



2022

PROGRESS REPORT OF THE PARTIES

Pursuant to the 2012 Canada-United States
Great Lakes Water Quality Agreement



Canada 

U.S. spelling is used throughout this report except when referring to Canadian titles. Units are provided in metric or U.S. customary units for activities occurring in Canada or the United States, respectively.

Discussions of funding levels or costs in dollars is provided using Canadian dollars for activities occurring in Canada and U.S. dollars for activities occurring in the United States.

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Acronyms

ACPF	Agricultural Conservation Planning Framework	CSMI	Coordinated Science and Monitoring Initiative
AFT	American Farmland Trust	CSO	combined sewer overflow
AIS	aquatic invasive species	CWMP	Great Lakes Coastal Wetland Monitoring Program
AM	adaptive management	CyAN	Cyanobacteria Assessment Network
AOC	Area of Concern	decaBDE	Decabromodiphenyl ether
ARS	Agricultural Research Service	DFO	Fisheries and Oceans Canada
ARTS	Agricultural Runoff Treatment System	DNA	deoxyribonucleic acid
BAFF	BioAcoustic Fish Fence	DNR	Department of Natural Resources
BMP	best management practice	DUC	Ducks Unlimited Canada
BPA	Bisphenol A	ECCC	Environment and Climate Change Canada
BUI	Beneficial Use Impairment	ECF	engineered containment facility
CANUSLAK	Canada-United States Great Lakes Geographic Annex	ECP	EPA Council on PFAS
CCCS	Canadian Centre for Climate Services	ECRA	Essex Region Conservation Authority
CCG	Canadian Coast Guard	EDBS	Electric Dispersal Barrier System
CEAP	Conservation Effects Assessment Project	eDNA	environmental DNA
CEC	chemical of emerging concern	EGLE	Michigan Department of Environment, Great Lakes and Energy
CFS	Canadian Forest Service	GBF	Georgian Bay Forever
CIGLR	Cooperative Institute for Great Lakes Research	GIS	geographic information system
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada	GLCA	Great Lakes Coastal Assembly
CMC	Chemical of Mutual Concern	GLEC	Great Lakes Executive Committee
CMIP	Coupled Model Intercomparison Project	GLERL	Great Lakes Environmental Research Laboratory
CMP	Chemicals Management Plan	GLFC	Great Lakes Fishery Commission
COA	Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health	GLIFWC	Great Lakes Indian Fish and Wildlife Commission
COIP	Canadian Ocean Infrastructure Portal	GLISA	Great Lakes Integrated Sciences and Assessments
CORDEX-NA	North American Coordinated Regional Climate Downscaling Experiment	GLP	Great Lakes Panel
CREP	Conservation Reserve Enhancement Program	GLPC	Great Lakes Phragmites Collaborative
		GLPI	Great Lakes Protection Initiative
		GLRI	Great Lakes Restoration Initiative

GLSHyFS	Great Lakes Seasonal Hydrologic Forecast System	MECP	Ministry of the Environment, Conservation and Parks
GLWQA	Great Lakes Water Quality Agreement	MNO	Métis Nation of Ontario
GPS	geographic positioning system	MPART	Michigan PFAS Action Response Team
GRIP	Great Lakes Runoff Intercomparison Project	NBIC	National Ballast Water Information Clearinghouse
HAB	harmful algal bloom	NCC	Nature Conservancy of Canada
HBCD	hexabromocyclododecane	NCCA	National Coastal Condition Assessment
IADN	International Atmospheric Deposition Network	NDMNRF	Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry
ICLEI	International Council for Local Environmental Initiatives	NEW Water	Green Bay Metropolitan Sewage District
ICRCC	Invasive Carp Regional Coordinating Committee	NOAA	National Oceanic and Atmospheric Administration
IDEM	Indiana Department of Environmental Management	NPS	U.S. National Park Service
IMC	Invasive Mussel Collaborative	NRCAN	Natural Resources Canada
IMO	International Maritime Organization	NRCS	Natural Resources Conservation Service
IPCA	Indigenous Protected and Conserved Area	NWM	National Water Model
ISC	Invasive Species Centre	NYSDEC	New York State Department of Environmental Conservation
LAMP	Lakewide Action and Management Plan	Ohio EPA	Ohio Environmental Protection Agency
LC-PFCA	long-chain perfluorinated carboxylic acid	OIT	Organisms in Trade
LEADS	Lake Erie Agriculture Demonstrating Sustainability	OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
LTBB	Little Traverse Bay Bands of Odawa Indians	OMECP	Ontario Ministry of the Environment, Conservation and Parks
LTVCA	Lower Thames Valley Conservation Authority	ORMGP	Oak Ridges Moraine Groundwater Program
MAEAP	Michigan Agriculture Environmental Assurance Program	PADEP	Pennsylvania Department of Environmental Protection
MARPOL	International Convention for the Prevention of Pollution from Ships	PAH	polycyclic aromatic hydrocarbon
MDARD	Michigan Department of Agriculture and Rural Development	PAMF	Phragmites Adaptive Management Framework
MDNR	Minnesota Department of Natural Resources	PBDE	polybrominated diphenyl ether
		PCB	polychlorinated biphenyl

PFAS	per- and polyfluoroalkylated substance	USACE	U.S. Army Corps of Engineers
PFOA	Perfluorooctanoic acid	USCG	U.S. Coast Guard
PFOS	perfluorooctane sulfonate	USDA	U.S. Department of Agriculture
POP	persistent organic pollutant	USEPA	U.S. Environmental Protection Agency
RAP	Remedial Action Plan	USFS	U.S. Forest Service
RV	research vessel	USFWS	U.S. Fish and Wildlife Service
SCCP	short-chain chlorinated paraffin	USGS	U.S. Geological Survey
SDWA	Safe Drinking Water Act	uv	ultraviolet
SOGL	State of the Great Lakes	UW	University of Wisconsin
SRMT	Saint Regis Mohawk Tribe	VAST	Visual Assessment Survey Tool
SWAT	Soil and Water Assessment Tool	VIDA	Vessel Incidental Discharge Act
TAM	Tribal Climate Adaptation Menu	VinES	Vested in Environmental Sustainability
TEK	traditional ecological knowledge	VPDCR	Vessel Pollution and Dangerous Chemicals Regulations
TMDL	total maximum daily load	WDNR	Wisconsin Department of Natural Resources
TNC	The Nature Conservancy	WLEB	Western Lake Erie Basin
TSCA	Toxic Substances Control Act	WRRF	Water Resource Recovery Facility
UNESCO	United Nations Educational, Scientific and Cultural Organization		



Executive Summary

Fifty years ago on April 15, 1972, in response to the significant deterioration of water quality, Canada and the United States committed to work together to restore and protect the Great Lakes through the signing of a new framework for binational cooperation: the Canada-United States Great Lakes Water Quality Agreement. The Agreement launched decades of intergovernmental collaboration on the development and implementation of water quality programs and actions to restore and protect the Great Lakes. Today comprehensive environmental programs are in place on both sides of the border, and with the involvement and cooperation of state and provincial governments, municipalities and local authorities, First Nations, Métis and tribal governments, industry, nongovernment organizations, and the public, Canada and the United States are continuing to work to achieve a healthy and sustainable Great Lakes ecosystem for the benefit of present and future generations. As we celebrate 50 years of collaborative efforts, we recognize that the job is not done and that continued action by both countries is needed to protect this invaluable resource. This Progress Report of the Parties is issued every 3 years to report on recent achievements in restoring and protecting Great Lakes water quality and ecosystem health. Over the last 3 years, governmental partners have made significant progress in implementing the Great Lakes Water Quality Agreement.

Key accomplishments described in this report include:

Annex 1. Areas of Concern

Over the past 3 years, unprecedented progress has been made to remediate and restore water quality and ecosystem health in Great Lakes Areas of Concern (AOC). Two AOCs have been formally delisted. Four

AOCs have had all management actions completed, setting them on a path to environmental recovery and eventual delisting. Twenty-four ecosystem impairments (known as Beneficial Use Impairments, or BUIs) have been removed in 19 AOCs. In addition, over 1,280,000 cubic yards of contaminated sediment was remediated throughout the Great Lakes.

Annex 2. Lakewide Management

Multi-agency Lake Partnerships are in place for each of the five Great Lakes. These Partnerships are actively assessing water quality and restoration progress at the lakewide scale, as well as developing multi-agency, ecosystem-based strategies for future improvements. Through the development and implementation of Lakewide Action and Management Plans (LAMPs), government and non-government partners are working together to reduce chemical contamination, eliminate excess nutrients, manage invasive species, and restore Great Lakes watersheds. Plans are updated on a rotating basis, with one of the five lakes being updated each year. By the end of this 3-year period, the Lake Michigan, Lake Superior, and Lake Huron LAMPs will have been updated.

Annex 3. Chemicals of Mutual Concern

Through domestic regulations and the implementation of binational strategies, significant progress has been made to reduce the release of chemicals of mutual concern into the Great Lakes over the past 3 years. The United States and Canada continue to take action on legacy contaminants, such as mercury and polychlorinated biphenyls (PCBs), and have stepped

up efforts to address newer chemical threats such as per- and polyfluoroalkyl substances (PFAS). Strategic plans are now in place to reduce threats to the Great Lakes from each of the Chemicals of Mutual Concern. Additional chemicals are being evaluated using new screening criteria.

Annex 4. Nutrients

Reducing excess nutrient (phosphorus) inputs to Lake Erie remains the highest priority for action. Implementation of on-the-ground actions identified in the Domestic Action Plans are slowing phosphorus inputs that cause toxic and nuisance algae blooms in Lake Erie. The United States reduced agricultural and municipal sources of phosphorus to the watershed by over 3 million pounds (1,361 tonnes) between 2015 and 2020. In Canada, a 20-tonne reduction in phosphorus has been achieved. These reductions indicate that current actions are on the right track, but significant additional work is needed to meet targets.

Annex 5. Discharges from Vessels

Over the last 3 years, the United States and Canada have managed vessel discharges and coordinated successful responses to vessel emergencies that had the potential for oil or hazardous substance discharges. In addition, the federal governments have both significantly advanced legislation that would further strengthen ballast water management programs.

Annex 6. Aquatic Invasive Species

Governmental partners continue to reduce populations of invasive carp in the Illinois River and in the tributaries of Lake Erie. New work was also initiated for the Brandon Road Lock and Dam to further prevent invasive carp from moving through Chicago-area waterways to Lake Michigan. In addition, government agencies and their partners have performed numerous invasive species control projects throughout the Great Lakes watershed over the last 3 years.

Annex 7. Habitat and Species

Over the last 3 years, United States and Canadian agencies have sponsored hundreds of projects that restore the health of Great Lakes watersheds, coastlines, and aquatic habitats. Both countries also enhanced their ability to conserve and manage coastal wetlands through complimentary domestic science initiatives.

Annex 8. Groundwater

Canadian and U.S. governmental agencies continue to actively manage contaminated groundwater sites that may pose a risk to the Great Lakes. To further improve binational coordination and management actions, both countries worked together to assess the state of groundwater science through the development of *Groundwater Science Relevant to the Great Lakes Water Quality Agreement: A Status Report*.

Annex 9. Climate Change Impacts

Over the last 3 years, the U.S. and Canadian governments increased awareness of climate change impacts through quarterly and annual reporting and hosting webinars on climate change topics and initiatives. This information helps support the development of climate change adaptation strategies throughout the Great Lakes.

Annex 10. Science

Over the last 3 years Canada and the United States have continued monitoring and research to understand and assess water quality and aquatic ecosystem health, measure progress and inform decision making. A Comprehensive State of the Lakes Report was issued in 2022, which assesses the overall health of the Great Lakes using a suite of ecosystem indicators. Engagement continued with Indigenous Peoples and Tribes on enhancing and promoting the common understanding of Traditional Ecological Knowledge and its application towards the restoration and protection of the Great Lakes.

OUR PROGRAMS

The Agreement provides the framework for binational cooperation towards restoration and protection of Great Lakes water quality; however, each country uses its own domestic programs to implement the Agreement's commitments



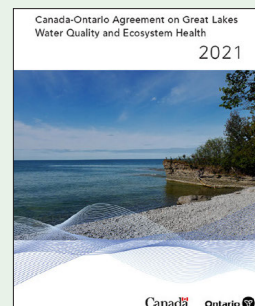
Within the United States, legislation at the federal, state, tribal, municipal, and local levels authorizes and directs environmental protection and restoration programs. These

programs are the foundation for the restoration and protection of the Great Lakes. In recent years, the Great Lakes Restoration Initiative has greatly increased implementation activities by funding over 6,000 new projects that address the most significant Great Lakes environmental issues, including restoring Areas of Concern, preventing and controlling invasive species, reducing excess nutrients, and restoring native habitats and species. In addition, the 2022 Bipartisan Infrastructure Law will deliver significant environmental, economic, health, and recreational benefits for communities throughout the Great Lakes region, including historically underserved and overburdened communities, by accelerating the cleanup of Areas of Concern.



Within Canada, a mix of national, provincial, and regional policies, programs, and initiatives are applied to restore and protect the Great Lakes. The Great Lakes Protection Initiative is a

key federal program that combines science and action to address the most significant threats to Great Lakes water quality and ecosystem health. Since protection and restoration of the Great Lakes is a shared responsibility, Canada also continues to work in close collaboration with the Province of Ontario through the 2021 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health. The Canada-Ontario Agreement is a targeted 5-year action plan that outlines how the governments of Canada and Ontario will cooperate and coordinate their efforts to restore, protect, and conserve the Great Lakes basin ecosystem and help meet Canada's obligations under the Canada-U.S. Great Lakes Water Quality Agreement.



**Visit the governments of Canada and United States
Great Lakes websites for further information:**

www.canada.ca/en/environment-climate-change/services/great-lakes-protection

www.canada.ca/en/environment-climate-change/services/great-lakes-protection/canada-ontario-agreement-water-quality-ecosystem

www.epa.gov/greatlakes

www.glri.us

binational.net/

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Introduction

For 50 years, the Canada-United States Great Lakes Water Quality Agreement (Agreement) has provided a binational framework for pursuing cooperative binational and domestic actions to restore and protect the water quality of the Great Lakes. Today, strong environmental programs are in place—in cooperation with federal, state and provincial governments, municipalities and local authorities, First Nations, Métis and Tribal governments, industry, nongovernment organizations, and the public—to make progress toward our shared General Objectives under the Agreement (see text box).

Canada and the United States recognize the integral relationship between an environmentally healthy Great Lakes system and the social and economic well-being of both countries, as well as the very direct connection between water quality and human health. Both countries are committed to protecting and restoring the water quality of the Great Lakes.

About this Report and the Great Lakes Executive Committee

Pursuant to Article 5, Section 2(e) of the Agreement, Canada and the United States produce and release a binational *Progress Report of the Parties* every 3 years to document recent binational and domestic actions taken to fulfill the commitments in the Agreement. This report provides an update on key activities called the “2020–2022 Binational Priorities for Science and Action” that were established by the United States and Canada at the beginning of this 3-year period. It also reports on other governmental actions that deliver on Agreement commitments. The development of this report was led by the governments of Canada and the United States in consultation and cooperation with the broader Great Lakes Executive Committee (GLEC).

As described in Article 5 Section 2, the GLEC oversees implementation of the Agreement. Environment and Climate Change Canada (ECCC) and the U.S. Environmental Protection Agency (USEPA), which serve as chairs, convened [meetings](#) of the GLEC twice per year during the 2020–2022 reporting period.

The General Objectives of the Great Lakes Water Quality Agreement

“The waters of the Great Lakes should:

- i. Be a source of safe, high-quality drinking water;
- ii. Allow for swimming and other recreational use, unrestricted by environmental quality concerns;
- iii. Allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants;
- iv. 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;
- v. Support healthy and productive wetlands and other habitats to sustain resilient populations of native species;
- vi. 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;
- vii. Be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the Waters of the Great Lakes;
- viii. Be free from the harmful impact of contaminated groundwater; and
- ix. Be free from other substances, materials or conditions that may negatively impact the chemical, physical or biological integrity of the Waters of the Great Lakes.”

Its membership consists of senior representatives of environmental protection and natural resource management agencies within the governments of Canada and the United States, state and provincial governments, tribal governments, First Nation and Métis peoples, municipal governments, watershed management agencies, and other local public agencies. In addition to its regular meetings, pursuant to Article 6(c), GLEC member agencies also provide [notification](#) of planned activities that could lead to a pollution incident or could have a significant cumulative impact on the waters of the Great Lakes.

While the report is an extensive account of GLEC member efforts over the last 3 years, this report cannot comprehensively describe all the restoration and protection efforts that are being implemented within the Great Lakes basin ecosystem.

This report is organized following the structure of the Agreement itself. The subsequent sections of this report describe implementation progress made under the 10 annexes of the Agreement. The 10 annexes, listed in the side box, are the major environmental issues that can affect the quality of the waters of the Great Lakes.

The Great Lakes Public Forum and Public Feedback on this Report

As described in Article 5, Section 1, the Agreement recognizes the importance of advice and public input. The Great Lakes Public Forum is the major event for public participation and feedback under the Agreement. The next Great Lakes Public Forum is scheduled to take place in Niagara Falls, Ontario, from September 27–29, 2022. In recognition of the 50th Anniversary of the Agreement this year, the theme for the forum is “Our Great Lakes: Celebrating Past Successes and Preparing for Future Challenges.”

More information on the Great Lakes Public Forum can be found at: <https://binational.net/2022/05/26/great-lakes-public-forum-2022/>

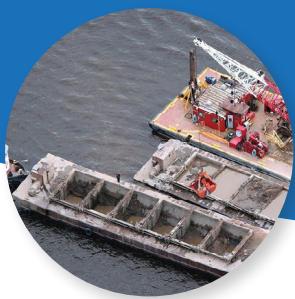
Major sections of the Agreement and the basic outline of this report:

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

The forum marks the ending of one 3-year management period under the Agreement and the beginning of the next. It is an opportunity to hear from the U.S. and Canadian governments on the environmental health of the Great Lakes, as well as proposed “Binational Priorities for Science and Action” for the next 3-year management cycle (2023–2025).

As described in Article 7.1(k) of the Agreement, the forum is also an opportunity for public input. The organization known as the [International Joint Commission](#) (IJC) was given the specific responsibility under the Agreement to discuss and receive public input on these *Progress Reports of the Parties*. The Commission will consider this public input while developing their Triennial Assessment of Progress report that provides recommendations to the United States and Canada with respect to the implementation of the Agreement.

In conjunction with the Great Lakes Public Forum, Canada and the United States will also convene a Great Lakes Summit to promote coordination amongst the Parties, the IJC, Great Lakes Commission, and the Great Lakes Fishery Commission to increase their effectiveness in managing the Great Lakes.



Annex 1: Areas of Concern

Over the past 3 years, unprecedented progress has been made to remediate and restore water quality and ecosystem health in Great Lakes Areas of Concern (AOC). Two AOCs have been formally delisted. Four AOCs have had all management actions completed, setting them on a path to environmental recovery and eventual delisting. Twenty-four ecosystem impairments (known as Beneficial Use Impairments, or BUIs) have been removed in 19 AOCs. In addition, over 1,280,000 cubic yards of contaminated sediment was remediated throughout the Great Lakes.

Key Achievements

- Two AOCs were delisted: Lower Menominee River and Ashtabula River.
- Management Actions were completed at four AOCs: Black River, Eighteenmile Creek, Manistique River, and Muskegon Lake.
- Canada assessed and removed seven BUIs in five AOCs. The United States assessed and removed 17 BUIs in 14 AOCs, and eight additional BUIs are projected for removal from six AOCs in 2022.
- The United States remediated 600,000 cubic yards of sediment. Canada managed 350,500 cubic meters (458,000 cubic yards) of contaminated sediment.

Purpose and Overview

The purpose of [Annex 1 \(Areas of Concern\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by restoring beneficial uses that have become impaired due to local conditions at Areas of Concern (AOCs), through the development and implementation of Remedial Action Plans (RAPs) for each AOC designated pursuant to this Agreement.”

The commitment to restore water quality and ecosystem health of designated AOCs was included in the 1987 GLWQA (Figure 1). An AOC is a geographic area where significant impairment of beneficial uses has occurred because of human activities at the local level. Forty-three AOCs were designated, including 26 in the United States, 12 in Canada, and five binational areas shared between the two countries.

The Agreement commits the United States and Canada to developing and implementing a RAP for each AOC to restore beneficial uses that have become impaired due to local conditions. A beneficial use impairment (BUI) is a reduction in the chemical, physical, or biological integrity of the Waters of the Great Lakes sufficient to cause any of the impairments listed on the next page. All AOCs have a RAP cleanup plan that identifies which of the 14 BUIs are present and why, what criteria are being used to confirm restoration of environmental quality, what remedial measures have and will be taken (and by whom), and what monitoring/evaluation program is being used to track progress towards restoration. Generally, AOCs have a “RAP Team” of local stakeholders that plan, develop, and implement remediation and monitoring actions to restore beneficial uses in their respective AOCs.

ANNEX IMPLEMENTATION

The U.S. Environmental Protection Agency (USEPA) and Environment and Climate Change Canada (ECCC) co-lead implementation of the AOC Annex. AOC cleanup efforts in the United States are led by USEPA, with significant contributions from other federal agencies (National Oceanic and Atmospheric Administration [NOAA], U.S. Army Corps of Engineers [USACE], U.S. Fish and Wildlife Service [USFWS], and U.S. Geological Survey [USGS]); state, tribal, and local governments; communities; and nongovernmental organizations. Within Canada, ECCC and the Ontario Ministry of the Environment, Conservation and Parks lead actions to restore AOCs, with significant contributions from other federal departments, provincial ministries, municipalities, conservation authorities, First Nations, Métis, and community stakeholders. Working with these key partners, the United States and Canada have continued efforts to restore environmental quality in all remaining AOCs.

Binational Actions and Achievements

Priority for Action: In the United States, complete the delisting process, including the public comment period, for the Lower Menominee River and Ashtabula River AOCs.

The Lower Menominee River was successfully delisted in September 2020 as a result of a variety of remediation and restoration activities conducted by USEPA and the states of Wisconsin and Michigan. This work resulted in a cleaner and healthier river bottom, a healthier fish and wildlife population, and improved fish and wildlife habitats. Michigan and Wisconsin worked closely with each other and with federal agencies, industry, private partners, and local citizens to restore the AOC. [More information is in the event's press release.](#)

The Ashtabula River AOC was successfully delisted in August 2021. This delisting was the culmination of over 30 years of work by USEPA, USACE, and the state of Ohio, including the creation of over 2,500 linear feet of fish habitat and the removal of more than 620,000 cubic yards of contaminated sediment containing 14,000 pounds of polychlorinated biphenyls (PCBs). These remediation and restoration projects allowed for the removal of six BUIs, which led to the ultimate delisting of the AOC. [More details can be found in the press release for this event.](#)

Priority for Action: In Canada, implement remedial actions to restore BUIs including in the St. Lawrence River and Bay of Quinte AOCs for the Eutrophication and Undesirable Algae BUI, the Detroit River AOC for the Loss of Fish and Wildlife Habitat BUI, and in the Hamilton Harbour AOC through management of contaminated sediment at Randle Reef.

Under the Great Lakes Protection Initiative (GLPI), Canada supported 40 fish and wildlife habitat restoration and nutrient reduction projects in seven AOCs in 2020–2021, including:

- Innovative cover crop projects with rural landowners to reduce nutrient runoff from 473 hectares of farmland in the Bay of Quinte AOC.

Beneficial Use Impairments

1. Restrictions on fish and wildlife consumption
2. Tainting of fish and wildlife flavor
3. Degradation of fish and wildlife populations
4. Fish tumors or other deformities
5. Bird or animal deformities or reproduction problems
6. Degradation of benthos
7. Restrictions on dredging activities
8. Eutrophication or undesirable algae
9. Restrictions on drinking water consumption, or taste and odor problems
10. Beach closings
11. Degradation of aesthetics
12. Added costs to agriculture or industry
13. Degradation of phytoplankton and zooplankton populations
14. Loss of fish and wildlife habitat



Figure 1. U.S. and Canadian Great Lakes Areas of Concern. Credit: USEPA and ECCC.

- Habitat restoration and nutrient reduction projects in the St. Lawrence River AOC, guided by the AOC Coastal Wetland Plan and Eutrophication Strategy.
- A large in-river restoration project to create fish and wildlife habitat in the Canadian side of the Detroit River AOC at the city of Windsor.
- Removal of 5 hectares of invasive phragmites to protect 25 hectares of wetland at Tommy Thompson Park in the Toronto and Region AOC.

Priority for Action: In the United States, implement remedial actions to remove BUIs, including sediment remediation at Spirit Lake in the St. Louis River AOC, sediment remediation at Ryerson Creek in the Muskegon River AOC, coastal marsh restoration at Kingsbury Bay and Grassy Point in the St. Louis River AOC, and Howard Marsh habitat restoration project in the Maumee AOC.

The United States initiated remediation and restoration projects at 10 AOCs, including sediment remediation at Spirit Lake in the St. Louis River AOC, sediment remediation at Ryerson Creek in the Muskegon River AOC, coastal marsh restoration at Kingsbury Bay and Grassy Point in the St. Louis River AOC, and Howard Marsh habitat restoration project in the Maumee AOC. In total, the United States completed:

- Thirteen sediment remediation projects in five AOCs:
 - Seven remediation projects in five AOCs in 2020
 - Six remediation projects in three AOCs in 2021
- Nineteen habitat restoration projects in seven AOCs:
 - Ten restoration projects in seven AOCs in 2020
 - Nine restoration projects in six AOCs in 2021

Priority for Action: Identify and prioritize AOC management actions using annual domestic strategic planning meetings.

In the United States:

- Convened a USEPA AOC conference in September 2019 and May 2022 to provide a forum for federal, state, and tribal agencies and local stakeholders to transfer knowledge, share information, and discuss key issues related to the AOC program.
- Convened annual AOC planning meetings with each of the Great Lakes states and the Saint Regis Mohawk Tribe to review progress to date and develop priorities for the upcoming years. The priorities discussed at these annual meetings include developing plans for implementing habitat restoration and sediment remediation projects, the status of BUI removal, and updates on delisting.
- Input from binational public advisory councils was included in the assessments of the Restrictions on Drinking Water Consumption BUI in the St. Clair River AOC and in the Degradation of Fish and Wildlife Populations BUI and the Restrictions on Dredging Activities BUI in St. Marys River AOC.

In Canada:

- ECCC engaged with Canadian provincial agencies, municipalities, regional health offices, Indigenous communities, public advisory councils, and the public, among others, on decisions to restore BUIs through in-person and virtual RAP committee meetings, events, websites, newsletters, and social media through the efforts of local RAP coordinators in nine AOCs.
- ECCC incorporated the expertise and Traditional Ecological Knowledge of First Nations and the Métis Nation of Ontario into the decision-making on contaminated sediment options, habitat restoration, and scientific studies for assessing the status of BUIs, including the Degradation of Fish and Wildlife Populations BUI in the St. Clair River AOC; the Restrictions on Fish and Wildlife Consumption BUIs in Spanish Harbour, Bay of Quinte, and St. Lawrence River AOCs; and, the evaluation of sediment management options in the Thunder Bay AOC.

Priority for Science: In the United States, conduct sediment sampling activities necessary for the

implementation of sediment remediation projects in AOCs, including sampling in the Milwaukee Estuary, Rouge River, and Torch Lake AOCs.

- Under the GLRI, the United States conducted multiple sampling activities necessary for the implementation of sediment remediation projects, including sampling in the Detroit River, Rouge River, Grand Calumet River, Niagara River, Maumee River, Milwaukee River, St. Louis River, and Torch Lake AOCs. This sampling will feed directly into remedial designs, which will lead to sediment cleanups.

Priority for Science: In Canada, conduct sampling to support long-term monitoring in AOCs, including in the Jackfish Bay AOC, the Spanish Harbour AOC, and the St. Lawrence River AOC.

- **Spanish Harbour:** Long-term monitoring supported the removal of the Restrictions on Dredging BUI, provided insight into the recovery of benthic community health, and confirmed that environmental contaminants are not detrimental to edible aquatic plants.
- **Jackfish Bay:** Long-term monitoring confirmed the improved sediment quality, improving benthic community health, and declining contaminant levels in fish.
- **St. Lawrence River:** Long-term monitoring established a baseline of sediment chemistry and toxicity as well as mercury in fish that will be used to assess future changes.

Priority for Science: In the United States, conduct monitoring activities to confirm that BUI removal criteria have been met, including monitoring in the Black River for the Fish Tumor and Other Deformities BUI; Buffalo River for the Degradation of Benthos BUI; and River Raisin for the Bird or Animal Deformities or Reproductive Problems BUI.

- **Black River:** Data from monitoring activities that took place in 2020 were used to assess the status of the Restrictions on Dredging Activities BUI. The assessment recommended that the BUI be removed, and Ohio is working for a 2022 BUI removal.
- **Manistique River:** Data from monitoring activities that took place in 2020 were used to assess the status of the Restrictions on Dredging Activities BUI. The assessment showed that the BUI removal

criteria were met; after a public comment period, the BUI was successfully removed in 2021.

- **Maumee River:** Data from monitoring activities that took place in 2020 were used to assess the status of the Fish Tumors and Other Deformities and the Degradation of Fish and Wildlife Populations BUIs.
- **Sheboygan River:** Data from monitoring activities that took place in 2020 were used to assess the status of the Fish Tumors and Other Deformities BUI.
- **Eighteenmile Creek:** Data from monitoring activities that took place in 2020–2021 were used to assess the status of the Degradation of Benthos and the Restrictions on Dredging Activities BUIs.
- **Buffalo River:** Data from monitoring activities that were completed by 2021 were used to assess the status of the Fish Tumors or Other Deformities, the Bird or Animal Deformities or Reproduction Problems, the Restrictions on Fish Consumption, and the Degradation of Benthos BUIs.
- **Saginaw River and Bay:** Data from monitoring activities that took place in 2021 were used to assess the status of the Degradation of Fish and Wildlife Populations BUI.
- **Grand Calumet River:** Data from monitoring activities that took place in 2021 were used to assess the status of the Degradation of Phytoplankton and Zooplankton Populations and the Eutrophication or Undesirable Algae BUIs.

Priority for Science: In Canada, conduct monitoring activities to confirm that BUI removal criteria have been met, including monitoring in the St. Clair River for the Loss of Fish and Wildlife habitat BUI, Toronto AOC for the Degradation of Fish and Wildlife Populations BUI, and the Niagara River and Thunder Bay AOCs for the Beach Closings BUI.

- **Thunder Bay:** Data from monitoring activities completed by 2020 were used to assess the status of the Beach Closings BUI. The assessment recommended the BUI be removed; community engagement on this recommendation is underway.
- **Niagara River:** Data from monitoring activities completed by 2020 were used to assess the status of the Beach Closings BUI. The assessment

recommended the BUI be removed; community engagement on this recommendation is underway.

- **Toronto and Region:** Data from monitoring activities completed by 2020 were used to assess the status of the Degradation of Fish Populations and the Loss of Fish Habitat BUIs. The status assessment found that BUI removal criteria have not been met. Monitoring activities based on the findings of the assessment will continue.
- **St. Clair River:** Data from monitoring activities completed by 2020 were used to assess the status of the Restrictions on Drinking Water Consumption BUI. The assessment recommended the BUI be removed; community engagement on this recommendation is underway. Monitoring data and geospatial information were compiled in 2020 to support the assessment of the Loss of Fish and Wildlife Habitat BUI in the St. Clair River. The monitoring data on wetland health show that the delisting criteria pertaining to wetland quality has been met, and analysis of the other delisting criteria continues.
- Supported 92 scientific studies of benthos, plankton, algae, fish, wildlife, habitat, and sediment in 12 AOCs from 2020 to 2021.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, the United States and Canada pursued a variety of domestic projects that also support Annex 1 (AOCs).

United States

- **Cuyahoga River AOC Brecksville Dam removal.** The Brecksville Dam was successfully removed in July 2020. Construction started in late May 2020 and began by notching the dam, which allowed for controlled water release while deconstruction occurred. This approach also allowed for the historic Pinery Feeder Dam to be uncovered. Removal of the Brecksville Dam returned the river to its original free-flowing conditions, which allows for increased fish passage, decreased sedimentation, and safer paddling and recreational opportunities. Extensive collaboration by U.S. National Park Service (NPS),



Crew begins removal of the Brecksville Dam structure.
Credit: NPS



Dredging taking place in the Manistique River.
Credit: EGLE

USACE, Ohio Environmental Protection Agency (Ohio EPA), Ohio Department of Natural Resources (Ohio DNR), and the Friends of the Crooked River made this project possible.

- **Maumee AOC Otter Creek Great Lakes Legacy Act sediment remediation.** Otter Creek is a small creek that flows southwest to northeast through the cities of Toledo and Oregon, Ohio, before emptying into South Maumee Bay as part of the Maumee AOC. The lower 1.7 miles of the creek flows through a highly industrial area containing an active railroad yard, oil refineries, and closed landfills. Initial sediment testing determined that this area of the creek contained elevated levels of polycyclic aromatic hydrocarbons (PAHs) and diesel range organics. This USACE-managed project used a hydraulic vacuum-like device to remove approximately 57,000 cubic yards of contaminated sediment from the creek's bottom, which was then pumped through a submerged pipeline to the nearby Toledo-Lucas County Port Authority's confined disposal facility. USEPA collaborated with Ohio EPA, Ohio DNR, USFWS, Toledo Port Authority, and industry partners to complete this project. Following the dredging, a sand cover was placed in the creek to create a barrier against any remaining contamination. The partners installed habitat improvements on the lower reach of the creek to create opportunities for fish and other aquatic species to rest and forage for food.

- **Manistique River AOC sediment remediation.** Between 2013 and 2020, the Michigan Department of Environment, Great Lakes, and Energy (EGLE) removed more than 50,000 cubic yards of PCB-contaminated sediment from the Manistique River and spread layers of sand and activated carbon over portions of the impacted river bottom. Removing these pollutants should support fish species that use the river for habitat, such as smallmouth bass and northern pike. Over the next several years, sampling will be performed to confirm reduced PCB levels in fish tissue and in the sediment in the navigation channel; this work should ultimately clear the way for removal of the two remaining BUIs and allow for elimination of the AOC designation for the Manistique River. This project represents the final management action needed to remove BUIs in the AOC.
- **Niagara River AOC Spicer Creek Wildlife Management Area habitat restoration.** USEPA began restoring 16 acres of habitat along the Grand Island shoreline in 2021. The project placed low-profile berms along the shoreline to deflect wave energy and to promote the growth of shallow-water vegetation near the Spicer Creek Wildlife Management Area's shoreline. Eighteen segmented rock structures, each about 71 feet long, crest above the river. Log structures and single boulders are installed to further deflect wave energy. The enclosure continues to allow a flow of river water



Log structures were installed at Spicer Creek Wildlife Management Area to deflect wave energy.
Credit: NYSDEC

through the 16-acre work area. Approximately 3,760 linear feet of shoreline are protected. In addition, planting native rooted vegetation and seed mixes to promote long-term naturalized growth enhance habitat. The new structures create a protected backwater area that is designed to shield the new habitat from boat wakes, ice scour, sediment, and other factors that can affect vegetation propagation. Construction was completed at the end of 2021.

- **St. Lawrence River at Massena/Akwesasne AOC mussel propagation.** While remediation in the AOC is ongoing, Saint Regis Mohawk Tribe (SRMT) has received GLRI funding to propagate three species of freshwater mussels that have been affected by remediation dredging and capping activities in the Lower Grasse River. This project will help remove the Degradation of Benthos BUI and aims to propagate 30,000 mussels by 2025. With this project, the SRMT is the first tribe to propagate freshwater mussels and to successfully raise juvenile mussels in New York. Other partners include USFWS Genoa National Fish Hatchery, New York State Department of Environmental Conservation (NYSDEC), and the New York State Museum. This project, along with NYSDEC's salvage and relocation project, will help freshwater mussel populations meet the 2025 goal for this AOC.
- **Muskegon Lake AOC: Lower Muskegon River habitat restoration.** Habitat restoration was completed in the Muskegon River in 2020. The site,



Successful habitat restoration at the Lower Muskegon River AOC. Credit: USEPA

a half-mile upstream from Muskegon Lake, was a former celery farm separated from the river by three concrete dikes. NOAA completed this project in collaboration with the Great Lakes Commission. The project was locally managed and implemented by the West Michigan Shoreline Regional Development Commission. By removing the dikes, this project reestablished hydrological connection between the river and the lake, which will help increase fish passage in the AOC. Over 53 acres of emergent wetland were restored by creating emergent wet meadow, shrub-carr, and floodplain forested wetlands. Over 34,000 native plants and 160 habitat structures were installed, providing habitat for fish, bird, and reptile populations. This project also removed 5.3 acres of fill and softened 2,700 linear feet of shoreline.

Canada

- **Hamilton Harbour AOC – Randle Reef contaminated sediment management.** [Randle Reef](#), located at the southwest corner of Hamilton Harbour, is the largest area of contaminated sediment in Canada—containing high concentrations of PAHs and heavy metals. In 2021, the dredging of contaminated sediment was completed. Sediment was placed into a 6.2-hectare engineered containment facility (ECF). The project entered its final stage in 2022, which involves placing an environmental cap over the ECF so the site can be developed for use as port lands. Completing this project will improve water quality, reduce contaminant levels in the harbor, provide

economic benefits for the Hamilton community, and have positive impacts on the Great Lakes ecosystem. This project is led by ECCC and is managed by Public Services and Procurement Canada with funding and in-kind contributions from the Government of Canada, the Province of Ontario, the cities of Hamilton and Burlington, Halton Region, Hamilton and Oshawa Port Authority, and Stelco.

- **Thunder Bay AOC – Community-led habitat restoration.** With funding from the GLPI, ECCC supported community action to restore habitat along urban tributaries and the shoreline of Lake Superior. Confederation College created 10 hectares of riparian habitat along the McIntyre River, and the Lakehead Region Conservation Authority revitalized 2.1 hectares of aquatic habitat along the Kaministiquia River and the Neebing-McIntyre floodway. The City of Thunder Bay restored 1 kilometer (km) of riparian habitat along McVicar Creek, and the Thunder Bay District Environmental Stewardship Council revitalized a former brownfield site by creating habitat at the mouth of the Current River where it meets Lake Superior. The North Shore Steelhead Association finalized designs that will enable fish passage between Thunder Bay and a 50-km segment of cold-water spawning habitat upstream in the Current River.
- **Detroit River AOC – Peche Island Erosion Mitigation and Fish Habitat Project.** This project, led by the Essex Region Conservation Authority

(ECRA), is protecting Peche Island in the upper Detroit River from erosion while also providing fish and wildlife habitat. ECRA completed construction of six offshore sheltering islands in 2021 with financial support from ECCC’s Great Lakes Protection Initiative; the City of Windsor; Swim Drink Fish Canada; and the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry. The sheltering islands added 6.8 hectares of calm water embayment to provide refuge for fish in this high-flow-velocity area of the Detroit River. Monitoring by Fisheries and Oceans Canada (DFO) shows that endangered fish, such as northern madtom and channel darter, are using the new habitat areas.

- **Toronto and Region AOC – Fish habitat assessment.** In 2020, DFO, with assistance from the local Toronto and Region Conservation Authority, assessed 30 years of electrofishing data, a decade of hydroacoustic and telemetry survey data, and long-term habitat restoration records to evaluate the effectiveness of habitat restoration along Toronto’s waterfront and to provide recommendations for targeted habitat restoration for priority fish species. The results demonstrate that restoration work has increased fish habitat and shoreline length and has led to positive change in the fish community at some locations. There is more to do, however. The assessment effort has prompted development of the Toronto Waterfront Integrated Restoration Prioritization (WIRP) tool, which will guide further



Four shoals created to protect Peche Island from erosion and create sheltered areas for fish and wildlife habitat. Credit: Jacqueline Serran, Essex Region Conservation Authority



Inserting telemetry tracer tag in fish at Toronto Islands, Toronto and Region AOC. Credit: Morgan Piczak, Carleton University

habitat restoration work on the Toronto waterfront. The WIRP will use existing environmental monitoring data to provide direction on how Toronto waterfront restoration should take place—and where it would be most beneficial based on known impairments and potential contributions to the natural system if restored, with a goal of identifying priority restoration work over the next 5–10 years.

