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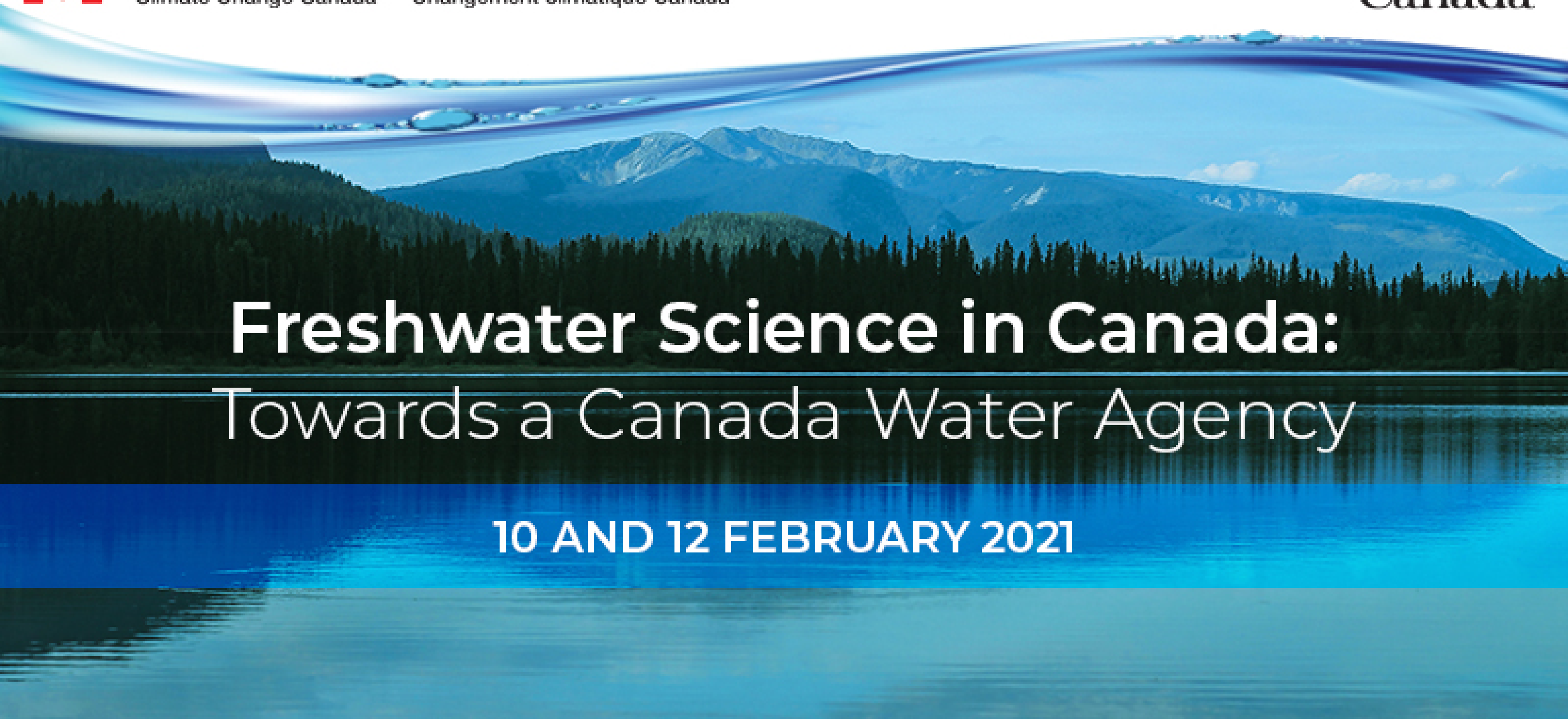

Workshop Background Material

Last Updated: January 27, 2021

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1. Purpose

The Government of Canada (GoC) Discussion Paper "Toward the Creation of a Canada Water Agency" presents key issues for consideration in the GoC's approach to creating a Canada Water Agency (CWA). Freshwater Science was identified as one of the topics in that paper, and it is an important element in the establishment of an Agency.

In the discussion paper's chapter on Freshwater Science, key opportunities put forward to support Freshwater Science include:

1. **Developing a national freshwater science agenda**
2. **Meeting regional water science needs**
3. **Co-development opportunities with Indigenous peoples**
4. **Scientific information sharing and knowledge mobilization**

The purpose of this workshop is to gather feedback from the scientific community on the **first two opportunities** listed above. Opportunities 3 and 4 are crucial and necessitate separate, more substantive discussions to ensure they are given sufficient focus and attention. Planning for these discussions will follow this initial workshop.

