Mackenzie River Basin State of the Aquatic Ecosystem Report – Summary

Prepared for:
Mackenzie River Basin Board

Authored by:
Associated Environmental Consultants Inc.
in partnership with Integral Ecology Group

Associated Environmental

IEG Integral Ecology Group

March 2021

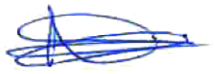
MESSAGE FROM THE CHAIR

The members of the Mackenzie River Basin Board (MRBB) are pleased to present Phase 1 of an online web-based State of the Aquatic Ecosystem Report for the Mackenzie River Basin. Submission of this report fulfills one of the duties of the Board as listed in the Mackenzie River Basin Transboundary Waters Master Agreement. The vision for this report considered feedback on the 2003 State of the Aquatic Ecosystem Report and the 2012 update that are available at mrbb.ca/resources. The decision to create an online web based report allows the Board to augment the information and knowledge shared on the site, and facilitates ongoing communication with those interested in the future development of this report.

The Mackenzie River Basin Board recognizes the basin has been home to Indigenous People for millennia, and that the Indigenous ways of knowing are seminal to any discussion about the land. This report attempts to consider the two knowledge systems, science and Indigenous Knowledge, through the concept of braiding. A braid symbolizes the interlocking process that is made of distinct and independent strands to form a whole. Each piece of shared knowledge stands on its own and tells it's own story, and also contributes to the overall story of the basin.

A report of this scope takes time and much effort to develop. The MRBB is grateful for past and present members of the State of the Aquatic Ecosystem Report Steering Committee, and Traditional Knowledge and Strengthening Partnerships Steering Committee, and all of the work and wisdom that guided the indicator workshops, reports and partnerships that informed this report. The report includes an assessment of six sub-regions: Peace, Liard, Peel, Athabasca, Mackenzie-Great Bear and Mackenzie-Great Slave. This report also includes some basin wide patterns in water levels, populations of wetland-dependent wildlife, contaminants in water and fish, air temperatures, and concentrations of ions in freshwater. Major themes that link these basin-wide patterns include ecological connections between discreet indicators, climate change, and resource use.

Future work on this report will focus on filling data gaps, where feasible, identified during the knowledge-gathering phase of this work and continuing to strive towards ensuring that the information is accessible and current. The MRBB will be looking to this report to inform its business plan into the future.
We hope you have the opportunity to spend some time on the website and encourage you to provide your feedback and insights.
Sincerely,



Nadine Stiller
Chair, Mackenzie River Basin Board
Environment and Climate Change Canada

ACKNOWLEDGEMENTS AND GRATITUDE

The Mackenzie River Basin Board (MRBB) acknowledges the Indigenous Peoples who live and have lived in the Mackenzie River Basin for thousands of years, since time immemorial, from the headwaters in the mountains, through the boreal forest and tundra, to the outlet at the Arctic Ocean. The many, diverse Indigenous Peoples of this basin include: Inuvialuit, Gwich'in, Sahtu Dene, Métis, Tlicho, Cree, Tr'ondek Hwech'in, Nacho Nyak Dun, Sekani (Tsay Keh Dene), South Slavey, Beaver, Tahltan, Saulteaux, Kaska, Dogrib (Tlicho), North Slavey, Dane-zaa, Woodland Cree, Secwepemc (Shuswap), Salish, Ktunaxa, Nakota/Stony, Denesoline, Akaitcho, Dehcho, Northwest Territory Métis Nation, Denesuline. The 'People and Places' section on each sub-basin page of the SOAER website offers further details and information.

Environmental stewardship is fundamental to Indigenous cultures and ways of life. The right to maintain and strengthen this relationship is recognized in Articles 24 through 29 in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and is a premise of many modern co-created agreements. Indigenous Peoples hold vast amounts of knowledge fundamental to understanding the state of the aquatic eco-system of the Mackenzie River Basin and these ways of knowing are integral to protecting the basin and ensuring its health for generations to come.

The MRBB acknowledges and thanks past and present members of the Traditional Knowledge and Strengthening Partnerships Steering Committee, and the State of the Aquatic Ecosystem Steering Committee for their vision, guidance and hard work. The MRBB would also like to acknowledge contributions from Federal, Provincial and Territorial governments, Indigenous communities and individuals in the Mackenzie River Basin. The information and resources shared with Board and committee members was important to the quality of this work.

The words and work shared through the Tracking Change project (http://www.trackingchange.ca/) are a crucial source of knowledge for this report. The Board extends a special thank you to; Dr. Brenda Parlee who led the Tracking Change project; the Indigenous members of the MRBB who participated on the Indigenous Steering Committee for the project and who served as a vital link between Tracking Change and the MRBB; and everyone involved in the Tracking Change Project with the University of Alberta.

MEMBERSHIP

Mackenzie River Basin Board Members, Committee Members and Secretariat Support (2012 – 2021)

The vision and thinking around parts of this project started years before the production of this web-based report. The lists below include past and present Board and committee members. We apologize to anyone who was missed. Our sincere gratitude goes to:

Current Members of the Mackenzie River Basin Board, TKSP Steering Committee, SOAER Steering Committee and MRBB Secretariat (March 2021)

Alberta

MRBB Government Member: Andrew Wilson
MRBB Government Alternate: Carmen de la Chevrotière
MRBB Indigenous Member: Chief Gerry Cheezie
SOAER Steering Committee Member: Gongchen Li
TKSP Steering Committee Members: Chief Gerry Cheezie and Karin Smith-Fargey

British Columbia

Government Member: Ted Zimmerman
Government Alternate: Sean Moore
Indigenous Member: Lana Lowe
SOAER Steering Committee Member: Lucie Thompson
TKSP Steering Committee Member: Lana Lowe

Northwest Territories

Government Member: John MacDonald
Government Alternate: Nathen Richea
Indigenous Member: Leon Andrew
SOAER Steering Committee Member: Jennifer Hickman
TKSP Steering Committee Member: Leon Andrew

Crown-Indigenous Relations and Northern Affairs Canada

Government Member: Matthew Spence
Government Alternate: Nicholas Mitchell
TKSP Steering Committee Member: George Lafferty

Secretariat

MRBB Executive Director: Paula Siwik

Saskatchewan

MRBB Government Member: John Fahlman
MRBB Government Alternate: Susan Ross
MRBB Indigenous Member: Vice Chief Joseph Tsannie
SOAER Steering Committee Member: Jeffery Sereda
TKSP Steering Committee Member: Vice Chief Joseph Tsannie

Yukon

Government Member: Heather Jirousek
Government Alternate: Emma Seward
Indigenous Member: Corrine Porter
SOAER Steering Committee Member: Emma Seward
TKSP Steering Committee Member: Corrine Porter

Environment and Climate Change Canada

Government Member: Nadine Stiller
Government Alternate: Patrick Cherneski
SOAER and TKSP Joint Steering Committee Chair: Bradley Summerfield
TKSP Steering Committee Member: Sharon Reedyk

Parks Canada Agency

Government Member: Jonah Mitchell
Government Alternate: Laurie Wein

Past members of the Mackenzie River Basin Board, TKSP Steering Committee, SOAER Steering Committee and MRB Secretariat (as of March 31, 2012)

Alberta

MRBB Government Member: Robert Harrison, Brian Yee
MRBB Government Alternate: Tim Toth
MRBB Indigenous Member: Cleo Reece, Darren Calliou
SOAER Steering Committee Member: Robert Harrison, Brian Yee, Cleo Reece,
TKSP Steering Committee Members: Tracy Howlett, Cleo Reece, Darren Calliou, Martina Kreiger, Andrea Westaway

Saskatchewan

MRBB Government Member: Bob Carles, Jim Gerhart
MRBB Government Alternate: Gary Neil
MRBB Indigenous Member: Don Deranger
SOAER Steering Committee Member: David Espeseth, Gary Neil
TKSP Steering Committee Member: Don Deranger, Jeff Olson

