANTS	
1	Federal, provincial, state and regulatory partners monitor and ensure compliance with clean water laws and regulations.	
	ADDRESSING SEDIMENT CHEMICAL CONTAMINANT REMEDIATION	
2	Continue the multi-year sediment remediation on the Tittabawassee River Floodplain – Dow Chemical Superfund site. The dioxin-contaminated floodplain includes approximately 4500 acres (1821 ha) and extends 21 miles (34 km) from Midland, Michigan, through several counties to Saginaw Bay.	MDEQ, Saginaw Chippewa Indian Tribe of Michigan (SCIT), USEPA
3	Continue efforts to develop a sediment management plan appropriate for the Canadian portion of the St. Marys River.	ECCC, OMOECC
4	Continue the multi-year sediment remediation on the Flint River at the former Chevy Commons Site in Flint, Michigan. To prevent the mobilization of contaminated sediments, the site is being capped and green infrastructure is being installed.	USEPA, USFS
	ADDRESSING NON-POINT SOURCE CHEMICAL CONTAMINANTS	
	Refer to *Chapter 5.2: Nutrients and Bacterial Pollution* section of the table for non-point source pollution actions.	
	ADDRESSING CONTAMINATED GROUNDWATER	
5	Track the investigation and mitigation of perfluorinated chemicals in groundwater at the former Wurtsmith Air Force Base in Oscoda, Michigan.	MDEQ
	ADDRESSING CHEMICAL CONTAMINANT MONITORING	
6	Continue monitoring and periodic reporting on atmospheric pollutant deposition at Great Lakes stations.	ECCC, USEPA
7	Conduct long-term sediment contaminant monitoring in the Spanish Harbour Area of Concern in Recovery to track recovery.	ECCC, OMOECC
8	Continue long-term monitoring of Lake Huron water and sediment contaminants to examine legacy organics, PAHs, trace metals, Hg, and selected new and emerging compounds.	ECCC, USEPA
9	Conduct fish contaminant monitoring in each year between 2017 and 2021.	CORA, MDHHS, MDNR, SCIT, USEPA
10	Conduct annual Herring Gull monitoring in each year between 2017 and 2021 at sampling locations within the Lake Huron basin.	ECCC, MDEQ
11	Update and, where needed, develop acceptable fish consumption guidance.	LTBB
	CHAPTER 5.2: NUTRIENTS AND BACTERIAL POLLUTION	
	POINT SOURCE POLLUTION	
12	***Wastewater Treatment Plants and Stormwater Management Systems:*** • Enforce permitted discharges to ensure receiving waters meet Water Quality Standards; • Enhance the use of green infrastructure and low impact urban development.	Conservation Authorities, MDEQ, OMOECC, SCIT, USACE, USEPA, USFS
	NON-POINT SOURCE POLLUTION IN AGRICULTURAL AREAS	
13	***Nutrient and Bacteria Control:*** Build on existing integrated and systematic efforts within targeted watersheds to improve soil health, reduce overland runoff of nutrients, sediments, and bacteria, and maintain and restore natural heritage features:	

	• Implement agricultural BMPs, for example, USDA NRCS' Regional Conservation Partnership Program titled 'Saginaw Bay Watershed Conservation Partnership', co-led by Michigan Agri-Business Association and The Nature Conservancy, within high-priority sub-watersheds (Shiawassee, Pigeon/Pinnebog, Cass, Pine/Chippewa, Sebewaing, and Kawkawlin Rivers); • Address nuisance and harmful algae and promote safe and clean beaches in priority watersheds in Ontario's southeast shore (Pine River, Garvey Glenn, North Bayfield, Main Bayfield, Lambton Shores) through the following actions: - Targeted agricultural BMP and edge-of-field monitoring; - Continuous flow and event-based water quality monitoring and reporting; - Identification of additional priority watersheds in the Lake Huron watershed; - Outreach and engagement with landowners and the public.	MDEQ, SCIT, USDA-NRCS Conservation Authorities, OMAFRA, OMNRF, OMOECC, Parks Canada
14	***Watershed Management Planning and Implementation:*** Renew and/or develop integrated watershed management plans and link to coastal and nearshore management and other nutrient reduction actions at a community level: • Build local capacity for monitoring and best management practice implementation, and encourage and promote community involvement; • Implement the Tipping Points Planner for communities to build local capacity; and • Continue to implement management plans under Section 319 Nonpoint Source Management Program of the U.S. Clean Water Act.	BMIC, Conservation Authorities, MDEQ, NOAA, OMAFRA, OMNRF, OMOECC, SCIT, USDA-NRCS, USEPA, USFS
SCIENCE, SURVEILLANCE, AND MONITORING		
15	***Open Water:*** Conduct spring and summer open water nutrient and lower foodweb surveys.	ECCC, USEPA
16	***Agricultural Areas***: Continue edge-of-field water quality monitoring in targeted Ontario and Michigan watersheds to assess effectiveness of best management practices.	Conservation Authorities, OMOECC, USDA-NRCS, USGS
17	***Streams***: Continue surface water quality monitoring and synthesis of information from various stream and river locations: • Joint program between the province of Ontario and conservation authorities via the Provincial Water Quality Monitoring Network (PWQMN); and • Continue to assess stream water quality under Section 305(b) of the U.S. Clean Water Act.	Conservation Authorities, MDEQ, OMOECC, USEPA
18	***Watershed***: • Continue a multi-watershed nutrient study, to assess the interaction between agricultural land use and nutrient loadings in southeast shore streams. • Continue surface water monitoring on lakes and wetlands under Tribal jurisdiction.	Conservation Authorities, LTBB, OMOECC
19	***Saginaw Bay Water Quality and Harmful Algal Bloom (HAB) Monitoring and Reporting:*** • Explore expanding real-time water quality and nutrient buoy system to several sites in inner Saginaw Bay; • Enhance monitoring and reporting of algal blooms on NOAA-GLERL's HAB and Hypoxia webpage to provide weekly updates from June through October; • Conduct experiments to understand the environmental factors that influence changes in algal bloom community composition, toxicity, and ecosystem services; • Develop a Saginaw Bay Harmful Algal Bloom Bulletin; and • Develop a Saginaw Bay 3D- HAB Tracker product similar to the current 3D-HAB Tracker developed for western Lake Erie.	NOAA-GLERL
20	***Science Synthesis:*** Assemble, synthesize, and report on nutrient and bacterial contamination science and monitoring results from projects funded by the Lake Simcoe/South-eastern Georgian Bay Clean Up Fund (2012-2017).	ECCC

21	***Research and Monitoring:*** Improve understanding of invasive mussels and their influence on phosphorus cycling in the aquatic system and *Cladophora* growth.	USEPA
OUTREACH AND EDUCATION		
22	***Communication***: Undertake outreach and education on local and regional scales to increase the understanding of water quality condition and management challenges, nearshore and beach health, and best management practices and policies.	Bay Mills Indian Community (BMIC), ECCC, LTBB, OMOECC, SCIT, USFS
CHAPTER 5.3: LOSS OF HABITAT AND SPECIES		
23	***Spawning Reefs and Shoals:*** Continue to develop strategies and implementation plans that rehabilitate and/or create nearshore reefs to support overall lake productivity.	MDEQ, MDNR, SCIT, USACE, USFWS, USGS
24	***Aquatic Habitat Protection and Restoration:*** Assess streams and estuaries to determine aquatic habitat significance, stressors, and limitations to fish spawning and migration, and consult with local partners, stakeholders, and governments to identify rehabilitation priorities, including: • Assessment of Eastern Georgian Bay estuaries with project implementation.	MDNR, OMNRF, SCIT, USFS
25	***Stream Connectivity:*** Restore stream connectivity and function through dam removal, the construction of fish passage alternatives (e.g., ladders), and stream culvert improvements to compensate for loss of riverine habitat.	Conservation Authorities, LTBB, MDEQ, MDNR, NOAA, OMNRF, USACE, USDA-NRCS, USFS, USFWS
26	***Habitat and Native Species Conservation***: Build on information in *"The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron"* through integrated conservation planning to identify areas of ecological significance and areas facing environmental threats and stressors: • Update and share Canadian geospatial information on ecosystem classification (Lead -OMNRF); • Engage stakeholders and the public; • Facilitate information sharing; • Develop regional conservation and stewardship plans (Ontario); and • Promote community-based conservation and stewardship.	Conservation Authorities, DFO, ECCC, USFS, MDEQ, MDNR, OMNRF, OMOECC, PC, USDA-NRCS, USEPA, USFWS
SPECIES RECOVERY AND MONITORING		
27	***Walleye Restoration***: Develop a Walleye Management Plan for the Ontario waters of Lake Huron and track the effectiveness of harvest regulations throughout Lake Huron.	OMNRF
28	***Cisco Restoration:*** Examine the benefits of reintroducing Cisco to targeted areas of the lake.	MDNR, OMNRF, USFWS, USGS
29	***Coastal Wetlands:*** Monitor coastal wetlands to assess coastal wetland water quality, species diversity, and the impacts of human activities; and promote protection, restoration and enhancement efforts. • Utilize green engineering to soften shorelines that have been previously hardened; and • Apply new decision support tools to help identify and prioritize coastal wetland restoration projects.	BMIC, Conservation Authorities, ECCC, NOAA, OMNRF, PC, SCIT, USACE, USEPA, USFWS
CHAPTER 5.4: INVASIVE SPECIES		
30	***Ballast Water:*** Establish and implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of AIS in ballast water, consistent with commitments made by the Parties through Annex 5 of the *GLWQA*.	Transport Canada, USCG, USEPA
31	***Early Detection and Rapid Response:*** Through the Annex 6 subcommittee, implement an 'early detection and rapid response initiative' with the goal of finding new invaders and preventing them from establishing self-sustaining populations.	DFO, LTBB, USFS, USFWS

32	***Canals and Waterways:*** Through the Asian Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead and Silver Carp in the Great Lakes.	USEPA, USFWS
33	***Sea Lamprey:*** • Control the larval Sea Lamprey population in the St. Marys River with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate. • Design and construct Au Gres Sea Lamprey Trap in Arenac County, Michigan. • Design and construct Au Sable Sea Lamprey Trap in Losco County, Michigan.	DFO, USACE, USFWS
34	***Improve understanding of invasive species impacts to inform management efforts:*** • *Impacts of Round Goby on the Foodweb:* Enhance assessment methods and technology to better understand Round Goby population density and distribution. • *Causes of Botulism Outbreaks:* Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl. • *Cladophora growth*: Work through the Annex 4 subcommittee to support the creation of Lake Huron sentinel *Cladophora* monitoring sites to determine the role of mussels in nearshore algae growth and possible mitigation efforts.	MDNR, NOAA, OMNRF, USGS
35	***Control of Terrestrial and Wetland Invasive Species:*** Maintain coastal and nearshore aquatic habitat diversity and function through appropriate control of *Phragmites* and other detrimental invasive species (e.g. Glossy Buckthorn, European Frog-bit, Purple Loosestrife, Japanese Knotweed) including monitoring, mapping, and control efforts guided by BMPs. • Coordinate *Phragmites* control efforts and share BMPs through the *Ontario Phragmites Working Group* and *Great Lakes Phragmites Collaborative.*	BMIC, MDNR, NVCA, OMNRF, Parks Canada, SCIT, SCRCA, USDA-NRCS, USEPA, USFS, USFWS
SCIENCE, SURVEILLANCE, AND MONITORING		
36	***Surveillance***: Maintain and enhance early detection and monitoring of non-native species (e.g. Asian Carp) through the Annex 6 *Early Detection and Rapid Response Initiative.*	DFO, MDNR, OMNRF, USEPA, USFS, USFWS
37	***Monitoring***: Maintain an index time series that shows the impact of Sea Lamprey control on Lake Trout population status.	MDNR
OUTREACH AND ENGAGEMENT		
38	***Communication***: Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage.	BMIC, DFO, LTBB, MDEQ, OMNRF, SCIT, SCRCA, USFS
CHAPTER 5.5: CLIMATE CHANGE IMPACTS		
CLIMATE CHANGE ACTIONS Actions identified for nutrients and bacterial pollution and loss of habitat and native species will help to maintain ecosystem function and enhance resilience to the impacts of climate change.		
39	***Watershed Resilience***: Continue efforts that engage landowners and the public to protect and enhance the function and resilience of watershed headwater features, streams, forests, and wetlands to maintain and enhance resilience to climate change impacts, including Conservation Authority Climate Change Strategies and Actions.	Conservation Authorities, MDNR, OMOECC, USDA-NRCS, USFS
40	***Coldwater Fishes and Streams:*** Support the protection and enhancement of coldwater fishes: • Develop Lake Trout monitoring and rehabilitation plans; • Identify potential restrictions preventing passage of migratory fish; and • Create and enhance coldwater refuges where appropriate to maintain appropriate habitat conditions for aquatic organisms.	Conservation Authorities, MDNR, OMNRF, USFS
41	***Critical Community Infrastructure:*** Plan and implement LID initiatives that are suited to future extreme weather events via watershed work that increases green space and	Conservation Authorities, OMOECC, SCIT, USFS

	green infrastructure. • Michigan Low Impact Development manual (section 319 funding supporting Michigan non-point source grant programs); • Ontario Low Impact Development manual; and • Lake Simcoe Low Impact Development Guidance Documents.	
42	***Coastal Resilience:*** Conduct study along Lake Huron shoreline to investigate opportunities to improve resilience within both the human and natural coastal environments.	NOAA, USACE
OUTREACH AND EDUCATION		
43	***Communications:*** Undertake and support outreach and education to stakeholders and the public on the impacts of climate change to the Great Lakes and Lake Huron through fact sheets, newsletters and other means.	Conservation Authorities, ECCC, NOAA, USFS

1.0 INTRODUCTION

The Lake Huron Lakewide Action and Management Plan (LAMP) is a five-year, ecosystem-based strategy for restoring and maintaining the water quality of Lake Huron and the St. Marys River.

The Lake Huron LAMP fulfills a United States (U.S.) and Canadian commitment of the Great Lakes Water Quality Agreement (the Agreement) to assess ecosystem conditions, identify environmental threats, and set priorities for research and monitoring. The Agreement recognizes that the best approach to restore the Lake Huron ecosystem and improve water quality is for the two countries to adopt common objectives, implement cooperative programs, and collaborate to address environmental threats.

The LAMP is a world-recognized model for cooperation among governmental jurisdictions and their management agencies. It represents a shared understanding of the health of Lake Huron and a means for coordinating and documenting management actions.

The LAMP was developed by member agencies of the Lake Huron Partnership, a collaborative team of natural resource managers led by the governments of the U.S. and Canada, in cooperation and consultation with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, and watershed management agencies. The LAMP supports an adaptive management approach (Figure 1) for restoring and maintaining Lake Huron water quality and will guide activities by management agencies for the years 2017 to 2021.

1.1 THE GREAT LAKES WATER QUALITY AGREEMENT and LAKEWIDE MANAGEMENT

Since 1972, the Agreement has guided U.S. and Canadian actions that restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes. In 2012, the U.S. and Canada amended the Agreement, reaffirming their commitment to protect, restore, and enhance water quality and to prevent further degradation of the Great Lakes basin ecosystem (Canada and United States, 2012).

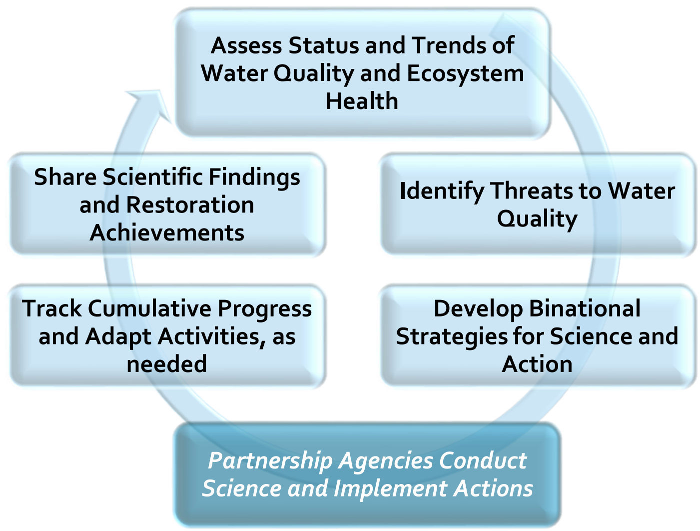


Figure 1. An adaptive lakewide management approach for Lake Huron.

Table 1. Great Lakes Water Quality Agreement Annexes.

1.	Areas of Concern
2.	Lakewide Management
3.	Chemicals of Mutual Concern
4.	Nutrients
5.	Discharges from Vessels
6.	Aquatic Invasive Species
7.	Habitats and Species
8.	Groundwater
9.	Climate Change Impacts
10.	Science

The Agreement commits Canada and the United States to address 10 priority issues or 'Annexes' (Table 1). The Lake Huron LAMP is a cross-cutting approach that integrates information and management needs from each of these Annexes, with a focus on Lake Huron-specific management needs to maintain, restore and protect water quality and ecosystem health.

1.2 ALIGNMENT WITH OTHER INTERNATIONAL RESOURCE MANAGEMENT EFFORTS

The Lake Huron Partnership actively works to ensure that management actions identified in this LAMP are complementary to several other international management efforts established under various binational treaties, agreements, and programs, and also work within the Lake Huron ecosystem.

Water Levels Management: The International Joint Commission provides oversight of water levels and flows in the Great Lakes, including the control structure in the St. Marys River. http://www.ijc.org/en_/Great_Lakes_Water_Quantity

Water Withdrawals Management: The Great Lakes–Saint Lawrence River Basin Sustainable Water Resources Agreement details how eight Great Lakes states and the provinces of Ontario and Quebec manage their water supplies. The Great Lakes-St. Lawrence River Basin Water Resources Compact is a legally binding interstate compact and a means to implement the governors' commitments.
http://www.glslregionalbody.org/index.aspx
http://www.glslcompactcouncil.org/

Fishery Management: The Great Lakes Fishery Commission (GLFC) facilitates cross-border cooperation to improve and preserve the fishery. The Lake Huron Committee is comprised of senior officials from state, provincial, and U.S. intertribal fishery agencies. The Committee is charged with collecting data, producing and interpreting science, and making recommendations. The Committee also develops shared fish community objectives, establishes appropriate stocking levels and harvest targets, sets law enforcement priorities, and formulates management plans.
http://www.glfc.org/joint-strategic-plan-committees.php
http://www.glfc.org/lake-huron-committee.php

ACTIVITIES THAT EVERYONE CAN TAKE

Public awareness and appreciation of water quality issues are important aspects of this LAMP. There are many opportunities to get involved in protecting Lake Huron water quality and ecosystem health.

Look for other '*Activities that Everyone Can Take'* information in the 'Actions' section of this LAMP; also refer to the Outreach and Engagement Chapter. Local watershed organizations also work to improve water quality - contact one near you to volunteer!

During the implementation of this LAMP, member agencies of the Lake Huron Partnership will assess the effectiveness of actions and adjust future actions to achieve the objectives of this plan, as outcomes and ecosystem processes become better understood.

The LAMP is intended for anyone interested in the Lake Huron ecosystem, its water quality, and the actions that will help restore this unique Great Lake.

Picturesque islands set within crystal waters provide important habitat and recreational opportunities (E. Perschbacher).

2.0 THE INHERENT VALUE, USE, AND ENJOYMENT OF LAKE HURON

Lakewide management is guided by a shared vision of a healthy, prosperous, and sustainable Great Lakes region in which the waters of Lake Huron are used and enjoyed by present and future generations.

The Lake Huron Partnership derives its vision for lakewide management from the Great Lakes Water Quality Agreement. The Lake Huron watershed is currently home to three million people (~1.4 million Ontarians and ~1.6 million Michiganders) and has been used and enjoyed for thousands of years. We continue to recognize the inherent natural, social, spiritual, and economic value of the Lake Huron basin ecosystem. Sound management and use will benefit present and future generations.

The following text provides a brief cultural description of the earliest inhabitants, how resource use supports the regional economy, and how tourism and recreation - a growing part of the economy - is supported by the many parks and conservation areas within the watershed.

2.1 INDIGENOUS PEOPLE AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The Anishinaabeg / Anishinabek people ("the Original People") have called the Lake Huron basin home for 15,000 years as evidenced by carbon-dating on Manitoulin Island (Mindo-mnising) and elsewhere. The shores, islands, and rivers acted as gateways that carried the Anishinaabeg / Anishinabek in all directions and provided a vast trading route and opportunities to hunt, trap, fish, and harvest plant materials for food, medicines, lodges, and canoes.

Spread across Michigan and Ontario, the Anishinaabeg / Anishinabek culture, traditions, and values link communities to the land and water. Figure 33 in Appendix A shows Lake Huron basin indigenous communities. The people have served as caretakers of the land, water, plants, and animals of Lake Huron (Gichi-aazhoogami-gichigami – Great Crosswater Sea) and the St. Marys River (Gichigami-ziibe – Sea River). This role maintains traditional ways of life dependent upon species such as White Cedar (*Giizhik / Giizhig*), Northern Pike (*Ginoozhe / Ngnoozhe*), Whitefish (*Adikameg / Tikmeg*), Wild Rice (*Minoomin / Manomin*), Sweetgrass (*Weengush / Wiingush*), and the earth itself in the form of clay (*waabigan / waabgan*) for use in pottery.

Figure 2: Lake Huron Basin Indigenous Communities. (Bay Mills Indian Community, Great Lakes Indian Fish and Wildlife Commission, Saginaw Chippewa Tribe, http://sidait-atris.aadnc-aandc.gc.ca/atris_online/home-accueil-eng.aspx)

Anishinaabeg / Anishinabek embrace water as a living being. It lives in all living things, water is life itself, and water is the lifeblood of Mother Earth (Shkakami-kwe). Language and the original names of the lakes, rivers, and streams give great meaning to each community's culture, identity, and heritage.

The cultures and traditions of the indigenous people are dependent upon Traditional Ecological Knowledge. The term "traditional" refers to the knowledge gathered over time and the close relationship and contact between the Anishinaabeg / Anishinabek and the environment (Shkakami-kwe - Mother Earth). It is the kind of intimacy that comes from knowing a place profoundly, not just as scenery, but also as sustenance; knowledge is passed on with a sense of trust through generations.

To continue this relationship, indigenous people integrate modern and advanced science to ensure the health of the natural world. The sacred responsibility entrusted to the Anishinaabeg / Anishinabek is to look after the four elements: earth (land), water, air, and fire. The Anishinaabeg / Anishinabek believe that everything is connected and that shared resources do not belong to any one person or nation; rather, they are viewed as part of an interconnected web of life fundamental to the traditional ways of life that must be treated with the utmost respect and care *(Content by the Union of Ontario Indians and Lake Huron Partnership members representing U.S. Tribes).*

2.2 NATURAL RESOURCES AND THE REGIONAL ECONOMY

The abundant natural resources within Lake Huron and its watershed support a strong regional economy. Extensive water-based industries, commercial and recreational fishing, commercial shipping, mining, forestry, and agricultural operations are major employers and contributors to the economy, as described below.

Water Use and Water-based Industries: Lake Huron provides 1,461.51 million litres of freshwater per day (6,136.9 Mgal/day) to the public, agricultural, industrial, and thermoelectric power industries. Over 2.3 million people get their drinking water from Lake Huron - including communities outside of the Lake Huron watershed such as parts of Detroit, Michigan and London, Ontario. Hydroelectric generation stations on the St. Marys River generate 115 million watts of power (International Upper Great Lakes Study, 2012).

Commercial and Recreational Fishing: Lake Huron is the second major fish producing Great Lake with Whitefish, Walleye, Yellow Perch, Lake Trout, and Ciscoes comprising the foundation of the commercial fishery (Environmental Commissioner of Ontario, 2011). The 2015 harvest statistics for Ontario exceeded $4.7 million dollars (OMNRF, 2015). Michigan's 2015 commercial harvest exceeded $2.5 million dollars (U.S.) (T. Goniea, MDNR, pers. comm., 2016). In Canada, direct recreational fishing expenditures are highest for Lake Huron relative to other Great Lakes, totaling over $92 million (OMNRF, 2016). Saginaw Bay supports a world class recreational fishery valued in excess of $33 million (U.S.) per year (Fielder, et al. 2014).

Commercial Shipping: The St. Marys River is an industrial hub for manufacturing. The river and the Soo Locks provide U.S. and Canadian Lakers and Salties access to Great Lakes ports and eventual overseas destinations delivering approximately 79% of the iron ore mined in the United States (Kakela, 2013). Shipping ports including Goderich, Sarnia, Port Huron, Mackinaw City and Saginaw, each with a positive economic impact on Ontario and Michigan's commerce, contribute over 90,000 jobs and $13.4 billion (Can) to both economies (Chamber of Marine Commerce, 2011).

Mining: Salt, limestone and metal mines support many local economies (OMNDM, 2011; GLEAM, 2014). The world's largest limestone and salt mines are located in Rogers City, Michigan and Goderich, Ontario.

Forestry: The northern watersheds abound with forest resources that have made significant contributions to the establishment of communities and that generate economic benefits from lumber sales. One pulp and paper mill still operates at Espanola, Ontario.

Agriculture: Agriculture is an important business sector. The southern watersheds of Ontario and Michigan contain some of the most productive farmland in the basin. Approximately 800,000 hectares (1.98 million acres) of farmland are under production on 6,500 farms throughout Lambton, Huron and Bruce counties of southwestern Ontario. Annual total farm receipts amount to just over $2 billion (Can) (OMAFRA, pers. comm., 2016). In the Saginaw Bay and thumb region, there are approximately 1 million hectares (2.7 million acres) under production on 11,000 farms with the Bay, Genesee, Gratiot, Huron, Isabella, Lapeer, Saginaw, Sanilac, Shiawassee and Tuscola counties totaling roughly $76 million dollars (US) in total gross income (2012 Census of Agriculture; USDA-National Agricultural Statistics Service).

Aquaculture: Parts of Manitoulin Island, the North Channel, and Georgian Bay support a number of cage aquaculture operations growing predominantly Rainbow Trout in Ontario waters. The 2015 production statistics indicate that approximately 4,500 tonnes of fish were produced with a farm-gate value of $23.2 million (Statistics Canada, 2016).

2.3 TOURISM AND RECREATION: PARKS, WILDLIFE REFUGES, AND CONSERVATION AREAS

Parks, wildlife refuges, and conservation areas provide opportunities for tourism and recreation, while also fostering connections with the unique places within the watershed. These areas also strengthen the resiliency of the watershed and the extraordinary diverse habitat and species found within it. Most of the nearshore waters now have established routes, known as "water trails", that provide spectacular opportunities to explore the coastline with kayaks, canoes, and other small watercraft. Despite Lake Huron's significant coastal and nearshore ecosystem, almost 82% of the shoreline is not protected. This highlights the importance of existing parks and protected areas as refuges for fish and wildlife and for the protection of biodiversity (Scott Parker, pers. comm., 2016).

The following information provides regional examples of the variety of protected areas along the shores of Lake Huron.

Southeast Shores: Few protected areas exist in the southern agricultural landscape of Ontario, making Provincial Parks like the Pinery, Point Farms, Inverhuron, and MacGregor Point important sanctuaries for rare and fragile savannahs, dunes, and vestiges of coastal wetlands. These shorelines contain some of the highest quality and longest freshwater sand beaches (e.g., Sauble Beach, Ontario) that attract residents and millions of tourists.

Sand beach and dune complex at Pinery Provincial Park, Ontario (Ausable Bayfield Conservation Authority).

Georgian Bay: On the Bruce Peninsula, 420 million year-old rock formations rise through the waters to form part of the Niagara Escarpment, one of the most prominent topographical features of southwest Georgian Bay. It is home to the Bruce Peninsula National Park and Fathom Five National Marine Park.

Crystal waters and trails provide connections to the ecology and geology of the Bruce Peninsula (G. Mayne).

Two of Canada's Biosphere Reserves are located in Georgian Bay, one on the Bruce Peninsula, and the other along the eastern Georgian Bay coast. They are recognized by the United Nations Educational Scientific and Cultural Organization as ecologically significant regions that strive to balance development and conservation.

The rugged landscape of eastern Georgian Bay and its 30,000 islands inspire tourists, artists, and nature lovers from far and near. The French River Provincial Park in north-eastern Georgian Bay protects a remarkable1,000 km (621 miles) of coastal and nearshore habitat; more than any protected area in the Great Lakes.

Scenic islands of eastern Georgian Bay (T. Morrissey).

North Channel: Recognized as one of the best freshwater cruising grounds in the world, the North Channel features a vast number of uninhabited islands with sheltered anchorages, a natural fjord, and the world's largest freshwater island – Manitoulin Island.

The many islands of the North Channel provide critical habitat and recreational opportunities (OMNRF).

St. Marys River: This River is both a Great Lakes connecting channel and an international boundary water that separates Ontario and Michigan. It is a complex mix of riverine and lake-like reaches that has been modified to accommodate shipping. To the southwest, Michigan's Straits of Mackinac, Les Cheneaux island complex, and Upper Peninsula port towns and marinas provide harbours, sheltered channels and bays for excellent fishing, boating and exploring.

Aerial view showing the complexity of the St. Marys River.

Michigan's Western Shores: Michigan's coastline offers many opportunities for tourists and seasonal vacationers to explore Lake Huron. Thunder Bay National Marine Sanctuary was expanded to 4,300 square miles (11,000 km^2) in 2014 protecting one of America's best-preserved collections of 116 shipwrecks.

Huron National Forest: Roughly 450,336 acres (182,244 ha) of public lands extend across the northeastern part of Michigan. The Au Sable River meanders across the Forest, and crystal blue lakes dot the landscape providing recreation opportunities for visitors, habitat for fish and wildlife, and resources for local industry.

Saginaw Bay: Saginaw Bay is a shallow productive bay with 240 miles (386 km) of shoreline and abundant coastal wetlands that support a world class fishery (Fielder et. al, 2014). The Bay is designated a globally Important Bird Area for migratory waterfowl and shorebirds (MDEQ, 2012).

Saginaw Bay coastal wetlands provide critical habitat and form part of coastal trails (Saginaw Bay Water Trails).

Shiawassee Wildlife Refuge: More than 9,800 acres (4,000 ha) of marsh, bottomland hardwood forest, and grasslands are found in this Refuge. It is designated as a United States Important Bird Area for its global significance to migratory waterfowl. The Refuge's mission is to preserve and manage an undeveloped expanse of floodplain forest, marshes, rivers, and associated habitat within an agricultural and urban landscape through habitat management, encouraging public stewardship, educational programs, and private land activities.

Through sound management, Lake Huron and its watershed will continue to provide sustenance, employment, rejuvenation and inspiration to its residents and visitors.

3.0 A HEALTHY WATERSHED, A HEALTHY LAKE HURON

The Lake Huron watershed is the area of land that drains rain and snow into streams that flow into the lake. It is the largest watershed of all the Great Lakes. The water quality of Lake Huron depends on the health of its watershed.

Lake Huron's large watershed (118,000 km^2; 45,600 mi^2) and long residence time (22 years) makes it vulnerable to water quality impacts that can originate in its watershed.

This chapter begins with a brief description of the large volumes of water that move through the watershed including the St. Marys River. A "healthy watershed" is described to illustrate how water quality is maintained as water moves from the headwaters, through inland lakes and wetlands, and into the streams that flow to the lake. The chapter concludes by describing how a healthy watershed is critical to ensuring healthy coastal wetlands, nearshore, and offshore waters.

3.1 LAKE HURON WATER SOURCES AND FLOWS

Lake Huron is downstream of Lakes Superior and Michigan and upstream of Lake Erie. On average, it holds about 3540 cubic kilometers (850 cubic miles) of water, depending on the various flows into and out of the lake in a given year, as described below.

If you emptied the water in Lake Huron on to the land of its watershed, it would cover the land to a depth of over 25 meters (85 feet).

Each hour, approximately 8 billion litres of water (~ 2 billion gal) flow from Lake Superior through the St. Marys River. An additional 5.4 billion litres (~1.4 billion gal) of water flow from Lake Michigan through the Straits of Mackinac. Lakes Michigan and Huron have the same surface elevation, hydrologically making them the same body of water.

The watershed itself contributes about 10.4 billion litres of water (~2.7 billion gal) per hour to the lake. About half of the input is from water flowing over the land and into streams that empty into the lake. Rain and snow falling directly on the surface of the lake and groundwater sources contribute the other half.

Water leaves the lake through the various consumptive uses, evaporation and downstream flows. Every hour, about 4.3 billion litres (~1.1 billion gal) of water evaporate from the lake into the atmosphere. An additional 19 billion litres (~5 billion gal) of water per hour exit through the St. Clair River and eventually flow into Lake Erie (Great Lakes Atlas, 1995).

3.2 A HEALTHY WATERSHED

The Lake Huron watershed is comprised of a diverse collection of habitat types, each playing a critical role in maintaining water quality. The following sections describe some of the habitat types and how a healthy watershed functions.

Headwaters and Uplands

Headwaters: Surface drainage features, groundwater seeps, and springs are the origin of streams and small watercourses that form the basis of ecological integrity of our watersheds.

Upland areas encompass the majority of the watershed land area and include both natural habitats and developed areas. Well-functioning uplands allow water to infiltrate into the soil, which minimizes stormwater run-off and reduces the probability of extreme flooding.

Headwaters of the Mad River in the Nottawasaga Valley, Ontario (Nottawasaga Valley Conservation Authority).