- Peninsula Harbour AOC – Long-term monitoring and assessment.** Actions to reduce environmental impacts of mercury and PCB-contaminated sediment in the Peninsula Harbour AOC have been successful. A 2020 assessment showed that the thin-layer cap placed on top of the most-contaminated sediment in 2012 has improved conditions for benthos, a requirement to meet the cleanup goals of the project. Study results and community support led to the removal of the Degradation of Benthos BUI in 2022. Long-term monitoring will continue to inform evaluation of the stability and effectiveness of the cap.
- Toronto and Region AOC – The Don Mouth Naturalization and Port Lands Flood Protection Project.** This ambitious waterfront revitalization project is in the city of Toronto's inner harbor. In 2019, Waterfront Toronto, a corporation with funding support from federal, provincial, and municipal governments, began construction of a new 1-km-long river valley, a re-naturalized river mouth, a spillway, and improved transportation routes and connections. By 2021, after 65% of a target of 1.4 million cubic meters soil was excavated, the alignment of the Don River valley and the created wetland project in the central river valley took shape. The project contoured the bottom, banks, floodplains, and mouth of the Don River. Woody material and boulders, cobbles, and gravels were installed in the new channel to create aquatic habitat. The project established two new coves for fish and wildlife habitat (West Habitat Cove and North Habitat Cove) and constructed another cove (Canoe Cove) as part of the revitalization of Polson Slip. Native fish species, including largemouth bass, pike, pumpkinseed, bluegill, rock bass, and white sucker, now frequent the new habitat. By 2024, approximately 14 hectares of aquatic habitat will enhance this renewed waterfront.




























































































































































































Scientist installing sampling device to extract water samples from the sand cap that isolates the contaminated sediment at the bottom of Peninsula Harbour AOC. Credit: Environment and Climate Change Canada, Water Science and Technology Directorate Dive Team



Tree logs being placed on sides of new river channel to create habitat for wildlife and shelter for fish, Don River Mouth Revitalization, Toronto and Region Area of Concern, Lake Ontario. Credit: Waterfront Toronto

More information about the U.S., Canadian, and binational AOCs is online at [USEPA's Great Lakes AOCs](#), [Canada's Great Lakes: AOCs](#), and local RAP websites. Tables 1 and 2 show the progress on restoring beneficial uses by removing BUIs in the United States and Canada. This progress represents years of focused domestic action and resources by all levels of government and local partners.

Table 1. Progress towards Removing Beneficial Use Impairments in the United States Great Lakes Areas of Concern

		 BUI Previously Removed	 BUI Removed 2020–2022	 BUI Impaired	 BUI Removals Projected, 2022										
AOC	State	Restrictions on fish and wildlife consumption	Tainting of fish and wildlife flavor	Degradation of fish and wildlife populations	Fish tumors or other deformities	Bird/animal deformities or reproduction problems	Degradation of benthos	Restrictions on dredging activities	Eutrophication or undesirable algae	Restrictions - drinking water consumption, taste/odor problems	Beach Closings	Degradation of aesthetics	Added costs to agriculture or industry	Degradation of phyto- and zooplankton populations	Loss of fish and wildlife habitat
Ashtabula River Delisted	OH	 2014		 2014	 2020		 2018	 2020							 2014
Black River	OH	 2017						 2022	 2017						
Buffalo River	NY		 2020									 2018			 2022
Clinton River	MI											 2020			
Cuyahoga River	OH	 2019							 2021			 2018			
Deer Lake Delisted	MI	 2014				 2011			 2011						
Detroit River	MI/ON		 2013							 2011					
Eighteenmile Creek	NY							 2020							
Grand Calumet River	IN									 2012			 2011		
Kalamazoo River	MI										 2011	 2012			
Lower Green Bay/Fox River	WI		 2020					 2021				 2022			
Lower Menominee River Delisted	MI/WI	 2018		 2019			 2017	 2017			 2011				 2019
Manistique River	MI						 2007	 2021			 2010				 2008
Maumee	OH												 2015		
Milwaukee Estuary	WI											 2021			
Muskegon Lake	MI	 2013		 2022				 2011		 2013	 2015	 2021			 2022
Niagara River	NY/ON				 2016										
Oswego River Delisted	NY	 2006		 2006					 2006						 2006
Presque Isle Bay Delisted	PA				 2013			 2007							
River Raisin	MI			 2015					 2013		 2013	 2012			 2015
Rochester Embayment	NY	 2021	 2018	 2021	 2015	 2022	 2017	 2019	 2019	 2011	 2019	 2022	 2011	 2016	 2022
Rouge River	MI														

AOC	State	Restrictions on fish and wildlife consumption	Tainting of fish and wildlife flavor	Degradation of fish and wildlife populations	Fish tumors or other deformities	Bird/animal deformities or reproduction problems	Degradation of benthos	Restrictions on dredging activities	Eutrophication or undesirable algae	Restrictions - drinking water consumption, taste/odor problems	Beach Closings	Degradation of aesthetics	Added costs to agriculture or industry	Degradation of phyto- and zoo-plankton populations	Loss of fish and wildlife habitat
Saginaw River & Bay	MI	■	* 2008	■		■	■	■	■	* 2008	■	■		■	* 2014
Sheboygan River	WI	■		■	■	■	◆ 2021	* 2015	* 2016					◆ 2021	■
St. Clair River	MI/ ON	■	* 2010			* 2017	* 2015	* 2011		■	* 2016	* 2012	* 2012		* 2017
St. Lawrence River at Massena/Akwesasne	NY/ ON	■		■	■	■	■							* 2015	■
St. Louis River	WI/ MN	■		◆ 2022	* 2019		■	■	◆ 2020		■	* 2014			■
St. Marys River	MI/ ON	■		* 2019	■	* 2014	■	* 2018	* 2017		* 2016	* 2014			* 2019
Torch Lake	MI	■			* 2007		■								
Waukegan Harbor	IL	■					* 2018	* 2014			* 2011			◆ 2020	* 2013

Table 2. Progress towards Removing Beneficial Use Impairments in the Canada Great Lakes Areas of Concern

AOC														
	Restrictions on fish and wildlife consumption	Tainting of fish and wildlife flavor	Degradation of fish and wildlife populations	Fish tumors or other deformities	Bird/animal deformities or reproduction problems	Degradation of benthos	Restrictions on dredging activities	Eutrophication or undesirable algae	Restrictions - drinking water consumption, taste/odor problems	Beach Closings	Degradation of aesthetics	Added costs to agriculture or industry	Degradation of phyto- and zooplankton populations	Loss of fish and wildlife habitat
Thunder Bay			■			■	★ 2012			■	★ 2019	★ 2004		■
Nipigon Bay Delisting Pending		★ 1995	★ 2016			★ 2016	★ 1995	★ 2016			★ 2016			★ 2016
Jackfish Bay In Recovery			■	★ 2010		■	★ 1998							■
Peninsula Harbour	■					◆ 2022	★ 2012							
St. Marys River	■		■	■		■	■	★ 2018		★ 2018	★ 2018			■
Spanish Harbour In Recovery	■		★ 1999			■	◆ 2020			★ 1999		★ 1999		
Severn Sound Delisted	★ 2002		★ 2002				★ 2002	★ 2002						★ 2002
Collingwood Harbour Delisted	★ 1994		★ 1994		★ 1994	★ 1994	★ 1994	★ 1994		★ 1994	★ 1994		★ 1994	
St. Clair River	■					■	★ 2018		■	★ 2018	★ 2016	★ 2012		■
Detroit River	■	★ 2014	■	◆ 2020	■	◆ 2020	★ 2019		★ 2010	★ 2016	★ 2016	★ 2010		■
Wheatley Harbour Delisted	★ 2010		★ 2010				★ 2010	★ 2010						★ 2010
Niagara River	■		■		★ 2009	■	★ 2009	★ 2019		■				■
Hamilton Harbour	■		■			■	■	■		■	■			■
Toronto and Region	■		■			★ 2016	★ 2016	■		■	◆ 2020			■
Port Hope Harbour							■							
Bay of Quinte	■		★ 2018			★ 2018	★ 2017	■	◆ 2020	★ 2019	◆ 2022		■	★ 2018
St. Lawrence River	■		■			★ 2007	★ 2007	■	★ 1997	■	★ 1997	★ 1997		■



Annex 2: Lakewide Management

Multi-agency Lake Partnerships are in place for each of the five Great Lakes. These Partnerships are actively assessing water quality and restoration progress at the lakewide scale, as well as developing multi-agency, ecosystem-based strategies for future improvements. Through the development and implementation of Lakewide Action and Management Plans (LAMPs), government and non-government partners are working together to reduce chemical contamination, eliminate excess nutrients, manage invasive species, and restore Great Lakes watersheds. Plans are updated on a rotating basis, with one of the five lakes being updated each year. By the end of this 3-year period, the Lake Michigan, Lake Superior, and Lake Huron LAMPs will have been updated.

Key Achievements

- Agencies implemented restoration and protection actions identified within the LAMPs in all five lakes.
- Published updated LAMPs for Lake Michigan, Lake Superior, and Lake Huron (projected by the end of 2022) containing priorities for science and action that are best addressed on a lake-by-lake basis.
- Completed Great Lakes nearshore assessments in both the Canadian and U.S. waters of the Great Lakes to guide protection and restoration actions.
- Established science and monitoring priorities for the Lake Huron, Lake Ontario, and Lake Erie Coordinated Science and Monitoring Initiative (CSMI) field years. See [Annex 10](#) for a

Purpose and Overview

The purpose of [Annex 2 \(Lakewide Management\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by assessing the status of each Great Lake, and by addressing environmental stressors that adversely affect the Waters of the Great Lakes which are best addressed on a lakewide scale through an ecosystem approach.”

Given the size and ecological complexity of the Great Lakes, restoring and protecting water quality requires an approach that is specifically tailored to an individual lake. In the Lakewide Management Annex, Canada and the United States commit to establishing LAMPs for each of the five Great Lakes and their connecting river systems:

- Lake Superior
- Lake Huron and the St. Marys River
- Lake Erie and the St. Clair River, Lake St. Clair, and the Detroit River
- Lake Ontario and the Niagara River and the St. Lawrence River to upstream of the international boundary
- Lake Michigan (for which United States has sole responsibility)

LAMPs are binational (except Lake Michigan, as noted above), 5-year ecosystem-based strategies that identify and prioritize restoration and protection activities required to attain the General Objectives for each of the Great Lakes. Each LAMP is developed by a Lake Partnership of environmental protection and natural resource management agencies working on that lake.

ANNEX IMPLEMENTATION

Environment and Climate Change Canada (ECCC) and the U.S. Environmental Protection Agency (USEPA) led the implementation of the commitments within Annex 2 (Lakewide Management), with support from a Lake Partnership for each of the Great Lakes. The Lake Partnerships are collaborative teams of environmental protection and natural resources managers led by the governments of Canada and the United States, in cooperation and consultation with state and provincial governments, tribal governments, First Nations, Métis, municipal governments, and watershed management agencies. A complete list of agency membership for each lake is found within the respective LAMP for that lake.

discussion of the intensive science and monitoring that occurred during these CSMI field years.

Binational Actions and Achievements

Priority for Action: Implement actions identified in LAMPs. Update and initiate implementation of the Lake Michigan LAMP in 2020, Lake Superior LAMP in 2021, and Lake Huron LAMP in 2022. Include results of the assessment of the nearshore waters in LAMPs to assist communities, agencies, and organizations in their identification and implementation of restoration and protection activities for the nearshore waters of the Great Lakes.

- The LAMPs for Lake Michigan, Lake Huron, and Lake Superior are expected to be finalized by the end of 2022. These documents incorporate recent information on the nearshore environment and identify actions that will further promote nearshore water quality.
- The LAMPs for Lake Erie and Lake Ontario, mentioned in the previous progress report, were published in 2021 after publishing delays.

Despite delays in publication, Lake Partnership agencies did not delay the implementation of key protection and restoration actions. (Please see below for significant Domestic Actions and Accomplishments.) The Lake Partnerships have also published [annual updates](#) to communicate implementation progress to the public.

Priority for Science: To support an assessment of the nearshore waters of the Great Lakes. In 2020, conduct the next National Coastal Condition Assessment in U.S. coastal waters of all Great Lakes. By 2022, complete the Nearshore Assessments and Light

Detection and Ranging (LiDAR) topobathymetry for the Canadian side of the Great Lakes.

Canada and the United States continued implementing their integrated [approach](#) for assessing nearshore health:

- In 2020–2022, Canada collected LiDAR topobathymetry for the Canadian side of Lake Huron and completed [Canada's nearshore assessments](#).
- In 2020–2021, the United States conducted the next [National Coastal Condition Assessment \(NCCA\)](#) in U.S. coastal waters of the Great Lakes to guide protection and restoration activities in the nearshore environment.

Priority for Science: Establish CSMI Priorities. In 2020, establish science and monitoring priorities for the 2022 Lake Huron CSMI field year. In 2021, establish science and monitoring priorities for the 2023 Lake Ontario CSMI field year. In 2022, establish science and monitoring priorities for the 2024 Lake Erie CSMI field year.

- In coordination with the Lake Partnerships, Canada and the United States established science and monitoring priorities for Lake Huron, Lake Ontario, and Lake Erie to help focus monitoring activities to support future management actions. These lake-specific priorities reflect the chemical contaminant, nutrient and bacterial pollution, food web impacts, and other issues currently facing each lake, and they will be used to focus CSMI field year activities for each lake.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, Canada and the



Waves on the shore at Marathon – Lake Superior. Credit: Chris Robinson

United States pursued a variety of domestic projects that also support Annex 2 (Lakewide Management).

Canada

Canada's domestic commitments in the LAMPs are delivered through federal, provincial, Indigenous, and nongovernmental efforts. Federally, implementation is supported through programs such as the [Great Lakes Protection Initiative](#) (GLPI), [Canada's Nature Fund](#), the [EcoAction Community Funding Program](#), and the [Investing in Canada Plan](#). LAMP implementation is also supported by Ontario's [Great Lakes Strategy](#), the [Great Lakes Local Action Fund](#), and the [Species at Risk Stewardship Program](#). The following actions are highlighted as examples of Canadian lakewide management restoration and protection efforts during the 3-year timeframe.

Canadian Great Lakes nearshore assessment

- Canada continued to implement the [binational Great Lakes Nearshore Framework](#). Through the GLPI, ECCCC completed a comprehensive assessment of the state of nearshore waters for lakes Superior (2020) and Huron (2021). In 2022, ECCCC made the results of the Canadian Nearshore Assessment for Lake Ontario, Lake Erie, Lake Superior and Lake Huron available through the Government of Canada's [OpenData](#) Portal. In 2022, the data were also provided through [OpenMaps](#) to allow the public to combine, visualize, and analyze the geospatial data and collaborate to support informed decision-making. The nearshore assessments identified areas that are or may become subject to high stress and areas of high ecological value. The assessments also identified factors and cumulative effects that are causing stress or are threatening areas of high ecological value. The nearshore data and reports were shared with the Great Lakes

community in 2021–2022 to guide priority-setting for restoring and protecting nearshore areas and to engage with partners that are developing and implementing these measures.

- One of the major factors causing stress in Lake Erie identified in the nearshore assessment is the current and future projected impacts from climate change, such as reduced winter ice cover, high water levels, and increased wave action from more intense storms. In 2020, Natural Resources Canada (NRCan) funded a project to develop climate change information on future ice conditions and storm extremes, including wave heights and storm surge, for the coastal zone of the Great Lakes region. To “mainstream” this information into coastal zone management, a comprehensive coastal vulnerability and risk assessment was completed for the Municipality of Chatham-Kent’s Lake Erie shoreline (including Rondeau Bay) with significant contributions from the Lower Thames Valley Conservation Authority (LTVCA). Extensive public engagement was completed (nine meetings with over 1,000 attendees) to share the technical findings on climate change impacts on future lake levels and coastal hazards and co-develop community-scale adaptation concepts. Recommendations were provided for 10 shorelines, and the findings were summarized in a detailed technical report.
- In 2021–2022, ECCC supported the implementation of a 2-year project led by the LTVCA to engage shoreline communities, stakeholders, and First Nations communities in sharing knowledge and collaboratively identifying priorities to reduce risks to nearshore water quality and ecosystem health. In 2021, the LTVCA investigated the supply of sediment within the Rondeau Bay nearshore area, a critical piece of information needed to develop priorities for its restoration. Public engagement was completed (two meetings with ~40 community members) to raise awareness of the project and share the technical findings. In 2022, the community, in collaboration with municipal, Indigenous, and conservation partners, will recommend a preferred approach to restoration that considers the social and economic co-benefits derived from the ecosystem services the coast provides, and they will seek appropriate funding to implement restoration. The

First Nations and Métis within the basin consider the Great Lakes to be of spiritual, cultural, and ceremonial significance to their communities, and have played an important role in their protection since time immemorial.

Through the GLPI, ECCC supports efforts to increase Indigenous participation in decision-making processes and actions to restore and protect Great Lakes water quality. During 2020–2022, ECCC continued to provide funding to Chiefs of Ontario and the Métis Nation of Ontario to support organizational capacity. With this support, the Chiefs of Ontario and the Métis Nation of Ontario have appointed staff dedicated to participating in governance processes under the Agreement, such as the Great Lakes Executive Committee and the lakewide management process, and engaging communities on Great Lakes issues and priorities of cultural and traditional importance.

community will share their approach to developing community-scale solutions to reduce nearshore threats with other communities along the Lake Erie coastline.

- Topobathymetric LiDAR data was collected in Lake Huron in 2020 to assist in updating essential depth and substrate information for lakebed mapping, habitat features, flood risk, and infrastructure management.

Community engagement across the Great Lakes

- **Community-based organizations, nonprofit organizations, municipalities, conservation authorities, and Indigenous communities and organizations across Ontario received support for local action-based projects.** These local projects produced measurable and positive effects on the environment, engaged communities, increased environmental awareness, and increased capacity in communities across the Great Lakes.
- **Multiple lakes:** Swim Drink Fish Canada, with support from the GLPI, continued to pilot a citizen science program to engage communities in collecting *Escherichia coli* recreational water quality samples, analyzing the samples, and making the

data available to the public during the 2020–2022 period. The program established monitoring hubs in six Great Lakes communities, including three First Nations.

- **Lake Superior:** In 2021, working with Parks Canada, the TransCanada Trail, and Wikwemikong Tourism, [Pawgwasheeng \(Pays Plat\) First Nation](#) continued development of a medicine trail. The trail will engage community members, especially youth, in wetland education, stewardship, and monitoring while Elders pass down Traditional Ecological Knowledge of medicinal plants and local fauna along interpretive trail walks.
- The [Métis Nation of Ontario](#) (MNO), with support from Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) and ECCC, initiated a Métis Guardians environmental monitoring pilot program to monitor the effects of climate change and pollution on important waterbodies. In 2021, over 50 citizens from across the MNO were trained in techniques to monitor water quality parameters such as pH, dissolved oxygen, temperature, and turbidity. Métis Guardians will sample waterbodies under spring, summer, and fall conditions annually. Monitoring locations being targeted in Lake Superior include the Black Sturgeon River, Black Bay, Red Rock Bay, Jackfish/Moberly Bay, and Michipicoten Harbour.
- **Lake Huron:** The [Wasauksing First Nation](#), located on an island in Mnidoo-gamii (Georgian Bay), is a community of Ojibway, Odawa, and Potawatomi peoples. In 2020–2021, with support from the Indigenous Habitat Participation Program through Fisheries and Oceans Canada and the First Nations Land Management Resource Centre, this community established an aquatic monitoring and training program to evaluate impacts to water quality, wetlands, fish habitat, and fish populations in response to increased development pressure in the area.
- Ontario also strengthened collaborations to address nearshore water quality concerns, such as nuisance algae and bacterial issues, and promote safe and clean beaches through initiatives such as the Healthy Lake Huron, Clean Water, Clean Beaches Initiative. Actions have focused on soil health,



Taking water quality and benthic invertebrate samples.
Credit: Wasauksing First Nation

erosion control, habitat restoration, and other stewardship activities.

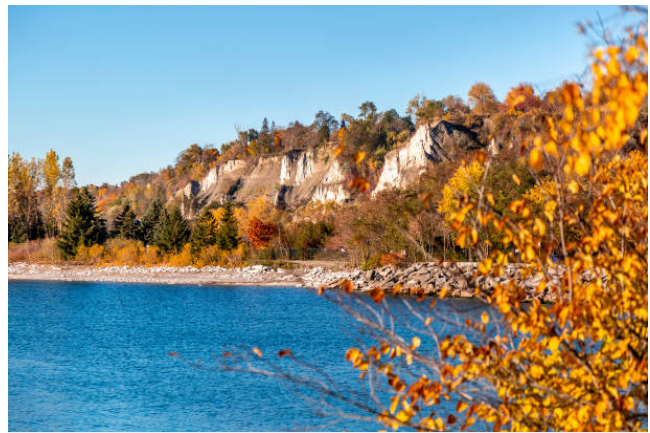
- **Lake Erie:** In 2021–2022, the Niagara Coastal Community Collaborative, Niagara College, and the [Niagara Peninsula Conservation Authority](#), with funding from the Ontario Ministry of the Environment, Conservation and Parks (MECP) and technical support from ECCC, developed the Visual Assessment Survey Tool. It provides an innovative platform for the collection and mapping of community monitoring data including *Cladophora* wash-up, shoreline erosion, water level changes, and aesthetics along the Lake Erie beaches in the Niagara Region. Through near real-time surveys and aerial imagery, areas under threat or in need of protection can be identified, with data and results available to the public in an open, readable format.
- **Lake Ontario:** The [Mohawk Council of Akwesasne Environment Program](#) collaborated with the Canadian Coast Guard to demonstrate

environmental stewardship by removing and disposing of toxic batteries that had been dumped in the St. Lawrence River. Through the Aids to Navigation Battery [clean-up project](#), 14 batteries were removed in 2019, and 14 more were located and removed in 2021.

- The University of Toronto Trash Team, in partnership with PortsToronto and with support from MECP and ECCC, has been capturing waste in Toronto Harbour using trash capture devices called SeaBins. In 2020, the team tested and refined methods to develop two standard protocols for waste characterization. In 2021, the team analyzed the contents of six SeaBins over a 7-week period. Seabin audits will continue in 2022 to further understand the quantities and types of floating litter, and results will help inform the implementation of upstream solutions. The team is using Global Positioning System-tagged water bottles to represent floating litter and is following the bottles' travels to reveal movement patterns and potential accumulation zones of floating litter. This will increase the team's understanding of how local litter sources move, which will inform future placement of trash capture devices (like SeaBins) to divert litter from Lake Ontario and engage the general public in reducing plastic pollution.

Managing pollutants and other threats

- Canadian federal, provincial, municipal and nongovernmental agencies continue to manage pollutants that could be harmful to human health, wildlife, or aquatic organisms through direct exposure or indirect exposure through the food chain, as well as to take action against other substances, materials or conditions that may negatively impact Great Lakes water quality. Key lake-specific activities from 2020–2022 are described below. Other Canadian activities that reduce lakewide pollutants are described in [Annex 1 \(Areas of Concern\)](#) and [Annex 3 \(Chemicals of Mutual Concern\)](#).
- **Lake Superior:** Thunder Bay's nearshore waters have some of the highest abundances of microplastics in Lake Superior. In response, an increasing number of people and businesses are helping to reduce the amount of plastic waste reaching Lake Superior. EcoSuperior, with support from MECP and ECCC,



Scarborough Bluffs, Toronto. Getty Images

are implementing clean-up activities, supporting businesses' efforts to reduce the use of single-use plastics, and delivering presentations to schools and the community to raise awareness. As of 2022, 26 Thunder Bay restaurants have joined The Last Straw – Thunder Bay Campaign to reduce single-use plastic waste in their operations. A growing number of individuals are cleaning up shorelines using supplied cleanup kits and recording the type of plastics being found such as cigarette butts, take-out containers, and fishing lines.

- **Lake Huron:** Communities in Lake Huron are taking action to reduce and clean up plastic pollution. In 2020, Georgian Bay Forever (GBF) joined the Great Lakes Plastic Cleanup, which deploys plastics-capture technologies to reduce pollution. In 2021, with support from Ontario's Great Lakes Local Action Fund, GBF analyzed the captured plastics and is using the waste characterization data to identify sources for further mitigation efforts as well as engage the public in taking action. The Great Lakes Plastic Cleanup is spearheaded by Pollution Probe and Council of the Great Lakes Region with funding from ECCC, MECP, and several private organizations.
- **Lake Ontario:** With support from the federal Investing in Canada Plan and the Province of Ontario, the City of Hamilton continued the Woodward Wastewater Treatment Plant upgrades, the largest single capital investment in Hamilton's history, to improve water quality in the Hamilton Harbour. The main objective of the project is to

meet effluent targets defined by the Hamilton Harbour Remedial Action Plan for phosphorus, ammonia, and suspended solids by increasing treatment capacity and upgrading to tertiary treatment. Between 2020 and 2022, construction continued on the tertiary treatment facility and a new chlorine contact tank, and improvements to Red Hill Creek were undertaken to convey the new tertiary-treated effluent. Work also continued on the main wastewater pumping station that will increase capacity to meet future wet-weather event flows and mitigate flooding.

Conserving, protecting, and enhancing natural habitat and species in the Great Lakes

- Canadian federal, provincial, municipal, and nongovernmental agencies continue to implement efforts to conserve, protect, and enhance natural habitat and species in the Great Lakes. Key lake-specific activities from 2020–2022 are described below. Other Canadian activities that support the resilience of native species and their habitat are found in the [Annex 7 \(Habitat and Species\)](#) chapter.
- **Lake Superior:** [Lakehead Region Conservation Authority](#), with support from the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry, launched Superior Stewards (2020–2025) to help promote shoreline naturalization, manage stormwater, raise awareness of invasive species, and support habitat enhancement through its [Shoreline Protection Program](#). Agencies and volunteer groups contributed to provincewide efforts to control invasive phragmites in Ontario.
- **Lake Huron:** Parks Canada continues to advance coastal conservation in all national parks and national marine conservation areas in Ontario. Example projects include Impede the Reed at Georgian Bay Islands National Park (Lake Huron) and the [Open Marsh, Healthy Marsh](#) at Point Pelee National Park (Lake Erie).
- **Lake Erie:** With support from the Natural Heritage Conservation Program, part of Canada's Nature Fund, Ducks Unlimited Canada acquired St. Luke's Marsh in 2020, one of the few remaining coastal wetlands on Lake St. Clair. This acquisition of 197 hectares (488 acres) of coastal shoreline, provincially significant coastal wetlands, and other

mixed wildlife habitats will ensure the protection of habitat in a critical region. Ducks Unlimited Canada is participating through a generous bequest from the late Louise Gendron and international contributors, including Ducks Unlimited, Inc.; the U.S. Fish and Wildlife Service (USFWS); and state agencies through the Fall Flights Initiative (including Ohio and Michigan, which directly border Lake St. Clair).

- **Lake Ontario:** The Region of Peel partnered with [Credit Valley Conservation](#) and the [Toronto and Region Conservation Authority](#) to create a new coastal conservation area on the shores of Lake Ontario. The Jim Tovey Lakeview Conservation



Jim Tovey Lakeview Conservation Area.
Credit: Credit Valley Conservation

Area, scheduled for completion in 2025, is reinvigorating the waterfront with 64 acres of new publicly accessible wetlands and streams, trails, and naturalized areas. Together, these efforts are supporting fish and other wildlife habitat and restoring native species.

United States

The United States uses federal, state, and tribal agency programs to implement actions that fulfill our domestic commitments in the LAMPs. The programs' success has been significantly enhanced by increased funding provided through the [Great Lakes Restoration Initiative \(GLRI\)](#). A full discussion of this multi-agency and enhanced approach is beyond the scope of this document; however, the following actions are highlighted as examples of U.S. lakewide management restoration and protection efforts during this 3-year period.

Integrated nearshore framework implementation.

- The U.S. approach to assessing and managing the nearshore environment is accomplished by the work of several environmental programs. Ecological conditions in the U.S. nearshore waters of the Great Lakes are assessed every 5 years by [USEPA's NCCA surveys](#). All Great Lakes states monitor water quality in their coastal areas to fulfill requirements of the [Clean Water Act](#), as well as work with the federal government to protect and enhance coastal and nearshore areas through the [National Coastal Zone Management Program](#). The 2020 NCCA survey of ecological conditions in U.S. nearshore waters of the Great Lakes started in 2020 and was completed in 2021 due to challenges associated with the global COVID pandemic. As part of the 2020 NCCA survey, additional sampling of Chequamegon Bay (Lake Superior), large islands of Lake Michigan, U.S. National Park Service (NPS) waters of Lake Michigan, and Green Bay was included to compare conditions in these areas to the adjacent nearshore areas. The Chequamegon Bay and Green Bay surveys were completed in 2021, and the NPS and Island surveys will be completed in 2022.

Managing chemical and bacterial contamination

- U.S. agencies continue to manage chemical and bacterial contamination that causes fish consumption advisories and episodic beach closings in the Great Lakes. Key lake-specific activities in 2020–2022 are described below. Other U.S. activities that reduce lakewide chemical and bacterial contamination are described in [Annex 1 \(Areas of Concern\)](#) and [Annex 3 \(Chemicals of Mutual Concern\)](#) sections of this Progress Report of the Parties and are supported by numerous other projects funded under the GLRI's [Focus Area 1: Toxic Substances and Areas of Concern](#).
- **Lake Superior:** The U.S. Geological Survey (USGS) [Mercury Research Laboratory](#) is using innovative methods to identify sources and bioavailability of mercury to fish in the St. Louis River Estuary in Minnesota and Wisconsin. This work will better inform restoration strategies for this large freshwater estuary and assess the impacts of climate change on mercury loadings.
- **Lake Michigan:** The Indiana Department of Environmental Management (IDEM) and beach managers have implemented a mobile-friendly



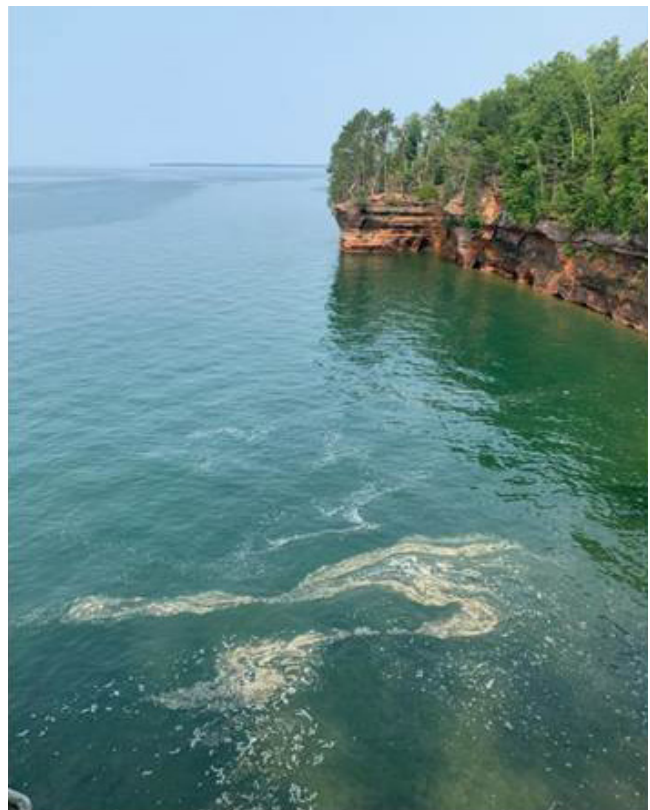
Beach status and water quality alert signs at Indiana Dunes State Park in Chesterton, IN. Credit: IDEM

beach monitoring and notification application called [IDEM BeachAlert](#) through the Lake Michigan Beach Monitoring and Notification Program. BeachAlert provides information on local beach amenities and allows users to check if their favorite beaches are under a contamination advisory or closure due to water safety concerns such as rip currents.

- **Lake Huron:** Michigan's Department of Environment, Great Lakes, and Energy (EGLE) continues to analyze fish for contaminants, including mercury, dioxin, polychlorinated biphenyls, and per- and polyfluoroalkyl substances. Michigan released an [updated version of their Eat Safe Fish Guide](#) in summer 2021.
- **Lake Erie:** Significant work to remediate contaminated bottom sediments and historical contaminant inputs from combined sewer overflows (CSOs) has resulted in the removal of the Tainting of Fish and Wildlife Flavor beneficial use impairment in the Buffalo River AOC. The Buffalo River's water quality will continue to be monitored through New York State Department of Environmental Conservation's (NYSDEC's) statewide Watershed Assessment and Monitoring program, and the Buffalo Sewer Authority is implementing an innovative long-term control plan to significantly reduce CSOs.
- **Lake Ontario:** New York State Department of Health issued [new advice about eating fish](#). Women and children can now eat more fish from Lake Ontario and the Niagara and St. Lawrence rivers. This new advice reflects the success of banning the use of certain industrial chemicals, combined with several decades of diligent efforts by governmental partners to clean up industrial contamination.

Managing excess nutrients

- U.S. agencies continue to manage excess nutrients and investigate the causes and impacts of algal blooms in the Great Lakes. Key lake-specific activities from 2020–2022 are described below. Other U.S. activities that reduce lake impacts from nutrients are found in the [Annex 4 \(Nutrients\)](#) section of this Progress Report of the Parties. Numerous other projects have been funded under the GLRI's [Focus Area 3: Nonpoint Source Pollution Impacts on Nearshore Health](#).



Algal bloom in Lake Superior. Credit: NPS

- **Lake Superior:** The NPS and USGS are installing low-cost toxin sampling equipment at selected U.S. national parks, including the Apostle Islands and Isle Royale. The equipment can detect up to 32 freshwater and 25 marine toxins. Sampling results will provide the data essential to establish management action thresholds for algal blooms. The project also involves engaging citizen science programs through the use of [BloomWatch](#), [CyanoScope](#), [CyanoMonitoring](#), and the [Phytoplankton Monitoring Network](#).
- **Lake Michigan:** Wisconsin's Kenosha County Division of Parks successfully completed two GLRI-funded projects that stabilized downcut and eroding portions of the Pike River streambank using native vegetation and other restoration techniques. This project is expected to prevent over 800,000 gallons of untreated stormwater and 360 pounds of phosphorus from entering Lake Michigan, and it will improve the water quality and ecological functioning of the Pike River and its riparian zone.

- **Lake Huron:** The Superior Watershed Partnership, supported by the U.S. Forest Service, acquired and will permanently protect, sustainably manage, and provide public access to a parcel of land in the St. Marys watershed that includes 17 acres (68,797 square meters) of coastal wetland and 1,700 feet (518 meters) of Lake Huron shoreline. The parcel includes forested, emergent, and rare fen coastal wetland types that help filter runoff to the lake.
- **Lake Erie:** The H2Ohio initiative implemented by the Ohio Department of Natural Resources (Ohio DNR), Ohio Environmental Protection Agency (Ohio EPA), Ohio Department of Agriculture, and Ohio Lake Erie Commission, provided \$89.6 million for 83 wetland restoration projects in 2020–2021 to create and restore 11,699 wetland acres across Ohio with a focus in the western basin of Lake Erie. These projects were selected to help filter nutrients from over 98,681 acres of land.
- **Lake Ontario:** With GLRI financial support, the American Farmland Trust (AFT) has furthered the goals of its [Genesee River Demonstration Farms](#)

[Network](#) by highlighting conservation systems that build soil health and benefit water quality. AFT has established collaborative agreements with five demonstration farms, worked with 10 farms to implement over 600 acres of cover crops, and put conservation practices on 769 acres of rented land.

Preventing and managing invasive species

- U.S. agencies continue to implement measures to prevent and manage the spread of invasive species populations in the Great Lakes. Key lake-specific activities in 2020–2022 are described below. Other U.S. activities that reduce, prevent, and manage invasive species are found in [Annex 6 \(Aquatic Invasive Species\)](#) section of this document and are supported by numerous other projects funded under the GLRI's [Focus Area 2: Invasive Species](#).
- **Lake Superior:** Minnesota Department of Natural Resources and the U.S. Forest Service are working together to minimize the impacts of the invasive rusty crayfish, which is destroying the spawning beds of native yellow perch in Pike Lake in the Superior National Forest. The partners have created



Aerial view of a 7-acre wetland restoration project in Crawford County, Ohio. The newly created wetland on a previously farmed agricultural field captures and filters agricultural runoff before it flows into the Sandusky River. Credit: Ohio Department of Natural Resources

large wooden structures along the shoreline that offer protected space for yellow perch to lay their eggs, and which also provide shade, resting cover, perches for birds and reptiles, and habitat for macroinvertebrate reproduction.

- **Lake Michigan:** West Michigan Conservation Network (formerly known as the West Michigan Cooperative Invasive Species Management Area), the Gun Lake Tribe, and EGLE partnered to control European frog-bit, a free-floating aquatic plant that can impede boat traffic and reduce oxygen and light in the water column. The invasive plant was first detected in the Lower Grand River and Pentwater Lake in 2019. In 2020, the partners treated infestations around heavily used boating access sites and protected culturally and ecologically significant wild rice beds in the Lower Grand River.
- **Lake Huron:** USFWS partnered with the Sault Ste. Marie Tribe of Chippewa Indians to conduct early detection monitoring aquatic invasive species at 12 locations from Saginaw Bay to the St. Marys River in 2020. Over 6,000 fish from 63 species were collected, but no novel invasive species were detected.
- **Lake Erie:** Efforts focused on implementing Ohio DNR's Lake Erie Grass Carp Response Strategy (2019–2023). Work included conducting targeted removal of grass carp in western Lake Erie, evaluating the feasibility of a seasonal barrier to disrupt the carp's spawning success in the Sandusky River, and researching to improve carp capture techniques.
- **Lake Ontario:** USFWS conducted early detection and monitoring of benthic invertebrate aquatic invasive species in summer 2020 and found no new invasive species. They surveyed 58 sites in the Lower Niagara River, Rochester, and Irondequoit Bay areas for amphipods, gastropods, and bivalves.

Restoring and protecting watershed health for healthy Great Lakes.

- U.S. agencies continue to implement efforts to restore and protect healthy watersheds in the Great Lakes. Key lake-specific activities in 2020–2022 are described below. Other U.S. activities that support a healthy watershed through habitat restoration are found in the [Annex 7 \(Habitat and Species\)](#) section

of this Progress Report of the Parties and are supported by numerous other projects funded under the GLRI's [Focus Area 4: Habitat and Species](#).

- **Lake Superior:** Using funding from the GLRI, the Town of Port Wing in close partnership with the Wisconsin Department of Natural Resources (WDNR), restored 10 acres (4 hectares) of wetlands from previously abandoned wastewater treatment ponds. The Flag River estuary, a high quality coastal wetland complex that includes the Port Wing Boreal Forest State Natural Area and Bibon Lake, is home to a wide variety of waterfowl, unique wetland habitats, and boreal forests that have been developed or lost to invasive species. The project restored hydrology, prevented additional invasive species and achieved high migratory bird use.
- **Lake Michigan:** The City of Niles, Michigan Department of Natural Resources, USFWS, the Southwest Michigan Planning Commission, and the Cass County Parks Department partnered to [finish removing the Pucker Street Dam](#) in 2021, which restored the Dowagiac River to a free-flowing condition and reopened passage to over 159 miles of critical mainstem and tributary cold-water habitats by steelhead, Chinook salmon, coho salmon, brown trout, white suckers, and walleye. Additional restoration efforts are now underway on the Dowagiac River, including a project by the Pokagon Band of Potawatomi Indians to re-establish the river's meanders.
- **Lake Huron:** The USGS, USFWS, Bay Mills Indian Community, and the Sault Ste. Marie Tribe of Chippewa Indians collaborated on a pilot project that used environmental DNA (eDNA) to evaluate tributary spawning by lake whitefish in Lake Superior, Lake Huron, and Lake Michigan. The pilot project showed that eDNA can detect these fish where conventional sampling methods cannot. In 2021–2022, the partners are trying to expand the use of this eDNA technique across the Great Lakes to assess lake whitefish populations and to set priorities for restoration and protection.
- **Lake Erie:** The Nature Conservancy (TNC) acquired 280 acres adjacent to Kitty Todd Nature Preserve as part of an ambitious overall effort to restore 23,000

acres of marginal agriculture land in northwest Ohio. With funding from Ohio EPA, TNC will restore hydrology—altered by tile drainage for decades—and small-scale surface features of this rare Oak Openings ecosystem. The project, called the Sandhill Crane Wetlands, will provide 900 acre-feet of additional stormwater storage capacity, enable groundwater recharge, and improve water quality in Lake Erie.