2. Workshop Objectives

Day One: Developing a National Freshwater Science Agenda

A national freshwater science agenda would galvanize efforts around key research priorities, improve science integration across a range of science experts and knowledge providers, and ensure the science is responsive to policy and program needs. The agenda could be underpinned by the following three pillars:

- Build scientific research needs around pressing national freshwater challenges
- Reflect regional freshwater management challenges
- Scientific knowledge mobilization to ensure research efforts align with user needs

Day One of this workshop will focus on how the Canada Water Agency could use a national freshwater science agenda to advance its mandate and what that agenda should include to address the needs of Canadians.

Anticipated Questions for Workshop Discussion:

1. **Is there a need for a national freshwater science agenda?**
2. **If so, could such an agenda revolve around the three pillars described above? Do these pillars resonate from your perspective? What is missing?**
3. What needs to be done in the short term (over next year) and medium term (2 – 3 years) to build/develop this agenda?
4. How can a Canada Water Agency move this agenda forward?

Day Two: Meeting Regional Water Science Needs

Canada's vast landscape and the varied challenges experienced concerning water necessitate a discussion on how a Canada Water Agency will meet regional water-science needs. Day Two of this workshop is intended to assess the need for freshwater science and knowledge to respond to unique regional water challenges in Canada, and how this might be supported, if desirable.

Anticipated Questions for Workshop Discussion

1. **What are Canada's regional freshwater challenges? Are they unique enough to warrant regional scientific focus, or might there be an opportunity to address them at a national level?**
2. **What approaches or existing examples might be suited for forming regional collaborative science and knowledge spaces?**
3. **Would the concept of forming regional centres of scientific expertise be a reasonable option to support addressing regional issues? How many regional centres (and where) would be useful?**
4. **How can a Canada Water Agency move these approaches forward?**

3. Draft Workshop Agenda

Wednesday February 10, 2021 13:00 – 15:35 EST

13:00	**Welcome** Anton Holland, President and CEO, NIVA Inc. **Indigenous Opening** **Keynote Address** Dr. Martine Dubuc, Associate Deputy Minister, ECCC **Overview of Workshop Day One** Dr. Kevin Cash, Director General Water Science and Technology Directorate, ECCC
13:30	**Panel Discussion: National Freshwater Science Agenda** Dr. Shawn Marshall, Departmental Science Advisor to the Minister of Environment and Climate Change Canada Dr. Fred Wrona, Research Chair, Department of Biology, University of Calgary Dr. Kyle Bobiwash, Professor, Indigenous Scholar, Faculty of Agricultural and Food Sciences, University of Manitoba Ms. Carolyn Dubois, Director, Water Program, The Gordon Foundation
14:30	**Breakout Session**
15:30	**Plenary Wrap Up**

Friday February 12, 2021 13:00 – 15:25 EST

13:00	**Welcome Back** Anton Holland, President and CEO, NIVA Inc. **Overview of Workshop Day Two** Dr. Kevin Cash, Director General Water Science and Technology Directorate, ECCC
13:10	**Panel Discussion: Meeting Regional Water Science Needs** Dr. Barrie Bonsal, Research Scientist, Water Science and Technology Directorate, ECCC Dr. Frances Pick, Research Chair, Department of Biology, University of Ottawa Dr. Alfonso Rivera, former Chief Hydrogeologist *(retired)*, Geological Survey of Canada, Natural Resources Canada Dr. Marten Koops, Research Scientist, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada Mr. Evan Derdall, Research and Development Engineer, Agricultural Water Management, Agriculture and Agri-Food Canada
14:10	**Breakout Session**
15:10	**Plenary Wrap Up**
15:15	**Indigenous Closing**

4. Panelists' Biographies

Dr. Shawn Marshall is a Professor in the Department of Geography at the University of Calgary, where he held the Canada Research Chair in Climate Change from 2007-2017 and is one of Canada's foremost climatologists with a focus on glacier and ice sheet response to climate change and the implications for regional water resources and global sea level rise. He is currently serving as the first Departmental Science Advisor to the Minister of Environment and Climate Change Canada.

Dr. Fred Wrona is a Professor in Integrated Watershed Science at the University of Calgary and previous Chief Scientist and ADM of the Environmental Monitoring and Science Division for Alberta Environment and Parks. Fred has >30 years of environmental research and science policy linkage experience in Canada and internationally working with indigenous communities, academia, multiple levels of government, stakeholder organizations and the private sector.

