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GARDE-RIVIÈRE des Outaouais

Assessing the Health of the Ottawa River Watershed

Phase One

Fondation ECHO Foundation

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Ville de Gatineau

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[1] Members of the Watershed Health Committee: Denise Cloutier, Peter Croal, Geneviève Gallerand, Ethan Huner, André Martel, Jérôme Marty, Catherine Paquette, Colin Rennie, Jeff Ridal, Nick Stow, Marilou G. Thomas, Mary Trudeau, Mike Yee.

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Patrick Nadeau
Executive Director

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1 Introduction

Participants at the Ottawa River Summit (2015) articulated an overwhelming interest in assessing the health of the Ottawa River (OR) and its watershed. This call to action was captured in the Gatineau Declaration that was co-created and presented at the 2015 Summit. Given that a full watershed assessment is a very large undertaking, Ottawa Riverkeeper agreed to begin the process. We convened a Watershed Health Committee and began a process and series of conversations to develop indicators that could be used to help assess watershed health.

This report, Assessing the Health of the Ottawa River Watershed: Phase One, recommends an initial set of indicators to assess the ecological health of the Ottawa River Watershed (ORW). This phase of work also includes first steps to establish a collaborative working relationship with the Algonquin First Nation (whose unceded territory includes the entire Ottawa River Watershed) to understand the health of the Ottawa River Watershed.

> Phase One is only the start of work needed to assess a full set of indicators that include environmental, social, and economic aspects of a health assessment.

In this report,

- Section 2 describes the broad collaborative approach that underpins this project.
- Section 3 identifies key characteristics of the Ottawa River Watershed to be considered when developing indicators.
- Section 4 outlines the initial steps in implementing collaborative work with the Algonquin First Nation.
- Section 5 describes the scope and criteria for developing indicators, outlines a framework for organizing ecological indicators, and presents an initial, short list of ecological indicators for Phase One.
- Section 6 discusses data availability and quality for the short-listed indicators.
- Section 7 offers a preliminary analysis for select indicators on the short list, where data were available.
- Section 8 identifies critical challenges in analyzing data, interpreting results, and achieving healthful management of the Ottawa River Watershed.
- Section 9 reports initial observations on the health of the Ottawa River Mainstem.
- Section 10 presents essential recommendations and next steps.

This report is written assuming the reader 1) recognizes the importance of a watershed health assessment and 2) is familiar with the Ottawa River Watershed.

Funding for this report was provided by Environment and Climate Change Canada (ECCC), the City of Gatineau, and Echo Foundation.

2 Implementing a collaborative approach

In preparing this report, we consulted with a wide range of organizations and individuals whose mandates include the protection, promotion, and/or regulation of the Ottawa River Watershed or one of its subwatersheds.

In the early days of this project, we consulted regularly with our own Watershed Health Committee, a group of volunteer water experts made up of academics, program managers, and other advisors. This meticulous groundwork allowed us to reach some preliminary decisions regarding which conceptual framework should be favoured and which categories of indicators should be explored. We then approached other stakeholders in our network and started putting in place the building blocks for this unprecedented watershed health assessment.

In November 2018, we convened more than 50 participants from these groups to an all-day, in-person meeting in Ottawa, where we presented the project, including an initial long list of indicators on which we solicited feedback. The input and additional information these watershed actors provided, along with the questions they raised, guided our development of the subsequent short list.

Organizations consulted: Agence de Bassin Versant des 7, Blue Fish Canada, Bonnechère River Watershed Project, Brookfield, Canadian Parks and Wilderness Society (CPAWS-Ontario), Comité du Bassin Versant de la Rivière du Lièvre (COBALI), Conseils des Bassins Versants des Mille-Île's (COBAMIL), Conservation Ontario, Ecology Ottawa, Energy Ottawa, Friends of Brewery Creek, Friends of the Gatineau, Lac Deschênes Sailing Club, Mississippi Valley Conservation Authority, Muskrat Watershed Council, National Capital Commission (NCC), Nature Conservancy of Canada, Ontario Landowners Association, Ontario Power Generation, Organisme de Bassins Versants des Rivières Rouge, Petite Nation et Saumon (OBVRPNS), Organisme de Bassin Versant du Témicamingue, Ottawa River Institute, Ottawa River Regulation Planning Board, Rideau Valley Conservation Authority, St Lawrence River Institute, Swim Drink Fish Canada, Watersheds Canada, World Wildlife Fund – Canada.

Also present at this gathering were three elected officials (from Ottawa, Gatineau, La Pêche) and two civil servants from Environment and Climate Change Canada's Water Policy unit.

An extensive outreach exercise with Algonquin communities throughout the Ottawa River Watershed was also led by our Indigenous Researcher. This took the form of several in-person meetings and presentations, followed by additional correspondence, all in effort to build mutual trust and establish new channels of communication. These actions and their outcomes are described in detail in Section 4 of this report.

In February 2019, to enhance our knowledge of what raw data is being collected in particular areas of the watershed in Québec, we facilitated a tele-conference with four Organismes de Bassin Versant (ABV des 7, COBALI, COBAMIL, OBVRPNS), as well as representatives from Nature Conservancy Canada and World Wildlife Fund Canada. This clarified our understanding of existing data gaps, jurisdictional discrepancies, local capacity, and respective program priorities.

3 Key characteristics of the Ottawa River Watershed

The Ottawa River is the largest tributary to the St. Lawrence River. The Ottawa River is unique in Canada because, for much of its length, it defines the provincial boundary between Quebec and Ontario. Of the 146 334 square kilometer[2] watershed, 65% is in Quebec and 35% is in Ontario. The length of the Ottawa River from its headwaters to the Carillon Dam is about 1130 km.

The watershed of the Ottawa River is vast and geographically diverse. Accordingly, the conditions and characteristics of the Ottawa River change substantially from the headwaters to its confluence with the St. Lawrence River. There is also dramatic variability in population densities within the watershed. Most of the watershed's land has natural cover but there are pockets of high population density, in particular to the south-east, on both sides of the river at Ottawa-Gatineau.

> The Ottawa River is the largest river in Canada lacking collaborative and coordinated management of water quality, water quantity, and biodiversity.

This natural variability is best represented by a health assessment that subdivides the Ottawa River Watershed into segments. Previous studies have identified segments using different approaches. WWF[3] (2015) identified three regions for its Watershed Report: headwaters, central, and lower. In a study on the natural environment and resource use, Haxton and Chubbuck (2002)[4] identified reaches of the Ottawa River Mainstem in seven intervals defined by dams, between Lake Timiskaming and the Carillon Dam. Eight regional organizations in Quebec and four in Ontario rely on natural terrain to define subwatersheds of the Ottawa River. However, large portions of northern and western Ontario—including part of the Ottawa River Watershed—are not covered by regional organizations. In addition, regional subwatersheds would be too numerous for the purposes of an initial assessment of the entire Ottawa River Watershed.

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[2] Statistics in this paragraph were sourced from a report by the Province of Quebec, *Summary Profile of the Rivière des Outaouais Watershed* (2015)

[3] WWF Watershed Reports, http://assets.wwf.ca/downloads/WWF_Watershed_Reports_Summit_FINAL_web.pdf?_ga=2.175707234.151515058.1550423873-627997127.1550423873 (2017)

[4] Tim Haxton and Don Chubbuck, *Review of the historical and existing natural environment and resource uses on the Ottawa River*, OMNR SCSI Technical Report #119 (2002)

For Assessing the Health of the Ottawa River Watershed: Phase One, we focus specifically on the mainstem of the Ottawa River. Moreover, for analysis, we have necessarily adopted the watershed delineations used by the individual organizations that provided existing data. As such, the specific subdivision of the watershed necessarily varies by indicator. However, note that the Phase One indicators are scalable, so they are equally applicable to subwatersheds and other subsets of the Ottawa River Watershed.

For more information on the Ottawa River Watershed, several available sources describe the ecological, cultural, social, and economic features of the watershed, including the history and governance of the watershed (see Section 5.3). The federal, provincial, and municipal governments also have information on the Ottawa River Watershed. In addition, websites of the subwatershed organizations can be accessed, including:

- Agence de Bassin Versant des 7 (ABV des 7);
- Comité du Bassin Versant de la Rivière du Lièvre (COBALI);
- Organisme de Bassin Versant Abitibi-Jamésie (OBVAJ);
- Organisme de Bassin Versant de la Rivière du Nord (ABRINORD);
- Organisme de Bassins Versants des Rivières Rouge, Petite Nation, et Saumon (OBVRPNS);
- Organisme de Bassin Versant du Témiscamingue (OBVT);
- Conseil du Bassin Versant de la région de Vaudreuil-Soulanges (COBAVER-VS);
- Conseil des Bassins Versants des Mille-Îles (COBAMIL);
- North Bay-Mattawa Conservation Authority;
- Mississippi Valley Conservation Authority;
- Rideau Valley Conservation Authority;
- South Nation Conservation Authority.

4 Initiating collaboration to include Indigenous Knowledge Systems

The Ottawa River flows throughout the unceded traditional territory of the Algonquin Nation. The Algonquin Nation have unextinguished Aboriginal rights and title on their territory which includes the Ottawa River Watershed. The Algonquin Nation's existing aboriginal rights are recognized and affirmed under Section 35 of Canada's *Constitution Act*.

Article 29 of the United Nations Declaration on the Rights of Indigenous Peoples states: "Indigenous peoples have the right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources. States shall establish and implement assistance programmes for indigenous peoples for such conservation and protection, without discrimination."

The Algonquin Nation continue to exercise their governance and jurisdiction on their unceded traditional territory and must have a prominent role in the development of indicators to monitor watershed health. The Algonquin Nation have a wealth of Indigenous Knowledge and their input on the development of indicators will ensure a holistic approach to monitoring and protecting the watershed. Undertaking a collaborative approach with the Algonquin Nation will help build positive relationships that will lead to a shared understanding on how to protect and restore the watershed.

Connecting Algonquin Traditional Knowledge (TK) with scientific knowledge is an essential step in developing relevant indicators for monitoring the ecological health of the Ottawa River Watershed. While the inclusion of "traditional knowledge" with scientific knowledge is a positive step, it can be problematic and therefore, would require further discussion and consensus amongst communities given the following considerations.

The term "traditional knowledge" is narrow, uncertain, and not defined. This creates uncertainty about what will be considered as "traditional knowledge". Indigenous Knowledge Systems is a term which captures the nature of Indigenous Knowledge and makes the distinction between the terms "use" and "knowledge" clearer. For example, the term "use" can include data about locations of current or historical resource harvesting versus "knowledge" which can include principles about sensitivities of animals or plants at a certain time of the year.

The use of the term "traditional" raises the concern that the "knowledge" being considered will be frozen in time, and that it could exclude the evolution of Indigenous Knowledge that occurs over time in response to new circumstances and changes in the environment. It is recommended that the term "traditional knowledge" be replaced with "Indigenous Knowledge" and the term be defined.

4.1 Scope of work

Initiating dialogue with the Algonquin Nation was an opportunity to share draft indicators and to seek interest in the co-development of a Memorandum of Understanding (MOU) between Ottawa Riverkeeper and the Algonquin Nation. A briefing note was shared with the Algonquin leadership for consideration on co-developing a MOU.

A contractor was hired to engage the following duly recognized Algonquin communities: Kabaowek First Nation, Conseil de la Premiere Nation Abitibiwinni, Conseil de Anicinapek de Kitcisakik, Algonquins of Barriere Lake, Wolf Lake First Nation, Conseil de la nation Anishinabe de Lac Simon, Temiskaming First Nation, Long Point First Nation, Algonquins of Pikwakanagan First Nation, Waghoshig First Nation, and Kitigan Zibi Anishinabeg.

A fact sheet on the Ottawa River Watershed Indicators Project was shared and presented at meetings with participating Algonquin communities. The intent of outreach and engagement with the Algonquin Nation was not to collect Indigenous Knowledge but rather to discuss how it can be included in the development of indicators. It's important to note that Algonquin protocols were respected and followed.

4.2 Engagement and outreach results

4.2.1 Collaboration

The Algonquin Nation continue to assert their responsibility for the land and water. The Algonquin Nation traditional management and jurisdiction of the land must be equally recognized within federal and provincial legislation. The Algonquin Nation must be an equal partner and influencing decisions versus being a consultation body in the process. For example, there are countless incoming consultation requests from all levels of government, industry, and organizations, the Algonquin Nation currently have lack of funding to formally respond to such requests.

Federal, provincial, and municipal governments have funding level supports to implement their mandates, rules, and legislation. Funding for the Algonquin Nation is also required in order to be an equal partner at the table. Long-term funding for the establishment of an Algonquin Nation governance body is required in order to support co-management and co-governance with federal, provincial, municipal governments, and other key stakeholders.

Algonquin communities need to be provided with the opportunity to participate in measuring and monitoring indicators through the following federal programs:

- Motion 104: In 2017, a motion (M-104) to create an Ottawa River Watershed Report which would bring a comprehensive, inclusive, co-management approach to the Ottawa River Watershed, was agreed to by the Federal Government. The value of Algonquin communities' feedback and contribution on this potential co-governance opportunity presented in their reporting cannot be stressed enough.
- Transport Canada: The Indigenous and Local Communities Engagement and Partnership Program (ILCEPP) https://www.tc.gc.ca/en/programs-policies/programs/indigenous-local-communities-engagement-partnership-rogram.html
- Nature Fund Challenge/Pathway to Canada Target 1 Challenge: https://www.canada.ca/en/environment-climate-change/services/environmental-funding/programs/pathway-canada-target-1-challenge.html
- Indigenous Guardians Program: https://www.canada.ca/en/environment-climate-change/services/environmental-funding/indigenous-guardians-pilot-program.html

Some Algonquin communities are undertaking environmental research projects and studies. A fully funded guardians' program within the Algonquin Nation will support capacity development and establish their role as a ministry on their unceded traditional territory. This will help avoid the administrative burden of reporting on short term projects.

The Algonquin communities want to work directly with Environment and Climate Change Canada in organizing their communities as Algonquin waterkeepers on their own territories in a co-governance structure and Nation to Nation with Canada, and they also want to be kept informed of the work being undertaken by Ottawa Riverkeeper. The development of a MOU between Ottawa Riverkeeper and the Algonquin Nation needs to be further explored and discussed. Establishing a process that shapes the relationship between Ottawa Riverkeeper and the Algonquin Nation can pave the way to enhance two-way communication and facilitate information sharing and collaboration on future initiatives.

4.2.2 Including Indigenous Knowledge

There is a shared understanding on the importance of including Algonquin Indigenous Knowledge with scientific knowledge to support informed decision making. In order to ensure the protection of Indigenous Knowledge, this knowledge needs to be collected by the Algonquin Nation for the Algonquin Nation as there is concern on how Indigenous Knowledge will be utilized and interpreted. Only the Algonquin people should determine how and when their Indigenous Knowledge can be put forward to support the co-development of indicators.

The recognition and protection of the intellectual property rights of First Nations for their knowledge requires more clarity on how their knowledge would be used and interpreted. It needs to be recognized that Indigenous Knowledge belongs to those who are the guardians of it, be it the Nation or individuals within a Nation. An attempt to include Indigenous Knowledge in watershed indicators should not have unintended consequences for the knowledge holder or communities sharing the knowledge. Confidentiality provisions would need to be adequate so that knowledge can not be disclosed without consent. This provides certainty to Algonquin communities that the information they provide will be treated respectfully or appropriately, for example, Indigenous values and knowledge are often marginalized while participating on a regional table or board represented by more dominant actors and it would be better not to provide Indigenous Knowledge if there is a significant risk that the information won't be recognized or protected.

Terms must be developed for the confidentiality and use of "Indigenous knowledge".

In addition, provisions should be added to respect any processes or protections for the consideration of Indigenous Knowledge, after consultation with the each of the Algonquin communities and their knowledge holders.

To understand nature's laws, there is a need to include Algonquin ancestral knowledge, traditional conservation methods and customs. Including Algonquin grassroots people in the dialogue is essential as they have the experience and knowledge based on their connection with the water, land, animals, plants, and fish, etc. As an example, grassroots people have the capacity to recognize indicators of concern in nature and providing them with an opportunity to share their knowledge can help protect critical habitat for fish spawning areas.

The Algonquin Nation are interested in hosting a water gathering for their membership. This will require funding to bring together community members to discuss their inherent right to the use and protection of the Ottawa River Watershed. Having a gathering is an opportunity to share Indigenous Knowledge and teachings of the land as this is what guides the Algonquin Nation governance. It’s important to recognize that the Algonquin people are occupying their unceded traditional territory and have an important role in the development, enforcement, and monitoring of indicators.

4.2.3 Indicator Considerations

The following recommendations need to be considered in the development of indicators:

- There is a need to have ecological thresholds to determine what the recommended rate would be for falling below a threshold;
- Questions on who will determine the ecological threshold and rates, and who will ensure reporting and compliance needs to be addressed;
- Include testing of water quality, water temperature, and clarity;
- Understanding pH levels and water chemistry are important factors to consider;
- Monitoring shoreline erosion utilizing GIS mapping;
- Understanding mining contamination and pollution on fish spawning areas and impacts to fish population;
- Need to determine the costs associated with developing indicators;
- Include cost analysis for persistent organic pollutants (POPs);
- Consider data sharing agreements between organizations to address liability issues associated with sharing of data;
- Develop habitat classification studies;
- Endangered and species at risk are relevant indicators:
- need to address zoning issues for classifying these species, for example, Lake Sturgeon and American Eel are not considered a protected or endangered specie in certain areas so how do we ensure a consistent approach to protecting these species;
- Blue-green Algae blooms are valid indicators;
- Socio-economic indicators can include cost to municipalities for their clean drinking water and research should be undertaken on the history of their water quality;
- Having one database system for Ottawa River watershed testing will support tracking of water quality;
- Address accountability concerns up river and monitoring communities down stream:
- need to undertake water testing up river and then test down river to identify where the source of pollution is coming from and to monitor water flow and temperature changes;
- Important to test waters during spawning periods for fish.

4.2.4 Invasive Species

Identifying and monitoring the impacts of invasive species is an important indicator raised by the Algonquin Nation. Algonquin people have been observing and monitoring the impacts of invasive species and therefore have an important role in mapping out their location. Some examples of invasive species that were identified include: Purple Loosestrife, Hogweed, Watercress, and Eurasian Water-milfoil.

The fresh water jelly fish is another invasive species that was identified. It is recommended that a lake analysis be undertaken to understand the impact of this invasive species. Identifying and mapping lakes can raise public awareness and larger understanding of environmental issues. Washing stations for trailers and boats around the vicinity of contaminated lakes is needed in order to avoid the spread of invasive species.

A holistic approach to monitoring the environment is needed in order to understand how invasive species upset nature's balance. It's important to monitor non-native species to ensure balance is maintained for aquatic life.

4.2.5 Identifying Threats

The Algonquin Nation's occupation of their unceded traditional territory can help support the identification of threats to the Ottawa River watershed. The Algonquin Nation identified the following concerns:

- Need for 200 meters of river protection where this area would be protected from any development, such as forestry;
- Impacts of development:
  - pipelines (Gazoduc);
  - Le Breton Flats re-development project;
- Chalk River release of radioactive toxins;
- Effluents from pulp mills:
  - reporting and accountability of Tembec's pulp and paper mill located within the municipality of Témiscamingue;
- Dissolved chloride:
  - winter road maintenance and use of salt;
  - monitoring levels of leaching into waterways;
- Socio-economic impacts to Algonquin people food source:
  - threats to our hunting, fishing, trapping, and harvesting rights;
- Impacts of dams:
  - impacting fish migration;
  - changing of water temperature and water levels;
  - sediments exposure to the atmosphere;
- Impacts of logging:
  - bark sediments;
  - underwater sunken logging permits and impacts to fish population when draining out lakes;
- Sewage:
  - municipality accountability and reporting on the release of raw sewage;
  - monitoring septic systems from cabins/cottages/houseboats;
  - no station for dumping which is creating blue/green algae;
- Hunting and Fishing Outfitters with exclusive rights:
  - what is their requirement to monitor and report;
  - who is monitoring and ensuring accountability; and
- Environmental concerns with pharmaceutical drugs entering the waterways.

