# Operationalizing an Early Warning System for the Great Lakes: Summary Report

International Joint Commission
Great Lakes Science Advisory Board

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# Acknowledgements

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# Introduction

The Laurentian Great Lakes are a globally significant resource, holding 20 percent of the world's surface fresh water, and providing ecosystem services to humans in the form of source drinking water, food, waste disposal, energy production, recreation, shipping, and cultural significance. But the delivery of those services and the quality of these fresh waters are threatened or degraded by human activities from within and outside the Great Lakes basin.

The nature of the Great Lakes basin makes it difficult to manage environmental changes due to the geographic scale of the region and the numerous agencies and entities responsible for environmental management. Had an appropriate monitoring and response framework been in place over the last century, many of the disturbances causing significant changes in the basin may have been better anticipated and managed. Given the tremendous inherent value of this freshwater system, it is notable that the region lacks a comprehensive Great Lakes Early Warning System (GLEWS) that monitors and tracks the entire array of emerging threats and stressors[1], including their interactions, and provides warnings with recommended resource management actions.

There are existing examples of geographically or topically specific early warning systems, including ones that address invasive species (Great Lakes Aquatic Nonindigenous Species Information System), contaminant spills (Huron to Erie Drinking Water Monitoring Network), hypoxia and harmful algal blooms (Experimental Lake Erie Hypoxia Forecast; Harmful Algal Bloom Early Warning System), and beach pathogens (various local and regional health departments). While these systems are valuable resources, there is a need for a basinwide early warning system that collects and consolidates data and information, identifies potential tipping points and risk and provides a plan of action for communicating and collaboratively responding to threats. The establishment of a basinwide warning system offers not only operational efficiencies but also the potential to identify threats that may be undetectable at local scales.

Prevention and precaution are two principles outlined in the 2012 Protocol to the Great Lakes Water Quality Agreement (the Agreement). Further, Article 8.3.(b) of the Agreement directs the IJC's Great Lakes Water Quality Board (WQB)[2] to report emerging issues to the Commission who then reports to the governments "identifying emerging issues and recommending strategies and approaches for preventing and resolving the complex

[1] A threat is a condition, event or trend that can ultimately lead to a stressor, while a stressor is a quantifiable chemical, physical or biological change capable of causing adverse effects. For example, reduced ice cover on the Great Lakes due to changing climate can resuspend contaminated sediments (a threat) which can lead to elevated toxins in fish (a stressor).

[2] The WQB is the principal advisor to the International Joint Commission under the Great Lakes Water Quality Agreement and assists the Commission by reviewing and assessing progress of the Parties in implementation of the Agreement, identifying emerging issues and recommending strategies and approaches for preventing and resolving the complex challenges facing the Great Lakes, and providing advice on the role of relevant jurisdictions to implement these strategies and approaches.

challenges facing the Great Lakes"[3]. The WQB currently fulfills this role on an *ad hoc* basis through its membership. Although there are also ongoing interactions between WQB and the IJC's Science Advisory Board (SAB)[4], a formal and structured system between the boards to identify and report on emerging issues has not been established.

To help fulfill the IJC's role in the Agreement to address emerging issues, the SAB undertook a two-phase project to develop an organizational approach and decision framework for a GLEWS to define the process by which different risks posed by existing and potential threats and stressors are evaluated and subsequently communicated and mitigated. The first phase of the project was completed between 2017 and 2020 and resulted in an SAB work group report and supporting contractor report (accessible here). The second phase of the project was completed between 2020 and 2023 and resulted in this Summary Report and a supporting contractor report (accessible here).

Both phases of the project benefited from the guidance and input of a work group (see Acknowledgements section). The project included a detailed literature review of early warning system approaches supplemented by responses to an online survey and select interviews. Draft project reporting was developed that included several candidate organizational approaches and case study analyses of five suspected stressors. Draft reporting was analyzed and critiqued at separate workshops held for each project phase, to develop the final contractor reports. The project also benefited from input received during International Association of Great Lakes Research Annual Conference sessions organized by the work group in 2019, 2021 and 2023.