Dr. Kyle Bobiwash is an Assistant Professor and Indigenous Scholar at the University of Manitoba where he focuses on understanding the ecology of beneficial insects in agro-ecosystems through characterization of landscape resources utilized by insects and how land management might affect insect communities and ecosystem services.

Ms. Carolyn Dubois is the Director of the Water Program at The Gordon Foundation where she works with partners across sectors in Canada's North. This work focuses on improving freshwater stewardship through community engagement in decision-making and the use of the best available evidence. Carolyn is a passionate advocate for open data and has led the development of Mackenzie DataStream, an online system that provides access to information about water quality. She holds a BSc in Biology from Mount Allison University and a Master's in Environmental Management from the Universitat Autonoma de Barcelona.

Dr. Barrie Bonsal is a Research Scientist at Environment and Climate Change Canada where he focuses on climate impacts on hydrology and ecology. He conducts research to examine past and projected future climate change and variability on freshwater availability, historical and future extreme hydro-climatic events, large to synoptic-scale atmospheric patterns influencing northern hemisphere hydro-climate, and assessment of modelled and observed climate across Canada.

Dr. Frances Pick is a Professor in the Department of Biology at the University of Ottawa where she focuses on microbial food chains and biogeochemistry. She examines the factors regulating the abundance and diversity of aquatic microbes in lakes and rivers, which includes examining general water quality problems related to excess nutrient loading. Dr. Pick also studies the biogeochemistry of trace metals in wetlands and the use of constructed wetlands for filtration of wastewaters.

Dr. Alfonso Rivera, former Chief Hydrogeologist of the Geological Survey of Canada (GSC) (*retired*), was a scientific advisor responsible for the National Groundwater Program of Canada with the Earth Sciences Sector (NRCan) and manager of hydrogeology regional projects of the GSC. His research focused on understanding the national scale for groundwater and aquifers and developing a platform for remote sensing and aquifer mapping. He currently serves as the Chairman for the IAH-Transboundary Aquifers Commission.

Dr. Marten Koops is a Research Scientist with the Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) at Fisheries and Oceans Canada. His research focuses on the dynamics of populations, the factors that affect population viability, and the application of these concepts to inform environmental and natural resource management. Dr. Koops studies also include the life history of fishes, population dynamics in response to human activities, and ecosystem structure and function.

Mr. Evan Derdall is a research and development Engineer (Biosystems) in the area of agricultural water management (irrigation and drainage) at Agriculture and Agri-Food Canada. His research focuses on improved environmental performance and agricultural productivity as well as improved management strategies in response to crop stress to utilize water resources in an environmentally sustainable manner. Mr. Derdall's research also includes the development and promotion of agricultural drainage water management technologies and practices as well as utilizing remote sensing technologies in the management of irrigation waters.

5. Background and Context

The Government of Canada has committed to establishing a Canada Water Agency (CWA) to "work together with the provinces, territories, Indigenous communities, local authorities, scientists and others to find the best ways to keep our water safe, clean and well-managed".

To hone in on a functional mandate for a CWA, Environment and Climate Change Canada along with Agriculture and Agri-Food Canada led an information gathering initiative on a broad range of national and regional freshwater opportunities including Water Governance, Indigenous Water Needs, the Canada Water Act, Climate Change, and Technology. Two ubiquitous topics covered in this initiative are Science and Data. To drive evidence-based decision-making in the establishment of a CWA, robust freshwater science is fundamental to inform – so too is the means to effectively communicate and mobilize this knowledge.

The CWA Discussion Paper offers information on each of these freshwater topics to initiate public engagement. As an extension of that exercise, the upcoming Freshwater Science in Canada Workshop will focus on the freshwater science opportunities to support such an Agency.

Canada has a wealth of academic, government, non-governmental, Indigenous, and community-based scientific water-related expertise. Many federal departments conduct scientific research, monitoring, and modeling on freshwater and related activities. Furthermore, research funding under the granting councils, including the Research Chair and Excellence programs, supports experts on water-related science outside of the federal government. Collaborative efforts with federal experts and through these programs have strengthened an already significant network of water science proficiency in academia.

Movement towards a CWA provides a unique opportunity to effectively convene and mobilize freshwater science across federal departments and other governments – in collaboration with experts and informed by Indigenous and local knowledge – to guide solutions to Canada's most pressing national and regional freshwater challenges and ensure that this knowledge optimally informs decision-making.