Forests: Remnants of Carolinian (i.e., Eastern temperate) forest still exist in the southern-most subwatersheds and support the most diverse flora and fauna assemblage of the basin. Large tracts of Great Lakes St. Lawrence mixed-wood forest are found in parts of Michigan, and in Ontario on the Bruce Peninsula, Georgian Bay and in the northern watershed within the Canadian Shield. All Lake Huron forests and small woodlands provide habitat for wildlife, protection of source water, and important functions such as canopy shade that moderates stream temperature.

Extensive and intact mixed-wood forest of the North Channel help maintain water quality of the North Channel (G. Mayne).

Agricultural Lands: When responsibly farmed, agricultural lands use drainage systems that mimic natural conditions while still allowing for seedbed preparation and planting. The use of buffer strips, cover crops, grassed waterways, and two-stage ditches help to minimize soil erosion and flooding.

Responsibly farmed fields showing grassed waterways that slow water runoff and trap sediments and nutrients (ABCA).

Lake Plain Prairies: Much of the Great Lakes St. Lawrence mixed-wood plains have been converted to agriculture due to their rich soils. However, important vestiges of prairies are still found in the southern part of the watershed. The extensive root systems of trees, shrubs and plants of these plant communities lock soil particles together, helping to prevent soil erosion and water pollution. These sites also support a number of amphibian and reptile species as well as several species of grassland songbirds.

Coastal lake plain prairie near Alpena, Michigan (Michigan Sea Grant).

Alvars: This globally rare habitat is found in areas dominated by limestone geology, including the Bruce Peninsula, Manitoulin Island, and Drummond Island. Alvars are flat, nearly treeless areas of exposed limestone bedrock and shallow soils. In spring, alvars collect water in shallow pools and bedrock pockets, and some areas remain flooded for weeks. By summer, the soils are dry. A number of endemic species have evolved to survive only in this environment (Rescheke et al., 1999; Brownell and Riley, 2000).

One of the globally rare alvars found on the Bruce Peninsula (G. Mayne).

Urban Centers: Well-designed urban centers contain sufficient green space and green infrastructure to manage stormwater and minimize flooding. Green space refers to urban areas covered with grass or trees, such as parks, playing fields, community gardens, and cemeteries. Green infrastructure includes rain gardens, permeable pavement, green roofs, and other stormwater management techniques that soak up, store and slow water. Projects big and small contribute to improved water quality.

Community rain garden in the village of Bayfield, Ontario as part of a green infrastructure project (ABCA).

Inland Lakes and Wetlands

Inland lakes and wetlands act as reservoirs that help to moderate the quantity of water moving through the watershed and remove excess nutrients and sediments otherwise released by severe storms.

Inland lakes: Lakes of all sizes are found throughout the watershed. The biggest inland lakes include Lake Simcoe in Ontario and Burt Lake in Michigan. Water levels in lakes rise with input from precipitation and gradually fall due to evaporation, flows to rivers and groundwater, and periods of drought.

Thousands of lakes dot the Lake Huron watershed like the sapphire waters of Killarney Provincial Park (G. Mayne).

Inland wetlands: Swamps, marshes, acidic bogs, and alkaline fens are all found within the watershed. These wetlands filter and absorb nutrients like phosphorus and nitrogen that can potentially stimulate algal blooms. Wetlands provide critical habitat, help to maintain water quality, slow water movement and minimize the impacts of flooding and pollution.

The Minesing Wetland is of international significance and is home to a diverse array of species (NVCA).

Streams

The 1,761 streams (1,334 Canada, 427 U.S.) throughout the watershed provide spawning habitat for one-third of Great Lakes fishes and allow movement between the headwaters and the lake (Liskauskas et al., 2007). In U.S. waters, over 10,000 km (6213.7 miles) of stream habitat were at one time accessible to Lake Huron fish; an even greater amount of streams habitat was available in Canada. Dams and barriers fragment and degrade river habitat and prevent fish migration; however, many northern streams continue to sustain stocks of Walleye, Pike, threatened Lake Sturgeon, and a tremendous biomass of Suckers.

The Moon River and basin of eastern Georgian Bay support critical spawning habitat (OMNRF).

Cold-water streams, such as the Au Sable River in northern Michigan and the Saugeen River in Ontario, are known world-wide as outstanding trout streams. Warm-water streams like the Ausable River in southwestern Ontario support as many as 26 species of freshwater mussels, up to 85 species of fish and several species of rare and endangered turtles (DFO, 2015).

Interconnected networks of springs, creeks, and streams contribute to biological diversity, water quantity, and quality of Lake Huron.

Coastal Shorelines

Lake Huron's coastal shorelines are renowned for their inspiring beauty. They are the place of greatest human interaction with the lake through recreational and commercial activities. Natural coastal systems are also the last line of defense for the lake, trapping pollution in water runoff before it enters the lake.

Human activities on the coastal shoreline have a direct effect on the lake.

The geology of the coast changes as you circle the lake. In the south, glacial deposits of sand, gravel and till predominate in coastal areas providing fine, white sand beaches. Limestone dominates much of the Bruce Peninsula, Manitoulin Island, the North Channel, and northern Michigan. Rocky shores associated with the Precambrian Shield extend across the eastern and northern shores of Georgian Bay and the North Channel. Natural and responsibly developed shorelines provide protection against erosion while also supporting water quality and ecosystem health.

A diverse mixture of cobble, sand, and dunes with adjacent forest cover on Christian Island, Ontario (G. Mayne).

3.3 HEALTHY WATERS OF THE ST. MARYS RIVER AND LAKE HURON

After water moves through the watershed, it flows into "the waters of Lake Huron". As described in the Agreement, the waters of Lake Huron include the St. Marys River and the interconnected zones of the lake: coastal wetlands, nearshore waters, and open waters. If pollution enters and mixes within these zones, it is nearly impossible to remove. A healthy watershed maintains the health of these waters.

The St. Marys River

The St. Marys River has a long and colourful history as an important Indigenous People gathering place, a center of French and British fur trading, and a 20th century hub for manufacturing. It is also a unique part of the aquatic ecosystem because of the large volume of water discharged (mean 2,140 m^3/s, 78,000 ft^3/s) through a relatively short river length (112 km, 80 mi).

The St. Marys River (M. Chambers).

The River includes three sections: a 22.5-km (14 mi) Lake Superior outlet section; a 1.2-km (0.75 mi) rapids section with facilities and channels for navigation, hydropower, water regulation, and an 88.3-km (55 mi) lower river section largely at Lake Huron elevation. The lower river has the morphology of a complex strait, with substantial water turnover. Narrow channels, broad and wide lakes, four large islands, and many small islands are present. The St. Marys River supports a diverse fish community and an intensive recreational, subsistence, and commercial fishery.

Coastal Wetlands

Lake Huron coastal wetlands represent 30% of those found in the Great Lakes. Wetlands link the open waters with the watershed. Coastal wetlands around the North Channel and Georgian Bay are rated among the most pristine of Great Lakes wetlands, with Silver Creek in the Collingwood area being the largest coastal wetland on Georgian Bay in Ontario. In Michigan, Saginaw Bay contains the largest freshwater coastal wetland system in the United States.

Coastal marshes (the predominant wetland type) provide nesting, resting, and feeding places for hundreds of thousands of migratory and nesting birdlife, including at least 30 species of shorebirds, 27 species of ducks, geese and swans, and several species of terns and gulls.

Over 40 species of rare plants and five rare reptile species are found in the coastal wetlands of Lake Huron. Fifty-nine species of fish are found in coastal wetlands. About 80% of Lake Huron fish species depend on coastal wetlands for some portion of their life cycles (Fracz and Chow-Fraser, 2013; Midwood et. al., 2015). Fish such as Northern Pike, Perch, Muskellunge, and Bowfin spawn in coastal wetlands.

Coastal wetlands are essential for supporting critical life stages of aquatic-dependent species.

Mississagi River delta riverine wetland system (OMNRF).

Nearshore Waters

The shallow nearshore waters are a highly-productive environment. Virtually all species of Great Lakes fish use nearshore waters for one or more critical life-stages or functions. As a result, the nearshore area hosts the highest diversity of fish species (Liskauskas et. al., 2007). The Agreement recognizes that nearshore waters must be restored and protected because urban and rural communities rely on this area for safe drinking water, recreational activities such as swimming, fishing and boating, and water withdrawals for industry and power generation. The nearshore is the hydrological and ecological link between watersheds and the open waters.

The quality of the shallow waters is primarily determined by land use. A sustainable and prosperous Great Lakes economy is dependent upon a healthy nearshore ecosystem.

Deep waters of Georgian Bay framed by the Niagara Escarpment on the Bruce Peninsula (G. Mayne).

Open Waters

When the open waters of Lake Huron are healthy, they support a robust and resilient fishery. Prior to the introduction of invasive species in the early 1900s, the deep waters of Lake Huron were dominated by Lake Trout, Lake Whitefish, and Burbot. The preyfish base was dominated by Cisco (or Lake Herring) and a number of other Deepwater Ciscos, including the Bloater, with Sculpins, Lake Whitefish and Round Whitefish contributing to a lesser extent (Lake Huron Action Plan, 2008).

Ongoing changes to the Lake Huron food web present new challenges for resource managers. Ecological changes that formerly occurred over decades have happened in just a few years. Many questions remain unanswered, and researchers continue to monitor Lake Huron in an effort to understand this dynamic system. Because these changes are profound, developing actions are a priority for member agencies of the Lake Huron Partnership. Current management goals involve maintaining a sustainable predator-prey balance with approaches that include monitoring fish community population trends, with consideration of the effects of several non-native fish species.

4.0 STATE OF LAKE HURON

Lake Huron is in "fair" condition. Chemical contaminants, nutrient and bacterial pollution, loss of habitat and native species, and the spread of non-native invasive species limit the health, productivity, and use of Lake Huron and the St. Marys River.

The U.S. and Canada have made significant progress toward restoring and maintaining water quality of Lake Huron and the St. Marys River since first signing the Agreement in 1972. Over the past four decades, management agencies and the public have worked to reduce chemical contamination, protect habitats and native species, and rehabilitate degraded areas, resulting in a cleaner, healthier Lake Huron.

This chapter informs the public and resource managers about the current condition and ongoing threats to water quality, habitats and native species. Many sources of information were used to inform this assessment including, but not limited to, the following:

- State of Great Lakes Indicator Reports (ECCC and USEPA, 2017);
- Proceedings from 2015 State of Lake Huron Meeting (LimnoTech, 2015);
- Lake Huron Binational Cooperative Science and Monitoring Synthesis (LimnoTech, 2015);
- The State of Lake Huron in 2010 report by the Great Lakes Fishery Commission - Lake Huron Technical Committee;
- *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* (Franks Taylor et al., 2010); and
- Literature reviews and information from scientists and resource managers.

Information is organized by each of the nine General Objectives of the Agreement (Table 2). Each section includes background information and methods used to determine the current status and trends. A discussion using supporting data and science-based indicators is provided along with an assessment of threats. Given that water quality is influenced by localized land use, the LAMP identifies current environmental threats by seven major regions around the Lake Huron watershed (Figure 3).

Table 2. The General Objectives of the 2012 Agreement.

	GENERAL OBJECTIVES
1.	Be a source of safe, high-quality drinking water.
2.	Allow for unrestricted swimming and other recreational use.
3.	Allow for unrestricted human consumption of the fish and wildlife.
4.	Be free from pollutants that could harm people, wildlife or organisms.
5.	Support healthy and productive habitats to sustain our native species.
6.	Be free from nutrients that promote unsightly algae or toxic blooms.
7.	Be free from aquatic and terrestrial invasive species.
8.	Be free from the harmful impacts of contaminated groundwater.
9.	Be free from other substances, materials or conditions that may negatively affect the Great Lakes.

Figure 3. Geographic regions of Lake Huron.

This is the first state of Lake Huron assessment under the 2012 Agreement. State of the Great Lakes indicators will be used to track progress toward achieving the General Objectives. The Lake Huron Partnership may develop more specific Lake Ecosystem Objectives (LEOs) as needed in the future.

4.1 BE A SOURCE OF SAFE, HIGH QUALITY DRINKING WATER

Lake Huron continues to be a safe, high-quality source of water for public drinking water systems.

4.1.1 BACKGROUND

Protecting drinking water and water resources from harmful pollutants is a priority for all levels of government and a shared responsibility involving many partners and communities.

Over 2.3 million people get their drinking water from Lake Huron.

4.1.2 HOW IS DRINKING WATER MONITORED?

The Ontario Ministry of Environment and Climate Change and the Michigan Department of Environmental Quality require municipal drinking water systems (treated water) to be regularly tested for many contaminants including inorganic (arsenic, cadmium, lead), organic (benzene, perchloroethylene, nitrilotriacetic acids, certain pesticides and PCBs) and radiological parameters (tritium and other radiological compounds).

For more information on the Ontario and Michigan drinking water programs, see:
www.ontario.ca/page/drinking-water
www.michigan.gov/drinkingwater

4.1.3 STATUS

When Lake Huron is used as a source of water, the status of municipal treated drinking water quality within the Great Lakes basin is in ‘good’ condition with an ‘unchanging’ trend for the years 2007 to 2014 (ECCC and USEPA, 2017).

4.1.4 DATA DISCUSSION

Ontario’s regulated treatment systems provide high quality drinking water to its residents. Drinking water test results for selected parameters met Ontario Drinking Water Standards nearly 100% of the time in recent years. In 2014-15, 99.8% of 533,457 treated drinking water test results from municipal residential drinking water systems met Ontario's drinking water quality standards (ODWQS, 2016; OMOECC, 2015).

From 2012 – 2014, over 95% of the total population within the Great Lakes states received treated drinking water from water supply systems that were in compliance and met health-based drinking water quality standards (ECCC and USEPA, 2017). Over 2.3 million Michiganders and Ontarians get their drinking water from Lake Huron - including communities as far away as Detroit and London.

4.1.5 THREATS

Lake Huron provides a safe source of treated drinking water. Potential threats include: over application of fertilizers, manure and pesticides that can enter groundwater and surface water; stormwater and wastewater sources, especially during and after extreme storm events; faulty septic systems that leach bacteria; emerging chemicals of concern, and chemical spills within the watershed and directly to Lake Huron. Continued progress toward addressing these issues will help to protect Lake Huron water quality and its use as a source of drinking water.

4.1.6 IMPACTED AREAS

There are currently no areas within the waters of Lake Huron that have significant drinking water impacts.

4.1.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

No specific actions other than ongoing monitoring and reporting by the state of Michigan and the province of Ontario are required to meet this General Objective. Actions that will continue to help protect Lake Huron as a source of drinking water can be found under *Chemical Contaminants* (5.1), *Nutrients and Bacterial Pollution* (5.2), and *Climate Change Impacts* (5.5).

4.2 ALLOW FOR SWIMMING AND OTHER RECREATIONAL USE, UNRESTRICTED BY ENVIRONMENTAL QUALITY CONCERNS

Most Lake Huron beaches offer safe and high-quality swimming and recreational opportunities. Some of the world's longest freshwater beaches are found in Lake Huron.

4.2.1 BACKGROUND

Beaches are a great place for recreation and relaxation and, if managed properly, provide many ecosystem services. They help create our sense of place, form part of our community personality, drive local economies and provide for a healthy active lifestyle. Beaches are also part of a dynamic ecosystem that can quickly change depending on localized wave energy, wind, currents, rainfall and inputs of pollutants.

4.2.2 HOW IS BEACH HEALTH MONITORED?

Water quality monitoring is conducted by county health departments (Michigan) and county health units (Ontario) at select beaches to detect bacteria that indicate the presence of disease-causing microbes (pathogens) from fecal pollution. Based on the number of *E. coli* forming units (cfu) in the water (100 cfu/100 millilitre in Canada, 300 cfu/100 millilitre of water in Michigan), and an assessment of environmental factors, health agencies may post swim advisories. Beach health for a given swimming season (Memorial/Victoria Day weekend to Labour Day) is evaluated differently in the U.S. and Canada as shown in Table 3 (ECCC and USEPA, 2017).

Table 3. Canada and U.S. beach health measures based on the percentage of days within a swimming season that monitored beaches are open and safe.

TARGET	CANADA	U.S.
Good	80% or more	90%
Fair	70-79,9%	80-90%
Poor	< 70%	< 80%

4.2.3 STATUS

Lake Huron beaches are in 'good' condition and allow for safe swimming and other recreational uses unrestricted from environmental concerns for the majority of the swimming season. During 2011 through 2014, the trend was 'unchanging' in the U.S. and Canada (Huron County Health Unit, 2015; ECCC and USEPA, 2017).

One of the many high quality beaches on the southeast shores (ABCA).

4.2.4 DATA DISCUSSION

During the swimming seasons from 2011 to 2014, monitored beaches were open and safe for swimming 82% of the time in Ontario and 99% of the time in Michigan (ECCC and USEPA, 2017). A total of 53 Michigan beaches were monitored in 2015, 28 of which had elevated counts of *E. coli* a total of 60 times throughout the season. This resulted in 48 actions (advisories or closures) at beaches (MDEQ, 2016).

4.2.5 THREATS

Many monitored beaches of Lake Huron are safe for swimming and recreational use throughout most of the swimming season. Threats to beach health exist and water quality can change hourly or daily depending on several human and natural factors. In rural areas, field drains and rivers can transport *E. coli* to the lake from agricultural lands treated with manure. In urban settings, faulty septic systems and stormwater runoff from roads, roofs, construction sites and parking lots can carry bacterial contamination to local beaches.

Climate change brings more frequent and intense rain events that have resulted in large pulses of stormwater runoff events and inputs from combined sewer overflows and sanitary sewer overflows. Beaches found within protected embayments or adjacent to groynes (groins U.S.) and jetties (e.g., Goderich, ON) are more susceptible to bacterial pollution due to poor water circulation and exchange with the open water system (Huron County Health Unit, 2016).

Given the dynamic nature of beach environments and natural influences, it is unlikely that beaches will remain open 100% of the time. Many natural factors that influence beach water quality exist, including:

- Wave height;
- Water clarity;
- Amount of rainfall;
- Solar radiation;
- Water temperature;
- Wind speed and direction;
- Lake water level;
- Shape/contour of coastline;
- Flocks of waterfowl and gulls; and
- Environmentally adapted strains of *E. coli* in beach sand (Huron County Health Unit, 2016).

4.2.6 IMPACTED AREAS

Regions and beaches identified as vulnerable to bacterial contamination are described in Table 4.

4.2.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address beach health and advance achievement of this General Objective can be found in Chapter 5.2 under *Nutrients and Bacterial Pollution*. Actions under *Loss of Habitat and Native Species* (5.3) and *Climate Change Impacts* (5.5) may also indirectly help to minimize bacterial contamination at beaches.

Table 4. Beach health related issues in the regions of Lake Huron.

LAKE HURON REGIONS	BEACH HEALTH RELATED ISSUES
Main Basin	• Covered in regional summaries below
St. Marys River	• The U.S. recently delisted the beach closings Beneficial Use Impairment (BUI) and a preliminary evaluation suggests BUI removal would be appropriate on the Canadian side • *E. coli* levels occur primarily in waters downstream of storm sewers. • Stormwater runoff entering small creeks, rivers and drains that pass through areas with higher concentrations of farming
North Channel/ Manitoulin Island	• Lack of information to determine local environmental threats to beach water quality
Georgian Bay	• Eastern Georgian Bay: Development pressure with potential septic inputs and black water discharges from power/touring boats. Periodic reports of cyanobacteria blooms • Southern Georgian Bay: Nottawasaga River plume and stormwater runoff from the agricultural-based watersheds of Nottawasaga Bay and Severn Sound • Inputs from household septics
Ontario's Southeastern Shores	• Stormwater runoff entering small creeks, rivers and drains from dense agricultural sectors (e.g., Huron County) • Inputs from household septics • Poor circulation due to shoreline shape and piers extending into the lake • Huron County: deteriorating beach water quality since 2013 for Black's Point, Goderich Main, Goderich St. Christopher's, Goderich Rotary Cove and St. Joseph's Beach (Huron County Health Report, 2015)
Saginaw Bay	• Stormwater from small creeks, rivers and drains from rural and urban areas • Inputs from household septics
Michigan's Western Shores	• Stormwater from small creeks, rivers and drains from rural and urban areas • Inputs from household septics

4.3 ALLOW FOR HUMAN CONSUMPTION OF FISH AND WILDLIFE UNRESTRICTED BY CONCERNS DUE TO HARMFUL POLLUTANTS

Lake Huron fish and wildlife are a nutritious food source, but should be consumed responsibly as chemical contaminants still trigger consumption advisories.

4.3.1 BACKGROUND

Commercial and sport fishing and hunting are popular and economically important activities. Yet, concentrations of mercury, PCBs, and dioxins/furans drive the majority of fish consumption advisories for large fish in Lake Huron (MDEQ, 2015; OMOECC 2015). Mercury is a naturally occurring metal found in the environment. It is used in numerous human applications and is released into the atmosphere when fossil fuels are burned. Polychlorinated biphenyls (PCBs) are a group of chlorinated organic compounds created in the late 1920s and banned in 1977. Dioxins and furans are unintentional by-products of several industrial processes and, in some cases, incomplete combustion. These and other toxic contaminants can persist in the environment and increase in concentration in living organisms (bioaccumulate) with each step of the foodweb (biomagnify).

4.3.2 HOW ARE FISH AND WILDLIFE CONTAMINANTS MONITORED?

Canadian and U.S. agencies monitor persistent, bioaccumulative and toxic compounds in edible portions of fish to determine potential risk to human health through fish consumption. Consumption advice is issued by the state of Michigan, tribes and the province of Ontario in efforts to avoid impacts of harmful pollutants found in some fish and wildlife in some areas. For fish and wildlife advisory information, visit:

www.michigan.gov/eatsafefish
www.ontario.ca/document/guide-eating-ontario-fish

4.3.3 STATUS

Contaminants in the edible portions of fish continue to drive fish consumption advisories. Its current status is 'fair' with an 'unchanging' trend in recent years (ECCC and USEPA, 2017).

4.3.4 DATA DISCUSSION

In Ontario waters, PCB concentrations have decreased (by 44% to 81%) since the 1970s in Chinook Salmon, Lake Trout, Lake Whitefish and Walleye; however, concentrations can trigger consumption advisories. Mercury concentrations have also declined by up to 45% in some sportfish and are mostly below the "do not eat" advisory level for women of childbearing age and children (Figure 4) (OMOECC, 2015).

Fish from Michigan waters show declines of roughly 6% per year in PCB concentrations in Carp and Walleye from Saginaw Bay, as well as Walleye and Lake Trout from Thunder Bay.

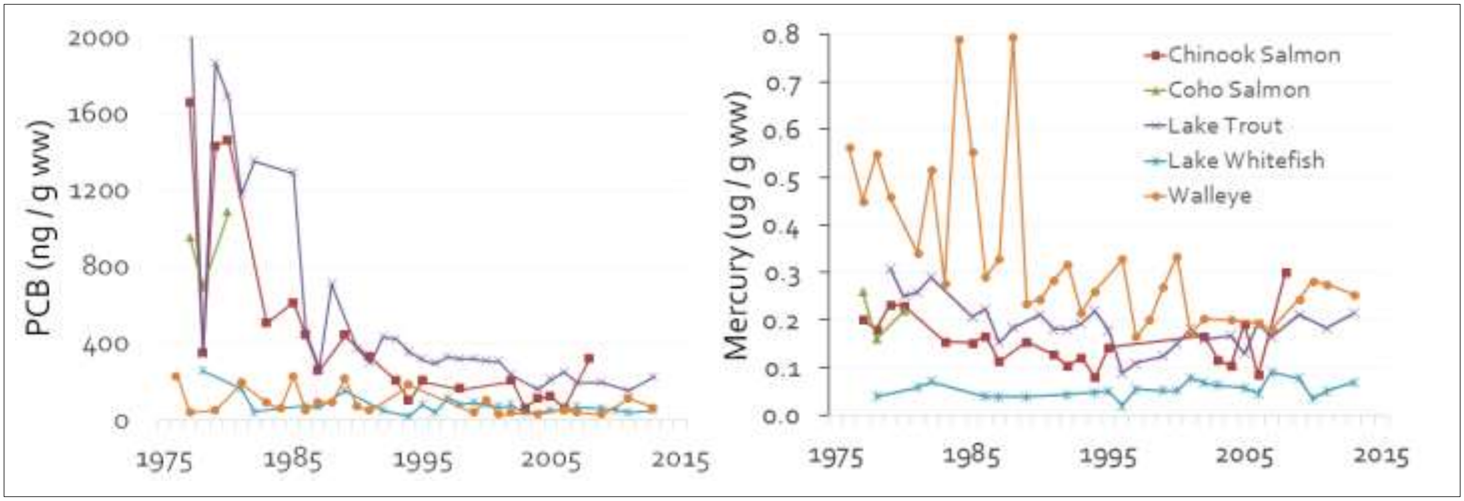


Figure 4. Concentrations of PCB and mercury for fish collected from Ontario waters of Lake Huron. Length of fish used: 55-65 cm for Chinook and Coho Salmon and Lake Trout; 45-55 cm for Lake Whitefish and Walleye (OMOECC, 2015).

Dioxins are also slowly declining in Saginaw Bay Carp (3%/year) and in Thunder Bay Lake Trout (5%/year). Mercury in U.S. fish populations is variable (MDEQ, 2015).

Dioxins, furans and dioxin-like PCBs in the floodplain of the Tittabawassee River and Saginaw River have prompted Michigan to issue wildlife (duck, deer, goose, rabbit, squirrel, and turkey) consumption guidelines.

Concentrations of flame retardants (PFOS) are declining in whole fish from U.S. waters. Michigan's Department of Health and Human Services has issued 'Eat Safe Guidelines' for PFOS contaminated fish.

4.3.5 THREATS

Several decades of environmental programs have significantly reduced the threat of chemical releases into the environment. Atmospheric deposition, contaminated sediments, and localized groundwater contamination represent localized sources of contaminants to fish and wildlife. Other potential sources of chemical contaminants include industrial spills to surface waters. Agencies are also tracking new contaminants that are components of personal care products and pharmaceuticals.

4.3.6 IMPACTED AREAS

Areas of localized sediment contamination are found in the St. Marys River (Ontario), Saginaw Bay and River, and the Spanish Harbour. Groundwater contamination at Oscoda, MI represents a source of PFOS to migratory fish that enter Lake Huron.

4.3.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address contaminants in fish and wildlife to achieve this General Objective are found in Chapter 5.1 under *Chemical Contaminants.*

Table 5. Fish and wildlife consumption related issues in the regions of Lake Huron.

LAKE HURON REGIONS	FISH AND WILDLIFE CONSUMPTION RELATED ISSUES
Main Basin	• Atmospheric deposition and bottom sediments continue to be a source of contaminants • Food web changes due to invasive species can alter contaminant fate, exposure, bioaccumulation rate and pathways with potential negative impacts to fish consumers
St. Marys River	• Improving conditions in the St. Marys River Area of Concern have led to U.S. and Canadian authorities reassessing the status of fish consumption advisories as a Beneficial Use Impairment in the Area of Concern • Continue effort to develop a sediment management plan appropriate for the Canadian portion of the St. Marys River
North Channel/ Manitoulin Island	• Existing sources of sediment contamination in the Spanish Harbour Area of Concern in Recovery. Advisories are most restrictive for bottom feeding White Sucker, and less so for Walleye and Northern Pike
Georgian Bay	• No known localized sources of contaminants of human origin identified that trigger fish consumption advisories
Ontario's Southeastern Shores	• No known localized sources of contaminants of human origin identified that trigger fish consumption advisories
Saginaw Bay	• Dioxin levels (total TEQs) above fish consumption guidelines in the Area of Concern • Dioxins in the floodplain soils of the Tittabawassee River and Saginaw Rivers have prompted Michigan to issue fish and wildlife (duck, deer, goose, rabbit, squirrel, and turkey) consumption guidelines
Michigan's Western Shores	• In the Au Sable River, groundwater contaminated with perfluorinated chemicals is triggering PFOS fish consumption guidelines

4.4 BE FREE FROM POLLUTANTS IN QUANTITIES OR CONCENTRATIONS THAT COULD BE HARMFUL TO HUMAN HEALTH, WILDLIFE OR ORGANISMS THROUGH DIRECT OR INDIRECT EXPOSURE THROUGH THE FOOD CHAIN

Many legacy chemical contaminant levels have decreased. Over the last decade the rate of decline has slowed. New classes of chemicals comprise the majority of the remaining contaminant burden measured in Lake Huron organisms.

4.4.1 BACKGROUND

Some chemicals have the potential to impact the health of humans and wildlife due to their ability to persist and bioaccumulate in the environment. Government programs have significantly reduced the level of contamination in the Great Lakes, but sources of contamination remain in the Lake Huron watershed.

4.4.2 HOW ARE CHEMICAL CONTAMINANTS MONITORED?

Long-term (> 25 years), basin-wide contaminant surveillance and monitoring programs are conducted by Environment and Climate Change Canada (ECCC) and the U.S. Environmental Protection Agency (USEPA). These programs are augmented by state, provincial, tribal, and First Nations and academic contaminant science and monitoring programs. Chemical contaminants are monitored in open water, air, sediments, whole fish and Herring Gull eggs.

4.4.3 STATUS

The overall status for chemical concentrations found in the air, water, sediment, fish and wildlife of Lake Huron range from 'fair' to 'excellent' (ECCC and USEPA, 2017). Chemical contaminant concentrations have generally decreased in all environmental media since the 1970s, and the trend in recent years appears to be 'improving' or 'unchanging' (Table 6; ECCC and USEPA, 2017).

The tissues of some fish and wildlife can contain chemical concentrations at levels that pose a human health risk. There is no evidence that the reproductive health of the Lake Huron fishery is impacted by chemical contaminants. The "bird or animal deformities or reproduction problems" is currently a beneficial use impairment in the Saginaw Bay Area of Concern (AOC).

Table 6. Chemical contaminants status and trends.

INDICATOR	STATUS	TREND
Chemical Concentrations in Open Water	GOOD	UNCHANGING
Atmospheric Deposition of Chemicals	FAIR	IMPROVING
Chemicals in Sediments	GOOD	UNCHANGING
Chemicals in Whole Fish	FAIR	UNCHANGING
Chemicals in Fish Eating Birds	GOOD	IMPROVING

4.4.4 DATA DISCUSSION

Open Water Contaminants

The current status of open water chemical contaminants is rated as 'excellent' with an 'unchanging' trend over time (ECCC and USEPA, 2017).
Lake Huron has one of the lowest levels of chemical contamination (open water) due to fewer industrial point sources.

Concentrations of PCBs are highest in Saginaw Bay. Concentrations in the main basin are low and decline from south to north. Mercury and several other legacy organochlorine pesticides show declining trends within the main basin (2004 to 2015). Polycyclic aromatic hydrocarbons (PAHs) are found in the St. Marys River and there is evidence of increasing levels in Georgian Bay (ECCC and USEPA, 2017).

Atmospheric Contaminants

The overall Great Lakes assessment of atmospheric deposition of toxic chemicals is 'fair' and 'improving' (ECCC and USEPA, 2017).

Long term (1992 and 2012) air contaminant monitoring data show a slow, but decreasing trend for PCBs (half-lives of between 9 and 39 years) suggesting a steady state with existing PCB-containing material in the Great Lakes basin. Organochlorine pesticides are declining; however, historical applications of some pesticides on surrounding agricultural cropland, including DDT, dieldrin, hexachlorocyclohexane and endosulfan (phased out in the U.S. and Canada in 2016), are ongoing sources (Shunthirasingham et al., 2016).

Sarnia, Ontario, located at the tip of Lake Huron, where approximately 40% of Canada's petrochemical industry is concentrated (Great Lakes Environmental Justice).

Sediment Contaminants

Sediment contaminant concentrations in the main basin are very low and therefore rated in 'good' condition with an 'unchanging' trend over time (ECCC and USEPA, 2017). However, localized areas of sediment contamination exist, particularly in Saginaw Bay, Spanish Harbour and Canadian portions of the St. Marys River.

Contaminants in Whole Fish

The current status of contaminants in whole fish is assessed as 'fair', and this condition remains 'unchanged' over a 15-year period (1999-2013) (ECCC and USEPA, 2017).

Total PCB concentrations in top predator fish such as Lake Trout have declined. Total mercury concentrations in fish declined throughout the 1970s and early 1980s but have shown large variability in recent years, likely due to the significant food web changes in Lake Huron, slower growth rates in fish, and the use of older fish in pooled samples used for contaminant analysis by the USEPA (Figure 5).

Polybrominated diphenyl ether (PBDE) concentrations in Lake Trout and Smelt increased during the early- to mid-1990s (Batterman et al., 2007), peaked in the mid-2000s, but show a slight decline in recent years (SOLEC, 2011). Perfluorooctane sulfonate (PFOS) concentrations are variable depending on sampling locations. They are generally above the Canadian Federal Environmental Quality Guidelines (FEQG) for mammalian diet of 4.6 ng/g ww in all five Great Lakes (2004-2013).