Further dialogue is required with the Algonquin Nation to discuss these threats in detail.

4.3 Recommendations

Meaningful engagement with all duly recognized Algonquin communities is required in the co-development of a full suite of indicators. Developing indicators based on Indigenous Knowledge will require financial resources to engage Algonquin communities effectively.

The Algonquin Nation must have the lead in undertaking further dialogue sessions with their membership. An Algonquin-led water gathering can bring together all Algonquin communities to discuss the protection and preservation of the Ottawa River Watershed and the sharing of Indigenous Knowledge.

Ensuring an equal voice by the Algonquin Nation requires dedicated long-term funding to support the establishment of an Algonquin Nation governance body. Dedicated resources and personnel are needed in order to increase the capacity within the Algonquin Nation. A fully funded guardian's program will support the Algonquin Nation to take their rightful place as a ministry on their unceded traditional territory.

In the spirit of reconciliation, there is an opportunity to develop partnerships between the Algonquin Nation and federal, provincial, and municipal governments, and other key stakeholders like Ottawa Riverkeeper. Further dialogue is required on co-management and co-governance of the Ottawa River Watershed and what role the Algonquin Nation will have as an equal partner.

5 Developing indicators of ecological health

This section introduces the ecological indicators recommended for Phase One. First though, the scope and criteria for developing these indicators is described, along with the approach, and the literature on watershed health indicators that was reviewed to develop the approach. A framework for organizing indicators is presented, with more detail for ecological health indicators than for socio-economic health indicators. Suggestions for additional indicators to consider in subsequent phases of work are presented.

> The ultimate goal of Ottawa Riverkeeper is to develop a full suite of indicators as part of building a comprehensive understanding of the health of the Ottawa River Watershed. The importance of diverse indicators is acknowledged, including ecological, social, and economic indicators, as well as indicators of climate adaptation by communities. Indicators for these dimensions of watershed health can be incorporated in future.

5.1 Scope and criteria

In Phase One, indicators focus on the ecological health of the Ottawa River Watershed. Within the realm of ecological health, the scope has been further refined to ensure **a feasible number** of indicators are identified. Phase One includes indicators **best suited to surface water in river systems**. Although indicators for groundwater, lake systems, and wetlands may overlap, refinement and additional indicators will be required to adequately assess these water systems. For example, additional indicators for lakes may pertain to stratification, oxygen at depth, and acidification. Socio-economic indicators for human health and well-being may be related to the use of river resources (e.g. drinking and recreational water quality at beaches), cultural aspects, economic activities, and/or valuation of ecosystem services.

The recommended indicators developed have, as a first priority, **scientific rigour**. One of the ultimate goals of the watershed health assessment is to communicate to all stakeholders and the public about the health of the watershed. However, the indicators must be scientifically defensible and as informative for scientists as they are for other stakeholders. Communications expertise will ensure that the trends indicated by the scientific indicators are understandable and meaningful to audiences with a range of expertise.

The first indicators focus on **quantitative** measures. Trends through time (past and on-going future) are needed for a full assessment. **Indicators with historic data are desirable**, although some of the short-listed indicators (such as Ecological Connectivity) currently have very little data.

Phase One of the health assessment focuses on the mainstem of the Ottawa River. However, indicators should be **scalable**, that is, applicable to the mainstem river, as well as to nested subwatersheds.

Indicators describe the status of an element (a feature) of the watershed or a threat to an element (a stressor that alters a feature), as elaborated in Section 5.4. As such, indicators can be **used as part of an analysis and decision-making framework**.

5.2 Identifying indicators

A long list of potential indicators was developed based on a literature review and meetings with the Watershed Health Committee in 2018. From this list, a short list was developed iteratively, based on 1) consultations with Watershed Health Committee, watershed agencies, and researchers; 2) data availability through online sources and responses to data requests; and 3) preliminary analyses of some indicators. Data collection efforts were made to assess the feasibility of implementing these indicators and to recommend data collection and/or harmonization of data collection throughout the watershed.

5.3 Key reference literature

To initiate the project, recent work on the Ottawa River Watershed was reviewed, including:

- The Province of Quebec's Summary Profile of the Rivière des Outaouais Watershed (2015);
- World Wildlife Fund Watershed Reports[5] (2017), in particular, information for the Ottawa River Watershed;
- ECCC's report, An Examination of Values, Existing Data, Potential Indicators, and Governance in The Ottawa River Watershed (2018)[6];
- Ottawa Riverkeeper maps and reports, including Ottawa Riverkeeper's River Report (2006); and,
- Records of discussions by the Watershed Health Committee (2017 and 2018).

As the project progressed, numerous other information sources were accessed, including documents from the Quebec Watershed Councils (Organismes de Bassin Versant (OBVs)), Ontario Conservation Authorities (CAs), and the City of Ottawa, as detailed in Section 6.

To develop a way of organizing indicators, a handful of indicator systems were reviewed, including:

- The European Union's (EU) Water Framework Directive (WFD) indicators;
- The Canadian Environmental Sustainability Indicators (CESI); and,
- A threats typology developed for the International Institute for Sustainable Development (unpublished).

The EU WFD framework was particularly useful and formed the basis for many indicator groupings recommended in this report. This framework assesses surface water status through indicators for both ecological and chemical status.

Ecological status for surface waters includes biological elements, hydro-morphological elements, and chemical and physio-chemical elements of the aquatic ecosystem. Other components outside our current scope include indicators for human use of water for drinking and bathing

[5] WWF's Canadian scale report available at URL:
http://assets.wwf.ca/downloads/WWF_Watershed_Reports_Summit_FINAL_web.pdf?_ga=2.175707234.151515058.1550423873-627997127.1550423873

[6] ECCC's report is available in draft (without appendices) at URL:
https://www.placespeak.com/uploads/5492/ENG_ORWS_Draft_Report_2018_09_28__Clean.pdf

Threats are stressors that may jeopardize the ecosystem and, therefore, the ecological status of the watershed. Indicators of threats to surface waters can be considered within a typology that groups threats to fundamental aspects of surface water systems: water quantity, water quality, and habitat. Cross-cutting threats, such as Change in Land Use or Climate Change, jeopardize two or more of these fundamental aspects. More specific information on the organization of ecological indicators for assessing watershed health is provided in Section 5.4.

5.4 A framework for organizing indicators of watershed health

As presented in Table 1, the indicators of watershed health are organized into three groups: indicators of ecological status, indicators of threats to ecological status, and socio-economic indicators. Each group includes a series of elements that represent categories of end-points of relevance to watershed health.

There are three elements for ecological status (biological, hydro-morphological, and chemical and physico-chemical). Biological elements include plants and animals (i.e., biota) living in the watershed. Hydro-morphological elements include water flows and the interaction of flows with the land (e.g., riverbed substrates). Hydro-morphologic elements are inherently dynamic but form predictable patterns over time unless perturbed. Chemical and physico-chemical elements include the chemistry of water, as well as the physical properties, such as temperature.

The threats indicator group includes four elements: threats to water quantity, threats to water quality, threats to habitat, and climate change. Climate change, a cross-cutting threat, threatens both ecological status and socio-economic elements. Similarly, cross-cutting threats have the potential to impair two or more of elements of ecological status: water quantity, water quality, and habitat and biota. Threat elements can be combined to reflect the nature of any specific threat that has cross-cutting effects.

Table 1. Indicator groups and elements.

Indicator Group	Element	Comments
Ecological Status	Biological elements	-specific indicators may differ for rivers versus groundwater, lakes, or wetlands
	Hydro-morphological quality elements	
	Chemical and physico-chemical elements	
Threats	To water quantity	- indicators for many threats overlap, e.g., land use can alter water quantity, water quality, habitat and biota
	To water quality	
	To habitat and biota	
	Climate Change (cross-cutting threat to water quantity, water quality, and habitat)	
Socio-economic	Human health and well-being	- for future development
	Adaptation and climate resilience	

The Socio-economic indicator group noted in Table 1 is not developed in Phase One. However, two elements are suggested: Human health and well-being; and Adaptation and climate resilience. Human health and well-being encompasses use of water for drinking, swimming, fishing, and economic activities. Adaptation and climate resilience includes issues such as flood and drought risk management; government and community preparedness; and awareness and training for a range of watershed conditions and water resource uses under potential climate scenarios.

5.5 Recommended indicators of ecological health

For Phase One, a short list of recommended indicators of Ecological Status and Threats was identified through the iterative process described in Section 5.2. These short-listed indicators are presented in Table 2. The remainder of this section describes and explains the rationale for each of the short-listed indicators. A long list of potential indicators was developed in the process of identifying the short list of indicators (see Appendix A).

Table 2. Short-listed indicators for Phase One, Ottawa River Mainstem.

Indicator Group	Element	Short-listed Indicators
Ecological Status	Biological elements	**Benthic Invertebrates (**Hilsenhoff Biotic Index)
		Fish Diversity (initially, Fish Richness, the number of species present, by mainstem reach)
	Hydro-morphological quality elements	**Overview of Historic Flow** (ratio of average annual flow in current year, to 20-year average)
		Minimum Flow (m^3/s and date)
		Maximum Flow (m^3/s and date)
		Ratio of Maximum to Minimum Flow (#)
	Chemical and physico-chemical elements	**Total Phosphorus** (TP mg/L)
		Dissolved Oxygen (O2 mg)/L)
		Maximum Annual Water Temperature (°C)
		Chlorophyll-a (µg/L)
		Water Mercury (mg/L)

Table 2 continues…

Table 2 continued …

Indicator Group	Element	Short-listed Indicators
Threats to Ecological Status	To water quantity	*Not included in Phase One*
	To water quality	**Dry Weather Sewage Releases** (number of sewage releases during dry weather)
		Blue-green Algae (Cyanobacteria) Blooms (number and dates of occurrence)
	To habitat and biota	**Flow Connectivity** (number of impassible or partially passible barriers to movement of aquatic biota)
		Riparian Connectivity (% undeveloped shoreline area within 25m or 50m of water)
		Fish contaminants-mercury (concentration of mercury in fish tissues, mg/kg)
		Invasive species (number of non-native aquatic plant, animal, and invertebrate species present)
	To quantity, quality, habitat and biota	**Change in Land Use** (ha, for Agriculture, Urban, Road Network, Natural Forest, Harvested Forest, Wetland)
	Climate Change (cross-cutting threat to water quantity, water quality, and habitat)	**Timing of Spring Freshet** (date)
		Timing of Ice-off (date)
		Water temperature (as above)
		Water flow (Minimum and Maximum, as above)

5.5.1 Indicators of ecological status: description and rationale

This section describes and explains the rationale for short-listing the following indicators of ecological status including Benthic Invertebrates, Fish Richness, Water flows, Total Phosphorus, Dissolved Oxygen, Maximum Annual Water Temperature, Chlorophyll-a, and Water Mercury.

5.5.1.1 Biological elements

Benthic Invertebrates is a measure describing the local community of benthic macroinvertebrates. This indicator provides an integrated view of water quality and habitat conditions for other aquatic biota, such as fish. Benthic macroinvertebrates are sedentary animals and thus cannot move to escape poor water quality or other impaired habitat conditions (e.g., low oxygen concentrations or contaminated sediments). There are numerous species of benthic invertebrates and their tolerance to environmental stressors varies widely, generally by taxonomic group. Scientific research has identified the most pollution-sensitive species of benthic invertebrates and the most pollution-tolerant. Therefore, species composition, and the presence or absence of sensitive species, can be linked to water quality and habitat quality.

Several indices have been developed to characterize benthic invertebrate communities, each with strengths and weaknesses. The indicator recommended for use in the Ottawa River Watershed is the Hilsenhoff Biotic Index (HBI)[7]. The HBI indicates the overall tolerance of an invertebrate community to pollutants. When organic pollutants and nutrients lower oxygen concentrations in the water column, the more tolerant species of benthic invertebrates increase relative to the less tolerant species. To estimate the HBI, the tolerance of a group of organisms is assigned a number from 0 to 10, with 0 being the most sensitive (i.e., least tolerant) and 10 being the least sensitive (i.e., most tolerant). Therefore, the higher the HBI, the more polluted the waterbody is likely to be (Table 3).

[7] The HBI was developed by W.L. Hilsenhoff; see *An Improved Biotic Index of Organic Stream Pollution*, 1987, available at URL: https://scholar.valpo.edu/cgi/viewcontent.cgi?article=1591&context=tgle

Table 3. Relation between scores for Hilsenhoff Biotic Indicator (HBI) and pollution.
(Source: University of New Hampshire Centre for Freshwater Biology)

HBI	Water quality	Probability and degree of organic pollution
0.00-3.75	Excellent	Unlikely
3.76-4.25	Very Good	Slight, possible
4.26-5.00	Good	Some, probable
5.01-5.75	Fair	Fairly substantial, likely
5.76-6.50	Fairly Poor	Substantial, likely
6.51-7.25	Poor	Very substantial, likely
7.26-10.00	Very Poor	Severe, likely

The HBI is recommended for Phase One because it is already in use by the Province of Quebec within the Ottawa River Watershed and it was estimated by researchers accessing data on benthic invertebrates from a range of sources in Ontario. It is unknown whether HBI is calculated as part of Environmental Effects Monitoring (EEM) in the Ottawa River Watershed, conducted in accordance with the federal *Fisheries Act*; a data request was not fulfilled by the time of writing. Where the HBI is not reported by other agencies, it can often be estimated based on raw data collected. Specialized training is required for macroinvertebrate identification, with the most reliable results reported by trained biologists.

Two other indicators commonly used to assess Benthic Invertebrates include:

1) EPT, which takes its name from the first initials of each of three groups of invertebrates: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These three groups generally represent the invertebrate species most sensitive to pollution and other adverse conditions. The EPT is calculated as the number of distinct taxa in the EPT group, divided by the total number of taxa in the sample. It is normally reported as a percentage (%EPT). The higher the %EPT, the more likely the water environment is to be favourable.

2) Index of Biotic Integrity (IBI) uses a suite of metrics to estimate the stream condition. The metrics used to estimate IBI can be tailored to reflect specific conditions in a study area. IBI protocols can be applied to invertebrates, fish, or vegetation for streams, wetlands, and other environments. The IBI for a reference site with minimal human impact is compared to results for sites with suspected impact. The original IBI systems (developed by Karr[8]) had 12 metrics for fish and 13 for invertebrates[9]. Since the IBI is adapted by researchers to meet site-specific needs, results are not directly comparable, unless it is known that the same metrics were applied with similar methodologies for data collection.

Fish Richness is the number of fish species present, by river reach. This is a limited, but feasible indicator of biodiversity. More specifically, biodiversity integrates the number of species, together with species abundance, and species evenness (i.e., whether one or few species dominate the population). However, abundance data are expensive to collect, whereas species presence is typically more accessible. Generally, higher Fish Richness indicates a better aquatic environment. However, when reported by river reach, differences in Fish Richness can indicate differences in habitat type, habitat quality, and riverine connectivity. Moreover, species richness provides limited information. For example, higher species richness is not necessarily better because invasive species can increase the species count while threatening the ecosystem.

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[8] Karr JR. 1981. Assessment of biotic integrity using fish communities. *Fisheries* 6:21–27; and, Karr JR, Fausch KD, Angermeier PL, Yant PR, Schlosser IJ. 1986. *Assessing biological integrity of running waters. A method and its rationale*. Illinois Natural History Survey Special publication #5. Champaign, Il.

[9] Source of statistics is a report by the Watershed Science Institute, available at URL: https://www.wcc.nrcs.usda.gov/ftpref/wntsc/strmRest/wshedCondition/IndexOfBioticIntegrity.pdf

5.5.1.2 Hydro-morphological elements

Overview of Historic Flow broadly indicates whether the average water flow in a given year was typical, high, or low compared to other years. It is calculated as the average flow in a year, relative to a 20-year average flow. This indicator provides important context for assessing trends in the concentrations of pollutants. Specifically, water chemistry is affected by flows; for example, low flow in a dry year can increase the concentration of chemical substances in the water.

Calculating the Overview of Historic Flow would entail analyzing sufficient information to identify trends in monthly flow over multiple years. In Phase One, it is recommended that efforts be allocated to other indicators rather than to analyzing detailed flow records, except to identify the lowest and highest monthly flow/level. In Phase One, this minimalist approach to water quantity indicators is based on the assumption that increasing or decreasing trends in flows will be detected by one or more of the agencies monitoring the Ottawa River for its power generation potential. (The Ottawa River is closely regulated so very detailed level and flow records are kept for many reaches of the mainstem and tributaries.)

Minimum Flow is the lowest flow by reach, in a year. It is most likely to occur in the summer. The date of the minimum flow is also useful to assess trends in the timing of the driest period of the year, over years.

Maximum Flow is the highest flow by reach, in a year. It is most likely to correspond with the spring freshet (the water flow resulting from melting snow and ice).

Ratio of Maximum to Minimum Flow indicates the degree of river regulation. Since reservoirs and dams reduce peak flows and sustain flows during low flow periods, they reduce the ratio of maximum to minimum.

The lowest flow and highest flow levels will also provide a baseline for climate change indicators (see Section 5.5.2.4).

Flow indicators are included in the Ecological Status Indicator Group because flow levels and dynamics are essential to ecological health. The short-listed indicators do not fully capture the importance of flows to aquatic biota. Rapid increases or decreases in flows, from hydro facility operations for example, can negatively impact spawning areas and fish populations, or adversely affect birds by flooding their nest sites. In addition, long-lasting low flows can result in low levels of dissolved oxygen during warm periods and compromise habitat. In future, more sophisticated flow indicators should be developed, including indices for ecological flows (see Appendix A).

5.5.1.3 Chemical and physico-chemical elements

Total Phosphorus is the concentration of phosphorus in the water column (mg/L), including both particulate and dissolved forms. This is an important indicator because phosphorus limits plant and algae growth in freshwater. Phosphorus can originate from natural sources, such as river substrates, or from human activities associated with crop and lawn fertilizers, excessive erosion, and wastewater effluents. Due to its significance in freshwater environments, phosphorus is commonly monitored within the Ottawa River Watershed and globally. Some agencies also report reactive phosphorus, which is the form that most readily contributes to plant and algae growth. Indicators for other forms of phosphorus may be added in future, although data collection for other forms is not as widespread among watershed agencies.

Dissolved Oxygen is the concentration of free oxygen molecules (O2 not bonded to any other element) in the water column. Dissolved oxygen is essential for aquatic life, including fish, invertebrates, plants, and bacteria, although the oxygen needs vary widely among organisms. Oxygen is also necessary for the decomposition of organic material, which introduces nutrients into the water column. Excess decaying organic matter (such as raw sewage) reduces the availability of dissolved oxygen for aquatic organisms. Oxygen is introduced to the water column from the atmosphere, augmented by wind, rapids, groundwater discharge, photosynthesis, and other processes. Deep waters may contain less oxygen due to reduced exposure to the atmosphere, wave action, and other processes. Water temperature, salinity, and pressure also affect dissolved oxygen levels.

Maximum Annual Water Temperature, the highest recorded water temperature in a year, is the temperature of interest for Phase One. More sophisticated analyses of prevailing water temperatures can be undertaken in future. Water temperature is an essential habitat feature in the aquatic environment. Water temperature is strongly correlated with oxygen concentration in the water; warmer water holds less oxygen than cooler water. Various fish species have preferences and tolerance limitations with respect to water temperature, specifically cold and cool water fish cannot survive in waters that exceed threshold temperatures. Water temperature is also important to track as climate change progresses. As air temperatures increase, water temperatures can be expected to increase. Initially, these changes will likely be more evident in smaller tributaries to the Ottawa River than in the mainstem of the river.

Chlorophyll-a is measured as a concentration in the water column. Since Chlorophyll-a is the predominant type of chlorophyll in green plants and algae, its concentration in the water column reflects the density of algae growing in a waterbody. This indicator is used to characterize the biological activity in a body of water (i.e., the trophic state), ranging from very low (oligotrophic), to excess (eutrophic or hyper-eutrophic). When algal growth is in balance, photosynthesis supplies oxygen to the water column; when algal growth is excessive, poor water quality (including decreased oxygen concentrations) results.