- **Lake Ontario:** NYSDEC, USFWS, and USGS reached a milestone following the collection of a spawning female lake sturgeon in the lower Genesee River for the first time in more than 50 years. A field crew from USGS was responsible for collecting the 61-inch, 70-pound female on the shores of the river in Monroe County, NY. NYSDEC began stocking lake sturgeon into the Lower Genesee River in 2003 as part of New York State's efforts to support the species' recovery as further outlined in the most recent NYSDEC's [Lake Sturgeon Recovery Plan](#); 2018-2024.



Lake sturgeon eggs. Credit: Marc Chalupnicki, USGS



Annex 3: Chemicals of Mutual Concern

Through domestic regulations and the implementation of binational strategies, significant progress has been made to reduce the release of chemicals of mutual concern into the Great Lakes over the past 3 years. The United States and Canada continue to take action on legacy contaminants, such as mercury and polychlorinated biphenyls (PCBs), and have stepped up efforts to address newer chemical threats such as per- and polyfluoroalkyl substances (PFAS). Strategic plans are now in place to reduce threats to the Great Lakes from each of the Chemicals of Mutual Concern. Additional chemicals are being evaluated using new screening criteria.

Key Achievements

- The governments of the United States and Canada continued to assess and manage the environmental and human health risks posed by chemicals, including CMCs, through national chemical management programs.
- Finalized and published strategies for CMCs:
 - Great Lakes Binational Strategy for Mercury Risk Management
 - Great Lakes Binational Strategy for Short-Chain Chlorinated Paraffins (SCCPs) Risk Management
 - Canada's Great Lakes Strategy for Perfluorooctane Sulfonate (PFOS), Perfluorooctanoic Acid (PFOA), and Long-Chain Perfluorinated Carboxylic Acids (LC-PFCAs) Risk Management and the U.S. Environmental Protection Agency's (USEPA's) PFAS Strategic Roadmap: [US]EPA's Commitments to Action 2021–2024

Purpose and Overview

The purpose of [Annex 3 \(CMCs\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by protecting human health and the environment through cooperative and coordinated measures to reduce the anthropogenic release of chemicals of mutual concern into the Waters of the Great Lakes.”

Annex 3 (CMCs) helps guide the protection of human health and the environment by reducing the release of specific chemicals. Chemicals management in the United States and Canada occurs primarily through national domestic programs and laws, such as the [U.S. Toxic Substances Control Act \(TSCA\)](#), the Canadian Environmental Protection Act (1999), and [Canada's Chemicals Management Plan \(CMP\)](#), as well as programs and restrictions at the provincial, state, tribal, and local levels. CMCs are human-made chemicals that are persistent and can bioaccumulate in the food web, exposing humans, wildlife, and the environment to potentially harmful chemicals through fish consumption as well as other routes of exposure. In designating substances as CMCs, the Parties have agreed that the chemical poses a threat to the Great Lakes and that further action is warranted. Annex 3 coordinates efforts to identify and reduce human-caused inputs of CMCs. Under the CMC Annex, the United States and Canada have committed to (1) identify CMCs and potential candidate CMCs on an ongoing basis; (2) act to prevent, control, and reduce CMCs; and (3) ensure that research, science, and monitoring programs are in place to guide management actions.

In 2016, the United States and Canada designated the following chemicals as CMCs under the GLWQA:

- [Hexabromocyclododecane \(HBCD\)](#)
- [PFOS, PFOA, and LC-PFCAs](#)
- [Mercury](#)
- [Polybrominated diphenyl ethers \(PBDEs\)](#)
- [PCBs](#)
- [SCCPs](#)

ANNEX IMPLEMENTATION

USEPA and Environment and Climate Change Canada (ECCC) led the implementation of the commitments within Annex 3 (CMCs) with support from an Annex 3 Subcommittee comprising members from provincial, state, and tribal governments; industry organizations; and nongovernmental organizations.

- Finalized and published the [Binational Screening Criteria for Nominated CMCs](#).
- Evaluated and finalized decisions on nominations for polycyclic aromatic hydrocarbons (PAHs) and sulphates as candidate CMCs (projected for completion by the end of 2022).

Binational Actions and Achievements

Priority for Action: Through existing programs, including the Toxic Substances Control Act (United States) and the Chemicals Management Plan (Canada), reduce Chemicals of Mutual Concern in the Great Lakes environment.

In the United States

- CMCs are regulated under a combination of federal, state, tribal, and local statutes and regulations, depending on the source, use, and release of the respective CMC. [TSCA](#) provides USEPA with authority to require reporting, record-keeping, and testing, and it outlines restrictions relating to chemical substances and/or mixtures. In addition, the [Toxics Release Inventory](#), [Safe Drinking Water Act](#) (SDWA), and [Clean Water Act](#) contribute to chemical management.
- To further enhance activities under TSCA, USEPA announced the [TSCA New Chemicals Collaborative Research Program](#). This program will be implemented in partnership with the USEPA Office of Research and Development and other federal entities to modernize the process and bring innovative science to the review of new chemicals before they can enter the marketplace. The results of the effort are expected to bring innovative science to new chemical reviews, modernize the approaches used, and increase the transparency of the human health and ecological risk assessment process.



Lake-side industrial facilities. Credit: Environment and Climate Change Canada

In Canada

- The Government of Canada continues to assess and manage the environmental and human health risks posed by chemicals, including CMCs, through its national [CMP](#). As of March 2021, over 3,900 substances on the Domestic Substances List have been assessed under the CMP, and over 330 of these substances have been found to be toxic to the environment and/or human health. A substance or group of substances found to be “toxic” under section 64 of the Canadian Environmental Protection Act, 1999, can be recommended for addition to the List of Toxic Substances (Schedule 1). For these substances, over 200 risk management actions have been implemented, and additional risk management measures are in development. All designated CMCs are listed as toxic substances in Canada. The manufacture, use, sale, and import of these substances, and products that contain them, are prohibited (with limited exemptions), which is helping to significantly reduce releases to the Great Lakes.
- As part of the CMP, the New Substances program ensures that new chemicals, polymers and living organisms undergo ecological and health assessments before they are introduced into the Canadian marketplace, and that appropriate control measures are taken, when required. The New Substances

program assesses approximately 400 new substances annually.

- Further action to reduce CMCs occurs through Canada’s [Great Lakes Protection Initiative](#) (GLPI). In 2020, GLPI supported three new partner-led projects. These projects will increase participation in the application of “beyond compliance” measures to reduce releases of CMCs to the Great Lakes from Canadian sources by developing, implementing, assessing, and promoting the use of innovative approaches (described in the [Domestic Actions and Achievements](#) section).

Priority for Action: Implement the management actions identified in the existing Great Lakes Binational Strategies for CMCs and track implementation through the 2022 Progress Report of the Parties.

- As of 2022, all eight designated CMCs have strategies in place. Binational strategies for mercury and SCCPs as well as the Canadian Strategy for PFOS, PFOA, and LC-PFCAs Risk Management were finalized during 2020–2022. The United States will continue to take action on PFAS, including advancing objectives in the Great Lakes region, as outlined in the PFAS Strategic Roadmap: [US]EPA’s Commitment to Action, 2021–2024.
- Implementing the actions identified in the strategies by the Parties, the many partners, and stakeholders continues; examples of these actions are reported in the Domestic Actions and Achievements section below.

Priority for Action: Recognizing that fish consumption is the major Great Lakes route of exposure for bio-accumulative CMCs, U.S. and Canadian jurisdictions will provide fish consumption advisories to minimize potential impacts to human health from these chemicals.

- Many CMCs are monitored by the states and Ontario to support fish consumption advice and minimize the potential risk to human health, as shown in Table 3. All eight U.S. states bordering the Great Lakes and Ontario conduct public outreach on fish consumption advice for the Great Lakes.
- The [Great Lakes Consortium for Fish Consumption Advisories](#) (Consortium) is a collaboration of fish advisory program managers from government health, water quality, and fisheries agencies in the eight states and Ontario. The purpose of the Consortium is to share information about contaminants found in fish of the Great Lakes region, evaluate human health effects of those contaminants, and develop protocols and methods for determining fish consumption advice and communications. Information on the Consortium is available online for [Great Lakes states](#) and [Ontario](#). Members of the Consortium also provide contaminant concentration data for the fish consumption indicator, reported via [State of the Great Lakes reports](#).
- In recognition of the importance of fish to traditional diets, the 2021 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem

Table 3. CMCs Monitored by States and Ontario.

	IL	IN	MI	MN	NY	OH	PA	WI	ON
Hexabromocyclododecane (HBCD)					✓				
Long-chain perfluorinated carboxylic acids (LC-PFCAs)		✓	✓	✓	✓		✓	✓	✓✓
Mercury	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Perfluorooctanoic acid (PFOA)		✓	✓	✓	✓		✓	✓	✓✓
Perfluorooctane sulfonate (PFOS)		✓✓	✓✓	✓✓	✓✓		✓✓	✓✓	✓✓
Polybrominated diphenyl ethers (PBDEs)		✓			✓				✓✓
Polychlorinated biphenyls (PCBs)	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Short-chain chlorinated paraffins (SCCPs)				✓	✓				

Notes: CMCs are monitored by Ontario and the eight Great Lakes states.
 ✓ = Monitors; ✓✓ = Monitors and issues fish consumption advice.

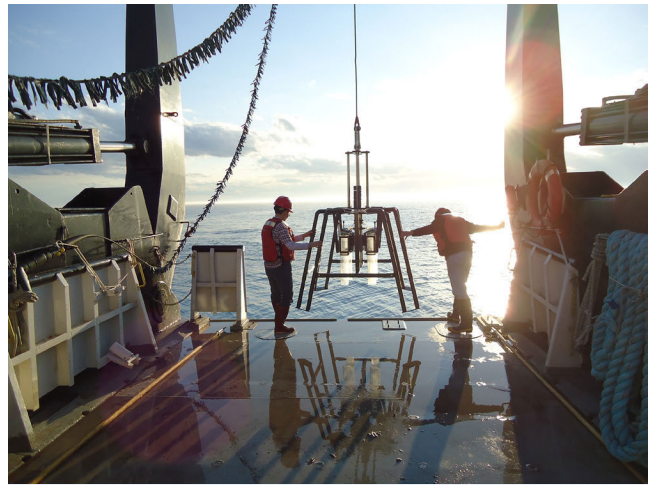


Processing Lake Superior lake trout for laboratory analysis. Credit: Jessica Deere, University of Minnesota

Health includes new commitments to engage with interested First Nations and Métis to ensure Great Lakes fish consumption advisories are appropriate for the protection of their communities.

Priority for Science: Conduct monitoring and surveillance in Great Lakes environmental media to track trends of CMCs and other priority chemicals.

- The United States and Canada are collaboratively monitoring CMCs and other chemicals in relevant environmental media. These monitoring and surveillance activities help track the effectiveness of national and binational pollution prevention and control measures, support the commitments of Annex 3, and assess progress made to address CMC levels in the Great Lakes. This information is critical for assessing trends and determining whether control measures are effectively reducing CMC concentrations in the Great Lakes.
- USEPA's contaminant monitoring and surveillance activities in the Great Lakes watershed include the Great Lakes Fish Monitoring and Surveillance Program, the International Atmospheric Deposition Network (IADN), the Great Lakes Sediment Surveillance Program, and the Toxics Release Inventory. Long-term monitoring and surveillance



Scientists aboard the USEPA Research Vessel Lake Guardian deploy the sediment multi-corer on a Great Lakes Sediment Surveillance Program survey in Lake Superior. Credit: Margaret Corcoran



Chinamekos (Lake Trout) captured at Buffalo Reef - Grand Traverse Bay during fall spawning surveys in Gitchigami (Lake Superior). Credit: Christopher Dean

programs develop their core analyte monitoring lists for chemicals that are routinely detected in Great Lakes media. Program results are available from agency websites, peer-reviewed journal articles, the [USEPA Central Data Exchange Great Lakes Environmental Database](#), and [IADN Data Viz](#).

- ECCC delivers ecosystem monitoring and surveillance programs in the Great Lakes watershed (such as the Freshwater Quality Monitoring Program and the Great Lakes Basin Monitoring and Surveillance Network), which include contaminant monitoring

in many media. Data are available through the [Government of Canada Open Data portal](#). These coordinated monitoring and surveillance activities provide information on the status and trends of CMCs as well as priority chemicals identified through [Canada's CMP](#).

- USEPA and ECCC hosted six webinars to share information on monitoring, surveillance, and research for CMCs and chemicals of emerging concern (CECs) in the Great Lakes, including:
 - Sources and Cycling of Mercury within the Great Lakes and Areas of Concern (2020)
 - Prioritizing Chemicals and Chemical Mixtures of Ecological Concern in Great Lakes Tributaries (2020)
 - Monitoring and Surveillance of PFAS in the Great Lakes (2020)
 - Spatial and Temporal Variability of PFAS in the Great Lakes (2020)
 - Overview of PFAS monitoring with a Focus on the Great Lakes (2021)
 - PFAS in the Great Lakes: Highlights of PFAS Efforts and Initiatives (2022)

Priority for Science: Coordinate research, monitoring, and surveillance activities to identify potential Chemicals of Emerging Concern.

- Results from research and monitoring completed or supported by ECCC were published for various CECs such as [PAHs](#), [plastics](#), and [siloxanes](#) in 2020–2022. These studies can highlight improvements in the ecosystem, support early warnings for chemicals that could become CMCs, and identify the need for further investigation and action in the Great Lakes.
- In 2021, ECCC scientists published [Bisphenol A \(BPA\) in the Canadian Environment: A multimedia analysis](#), which evaluated trends and inferred the mechanisms and media that influence the patterns of BPA in the environment. Overall, the study provided evidence that the Government of Canada's actions have been generally successful in reducing BPA concentrations in the Canadian environment.

- Through Great Lakes Restoration Initiative (GLRI) funding, the U.S. Geological Survey (USGS), USEPA, U.S. National Oceanic and Atmospheric Administration; U.S. Army Corps of Engineers; and U.S. Fish and Wildlife Service (USFWS) conducted a CEC Surveillance and Assessment Program, which monitored CECs in Great Lakes tributaries and assessed biological effects of monitored chemicals. A high-level summary report and journal publications on the results of the program will be available in late 2022.
- In 2022, USGS will characterize the prevalence and potential biological effects of several contaminants of interest in Lake Superior tributaries, as identified through the Lake Superior Lakewide Action and Management Plan and by stakeholders. Contaminants of interest include PFAS, BPA, nonylphenols, neonicotinoids, and PAHs.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, the United States and Canada pursued a variety of domestic projects that also support Annex 3 (CMCs).

United States

HBCD

- **HBCD risk evaluation.** In September 2020, USEPA released [the final Risk Evaluation for HBCD](#) under the amended TSCA regulation. USEPA found that the import, processing, recycling, commercial use, and disposal of HBCD present unreasonable risk to the environment. USEPA's next step is to establish risk management regulations.

PFOS, PFOA, and LC-PFCAs

- **New [US]EPA Council on PFAS (ECP) created.** Charged with building on the agency's ongoing work to better understand and ultimately reduce the potential risks caused by PFAS, USEPA established the ECP, which has:
 - Issued PFAS Strategic Roadmap: [US]EPA's Commitments to Action 2021–2024, a multiyear strategy to deliver critical public health protections to the American public.



PFAS foam on Sarkweather Creek, Wisconsin. Credit: Wisconsin Department of Natural Resources

- Continued close interagency coordination on region-specific and cross-media issues to assist states, tribes, and local communities faced with significant and complex PFAS challenges.
- Worked with national program offices and regions to maximize the impact of USEPA's funding and financing programs to support cleanup of PFAS pollution, particularly in underserved communities.
- Expanded engagement opportunities with federal, state, and tribal partners to ensure consistent communications, exchange information, and identify collaborative solutions.
- **Research on PFAS and mercury effects on mussels.** Under GLRI, USFWS is undertaking a study designed to assess the impacts that PFAS and mercury may have on endangered native freshwater mussel recovery efforts.
- **Michigan PFAS Action Response Team (MPART) efforts.** MPART has updated its groundwater cleanup criteria for PFOS and PFOA and developed groundwater cleanup criteria for five additional PFAS. MPART also created a Citizen Advisory Workgroup of community members who are impacted by PFAS.
- **Michigan standards for PFAS in drinking water.** Michigan sampled public water supplies throughout the state and developed drinking water standards for seven PFAS that apply to public water supplies.
- **Michigan groundwater sampling.** Sampling has occurred at hundreds of sites and information about each new site is shared with local officials before it is added to what has evolved into a very robust dataset. (More information is available at: <http://www.michigan.gov/pfasresponse>.)
- **Michigan Great Lakes PFAS Summit.** Michigan hosted the first-ever Great Lakes PFAS Summit in 2020 and a second summit in December 2021. These summits provided the most current and reliable PFAS-related science and policy, facilitated information sharing, and explored current and future research topics related to PFAS.
- **Minnesota PFAS Blueprint.** Minnesota announced in February 2021 the development of a new [PFAS Blueprint](#) calling for increased regulation of PFAS through a combination of legislation and agency rulemaking. The blueprint identifies 10 regulatory priorities, including understanding risks from PFAS air emissions, preventing PFAS pollution, remediating contaminated sites, and managing PFAS in waste.
- **Wisconsin PFAS Action Council.** In August 2019, Wisconsin created the Wisconsin PFAS Action Council, which is charged with developing statewide initiatives to address public health and environmental concerns regarding PFAS. These initiatives are outlined in the state's PFAS Action Plan released in December 2020.
- **New York food packaging PFAS ban.** In December 2020, New York became the third state to ban PFAS in food packaging. The law, which goes into effect in 2023, broadly bans the use of all PFAS, and prohibits anyone from "distributing, selling, or offering for sale" any food in packaging containing PFAS.
- **The Little Traverse Bay Bands of Odawa Indians (LTBB) monitoring for PFAS in surface waters.** LTBB will evaluate PFAS concentrations in: (1) surface waters currently monitored by LTBB for water quality; (2) surface waters at *manoomin* (wild rice) restoration sites; and (3) other 1836 Ceded Territory surface waters near potential contamination sources.

Mercury

- **First triennial report on mercury.** USEPA published an inventory report on the supply, use, and trade of mercury in the United States, as required by the TSCA. The March 2020 report is the first in a series of triennial reports supported by USEPA's [mercury inventory reporting rule](#). USEPA will identify any manufacturing processes or products that intentionally add mercury and will recommend actions to achieve further reductions in mercury use.
- **National mercury emission reported electronically.** In July 2020, USEPA [finalized revisions to the 2012 Coal- and Oil-Fired Electric Utility Steam Generating Units National Emission Standards for Hazardous Air Pollutants](#), known as the Mercury Air Toxics Standards. This final action identifies data elements to be reported electronically by power plants using the Emissions Compliance and Monitoring Plan System Client Tool. More information is available on USEPA's [mercury](#) webpage.
- **Methylmercury bioaccumulation research.** USGS' and USEPA's research project shows high susceptibility for methylmercury to enter the Great Lakes food web. Research from this study, [Enhanced Susceptibility of Methylmercury Bioaccumulation into Seston of the Laurentian Great Lakes](#), published in August 2021 in *Environ. Sci. Technol.* (55[18]:12714–12723), shows that despite low methylmercury concentrations, the susceptibility for methylmercury to enter the Great Lakes food web via phytoplankton is among the highest reported rate on record, indicating that the Great Lakes are excellent sentinels to trace the success of efforts to decrease global mercury emissions.
- **Research on estuarine methylmercury sources.** A USGS/USEPA St. Louis River Area of Concern (AOC) assessment indicated that mercury concentrations in the estuary are higher than surrounding areas, which prompted a food chain study using mercury isotopes to identify the contributing sources. The [USGS study](#) results, published in March 2021 in *Sci. Total Environ* (779 [2021]:14628), show significant watershed and industrial sources of mercury in the estuary. This information better informs restoration strategies for other impaired Great Lakes coastal zones.
- **Wisconsin mercury webpage update.** Wisconsin Department of Natural Resources' (WDNR's) web pages devoted to mercury were updated to include additional information on the mercury product ban, associated exemptions, and the mercury ban in K–12 schools. Guidance clarifying the mercury product ban and exemption criteria is expected to be released in 2022. Additional mercury updates are provided on the WDNR Mercury website.
- **Keweenaw Bay methylmercury research.** The Keweenaw Bay Indian Community is conducting methylmercury sampling, results analysis, and mercury bioaccumulation modeling to evaluate whether measured concentrations in Torch Lake are adequate to explain mercury concentrations in fish. This will also help to identify priority sources and highlight areas in the Torch Lake watershed that can be used to inform remediation efforts and fish consumption decisions.
- **Ojibwe tribes' mercury research.** The Ojibwe tribes' Great Lakes Indian Fish and Wildlife Commission's (GLIFWC's) Mercury Program helps reduce the health disparities caused by mercury in fish within the Ojibwe tribes, which consume fish at higher rates than the general population. Each year, GLIFWC collects relevant fish species from the Lake Superior basin and tests for mercury levels. The information is used to develop culturally appropriate fish consumption advisories for GLIFWC's member tribes. The advisories are communicated via color-coded, site-specific mercury maps that facilitate continued fish harvest and consumption by tribal members while also providing information to reduce their mercury exposure.

PBDEs

- **New PBDE rule.** In February 2021, USEPA issued a final rule that prohibits all manufacture (including import), processing, and distribution in commerce of Decabromodiphenyl ether (decaBDE) or decaBDE-containing products or articles, with some exclusions. These requirements will result in lower amounts of decaBDE being manufactured, processed, distributed in commerce, used, and disposed, thus reducing the exposures to humans and the environment. More information is available on USEPA's [PBDEs](#) website.



Fishing in the Great Lakes. Credit: Nancy Stadler-Salt

PCBs

- **PCB fluorescent light ballasts fact sheet released.** In July 2020, USEPA released a [fact sheet](#) for PCBs in fluorescent light ballasts to provide information on how to investigate for, remove, store, or dispose of the light ballasts. More information is available on USEPA's [PCBs](#) website.
- **Wisconsin PCB project.** The Fox River PCB clean-up project, one of the largest of its kind worldwide, started in 2004 and was completed in 2020. Thirty-nine miles (~63 kilometers) of river plus lower Green Bay were remediated. In four assessment areas that are at least 5 years post-remediation, PCB concentrations in carp, a bottom feeder, show average concentration reductions of between 47% and 80%. One natural recovery area showed a 28% concentration reduction.
- **Great Lakes states PCB- and mercury-related total maximum daily loads (TMDLs).** Some Great Lakes states, such as Michigan (which has a statewide TMDL for mercury and PCBs) and Minnesota (which has a statewide TMDL for mercury), developed several large-scale TMDL projects that establish

loading targets that must be met to address PCB and mercury impairments. In general, these TMDLs establish the reductions needed in airborne loadings of mercury or PCBs to bring levels in fish to acceptable levels for consumption by people and wildlife. The TMDLs describe the relative sources and loadings of the pollutants as well as the federal, state, and other efforts to reduce the loadings. While the Michigan and Minnesota efforts focus on inland waters, addressing the sources contributing to inland water impairments would be expected to also reduce loadings both directly and indirectly to the Great Lakes.

- **Pokagon Band of Potawatomi Indians mercury and PCB sampling.** The Pokagon Band of Potawatomi Indians is capturing three fish species at seven tribal waterbodies. At each waterbody, six fish of each species (two in each of three size classes) for a total of 18 fish per waterbody are being collected. An outside lab is analyzing 126 whole fish for mercury and PCB levels.

Multiple Chemicals

- **Contaminants put forth for regulatory consideration under the SDWA.** In July 2021, USEPA published a [draft list](#) of contaminants that are currently not subject to any proposed or promulgated national primary drinking water regulations for public review and comment ([86 Federal Register 37948](#), March 11, 2021). These contaminants are known or anticipated to occur in public water systems and may require regulation under SDWA. This draft list includes 66 chemicals, three chemical groups (PFAS, cyanotoxins, and disinfection by-products), and 12 microbial contaminants. Among these contaminants under consideration is the PFAS chemical group and methylmercury.
- **Grand Portage Band of Lake Superior Chippewa priority chemicals research.** The Grand Portage Band of Lake Superior Chippewa is evaluating the presence of priority chemicals in fish and wildlife species that are regularly consumed by Grand Portage Band and community members.
- **Grand Portage Band of Lake Superior Chippewa researching presence of a tire-derived chemical.** The Grand Portage Band of Lake Superior Chippewa is evaluating the presence of the tire-derived chemical commonly known as 6PPDq (N-[1,3-dimethylbutyl]-N'-phenyl-p-phenylenediamine quinone) in the fish and wildlife species that are regularly consumed by Grand Portage Band and community members.
- **Saginaw Chippewa Indian Tribe education.** The Saginaw Chippewa Indian Tribe is developing easy-to-use information that accounts for tribal-specific concerns to educate the tribal community on how to safely consume fish and aquatic wildlife.
- **Keweenaw Bay Indian Community evaluation of the spatial distribution of contaminants.** The Keweenaw Bay Indian Community will evaluate the spatial distribution of contaminants in Lake Superior, Torch Lake, and Portage Lake fish and assess causes for this distribution. These results will guide an update to the fish consumption advisories for the Keweenaw Bay Indian Community.
- **Red Cliff Band of Lake Superior Chippewa monitoring for chemicals and nutrients.** The Red Cliff Band of Lake Superior Chippewa will test water,

fish, and compost derived from fish carcasses for various CMCs to assess the levels remaining in the compost. The tribe will also test nearby waters to monitor for potential nutrient loading from an existing fish composting project.

- **Saginaw Chippewa Indian Tribe of Michigan evaluating effects of contaminants on a local river.** The Saginaw Chippewa Indian Tribe of Michigan, in partnership with Central Michigan University, is evaluating the influence of contaminants from current and historical land use on the ecology of the Chippewa River, which runs through the Isabella Reservation and is a tributary to the Saginaw River and Saginaw Bay, a Great Lakes AOC.

Canada

The Government of Canada, through programs such as CMP and GLPI, is taking risk mitigation and management actions to address and reduce releases of all eight CMCs. Selected projects and actions are highlighted below.

HBBCD and other CMCs

- **Proposed tightened restrictions for multiple CMCs.** HBBCD; PBDEs; and PFOS, PFOA, LC-PFCAs, and their salts and precursors have been found to be toxic to the environment and are currently prohibited under Canada's Prohibition of Certain Toxic Substances Regulations, 2012. Work is underway to further restrict the limited number of uses that are currently allowed, and the proposed [Prohibition of Certain Toxic Substances Regulations, 2022](#) were published in the *Canada Gazette, Part I*, on May 14, 2022. Comments and information received during the 75-day public comment period will be considered during the development of the final regulations.

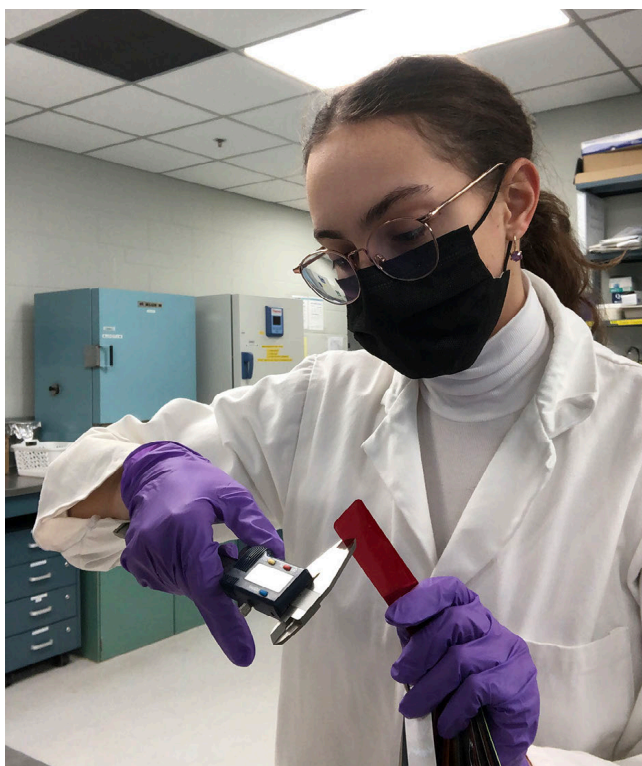
PFOS, PFOA, and LC-PFCAs

- ECCC released [Canada's Great Lakes Strategy for PFOS, PFOA, and LC-PFCAs Risk Management](#) in March 2022. The strategy is comprised of 16 management actions to address threats to the Great Lakes by reducing the release of PFOS, PFOA, and LC-PFCAs to the Great Lakes basin.



Leachate collection to study microbes that can degrade selected LC-PFCAs. Credit: Rama Pulicharla, York University

- The Government of Canada funded three new projects in 2020–2022 through the GLPI that focus on PFAS:
 1. **Microbes research.** York University assessed microbes that can degrade selected LC-PFCAs; this research supports efforts to reduce the release of LC-PFCAs in landfill leachate.
 2. **Activated carbon effectiveness.** The University of Toronto assessed the use of activated carbon in municipal wastewater treatment plants to prevent PFOS and PFOA from entering the Great Lakes. This project explored the efficacy of removal of perfluorinated compounds and the cost-effectiveness of this technology for municipalities in the basin.
 3. **Consumer products research.** The University of Toronto identified consumer products containing PFOS, PFOA, and LC-PFCAs, including PFAS chemicals in cosmetics. In addition to the direct exposure routes, PFAS can enter drinking water, air, and food (via wastewater biosolids applications to land) during the manufacturing process and after it is washed down the drain.
- **Addressing PFAS as a class of chemicals.** The Government of Canada announced, in April 2021, its intent to move toward addressing PFAS as a class. Evidence to date indicates that the PFAS used to replace regulated PFOS, PFOA, and LC-PFCAs may also be associated with environmental and/or human health effects. A class-based approach will address situations where exposure occurs to multiple PFAS at the same time; it will also consider cumulative effects and prevent regrettable substitutions. Canada will continue to invest in PFAS research and monitoring, and it will publish a state-of-PFAS report in 2023 to summarize relevant information on the class of PFAS chemicals.
- **Nominated LC-PFCAs as a persistent organic pollutant (POP).** The Government of Canada nominated LC-PFCAs for consideration under the Stockholm Convention on POPs in August 2021. The Government of Canada published a [health science summary](#) that examined the science as



Testing for PFAS in metals. Credit: Anna Shalin, University of Toronto

it relates to human health for LC-PFCAs. The Stockholm Convention is a multilateral treaty aimed at eliminating or restricting the global production and use of POPs to better protect human health and the environment.

- **PFOS guidelines published.** The Canadian Council of Ministers of the Environment published [The Canadian Soil and Groundwater Quality Guidelines for the Protection of Environmental and Human Health: Perfluorooctane Sulfonate \(PFOS\)](#) in September 2021. These guidelines specify levels of toxic substances or other parameters in soil that are recommended to maintain, improve, or protect environmental quality or human health.
- **Declines of PFOS and PFOA water concentrations.** [Results](#) published in 2020 of water samples at Great Lakes Nearshore Monitoring and Assessment Program sites on Lake Ontario in 2018 showed that concentrations of PFOS and PFOA have declined since previous measurements in 2006, demonstrating that measures to reduce PFOS and PFOA have been successful.

- **Monitoring landfills and landfill leachate for PFAS.** In 2020, the Ontario Ministry of the Environment, Conservation and Parks initiated a project that will monitor certain landfills and landfill leachate for the presence of select PFAS and the potential to impact groundwater systems and drinking water wells.
- In addition, Ontario has funded two research projects to help better understand the prevalence of PFAS in the environment:
 - From 2017 to 2021, a project evaluating groundwater transport of leachate from old, closed landfills in Ontario as a potential source of harmful pollutants, including PFAS.
 - From 2017 to 2021, a project estimating the number of sites potentially contaminated with PFAS across Ontario through a risk-based assessment of land uses (e.g., industrial sectors, waste, etc.).

Mercury

- **Mercury-containing lamp disposal guidance.** In 2019, ECCC published the collaborative [National Strategy for Lamps Containing Mercury](#). Reporting on the strategy's implementation and actions will occur in 2024 and every 5 years thereafter.
- **Mercury Risk Management Report.** The Government of Canada published the report [Evaluation of the Effectiveness of Risk Management Measures for Mercury](#) in 2020. The report concluded that continued sustained risk management actions on mercury are needed to protect the health of Canadians and their environment from mercury, and it committed Canada to continue its efforts to (1) monitor, (2) manage risks associated with mercury, (3) communicate with the public, and (4) engage internationally.
- **Passive mercury air sampler.** The Government of Canada developed a passive air sampler for gaseous mercury monitoring in ambient air. Canada is implementing this sampler in various geographic locations, including a one-year study site in the Great Lakes basin, to test how it compares to traditional air monitors.
- **Mercury regulation amendments.** ECCC focused on developing proposed amendments to the *Products*

Containing Mercury Regulations (target publication date is fall 2022).

PBDEs

- **PBDE Risk Management Report.** The Government of Canada published the 2020 report [Evaluation of the Effectiveness of Risk Management for PBDEs](#), which assessed whether the risk management actions taken for PBDEs were effective in meeting the objective outlined in the Risk Management Strategy. The performance measurement evaluation found that domestic actions have minimized releases and are making steady progress towards preventing the manufacture, import, and use of PBDEs in Canada. The performance measurement evaluation recommends that ECCC continue focused efforts to address PBDEs through: (1) environmental monitoring of PBDEs, (2) managing risks associated with PBDEs, (3) communicating with the public, and (4) engaging nationally and internationally.

PCBs

- **PCB inventory update.** A publication focusing on the successes and challenges of managing PCBs is anticipated in spring 2022. This publication includes results from a project supported by ECCC that sought to update the inventory of Aroclor PCBs “in-use” and “in-storage” in the Great Lakes. Using Toronto as a case study, the updated inventory revealed that the mass of pure PCBs, in-use and in-storage, decreased from 424 tonnes to 0.8 tonnes over a 10-year period (2006–2016). This demonstrates effective progress on regulatory compliance and effective action.

SCCPs

- **Study identifying indoor and outdoor sources of SCCPs.** A GLPI-funded project (2018–2020) developed a novel methodology for detecting and analyzing SCCPs, and initial results show that indoor emission via laundry wastewater may be the primary pathway for SCCPs and other chlorinated paraffins to enter sewage treatment plants.

- **SCCP monitoring in Herring Gull and European Starling eggs.** In 2022, as part of CMP, ECCC analyzed chlorinated paraffins in eggs of herring gulls and European starlings at sites across Canada, including the Great Lakes. SCCPs were not detected in gull or starling eggs collected in years ranging from 2009 to 2019. When detected, medium-chain chlorinated paraffin concentrations varied widely in eggs among collection sites in 2019 and also within colonies/sites.



Herring Gull eggs. Credit: Shane DeSolla, Environment and Climate Change Canada

Multiple Chemicals

- **Washing machine CMCs and microplastics study.** A publication highlighting the results of a study funded by GLPI is anticipated in summer 2022. A University of Toronto (2018–2020) project examined the feasibility and effectiveness of adding mechanical filters on washing machines and dryers to collect and divert lint that contains CMCs, including PCBs, PBDEs, mercury, and SCCPs, that are present in household textiles and released during laundering processes. While diversions of CMCs were minimal, related project results also helped inform proposed Ontario legislation in 2021 that would require new washing machines to be equipped with a filter for removing microplastics.



Annex 4: Nutrients

Reducing excess nutrient (phosphorus) inputs to Lake Erie remains the highest priority for action. Implementation of on-the-ground actions identified in the Domestic Action Plans are slowing phosphorus inputs that cause toxic and nuisance algae blooms in Lake Erie. The United States reduced agricultural and municipal sources of phosphorus to the watershed by over 3 million pounds (1,361 tonnes) between 2015 and 2020. In Canada, a 20-tonne reduction in phosphorus has been achieved. These reductions indicate that current actions are on the right track, but significant additional work is needed to meet targets.

Key Achievements

- Implemented new and enhanced programs to substantially reduce phosphorus loads to Lake Erie through the Domestic Action Plans.
- Re-evaluating the viability of setting targets to address *Cladophora* growth in the eastern basin of Lake Erie.
- Initiated review of Lake Ontario nutrient targets to meet nutrient Lake Ecosystem Objectives.
- Released new progress indicators on the redesigned Blue Accounting [ErieStat](#) website in 2022.

Binational Actions and Achievements

Priority for Action: Take action to reduce phosphorus through implementation of the binational phosphorus reduction strategy and domestic action plans for Lake Erie.

Purpose and Overview

The purpose of [Annex 4 \(Nutrients\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by coordinating binational actions to manage phosphorus concentrations and loadings, and other nutrients if warranted, in the Waters of the Great Lakes.”

Harmful and nuisance algal blooms continue to be of concern in the Great Lakes, with Lake Erie experiencing the most significant impacts. In warm, nutrient-rich water, cyanobacteria (also known as blue-green algae), can multiply quickly and create blooms that form at or just below the water’s surface. These algal blooms can use up the oxygen and nutrients in the water that other organisms need to live. Some algae create toxins, called cyanotoxins, that can poison people, pets, and wildlife.

The Nutrients Annex guides Canadian and U.S. efforts to meet objectives related to algae development in each of the Great Lakes, which includes: (1) keeping levels of blue-green algae low enough to prevent formation of harmful toxins, (2) reducing areas of low dissolved oxygen water, and (3) ensuring that algae species in nearshore waters are consistent with those found in healthy aquatic ecosystems. To meet these objectives, Canada and the United States have established binational phosphorus concentrations and loading targets for each lake, while also continuing to assess and implement programs and measures designed to reduce phosphorus loadings from point and nonpoint sources.

ANNEX IMPLEMENTATION

Implementation of Annex 4 (Nutrients) was supported by the Nutrients Annex Subcommittee, which was co-led by Environment and Climate Change Canada (ECCC) and the U.S. Environmental Protection Agency (USEPA). Other subcommittee members include Agriculture and Agri-Food Canada; Chiefs of Ontario; Conservation Ontario; Ontario Ministry of Agriculture, Food and Rural Affairs; Ontario Ministry of the Environment, Conservation and Parks (MECP); the Ontario Ministry of Northern Development, Mines, Natural Resources, and Forestry; the Great Lakes and St. Lawrence Cities Initiative; Indiana Department of Environmental Management; Indiana State Department of Agriculture; Michigan Department of Agriculture and Rural Development (MDARD); Michigan Environment, Great Lakes, and Energy (EGLE); New York State Department of Environmental Conservation (NYSDEC); Ohio Department of Agriculture; Ohio Environmental Protection Agency (Ohio EPA); Pennsylvania Department of Environmental Protection (PADEP); Wisconsin Department of Natural Resources (WDNR); U.S. Army Corps of Engineers (USACE); U.S. Department of Agriculture (USDA); U.S. Geological Survey (USGS); and U.S. National Oceanic and Atmospheric Administration (NOAA).

- Actions to reduce phosphorus loads are underway in all Lake Erie jurisdictions. Specific actions and progress are described in the [Domestic Actions and Achievements](#) section of this report.
- Overall, Canadian edge-of-field studies are showing that management actions successfully result in a 20-tonne reduction in phosphorus runoff. The United States reduced agricultural and municipal sources of phosphorus to the watershed by over 3 million pounds between 2015 and 2020.

Priority for Action: Monitor Lake Erie phosphorus concentrations and report on progress towards achieving the binational phosphorus reduction targets through annual newsletters and webinars, and the triennial Progress Report of the Parties.