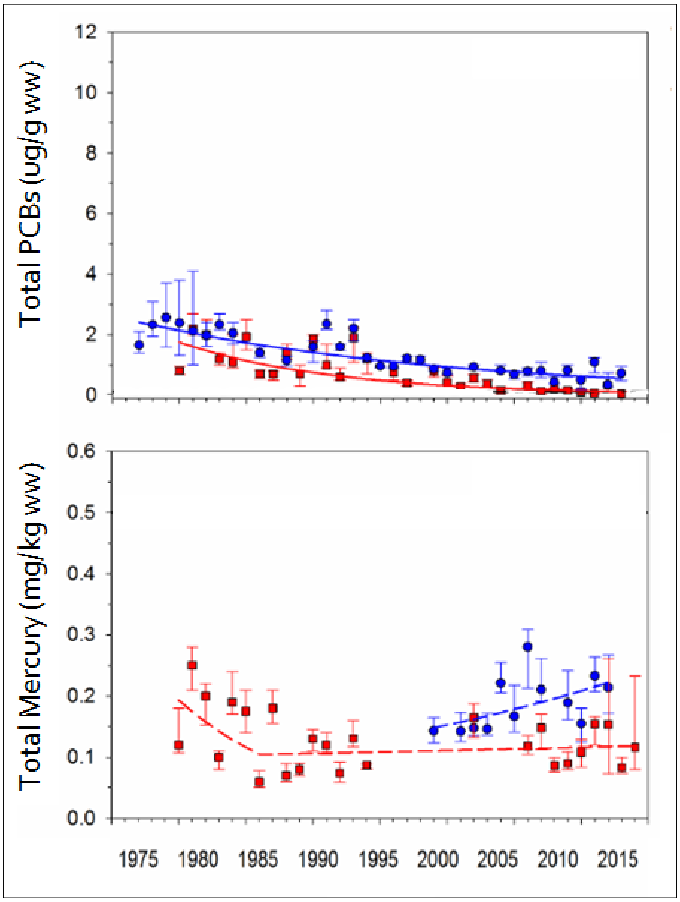


Figure 5.Total PCB and mercury concentrations in Lake Huron Lake Trout. ECCC data in red and USEPA data in blue.

There is increasing interest in per- and polyfluoroalkyl substances (PFAS) given their wide use and persistence in the environment. PFAS has been detected in Lake Huron at levels comparable to PFOS (Figure 6) (De Silva et al., 2011).

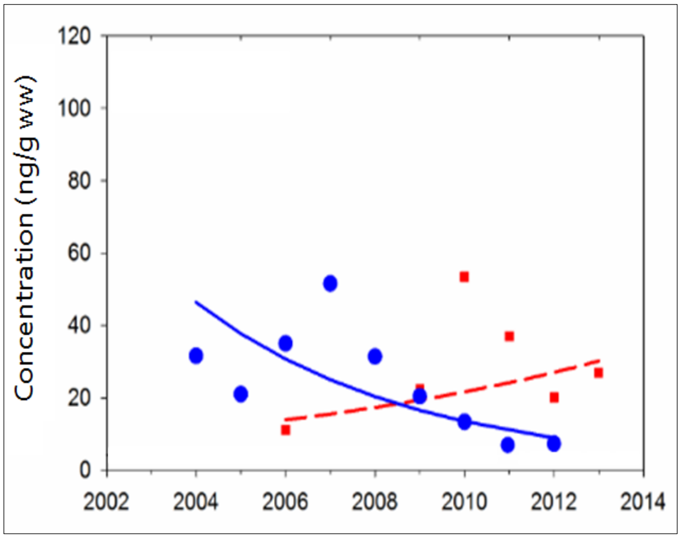


Figure 6. Mean PFOS concentrations for whole body Lake Huron Lake Trout (ECCC (red) and the USEPA (blue)).

Contaminants in Fish-Eating Birds

The current status of toxic contaminants in Herring Gull eggs is assessed as 'good' and 'improving' (1999-2013) (ECCC and USEPA, 2017).

Legacy contaminant concentrations of PCBs (Figure 7), and dioxins (2,3,7,8-TCDD) (Figure 8) measured in Herring Gull eggs have decreased since the 1970s but have stabilized in recent years. Eggs collected from Double Island (North Channel) and Chantry Island (Lake Huron) show similar dioxin concentrations, and higher concentrations are found at Channel Shelter Island (Saginaw Bay) (de Solla et al., 2016).

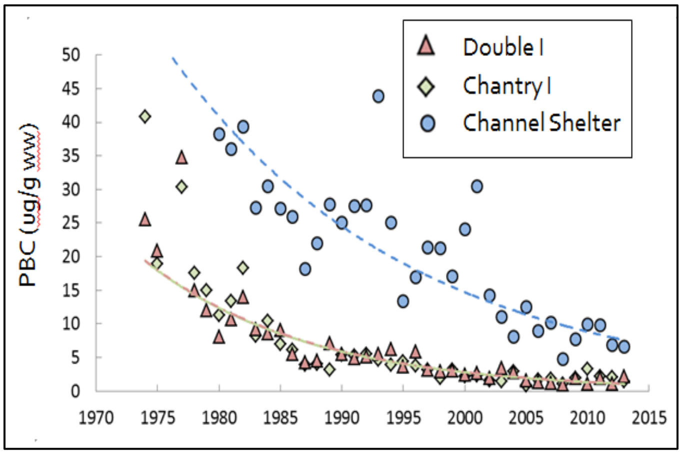


Figure 7. Trend in PCB concentrations in Lake Huron Herring Gull eggs (de Solla, 2016).

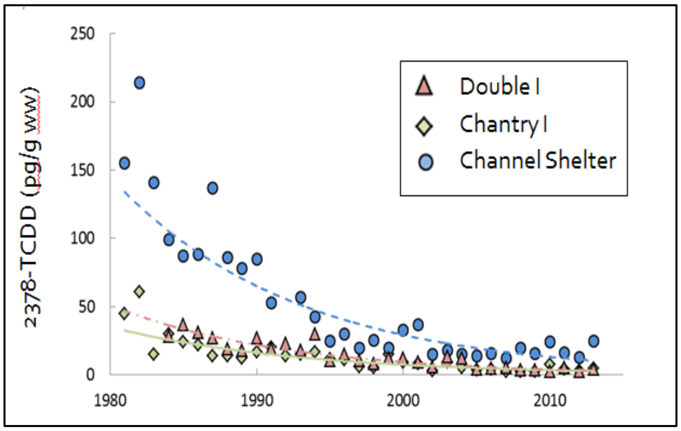


Figure 8. Trend in dioxin (2378-TCDD) concentrations in Lake Huron Herring Gull eggs (de Solla, 2016).

In contrast, egg concentrations of the flame retardant Dechlorane Plus (Σ2DDC-CO) have increased between 2008 and 2012, with the highest concentrations found in eggs from Five Mile Island located in the upper St. Marys River (data not shown, Su et al., 2015).

Dioxin, PCBs, and mercury in Herring Gull and Double-crested Cormorant eggs collected from colonies near the Spanish Harbour Area of Concern in Recovery in 2011 and 2012 were low and considered to be below levels associated with adverse effects (Hughes et al., 2014b). Reproduction and development for Herring Gulls and Common Terns breeding within the St. Marys River AOC are not associated with health impacts (data not shown, Hughes et al., 2014a).

4.4.5 THREATS

Chemical contaminant trends show a general decreasing trend, yet atmospheric deposition of chemicals like metals and PAHs is an ongoing source of chemicals. Contaminated sediments represent a pollutant sink and potential source of toxic substances through resuspension and redistribution. Legacy contaminants persist in Lake Huron, and flame retardants, current-use pesticides, and pharmaceuticals and personal care products represent future stressors.

Petroleum transportation within the Lake Huron basin, by various modes (e.g., pipeline, rail, and marine shipping), has been raised as a concern by tribes with reserved treaty rights and the public over potential risks to the ecosystem. Risk of environmental impacts is posed by potential accidental releases of petroleum and refined petroleum products from pipelines located underwater and crossing tributaries; commercial shipping throughout the system; and rail transport, particularly at tributary crossings. Most oil transported on or near water in the Great Lakes is moved by pipeline (135 billion gallons or 512 billion liters of crude oil and refined petroleum product), followed by rail (10 billion gallons or 40 billion liters of crude oil) and then marine shipping (0.69 billion gallons or 2 billion liters of refined petroleum products) (Marty and Nicoll, 2017).[1] Appendix C presents maps showing crude oil pipelines, petroleum product pipelines, and railways that transport petroleum and petroleum products in Canada and the United States. In the event of a spill to water, strong and shifting currents, as well as winds, can carry oil significant distances in Lake Huron. The region contains numerous sensitive areas of streams and wetlands, as well as high-

[1] Annual mean volumes for the 2011-2014 time period.

quality habitat for many important at-risk species.

4.4.6 IMPACTED AREAS

Localized sediment contamination is found in Canadian portions of the St. Marys River, Saginaw Bay and River, and Spanish Harbour. These areas represent sources of PCBs, mercury, dioxins and PAHs. Elevated dioxin and furan levels (byproducts from the manufacture of chlorine-based products) are found along the Tittabawassee River and downstream at sites within the Saginaw River and Bay.

4.4.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address chemical contaminants and advance achievement of this General Objective can be found in Chapter 5.1 under *Chemical Contaminants*. Actions that address non-point sources of pollutants can be found in *Nutrients and Bacterial Pollution* (5.2), and *Climate Change Impacts* (5.5) may also indirectly help to minimize chemical exposure and effects to humans and wildlife.

Table 7. Chemical contaminant related issues in the regions of Lake Huron.

LAKE HURON REGIONS	CHEMICAL CONTAMINANT RELATED ISSUES
Main Basin	• Atmospheric deposition contributes contaminant sources • Food web changes due to invasive species can alter contaminant fate, exposure, bioaccumulation rate and pathways with potential negative impacts to aquatic organisms and fish consumers
St. Marys River	• Canada: Sediment contamination of PAHs and the health impacts on fish is a current management focus for the Area of Concern • U.S.: All actions to address known sites of contaminated sediment are complete on the U.S. side of the St. Marys River Area of Concern
North Channel/ Manitoulin Island	• Concentrations of dioxins and furans are above the Ontario provincial sediment quality guidelines in the Spanish Harbour Area of Concern in Recovery and the Whalesback Channel (ECCC and USEPA, 2017). Monitoring is underway to track recovery • Elevated sediment concentrations of PBDE (Guo, 2016)
Georgian Bay	• Low but increasing PAHs in Georgian Bay (driven by naphthalene concentrations), possibly due to heavy recreational boat traffic
Ontario's Southeastern Shores	• No known localized sources of chemical contaminants of human origin that are harmful to human and wildlife health
Saginaw Bay	• Contaminants include dioxins, furans, PCBs, metals • Dioxin-contaminated sediment in the floodplain of the Tittabawassee and Saginaw Rivers • Elevated sediment concentrations for PBDE and BDE in Lake Huron (Guo, 2016) • "Bird or animal deformities or reproduction problems" and "Restrictions on fish and wildlife consumption" Beneficial Use Impairments have not been removed
Michigan's Western Shores	• Contaminated groundwater is a source of perfluorinated chemicals from use of flame retardants at the former Wurtsmith Air Force Base in Oscoda, MI

4.5 SUPPORT HEALTHY AND PRODUCTIVE WETLANDS AND OTHER HABITAT TO SUSTAIN RESILIENT POPULATIONS OF NATIVE SPECIES

Lake Huron's habitats and species are in fair condition. Continued loss and deterioration of habitats, spread of invasive species, climate change impacts and pollution are of concern.

4.5.1 BACKGROUND

Lake Huron's geological past provides a setting for a high level of diversity in its natural environment, including: the southern glacial till (deposits of clay, sand and gravel); the Niagara Escarpment, or 'Great Arc' of limestone extending through the Bruce Peninsula, Manitoulin Island and Michigan's Upper Peninsula; and the northern Precambrian Shield. The open lake ecosystem, coastal wetlands, islands, rocky shorelines, sand and cobble beaches, dunes, alvars, and the hundreds of interconnected streams and their headwaters provide the essentials of life for a multitude of species.

4.5.2 HOW IS HABITAT AND NATIVE SPECIES HEALTH MEASURED?

The Lake Huron Biodiversity Conservation Strategy provided a health assessment of seven conservation features that represent the lake's biological health (Franks Taylor et al., 2010). Updated and revised *State of the Great Lakes Ecosystem* indicator reports provide recent information on status and trends (ECCC and USEPA, 2017). A coastal wetland science synthesis amalgamates several information sources to provide a comprehensive assessment for Lake Huron (Ciborowski et al., 2015). Several indicator assessment reports from the '2016 State of the Great Lakes' series are used in this assessment, as are submissions from various scientists and members of the Lake Huron Technical Committee.

BIOLOGICAL DIVERSITY

Biodiversity refers to the variety of life, as expressed through genes, species and ecosystems, and is shaped by ecological and evolutionary processes.

4.5.3 STATUS

As summarized in Table 8, the overall condition of Lake Huron's habitats and species (its ***biological diversity***) is 'fair', and the trend has remained constant since the 2010 evaluation (Franks Taylor et al., 2010; ECCC and USEPA, 2017).

Table 8. A summary of the Lake Huron status and trends for habitat and species by State of Great Lake indicator and other data (SOGL, 2016).

FEATURE[1]	INDICATOR	STATUS	TREND
Coastal Wetlands	Plants	FAIR	DETERIORATING
	Fish	FAIR	IMPROVING
	Birds	GOOD	UNCHANGING
Native Migratory Fish	Lake Sturgeon	POOR	IMPROVING
	Walleye	GOOD	UNCHANGING
	Aquatic Habitat Connectivity	POOR	IMPROVING
Open Water	Open Water (Total Phosphorus)	FAIR	NEEDS FURTHER ASSESSMENT
	Phyto-plankton	FAIR	DETERIORATING
	Zooplankton	FAIR	UNCHANGING
	Diporeia	POOR	DETERIORATING
	Preyfish	FAIR	UNDETERMINED
	Lake Trout	GOOD	IMPROVING
	Lake Whitefish	POOR	NEEDS FURTHER ASSESSMENT
	Ciscoes	UNDETERMINED	UNDETERMINED
Aerial Migrants	Colonial Nesting Waterbirds	FAIR	UNCHANGING

[1] Conservation features of the Lake Huron Biodiversity Conservation Strategy

4.5.4 DATA DISCUSSION

This section reports on the status and trends of several habitat types and the native species that depend upon them. It begins with an assessment of coastal wetlands given the essential role they play in maintaining the health of the aquatic ecosystem. Nearshore areas are discussed given the current management focus for restoration and protection and the ecological connection between the watershed and the open waters. The open water ecosystem is explained using a bottom-up approach (open water nutrients, plankton to top predators) to illustrate the interconnection within the aquatic food web. We also include colonial fish-eating waterbirds in this assessment as they serve as sentinels of aquatic ecosystem health.

Coastal Wetlands

Lake Huron coastal wetlands account for roughly 64,641 ha (159,663 acres), almost 30% of the total wetland area for all five Great Lakes (Chow-Fraser, 2008). More than 3700 coastal wetlands (17,350 hectares; 42,873 acres) are found along the eastern Georgian Bay coast (Fracz and Chow-Fraser, 2013), and the St. Marys River contains approximately 10,790 ha (26,663 acres).

A synthesis of 157 wetlands sampled in 30 quaternary watersheds using several U.S. and Canadian datasets provides a comprehensive analysis of wetland condition. Index scores for water-quality data and the presence of wetland vegetation and fishes are presented (Figure 9). All three indices indicate a 'very good' to 'excellent' condition for coastal wetlands along the Canadian shoreline, especially those in eastern and northern Georgian Bay. However, wetlands assessed as 'fair' or 'good' condition are found near towns and marinas of southern Georgian Bay. Some coastal wetlands of the Bruce Peninsula were rated as 'fair' or 'poor' condition. Results are more variable for Michigan wetlands with most being in 'poor' or 'fair' condition. These patterns are consistent with the increased level of anthropogenic stressors on U.S. coastal wetlands and the largely undisturbed watersheds in eastern and northern Georgian Bay (Ciborowski and Chow-Fraser, 2015).

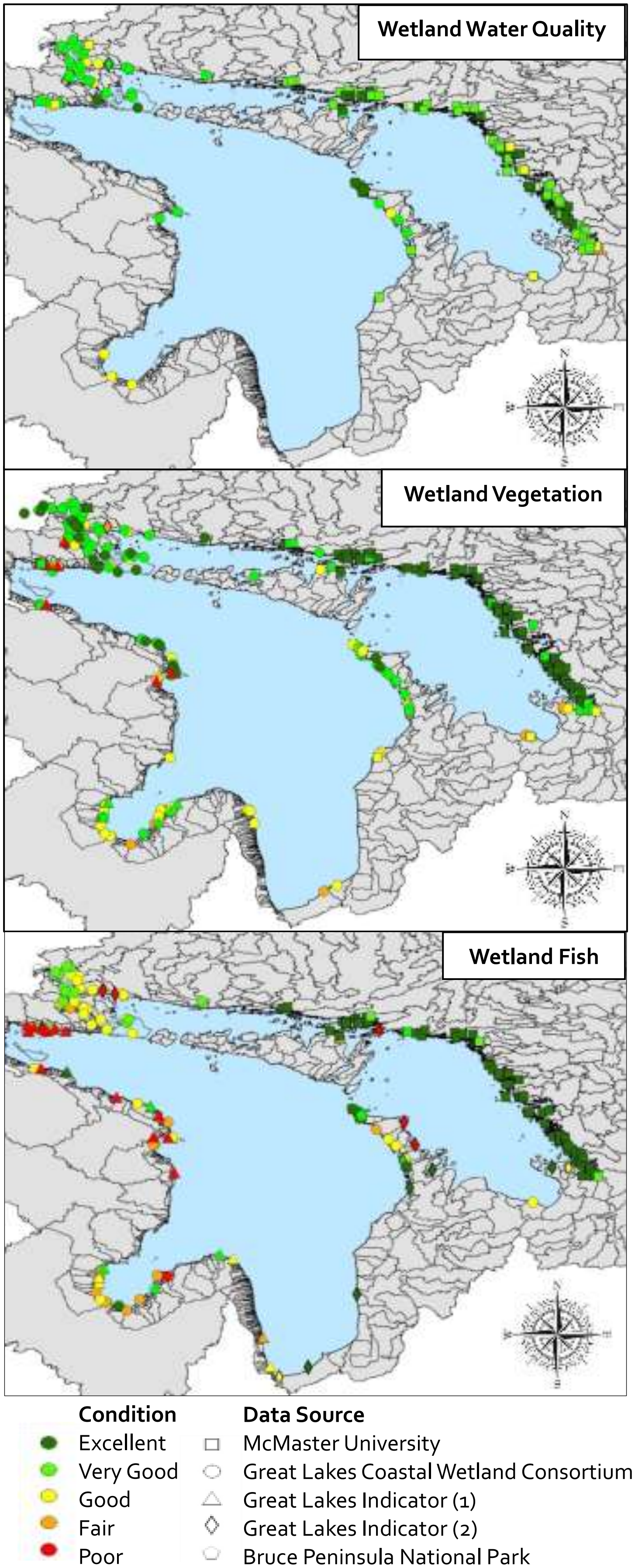


Figure 9. Coastal wetland health as represented by indices of water quality, wetland vegetation and wetland fish.

Nearshore Ecosystem

In shallow nearshore waters of Ontario, there is a high level of diversity of small fishes (>60 species), the majority of which are native to Lake Huron (Mohr et al. 2013). In Michigan waters, the diversity of the nearshore fish community has decreased following the spread of invasive non-native species (Loughner, unpublished data). Saginaw Bay shows an increase in Walleye abundance (Fielder et al. 2010), and eastern Georgian Bay shows an increase in Smallmouth Bass (Fielder et al., 2013).

Native Migratory Fish

Lake Sturgeon population structure is rated as 'poor' (five of the 33 historical spawning populations are self-sustaining) except where consistent spawning occurs in three streams of the North Channel, the Nottawasaga River, and the mouth of the St. Clair River (Franks Taylor et al., 2010; Chiotti et al., 2013). The trend may be improving, as spawning activity is observed in new locations including the Moon and Musquash Rivers in eastern Georgian Bay and the Manitou River on Manitoulin Island. Lake Sturgeon no longer spawn in the Saginaw River watershed although spawning habitat exists below the Dow Dam on the Tittabawassee River and below Hamilton Dam on the Flint River (Boase, 2007). Stream-side hatcheries and stocking have been initiated to help restore Sturgeon populations in the U.S.

Spawning Lake Sturgeon near the Bluewater Bridge, Sarnia, Ontario (A. Lintz).

The health of native ***Walleye*** populations range from 'fair' (Franks Taylor et al., 2010) to 'good' (ECCC and USEPA, 2017). Saginaw Bay contains the largest Walleye stock in Lake Huron (Figure 10) and its recovery was aided by stocking and ecosystem changes that led to the decline of non-native prey fish such as Alewife. In Ontario, the majority of Walleye stocks are far below historic levels and reflect a legacy of habitat alteration and exploitation. Remaining stocks are associated with tributaries draining the North Channel and Georgian Bay (Fielder et al., 2010).

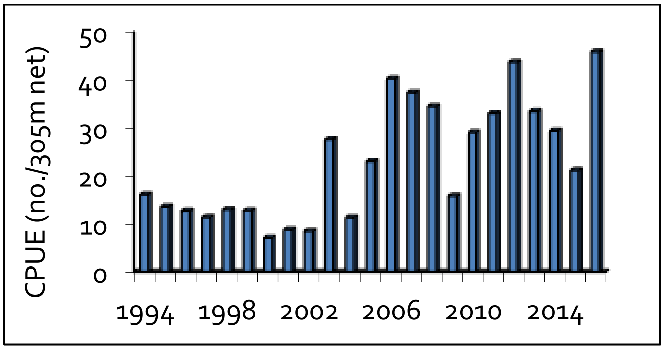


Figure 10. Saginaw Bay Walleye abundance as determined by CPUE (catch per unit effort) (Fielder, pers. comm., 2016).

Open Water Ecosystem

In general, the open water ecosystem is in 'fair' condition. The trend is variable, and there is uncertainty around lake productivity and changes in the composition and abundance of phytoplankton, zooplankton and some species of the lower and upper food web. Future trends may be dependent upon dreissenid mussel density and nutrients.

The status of ***open water nutrients*** for Lake Huron is "fair" and generally consistent with an oligotrophic (low nutrient) status. Data, however, show decreasing phosphorus concentrations (mid-2000s), but this trend may be reversing (Figure 11). Additional research is needed to better understand the spatial and temporal trends and the related impacts on productivity.

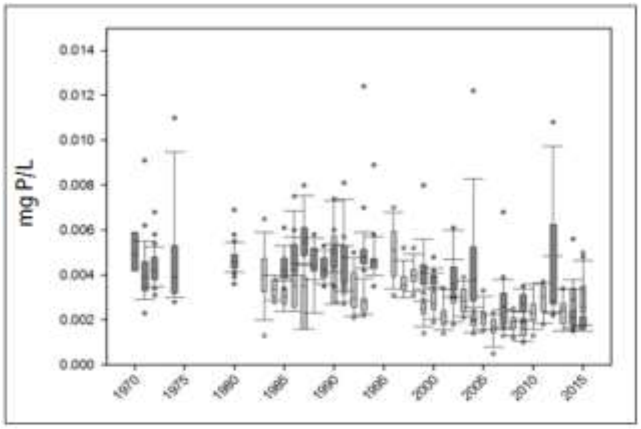


Figure 11. Main basin long-term phosphorus concentrations in the open waters (USEPA (grey) and ECCC (black)).

Phytoplankton abundance and community composition in the open water reflect a system in 'fair' condition with a 'deteriorating' trend. The significant decline in spring diatom bloom that occurred around 2003 continues to this day (ECCC and USEPA, 2017). The mean phytoplankton abundance declined 88% between 1971 and 2013 (Figure 12) (Reavie et al., 2014).

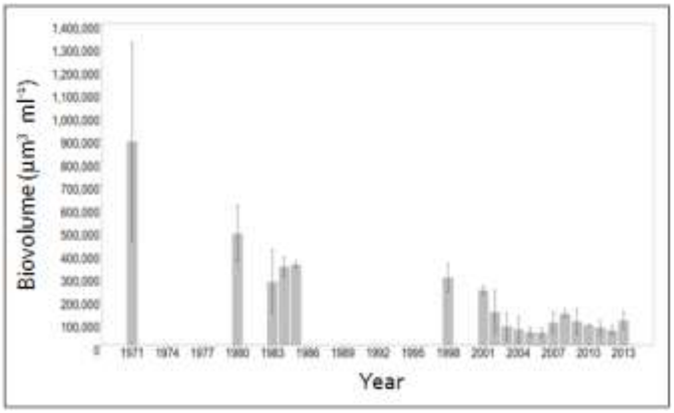


Figure 12. Lake Huron biovolume (± SE) of phytoplankton displayed as the mean of April and August estimates (multiple data sets combined by Reavie et al., 2014).

Diporeia (a freshwater shrimp-like crustacean) is one of the most important organisms in the Great Lakes food web. It supported most species of Lake Huron fish, including Whitefish and many smaller fish eaten by Lake Trout and Walleye. The abundance of *Diporeia* has drastically declined (Nalepa et al., 2007; Barbiero et al., 2011) (Figure 13). The status is 'poor' with a 'deteriorating' trend (ECCC and USEPA, 2017).

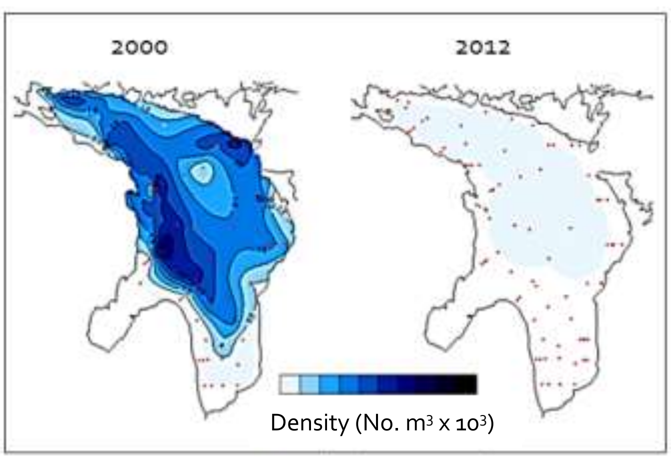


Figure 13. Trends in *Diporeia* showing the decline in density and distribution (Nalepa et al., in prep).

The status of ***zooplankton*** is in 'poor' with an 'unchanging' condition. Zooplankton declined significantly between 1998 and 2006 (Barbiero et al., 2009, 2012) driven by a 95% decline in the abundance of herbivorous crustaceans like cladocerans (Bunnell et al., 2012). Other forms of crustaceans (calanoid copepods) now dominate (Pothoven et al., 2013) Lake Huron and Saginaw Bay. Declines are attributed to changes in the fish community, the non-native, predatory Spiny Water Flea (*Bythotrephes)* and nutrient availability.

Preyfish historically consisted of a mixture of native species but became dominated by non-native Alewife and Rainbow Smelt from the 1970's to the early 2000s. Over the last two decades, Alewife populations declined significantly (Riley et al., 2008; Roseman and Riley, 2009), Rainbow Smelt and native Sculpin species reached record low abundance (O'Brien et al., 2009; O'Brien et al., 2014; Roseman et al., 2015), and there is uncertainty as to the abundance and spread of Round Gobies. The result is a preyfish community that is lower in abundance and diversity. Its status is 'fair' with an undetermined trend (Figure 14).

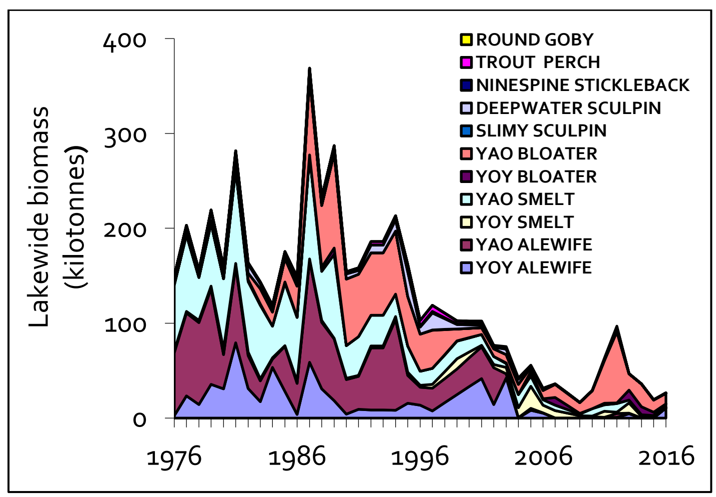


Figure 14. Lake Huron biomass of major pelagic fish species (1976-2014) (USGS, 2016).

Cisco is a general term to describe a flock of seven coregonid species that occurred in Lake Huron during the early 20th century and in the same genus as the commercially important Lake Whitefish. Only two species still remain, and taxonomic uncertainty remains an ongoing research question for *Coregonus artedi* ("Cisco", previously known as "Lake Herring") and *C. hoyi* ("Bloater"). *C. artedi* mainly occur in the

North Channel and in the very northern part of the main basin, but are much less abundant than in the early 20th century. *C. hoyi* occur throughout the basin, and their abundance has approached near record-high levels over the past five years. The commercial harvest of these two coregonid species, however, remains a fraction of historic levels (B. Bunnell, pers. comm., 2016).

Lake Whitefish harvests have declined from peak levels of the early 2000s (Figure 15). This is largely due to fewer adult fish and low recruitment of young fish to the adult stock, particularly in the north. Researchers speculate that this may be due to limited nearshore plankton food, loss of *Diporeia*, a shift to less nutrient-rich food (e.g., dreissenids) and the rising predation on small fishes as predators shift from Alewives to juvenile life stages (S. Lennart, pers. comm., 2016).

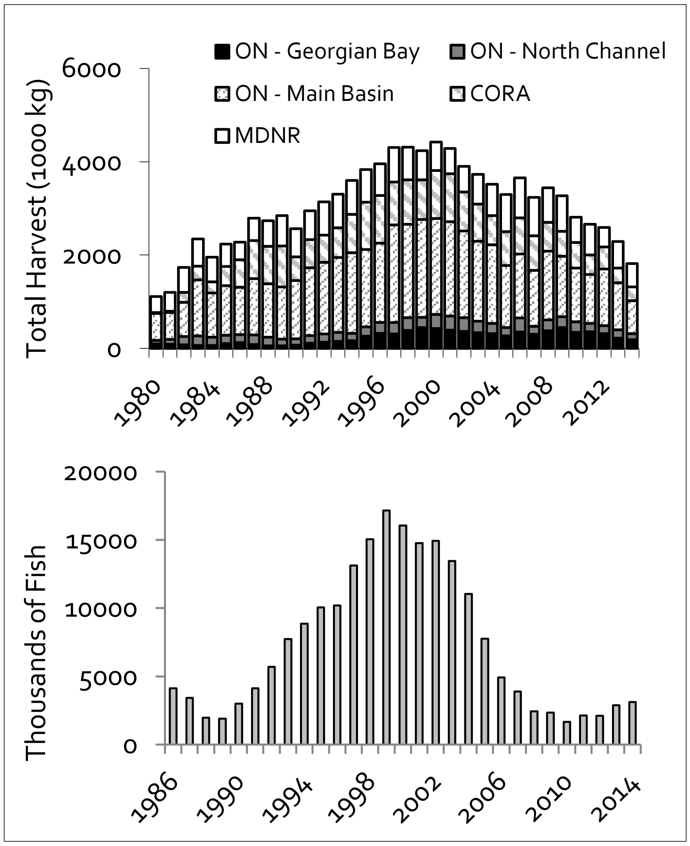


Figure 15. Trends in commercial yield of Lake Whitefish by (top) jurisdiction and basin, and (bottom) estimates of recruitment at age 4 in the 1836 Treaty waters of Lake Huron (U.S. waters north of Alpena) (Mohr et al., 2015; 2000 Consent Decree Modeling Subcommittee (MSC)).

The status for ***Lake Trout*** is 'good' and the trend is 'improving (ECCC and USEPA, 2017) as progress towards Lake Trout rehabilitation is evident in the main basin and North Channel (Figure 16). Wild fish now compose nearly half of the adult population, and wild juvenile abundance reached a new high since 2010. Less progress toward rehabilitation has been observed in Georgian Bay, and populations there remain largely dependent on stocking to maintain current levels (GLFC, 2013; SORR, 2010).

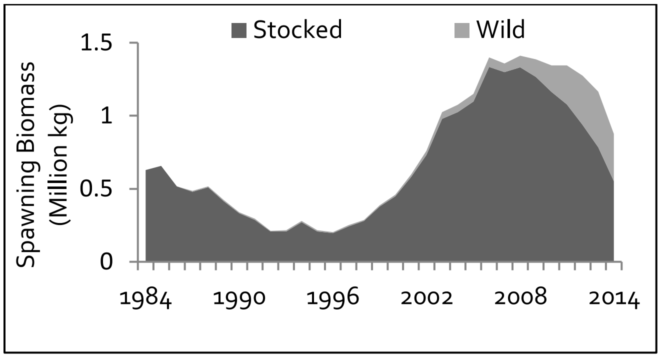


Figure 16. Trends in main basin spawning biomass (millions kg) of stocked and wild Lake Trout (He et al., 2012).