British Columbia

Government Member: Lynn Kriwoken
Government Alternate: Pieter Bekker
Indigenous Member: Vera Nicholson
SOAER Steering Committee Member: Vera Nicholson, Pieter Bekker, Celine Davis, Kevin Reiberger, Stephanie Hazlitt, Heike Lettrari
TKSP Steering Committee Member: Vera Nicholson

Yukon

Government Member: Jon Bowen
Government Alternate: Robert Truelson
Indigenous Member: Sharon Peter
SOAER Steering Committee Member: Tyler Williams, Sharon Peter, Veronica Huggart, Ellen Ward,
TKSP Steering Committee Member: Sharon Peter, Veronica Huggart

Northwest Territories

Government Member: Ray Case, Shannon Cumming, Erin Kelly
Government Alternate: Meghan Beveridge, Robert Jenkins
Indigenous Member: Sonny MacDonald
SOAER Steering Committee Member: Andrea Czarnecki, Ray Case, Erin Kelly, Jennifer Fresque-Baxter, Nathen Richea
TKSP Steering Committee Member: Sonny MacDonald, Shannon Cumming (Champion), Bea Lepine, Jennifer Fresque-Baxter (Chair), Ray Case

Environment and Climate Change Canada

Government Member: Mike Norton, Richard Smith, Cheryl Baraniecki
Government Alternate: Mike Renouf
SOAER Steering Committee Member: Lynne Quinnett-Abbott (Chair), Cecelia Wong, Mike Norton, Christine Best

Crown-Indigenous Relations and Northern Affairs Canada

Government Member: Trish Merrithew-Mercredi, Kathryn Bruce, Mohan Denetto
Government Alternate: Teresa Jourdie, Robert Jenkins, Jennifer O'Neill, Mike Roesch
SOAER Steering Committee Member: Dinah Elliott, Trish Merrithew-Mercredi (Champion), Carole Mills (Chair), Greg Bereza, Kathryn Bruce

Health Canada

Government Member: Ward Chickoski, Teressa Laforest, Chantal Roberge
Government Alternate: David Muddle, Mary Frances MacLellan-Wright

Secretariat

MRBB Executive Director, Don Pittman
MRBB Secretariat, Jenny Ferone

EXECUTIVE SUMMARY

The Mackenzie River Basin Transboundary Waters Master Agreement[1] directs the Mackenzie River Basin Board (MRBB) to report on the State of the Aquatic Ecosystem every five years. The State of the Aquatic Ecosystem Report (SOAER) brings together available information within the Mackenzie River Basin (MRB) to help the MRBB, residents and decision makers understand and track aquatic ecosystem health in the basin. The 2021 SOAER describes changes to aquatic ecosystem health in the MRB that have been documented since the first SOAER was released in 2003.

A “braided approach” was used to bring together Indigenous knowledge and scientific information to tell the story of aquatic ecosystem health in the Mackenzie River Basin.

The 2021 SOAER showcases the value of Indigenous knowledge as a credible and integral component in aquatic ecosystem assessment. By presenting Indigenous knowledge and scientific evidence as a braided approach, this report is intended to tell the story of the basin to inform and be used by basin residents and decision makers alike. Published sources of Indigenous knowledge were consulted, scientific data were analyzed and other literature reviewed. A “braided approach” was used to bring together Indigenous knowledge and scientific information to tell the story of aquatic ecosystem health in the Mackenzie River Basin. The information was paired with relevant supporting visuals and used to develop a web-based report.

The aquatic ecosystem assessment followed a conceptual framework of signs and signals related to water quantity, water quality, habitat and species, and health and wellbeing. The framework was developed by the MRBB through extensive research and consultation efforts leading up to the 2021 SOAER. The focus of the assessment was to identify the degree of change from “normal” or natural conditions and resulting impacts on ecosystem health and people. The results of the assessment are presented for each of the six sub-basins: Mackenzie Great Bear, Peel, Liard, Great Slave, Peace and Athabasca.

Changes in aquatic ecosystem signs and signals related to water quantity, water quality, habitat and species, and health and wellbeing were observed in all sub-basins. The main basin-wide patterns in aquatic ecosystem change identified in this report are summarized below.

- Rising air temperatures, mostly in winter, have led to increased winter stream flows across the basin, the appearance of new fish species in northern rivers, and reduced ice and snow cover in many areas.
- Changing populations of wildlife, such as muskrat (*Ondatra zibethicus*) and fish, have been observed by Indigenous communities and recorded in fish stock information in most sub-basins, leading to a decline in the consumption of these and other country foods.
- Indigenous communities across the basin share concerns about the potential contamination of water and fish from local and upstream industrial development, and many communities have observed changes in the water quality and the health of fish. Scientific data generally do not show

[1] Mackenzie River Basin Transboundary Waters Master Agreement 1997. Between the Government of Canada, the Government of Province of British Columbia, the Government of the Province of Alberta, the Government of the Province of Saskatchewan, the Government of the Northwest Territories and the Government of the Yukon.

impacts on water quality and fish health, except in localized areas downstream of wastewater discharges, the Lower Athabasca oil sands, and agricultural watersheds.

- Increased concentrations of ions (which are mainly dissolved salts) were measured in surface waters across the basin, but these changes did not result in exceedances of guidelines for aquatic life. Increased groundwater contribution related to permafrost thaw has been hypothesized as a driving factor for this trend in the Peel, Liard and Mackenzie Great Bear sub-basins, but reasons for this change in other areas of the basin are currently unknown.

The most common pressures that have impacted aquatic ecosystem health in the MRB are related to climate change, land use, and overfishing. Climate change has affected aquatic ecosystems basin-wide and in various ways. For example, rising air temperatures are leading to changes in ice and snow cover and changes in river flow patterns are impacting the ability of Indigenous communities to use the land and support their traditional way of life. Agriculture and industrial development has resulted in reduced water quality, reduced habitat quality and availability, and reduced fish health and populations in some areas of the MRB. Fishing pressure has been identified as a major contributor to the decline of some fish populations in parts of the basin.

The 2021 SOAER is presented for the first time exclusively on the web and is envisioned as a living document. It is intended to evolve over time, as it is updated with additional signs and signals, Indigenous knowledge from communities, and scientific data and analysis results, as these materials become available. The identified gaps and inconsistencies in knowledge and recommended potential improvements may guide next steps in collaboratively building the SOAER as the reference document on aquatic health in the MRB.

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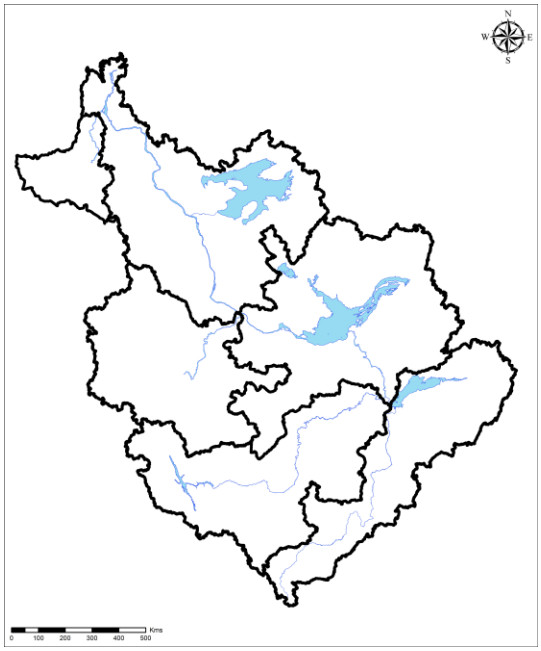
1 INTRODUCTION

The Mackenzie River Basin (MRB) is the largest watershed in Canada and includes parts of five territories and provinces. The Mackenzie River Basin Transboundary Waters Master Agreement[2] directs the Mackenzie River Basin Board (MRBB) to report on the State of the Aquatic Ecosystem every five years. The State of the Aquatic Ecosystem Report (SOAER) brings together the available information within the Mackenzie River Basin to help the MRBB understand and track conditions in the basin. The 2021 SOAER describes changes to aquatic ecosystem health in the Mackenzie River Basin since the first SOAER was released in 2003.