Water Mercury, the concentration of mercury (mg/L) in the water column, yields insight into changes in water quality as human uses of the watershed resources change. Mercury is a toxic element that naturally occurs in the Ottawa River Watershed. Under natural conditions, mercury is bound up (i.e., sequestered) in sediments and vegetation. However, human activities in the Ottawa River Watershed have mobilized mercury, triggering releases from trees and vegetation when reservoirs were flooded for hydro power, from trees formerly transported in the water by the forestry industry, and from industrial releases, for example from pulp and paper mills, and from Canadian Nuclear Laboratories at Chalk River, Ontario. Other potential mercury sources include global atmospheric deposition and waste water from certain dental procedures. Mercury levels decline with time as the mobilized mercury is re-sequestered or transported out of the watershed. Due to the high toxicity of mercury, this indicator also guides fish consumption advisories (see Section 5.5.2.2).

5.5.2 Indicators of threats to ecological status: description and rationale

This section describes and explains the rationale for short-listed indicators of threats to ecological status including: Dry Weather Sewage Releases, Blue-green Algae Blooms, Flow Connectivity, Riparian Connectivity, Fish Contaminants - Mercury, Invasive Species, Change in Land Use, Timing of Spring Freshet, and Timing of Ice-off.

The short list of indicators does not include threats to water quantity. Phase One of the health assessment focuses on the mainstem of the Ottawa River, which is one of the largest rivers in eastern Canada. Threats that may significantly reduce water quantity are more likely to occur in the smaller tributaries of the Ottawa River. Threats to water quantity can result from water withdrawals that exceed the capacity of the river to sustain ecological flows. Water withdrawals occur for irrigation, industrial demands, municipal uses, and recreational uses, such as for golf course maintenance. Power generation also alters water flow, and, in future, water quantity threat indicators can be developed to capture changes to the flow and sediment regimes attributable to dams. In Phase One, the short list of indicators includes an indicator for the loss of connectivity, which includes lost connectivity for biota due to dams. In future, indicators can be developed to track potential impacts on water quantity due to climate change, such as shifts in precipitation and evaporation patterns.

5.5.2.1 Threats to water quality

Dry Weather Sewage Releases (the number of sewage releases from combined sewers during dry weather) is the recommended indicator for Phase One. Discharging untreated or inadequately-treated sewage to the river can pose an acute threat to water quality. It may jeopardize aquatic life because the decomposition demand on dissolved oxygen in the water column may exceed the oxygen carrying capacity of the water column, causing low oxygen levels that stress or even kill aquatic organisms. Untreated or inadequately treated sewage releases also pose a health risk for people exposed to contaminated water, through recreational activities for example. Combined sewers carry both stormwater and sanitary sewage. During extreme rainfall events, these sewer systems can surcharge, releasing rainwater and sewage to watercourses. These events are not desirable, but at least occur during higher flow periods (because of rainfall runoff), which eases the assimilation of the wastes in the aquatic environment. The threat to water quality is potentially very serious when sewage releases occur during dry weather, at times of lower river flows. Dry weather flows should be preventable when sewer systems are well-maintained, except in cases of catastrophic equipment failure or similar unforeseeable events. Tracking the total volume of combined sewage released is ambiguous because the volume is as much an indicator of intense rain events in modern day, as it is an indicator of sewage disposal practices from decades passed.

In future, a more sophisticated indicator of sewage levels could be developed to reflect changes in wastewater management. For instance, a Sustainable Development Goal (SDG) indicator for the availability and sustainable management of water and sanitation (Goal 6[10]) is the proportion of wastewater safely treated. Sewage infrastructure is immensely expensive to build, replace, maintain, and operate. Over time, an indicator of the proportion of sewage treated prior to release to watercourses should reflect improvements brought through investments, by all levels of government, to upgrade wastewater treatment and sewage collection systems. The indicator could include the level of treatment by proportion (e.g. untreated, primary, secondary, better than secondary treatment).

Blue-green Algae Blooms is measured as the number of bloom occurrences and dates. Blue-green Algae (Cyanobacteria) occur naturally and some carry toxic substances called cyanotoxins. Blooms of Blue-green Algae indicate stress in the aquatic environment. The Quebec MELCC has defined a Blue-green Algae bloom to be 20,000 cells per millilitre in at least one location of a water body. Typically, lakes are more affected than riverine systems because lower flow and water stagnation contribute to conditions that are prone to blooms. Another key contributing factor is nutrient inputs: specifically, phosphorus. Water temperature and sunlight also contribute to conditions prone to blooms. Although these contributing factors are known, it is not yet possible to predict blooms.

[10] SDG Goal 6 is described at URL: https://sustainabledevelopment.un.org.sdg6e

5.5.2.2 Threats to habitat and biota

Flow Connectivity indicates the continuity of the aquatic ecosystem throughout the watershed. In Phase One, it is measured as the total number of barriers (such as dams and culverts) to the movement of aquatic species, including an assessment of passible, partially passible, or impassible. Flow connectivity provides fish and other aquatic organisms access to the complete range of habitats needed to fulfill the prerequisites of survival: feeding, sheltering, migrating, reproducing etc. In addition to threatening ecological connectivity, structures that reduce Flow Connectivity also change the geomorphic processes, such as sediment transport, within the watershed. Dams and even culverts may negatively affect connectivity. Perched culverts, with outlets that are higher than the water surface to which they discharge, create physical barriers to movement upstream. Properly designed culverts support ecological connectivity and also have lower overall costs due to increased flood resiliency, and reduced maintenance and replacement costs.[11] In a study of the Great Lakes Basin, over 60% of stream crossings were found to be fully or partially impassible by fish[12]. This finding is changing the way decisions are made on culvert design and replacement priorities.

Riparian Connectivity, a measure of shoreline fragmentation, refers to the shoreline conditions extending inland from the water's edge (per NRCan land use maps). For Phase One, Riparian Connectivity is measured as the proportion of undeveloped shoreline. In research by Ottawa Riverkeeper, distances of 25m and 50 m meters inland are being examined. Natural shorelines play multiple roles in healthy watercourses, such as providing nearshore habitat, filtering runoff from lands, supplying natural nutrients to the aquatic ecosystem, shading watercourses to moderate summer temperatures, stabilizing shoreline soils, and reducing erosion. Fragmentation of the riparian zone creates many adverse effects, which are exacerbated if the riparian zone is hardened, dredged, or used for purposes that release pollutants into the water.

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[11] O'Shaughnessy, E. *et al*. Conservation Leverage: Ecological Design Culverts also return Fiscal Benefits, 2016, *Fisheries*, 41(12):750-757

[12] Januchowski-Hartley, S. R., M. Diebel, P. J. Doran, and P. B. McIntyre. 2013. Predicting road culvert passability for migratory fishes. *Diversity and Distributions* 20:1414–1424.

Fish Contaminants-Mercury, measured as the concentration of mercury in fish tissue (mg/kg), reflects ambient conditions in the aquatic environment. Circulation of mercury in the environment is very complex[13] and the full effects of mercury on aquatic species are not fully understood. Mercury bioaccumulates, as methylmercury, up the food chain which means it is present in greater concentrations in older individuals of predatory fish species. Studies indicate that chronic exposure to mercury affects neurological and hormonal systems in vertebrates, including schooling abilities of fish.

Invasive Species are species that have been introduced, intentionally or accidentally, to a habitat outside their natural range and that out-compete native species. In Phase One, this is measured as the number of non-native aquatic species (plants, animals, and invertebrates) in a given area. The long-term effect of newly introduced species is often unknown, so no distinction is made herein among non-native species. Commentary can be provided on the aggressiveness or consequences for the species in the watershed, where it is known. There is a temporal limitation in assessing invasive species since the introduction of non-native species to ecosystems dates back many decades.

5.5.2.3 Threats to water quantity and quality, and habitat and biota

Change in Land Use is measured as the area (ha) of land converted from one use to another, over time. For the short-listed indicator, relevant categories of land use include agriculture, urban, road networks, natural forest, harvested forest, and wetlands. In future, additional areas of interest will include industrial sites, contaminated sites, abandoned mines, and the extent of area flooded for power generating reservoirs. Understanding changes in land use is integral to understanding changes in the interaction of water with the landscape of a watershed. Over time, changes to the extent of natural areas, including forests and wetlands, have profound cumulative effects on runoff quantity, in terms of the volume and the momentum of the water as it runs off the land. The introduction of impermeable surfaces (e.g., roads and roofs) means less water is retained on the land. The increased runoff quantities have greater power to erode streams and to carry pollutants. Further, with transportation networks, industrialization and urbanization, pollutant sources are introduced that affect water quality. In turn, these changes alter the quality of aquatic habitat and the biota supported within the altered areas. Research in urban areas indicates

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[13] See for example USGS information at URL: https://www.usgs.gov/mission-areas/environmental-health/science/roadmap-understanding-factors-influencing-mercury?qt-science_center_objects=0#qt-science_center_objects

that dramatic negative changes in aquatic biota occur by the time 10% of a watershed or subwatershed is urbanized[14]. The concurrent changes to flow, quality and habitat in urban streams, and the degraded conditions with urbanization, have been identified worldwide. These conditions, including increased flow flashiness (i.e., frequent, rapid flow in response to rain), increased pollutant loads, altered biotic communities and altered ecosystem function, are known as *urban stream syndrome*[15]. Agricultural land uses and operations also alter runoff quantity and affect the quality of water.

5.5.2.4 Climate change

Timing of Spring Freshet is the date of peak spring flows. Peak flows in the spring correspond to the release of melt water from ice and snow accumulated during the winter. This date may correspond with the maximum flow in a year (see Section 5.5.1.2). However, some cities (e.g., Toronto) have noted a shift away from peak flows corresponding to spring melt. The loss of classic spring freshet patterns is attributed to frequent freeze-thaw cycles that reduce the snow pack throughout the winter. Ottawa River subwatersheds may demonstrate a similar pattern as climate change progresses, in particular within the urbanized catchments.

Timing of Ice-off is the date ice disappears from the water surface. Ice-off dates provide an integrated measure for the timing of warmer air temperature, warmer water temperature, and spring conditions, including flow.

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[14] Schueler, T., L. Fraley-McNeal and K. Cappiella, 2009. Is impervious cover still important? Review of recent research. *Journal of Hydrologic Engineering*, 14(4):309-315.
[15] Walsh, C. J., A. H. Roy, J. W. Feminella, P. D. Cottingham, P. M. Groffman and R. P. Morgan, 2005. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society*, 24(3):706-723.

5.6 Additional indicators for future consideration.

Additional research and consultation with the Watershed Health Committee, and others, is recommended before finalizing the priorities for indicators to include in subsequent work. During the development of this report, additional indicators were identified by agencies and experts. More sophisticated indicators for elements already on the short list should also be considered. Indicators to consider in subsequent phases of work are summarized in Table 4.

Table 4. Additional indicators for future consideration.

Indicator Group	Element	Short list Indicators
Ecological Status	Biological elements	Threatened and endangered and/or culturally significant species in the watershed: Lake Sturgeon; American Eel; River Redhorse; frogs
	Hydro-morphological quality elements	Ecological flow indicators
		Rainfall/ precipitation/ snow pack indicators
	Chemical and physico-chemical elements	Alkalinity (as $CaCo_2$)
		pH
		Conductivity
		Salts
		Metals
		Total suspended solids (TSS), or a measure of turbidity, such as Secchi disk
Threats to ecological status	To water quality	Number, locations and status of contaminated sites (remediation planned; no current plan; abandoned)
		Pesticides
Socio-economic Status	Human health and well-being	*E Coli* and beach closures
		Liability in the watershed (i.e. economic risk posed by existing or proposed contaminated sites, pipelines, and other works)
	Adaptation and climate resilience	Status of floodplain mapping (e.g. percent of the watershed area with updated floodplain mapping)

6 Available data

The amount and type of data collected within the Ottawa River Watershed and available for analysis varies among the short-listed indicators. This section identifies data sources for an analysis of the Ottawa River Mainstem, with comments on spatial and temporal coverage of the datasets identified to date. A concurrent analysis of the Gatineau and Lievre watersheds was undertaken for a subset of the short-listed indicators.

Data were collected from numerous agencies. For some indicators, data are only available for some geographic regions and/or for certain times. Table 5 summarizes the sources of data discussed in this section, as well as spatial and temporal coverage for the Ottawa River Mainstem.

Table 5. Data sources and spatial-temporal availability for the Ottawa River Mainstem.

Colour codes indicate the availability of data for analysis of current conditions (spatially) and trends through time (temporal coverage). Green: good; Yellow: acceptable; Orange: limited; Red: significant gaps.

Indicator	Agency Collecting/ Spatial Coverage within Ottawa River Watershed	Temporal coverage in the database assembled for Phase One
Ecological Status Indicators		
Benthic Invertebrates	• City of Ottawa monitoring. Data available in the watershed for subwatersheds in south and east Ontario, subwatersheds in east Quebec (east of the Lievre)	• City of Ottawa: 1998 to 2017 • Other records for subwatersheds: 2000 to 2018
Fish Diversity (specifically richness)	• Quebec-Ontario border (Timiskaming to just east of Carillon dam at Pointe Fortune)	• 1997 to 2010 • Creel surveys date as early as 1984 in the Lac des Chats reach

Indicator	Agency Collecting/ Spatial Coverage within Ottawa River Watershed	Temporal coverage in the database assembled for Phase One
Hydro-morphological quality elements	• The Water Survey of Canada sites (Note the data were not collected for Phase One): In Ontario: • Britannia (Lac Deschênes) • Chats Falls • Des Joachims • La Cave Rapids • Near Timiskaming In Quebec: • Marina de Sainte-Anne-de-Bellevue • Sortie du Lac Granet • Quyon • Terrasse-Vaudreuil • Barrage De Carillon • Barrage De Rapide -Sept • Barrage Des Rapides des Iles • Reservoir Dozois • Aux Rapides 2 • Barrage Des Rapides des Quinze • Bryson • Hull • Premiere Chute • Rapide Des Iles • Rapide DESQUINZE • Amont de la Rivière Kinojevis • Barrage Des Quinze • Pres de Portage-du-Fort	 1915-2017 1915-1994 1950-1994 1952-1994 1911-1951 1978-2017 1977-2013 1928-1931 2009-2017 1962-1994 1939-1994 1967-1994 1965-1994 1954-1994 1965-1994 1985-1994 1985-1994 1985-1994 1985-1994 1985-1994 1933-1941 1936-1966 1942-1948
Total Phosphorus	• Ontario: 7 stations from Otto Holden Dam (Mattawa) to Hawkesbury • Quebec: 5 stations from Lake Timiskaming to Carillon • City of Ottawa water quality data • Water purification plants (Ottawa, Montreal) • Older paper reports and records • Quebec municipal water purification plants have been	• Database: 1966 to 2016 with highly uneven distribution of the number of records among sites • Older paper reports and records: 1960s to 1980s

Indicator	Agency Collecting/ Spatial Coverage within Ottawa River Watershed	Temporal coverage in the database assembled for Phase One
Total Phosphorus continued …	required to collect Total Phosphorus data since 2015	
Oxygen	• Ontario and City of Ottawa water quality monitoring stations • City of Ottawa Water Purification Plants • Quebec collects O2 data but does not report it on its website	• 1966 to 2016, with some missing years
Water temperature (maximum annual)	• Quebec, Ontario provincial monitoring sites • City of Ottawa water quality monitoring stations • Ottawa and one City of Montreal water purification plant • Gatineau, Hull, and Aylmer water infrastructure monitoring	• 1966 to 2016 (maximum temperature)
Chlorophyll-a	• Province of Quebec sites only	• 2004 to 2016
Mercury	• Ontario and Quebec sites and City of Ottawa water monitoring program; City of Ottawa water purification plants • Canadian Nuclear Laboratories (data not accessed during this study)	• 1969, 1970, 1971, 1984 to 1990, 1992, 1999, 2006 to 2016
Threats Indicators		
Dry weather sewage releases	• ECCC • Province of Quebec website • City of Gatineau • City of Ottawa	• Quebec sewage release reports are available online 2001 to 2013; a searchable database is also available in Quebec

Indicator	Agency Collecting/ Spatial Coverage within Ottawa River Watershed	Temporal coverage in the database assembled for Phase One
Blue-green Algae (Cyanobacteria) blooms	• No sources identified for the Ottawa mainstem; academic research is a possible source • Quebec collects data on lakes in the watershed	• For lakes in Quebec, since 2004
Flow connectivity	• No sources identified (other than dam locations)	•
Riparian area connectivity	• Provincial land use files (Ontario and Quebec) • Federal land use files (NRCan)	• ORK research is on-going; details not yet available
Fish contaminants (mercury)	• Province of Quebec (20 sites in the Ottawa River Mainstem) • Province of Ontario (data not obtained)	• Quebec sites on the Ottawa River: 1980 to 2016 (uneven coverage by year, with gaps)
Invasive species (number)	• WWF report • Data sources are dispersed, including academic literature	• Intermittent data coverage
Change in land use	• AAFC Land Use data • Federal CanVec topographic data • Statistics Canada road network data • Ag Canada Environmental Indicators Map • Ontario Land Information Office • NRCan • Conservation Authorities	• Ag Can land use 1990, 2000, 2010 • Statistics Canada road network: census years (2001, 2006, 2011, 2016) and intercensal years • Ag Canada map uses 2011 data
Timing of ice-off conditions	• Pembroke (at Allumette Island) • Ice bridge at Hudson Oka (in operation since ~1900)	• Pembroke: 1984 to 2014

6.1 Indicators of ecological status: data sources, consistency, and gaps

This section identifies sources of data collected in the Ottawa River Mainstem, for each short-listed indicator of ecological status. This section also describes data gaps (missing data) and the consistency of protocols for collecting, analyzing, and reporting data across sources, locations, and times.

6.1.1 Biological elements

The following section describes available data in terms of sources, consistency, and gaps for Biological elements including **Benthic Invertebrates** and **Fish Richness.**

6.1.1.1 Benthic Invertebrates

The following organizations collect and store benthic invertebrate data:

- ECCC manages the Canadian Aquatic Biomonitoring Network (CABIN) program[16], which houses benthic invertebrate data collected by the federal government and other agencies or researchers. Data have been collected by pulp and paper mills, and mines in the Ottawa River Watershed, pursuant to the *Fisheries Act*. The EEM data are housed by ECCC. A data request for EEM benthic invertebrate data was submitted on January 2, 2019, but no data were received by time of writing.
- The province of Ontario, several Conservation Authorities, and other researchers pool data in the Ontario Benthos Biomonitoring Network (OBBN)[17], run out of the Ontario Government Dorset Environmental Science Centre. The OBBN website has an interactive map to locate publicly available data[18]. OBBN data are available via a data request form. Raw data were not requested for most of the Ontario sites

[16] CABIN website with links to datasets is available at URL: https://open.canada.ca/data/en/dataset/13564ca4-e330-40a5-9521-bfb1be767147
[17] Ontario Benthos Biomonitoring Network (OBBN) website available at URL: https://desc.ca/programs/obbn
[18] OBBN interactive map website at URL: https://envconnections.maps.arcgis.com/apps/webappviewer/index.html?id=5c3a6be1b94347a6b8c8523e0c22b8fc

because a research consortium of specialists provided analyzed data that had been collected through OBBN (including Conservation Authorities) for a study organized by Les Stanfield in collaboration with the Universities of Ottawa and British Columbia, and others.

- The province of Quebec collects benthic invertebrate data, housed in its Aquatic Environmental Quality Database (AQBD), which has data dating as early as 1979. An interactive map is available on a provincial website[19], with sampling stations indicated and datasets that can be downloaded directly from the site.
- The City of Ottawa has conducted benthic invertebrate sampling under a combined sewer overflow monitoring program and as part of an EEM program (recently discontinued). The EEM sampling protocol was based on the approach for the pulp and paper sector under the *Fisheries Act* regulation.
- Additional sources of data can be found in studies by various academics and their students; these data are scattered, difficult to access, and may follow different sampling protocols from provincial standards.
- Citizen science results, collected by Ottawa Riverkeeper, G3e[20] including the interactive map of data collection sites[21], Bonnechere River Watershed Project[22], and others, can also be assembled for application to the health assessment.