Aerial Migrants

The status for ***colonial nesting water birds*** is 'fair' based on a low degree of disturbance and high availability of nesting habitat on islands, as well as the population size and structure, which tend to range from 'good' to 'very good' in the northern basin and 'fair' to 'good' in the south (Franks Taylor et al., 2010; ECCC and USEPA, 2017).
Populations of Double-crested Cormorants, Great Egrets and Black-crowned Night Herons have increased since 1976 (Figure 17).

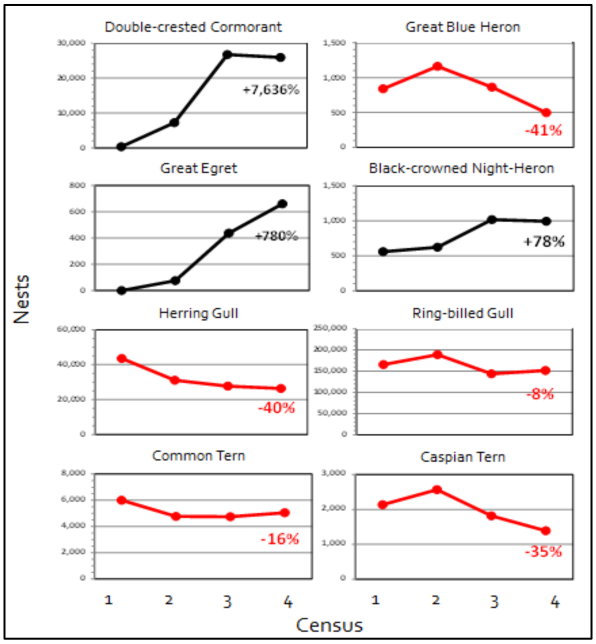


Figure 17. Changes in nest numbers for eight waterbird species during four census periods (1 = 1976-80; 2 = 1989-91; 3 = 1997-2000; 4 = 2007-09) (D. Moore, pers. comm., 2015).

Over the same time period, populations of Great Blue Herons, Herring Gulls, Ring-Billed Gulls, Common Terns and Caspian Terns declined, consistent with Great Lake wide trends. The observed declines in Caspian Terns on Lake Huron are in contrast to increases on the other Great Lakes. Herring Gull egg size and development, and possibly population-level effects, have been linked to the decline of prey fish abundance (Hebert et al., 2008, 2009; Hebert et al., 2000).

4.5.5 THREATS

The Great Lakes Fishery Commission's Environmental Objectives for Lake Huron (Liskauskas et al. 2007) and the Lake Huron Biodiversity Conservation Strategy (Franks Taylor et al., 2010) identified chemical contaminants, excess nutrients, loss and degradation of habitat and native species, non-native invasive species, and climate change as critical threats to biological diversity. These threats impede the full achievement of the General Objective to "support healthy and productive wetlands and other habitat to sustain resilient populations of native species". Three of these threats are covered in other "state of" chapters and include *Chemical Contaminants* (4.4), *Nutrients and Algae* (4.6), and *Invasive Species* (4.7).

Shoreline development and dams and barriers are two additional management challenges. Shoreline development, hardening, and the construction of groynes, dredging and infilling are widespread and have destroyed or degraded coastal wetlands and other nearshore habitat negatively impacting native fish species (Dodd and Smith, 2003; Franks Taylor et al., 2010; Leblanc et. al., 2014). Dams and hydropower facilities and other barriers have reduced stream habitat connectivity and altered in-stream flow, temperature, and stream habitat (Gebhardt et al., 2005; Franks Taylor et al., 2010). As a result of these dams and barriers, only 30% of the naturally connected stream habitat remains connected to Lake Huron. (unpublished data, The Nature Conservancy et al. 2017).

4.5.6 IMPACTED AREAS

Degradation and loss of habitat in streams, upland and nearshore areas, and coastal wetlands are major stressors throughout Lake Huron and its watershed; however, parts of the basin still exhibit a high level of biological and geophysical diversity that supports productive aquatic habitat and native species.

While a small fraction of pre-settlement wetlands remain (Krieger et al., 1992), no comprehensive estimate of wetland loss is available. Large scale loss has not occurred in the North Channel and Georgian Bay to the extent of southern regions, mostly due to sparse population and the irregular and, in some cases, remote shoreline of the northern coast. Wetland loss and degradation continue to occur in developed areas, adjacent to high road density and near cottage development.

Non-native invasive species such as Quagga Mussels, Sea Lamprey, and Round Goby are found throughout the basin. The Common Reed known as *Phragmites* is most dense along the southern coastlines but continues its northward spread throughout the watershed via roads, ditches and shorelines.

Privately owned shorelines and areas with high wave-energy are most prone to alteration by landowners. Shallow-sloping shorelines are vulnerable to sustained low water levels, and landowners have extensively dredged to gain

Table 9. Habitat and species related issues in the regions of Lake Huron.

LAKE HURON REGIONS	HABITAT AND SPECIES RELATED ISSUES
Main Basin	• Non-native invasive dreissenid mussels in the nearshore and offshore are taking nutrients from the water column and moving them to the benthic zone of the lake • The abundance of *Diporeia* has drastically declined in offshore waters. The cause is unknown
St. Marys River	• Shoreline development and alteration • Altered flow regime of the St. Marys River and watershed streams due to agriculture, deforestation, urban development, drainage, channelization, dams and barriers • Historic loss of rapids habitat due to navigational structures requires remedial action in Canada • Historic wetland loss
North Channel / Manitoulin Island	• *Phragmites* continues to spread northward to the North Channel and Manitoulin Island • Non-point sources of sediment and excess nutrients cause algal blooms degrading habitat • Stream habitat fragmentation and altered hydrological flow due to dams and barriers
Georgian Bay	• Stream habitat fragmentation and altered hydrological flow due to dams and barriers • Parry Sound, Severn Sound, Nottawasaga Bay experience population growth, shoreline development pressure, intense recreational use, historic and present industrial activities with wetland and island habitat impacts • Eastern and southern Georgian Bay vulnerable to shoreline alteration under sustained low water levels; ranging from rock blasting to extensive nearshore dredging (> 30 cuts/km) • Southern Georgian Bay: non-point sources of pollution mostly in the agricultural south • *Phragmites* spread to coastal wetlands and river mouths of southern and eastern Georgian Bay
Ontario's Southeastern Shores	• Stream and nearshore water quality impacts on aquatic habitat due to non-point source pollution from dense agricultural sector • Stream habitat fragmentation due to dams and barriers • Continued loss and degradation of coastal wetlands • Dense stands of *Phragmites* continue to spread northward
Saginaw Bay	• Stormwater runoff from urban areas and dense agricultural activity with impacts to stream and nearshore habitats • Wetland loss and degradation; areas of native wetland have been replaced by *Phragmites* • Stream habitat fragmentation due to dams and barriers • Loss of offshore reef spawning habitat for native fish species
Michigan's Western Shores	• Wetland loss and degradation • Non-point sources of pollution • Stream habitat fragmentation due to dams and barriers • Loss of offshore reef spawning habitat for native fish species

water access. Dams and other barriers to fish movement are found throughout the basin. In some areas, dams and low-head barriers are a major Sea Lamprey control mechanism. Therefore, decisions on dam removal must balance competing environmental interests and goals.

4.5.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address loss of habitat and native species and advance achievement of this General Objective can be found in Chapter 5.3 – *Loss of Habitats and Species*.

Actions that address other threats such as *Chemical Contaminants* (5.1), *Nutrients and Bacterial Pollution* (5.2), *Invasive Species* (5.4), and *Climate Change Impacts* (5.5), will also help to minimize the loss of habitat and the native species that they support.

4.6 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

Elevated nutrients in some areas of the nearshore contribute to excessive amounts of nuisance algae and cause episodic outbreaks of cyanobacteria blooms.

4.6.1 BACKGROUND

Nutrient pollution is one of the most challenging environmental problems and is caused by excess nitrogen and phosphorus, which includes the bioavailable portion SRP (soluble reactive phosphorus), in the water. As a natural and essential part of aquatic ecosystems, nutrients play an important role in supporting the production of aquatic plants and algae which provide food and habitat for small organisms and fish. When too much nitrogen and phosphorus enter the environment, the water can become polluted and lead to excessive amounts of benthic macro-algae (e.g., *Cladophora, Chara* and periphyton) and harmful algal blooms (*Cyanobacteria*).

POTENTIAL FACTORS THAT CONTRIBUTE TO ALGAE BLOOMS

1) Excess nutrients (nitrogen and phosphorus)
2) Warm water temperatures and sunlight
3) Increased light penetration
4) Calm and slow-moving water

CLADOPHORA

CYANOBACTERIA

4.6.2 HOW IS NUTRIENT POLLUTION MONITORED?

In Canada, the Ministry of the Environment and Climate Change oversees long term water monitoring and science programs that provide information on nearshore water quality condition and identification of threats.
In the U.S., EPA's Office of Water in partnership with States and Tribes conducts the National Coastal Condition Assessment. This assessment is designed to yield unbiased estimates of the condition of the nearshore waters based on a random stratified survey and to assess changes over time.

4.6.3 STATUS

Management actions have reduced the amount of phosphorus discharged from sewage treatment plants, and concentrations in the Great Lakes nearshore zone declined significantly between the 1970s and 1990s. The overall status of nearshore health (<30m) of Lake Huron as determined by the presence of nuisance and harmful algae is currently 'fair' with an 'undetermined' trend (Table 10; ECCC and USEPA, 2017).

Table 10. Current status and trends of nutrient concentrations and occurrence of algal blooms.

NUTRIENTS AND ALGAE	INDICATOR	STATUS	TREND
Nuisance Algae	*Cladophora*	FAIR	UNDETERMINED
Harmful Algal Blooms	*Cyano-bacteria*	FAIR	UNDETERMINED

4.6.4 DATA DISCUSSION

Nutrient levels are highest in nearshore waters near stream mouths that drain urbanized or agricultural areas (Figure 18). In some nearshore areas, elevated nutrient levels and environmental conditions result in episodic nuisance algae growth and harmful algal blooms.

In Ontario, elevated phosphorus and nitrate concentrations occur along the southeast shores (Dove, pers. comm., 2016). Four of the top ten Canadian subwatersheds with the highest intensities of nitrogen and phosphorus production from livestock manure are located along the southeast shores of Lake Huron (Statistics Canada, 2013).

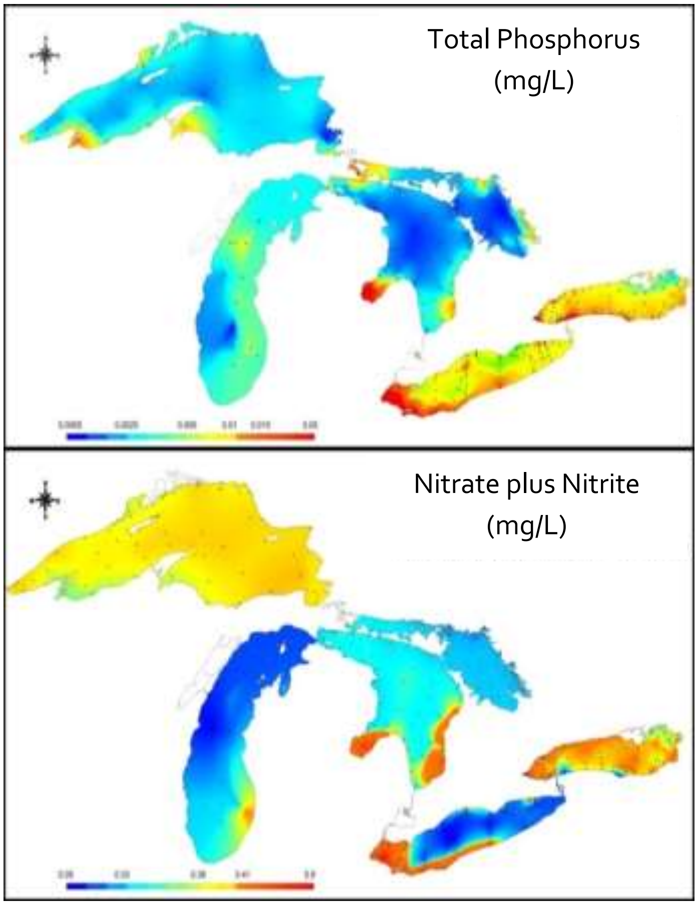


Figure 18. Spring surface total phosphorus (mg/L) and nitrate plus nitrite (mg/L) concentrations in the Great Lakes (2013-2014) (ECCC and the USEPA, 2014).

Signs of nutrient enrichment in this area occur from the outlet of Saugeen River south to Kettle Point near Sarnia, where the density of bottom-dwelling worms (indicators of organic pollution) increased 20-fold since the early 2000s (Figure 19) (Nalepa et al., in prep).

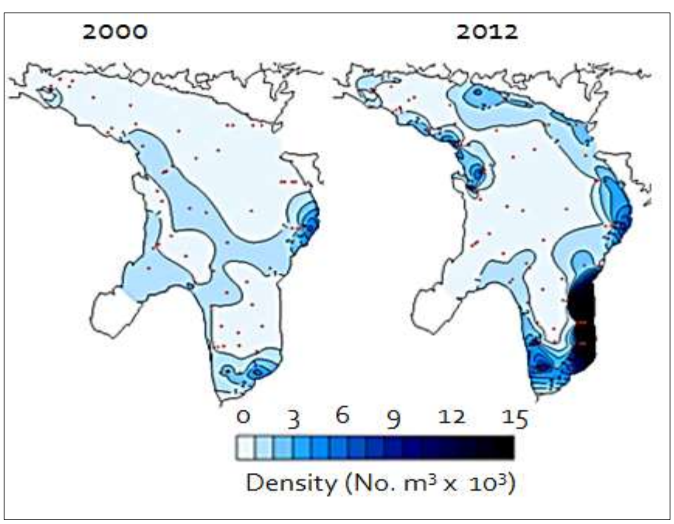


Figure 19. Oligochaete (blood worm) density change between 2000 and 2012 (Nalepa et al., in prep.)

In the U.S, Saginaw Bay was highly eutrophic in the late 1990s, improved to mesotrophic in 2002, but is again trending toward eutrophic (ECCC and USEPA, 2017). Saginaw Bay continues to exceed the interim total phosphorus loading target for a mesotrophic aquatic ecosystem due to its dense agricultural and urban development (Robertson and Saad, 2011; Stow et al., 2014). It is important to note that the validity of this nutrient target, which was established in the 1980's prior to the Zebra Mussel invasion, is uncertain. (This is discussed further in Stow et al., 2014.) High levels of soluble reactive phosphorus (SRP) have not been documented in Saginaw Bay, and recent studies seem to indicate that concentrations of SRP have declined since the late 1990s (Stow et al., 2014). Under current ecological conditions, nutrient levels in Saginaw Bay support a productive fishery (Sesterhenn et al., 2014) and are a significant source of nutrients (~28% of total loads) to the open waters of Lake Huron.

In general, the U.S. nearshore water quality is in good condition based on the results of an extensive Coastal Condition Assessment conducted in 2010 (Figure 20; Nord et al., 2015).

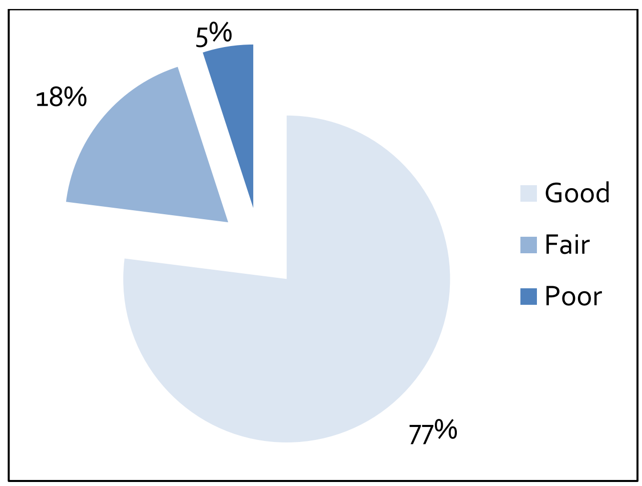


Figure 20. Water quality index results showing overall good nearshore and embayment water quality condition with some areas exhibiting fair (18%) and poor (5%) condition (Nord et al., 2015).

Nuisance Algae

The current status of the *Cladophora* indicator for Lake Huron is 'fair' with an 'undetermined' trend (ECCC and USEPA, 2017).

Approximately 15% of the Lake Huron shoreline is impacted by submerged macro-algae, predominately *Cladophora, Chara* and periphyton, found mostly near the mouths of drains and streams (Barton et al., 2013; Grimm et al., 2013). *Cladophora* occurs at some shoreline locations associated with areas of local nutrient inputs; *Chara* fouling occurs at depths of 2-3 m, but the causes are unknown. Deepwater periphyton has been observed by divers and with video reconnaissance at depths of up to 20 m (Barton et al., 2013).

Cladophora can reach nuisance levels in some reaches of the southeast shores. Little growth of *Cladophora* is detected on the nearshore lakebed of eastern Georgian Bay (Howell, 2015, unpublished data). *Cladophora* is part of an assemblage of benthic macro-algae in Saginaw Bay linked to episodic fouling due to decaying organic matter (beach muck) (ECCC and USEPA, 2017). Fouling within Lake Huron has caused commercial fisherman to occasionally report collecting algae in their deep water nets.

Cladophora muck along the shoreline in Saginaw Bay near Bay City (NOAA).

Harmful Algal Blooms (HABs)

The current status of harmful algal blooms is 'fair' with an 'undetermined' trend offshore, and a 'deteriorating' trend nearshore (ECCC and USEPA, 2017).

Other than episodic summer blooms that occur in Saginaw Bay, Sturgeon Bay and Deep Bay (Georgian Bay), and parts of the North Channel where farming occurs, Lake Huron waters are safe and substantially free from toxic and/or high abundances of harmful algae (ECCC and USEPA, 2017).

4.6.5 THREATS

A variety of human activities can increase nutrient pollution and promote nuisance and harmful algae growth. Sources of excess nutrients from urban areas include runoff and sewer overflows. In rural areas, the mishandling of animal waste or fertilizers can contribute to excess nutrients. Cage aquaculture operations must be properly sited and managed to minimize enrichment of nearby waters. Faulty septic systems can leak nutrients (and bacterial pollution) into nearshore waters. The impacts of climate change are causing increased nutrient pollution due to severe rain events and warmer conditions that promote nuisance and harmful algae growth.

4.6.6 IMPACTED AREAS

Regions with intensive agricultural activity are most at risk. Embayments with limited circulation and mixing with the open waters are more vulnerable to landscape-derived stressors than high energy nearshore areas. These areas may serve as water quality sentinels (Table 11).

Stormwater runoff from farmland (ABCA).

4.6.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions and control measures that address excessive nutrient inputs and nuisance and harmful algal blooms are presented in Chapter 5.2 – *Nutrients and Bacterial Pollution*. Actions that address the *Loss of Habitat and Native Species* (Chapter 5.3) and *Climate Change Impacts* (Chapter 5.5) will indirectly help to address excess nutrients and algal blooms.

Table 11. Nutrient related issues in the regions of Lake Huron.

LAKE HURON REGIONS	NUTRIENT RELATED ISSUES
Main Basin	• No nuisance algae growth or harmful algal blooms • Anecdotal reports from commercial fisherman suggest that nearshore *Cladophora* growth is sloughed off and transported to the main basin, as evidenced by undecomposed filamentous algae caught in fishing nets
St. Marys River	• Urban development a source of stormwater runoff and nutrients • Surrounding agricultural areas include a number of streams that drain to the St. Marys River through subsurface drainage tile and agricultural land stormwater runoff to streams • Inputs from household septics
North Channel/Manitoulin Island	• Occasional *Cyanobacteria* blooms at Desbarats Lake watershed
Georgian Bay	• Enclosed embayments of most concern due to relatively high phosphorus concentrations; episodic *Cyanobacteria* blooms at Sturgeon Bay and Deep Cove in eastern Georgian Bay • Phosphorus concentrations at the mouth of the French River are relatively high, and cyanobacteria blooms are reported upstream • Go-Home Bay, Twelve Mile Bay, Cognashene Lake, Honey Harbour, North Bay, South Bay, Church Bay, the Severn River and Port Severn experience one or more of the following conditions: high phosphorus concentrations; increased filamentous algae and aquatic plant growth; low dissolved oxygen concentrations impacting fish habitat; declines in water clarity, and shifts in aquatic invertebrate and phytoplankton community structure • The Lower and Middle Nottawasaga River reaches and the Innisfil Creek have the lowest stream health ranks with high phosphorus concentrations and turbidity due to agriculture and wastewater inputs from high density residential development • Inputs from household septics
Ontario's Southeastern Shores	• High density agriculture and intensive livestock operations contribute phosphorous and nitrate concentrations to the nearshore • Extensively farmed region with subsurface drainage tiles resulting in agricultural land stormwater runoff to area streams and nearshore • Signs of excessive nutrients; nuisance *Cladophora*, *Chara* and periphyton (beach muck) • Inputs from household septics
Saginaw Bay	• "Eutrophication or undesirable algae" is a Beneficial Use Impairment in the Area of Concern • High density agriculture contributes elevated phosphorous and nitrate concentrations • Episodic summer outbreaks of *Cyanobacteria* blooms • Episodic algal fouling with *Cladophora*, *Chara* and periphyton (beach muck) • Inputs from household septics
Michigan's Western Shores	• Stormwater runoff from urban, rural and agricultural areas • Inputs from household septics

4.7 BE FREE FROM THE INTRODUCTION AND SPREAD OF AQUATIC INVASIVE SPECIES AND FREE FROM THE INTRODUCTION AND SPREAD OF TERRESTRIAL INVASIVE SPECIES THAT IMPACT THE QUALITY OF WATERS OF LAKE HURON

Aquatic invasive species, such as Zebra and Quagga Mussels, and terrestrial invasive species, such as Emerald Ash Borer and Garlic Mustard, continue to impact water quality and limit the productivity of Lake Huron.

4.7.1 BACKGROUND

Aquatic and terrestrial invasive species impact Lake Huron water quality by disrupting chemical, physical, and biological processes in the ecosystem. They also directly compete with native species for food and habitat.

There are now over 75 aquatic invasive species that have been detected within Lake Huron (Bunnell et al., 2014; Nelapa, 2015, unpublished; ECCC and USEPA, 2017). Several of these are causing both direct and indirect impacts to water quality. Limited information is available on the impact of terrestrial invasive species, but land managers are concerned by the presence of species in the watershed that are known to cause water quality impacts.

4.7.2 HOW ARE INVASIVE SPECIES MONITORED?

Monitoring and assessing the impacts of invasive species is a significant challenge for management agencies. The sheer size of Lake Huron and its watershed makes a comprehensive assessment nearly impossible. As a result, estimates of the status and trends of aquatic and terrestrial invasive species are based on limited information, as described below.

Aquatic Invasive Species: Most of the monitoring of aquatic invasive species occurs as a part of routine surveillance programs by environmental protection and natural resource management agencies. Only a few aquatic invasive species have targeted monitoring programs. Adult Sea Lamprey status is measured annually by the Sea Lamprey Program of the Great Lakes Fishery Commission. The population size of invasive Zebra and Quagga Mussels is estimated on a five-year cycle through a multi-agency sampling effort.

The binational "Early Detection and Rapid Response Initiative", recently established by experts working under the Aquatic Invasive Species Annex of the Agreement, is now monitoring additional locations in Lake Huron that are potential points of invasion by new aquatic invasive species.

Terrestrial Invasive Species: Due to the variety of different governmental jurisdictions and the mix of public and private land ownership, there is no single method that assesses the location and spread of terrestrial invasive species in the Lake Huron watershed.

New internet-based technologies, including the Early Detection and Distribution Mapping System (EDDMapS) (http://www.eddmaps.org/), allow land managers and private citizens to voluntarily share information. EDDMapS provides some limited spatial data that helps track the spread of terrestrial invasive species, including Emerald Ash Borer, European Buckthorn, Garlic Mustard, *Phragmites* and Purple Loosestrife.

The USDA Forest Service and Michigan State University maintain the Emerald Ash Borer Information Network website, which includes monthly updates on the confirmed locations for this species in the U.S. and Canada: http://www.emeraldashborer.info/about-eab.php

4.7.3 STATUS

Lake Huron water quality is significantly impacted by invasive species. The overall status of this general objective is 'poor', and most of the indicators report a deteriorating trend (Table 12). There is, however, some good news. Sea Lamprey control has successfully suppressed Sea Lamprey populations in the St. Marys River to all-time lows, and the adult Sea Lamprey populations in Lake Huron are now at target levels.

Table 12. Current status and trends of invasive species impacts to Lake Huron.

INDICATOR	STATUS	TREND
Aquatic Invasive Species	POOR	DETERIORATING
Sea Lamprey	GOOD	IMPROVING
Dreissenid mussels	POOR	DETERIORATING
Terrestrial Invasive Species	POOR	DETERIORATING

4.7.4 DATA DISCUSSION

Environmental policies have reduced the rate that new invasive species are introduced into the Great Lakes; however, species which have already been established are becoming more widespread within the Lake Huron watershed and have caused significant ecological change and impacts to water quality (Bunnell et al., 2014; Nelapa, 2015, unpublished; ECCC and USEPA, 2017).

Presence, Number and Distribution of Aquatic Invasive Species

The Great Lakes Aquatic Non-Indigenous Species Information System (GLANSIS) and the State of the Great Lakes report 75 to 77 known non-native aquatic species including fishes, plants, invertebrates, and diseases (Table 13) (NOAA, 2012; USGS, 2012; ECCC and USEPA, 2017).

Table 13. Population status and vector of entry for established populations of selected invasive species in Lake Huron (USGS, 2012).

SPECIES	ABUNDANCE	VECTOR
Sea Lamprey	Abundant	Canals
Zebra Mussel	Abundant[1]	Ballast water
Quagga Mussel	Abundant[1]	Ballast water
Round Goby	Abundant[1]	Ballast water
Alewife	Rare[2]	Canals
Rainbow Smelt	Abundant[2]	Stocked
Spiny Waterflea	Abundant[1]	Ballast water
Fishhook Waterflea	Rare[1]	Ballast water
Rusty Crayfish	Common	Bait release[3]
European Frog-bit	Unknown	Introduced
Eurasian Watermilfoil	Abundant	Introduced

[1]Bunnell et al., 2014; [2]Roseman et al., 2015; [3]DiDonato and Lodge, 1993.

The GLANSIS records show three new species established in 2016: New Zealand Mudsnail, European Frogbit, and Yellow Iris.

There are currently limited management tools to significantly limit the spread of aquatic invasive species once they have become established in the waters of Lake Huron. Records indicate range expansion for 54 species within the Lake Huron basin; many are high impact species (ECCC and USEPA, 2017).

Sea Lamprey: Unlike most other aquatic invasive species, there are management tools available for controlling Sea Lamprey. Using barriers, chemical lampricides, and other techniques, Sea Lamprey populations have been reduced to about 10% of their historic levels. Sea Lamprey abundance has decreased, due to effective control, and is in 'good' condition and 'improving' (ECCC and USEPA, 2017).

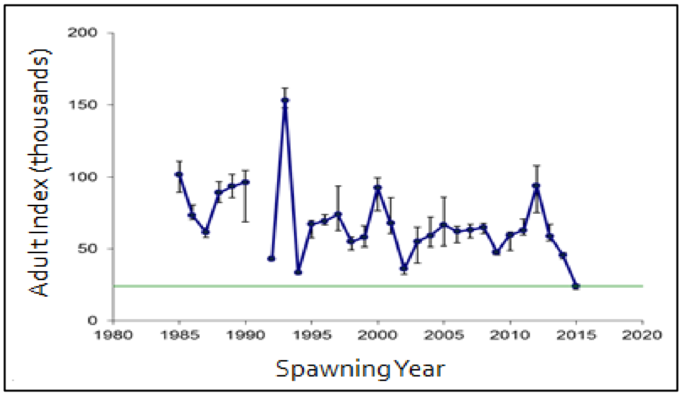


Figure 21. Adult Sea Lamprey index estimate showing achievement of target in 2015 (Sullivan and Adair, 2015).

In 2015, the Lake Huron population control target was achieved for the first time in 30 years (Figure 21). However, marking rates on Lake Trout still exceed the lakewide target of 5 per 100 fish greater than 533mm in length (Sullivan and Adair, 2015).

Most of the adult Sea Lamprey population comes from spawning in just ten Lake Huron streams; however, there are many other streams with suitable spawning habitat that are currently inaccessible due to dams at the river mouths. As discussed in section 5.4, the removal of any dams to improve habitat connectivity must consider the potential for Sea Lamprey to access additional spawning habitat and the resulting increases in parasitism of Lake Huron fish.

Dreissenids: The overall status of dreissenids is 'poor' and 'deteriorating' (ECCC and USEPA, 2017). Invasive mussel populations continue to expand in Lake Huron. These filter-feeding organisms remove algae and small zooplankton from the water, reducing the food available for young fish and other native species.

This filter-feeding activity has resulted in greater water transparency, while "pseudo-feces" excreted by the mussels create a localized source of fertilizer. Increased light availability and more nutrients have contributed to excess algal growth – even in areas which do not have significant land-based sources of nutrient pollution.

Quagga Mussels appear to have replaced Zebra Mussels, except in shallow, nearshore zones. The population density appears to have stabilized at 31-91m, but is increasing at depths greater than 90 m. Densities in Georgian Bay (at 31-90m) decreased two-fold between 2007-2012, and no Quagga Mussels were observed at sampling sites in the North Channel (Figure 22). Few Zebra Mussels were found at sampling sites throughout the Lake Huron basin in 2012 (Nalepa et al., 2007; Bunnell et al., 2014; Nalepa, 2015, unpublished). The filter-feeding activity of Quagga Mussels in the constantly-cold, offshore environment is believed to remove nutrients and plankton that historically drove the springtime diatom bloom.

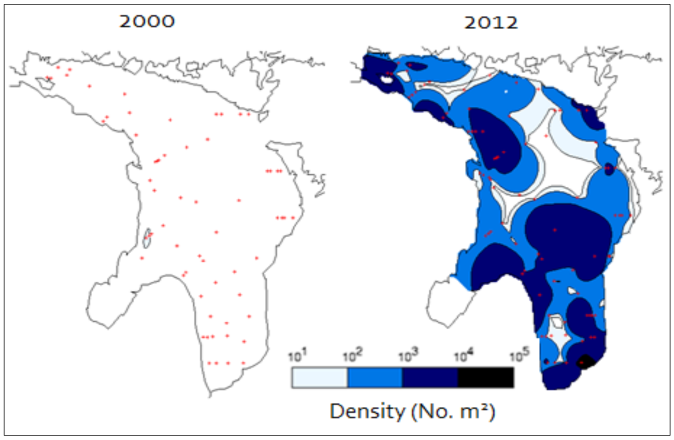


Figure 22. Comparison of densities (m²) of Quagga Mussels in the main basin of Lake Huron, 2000-2012 (Nalepa, 2015).

Dreissenids are also linked to recent outbreaks of botulism. Botulism is a food-borne, paralytic illness produced by the bacteria *Clostridium botulinum* and caused by the toxin botulinum. The bacterium is widely distributed in the Great Lakes. The strain of toxin (Type-4) it produces (under anaerobic conditions) is a highly toxic substance. Outbreaks of Type E botulinum have been a recurrent event in Ontario waters since the late 1990s on beaches between Sarnia and Tobermory and especially in southern Georgian Bay, killing hundreds of Lake Sturgeon and thousands of shorebirds, gulls, terns, diving ducks, mergansers, grebes and loons. Researchers suspect that mussels facilitate toxin

A bird's carcass following a botulism outbreak on the shores of Lake Huron (OMNRF).

production by 1) allowing light to penetrate deeper due to filtering the water, 2) providing a hard substrate for *Cladophora* colonization, and 3) providing soluble phosphorus to *Cladophora*. High levels of *Cladophora* growth result in large amounts of algae being sloughed during storms and deposited on the lake bottom, which rot and provide the anaerobic environment required by the bacteria. It is not certain what invertebrates ingest and move the toxin up the food web, but it is unlikely that mussels are the vector. Round Gobies have been implicated as a vector to birds because they are often found in the guts of infected birds.

Terrestrial Invasive Species

The status of invasive species in the terrestrial and coastal ecosystem is rated as 'poor' condition with a 'deteriorating' trend (ECCC and USEPA, 2017). Despite ongoing management efforts, terrestrial invasive species that are associated with water quality impacts continue to spread within the Lake Huron watershed.

The **Emerald Ash Borer** (*Agrilus planipennis*) was first discovered in North America in the

Detroit-Windsor area in the early 2000s and has quickly spread throughout Michigan and into southern Ontario. This insect feeds on green, red, white, black and blue ash. High mortality rates are typical once an infestation occurs; after 6 years of initial infestation, roughly 99% of ash trees are killed in the woodlot (NRCAN, 2016). Deforestation in natural areas can increase erosion, runoff, and water temperature in previously-shaded streams. In urban centers, the loss of ash trees can increase the amount of stormwater runoff and exacerbate the urban heat island effect (Wisconsin Department of Natural Resources, n.d.).

European Buckthorn (*Rhamnus cathartica*) and Garlic Mustard (*Alliaria petiolata*) impair watersheds by altering forest composition and understory growth. Buckthorn takes over forest understories, choking out native plants and preventing native hardwood saplings from becoming established. Rain quickly washes exposed soil under the Buckthorn into nearby water bodies, causing erosion and water pollution. Garlic Mustard can control the nutrient supply in soil, making it difficult for tree seedlings to germinate (Rodgers, Stinson & Finzi, 2008). It is also toxic to the larvae of some butterflies, which results in a reduction of plant pollination (Lake Huron Centre for Coastal Conservation, n.d.).