- ECCC and USEPA continue their long-term monitoring of the Great Lakes, which includes annual spring and summer surveys of Lake Erie's water quality. However, due to field constraints during the pandemic, USEPA's and ECCC's 2020 spring and summer water quality surveys did not occur, and ECCC conducted only three Lake Erie water quality cruises (in 2019 and 2021). In 2019, the ECCC cruises focused on contaminants including trace metals and mercury, legacy organic pollutants, and chemicals of mutual concern (spring cruise); nutrients (all cruises); and harmful algal blooms (HABs) (summer cruises). In 2021, ECCC collaborated with Fisheries and Oceans Canada and USEPA to address multiple mutual priorities including water quality, lower food web, and benthos. USEPA expects to release a technical report



Scientists aboard a small aircraft obtaining hyperspectral imagery of a Lake Erie algal bloom. Credit: NOAA

- in 2022 that presents the results of long-term trend analyses of chemistry and nutrient data for each of the Great Lakes from 1983 through 2018.
- During 2019–2022, NOAA continued their weekly water quality sampling in Lake Erie, coupled with airborne hyperspectral overflights and real-time buoys. These [data](#) provide decision-support tools for western Lake Erie researchers and drinking water managers, including the HABs [Tracker](#), seasonal HABs [forecasts](#), and biweekly HABs Bulletins. In 2021, NOAA added a series of transects across the interface with the Detroit River plume to examine the gradient of nutrient conditions.
- USGS researchers, in collaboration with academic and other agency teams, continued to explore

Measuring Progress Towards Phosphorus Load Reduction Targets in Lake Erie

Since the mid-1990s, Lake Erie has experienced a resurgence in harmful and nuisance algal blooms and expanding zones of low oxygen (hypoxia) resulting from excess nutrients, specifically phosphorus, which is the primary nutrient limiting algal growth in the lake.

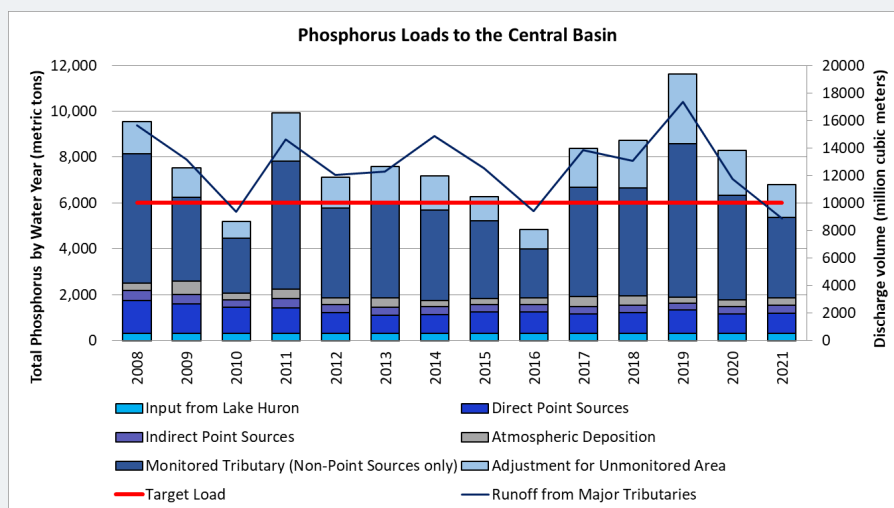
To reduce algal blooms and minimize hypoxia, in 2016 Canada and the U.S. established an annual load target of 6,000 tonnes of total phosphorus (TP) to the western and central basins of Lake Erie. This represents a binational effort to achieve a 40% reduction in phosphorus loads (from 2008 levels) by Canada and the U.S. To accomplish this, each country was allocated a load reduction based on its 2008 contribution. For Canada, this means an annual load reduction to Lake Erie of 212 tonnes from 2008 levels; for the U.S., the annual load reduction to Lake Erie is 3,316 tonnes. Furthermore, seasonal (March–July) targets of 860 tonnes of total phosphorus and 186 tonnes of dissolved reactive phosphorus were established for the Maumee River in the U.S., as it is a major driver of the algae bloom in the western basin of Lake Erie.

Since 2018, Canada and the U.S., along with their partners, have enhanced their support for on-the-ground actions to reduce sources of phosphorus to Lake Erie as identified in their respective Domestic Action Plans. These actions are slowing phosphorus inputs that cause algae blooms in the lake. Since 2015, the U.S. has reduced phosphorus loading from agricultural and municipal sources to the watershed by over 3 million pounds (1,361 tonnes) per year. In Canada, edge-of-field studies indicate a 20-tonne annual reduction in phosphorus loads since 2020. These reductions are early indications that actions being taken by the U.S. and Canada are on the right track, but the Parties are still a long way from meeting the 40% reduction target.

Modeling suggests that at least 50% of the agricultural landscape in Canada and the U.S. will need to have conservation practices implemented to achieve the targets and reduce harmful algal blooms and hypoxia in Lake Erie. To date, there is no evidence of a declining trend in phosphorus loads, as shown in the figure below. Across the basin, progress has been highly variable with some tributaries showing improvement and yet others remain stable or are degrading. For example, long term data in the Maumee River indicate that total phosphorus concentrations are stable while dissolved reactive phosphorus may be declining.

Many factors contribute to the difficulty in meeting the 40% reduction target. For example, increasing temperatures in recent years are creating longer growing seasons for algae, and more frequent high-intensity precipitation

events during the spring are delivering phosphorus to the lake during a time of year that promotes the intensity and duration of summer algal blooms. These factors combined with the intensification of land use and changes in land management, such as increases in fall application of fertilizers and increases in urban runoff due to expanding areas of impermeable surfaces, can serve to offset the overall impact of phosphorus load reduction actions being implemented.



Total Phosphorus loading to the Central Basin of Lake Erie (which includes loads to the Western Basin), 2008–2021. NPS = Non-Point Sources.

Source: USEPA and ECCC.

the spatial and temporal distribution of western Lake Erie HABs; they use multiple data sources to improve estimates of [areal extent](#), the potential [spatial distribution](#) of benefits of phosphorus load reduction, and [bloom timing](#).

- Routine nutrient and cyanobacterial toxics monitoring was enhanced in 2019 when ECCC, Fisheries and Oceans Canada, USEPA, NOAA, and academic researchers collaborated to conduct [the Lake Erie HABs Grab](#), demonstrating that high-frequency sampling coupled with remote sensing and forecasting tools provides a more comprehensive measure of bloom conditions.
- Hypoxia monitoring by USEPA, NOAA, USGS, and others is ongoing, and a workshop with partners took place in October 2021. In 2022, USEPA will release results for a pilot program that used data loggers to increase the temporal resolution of hypoxia conditions observed in 2017–2020. NOAA deployed a new mooring system in Lake Erie in 2017–2021 to quantify the duration, spatial extent, and thickness of the hypoxic layer. These moorings will produce data to further characterize and quantify the extent of hypolimnetic hypoxia around Lake Erie's central basin to measure progress in response to phosphorus targets.
- Binational scientists continue to assess the best methods to estimate binational phosphorus loads and trends that account for changes in annual data collection and fluctuations in precipitation, including [flow normalization](#) techniques.
- In 2021, the Annex subcommittee drafted a Binational Adaptive Management Framework for Lake Erie. The framework outlines the evaluation, coordination, and communication activities necessary to actively assess whether the current phosphorus targets will achieve the lake ecosystem objectives.
- Progress towards achieving the binational phosphorus reduction targets is reported through various means including the [Blue Accounting](#) website, the [Canadian Environmental Sustainability Indicators](#), Ontario's website regarding the Canada-Ontario Lake Erie Action Plan, lakewide annual reports, the Ohio Lake Erie Commission's Annual [Water Monitoring Summary](#), Nutrients Annex

Subcommittee webinars, and the Great Lakes Executive Committee.

Priority for Action: By 2020, evaluate *Cladophora* research findings and determine whether the science is sufficient to establish phosphorus load reduction targets for the eastern basin of Lake Erie.

- In 2020, ECCC, USGS, and USEPA and numerous participating agencies initiated an evaluation of the latest science on *Cladophora* and the factors contributing to its growth in Lake Erie. Canada and the United States, with the support of Ontario and Great Lakes states, continue to implement the binational *Cladophora* research plan, analyze the monitoring data, and use predictive models to address knowledge gaps.



A diver collects benthic samples of *Cladophora* and dreissenid mussels from Sleeping Bear Dunes, Lake Michigan. Credit: USGS

Priority for Science: Update and use watershed loading and aquatic ecosystem models to improve our ability to predict ecosystem response to nutrient load reduction efforts.

Several models have been developed and applied to evaluate the impact of nutrient loadings on in-lake HABs, hypoxic conditions, and nuisance *Cladophora* growth. Examples include:

- From 2019 to 2021, USEPA partnered with USACE and LimnoTech to expand the *Western Lake Erie Ecosystem Model* to create a whole-lake ecosystem model. The new model is being used to simulate the impact of various nutrient reduction scenarios.

- From 2017 to 2022, NOAA's Great Lakes Environmental Research Laboratory (GLERL) and Cooperative Institute for Great Lakes Research (CIGLR) continued developing a [Lake Erie hypoxia early warning system](#). This new tool provides water intake managers with early warnings when hypoxic events are likely.
- From 2018 to 2021, ECCC applied the Soil and Water Assessment Tool (SWAT) model to assess the impact of land management practices on nutrients, sediment, and flow for the Grand, Thames, and Sydenham watersheds.
- From 2020 to 2022, ECCC integrated the watershed models of the Grand, Thames, and Sydenham rivers into lake ecosystem models for Lake St. Clair and Lake Erie.
- From 2020 to 2022, ECCC applied lake ecosystem models to assess the impacts of phosphorus loads and the presence of Dreissenid mussels on the development of *Cladophora* in Lake Erie's eastern basin.
- From 2016 to 2022, USDA developed an updated version of the USDA SWAT model (called [SWAT+](#)) and made numerous enhancements to the Agricultural Policy Extender model. These are the two major models being used in the Conservation



Scientists from NOAA and Monterey Bay Aquarium Research Institute aboard a NOAA research vessel deploying a long range autonomous underwater vehicle (LRAUV) in Lake Erie's harmful algal bloom. This LRAUV's mission is to map algae concentrations throughout the bloom and tell the 3rd generation environmental sample processor where to measure microcystin toxin levels. Credit: David J Ruck, Great Lakes Outreach Media

Effects Assessment Project (CEAP) to [document](#) the benefits of conservation practices and evaluate the remaining conservation treatment needs in the western Lake Erie watershed. The latest [CEAP crop-land study](#) was published in March 2022. Long-term [watershed assessments](#) are also underway in two subwatersheds of the Maumee River: the Blanchard River in Ohio and the Saint Joseph River in Indiana.

Priority for Science: Conduct research and monitoring to improve our understanding of (1) interlake transport and sources of phosphorus in the Huron-Erie Corridor and Niagara River; (2) factors driving toxicity in harmful algal blooms, including the role of nitrogen; (3) how future climate conditions may affect nutrient conditions in the Lake Erie basin; and (4) techniques for controlling particulate and soluble reactive phosphorus.

(1) Interlake transport and sources of phosphorus in the Huron-Erie Corridor and Niagara River.

- From 2020 to 2021, using over 40 years of data (1975–2018), [ECCC examined](#) the status and trends of concentrations and loadings of nutrients at two stations on the Niagara River to understand how phosphorus loadings to Lake Ontario have changed over time. ECCC found that inputs from Lake Erie via the Niagara River are much higher than previously estimated, account for a significant portion of phosphorus loading to Lake Ontario and, in some years, exceed the 7,000 metric tonnes per annum Lake Ontario target.

(2) Factors driving toxicity in HABs.

- ECCC and NOAA are supporting research to develop novel approaches to predict toxin concentrations associated with cyanobacterial HABs. A forecasting [system](#) published in 2020 predicts microcystins' spatial distribution in Lake Erie's western basin using satellite data, in situ observations, and numerical [models](#).
- ECCC, USEPA, and NOAA participated in a binational, university-led research study to characterize the western basin cyanobacterial harmful algal blooms at an unprecedented high-resolution spatial scale. This project, among others, further demonstrated that nitrogen appears to have a role in toxin production (see University of Toledo, Ohio State

University, and Bowling Green State University's [The Lake Erie HABs Grab](#), published in 2021).

(3) How future climate conditions may affect nutrient conditions in the Lake Erie basin.

- In 2019, [a modeling study](#) by NOAA's GLERL and CIGLR showed that higher river flows in the spring could bring higher phosphorus loads and carry them farther into the lake, where variable circulation patterns could widely distribute the phosphorus and lead to more spatially extensive blooms.
- NOAA researchers completed a study in 2021, [Seasonal Overturn and Stratification Changes Drive Deep-Water Warming in One of Earth's Largest Lakes](#), that indicates a shortened winter season will cause higher subsurface temperatures and earlier onset of summer stratification. The results indicate that mixing regime shifts in large lakes can lead to a reorganization of food web structure and possible proliferation of non-native invasive species.

(4) Techniques for controlling particulate and soluble reactive phosphorus.

- Agricultural research projects are underway to improve understanding of how phosphorus moves and how effectively best management practices (BMPs) can manage nutrient losses. Applied research and monitoring serves to facilitate peer-to-peer knowledge transfer and capacity-building in the agricultural sector. For example:
 - Between 2019 and 2021, Agriculture and Agri-Food Canada improved the model for its national [Indicator of Risk of Water Contamination from Phosphorus](#) based on [work to better account for losses of particulate and dissolved phosphorus](#) through surface and tile drain pathways from [accumulation of phosphorus on agricultural land](#), as well as [losses incidental to fertilizer and manure application](#). The improvements have also been incorporated into the field-scale [Phosphorus Loss Assessment Tool](#) for Ontario.
 - Under [CEAP](#), the USDA Natural Resources Conservation Service (NRCS) partners with the USDA Agricultural Research Service (ARS) to operate approximately 20 pairs of edge-of-field water quality monitoring [sites](#) to evaluate BMP effects in the western Lake Erie watershed.



Rocks covered with algae in Lake Ontario.
Credit: ©iStock

- USDA NRCS and Ohio Farm Bureau also support a demonstration farm [network](#) in the Blanchard River (Maumee) watershed to demonstrate and extend innovations to agricultural producers.

Priority for Science: Implement coordinated binational research and monitoring to improve our understanding of factors affecting *Cladophora* growth and support the development of phosphorus reduction targets, where required.

- From 2020 to 2022, coordinated research was implemented by ECCC, MECP, USGS, and USEPA at several sentinel sites in the Great Lakes basin. Due to COVID impacts and restrictions, ECCC conducted limited monitoring in 2020–2021, but plans to resume regular monitoring in 2022, including diver-led monitoring and in-situ sensor deployment at sites in lakes Erie and Ontario.
- USGS is testing new methods to remotely sense *Cladophora* using autonomous underwater vehicles.
- ECCC modelers coordinated with USEPA and LimnoTech to simulate *Cladophora* growth in response to nutrient inputs. Preliminary analysis suggests that *Cladophora* biomass is influenced by many other factors in the nearshore environment, including light, substrate type, and invasive mussels.

Priority for Science: Beginning with Lake Ontario, commence review of GLWQA interim phosphorus concentration and phosphorus loading targets to assess their adequacy for the purpose of meeting Lake Ecosystem Objectives for the other Great Lakes.

- In 2020, ECCC and USEPA initiated a review of Lake Ontario objectives and targets for water quality to assess and update (if necessary) nutrient targets for Lake Ontario. The assessment is also considering other key issues of relevance in the Great Lakes, such as declining offshore productivity, climate change, and how water quality and fisheries managers can continue to work together to understand the implications of management actions on water quality and aquatic ecosystem health.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, Canada and the United States pursued a variety of domestic projects that also support Annex 4 (Nutrients).

Canada and Ontario

- **Reducing phosphorus loads to Lake Erie.** Canada committed to reduce loads from Canadian sources to achieve a 40% reduction to Lake Erie (212 tonnes). Implementation partners are taking action to achieve reductions. In 2018, the Canada-Ontario Lake Erie Action Plan was released, which summarized actions to be taken during 2018–2023 and the expected subsequent phosphorus load reductions.
- From 2020–2022, through the Great Lakes Protection Initiative (GLPI), ECCC continued to fund implementation partners' efforts to: (1) develop and implement new technologies, approaches, and BMPs to reduce phosphorus loads from agricultural and urban sources, including projects to remove phosphorus from manure, urban wastewater, municipal drains, and on farm runoff; (2) evaluate effectiveness at controlling phosphorus; and (3) undertake outreach and engagement activities to communicate results, demonstrate BMP effectiveness, and encourage BMP use.
- Ontario continues to collaborate with municipal partners to support optimization of wastewater treatment plants to reduce phosphorus loadings, including funding for optimization projects in Leamington, Oxford County, Sarnia, and Kingsville, and funding watershedwide optimization in the Grand River watershed. Ontario encourages and facilitates the uptake of optimization methods at wastewater treatment plants through twice-yearly meetings of municipal wastewater practitioners. Municipal wastewater phosphorus loadings have been reduced significantly since 2008 and continue to show a decreasing trend.
- Ontario is working to establish a 0.5 milligrams per litre (mg/L) total phosphorus legal effluent limit in Environmental Compliance Approvals for all wastewater treatment plants in the Lake Erie basin with capacities over 3.78 million litres per day (1 million gallons per day).
- Canada, with Ontario's support, provides annual assessments of phosphorus loads entering Lake Erie from Canadian sources.
- ECCC continues to conduct research, monitoring, and modeling to further understand the factors that contribute to algal blooms and the development of hypoxia in Lake Erie.
- ECCC operationalized whole-lake ecosystem models for Lake Erie and developed and implemented satellite-derived algal bloom products with [EOLakeWatch](#). Information is posted daily to a public [web interface](#) that documents seasonal progression of blooms. This information is consolidated annually into summary reports.
- In 2020–2021, ECCC undertook a study to understand the costs and benefits of achieving Canadian phosphorus load reduction targets for Lake Erie. Results indicate that the costs of implementation are approximately \$50/hectare (ha) while benefits are around \$240/ha—demonstrating that investments in BMPs yield benefits that outweigh the costs.
- ECCC and MECP led the development and implementation of the Canadian Lake Erie Adaptive Management process, which included developing a modeling framework to target actions and track progress and conducting a 5-year synthesis of knowledge around key themes to inform future actions and science.
- In 2020, Agriculture and Agri Food Canada (AAFC) launched the [Living Lab Ontario project](#) to address persistent agri-environmental challenges in the Lake Erie basin (water quality, soil health, and watershed

management). On-farm trials focus on reducing tillage and promoting year-round living cover. Led by the Ontario Soil and Crop Improvement Association, the Living Lab-Ontario collaborators include farmers, agricultural and conservation organizations, and scientists from AAFC and ECCC.

- Since 2020, 12 sites have become 4R-Certified through the 4R Nutrient Stewardship Program—which refers to using the Right Source of Nutrients at the Right Rate and Right Time in the Right Place—verifying an additional 88,583 hectares of farmland in Ontario and 922 farms. This program is led by Fertilizer Canada and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Ontario Agri Business Association, Grain Farmers of Ontario, Ontario Federation of Agriculture, and Christian Farmers Federation of Ontario.
- Between 2019 and 2022, the On-Farm Applied Research and Monitoring demonstration project has been developing comprehensive, science-based methods to measure soil health in Ontario and evaluate the use of various BMPs for improved soil health and water quality. The Ontario Soil and Crop Improvement Association is delivering the programming through the end of 2023, with funding support from the Canadian Agricultural Partnership.
- Ontario supports research and innovation projects through the Ontario Agri-Food Innovation Alliance to address various priorities of the agri-food sector, including water and soil nutrient use efficiency, to reduce the loss of nutrients to streams and lakes. In 2020–2021, the Ontario Agri-Food Innovation Alliance funded 15 research and knowledge transfer projects addressing water and soil nutrient management with funding support from OMAFRA.
- From 2018 to June 2021, Ontario farmers in the Lake Erie watershed completed approximately 1,000 projects with support from the Canadian Agricultural Partnership's (CAP) province-wide program and Lake Erie Agriculture Demonstrating Sustainability (LEADS) Initiative cost-share program. Farmers have reported that implementing CAP cost-shared projects have reduced the risk of soil loss from approximately 118,700 ha of agricultural land.
- Through the LEADS Initiative, farmers work one-on-one with a participating certified crop advisor or

professional agrologist to conduct Farmland Health Check-Ups to identify BMPs tailored to the specific needs of their operation. Since 2018, more than 460 check-ups have been completed.

- Beginning in 2018 and continuing during the reporting period from 2020 to 2022, agricultural partners in Ontario surveyed over 750 producers to identify barriers and opportunities for adoption of cover crops.
- Ontario continues to work collaboratively with the greenhouse sector while improving guidance to support compliance efforts. MECP is making it easier for the greenhouse sector, such as vegetable and flower growers, to sample and report on their stormwater discharges. Creating simple, clear sampling and reporting requirements will save growers time and money as we work together to reduce phosphorus discharges that contribute to blue-green algae in our lakes and waterways.
- The Lower Thames Valley and Upper Thames River conservation authorities are working in the McGregor Creek, Jeannettes Creek, and Medway Creek subwatersheds to measure the water quality benefits of agricultural practices that reduce soil and nutrient loss.
- Through the Wetlands Conservation Partner Program, Ontario is providing funding over 5 years beginning in 2021 to restore and enhance wetlands that could result in phosphorus load reductions. Ontario is supporting Ducks Unlimited Canada (DUC) through this program for efforts in the watersheds of Lake Ontario and Lake Erie and connecting waterways. In 2021, DUC implemented 19 projects to restore approximately 430 ha of wetlands within the Lake Erie watershed. DUC also created an [interactive story map for the program](#) that will expand as more projects are completed.
- Ontario is undertaking research studies to better understand phosphorus loadings and algal blooms. For example, the Multi-Watershed Nutrient Study is analyzing its 5 years of field data to examine and report on how agricultural land management and landscape features relate to phosphorus loadings in streams in the Great Lakes basin.
- In addition, Ontario is providing support to the following university projects:

- University of Guelph, with support from Ontario in 2020, began a project to develop a watershed model for the entire Canadian Lake Erie Basin to assess the impact of climate change, land use, and land management scenarios (including BMPs) on phosphorus loads from Canada to Lake Erie, and to identify vulnerable watersheds for phosphorus loss to enable better targeting of BMPs to more effectively reduce nonpoint source phosphorus loads.
- Toronto Metropolitan University is using sensors to estimate nutrient loadings and is enhancing existing regional models with data on farmer activities, reservoir nutrient dynamics, and in-stream processing of nutrients.
- University of Waterloo is advancing understanding of how phosphorus loadings from the landscape translate to phosphorus loadings to receiving water bodies, with a focus on the Thames River watersheds.
- Western University is evaluating how stormwater management practices, including low impact development, affect hydrology and phosphorus losses. This work will enable targeting of stormwater management practices to reduce nonpoint source (NPS) phosphorus loads and will improve NPS phosphorus load estimates for an urban subwatershed to Lake Erie.
- Conservation authorities have continued to lead the development and implementation of watershed management plans, with funding support from ECCC's GLPI and Ontario, and working in partnership with municipalities, local communities, and Indigenous Peoples.
- Ontario continues to support youth engagement, including by providing funding for First Nations Youth Stewardship for the development of *The Thames River (Deshkan Zibi) Shared Waters Approach to Water Quality and Quantity (final draft)* in 2020–2022. Ontario also worked with partners including teachers, school boards, and conservation authorities (e.g., the Upper Thames River Conservation Authority, St. Clair Region Conservation Authority) to engage students and youth on Lake Erie issues through two Western Lake Erie Student Summits

and a [Huron-Erie Corridor Virtual Field Trip](#), which includes [resources](#) for teachers.

- From 2020 to 2021, ECCC commissioned a study to estimate the costs of nutrient-related water-quality impacts to the Canadian Lake Ontario economy. The study estimated that the lakewide baseline cost due to *Cladophora* and cyanobacteria in 2020 was \$522 million. The study also estimated \$1 billion in additional costs by 2050 under a business-as-usual scenario over a managed-recovery scenario in two embayments (Hamilton Harbour and Bay of Quinte) that experience cyanobacteria blooms.

United States

Programs to Reduce Phosphorus Loadings from Agricultural Sources

- **Ramping up federal cost-share programs.** The United States committed to reduce phosphorus loads to Lake Erie by 40%, a reduction of 3,311.2 tonnes (7.3 million pounds), the bulk of which will come from agricultural sources in the western Lake Erie watershed. In response, federal agencies have doubled the amount of cost-share funding available to farmers over the past 5 years. According to NRCS, approximately 30% of these funds have gone to nutrient management practices, 41% to cover crops, and 20% to animal waste storage and management. It is assumed that an average edge-of-field phosphorus reduction of 2 pounds per acre would yield a total phosphorus reduction of 529.7 tonnes (1,167,750 pounds) because of these practices.
- **H2Ohio Initiative.** [H2Ohio](#) represents a financial commitment by the state of Ohio of over \$120 million to install agricultural BMPs in 2020–2023. The program enrolled an additional 1.1 million acres, accounting for over 40% of the cropland in the project area. In addition, through H2Ohio, Ohio Department of Natural Resources (Ohio DNR) has contracted to create, restore, or enhance 8,405 acres of wetlands (at a cost of \$64.5 million) that will filter runoff from over 100,000 acres of agricultural land. Ohio estimates that these programs removed over 127 tonnes (280,000 pounds) of phosphorus from the Maumee River watershed through summer 2021, which is 28% of Ohio's annual reduction goal of 453.6 tonnes (1 million pounds).

- **Targeting Great Lakes Restoration Initiative (GLRI) funds.** USEPA estimates that approximately \$10 million in GLRI funds is invested in Lake Erie nutrient reduction efforts each year. In addition to the NRCS cost-share programs mentioned above, since 2018 USEPA has awarded 12 GLRI grants totaling over \$7 million in nutrient reduction projects, for an estimated phosphorus reduction of over 152,000 pounds.
- **Expanding Agricultural Programs in Indiana.** The number of Indiana acres planted in cover crops hit a record high in 2021. Indiana now has a statewide 4R program, and interest in the program is growing. From 2015 to 2020, the Indiana Conservation Partnership provided cost-share for 8,105 BMPs on agricultural lands in its portion of the western Lake Erie watershed to reduce phosphorus loss by 261.8 tonnes (577,115 pounds) according to the Region 5 Model.
- **Expanding Agricultural Programs in Michigan.** Michigan departments are working on several joint project initiatives in the Western Lake Erie Basin (WLEB), including USDA's Regional Conservation Partnership Program and Conservation Reserve Enhancement Program (CREP), which help Michigan's agricultural producers implement BMPs. They are also encouraging farmers to participate in the Michigan Agriculture Environmental Assurance Program (MAEAP), a voluntary effort to provide technical assistance to farmers so they can reduce the loss of nutrients from their farm fields. In 2022, Michigan added four new MAEAP technicians to the WLEB to provide focused assistance in five prioritized subwatersheds of the WLEB.
- **New concentrated animal feeding operation rules.** In 2019, WDNR revised [specific rules \(NR 243\)](#) for the Wisconsin Pollutant Discharge Elimination System for [permitting large dairies](#). Note: all farms are required to comply with [agricultural performance standards \(NR151\)](#) regardless of size.
- **Ohio nutrient management standard update.** Ohio NRCS revised its 590 Nutrient Management Standard in 2021 to better address phosphorus management needs. More than 20 different state, local, academic, farm organizations, and nongovernmental organization representatives served on the advisory board for the revision.
- **Agricultural runoff treatment systems.** The Nature Conservancy, University of Wisconsin (UW) - Green Bay, and Outagamie County piloted and monitored three Agricultural Runoff Treatment Systems (ARTS) in the Lower Fox watershed from 2017 to 2020. ARTS consist of a series of BMPs that capture runoff, attenuate flow, and provide nutrient reduction. In 2021, local partners added an innovative [phosphorus-removal structure](#) to remove dissolved phosphorus at one of these systems. Phosphorus removal structures are planned at the other two ARTS in 2022.
- **PA VinES.** PADEP continues partnering with the Erie County Conservation District to implement the Pennsylvania Vested in Environmental Sustainability (PA VinES) agricultural outreach and cost-share program. Since 2017, the program has distributed 58 PA VinES workbooks to Lake Erie vineyard owners and has installed numerous BMPs. From 2019 to 2022, practices implemented include 2,658 acres of cover crop, a sediment retention pond, a roof runoff management system, and two large stream channel stabilization projects.

Programs to Reduce Phosphorus Loadings from Municipal Sources

- **Major reductions from Detroit wastewater and combined sewer overloads (CSOs).** The Great Lakes Water Authority operates the City of Detroit Water Resource Recovery Facility (WRRF)—the largest municipal source of phosphorus to Lake Erie. To date, 95% of Detroit's annual CSO volume has been treated and the remainder is being addressed with



View of secondary clarifiers at the Great Lakes Water Authority's Water Resource Recovery Facility.
Credit: Michigan EGLE

a long-term control plan. In total, the phosphorus load from treated wastewater from the WRRF, CSO treatment facilities, and untreated CSOs has been reduced by approximately 400 tonnes annually.

- **Fort Wayne Deep Tunnel.** In Indiana, 5 miles of the Fort Wayne Deep Tunnel project, an essential part of its CSO long-term control plan, was completed in June 2021. When operational in 2023 (2 years ahead of schedule), the Deep Tunnel project will reduce CSOs into the St. Marys and Maumee rivers from 72 per year to four per year or fewer.
- **Water quality trading and adaptive management as permit compliance options.** Wisconsin developed a statewide [water quality trading](#) framework after phosphorus water quality standards were approved in 2010. From 2019 to 2021, three successful trades occurred in the Great Lakes basin. Project locations and associated documents are available [online](#). Notably, NEW Water (Green Bay Metropolitan Sewage District) recently completed a [multiyear pilot project](#) to consider feasibility of incorporating adaptive management (AM) in their wastewater permit as a method for compliance. Based on their experience, NEW Water submitted an AM Plan for inclusion in the 2022 permit reissuance.
- **New York invests in nutrient-reduction projects.** In 2020, NYSDEC awarded over \$13.5 million for project implementation to multiple grantees located within the Lake Erie and Lake Ontario watersheds. Projects included, but were not limited to, wastewater disinfection improvements, green infrastructure, and land acquisitions for source water protection.
- **Erie County, Pennsylvania, municipal improvements.** PADEP partnered with the Erie County Department of Health to increase inspections of small-flow treatment facility wastewater discharges to identify and correct water quality problems. As of 2021, the Erie County Department of Health conducts annual inspections of approximately 300 small flow systems that drain into Lake Erie, and compliance rates are improving as a result of this program. PADEP partnered with the Erie County Department of Planning and Economic Development to create the Municipal Stormwater Assistance Program. This program has improved data collection and public outreach on stormwater infrastructure needs.

Watershed-Based Planning and Restoration Efforts

- **Maumee River Total Maximum Daily Load (TMDL).** Ohio EPA is developing a TMDL for the Maumee River to address impairments in western Lake Erie due to HABs. The draft TMDL report is planned to be submitted to USEPA for approval by the end of 2022. The TMDL will include phosphorus load allocations for point source and nonpoint source pollution occurring throughout Ohio's portion of the Maumee drainage basin to meet the reduction goals established under Annex 4.
- **New watershed-based plans.** Ohio's Lake Erie watershed currently has 111 approved watershed plans in place, with 48 of those developed since 2020, and another 29 currently under development. All subwatersheds in Indiana, except the Auglaize River, have approved watershed management plans that are being implemented and/or updated; a watershed management plan is underway for the Auglaize River and will be completed by May 2022. Wisconsin approved six new [watershed plans](#), for a total of 12 plans representing the highest-loading subwatersheds to support implementation of the [Lower Fox River Basin and Lower Green Bay Phosphorus TMDL](#). Recognizing that approximately 50% of the load in the Lower Fox River comes from Lake Winnebago, WDNR developed the [Upper Fox and Wolf Rivers](#) TMDL (approved in 2020) and approved four new watershed plans in that area. In New York, the [Lake Erie Watershed Protection Alliance](#) is leading the development of a watershed-based plan for the eastern basin. Although this work has been delayed, steady progress continues on modeling and plan development; it is projected for completion in 2023.
- **Nutrient-focused watershed prioritization.** Indiana Department of Environmental Management, in conjunction with other partners conducting water quality monitoring in the WLEB, has identified and prioritized in Indiana's Domestic Action Plan those subwatersheds that indicate the greatest phosphorus losses for targeting watershed restoration efforts. Native vegetation riparian buffers have been installed to intercept and infiltrate runoff and prevent streambank erosion.

- **Applying the ACPF in Michigan.** EGLE and MDARD are developing agricultural inventories in high-priority subwatersheds in the Bean Creek watershed (a subwatershed of the Maumee River watershed), the S.S. LaPointe Drain watershed, and the River Raisin watershed. The agricultural inventory process will collect data to locate and prioritize sites that have the potential to address nutrient runoff and will have a positive impact on water quality.
- **Agricultural Wetland Enhancements.** Ohio Department of Agriculture's engineering staff worked with local soil and water conservation district personnel to develop wetland designs for the Lake Erie CREP. H2Ohio incentives for Lake Erie CREP through the Ohio DNR generated over 100 additional wetland applications that will be constructed in 2022.

Science, Research, and Monitoring

- **Ohio SWAT modeling.** In 2022–2023, Ohio is investing \$250,000 into enhancements to the Maumee River SWAT models that will allow the state to refine its predictions of the effectiveness of H2Ohio and suggest refinements that will increase its cost effectiveness and overall success.
- **Supporting science under GLRI.** From 2018 to 2020, NOAA, USGS, and USACE conducted over \$15 million in critical science activities to support



A Soil and Water Conservation District staff member standing in a field of sunflowers in Putnam County, Ohio. Overwintering cover crops, such as sunflowers, are one of the priority practices under the H2Ohio Initiative to help reduce erosion, hold nutrients in the soil, and improve soil health. Credit: Ohio Department of Agriculture

Lake Erie nutrient-reduction goals. GLRI supports HABs monitoring and decision-support tools, including the Lake Erie HABs Tracker tool and biweekly forecasts; tributary and edge-of-field monitoring and nutrient load computations; and ecosystem and watershed modeling.

- **New water quality criteria.** In 2021, USEPA published new recommended ambient water quality [criteria](#) to address nutrient pollution in lakes and reservoirs under Section 304(a) of the Clean Water Act. These criteria replace the 2001 guidance. The updated criteria are based on data from USEPA's National Aquatic Resource Surveys and include stressor-response models linking protection of designated uses to nutrient concentrations.
- **Great Lakes Coastal Condition.** In August 2021, USEPA released a new [report](#) showing that eutrophication is a persistent problem in Great Lakes nearshore waters, and that Lake Erie experienced the most eutrophication, with 67% of the nearshore waters in fair or poor condition.
- **Wetlands research.** In 2020, USACE built a phosphorus-optimized [demonstration wetland](#) in Defiance, Ohio, that will be monitored for at least 5 years. This project builds on several years of research on soil sorption capacity, which is being used to validate the effectiveness of wetlands to mitigate soluble and particulate forms of phosphorus over time.



Aerial view of the 10-acre Phosphorus Optimal Demonstration Wetland in Defiance, Ohio. Credit: USACE

- **NowCast.** USGS continues supporting local and state cooperators in Ohio, Pennsylvania, and New York with the Great Lakes NowCast system, which uses mathematical models to predict recreational water quality conditions based on easily measured environmental parameters. NowCast can be used to predict exceedances for fecal-indicator [bacteria](#) and [cyanotoxins](#). A [review](#) of the method, which includes a case study of the Great Lakes NowCast system, was published in 2020.
- **Edge-of-field data analysis.** USGS is integrating edge-of-field and headwater tributary data at several sites in the Great Lakes basin, to evaluate links in timing and concentrations of nutrient and sediment loads. In 2021 they [published data](#) from 85 edge-of-field sites that were developed from five local, state, and federal programs.
- **Sediment fingerprinting.** In 2021, USGS published a new geomorphic assessment for [Black Creek](#), a headwater tributary of the Maumee River, using sediment fingerprinting. USGS is working to extend this technique, which uses isotopic signatures to quantify the relative contribution to loads from various land use sources to larger streams.
- **HAB Research Initiative (HABRI).** Since 2020, a total of \$4 million has been made available through the Ohio Department of Higher Education to support 20 HABRI projects. Project selection, which is guided by the technical needs of state agencies and supports the Governor's H2Ohio Water Quality Initiative, gives both short-term assistance and long-term solutions for a suite of issues surrounding HABs in Ohio. Currently, an additional \$5 million is being competed, which represents 2022 and 2023 dollars.
- **Controlled drainage research.** MDARD, in partnership with EGLE, Michigan State University, farmers, and partners, are currently investigating the effectiveness of controlled drainage in Lenawee County at two on-farm sites with varying soil types. This [research](#), which began in 2020, will likely be extended into 2025 in order to determine how effectively this practice can reduce nutrient load at the field scale.
- **Algal bloom study.** WDNR, UW, and NEW Water completed a 5-year study in 2022 of algal bloom



Algal scum in Green Bay extends toward the mouth of the Fox River. Credit: NEW Water

dynamics in Lower Green Bay. Modeled after monitoring occurring in Lake Erie, the study included both continuous buoys and discrete samples to characterize the algal community and toxin profile, nutrients, chlorophyll *a* and phycocyanin, dissolved oxygen, and other parameters useful in understanding bloom formation and transport. In 2020, cameras were added to the buoys to monitor surface scums. Project data were used to calibrate NOAA models generated from satellite data. NOAA is supporting continued operation of the buoys through 2023.

- **Wisconsin testing of Cyanobacteria Assessment Network (CyAN).** WDNR staff collaborated on developing and beta testing the [CyAN](#) web app for identifying cyanobacteria blooms. Since its release in 2021, CyAN is one of the tools used to track algal blooms and to respond to illnesses reported to the Wisconsin Department of Health Services.
- **Watershed model.** After completing 2 years of baseline nutrient and sediment water quality

data in November 2019, NYSDEC and USGS began developing a watershed model, including tributary-specific SWAT models, that will aid in determining loading contributions to the eastern basin of Lake Erie.

- **HABs Mitigation and Research.** NYSDEC continues to collaborate with various partners to develop and [pilot mitigation technologies](#) in support of [HAB action plans](#) for 13 priority inland lakes, including five finger lakes in New York's Great Lakes watershed. Since 2020, HAB mitigation pilot projects have been implemented on some of these priority inland lakes; the technologies used include electrochemical oxidation (with Clarkson University), hydrodynamic cavitation (with State University of New York College of Environmental Science and Forestry) and interception/treatment/transformation (with USACE's Harmful Algal Bloom Interception, Treatment, and Transformation System, or [HABITATS](#)). In 2021, New York released a HABs [research guide](#) to further advance the study, management, and mitigation of HABs in New York.

Communication and Outreach

- **Michigan's Adaptive Management Plan.** The Michigan Domestic Action Plan team [released](#) the Lake Erie AM Plan in December 2021, in response to public comment and stakeholder feedback. Michigan is using the Taking Action on Lake Erie website to provide frequent updates on the planning and implementation of Michigan's Domestic Action Plan and companion AM Plan. The AM Plan will allow for a more structured way to learn about the impacts of actions to reach the state's reduction goals and then use the results of those actions to adjust future paths forward. Michigan will form an advisory group to guide the AM process in 2022.
- **Ohio coordination on HABs.** Annually, Ohio Sea Grant and the University of Toledo host a 2-day meeting with agency leadership and staff to communicate how funded research might impact management decisions and provide tools and approaches to address the HAB issue. These findings are then incorporated into many of the outreach events lead by Ohio Sea Grant.
- **Citizen-led *Cladophora* monitoring.** Since 2019, NYSDEC has been working to increase awareness of nuisance *Cladophora* growth by launching a new web page and a [geographic information system-based reporting tool](#) to encourage citizens to report occurrences of *Cladophora* along Great Lakes shorelines.
- **Wisconsin citizen monitoring network.** WDNR continues to engage volunteers to collect baseline water quality data, including dissolved reactive phosphorous in 16 tributaries (20 sites) within the Lower Fox River basin. Results from this ongoing effort indicate that greater than 50% of total phosphorus is dissolved reactive phosphorus in these waterways.
- **Green Bay watershed collaboration.** WDNR has engaged community leaders, decision-makers, and nontraditional stakeholders in broader watershed planning to comprehensively address nutrient reductions to Green Bay. Several counties in northeast Wisconsin are collaborating on innovative conservation projects, sharing expertise and staff resources. GLRI funding supports a successful [demonstration farm network](#)—the first of its kind in the Great Lakes region—that continues to grow. Since 2019, NRCS Wisconsin added two new networks for a total of six networks with 33 farms participating as of 2022. These networks are designed to showcase and demonstrate leading-edge BMPs that improve Great Lakes water quality by reducing phosphorus and sediment from entering Green Bay and Lake Michigan.
- **USDA Video.** In April 2022, USDA released a new [video](#) that provides a closer look at the collaborative partnerships driving innovative water quality assessment and conservation in the WLEB. The video shows how USDA's CEAP watershed studies in the WLEB bring researchers, farmers, government agencies and nonprofit organizations together to develop science-based solutions and strategically place them where they can deliver the greatest conservation benefits.