An assessment by the World Wildlife Fund (WWF) of Canadian watersheds drew on data from CABIN and the OBBN databases. However, at the time of the WWF assessment, the benthic invertebrate data were insufficient for conclusions to be drawn by WWF. A new technique for identifying species present in watercourses is being developed using DNA analysis. This technique, called environmental DNA or eDNA, is in use by the Department of Fisheries and Oceans[23] and others. The technique can detect the presence of fish and invertebrates, including rare or endangered species that are very difficult to locate using conventional methods. It is also being tested to assess fish abundance. The technology has the potential to dramatically change the ability of scientists and citizen science to monitor aquatic biota.

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[19] Atlas interactif de la qualité des eaux de surface et des écosystèmes aquatiques, available at URL: http://www.environnement.gouv.qc.ca/eau/Atlas_interactif/donnees_recentes/donnees_iqbp.asp#onglets

[20] Information on G3e can be found on the website at URL: http://www.g3e-ewag.ca/about-us/EWAG.html

[21] G3e's interactive map is at URL: http://www.g3e-ewag.ca/programmes/carte-interactive/index.php

[22] Information on the Bonnechere River Watershed Project can be found on the website at URL: http://www.bonnechereriver.ca

[23] See an eDNA description at URL: http://www.dfo-mpo.gc.ca/science/sec-ces/atlantic-atlantique/blog/2019-01-30/index-eng.html

It is easiest to collect benthic invertebrate samples in smaller (i.e., wadable) streams but sampling protocols also exist for deeper rivers, such as the Ottawa River Mainstem and its larger tributaries. There are more datasets available for tributaries than for the Ottawa River Mainstem (see Figure 2). Figure 2 in Section 7.2.1 illustrates benthic invertebrate sampling sites with at least one record available.

CABIN has developed nationally standardized protocols for field collection[24], and laboratory and data analyses; training courses are also offered on the CABIN protocols. ECCC also provides guidance to comply with the Environmental Effects Monitoring (EEM) requirements[25] under the *Fisheries Act*. Ontario developed a protocol[26] for benthic data collection in streams to ensure sampling results are comparable within the province. Conservation Authorities in the Ottawa River Watershed follow this protocol. Data are also collected in Ontario by the Ministry of Natural Resources and Forestry following this protocol. Quebec has published protocols for benthic invertebrate collection in soft and course substrates[27]. No comparison of the two provincial and the federal protocols has been undertaken to assess consistency across jurisdictions although Quebec has undertaken a comparison of the CABIN protocol and Quebec protocols[28].

Federal government data are not indicated on Figure 2. CABIN data sites in Quebec within the Ottawa River Watershed are indicated on the federal website only in the Rouyn-Noranda region but all those sites have only legacy data that needs updating (see CABIN interactive map URL in footnotes). Spatial coverage of CABIN data in Ontario within the watershed is most concentrated in the Petawawa region, collected by 4th Canadian Division Support Base Petawawa in response to concerns over contaminants in sediments and water arising from military training activities (CABIN website, interactive map). One site indicated at Remic Rapids in the Ottawa River Mainstem (site OTW01, Lat. 46.354214, Long. -79.11026, collected by an NGO) was not in the CABIN file available for download online. Similarly, a

[24] For guidance documents, see URL: https://www.canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring-network/resources.html
[25] For example, the Metal Mining Technical Guidance for Environmental Effects Monitoring is available at URL: https://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=AEC7C481-1&offset=6&toc=hide#s4.5
[26] Ontario Stream Assessment Protocol, edited by L. Stanfield (2017), available at URL: https://trca.ca/app/uploads/2018/02/osap-master-version-10-july1-accessibility-compliant.pdf
[27] For course and soft substrate guidance documents, see, respectively, URLs: http://www.environnement.gouv.qc.ca/eau/eco_aqua/macroinvertebre/surveillance/index.htm; http://www.environnement.gouv.qc.ca/eau/eco_aqua/macroinvertebre/protocole/index.htm
[28] The English version of this comparison is at URL: http://www.protegerlenord.mddep.gouv.qc.ca/eau/eco_aqua/macroinvertebre/protocole/etude-comparative-protocole-Quebec-Canada_en.pdf

reference site located near North Bay but within the Ottawa River Watershed (site NBA103, Glassy Creek, Lat. 46.354214, Long. -79.11026) was not in the CABIN file.

The federal EEM records may provide reference site data for mines and pulp mills in the north and western portion of the Ottawa River Watershed, which is currently the most significant gap in benthic invertebrate data for the Ottawa River Mainstem. A data request for the federal EEM data was not fulfilled by time of writing.

6.1.1.2 Fish Richness

As indicated above, for the short-listed indicators, **Fish Richness** is the metric examined to approximate diversity because data is available to evaluate presence but not abundance. The Ontario Ministry of Natural Resources and Forestry (OMNRF) compiled numerous data sources from both Ontario and Quebec agencies for its 2016 report, *Background Information to the Fisheries Management Plan, Fisheries Management Zone 12 in Ontario, Fisheries Management Zone 25 in Quebec* (OMNRF Background Report 2016). This report covers 590 km of the Ottawa River, where the river forms the border between the two provinces. There are 10 reaches defined by dams and rapids in this portion of the mainstem (from north to south): Lake Timiskaming; Lac la Cave; Lake Holden; (Upper) Allumette Lake; Lower Allumette Lake; Lac Coulonge; Lac du Rocher Fendu; Lac des Chats; Lac Deschênes; Lac Dollard des Ormeaux. The province has instituted the Broad-scale Monitoring (BsM) component of its Ecological Framework for Fisheries Management, which is designed to measure the status of fish populations on five-year cycles and includes contaminant sampling, water chemistry data, and an invasive species assessment. The OMNRF Background Report provides results for the 2008-2010 BsM cycle, as well as records from literature and other research studies. The OMNRF Background Report (2016) identifies fish inventories and studies by reach dating back as far as 1998.

Prior to 1997, there were no standardized netting techniques in use by the Ontario government (OMNRF Background Report, 2016). Since that time, Ontario's MNRF has used several protocols for assessing fish communities in the Ottawa River, including: Nearshore Community Index Netting, Fall Walleye Index Netting, BsM and creel surveys on recreational fishing, as well as telemetry and tagging fish studies. The BsM program is planned to be undertaken by Ontario on five-year cycles.

A lack of consistent data collection for fish records and the absence of historical fish abundance studies create a significant data gap for assessment of long-term trends in fish biodiversity. Such an assessment would include fish abundance and the evenness of species (i.e., the relative proportions of fish species present). Together with the number of species present, biologists calculate the Shannon Index of Diversity, a measure of species richness, abundance, and evenness. OMNRF has calculated the Shannon Index of Diversity by reach for 2008-2010 (See Section 7.2.2) but the historic context for these estimates is missing. Fish presence and, possibly, fish abundance may be accessible through Indigenous Knowledge.

Presence of fish species provides sufficient information to make decisions on habitat protection or restoration, in particular for reaches with species at risk.

6.1.2 Hydro-morphological elements

The following section describes available data in terms of sources, consistency, and gaps for Hydro-morphological elements including **Historic, Minimum, Maximum, and Ratio of Maximum to Minimum Flows** and **Maximum Annual Water Temperature.**

6.1.2.1 Flows

The Water Survey of Canada coordinates water level and/or flow at monitoring locations on the Ottawa River Mainstem. Some locations have been monitored for over 100 years. Data can be downloaded from the ECCC website, wateroffice.ec.gc.ca. The Ottawa River Regulation Planning Board reports water levels and flows at ottawariver.ca.

For this report, data summaries of a Water Survey of Canada dataset were made available by the City of Ottawa Water Purification Plant staff for the monitoring station at Lac Deschenes (Britannia). These data were used because they were already compiled for the years 1960 to 2017 for a station with one of the longest records for the Ottawa River Mainstem. Data includes average, maximum, and minimum flows by month and year.

Numerous flow monitoring locations were discontinued in 1994 (See Table 5 above). For the Ottawa River Mainstem, only the station at Britannia has a consistent record from 1911 to 2017. It will be very important to maintain the station at this location for reliable long-term trend monitoring of flows of the Ottawa River Mainstem.

To fully assess water flows, precipitation records are required. As climate change progresses, having a more complete picture of the water cycle components will be important to understand flow trends in context of prevailing weather patterns.

6.1.3 Chemical and physico-chemical elements

The following section describes available data in terms of sources, consistency, and gaps for Chemical and physico-chemical elements including **Total Phosphorus**, **Dissolved Oxygen**, **Maximum Annual Water Temperature**, and **Water Mercury**.

The data sources identified in this section include only those with data in electronic format. Numerous paper reports are available from previous decades with information on water chemistry and other properties. These historic reports could be mined for data in future, although digitizing the information will be labour intensive.

6.1.3.1 Total Phosphorus

Virtually all government agencies and watershed authorities that monitor water quality in the Ottawa River Watershed collect and report on Total Phosphorus (TP). Raw data for total phosphorus were collected through data requests and from online databases from Ontario (5 stations), Quebec (7 stations), the City of Ottawa (31 stations, including 9 transects across the river), and one location at Montreal. (See Section 7.2.4 for more information on sampling locations.) This database for the Ottawa River Mainstem had 3794 records, recorded at 44 stations, dating between 1966 and 2018 from Lake Timiskaming (most western/northern station) to Montreal (most easterly station). A recent source of data comes from municipal water purification plants in Quebec; WPPs in Quebec have been required to monitor phosphorus monthly between May and October since 2015. At the scale of the St Lawrence Basin, ECCC reports on water quality[29], including phosphorus.

[29] Report (2019) available at URL: https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/water-quality/2019/water-quality-canadian-rivers-pdf-en-2019.pdf

The years of record by station are inconsistent. For example, there are no records at Hawkesbury post year 2000; monitoring at Hawkesbury would be useful to determine whether the Total Phosphorus concentrations have increased or decreased because the average concentration according to available records exceeds 0.030 mg/L (see Section 7.2.4). Similarly, the recent records from Lake Timiskaming indicate elevated levels of phosphorus; records prior to 2014 were not obtained. Only one location was identified downstream of Carillon.

6.1.3.2 Dissolved Oxygen

Dissolved Oxygen data are available for monitoring sites for the Province of Ontario (Site identification: Hawkesbury (2 sites), Chats Falls, Chenaux Dam, Otto Holden Dam) and the City of Ottawa mainstem sites (9 transects across the Ottawa River). The City of Ottawa dataset includes dissolved oxygen at depths from just below surface to several meters deep. There are just over 10,100 records for Ottawa River mainstem stations, spanning 1966 to 2016. The Province of Quebec collects dissolved oxygen data but does not report raw data or analyzed data results through its website. Mean, maximum, and minimum yearly averages were available from the Ottawa Water Purification Plants for the years 1995 to 1999; raw data were not obtained but may be available.

The database with information from the City of Ottawa and Ontario sites has no information for the years 1993, 1995, and 1996. However, the City of Ottawa water purification plants did provide mean oxygen concentrations, somewhat filling the data gap for the missing years for this one reach of the river.

6.1.3.3 Maximum Annual Water Temperature

Water temperature data for the Ottawa River Mainstem are available in raw data format for Ontario sites (Hawkesbury, Chats Falls, Chenaux Dam, Otto Holden Dam), City of Ottawa sites (9 transects across the Ottawa River Mainstem), and six Quebec sites (Carillon Dam, north of Saint Bruno-de-Guigues, Chenaux, Témiscamingue, Notre-Dame-du-Nord, Masson-Cumberland). Temperature data were also obtained for locations monitored by water purification plants at the Cities of Ottawa and Montreal. The record for the Montreal location is continuous but only dates back to March 2015. The data from the City of Ottawa water purification plants is in the format of summarized annual minimum, maximum, and mean temperatures.

The measure of interest for Phase One is the **Maximum Annual Water Temperature**. In a database of raw data for provincial and City of Ottawa sites for the months from May to September, there are 383 records (maximum temperature by station and year) between 1966 and 2015. In addition, annual maximum water temperatures from the City of Ottawa Water Purification Plant are available from 1960 to 2015. The data for 2015 to 2019 from a City of Montreal monitoring location were not incorporated into the dataset.

Data were collected in degrees Fahrenheit in previous decades, but conversion is simple so there are no issues using earlier records. The raw data records can be analyzed in several ways, whereas summarized annual records are of limited use in the future for more sophisticated water temperature indicators, if developed.

6.1.3.4 Chlorophyll-a

Only the province of Quebec collects **Chlorophyll-a** data in the Ottawa River Mainstem. Data are available at 7 stations (at Carillon Dam[30], north of Saint Bruno-de-Guigues, Chenaux, Témiscamingue, Notre-Dame-du-Nord, Masson-Cumberland). The database assembled has 288 observations for the Ottawa River Mainstem.

For **Chlorophyll-a** to be used as an indicator at multiple scales, data would also need to be collected in Ontario for the Ottawa River and subwatersheds.

6.1.3.5 Water Mercury

Mercury concentrations in water samples are available for 5 Ontario government sites, 7 Quebec sites, and 11 City of Ottawa sites across four transects (identified by numbers 100, 210, 430, 500). Mean records by year are available from the Ottawa Water Purification Plants

[30] Two stations are at Carillon Dam, but these stations have different latitude and longitude coordinates.

for 1995 to 1999 inclusive. Records for Hull, Aylmer, and Gatineau water quality were provided by the City of Gatineau in a password protected database with limited potential for analysis. The Canadian Nuclear Laboratories also has collected mercury data at sites from northern and middle mainstem watersheds; these data were not accessed during this study.

There are gaps in the record for some years. One consistency issue for the analysis of mercury records will be to agree on a consistent approach for analyzing trends when many records are below detection limits. The database with Ontario, City of Ottawa, and the Carillon site has inconsistent units of measure for mercury (micrograms and milligrams per litre); records will need to be adjusted to one consistent unit for analysis.

6.2 Indicators of threats to ecological status: data sources, consistency, and gaps

6.2.1 Threats to water quality

The following section describes available data in terms of sources, consistency, and gaps for Threats to water quality including **Dry Weather Sewage Releases** and **Blue-green Algae Blooms**.

6.2.1.1 Dry Weather Sewage Releases

Quebec municipalities report combined sewage overflows (CSOs) to the provincial government. The requirements for monitors on sewer systems are set out in provincial guidelines[31]; monitors were required in locations that experienced overflows in the previous three years. Municipal reports on CSO events are available online through a Province of Quebec website[32]; among other resources, this site has reports on the performance of municipal systems for the years 2001 to 2013 (including summaries of CSO events in pdf format). The province also has a searchable database for CSO reports, available to registered users[33]. A data request by Ottawa Riverkeeper to the City of Gatineau provided records for combined sewer overflows from that municipality for four years, from 2013 to 2016. Ontario municipalities must provide reports on CSOs to ECCC to comply with the federal *Fisheries Act*. In Ontario, CSOs must also be reported to Ontario under Ontario's *Environmental Protection Act*. Further review of data available through ECCC and the Province of Quebec for municipalities in the watershed is needed to assess data availability for all municipalities.

Municipalities in the Ottawa River Watershed use different codes to define dry weather overflows. For example, in Quebec, overflows during certain spring melt events are not defined to be dry weather events. Also, data are available in a variety of formats, including

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[31] See *Guide d'interprétation du Règlement sur les ouvrages municipaux d'assainissement des eaux usées* (2014) at URL: http://www.environnement.gouv.qc.ca/eau/eaux-usees/guide-interpretation.pdf

[32] See the website Eaux uses domestiques, communautaires et municipales at URL: http://www.environnement.gouv.qc.ca/eau/eaux-usees/domest-communautaire-municipal.htm

[33] A Guide to use the searchable database is available at URL: http://www.environnement.gouv.qc.ca/eau/eaux-usees/somaeu/Guide_utilisateur_SOMAEU.pdf

pdf, which is time-consuming for data analysis. There is a gap in data prior to 2001; considering the prevalence of CSO events in earlier decades, a lack of historic data will under-emphasize the improvements made to sewage management within the watershed.

6.2.1.2 Blue-green Algae Blooms

Since 2004, the QC MELCC has assessed lakes in the Quebec portion of the Ottawa River Watershed that are affected by Blue-green Algae (cyanobacteria). No sources of information were identified from Ontario agencies for the Ottawa River Mainstem. Academic researchers at the University of Montreal (Sebastien Sauve) and at the University of Ottawa (Francis Pick) research algal blooms and may have data sources to share for the Ottawa River Watershed. This indicator is of particular concern for slower moving water. In the Ottawa River Mainstem, therefore, the headwaters lakes are the most critical for monitoring algal blooms.

6.2.2 Threats to habitat and biota

The following section describes available data in terms of sources, consistency, and gaps for threats to habitat and biota including **Flow Connectivity**, **Riparian Connectivity**, **Fish Contaminants – Mercury**, and **Invasive Species**.

6.2.2.1 Flow Connectivity

Other than dams, information is lacking on Flow Connectivity in the Ottawa River Watershed. The Province of Quebec's *Summary Profile of the Rivière des Outaouais Watershed* (2015) identifies the number of dams by type in the Ottawa River Watershed (Quebec portion), sourced from an inventory of Quebec dams (Répertoire des barrages du Québec). Quebec provides guidance on dam type and information to be reported on dams in the province[34]. NRCan has an archived inventory of dams of at least 10 meters in height[35]. Ottawa Riverkeeper's River Report (2006) lists major dams and owners in the Ottawa River Watershed. The lack of an inventory and assessment of the potential for fish passage for culverts and other stream crossings is a significant information gap.

6.2.2.2 Riparian Connectivity

Ottawa Riverkeeper is undertaking GIS analysis of riparian zones in the Ottawa River Mainstem and two subwatersheds. A methodology to assess riparian zones using GIS information is being developed. This work is being undertaken for the main channel east of Mattawa for riparian buffer depths of 25 m and 50 m, using information available from NRCan aerial maps on structures within the riparian zone. No information can be provided at the time of writing as the work is in its preliminary stages. In the absence of this work, there are no information sources for riparian connectivity in the Ottawa River Watershed.

6.2.2.3 Fish Contaminants-Mercury

Quebec data on mercury in fish in the Ottawa River was obtained by Ottawa Riverkeeper through a data request. There are 20 fish monitoring sites in the Ottawa River Mainstem, with records dating between 1980 and 2016. The most continuous record is close to Morrison Island east of Pembroke, with records between 1985 and 2010. Data are also collected and available from Ontario but were not available at the time of writing.

[34] The guidance document is available at URL (French):
http://www.cehq.gouv.qc.ca/barrages/guides/guide_fiche_technique.pdf (French)
[35] The NRCan website for geospatial data (see Archived Collections) is at URL:
https://www.nrcan.gc.ca/earth-sciences/geography/topographic-information/download-directory-documentation/17215

6.2.2.4 *Invasive Species*

No comprehensive sources of information on invasive species were identified. This lack of data is similar to the finding of the WWF[36]. Potential sources for the Ottawa River Watershed may include those accessed by WWF for its analysis, including the Global Biodiversity Information Facility (GBIF), EDDMapS, Natureserve[37], Ontario's Invading Species Awareness Program[38], and various provincial sources.

Non-native fish in the Ottawa River are reported in the OMNRF Background Report (2016).

ECCC has a Newly Established Invasive Alien Species Indicator[39]. The baseline year for the indicator is 2012; between January 2012 and December 2015, no new invasive alien species are known to have become established in Canada. (Note some existing invasive species may have become newly established in the Ottawa Watershed since 2012.) Primary sources of information for this federal indicator come from data collected by the Canadian Food Inspection Agency, Fisheries and Oceans Canada, and ECCC. Secondary data sources include data reported to Agriculture and Agri-Food Canada, Canada Border Services Agency, NRCan's Canadian Forest Service, Parks Canada Agency, the Canadian Wildlife Health Cooperative, provincial and territorial governmental organizations, and other organizations that work to control invasive species.

There are significant gaps in the information available to understand invasive species, including how to define these species and what year to use as a baseline. In addition, data sources are scattered and contain temporally intermittent information.