Purple Loosestrife (*Lythrum salicaria*) and invasive *Phragmites* (Common Reed *Phragmites australis* subsp. *australis*) directly degrade inland and coastal wetlands by reducing plant species richness and diversity. Purple Loosestrife weaves thick mats of roots that cover vast areas, impacting the quality of habitat for birds, insects and other plants (Government of Ontario, 2012). Furthermore, Purple Loosestrife threatens wetland ecosystems by altering water levels and reducing food sources for both aquatic and terrestrial native species (Thompson, Stuckey & Thompson, 1987).

Phragmites is considered to be the most aggressive, invasive species of marsh ecosystems in North America (Bains et al. 2009), and Canada's worst invasive plant (Catling & Mitrow, 2005). This aggressive spreading invasive plant out-competes all native vegetation and expands into massive mono-culture stands. The loss of native plant diversity and habitat complexity directly impacts wildlife by reducing suitable habitat. There are also negative impacts on tourism, society and local economies due to loss of shoreline views, reduced recreational use and access, fire risks, declining property values, and plugged roadside and agricultural drainage ditches (Gilbert, pers. comm., 2016; Kowalski et al., 2015). No natural controls exist to regulate *Phragmites* populations, underscoring the need for human intervention. It is now found extensively throughout the Lake Huron basin. In Michigan, over 10,000 hectares (24,711 acres) of dense *Phragmites* stands were detected by radar imagery in 2010 (ECCC and USEPA, 2017).

4.7.5 THREATS

The spread of aquatic and terrestrial invasive species occurs as an unintended consequence of global trade, movement of people, and recreational activities like boating and fishing.

Potential pathways for the introduction of invasive species include canals and waterways, boating and shipping, illegal trade, and the release of aquarium species and live bait. Plant species purchased through nurseries, internet sales and water garden trade can also be vectors of spread. Private sector activities related to aquaria, garden ponds, baitfish and live food fish markets continue to be of concern.

Silver and Bighead Carp escapees from southern U.S. fish farms have developed into large populations in the Mississippi River, threatening the Great Lakes. While no Silver and Bighead Carp have been observed in Lake Huron or its tributaries, the hydrological connection with the Mississippi River via the Chicago Sanitary and Ship Canal represents a potential pathway for invasive species to the Great Lakes.

Changes in water quantity and quality, climate change impacts, land use changes, and alterations to the nearshore and shoreline may make Lake Huron more hospitable for new invasive species and the spread of existing invasive species.

4.7.6 IMPACTED AREAS

Non-native invasive species have impacted Lake Huron water quality and ecosystem health and integrity, as explained in Table 14.

4.7.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address invasive species and advance the achievement of this General Objective can be found in Chapter 5.4 – *Invasive Species*. Actions under *Loss of Habitat and Native Species* (5.3) will also help to minimize the impact of invasive species.

Table 14. Invasive species related issues in the regions of Lake Huron.

LAKE HURON REGIONS	INVASIVE SPECIES RELATED ISSUES
Main Basin	• Potential vectors for the spread of invasive species* • Quagga Mussels have altered the food web, energy cycle and lake productivity by removing large energy resources from the water column and concentrating it in their tissue, bottom sediments and algae; degrading native fish spawning and nursery habitat on reefs • Round Goby have been implicated as a vector of botulism poisoning to waterfowl
St. Marys River	• Potential vectors for the spread of invasive species* • The St. Marys River continues to be an important Sea Lamprey producer, requiring significant control effort on an annual basis • Potential for spread of terrestrial invasive species, including Purple Loosestrife, European Buckthorn, Emerald Ash Borer and *Phragmites*
North Channel/ Manitoulin Island	• Potential vectors for the spread of invasive species* • Several important tributaries for Sea Lamprey production, including the Garden, Thessalon and Mississagi Rivers • Spread of terrestrial invasive species, including *Phragmites*
Georgian Bay	• Potential vectors for the spread of invasive species* • Spread of *Phragmites* • Quagga Mussels have increased in abundance, resulting in declining levels of *Diporeia*, which has impacted nutrient dynamics
Ontario's Southeastern Shores	• Potential vectors for the spread of invasive species* • Quagga Mussels have changed the nearshore system by increasing water clarity, altering nutrient pathways, and causing increased density of macro-algae such as *Cladophora* • Spread of *Phragmites*
Saginaw Bay	• Potential vectors for the spread of invasive species* • Quagga Mussels have changed the nearshore system by increasing water clarity, altering nutrient pathways, and causing increased density of macro-algae such as *Cladophora* • Important Sea Lamprey producing streams include tributaries to the Saginaw River and the Rifle River • Spread of terrestrial invasive species, including Purple Loosestrife, European Buckthorn, Emerald Ash Borer and *Phragmites*
Michigan's Western Shores	• Potential vectors for the spread of invasive species* • Spread of terrestrial invasive species, including Purple Loosestrife, European Buckthorn, Emerald Ash Borer and *Phragmites*

*Includes, but is not limited to, recreational boating and fishing, illegal trade and transport of banned species, and deliberate and accidental release of aquarium pets and water garden plants.

4.8 BE FREE FROM THE HARMFUL IMPACT OF CONTAMINATED GROUNDWATER

There is no evidence of significant impacts of contaminated groundwater to Lake Huron. Known contaminated groundwater sites are actively managed and monitored through environmental programs.

4.8.1 BACKGROUND

Shallow groundwater is linked with surface water and other parts of the water cycle. Groundwater influences water quality and the availability, amount, and function of habitats for aquatic life within streams, inland lakes, coastal wetlands, and nearshore waters (Grannemann et al., 2000). Lake Huron cannot be protected without protecting the groundwater resources in the Great Lakes basin (IJC, 2010).

4.8.2 HOW IS GROUNDWATER MONITORED?

Groundwater quality is monitored and reported by Ontario Conservation Authorities, partnered with the Ontario Ministry of the Environment and Climate Change (OMOECC) as part of a provincial groundwater monitoring network. Nitrate and chloride are used as anthropogenic impact indicators in groundwater quality as both come from multiple contaminant sources in rural and urban areas. Elevated concentrations of these compounds have detrimental effects on aquatic ecosystems and human health.

In the U.S., contaminated groundwater is monitored on a site-by-site basis. Several sites within the Lake Huron watershed are managing contaminated groundwater plumes. Contaminated site information is available at the Cleanups in My Community (CIMC) website: www.epa.gov/cleanups/cleanups-my-community.

4.8.3 STATUS

The full extent of groundwater contamination and the overall status of this General Objective are not fully understood for Lake Huron. Limited information suggests that Lake Huron has not been adversely impaired by groundwater with excessive levels of nutrients, chloride or other contaminants in the relatively pristine northern region of Lake Huron, and the undeveloped, mostly forested areas in the northern Lower Peninsula of Michigan (Grannemann and Van Stempvoort, 2016). The overall quality of groundwater in the southern watershed, for which data exist, appears to be in 'good' condition with an 'undetermined' long-term trend (ECCC and USEPA, 2017).

4.8.4 DATA DISCUSSION

Ontario's groundwater monitoring network rarely found levels of contaminants above Ontario drinking water quality standards. In the south and particularly in the agricultural areas of Ontario, of the 77 wells that were assessed, groundwater quality was 'poor' in 14 (18%), 'fair' in 16 (21%), and 'good' in 47 (61%). Groundwater quality is generally in good condition throughout the agricultural watersheds of southern Ontario (ABCA, 2013). The Maitland and Saugeen Valley Conservation Authorities report excellent groundwater quality based on indicators of nitrites, nitrates, and chlorides (MVCA, 2013; SVCA, 2013). Annual monitoring by the Nottawasaga Valley Conservation Authority indicates that all monitoring wells (19) meet Ontario Drinking Water Quality Standards. Chlorides are slightly elevated, suggesting that road salts may be infiltrating into these aquifers (NVCA, 2014). Less information is available for the northern region of the Lake Huron basin.

A few industrial sites within the Saginaw Bay region are currently undergoing groundwater remediation. These sites are well-mapped and managed.

The use of flame retardants at the former Wurtsmith Air Force Base in Oscoda, MI has resulted in groundwater contamination of perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), and other perfluorinated chemicals (PFCs). The full extent of this groundwater contamination is currently under investigation by the Michigan Department of Environmental Quality and Michigan Department of Health and Human Services (MDHHS). Additional information and updates on this contaminated site are available at:
www.michigan.gov/mdhhs/0,5885,7-339-71551_2945_5105-285528--,00.html
www.dhd2.org/index.php/wurtsmith-activities.

4.8.5 THREATS

Many potential sources of groundwater contamination exist (Grannemann and Van Stempvoort, 2016). Spills and legacy contamination at industrial sites are potential sources. Improper use or management of fertilizers, manure, or pesticides in agricultural operations can find their way into groundwater. Faulty septic systems and underground storage tanks that contain home heating oil, diesel or gasoline are also potential sources.

In the southern watershed, glacial deposits (clay, silt, sand, gravel, rock) are associated with shorter transport pathways and residence times in the aquifer, leaving the aquifer vulnerable to contamination from human activities. Here, shallow groundwater is more likely to be impacted by nutrients and pesticides from agricultural activity. The Karst topography of the Bruce Peninsula is also vulnerable to human activity leading to groundwater contamination. Development in urban areas depletes direct recharge to groundwater, and there is considerable evidence indicating that urbanization radically alters the entire urban water cycle (Custodio, 1997; Lerner, 2002). Chloride contamination from salts is likely to occur wherever road density is greatest. It is estimated that 20% of septic systems cause excessive nutrient leaching into groundwater due to poor design, poor maintenance and inappropriate site conditions (CCA, 2009; IJC, 2011).

4.8.6 IMPACTED AREAS

The use of flame retardants at the former Wurtsmith Air Force Base in Oscoda, MI has resulted in groundwater contamination of perfluorinated chemicals (PFCs). Other areas where groundwater is most adversely impacted are described in Table 15.

4.8.7 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Many of the actions identified in Chapter 5 advance the achievement of this General Objective, particularly Chapter 5.1 – *Chemical Contaminants* and Chapter 5.2 – *Nutrient and Bacterial Pollution*.

Table 15. Groundwater related issues in the regions of Lake Huron.

LAKE HURON REGIONS	GROUNDWATER RELATED ISSUES
Main Basin	• Not applicable
St. Marys River	• No information available
North Channel/ Manitoulin Island	• Agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination if not properly used
Georgian Bay	• In southern Georgian Bay, agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination if not properly used • Inputs from household septics
Ontario's Southeastern Shores	• Agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination if not properly used
Saginaw Bay	• Agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination if not properly used • Several industrial sites have active groundwater mitigation programs • Inputs from household septics
Michigan's Western Shores	• Groundwater contamination of perfluorinated chemicals from use of flame retardants at the former Wurtsmith Air Force Base in Oscoda, MI • Inputs from household septics

4.9 BE FREE FROM OTHER SUBSTANCES, MATERIALS OR CONDITIONS THAT MAY NEGATIVELY AFFECT THE GREAT LAKES

Most threats to Lake Huron are being addressed through ongoing environmental programs. Microplastics are a recent concern in freshwater environments, yet sources, transport, and fate remain unclear.

4.9.1 CURRENT CONCERNS

Other issues of public concern may impact ecosystem health and impede progress to achieve this General Objective. Understanding these threats will help inform the public and guide management decisions and priority actions.

Microplastics

Defined as plastic particles generally less than 5 millimeters (0.2 inches) in size, microplastics are non-biodegradable organic polymers such as polyethylene, polypropylene, and polystyrene. Fibers from clothing and rope, plastic particles from the breakdown of bags, packaging and containers, and plastic beads (from personal care products) are part of the mix.

Studies on the effects on freshwater fish are still in their early stages, but experts agree microplastics (and microfibers in particular) may be a growing threat to water quality and wildlife. U.S. researchers recently examined plastic pollution in 29 streams of the Great Lakes and found that 98% of plastics collected were microplastics; 71% of these were microfibers (Knezevic, 2016). An open water survey of plastic pollution within Lakes Superior, Huron and Erie showed that concentrations of plastic particles increased from Lake Superior to Lake Erie, consistent with populations (Figure 23) (Eriksen et al., 2013).

The U.S. government signed into law H.R. 1321, the Microbead-Free Waters Act of 2015 on Dec. 28, 2015. The bipartisan legislation will begin the phase out of plastic microbeads from personal care products on July 1, 2017. The Canadian government released proposed regulations on Nov. 4, 2016, to ban the sale of microbeads in toiletries by July 2018. By July 2019, natural health products and non-prescription drugs containing microbeads will be banned.

The ban on the use of microbeads in personal care products was an important first step in reducing the flow of microplastics into the Great Lakes, but numerous other, potentially more important sources of microplastics remain. These sources include: urban runoff (Styrofoam, plastic bags, bottles, wrappers, cigarette butts, and tire particles), fishing gear and discarded debris from boats, plastic shavings and dust from factory floors, wastewater treatment facility effluent (synthetic fibers from clothing and textiles, fragments of larger debris), combined sewer overflows, and atmospherically-deposited synthetic fibers.

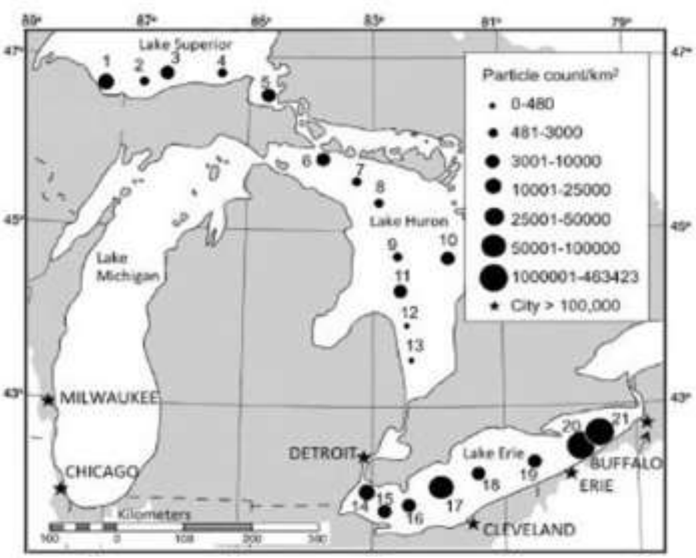


Figure 23. Distribution of plastic particles by count for three of the Great Lakes (Eriksen et al., 2013).

5.0 ACTIONS THAT ADVANCE ACHIEVEMENT OF THE GENERAL OBJECTIVES

Member agencies of the Lake Huron Partnership have developed an ecosystem-based strategy to improve the water quality of Lake Huron. Government agencies, stakeholders, and the public all have an important role in implementing priority actions over the next five years.

As reported in Chapter 4, several of the Agreements' General Objectives are not being fully achieved (Table 16). Fish consumption advisories are in place due to legacy contaminants and other chemicals of concern. The majority of nearshore waters are of high quality; however, areas of the southeast shores, Saginaw Bay, and parts of eastern Georgian Bay experience episodic algal blooms. Aquatic habitat and native species face multiple threats and *Diporeia*, an important native species and food source for prey fish has declined, significantly impacting native fish production. Quagga Mussels are expanding in the deep waters of Lake Huron and are associated with nuisance algal growth and food web changes. These threats interact with a changing climate to produce complex management challenges.

Table 16. The status of Lake Huron by General Objective.

	GENERAL OBJECTIVE	STATUS
1.	Be a source of safe, high-quality drinking water.	GOOD
2.	Allow for unrestricted swimming and other recreational use.	GOOD
3.	Allow for unrestricted human consumption of the fish and wildlife.	FAIR
4.	Be free from pollutants that could harm people, wildlife or organisms.	GOOD/FAIR
5.	Support healthy and productive habitats to sustain our native species.	FAIR
6.	Be free from nutrients that promote unsightly algae or toxic blooms.	FAIR
7.	Be free from aquatic and terrestrial invasive species.	POOR
8.	Be free from the harmful impacts of contaminated groundwater.	GOOD
9.	Be free from other substances, materials or conditions that may negatively affect the Great Lakes.	FAIR

This chapter describes five binational strategies and identifies actions that address key environmental threats discussed in Chapter 4. The strategies are based on an assessment of the scope and severity of impacts to water quality. Each strategy has links with various General Objectives as illustrated in Table 17.

Table 17. Crosswalk between LAMP binational strategies and each of the Agreement's General Objectives.

Binational Strategy	General Objective Not Achieved
Chemical Contaminants	3, 8*
Nutrients and Bacterial Contamination	5, 6,
Loss of Habitat and Native Species	5, 6, 7
Invasive Species	5, 7
Climate Change Impacts	5, 6, 7

Actions in binational strategies will also help to maintain General Objectives (1, 2, 4, 8, and 9) in "Good" condition.
*Due to PFOS concerns, as noted in section 4.8.

The Lake Huron Partnership will work with many others, including watershed management agencies, local public agencies, non-profit environmental groups, and the public, to address key environmental threats through the implementation of 43 management actions between the years of 2017 to 2021. Management actions will build off of the many achievements already observed from ongoing science, monitoring and binational and domestic initiatives. Actions will focus cooperative, collaborative implementation efforts and reporting under the Lake Huron LAMP, and will be implemented to the extent feasible, given available resources and domestic policy considerations by the agencies with corresponding mandates.

A summary of regional threats is provided (Figure 24) that summarizes chemical contaminants (CC), nutrients and bacterial pollution (N), loss of fish and wildlife habitat and native species (FWH), and invasive species (IS). Climate change impacts are not included in this summary; however, documented climatic trends, such as increasing water temperatures and severe weather events, have implications on the ecology and water quality of Lake Huron.

MAIN BASIN

CC: Atmospheric deposition of persistent organic pollutants – decreasing but still occurring
N: Watershed nutrient and sediment inputs from agriculture, overland runoff, and erosion
FWH: Food web changes with variable energy resources available to aquatic organisms, loss and degradation of nearshore and offshore reef habitat for native fish spawning across the basin
IS: *Dreissenid* mussels in the nearshore and offshore remove nutrients from the water column and shunt to lake bottom. Sea Lamprey impacts to valuable commercial and sport fish populations

ST. MARYS RIVER

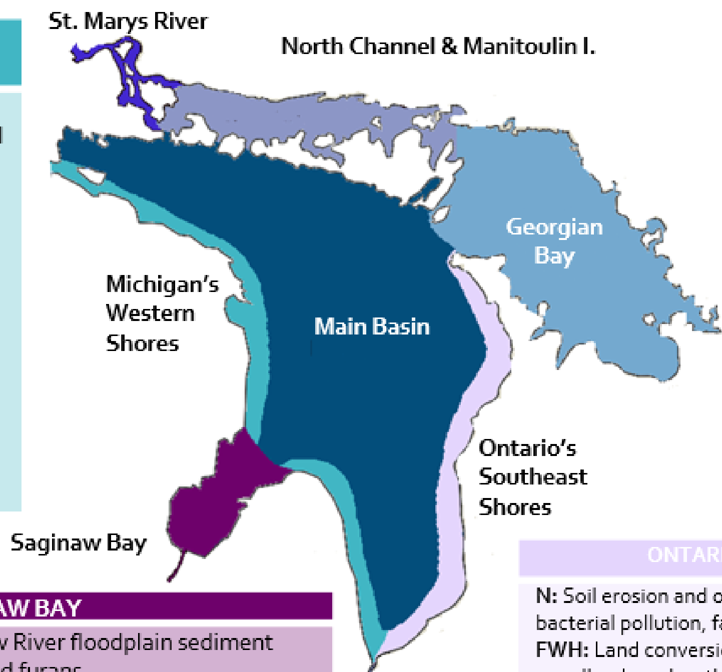
CC: Localized sediment contamination in Canadian waters
N: Urban stormwater runoff and faulty septic systems
FWH: Shoreline development and alteration, altered flow regimes, historic loss of wetland and river rapid habitat
IS: High level of Sea Lamprey production, Purple Loosestrife, Buckthorn, Emerald Ash Borer

NORTH CHANNEL & MANITOULIN I.

CC: Sediment contamination (Spanish Harbour)
N: Agricultural nutrient inputs, livestock access to rivers, river bank erosion, faulty septic systems
FWH: Loss and degradation of stream habitat, loss of hydrological connectivity due to dams and barriers, lack of protection of coastal wetlands
IS:. *Phragmites* degrading river mouths and wetlands

MICHIGAN WESTERN SHORES

CC: PFOS groundwater contamination near Oscoda, MI
N: Faulty septic systems and urban, rural and agricultural runoff
FWH: Non-point source pollution, loss and degradation of stream habitat, loss of hydrological connectivity due to dams and barriers
IS: Purple Loosestrife, Buckthorn, Emerald Ash Borer and *Phragmites*



GEORGIAN BAY

N: Shoreline development in enclosed embayments, faulty septic systems, agricultural nutrient inputs to Nottawasaga Bay and Severn Sound
FWH: Non-point source pollution, shoreline dredging, hardening, loss and degradation of stream habitat, loss of hydrological connectivity due to dams and barriers, lack of protection of coastal wetlands
IS: Spread of *Phragmites* and wetland degradation

SAGINAW BAY

CC: Tittabawassee and Saginaw River floodplain sediment contamination due to dioxin and furans
N: Land runoff, soil erosion, faulty septic systems
FWH: Agricultural nutrient inputs, dams and barriers result in habitat fragmentation
IS: *Dreissenid* mussels, Sea Lamprey, Purple Loosestrife, Buckthorn, Emerald Ash Borer and *Phragmites*

ONTARIO SOUTHEAST SHORES

N: Soil erosion and overland runoff of soil, nutrients, and bacterial pollution, faulty septic systems
FWH: Land conversion with loss/fragmentation of woodlands and wetlands, shoreline alteration and development, loss of stream connectivity due to dams and barriers
IS: *Dreissenid* mussels, Sea Lamprey, Emerald Ash Borer and *Phragmites*

CC: Chemical Contaminants **N:** Nutrients and Bacterial Pollution **FWH:** Fish & Wildlife Habitat **IS**: Invasive Species

Figure 24. A simplified summary of regional threats to Lake Huron addressed by binational strategies in Chapter 5.

5.1 CHEMICAL CONTAMINANTS

5.1.1 BACKGROUND

While most areas of Lake Huron are not significantly impacted by chemical contaminants, environmental concentrations of some compounds are an ongoing problem and may limit the full achievement of the following General Objectives in the waters of Lake Huron:

- #3: Allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants;
- #4: Be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife or aquatic organisms through direct exposure or indirect exposure through the food chain; and
- #8: Be free from harmful impact of contaminated groundwater.

Numerous environmental programs have been established over the last several decades to control the release of municipal and industrial chemicals into the environment and remediate contaminated sites. As a result, environmental concentrations of most chemicals taken from air, water, sediment, fish and wildlife samples are declining and at low levels. Further reductions in chemical contaminants will be achieved by a combination of in-basin and out-of-basin programs. The following section describes actions that will be taken to reduce chemical contaminants in Lake Huron and how reductions in the environment will be monitored.

5.1.2 MAJOR POLLUTANT SOURCES

Chemical pollutants enter Lake Huron in many different ways including: atmospheric deposition; point source; non-point source; and existing contaminated bottom sediments. Continued efforts by Canada and the U.S. are needed to coordinate action at the regional and international levels, supported by sustained monitoring efforts within the Great Lakes basin to determine program effectiveness.

Atmospheric Pollution

Atmospheric deposition has been recognized as a significant source of certain toxic pollutants to the Great Lakes since the 1970s. Canada and the United States acted on a Great Lakes regional scale by establishing the Integrated Atmospheric Deposition Network in 1989 as a joint effort in support of the Agreement. The Network measures atmospheric concentrations of toxic chemicals to determine temporal and spatial trends and the effectiveness of national and international control measures.

CHEMICAL CONTAMINANTS: ACTIONS AT A GLANCE

- Continue to implement regulations to control end-of-pipe sources of pollution
- Continue national and international efforts to reduce atmospheric inputs of chemical contaminants
- Continue work developing a sediment management plan for the Canadian portion of the St. Marys river
- Pursue site specific remediation to address contaminated sediments
- Pursue site specific remediation to address contaminated groundwater
- Assess effectiveness of actions through surveillance and monitoring
- Note: actions described in Chapter 5.2 to address non-

Atmospheric pollutant deposition is also evaluated and regulated on an out-of-basin regional or international scale. Examples of actions include the Stockholm Convention on Persistent Organic Pollutants and the United Nations' Economic Commission for Europe's Convention on Long Range Transboundary Air Pollution. Reducing atmospheric deposition requires continued permitting and enforcement of air discharges in North America and participation with international efforts to reduce chemical contaminants worldwide.

Point Source Pollution

Few high-density areas of industrial activity exist in the Lake Huron watershed, and therefore pollutant loadings are low. Several Acts and pieces of legislation support compliance (permitting) and enforcement programs that prevent the creation of contaminants at the source, control the direct discharge of contaminants, and reduce public and environment risks posed by chemicals (Table 18).

Non-Point Source Pollution

Diffuse chemical pollution from agricultural, forestry, and urban activities can occur throughout the Lake Huron watershed. Non-point source pollution programs, described in Chapter 5.2 – *Nutrients and Bacterial Pollution*, will also help reduce chemical loadings to Lake Huron.

Contaminated Bottom Sediments

Before modern pollution laws went into effect, pollutants were released to surface waters and settled into sediment at the bottom of rivers and harbours. Sediment is most often contaminated with toxic chemicals such as PCBs, dioxins,

Table 18. Regulatory chemical contaminant reduction initiatives by different government levels.

REGULATORY CONTAMINANT PROGRAMS AND REDUCTION MEASURES	
Canada Shipping Act, 2001	Prevention of pollution from ships.
Canada Environmental Protection Act, 1999	Pollution prevention and the protection of the environment and human health to contribute to sustainable development.
Canada Fisheries Act, 2016	Section 36 prohibits the deposit of deleterious substances into waters frequented by fish, unless authorized. The 2015 Wastewater Systems Effluent Regulations is Canada's first national standards for wastewater treatment.
Canada Pipeline Safety Act, 2016	Sets technical standards for the design, construction, operation, maintenance, and decommissioning of Canada's oil and gas pipelines.
U.S. Protecting our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act, 2016	Requires annual federal reviews of all pipelines' age and integrity.
U.S. Clean Air Act, 1990	Federal law regulates air emissions from stationary and mobile sources and establishes National Ambient Air Quality Standards to protect public health.
U.S. Clean Water Act, 1972	Regulates discharges of pollutants into the waters of the U.S. and establishes water quality standards for surface waters.
Ontario Water Resources Act, 1990, and Environmental Protection Act, 1990	Provincial regulation of wastewater discharges. The *Municipal-Industrial Strategy for Abatement* regulates industrial discharges of contaminants from prescribed industrial sectors into surface waters.
Michigan Natural Resources and Protection Act, 1994	Establishes permitting and regulatory programs for water quality.

heavy metals like mercury, as well as oil, grease or other petroleum byproducts. In Lake Huron, this has been a focus at the Saginaw River and Bay AOC, the St. Marys River Binational AOC, and the Spanish Harbour AOC in Recovery. Appendix B discusses AOCs in Lake Huron. Ongoing work within these AOCs is reducing the impact of contaminated sediments, and other site-specific remediation efforts will remove contaminant sources. Communities are seeing success from federal, state, provincial, municipal and industry funding partnerships and regulations, including:

- Dow Chemical Superfund site within the Tittabawassee and Saginaw Rivers, a multi-year effort to clean up dioxin-contaminated soil in the floodplain;
- Clean up of the U.S. St. Marys River manufactured gas plant site as part of the Great Lakes Legacy Act, wherein 26,000 cubic yards of PAH–contaminated sediment were removed from the site;
- Clean up of the Canadian St. Marys River by Essar Algoma Steel, wherein process changes and upgrades reduced oil and grease (96%) and suspended solids (94%); and
- A Canadian multi-agency technical team has been working toward developing a sediment management plan appropriate for the St. Marys River in Ontario.

Investigating Groundwater Contaminants

The 5,223-acre former Wurtsmith Air Force Base is located on the northeastern part of Michigan's Lower Peninsula. Leaking chemical storage tanks and waste disposal operations have contaminated soil and groundwater with hazardous chemicals. Clean up, operation and maintenance activities are ongoing with some areas still under investigation, including U.S. federal and state efforts to address perfluorinated chemical contamination originating from the former Wurtsmith Air Force Base.

5.1.3 MANAGEMENT LINKAGES WITH THE *AGREEMENT*

Article 4 of the 2012 Agreement commits the Parties to implement programs for pollution abatement, control, and prevention for industrial sources, contaminated sediments, and radioactive materials. Article 6 commits the Parties to notification and response under the Canada-United States Joint Inland Pollution Contingency Plan to advise each other of threats of a pollution incident, or planned activities that could lead to a pollution incident. To address chemical contaminants, binational efforts are also being taken through the Agreement's Chemicals of Mutual Concern (CMC) Annex, such as:

- Preparing binational strategies for CMCs;
- Coordinating the development and application of water quality standards, objectives, criteria, and guidelines;
- Reducing releases and products containing CMCs throughout entire life cycles; and
- Promoting the use of safer chemicals.

Canada and the United States have designated a list of eight chemicals as the first set of CMCs:

- Hexabromocyclododecane (HBCD);
- Long-Chain Perfluorinated carboxylic acids (LC-PFCAs);
- Mercury;
- Perfluorooctanoic acid (PFOA);
- Perfluorooctane sulfonate (PFOS);
- Polybrominated Diphenyl Ethers (PBDEs);
- Polychlorinated Biphenyls (PCBs); and
- Short-Chain Chlorinated Paraffins (SCCPs).

The 2012 Agreement reaffirms the commitment to restore water quality and ecosystem health in Great Lakes ***Areas of Concern (AOCs)***. Federal, provincial, and state agencies, continue to work with local stakeholders to implement Remedial Action Plans for the St. Marys River, Saginaw River and Bay AOCs, and the Spanish Harbour AOC in Recovery– available at http://www.michigan.gov/deq/0,4561,7-135-3313_3677_15430-240913--,00.html and http://www.ec.gc.ca/raps-pas/.

5.1.4 ASSESSING CONTAMINANT TRENDS

Chemical contaminant monitoring and surveillance programs assess the status and trends of chemical contaminants and demonstrate the presence or absence of new compounds. Examples of domestic and binational surveillance and monitoring programs include:

- ***Open Water Chemical Monitoring Programs***: ECCC and the USEPA conduct ship-based open water monitoring of chemicals in water, fish and bottom sediment as part of Great Lakes surveillance.
- ***Wildlife Contaminants***: ECCC annually monitors concentrations of persistent organic pollutants and metals in Herring Gull eggs from three U.S. and Canadian colonies in Lake Huron. Three additional colonies are monitored by the MDEQ in Michigan.
- ***Fish Contaminants***: The Ontario Ministry of Natural Resources and Forestry and the MDNR collect fish samples for analysis by the OMOECC and the Michigan Department of Community Health, who then release public fish consumption advisories. Top predator fish are also sampled by the USEPA's Great Lakes National Program Office and ECCC's Fish Contaminants Monitoring and Surveillance Program.
- ***Michigan DEQ's Surface Water Quality Monitoring Program:*** Assesses for impaired waters (303d list), Total Maximum Daily Load (TMDL), biological status, trend and targeted contaminant levels, water chemistry, and fish contaminants.

5.1.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS CHEMICAL MANAGEMENT

In consideration of the chemical contaminant trends, the main contaminant sources, and localized impacts as explained in Chapters 4.3 and 4.4 and above, the member agencies of the Lake Huron Partnership have developed chemical management actions and identified the agencies who will lead project implementation (Table 19).

Over the next five years, member agencies of the Lake Huron Partnership will encourage and support chemical contaminant reduction efforts and work with scientists and Great Lakes experts to understand and reduce the impacts of chemicals in the waters of Lake Huron. This will be achieved by a combination of binational and domestic programs and other measures.