The development and publication of the SOAER serves several other purposes:

- Informs basin residents, decision makers, and Ministers about the ecological integrity of the basin using multiple knowledge systems.
- Identifies gaps and inconsistencies in knowledge and monitoring practices, and makes recommendations, building on previous efforts by the MRBB and its committees.
- Guides future MRBB decisions by communicating current conditions (both in terms of health and threats) as well as changes within the basin.
- Profiles the value of Indigenous knowledge as a credible and integral component in aquatic ecosystem assessment.
- Recognizes that humans are a part of and connected to the aquatic ecosystem and that the basin represents a place of meaning for the residents who inhabit it.
- Provides a template as a living document that will grow and evolve over time.



The 2021 SOAER is presented for the first time as a braided story published exclusively on the web. The vision is to update it overtime, with additional signs and signals, Indigenous knowledge from communities, in-depth analysis, and scientific information, as these materials become available.

[2] Mackenzie River Basin Transboundary Waters Master Agreement 1997. Between the Government of Canada, the Government of Province of British Columbia, the Government of the Province of Alberta, the Government of the Province of Saskatchewan, the Government of the Northwest Territories and the Government of the Yukon.

1.1 THE MACKENZIE RIVER BASIN

The MRB covers one-fifth of Canada's landmass. The rivers of the MRB flow 4,241 kilometres from the Columbia Icefield in Jasper National Park and the deep snowfields of the upper Peace River in northeastern British Columbia, to the mouth on the Beaufort Sea of the Arctic Ocean. The basin is home to three large deltas: the Peace-Athabasca Delta (designated as a Wetland of International Significance), the Slave River Delta, and the Mackenzie River Delta. The basin plays a major role in regulating global ocean circulation and Arctic climatic systems and supports a variety of plants and wildlife.

The MRB is home to Indigenous Peoples who live and have lived in the area for thousands of years, since time immemorial. The many, diverse Indigenous Peoples of this basin include: Inuvialuit, Gwich'in, Sahtu Dene, Métis, Tlicho, Cree, Tr'ondek Hwech'in, Nacho Nyak Dun, Sekani (Tsay Keh Dene), South Slavey, Beaver, Tahltan, Saulteaux, Kaska, Dogrib (Tlicho), North Slavey, Dane-zaa, Woodland Cree, Secwepemc (Shuswap), Salish, Ktunaxa, Nakota/Stony, Denesoline, Akaitcho, Dehcho, Northwest Territory Métis Nation, Denesuline.

The rivers in the basin cross multiple political boundaries and land use activities of upstream jurisdictions may affect the quality and quantity of water that reaches downstream jurisdictions.

The rivers in the basin cross multiple political boundaries and land use activities of upstream jurisdictions may affect the quality and quantity of water that reaches downstream jurisdictions. People use water and discharge wastes for a variety of industrial activities in the basin. The largest natural resource industries are agriculture, fossil energy, forest products, hydroelectricity, and mineral extraction.

1.2 THE MACKENZIE RIVER BASIN TRANSBOUNDARY WATERS MASTER AGREEMENT AND THE MACKENZIE RIVER BASIN BOARD

The Mackenzie River Basin Board (MRBB) was established to implement the *Mackenzie River Basin Transboundary Waters Master Agreement* that was signed by the governments of Canada, British Columbia, Alberta, Saskatchewan, Yukon and the Northwest Territories in 1997. The agreement commits all six governments to work together to manage the water resources of the Mackenzie River Basin, and makes provision for neighboring jurisdictions to negotiate bilateral water management agreements to address water issues at jurisdictional boundaries. The board has 13 members, three representing the federal government and ten representing the provinces and territories. Each of the provinces and territories has a member representing their government and a member representing an Indigenous perspective.

The SOAER Joint Steering Committee (JSC) is made up of two committees that support the work of the MRBB: the SOAER Committee and the Traditional Knowledge and Strengthening Partnerships (TKSP) Committee. The SOAER JSC has Members from all five provincial and territorial governments, the federal government and the MRBB Indigenous member from each jurisdiction. The JSC is chaired by Environment and Climate Change Canada (ECCC) and is supported by the MRBB Secretariat. The JSC and its members report to the MRBB on SOAER project progress and issues regularly, including an update at MRBB formal meetings bi-annually. The JSC met bi-weekly for most of the SOAER development process to discuss key decisions and progress, review deliverables and provide valuable feedback to the SOAER Project consultants.

1.3 THE STATE OF THE AQUATIC ECOSYSTEM REPORT – HISTORY AND PARTNERSHIPS

The MRBB produced its first State of the Aquatic Ecosystem Report in 2003. The 2003 report was a large 200+ page document that focused primarily on climate change and contaminants because of their impact on the aquatic environment within the basin. Signs and signals were used to assess water quality, water quantity, in-stream water uses, and aquatic species and habitat. The report suggested that environmental quality was changing because of climate change but noted that many of the indicators showed no clear trend due either to a lack of information or the presence of mixed signals. The report noted the need for improved monitoring programs, compatible data collection methods and comprehensive evaluation of information. The 2003 report acknowledged the importance and value of Indigenous Knowledge but noted that more resources and effort would be required to make sure it was better represented in future reports.

In contrast, the MRBB 2012 Issues Report is a short document that focused on three key issues in the Mackenzie River Basin: oil sands development, hydroelectric development, and climate change. The document presented an overview of the issues but did not assess indicators or comment on the state of the aquatic ecosystem. As with the 2003 SOAER, the 2012 report noted a paucity of documented Indigenous Knowledge on the issues discussed.

The MRBB took steps to help address the gaps in Indigenous Knowledge identified in both the 2003 SOAER and the 2012 update. In 2012, the Board commissioned a report entitled "*Towards a New Current of Thought: Best Practises for Gathering and Incorporating Traditional Ecological Knowledge into Environmental Monitoring and Assessment*". The Board also began to discuss and seek input on indicators for a future SOAER report and hosted two workshops: Edmonton in 2013 and Dettah in 2017. The Board, specifically the Traditional Knowledge and Strengthening Partnerships Steering Committee members, worked with Dr. Brenda Parlee (University of Alberta) to support the Tracking Change program (2015-2022). Tracking Change is funded through a 6-year SSHRC grant. The program has funded many community led projects on fish and water in the Mackenzie River Basin, produced literature reviews of local and Indigenous Knowledge in the six sub basins of the Mackenzie River basin, hosted knowledge fairs and participated in Global Knowledge Symposiums. The Indigenous members of the Mackenzie River Basin Board support the projects governance, and the results of the project are a significant source of knowledge and learning.

Timeline of Events Leading up to the 2021 SOAER

1.4 BRAIDING KNOWLEDGE

A fundamental recognition in the development of the 2021 SOAER was the need to emphasize the inclusion of Indigenous knowledge. Indigenous knowledge is often overshadowed by scientific information in web-based reports, publications, and other outcomes of state of the environment reporting, despite the fact that Indigenous knowledge offers a holistic understanding of environmental change and its consequences. In the past four or five decades, several methodological approaches have emerged to bring together Indigenous knowledge and scientific knowledge systems to improve understandings of the environment, including various approaches for "braiding" knowledge systems.