6. Synthesis of the Science

Report on the Current State of Freshwater Science

To inform the science component of a CWA, the GoC is currently developing a synthesis of freshwater science in Canada, including the current status of scientific knowledge, ongoing initiatives and activities, gaps and needs, and opportunities for better coordination going forward. Given that the specific activities of a CWA have not yet been defined, this assessment takes the approach of identifying key stressors and issues related to water quality, quantity and aquatic ecosystem health. The intent is to help guide the eventual scope of activities of a new CWA and identify opportunities to better integrate the scientific knowledge on Canada's most pressing freshwater challenges. While a first complete draft is expected for Spring 2021, the table in

Section 7 highlights a subset of early observations from this developing report. We acknowledge that such an assessment of scientific status must be viewed as evergreen given that scientific knowledge is constantly evolving. Additional work is also planned to canvass the users of freshwater scientific information – targeting those that develop policy, regulation, enforcement, manage programs and other initiatives, and other 'clients' that require critical scientific information - to better match the scientific effort with the needs of freshwater managers.

Braiding Indigenous Knowledge with Western Science

First Nations, Inuit, and Métis Peoples have culturally distinct and diverse relationships with the land and water that have existed for tens of thousands of years. With cultures rich in knowledge, history, and innovation, Indigenous Peoples have developed distinct Indigenous Knowledge systems that are deeply rooted in environmental stewardship, including stewardship over water. Braiding is relevant to many Indigenous traditions in Canada. Braiding is the weaving of different traditions and the drawing together of strength, power, and healing. Braids contain many separate strands and strength is built from weaving together different fibres. Concerted efforts to braid together strands of Indigenous Knowledge, environmental stewardship, and water governance would greatly support environmental solutions that are long-term, collaborative and respectful of decision-making processes. Co-development and the delivery of freshwater science programs and strategies is but one example of the potential in this area that extends beyond this immediate workshop, and additional work on this is being planned.

7. Early Observations Table

Draft information gathered on Key Stressors and Cross-Cutting Themes

Key Stressor or Theme	Concern/Issue	Synthesis of the Science – Early Observations
Climate Change Impacts – Hydro-Climatic Extremes (floods and droughts)	Floods and droughts significantly influence ongoing and projected changes to components of the water cycle. With considerable potential impact on socio-economic and environmental factors, floods and droughts are a public safety concern and can be major threats to Canada's freshwater resources and aquatic ecosystems.	• **Status** – With a wide range of potential drivers, flooding can occur any time of the year somewhere in Canada; Historical flood and drought events exhibit varying trends in magnitude, timing, number, and duration across Canada; Drought risk is expected to increase in many regions of the country; Droughts have major impacts on a wide range of water-sensitive sectors including agriculture, industry, municipalities, recreation, and aquatic ecosystems; Changing climate will impact several factors that influence flooding and drought events but short-term predictions and long-term projections remain uncertain. • **Key Needs** – Improved climatic, hydrologic, deterministic, and statistical modelling including improved integration of Global and Regional Climate Models with distributed water balance models to better model future flood and drought conditions; Improved confidence in precipitation estimates in models; High-resolution precipitation data; Monitoring of streamflow (water level and discharge) under ice-covered conditions as well as during break-up and ice-jam events; Improved monitoring of drought and inundation extents and water levels at broader spatial scale via remote sensing technologies. • **Going Forward** – Work towards improved understanding of how a warming climate will impact known flood-causing factors on individual river reaches and at watershed scales; Efforts to better understand how a warming climate will impact the frequency, intensity, duration, spatial extent, onset, and termination of warm and cold-season droughts as well as the amount and distribution of groundwater resources particularly under drought conditions.
Climate Change Impacts – Water Balance, Availability, and Sustainability	Freshwater availability, both in terms of timing and quantity, are increasingly affected by the changes in precipitation, evaporation, snow cover, groundwater discharge (and	• **Status** – Increase in mean annual precipitation will result in more precipitation by late century but it is uncertain how projected warming and resultant changes in atmospheric circulation and evapotranspiration will offset this increase, particularly during summer; A shrinking cryosphere will have profound effects on how streamflow is generated; These projected changes imply an increased risk of summer water supply shortages.