Project tracking and reporting on the status and achievements of chemical contaminant monitoring and site remediation will be undertaken by the Lake Huron Partnership. Not all of the member agencies of the Lake Huron Partnership are responsible for contaminant monitoring, surveillance, and implementation. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 19. Lake Huron Partnership actions that address chemical contaminants over the next five years.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
ADDRESSING POINT SOURCE CHEMICAL CONTAMINANTS		
1	Federal, provincial, state and regulatory partners monitor and ensure compliance with clean water laws and regulations (see Table 18 above).	
ADDRESSING SEDIMENT CHEMICAL CONTAMINANT REMEDIATION		
2	Continue the multi-year sediment remediation on the Tittabawassee River Floodplain – Dow Chemical Superfund site. The dioxin-contaminated floodplain includes approximately 4500 acres (1821 ha) and extends 21 miles (34 km) from Midland, Michigan, through several counties to Saginaw Bay.	MDEQ, Saginaw Chippewa Indian Tribe of Michigan (SCIT), USEPA
3	Continue efforts to develop a sediment management plan appropriate for the Canadian portion of the St. Marys River.	ECCC, OMOECC
4	Continue the multi-year sediment remediation on the Flint River at the former Chevy Commons Site in Flint, Michigan. To prevent the mobilization of contaminated sediments, the site is being capped and green infrastructure is being installed.	USEPA, USFS
ADDRESSING NON-POINT SOURCE CHEMICAL CONTAMINANTS		
	Refer to Chapter 5.2 – *Nutrients and Bacterial Pollution* for non-point source pollution actions.	
ADDRESSING CONTAMINATED GROUNDWATER		
5	Continue investigation and mitigation of perfluorinated chemicals in groundwater at the former Wurtsmith Air Force Base in Oscoda, Michigan.	MDEQ
ADDRESSING CHEMICAL CONTAMINANT MONITORING		
6	Continue monitoring and periodic reporting on atmospheric pollutant deposition at Great Lakes stations.	ECCC, USEPA
7	Conduct long-term sediment contaminant monitoring in the Spanish Harbour Area of Concern in Recovery to track recovery.	ECCC, OMOECC
8	Continue long-term monitoring of Lake Huron water and sediment contaminants to examine legacy organics, PAHs, trace metals, Hg, and selected new and emerging compounds.	ECCC, USEPA
9	Conduct fish contaminant monitoring in each year between 2017 and 2021.	CORA, MDHHS, MDNR, SCIT, USEPA
10	Conduct annual Herring Gull monitoring in each year between 2017 and 2021 at sampling locations within the Lake Huron basin.	ECCC, MDEQ
11	Update and, where needed, develop acceptable fish consumption guidance.	LTBB

5.1.6 ACTIVITIES THAT EVERYONE CAN TAKE

The public is encouraged to do its part to prevent chemical contaminants from entering the Lake Huron ecosystem, including watershed streams, lakes, wetlands and groundwater by undertaking the following actions:

- Follow the 6 R's: rethink, refuse, reduce, reuse, repair, and recycle (Figure 25);
- Take household hazardous materials to hazardous waste collection depots;
- Never burn garbage in barrels, open pits, or outdoor fireplaces, to prevent the release of toxic compounds like dioxins, mercury, lead, etc.;
- Use pharmaceutical take-back programs to properly dispose of unused or expired medication;
- Choose eco-friendly household cleaning and personal care products;
- Use more environmentally-friendly asphalt-based sealants as an alternative to those with coal tar, which contain toxic substances;
- Consider using natural pest-control methods – not toxic chemicals; and
- Always follow the recommendations found in provincial and state guides/advisories to eating sport fish, especially children and pregnant women.

Figure 25. The 6 R's to sustainability.

5.2 NUTRIENTS AND BACTERIAL POLLUTION

5.2.1 BACKGROUND

While most areas of Lake Huron are not impacted by excessive nutrients (phosphorus and nitrogen) that lead to nuisance or harmful algal blooms and bacterial pollution that make beaches unsafe, localized nutrient and bacterial pollution is an ongoing issue that is limiting the full achievement of the following General Objectives:

- #5: support healthy and productive wetlands and other habitats to sustain resilient populations of native species; and
- #6: 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.

Actions that control excess nutrient and bacterial pollution will also help to maintain nearshore water quality and maintain the status of the General Objective:

- #2: Allow for swimming and other recreational use, unrestricted by environmental quality concerns.

Many domestic initiatives and programs are in place (Table 20) to address nutrient and bacterial pollution, including: priority watershed identification; monitoring; incentive programs for local landowners to undertake best management practices (BMPs); regulatory measures; and upgrades to municipal wastewater treatment plants.

NUTRIENT AND BACTERIAL POLLUTION: ACTIONS AT A GLANCE

- Maintain, and where possible, optimize wastewater treatment plants and stormwater management facilities
- Use green infrastructure and low impact development
- Continue/enhance integrated, systematic, and targeted nutrient reduction efforts in priority watersheds
- Develop, renew, and revise integrated watershed management plans
- Conduct research and monitoring to better understand nutrient dynamics in Lake Huron and its watershed
- Assemble, synthesize, and report on nutrient and bacterial pollution and beach health
- Improve engagement, communication and coordination to build awareness and improve understanding

5.2.2 MAJOR POLLUTANT SOURCES

Excessive nutrients and bacteria can enter Lake Huron through "point sources" and "non-point sources." Point sources originate from single locations that are relatively easy to identify, such as a wastewater treatment facility. Non-point sources originate from less easily identified sources, such as runoff from agricultural fields, forestry, golf courses, and subdivisions.

Point Sources of Pollution

Efforts to protect water quality by regulating "end-of-pipe" point discharges from outfalls have been generally successful. Industrial and municipal wastewater facilities must have an environmental compliance approval to establish, use, and operate facilities, and there are site-specific effluent limits and monitoring and reporting requirements for operation.

Table 20. National pollution reduction initiatives.

EXAMPLES OF NUTRIENT POLLUTION REDUCTION MEASURES	
Agricultural Act of 2014 (aka U.S. Farm Bill)	Provides authorization for services and programs by the U.S. Department of Agriculture.
Nutrient Management Act, 2002	A nutrient management framework for Ontario's agricultural industry, municipalities, and other generators of materials containing nutrients, including environmental protection guidelines.
Environmental Protection Act / Water Resources Act, 1994	Environmental approval is required by every business or facility in Ontario that creates a discharge to the natural environment.
The Fisheries Act, 1985	Section 36: prohibits the deposit of deleterious substances into waters frequented by fish, unless authorized. The 2015 Wastewater Systems Effluent Regulations: Canada's first national standards for wastewater treatment.
Clean Water Act, 1972	Regulates discharges of pollutants into the waters of the United States and establishes quality standards for surface waters.

Opportunities exist to optimize the performance of treatment plants, and to reduce the volume and frequency of bypasses and overflows. During heavy storm events or snowmelt, the volume of runoff, domestic sewage, and industrial wastewater can exceed the capacity of combined sewer systems resulting in combined sewer overflows. When this occurs, untreated stormwater and wastewater discharge directly to nearby streams, rivers, and lakes with potential negative impacts to water quality.

- The USEPA has a combined sewer overflow control policy and a national framework for controlling combined sewer overflows through the National Pollutant Discharge Elimination System permitting program.
- The National Pollutant Release Inventory (NPRI) is Canada's legislated inventory of pollutant releases and a resource for encouraging actions to reduce the release of pollutants.

Non-Point Source Pollution

Diffuse pollution occurs when excess nutrients and bacteria leach into surface waters and groundwater as a result of rainfall or snowmelt moving over and through the ground.

Agricultural operations are most dense in Ontario's southeast shores of Lake Huron and in Michigan's Saginaw Bay watershed. High-density confined animal feeding operations can generate large amounts of animal waste and excess nutrients and bacteria if not properly managed. Commercial fertilizers and animal manure can be a threat to water quality if they are over-applied, applied too close to a watercourse, applied on frozen ground, or just before a heavy rain. Row-cropping has generally moved toward larger fields. Threats to water quality from row-cropped fields can increase if best management practices such as riparian buffers or cover crops are not practiced. Extensive tiling and draining can compound non-point source pollution problems.

- The 2012-2017 Lake Simcoe/South-eastern Georgian Bay Clean-Up Fund supported community-based projects that reduced phosphorous inputs from urban and rural sources to address algal blooms. https://www.ec.gc.ca/eau-water/default.asp
- Since 2010, the Healthy Lake Huron: Clean Water, Clean Beaches Initiative has been implementing actions in priority watersheds with landowners to ensure safe and healthy beaches between Sarnia and Tobermory, Ontario. http://www.healthylakehuron.ca/

- Voluntary farm assistance programs support farms of all sizes to engage in agricultural pollution prevention practices that comply with state, provincial, and federal environmental regulations. Programs are implemented in Michigan by the Michigan Agricultural Environmental Awareness Assurance Program http://www.michigan.gov/mdard and through the USDA Natural Resources Conservation Service (NRCS) https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/, and in Ontario through the Canada-Ontario Environmental Farm Plan http://www.omafra.gov.on.ca

Before and after photos of sediment trap and municipal drain project (Maitland Valley Conservation Authority).

Soil erosion from poor ***forestry and logging*** practices, road building, fertilizer application, and burning can also be potential sources of water contamination. Practices have improved to such an extent that impacts on Lake Huron are generally localized.

Residential, urban and shoreline development can disrupt natural water flows, generate nutrients from lawn fertilizers, cause sediment pollution from land clearing and road development, and create high volumes of runoff from impervious surfaces. Failing ***septic systems*** can contribute bacteria and phosphorus to waterways.

5.2.3 MANAGEMENT LINKAGES WITH THE *AGREEMENT*

Article 4 and the Nutrients Annex of the 2012 Agreement commits the Parties to implement programs for pollution abatement and enforcement for municipal sources (including urban drainage), industrial sources, agriculture, and forestry.

Annex 4 "Nutrients" is co-led by ECCC and USEPA. Efforts under this Annex are developing the scientific information and modeling techniques required to develop nutrient targets for the Great Lakes. Annex 4 is currently focused on Lake Erie; however, the approaches for monitoring and modeling Lake Erie algal blooms and *Cladophora* growth could be applied to Lake Huron in the future. Ideally, there should be enough nutrients in the water to support a productive fishery, while at the same time, nuisance algae growth and beach fouling are minimized.

In fulfillment of a U.S. and Canadian commitment under the Lakewide Management Annex of the Agreement, '*The Great Lakes Nearshore Framework'* was completed to provide an approach for assessing nearshore waters, sharing information, identifying stressors and areas requiring protection, and restoring or prevention activities.

Nearshore areas are a source of drinking water and link the watersheds with the open waters (ABCA).

Agencies can then factor findings from such an approach into priority setting, and to create collaborative approaches to address water quality issues. The Nearshore Framework will be implemented through the lakewide management process. See www.binational.net for details.

5.2.4 ASSESSING NUTRIENT CONTROL PROJECT EFFECTIVENESS

Ship-based monitoring of offshore nutrient concentrations and the productivity of the lower food web is performed by ECCC and USEPA as a part of Great Lakes surveillance.

Edge-of-field monitoring is now used to test the effectiveness of agricultural best management practices. County Health Units and Departments monitor select beaches for *E. coli* levels and publish annual results. Routine stream and open water monitoring is conducted by federal, provincial, and state agencies to report on nutrient trends.

Saginaw Bay water quality and algal bloom conditions are monitored every second week by the National Oceanic and Atmospheric Administration. Results are posted online at https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/.

5.2.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS NUTRIENT POLLUTION

In consideration of the current trends, main sources of nutrients and bacterial pollution, geographic scope of the issue, and localized impacts (as explained in Chapter 4.6 and above), member agencies of the Lake Huron Partnership have developed nutrient monitoring and management actions and identified the agencies who will lead project implementation (Table 21).

Over the next five years, the Lake Huron Partnership will encourage and support nutrient and bacterial pollution reduction efforts and work with scientists and Great Lakes experts to understand and reduce the impacts of nutrients (including SRP) in the waters of Lake Huron and to reduce harmful and nuisance algal blooms. This will be achieved through binational and domestic initiatives.

Project tracking and reporting on the status and achievements of nutrient monitoring and management actions will be undertaken by member agencies of the Lake Huron Partnership. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 21. Lake Huron Partnership actions that address nutrients and bacterial pollution over the next five years.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
	POINT SOURCE POLLUTION	
12	***Wastewater Treatment Plants and Stormwater Management Systems:*** • Enforce permitted discharges to ensure receiving waters meet Water Quality Standards; • Enhance the use of green infrastructure and low impact urban development.	USEPA, USACE, MDEQ, OMOECC, SCIT, USFS, Conservation Authorities
	NON-POINT SOURCE POLLUTION IN AGRICULTURAL AREAS	
13	***Nutrient and Bacteria Control:*** Build on existing integrated and systematic efforts within targeted watersheds to improve soil health, reduce overland runoff of nutrients, sediments, and bacteria, and maintain and restore natural heritage features: • Implement agricultural BMPs, for example, USDA NRCS' Regional Conservation Partnership Program titled 'Saginaw Bay Watershed Conservation Partnership', co-led by Michigan Agri-Business Association and The Nature Conservancy, within high-priority sub-watersheds (Shiawassee, Pigeon/Pinnebog, Cass, Pine/Chippewa, Sebewaing, and Kawkawlin Rivers); • Address nuisance and harmful algae and promote safe and clean beaches in priority watersheds in Ontario's southeast shore (Pine River, Garvey Glenn, North Bayfield, Main Bayfield, Lambton Shores) through the following actions: - Targeted agricultural BMP and edge-of-field monitoring; - Continuous flow and event-based water quality monitoring and reporting; - Identification of additional priority watersheds in the Lake Huron watershed; and - Outreach and engagement with landowners and the public.	MDEQ, SCIT, USDA-NRCS Conservation Authorities, OMAFRA, OMNRF, OMOECC, Parks Canada
14	***Watershed Management Planning and Implementation****:* Renew and/or develop integrated watershed management plans and link to coastal and nearshore management and other nutrient reduction actions at a community level: • Build local capacity for monitoring and best management practice implementation, and encourage and promote community involvement; • Implement the **Tipping Points Planner** for communities to build local capacity; and • Continue to implement management plans under Section 319 Nonpoint Source Management Program of the U.S. Clean Water Act.	BMIC, Conservation Authorities, MDEQ, NOAA, OMAFRA, OMNRF, OMOECC, SCIT, USEPA, USDA-NRCS, USFS
	SCIENCE, SURVEILLANCE, AND MONITORING	
15	***Open Water:*** Conduct spring and summer open water nutrient and lower foodweb surveys.	ECCC, USEPA
16	***Agricultural Areas*****:** Continue edge-of-field water quality monitoring in targeted Ontario and Michigan watersheds to assess effectiveness of best management practices.	Conservation Authorities, OMOECC, USDA-NRCS, USGS
17	***Streams*****:** Continue surface water quality monitoring and synthesis of information from various stream and river locations: • Joint program between the province of Ontario and conservation authorities via the Provincial Water Quality Monitoring Network (PWQMN); and • Continue to assess stream water quality under Section 305(b) of the U.S. Clean Water Act.	Conservation Authorities, MDEQ, OMOECC, USEPA
18	***Watershed***: • Continue a multi-watershed nutrient study, to assess the interaction between agricultural land use and nutrient loadings in southeast shore streams. • Continue surface water monitoring on lakes and wetlands under Tribal jurisdiction.	Conservation Authorities, LTBB, OMOECC

[continued on next page]

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021 (continued)	AGENCIES INVOLVED
19	***Saginaw Bay Water Quality and Harmful Algal Bloom (HAB) Monitoring and Reporting:*** • Explore expanding real-time water quality and nutrient buoy system to several sites in inner Saginaw Bay; • Enhance monitoring and reporting of algal blooms on NOAA-GLERL's HAB and Hypoxia webpage to provide weekly updates from June through October; • Conduct experiments to understand the environmental factors that influence changes in algal bloom community composition, toxicity, and ecosystem services; • Develop a Saginaw Bay Harmful Algal Bloom Bulletin; and • Develop a Saginaw Bay 3D- HAB Tracker product similar to the current 3D-HAB Tracker developed for western Lake Erie.	NOAA-GLERL
20	***Science Synthesis:*** Assemble, synthesize, and report on nutrient and bacterial contamination science and monitoring results from projects funded by the Lake Simcoe/South-eastern Georgian Bay Clean Up Fund (2012-2017).	ECCC
21	***Research and Monitoring:*** Improve understanding of invasive mussels and their influence on phosphorus cycling in the aquatic system and *Cladophora* growth.	USEPA
OUTREACH AND EDUCATION		
22	***Communication***: Undertake outreach and education on local and regional scales to increase the understanding of water quality condition and management challenges, nearshore and beach health, and best management practices and policies.	Bay Mills Indian Community (BMIC), ECCC, LTBB, OMOECC, SCIT, USFS

5.2.6 ACTIVITIES THAT EVERYONE CAN TAKE

Landowners and the public are encouraged to do their part to prevent nutrient and bacterial pollutants from entering groundwater, streams, lakes, wetlands, and Lake Huron by undertaking the following actions:

- Choose phosphate-free detergents, soaps, and cleaners - use appropriate amounts;
- Avoid using lawn fertilizers;
- Always pick up pet waste;
- Use natural processes to manage stormwater runoff and reduce the amount of impervious surfaces;
- Install a rain barrel and plant a rain garden with native plants, shrubs, and trees so that water soaks into the ground;
- Inspect and pump out your septic system regularly;
- Implement improved septic technologies, including conversion of septic systems to municipal or communal sewage systems;
- Incorporate agricultural best management practices, such as grassed swales, filter and/or buffer strips to control and reduce store stormwater runoff; and
- Keep cattle out of streams; leave a buffer strip to trap nutrient and sediment runoff; and plant a shelter belt.

Agricultural BMP showing extensive grassed waterways (ABCA).

One of the many alternate watering devices and fencing projects that restrict cattle from streams to improve local water quality and aquatic habitat (Bruce Peninsula Biosphere Association).

5.3 LOSS OF HABITAT AND NATIVE SPECIES

5.3.1 BACKGROUND

The main factors contributing to the loss of biological diversity are habitat alteration, destruction and fragmentation-on land, in streams, in rivers, and along the shores of Lake Huron. Other threats include: non-point source pollution, non-native invasive species, climate change, unsustainable shoreline development and alterations, and dams and barriers. These factors may prevent the achievement of the following General Objective:

- #5: Support healthy and productive wetlands and other habitats to sustain resilient populations of native species.

Actions that restore and protect habitat and species will also indirectly benefit other General Objectives:

- #6: 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.

In 2010, the former Lake Huron Binational Partnership built on numerous strategies to complete *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* (Franks Taylor et al., 2010). This involved a two-year consultation period with more than 300 individuals representing approximately 100 agencies, Tribal, First Nations and Métis governments, conservation authorities, non-government organizations and universities. The Strategy discusses ecological condition, identifies key threats to biodiversity, prioritizes conservation action sites, and recommends 21 conservation strategies for Lake Huron. For more information, go to: https://www.conservationgateway.org.

Numerous other binational, regional, and place-based plans and ecological assessments have been developed or are ongoing to identify threats, recommend conservation action, and implement restoration projects. Some examples include the following:

Lake Huron's biodiversity conservation strategy developed in partnership with the Lake Huron conservation community.

- The Great Lakes Fishery Commission's Lake Huron Technical Committee works across borders to implement fisheries management plans, report on the fishery, and develop *Fish Community Goals* and *Environmental Objectives* (Liskauskas et al., 2007);
- The State of the Lakes Ecosystem Conference 1998 Biodiversity Investment Areas for Aquatic Ecosystems (Koonce et al., 1999); and
- Michigan Department of Natural Resources Watershed Assessment Reports.

HABITAT AND NATIVE SPECIES: ACTIONS AT A GLANCE

- Nearshore reef and shoal spawning habitat rehabilitation
- Aquatic habitat assessments and rehabilitation
- Stream connectivity restoration and enhancement
- Shoreline management planning and actions that address regional stressors and threats
- Watershed restoration and protection
- Walleye, Lake Trout, Cisco and other native species restoration planning efforts
- Monitor, map and report on coastal wetland condition
- Science to inform management and assess effectiveness of actions through monitoring

5.3.2 THREATS TO LAKE HURON'S HABITATS AND SPECIES

Environmental issues and threats to Lake Huron's biodiversity were determined through a binational, collaborative process and are detailed in *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* (Franks Taylor et al., 2010). Many of these threats and the actions to address them are covered in other sections of the chapter, including: *Nutrient and Bacterial Pollution* which covers non-point source pollution (Chapter 5.2); *Invasive Species* (5.4); and *Climate Change Impacts* (5.5). Other issues that directly and negatively impact Lake Huron habitat and native species are covered in this section.

Shoreline Development and Alterations

While directly degrading and destroying nearshore and coastal wetland habitat, shoreline development and alteration also disrupt natural circulatory patterns, nutrient cycles, sediment transport, and other coastal processes and pathways. Lake bed modifications due to jetties, groins, and shoreline armoring also provide hard surfaces that may facilitate the spread of invasive dreissenid mussels.

Extensive dredging in the nearshore at Collingwood, Ontario (OMNRF).

Regional, multi-jurisdictional initiatives that address and monitor shoreline development and alterations include:

- The Michigan State Coastal Zone Management Program promotes wise management of the cultural and natural resources of Michigan's Great Lakes coast;
- Under the Ontario government plan to conserve biodiversity, and *Ontario's Great Lakes Strategy*, the Ontario Ministry of Natural Resources and Forestry supports biodiversity conservation to reduce ongoing shoreline erosion, and improve the ability of coastal and inland wetlands to control water flow and reduce sediment phosphorus loads;
- Great Lakes Coastal Wetland Monitoring Program and McMaster University monitor coastal wetland biota, habitat, and water quality and developed a GIS-based inventory;
- The Southern Georgian Bay Shoreline Initiative coordinates efforts for monitoring shoreline alterations and water quality, and promotes community-based stewardship and information sharing.

Dams and Barriers

The installation and management of hydropower dams, low head dams, culverts, and water-control structures threaten the diversity of native fishes by restricting or eliminating connectivity between the lake and critical spawning, nursery, and overwintering habitat.

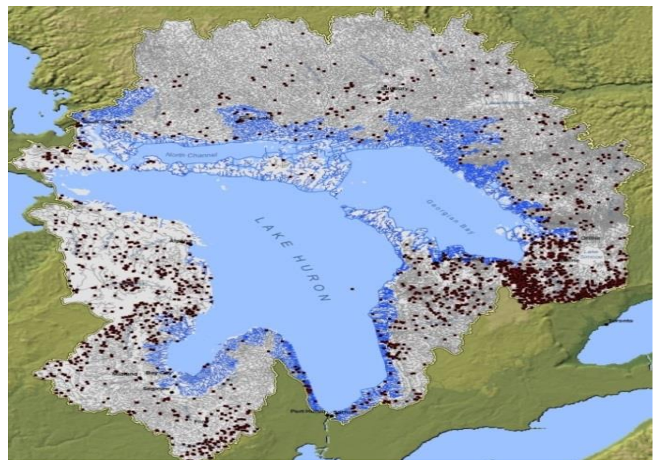


Figure 26. Map of Lake Huron dams and barriers (SOGL).

Dams, impoundments, and barriers also interrupt the natural flow of water, nutrients, and sediment to Lake Huron, alter temperature regimes (e.g., thermal heating), and increase the transformation and exposure of toxic pollutants (e.g. mercury) (St. Louis et al., 2004; Calder et al., 2016). Dams, however, help prevent the spread of Sea Lamprey and other aquatic invasive species, and management decisions must consider their benefit as tools of Lamprey control before decommisioning and replacement (Figure 26).

Federal, regional, and multi-jurisdictional initiatives that examine opportunities for dam decommissioning and removal include:

- Fishwerks is a web-based GIS platform that allows users to access tools that identify barriers which, if removed, would maximize habitat improvements for migratory fish. www.greatlakesconnectivity.org.

- The Great Lakes Restoration Initiative funded partners to remove the Cass River Dam at Frankenmuth, Michigan to allow passage of fish species, such as Walleye and Lake Sturgeon. Fourteen separate weirs and adjacent "resting pools" have been constructed over a span of approximately 350 feet for non-jumping species.
- The Canadian Government, through the Recreational Fisheries Conservation Partnership Program, supported the Saugeen Valley Conservation Authority to remove the Lockerby Dam on the Saugeen River.

Other Issues and Opportunities

With the variability in open water nutrients and abundance of prey fish, researchers have been examining additional means to increase the productivity of Lake Huron. Artificial reefs and strategic rock placements are ongoing efforts that have helped to produce positive, localized responses by fishes.
In addition to shoreline alterations, land cover change in the watershed can lead to losses of habitat and native species.

The reintroduction of Cisco (formerly known as Lake Herring), one of nine related coregonid species that originally occurred in Lake Huron, has been a focus for Lake Huron fisheries managers. The introduction of invasive species (e.g., Alewife), overfishing, and eutrophication were responsible for its collapse. Cisco rehabilitation would help to maintain a diverse prey fish community, reestablish the linkage between the inner and outer Saginaw Bay, and enhance foraging options for Walleye. It could also reduce predation to Yellow Perch.

National, provincial, and state parks dot the shores of Lake Huron. Still, almost 82% of the shoreline is unprotected (Parker, pers. comm., 2016), highlighting the importance of existing parks and the need for new protected areas and new protective actions. Recognizing the role of non-government organizations and the public, many funding programs facilitate habitat and native species conservation (Table 22).

Artificial shoals and rock clusters improved Walleye spawning habitat at the Moon River basin (OMNRF).

Table 22. Examples of Canadian and U.S. funding programs that support rehabilitation of aquatic habitat and native species.

UNITED STATES	CANADA
• U.S. Great Lakes Restoration Initiative https://www.glri.us// • USDA, NRCS Conservation Programs https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ • USEPA Environmental Justice Grants https://www.epa.gov/environmentaljustice • USFWS Partners for Fish and Wildlife https://www.fws.gov/partners/ • USFWS National Fish Passage Program https://www.fws.gov/fisheries/whatwedo/nfpp/nfpp.html • Great Lakes Fish Habitat Partnership http://www.fishhabitat.org/the-partnerships/great-lakes-basin-fish-habitat-partnership • USFWS National Wildlife Refuge System https://www.fws.gov/refuges/ • USFWS National Coastal Wetlands Conservation Grant Program https://www.fws.gov/coastal/coastalgrants/ • Sustain Our Great Lakes http://www.sustainourgreatlakes.org/	• ECCC Eco-Action Community Funding Program • ECCC National Wetland Conservation Fund; Habitat Stewardship Program • ECCC Environmental Damages Fund • ECCC Aboriginal Fund for Species at Risk • ECCC Great Lakes Sustainability Fund - Link to all ECCC programs: http://www.ec.gc.ca/financement-funding/default.asp?lang=En&n=923047A0-1 • Recreational Fisheries Conservation Partnerships Program http://www.dfo-mpo.gc.ca/pnw-ppe/rfcpp-ppcpr/index-eng.html • Ontario's Great Lakes Guardian Fund https://www.ontario.ca/page/great-lakes-guardian-community-fund • Provincial COA and Great Lakes Strategy Funding

5.3.3 MANAGEMENT LINKAGES WITH THE *AGREEMENT*

Article 4 (2.c) of the Agreement commits the U.S. and Canada to implement conservation programs to restore and protect habitat and recover and protect species. Annex 7 of the Agreement calls for a "baseline survey" of existing habitat against which to establish an ecosystem target of net habitat gain to measure progress.

5.3.4 ASSESSING PROGRAM EFFECTIVENESS

Federal, state, provincial, and tribal governments, academic institutions, and not-for-profit organizations work to assess aquatic habitat and native species populations and trends, including:

- Lake Huron Technical Committee – Technical Report Series and Publications;
- Bottom Trawl and Acoustics Surveys (USGS);
- St. Marys River and Saginaw Bay Area of Concern Programs;
- Great Lakes Coastal Wetland Consortium, the Great Lakes Coastal Wetland Monitoring Program, and McMaster University Coastal Wetland monitoring, assessment and Inventories; and

Provincial, state and tribal fish community monitoring programs.

5.3.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS HABITATS AND SPECIES

In consideration of the current condition of aquatic habitat and native species, and an understanding of the geographic scope of threats and extent of localized impacts, as explained in Chapter 4.5 and above, member agencies of the Lake Huron Partnership have developed habitat and species monitoring and management actions and the agencies who will lead project implementation (Table 23).

Over the next five years, the Lake Huron Partnership, in collaboration with partners leading domestic programs and other initiatives, will work to better understand and address loss of habitat and the impacts to native species. This will be achieved by a combination of binational and domestic initiatives and other measures.

Project tracking and reporting on the status and achievements of habitat and species monitoring and management actions will be undertaken by the Lake Huron Partnership. Not all of the member agencies of the Lake Huron Partnership are responsible for monitoring and project implementation. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 23. Lake Huron Partnership actions that address loss of aquatic habitat and native species.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
23	***Spawning Reefs and Shoals:*** Continue to develop strategies and implementation plans that rehabilitate and/or create nearshore reefs to support overall lake productivity.	MDEQ, MDNR, SCIT, USACE, USFWS, USGS
24	***Aquatic Habitat Protection and Restoration:*** Assess streams and estuaries to determine aquatic habitat significance, stressors, and limitations to fish spawning and migration, and consult with local partners, stakeholders, and governments to identify rehabilitation priorities, including: • Assessment of Eastern Georgian Bay estuaries with project implementation.	MDNR, OMNRF, SCIT, USFS
25	***Stream Connectivity:*** Restore stream connectivity and function through dam removal, the construction of fish passage alternatives (e.g., ladders), and stream culvert improvements to compensate for loss of riverine habitat.	Conservation Authorities, LTBB, MDEQ, MDNR, NOAA, OMNRF, USACE, USDA-NRCS, USFS, USFWS
26	***Habitat and Native Species Conservation***: Build on information in "*The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron"* through integrated conservation planning to identify areas of ecological significance and areas facing environmental threats and stressors: • Update and share Canadian geospatial information on ecosystem classification (Lead -OMNRF); • Engage stakeholders and the public; • Facilitate information sharing; • Develop regional conservation and stewardship plans (Ontario); and • Promote community-based conservation and stewardship.	Conservation Authorities, DFO, ECCC, MDEQ, MDNR, OMNRF, OMOECC, PC, USEPA, USDA-NRCS, USFS, USFWS

[continued on next page]

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021 (continued)	AGENCIES INVOLVED
SPECIES RECOVERY AND MONITORING		
27	***Walleye Restoration***: Develop a Walleye Management Plan for the Ontario waters of Lake Huron and track the effectiveness of harvest regulations throughout Lake Huron.	OMNRF
28	***Cisco Restoration:*** Examine the benefits of reintroducing Cisco to targeted areas of the lake.	MDNR, OMNRF, USFWS, USGS
29	***Coastal Wetlands:*** Monitor coastal wetlands to assess coastal wetland water quality, species diversity, and the impacts of human activities; and promote protection, restoration, enhancement, and protection efforts. • Utilize green engineering to soften shorelines that have been previously hardened. • Apply new decision support tools to help identify and prioritize coastal wetland restoration projects.	BMIC, Conservation Authorities, ECCC, NOAA, OMNRF, PC, SCIT, USACE, USEPA, USFWS

5.3.6 ACTIVITIES THAT EVERYONE CAN TAKE

Protecting and restoring habitats and species involves the coordination of many different agencies, non-governmental organizations, professions and the pursuit of management actions by various partners and the public. Here are some suggestions on how to do your part:

- Maintain natural vegetation along the coast and streams;
- Resist the urge to “tidy up” the beach. Natural vegetation and debris serve as habitat;
- Plant native trees and shrubs on your property;
- Get involved with shoreline clean up events;
- Consider working with neighbours, not-for-profit organizations and municipalities, to restore beach-dune health by installing sand fencing and planting dune grasses;
- Stay on constructed beach and dune paths and avoid trampling the sparse and fragile vegetation in these areas;
- Support and/or volunteer with local conservation authorities, stewardship councils and non-governmental environmental organizations;
- Access shoreline stewardship guides for advice, see https://www.lakehuron.ca/stewardship-plans-and-guides; and
- Share your knowledge with your friends, neighbours, cottage renters or even strangers, about the rarity and ecological importance of each of the special shoreline types.

High school students erecting fence designed to keep reptiles off highway as part of a Lake Huron Youth Summit (ECCC).

River restoration and tree planting at the Kagawong River (Manitoulin Island Stream Improvement Association).

5.4 INVASIVE SPECIES

5.4.1 BACKGROUND

The introduction, establishment, and spread of invasive species are significant threats to Lake Huron water quality and biodiversity. An aquatic invasive species (AIS) is one that is *not native* and whose introduction *causes harm*, or is likely to cause harm to the economy, environment, or human health. Sea Lamprey continue to impact valuable commercial and sport fisheries. Dreissenid mussels have altered the food web in the open waters and are thought to increase nutrient levels, water clarity, and algal biomass in nearshore waters. The ecological link between mussels, nuisance rotting algae, and Round Goby is also speculated to enhance the transfer of botulinum toxin through the food web, resulting in Type E botulism-related deaths of loons, waterfowl, shorebirds, and fish; some of which are species at risk. Aquatic non-native invasive species are undermining efforts to restore and protect ecosystem health, water quality, and the full achievement of the following General Objectives:

- #4: Be free from pollutants (i.e., botulinum toxin) in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms, through direct exposure or indirect exposure through the food chain;
- #5: Support healthy and productive wetlands and other habitats to sustain resilient populations of native species; and
- #6: 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.

INVASIVE SPECIES: ACTIONS AT A GLANCE

Undertake a basin-wide approach to:

- Prevent introductions from ballast water;
- Detect and respond to new introductions; and
- Stop the establishment of Bighead and Silver Asian Carp in the Great Lakes.

Work within Lake Huron to:

- Reduce the impacts of invasive species, including *Phragmites;* and
- Minimize the spread of invasive species by recreational boating, fishing equipment, and other recreational activities.

The government of Ontario released the Ontario Invasive Species Act (2015) and published an Invasive Species Strategic Plan (2012) that coordinates actions by provincial and federal organizations. It builds on Canada's Invasive Alien Species Strategy (2004).

Table 24. Examples of invasive species reduction initiatives by the various government departments.