Annex 5: Discharges from Vessels

Over the last 3 years, the United States and Canada have managed vessel discharges and coordinated successful responses to vessel emergencies that had the potential for oil or hazardous substance discharges. In addition, the federal governments have both significantly advanced legislation that would further strengthen ballast water management programs.

Key Achievements

- As directed by the 2018 Vessel Incidental Discharge Act (VIDA), in November 2020 the U.S. Environmental Protection Agency (USEPA) proposed its [Vessel Incidental Discharge National Standards of Performance](#). This proposed rule would establish national standards of performance for all discharges incidental to the normal operation of a vessel.
- As part of its VIDA responsibilities, the U.S. Coast Guard (USCG) created a working group to coordinate provincial, federal, and state government discussions of VIDA provisions, including state access to vessel databases and location information.
- In 2021, Canada published new [Ballast Water Regulations](#) in the *Canada Gazette, Part II*, which include specific standards for the control and management of ships' ballast water and timelines for compliance for domestic ships nationwide, including Great Lakes ships. The intent of the new regulations is to further manage the movement of ballast water in the Great Lakes to minimize the introduction and spread of aquatic invasive species (AIS).

Purpose and Overview

The purpose of [Annex 5 \(Discharges from Vessels\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by preventing and controlling vessel discharges that are harmful to the quality of the Waters of the Great Lakes, through the adoption and implementation of regulations, programs, and other measures that facilitate coordinated and cooperative implementation and enforcement, where appropriate.”

The Discharges from Vessels Annex guides responsible authorities in the United States and Canada as they work to protect water quality, ensure safety, consider the standards and guidance of the International Maritime Organization, implement vessel discharge-related domestic laws and regulations while accounting for the best available science, and prohibit and penalize (as appropriate) vessel discharges that harm the Great Lakes. This annex focuses on preventing and controlling the following vessel discharges that are harmful to the waters of the Great Lakes:

- Oil and hazardous polluting substances
- Biofouling
- Garbage
- Antifouling system compounds
- Wastewater and sewage
- Ballast water

ANNEX IMPLEMENTATION

Implementation of Annex 5 (Discharges from Vessels) is led by USCG and Transport Canada with support from USEPA, Fisheries and Oceans Canada (DFO), and the Canadian Coast Guard (CCG). Pursuant to Annex 5, the authorities responsible for implementing the commitments of the Discharges from Vessels Annex met annually to discuss and manage the vessel discharges addressed by the Annex. In 2020–2022, the Annex 5 authorities focused on the activities associated with the Science and Action Priorities, pollution prevention, and response initiatives through the United States and Canada's respective regulatory regimes, as well as cooperative work at the International Maritime Organization (IMO). In addition to the responsible authorities listed above, the U.S. Department of State and Global Affairs Canada also participated in the responsible authorities' discussions.

Annex 5 Subcommittee membership, co-led by the USCG and Transport Canada, includes the responsible authorities noted above, as well as members from Wisconsin Department of Natural Resources, Indiana Department of Environmental Management, the Lake Carriers' Association, the Chamber of Marine Commerce, the Shipping Federation of Canada, and Ontario Ministry of Transport. The Annex 5 Subcommittee provides a forum to discuss vessel discharge standards development, implementation, and compliance, as well as shared issues and concerns related to vessel discharges that are brought to their attention by members, constituents, and other stakeholders.

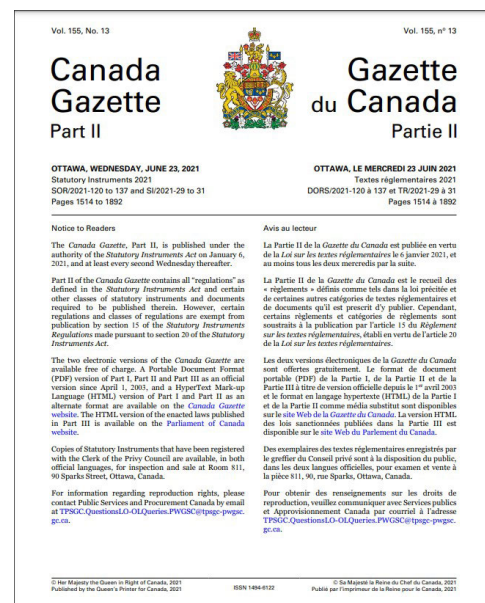
Binational Actions and Achievements

Priority for Action: Work toward amending the respective U.S. and Canadian ballast water regulatory regimes, and work together, in consultation with stakeholders, towards compatible, fair, practicable, and environmentally protective requirements for ballast water management.

- Throughout the reporting period, Annex 5 co-leads continued to share information on the United States' and Canada's plans and progress with respect to ballast water, as well as the other vessel discharges (see Other Binational Achievements below). These subcommittee meetings updated vessel associations and state and provincial representatives on Annex 5-related issues, and they provided an opportunity for participants to share concerns and report on progress, including:
 - To meet some of the initial requirements of VIDA, to better prepare the Coast Guard for its VIDA rulemaking responsibilities, and to identify areas where the United States and Canada can better align their regulatory regimes, the United States created VIDA working groups with states and the provinces of Quebec and Ontario to coordinate discussions about VIDA provisions between state

and federal governments. Additional details and results are included in the *Domestic Achievements and Actions* section below.

- Canada published new [Ballast Water Regulations](#) in the *Canada Gazette, Part II* in June 2021 to bring the IMO Ballast Water Convention into effect. These new regulations strengthen existing rules for vessels on international voyages and



Canada's new Ballast Water Regulations published in the *Canada Gazette, Part II*.

introduce new rules for vessels that remain in Canada and on the Great Lakes. International ships traveling to the Great Lakes (and other Canadian fresh waters) will be required by Canada to exchange and treat ballast water before arrival. The ballast water of Great Lakes and other domestic vessels that load or unload ballast water in Canada (other than for safety reasons) will be regulated at launch either in 2024 or in 2030, depending on when they were built.

Priority for Action: Meet annually to share best practices and develop compatible approaches to compliance monitoring, data collection, and analysis of ballast water management in the Great Lakes.

Annual meetings were held in 2020–2022 to share best practices and compatible approaches, such as:

- Accomplishments and results of the efforts of the binational Great Lakes Seaway Ballast Water Working Group (see Other Binational Achievements below).
- DFO shared [results of modeling different ballast water management scenarios](#) by international and domestic vessels, which informed Canada's new ballast water regulations.

Priority for Science: Meet annually to share best practices and develop compatible U.S. and Canadian approaches to sampling and analysis of ships' ballast water.

- The Annex 5 co-leads and the authorities responsible for delivering on the Annex commitments met in-person and virtually in spring 2020, 2021, and 2022, and engaged on the following best practices and compatible approaches:
 - Published [a joint report on the status of sampling ports used for collecting samples of ballast water on ships](#). The ballast water samples are tested for viable organisms, to assess ships' compliance with ballast water regulations (DFO, USCG Office of Operating and Environmental Standards).
 - Continued to share records and examine sampling and analysis methods in partnership with DFO and the U.S. Naval Research Lab.



Sampling Laker ballast tank with plankton net.
Credit: Fisheries and Oceans Canada




- Worked together through an international Working Group on Ballast and Other Ship Vectors to propose a [protocol](#) for the verification of ballast water compliance monitoring devices.
- DFO conducted and shared research that measured results of discharge samples against the IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 D-2 Standard (See [Implementing the Ballast Water Management Convention](#) for more details.) This [research](#) involved sampling treated ballast water for exceedance of the D-2 standard for both the smaller and larger size classes of organisms.
- DFO shared the results of an [evaluation of the performance](#) of indicative tools that assess the 10–50 micron size class of AIS. DFO also shared progress on research for tools assessing the greater than 50 micron size class of AIS.

Other Binational Achievements

- In addition to the Action and Science priorities, the United States and Canada continued to work together during the reporting period to further international efforts related to the other vessel discharges outlined in Annex 5, including:
 - Contributed to the IMO Subcommittee on Pollution Prevention and Response to review and improve international biofouling guidelines.
 - Actively participated in IMO Marine Environment Protection Committee to support controls on anti-fouling systems containing cybutryne through amendments to the International Convention on the Control of Harmful Anti-Fouling Systems on Ships.
 - Actively participated in the Pollution Prevention and Response Subcommittee Correspondence Group of the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex IV focused on the prohibition of sewage discharge.
- Binational Great Lakes Seaway [Ballast Water Working Group](#) accomplishments and results include:
 - Continued to oversee ballast water compliance and enforcement for vessels arriving from outside Canada's Exclusive Economic Zone.
 - Ensured that no noncompliant ballast water was discharged in the Great Lakes Seaway

system during the reporting period. [Independent research](#) indicates that the risk of a ballast water-mediated introduction of AIS into the Great Lakes by transoceanic ships has been mitigated to low levels.

- Published annual Great Lakes Seaway Ballast Water Working Group summary reports, which assess compliance with ballast water regulations throughout the Great Lakes:
 - [2021 Summary of Great Lakes Seaway Ballast Water Working Group](#)
 - [2020 Summary of Great Lakes Seaway Ballast Water Working Group](#)
 - [2019 Summary of Great Lakes Seaway Ballast Water Working Group](#)
- Canada and the United States continued to implement the Canada-United States Joint Marine Pollution Contingency Plan (JCP), which provides a coordinated mechanism for planning, preparing for, and responding to discharges and releases in contiguous waters and provides established procedures for the coordination of spill response efforts between the United States and Canada. There are six regional annexes to the JCP; the Great Lakes Geographic Annex (CANUSLAK Plan) covers the Great Lakes and St. Lawrence River. The Plan covers all potential sources of marine pollution (e.g., ships, offshore platforms, mystery spills).

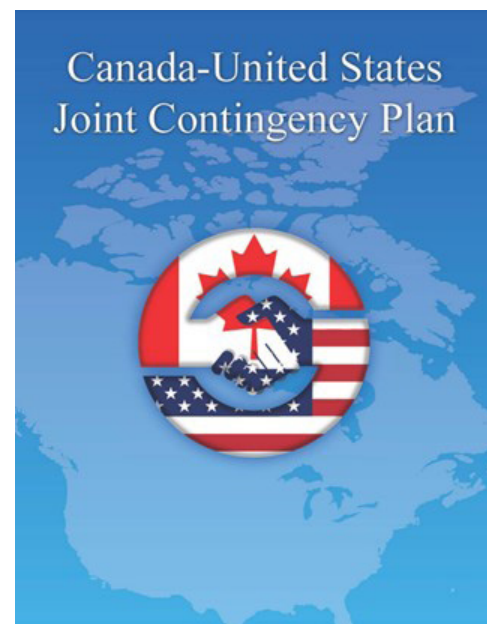
2019 Summary of Great Lakes Seaway Ballast Water Working Group January 2020	2020 Summary of Great Lakes Seaway Ballast Water Working Group February 2021	2021 Summary of Great Lakes Seaway Ballast Water Working Group February 2022
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2019, 2020, and 2021 Summaries of Great Lakes Seaway Ballast Water Working Group.

- During the reporting period, the following work was completed under the Great Lakes Annex (CANUSLAK Plan), which covers all potential sources of marine pollution (e.g., ships, offshore platforms, mystery spills) to the Great Lakes and St. Lawrence River:
 - The United States and Canada continued to coordinate planning, preparedness, and response to harmful substance incidents in the contiguous waters along shared marine borders.
 - An update to the CANUSLAK Plan was completed in 2021 and signed by USCG's Ninth District Commander and CCG's Central Region Assistant Commissioner in early 2022.
 - In 2020, there were six significant marine casualties with an actual or potential oil or hazardous substance discharge that resulted in both parties activating the CANUSLAK Plan and mobilizing personnel and equipment. No activations occurred in 2021 or the first half of 2022. The 2020 casualties included:
 - Apr. 13, 2020 – Barge Margaret Grounding (Lake St. Clair/Peche Island).
 - Jun. 12, 2020 – Barge PML 2501 Grounding (St. Marys River, Sweets Point, MI).
 - Aug. 20, 2020 – Island Duchess Casualty (Sunnyside Island, Alexandria Bay, NY).
 - Sept. 3, 2020 – Wendy K Vessel Fire (St. Clair River, Mooretown, ON).
 - Sept. 10, 2020 – Federal EMS Grounding (St. Lawrence Seaway, Massena, NY).
 - Dec. 2, 2020 – Harvest Spirit Grounding (Livingstone Channel, Amherstburg, ON).
 - In addition to actual activations, the CANUSLAK Plan is regularly tested through exercises and drills. CCG and USCG participated in one virtual exercise in 2021 (no exercises were held in 2020 due to the COVID-19 pandemic):
 - May 11–12, 2021 – Isle Royale Exercise (Day one = Notifications; Day two = Operations).
 - Aug. 18, 2021 – St. Clair Flats Full Scale Exercise (Postponed to May 18, 2022, due to the COVID-19 pandemic).



Rear Admiral Johnston, Ninth U.S. Coast Guard District Commander, and Canadian Coast Guard Assistant Commissioner Marc-Andre Meunier sign an update for the Great Lakes Annex to the Canada-U.S. Joint Marine Pollution Marine Contingency Plan, on March 14th, 2022, in Montreal. Credit: Lorne Thomas, Ninth District External Affairs



Canada-U.S. Joint Marine Pollution Contingency Plan (CANUSLAK).

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, the United States and Canada pursued a variety of domestic projects that also support Annex 5 (Discharges from Vessels).

Oil and Hazardous Polluting Substances

- **USCG Oil Spill Response Research.**
 - [Mitigation of Oil Moving along the Waterway Bottom](#), November 2019
 - [Oil Sands Products Spill Response](#), August 2020
 - [Freshwater In-situ Oil Burning](#), USCG Research and Development Center, February 2021
 - [Oil Spill Response Technology: Evaluation Process](#), December 2020
- **Update Vessel Pollution and Dangerous Chemicals Regulations (VPDCR).** In 2022, Canada plans to begin updating the VPDCR to comply with corresponding provisions from MARPOL and implement upcoming MARPOL amendments, including new short-term greenhouse gas reduction measures and modifications to the energy efficiency requirements for ships. These amendments will address ongoing and emerging environmental issues related to vessel pollution prevention in Canadian waters. Phased amendments are anticipated to begin in 2023.

Biofouling

- **Risk assessment for biofouling.** Work began on a national risk assessment for biofouling for improved understanding of risks posed by shipping types across Canada.
- **Public engagement related to biofouling.** Developed [Draft Voluntary Guidance for Relevant Authorities on In-Water Cleaning of Vessels](#) and engaged in public consultations on the draft, which concluded August 2021.

Garbage

- **Guidance for managing plastic waste from ships.** Canada commissioned a study to assess the capacity of Canadian ports to manage plastic waste from ships.

Wastewater and Sewage

- **Wastewater and sewage regulation.** The United States has been working on issues related to vessel wastewater and sewage regulation at both the national and international levels, focusing on rates of discharge and no-discharge areas. As graywater is incorporated into VIDA, efforts continue to determine the best methods for ensuring compliance and enforcement of the forthcoming USEPA standard. This includes completing some preliminary research and development to better understand the limitations of current graywater treatment technology.

Ballast Water

- **Reports published.** In 2020, Canada published a DFO science response report, [Additional Analyses of Ballast Water Management Scenarios to Reduce the Establishment of Harmful Aquatic Species Across Canada and the Great Lakes](#), which quantified the expected reduction in the spread of AIS if ballast water management systems were used (at current performance levels) and if ballast water exchange and treatment were combined.
- **Ballast water performance standards.** USCG continues to implement rulemaking that established a performance standard for the allowable concentration of living organisms in ballast water discharged from ships in waters of the United States.
 - Several independent laboratories are testing systems for type approval. The multifaceted type approval process consists of land-based and shipboard-based testing that focuses on the biological efficacy of the ballast water management system and includes additional testing criteria for operation in the cold, turbid fresh water of the Great Lakes.
 - Since June 2019, the USCG Marine Safety Center has issued type approval certificates for 25 ballast water management systems (of a total of



Ocean ship discharging ballast water. Credit: Fisheries and Oceans Canada

47 certificates issued). Many vessels entering the Great Lakes have these types of approved systems aboard for use during ballasting operations.

- **Developing vessel incidental discharge national standards of performance.** In 2020–2022, USEPA and USCG worked on their respective regulatory mandates per the 2018 VIDA. The statute directs agencies to develop a uniform national standard to govern 27 discharges that are incidental to vessel operations, such as ballast water discharges. Per VIDA, USEPA is the lead for establishing these standards and USCG is the lead for implementing compliance and enforcement regulations.
 - On Monday, October 26th, 2020, USEPA published its [Vessel Incidental Discharge National Standards of Performance](#) proposed rule in the Federal Register. This proposed rule would establish national standards of performance for discharges incidental to the normal operation of a vessel. Public comments on the proposed

rule were accepted for 30 days, and USEPA is addressing public and state concerns as the Final Rule is developed. Publication of the Final Rule is planned in late 2022 or early 2023.

- USCG established a working group in December 2019 to implement state coordination requirements required by the statute. The Ballast Water Reporting and Enforcement Data Working Group, with interested state partners (e.g., the USCG's Navigation Center, Smithsonian's National Ballast Water Information Clearinghouse [NBIC]), have continued their work virtually. This working group has provided state agencies with access to the Automated Information System vessel arrival system, and it developed an online portal to share NBIC Ballast Water Reports with interested states. State access to these systems and reports will greatly assist state efforts to enforce their ballast water permit and regulatory requirements. USCG is currently making preparations to expand the scope of (and to resolicit participation for) the working group to include enforcement coordination on all discharges covered by VIDA versus just ballast water.
- **AIS regulatory approach established.** Canada finalized its regulatory approach for protecting the Great Lakes from the spread of AIS (*Ballast Water Regulations*), based on the [2020 science advice](#), under which ballast water will be deemed to comply with standards when treated using an approved ballast water management system that is correctly installed, operated, and maintained.
- **Science advisory report on Regulation A-4 exemptions.** Canada published science advice on the IMO Ballast Water Convention's Regulation A-4 exemptions, entitled [Science Advice on Risk Assessment Methods for Granting Ballast Water Management Exemptions](#).
- **Ballast Water Research.**
 - [Design and installation of ballast water sample ports: Current status and implications for assessing compliance with discharge standards](#), June 2021
 - [Protocol for the verification of ballast water compliance monitoring devices](#), June 2020



Tank entering Byng Inlet, Georgian Bay, Ontario, Canada. Credit: Great Lakes Western Pilots District

- [Additional Analyses of Ballast Water Scenarios to Reduce the Establishment of Harmful Aquatic Species Across Canada and the Great Lakes](#), December 2020
- [Effectiveness of Ballast Water Exchange Plus Treatment as a Mechanism to Reduce the Introduction and Establishment of Aquatic Invasive Species in Canadian Ports](#), February 2022
- [Science advice on risk assessment methods for granting ballast water management exemptions](#), September 2021
- [Do Ballast Water Management Systems Reduce Phytoplankton Introductions to Canadian Waters?](#), August 2021.
- [Independent Laboratory Auditing Protocol for Facilities Performing Type Approval Testing of Ballast Water Management Systems](#), June 2020



Annex 6: Aquatic Invasive Species

Governmental partners continue to reduce populations of invasive carp in the Illinois River and in the tributaries of Lake Erie. New work was also initiated for the Brandon Road Lock and Dam to further prevent invasive carp from moving through Chicago-area waterways to Lake Michigan. In addition, government agencies and their partners have performed numerous invasive species control projects throughout the Great Lakes watershed over the last 3 years.

Key Achievements

- Developed and tested new state-of-the-art technologies to prevent the introduction and spread of aquatic invasive species (AIS) in the Great Lakes.
- Developed and implemented early detection and rapid response strategies to prevent the establishment of AIS.
- Enhanced coordination and contingency planning between Canadian and U.S. federal agencies in the Great Lakes basin to support state- and province-led AIS response actions.
- Prevented the introduction of bighead carp and silver carp into the Great Lakes from populations established downstream in the Illinois River and Mississippi River basin.
- Established new Provincial regulations to halt the introduction and spread of AIS through recreational boating pathways in Canada.
- States, provinces, municipalities, and community organizations around the Great Lakes undertook extensive and coordinated efforts to control existing invasive plants, like phragmites, and to eradicate new invasive plants, like water soldier.

Purpose and Overview

The purpose of [Annex 6 \(Aquatic Invasive Species\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement. Through this Annex the Parties shall establish a binational strategy to prevent the introduction of Aquatic Invasive Species (AIS), to control or reduce the spread of existing AIS, and to eradicate, where feasible, existing AIS within the Great Lakes Basin Ecosystem.”

The mission of the 2012 Canada-United States GLWQA’s Annex 6 (AIS) is to address the threat posed by AIS to the Great Lakes and support the function, health, and sustainability of native aquatic ecosystems. Priorities of the AIS Annex include preventing the introduction of new AIS and controlling, reducing, and eradicating (where possible) existing AIS within the ecosystem. The AIS Annex recognizes prevention as the single-most strategic AIS management option, with an emphasis on enhanced species risk screening, early detection, rapid response, and development and implementation of control technology. The AIS Annex further recognizes the importance of information exchange, with the long-term goal of preventing or minimizing significant social and economic impacts of AIS to Great Lakes water quality and the region’s millions of stakeholders.

ANNEX IMPLEMENTATION

The AIS Annex Subcommittee is co-led by Fisheries and Oceans Canada (DFO) and the U.S. Fish and Wildlife Service (USFWS). Organizations within the extended subcommittee include Environment and Climate Change Canada (ECCC); Great Lakes Commission; Great Lakes Fishery Commission (GLFC); Great Lakes and St. Lawrence Cities Initiative; The Nature Conservancy; Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF); the Ontario Federation of Anglers and Hunters; Invasive Species Centre; 1854 Treaty Authority; Chippewa Ottawa Resource Authority; Illinois Department of Natural Resources; Great Lakes Indian Fish and Wildlife Commission; Michigan Department of Environment, Great Lakes, and Energy (EGLE); Michigan Department of Natural Resources (MDNR); Minnesota Department of Natural Resources; National Oceanic and Atmospheric Administration; New York State Department of Environmental Conservation (NYSDEC); Ohio Department of Natural Resources (Ohio DNR); U.S. Environmental Protection Agency (USEPA); U.S. Geological Survey (USGS); and Wisconsin Department of Natural Resources (WDNR).

The work of the AIS Annex acknowledges, leverages, and supports the strategic planning and management efforts of interjurisdictional collaborations, including the Great Lakes Panel on Aquatic Nuisance Species (GLP), the Great Lakes and St. Lawrence Governors' and Premiers' Aquatic Invasive Species Task Force, the Council of Great Lakes Fishery Agencies Invasive Fish Committee, and the Invasive Carp Regional Coordinating Committee (ICRCC). These collaborations are well established in the Great Lakes basin, with strong coordination occurring through a network of binational and regional domestic AIS partnerships.

Binational Actions and Achievements

Priority for Action: Improve the effectiveness of early detection and rapid response activities through the development of a United States–Canada Great Lakes Federal Agency Mutual Aid Agreement for Early Detection and Rapid Response that compliments and supports the Great Lakes Governors' and Premiers' Mutual Aid Agreement and other actions.

- DFO and USFWS coordinated development of an interagency mutual aid framework to support federal agency response to invasive species in the Great Lakes basin. The framework complements the existing mutual aid agreement now used by states and provinces under the Conference of Great Lakes and St. Lawrence Governors and Premiers. A draft general framework has been developed and a work-group of Canadian and U.S. federal agencies and other Annex 6 Subcommittee members convened to scope key actions and recommendations to be included in the framework. This work is expected to be completed by 2022.
- The Council of Great Lakes Fisheries Agencies released [The Invasive Fishes Communications Protocol](#) in February 2021, which guides interagency

communication of new information involving invasive fish in the Great Lakes. The Council, which includes leaders from Canadian and U.S. federal, state, provincial, and tribal fisheries agencies, oversees the delivery of [A Joint Strategic Plan for Management of Great Lakes Fisheries](#). The communication protocol aims to ensure timely and accurate sharing of information, which is essential for addressing risks from invasive fish to Great Lakes fisheries.

Priority for Action: Prevent introductions of new invasive species into the Great Lakes, including silver carp, bighead carp, and black carp.

- In 2020–2022, the ICRCC supported interagency coordination of efforts to prevent the introduction and establishment of invasive carp in the Great Lakes basin. The ICRCC developed and implemented its annual Action Plan (see [2020 Asian Carp Action Plan](#), [2021 Asian Carp Action Plan](#), and [2022 Invasive Carp Action Plan](#)), comprised of agency detection, prevention, and control projects focusing on reducing risks from expanding populations established in the Mississippi River basin. Actions in Canada and the United States continue to focus on the early detection and suppression of silver carp, bighead carp, and black carp; no populations have been introduced and established in the Great Lakes.

- The U.S. Army Corps of Engineers (USACE) operated and upgraded the Electric Dispersal Barrier System (EDBS) in the Chicago Sanitary and Ship Canal near Chicago, Illinois. The EDBS serves as a primary measure for defending the Great Lakes from invasive carp. USACE completed construction of a new northern array of Permanent Barrier 1; construction of the new southern array is expected in 2022. Completion of this project will add a third permanent electric barrier array at the EDBS, providing enhanced protection for the Great Lakes. USACE and the State of Illinois, with substantial financial support from the State of Michigan, continued progress on the design, construction, and implementation of the [Brandon Road Interbasin Project](#) on the Des Plaines River near Joliet, Illinois. The project is designed to prevent the upstream transfer of AIS (including invasive carp) from the Mississippi River basin toward the Great Lakes. Pre-construction engineering and design was initiated in December 2020. In 2022, the Bipartisan Infrastructure Law provided USACE significant funding to complete design and initiate construction of the AIS barrier at the Brandon Road Lock and Dam. This project will consider structural barriers and deterrents including an electric barrier, acoustic deterrent, bubble curtain, and flushing lock.



Diagram of the Brandon Road Interbasin Project Recommended Structural Plan at the Brandon Road Lock and Dam on the Illinois Waterway near Joliet, Illinois. Credit: USACE

- A binational ecological risk assessment for black carp in the Great Lakes basin was carried out involving leading researchers and invasive species managers from around the basin with leadership

Why Target Aquatic Invasive Species?

Prevention and control actions conducted by Annex 6 partners target invasive aquatic species with a high risk of impacting native fish, animals, plants, and their habitats. Invasive fish, crustaceans, and aquatic and nearshore terrestrial plants degrade healthy ecosystems in the Great Lakes basin. AIS can outcompete native species for critical food and habitat needed for spawning and rearing, often leading to population declines. Invasive carp compete directly with native fish species for needed forage, including plankton, benthic invertebrates, and other food sources. Red swamp crayfish, more aggressive than native crayfish, outcompete native species for shelter and food and cause destruction of nearshore habitats by extensive burrowing. Hydrilla, water soldier, and water chestnut create dense vegetation patches with limited wildlife value, often clogging waterways and negatively impacting recreational uses. Non-native phragmites can form dense, single-species stands that negatively affect the biodiversity and ecological function of invaded habitats, compromising the use of wetlands and shorelines for recreational activities and potentially decreasing property values.

from DFO and support by the GLFC. The risk assessment forecasts the vulnerability of the lakes to the introduction, establishment, and spread of black carp and makes prediction of the damage it would cause to Great Lakes ecosystems. The peer-reviewed findings conclude that black carp, which feed on mussels and snails, pose a significant risk to the food webs of the lakes.

Priority for Action: Conduct rapid response actions, including continuing efforts to prevent the establishment of grass carp in the Great Lakes.

- In 2020–2022, agencies in Canada and the United States continued to conduct monitoring and removal efforts of grass carp in the Lake Erie basin, in support of the [Lake Erie Grass Carp Adaptive Response Strategy 2019-2023](#). Agencies signatory to the strategy include NDMNRF, Ohio DNR, MDNR, Pennsylvania Fish and Boat Commission, and NYSDEC. Additional partner agencies include USFWS, USGS, and DFO. Actions focused on

eradication or suppression of the population of grass carp in Lake Erie included:

- Conducting targeted interjurisdictional response actions.
- Informing seasonal habitat use and movement patterns via acoustic telemetry to evaluate potential control options.
- Evaluating the feasibility of seasonal barriers in identified spawning tributaries.
- Providing a bounty payment to commercial fishers to incentivize grass carp removals.
- Developing, implementing, and evaluating novel control methods.

Priority for Action: Implement control projects for invasive species already in the Great Lakes basin, including red swamp crayfish, monecious hydrilla, water soldier, water chestnut, and phragmites.

Red swamp crayfish

- MDNR, in collaboration with Michigan State University and USGS, are taking actions to eradicate red swamp crayfish from specific locations in the state. In addition to traditional methods of trapping and removal, innovative approaches were explored for a chemical application to be implemented and evaluated in 2022.

Hydrilla

- USACE served as the proponent of the [Great Lakes Hydrilla Collaborative](#) and conducted surveys and treatments of hydrilla in the Erie Canal and Tonawanda Creek, a tributary of the Niagara River in western New York.
- Ohio DNR collaborated with Cleveland MetroParks on early detection and eradication efforts for hydrilla in the Lake Erie watershed and with the state of Pennsylvania on hydrilla control at Pymatuning Lake.

Water soldier and water chestnut

- In 2020, NDMNRF developed prevention and response plans for the invasive plants [European water chestnut](#) and [water soldier](#), which are prohibited species under Ontario Invasive Species Act, 2015. The plans enable people and organizations to assist with monitoring and control activities for

these invasive plants without the need for an authorization under the Invasive Species Act.

- NDMNRF, Parks Canada, the Ontario Federation of Anglers and Hunters, Ducks Unlimited Canada, and others partnered to: (1) control water soldier in the Trent Severn Waterway and the Bay of Quinte and (2) control European water chestnut in Lake Ontario. Rapid response efforts led by Ontario Federation of Anglers and Hunters were also undertaken at Red Horse Lake (in the Gananoque River watershed of the St. Lawrence River).
- Efforts to engage citizens in surveillance were enhanced through public outreach by partners, including the Invasive Species Centre's (ISC) Early Detection and Rapid Response Network.
- In collaboration with NDMNRF, in 2021, the ISC launched a community action program called [IsampleON](#) to engage citizen science in sampling for AIS. Initially focused on sampling inland Ontario lakes for invasive mussels, the IsampleON and other strategic community science partnerships allowed ISC to pilot the use of new environmental DNA (eDNA) sampling techniques for public use in early detection of priority AIS (e.g., water soldier, invasive mussels, water chestnut).

Phragmites

- The Great Lakes Phragmites Collaborative (GLPC) continued to support actions to control phragmites across the basin. The GLPC is an adaptive management program designed to learn from phragmites management efforts across the landscape and support the informed use of best management practices (BMPs) for effective treatment. The



Flowering hydrilla. Credit: Michael Figiel, flickr.com

GLPC's [Phragmites Adaptive Management Framework \(PAMF\) Strategic Plan 2020–2026](#) establishes goals and objectives for the next 5 years. In 2020–2021, the GLPC grew its PAMF by enrolling 71 additional managements units and 17 new participants.

- Ohio DNR continued ongoing work to control invasive phragmites in the Lake Erie watershed in Ohio.
- WDNR conducted phragmites control efforts in the Great Lakes basin, including approximately 440 acres in 2020 and 140 acres in 2021, with follow-up monitoring performed to check for regrowth of previously controlled populations. Additional control work is planned for 2022.
- USGS, USACE, and academic partners continued to develop species-specific bioherbicidal treatments for control of phragmites and other invasive plants, focusing on genetic biocontrol treatments that limit the expression of characteristics that help invasive plants outcompete native plants.
- The [Long Point Phragmites Action Alliance](#), led by NDMNRF, the Nature Conservancy of Canada, Ontario Parks, ECCC, municipalities, and landowners continued successful efforts to control over 1,400 hectares of phragmites in the Long Point Region. This project, which includes the UNESCO Biosphere Reserve, is restoring coastal wetlands and protecting habitat for at-risk species and other fish and wildlife.
- NDMNRF is supporting work by Agriculture and Agri-Food Canada and academic partners, such as University of Waterloo and University of Toronto, to advance research into management practices (e.g., herbicides, native plant restoration, biological controls) for this invasive plant.
- In 2021, NDMNRF supported successful control of invasive phragmites within the city of Thunder Bay and within the highway 11/17 right-of-way. NDMNRF will continue to monitor these areas.
- NDMNRF supported work by the [ISC's Green Shovels Collaborative](#) to develop a [strategic framework for the management of phragmites in Ontario](#), which will help guide and inform control activities for this invasive plant in the province. Ten priority community initiatives received funding in 2021 to further community action on phragmites.

- The [Ontario Phragmites Working Group](#), with its membership of communities, organizations, and industry, provided guidance and coordination for multiple initiatives aimed at phragmites control throughout the Great Lakes basin. For example, Georgian Bay Forever, a charity group focused on ecosystem protection, delivered significant efforts to reduce and eliminate this invasive plant on the [eastern shores of Georgian Bay](#).

Invasive Mussels

- The Invasive Mussel Collaborative (IMC) continued to support actions to control zebra and quagga mussels across the basin. In 2021, the IMC developed an interactive geographic prioritization tool to identify critical coastal habitats that would most benefit from zebra and quagga mussel control efforts. The IMC anticipates release of a control method summary for management of zebra and quagga mussels in the Great Lakes.



Zebra mussels encrusting a propeller. Credit: USFWS

- Annex agency partners conducted key research focused on developing and testing new species-specific management tools. USGS conducted research to develop methods for open-water application of copper-based molluscicides to suppress zebra and quagga mussel populations.

Priority for Science: Test technology that prevents the spread of AIS while allowing the movement of other ecosystem components through canals and waterways.

- The ICRCC, a binational partnership of 28 Canadian and U.S. federal, state, provincial, tribal, and local

agencies, supported development and testing of new technologies focused on preventing the movement of invasive carp into the Great Lakes from the Mississippi River basin. Agencies conducted large-scale field evaluations of barrier technologies, including underwater sound, bubbles, lights, and carbon dioxide. These deterrent barriers could be deployed at strategic waterway “choke points” to prevent further range expansion by invasive carp.

- USGS initiated a multiyear study at Lock and Dam 19 on the upper Mississippi River to determine the effectiveness of an underwater acoustic deterrent system as a barrier to invasive carp. The sound-only deterrent was designed by USGS and USACE to prevent upstream movement of invasive carp through navigation locks with potentially lesser effects on native species; this deterrent system has

potential for use in protecting the Great Lakes. The field study will conclude by 2023.

- USFWS, USGS, and USACE are conducting a field study of the effectiveness of a BioAcoustic Fish Fence (BAFF) as a behavioral invasive carp deterrent. Installed in 2019 at Barkley Lock and Dam in Kentucky, the BAFF uses a combination of underwater sound, bubbles, and lights to create a barrier to fish movement. If effective, the technology could be strategically deployed at navigation locks (potential “pinch points” for fish passage) to prevent upstream movement of invasive carp. The field study will conclude in 2023.
- ICRCC agencies are collaborating on a study to evaluate the effectiveness of bubbler technology for removing entrained small fish from commercial barges before they enter a navigation lock. The



Installation of a multi-speaker soundbar at Lock 19 on the Mississippi River (Keokuk, Iowa), February 2021. This project is testing a prototype underwater acoustic deterrent system at a known invasive carp fish passage “pinch-point”.
Credit: Marybeth Brey, USGS

primary field study is proposed for 2022 and will use barges deployed under normal operating conditions in the Illinois Waterway. Testing will be conducted to ensure that bubble arrays do not interfere with safe vessel operation.

Other Binational Achievements

- In May 2021, the Great Lakes and St. Lawrence Governors' and Premiers' member agencies conducted a virtual AIS response exercise to foster collaboration and enhance response capabilities among the signatory agencies of the Great Lakes and St. Lawrence Governors' and Premiers' [*Mutual Aid Agreement for Combating AIS Threats to the Great Lakes – St. Lawrence River Basin*](#). The exercise, hosted by WDNR, focused on species on the Great Lakes and St. Lawrence Governors' and Premiers' "Least Wanted" AIS list and involved responding to detection of invasive carp in the St. Croix River.
- The GLP and GLFC convened an Organisms in Trade (OIT) symposium in June 2021 with AIS managers and conservation law enforcement to identify gaps in current management and opportunities for enhanced coordination. Law enforcement and AIS managers from federal, state, and provincial agencies around the Great Lakes discussed case studies, legislation, tools, and common issues associated with invasive species in trade. The GLP and the GLFC Law Enforcement Committee continued coordinating in 2022 to collaboratively address gaps in regulations and to improve efficiency in detecting invasive species moving through OIT pathways.
- The Great Lakes Commission and The Nature Conservancy developed a [*virtual information "dashboard"*](#) through the Blue Accounting initiative, which outlines recreational boating pathway prevention programs among Great Lakes states and provinces. Users can navigate the interactive dashboard to better understand the current level of consistency between jurisdictions' prevention strategies. An accompanying table outlines gaps and opportunities for continued development for each jurisdiction.
- The Great Lakes Commission and The Nature Conservancy developed a virtual dashboard outlining OIT pathway prevention strategies via analysis of regulated species lists. Users can navigate an interactive map to compare how many predefined

priority species (i.e., "Least Wanted" AIS List, Canadian and U.S. federally regulated species) are regulated by different jurisdictions. Companion tables compare the protectiveness of species regulations by highlighting what activities are regulated (e.g., possession, sale).

- The GLP and the GLFC's Great Lakes Law Enforcement Committee partnered with the National Sea Grant Law Center to conduct a legal assessment of variability in federal/state/provincial/tribal-regulated species lists and related authorities and to identify priority actions to address identified gaps and vectors of concern. The project, Building Consensus to Identify and Address Priority Aquatic Invasive Species and Vectors in the Great Lakes, is aimed at developing model legal frameworks to deal with pathways and species of concern.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, Canada and the United States pursued a variety of domestic projects that also support commitments under Annex 6 (AIS).

Canada

- Science to support preventing the spread of AIS.
 - DFO completed modeling research on the sampling effort needed to inform surveillance strategies for early detection of and response to Asian carps. This research was peer reviewed and the resulting science advice regarding optimizing the design of early detection will be published in 2022.
 - Researchers at the University of Toronto, working with DFO, have completed research on: (1) how sound and light can be used as controls for Asian carps; (2) the potential for Asian carp to spawn in Great Lakes tributaries; and (3) the dynamics of Asian carp egg and larval movement in rivers to inform detection and potential control actions.
 - DFO, with collaborators, has completed modeling and collected supporting data on the Thames River, a tributary identified as high risk, with the aim of identifying potential spawning locations

for invasive carps and to determine possible areas that may require attention for their removal.

- Prevent introductions of new invasive species into the Great Lakes.
 - Through the [Asian Carp Response Plan](#), DFO and NDMNRF coordinated extensive early detection surveillance for the four Asian carp species (silver carp, bighead carp, black carp, and grass carp) focused on high-risk locations to enable response actions and prevent establishment of these high-risk species.
 - DFO's Asian Carp Program crews conducted early detection surveillance despite challenges posed by COVID. The surveillance involved a full range of techniques, including traditional sampling gear for all life stages (eggs and larvae) for the four Asian carp species. Surveys were focused on high-risk sites in western Lake Ontario, western Lake Erie, and southern Lake Huron.
 - NDMNRF amplified early detection efforts for the Asian carp species with broad-scale eDNA sampling as another tool for detecting organisms at low abundance. They did not detect eDNA for any of the Asian carps in 2020 or 2021.
 - DFO Science led a Canadian Science Advice Secretariat peer review of early detection effectiveness for Asian carps, including grass carp. Using analyses of detection results since the program's inception, this peer-review provides science advice about catchability and improving the detection of Asian carps. Publications will be available in 2022.
 - DFO's Asian Carp Program developed a series of new initiatives to engage the public and partner agencies in efforts to detect and prevent Asian carps in the Great Lakes:
 - A new image-recognition mobile app for public identification of fish and a response communications protocol and tool kit for partners are being completed during 2022.
 - New public outreach tools include a [documentary-style film featuring recreational anglers](#) and the construction of an exhibit at Ripley's Aquarium in Toronto.