Key Stressor or Theme	Concern/Issue	Synthesis of the Science – Early Observations
	ultimately recharge) resulting in impacts to regional and seasonal sustainability.	• **Key Needs** – Enhanced integration of climatic, hydrologic and groundwater models, including dynamic terrestrial ecosystem and permafrost models to determine sensitivity of hydrologic regimes to climate and land use decisions; Better understand representation of dynamic terrestrial conditions (feedback and influences) and incorporate in prediction systems; Better understanding of hydrological process for model integration. • **Going Forward** – Stronger inter- and intra-departmental collaboration among federal agencies as well as improved leveraging of academic research to support more impactful water management decision-making; National scale examination of projected changes in streamflow; Improve and integrate remote sensing monitoring and assessment methods for water budget and water balance; Generation of Earth Observation-based long-term water budget databases; Improve data collection, coordination, and sharing; Promote existing governance structures of co-management water research.
Climate Change Impacts – Water Quality Impacts	Changing water quality underpins many aspects of aquatic ecosystem function, as well as human use of water resources.	• **Status** – Temperature and ice cover regime shifts, precipitation changes, and permafrost thaw have led to significant environmental impacts; Thawing permafrost is causing dramatic changes to the overall ecosystem structure of the tundra landscape, deepening the active layer and changing flow pathways, creating thermokarst lakes and rivers, and consequently the mobilization of metals, nutrients, and organics material; Microbial communities are impacted by this influx of particulates, as well as acute and chronic toxicity to the fish and benthic invertebrate communities. • **Key Needs** – The development of a comprehensive, integrated approach to quantifying water quality on a national scale; Research on the systemic response to shifting communities and the subsequent changes to pathways of material and energy transport in aquatic food webs that alter dynamics for nutrients, carbon, and contaminants. • **Going Forward** – Nationally coordinated mechanisms to quantify the impacts climate change on water quality on aquatic ecosystems at regional and national scales, including the co-development of data collection practices to obtain simultaneous climate-relevant and water quality information.
Climate Change Impacts – Aquatic	Rapid climate change is predicted to dramatically alter the biodiversity in Canadian	• **Status** – Aquatic biodiversity is impacted by altered thermal, precipitation, and hydrology regimes, eutrophication, brownification, landscape changes and habitat loss, reduced ice cover, and permafrost thaw, all of which are driven by or exacerbated by

Key Stressor or Theme	Concern/Issue	Synthesis of the Science – Early Observations
Biodiversity Impacts	freshwater ecosystems. Measuring and protecting the biodiversity of our aquatic ecosystems is essential to support wise stewardship, maintain critical ecosystem services to reduce the risk to human security, and promote resilience to ongoing global change processes.	climate change; Anticipated biodiversity changes include shifts in species distribution, genetic and ecosystem diversity, and extinction. ● **Key Needs** – Consistently-observed biotic data at a national scale to assess the impacts of rapid climate warming in biodiversity and linkages to ecosystem function; Long-term observations for predictive model development to better understand the structural and functional changes to biodiversity related to increasing severity of climate-driven landscape changes (i.e., permafrost thaw, habitat loss, wildfire, flooding/drought); Characterization data of food webs including microbial diversity, their response to various drivers and stressors and contribution to nutrient and carbon cycling that further enhance greenhouse gas production; Better understanding of change in biodiversity impacts with respect to Indigenous traditional resource use for trends in a historical context and for conservation planning. ● **Going Forward** – Generate knowledge by collecting consistently-observed genus/species-level biotic data at a national scale or within focused regions most vulnerable to climate change; Provide and promote nationally-validated tools and methods to support consistent national-scale freshwater biodiversity assessment that can be evaluated for integration into national programs (i.e., CABIN, STREAM); Establish partnerships with Indigenous Peoples and remote communities throughout Canada to co-develop biodiversity data collecting initiatives; Incorporate existing and establish new sentinel sites for long-term data collection.
Climate Change Impacts – Groundwater	Climate change impacts several processes that control groundwater quantity and quality.	● **Status** – Unknown changes to magnitude and direction of recharge and hence groundwater availability and contribution to base flow and other ecosystem services (such as thermal regulation); Likely growing demand for groundwater in regions where surface water quality and quantity will be affected, which will add to existing growing demand for water; Lack of data is impeding understanding of key hydrologic processes and adds uncertainty to predictive models. ● **Key Needs** – Better understanding of role of groundwater in key interactions with surface water, vegetation, permafrost and atmosphere; Assessing impacts of changing groundwater availability and use; Research on moisture, carbon, and energy fluxes across the water table in the critical zone and linkage with climate models; Integration of data from various providers and disciplines;