A "braided approach" was chosen for the 2021 SOAER to bring together Indigenous knowledge and scientific information to inform the assessment. The SOAER JSC felt it was important to select a methodological approach that brings together Indigenous knowledge and scientific knowledge without comparison or integration of one knowledge system into the other. Knowledge from both systems is considered valuable and used to inform a holistic understanding of current conditions and environmental change. Although there are limitations for bringing together knowledge systems[3,4] braiding and other approaches present an opportunity to shift how, and by whom, environmental changes are reported.

Channels weaving into the Mackenzie River Delta.

Credit: With permission, Chris Burn, Carleton University.

[3] Nadasdy, P. 2003. Hunters and Bureaucrats: Power, Knowledge, and Aboriginal-State Relations in the Southwest Yukon. University of British Columbia Press, Vancouver.
[4] Nadasdy, P. 2005. The Anti-Politics of TEK: The Institutionalization of Co-management Discourse and Practice. Anthropologica 47(2): 215-232

The concept of "braiding" or "weaving" knowledge systems has gained traction in many jurisdictions in recent decades, including areas within the Mackenzie River Basin.[5,6] Broadly, a "braided approach" involves bringing together Indigenous knowledge and scientific information as multiple lines of evidence, like the strands of a braid. When the different strands are brought together, opportunities are created to develop deeper understandings of the observed events and their consequences, beyond what could be achieved through one knowledge system alone. The "braided approach" used to guide the 2021 SOAER consists of a three-part braid, where the strands represent Indigenous knowledge, science, and the co-created story about the Mackenzie River Basin as told through the two knowledge systems. Although this approach is not without its limitations, it served to elevate Indigenous knowledge alongside science for the development of the SOAER.

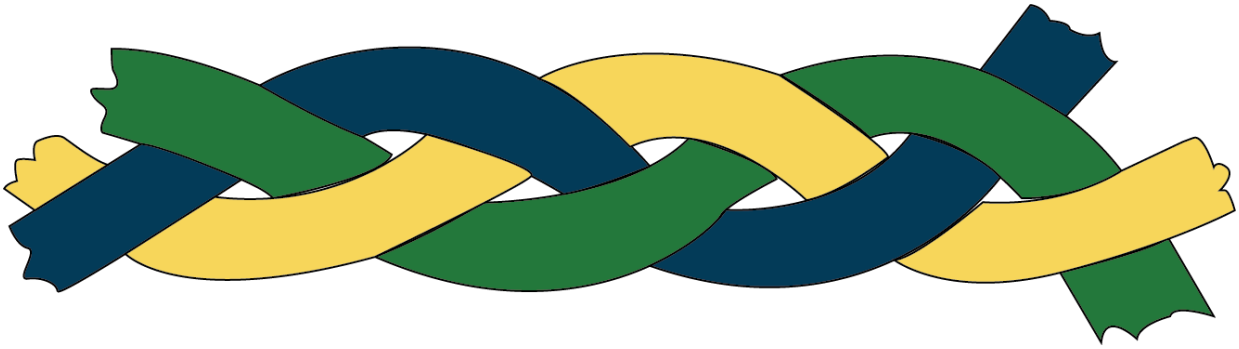


Image of a three-stranded braid representing Indigenous knowledge, science, and the story they tell together.

Credit: Reproduced with permission from U.S. National Parks Service.

[5] Hopkins, D., Joly, T. Sykes, H., Waniandy, A., Grant, J., Gallagher, L., … & Bailey, M. 2019. "Learning Together": Braiding Indigenous and Western knowledge systems to understand freshwater mussel health in the Lower Athabasca region of Alberta, Canada. Journal of Ethnobiology 39(2): 315–336.
[6] Tengo, M., Hill, R., Malmer, P., Raymond, C., Spierenburg, M., Danielsen, F., … & Folke, C. 2017. Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability. Current Opinion in Environmental Sustainability 26: 17–25.

2 METHODOLOGY

The 2021 SOAER is a summary of the information that was deemed by the project team to best contribute to telling the braided story of aquatic ecosystem health in the Mackenzie River Basin. It was intentionally built to be suitable for web presentation and can be updated and expanded in the future with new and more detailed information.

A conceptual framework was used to direct assessment efforts among the major components of aquatic ecosystem health and the major pressures facing local and Indigenous communities. This framework includes several signs and signals organized by the four indicators: (1) water quantity, (2) water quality, (3) habitat and species, (4) and health and wellbeing. This framework was developed prior to starting the work on the 2021 SOAER and was the result of extensive research and consultation efforts by the MRBB.

The methodology used to collect, analyze, and present data in the aquatic ecosystem assessment was developed and implemented over five phases of the project. Details on each individual phase of the project are provided in the methodology report that is available upon request from the MRBB. The key elements of the approaches to analyzing data, assessing information with respect to the degree of change and to braiding information from science and Indigenous knowledge are summarized below.