EXAMPLES OF INVASIVE SPECIES REDUCTION MEASURES	
Ontario Invasive Species Act, 2015	Rules to prevent and control the spread of invasive species in Ontario.
National Invasive Species Act, 1996	U.S. Federal law intended to prevent invasive species from entering inland waters through ballast water carried by ships.
Michigan's Natural Resources and Environmental Protection Act, 1994 (NREPA)	Part 413 of *NREPA* defines prohibited and restricted species in Michigan and limits the possession, import or sale of such species.
Canada Fisheries Act, 1985	Aquatic Invasive Species Regulations (2015) made under this act on import, possession, transport, release.
Lacey Act, 1900	U.S. Federal act that prevents transport of species designated as 'Injurious to Wildlife'.

In the United States, the National Invasive Species Council published a four-year National Invasive Species Management Plan (2008) to direct the actions of federal agencies. The U.S. Forest Service also published a National Strategic Framework for Invasive Species Management (2013). The state of Michigan published the Aquatic Invasive Species Management Plan (2013) with actions for implementation as well as maintaining and enhancing existing efforts to prevent the introduction and dispersal of aquatic invasive species, detect and respond to new invaders, and minimize the harmful effects of aquatic invasive species in Michigan waters.

Ontario's Invasive Species Strategic Plan (2012) prevents new invaders from arriving and surviving in the province, slows or reverses the spread of existing invasive species and reduces the harmful impacts of existing invasive species.

5.4.2 KEY PATHWAYS FOR INTRODUCTION AND SPREAD

The most effective approach to prevent the introduction and spread of new invasive species is to manage the pathways through which invasive species enter and spread. Below are the key pathways and examples of existing management approaches.

Ballast Water

Eggs, larvae, and juveniles of larger species (fish, mollusks, crustaceans) and the adults of smaller species can be transported by ship ballast water. Historically, an average of one non-native species was found to be established in the Great Lakes about every 8 months. Recent practices, including ballast water exchange or treatment and sediment management, have significantly reduced the rate of introduction. Because of compatible ballast water exchange regulations between Canada and the United States and stringent binational enforcement, no new aquatic invasive species attributable to the ballast water of ships have been reported in the Great Lakes since 2006.

- In 2009, the U.S. Saint Lawrence Seaway Development Corporation, in conjunction with the International Joint Commission, initiated the formation of the Great Lakes Ballast Water Collaborative to share information and facilitate communication and collaboration among key stakeholders.
- Significant work is underway on the design and performance testing of ballast water management systems.

Illegal Trade of Banned Species

Invasive, non-native plants and animals could potentially cause significant harm to the Great Lakes region through illegal trade.

- A risk analysis of illegal trade and transport into Great Lakes jurisdictions was completed and a report of these findings was delivered to the Great Lakes Fishery Commission's binational Law Enforcement Committee. The report recommends risk management efforts to address the unacceptable risks documented for species regulated by state, provincial, and federal agencies in the internet, live bait, live food, aquaculture, private pond/lake stocking, water garden, aquarium/pet, and cultural release pathways. The aquatic invasive species Subcommittee will continue to work with the Law Enforcement Committee to address risk management needs described in the risk analysis report.
- The Ontario Invasive Species Act (2015) prohibits the import, possession, deposit, release, transport, purchase or sale of selected invasive species to prevent their arrival and control their spread. For more information, go to https://news.ontario.ca/mnr/en/2016/11/prohibited-and-restricted-invasive-species.html.

Recreational Activities

Float planes, sailboats, personal watercraft, kayaks, diving equipment, ropes, and fishing gear may transport the attached fish, fragments, larvae, and eggs of invasive species to new bodies of water. Currently there are few specific regulations directed at recreational and commercial boating related to preventing the spread of aquatic invasive species. Education and voluntary compliance are key activities, and governments and non-government organizations offer public awareness programs. For example, boat inspection programs can serve the dual purpose of heightening public awareness of aquatic invasive species and providing inspection of trailered watercraft.

- In the United States, a government-industry partnership is working toward development of new recreational boat design standards for building new "AIS-Safe Boats," and development of United States standards for aquatic invasive species removal from existing recreational boats.
- In Canada, a National Recreational Boating Risk Assessment, with focus on the potential movement of aquatic invasive species within Canadian and United States waters of the Great Lakes, was carried out during 2015, and the products of this assessment will assist in identifying areas to focus on minimizing risk of recreational boaters spreading aquatic invasive species.

Canals and Waterways

Connecting rivers and canals allow free movement of aquatic invasive species across watersheds and lakes:

- Conducted by the U.S. Army Corps of Engineers (USACE), the Great Lakes and Mississippi River Interbasin Study (GLMRIS) Report presents results of a multi-year study regarding the range of options and technologies available to reduce the risk of future aquatic nuisance species movements between the Great Lakes and Mississippi River basins through aquatic pathways. For more information, go to http://glmris.anl.gov/glmris-report/.
- The Asian Carp Regional Coordinating Committee (ACRCC), formed in 2009, works to prevent the introduction, establishment, and spread of Bighead, Black, Grass, and Silver Carp populations in the Great Lakes. The ACRCC developed a comprehensive approach focused on prevention and control opportunities in the Illinois Waterway and Chicago Area Waterway System as the primary potential pathway; binational surveillance and early detection of Asian Carp, and assessment and closure of secondary pathways of potential introduction in Indiana and Ohio, are explained in the Asian Carp Action Plan. For more information, go to http://www.asiancarp.us/documents/2016AsianCarpActionPlan.pdf.

Additional Efforts Underway

Domestic efforts in Canada and the United States are underway to address non-native species.

Sea Lamprey management and control have been ongoing since 1960 by the Great Lakes Fishery Commission in collaboration with all levels of government. Lampricide was applied to 28 streams and five lake areas as well as the St. Marys River in 2015. In addition, 17 barriers and dams that were specifically constructed or modified to block Sea Lamprey spawning migrations in Lake Huron streams were operated and maintained. Research continued into other alternatives to lampricide, such as attractants (e.g. pheromones), repellents (e.g. alarm cues), juvenile trapping, nest destruction, and new adult trapping designs. Sea Lamprey abundance has recently declined, and in 2015, the Lake Huron suppression target was achieved for the first time in 30 years.

Invasive Phragmites is mapped using satellite imagery (U.S.) and aerial photographs to monitor its spread. Efforts are underway in the U.S. by the *'Great Lakes Phragmites Collaborative' (www.greatlakesphragmites.net)* and in Ontario by the *'Ontario Phragmites Working Group' (www.opwg.ca)*. These partnerships were established to improve communication and collaboration and implement a more coordinated, efficient, and strategic approach to managing this invasive plant species. Non-governmental, place-based programs are also active in the control of highly invasive *Phragmites*.

Outreach and Engagement efforts are implemented domestically in Michigan and Ontario to increase public awareness and involvement in the control of aquatic invasive species. Experts are also working across jurisdictions to support the work of the Great Lakes Panel on Aquatic Nuisance Species, a binational body comprised of representatives from government (State, Provincial, Federal, and Tribal), business and industry, universities, citizen environmental groups, and the public.

5.4.3 MANAGEMENT LINKAGES WITH THE *AGREEMENT*

Article 4 of the 2012 Agreement commits the Parties to implement aquatic invasive species programs and other measures to prevent the introduction of new species; control and reduce the spread of existing species; and when feasible, eradicate existing aquatic invasive species.

Annex 5 "Discharges from Vessels" is co-led by Transport Canada (TC) and United States Coast Guard (USCG). Efforts under this Annex will establish and implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of aquatic invasive species in ballast water.

Annex 6 "Aquatic Invasive Species" is co-led by Fisheries and Oceans Canada (DFO) and the United States Fish and Wildlife Service (USFWS). Coordinated and strategic binational responses to invasive species management are ongoing. Efforts under this annex will identify and minimize the risk of Asian Carp and other species invading the Great Lakes using a risk-assessment approach to better understand the risks posed by species and pathways and by implementing actions to manage those risks. Through efforts of federal, state, and provincial agencies, Canada and the United States have developed and implemented an Early Detection and Rapid Response Initiative with the goal of finding new invaders and preventing them from establishing self-sustaining populations.

Key components of the Early Detection and Rapid Response Initiative include:

- A "species watch list: of those species of the highest priority and likelihood of risk of invading the Great Lakes;
- A list of priority locations to undertake surveillance on the "species watch list";
- Protocols for systematically conducting monitoring and surveillance methodologies and sampling;
- The sharing of relevant information amongst the responsible departments and agencies to ensure prompt detection of invaders and prompt coordinated actions; and
- The coordination of plans and preparations for any response actions necessary to prevent the establishment of newly detected aquatic invasive species.

5.4.4 ASSESSING AQUATIC NON-NATIVE AND INVASIVE SPECIES PROGRAM EFFECTIVENESS

The effectiveness of invasive species programs is tracked through several basin wide initiatives. The overall success in preventing new introductions will be tracked as part of Annex 6's Early Detection and Rapid Response Initiative and NOAA's Great Lakes Aquatic Non-Indigenous Species Information Systems https://www.glerl.noaa.gov/res/Programs/glansis/.

The Great Lakes Fishery Commission will continue to control Sea Lamprey populations in Lake Huron. Annual reports that evaluate the Sea Lamprey Control Program are produced by DFO and USFWS. The Asian Carp Regional Coordinating Committee provides a forum for coordination of new research about how to detect, control, or contain Asian Carp.

5.4.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS INVASIVE SPECIES 2017-2021

In consideration of the pathways, distribution, and ecosystem impacts of aquatic invasive species, as explained in Chapter 4.7 and above, member agencies of the Lake Huron Partnership have developed actions and projects that address this threat and the responsible implementing agencies (Table 25).

Over the next five years, the member agencies of Lake Huron Partnership will encourage and support invasive species management efforts and work with scientists and Great Lakes experts to understand and reduce ecosystem impacts in the waters of Lake Huron.

Project tracking and reporting on the status and achievements of monitoring and management actions will be undertaken by the Lake Huron Partnership. Not all of the member agencies of the Lake Huron Partnership are responsible for contaminant monitoring, surveillance, and implementation. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 25. Lake Huron Partnership actions that address aquatic and terrestrial invasive species over the next five years.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
30	***Ballast Water:*** Establish and implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of AIS in ballast water, consistent with commitments made by the Parties through Annex 5 of the *GLWQA*.	Transport Canada, USCG, USEPA
31	***Early Detection and Rapid Response:*** Through the Annex 6 subcommittee, implement an 'early detection and rapid response initiative' with the goal of finding new invaders and preventing them from establishing self-sustaining populations.	DFO, LTBB, USFS, USFWS
32	***Canals and Waterways:*** Through the Asian Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead and Silver Carp in the Great Lakes.	USEPA, USFWS

[continued on next page]

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021 (continued)	AGENCIES INVOLVED
33	***Sea Lamprey:*** • Control the larval Sea Lamprey population in the St. Marys River with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate. • Design and construct Au Gres Sea Lamprey Trap in Arenac County, Michigan. • Design and construct Au Sable Sea Lamprey Trap in Losco County, Michigan.	DFO, USACE, USFWS
34	***Improve understanding of invasive species impacts to inform management efforts:*** • *Impacts of Round Goby on the Foodweb:* Enhance assessment methods and technology to better understand Round Goby population density and distribution. • *Causes of Botulism Outbreaks:* Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl. • *Cladophora growth*: Work through the Annex 4 subcommittee to support the creation of Lake Huron sentinel *Cladophora* monitoring sites to determine the role of mussels in nearshore algae growth and possible mitigation efforts.	MDNR, OMNRF, USGS
35	***Control of Terrestrial and Wetland Invasive Species:*** Maintain coastal and nearshore aquatic habitat diversity and function through appropriate control of *Phragmites* and other detrimental invasive species (e.g. Glossy Buckthorn, European Frog-bit, Purple Loosestrife, Japanese Knotweed) including monitoring, mapping, and control efforts guided by BMPs. • Coordinate *Phragmites* control efforts and share BMPs through the *Ontario Phragmites Working Group* and *Great Lakes Phragmites Collaborative.*	BMIC, MDNR, NVCA, OMNRF, Parks Canada, SCIT, SCRCA, USDA-NRCS, USEPA, USFS, USFWS
SCIENCE, SURVEILLANCE, AND MONITORING		
36	***Surveillance***: Maintain and enhance early detection and monitoring of non-native species (e.g. Asian Carp) through the Annex 6 *Early Detection and Rapid Response Initiative.*	DFO, MDNR, OMNRF, USEPA, USFS, USFWS
37	***Monitoring***: Maintain an index time series that shows the impact of Sea Lamprey control on Lake Trout population status.	MDNR
OUTREACH AND EDUCATION		
38	***Communication***: Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage.	BMIC, DFO, LTBB, MDEQ, OMNRF, SCIT, SCRCA, USFS

5.4.6 ACTIVITIES THAT EVERYONE CAN TAKE

Learn how Canada and the U.S. are contributing to aquatic invasive species science through the work of federal scientists, collaboration with national and international interest groups, and funding of partnership projects.

- Learn how to identify, report, and stop the spread of *Phragmites*;
- Use non-invasive plants for your yard or garden;
- Clean your boots before you hike in a new area to prevent the spread of weeds, seeds and pathogens;
- Drain and clean your boat before using it on a different body of water;
- Do not move firewood that can harbor forest pests; Do not release aquarium fish and plants, live bait or other exotic animals into the wild;
- Volunteer at a local park to help remove invasive species. Help educate others about the threat.

If you think you have discovered an aquatic invasive species, please contact the following references:

- Ontario Invasive Species - 1-800-563-7711 or http://www.eddmaps.org/ontario/
- Michigan Invasive Species - http://www.michigan.gov/invasives

Signs in Ontario (left) and Michigan (right) informing and encouraging best practices to prevent invasive species.

5.5 CLIMATE CHANGE IMPACTS

5.5.1 BACKGROUND

Impacts from a changing climate include: warming air and water temperatures, changing precipitation patterns, decreased ice coverage, and water level fluctuations. These climate-related impacts interact with one another; alter the physical, chemical, and biological processes in the lake and surrounding watershed; and pose challenges to management agencies as they work to achieve many of the Agreement's General Objectives (Figure 27).

5.5.2 CLIMATE CHANGE OBSERVATIONS AND PROJECTIONS

The following observed and projected Great Lakes climate changes are taken from *State of Climate Change Science in the Great Lakes Basin* (McDermid et al., 2015) and other cited sources.

Temperature

- Summer surface water temperatures in Lake Huron increased 2.9°C between 1968 and 2002 (Dobiez and Lester, 2009);
- Projected 1.5-7°C increase in air temperature by 2080s in the Great Lakes basin;
- Projected 0.9-6.7°C increase in surface water temperature in the Great Lakes (2080s); and
- Projected increase in the number of frost-free days (Davidson-Arnott, 2016).

Precipitation

- Total annual precipitation in the Great Lakes region increased by 10.7 cm (~13%) between 1955 and 2004, with the majority of change occurring during the summer and winter (Andresen et al., 2012; Hodgkins et al., 2007);
- Projected 20% increase in annual precipitation across the Great Lakes basin by 2080s, with greater variability in winter precipitation;
- Projected decrease in snowfall, with accompanying decrease in duration and depth of snow cover; and
- Changes in frequency and magnitude of extreme weather events with increased flooding and intensity of storms while at the same time increased risk of drought and drier periods in between (Winkler et al., 2012).

Ice Cover

- Average ice coverage for the Great Lakes basin has decreased by more than 50% over the last two decades (Wang et al., 2012);
- Projected annual average ice cover, thickness, and duration (across all Great Lakes) could fall to near zero by 2050s (Hayhoe et al., 2010; Music et al., 2015);
- Annual lake ice coverage for Lake Huron decreased on average about 2% per year between 1973-2010, (Austin and Colman, 2007; Wang et al., 2010); and

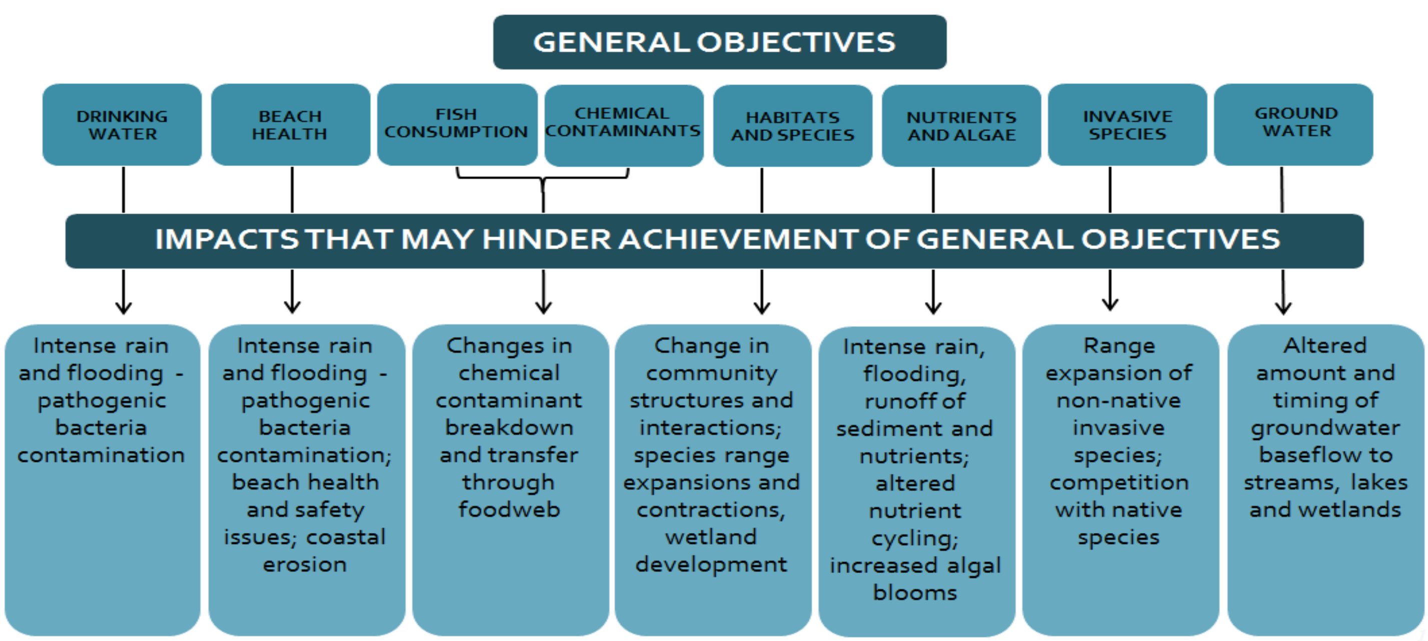


Figure 27. Potential climate change impacts, and challenges to achieving the General Objectives of the 2012 *GLWQA*.

- Reduction of lake ice cover resulting in an early onset of stratification and longer surface water temperature warming period (Austin and Colman, 2008; Franks Taylor et al., 2010).

Projected Seasonal Changes

- Models that forecast climate-related impacts on the Great Lakes suggest a downward shift in water level range with less inter-annual fluctuation (Abdel-Fattah and Krantzberg, 2014; Bartolai et al., 2015);
- Changes in precipitation and ice cover lead to a change in the seasonal lake level cycle with somewhat lower levels at the end of the summer and higher levels in the winter (MacKay and Seglenicks, 2013);
- Shorter, warmer winters and longer and hotter summers;
- Fluctuations around lower mean water levels; and
- Increases in the direction and strength of wind and water currents.

Biological Impacts

The first evidence of biological change in the Great Lakes shows that the diatom (phytoplankton) taxa in the group *Cyclotella sensu lato* are increasing in abundance in correlation with recent and rapid atmospheric warming (Reavie et al., 2016).

5.5.3 LAKE HURON CLIMATE-RELATED CHALLENGES AND INTERVENTIONS

Responses to climate change are organized around two main interventions: 1) those that are ongoing by Federal, State, and Provincial governments focused on reducing greenhouse gas emissions (Table 26) and, 2) those aimed at reducing ***vulnerability*** and improving environmental and societal ***resilience*** to increased climate variability and long-term climatic changes ***(adaptation)***. The latter is considered essential and is in accordance with the Agreement's commitment to address climate change impacts by using available domestic programs to achieve the General Objectives.

Table 26. Examples of strategies or actions that manage the amount of greenhouse gases in the atmosphere.

GOVERNMENT	POLICY OR PLAN
International	• 2015 – United Nations 21st Conference of Parties (COP21) Paris Agreement • 2015 – Climate Summit of the Americas • 2012 – Climate and Clean Air Coalition to reduce Short Lived Climate Pollutants • 1987 – Montreal Protocol
Canada	• 2016 – Pan-Canadian Framework on Clean Growth and Climate Change • 2016 – Vancouver Declaration on Clean Growth and Climate Change • 2011 – Federal Adaptation Policy Framework
United States	• 2014 - Federal Agency Climate Adaption Plans
Ontario	• 2016 – Ontario's Five Year Climate Change Action Plan 2016-2020 • 2016 – Climate Change Mitigation and Low-Carbon Economy Act • 2015 – ON and QC Cap and Trade • 2009 – Green Energy and Green Economy Act
Michigan	• 2012 – Climate Change Adaptation Plan for Coastal and Inland Wetlands 2009 – MDEQ Climate Action Plan

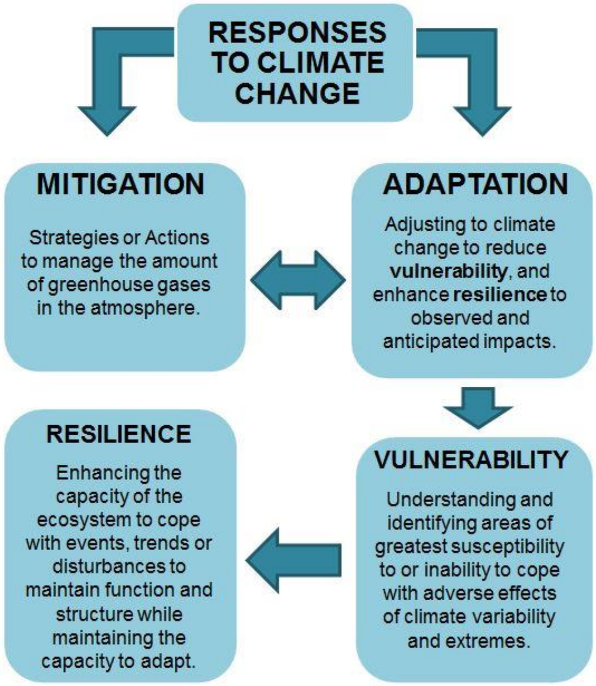


Figure 28. Climate change definitions used in this LAMP.

Protecting Against Loss of Habitat and Species and Enhancing Resiliency

Lake Huron's shorelines and wetlands are already subject to a range of social and environmental stressors, and climate change can exacerbate habitat loss and degradation. Previous sustained low water levels resulted in extensive dredging in areas with shallow sloping shorelines; by contrast, landowners harden shorelines to prevent erosion under high water levels. Each has negative ecological and water quality implications. Lake Huron water levels are currently above the long-term mean (176.45 m) following a 15-year sustained low water level and an all-time low set in December of 2013 (Figure 29).

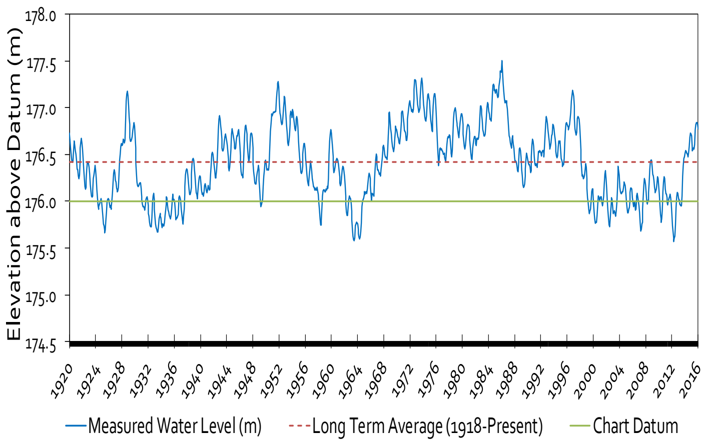


Figure 29. Lake Huron monthly average water levels in metres (1920-2016).

Impacts observed throughout the basin during long-term low levels include:

- Temporary disconnection and loss of wetland function with negative impacts to spawning fish such as Muskellunge and Northern Pike (Weller, Leblanc, Liskauskas & Chow-Fraser, 2016), migrating birds and aquatic plants;
- Reduced structural complexity and increased homogeneity of wetland plant communities (Midwood and Chow-Fraser, 2012); and
- Conditions for the highly invasive plant, *Phragmites*, to spread throughout the basin and outcompete native plant species (Tulbure and Johnston, 2010).

Coldwater fishes are critical to the economy of Lake Huron and are important ecological indicators of climate change. Potential climate-related impacts to lake ecology include: range contraction (e.g., Brook Trout, Lake Trout); competition due to range expansions and contractions of other species; and loss of hydrological connectivity between streams/rivers and Lake Huron may impede movement of migratory species.

Adaptive Measures: Climate change adaptation strategies to protect vulnerable coastal wetland habitat and fragile coldwater fish and fisheries are underway, including:

- The U.S. Resilient Lands and Waters Initiative supports the National Fish, Wildlife, and Plants Climate Adaptation Strategy. The goal of the initiative is to build and maintain an ecologically connected network of terrestrial, coastal, and marine conservation areas likely to be resilient to climate change; https://www.wildlifeadaptationstrategy.gov/partnerships.php
- Development of new coastal wetland decision support tools that support the identification and prioritization of restoration actions for existing and historical coastal wetlands between Saginaw Bay and central Lake Erie; https://greatlakeslcc.org/issue/landscape-conservation-planning-and-design
- Stream rehabilitation and enhancement projects that include modifications that provide fish refuge from thermal heating and low flow conditions (e.g., Manitoulin Streams Improvement Association); and
- Evaluation of migratory fish aquatic habitat significance, limitations under water level fluctuations, and stream habitat rehabilitation and enhancement projects in Eastern Georgian Bay.

The Lake Huron shoreline at Tawas Point, Michigan; part of the Great Lakes Coastal Wetlands Resilient Lands and Water Partnership (NOAA).

Protecting Against Excessive Nutrient, Sediment, and Impaired Water Quality
As the climate has changed, severe storm events, flooding, and overland runoff have increased in frequency and magnitude. These storms increasingly wash nutrients, sediments, and pathogenic bacteria into waterways, setting the stage for algal blooms and unsafe beaches.

Adaptive Measures: Enhancing farm soil health, planting cover crops, and using no-till soil management increase carbon storage and reduce energy use. Such Agricultural BMPs improve water quality by reducing the loss of sediments and nutrients from farm fields.

Before and after ditch and sediment trap as part of municipal drain project (Maitland Valley Conservation Authority).

Protecting Critical Community Infrastructure:
Flooding due to more frequent and intense storms throughout the Great Lakes has the potential to threaten urban waste and stormwater facilities and operations. More frequent and intense storms could result in sewer system overflows and reduced wastewater treatment capacity, which in turn could impact drinking water.

LOW IMPACT DEVELOPMENT

A green infrastructure approach to stormwater management uses landscaped features and other techniques to reduce flood risks and clean, store, and conserve stormwater.

Adaptive Measures:
Climate change adaptation measures to reduce the vulnerability of urban stormwater management systems and wastewater infrastructure from future extreme storm events are underway. All levels of government are investigating and promoting Low Impact Development (LID) and its important role in climate adaptation planning for municipalities. Through the use of LID practices, watershed resiliency can be enhanced to help mitigate the impacts of excess stormwater and flooding on social and environmental health.

- The Ontario Centre for Climate Impacts and Adaptation Resources is a university-based resource hub for information on climate change impacts and adaptation;
- An Implementation Framework for Climate Change Adaptation Planning at a Watershed Scale (2015) was developed by the Water Monitoring and Climate Change Project Team of the Canadian Council of Ministers of the Environment; and http://www.climateontario.ca/tools.php
- The state of Michigan, the province of Ontario, and several conservation authorities and municipalities are developing LID manuals.

5.5.4 MANAGEMENT LINKS WITH THE *AGREEMENT*

Under Annex 9 of the Agreement, the governments are tasked with coordinating efforts to identify, quantify, understand, and predict climate change impacts on the quality of the waters of the Great Lakes. Provisions for science include coordinating binational climate change science activities (including monitoring, modeling, and analysis) to quantify, understand, and share information that Great Lakes resource managers need to address climate change impacts on the quality of the waters of the Great Lakes and to achieve the General Objectives of this Agreement.

5.5.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS CLIMATE CHANGE (2016-2021)

In consideration of the current and future potential challenges to water quality, coldwater fishes and other species vulnerable to climate change impacts, as explained in Chapter 4. and above, member agencies of the Lake Huron Partnership have developed actions and identified the management agencies involved in implementing them (Table 27).

Over the next five years, the Lake Huron Partnership will encourage and support efforts that address the impact of climate change and work with scientists and Great Lakes experts to understand and reduce the impacts of climate change in the waters of Lake Huron.

Project tracking and reporting on the status and achievements of nutrient monitoring and management actions will be undertaken by the Lake Huron Partnership. Not all of the member agencies of the Lake Huron Partnership are responsible for monitoring, surveillance, and implementation. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 27. Lake Huron Partnership actions that address climate change impacts over the next five years.

#	LAKE HURON PARTNERSHIP ACTIONS (2017-2021)	AGENCIES INVOLVED
	CLIMATE CHANGE ACTIONS Actions identified for nutrients and bacterial pollution and loss of habitat and native species will help to maintain ecosystem function and enhance resilience to the impacts of climate change.	
39	***Watershed Resilience***: Continue efforts that engage landowners and the public to protect and enhance the function and resilience of watershed headwater features, streams, forests, and wetlands to maintain and enhance resilience to climate change impacts, including Conservation Authority Climate Change Strategies and Action.	Conservation Authorities, MDNR, OMOECC, USDA-NRCS, USFS
40	***Coldwater Fishes and Streams:*** Support the protection and enhancement of coldwater fishes: • Develop Lake Trout monitoring and rehabilitation plans; • Identify potential restrictions preventing passage of migratory fish; and • Create and enhance coldwater refuges where appropriate to maintain appropriate habitat conditions for aquatic organisms.	Conservation Authorities, MDNR, OMNRF, USFS
41	***Critical Community Infrastructure:*** Plan and implement LID initiatives that are suited to future extreme weather events via watershed work that increases green space and green infrastructure. • Michigan Low Impact Development manual (section 319 funding supporting Michigan non-point source grant programs); • Ontario Low Impact Development manual; and • Lake Simcoe Low Impact Development Guidance Documents.	Conservation Authorities, OMOECC, SCIT, USFS
42	***Coastal Resilience:*** Conduct study along Lake Huron shoreline to investigate opportunities to improve resilience within both the human and natural coastal environments.	USACE
	OUTREACH AND EDUCATION	
43	***Communications:*** Undertake and support outreach and education to stakeholders and the public on the impacts of climate change to the Great Lakes and Lake Huron through fact sheets, newsletters and other means.	Conservation Authorities, ECCC, USFS

5.5.6 ACTIVITIES THAT EVERYONE CAN TAKE

Personal Climate Change Mitigation Actions

Here are some solutions that you can use to reduce your personal contribution to greenhouse gas emissions:

- **Be energy efficient by greening your home.** Change your lightbulbs to LED bulbs; turn off the lights and unplug electronics and appliances when not in use; look for ENERGY STAR labels when buying new electronics or appliances; heat and cool smartly; and seal and insulate your home. You will also save money on your electricity bill!
- **Choose green power.** Switch your energy source to renewable energy such as wind or solar.
- **Plant trees!** Trees should be native or adapted to the local climate. Trees sequester carbon, helping to remove carbon dioxide and other greenhouse gases from the air.
- **Choose sustainable transportation**. Transportation produces about 14% of global greenhouse gas emissions (IPCC, 2014).

Walk, cycle, carpool, or take public transit when you can. Fly less or consider taking buses or trains. Purchase a smaller, fuel-efficient, low-greenhouse gas vehicle. Drive efficiently.

- **Conserve water**. Take shorter showers; install low-flow shower heads and toilets. Use the dishwasher and washing machine only when you have full loads. Wash clothes in cold water.
- **Eat locally**. Buy organic and locally grown food, as it does not have to travel as far. Avoid buying processed foods.
- **Reduce your waste**. Garbage buried in landfills produces methane, a potent greenhouse gas. Compost when you can. Recycle paper, plastic, metal, and glass. Buy products with minimal packaging. Buy less stuff.
- **Follow the 6 Rs of Sustainability:** Rethink, refuse, reduce, reuse, repair, and recycle.
- **Get involved and informed!** Follow the latest news on climate change, voice your concerns via social media, and s**pread the word to your family and friends**!

Climate Change Adaptation Planning at the Community Level

Climate adaptation planning is used to develop and apply plans to reduce the impacts and consequences of climate change and climate variability. There are a variety of approaches to climate adaption planning. Some communities create a dedicated climate adaptation plan — a document describing strategies for how to address impacts of climate change — while others focus on existing goals, adding the lens of climate variability to assess implications for stated goals, objectives, and strategies. If such large-scale efforts are not possible, you can focus on a specific project to ensure that environmental variability is addressed in a proactive way. Even without a dedicated adaptation planning process, a community can do a broad assessment of what fluctuating environmental conditions will mean for existing goals, objectives, and strategies.