Key Stressor or Theme	Concern/Issue	Synthesis of the Science – Early Observations
		• **Going Forward** – Work toward models that consider surface water – groundwater – atmosphere interactions in General Circulation Models; Understand change in groundwater quality under a changing climate; Develop integrated groundwater-surface water models at local to national scale.
Agricultural-Sourced Stressors	Agricultural land use activities can have significant impacts on water quality, quantity, and aquatic ecosystem health. A changing climate will exacerbate these impacts. Reducing this sector's environmental footprint is a key focus of the science effort going forward.	• **Status** – Issues relating to water quality in Canadian agriculture primarily relate to the impacts of fertilizers and pesticides on hydrological systems, while those relating to water quantity primarily relate to having too little (drought) or too much (excessive moisture and flooding) of this resource. • **Key Needs** – Research to support accurate mapping of irrigated fields; Spatial variability of soil erosion; Effects of nutrient management scenarios, intensive greenhouse production, and soil health; Interactions of farming systems at a watershed scale and of best management practices; Producer level detail in metadata to support data; Irrigated fields at the national scale; Quantification of the impacts of drought and extreme weather; Soil data to model soil erosion; Space-based observations; IT infrastructure to support modelling and knowledge transfer; Synergies with Indigenous knowledge; Disentangling the roles of climate and agricultural practices, particularly drainage, on streamflow. • **Going Forward** – National space-based irrigation monitoring system; Priority setting for large water bodies; Relationship-building and co-development with Indigenous partners; Science coordination committees for regional watersheds; Enhanced integrated research with stakeholders; Stronger federal department coordination; Leverage soil moisture research and data; Data sharing and coordination.
Excess Nutrients	Point and non-point sources of excess nutrients in both surface and ground waters continue to challenge aquatic ecosystem health in many regions of Canada.	• **Status** – Urbanization, agriculture and climate change are the primary drivers of excess nutrients delivered to our freshwater ecosystems; Eutrophication is possibly the most pervasive, significant threat to Canada's waterways. • **Key Needs** – Effects of nutrient discharge from wastewater treatment lagoons on aquatic ecosystem health, especially in the North; Early warning indicators (i.e., metabolomics, eDNA technologies) to better evaluate effects; Nutrient uptake, retention, and storage provided by wetlands, streams and rivers; Expanded monitoring, especially in the North, in groundwater, and in well water drinking supplies. • **Going Forward** – Multi-sector initiatives such as Living Labs and citizen science activities, at the catchment level, show promise for more coordinated science efforts.

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Cyanobacterial and Harmful Algal Blooms (HABs)	There continues to be growing evidence that blooms can foul beaches, clog water intakes, impair recreational and commercial fishing, and in some cases have serious health, economic, and aesthetic consequences.	• **Status** – HABs have socio-economic and ecosystem impacts but there is a lack of timely, consistent, and large-scale information on the full extent and severity of blooms, limiting mitigation strategies; Nutrient loading and climate change are major drivers of bloom events but the role of food web disruption/modification, bioactive metabolites, and microbial communities less understood; Earth Observing satellites showing promise to deliver cost-effective large-scale measures of bloom spatial extent, intensity and duration. • **Key Needs** – Timely, large-scale detection of HABs is vital to inform response; Characterization and treatment of cyanobacterial toxins; Infrastructure and tools to support predictive modelling. • **Going Forward** – A coordinated national response to HABs in terms of prompt detection, adequate spatio-temporal monitoring, identification, and reporting (i.e., communication of risk) is a critical gap; The use of space-based earth observation is rapidly evolving and the expansion of tools like EOLakeWatch in addition to new hyperspectral space-based observations will be necessary to address HABs across Canada.
Contaminants and Pollution - Legacy and Emerging Contaminants	Emerging contaminants and legacy contaminants of emerging concern in the environment posing a major challenge to both environment and human health due to their potential toxicological effects and related risks to freshwater ecosystems in Canada.	• **Status** – Emerging and legacy contaminants of concern are widely present and distributed in the aquatic environment, including pharmaceuticals, personal care products, industrial additives, pesticides, manufactured nanomaterials, flame retardants and surfactants, hormones and endocrine disrupting compounds, microplastics, and rare earth elements; Many are not effectively removed by wastewater treatment plants and residual concentrations are reaching surface and ground waters; Advances in analytical methodology allow previously unidentifiable and undetectable chemical and microbial contaminants of emerging concern to be detected throughout the water cycle. • **Key Needs** – Identification and prioritization of new emerging contaminants and legacy contaminants of emerging concern; Development of analytical tools, methods, and prediction models for the description of their fate, transport and transformations in the environment based on a life-cycle approach (i.e., production, consumption, and disposal routes); Technological upgrading of wastewater treatments facilities; Scientific and research capacity building and infrastructure; International regulatory cooperation to modernize the management of these contaminants.