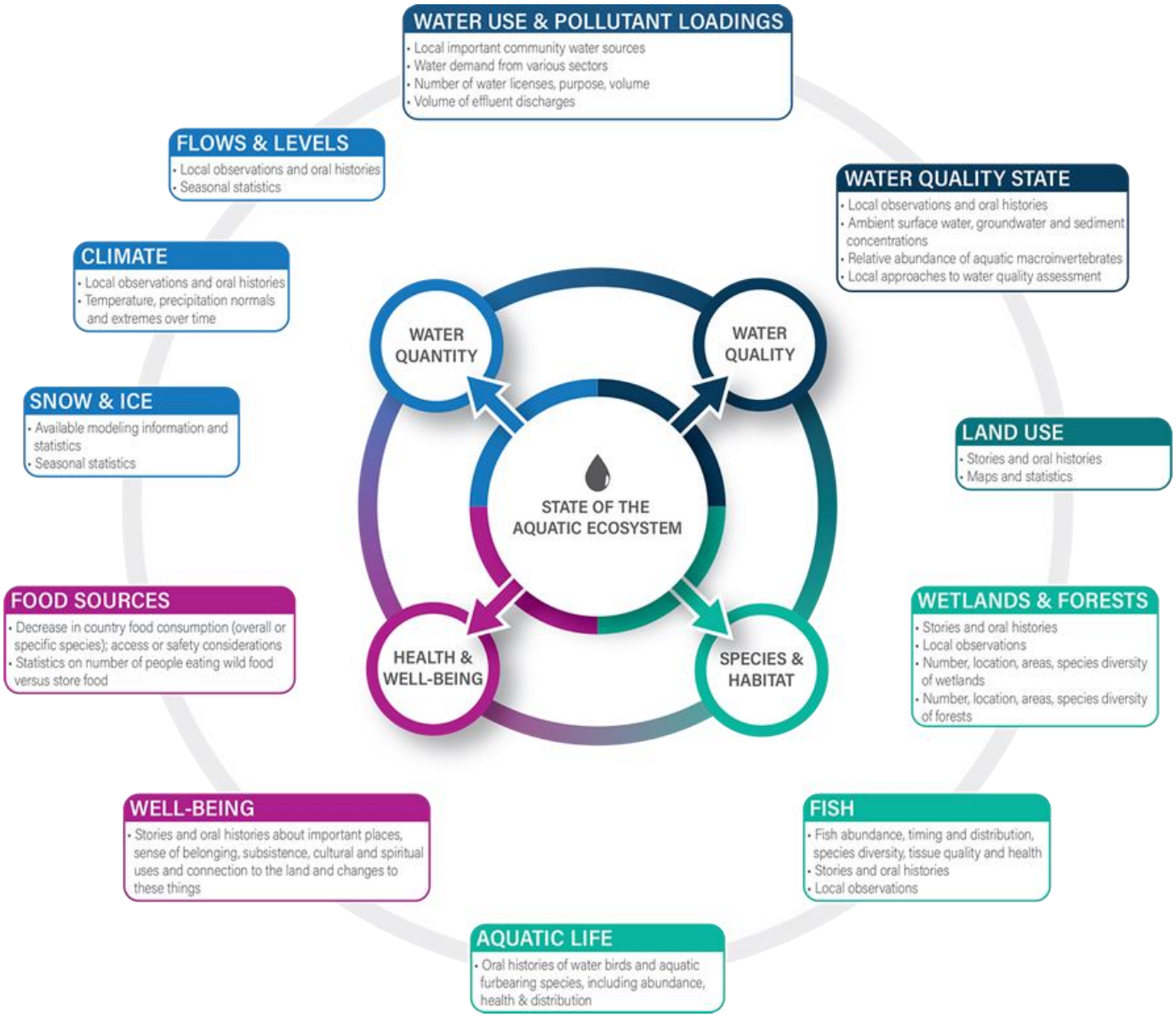
2.1 DATA ANALYSIS AND INTERPRETATION

Materials for Indigenous knowledge and scientific information relevant to the indicators of aquatic ecosystem health were reviewed, with a focus on materials published since 2003, when the first SOAER was released. For Indigenous knowledge information, identification of key patterns and trends was primarily determined based on whether more than one Indigenous knowledge holder or community shared the observation. Key patterns and trends presented in scientific publications were chosen based on their relevance to the signs and signals in the conceptual framework, their significance for ecosystem health and the degree to which the results were deemed to be representative for the respective sub-basin.

The project team analyzed the observations informed by local and Indigenous knowledge and scientific information to determine Health Index ratings.

Scientific data were analyzed for a few selected signs and signals that represented key questions and concerns for Indigenous communities and where data were available basin-wide and readily accessible. These were stream flow and lake level data from Water Survey of Canada, water quality data from Environment and Climate Change Canada, and land cover (Government of Canada 2020, source for sub-basin statistics on website). Results of basin-wide data analyses on two additional signs and signals (climate, snow mass) were available from external contributors.

The selection of some signs and signals for analysis followed a structured process of prioritization. The main prioritization criterion was the basin-wide availability, accessibility, and comprehensiveness of information on signs and signals from both Indigenous knowledge and science. As a result, some signs and signals were selected for analysis, as discussed above, others received less focused assessment (e.g., aquatic macroinvertebrates), or were omitted for this phase, e.g. groundwater quality and quantity.



Conceptual Framework for the SOAER

2.2 ASSESSMENT APPROACH

Although the SOAER does not make explicit comparisons to previous science or publications, the Indigenous knowledge used to inform the assessment is focused on observations of environmental change over time. Much of the scientific data in the assessment, such as water flow and levels and climate data, can be interpreted to show changes as well. The SOAER JSC therefore decided that this SOAER would primarily illustrate changes in ecosystem health signs and signals where enough information or data was identified, while also providing a snapshot of the current state of the Mackenzie River Basin.

For the 2021 SOAER, new or raw information or data was not collected. As such, an extensive literature review was undertaken for the signs and signals selected in all of the sub-basins and a few available, basin-wide datasets were analyzed for changes over time. The literature review was completed for both Indigenous knowledge and science, and although by no means exhaustive, it has highlighted where there could be information gaps of importance that could help to inform future research and areas of focus.

The project team analyzed the observations informed by local and Indigenous knowledge and scientific information to determine Health Index ratings. The ratings were the result of qualitative assessments of published information and available data, as listed below.

1) **Minimal or No Change:** near 'normal' or natural conditions with minimal impacts on ecosystem health and people; represented by the following situations:
   a. no change in the published observations, data or level of concern among Indigenous communities or local residents for a given indicator;
   b. minor degree of change, such as non-significant changes in scientific data ($p>0.05$); and
   c. good or 'intact' conditions in aquatic ecosystems, indicated by the absence of or minimal impacts from land development (e.g. minimal or no forestry, mining, or oil and gas activity).

2) **Moderate Change:** altered conditions from a 'normal' or natural state, resulting in some level of change to ecosystem health and people, including the following situations:
   a. heightened concern or published observations of some level of change by Indigenous communities or local residents for a given indicator. The changes are reported by more than two Indigenous communities or in more than two locations within a sub-basin;
   b. any significant trends in scientific data analysis, but only at a few locations; and
   c. significant trends in scientific data analysis, but not with any anticipated impact on the health of aquatic life.

3) **Significant Change:** significantly altered conditions from a 'normal' or natural state, resulting in significant changes to ecosystem health and people:
   a. widespread changes in signs and signals across the sub-basin, as indicated by changes reported by more than three Indigenous communities or in more than three locations within a sub-basin, or as indicated by scientific data showing changes in many locations;
   b. significant trends in scientific data with clear impact on aquatic life, such as reduced or extirpated fish populations; and
   c. high degree of impacts from land development.

2.3 BRAIDING INDIGENOUS KNOWLEDGE AND SCIENTIFIC OBSERVATIONS

Written summaries of the aquatic ecosystem assessment were prepared collaboratively by the project team for each of the six sub-basins. A "braided approach" to bring together Indigenous knowledge and scientific information across knowledge systems was used, consistent with the following elements described by Tengo et al (2017):

- Local and/or Indigenous knowledge and science data were assessed to identify points of divergence and convergence. Findings through one knowledge system were not used to validate findings from the other. In cases of divergence, understandings from both knowledge systems were reflected;
- One way of knowing was not privileged over the other; and
- Data was described using accessible terminology and language to promote readability.

Decision making during the braiding process was based on consensus within the SOAER JSC. Through consensus decision making, issues were identified, discussed, and debated leading to an agreed upon path forward. In addition and where appropriate, decisions were made through professional judgement of researchers.

A Health Index Rating (e.g. Minimal or No Change, Moderate Change, Significant Change) was determined across knowledge systems for the individual signs and signals and indicator categories used in the assessment. In cases where the individual ratings differed across the knowledge systems, both ratings were preserved to reflect the divergence (e.g., "Moderate to Significant").

The SOAER website contains the findings of the assessment, presented by sub-basin, reporting on the findings for each indicator, where scientific evidence and Indigenous knowledge are braided.

The Delta Braid.

Photo taken by Mark Hughes Photography 2021. Braid made by Molly Goose of Tuktoyaktuk. Molly has been sewing Delta Braids for around 40 years.

The Delta Braid originates from the Beaufort Delta Region and is a rare form of art still practiced today. This beautiful form of appliqué is ribbons of geometric patterns made from layers of multi-coloured bias tape and seam bindings. Used for generations to distinctly decorate parkas and dresses, artists originally used fur or skins to create the intricate patterns. When fur traders arrived in the region, they brought colourful European fabrics and threads, enabling artists to embellish their patterns with bright colours. Each Delta Braid is unique and tells a story about the history of its artist and how they choose to create this cultural piece of art. (NWT Arts)
https://www.nwtarts.com/region/inuvik

3 STATE OF THE AQUATIC ECOSYSTEM ASSESSMENT

3.1 KEY FINDINGS

Some key changes in the indicators of aquatic ecosystem health have been observed by Indigenous and local communities and detected in data from across the basin. These basin-wide patterns are summarized below. Most of these patterns are evident in both Indigenous knowledge accounts and scientific analyses results, while some are unique to each knowledge system.

Key changes include:

- Rising air temperatures
- More variable surface water levels
- Changing populations of wetland-dependent wildlife
- Concerns regarding contamination of water and fish
- Increased concentrations of ions

Rising air temperatures. Scientific data indicate that air temperatures have increased over the past few decades, especially in winter, which has also been observed by some Indigenous communities in the northern sub-basins. Rising temperatures have led to increased winter stream flows across the basin, the appearance of new fish species in northern rivers, and reduced ice and snow cover in many areas. These changes have impacted the ability for Indigenous communities to access traditional land use areas in winter.