Crews searching for invasive Asian carp. Credit: USACE, Chicago District

- DFO's Asian Carp Program worked with ISC to raise public awareness about the threats Asian carps pose to the Great Lakes.
- The [Asian Carp Canada website](#) has been updated with new elements that highlight the specific risks posed by silver carp, bighead carp, and black carp.
- The ISC used influencer marketing, digital advertising on various angler networks, and social media posts to highlight the impacts of Asian carps.
- The threats of Asian carps were communicated through the Asian Carp Canada webinar series and ISC's monthly webinar series.
- NDMNRF continued early detection and rapid response activities for AIS identified on the "Least Wanted" AIS list. In 2021, NDMNRF carried out standardized lake-wide early detection and monitoring following the AIS protocol at sites in the upper Great Lakes, including Thunder Bay, Nipigon Bay, and the Upper St. Marys River, where they were assisted by DFO Science. This protocol employs three different assessment techniques: small-mesh gillnetting, fyke trap nets, and boat electrofishing. No new invasive species were found.
- Water samples collected for Asian carp early detection are also tested by NDMNRF for other high-priority species that are included on the "Least Wanted" AIS list.

- NDMNRF continued its [Broad-scale Fisheries Monitoring Program](#) within inland lakes in the Great Lakes watershed, which includes surveillance for AIS. This program of annual sampling of select lakes includes zooplankton hauls and netting to detect invasive fish.
- NDMNRF continued to collaborate to increase public interest and engagement about prevention and detection of other invasive species with partners such as the ISC's Green Shovels Collaborative and the Ontario Federation of Anglers and Hunters.
- NDMNRF continued to collaborate with DFO Science and other agencies with an interest in the management of the St. Lawrence River through the Tench Binational St. Lawrence River Working Group. The working group coordinated and discussed relevant surveillance activities, reporting, and research projects with the aim of preventing a [Tench invasion](#) of the Great Lakes.
- Conduct response actions.
 - DFO's Asian Carp Program captured one grass carp in Jordan Harbour in Lake Ontario during 2020. The specimen was a diploid female, and as a result, an Incident Command System (ICS) response was completed as per the Strategic Response Protocol. Three DFO crews sampled intensively for 5 days and did not capture additional grass carp.
 - The challenges of the COVID-19 global pandemic continued through 2020 and 2021, forcing a shortened early detection surveillance season with reduced crew capacity. During 2021, two early detection surveillance crews sampling throughout the summer and fall, prioritizing locations with the highest risk of invasion in Lake Ontario, Lake Erie, and Southern Lake Huron. No grass carp or other Asian carp species were captured during the field season. Plans for 2022 include steps toward resuming full pre-pandemic detection surveillance with new approaches including expanding training opportunities and updates to the ICS protocols to accommodate the engagement of staff working virtually from a variety of locations.



Grass carp. Credit: USFWS

- DFO's Asian Carp Program worked with the ISC to focus public outreach efforts on grass carp as the most immediate threat to Canadian waters of the Great Lakes. Targeted digital outreach work has focused on grass carp (webinars, videos, social media campaigns, influencer marketing, and ads in angler-specific publications). Partners of Asian Carp Canada developed an identification guide that highlights the specific features of grass carp that sets them apart from common look-a-like species, and the guide provides detailed steps on how to report and retain grass carp legally for analysis. To develop and target future campaigns, the ISC conducted a survey for anglers that assessed their knowledge of grass carp and their preferred sources of information (e.g., magazines, online sources).
- Identify gaps in AIS policies and regulations.
 - The [Ontario Invasive Species Strategic Plan \(2012\)](#) and the [Made in Ontario Environment Plan \(2018\)](#) continue to guide the actions of the NDMNRF to prevent new invasive species introductions into the Great Lakes. The province takes a multi-pronged approach to prevention, which includes regulation, enforcement action, and public outreach.
 - NDMNRF identified important regulatory gaps for several priority invasive species. In response, starting January 1, 2022, [13 additional invasive species and watercraft as a carrier of invasive species](#) are regulated under the Invasive Species Act, 2015. Ontario now joins several other jurisdictions in regulating all species on the

“Least Wanted” AIS list. NDMNRF is working on outreach and public engagement on the new recreational watercraft regulations.

- NDMNRF’s Enforcement Branch continued to implement an AIS-focused action plan that was developed in 2014. The action plan focuses efforts on industries as potential pathways for AIS to enter or spread in Ontario through live baitfish, pet/aquarium supplies, water garden supplies, and food fish. Strategies under the action plan include increasing affected sectors’ awareness of rules through outreach, education, and promotion; understanding markets and movements of invasive species through information gathering; and inspecting the regulated sectors for compliance.
- In 2021, the Government of Canada introduced new [Ballast Water Regulations](#) to reduce the spread of AIS within Canada. The important new regulations transition from the traditional method of ballast water management (the exchange of ballast water in mid-ocean) to the use of modern ballast water management systems (the cleaning of ballast water to remove organisms before release). Canadian ships traveling abroad and those coming into Canada from abroad are required to meet standards by 2024. Canadian vessels that do not voyage internationally (other than to U.S. Great Lakes ports) will need to meet the new standards depending on when they were built. For further details about regulations and actions about shipping and vessel discharges see [Annex 5: Discharges from Vessels](#) for more information.

United States

- Test technology that prevents the spread of AIS.
 - Ohio DNR partnered with the GLFC, MDNR, and USGS to conduct a feasibility study for a grass carp barrier alternative on the Sandusky River in Ohio, a main tributary of Lake Erie where grass carp spawning has been documented. A behavioral deterrent was identified as the best alternative through the initial assessment. Building on results from the study, in 2022, USACE is conducting a Federal Interest Determination (FID) for the project, which is being

implemented through the Great Lakes Fishery and Ecosystem Restoration program (GLFER). USACE is expecting the FID to be formally completed later in summer 2022. Assuming there is a federal interest, the USACE will develop a Feasibility Cost Sharing Agreement to continue with the feasibility and design process in advance of construction. As the USACE proceeds with its FID, it is also partnering with Ohio DNR, GLFC, USGS, USFWS, DFO, University of Toledo, and Michigan DNR through the Grass Carp Advisory Committee to further evaluate design and implementation considerations for a potential barrier on the Sandusky River through the GLFER.

- Prevent introductions of new invasive species into the Great Lakes.
 - USFWS completed [AIS Ecological Risk Screening Summaries](#) to identify highest-risk aquatic species that are not yet present in the Great Lakes, but which have a history of invasiveness and a climate match to the region. Risk screening summaries are used by resource agencies to inform options and strategies for managing risk.
 - The Great Lakes Commission and The Nature Conservancy collaborated with the Great Lakes states to develop a regional communications plan to support the existing Interstate Surveillance Framework for the U.S. Waters of the Great Lakes and Great Lakes Basin AIS Interstate Response Framework.
 - The Ohio DNR, USACE, and other partners continued AIS pathway closure actions for three Great Lakes/Mississippi River interbasin connections at the Ohio Erie Canal, Little Killbuck Creek, and Grand Lake St. Marys. The USACE completed the closure of the Ohio Erie Canal connection in March 2020. Also, Ohio DNR completed appraisals for property acquisition to support closure of the Little Killbuck Creek pathway and initiated landowner negotiations in 2022. The final design for the Little Killbuck Creek closure was initiated in 2022 and will be completed in 2023. The preliminary design for the final phase to close the connection at Grand Lake St. Marys has been completed, and a final design will be completed in 2022.



USFWS (Alpena Fish and Wildlife Conservation Office) AIS early detection and monitoring team members sort the catch from a gill net deployed on Lake Erie offshore from Cleveland, Ohio during the 2021 Comprehensive Early Detection and Monitoring Program. Credit: Janine Lajavic, USFWS

- WDNR continued their Clean Boats/Clean Waters Education and Outreach program to inspect boats and educate boaters about actions they can take to prevent the introduction and movement of AIS from lake to lake. The program uses citizen volunteers and boat inspectors deployed at public boating access locations. In 2020 and 2021, over 245,000 boats were inspected and over 475,000 stakeholders were contacted.
- During the 2021 boating season, MDNR conservation officers continued with efforts to enforce “Clean, Drain, Dry” regulations and educate hunters, anglers, and boaters about AIS regulations. Officers focused on collaborating with lake associations and others during the annual [AIS Landing Blitz](#) and peak boating period around



1854 Treaty Authority biologist conducting surveillance for new infestations of rusty crayfish, *Orconectes rusticus*, in the Lake Superior basin and 1854 Ceded Territory, Summer 2021. Credit: 1854 Treaty Authority

- the Independence Day holiday, as well as educating waterfowl hunters. Nearly 10,000 individual AIS-focused contacts were made, and most of those individuals were already familiar with AIS issues and compliant with all regulations.
- In September 2021, officers from the Great Lakes Enforcement Unit of the MDNR partnered with officers from the Motor Carrier Division of the Michigan State Police to identify and inspect fish haulers in southeast Michigan. Over a 3-day period, officers monitored commercial traffic and inspected multiple vehicles that were transporting aquatic cargo that could potentially aid in the spread of invasive species. Cargo included pet store deliveries and fresh seafood being transported both to and through Michigan. All haulers were found to be in compliance with Michigan AIS regulations, including the recently signed MDNR’s Director’s Order requiring invasive fish species to be eviscerated. This detail marked the beginning of a partnership between two state law enforcement agencies that continues to produce valuable intelligence and a heightened level of protection against AIS. Plans are already in the works to expand this partnership in the future.
- The Michigan Department of Natural Resources approved an order to require evisceration of

prohibited species for transport including grass, bighead, silver, and black carp. This order will prevent the accidental introduction of live fish transported on ice for the food trade.

- Conduct response actions.
 - Agency and academic partners collaborated to monitor and contain grass carp populations in the Lake Erie basin following the [Lake Erie Grass Carp Response Strategy \(2019–2023\)](#). The strategy, finalized in 2019 by Ohio DNR, MDNR, and other Lake Erie agency partners, provides a road map for grass carp management over the 5-year period.
 - In 2020–2022, partners established and deployed dedicated grass carp “strike teams” focused on capture and removal of grass carp from the western basin of Lake Erie, including the key tributaries of the Sandusky River and Maumee River. Effort included tagging and tracking grass carp with the Great Lakes Acoustic Telemetry Observation System and real-time receivers.
 - Ohio DNR partnered with the University of Toledo, MDNR, GLFC, USFWS, and USGS to determine grass carp catchability and population size; additional work is focusing on developing this data for the Sandusky River, a key focal area for grass carp control in the western basin.
 - USGS conducted model simulations to identify probable grass carp spawning areas in the Maumee River using the “FluEgg” drift model as well as analyses of grass carp eggs and larvae previously captured by field crews. Analyses focused on identifying the hydrologic conditions and other parameters that lead to the highest potential for grass carp recruitment in the Maumee River. Other work by USGS included developing and testing of a “SpawnCast” dashboard to provide grass carp strike team leaders with forecasts of potential grass carp spawning events.
 - WDNR conducted numerous AIS response actions in 2020–2022, which were informed by results from early detection surveys and stakeholder updates. Response actions were focused on control of floating marsh pennywort, starry stonewort, graceful cattail, butterfly dock, water lettuce, Japanese stilt grass, New Zealand mudsnail, and European frogbit. WDNR led an investigation into an illegal operation which had reared, sold, and shipped over 1,000 marbled crayfish to 12 other states. The discovery of a red swamp crayfish in a pet store led to an investigation by WDNR that revealed 900 others of this species in pet stores throughout the state. Investigations concluded on this case in 2021 with a total of 38 charges and thousands of warnings issued.
- Implement control projects for invasive species already in the Great Lakes basin.
 - In 2020, EGLE Water Resources Division led response efforts on Michigan’s watch list of aquatic invasive plants, which included actively working toward eradication at 14 locations. Control actions (herbicide/hand pull) were implemented at nine of those locations. Post-treatment monitoring was implemented at the remaining sites to monitor treatment efficacy and ensure long-term control. Though no sites were deemed eradicated (3 years without the target species), five sites are nearing eradication. Response efforts continued in 2021, focused on actively working toward eradication at 13 locations. Control actions (herbicide/hand pull) were implemented at nine of those locations. One location previously infested with parrot feather was deemed to be fully eradicated (three consecutive years without regrowth) after control actions were implemented in 2016–2017. Three additional sites are nearing eradication. Michigan EGLE Water Resources Division will continue to lead response efforts on Michigan’s aquatic invasive plants; three locations are anticipated to be eradicated in 2022.
 - In 2020, the Ohio Administrative Code was revised to allow the expeditious listing of animal species as injurious through reference instead of following the normal rulemaking process. Ohio subsequently added the marbled crayfish and New Zealand mudsnail to the state’s injurious list in 2021 due to their high risk to native species and to align with the “Least Wanted” AIS List. In 2022, Ohio DNR is working with the Ohio Department of Agriculture to list the water soldier plant as a prohibited species.



Annex 7: Habitat and Species

Over the last 3 years, United States and Canadian agencies have sponsored hundreds of projects that restore the health of Great Lakes watersheds, coastlines, and aquatic habitats. Both countries also enhanced their ability to conserve and manage coastal wetlands through complimentary domestic science initiatives.

Key Achievements

- Protected and restored habitat and species that support Great Lakes water quality.
- Assessed and reported on coastal environments to support protection and restoration efforts and to increase the resiliency of coastal habitats.

Binational Actions and Achievements

Priority for Action: Through existing programs, including the U.S. Great Lakes Restoration Initiative (GLRI) and Canada Nature Fund, protect and restore habitat and species that support Great Lakes water quality.

- Through existing programs, including the U.S. GLRI and Canada Nature Fund, Great Lakes habitat and species are being protected and restored; highlights of these efforts are described under the Domestic Actions and Achievements section, below.

Purpose and Overview

The purpose of [Annex 7 \(Habitat and Species\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by conserving, protecting, maintaining, restoring, and enhancing the resilience of native species and their habitat as well as by supporting essential ecosystem services.”

The Habitat and Species Annex focuses on restoring and protecting native species and their habitats. The Great Lakes support a rich diversity of fish, wildlife, and plant species. Thriving habitats and native fish and wildlife communities contribute to the social and economic vitality of the Great Lakes region and provide significantly important ecosystem services. Unfortunately, many human activities put pressure on the ecosystem and result in the loss or degradation of habitats, fragment habitats and natural systems, threaten adverse effects from invasive species, and reduce the health and abundance of native species. This annex guides and facilitates collaborative efforts to restore, protect, and conserve the health, diversity, and resilience of Great Lakes habitats and species to help attain the GLWQA's General Objectives for the Great Lakes.

ANNEX IMPLEMENTATION

Implementation of the Annex 7 commitments was led by the U.S. Fish and Wildlife Service (USFWS) and Environment and Climate Change Canada (ECCC) and supported by the Annex 7 Subcommittee, which includes members from Great Lakes Fishery Commission; Indiana Department of Environmental Management; Michigan Department of Environmental Quality; National Oceanic and Atmospheric Administration; U.S. Army Corps of Engineers (USACE); U.S. Environmental Protection Agency (USEPA); U.S. Geological Survey (USGS); U.S. National Parks Service; Wisconsin Department of Natural Resources; Fisheries and Oceans Canada; Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry; and Parks Canada.

Priority for Science: Assess coastal environments, with a binational focus on coastal wetlands through the Great Lakes Coastal Wetland Monitoring Program (United States) and the Assessing and Enhancing the Resilience of Great Lakes Coastal Wetlands initiative (Canada), to support protection and restoration efforts and other actions that increase resiliency of coastal habitat and species.

- The United States assesses coastal environments through USEPA's [Great Lakes Coastal Wetland Monitoring Program \(CWMP\)](#), a collaboration between USEPA's Great Lakes National Program Office and academic partners located in both the United States and Canada. The CWMP uses a comprehensive approach to sample and assess [all major coastal wetlands](#) throughout the Great Lakes basin using standardized procedures. Monitoring of birds, amphibians, fish, macroinvertebrates, plant communities, and water quality occurs at a subset of the Great Lakes coastal wetland sites annually, and these data are used to assess the status and trends of Great Lakes coastal wetland conditions.
- To better understand coastal wetland vulnerability to climate change, and to determine how resource managers can enhance wetland resilience, in 2022, ECCC completed a project under the Great Lakes Protection Initiative (GLPI) focused on [Assessing and Enhancing the Resilience of Great Lakes Coastal Wetlands](#), which included an integrated climate change vulnerability assessment for 20 Canadian coastal wetlands. Study findings show that the projected lake level variations and extremes put coastal wetlands at risk, with significant losses in wetland area anticipated during high-water events. Canadian coastal wetlands in the St. Clair–Detroit River System and on the north shore of Lake Erie are most vulnerable, with limited capacity to adapt based on existing land-based stressors and natural characteristics. This information was shared with resource managers, scientists, stakeholders, and policymakers to develop adaptation strategies to enhance coastal wetland resilience based on local conditions and to collectively implement concrete adaptation actions.
- Natural resource practitioners working in Great Lakes coastal ecosystems face the daunting challenge of identifying and implementing efforts to facilitate adaptation of coastal systems to climate change. Since 2020, the United States has led, in collaboration with Canada and many stakeholders, the development of a menu of climate adaptation strategies and approaches for Great Lakes coastal ecosystems. The [Coastal Adaptation Menu](#) will be finalized in 2022 and will provide coastal resource managers with options for ways to integrate climate change adaptation into on-the-ground project planning and implementation.
- Coastal environments are critically important production areas for fish communities that support highly valued fisheries. Through the lake committees of the Great Lakes Fishery Commission, fisheries management agencies have collectively [identified key coastal areas in their environmental priorities](#) for attaining fish community objectives in all Great Lakes. Coastal assessments support management actions to improve fish production through wetland restoration and other nearshore projects.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, the United States and Canada pursued a variety of domestic projects that also support Annex 7 (Habitat and Species).

United States

- **Lake trout restoration.** Collaborative efforts to restore populations of lake trout, a native offshore predator, supplemented with GLRI funding, continued in lakes Michigan, Huron, Erie, and Ontario. Long-term monitoring surveys conducted annually by the USFWS since 1994 reveal that more than 80% of lake trout captured in the northern part of Lake Huron were of wild origin. Continued recruitment and catch rates of wild lake trout have increased markedly since 2008. Increased stocking in Lake Michigan and a reduction in mortality caused by sea lampreys has increased lake trout abundance in northern management units, with natural reproduction being evident throughout the Great Lakes basin. In Lake Ontario, annual surveys revealed that catch per unit effort for adult lake trout of hatchery origin was the greatest since 1998.
- **Fish habitat utilization/mass marking.** Supported in part by GLRI, the Great Lakes Mass Marking Program continued at the request of the Great Lakes Fisheries Commission, with the overall goal of marking/tagging all salmonines stocked into U.S. waters of the Great Lakes. COVID-19 pandemic-related restrictions limited tagging efforts to federal lake trout hatcheries in 2020 and cancelled field operations to recover biodata and tags from the sport fishery. Accordingly, staff scientists redirected efforts to conduct a comprehensive review of past years' field and coded-wire tag extraction data. In 2021, a full program of marking nearly nine million fish and providing a full suite of data analyses and science support is ongoing.
- **Reef Protection.** The Buffalo Reef Task Force (a state, federal, and tribal partnership) is developing a report that will detail the cost, timeline, and requirements for potential solutions to the stamp sands (mine tailings) impacting a 2,200-acre spawning reef in Michigan's Upper Peninsula. The Michigan



USFWS biologists with the Green Bay Fish and Wildlife Conservation Office measure lake trout captured during an annual survey on Lake Michigan. Credit: USFWS

Department of Environment, Great Lakes, and Energy; Michigan Department of Natural Resources (Michigan DNR); USACE, and the Keweenaw Bay Indian Community have spent the past 3 years keeping juvenile whitefish habitat near Grand Traverse Harbor/Buffalo Reef clear during fall and winter storm events. Michigan DNR removed a 30-foot eroding cliff of stamp sands from the water's edge, and the USACE removed 112,000 cubic yards of stamp sands from a submerged ancient riverbed north of the reef. The USGS and Great Lakes Indian Fish and Wildlife Commission have been conducting studies to determine where lake trout and lake whitefish spawn on the reef by using otoliths (i.e., fish ear bones used to evaluate fish age), egg traps, and telemetry.

- **Restoring river connectivity for native fish after removal of Elkhart Dam, Indiana.** The Elkhart River is a tributary to the St. Joseph River and extends a total of 210 miles through portions of northern Indiana and southern Michigan before flowing into Lake Michigan. The Elkhart Dam substantially altered the character of the riverine water system. It played a central role in the decline of migratory aquatic species by severing historic migration routes and preventing healthy recruitment, effectively obstructing passage of 20–30 native fish species, including the state endangered greater redhorse and the highly prized walleye. In 2020, removal of the Elkhart River Dam in Elkhart, Indiana, was

completed and made possible by GLRI funding. More than 47 miles of stream connectivity and improved riverine habitat were created by providing more natural hydrology, temperature, flow pattern, and sediment transport, while also providing additional education and recreational opportunities. The completed restoration project enables the passage of aquatic species to areas far upstream of the dam, improves riverine habitat for endangered and threatened fish and mussel species, and stabilizes the stream bank.

- Lake sturgeon streamside rearing.** Streamside rearing, which refers to raising juvenile lake sturgeon in water that is pumped from the target river, promotes imprinting and site fidelity, increases exposure and adaptation to natural environmental conditions, and acclimates the lake sturgeon to the river in which they are stocked. Multiple streamside rearing facilities currently operate in Great Lakes tributaries and are supplemented with GLRI funding. Young-of-year lake sturgeon have been reared at streamside facilities and released, including more than 3,000 fish released in the Saginaw River in Michigan and more than 5,000 fish released in both the Ontonagon River in Michigan and the Maumee River in Ohio to date. More than 50,000 fall fingerlings have been stocked from the Lake Michigan facilities to date with the intent to establish founding populations of 750 adults in each river over a 25-year period.
- Stream restoration and eastern brook trout introduction by the Seneca Nation of Indians.** The eastern brook trout is a culturally and traditionally important species for the Seneca Nation and provides sustenance for the Tribe and their neighbors. This species is widely considered an indicator of clean freshwater but has experienced a dramatic decrease in the Great Lakes due to water quality and habitat loss. In 2021, the Seneca Nation of Indians implemented an in-stream and riparian restoration of a tribally important stream along with the introduction of eastern brook trout. Using GLRI funds, the Seneca Nation of Indians continued to conduct in-stream and riparian restoration projects in the Cattaraugus Territory that will create additional suitable and sustainable environments for the eastern brook trout. The Cattaraugus Territory



A biologist with the Conservation Resource Alliance monitors water depth and velocity at a restoration site on the Platte River in Northwest Michigan.
Credit: Conservation Resource Alliance

is also home to a genetically unique population of eastern brook trout. To increase habitat and improve water quality for this important species, the Tribe has reduced barriers to connectivity and increased natural stream flows. In 2021, the Seneca Nation removed an old collapsed pipe in the Longhouse Road Spring Fed Creek and replaced it with a new pipe. Limestone was also added to the banks to reduce the potential for erosion along the streambank and around the culvert. Additionally, eastern brook trout were released into the stream in 2020–2021 to increase native population size.

- Coregonid (cisco/bloater) propagation and stocking.** More than 4 million fingerling cisco have been cultured and released to date through year four of a 10-year restorative stocking evaluation in Saginaw Bay, which is supported in part by GLRI. Targeted summer and fall assessments were implemented in fall 2021 to determine if stocked cisco have recruited and are returning to spawn. A total of four fish were recaptured in 2021, and all were determined to be from fall releases. Processing of aging structures is ongoing to estimate release year/year class. A total of 60,500 fingerling cisco and 63,000 spring yearling bloater were stocked into Lake Ontario in October 2020 and April 2021, respectively. Work continued towards establishing multiple hatchery brook stock lines for both species. Egg production from these lines is anticipated in 2022.

- **Successful manoomin management and restoration by the Fond du Lac Band.** In 2020, the Fond du Lac Band of Lake Superior Chippewa used GLRI funding to continue manoomin (wild rice) management, habitat enhancement, and restoration activities. Manoomin is a critically important cultural resource whose habitat also supports numerous wildlife species, both migratory and resident, which are of great importance to Fond du Lac Band members. The Tribe was able to focus its beaver dam removal, beaver trapping, water level recording, management of water control structure gate and stop log openings, and mechanical vegetation removal to manage manoomin in Perch Lake. During the same period, the Fond du Lake Resource Management Program also constructed eight 20-foot by 100-foot exclosures in Duck Hunter Bay North to prevent waterfowl herbivory; monitored germination and growth of 86 acres of manoomin in bays reseeded in 2019; purchased 13,816 pounds of seed from tribal harvesters; reseeded 132 acres at a minimum of 100 pounds per acre under guidance from project partners; and removed exclosures following seed formation. The Fond du Lac Band will continue managing this critically important species in future years.
- **Protecting and maintaining a rare and important Great Lakes forested habitat.** The U.S. Forest Service (USFS) Huron-Manistee National Forest restored and improved connectivity within oak savannas and barrens habitats. In 2020, USFS staff continued treatments, including manual, mechanical, and chemical removal of trees and shrubs; prescribed burning; mechanical site preparation; seeding and planting native forbs and grasses; and other activities necessary to maintain 2,300 acres of oak savanna and 515 acres of associated upland habitat. These activities build on an ongoing multiphase, large-scale cooperative project with over 34 partners in the western Lower Peninsula of Michigan. Many of these habitat types have declined over the past century due to reforestation, fire control efforts, natural succession of woody vegetation, and human development. Oak savannas are now estimated to cover less than 1% of their historic extent. Plants and animals that depend on these habitats have decreased in numbers, including the federally endangered Karner blue butterfly. Karner blue butterflies now occupy more than 29
- of the new savanna creation areas. Observations of other plant and wildlife species, including the federally threatened eastern massasauga rattlesnake and other species at risk, are also increasing.
- **Restoration of bees native to the Great Lakes basin.** The GLRI continued to fund USFWS-led collaborative efforts with the USFS, National Park Service, USGS, and Natural Resources Conservation Service to conserve native insect pollinators throughout the Great Lakes basin. This landscape-scale effort is engaging federal, state, tribal, private, academic, utility, and other partners to conduct native bee research, surveys, habitat restoration, and outreach within the basin. Accomplishments during the reporting period include developing a habitat restoration project site ranking tool; selecting and prioritizing pilot focus areas; restoring more than 100 acres of native habitat; developing a pollinator landscape guide; surveying native bees on national forest, national park, national wildlife refuge, and private lands in focus areas; conducting virtual pollinator workshops; conducting research on native bees; identifying bee specimens collaboratively within and between agencies; and assessing pollinator stressors and threats, including pesticides.
- **Advancing state-of-the-art reef creation at Fort Sheridan, Illinois.** The USACE Chicago District completed construction of the Fort Sheridan Great Lakes Fishery and Ecosystem Restoration project at the Fort Sheridan Forest Preserve in unincorporated Lake County, Illinois. Most of the \$9.1 million federal share was supported by GLRI funds. This final project phase included placing underwater living reef structures near shore along the Fort Sheridan Forest Preserve. Materials and design of the constructed reef were based on surveys of historic reefs important to fish in southern Lake Michigan. In total, the project included restoring 75 acres within four main ravines, 40 acres of bluff and 12 acres of dune along the coastline, and about 60 acres of riparian woodland.
- **Restored wetlands lessen historic Michigan flooding.** Historic heavy rainfall in mid-May of 2020 in Michigan caused two dams on the Tittabawassee River—a tributary of the Saginaw River in the Lower Peninsula—to fail, creating extreme flooding and forcing more than 10,000 people from their homes.

A massive, ongoing GLRI wetland restoration project by USFWS, Ducks Unlimited, the University of Michigan, and other partners helped lessen some of the impact of that flooding, again underscoring the importance restoring wetland habitats to achieve multiple benefits for fish and wildlife, water quality, flood retention, and property protection. As the historic water levels traveled down the Saginaw River watershed, managers at the USFWS's Shiawassee National Wildlife Refuge monitored flooding and took action. More than 1,000 acres of former agriculture land recently restored in flood-plain wetlands were reconnected to the adjacent Shiawassee River for the first time in more than a century. That reconnection proved beneficial to residents in the Saginaw River watershed, allowing flood waters to inundate 10,000 acres as opposed to downstream areas.



Migratory birds feeding at Shiawassee National Wildlife Refuge. Credit: Kenneth Bailey, Friends of Shiawassee National Wildlife Refuge

- **National Fish Habitat Program/National Fish Habitat Partnership.** USFWS and multiple partners continued to establish goals for restoring priority species and their habitats across the Great Lakes basin. In 2020–2021, USFWS funded 14 projects targeting restoration of brook trout populations. Most notably, funding supported removal of key barriers to brook trout in Michigan's Maple River and Black River watersheds. Anticipated completion of these remaining projects in 2022 will reconnect 149 miles of high-quality brook trout habitat.

- **Removing abandoned infrastructure to reconnect Lake Superior Coastal Wetlands.** In 2021, the Town of Port Wing finished restoring and reconnecting 10 acres of coastal wetlands. Abandoned wastewater treatment ponds that had been constructed in 1968 within wetlands of the Flag River Estuary were returned to their historic condition. Using GLRI funding support, the Town of Port Wing and Wisconsin Department of Natural Resources teamed up to develop and implement a restoration plan. The Flag River estuary, a high-quality coastal wetland complex that includes the Port Wing Boreal Forest State Natural Area and Bibon Lake, is home to a wide variety of waterfowl, unique wetland habitats, and boreal forests that have been developed or lost to invasive species. Several rare plants and animals have been documented at this wetland. Vegetation assessment, establishment, and management began in 2020 and is planned through 2023 to see if project successes are maintained. This project also incorporated the community needs of Port Wing, providing education opportunities to local school children.
- **Creating nearshore habitat and providing shoreline erosion protection to Michigan residents.** A \$1.3 million habitat restoration project was completed in 2021 on the shore of Lake St. Clair, which is at the heart of the St. Clair-Detroit River System within the Great Lakes. This project was the result of a regional partnership between the National Oceanic and Atmospheric Administration and Great Lakes Commission, and it highlights how habitat can be restored while providing recreational access and erosion protection. The project improved habitat for fish and wildlife after replacing 740 feet of failing steel seawall by softening the shoreline with a combination of native vegetation and rocky habitat in Lake St. Clair at the popular Brandenburg Township Park. Lake St. Clair now offers low profile habitat shoals, deepwater habitat, native submerged aquatic vegetation, and numerous habitat structures for fish spawning, nursery, and feeding. The project is expected to benefit native fish species including smallmouth bass, Great Lakes muskellunge, northern pike, yellow perch, lake sturgeon, and walleye. The 1.5-acre of restored nearshore aquatic habitat also provides breeding and spawning areas for



Midwest Coastal Program staff work with endangered species biologists to recover Great Lakes Piping Plover through habitat restoration, beach user education and monitoring, and nest site protection.
Credit: Joel Trick, USFWS

amphibians, like the mudpuppy, as well as feeding areas for waterfowl. The project provides additional recreational access for county residents to supplement the existing public boat launch and fishing pier.

- Coastal upland and wetland habitat restoration.** USFWS's Great Lakes Coastal Program, supported by agency base funding and additional GLRI funding, works to protect, restore, and enhance shoreline areas that are important to federally listed species, migratory birds, and interjurisdictional fish. In 2019–2022, the Coastal Program completed 26 projects in collaboration with state and federal agencies, tribes, nongovernmental organizations, universities, and others. These projects restored more than 4,000 acres of coastal upland and wetland habitats that directly benefit species such as piping plover, common tern, black tern, Hine's emerald dragonfly, monarch, brook trout, and lake sturgeon. In addition to on-the-ground projects, the Coastal Program assists with regional planning efforts.

- Great Lakes Coastal Wetland Framework (Framework).** USFWS and Wisconsin Department of Natural Resources co-lead the Great Lakes Coastal Assembly (GLCA)—a binational consortium of federal, state, academic, and other collaborators—the efforts of which are supported in part by GLRI funds. The GLCA finalized the Framework in 2021 to help advance and accelerate strategic coastal wetland conservation efforts. The Framework is the product of the leadership of the GLCA shaped by input, feedback, and recommendations from more than 30 organizations and 70 individuals representing various stakeholder groups. The Framework comprises three interrelated and interdependent objectives that include establishing existing baseline extent and condition of Great Lakes coastal wetlands, determining extent and condition of coastal wetland types needed to help achieve healthy Great Lakes and coastal communities, and identifying where to focus coastal wetland efforts. The Framework is scheduled to be piloted in Lake Erie beginning in 2022. Anticipated

products of this effort include: (1) data quantifying the range of total existing wetland acres, wetland acres by geomorphic type or classification type, ecological conditions of existing wetlands, and annual variation and change over time; (2) information describing (qualitatively or quantitatively) the desired status for extent and condition for coastal wetland types; (3) maps depicting metrics associated with desired status and a decision-support tool that helps partners identify where to focus coastal wetland efforts to achieve desired status; and (4) outreach materials, including a publicly available web browser-based dashboard for data access and visualization. The Framework is intended to be implemented on a lakewide scale (e.g., all of Lake Michigan or all of Lake Superior). The Framework is intended to be iterative and flexible, promoting learning and adapting to the unique circumstances and partnerships within each lake. Pending availability of financial and technical resources, the GLCA anticipates significant progress in piloting the Framework over the next 3 years.

- **A Great Lakes endemic species, lakeside daisy, is re-established.** In 2021, USFWS and Ohio Department of Natural Resources completed projects that significantly improve the condition of a federally threatened plant, the lakeside daisy. Several years ago, a GLRI goal was set to establish a genetically diverse and self-sustaining population of these daisies on Kelley's Island in Ohio. A site acquired and protected by the Cleveland Museum of Natural History and the Western Reserve Land Conservancy was surveyed and determined to have appropriate habitat. In fall 2012, GLRI-supported restoration efforts began at the Huntley-Beatty Preserve on Kelley's Island. Data from 2021 documents show that, since the original seeding in 2012, the site has progressed from having no plants to having more than 138,000 daisies. Due to this dramatic spread, the population now is self-sustaining. This additional population will provide the resiliency needed for recovery of the species. Lakeside daisies are endemic (restricted to) the Great Lakes, and are one of the lakes' rarest plant species. This reestablishment is indicative of broader, pollinator-friendly restoration efforts that GLRI continues to support basinwide.

- **Imperiled species habitat support.** GLRI has funded many projects critical to moving species away from risk of extinction and toward recovery. With support from academic and governmental partners, several projects that focused on improving the Great Lakes population of piping plovers yielded 74 nesting pairs and fledged 124 young in 2021. Project funding supported banding, monitoring, and protecting nesting piping plovers at dispersed breeding sites, as well as the recovery and rearing of abandoned eggs in captivity. Other projects included acquiring and protecting a fen that supports the Mitchell's satyr butterfly in Indiana; providing additional protection for the Chittenango ovate amber snail in its only known location at Chittenango Falls State Park in New York; and supporting a program for captive rearing of Poweshiek skipperlings through Michigan State University.

Canada

- **Baseline Coastal Habitat Survey.** ECCC, Fisheries and Oceans Canada, and the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) completed a Baseline Coastal Habitat Survey of existing habitat for the Canadian portion of Lake Erie in 2020 and Lake Ontario in 2021 and started a survey for Lake Huron, applying consistent methods to assess and report on these coastal ecosystems. The geographic scope of the survey focuses on the coastal margin (from the shoreline to approximately 2 kilometers [km] inland) of the Canadian Great Lakes and connecting channels. The survey includes metrics for coastal wetland habitat, coastal terrestrial habitat, tributary habitat and habitat protection and restoration. The survey results establish a benchmark on coastal habitat extent, condition, function, and level of protection, and the spatial data produced will help resource managers identify place-based conservation goals and actions. The results have been shared with resource managers to advance the goal of establishing a Great Lakes Basin Ecosystem target of net habitat gain and to allow for the measuring of future progress against the baseline. Geospatial data produced is available through [OpenData](#).

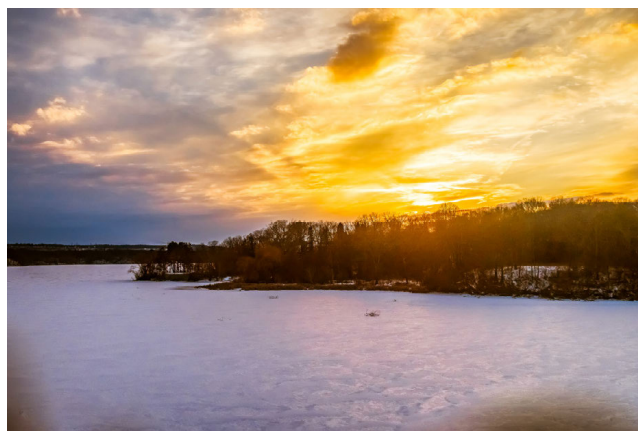


Releasing Fish. Credit: Shawanaga First Nation

- **North American Waterfowl Management Plan.** Canada's [Nature Fund](#) supported the protection of Canada's biodiversity by creating protected and conserved areas and by launching initiatives that help at-risk species recover. To help protect wetlands and migratory birds, in 2020–2022, Canada supported the North American Waterfowl Management Plan, which is an international partnership to conserve and protect wetland and upland habitats and waterfowl populations by securing and improving wetlands. Canada worked with partners (e.g., Ducks Unlimited Canada) to protect waterfowl and create habitat such as new wetlands in the city of Woodstock.
- **Indigenous Protected and Conserved Areas (IPCAs).** Canada has supported the creation of IPCAs as part of its commitment to conserving 30% of the country's lands and waters by 2030. An IPCA is a place where Indigenous Peoples lead the protection and care of lands and waters using

Indigenous laws and knowledge. Since 2019, in collaboration with Canada, Ontario, the Georgian Bay Biosphere Reserve, and the Georgian Bay Land Trust, the Shawanaga First Nation has continued efforts to create an IPCA on Shawanaga Island, an area within their Traditional Territory with rich forest and wetland habitats that are home to traditionally important and ecologically rare plants and animals.

- **Conserving Long Point Walsingham Forest.** Long Point Walsingham Forest on Lake Erie's coast was designated as a "Priority Place" for conservation in 2017 under Canada's Nature Fund. The Long Point region includes two National Wildlife Areas, a provincial park, and other conservation lands, and it is recognized internationally as a UNESCO Biosphere Reserve and a Ramsar Wetland of International Importance. Forty-two partners have been implementing ongoing conservation work in this Priority Place that is expected to benefit 54 at-risk species. Canada, Ontario, and their partners have supported and implemented projects addressing key threats to at-risk species. ECCC-funded actions since 2018 have conserved more than 3,200 hectares (7,900 acres) of habitat, which includes management of more than 400 hectares (988 acres) of the invasive phragmites.
- **Restoring Habitat in Hamilton Harbour.** With support from ECCC's GLPI in 2021, the Royal Botanical Gardens began efforts to restore 110 hectares of wetlands within the Royal Botanical Gardens Nature Sanctuary in Hamilton Harbour. The project supports the expansion of native species and the management of invasive species' stressors



Cootes Paradise. Credit: ©iStock

(European manna grass, phragmites, common carp), to restore fish and wildlife wetland habitat. Monitoring of water quality, aquatic vegetation, the fish community, and amphibians is being undertaken to assess the effectiveness of restoration to meet ecological targets.

- **Shoreline Restoration in the St. Lawrence River.**

In 2021, Watersheds Canada, with support from ECCC's GLPI, began implementation of a 3-year project to collaborate with local partners and waterfront property owners in Akwesasne and around Lake St. Francis to plant 12,500 native species and restore 12,500 square meters of riparian habitat along 3 km of degraded shoreline. They are also building capacity with local delivery partners to continue this work in the future.

- **Bainsville Bay Marsh Restoration.** In 2021, the Raisin Region Conservation Authority, with support from ECCC's GLPI, began implementation of a 3-year project to restore and protect the Bainsville Bay Marsh, a provincially significant coastal wetland, in collaboration with local and provincial partners. Several actions are underway to restore a portion of the marsh including: erosion control, restoration of wet meadow habitat, and the enhancement of key habitat features through the creation of open water, water level management, and native plantings. This project will also identify land parcels that are critical for ensuring the long-term conservation and health of this wetland.