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		• **Going Forward** – To address these emerging scientific and research knowledge gaps and key needs, there is a critical need for a whole-of-government approach in the development of a national strategy for emerging contaminants in the environment; Establishment of a national centre of excellence for emerging contaminants in the environment, community-based monitoring; Establish a national wastewater treatment action plan.
Contaminants and Pollution - Endocrine Disrupting Substances (EDS)	EDS have diverse mechanisms of action and uses (in agriculture, manufacturing and consumer products) which end up in river and lake waters across Canada and can cause adverse health effects in organisms at low concentrations.	• **Status** – EDS are found in Canadian environments including pulp mill effluents, municipal wastewater effluents and as legacy contaminants in the Great Lakes; Species sensitivity and level of exposure can affect the potency of a given EDS; There are critical "windows of exposure" where changes to organisms can be irreversible (i.e., growth, reproduction, mortality). • **Key Needs** – Validated test methods to assess a broader spectrum of effects from EDSs; Better understanding of complex endocrine alterations induced by chemical mixtures in situ; Better understanding of linkages between EDS-related changes and outcomes at the population and ecological community levels. • **Going Forward** – Improved tools to detect and understand how EDS affect organisms and their ecosystems to better prioritize contaminants and associated hazards; Build on understanding of basic reproductive biology of aquatic biota and the interactions of species with their natural environment and ecosystem; Develop methods to assess the effects of mixtures of EDS and mixtures with other chemicals; Define scientifically-informed discharge limits for sewage treatment plants.
Contaminants and Pollution - Pesticides	Pesticide use has created environmental degradation, contamination of ground and surface waters, bioaccumulation in food webs, and unintended impacts on non-target species.	• **Status** – Agriculture, forestry, and vegetation management for various industries are major drivers; Current work on neonicotinoid insecticides has highlighted that pesticide dynamics are not uniform across Canadian provinces, and pesticide physicochemical properties cannot be solely relied upon to determine fate and transport in the environment; Natural populations are more variable and can increase background variability in responses to pesticides and their risks to aquatic environments. • **Key Needs** – Better understanding of pesticide dynamics in water/soil mixtures, their binding and breakdown properties, and interactions with other stressors (e.g., nutrients); Pesticide loading information from different sectors (i.e., agriculture, transportation, forestry); Effects of long term-loading, interaction with multiple stressors and cumulative effects, and impacts on aquatic organisms.

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		• **Going Forward** – Suggest strong inter-departmental coordination to integrate knowledge and research efforts on loading and transport of pesticides across habitats (i.e., soil, groundwater, surface waters) to support greater understanding of the fate and sorption of different pesticides in different aquatic environments; Invest in infrastructure and platforms for better integration of water quality data to support programs and initiatives at the national-scale.
Contaminants and Pollution - Plastics	The improper management of plastic waste has led to plastics becoming ubiquitous in all major compartments of the environment. In water bodies, plastics pose potential problems for ecosystem function, biodiversity and habitat integrity. With slow degradation and persistence in the environment, plastic pollution is anticipated to increase over time.	• **Status** – Single-use plastics make up the bulk of macroplastics along shorelines; Microplastics such as microbeads, fibres and fragments are found in surface waters, benthic zones as well as surface and bottom sediments; There is potential for microplastics to leach into groundwater aquifers due to downward drainage; Plastics cause physical impacts on ecosystems and aid in the transfer of chemicals or non-native species; Plastic degradation is slow and can be affected by multiple factors. • **Key Needs** – Better understanding of the distribution and fate in the environment; Consistency and reliability in the methods used to sample and quantify microplastics in the environment and other media (e.g., drinking water and food) and develop methods for testing the potential for adverse effects associated with exposure to plastic (relationship between plastic properties and toxicity); Better understanding of potential effects of microplastic pollution on environmental receptors and on human health. • **Going Forward** – Develop standardized methods for sampling, quantifying, characterizing, and evaluating the effects of macro and microplastics; Expand and develop consistent monitoring efforts to include poorly characterized environmental compartments.
Contaminants and Pollution - Municipal Wastewater Effluents (MWWE)	In spite of improvements in treatment processes, some freshwater ecosystems continue to be negatively impacted by effluents. Direct release of municipal wastewater is the largest source of effluent to	• **Status** – Metals, legacy and conventional contaminants, algal toxins, and emerging substances of concern such as flame retardants, surfactants, antioxidants and pharmaceutical substances are detected and being measured in wastewaters; Municipal effluents are complex mixtures that can have additive, synergistic and/or antagonist effects on aquatic communities. • **Key Needs** – Better understanding of mixture effects and the cumulative effects from multiple effluent discharges in the same watershed; Knowledge on pathogens and viruses that may generate ecological and human health problems; Genotoxic and endocrine disrupting activities from natural and wastewater treatment processes.