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[36] WWF-Canada, Technical Protocol for the Freshwater Threats Assessment, 2015.
[37] Natureserve's website is at URL: http://www.natureserve.org
[38] Ontario's Invading Species Awareness Program is at URL: http://www.invadingspecies.com
[39] Report (2017) available at URL: https://www.canada.ca/content/dam/eccc/migration/main/indicateurs-indicators/dd557620-10cb-4d10-b77d-97b0e5e3be98/4.6.1-20invasive-20species_pdf_en.pdf

6.2.3 Threats to water quantity and quality, and habitat and biota

The following section describes available data in terms of sources, consistency, and gaps for threats to water quantity and quality, and habitat and biota through **Change in Land Use**.

6.2.3.1 Change in Land Use

The key data sources for Change in Land Use in this report are spatial data available through Agriculture and Agri-Food Canada for 1990, 2000, and 2010. Other land-based data are available from a range of government agencies, including:

- Statistics Canada provides data on road networks[40];
- Canada's Open Government series, which can be used for spatial analysis of transport, hydro, land, and other features, called the Topographic data of Canada - CanVec Series[41];
- Province of Ontario Land Information Office (LIO),[42] which has many land-based information resources, including shapefiles for watershed/subwatershed boundaries.

The data for the watershed was analysed on a subwatershed basis, in groups available through ArcGIS (Figure 1). Note that these subwatersheds partition some of the larger sub-basins into two parts, upper and lower. For example, both the Gatineau and Lievre watersheds have an upper and lower subwatershed in this layout.

[40] Available at URL: https://www12.statcan.gc.ca/census-recensement/2011/geo/RNF-FRR/index-eng.cfm
[41] Available at URL https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056
[42] Available at URL: https://www.ontario.ca/page/land-information-ontario

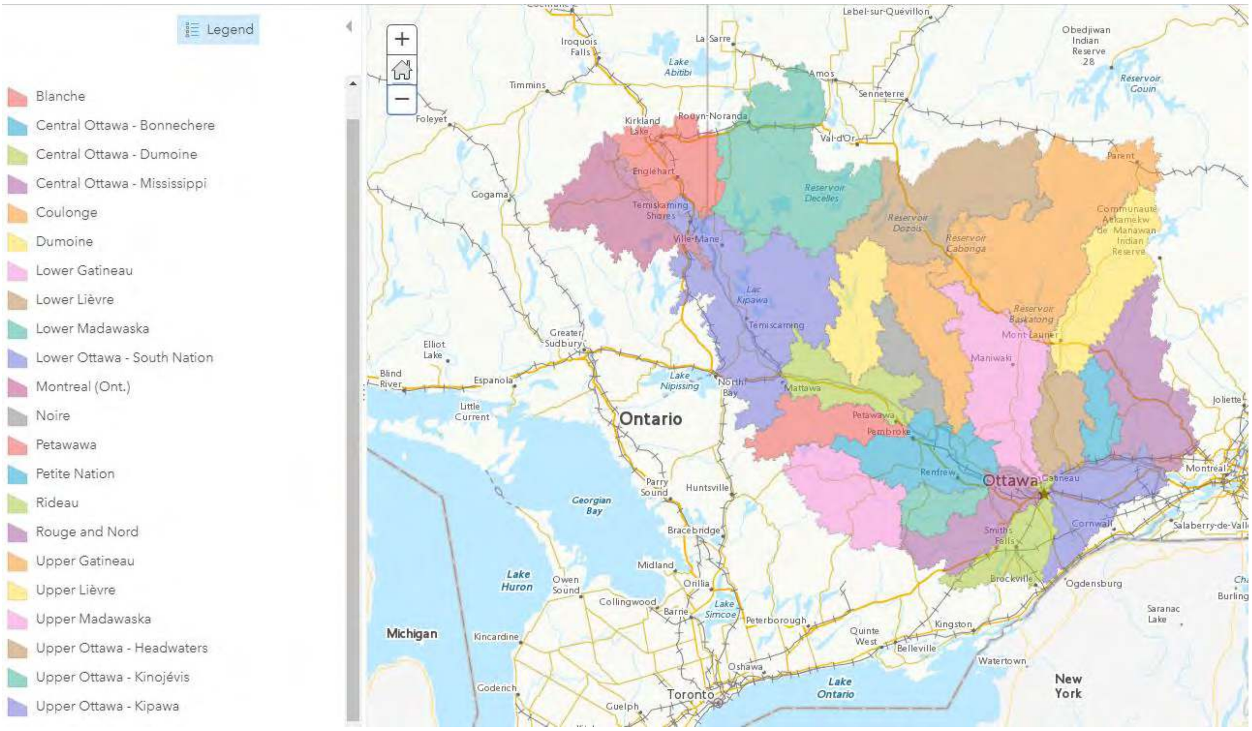

Figure 1. Subwatersheds of the Ottawa River Watershed.

(used to assess Change in Land Use, Source URL: http://arcg.is/1TXKH)

6.2.4 Climate change

The following section describes available data in terms of sources, consistency, and gaps for threats to water quantity and quality, and habitat and biota through **Climate Change**. Note that **Maximum Annual Water temperature** and **Minimum** and **Maximum Flows** are discussed above (see Sections 6.1.3 and 6.1.2 respectively). **Timing of Spring Freshet** and **Timing of Ice-off** are discussed here.

6.2.4.1 Timing of Spring Freshet

There are two spring freshets: one peak flow in early spring with snowmelt runoff from the lower watershed region, followed by a second, higher peak in later spring when the snow melts in the upper basin (OMNRF Background Report, 2016). The magnitude of the peaks has diminished with the reservoirs installed for regulation of the river. As indicated above, there are detailed records at flow monitoring stations that would enable identification of spring freshet timing. Those detailed records were not accessed for this report so no comment can be made on the consistency of records.

6.2.4.2 Timing of Ice-off

The OMNRF Background Report (2016) presents records kept by the Pembroke Area Field Naturalists of ice loss at Pembroke (at Allumette Island) since 1984. There may be other records in the Ottawa River Watershed. This data gap is one with potential to be filled through citizen science. An additional potential source of information is the records of duration of an ice bridge at Oka,[43] which has been in operation since about 1900.

[43] A newspaper article on the Oka ice bridge is available at URL: https://globalnews.ca/news/5054004/hudson-oka-ice-bridge-closes-march-2019/

7 Preliminary analysis

The results provided in this section are preliminary only and are primarily intended to provide an indication of the data coverage discussed in Section 6. A full analysis is beyond the scope of this report. Select short-list indicators for which there was sufficient data for some analysis are presented in this section, including:

- **Benthic Invertebrates:** a map indicating HBI scores
- **Fish Richness**: information from the OMNRF Background Report (2016)
- **Average, Minimum, and Maximum Flows:** at Lac Deschenes (Britannia), 1960 to 2017
- **Total Phosphorus**: analysis of an assembled database
- **Water Temperature**: water purification plant records
- **Chlorophyll-a:** information from Province of Quebec by year and station
- **Water Mercury**: Ottawa Water Purification Plant records
- **Blue-green Algae Blooms**: information from Quebec reporting
- **Flow Connectivity:** summary of dams in Quebec portion of the watershed
- **Invasive Species:** information from the OMNRF Background Report (2016)
- **Change in Land Use:** analysis based on AgCan maps
- **Timing of Ice-off:** data reported by Pembroke Area Field Naturalists

7.1 Methodologies for analyzing available data

The methodology for analyzing each indicator varies with the information available. For some indicators, this section reports summaries from other sources (e.g., fish diversity). In other cases, analyses of datasets were conducted using GIS and statistical analysis as described in the following subsections.

7.1.1 GIS analysis

Land use analysis was done using GIS software and Agriculture and Agri-foods spatial information for 1990, 2000, and 2010.

7.1.2 Statistical analysis

Data from various organizations were combined into one dataset where feasible, within the time available. This dataset was examined using the statistical software package R. In some cases, data were not combined. For example, two databases were examined for water temperature because one dataset held raw data and another had mean annual records, including records for maximum temperature.

7.2 Preliminary results for select short-listed indicators

7.2.1 Benthic Invertebrates

The estimates of benthic invertebrate HBI were calculated by others, including the Province of Quebec and a consortium of biologists for an Ontario study. The City of Ottawa also has undertaken comprehensive benthic invertebrate analyses but HBI scores were not calculated for City sites. Figure 2 spatially displays the data reported by these sources where coordinates were available in a compatible format. For Ontario, the most recent HBI result is reported by site. For Quebec sites, the HBI reported on interactive maps online, are displayed.

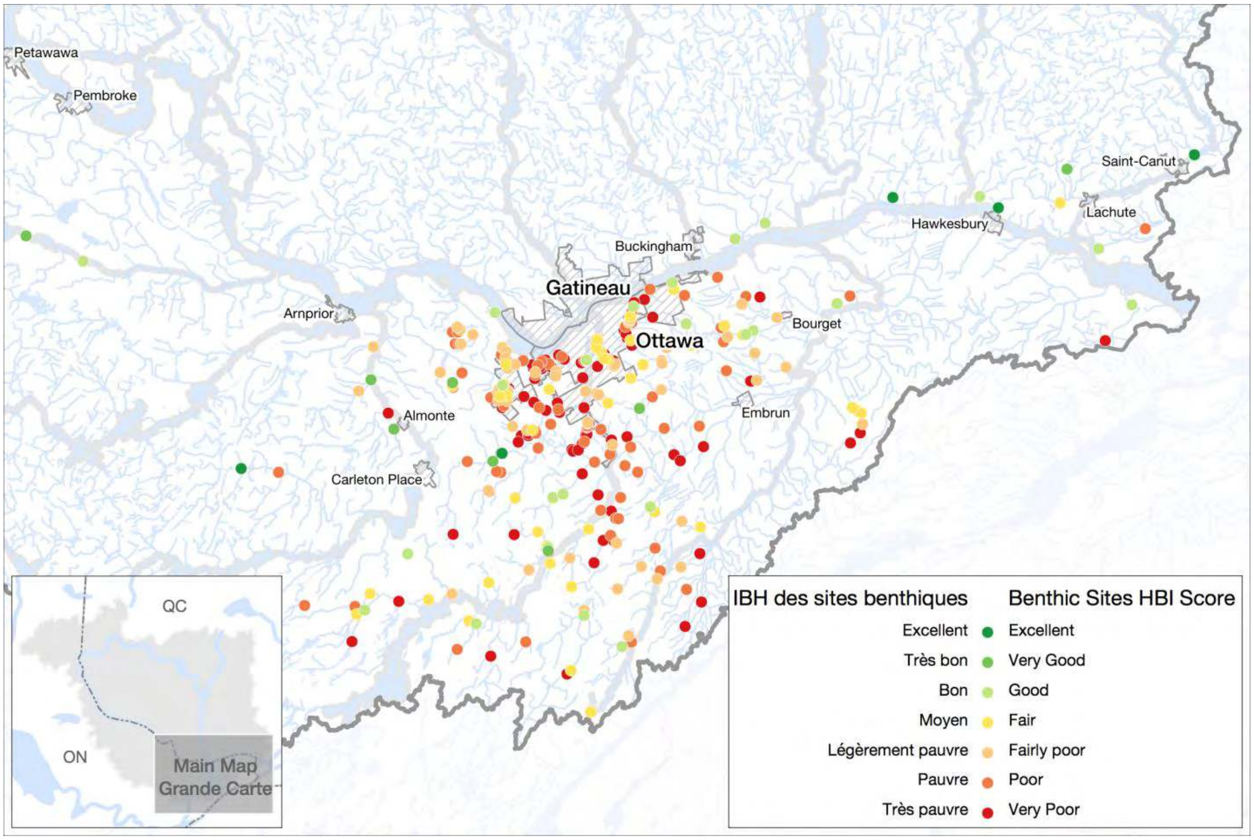

Figure 2. Locations of Benthic Invertebrate Monitoring Sites.

See text (Section 6.1.1.1) for sources of data. Note this map displays the most recent HBI result by location; the map does not reflect an analysis of the data and should be interpreted only to indicate sites offering data.

7.2.2 Fish Richness

There are at least 85 fish species documented in the Ottawa River (OMNRF Background Report, 2016), but the number of species varies by reach. Historic records indicate there was high fish abundance in the Ottawa River, but this abundance has diminished due to resource extraction (forestry and energy), reduced connectivity of tributaries throughout the watershed, and other threats.

Table 6 summarizes the fish species counts reported in the OMNRF Background Report (2016). These numbers include historic and literature records of fish presence, including non-native fish (column 3) and the results of the 2008-2010 BsM survey. The difference between reported number of species and the BsM survey is presented in column 5; it is important to note that some fish species may still be present but were not identified during the 2008-2010 survey.

Table 6. Fish Richness and biodiversity by reach, on the Ottawa River Mainstem.[44]

Reach	Literature Reports: Number of native species of fish	Literature Reports: Number of non-native species of fish	OMNRF BsM Survey 2008-2010: Number of fish	Difference between BsM and literature	Shannon Index 2008-2010
Timiskaming	27		25	-2	2.15
Lac la Cave	38		20	-18	1.73
Holden Lake	45		21	-24	2.08
Allumette Lake	62	1	24	-38	2.13
Lower Allumette Lake	35		19	-16	2.05
Lac Coulonge	37		18	-19	1.95
Lac du Rocher Fendu	31		11	-20	1.79
Lac des Chats	45		18	-27	1.63
Lac Deschênes	61	2	20	-41	1.85
Lac Dollard Des Ormeaux	69	4	21	-48	2.21

[44] Published in the OMNRF Background Report (2016)

From Table 6, all reaches of the river had fewer species identified in Ontario's 2008-2010 BsM survey than were reported in the literature. The Lake Timiskaming reach had two fewer species, Lake Trout and Rainbow Smelt[45]. These species may still be present in this reach and were simply not located during the BsM survey. Other reaches have much more dramatic differences in the number of species identified, for example Upper Allumette Lake (-38 species), Lac Deschênes (-41 species) and Lac Dollard des Ormeaux (-48 species). River Redhorse is a species missing in the BsM for these three reaches. River Redhorse has a COSEWIC designation as a species of special concern; because they are rare, locating them, if present, will take additional effort[46]. Other fish not recorded in one or more of these three reaches include: Muskellunge, Rainbow Smelt, Central Mudminnow, Log Perch, Trout-Perch, Burbot, Emerald Shiner, Longnose Sucker, Common Shiner, Fallfish, Creek Chub, Bluegill, and the Freshwater Drum.

The Shannon Index is a measure of biodiversity that considers both the number and the relative abundance of species in an area. The Shannon Index for fish biodiversity was estimated in the OMNRF Background report (2016) (column 6, Table 6). Unfortunately, insufficient data are available to estimate historic Shannon Indices prior to about 2000. Future trends can be tracked on the assumption that government monitoring programs will continue to collect sufficient abundance and evenness data.

7.2.3 Flows

River regulation has reduced the **Ratio of Maximum to Minimum Flow** from approximately 10:1 in 1870 to 5:1 by 1930 (*in* OMNRF Background Report, 2016). Over the last 40 years, the **Maximum and Minimum monthly flows** averaged 5374 m^3/s and 736 m^3/s respectively (OMNRF Background Report, 2016).

Data summarized by Ottawa's Water Purification Plant staff are illustrated in the following graphs.

[45] Inferred from Tables 8 and 9 in the OMNRF Background Report, 2016.
[46] See ontariofishes.ca

Average flows 1960 to 2017 indicate a slight increasing trend but more detailed analysis is required to assess whether this trend is statistically significant or evident when the analysis is extended earlier than 1960 (Figure 3). Rainfall records are needed to fully assess trends in water flows.

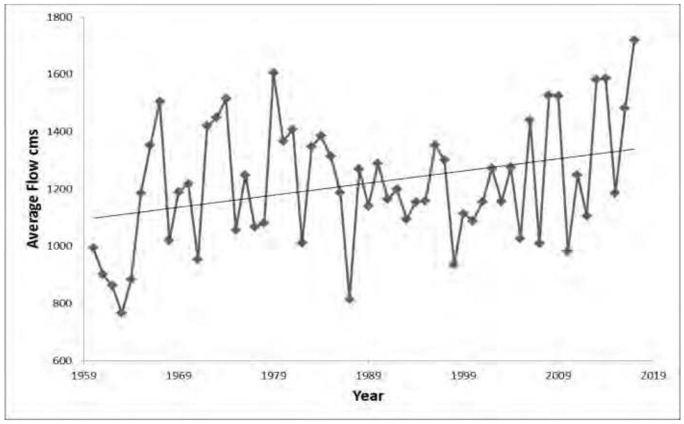

Figure 3. Average Flows at Lac Deschênes (Britannia), 1960 to 2017.

(Source: Data summary from City of Ottawa WPPs)

Minimum flows 1960 to 2017 indicate a slight decreasing trend but, again, more detailed analysis and rainfall records are required to assess whether this trend is statistically significant or evident when the analysis is extended earlier than 1960 (Figure 4).

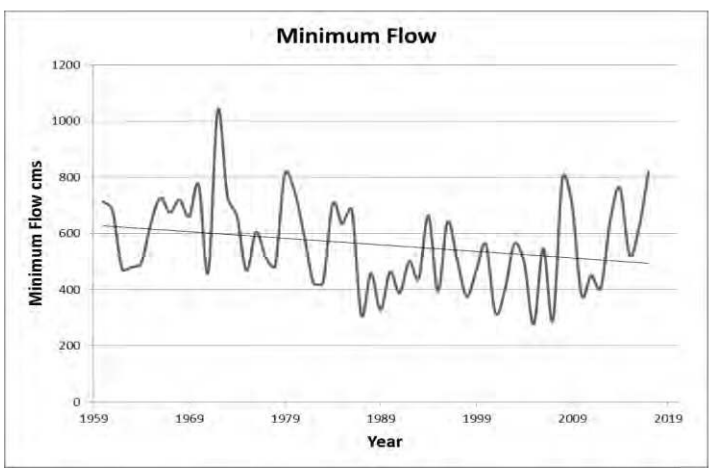

Figure 4. Minimum Flows at Lac Deschenes (Britannia), 1960 to 2017.

(Source: Data summary from City of Ottawa WPPs)

Maximum Flows 1960 to 2017 indicate a slight increasing trend, but more detailed analysis is required to assess whether this trend is statistically significant or evident when the analysis is extended earlier than 1960 (Figure 5).

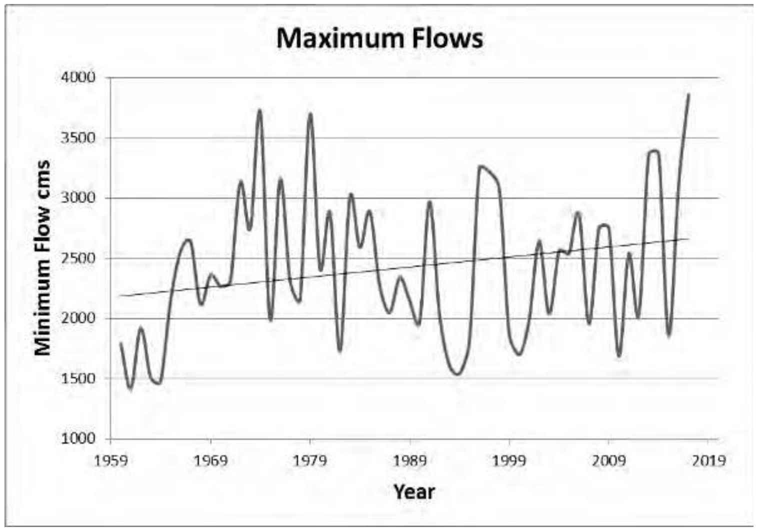

Figure 5. Maximum Flows at Lac Deschenes (Britannia), 1960 to 2017.

(Source: Data summary from City of Ottawa WPPs)

7.2.4 Total Phosphorus

Phosphorus is not well understood. Observations presented here are described in relation to the Provincial Water Quality Objectives of Ontario.