- **Planting today for a better tomorrow.** Canada's [Two Billion Trees](#) program supported the restoration of wildlife habitat throughout the Great Lakes. Between 2021 and 2022, in partnership with the Central Lake Ontario Conservation Authority, Canada helped enhance the Lynde Shores Conservation Area with the planting of 3,500 trees to further protect the natural heritage features and functions found within the two Provincially Significant Wetlands located within this 960-hectare conservation area.

- **Acquisition of new conservation areas.** Through Canada's Nature Fund and the [Natural Heritage Conservation Program](#), Canada supported land acquisitions to establish new protected and conserved areas. Acquisitions were administered by the Nature Conservancy of Canada (NCC), in partnership with Ducks Unlimited Canada and



Apostle Islands, Lake Superior. Credit: Nancy Stadler-Salt, Environment and Climate Change Canada

Wildlife Habitat Canada. In 2021, the NCC acquired an 83-hectare (205-acre) property along Devil Lake in the Frontenac Arch, an area recognized as a UNESCO Biosphere Reserve. NCC also acquired 7,608 hectares (18,800 acres) on Manitoulin Island at Vidal Bay. When combined with nearby and adjacent conservation lands, this forms a protected area complex of 250 square km (24,860 hectares/61,435 acres). In total, it will conserve 86 km (53 miles) of Great Lakes shoreline.

- **Protecting and restoring coastal, shoreline and nearshore areas of the Great Lakes.** In 2020–2022, the Ontario Ministry of the Environment, Conservation and Parks (MECP) continued to support projects that help communities to protect and restore the Great Lakes and their connecting rivers. Projects were supported through the [Great Lakes Local Action Fund](#), including:
 - Creating an elevated boardwalk within Ojibway Park to stimulate ecotourism solutions while protecting the Great Lakes wetlands, led by the Garden River First Nation.
 - Protecting habitats and species and enhancing biodiversity through reforestation of privately owned and marginally operable or abandoned agricultural lands within the Lake Erie and Ontario watersheds, led by the Haldimand Stewardship Council Inc.
 - Protecting and providing public access to a rare wetland in Goulais Bay in Lake Superior, with

a new boardwalk, trail, and educational opportunities, led by the Lake Superior Watershed Conservancy.

- Turning an existing undeveloped municipal parkland into a Climate Change Awareness Park—including enhancing wetlands, remediating shorelines, revegetating areas, and establishing pollinator gardens—while also providing a space to educate and address environmental and climate impacts on Lake Superior, led by the Lakehead Region Conservation Authority.
 - Restoring in-stream habitat, planting, removing invasive species, cleaning up shorelines in the Wiikwemkoong Unceded Territory, led by the Manitoulin Streams Improvement Association.
 - Engaging local community groups and residents in restoration and a learning discovery program (Bring Back the Brookies) to preserve and protect aquatic habitat in Upper Twelve Mile Creek, a tributary of Lake Ontario. Participants engaged in planting vegetation and cleaning up shorelines to support improving water quality, reducing erosion and sedimentation, expanding habitat connectivity, and mitigating climate change. This project was led by the Niagara Chapter of Trout Unlimited Canada.
 - Improving headwater tributaries in the Humber River, Rouge River, Credit River, and Don River watersheds, by increasing fish habitats, improving fish passages, and planting native trees and shrubs to increase riparian cover, led by Ontario Streams.
- **Protection of at-risk aquatic species.** Through the [Canada Nature Fund for Aquatic Species at Risk](#), Canada supported the design and delivery of stewardship projects in 2020–2022 to advance the recovery and protection of at-risk aquatic species. Land use in the lower Great Lakes watershed priority area is primarily urban development and prime agricultural areas. The Ausable Bayfield Conservation Authority implemented projects to improve and preserve natural habitat within the Ausable River watershed by encouraging landowners to adopt best management practices to help minimize nutrient and sediment runoff. Halton Region Conservation Foundation engaged landowners along Bronte Creek, Fourteen Mile Creek,

and Sixteen Mile Creek in stewardship activities to improve water and habitat quality. The St. Clair Region Conservation Authority helped communities organize conferences, workshops, and outreach activities that provided local landowners, farmers, stakeholders, and students with the knowledge and resources necessary to participate in stewardship programs.

- MECP continued to support commitments to protect and recover species at risk and their habitats. In 2022, ongoing and new projects were supported through the [Species at Risk Stewardship Program](#), including:
 - Mitigating drainage impacts on the Wainfleet Bog for the purpose of managing species-at-risk habitat. The drainage effects on this wetland's water level cycles impact reptile habitat to the point where it affects the survivorship of species-at-risk. The Wainfleet Bog is home to several species-at-risk including four turtle species and two species of snakes. This project is led by 8 Trees.
 - Protecting and recovering at-risk turtles, including Blanding's turtle, through rehabilitation of adult turtles, education, field research, and disease surveillance, led by the Ontario Turtle Conservation Centre.



Blanding's Turtle. Credit: ©iStock

- Outreach and habitat management for 21 species at risk, including the monarch butterfly, eastern ribbonsnake, and dwarf lake iris, in the Point Grondine area and on Manitoulin Island, led by the Wiikwemkoong Unceded Indian Reserve.

- Restoring 50 hectares of tallgrass prairie, oak savanna, and oak woodland habitat for species at risk, including the red-headed woodpecker and eastern hog-nosed snake, led by the Long Point Basin Land Trust.
- Protecting, enhancing, and connecting habitat in Windsor-Essex County to support the recovery of Butler's garter snake, led by the Wildlife Preservation Trust Canada. The remnants of the Ojibway Prairie in Ontario's Windsor-LaSalle region are home to several reptiles threatened by urban development, including eastern foxsnakes, Butler's garter snakes, and a critically endangered population of massasauga rattlesnakes.
- Restoring and enhancing coastal wetlands in Lambton Shores through invasive phragmites control, led by the Lambton Shores Phragmites Community Group.
- **Protection and Restoration of bees native to the Great Lakes basin.** In 2022, ECCC [published](#) the proposed recovery planning document (i.e., management plan) for the yellow-banded bumble bee (*Bombus terricola*) in Canada, listed as a species of special concern under the Species at Risk Act. The plan identifies conservation measures and strategies necessary to achieve management objectives. It promotes stewardship by landowners, government agencies, and holders of government reserves. The plan also includes a measure to minimize the use of pesticides. In Canada, the effects of neonicotinoids on pollinators have been reviewed by Health Canada's Pest Management Regulatory Agency; in general, application of these neonicotinoids across Canada, including in the Great Lakes region, were cancelled or restricted for certain uses, especially those related to foliar or soil applications on fruits, nuts, ornamentals, and outdoor-grown fruiting vegetables. Cereal and legume seed-treatment uses received additional label instructions, which were to be implemented on all product labels sold by registrants no later than April 11, 2021.
- In 2022, MECP through its [Species at Risk Stewardship Program](#), supported Wildlife Preservation Trust Canada in a project to assess changes to diversity and abundance of bumble bees over the last 50 years.



Lake Erie Shoreline Marsh, Point Pelee National Park.
Credit: ©iStock

- **Ecosystem protection.** [National Parks](#) and [National Marine Conservation Areas](#) protect approximately 4.8% of Canada's Great Lakes coast and 12% of Canada's Great Lakes waters, and provide a foundation for biodiversity conservation, nature-based solutions, and places to connect with nature. Within these sites, Canada continues to prioritize the conservation and restoration of ecosystems. For example, around Fathom Five National Marine Park, the Saugeen Ojibway Nation, Ontario, and other partners are applying the principles of "two-eyed seeing" in the [Together with Giigoonyag](#) project, an examination of lake whitefish population decline. Additionally, the [On the Road to Recovery](#) project at Bruce Peninsula, Georgian Bay Islands, and Thousands Islands national parks is helping to decrease amphibian and reptile road mortality, improve habitat connectivity, and increase public awareness of road ecology. With respect to species at risk, Multi-species Action Plan Implementation Reports (2016 – 2021) for Georgian Bay Islands, Thousand Islands, Bruce Peninsula, and Point Pelee national parks are posted on the [Species at Risk Public Registry](#) and highlight the ongoing efforts to conserve and recover species at these sites.



Annex 8: Groundwater

Canadian and U.S. governmental agencies continue to actively manage contaminated groundwater sites that may pose a risk to the Great Lakes. To further improve binational coordination and management actions, both countries worked together to assess the state of groundwater science through the development of *Groundwater Science Relevant to the Great Lakes Water Quality Agreement: A Status Report*.

Key Achievements

- Completed the groundwater science report entitled *Groundwater Science Relevant to the Great Lakes Water Quality Agreement - 2022 Update* (projected for publication later in 2022).
- In support of the 2022 State of the Great Lakes (SOGL) groundwater quality subindicator, addressed spatial data gaps in groundwater quality (i.e., nitrate and chloride concentrations).
- Developed groundwater mapping and modeling.

Binational Actions and Achievements

Priority for Action: Update the 2016 binational groundwater science report entitled *Groundwater Science Relevant to the Great Lakes Water Quality Agreement: A Status Report*, by summarizing new knowledge on groundwater in the Great Lakes region, including an assessment of the geographic distribution of known and potential sources of groundwater contaminants relevant to Great Lakes water quality.

- In 2020–2022, the Annex 8 Subcommittee engaged groundwater experts to update the 2016 binational groundwater science report and produce *Groundwater Science Relevant to the Great Lakes Water Quality Agreement - 2022 Update*, which will be made available later in 2022 on binational.net. Key aspects of the update to the 2016 report included examining

Purpose and Overview

The purpose of [Annex 8 \(Groundwater\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by coordinating groundwater science and management actions.”

Groundwater is an important component of the water entering the Great Lakes, either directly (via groundwater discharge into the lakes or along the coasts) or indirectly (via discharge into rivers, wetlands, and lakes). Contaminants or excessive nutrients in groundwater can impair the quality of the waters of the Great Lakes, particularly the nearshore region, and could potentially cause negative effects on aquatic species and recreational waters. Conversely, groundwater often mitigates contamination and provides stable temperature for streams, wetlands, and coastal areas of the Great Lakes.

The Groundwater Annex focuses on increasing the understanding of how groundwater influences Great Lakes water quality and ecosystem health, while also identifying priority areas for future action. It coordinates binational groundwater activities with domestic programs to protect and manage groundwater quality and to understand and manage groundwater-related stresses.

ANNEX IMPLEMENTATION

The implementation of commitments under Annex 8 (Groundwater) is led by Environment and Climate Change Canada (ECCC) and the U.S. Geological Survey (USGS) supported by the Annex 8 Subcommittee, which includes members from ECCC; Toronto and Region Conservation Authority; Upper Thames River Conservation Authority USGS; U.S. Environmental Protection Agency (USEPA); Ontario Ministry of the Environment, Conservation and Parks (OMECP); Michigan Department of Environment, Great Lakes, and Energy; Ohio Environmental Protection Agency, Ohio Department of Natural Resources; Indiana Department of Environmental Management; New York State Department of Environmental Conservation (NYSDEC); and Minnesota Department of Health.

whether the science needs and gaps outlined in the 2016 report have been fully addressed or, if not, whether significant progress has been made. The updated report also addresses if there are any new or recently identified science needs that should be considered and documented in the 2022 report.

Other Binational Achievements

- In 2021, ECCC, USGS, and OMECP groundwater subject matter experts contributed to updating the SOGL groundwater quality subindicator report, which will be published as part of the SOGL Report 2022 (see [Annex 10: Science](#) for more information). Previously identified spatial data gaps in groundwater quality (i.e., nitrate and chloride concentrations) were addressed by integrating groundwater monitoring data from various sources.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, Canada and the United States pursued a variety of domestic projects that also support Annex 8 (Groundwater).

Canada and Ontario

The Groundwater Quality Annex of the 2021 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (COA) commits the governments of Canada and Ontario to continue their focus on understanding how groundwater influences Great Lakes water quality and ecosystem health and on identifying priority areas for action. The 2021 COA includes new concepts, such as recognizing that clean groundwater is important for Great Lakes water quality and ecosystem

health and that understanding groundwater-surface water interactions via field monitoring and modeling is essential. Specific groundwater-related activities are described below.

Groundwater Modeling and Groundwater-Surface Water Interaction

- OMECP has funded work to establish integrated climate, surface water, and groundwater models to test the feasibility of accurately forecasting groundwater levels along with other hydrologic factors using real-time weather forecast data on a watershed basis. OMECP has made the forecasting results available since April 2021.
- **Development of a groundwater-surface water model.** In support of the 2021 COA, OMECP initiated a project to build fully integrated groundwater-surface water models within the Canadian side of the Lake Huron, Lake Erie, and Lake Ontario basins at subwatershed, watershed, and regional scales. The models will be used to simulate groundwater flow paths and the dynamics of groundwater discharge into surface waters over 5 years (2013–2018). The model, which will be validated with extensive datasets collected by OMECP and ECCC, will inform development of tools and methodologies for improving the understanding of groundwater-surface water interaction and the influence it has on water quantity and quality in the Great Lakes.
- **Research on surface and groundwater interactions.**
 - Natural Resources Canada (NRCan), in collaboration with U.S. scientists, continued work on understanding the contribution of groundwater to the Great Lakes water balance and the interaction of groundwater and surface water in the Great

Lakes basin to support decision-making. Papers on the effect of earth crust rebound following ice sheet collapse and its impact on assessment of water balance of the Great Lakes were published by a team of U.S. and Canadian authors: [*Rise of Great Lakes Surface Water, Sinking of the Upper Midwest of the United States, and Viscous Collapse of the Forebulge of the Former Laurentide Ice Sheet*](#) and [*Surface deformation observed by InSAR shows connections with water storage change in Southern Ontario*](#).

- In 2021, NRCan and collaborators initiated [*a 3-year project that couples a state-of-the-art modeling framework with high-resolution climate projection data*](#) to produce an assessment of projected climate change impacts on surface and groundwater resources. Canada will be modelled as six large continental watersheds, including the Great Lakes basin. The study is integrated with Gravity Recovery and Climate Experiment satellite data analysis at NRCan.

Contaminant Research

- Research on linkage between groundwater influences on stream and lake chloride, with focus on road salt.
 - ECCC is collaborating with Western University to examine river reach-scale impacts from road salt-contaminated groundwater on benthic ecosystems, groundwater discharge effects on stream chloride concentrations, and potential influences of high-chloride groundwater on metal mobilization from streambed sediments.
 - ECCC is collaborating with Toronto Metropolitan University to investigate year-round dynamics of stream chloride concentrations across eight urban streams in Hamilton region, with a focus on base flow periods and aquatic life exposure periods.
- Research on linkage between groundwater and movement of contaminants, such as chloride.
 - OMECP initiated a project with the Oak Ridges Moraine Groundwater Program (ORMGP) to improve understanding of the link between direct groundwater discharge to the northern shore of western Lake Ontario and its associated



Excessive road salt application.
Credit: James Roy, ECCC

contaminant loadings (such as road salts) by using the existing information managed by the ORMGP.

- OMECP is supporting a study in the western Lake Ontario basin with University of Guelph researchers (working with ORMGP, various conservation authorities, and other governmental organizations and universities) to better understand how groundwater receives chloride and ultimately delivers it to the Great Lakes. The project will create a comprehensive database of historical and existing chloride concentration data for groundwater and surface water in Ontario. It will also examine relationships between groundwater and surface water chloride concentrations, land use, and surficial geology, and it will evaluate groundwater-surface water interactions and seasonal trends in concentrations.
- **Research on the influence of septic systems.** To inform Lake Erie nutrient management initiatives, OMECP funded a Western University project estimating phosphorus loads from septic systems. In collaboration with ECCC, this work uses artificial sweeteners and microbial markers as human wastewater tracers, combined with Lake Erie geospatial

modeling tools developed by Western University. The geospatial tool allows for the identification of locations of individual septic systems using publicly available data sets and can be used to estimate, at the watershed level, [phosphorus loads from septic systems that reach Lake Erie tributaries](#). To improve prediction of nutrient and contaminant loads from septic systems, OMECP is funding another project, which, in collaboration with ECCC, is using this geospatial tool to investigate septic system failure types and rates and the associated pathways by which septic effluent reaches tributaries.

- **Research on nutrients in groundwater.** In support of efforts to address excessive nutrients in Lake Erie, several projects by ECCC and collaborators, some via funding by OMECP, are assessing the role of groundwater in delivery of nutrients to agricultural streams in the Thames watershed, with related examination of potential for riparian areas to mitigate these inputs and the potential impacts of groundwater phosphorus inputs on stream ecology.
- **Research on emerging contaminants, including per- and polyfluoroalkylated substances (PFAS) in groundwater.** OMECP has funded the Royal Military College of Canada to develop a framework to estimate the number of potential sources of PFAS contamination to groundwater in Ontario based on land-use activities. This work will develop risk-based



Sampling a shallow well for groundwater affected by leachate from a historic landfill (under the baseball field). Credit: James Roy, ECCC

categories to help create an inventory of PFAS-contaminated sites, including an interactive map, to help guide follow-up actions. With funding support from OMECP, ECCC is continuing investigations of the threat that Ontario landfills pose to Great Lakes surface waters via groundwater. A primary focus of this study is emerging contaminants, such as PFAS (Figure 2), bisphenols, and pharmaceuticals, as well as the dynamics of exposure and measuring direct

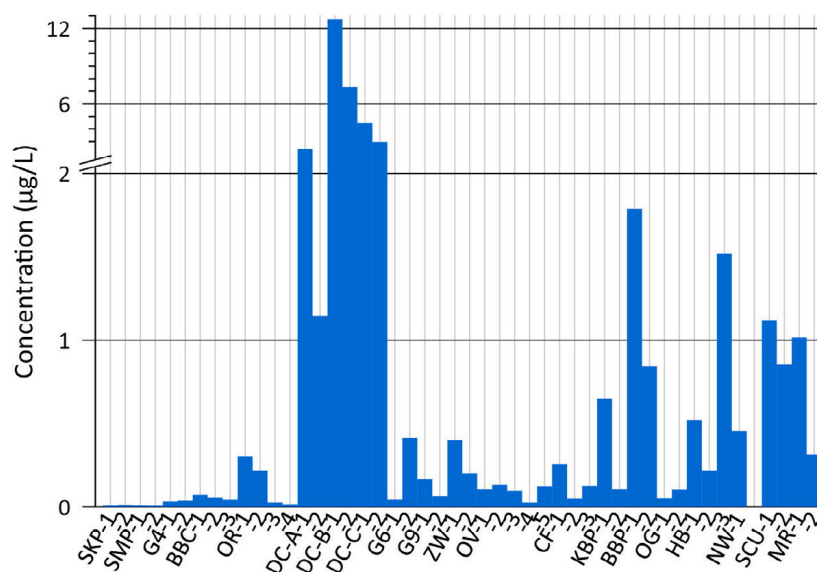


Figure 2. Sum of concentrations of 17 PFAS (per- and polyfluoroalkylated substances) compounds detected in leachate-affected groundwater samples (2–5 per site) collected at 20 Ontario historic landfill sites; ordered from the oldest (closed ~ 1920s) at left, to the most recent (closed early 1990s) at right. From [Propp et al. 2021](#).



Iron staining (orange color) at a groundwater seep emanating from a historic landfill along a streambank. Credit: James Roy, ECCC

impacts to aquatic organisms of receiving surface waters.

Climate Change

- **Research on groundwater-surface water interaction and climate change impact.** To better understand groundwater-surface water interactions and the relationships between climate and water in northern Great Lakes watersheds, OMECP is supporting studies in subwatersheds in the northern Lake Huron and Lake Superior basins with Nipissing University and Lakehead University, respectively. This work uses data collected from two integrated water and climate change monitoring stations that are part of a network of seven sites established in 2012. OMECP continues to support University of Guelph studies in a clay-dominated agricultural watershed at another integrated monitoring site in the southern Lake Huron basin. These studies will examine the movement of phosphorus and nitrogen between groundwater and surface water that flow into Lake Huron.

United States

Monitoring

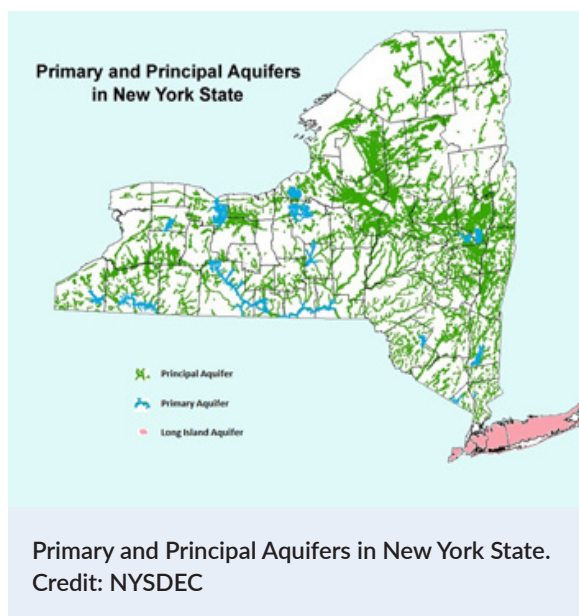
Groundwater levels and groundwater quality are monitored in the U.S. Great Lakes states by local, state, and federal agencies. For example, in New York, the USGS is coordinating with NYSDEC to monitor a statewide network of groundwater observation wells that provides real-time groundwater elevation data, which are used in concert with other data to make drought-related decisions. In Minnesota, a network of over 270 wells is sampled for 100 different chemicals, including nutrients, major ions, volatile organic compounds, and trace metals. Data from field-measured parameters, including pH, specific conductance, dissolved oxygen concentration, and temperature, also are collected ([Minnesota Pollution Control Agency groundwater monitoring](#)). The State of Ohio monitors over 200 wells for ambient groundwater quality ([Ohio Environmental Protection Agency Ground Water Characterization Program](#)) primarily to provide data and information to protect drinking water supplies.



USGS personnel making a groundwater level measurement. Credit: USGS

Mapping

USGS, with support from NYSDEC, continues to develop detailed maps of stratified drift aquifers throughout New York State. The primary objective of the Detailed Aquifer Mapping Program in New York State is to define the hydrogeology of the state's principal aquifers in support of NYDEC's many regulatory activities. For each selected study area, the program provides detailed reports and



interpreted hydrogeologic data in map format, which are also integrated into geographic information system (GIS) datasets. USGS and NYSDEC recently released a report and GIS data for the Conklin-Kirkwood Aquifer in Broome County. A summary report and GIS data release are pending final review for the Fairport-Lyons Study Area spanning Wayne, Ontario, and Seneca counties. USGS is currently developing detailed aquifer maps for the following study areas:

- The Owasco Inlet watershed, spanning Cayuga and Tompkins counties
- The Oneonta area, spanning Otsego and Delaware counties
- The Malone area, spanning Franklin, Clinton, and Saint Lawrence counties

Contaminant Research

- **Groundwater Contributions to Lake Superior.** To better understand the role of groundwater as a source of contaminants to the Great Lakes, USGS started a study as part of the 2021 Great Lakes Cooperative Science and Monitoring Initiative to improve the characterization of aquifers contributing groundwater to Lake Superior and assess the potential for groundwater to deliver contaminants to Lake Superior.
- **Nutrients in Groundwater.** USGS worked with the Wisconsin Department of Natural Resources and researchers at the University of Wisconsin–Madison to develop a Nitrate Decision Support Tool. This

statewide tool combines GIS and well data with a Machine Learning model of groundwater age and nitrate leaching estimates; the tool estimates the concentration of nitrate at specified wells over time and forecasts how changing nutrient leaching below the land surface could affect concentrations. An important feature of the tool includes its ability to incorporate model uncertainty into estimates of time delays between management actions and improved concentration at receptor wells.



Nutrient application on agricultural fields can be a source of nitrate in groundwater. Credit: USGS

Policy Studies

- Michigan Department of Environment, Great Lakes, and Energy awarded a grant in March 2021 to Michigan State University's Institute of Water Research to conduct a 2-year economic study of Michigan's use of institutional controls for managing groundwater contamination. (Institutional controls are administrative and legal controls imposed to help minimize the potential for exposure to contaminated groundwater. For more information, see USEPA's 2005 [A Citizen's Guide to Understanding Institutional Controls at Superfund, Brownfields, Federal Facilities, Underground Storage Tanks, and Resource Conservation and Recovery Act Cleanups](#).) The research team will use case studies to better understand the long-term implications, risks, and costs of using institutional controls and other restrictive actions, such as limiting the use of an aquifer when managing risks associated with groundwater that has become unusable due to contamination. They will also develop a framework to guide future decision-making. This work will clarify how Michigan currently manages contaminated groundwater and will inform decisions about future uses of institutional controls.



Annex 9: Climate Change Impacts

Over the last 3 years, the U.S. and Canadian governments increased awareness of climate change impacts through quarterly and annual reporting and hosting webinars on climate change topics and initiatives. This information helps support the development of climate change adaptation strategies throughout the Great Lakes.

Key Achievements

- Developed [quarterly and annual climate change impacts information](#).
- Summarized key Great Lakes climate change impacts through a climate change video, an infographic, and reports.
- Engaged climate change modeling experts and stakeholders to review and discuss regional climate modeling, gaps and uncertainty, and recommendations for future work.
- Hosted webinars and discussions on climate change topics and initiatives.

Binational Actions and Achievements

Priority for Science: Improve coordination and knowledge exchange to address climate science gaps in the Great Lakes, including hosting a gathering of experts for a workshop on **Climate Change Modeling in the Great Lakes Basin**.

- Implemented an Annex 9 (Climate Change Impacts) webinar series beginning in January 2020, which enhanced coordination and knowledge exchange between experts, stakeholders, resource managers, and the public on various climate change studies and programs conducted within the Great Lakes basin:
 - Great Lakes Indian Fisheries and Wildlife Commission's Tribal Climate Adaptation Menu

Purpose and Overview

The purpose of Annex 9 ([Climate Change Impacts](#)) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement by coordinating efforts to identify, quantify, understand, and predict the climate change impacts on the quality of the Waters of the Great Lakes, and sharing information that Great Lakes resource managers need to proactively address these impacts.”

Changes in climate affect naturally occurring physical, chemical, and biological systems, such as runoff and erosion patterns, nutrient cycling, and wetland development in the Great Lakes. Climate change impacts, such as warming air and water temperatures, changing precipitation patterns, decreased ice coverage, and alterations to water levels, are occurring across the Great Lakes basin. Understanding how climate change affects these processes now and in the future is important for making informed management decisions for the Great Lakes. The purpose of the Climate Change Annex is to coordinate efforts to find, quantify, understand, and predict how climate change affects Great Lakes water quality and to share information that Great Lakes resource managers need to proactively address these impacts.

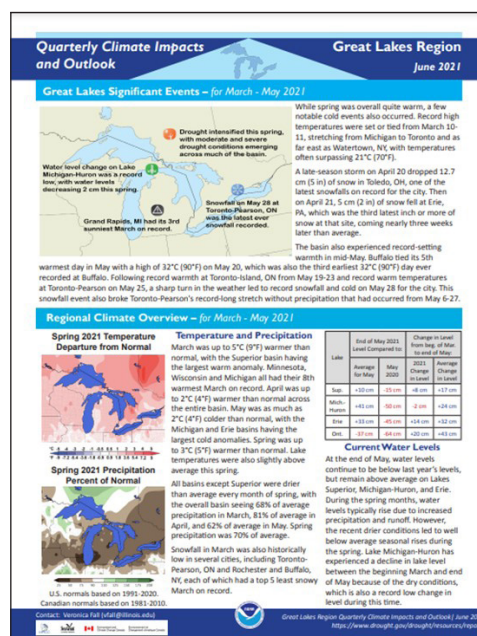
ANNEX IMPLEMENTATION

The implementation of this Annex is supported by an Annex 9 Subcommittee, co-led by the U.S. National Oceanic and Atmospheric Administration (NOAA) and Environment and Climate Change Canada (ECCC), with members from ECCC and NOAA; Great Lakes Indian Fish and Wildlife Commission (GLIFWC); Keweenaw Bay Indian Community; Michigan Office of the Great Lakes; Oneida Tribe of Indians of Wisconsin; U.S. Army Corps of Engineers (USACE); U.S. Bureau of Indian Affairs; U.S. Department of Agriculture (USDA); U.S. Environmental Protection Agency (USEPA); Chiefs of Ontario; Fisheries and Oceans Canada; Grand River Conservation Authority; Ontario Ministry of the Environment, Conservation and Parks (OMECPP); Ontario Ministry of Northern Development, Mines, Natural Resources, and Forestry; and Parks Canada.

- Toronto's Port Lands Flood Protection and Enabling Infrastructure Project
- Indiana University's Environmental Resilience Institute
- 2021 Climate Change Modeling Experts Workshop
- [Chatham-Kent Lake Erie Shoreline Study](#)
- Canada's National Issues Report and the Adaptation Actions Map
- In 2019, the Great Lakes Integrated Sciences and Assessments (GLISA)—a collaboration between the University of Michigan and Michigan State University, supported by NOAA—hosted the first Great Lakes Climate Modeling workshop. Building on this workshop, a second workshop was held virtually in March 2021 that focused on physical climate modeling, bias and bias adjustment, lake level impacts modeling, and translating climate information. The 2019 and 2021 workshop reports are available [online](#).

Priority for Action: Produce and share climate information of relevance to the Agreement to the Great Lakes community, including regularly issuing the binational *Quarterly Climate Impacts and Outlook* report and the *Annual Climate Trends and Impacts Summary for the Great Lakes Basin* report.

- Providing climate-related information to governmental agencies and the public.
 - [Great Lakes Climate Quarterly Impacts and Outlook newsletters](#) continue to be published, providing easy-to-understand overviews of the most recent season's weather, climate, and water



Quarterly Climate Impacts and Outlook published June 2021.

level conditions; impacts related to weather, climate, and water level changes; and an outlook for the upcoming quarter.

- The [2021 Annual Climate Trends and Impacts Summary](#) was released July 21, 2022, which summarizes the year's major climate trends; notable climate-related events; and new research, assessments, and activities that are relevant to the Great Lakes. These summaries have been produced since 2018 by Canadian and U.S. agencies and organizations, including ECCC, NOAA and NOAA's Great Lakes Environmental Research Laboratory (GLERL), the Midwest Regional Climate Center, and the GLISA partnership.

- In 2020, the Subcommittee initiated a data visualization project with the help of the Ontario Climate Consortium. Climate change data from ECCC's Meteorological Service of Canada and the University of Wisconsin–Madison were compiled to develop a climate change video, an infographic, and a report summarizing the anticipated impacts of climate change in the Great Lakes basin from the early 2000s to 2100. The project observed and summarized over-lake precipitation, over-land air temperatures, lake water levels, and ice cover using two climate change scenarios. These materials were created to raise awareness and increase the general understanding of climate change impacts in the Great Lakes region using visually appealing graphics and accessible language.
- In 2020, the University of Illinois at Urbana–Champaign, working jointly with Argonne National Laboratory, began dynamically downscaling global climate model data to a grid resolution of ~4 kilometer (km) by 4 km over North America, including the Great Lakes basin, with explicit convection. These high-resolution data will generate climate change projections with sufficient accuracy across the Great Lakes to be input into hydrological models that will improve the accuracy of modeled potential climate change impacts for the Great Lakes and the surrounding communities.
- In 2021, the Annex 9 Subcommittee partnered with GLISA and began developing a 50-year, lake-by-lake climate retrospective and prospective reports that summarize: (1) key climate change impacts that have occurred in the Great Lakes since the first signing of the GLWQA in 1972 and (2) the projected impacts to come in the next half-century (~2072). These reports detail the key past and projected climate trends and impacts, and they communicate important information about climate change impacts on the Great Lakes.

Other Binational Achievements

- **Uncertainty of water balance in the Great Lakes.** USACE and NOAA's GLERL developed a tool that addresses the uncertainty in the water balance (the flow of water in and out of the lakes) for each



NOAA GLERL engineers deploying a remotely operated vehicle to install flow meters at the Middle Island Sinkhole in Lake Huron. Credit: David J Ruck, Great Lakes Outreach Media

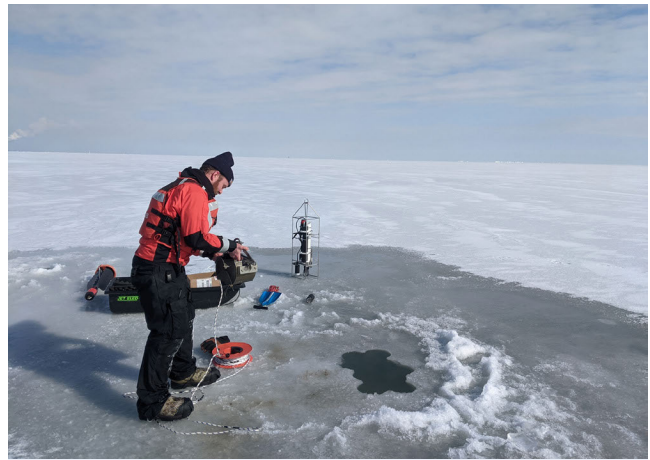
of the Great Lakes. The tool provides estimates of precipitation, evaporation, runoff, and connecting channel flows, which can be analyzed for trends or changes due to changing climate. The [Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data](#) (Coordinating Committee) is running the tool monthly and is evaluating the input datasets to better understand the drivers of observed water level changes.

- **Hydro-climate variable comparisons.** USACE and ECCC, through the Coordinating Committee, continue to provide monthly updates during this reporting period of measured hydro-climate variables (including comparisons of available methods of measuring precipitation, evaporation, and runoff) to the participating federal agencies in the committee to help decision-makers understand recent basin conditions.
- **Hydro-climate data analyses.** The USACE continues to provide routine hydro-climate data analyses in support of the [Great Lakes-St. Lawrence River Adaptive Management Committee](#). These analyses involve monitoring trends of hydro-climate variables, including monthly precipitation, monthly evaporation, monthly runoff, and surface water temperatures. These data analyses are accomplished through routine updating of standard plots and trend lines, which are analyzed annually for the Adaptive Management Committee.
- **Great Lakes adaptation data suite and the delineation of Ontario climate divisions.** As part of the [Great Lakes Adaptation Data Suite](#), GLISA recently

developed climate divisions for Southern Ontario (similar to U.S. climate divisions), which represent an intermediate spatial scale for the region. The climate divisions were delineated with support from multiple conservation authorities; Conservation Ontario; ECCC; Natural Resources Canada (NRCan); OMECP; and other Canadian climate service centres.

The climate divisions are based on conservation authority boundaries and also consider watershed boundaries, geological features, and distance/elevation from lakes (i.e., areas that experience enhanced lake-effect precipitation). The climate division boundaries are available in geographical information system formats, and climate projection information for those divisions is available on [GLISA's website](#).

- **Great Lakes Runoff Intercomparison Project (GRIP).** In 2019–2021, the University of Waterloo, in collaboration with ECCC, NOAA, USACE, USEPA, and other academic institutions, conducted the third phase of the GRIP for Lake Erie. Seventeen hydrologic and land-surface models were set up throughout the Lake Erie watershed to understand the agility of models to simulate streamflow and to encourage collaborative data sharing. These studies provide additional insight into the sources and pathways into Lake Erie and will aid in predicting and managing future flooding, shoreline erosion, and nutrient loading. In addition, the GRIP covering the entire Great Lakes basin is currently underway; it will evaluate the agility of models to simulate streamflow and internal variables such as snow-water equivalent, evaporation, and soil moisture.
- **Great Lakes Commission Standing Committee on Climate Resilience.** In January 2020, the Great Lakes Commission formed the Great Lakes Commission Standing Committee on Climate Resilience to undertake seven recommendations outlined in a previously adopted Framework for Action to address climate resilience throughout the Great Lakes basin. The committee includes representatives from the eight states and two provinces (Quebec and Ontario) that surround the Great Lakes. The committee also includes representatives from federal agencies and regional entities. The committee has been working collaboratively to propose recommendations on resiliency efforts for the Great Lakes basin for the Great Lakes Commission's consideration.



Collecting samples on Lake Erie to study wintertime physical, chemical, and biological conditions in the lake, as part of the 2022 Great Lakes Winter Grab. Credit: Paul Glyshaw, NOAA GLERL

- **Water levels in the Great Lakes.** Canadian and U.S. agencies continue their ongoing monitoring of water levels through a network of water level monitoring stations. (For more information, visit GLERL's [Great Lakes Water Levels](#) site). The data are used to provide current and historical water level conditions, as well as future projections for Great Lakes water levels.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, Canada and the United States pursued a variety of domestic projects that also support the Climate Change Annex.

United States

Climate change impacts and adaptation

- **Great Lakes Shoreline Assessment.** NOAA, in partnership with the Coastal States Organization (CSO), is engaged in coastal resiliency along the Great Lakes shoreline. Along many Great Lakes shorelines, land use change, shoreline alterations, and coastal infrastructure have resulted in a loss of coastal biodiversity and ecological resilience. Restoring these shorelines requires an integrated systems approach, applied at scale, to identify specific nearshore management goals and place-based

actions that will restore coastal biodiversity and ecological resilience. This project engaged in three primary tasks: (1) implementing engineering and design plans for two site-specific projects as identified in the NOAA/CSO/Coastal Zone Management Program workshops held through the Great Lakes basin in 2020; (2) implementing on-the-ground living shoreline restoration projects identified by the State of Minnesota; and (3) conducting workshops that identified municipal restoration project needs, pinpointed data gaps, and selected sites for engineering and design plans for some of the top-ranked projects. These projects target nearshore habitat benefits for lake trout, walleye, lake sturgeon, yellow perch, cisco, and migratory birds and ducks, among other state-identified priorities.

- **Dibaginjigaadeg Anishinaabe Ezhitwaad: A Tribal Climate Adaptation Menu (TAM).** Building on the [TAM](#) released in April 2019 by the GLIFWC and partners, the TAM author team facilitated five workshops hosted by tribal communities in the U.S. Midwest and Northeast in 2019–2020. In these workshops, participants used the menu to plan real-world climate adaptation projects in their own communities. To date, over 30 projects have been planned using the menu. As in-person workshops halted during the pandemic, the TAM team developed informational webinars and meetings to promote the menu to practitioners across the United States and Canada. GLIFWC and the TAM team were recently funded by the USDA Forest Service to facilitate workshops with national forests and adjoining tribal communities in the Great Lakes region to plan tribally led adaptation projects on national forest land under the auspices of the U.S. Tribal Forest Protection Act. This series of workshops will begin in 2022.
- **Climate Change Vulnerability Assessment.** In 2020–2021, GLIFWC climate change staff continued work on their Climate Change Vulnerability Assessment, which is slated for release in 2022.

Planning, meetings, and conferences

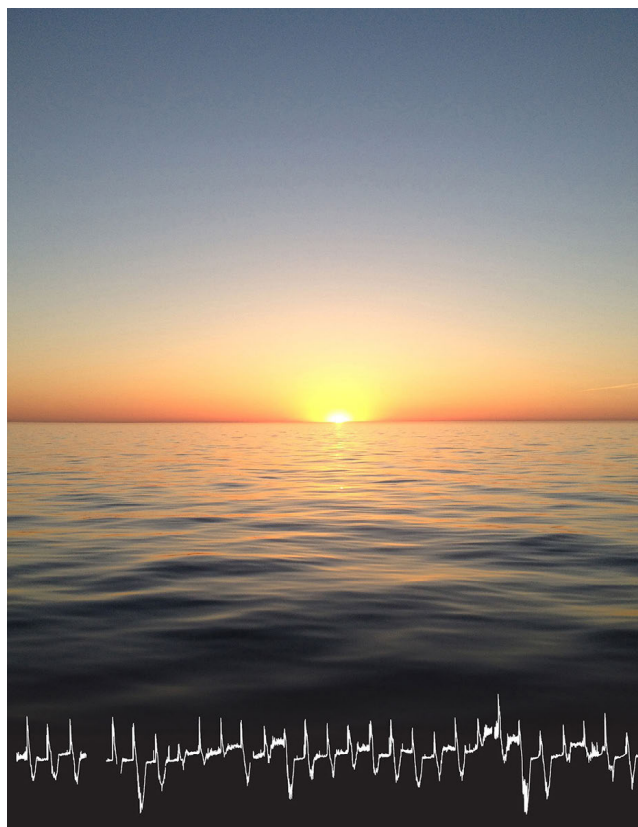
- **State Climate Services Summits.** NOAA conducted State Climate Service Summits with partnership and leadership from the state climate offices and the American Association of State Climatologists; meetings were held in June 2019 in Ohio and in

June 2021 in Indiana (held virtually). In-person meetings are planned for summer 2022 in Michigan and Illinois. These state-focused meetings involve various NOAA entities, including the National Weather Service, National Centers for Environmental Information, the GLISA partnership, Midwest Regional Climate Center, and Sea Grant. The Indiana summit was also a partnership with the USDA Climate Agricultural Hub and focused on the agricultural sector of that state. The meetings are designed to bring federal, state, local, and tribal governments together to collaborate on climate service issues, including climate and drought monitoring and value-added regional and local services such as interpretation and translation. These meetings produced a gap analysis that identified needs for better state climate office recognition, improved predictions at various scales, and better climate change information to support adaptation responses.