The project work group conceptualized the GLEWS according to a range of factors shown in Figure 1. For the purposes of this project, the work group focused primarily on suspected[5] slow onset[6] basinwide stressors. Both positivist science and Indigenous Knowledge were considered, although due to its prevalence the former received greater consideration.

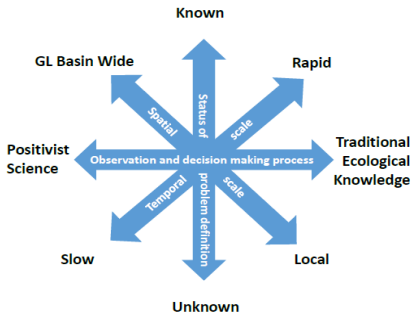


**Figure 1 Four axes of emerging issues**

[3] Canada and the United States, 2012. Great Lakes Water Quality Agreement, entered into force February 12, 2013. Accessed at https://ijc.org/sites/default/files/2018-07/GLWQA_2012.pdf, July 11, 2023. 56 p.
[4] The SAB provides advice on research and scientific matters to the Commission and to the WQB.
[5] A stressor that may or may not currently affect the Great Lakes but is predicted or expected to occur in the future, with some level of confidence.
[6] The project examined early warning systems as distinct from early detection systems. Early warning systems examine gradual or slow onset stressors and threats that are expected to take many months or years to materialize and are expected to affect large geographic areas (e.g., one or more of the lakes). For example, early detection of an invasive species can be considered a component of an early warning system due to the potential far-reaching impacts of a new invader. In contrast, early detection systems are in place to address rapid onset stressors and threats that take minutes, hours or days to materialize and are of smaller spatial scale. An example of an early detection system includes real-time water quality monitoring to alert drinking water plant operators about the presence of contaminants moving towards plant intakes so that appropriate adjustments to treatment processes can be applied.

The primary audience for the Great Lakes Early Warning System is the federal governments of the United States and Canada, who are signatory to the Agreement and hold primary responsibility for achieving its objectives. Project reporting may also be of interest to state and provincial governments, First Nations and Tribal governments, universities, and non-government organizations.

# Components of an Early Warning System

The peer-reviewed and gray literature identifies four primary components for environmental Early Warning Systems. These components were considered during the case study analyses to provide insights for the design of the GLEWS decision framework.

## Monitoring

The core of an early warning system is data collection associated with research and monitoring activities which allow us to assess status and trends of parameters and phenomena and predict future hazards. Monitoring programs must include appropriately calibrated indicators/metrics that provide pertinent information and can be used to infer or represent the state of a system. The most useful indicators are linked to endpoints that are familiar and relevant to the public and managers and are appropriately benchmarked to a response that is meaningful[7]. Such benchmarks provide the basis for triggering a warning that is communicated to appropriate management agencies to initiate action in response to the threat.

The Parties' State of the Great Lakes report describes the status and trends of indicators related to the nine General Objectives of the Agreement; most indicators cover the status or condition of various resource values (e.g., wetlands) or stressors (e.g., aquatic invasive species). Such indicators are useful towards developing a GLEWS but because they are focused exclusively on the Agreement's nine General Objectives and more generally on legacy stressors and impacts, additional attention to indicators/metrics is needed to implement an early warning system.

The work group found that data accessibility and usability are key elements – in many cases adequate data are available but we may lack the expertise to use the data effectively or they may be underused for decision-making, which affirms the finding of an earlier SAB project[8] which identified barriers to information flow and offered recommendations related to

[7] Jackson, L.E., Kurtz, J.C., Fisher, W.S., 2000. Evaluation guidelines for ecological indicators. EPA/620/R-99/005. US Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC. 107 p.

[8] IJC Science Advisory Board, 2018. Information Coordination and Flow in the Great Lakes Basin. Submitted to the International Joint Commission. Accessed July 27, 2023 at https://ijc.org/sites/default/files/information-coordination-flow-great-lakes-basin-sab-2018.pdf.

improving information flow to decision-makers and the public. The work group also identified that standardizing data structure is critical for data sharing, integration, and interoperability.