In Ontario, the Provincial Water Quality Objectives for phosphorus state:

> *"Current scientific evidence is insufficient to develop a firm Objective at this time. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site-specific studies:*
>
> - *To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 0.02mg/L;*
> - *A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 0.01 mg/L or less. This should apply to all lakes naturally below this value;*
> - *Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 0.03 mg/L." (Ontario PWQO[47]).*

Summary of Total Phosphorus

- The average Total Phosphorus of the Ottawa River is below the target level of 0.03 mg/L, between the Otto Holden Dam (upstream of Mattawa) and Gariepy Marsh (downstream of the Cities of Gatineau and Ottawa).
- The average Total Phosphorus at Hawkesbury exceeds the target level of 0.03 mg/L, however, records at Hawkesbury were only available until the year 2000.
- At Chenaux Dam and Carillon Dam, Total Phosphorus is under the target level of 0.03 mg/L on average, but the values fluctuate and include several records that exceed the target.

[47] See URL: https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives#section-13

- Total Phosphorus tends to be higher along the shorelines of the Ottawa River as it flows past the cities of Gatineau and Ottawa in comparison with the center channel.
- Of 44 individual sampling locations, only 12 never exceeded the target level of 0.03 mg/L Total Phosphorus during the years on record.

In the raw data records analyzed for this report, Total Phosphorus ranged from below detection limit (for four samples) to 1.10 mg/L. Average Total Phosphorus values were estimated excluding the four samples with Total Phosphorus results below detection limit since these samples were each from different locations (and dates): one each at ORS-100.10 (09/2011), ORS-210.40 (08/1998), ORS-420.30 (10/ 2011), ORS-430.30 (08/2011). The highest Total Phosphorus value was recorded at Hawkesbury mid-channel in 1973 (station 18000007883); this record was removed as an outlier for purposes of estimating the average Total Phosphorus at that station. Note one record at a Quebec station was reported to be 0.65 mg/L; this record was altered to 0.065 mg/L (station 4290002, December 2015).

Where the City of Ottawa sampled at multiple points along transects across the Ottawa River, the Total Phosphorus measurements were assessed to see if there were significant differences among stations for each transect. There were no statistically significant differences among the City of Ottawa stations at transects ORS-100, ORS-210, ORS-410, ORS-420, ORS-600 but at least one station in transects ORS-430, ORS-450, and ORS-500 had statistically different results for Total Phosphorus relative to other stations in the transect. A full analysis of the number and amplitude of exceedances, and trends by year or station were beyond the scope of this initial assessment. Figure 6 following presents the average Total Phosphorus values by station. Appendix B provides a summary, by station, of the average Total Phosphorus, standard deviation, maximum and minimum Total Phosphorus in the calculated average, span of years on record, number of years, and number of records, excluding six Quebec stations.

In addition to raw data, **Total Phosphorus** average concentrations for the years 2008 to 2010 from Ontario's BsM Cycle monitoring program, published in the OMNRF Background Report (2016) (Table 7).

Table 7. Ontario's BsM cycle monitoring program results for Total Phosphorus.[48]

Reach	Total Phosphorus (mg/L) from BsM cycle 2008-2010
Timiskaming	0.0308
Lac la Cave	0.0166
Holden Lake	0.0109
Allumette Lake	0.0126
Lower Allumette Lake	0.0134
Lac Coulonge	0.0148
Lac du Rocher Fendu	0.0130
Lac des Chats	0.0164
Lac Deschênes	0.0213

[48] Published in the OMNRF Background Report (2016)

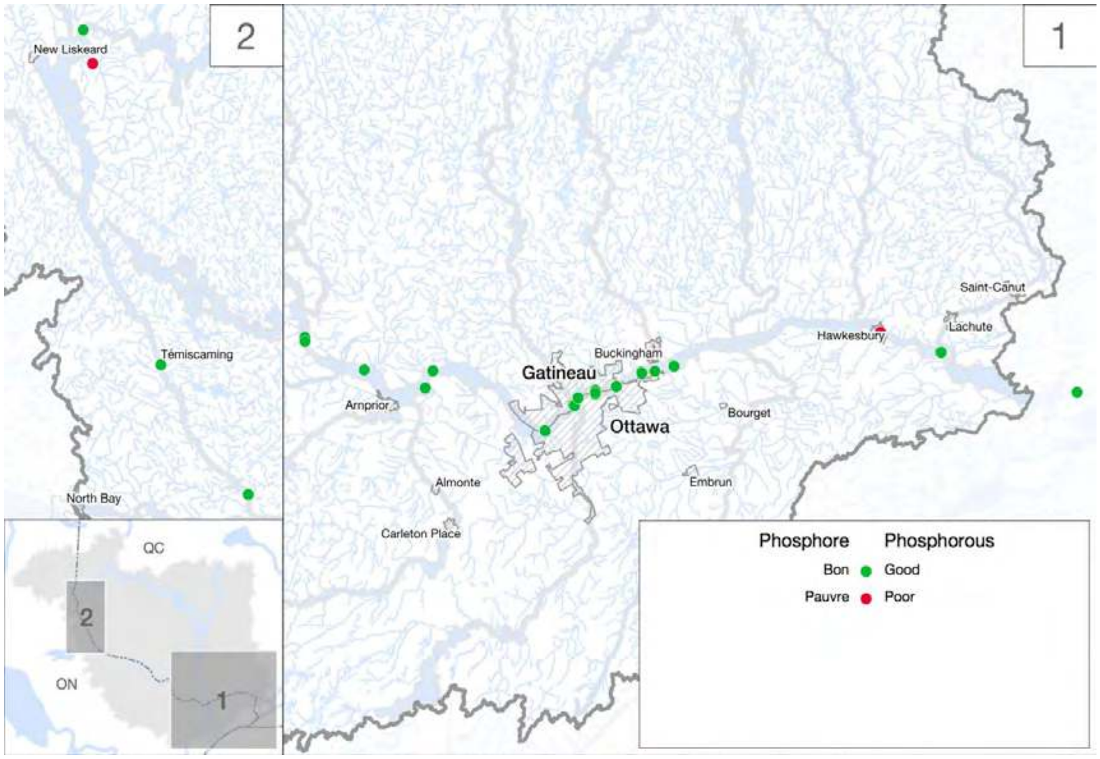

Figure 6. Average Total Phosphorus by station, on the Ottawa River Mainstem.

Red dots indicate results that exceed the water quality objective for Total Phosphorus of 0.030 mg/L. The location outside the watershed boundary to the east is at Montreal at a location fed exclusively by the Ottawa River. Note information in Section 6.1.3.1 for data sources. A full statistical analysis was outside the scope of this project.

7.2.5 Maximum Annual Water Temperature

There is no discernable trend in **Maximum Annual Water Temperature** for records taken by Ottawa's water purification plants between 1960 and 2015 (Figure 7). The average maximum temperature over the 56-year record is 25.7 C° (standard deviation 1.9 C°).

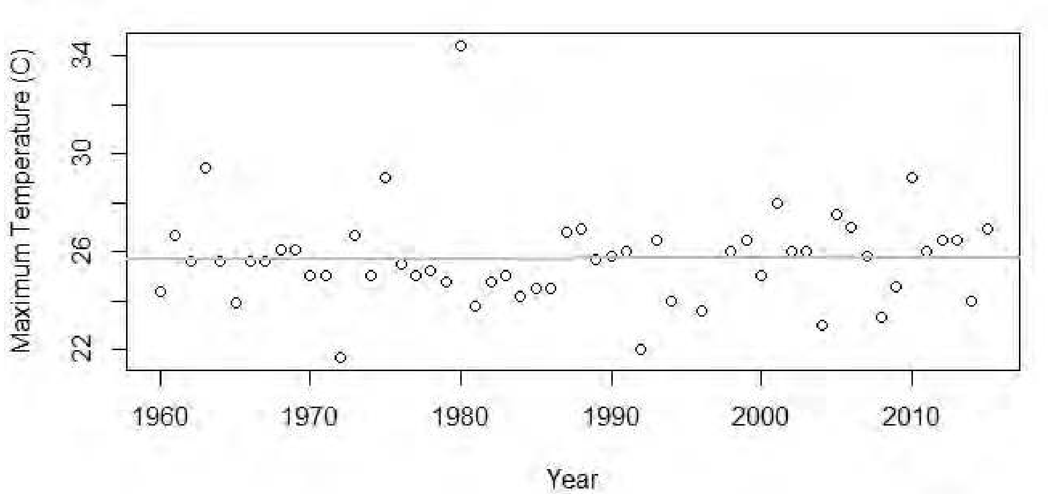

Figure 7. Maximum Annual Water Temperature, Ottawa.
(Data source: City of Ottawa Water Purification Plants)

The grey line through the points is a simple regression, indicating no trend.

Similarly, there is no discernable trend in **Maximum Annual Water Temperature** in a database assembled from data for water quality stations monitored by the provinces of Quebec and Ontario, and the City of Ottawa water quality monitoring sites during the months between May and September (Figure 8). Additional analysis is warranted to combine and assess trends in the maximum temperature database.

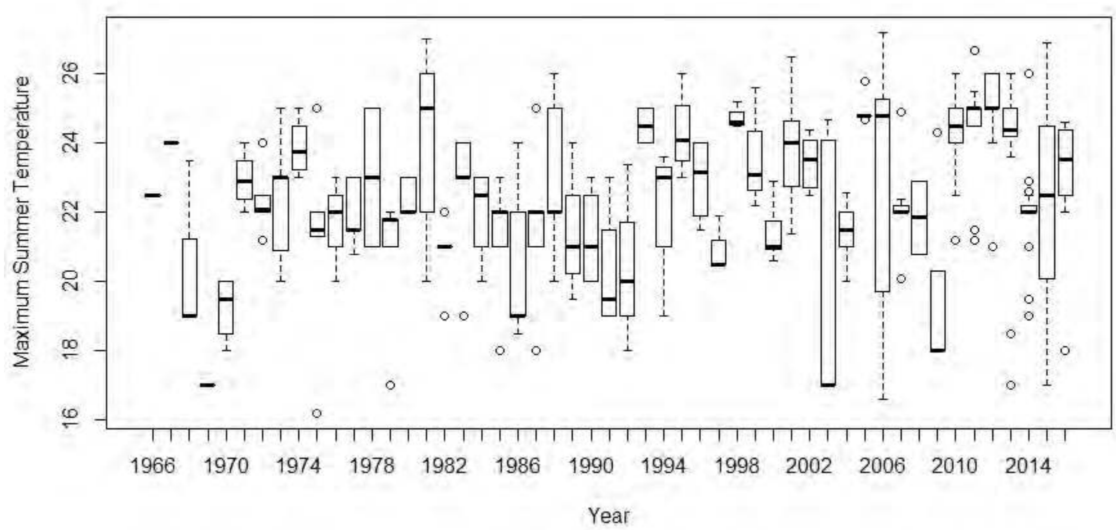

Figure 8. Maximum Annual Water Temperature on the Ottawa River Mainstem.
(Data sources: Ontario, Quebec, City of Ottawa Water Quality Monitoring)

7.2.6 Chlorophyll-a

Chlorophyll-a concentrations recorded for the Ottawa River Mainstem by the Province of Quebec are plotted by year (Figure 9) and by station (Figure 10). One extreme value for Chlorophyll-a (55.7 μg/L) needs to be verified. Data variability appears to increase with year for the available data, but further statistical analysis is needed to assess statistical significance. Similarly, two stations appear to indicate more variability than others, in particular the stations at Saint Bruno-de-Guigues (4290002) and Carillon Dam (QU02LB9001).

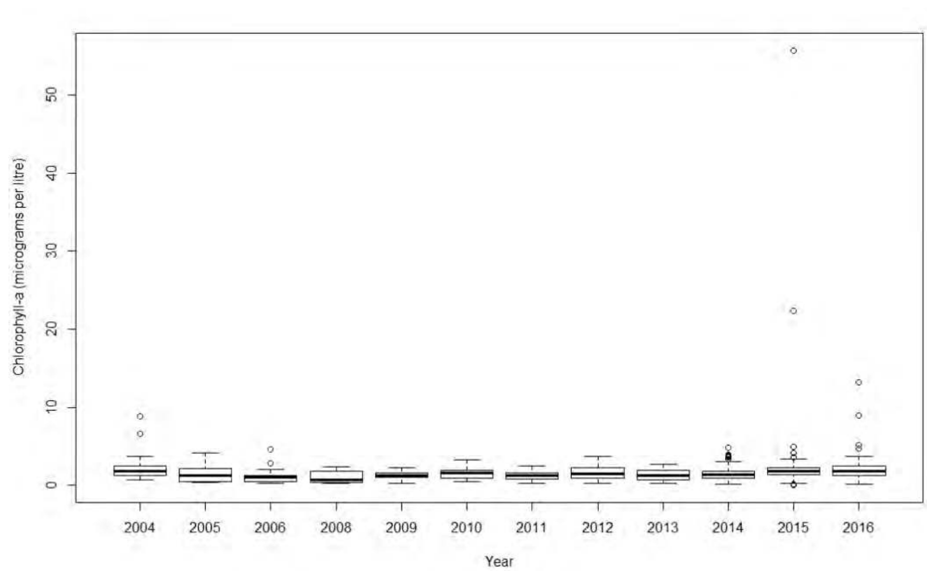

Figure 9. Chlorophyll-a by year, on the Ottawa River Mainstem.
(Data source: Province of Quebec)

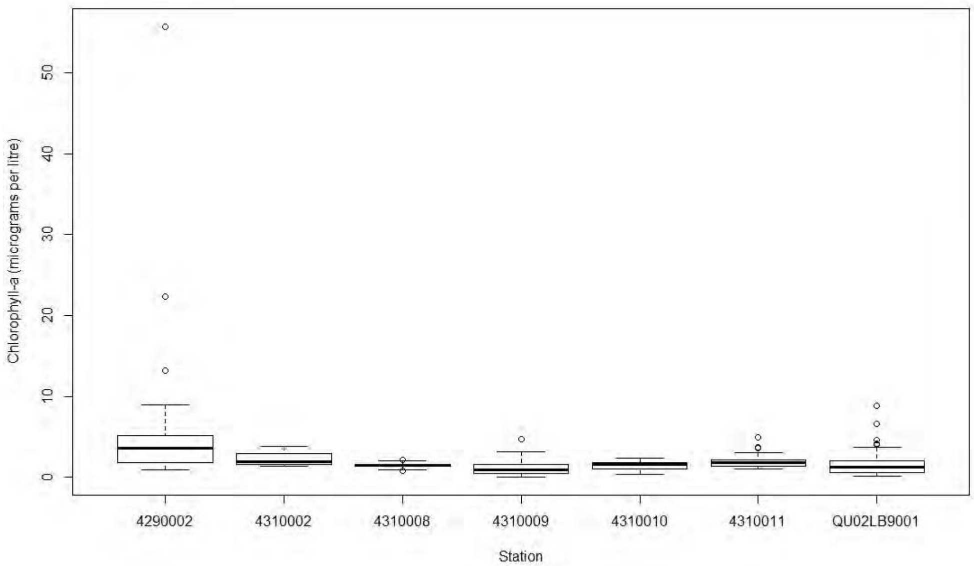

Figure 10. Chlorophyll-a concentrations by station, on the Ottawa River Mainstem.
(Data source: Province of Quebec)

Station codes correspond to locations as follows:
4290002 Saint Bruno-de-Guigues; 4310002 Carillon dam (1); 4310008 Chenaux;
4310009 Témiscamingue; 4310010 Notre-Dame-du-Nord;
4310011 Masson-Cumberland; QU02LB9001 Carillon dam (2).

7.2.7 Water Mercury

Mercury concentrations in water were not analysed because further work is required to agree on an approach to assess trends in the data with multiple records below the detection limit. The Ottawa Water Purification Plant records for the average annual mercury concentrations indicate average concentrations were below detection limits at the raw water intakes for the years 1995 to 1999; the detection limits during this period were not investigated, nor were methodologies used by the Water Purification Plants to estimate averages if mercury levels were detectable for some individual records.

7.2.8 Blue-green Algae Blooms

Within the Ottawa River Mainstem, Lake Témiscamingue had **Blue-green Algae Blooms** every year from 2007 to 2013. This recurrence rate of seven consecutive years is the highest in the watershed (Quebec, 2015).

The Province of Quebec's *Summary Profile of the Rivière des Outaouais Watershed* (2015) reports that from 2004 to 2012, there were Blue-green Algae blooms in 178 water bodies in 14 subwatersheds of the Ottawa River Watershed. From 2004 to 2012, 26 waterbodies in the Gatineau subwatershed experienced Blue-green Algae blooms, including 11 lakes in 2007.

7.2.9 Flow Connectivity

Although there are no data sources for culverts, the information on dams in Quebec indicates low **Flow Connectivity** (i.e., high fragmentation) of the Ottawa River Watershed. There are 1093 dams[49] in the Ottawa River Watershed on the Quebec side, including 201 small dams, 468 low capacity dams and 418 high capacity dams. Some of these dams may no longer serve a purpose, for example 52 former log rafting dams. The purpose of dams and number in Quebec in the watershed (sorted from highest to lowest) are:

- Recreation (577)
- Hydroelectric production (125)
- Regulation (106)
- Wildlife (61)
- Other or unknown (61)
- Log rafting (formerly) (52)
- Water catchment (45)
- Flood protection (33)
- Fish farming (12)
- Fire fighting (10)
- Agriculture (8)
- Historical site (2).

[49] Reported in Quebec's Summary Profile report (2015) using information from the Répertoire des barrages du Québec

7.2.10 Invasive Species

As indicated in Section 6.2.2.4, the information on invasive species is ill-defined. Non-native species may become invasive with time, so no distinction is made between non-native and invasive species at this time. The methodology and data sources accessed by WWF could be reviewed in future.

Non-native fish reported in the Ottawa River (OMNRF Background Report, 2016) include:

- Alewife (*Alosa pseudoharehgus*) in the Lac Dollard des Ormeaux reach
- Rainbow trout (*Oncorhynchus mykiss*) in the (Upper) Allumette Lake reach (possibly from stocking in tributaries)
- Brown trout (*Salmo trutta*) in the Lac Deschênes and Lac Dollard des Ormeaux reaches (a fish stocked by the Ontario Government in the Ottawa River)
- Common carp (*Cyprinus carpio*) in the Lac Deschênes and Lac Dollard des Ormeaux reaches
- White perch (*Morone americana*) in the Lac Dollard des Ormeaux reach

> In conversations while developing this report, a freshwater jelly fish[50] originally from China was noted in several locations within the watershed. Additional research and analysis of this invasive species is recommended for future work.

[50] See URL: https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1068

7.2.11 Change in Land Use

An analysis of land use was undertaken for 13 land use types: Settlement; Roads; Cropland; Water; Forest; Forest Wetland; Trees; Treed Wetland; Unmanaged Grassland; Wetland; Shrub Wetland; Herbaceous Wetland; Other. Nine of these types are natural cover, whereas settlement and roads indicate a high likelihood of impervious land cover. The following tables summarize the proportion of natural cover by subwatershed (Table 8), the subwatersheds with the highest proportion of settlement and road cover (Table 9) and the highest proportion of crop cover (Table 10). Figures 11 and 12 depict land use by subwatershed for natural land use, and settlement and roads (respectively).

Numerous studies of watersheds in Canada and elsewhere have found that aquatic biodiversity is fundamentally altered at a threshold of about 10% conversion of natural landcover to urban use. Studies have identified changes in flow regime at just 4% urban land use. On a subwatershed basis, the Rideau Watershed exceeds 10% settlement and roads, South Nation Watershed is almost 10%, and the Mississippi and Rouge-Nord systems experienced among the highest proportion of land conversion to settlement and road use in the 20 years of available record. Agricultural land uses also alter flow and water quality. The South Nation Watershed is over 50% cropland. The Rideau, Bonnechere, and Mississippi Watersheds have over 10% crop cover.