- If you are looking for information on climate adaptation, visit Great Lakes Climate: A collection of Great Lakes climate change resources to help educators, government officials, community planners, and the public (http://climategreatlakes.com/) and Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR): A university-based resource hub for researchers and stakeholders (http://www.climateontario.ca/);
- Develop new or revise existing conservation, restoration, and management plans, guidelines and regulations as required in response to projected climate change impacts;
- Create coastal development setbacks to allow vegetation communities (e.g., coastal wetlands) to migrate in response to water level fluctuations;
- Incorporation more climate change information into the communications, management, technical assistance, science, research, and development programs of parks and protected areas;
- Undertake climate change education and outreach activities, with a focus on disseminating materials and information available from climate change programs; and
- Use parks or sentinel sites as long-term integrated monitoring sites for climate change impacts (e.g., monitoring of species, especially those at-risk or extinction-prone).

Protected Areas as a "Natural Solution" to Climate Change

Increasing the amount of protected areas not only conserves species and habitat, it also provides essential ecosystem goods and services and offers a cost-effective "natural solution" to climate change through the following ways:

- Mitigates climate change through the sequestration and storage of vast amounts of carbon in forests, wetlands and other natural ecosystems;
- Serves as a safe haven for species and as climatic conditions shift, networks of protected areas can facilitate species movement and connectivity, increasing ecosystem resilience and adaptive capacity;
- Natural ecosystems, such as wetlands and forested riparian areas, can help to clean water, mitigate floods and prevent erosion;
- Prevents biodiversity loss; and
- Serves as a benchmark for research and monitoring and demonstrate evidence-based planning and management.

6.0 SCIENCE AND MONITORING

This section provides information on science and monitoring priorities to be considered by all management agencies and scientists in an effort to enhance the understanding of Lake Huron.

6.1 GREAT LAKES COOPERATIVE SCIENCE AND MONITORING INITIATIVE (CSMI)

The Cooperative Science and Monitoring Initiative (CSMI) is a joint United States and Canadian effort implemented under the Science Annex of the Great Lakes Water Quality Agreement. CSMI provides environmental and fishery managers with the science and monitoring information necessary to make management decisions on each Great Lake. The intensive CSMI field year follows a five-year rotating cycle in which the lakes are visited one per year. The emphasis on a single Lake per year allows for coordination of science and monitoring activities focused on information needs of lakewide management. Previous Lake Huron intensive field years took place in 2002, 2007 and 2012.

In the fall of 2015, the Lake Huron Partnership agencies convened over 40 Canadian and U.S. resource management agencies, environmental non-governmental organizations, academic scientists, and the public to share information and establish joint science and monitoring priorities for the 2017 CSMI field year.

As explained in more detail below, the results from science and monitoring studies confirmed that Lake Huron has undergone significant system-wide changes in nutrient concentrations, lake productivity, and the abundance and distribution of native species.

The specific processes causing changes to lake productivity (i.e., the diversity and abundance of living organisms in the system) are not well understood; however, it is clear that filter-feeding invasive dreissenid mussels (Zebra and Quagga Mussels) are intercepting nutrients arriving from streams and rivers and creating a series of cascading changes in the food web. The non-native Round Goby further complicates the food web by eating mussels and being a prey item for larger fish.

The Lake Huron Partnership has identified the need to better understand the relationship between nutrient loadings and lake productivity. Additional information is needed on the status and trends of the lower and upper food web components and the health of the fishery. The findings from the 2017 CSMI year of study will be shared with resource managers to better inform management programs, future CSMI activities, and the next Lake Huron LAMP.

6.2 LAKE HURON SCIENCE AND MONITORING PRIORITIES

Nutrient Loading, Fate, and Transport

Historically, productivity in the offshore waters of Lake Huron was directly linked to nutrient inputs from streams and rivers. This simple relationship is now complicated by dreissenid mussel densities in the nearshore and offshore waters. Relatively stationary, these filter-feeding mussels remove nutrients and suspended algae, phytoplankton, and zooplankton from the water column, redistributing it in the form of feces and bio deposits (loose pellets of mucous mixed with particulate matter), nourishing nearshore algae and aquatic plants. Algal fouling is now found in areas not typically associated with elevated ambient nutrient levels, presumably caused by increased transparency and the "fertilizing" effect of mussel beds.

Recommended science activities to help explain nearshore and offshore nutrient dynamics consist of the following:

- Continue to characterize land use and nutrient loading linkages;
- Quantify nutrient loadings to the lake; and
- Improve the understanding of physical and biological processes that move nutrients/energy from the nearshore to offshore, with consideration of the influence of invasive species (e.g., mussels, gobies) and nearshore algal growth (e.g., *Cladophora, Chara,* and periphyton).

Lower and Upper Food Web Linkages

Lake productivity and the lower and upper food web responses to the change and variability in nutrient cycling are not well understood.

In the deep offshore waters, Quagga Mussels continue to increase. Their filter-feeding activities in the constant cold depths of Lake Huron are believed to remove nutrients and plankton, that historically drove the spring diatom bloom, from the water column.

For reasons still unknown, important native invertebrates are not thriving. The small, shrimp-like crustacean *Diporeia,* for example, is one of the most important organisms in the Great Lakes food web. It provides a rich source of food to many fish species, including Whitefish, as well as smaller fish which are eaten by Lake Trout and Walleye. *Diporeia* populations, however, have disappeared at an alarming rate, and only remnant populations exist. Preyfish abundance and diversity have decreased over the years, Yellow Perch populations have declined in Saginaw Bay, and Walleye production has remained low in Georgian Bay and the North Chanel.

Whitefish populations are in decline, with fewer adult fish and low recruitment of young fish to the adult stock. This could be due to factors such as inadequate nearshore plankton food, loss of *Diporeia*, a shift to less nutrient-rich food (e.g., dreissenids) and the rising predation on juvenile fish following the decline of the Alewife.

The following studies are recommended to better characterize the linkages between the lower and upper food web and to inform the implementation of both environmental protection and natural resource management programs:

- Assessment of spring diatom bloom conditions and possible larval fish bottlenecks;

- Measurement and understanding of lower food web productivity, with a better characterization of the spatial differences across Lake Huron, including under-sampled species and aquatic habitat types (e.g., rocky substrates and depositional areas);

- Improve the understanding of lower to upper food web linkages, including the use of diet studies and stable isotope analyses; and

- Better estimate predatory fish growth, production, and recruitment into the population, including age structure of fish populations.

Contaminant Loading and Cycling

Long-term monitoring of environmental media (air, water, sediment, fish, and wildlife) generally shows decreasing levels of contaminants. However, fish and wildlife consumption advisories are still required to protect human health. Contaminants of emerging concern continue to warrant investigation due to their distribution and persistence in the environment.

The following studies are recommended by water quality managers to track the effectiveness of restoration and protection programs:

- Long-term monitoring of environmental media (air, water, sediment, plants, fish, and wildlife) to track progress and inform environmental protection, natural resource management, and human health programs;

- Continued monitoring of sentinel species like colonial water birds and Lake Trout to support long-term chemical contaminant assessments for the Lake Huron basin; and

- Continued Great Lakes-wide efforts to assess fate, distribution, and effects of chemicals of emerging concern.

Open water research on Lake Huron with help from the Limnos (ECCC).

Figure 30 demonstrates the spatial extent of Lake Huron science and monitoring efforts in support of various initiatives discussed in this chapter.

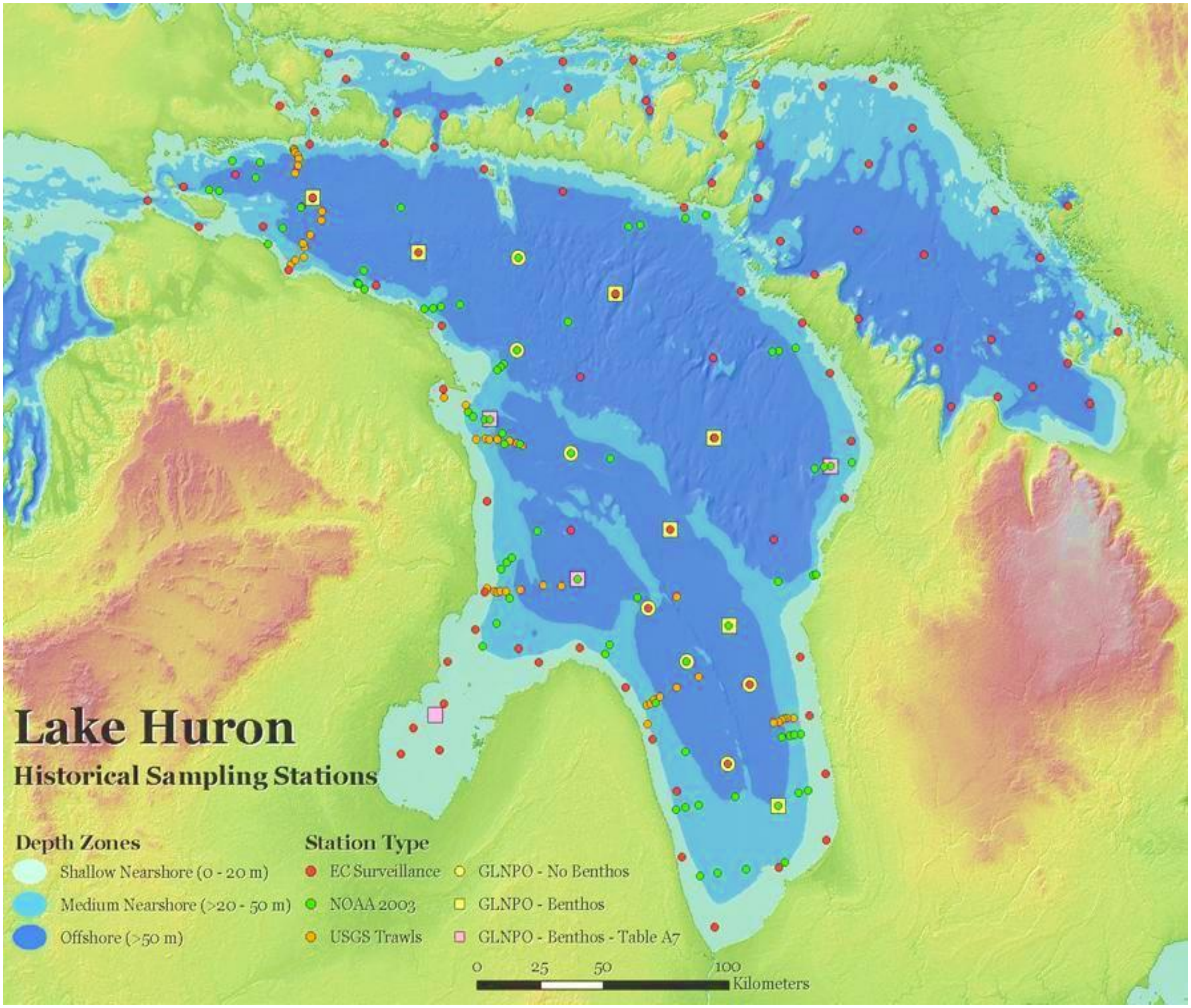


Figure 30. Lake Huron open water sampling stations and transects used by Environment and Climate Change Canada, the United States Geologic Survey, National Oceanic and Atmospheric Administration, and the United States Environmental Protection Agency – Great Lakes National Program Office.

7.0 OUTREACH, ENGAGEMENT AND EDUCATION

Everyone has a role to play in protecting, restoring, and conserving Lake Huron. Engagement, education, and involvement will support and move the public from the role of observer to active participant.

Engagement, collaboration and active participation of all levels of government, watershed management agencies, and the public are the cornerstone of current and future actions and essential for the successful implementation of this LAMP, and to achieving the General Objectives of the Agreement. The challenges and threats to Lake Huron need to be more widely recognized, as do opportunities for everyone to play a role in finding solutions that ensure a healthy watershed and lake ecosystem now and into the future. While member agencies and organizations operate independently, they are formally linked under the Lake Huron Partnership to represent a force stronger than the individual parts.

Local communities, groups, and individuals are among the most effective champions to achieve environmental sustainability in their own backyards and communities. Member agencies of the Partnership will pursue binational and domestic outreach and engagement activities to consult on challenges, priorities, and strategies and to encourage and support active community-based environmental action.

7.1 ENGAGEMENT IN THE DEVELOPMENT OF THIS LAMP DOCUMENT

As identified earlier, the development of this LAMP was informed by research, monitoring, and consultation with partnering agencies, academia scientists, non-governmental environmental organizations, and the public at a State of Lake Huron Meeting in Alpena, Michigan in 2015. The Lake Huron Partnership also informed the general public that the Lake Huron LAMP was under development and invited public comment in the spring of 2016 via the Great Lakes Information Network (http://www.great-lakes.net/) and during the triennial Great Lakes Public Forum in Toronto, Ontario in the fall of 2016. Lake partners, stakeholders, and the general public were also consulted on a Draft Lake Huron LAMP in the winter/spring of 2017 via https://binational.net/.

7.2 LAKE HURON OUTREACH AND ENGAGEMENT EFFORTS

PURPOSE OF OUTREACH AND ENGAGEMENT

- Improve appreciation and understanding of Lake Huron
- Share information on issues, threats, management needs, and achievements
- Broaden involvement in the restoration and protection of Lake Huron

Because the public plays such a critical role as partners, advocates, and implementers, the Lake Huron Partnership established an Outreach and Engagement Subcommittee to enhance opportunities for the public to engage in lakewide management and to foster actions that sustain the health of Lake Huron. The Subcommittee will work with the Lake Huron Partnership agencies to:

- Report annually on Lake Huron management successes, challenges, and next steps;
- Advertise opportunities for public input and participation in Lake Huron activities on binational.net, the Great Lakes Information Network, and other online venues;
- Promote and encourage restoration and protection initiatives that can be adopted and implemented by individuals, groups, and communities to support the stewardship of Lake Huron; and
- Develop and implement new outreach and engagement activities.

How can the public become more involved?

The public can get involved through the following ways, including:

- Keep informed by accessing Annual LAMP Reports from https://binational.net/;
- Review and provide input on the development of Lakewide Action and Management Plans;

- Attend one of the State of the Lake Huron meetings and learn about new initiatives, monitoring results, and recent science;
- Attend one of the meetings or summits hosted by the multi-agency domestic initiatives; and
- Learn about all the Great Lakes issues and events on http://www.great-lakes.net/.

7.3 COMPLIMENTARY BINATIONAL AND DOMESTIC OUTREACH AND ENGAGEMENT INITIATIVES

Several opportunities exist for the Lake Huron community to get involved. The Great Lakes Public Forum (GLPF) takes place every three years during which Canada and the U.S. review the state of the Great Lakes, highlight ongoing work, discuss binational priorities for science and action, and receive public input.

There are many domestic initiatives that engage all levels of government, watershed management agencies, environmental organizations, community groups, and the public.

Lake Huron-Georgian Bay Watershed: A Canadian Framework for Community Action

The Framework promotes community-based actions that address environmental threats to Lake Huron. It is based on the belief that individuals, communities and organizations in the watershed operate independently, yet are united by a common cause of maintaining, restoring, and protecting the health of Lake Huron. The Framework connects the actions of government, non-government organizations, and the public, and raises awareness, builds capacity, and supports community involvement.
The Framework sets out to do the following:

- Encourage active public participation;
- Promote environmentally responsible decisions and activities;
- Establish a shared network of contacts and environmental information; and
- Promote local restoration and protection initiatives that can be adopted and implemented.

Member agencies and community groups are involved through collaboration on domestic projects, attending think tanks and information sharing sessions, and sharing information at: http://www.lakehuroncommunityaction.ca/

Healthy Lake Huron: Clean Water, Clean Beaches Initiative – Communication Efforts

The Healthy Lake Huron Initiative engages landowners, increases awareness, and promotes science, monitoring, and restoration activities to manage nutrient and sediment pollution for safe and clean beaches and shorelines from Sarnia to Tobermory. As a result of this initiative, community-based groups and landowners are informed through newsletters, beach education and outreach tours, and a website that invites dialogue and questions from the public about:

- The problems related to beach closures and nuisance algae on Lake Huron's Southeast Shore;
- The actions needed to improve water quality to reduce beach closures and nuisance algae;
- Project implementation, achievements, and findings from science and monitoring; and
- How they can participate in or support the actions being taken. http://www.healthylakehuron.ca/index.php

Lake Huron's Student Stewards and Citizen Science: Northeast Michigan Great Lakes Stewardship Initiative

Place-based education is a proven method of bringing students closer to their communities and developing knowledgeable and active stewards of the environment. Citizen science enlists members of the public in the collection of valuable scientific data. Combining the two, the Northeast Michigan Great Lakes Stewardship Initiative (NEMIGLSI) sponsors a suite of programs that promotes place-based stewardship education experiences for K-12 students that live along the shores of Lake Huron. Alongside Great Lakes scientists and natural resource professionals, youth help to conserve Lake Huron's biodiversity, map threatened and endangered species habitat, restore native fisheries, investigate marine debris, monitor vernal pool wetlands, and preserve our Great Lakes maritime heritage. These research projects are sponsored by the partnership and facilitated by Michigan Sea Grant, Michigan State University Extension, the National Oceanic and Atmospheric Administration Thunder Bay National Marine Sanctuary, and other partners. During the 2015-2016 school year, support was provided to 94 educators in 32 schools across eight northern Lake Huron counties, involving more than 4,100 youth (approximately 20% of the region's total student population) in stewardship projects. For more information, see www.nemiglsi.org

Students explore their watershed and monitor water quality (Northeast Michigan Great Lakes Stewardship Initiative).

Rain garden planting (ABCA).

Community tree planting (Manitoulin Streams Improvement Association).

8.0 CONCLUSION

Achieving the General Objectives of the Agreement is a challenging task and one that will require the collective action by many partners throughout the Lake Huron basin.

The health of Lake Huron (including the St. Marys River, North Channel, Georgian Bay and Saginaw Bay), and the condition of its watershed are interconnected. A host of factors – chemical contaminants, urbanization, shoreline development, sediment-bound nutrient loading, non-native invasive species, and degraded or fragmented habitat – interact with a changing climate to produce complex changes.

To help achieve the Agreement's General Objectives, 43 management actions are put forth in this LAMP. These actions will address key environmental threats using an integrated management approach that recognizes the interactions across Lake Huron, including humans, and the need to maintain and enhance ecosystem resilience in view of climate change.

Implementation and Accountability

As demonstrated in Chapter 5, Lake Huron Partnership agencies commit to incorporating, to the extent feasible, LAMP actions in their decisions on programs, funding, and staffing. These agencies will be guided by a set of principles and approaches (Table 28) and a shared commitment to ensure that the chemical, physical, and biological integrity of the waters of Lake Huron is maintained or restored for current and future generations.

Implementation of LAMP actions is guided by a governance system (Figure 31) wherein coordination and implementation of the Agreement occurs on a basin-wide scale with oversight provided by the Great Lakes Executive Committee. A Management Committee evaluates progress and provides direction and coordination of implementation efforts, and a Working Group performs the day-to-day operations necessary to implement the LAMP, including regular communication and reporting. The committees are co-chaired by the U.S. Environmental Protection Agency (USEPA) and Environment and Climate Change Canada (ECCC).

Table 28. Principles and approaches to achieving the nine General Objectives of the Agreement.

PRINCIPLES & APPROACHES	IMPLEMENTATION DESCRIPTION
Accountability	Evaluating actions by individual partner agencies, tracked and reported through LAMP annual and five-year reports.
Adaptive Management	Assessing actions that will be adjusted to achieve General Objectives when outcomes, ecosystem processes, and new threats are better understood.
Coordination	Managing, planning and coordinating actions across all agencies and stakeholders.
Prevention	Anticipating and preventing pollution and other threats to quality of waters to reduce risks to environment and human health.
Public Engagement	Integrating public opinion and advice when appropriate; providing information and opportunities for participation to achieve GOs.
Science-based Management	Implementing management decisions, policies, and programs based on best available science, research, and knowledge, as well as traditional ecological knowledge.
Sustainability	Considering social, economic, and environmental factors in a multi-generational standard to meet current and future needs.

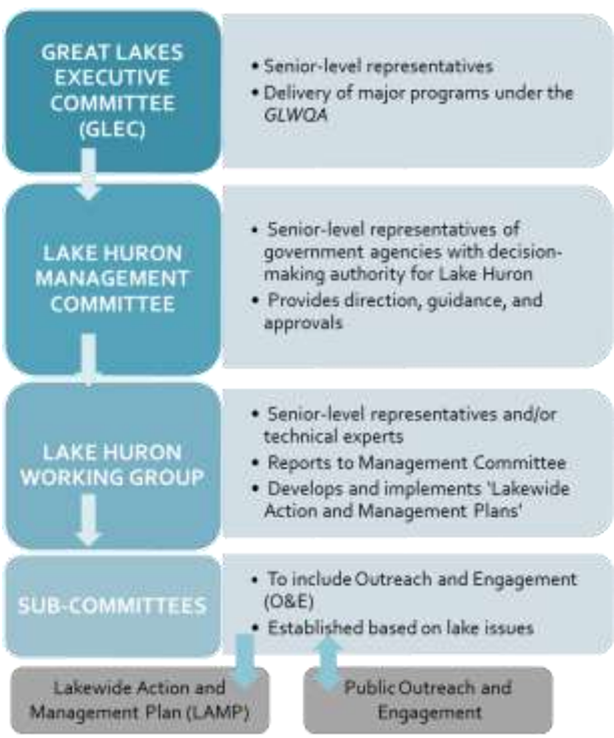


Figure 31. Lake Huron lakewide management governance.

APPENDIX A: MAP OF LAKE HURON BASIN INDIGENOUS COMMUNITIES

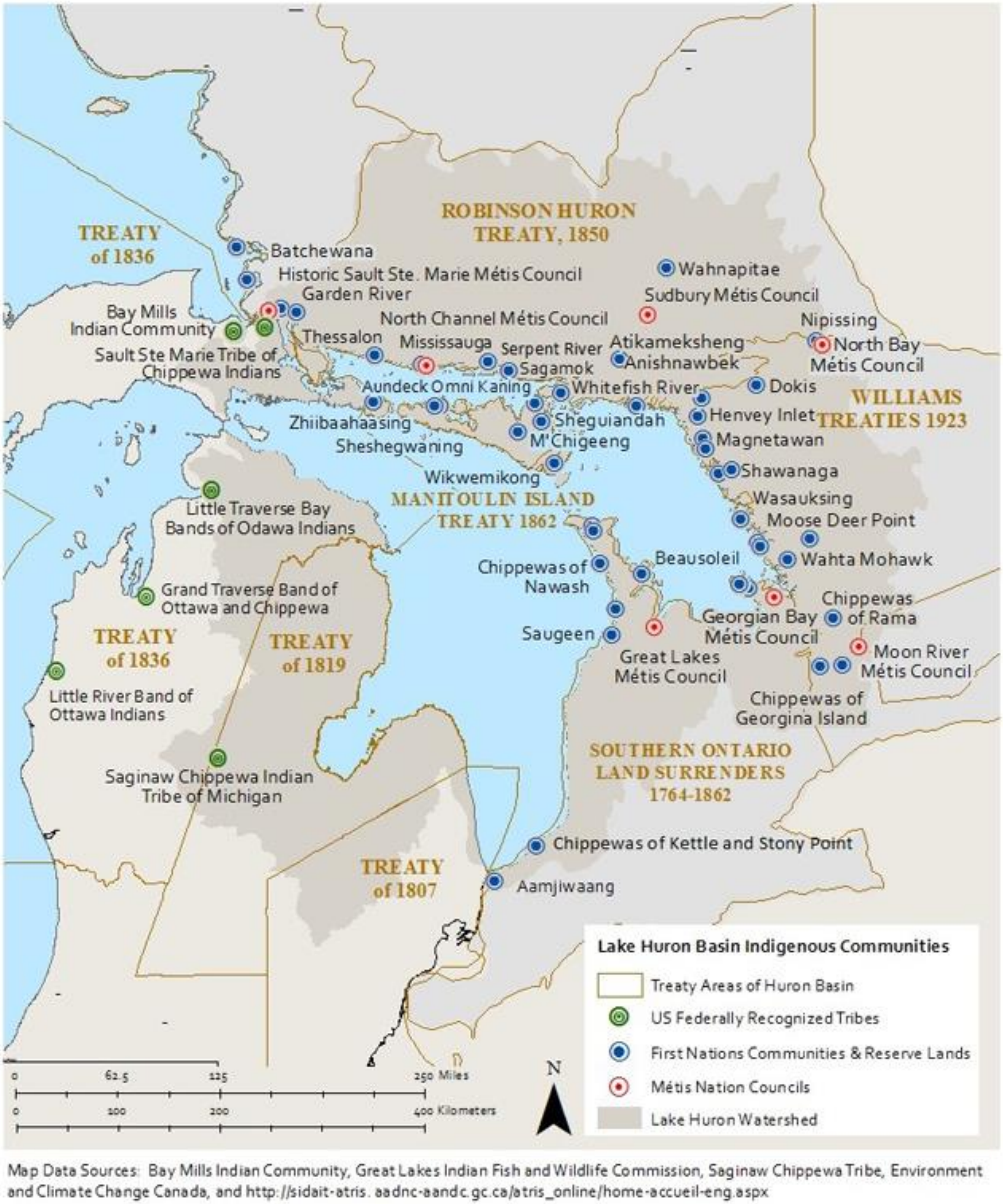


Figure 32: Lake Huron Basin Indigenous Communities. Map Data Sources: Bay Mills Indian Community, Great Lakes Indian Fish and Wildlife Commission, Saginaw Chippewa Tribe, ECCC, and http://sidait-atris.aadnc-aandc.gc.ca/atris_online/home-accueil-eng.aspx

APPENDIX B: AREAS OF CONCERN (AOC)

The 2012 Agreement defines an Area of Concern (AOC) as a geographic area designated by the U.S. and Canada, where significant impairment of beneficial uses has occurred as a result of human activities at the local level. An impaired beneficial use is a reduction in the chemical, physical, or biological integrity of the waters of the Great Lakes sufficient to cause environmental issues.

Following management actions, the Canadian government delisted the Collingwood Harbour AOC (1994) and Severn Sound AOC (2003). The status of the remaining three Lake Huron AOCs and Beneficial Use Impairments is shown in Table 29.

In 1999, the **Spanish Harbour AOC** was redesignated as an *AOC in Recovery* (AOCiR); indicating that all management actions to restore water quality and ecosystem health have been completed. The historical sediment contamination (including dioxin and furans), while much improved since the 1980s, will take more time to fully recover. Monitoring is ongoing.

The **St. Marys River** was designated as a binational AOC due to impairments of water quality, sediment, and biota that resulted in beneficial use impairments on both sides of the river.

The **Saginaw River and Bay** was designated as an AOC due to contaminated sediments, fish consumption advisories, degraded fisheries, and a loss of significant recreational values.

Remedial Action Plans for the St. Marys River and Saginaw River and Bay AOCs are being implemented to restore the remaining beneficial use impairments within each AOC. Information is available online for the St. Marys River RAP (Michigan); St. Marys River RAP (Canadian); Saginaw River and Bay RAP and progress reports.

Table 29. Beneficial Use Impairments of the AOCs of Lake Huron.

BENEFICIAL USE IMPAIRMENT (BUI)	AREA OF CONCERN			
BUI Restored ☑ / BUI Impaired ☐ / Not Applicable	SAGINAW BAY	ST. MARYS RIVER U.S.	ST. MARYS RIVER CANADA	SPANISH HARBOUR
Loss of fish and wildlife habitat	☑	☐	☐	☑
Beach closings	☐	☑	☐	☑
Degradation of fish and wildlife populations	☐	☐	☐	☑
Degradation of aesthetics	☐	☑	☐	
Bird or animal deformities or reproductive problems	☐	☑	☑	☑
Fish tumors and other deformities		☐	☐	
Restrictions on drinking water consumption or taste/odor	☑			
Tainting of fish and wildlife flavor	☑			
Added costs to agriculture or industry				☑
Degradation of phytoplankton/zooplankton populations	☐			☑
Degradation of benthos	☐	☐	☐	☐
Restrictions on fish and wildlife consumption	☐	☐	☐	☐
Eutrophication or undesirable algae	☐	☑	☐	
Restriction on dredging activities	☐	☑	☐	☐

APPENDIX C: PETROLEUM TRANSPORTATION MAPS

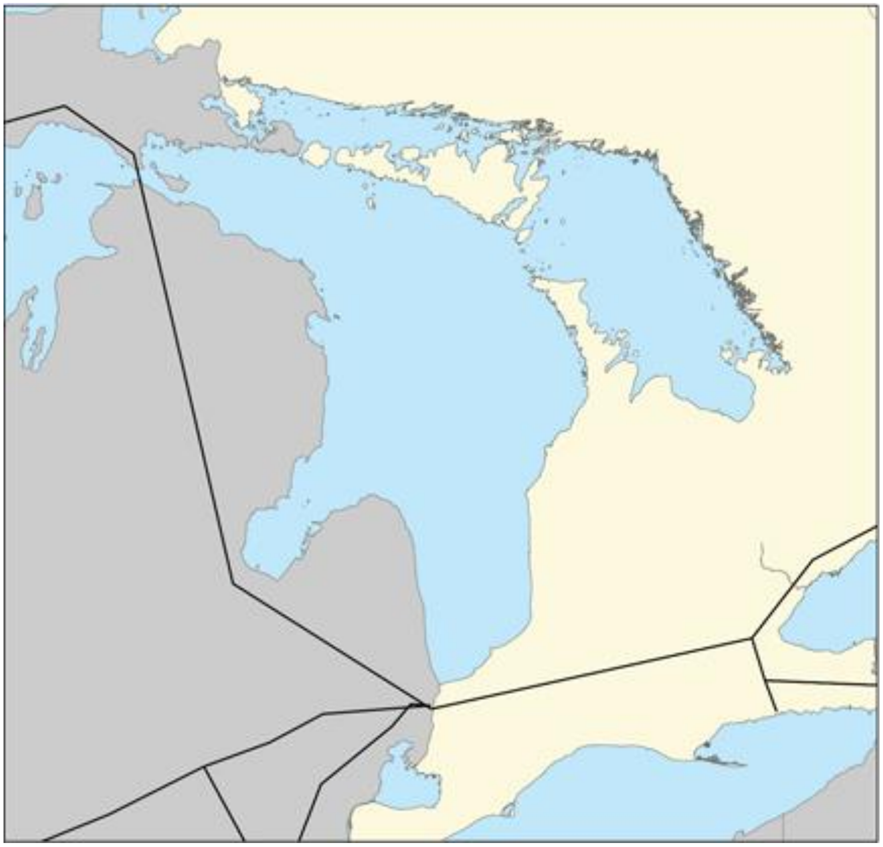


Figure 33. Map showing crude oil pipelines in the Lake Huron basin. Used with permission from Marty and Nicoll, 2017.

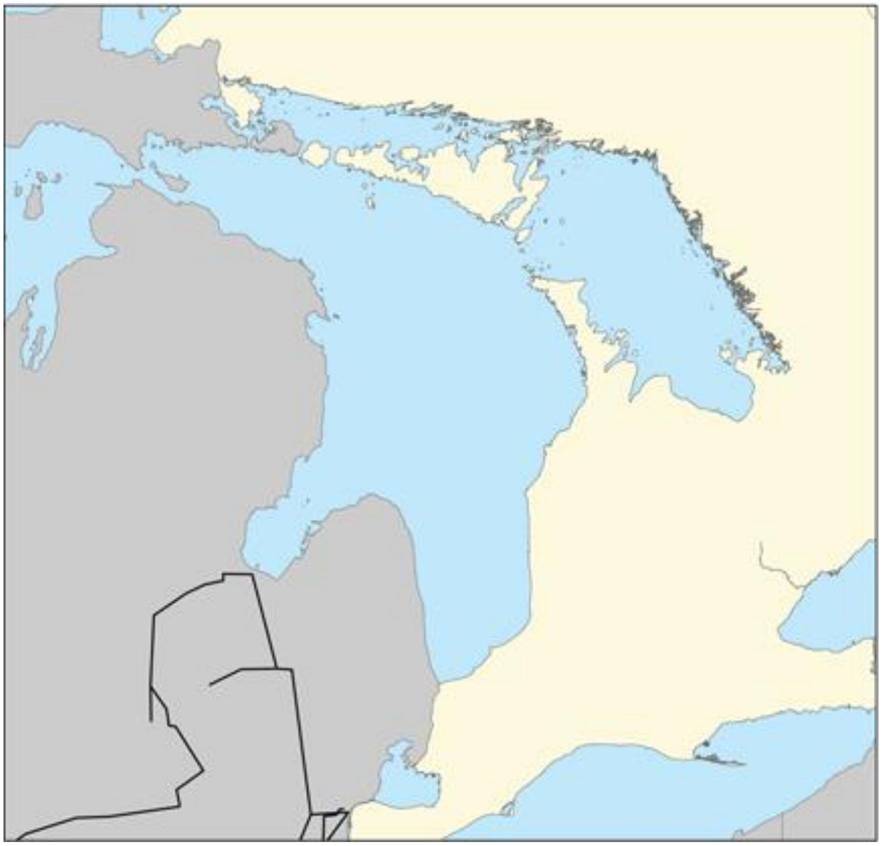


Figure 34. Map showing petroleum product pipelines in the Lake Huron basin. Used with permission from Marty and Nicoll, 2017.

Figure 35. Map showing rail lines in the Lake Huron basin. Data sources: Michigan Geographic Data Library; Land Information Ontario 2017.

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