## Risk knowledge

An early warning system requires an ability to anticipate possible futures and develop responses to eliminate or mitigate negative impacts identified in the futures. An example includes the Great Lakes Aquatic Nonindigenous Species Information System which has been developed to detect new invaders to the Great Lakes. Risk assessment identifies the potential hazards and vulnerabilities by means of a systematic process[9]. Several risk assessment approaches have been developed; a common one is horizon scanning, which provides a systematic way of improving foresight of otherwise unexpected environmental issues[10]. Regardless of the foresight technique applied, models (e.g., conceptual, statistical and mechanistic) should be employed and should reflect potential state changes and inflection points to avoid the risk of locking in assumptions about the system that are not supportable going forward[11].

## Communication and dissemination

Once a threat is recognized, a mechanism must be in place to transmit information to the appropriate decision-makers and responders. Rapid onset threats, such as accidental chemical spills or extreme weather events, generally have well-defined response protocols embedded within agencies with emergency management responsibility, although there may be gaps in areas that cross jurisdictional boundaries[12]. However, slow onset threats are a challenge to communicate to appropriate responders and may require a broad range of local to regional to basinwide management practices and policies, each with their associated communication strategies. Although there may be multiple practices and policies given the diversity of the system, integrated and consistent messaging is needed.

## Response

In most cases, responding to emerging stressors is the responsibility of one or more government agencies. Coordination among appropriate responders is critical for successfully addressing the threats identified by an early warning system. While coordination among agencies within a country or among countries associated with emergency response organizations is known to be improving, the GLEWS decision framework developed as part of this project provides a structured approach to identifying the range of slow onset basinwide threats.

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[9] United Nations Office for Disaster Risk Reduction, 2018. Annual Report 2017, 2016-17 Biennium Work Program Final Report. Accessed at https://www.unisdr.org/files/58158_unisdr2017annualreport.pdf, July 11, 2023. 64 p.

[10] Sutherland, W.J., Woodroof, H.J., 2009. The need for environmental horizon scanning. Trends in Ecol. Evol. 24(10), 523–527.

[11] Beck, M.B., 2005. Environmental foresight and structural change. Environ. Model. Softw. 20(6), 651–670.

[12] Personal communication, Dr. Carolyn Johns, Ryerson University, February 2020

# Early Warning System Decision Framework

The work group applied available insights, from the literature, supplemented by online surveys and interviews with subject matter experts and knowledge holders, to five detailed case study topics to inform the development of a GLEWS decision framework. The case study topics were carefully selected to represent several stressor categories (chemical, nutrients, climate change, biological, human/behavioral). The set of suspected stressors and threats examined in the case studies and further evaluated in a project workshop included:

1. Changes in concentrations of nitrogen and other key non-phosphorus nutrients.
2. Climate change impacts on agricultural ranges and practices, and on aquatic species ranges.
3. Introduction and spread of fish pathogens.
4. Shifts in groundwater usage and related ecological impacts.
5. Occurrence and impacts of contamination by per- and polyfluoroalkyl substances (PFAS).

The resulting decision framework can be used to identify benchmarks and indicator thresholds of various groups of threats and stressors and, in so doing, rank and prioritize or re-prioritize them for action on an iterative basis. The resulting decision framework is depicted in the figure overleaf, and includes three functional blocks:

1. Identify & Screen: (1) Use expert elicitation processes and ongoing monitoring of chatter[13] by stakeholders and others to build and maintain libraries of possible threats for screening and prioritization, and (2) regularly screen existing datasets for data anomalies that may portend emerging threats, for further examination.

2. Understand & Design: Build a sufficient knowledge base and understanding of the state of the science for the suspected threat to confirm the threat's importance and establish a preferred approach for responding to the threat.

3. Implement & Operate: (1) Communicate the findings of earlier steps to appropriate management and response agencies and entities, taking full advantage of existing programs, activities and arrangements, and (2) use an adaptive management approach to periodically revisit the state of the science and confirm risk at appropriate intervals (e.g., annually).