Related Signs and signals:

- *Temperature, precipitation normals and extremes over time; and*
- *Local observations and oral histories of temperature, precipitation normal and extremes over time.*

More variable surface water levels. Indigenous knowledge-holders across the basin have observed that water levels in many rivers, lakes and deltas are more variable than in the past. Fluctuating high and low water levels pose challenges in reaching traditional harvesting areas by boat and are often associated with increased observations of sand bars and navigable hazards. Scientific evidence similarly indicates that climate change, in combination with river regulation, has resulted in various degrees of reduced water levels, primarily in the three major deltas of the basin, the Peace-Athabasca, Slave and Mackenzie River Deltas.

Related Signs and signals:

- *Local observations and oral histories of changing flow, water levels in rivers, and lakes over time; and*
- *Seasonal statistics including changes in flow, water levels in rivers, and lakes over time.*

Changing populations of wetland-dependent wildlife. Reduced populations of wildlife such as muskrat (*Ondatra zibethicus*) and fish have been observed by Indigenous communities in most sub-basins, leading to a decline in the consumption of these and other country foods. A basin-wide trend in declining populations, especially in popular sport fish in accessible surface waters, has been documented in fish stock information as well.

Related Signs and signals:

- *Oral histories of aquatic furbearing species, including abundance, health and distribution;*
- *Local observations about changes in timing of local fishing activity and yield;*
- *Oral histories and local observations of fish abundance, timing and distribution, species diversity and fish health condition; and*

- *Fish (including salmon, suckers (Catastomus spp.), pickerel (Sander vitreus), burbot (Lota lota)) abundance, timing and distribution, species diversity and fish health condition.*

Concerns regarding contamination of water and fish. Indigenous communities across the basin share concerns about the potential contamination of water and fish from local and upstream industrial development, and many communities have observed a decline in water quality and the health of fish. Scientific data generally do not show widespread impacts on water quality or on fish health, as indicated by the absence of trends from 2000 to 2018 in water quality parameters that have guidelines, and only locally detected fish tissue contamination. Exceptions to these general trends were found in specific areas: downstream of wastewater discharges and near mining sites in the Athabasca River and its tributaries in the Lower Athabasca Oil Sands Region, and in watersheds developed for agriculture.
Related Signs and signals:

- *Local observations and oral histories of good water, poor water, seasonal differences, land-based consumption practices;*
- *Oral histories and local observations of fish abundance, timing and distribution, species diversity and fish health condition;*
- *Ambient surface and ground water concentrations; and*
- *Fish (including salmon, suckers, pickerel, burbot) abundance, timing and distribution, species diversity and fish health condition.*

Increased concentrations of ions. An increase in ions (which are mainly dissolved salts) were measured in surface waters across the basin, but these changes did not result in exceedances of guidelines for aquatic life. While increased groundwater contribution to subarctic watersheds related to permafrost thaw has been hypothesized as a driving factor in the Peel, Liard and Mackenzie Great Bear sub-basins, the reasons for this change in other areas of the basin are currently unknown.
Related Signs and signals:

- *Ambient surface water concentrations.*

3.2 IMPORTANT CONNECTIONS

Everything is connected. The signs and signals assessed in the SOAER do not stand in isolation. Rather, together they represent an overall status of aquatic ecosystem health. This means that signs and signals are connected – the change in one will affect others. For example, some signs and signals are direct indicators of aquatic ecosystem health, such as water levels, water quality, and fish populations. These signs and signals are often correlated with signs and signals related to human activities that cause impacts to the aquatic environment, such as water use, effluent discharges, land use. The most important connections between signs and signals identified in the SOAER are summarized below.

The signs and signals assessed in the SOAER do not stand in isolation. Rather, together they represent an overall status of aquatic ecosystem health.

Climate change is the most common cause for changes in aquatic ecosystem signs and signals. It is a widespread stressor on aquatic ecosystem health across the basin. Increased air temperatures and, to a lesser degree, changes in precipitation patterns, have changed ice and flow patterns in rivers, changed snow-cover in many areas, reduced water levels in deltas, and impacted water quality in northern parts of

the basin through permafrost slumps. The quality of habitat, such as wetlands in deltas and distribution of fish species, has been altered. Climate change has also affected access to traditional land use areas, in particular in winter in the northern part of the basin, and thus has impacted the health and wellbeing of Indigenous communities.

Land use has impacted aquatic ecosystem health in the basin in many ways, in particular in the Peace and Athabasca sub-basins. The human footprint from agriculture and industrial development has resulted in reduced water quality, reduced habitat quality and availability, and reduced populations of fish species, some to extirpation. These impacts have resulted in reduced confidence and access to traditional land use areas and country foods in these sub-basins.

Fishing pressure has likely been a factor in many of the historical fish population declines across the basin, including lake and river populations of sport fish in the Peace and Athabasca sub-basins and in Great Bear and Great Slave Lakes.

3.3 RECENT AND EMERGING PATTERNS

The most significant emerging trend since the publication of the 2003 SOAER is the more widespread and stronger evidence of climate change impacts. Examples are the basin-wide increase in winter flows, expanding lakes in the Great Slave sub-basin, the appearance of new fish species in subarctic regions, and the significant consequences of permafrost thaw on the landscape through erosion and impacts on water quantity and quality in the northern sub-basins. These changes may warrant more research and monitoring to better understand their impacts on the integrity of the aquatic ecosystem and populations of native species. Observations by Indigenous and local communities can direct scientific research and monitoring; for example, the observed changes in taste and odour of water and fish may be early warning signs of climate impacts on water quality and fish health.

The most significant emerging trend since the publication of the 2003 SOAER is the more widespread and stronger evidence of climate change impacts.

Some recent trends in aquatic ecosystem signs and signals show a recovery owing to management intervention. For example, phosphorus concentrations in rivers downstream of wastewater discharges have stabilized or declined due to improved wastewater treatment technology. Some fish populations are recovering in response to fishery management strategies.

This report shows that much of the information gathered from Indigenous knowledge and scientific sources is complementary and paints a clear picture of the status of aquatic ecosystem health and the key pressures upon it. Informed by Indigenous and scientific understanding, some parts of the assessment result in different pictures of the status of aquatic ecosystem health and pressures, for example, the degree of concern over contamination of water and country foods. This may indicate an inherent difference in perspective and the way the knowledge is derived in each knowledge system. It may also indicate a degree of uncertainty over the multitude of potential ways land development and water and air emissions can influence downstream water and fish quality and their consumers. Much work using both Indigenous knowledge and science remains to be done to better characterize, track, and communicate local, regional and basin-wide human health risks associated with the consumption of water and country foods from the MRB, using both Indigenous knowledge and science.

3.4 SUB-BASIN HIGHLIGHTS

The web-based SOAER is presented by sub-basin and indicators. The highlights of each sub-basin assessment are summarized below. These high-level conclusions are based on a balanced assessment of Indigenous knowledge and scientific information collected for each sub-basin and indicator.

3.4.1 Mackenzie Great Bear

The Mackenzie Great Bear sub-basin is sparsely populated and is the largest of the six sub-basins in the Mackenzie River Basin. The sub-basin overlaps with the traditional territories of at least six Indigenous groups. The Mackenzie River Delta and the surrounding region spans the lands of the Inuvialuit and Gwich'in and the settlements of Aklavik, Inuvik, Tsiighetchic, and Fort McPherson. The Sahtu Dene and Métis lands are around Great Bear Lake (or Sahtú, in the Dene language), with settlements at Fort Good Hope, Colville Lake, Norman Wells, Tulít'a and Déļnę. To the south of Great Bear Lake are the lands of the Dehcho and Tlicho and the communities of Gamèti, Whati, Wrigley, and Fort Simpson.