Table 8. Proportion of natural land cover by subwatershed.
(Source: Analysis based on AgCan maps)

Watershed	Percent Natural Cover	Percent change (1990 to 2010)
Headwaters	99.7	0
Upper Dumoine	99.7	0
Noire	99.6	-0.1
Upper Gatineau	99.6	0
Coulonge	99.5	-0.1
Montreal	99.5	0
Petawawa	99.3	-0.1
Lower Dumoine	98.3	-0.5
Upper Madawaska	97.3	-0.4
Upper Lievre	96.6	-0.2
Kinojevis	96.4	-0.3
Kipawa	95.0	-0.3
Lower Gatineau	94.7	-0.8
Lower Madawaska	93.9	-0.4
Lower Lievre	92.9	-1.2
Petite Nation	91.4	-0.9
Blanche	90.4	-0.3
Rouge Nord	90.3	-2.1
Mississippi	78.0	-1
Bonnechere	76.9	-0.9
Rideau	64.4	-1.3
South Nation	40.2	-0.6

Table 9. Subwatersheds with highest proportion of settlement and road cover.
(Source: Analysis based on AgCan maps)

Watershed	Percent Settlement and Roads (2010)	Percent increase (1990 to 2010)
Rideau	12.1	1.8
South Nation	8.9	0.8
Mississippi	7.2	1.1
Rouge Nord	6.2	2.1
Bonnechere	4.1	0.4
Lower Lievre	3.9	1.2
Petite Nation	3.2	0.7
Lower Gatineau	2.8	0.8

Table 10. Subwatersheds with highest proportion of crop cover.
(Source: Analysis based on AgCan maps)

Watershed	Percent Crop Land Cover
South Nation	50.8
Rideau	23.4
Bonnechere	18.8
Mississippi	14.6
Blanche	7.8
Petite Nation	5.4
Kipawa	3.7
Rouge Nord	3.6
Lower Madawaska	3.5
Lower Lievre	3.2
Lower Gatineau	2.5

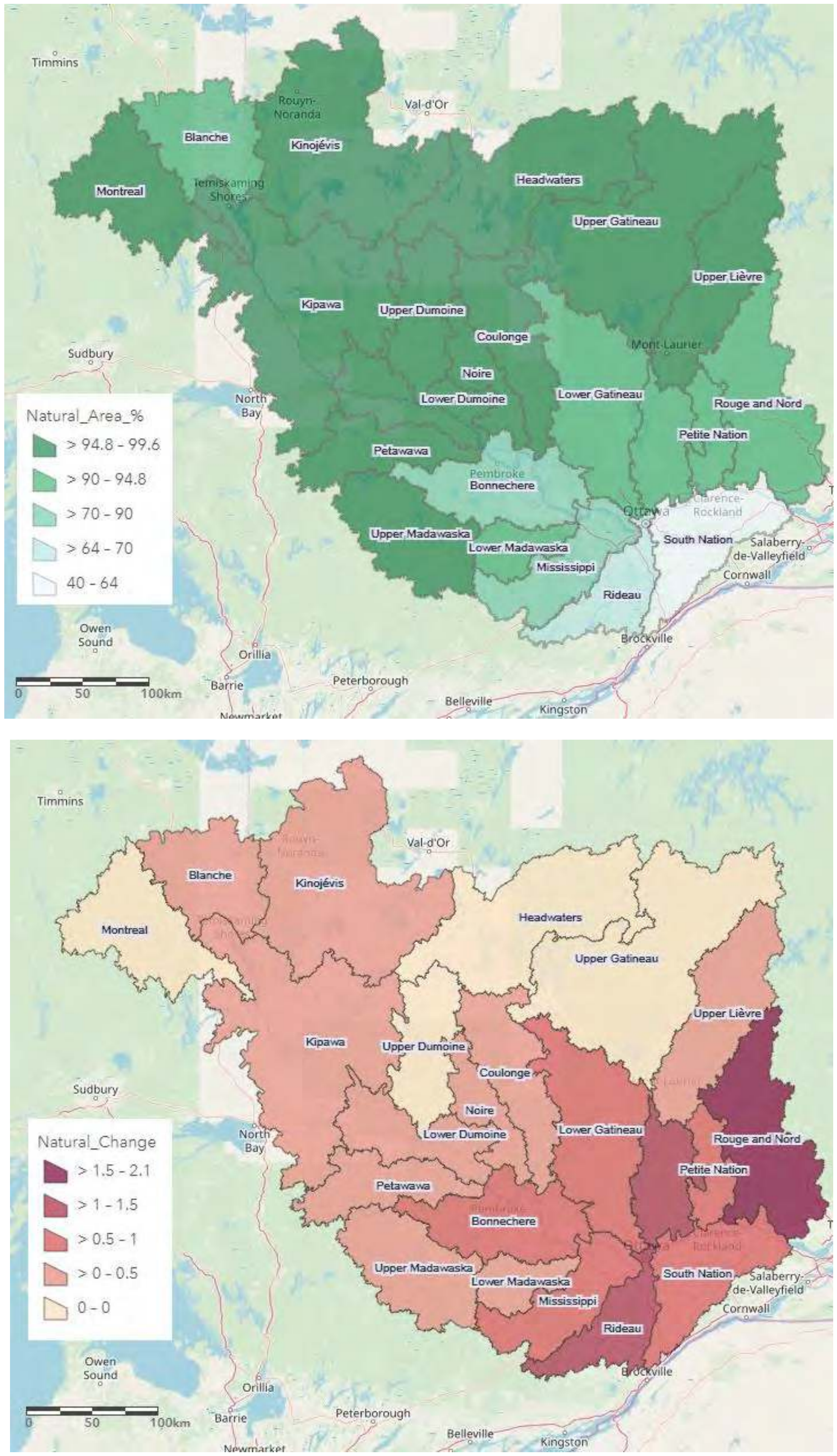

Figure 11. Land use by subwatershed, for natural cover.

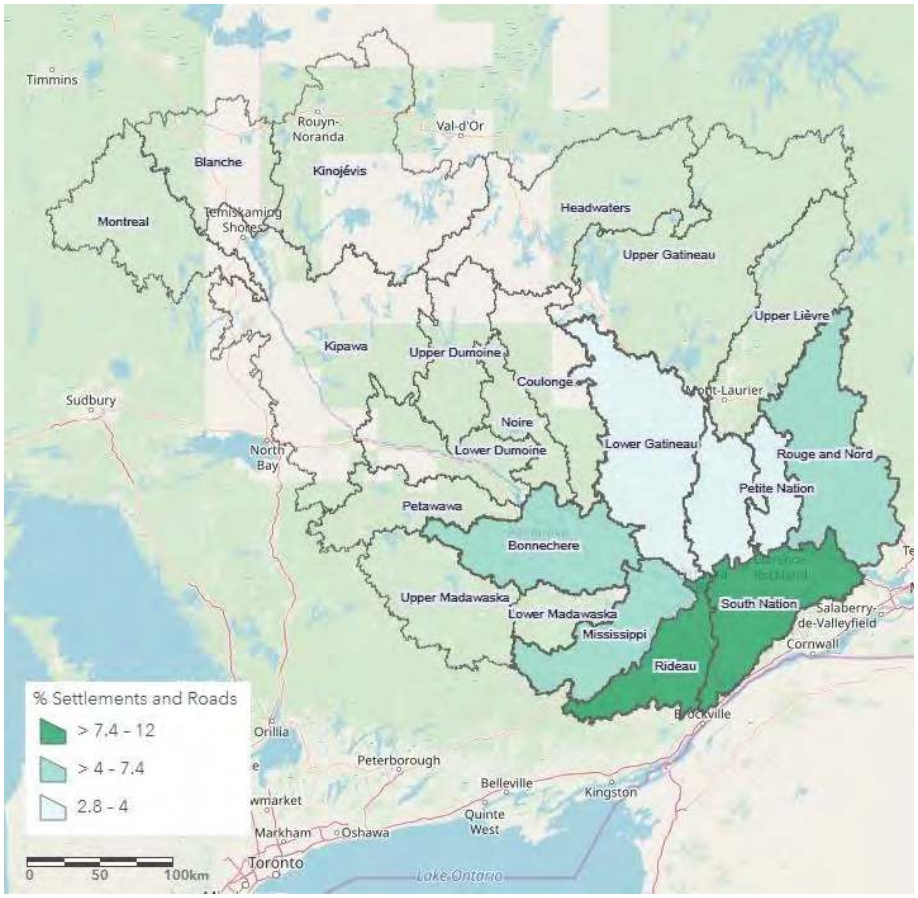

Figure 12. Land use by subwatershed for settlement and roads.

7.2.12 Timing of Ice-off

There are two spring peak flows in the Ottawa River Mainstem, one in early spring with snowmelt runoff from the lower watershed region, followed by a second, higher peak in later spring when the snow melts in the upper basin (OMNRF Background Report, 2016). Historically, the magnitude of the peaks has diminished since the creation and operation of reservoirs for power generation.

As a surrogate for spring freshet, based on the Field Naturalists observations at Pembroke since 1984, there is no discernable trend in the timing of ice breakup since 1984 (Figure 13). The earliest breakup in that record occurred in 2012 on March 26.

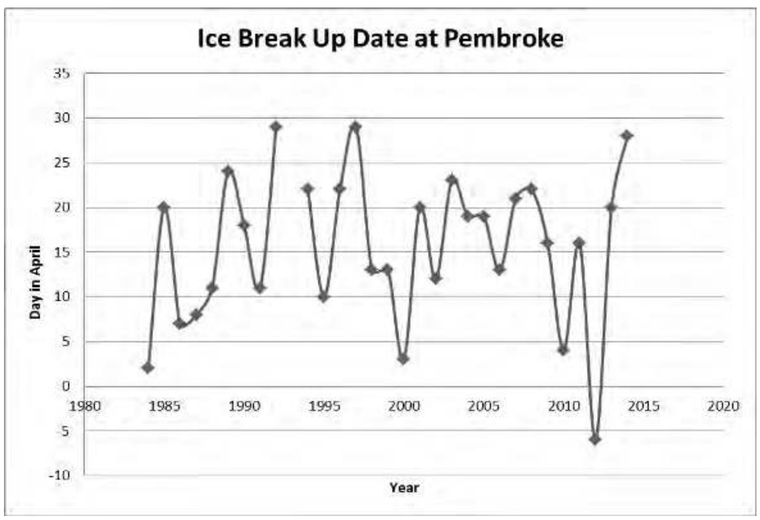

Figure 13. Date of Ice Breakup at Pembroke.
(Data reported by the Pembroke Area Field Naturalists)

Data collected at Pembroke, in the reach of Allumette, 1984-2014.
No clear trend is indicated.

8 Fundamental challenges

Gaps in individual datasets are discussed in Section 6. The intention of this section is to identify fundamental challenges in assessing the health of the Ottawa River Watershed. Three key challenges are identified, relating to the present, the past, and the future, respectively.

8.1 Piecemeal management results in patchwork data

Firstly, the piecemeal and fragmented approach to managing water quality, water quantity, and biodiversity across the Ottawa River Watershed has resulted in a patchwork of data sources, collection methods, and priorities. Data sets are comparable across jurisdictions where the federal government and provinces coordinate data collection nationally. Datasets are comparable across subwatersheds on one side of the river or the other, where provincial governments stipulate requirements or collect data themselves. However, across the Ottawa River Watershed, enormous effort is required to assemble and attempt to harmonize essential data, for example information on fish, benthic invertebrates, and algal blooms. Data collection on other aquatic biota, such as frogs, turtles, and water birds, was not even attempted because the data are so scattered and piecemeal.

8.2 Baseline unknown because change predates historical data

Secondly, the history of change in land use and resource extraction in the watershed predates available data by centuries. For instance, standardized data collection methods for fish sampling date back only to the late 1990s in Ontario. By that time, populations of Lake Sturgeon, American Eel, and many other aquatic species had already been dramatically reduced. Identification of a baseline against which to assess watershed health is inherently problematic, especially where there are significant historic data gaps. However, the health of the watershed cannot be adequately assessed against a baseline that is simply defined by the oldest available western scientific data.

8.3 A proactive, watershed-wide decision-making framework is crucial

Finally, on-going resource use and development pressures are taking place throughout the watershed even as alarming global-scale trends emerge. Climate change, biodiversity decline, intensified agriculture, urbanization, and mass movements of human populations are trends with significant implications for the ongoing health of the Ottawa River Watershed. Even if fully coordinated, data collected now will need to be supplemented with a process to develop scenarios for potential future outcomes, in order to make decisions that protect valued ecosystem components. At present, there is no coordinated decision-making framework to support the translation of data to knowledge and, ultimately, into adaptive approaches to sustain or improve watershed health.

9 Observations on the ecological health of the Ottawa River Watershed

This report does not include a full assessment of the health of the Ottawa River Watershed. However, some observations can be made about the Ottawa River Mainstem based on the information gathered.

> In some reaches of the Ottawa River, the number of fish species present today is far lower than the number known to be present historically.

In terms of the biological elements indicating ecological status, **Fish Richness** is low in some reaches of the Ottawa River, relative to the number of species known to be present historically (see Section 7.2.2, Table 6, column 5, Difference between BsM and literature). In particular, there were almost 40 fewer species identified in the Allumette Lake reach, and even fewer in the Lac Deschênes and the Lac Dollard des Ormeaux reaches, during the 2008-2010 survey. It is possible some species were present but not found during the survey period. Nevertheless, the significant differences in these and other reaches warrant attention to identify possible causes of the apparent reductions in **Fish Richness**.

> Lake Timiskaming has experienced blooms of Blue-green Algae for multiple consecutive years.

Although there are occasional exceedances, **Total Phosphorus** concentrations are predominantly within guidelines for the Ottawa River Mainstem downstream of Mattawa, with possible exceptions at Hawkesbury. In the headwaters, there are multi-year recurrences of **Blue-green Algae Blooms** in Lake Timiskaming and the available records indicate sustained elevated concentrations of phosphorus levels in the vicinity of Timiskaming. Other contributing factors, such as increased water temperatures, may also play a role. Additional data on phosphorus and temperature records would need to be located/collected to better understand conditions in Lake Timiskaming and elsewhere in the headwaters.

Land cover in the watershed is predominantly natural cover, including water, forest, wetlands, and unmanaged grasslands. The natural condition of the lands is protective of aquatic ecological status. However, land use conversion at rates under 10% have measurable effects on flow and aquatic biota. The natural conditions of the watershed, as a whole, are not sufficient to prevent local or sub-regional scale effects of land use or resource extraction. It is important to manage change in land use on smaller watershed scales where agriculture, urbanization, or road networks may affect watershed health in a way that is not readily detectable at the larger scale. Note that land cover statistics do not capture point sources of pollution, such as mines or contaminated sites, which may have significant effects on downstream water quality and biota.

> The natural conditions of the watershed, as a whole, are not sufficient to prevent local or sub-regional scale effects of land use or resource extraction.

10 Recommendations and next steps

Important recommendations are grouped into three categories, as follows:

- Suggested indicators
- Data availability and dissemination
- Improvements to watershed-scale coordination and decision-making

Suggested indicators

1. Watershed stakeholders should endorse and **apply the following short-listed suite of indicators** as a starting point for the assessment and common understanding of Ottawa River watershed health.

Indicators of Ecological Status	Indicators of Threats to Ecological Status
• Benthic invertebrates (HBI)* • Fish Diversity (initially, the number of fish species by reach) • Hydro-morphological quality elements (Broad characterization of the average flow in a year relative to a 20-year average; Minimum Flow; Maximum Flow; Ratio of Maximum to Minimum Flows) • Total Phosphorus* • Dissolved Oxygen* • Maximum Annual Water Temperature* • Chlorophyll-a • Water Mercury (Concentration in water column)	• Dry Weather Sewage Releases (Number of incidents) • Blue-green Algae (cyanobacteria) Blooms* (Number of occurrences and dates) • Flow Connectivity (Number of impassible or partially passible barriers to movement of aquatic biota) • Riparian Connectivity (Percent undeveloped shoreline area) • Fish Contaminants – Mercury (Concentration in tissue) • Invasive species (Number of non-native aquatic plant, animal, and invertebrate species, and commentary)* • Change in Land Use (Number of ha converted) • Timing of Spring Freshet (Date) • Timing of Ice off (Date)*

*See Recommendation #3.

2. Watershed stakeholders should **identify**, or create where not already established, **sites throughout the watershed to assess the indicators noted in Recommendation #1**. For example, water quality monitoring sites close to the confluence of tributaries with the Ottawa River mainstem can inform cumulative effects assessments within the tributary watersheds and also provide information on relative contributions of pollutants at the watershed scale. Reference sites that are representative of undeveloped, natural conditions should also be included to provide controls and avoid shifting baselines.

3. Ottawa Riverkeeper should **initiate and/or consolidate community-based monitoring (CBM) for the Ottawa River Watershed**. Among the short-listed indicators above, we recommend those listed with an asterisk as particularly appropriate for CBM. This monitoring would leverage the power of engaged citizens, build capacity and understanding at the community level, and fill some data gaps throughout the Ottawa River Watershed. Where appropriate, CBM should adhere to monitoring protocols that will allow data to be standardised. The CBM program should include partnerships with First Nation communities and ensure that the monitoring program reflects the data gaps and needs within their respective communities (see Section 4.2).

4. A lead agency or body should **undertake a watershed health assessment every 5 years**. The assessment could begin with the short-listed indicators noted in Recommendation #1, with additional indicators to be added as outlined in Appendix A, as well as additional socio-economic indicators finalized through stakeholder engagement. Moreover, **meaningful engagement with all duly recognized Algonquin communities** is required in the co-development of a full suite of indicators. Effectively engaging Algonquin communities to further develop indicators based on Indigenous Knowledge will require financial resources.

5. Watershed stakeholders should **prioritize data collection and analysis of short-listed and long-listed indicators** according to existing data gaps (see colour code Table 5; Appendix A) as well as perceived urgency based on preliminary analysis. For example, available data shows **an alarming trend of decreasing fish diversity** across the watershed, which should be further investigated and quantified. The causes should be identified and incorporated into an action plan (see Recommendation #12).

Data availability and dissemination

6. Agencies should **make their data available in raw form**, not summarized results for indicators, so that individual jurisdictions can manipulate the data per their own conventions (e.g. ECCC's CESI, Québec's IQBR).

7. Watershed stakeholders should make every effort to **standardize data collection** (especially for biological indicators) so that datasets from multiple sources can be used for analyses.

8. A lead agency or body should **create a virtual information hub to consolidate all sources of watershed-based knowledge** (i.e. reports, studies, repository of monitoring activities throughout the watershed). It would include reports on the Ottawa watershed dating back decades, many of which are not widely accessible. This library does not need to contain datasets - rather, it would centralize information about who is collecting data and how (e.g. monitoring location, indicators being measured, frequency of measurements, owner of data, etc.). Such a hub would be useful for governments, academics, consultants, and non-government organizations. It would increase the efficiency of researchers and promote increased research and collaboration in the watershed.

Watershed-scale coordination and collaboration

9. **Establish an Ottawa River Watershed Council** as a forum for discussion and collaboration, including all levels of government as well as industry. This recommendation has previously been made by Ottawa Riverkeeper and is currently being studied by ECCC. The concept already has support as indicated by signatories to The Gatineau Declaration of 2015[51]. The unique trans-provincial characteristics of the mainstem river warrant a unique arrangement for collaboration on a watershed scale.

[51] The Gatineau Declaration can be accessed at URL: https://www.ottawariverkeeper.ca/ottawa-river-watershed-declaration/

10. The Algonquin Nation must have the lead in undertaking further dialogue sessions with their membership. **An Algonquin-led water gathering** can bring together all Algonquin communities to discuss the protection and preservation of the Ottawa River Watershed and the sharing of Indigenous Knowledge.

11. Ensuring an equal voice by the Algonquin Nation requires dedicated long-term funding to **support the establishment of an Algonquin Nation governance body**. Dedicated resources and personnel are needed in order to increase the capacity within the Algonquin Nation. A fully funded guardian's program will support the Algonquin Nation to take their rightful place as a ministry on their unceded traditional territory.

12. Create an **action plan for restoration and protection of the Ottawa River Watershed**. The action plan would build on findings from the Watershed Health Assessment and present priorities for investment, monitoring, protection, and restoration. The action plan should be based on a decision-making framework that includes ecological thresholds indicating conditions requiring management responses and scenario development for potential future scenarios. It should be developed with an adaptive management approach that recognizes the need for continuous learning in response to climate change and biodiversity decline.