The outcome of applying the decision framework is a list of suspected threats or of data anomalies that suggests an emerging threat(s) or stressor(s). Separate assessments of each threat's importance means that there may be multiple independent Understand & Design efforts going on at a given time. The Understand & Design step will result either in the demotion of the suspected threat and its return to the Library (due to insufficient

[13] Qualitative input derived from observation and analysis of social media, media reports, news feeds, and related sources that may characterize development or impacts of a stressor, threat or impact.

importance) or recommendation and furnishing of an EWS design for implementation and operation. In the Implementation & Operation step, operational monitoring for the threat will continue until reassessment of the state of the science demonstrates that the threat level has sufficiently decreased.

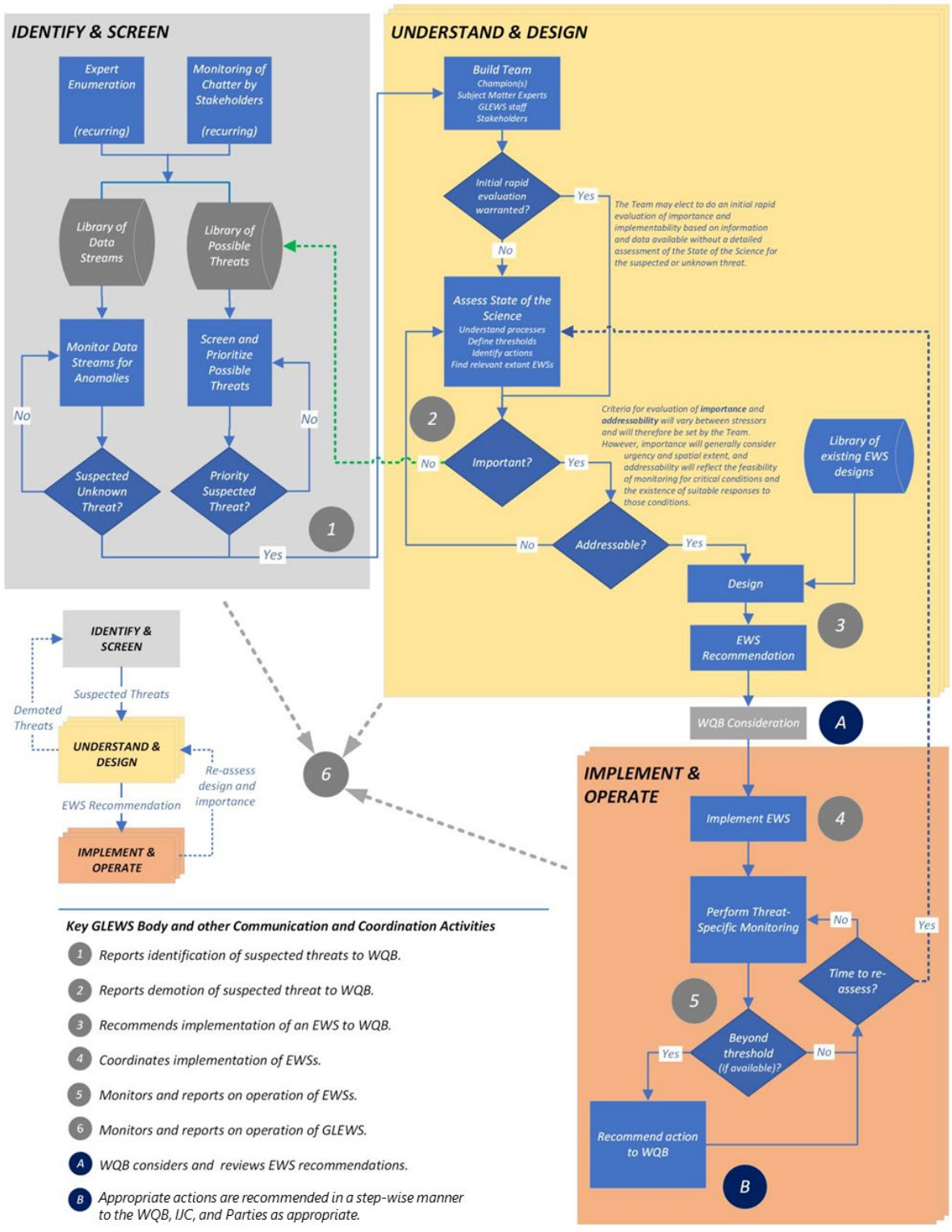


**Figure 2 GLEWS Decision Framework**

# Findings & Recommendations

**The project work group finds that:**

1. Several structures, programs, and knowledge systems that exist within IJC and externally can be leveraged or adapted to implement elements of the GLEWS, including IJC advisory boards, committees of other commissions, Indigenous Knowledge systems, agency reporting systems, community science networks, and outdoor recreation groups.

2. Although the IJC itself does not have sufficient resources to conduct or support the research and monitoring needed to fill critical gaps related to suspected threats, the IJC may be positioned to provide support (e.g., staff time, convening costs) to coordinate binational assessment activities and development of tracking and scoping documents through its boards and work groups and related strategic partnerships that can guide federal agencies and external organizations in conducting priority research and monitoring.

3. Some suspected and emerging threats may have both upper and lower thresholds of impacts, which complicates defining threat states and management responses. Additionally, natural baselines and ranges are also not known in all cases.

4. Professional associations (e.g., the International Association for Great Lakes Research [IAGLR] which has a primary focus on aquatic ecology) can play a convening role in horizon scanning and threat assessment. Some threats, however, fall outside the purview of IAGLR and similar biophysically oriented scientific societies and may require engagement with other professional organizations and communities to develop detection, monitoring, and warning approaches that encompass the full range of threats to the Great Lakes basin.

5. Ensuring the participation of response agencies/organizations in the application of the GLEWS decision framework is important to ensuring successful response activities.