Moderate changes to aquatic ecosystem health have occurred in the Mackenzie Great Bear sub-basin, according to most signs and signals considered in the assessment. Climate change was identified as a key driver of aquatic ecosystem change in the sub-basin, mainly through warmer winters that resulted in higher winter and spring stream flows.

Water Quantity:

- Lower water levels in many waterbodies observed by Indigenous communities,
- Seasonal changes in monitored flows (increased winter and spring flows),
- Warmer air temperatures, especially in winter.

Water Quality:

- Higher observed levels of turbidity and sedimentation in the Mackenzie River,
- Increasing trends in ions and potential increasing trends in some dissolved metals in scientific monitoring data.

Habitat and Species:

- Less healthy fish and declines in fish populations reported by traditional harvesters,
- New fish species are present and more commonly sighted (such as chum salmon; *Oncorhynchus keta*) due to range expansion.

Health and Wellbeing:

- Changes in aquatic ecosystems have disrupted travel routes and access to harvesting areas and raised concerns about the contamination of water and country foods.

3.4.2 Peel

The Peel sub-basin is the smallest and northernmost sub-basin in the Mackenzie River Basin. The sub-basin is primarily accessed on a seasonal basis for subsistence harvesting, tourism, and outdoor recreation. The traditional territories of at least seven Indigenous groups overlap with the sub-basin. The Mackenzie River Delta and the surrounding region spans the lands of the Inuvialuit and Tetlit Gwich'in, with communities based in Fort McPherson and outside the sub-basin at Aklavik, Inuvik, and Tsiighetchic. The

Vuntut Gwitchin lands are located in the region surrounding Old Crow, while the lands of the Tr'ondek Hwech'in and Nacho Nyak Dun are primarily located further south, near Dawson City and Mayo, respectively.

Moderate changes to aquatic ecosystem health have occurred in the Peel sub-basin, according to most signs and signals considered in the assessment. Climate change was identified as a key driver of aquatic ecosystem change in the sub-basin, resulting in changes to water quality and quantity related to permafrost thaw and slumping, and affecting access to traditional land use areas.

Water Quantity:

- Warmer air temperatures have caused permafrost thaw and slumping,
- Increased groundwater discharge has led to higher annual and winter stream flows, while traditional land users have observed drying in some areas.

Water Quality:

- Increased solute concentrations and sediments in surface waters,
- Warmer water temperatures observed by Indigenous communities.

Habitat and Species:

- Overall fish are plentiful, but some fish populations and metrics of fish health have declined as reported by traditional harvesters,
- In some areas, a rise in otter (*Lutra canadensis*) and beaver (*Castor canadensis*) populations alongside a significant decline in muskrat populations has been documented.

Health and Wellbeing:

- Changes in aquatic ecosystems have resulted in reduced confidence in country foods and reduced access to traditional land use areas.

3.4.3 Liard

The Liard sub-basin is a sparsely populated region with small settlements located throughout the watershed. The sub-basin overlaps with the traditional territories of at least eight Indigenous groups. The lower Liard spans the lands of the Sekani (Tsay Keh Dene), South Slavey, Beaver, Tahltan and Saulteaux, with settlements located at Fort Ware, Prophet River, Fort Nelson, and Liard River. The lands of the Kaska, Dogrib (Tlicho) and North Slavey are located in the upper Liard, which includes the communities of Lower Post, Watson Lake, and Fort Liard.

Changes to aquatic ecosystem health in the Liard sub-basin were minor and localized, as there is little land disturbance in the sub-basin. Moderate localized changes were observed in water quantity, likely related to climate change, and in community health and wellbeing, as a result of industrial development.

Water Quantity:

- River flows have increased, in particular in winter and during spring freshet,
- Air temperatures and precipitation have increased, with greatest warming occurring in winter.

Water Quality:

- Instances of poor water quality and fish contamination have been observed locally near Watson Lake and Ross River by some Indigenous communities,
- There is scientific evidence of local water quality impacts of oil and gas operations in the Horn River subwatershed in BC, however further work is needed for a complete assessment,
- Water quality data in the Liard River did not show signs of impact but there was an increasing trend in ion concentrations.

Habitat and Species:

- Riparian areas in the BC portion of the sub-basin are largely intact.
- No readily available information was found on fish populations or wetlands.

Health and Wellbeing:

- Some Indigenous communities consume less country foods and have less confidence in the quality of country foods,
- Access to fishing and trapping areas is disrupted by lower populations of harvestable species, higher costs of transportation, increased competition for resources, and other factors.

3.4.4 Great Slave

The Great Slave sub-basin is sparsely populated with settlements primarily situated along the shores of Great Slave Lake. Yellowknife, the largest city and capital of the Northwest Territories, is situated on the north shore of the lake near the Yellowknife River. The sub-basin overlaps with the traditional territories of at least five Indigenous groups. The lands of the Akaitcho and Tlicho are north of Great Slave Lake, with settlements located at Gamèti, Wekweètì, Whatì, and Behchoko. The Dehcho region is located west of Great Slave Lake and spans the territories of Dehcho First Nations, with settlements located at Wrigley, Fort Simpson, Jean Marie River, Kakisa, Sambaa K'e, Hay River, and Fort Providence. To the south are the lands of the Akaitcho, Northwest Territory Métis Nation and Denesuline, with communities located at Fort Resolution, Fort Smith and Lutsel K'e.

Moderate changes to aquatic ecosystem health have occurred in the Great Slave sub-basin, according to most signs and signals considered in the assessment. Observed changes were mainly related to climate change, upstream regulation of river flows, contamination from mining activities and historical overharvest of fish stocks.

Water Quantity:

- Lower water levels in the Slave River Delta and rivers in the southern portion of the sub-basin,
- Significant expansion of lake surface areas and associated increases in river flows west of Great Slave Lake, related to climate change,
- Increases in winter air temperatures and variable precipitation

Water Quality:

- Increases in sediment and contaminants in the water, and warmer surface water temperatures have been reported by Indigenous communities, but have not been detected in scientific data.

Habitat and Species:

- Declines in fish health condition reported by Indigenous communities, historical decline in fish populations and reduced commercial fishery participation have all led to reduced annual fish production,
- Measured contaminant levels in fish are safe for consumption, except in specific water bodies contaminated by active and abandoned mines.

Health and Wellbeing:

- Less consumption of fish, muskrat and other country foods, due to reduced access, concerns for contamination, and some reduced fish stocks,
- Access to preferred fishing sites and harvesting areas is reduced due to lower water levels such as in the Mackenzie River, Slave River and Slave River Delta.

3.4.5 Peace

The Peace sub-basin is a moderately populated region with settlements primarily located along the Peace River and major tributaries. The sub-basin overlaps with the traditional territories of at least four Indigenous groups. The upper Peace and the region surrounding Williston Lake spans the lands of the Dane-zaa and Sekani (Tsay Keh Dene), with settlements located at Tsay Keh Dene, Hudson's Hope, Fort St. John, Doig River, and Taylor. The lands of the Woodland Cree and Métis are located in the middle and lower Peace and Peace-Athabasca Delta, which includes the communities of Grande Prairie, Fort Vermillion, Peace Point, and Fort Chipewyan.

Moderate to significant changes to water levels, water quality and fish populations, have occurred in the Peace sub-basin, resulting in reduced community access to harvesting areas, contamination of water and fish and thus reduced consumption of country foods. These changes are related to river regulation and the widespread and regionally high-density human footprint, in particular due to agriculture, forestry, and oil and gas development.

Water Quantity:

- More variations and generally lower water levels in rivers, streams and lakes have been observed by Indigenous communities,
- River regulation and climate change have modified river flow patterns across the basin and caused a reduction in ice-jams in the lower Peace, reducing flooding in Peace Athabasca Delta.