Appendix A. Initial long list of indicators of ecological status and threats

This long list of potential indicators includes the short-listed indicators for which data were collected in Phase One. A draft of this long list was circulated for input by experts and agencies at the commencement of the Phase One study. Note that this list does not include socio-economic indicators as these were not within scope for Phase One. Similarly, this list addresses indicators for river systems; additional indicators are needed for lakes, wetlands, and groundwater systems.

Table A. Long list of potential indicators of ecological status and threats.

Indicator Group/ Element	Qualitative description of what might be assessed	Potential Indicator(s)	Specific Measurement
Ecological Status/ Biological elements	Composition and abundance of benthic invertebrate fauna	Ratio of disturbance sensitive taxa to disturbance insensitive taxa	- EPT[52] as a % of benthic sample, including spatial trends through the watershed and in single locations through time
	Composition and abundance of fish populations	Population and age structure of predatory game fish	- Catch per unit effort for Walleye, Pike, Bass, Muskie at monitoring locations through watershed
	Abundance of rare, endangered species or species of traditional value	Population and age structure of species at risk	- Counts of American Eel and Lake Sturgeon at monitoring stations, through time (possibly including age distribution) - Number of species (fish, herptiles, plants, possibly water birds) at risk, threatened, endangered, extirpated in the watershed / subwatershed

[52] EPT: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Indicator Group/ Element	Qualitative description of what might be assessed	Potential Indicator(s)	Specific Measurement
	Composition and abundance of aquatic flora	Frequency, intensity and duration of phytoplankton blooms	- Number, location, and date of Blue-green Algae blooms - Presence/ absence of toxins in the blooms
	Health of fish and other aquatic biota in terms of tissue contaminants and other health conditions	Concentrations of chemicals or other substances in fish tissue indicating pervasive presence in the environment	- Mercury in fish tissue (where other contaminants measured) - Microbead plastics in fish tissue/organs - Plastics in fish stomachs - Feminized male fish
	Biota present in the watershed	Technology is developing to allow detection of the presence of biota	- e-DNA indicator
	Aquatic birds	Change in population size over time	-
Ecological Status / Hydro-morphological quality elements	Hydrological regime	Peak flow volume and timing Low flow volume and duration	- Maximum water flow during the year (or season) - Date of maximum water flow - If applicable, duration of maximum water flow event in a year (days level was less than average of previous 20 years) - Minimum water flow during the year (or season) - Date of minimum water flow - If applicable, duration of minimum water flow event in a year (days level was less than average of previous 20 years) - Ratio of maximum to minimum flows (trends over time, including prior to dam construction)

Indicator Group/ Element	Qualitative description of what might be assessed	Potential Indicator(s)	Specific Measurement
		Ecological flows, including variability in water quantity/ water levels	- Abruptness of change (variability or rate of change) in water levels (i.e. maximum drop and rise within minutes or seconds in a season); - Range of water level change (highest level minus lowest level in a year or season) - Other ecological flow indicators need to be developed
		Precipitation patterns and river flow response	- Total precipitation depth per year - Rainfall total depth, and storm intensity and duration - Trends in flow response to rainfall - Snowpack depth and melt rate (maximum snow pack depth as an initial indicator) - Number of consecutive days without precipitation
	Sediment regime	Sediment characteristics and transport	- volume of sediment transported - Change in sediment transport and loss of connectivity for sediment regime stability - Characteristics of sediment (coarse, fine) and changes over time
	Morphological regime	Meander characteristics	- Meander belt characteristics - - Changes to thalweg
	Morphological conditions that indicate erosion or natural flow disruption	Riparian zone condition	- % riparian area protected by vegetation (to 10, 30, and 50 metres inland from high water line)

Indicator Group/ Element	Qualitative description of what might be assessed	Potential Indicator(s)	Specific Measurement
	Habitat quantity and quality for various biota (based on hydro-morphological conditions)		- Number of nesting sites or young of the year nursery areas for indicator biota or endangered species
Ecological Status/ Chemical and physico-chemical elements	Water quality or physical conditions important to aquatic life	Concentrations of nutrients, other naturally occurring elements, temperature	- Total phosphorus - Oxygen - Temperature (at various depths) - Chlorophyll-a - Mercury - Total nitrogen - Ammonia (unionized) - pH - Calcium carbonate - Total suspended solids - Dissolved oxygen - Conductivity - Turbidity
Threats to ecological status	Water quantity	Water extraction or use as a resource	- Volume of water withdrawn for various uses (municipal, industrial, commercial) - Ratio of volume withdrawn to minimum flow (based on lowest flow in 20 years over a 7-day period, or similar) - Number of dams - Number of water intakes (urban, agricultural, industrial)
	Water quality	Indicators for known hazards in the watershed	- Tritium concentration - Number of outfalls (combined sewer, storm sewer, sanitary sewer overflows) - Number of raw sewage releases (dry weather)

Indicator Group/ Element	Qualitative description of what might be assessed	Potential Indicator(s)	Specific Measurement
			- Proportion of wastewater treated (raw, primary, secondary, better than secondary) - Number of bridge crossings (highway, rail)
		Incidents of hazardous conditions for wildlife	- Blue-green algae (Cyanobacteria) blooms (number of occurrences)
	Water quantity, quality, habitat	Area of watershed/ subwatershed with land use altered from natural conditions	- In hectares, area of: · Agriculture · Urban · Road network · Forest · Harvested forest · Wetland - Road network length per hectare of watershed area - % protected area
	Habitat	Invasive species, especially with potential to disrupt natural environment	- Number of non-native/ invasive species - Zebra mussel presence/ concentrations - Eurasian milfoil presence - Asian Carp presence
		Regional scale fragmentation/ departure from connectivity for species in water and relying on water habitat	- Number of upstream impediments to safe fish migration - Number of downstream impediments to safe fish migration - Number of perched culverts - Research required to identify indicators (GIS analysis); characterization of features that disturb the migration of aquatic

Indicator Group/ Element	Qualitative description of what might be assessed	Potential Indicator(s)	Specific Measurement
			organisms and sediment transport
	Concentrations of chemicals or substances of potential concern to aquatic life	Concentrations of chemicals in ambient conditions (i.e. not downstream from a known point source)	- Pesticide concentrations (specific pesticides TBD; possibly atrazine; glysophase) - BOD5 - Heavy metal concentrations · Cadmium · Chromium · Lead · Mercury - Pharmaceuticals and endocrine disruptors (codeine, estrogen, diabetes drug; DEET; ASA, caffeine) - Triclosan
	Climate change	Indicators of the extremes that may occur within the watershed as a result of changing climate	- Dates of spring freshet - Water temperature (maximum) - Water level minimum and maximum - Maximum precipitation depth during a single event in a year - Maximum air temperature per year - Duration of days with air temperature exceeding previous 20-year average

Appendix B. Statistical analysis of water quality - Total Phosphorus

This appendix provides details on estimates of average **Total Phosphorus** results for stations except the six stations monitored by the Province of Quebec and the station at Montreal.

B.1 City of Ottawa Data

For City of Ottawa Total Phosphorus results at transects across the mainstem Ottawa River, there were no statistically significant differences in records for Total Phosphorus at stations across the ORS-100 transect, the ORS-200 transect, the ORS-410 transect, the ORS-418 transect, the ORS-420 transect, or the ORS-600 transect (see Table B.1 below for Analysis of variance (ANOVA) results). There was at least one station with significantly different Total Phosphorus results for transects at ORS-430, ORS-450, and ORS-500 (see Table B.1).

Table B.1 Comparison of Total Phosphorus results at transect stations across the Ottawa River.
(City of Ottawa data)

Stations	ANOVA result comparing TP, pooled by year and depth	Comment
ORS-100.10, ORS-100.20, and ORS-100.30	p=0.495	No significant difference among stations for Total Phosphorus results
ORS-200.10, ORS-200.30, and ORS-200.40	p=0.329	
ORS-410.10, ORS-410.40, and ORS-410.70	p=0.486	
ORS-418.10, ORS-418.20, and ORS-410.30	p=0.689	
ORS-420.10, ORS-420.20, ORS-420.30	p=0.428	
ORS-600.10, ORS-600.20, ORS-600.30, ORS-600.40, ORS-600.50	p= 0.737	
ORS-430.10, ORS-430.30, ORS-430.60, ORS-430.70	p= 6.5 e-07	At least one station had significantly different TP results
ORS-450.10, ORS-450.20, ORS-450.30, ORS-450.40	p= 9.29 e-09	
ORS-500.10, ORS-500.20, ORS-500.50	p= 3.55 e-08	

The City of Ottawa samples at depths in the Ottawa River mainstem ranging from 0.3 meters to 7 meters. At most transects, there is no statistically significant difference in Total Phosphorus by depth. Exceptions include stations at transect ORS-430 (sampled at depths 0.3, 0.5, 3 meters) (ANOVA p= 0.0002), at transect ORS-450 (sampled at depths 0.5 and 6 meters) (ANOVA p= 0.0356), and at transect ORS-500 (sampled at depths 0.5, 0.3, 6 meters) (ANOVA p=0.0001).

B.2 Average Total Phosphorus Estimates

Figure B.1 is a box plot of Total Phosphorus records by station. As indicated by this figure, the variation in Total Phosphorus values is higher for the provincial stations than the records for City of Ottawa stations. This variation may be attributable in part to the fact that Ontario's stations date back farther, with up to 50 years of records. However, the Quebec station (QU02LB9001) only has 12 years of records but is among the most variable stations and it also has one of the highest maximum Total Phosphorus values although, on average, it is under 0.030 mg/L. Figure B.2 is a box plot of Total Phosphorus records by year. Table B.2 summarizes the results of average total phosphorus calculations and the data supporting the estimate for each station. Note that an outlier record of 1.1 mg/L at station 18000007883 was removed as were four records with no detectable results at stations ORS-100.10 (09/2011), ORS-210.40 (08/1998), ORS-420.30 (10/ 2011), ORS-430.30 (08/2011).

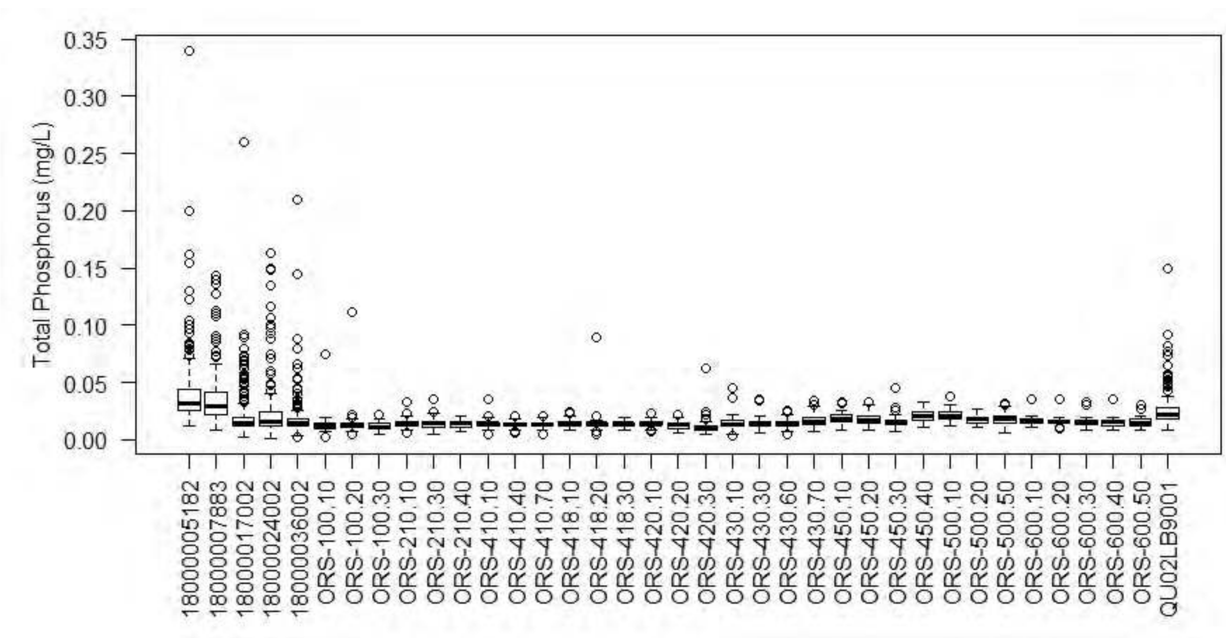

Figure B.1 Box plot of Total Phosphorus by Station.

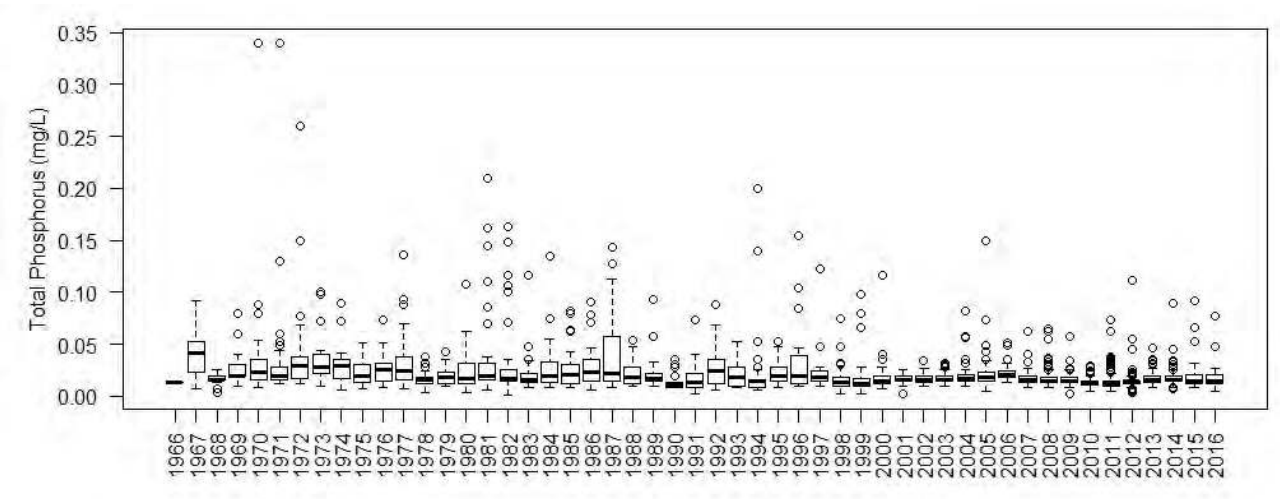

Figure B.2 Box Plot of Total Phosphorus by year.

Table B.2 Database summary for average Total Phosphorus estimations.
Bold numbers indicate exceedances of the 0.030 mg/L target for Total Phosphorus.

Station	Average Total Phosphorus (mg/L)	Standard Deviation (mg/L)	Highest TP Value (mg/L)	Lowest TP Value (mg/L)	Earliest Year of Record	Latest Year of Record	Number of Records	Number of Years with Records
18000036002	0.018	0.017	**0.210**	0.002	1968	2016	297	36
18000024002	0.024	0.026	**0.163**	0.001	1968	2000	229	31
18000017002	0.019	0.018	**0.260**	0.002	1966	2016	367	50
ORS-100.10	0.013	0.010	**0.075**	0.003	1998	2014	43	6
ORS-100.20	0.013	0.009	**0.111**	0.005	1998	2014	132	17
ORS-100.30	0.012	0.004	0.022	0.005	1998	2014	43	6
ORS-210.10	0.014	0.004	**0.033**	0.006	1998	2014	93	17
ORS-210.30	0.014	0.004	**0.036**	0.005	1998	2014	117	17
ORS-210.40	0.013	0.003	0.021	0.007	1998	2014	92	17
ORS-410.10	0.014	0.004	**0.036**	0.005	2008	2014	41	7
ORS-410.40	0.013	0.003	0.021	0.006	2008	2014	71	7
ORS-410.70	0.013	0.003	0.021	0.005	2008	2014	41	7
ORS-418.10	0.015	0.004	0.024	0.009	2010	2014	29	5
ORS-418.20	0.015	0.011	**0.090**	0.005	2010	2014	58	5
ORS-418.30	0.014	0.002	0.019	0.009	2010	2014	29	5
ORS-420.10	0.014	0.003	0.023	0.007	2008	2014	41	7
ORS-420.20	0.012	0.003	0.022	0.006	2008	2014	71	7
ORS-420.30	0.012	0.009	**0.063**	0.005	2008	2014	40	7
ORS-430.10	0.014	0.005	**0.045**	0.003	1998	2014	106	17
ORS-430.30	0.014	0.004	**0.035**	0.006	1998	2014	135	17
ORS-430.60	0.014	0.003	0.025	0.004	1998	2014	106	17
ORS-430.70	0.017	0.005	**0.034**	0.007	1998	2014	106	17
ORS-450.10	0.019	0.005	**0.033**	0.008	2002	2014	69	13
ORS-450.20	0.018	0.005	**0.033**	0.009	2002	2014	69	13
ORS-450.30	0.016	0.005	**0.045**	0.007	2002	2014	96	13
ORS-450.40	0.021	0.005	**0.033**	0.011	2002	2014	69	13
ORS-500.10	0.021	0.004	**0.038**	0.012	1998	2014	101	17
ORS-500.20	0.018	0.004	0.027	0.011	1998	2014	128	17
ORS-500.50	0.018	0.004	**0.032**	0.006	1998	2014	101	17
ORS-600.10	0.017	0.004	**0.035**	0.011	2000	2014	25	6
ORS-600.20	0.016	0.004	**0.035**	0.010	2000	2014	25	6
ORS-600.30	0.016	0.004	**0.033**	0.009	2000	2014	49	6
ORS-600.40	0.015	0.005	**0.035**	0.008	2000	2014	25	6
ORS-600.50	0.016	0.005	**0.031**	0.008	2000	2014	25	6
18000007883	**0.037**	0.025	**0.143**	0.009	1972	2000	142	27
18000005182	**0.044**	0.041	**0.340**	0.012	1970	2000	177	29
QU02LB9001	0.026	0.016	**0.150**	0.008	2004	2016	189	12

Appendix C. Categories and names of recommended indicators.

Indicator Group	Element	Indicator Category	Indicator Name
Ecological Status	Biological elements	Benthic invertebrates	**Benthic Invertebrates** (HBI)
		Fish diversity	**Fish Richness** (# of species by river reach)
	Hydro-morphological elements	Water flow level	**Overview of Historic Flow** (ratio of average annual flow in current year, to 20-year average)
			Minimum Flow (volume/time and date)
			Maximum Flow (volume/time and date)
			Ratio of Maximum to Minimum Flow
	Chemical and physico-chemical elements	Total Phosphorus concentration in water column	**Total Phosphorus** (mg/L)
		Dissolved Oxygen concentration in water column	**Dissolved Oxygen** (O2 mg)/L)
		Chlorophyll-a concentration in water column	**Chlorophyll-a** (ppb)
		Mercury concentration in water column	**Water Mercury** (mg/L)
		Water temperature	**Maximum Annual Water Temperature** (°C)

Indicator Group	Element	Indicator Category	Indicator Name
Threats to ecological status	To water quantity	Not in Phase One	
	To water quality	Sewage release incidents	**Dry Weather Sewage Releases** (# of releases during dry weather)
		Blue-green Algae blooms	**Blue-green Algae Blooms** (# of occurrences and dates)
	To habitat and biota	Aquatic habitat fragmentation	**Flow Connectivity** (# of impassible or partially-passible barriers to movement of aquatic biota)
		Shoreline habitat fragmentation	**Riparian Connectivity** (% undeveloped shoreline)
		Fish contaminants	**Fish Contaminants - Mercury** (concentration of mercury in tissue mg mercury /kg tissue)
		Invasives	**Invasive Species** (# of non-native aquatic plant, animal, and invertebrate species present, with commentary)
	To quantity and quality of habitat, and biota	Changing Land Use	**Change in Land Use** (ha) for landcover categories including Agriculture, Urban Development, Road Network, Natural Forest, Harvested Forest, and Wetland
	To water quality and quantity, habitat and biota	Climate change	**Timing of Spring Freshet** (date)
			Timing of Ice-off (date)
			Water temperature (as above)
			Water flow levels (as above)

Appendix C. Categories and names of recommended indicators.

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