**The project work group recommends that:**

1. Recommendation from Phase 1 GLEWS project: The IJC create a GLEWS Committee that would operate as an entity reporting to the Great Lakes Water Quality Board, which in turn would alert the Commission to prioritize suspected or emerging stressors. To function appropriately, a GLEWS Committee requires highly qualified personnel and resources to assemble, assess, prioritize, and report on emerging threats that the Parties (e.g., the governments of Canada and the United States) have available in their agencies. Therefore, the GLEWS Committee should be supported by subject matter experts provided by the Parties. The IJC would serve the role of oversight by convening additional highly qualified personnel to evaluate the effectiveness of the GLEWS Committee.

The precedent for a similar functioning group is the IJC's Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee. The GLAM Committee undertakes monitoring, modeling and assessment needed to support ongoing evaluation of the regulation of water levels and flows in the Great Lakes-St. Lawrence River system. Accordingly, the GLAM Committee reports to the Lake Superior Board of Control, Niagara Board of Control, and International Lake Ontario-St. Lawrence River Board.

2. Recommendation from Phase 2 GLEWS project: Undertake a pilot project to implement the GLEWS decision framework described in this report that focuses on one of the potential stressors identified during Phase 1, or one of the case studies examined during Phase 2. Related activities would include:

    - Develop terms of reference for a provisional GLEWS Committee that will exist as a standing subcommittee or work group under the IJC Water Quality Board. The terms of reference should include its composition, membership (including but not limited to agency staff), duration, meeting frequency and format, IJC staff support, funding requirements, data management and communication, and reporting expectations.

    - Coordinate the establishment of the GLEWS Committee with federal agencies, state/provincial agencies, First Nations, Tribes, Métis, IJC staff and advisory boards, and key stakeholders (e.g., IAGLR).

    - Develop scoping documents for the GLEWS technical infrastructure for decision-support, including data, models, tracking of published research, and communications.

The Great Lakes science and management community has successfully remediated many established Great Lakes stressors. Those resource-intensive experiences have highlighted the prudence of anticipating and preventing threats and stressors before they become established. The SAB hopes that the analysis and decision framework included in this report provides a useful description of the elements of an effective Great Lakes Early Warning System and its associated organizational structure.