Water Quality:

- Surface water quality in several waterbodies is impacted by agricultural land use and point source effluent discharges, despite treatment improvements.

Species and Habitat:

- Some fish populations have been severely impacted across large areas of the basin,
- Riparian health and wetlands have been severely altered in the agricultural areas of the upper Peace and Smoky-Wapiti watersheds.

Health and Wellbeing:

- Access to harvesting areas is reduced due to low water levels,

- Communities consume less country foods due to declining fish and muskrat populations and concerns about contamination.

3.4.6 Athabasca

The Athabasca sub-basin is the southernmost sub-basin in the Mackenzie River Basin with settlements primarily located along the Athabasca River. The sub-basin overlaps with the traditional territories of at least nine Indigenous groups. The lands of the Dane-zaa, Sekani (Tsay Keh Dene), Secwepemc (Shuswap), Salish, and Ktunaxa span the upper Athabasca, with major settlements located at Jasper and Hinton. The lands of the Nakota/Stony and Woodland Cree are located further east in the middle Athabasca, with settlements at Slave Lake and Swan Hills. The lower Athabasca and Peace-Athabasca Delta spans the territories of the Denesoline and the Métis and includes the communities of Fort McMurray, Fort McKay, Fort Chipewyan, Fort Fitzgerald, Fort Smith, Fond du Lac and Black Lake.

Moderate to significant changes have been observed in the Athabasca sub-basin in most aquatic ecosystem signs and signals. This was due to widespread and regionally high-density human footprint, with agriculture impacting mostly the middle reach, oil and gas development in the lower Athabasca and forestry in the entire watershed, except in the protected areas of the headwaters.

Water Quantity:

- Reduced snow cover and warmer winter temperatures,
- Reduced flows in Athabasca River, more sandbars and difficult navigation, and concerns about water withdrawals for industrial use,
- Reduced water levels in the lower Athabasca River and Peace Athabasca Delta,
- Snow contamination near oil sands upgrading facilities in the Lower Athabasca Region.

Water Quality:

- Significant human footprint due to forestry in the entire sub-basin, agriculture in the Pembina watershed and surface bitumen mining footprints in the lower Athabasca,
- Cumulative point source impacts from pulp and paper mills have reduced dissolved oxygen and caused nutrient enrichment downstream of each source,
- Oil sands development has resulted in changes to water quality in the Lower Athabasca Region; however, these are more prominent in the tributaries than in the mainstem.

Species and Habitat:

- Significant reductions in fish populations, such as bull trout (*Salvelinus confluentus*) and Athabasca rainbow trout (*Oncorhynchus mykiss*),
- Significant reductions in muskrat populations in the Peace-Athabasca Delta,
- Fish contamination in the middle and lower Athabasca River.

Health and Wellbeing:

- Reduced access to traditional harvesting areas, particularly in the lower Athabasca River,
- Reduced fish consumption due to contamination and reduced muskrat consumption due to declining populations in the Peace-Athabasca Delta.

4 INFORMATION GAPS AND RECOMMENDATIONS

Information gaps for the signs and signals assessed in the 2021 SOAER (based on the methodology described in the previous section), have been identified. These data gaps, and recommendations to fill them, are presented in the table below. The informational gaps exist primarily because, 1) the information does not exist or was not available within the public domain or 2) the data was available but was not summarized or analyzed for the 2021 SOAER. Filling these information gaps will likely require the involvement of Indigenous communities, and provincial, territorial and federal government agencies, either through agency staff, grant programs or collaborative initiatives. Academia and other research institutions may help answer research-type questions.

The 2021 SOAER is informed by Indigenous knowledge and information previously collected and publicly reported. There is a clear need to meaningfully engage and work with Indigenous communities in all parts of the basin to better understand Indigenous knowledge, observations, and concerns regarding the basin's aquatic ecosystems. At minimum, opportunities should be provided to meet with Indigenous communities to determine their research priorities and protocols for documenting Indigenous knowledge, and communities should be provided with support and resources to document their knowledge through community-based monitoring programs, on-the-land programs, and other initiatives. Outcomes of an engagement process may help to address the information gaps identified below and contribute to, or supplement, the information presented in the 2021 SOAER.

Information Gaps and Recommendations

Information Gap	Sub-basins	Recommendation
Indigenous knowledge related to changes in climate, snow and ice cover, and wetlands	All	Meaningfully engage Indigenous communities to understand and document observations and concerns related to changes in climate, snow and ice cover, and wetlands
Scientific data regarding degree of historical changes in wetland cover	All	Conduct research to develop and validate methods to assess changes in wetland cover over time
Scientific assessments of the status of riparian forests	All, except Peace Basin	Develop and validate remote sensing methods to assess riparian areas
Statistics regarding the number of people who consume wild foods versus store-bought foods	All	Analyze existing data for NWT communities, Conduct community surveys, verify with Stats Canada if raw data are available by community
Regional scientific analyses of benthic invertebrate data	All	Develop reference conditions models based on CABIN data, as done in BC; analyze long-term datasets for representative stations across the sub-basins, if available.

Information Gap	Sub-basins	Recommendation
Indigenous knowledge related to ice quality and thickness and scientific knowledge regarding ice thickness	All	Meaningfully engage Indigenous communities to understand and document observations and concerns related to changes in ice quality and thickness. Analyze existing ice thickness records in key locations (e.g. Inuvik, Yellowknife, Fort Chipewyan) and link with community-based ice monitoring programs, where possible.
Indigenous and scientific knowledge regarding ice breakups and –freeze up dates for lakes and rivers	All	Meaningfully engage Indigenous communities to understand and document observations and concerns related to changes in the timing of ice breakup and freeze up. Analyse existing information in Water Survey of Canada records and link with community-based ice monitoring programs, where possible.
Summaries of effluent volume	Peel, Mackenzie Great Bear, Liard, Great Slave	Summarize effluent volumes and pollutant loads from available data bases
Summaries of water allocations and water use	Peel, Mackenzie Great Bear, Liard, Great Slave	Summarize data from available databases
Ground-validated wetland mapping	Peel, Mackenzie Great Bear, Liard, Great Slave	Develop and validate the available remote sensing methods
Water Quality	Peel, upper watershed	Add water quality sampling in upper Peel watershed
Indigenous and scientific knowledge regarding changes in fish stocks	Peel, Mackenzie Great Bear, Liard	Meaningfully engage Indigenous communities to understand and document observations and concerns related to changes in fish stocks. Analyze available scientific data for fish stocks and link with community-based fish monitoring programs, where possible.
Driving factors for increased ion concentrations in surface waters basin-wide	All	Conduct research into trends in ion concentrations and driving factors.

5 NEXT STEPS

The goal of the 2021 SOAER is to present the braided story of aquatic ecosystem health in the Mackenzie River Basin and to provide a template for an evolving SOAER over time. This report is therefore neither complete nor comprehensive. However, it provides a platform for the MRBB and its partners to add more information in the future. Opportunities to contribute could entail, for example, Indigenous knowledge from more communities and about more signs and signals, results of in-depth analyses of available scientific data, updates to presented information using more recent data, summaries of available information in various databases, and place-based insights and assessments on a local scale.

The goal of the 2021 SOAER is to present the braided story of aquatic ecosystem health in the Mackenzie River Basin and to provide a template for an evolving SOAER over time.

In addition to presenting existing data and information, the SOAER has identified knowledge gaps that can guide the collection of additional information from Indigenous knowledge and science sources in the basin. Filling these gaps will provide a greater understanding in the ecosystem assessments across signs and signals and sub-basins. It may even clarify more connections between signs and signals and basin-wide patterns in aquatic ecosystem health. Finally, it is hoped that the approach of braiding knowledge in the 2021 SOAER will encourage Indigenous knowledge holders and scientists to increase collaboration in the pursuit of a holistic understanding of the basin's ecosystems.