- **Climate and Equity Roundtables.** On October 12, 2021, NOAA hosted a climate and equity roundtable in Detroit, Michigan, that focused on urban flooding in the region. The purposes of the roundtable were to: (1) learn about efforts to advance equity and environmental justice in climate planning in southeast Michigan, (2) elevate understanding of activities to address flooding and impacts in communities with aging infrastructure, and (3) identify ways NOAA can partner with communities to complement these efforts. The result will be a joint project between NOAA and the Southeast Michigan Council of Governments and other partners to create a Climate Action Plan for the Southeast Michigan Region.
- **Michigan Council on Climate Solutions.** Michigan formed a Council on Climate Solutions in 2019 to advise the governor and the Michigan Department of Environment, Great Lakes, and Energy in formulating and overseeing the implementation of the Michigan Healthy Climate Plan, which will serve as the action plan for Michigan to reduce greenhouse gas emissions and transition toward economywide carbon neutrality. The first draft of the Healthy Climate Plan was released for public comment in 2022. It will be integrated with Michigan's Clean Water Plan to assure that Michigan's drinking water and the Great Lakes are protected in an environmentally sustainable manner.

Climate modeling and monitoring

- **Improving 5-year water level forecasts.** In spring 2021, the [NOAA National Water Model \(NWM\)](#) v2.1 became operational. Among other upgrades, this version expanded streamflow forecasts and data assimilation into the Canadian portion of the Great Lakes and Lake Champlain basins. That effort included the development of a hydrofabric that resolved data discontinuities across the border as well as calibration of the model at Canadian gaging stations. Streamflow predictions are now output operationally in the Canadian portion of the Great Lakes basin. The expansion of this model to the full Great Lakes basin has the potential to inform net basin supply forecasts used in water level projections.
- **Great Lakes Seasonal Hydrologic Forecast System.** In June 2021, after over 2 years of testing in the operational environment, the Great Lakes Seasonal Hydrologic Forecast System (GLSHyFS) was fully transitioned from research at NOAA's GLERL to operations at USACE-Detroit. This system replaces the Great Lakes Advanced Hydrologic Prediction System. GLSHyFS is an ensemble forecast that compiles surface meteorology and runs the Large Basin Runoff Model (LBRM) and the Large Lake Thermodynamic Model to compute net basin supply (NBS) forecasts. The forecast is one of a suite of NBS forecasts used as guidance for the U.S. contribution to the internationally coordinated 6-month water level forecast. The upgrade to GLSHyFS incorporates a new formulation of evapotranspiration within the LBRM that is based on the Clausius-Clapeyron relation, allowing better representation of evapotranspiration in a warming climate. In addition, upgrades include added flexibility and functionality that will allow future developments in model formulation and alternative forcings (i.e., types of physical processes that drive the climate to change).
- **Great Lakes Ensemble.** GLISA performed ongoing evaluation of global and regional climate models to determine which ones best represent the climate of the Great Lakes region and deliver the highest-quality information to regional stakeholders. Many climate models do not provide credible information for the Great Lakes region because they poorly represent the Great Lakes and the lake-land-atmosphere dynamics. However, there is a small set of



Lake Michigan sunset from the R/V Laurentian. The 30-year, deep-water temperature dataset overlaying this photo (the “heartbeat of Lake Michigan”) reveals a hidden story about how the lake’s deep waters are responding to climate change. Credit: NOAA

models designed specifically for the Great Lakes, and new ones are being developed. GLISA's [Great Lakes Ensemble](#) project tracks progress made in regional climate modeling by evaluating the representation of lakes and important lake-land-atmosphere processes and climate model biases. The project also assessed data processing techniques, such as downscaling and bias correction, and developed guidance to help practitioners choose and use climate projections.

- **Protecting Great Lakes shoreline investments, in the face of a changing climate.** As described in more detail under the U.S. domestic activities under the Science Annex, governmental partners have launched a multiyear “Framework for Resilient GLRI Investments” effort to predict and communicate the range of possible Great Lakes climate change scenarios to support the operation and maintenance of current and future GLRI investments.

- **Modeling sediment movement and ecosystem impacts due to intense storms in Lake Superior.** The [Lake Superior National Estuarine Research Reserve](#) continued to operate a Sentinel Site located in Lake Superior's Pokegama Bay. With funding support from NOAA, this Sentinel Site includes: (1) a weather/meteorological station; (2) a water quality sonde to measure water quality parameters; (3) surface elevation tables, which are devices for measuring the relative elevation change of wetland sediments; (4) permanent vegetation transects, which are permanent sampling plots along fixed transects to monitor vegetation; and (5) geodetic vertical referencing benchmarks to provide a consistent and integrated reference surface for data analysis. Since 2020, this site has been recording monthly water quality sampling for nutrients and chlorophyll. The primary goal is to understand how sediment moves and how this sediment transfer affects nearshore marsh environments as the frequency and intensity of storm events increase.

Community-based data and portals

- **U.S. Climate Resilience Toolkit – Great Lakes region.** The U.S. Climate Resilience Toolkit continues to provide an online resource to help people find and use tools, information, and subject matter expertise to build climate resilience. The toolkit offers region-based information from across the U.S. federal government in one location, including a Great Lakes-specific node ([U.S. Climate Resilience Toolkit: Great Lakes](#)) that NOAA added in 2019.
- **Water Levels Visual Database.** The Lake Superior National Estuarine Research Reserve has launched a baseline visual database with hundreds of images to support the visual lake levels monitoring project developed in 2020. The team built a protocol for collecting the photos so that, as lake levels shift, the images in the database can be used to help guide development and restoration projects. The project has also led to the [Lake Superior High Water Spotter](#), a citizen science project where community members upload and geo-reference photos of water levels on Lake Superior.
- **Sustained Assessment of the Great Lakes.** The [Sustained Assessment of the Great Lakes](#) is an online GLISA product intended to be a continuous, sustained, community-based process to assess knowledge of Great Lakes ice cover, lake levels, hydrology, and climate. In 2021, GLISA published the first iteration of this resource with five [Lake Climatology pages](#), an [overview page on lake levels](#), an [overview page on ice cover](#), a [state of the research page](#) synthesizing relevant journal articles, and a [data sources page](#).

Canada

Modeling, tools, resources, and analysis to improve understanding of changing climate and weather, and their effects

- **Map of Adaptation Actions.** The [Canadian Centre for Climate Services \(CCCS\)](#), established in support of the implementation of the [Pan-Canadian Framework on Clean Growth and Climate Change](#), continues to provide information and support to help Canadians consider climate change in planning and decision-making processes. In July 2021, the CCCS and NRCan launched the Map of Adaptation Actions (accessible on [ChangingClimate.ca](#)), which provides an interactive and searchable map of hundreds of climate change adaptation examples and case studies across Canada, including the Great Lakes. The maps may be useful to decision-makers and those taking action on climate change adaptation and provides peer-to-peer learning opportunities, including opportunities to learn how others have used climate data to inform climate vulnerability and risk assessments, adaptation plans, and actions in the Great Lakes region.
- **Ontario Climate Data Portal.** Ontario continues to partner with York University to maintain and improve the [Ontario Climate Data Portal](#), which disseminates Ontario-specific, high-resolution regional climate projections based on the most up-to-date methodology using data from credible academic sources. Since its launch in 2018, the data portal has been used by a wide variety of practitioners to support development of risk and vulnerability assessments and climate change adaptation strategies. Ontario is also exploring other tools to help facilitate the communication and application of climate data and science to a broad range of stakeholders.
- **North American Precipitation and Surface Reanalysis.** Starting in 2015, ECCC initiated the production of a 1980–2018 North American

precipitation and land-surface reanalysis. The output is a result of coupling the Regional Deterministic Reforecast System with the Canadian Land Data Assimilation System and the Canadian Precipitation Analysis. In 2021, the analyses completed for the years 2000–2017 were made publicly available (caspar-data.ca); earlier years are currently being calculated. This reanalysis will improve calibration of future climate change projections with historical records, including over-lake precipitation and evaporation, which are especially important components in the Great Lakes region.

- **Statistically Downscaled Climate Projections.** ECCC's [suite of climate indices](#), based on statistically downscaled temperature and precipitation projections (e.g., changes in temperature extremes, precipitation intensity), contribute to understanding future changes to climate conditions in the Great Lakes basin.
- **Multi-model drought dataset.** ECCC is undertaking the next phase of its [multi-model drought dataset](#), which will provide the drought indicator and statistically downscaled indices results based on the Coupled Model Intercomparison Project (CMIP) Phase 6 projections. The current [multi-model drought dataset](#), which uses climate projections from the CMIP Phase 5, is being used to inform changes in water availability. These data are publicly available through the [Canadian Climate Data site](#).
- **Assessing and enhancing the resilience of Great Lakes coastal wetlands study.** In 2017–2022, with support from Canada's Great Lakes Protection Initiative, ECCC developed projections of Great Lakes water levels using information from the [North American Coordinated Regional Climate Downscaling Experiment](#) (CORDEX-NA). Also using data from CORDEX-NA, ECCC developed projections of Great Lakes basinwide hydro-climate variables such as precipitation, temperature, soil moisture, snow water equivalent, soil moisture, and streamflow. These analyses provide a better understanding of how changes to the hydrological cycle under future climate conditions might affect the Great Lakes and coastal wetland habitat. Water level projections have been used to drive coastal wetland response models whose outputs will contribute to identifying and developing actions and strategies to enhance

wetland resilience. More information on the project can be found in [Annex 7: Habitat and Species](#).

- **Artificial intelligence approach to quantify the current and future flood and ecosystem risks in the Lake Ontario basin (March 2021 to October 2022).** In partnership with York University, the Toronto and Region Conservation Authority, University of Victoria, and the University of Calgary, the Government of Ontario supported the Artificial Intelligence Approach to Quantify the Current and Future Flood and Ecosystem Risks in the Lake Ontario Basin project. Through this partnership, models have been created using artificial intelligence that will improve understanding of climate change trends, risks, and vulnerabilities in the Lake Ontario basin. The project will also generate updated floodplain maps based on climate projections and will support the development of adaptive management actions to reduce flood risk and water quality deterioration.
- **Identifying effects of climate change on low-flow water characteristics in Ontario (March 2021 to April 2022).** Through partnership with the National Research Council, the Government of Ontario is working to identify the effects of climate change on the low-flow characteristics of the rivers and streams in Ontario, including tributaries of the Great Lakes. Through this work, outdated low-flow information has been updated by analyzing stream flow data from over 400 hydrometric monitoring stations, including those in the Great Lakes basin. The work also considers the possible effects of climate change on low flows in the current setting and provides guidance on how to refine low-flow estimation by factoring in potential climate change effects. The updated low-flow information will help improve the understanding of the hydrology of the Great Lakes and their tributaries as well as implications for water chemistry and aquatic ecosystem health. This will ultimately help to identify priority areas where management actions could be pursued to improve water quality and ecosystem health.

Climate change communication and engagement

- **Climate change summaries of National Parks, National Marine Conservation Areas, and National Historic Sites.** Parks Canada and CCCS are developing

a series of bilingual summaries of climate change trends and projections for Parks Canada-administered places. This work builds on a series of Parks Canada regional and site-specific reports that summarized the evolution of climatic conditions and the potential impacts that projected changes may cause.

- **Carbon Atlas Series.** Parks Canada, the Canadian Forest Service (CFS), and other organizations, are developing the Carbon Atlas series, which will assess and map ecosystem carbon stocks and dynamics within the terrestrial and aquatic ecosystems of Canada's National Parks and National Marine Conservation Areas.
- **Water science and sustainable forest management.** CFS is continuing work on a number of projects aimed at understanding how forest and climate change within the Great Lakes basin are impacting water quantity and quality. These projects are a combination of CFS-funded research, as well as collaborations with universities, industries, and other government agencies. These projects include observations of forest-water interactions throughout the eastern basin of Lake Superior, such as the 40+ year monitoring occurring at the Turkey Lakes Watershed Study site—an internationally renowned research station located north of Sault Ste. Marie, Ontario, that is operated by the Great Lakes Forestry Centre. These observations are being used to develop models of forest watersheds within the Great Lakes basin to inform sustainable forest management approaches to protect water resources under a changing climate.
- **Engaging coastal communities.** With support from Ontario's Great Lakes Local Action Fund, multiple partners (i.e., Niagara Coastal Community Collaborative, Niagara Peninsula Conservation Authority, and Niagara College) launched a [community-based monitoring program to engage the coastal communities of Lake Erie](#) and encourage stewardship of shoreline resiliency and healthy coastal ecosystems. Community members used the innovative [Visual Assessment Survey Tool](#) platform to track changing conditions along Niagara's coasts, submit photos, or complete a short survey. The collected information created a real-time map of coastal conditions that will be used to inform local landowners and coastal managers and track results over time.



Waves crashing during a storm. Credit: ©iStock

Climate change adaption, resilience, and vulnerabilities efforts

- **Great Lakes Climate Landscape Assessment and Municipal Guide (March 2020 to February 2021).** Through partnership with the International Council for Local Environmental Initiatives (ICLEI), local governments, and organizations, Ontario has supported the development of the *Great Lakes Climate Landscape Assessment and Municipal Guide*. This guide presents the status of climate change adaptation planning and implementation in Great Lakes municipalities and communities, and will help them to evaluate current information, determine knowledge gaps, and develop appropriate resources to fill those gaps.
- **Great Lakes Adaptation Project (March 2021 to December 2022).** The Government of Ontario and ECCC have contributed to a 3-year capacity building project led by ICLEI-Canada, called the Great Lakes Adaptation Project: Taking Community Action to Plan for and Address Climate Risks. The project is a training initiative designed to build climate change adaptation capacity and resilience. It will also support new adaptation initiatives in communities throughout Ontario. The project will enhance communities' abilities to plan and prepare for the impacts of a changing climate.
- **Climate resilience roadmap for municipal infrastructure and systems (March 2021 to October 2022).** Through partnership with the City of Thunder Bay, Regional Public Works Commissioners of Ontario-Durham Region, and the Lakehead Conservation Authority, the Government of Ontario supported

the promotion and implementation of the new Climate Resilience Roadmap for Ontario Municipal Infrastructure and Systems. This project consists of conducting pilot projects, holding training events, and promoting the climate resilience roadmap, which will help Ontario municipalities to improve their infrastructure and systems' resilience to climate change impacts and to better understand climate change vulnerabilities for communities in the Great Lakes basin.

- **Building beach resilience in Ontario (March 2020 to December 2022).** Through partnership with Zuzek, Inc., the Regional Municipality of Halton, the City of Burlington, Halton Conservation Authority, and the Town of Wasaga Beach, the Government of Ontario supported the Building Beach Resilience in Ontario study. This study aims to increase the resilience of two high-use urban beaches to high Lake Ontario water levels; climate change impacts (e.g., erosion, flooding); and expanded usage through nature-based adaptation solutions, community engagement, and cell phone technology that shares information with beach users. The studies will serve as examples for beach planning and conservation within Ontario and throughout the Great Lakes basin.
- **Adaptation actions for coastal storms and declining ice cover (Completed April 2021).** NRCan provided funding to partners for the [Adapting to the Future Storm and Ice Regime in the Great Lakes](#) study, which investigated the effects of climate change on



Flooding on Central Island, Toronto, Ontario.
Credit: ©iStock

coastal storms and ice cover. Funding also supported integrating the study findings into adaptation actions. Following this, the Government of Ontario supported partners to complete the Rondeau Barrier Beach and Navigation Channel Advisory Committee study, which enhanced the Chatham-Kent Lake Erie Shoreline Study and is a part of the broader NRCan-funded project. These two projects will enhance the knowledge base and the adaptive capacity of practitioners managing the coastal zones and communities in the Great Lakes basin.

- **Vulnerability assessment of Ontario's aquatic ecosystems to invasive species.** Ontario government researchers and partners at University of Toronto completed research to evaluate the vulnerability of Ontario's aquatic ecosystems to invasive species and their potential for arrival, survival, and spread in a changing climate, with a special focus on the Great Lakes. This work is one of the first-ever analyses to jointly consider the effects of human population and climate change on species invasions. It shows that prevention requires a combination of targeting spread methods and species-specific focus. Researchers developed models that can be used to predict which regions of Ontario are at highest risk for new invasions under current and future climate. Their assessment factored in human-mediated spread and relative suitability of recipient ecosystems for aquatic invasive species survival, and it estimated natural dispersal as a function of habitat suitability.
- **Impacts of wind on water quality and ecosystems in Lake Erie.** Ontario government researchers and partners from University of Guelph and Queen's University have explored [how extreme wind affects both water quality and ecosystems in Lake Erie](#). The research found that extreme wind events resulting from climate change are occurring more frequently and are causing increasing wave power over time. Researchers examined the thermocline, which divides the shallower, warmer portion of the lake from the deeper portion that remains cool; the deeper waters are oxygen depleted and have high phosphorous levels. The study found that extreme wind events can cause the thermocline to tilt and the deeper water to flow into the western basin, which affects water quality and fish populations.



Annex 10: Science

Over the last 3 years Canada and the United States have continued monitoring and research to understand and assess water quality and aquatic ecosystem health, measure progress and inform decision making. A Comprehensive State of the Lakes Report was issued in 2022, which assesses the overall health of the Great Lakes using a suite of ecosystem indicators. Engagement continued with Indigenous Peoples and Tribes on enhancing and promoting the common understanding of Traditional Ecological Knowledge and its application towards the restoration and protection of the Great Lakes.

Key Achievements

- Released the *State of the Great Lakes 2022* (SOGL) report.
- Implemented the Cooperative Science and Monitoring Initiative (CSMI), which included: (1) planning field years in Lake Michigan (2020), Lake Superior (2021), and Lake Huron (2022); and (2) releasing CSMI synthesis reports for Lake Superior (2016 CSMI), Lake Huron (2017 CSMI), Lake Ontario (2018 CSMI), and Lake Erie (2019 CSMI). CSMI results were highlighted at the 2021 and 2022 International Association for Great Lakes Research State of Lakes conferences.
- Organized a speaker series with knowledge holders and academics in support of integrating Traditional Ecological Knowledge (TEK).

Purpose and Overview

The purpose of [Annex 10 \(Science\)](#) of the 2012 Great Lakes Water Quality Agreement (GLWQA, or Agreement) is to “contribute to the achievement of the General and Specific Objectives of this Agreement to enhance the coordination, integration, synthesis, and assessment of science activities. Science, including monitoring, surveillance, observation, research, and modeling may be supplemented by other bodies of knowledge, such as traditional ecological knowledge.”

Science is the basis for shared understanding of the chemical, physical, and biological integrity of the Great Lakes and for ensuring effective decision-making and actions. Science in the context of the GLWQA includes monitoring, surveillance, observing, research, and modeling. Science undertaken in support of the GLWQA must be coordinated, integrated, synthesized, shared, reported, and effectively communicated to ensure that Great Lakes basin resource managers have the information needed to restore, protect, and conserve the Great Lakes. The Science Annex enhances the effectiveness and efficiency of Great Lakes science activities through planning, cooperation, coordination, and communication.

ANNEX IMPLEMENTATION

These efforts and the implementation of the commitments within Annex 10 (Science) were led by Environment and Climate Change Canada (ECCC) and the U.S. Environmental Protection Agency (USEPA), supported by an Annex 10 Subcommittee with members from Fisheries and Oceans Canada (DFO); Natural Resources Canada (NRCan); Ontario Ministry of the Environment, Conservation and Parks (OMECOP); Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry; Conservation Ontario; Conservation Halton; the City of Ajax (Canada); and Chiefs of Ontario; U.S. Army Corps of Engineers (USACE); U.S. Geological Survey (USGS); U.S. National Oceanic and Atmospheric Administration (NOAA); U.S. National Park Service (NPS); Great Lakes Indian Fish and Wildlife Commission (GLIFWC); Ohio Environmental Protection Agency; Ohio Lake Erie Commission; and Wisconsin Department of Natural Resources. Additional organizations and experts from research and academia with Great Lakes science interests also participated.

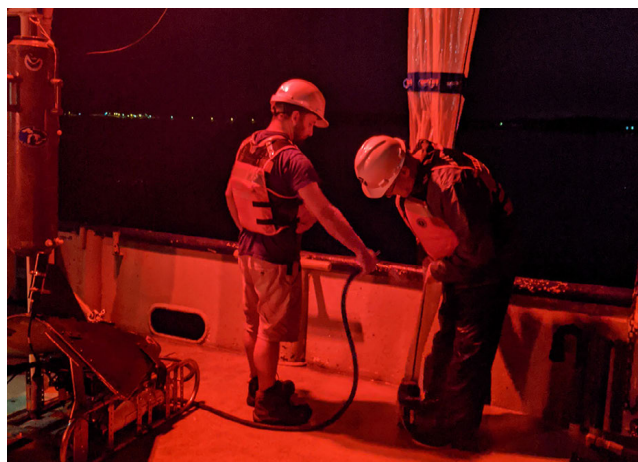
Binational Actions and Achievements

Priority for Action: Implement the Cooperative Science and Monitoring Initiative to coordinate planning, delivery, and reporting of science in relation to the specific priorities identified through the Lakewide Management process.

- Canada and the United States implemented the CSMI, which follows a 5-year rotating cycle with an intensive CSMI field year focusing on one of the Great Lakes in each year. During a lake's intensive CSMI field year, research and monitoring activities for that lake are coordinated and focus on the science priorities identified by the Lake Partnerships under Annex 2 (Lakewide Management). Ongoing Canadian and U.S. long-term monitoring programs for contaminants, nutrients, lower food web, prey fish, and fish communities also help address overarching science priorities for each lake. Due to challenges brought on by COVID-19 and vessel repair delays, some lake-specific CSMI field year activities required 2 years to complete.

2020–2021 Lake Michigan CSMI Intensive Field Year:

- Multiple agencies conducted coordinated sampling to address the Lake Michigan Partnership's CSMI priorities that included the assessment of lower food web health and drivers of changes to Lake Michigan's open water food web structure. Agencies also investigated how declining nutrients and zooplankton influence prey fish (e.g., alewife), lake whitefish, and salmon and trout fisheries.



NOAA GLERL and CIGLR scientists collect a zooplankton sample at night on a 2021 Lake Michigan CSMI survey aboard the RV Laurentian. Samples were collected to compare spatial trends in zooplankton distribution along a depth transect off of Muskegon, MI and to further studies on zooplankton response to UV radiation. Credit: Paul Glyshaw, NOAA



Scientists from Buffalo State College and USEPA rinse a Ponar sample on the 2021 Lake Michigan CSMI lakewide benthic survey. Credit: Alexander Karatayev



USGS Great Lakes Science Center scientists rinse a larval fish sampling net on the RV Sturgeon during the July 2020 Lake Michigan CSMI survey. Credit: Patty Dieter, USGS



A NOAA GLERL scientist shucks invasive quagga mussels to study how mussel condition varies with depth in Lake Michigan. Information gleaned from these mussel samples complements the broader lakewide quagga mussel distribution information collected during the 2021 Lake Michigan CSMI benthic survey. Credit: Ashley Elgin, NOAA

- A whole-lake benthic survey was completed to track spatial and temporal changes in the benthic community, including *Diporeia* and dreissenid mussels. Moorings were deployed off the Muskegon region to study dreissenid mussel growth, mortality, and shell dissolution rates. Nearshore phytoplankton community structure was assessed to investigate links between watershed stressors, nearshore nutrients, and nearshore algal community characteristics.
- Trophic transfer of contaminants through the Lake Michigan food web to top predator fish was assessed via targeted sampling of water and food web biota.

2021–2022 Lake Superior CSMI Intensive Field Year:

- Partners investigated Lake Superior's lower food web health and trends of species across multiple trophic levels. These results, along with diet studies, will help identify bottlenecks that can limit production, sustainability, and health of the lake trout population; they will also be used to evaluate the effect that declining populations of long-lived native pelagic species are having on other ecosystem components, such as zooplankton populations, and to describe the role of invasive species on native species trophic dynamics.
- To determine if progress is being made to rehabilitate native fish species of conservation concern, new techniques were developed to identify the movement of adfluvial (i.e., fish that spawn and live 1–4 years in streams before migrating to a lake) coaster brook trout from Lake Superior tributaries into shoreline waters.
- Wetland inundation maps were developed to determine the inundation extent for Lake Superior coastal wetlands and connection extent at low, average, and high water levels. The maps will show how wetland areas and types might change as water level fluctuations potentially become more rapid and extreme under future projected climate scenarios, and they will assist in quantifying the benefits of protecting coastal wetlands.
- A multiagency investigation of the spatial distribution of persistent bioaccumulative and/or toxic chemicals in the sediments of Lake Superior was conducted, along with an assessment of concentrations of legacy

contaminants and chemicals of emerging concern in the Lake Superior offshore lower food web.

- An U.S. interagency collaboration collected and is analyzing biweekly water quality samples from along the Wisconsin south shore of Lake Superior to better understand the mechanistic drivers, development, and temporal nature of cyanobacterial blooms in Lake Superior. These efforts will incorporate five components: (1) tributary water quality sampling; (2) determination of phosphorus cycling; (3) near-shore monitoring, water quality transects, and data synthesis; (4) mechanistic studies addressing bloom drivers; and (5) historical data analyses. The [CSMI 2021 website](#) offers other highlights from U.S.-led Lake Superior CSMI 2021 projects.

2022 Lake Huron CSMI Intensive Field Year:

- Partners conducted coordinated monitoring to investigate bottlenecks that limit survival of larval lake whitefish. Using beach seines and small vessels, they sampled larval lake whitefish across sites with differing primary production and dreissenid mussel densities to identify the factors that have led to declining whitefish health. Data collected in Saginaw Bay, Thunder Bay, and Hammond Bay include fish early-life history information as well as environmental data (e.g., habitat classifications, water clarity), zooplankton samples, and diets from larval catches. Partners assessed the spatiotemporal variation in lower trophic levels across Lake Huron (including North Channel, Georgian Bay, and Saginaw Bay) and its effects on larval fish production.
- Partners conducted a food web spatial study to define the fine-scale spatial structure and function of the Lake Huron food web, including the impact of phosphorus from the Saginaw River. Partners sampled major components of the food web, from microbes to fish; they focused on larval fish and plankton interactions and abiotic (nutrients, temperature, visible and ultraviolet [UV] radiation) and biotic drivers (fish, *Bythotrephes*, *Mysis*).
- To understand how penetration of UV and visual wavelengths has interacted with changes in the lower food web, partners measured the optical properties of seston in Thunder and Saginaw bays and conducted mechanistic experiments on the effects of light on primary producers.



USGS scientific diver collects water samples for nutrient analysis over a bed of *Cladophora* in Lake Huron.
Credit: Jim McKenna, Jr.

- Partners conducted a whole-lake benthic survey to track spatial and temporal changes in the total benthic community, including *Diporeia* and dreissenid mussels. In addition, partners developed an environmental DNA-based predictive model to estimate mussel abundance. Whole-lake lower food web surveys, which were focused on productivity and ecosystem changes and were accompanied by a deepwater sculpin survey, were conducted in Canadian waters to support species-at-risk assessments.
- Partners are sampling the nearshore waters of Lake Huron and Georgian Bay in 2022 to identify temporal and spatial trends in sediment and water quality (nutrients, organics, metals, phytoplankton, and zooplankton) and benthic community composition.
- Partners characterized the chemistry and biology of nearshore karst groundwater systems in coastal areas of Lake Huron near Rockport, Michigan, to investigate the lesser-known role of deeper groundwater on the quality and quantity of Lake Huron waters in karst areas. Partners assessed groundwater contributions to the water and nutrient budget of Lake Huron by studying patterns of direct groundwater discharge to streams and to Lake Huron and by mapping where threats to groundwater quality have the potential to impact Lake Huron. A multiagency investigation examined the spatial distribution of persistent bioaccumulative and/or toxic chemicals in the sediments of Lake Huron and assessed concentrations

of legacy contaminants and chemicals of emerging concern in the Lake Huron offshore lower food web.

Priority for Science: Issue the SOGL 2022 Report.

- Canada and the United States maintained a suite of comprehensive, science-based ecosystem indicators to assess the state of the Great Lakes, anticipate emerging threats, and measure progress in relation to the GLWQA's General and Specific Objectives. In this reporting cycle, 40 subindicators were used to support and assess nine indicators aligned to the nine General Objectives of the GLWQA.
- For the 2022 reporting year, the scientific integrity of subindicator assessments was strengthened by a technical feedback comment period by subject matter experts. In addition, the SOGL web-based content on binational.net was enhanced to increase public interaction with the SOGL subindicator assessments and information regarding status and trends and key messages from the 2022 SOGL report.
- The 2022 SOGL report was released in 2022 on binational.net to provide an opportunity for public review in advance of discussions at the 2022 Great Lakes Public Forum.

Priority for Science: Encourage opportunities for sharing TEK and apply to GLWQA activities.

- In 2021, a U.S. caucus of the Annex 10 Subcommittee finalized and released a [Guidance Document on Traditional Ecological Knowledge Pursuant to the Great Lakes Water Quality Agreement](#) to enhance the common understanding of TEK and its application towards Great Lakes work. The paper includes: (1) information on how TEK is appropriately gathered and transmitted, (2) examples of how TEK is currently integrated into natural resource management in the Great Lakes basin, and (3) suggestions about how TEK can be incorporated into work already occurring under the GLWQA.
- In 2021, a Great Lakes TEK speaker virtual series was held with the University of Minnesota–Twin Cities' Department of American Indian Studies. This 6-week series brought together tribal, First Nations, Métis, state, provincial, federal, academic, and nongovernmental participants in the United States and Canada, within and beyond the Great Lakes, who share an interest in the role of Indigenous

Great Lakes Traditional Ecological Knowledge (TEK) Webinar Series

2021



6-week Great Lakes Traditional Ecological Knowledge Webinar Series occurred in 2021.
Credit: Science Annex TEK Team of the GLWQA

knowledge. The purpose was to share information with Great Lakes scientists and restoration practitioners on how to appropriately bridge TEK and western science knowledge systems to guide protection and restoration of the Great Lakes and connected ecosystems and traditional lifeways. The speaker series discussed the following topics:

- TEK Guidance Initiatives in the United States and Canada
- Braiding Ways of Knowing: TEK Theory, Methods, and Ethics
- TEK in Great Lakes Area of Concern Priority-Setting Processes
- TEK Guided Research to Address Community-Based Chemical Concerns
- Restoring Culture and Seed Knowledge through Native Plant Restoration
- Bridging Knowledge Systems for Monitoring Initiatives and Climate Adaptation
- *Cladophora* monitoring and assessment

Other Binational Accomplishments

- Binational efforts are underway to understand the conditions that lead to *Cladophora* growth throughout the Great Lakes. During the 2020–2021

Cladophora monitoring and assessment

Overgrowth of *Cladophora* in Great Lakes nearshore environments has negatively affected fisheries, wildlife, and coastal areas by altering food webs, harboring pathogens, and fouling shorelines. *Cladophora* occurrence has substantially increased in recent years (for some Great Lakes), largely because of the complex influence of invasive zebra and quagga mussels. Mussel filtration has altered coastal light regimes and physical habitat, allowing *Cladophora* to colonize deeper areas of the lakebeds.

Cladophora growth season, USGS scientists and divers collected samples each month in lakes Michigan, Huron, Erie, and Ontario to examine the influence of nutrient concentrations and invasive mussels on *Cladophora* growth. Collaborations with universities yielded additional investigations to help managers understand the microbial ecology of *Cladophora* (i.e., how microbes interact with the algae to encourage *Cladophora* growth). The field data will be used to populate models that can help to develop *Cladophora* management strategies to address *Cladophora* impacts. This broad-scale, logistically complex effort is made possible with the help of multiple agency partners, including USEPA, NPS, ECCC, and state agencies. ECCC, with support from Ontario, developed and implemented field and laboratory protocols to assess benthic conditions. These are consistent with other binational agencies and include metrics to assess *Cladophora* and dreissenid mussel status, such as abundance, density, size distribution, and tissue phosphorus content in the eastern basin of Lake Erie and nearshore waters of Lake Ontario. ECCC also collected the data necessary to develop and integrate nearshore and lakewide hydrodynamic and water quality models for developing *Cladophora* response to tributary nutrient inputs.

- Results were used to inform the GLWQA Nutrients Annex Eastern Basin Task Team's assessment of whether current science is sufficient to warrant development of binational phosphorus load and *Cladophora* targets to meet the GLWQA Nutrients Annex Lake Ecosystem Objectives for the eastern basin of Lake Erie.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, Canada and the United States implemented a variety of domestic projects that also support Annex 10 (Science) commitments.

Canada

- **ECCC and DFO sampling cruises.** Although COVID-19 prevented ECCC water quality monitoring on Lake Superior, ECCC and DFO completed whole-lake surveys of Lake Ontario and Lake Erie between August 2021 and September 2021. These cruises incorporated sampling of water chemistry, contaminants, benthos, and planktonic community composition and productivity. Water quality and biota samples were also collected from these lakes in support of USEPA's Great Lakes National Program Office annual summer water quality and biology monitoring program surveys.
 - During the COVID-19 restrictions on fieldwork, DFO's Research Vessel (RV) *Cisco*'s speed, range, and crew of two allowed it to operate between Burlington and Oswego and return with no overnighting or refueling requirements. These capabilities allowed completion of the lakewide Lake Ontario summer zooplankton sampling for the cancelled 2020 USEPA Lake Guardian and Canadian Coast Guard *Limnos* cruises.
 - In June 2020, Phase 1 of the [Canadian Ocean Infrastructure Portal \(COIP\)](#) was launched to facilitate planning of ship-time on the DFO Science-funded science fleet operated by Canadian Coast Guard. Within the Great Lakes, this includes the ships *Limnos* and *Kelso*. This system will be used to identify life-cycle replacement for the fleet, issues of science capacity, and the best uses of DFO Science's \$3.6 million budget to support governmental science priorities for the Great Lakes.
- **Great Lakes DataStream.** Through the Great Lakes Protection Initiative, ECCC funded The Gordon Foundation in 2021–2022 to:

- Support networking among Great Lakes water monitoring groups by engaging diverse audiences (e.g., academic researchers, First Nations, Métis-led monitoring/research programs, cottager associations, conservation authorities, and nongovernmental organizations) to share best practices in collecting, managing, and using water data. The primary area of focus was to build capacity and an understanding of the importance of data management and the benefits of open data sharing.
- Profile monitoring and research efforts are underway in the Great Lakes through networking and through online content development and delivery, including a “communities page” on the Great Lakes DataStream site (an [open access hub for sharing Great Lakes water data](#)) and multi-media storytelling to raise the profile of community and other monitoring efforts in the region.
- **Indigenous led-science and TEK.** During 2020–2022, Canada provided Great Lakes Protection Initiative funding to several multiyear Indigenous-led projects along the Great Lakes to use TEK to address locally significant issues. Many of these projects focused on monitoring local waters and aquatic habitats:
 - Engaging and raising awareness of Great Lakes water quality and ecosystem health issues amongst Métis citizens and communities; providing opportunities for Métis communities to identify their local priorities for science and action.
 - Collecting and analyzing information on the species caught, meal preparation, size and frequency of meals, and contaminant levels of specific species by engaging one or more First Nations communities that rely on Lake Huron or Lake Superior fish in their diet.
 - Engaging members of the Chippewas of the Thames First Nation in Great Lakes water quality and ecosystem health monitoring and restoration activities.
 - Supporting the Chippewas of the Thames First Nation’s efforts to manage agricultural activities on their land, collect data, and promote best practices to reduce phosphorus loadings to the Thames River.
- Expanding the existing Anishinabek coastal wetland monitoring project, focusing on monitoring fish habitat in coastal marshes and the movements and habitat use of Blanding’s turtles.
- Developing an aquatic monitoring program for Shawanaga First Nation to assess the impacts of pollution, excess nutrient loads, and climate change on the Great Lakes environment; and developing community capacity to protect the local watershed and to support delivery of the First Nation’s walleye fishery and hatchery programs.
- Sampling of water, soil, and sediment and conducting monitoring on the Pays Plat First Nation’s Traditional Territory on Lake Superior to establish baseline data and to help signal future risks facing native species.
- **Assessing Jackfish Bay.** ECCC conducted work in Jackfish Bay to assess recovery of fish health, benthos community, and sediment chemical characteristics.
- **Lake Superior survey.** DFO conducted a pre-impact survey of benthos and water properties around proposed aquaculture facilities along the north shore of Lake Superior.
- **Assessing the vulnerability of Lake Erie and Lake Ontario shorelines.** The project [Adapting to the Future Storm and Ice Regime in the Great Lakes](#), supported by NRCan’s Climate Change Adaptation



Shoreline flooding. Credit: Zuzek, Inc.

Program, was completed in 2020. It assessed the vulnerability of Lake Erie and Lake Ontario shorelines to coastal hazards, including the projected impacts of climate change on future lake levels, ice cover, storm surge, and the nearshore wave climate. The study found that mean lake levels are projected to increase, and higher levels are anticipated during periods of above-average rainfall. Lake ice cover will continue to decrease, possibly leading to ice-free conditions on Lake Erie and Lake Ontario later this century. Less ice cover will result in more storms that may affect shoreline communities and cause erosion rates to accelerate, which can also cause an increase in the frequency and magnitude of coastal flooding.

- **OMECP studies and efforts.** OMECP collected and analyzed samples for the Northern Wood Preservers Alternative Remediation Concept Sediment and Biological Assessment. Other OMECP projects in 2021 included fish community studies in Areas of Concern, fish population and habitat dynamics (brook trout, walleye, cisco, lake trout), aquatic invasive species detection and monitoring (e.g., dreissenid mussels, phragmites, ruffe), and lower trophic level invertebrate assessment.

United States

Great Lakes Restoration Initiative (GLRI) Science Foundations for Future Restoration Actions. Under GLRI Action Plan III, 16 federal agencies and their partners continue to investigate the most significant ecological problems in the Great Lakes. GLRI partners have identified cross-Focus Area science priorities to support implementation of the GLRI Action Plan III and the GLWQA, including reducing harmful algal blooms and enhancing coastal resiliency, as described in more detail below. Other scientific studies are also described in the other annexes. In total, 30 GLRI projects that identified and addressed science priorities were conducted in fiscal years 2020–2022 to support GLRI and the GLWQA implementation.

- **Understanding drivers of harmful algal bloom toxicity.** Under GLRI, USGS and NOAA are collaborating on a multiyear project to quantify and characterize the harmful algal bloom toxicity, bloom succession, and relationship to bloom biomass and

nutrient conditions in the western basin of Lake Erie and Saginaw Bay in Lake Huron. This work will fill an important knowledge gap regarding drivers of toxin production and a greater understanding of conditions that promote more toxic strains of cyanobacteria. USGS is analyzing archived samples for microcystin congeners and other classes of cyanotoxins to determine shifts in congener profiles as a function of environmental conditions. NOAA is performing genetic analyses to assess the microbial community response under different environmental conditions in relation to cyanotoxin production.

- **Protecting Great Lakes shoreline investments in the face of a changing climate.** In 2021, USACE, USGS, and NOAA began developing the multiyear Framework for Resilient GLRI Investments effort to identify the range of possible future Great Lakes water levels, wave heights, and ice conditions under various long term (multidecadal) climate change scenarios. These partners are mapping the likelihood of near-term coastal change (within 10 years) using a decision-support tool that synthesizes existing datasets and hazards that may impact the coast. Along with modeled total water levels that account for waves, surges, and changes in potential ice coverage, the partners are developing guidance and checklists that will be made publicly available through a web-based platform to enable the planning, design, implementation, adaptive management, and operations and maintenance of current and future GLRI investments.



Coastal storm on Lake Michigan. Credit: Michigan Sea Grant