Key Stressor or Theme	Concern/Issue	Synthesis of the Science – Early Observations
	freshwater ecosystems in Canada.	● **Going Forward** – Promote strong national coordination on research into mixtures of substances by developing the tools and approaches to address the risks posed by contaminants and their transformation products released from municipal wastewater plants; Define scientifically-informed discharge limits for sewage treatment plants.
Contaminants and Pollution - Urban Runoff	Untreated urban wastewaters (mixtures of contaminants that generate adverse toxic and cumulative effects) remain a challenge in terms of water pollution, population growth, urbanization, and non-predictable runoff.	● **Status** – Wastewater treatment plant capacity remains limited in Canadian municipalities as there are still many untreated waters bypassing the plants. ● **Key Needs** – Better understanding of impacts of increased releases of untreated wastewater plus the cumulative effects in a changing climate (e.g., more frequent and intense rainfall events); Development of ecotoxicological approaches including chronic tests for long-term exposures to untreated wastewaters and non-lethal effects. ● **Going Forward** – Coordinated efforts to assess composition and environmental impacts of contaminant mixtures released from untreated wastewaters, exposure conditions such as intensity, period and duration of discharge events.
Aquatic Invasive Species (AIS)	AIS are a main cause of global extinction and are one of the leading and fastest growing threats to food security, human and animal health, and biodiversity. They significantly contribute to cumulative effects and multiple stressors such as destruction of habitats already impacted by habitat loss, urban runoff, and wastewater, and climate change will continue to shift their range and abundance.	● **Status** – Prevention and early detection measures are more cost effective and efficient than control and long-term management after AIS have established; Over 60% of freshwater species currently at risk are threatened by AIS; They are the primary factor in 4 out of 5 extinctions of Canadian freshwater fishes. ● **Key Needs** – Consistent and dedicated resources for activities on prevention, early detection, response, and control; A national data platform for AIS information sharing; Watch list and assessment of vectors of spread to stop primary introductions; Guideline development for pathway risk assessments; Improved technical capacity for emerging and priority freshwater AIS; Evidence-based rapid response, control, and mitigation methods for emerging issues; Cost-benefit analyses of control actions (e.g., fish passage). ● **Going Forward** – Partnership with academia on dedicated and permanent resources for AIS; Clear, articulated freshwater roles and responsibilities on AIS between provinces, territories, and federal government in all regions; Extensive targeted AIS monitoring and subsequent response planning; Development of molecular detection methods (i.e., eDNA); Improved environmental assessment and monitoring of freshwater habitats; Indigenous engagement in monitoring, particularly in remote or large areas (e.g., Arctic); international and cross-boundary collaboration.

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Hydropower	The transformation of fluvial habitat to lacustrine habitat (reservoirs) upstream of dams can alter the flow regime and available habitat, alter species composition, change thermal dynamics, and alter water quality. The downstream impact largely depends on the operational regime of the facility.	• **Status** – There is growing understanding of how hydropower production can not only affect aquatic biota and habitat, but how it can be mitigated to reduce those impacts; The scale and magnitude of effects are often dependent on the size and configuration of the dam, and the severity of alteration from the natural flow regime; Bioaccumulation of mercury as a result of reservoir operations continues to be a concern, particularly in boreal regions. • **Key Needs** – New technologies such as micro-hydropower facilities and hydrokinetic turbines hold promise, but may result in unintended cumulative effects that would require study considering the large number of small facilities required to produce equivalent power; Research into innovative mitigation solutions (e.g., creating downstream retention basins to mitigate hydropeaking effects) for new and existing facilities deserves focus. • **Going Forward** – New and large dams may be few and far between, but hydroelectric power production is projected to increase with movement away from fossil fuels; Research into the effects of hydropower remain piecemeal and largely focused on monitoring programs tied to individual hydropower facilities.
Aquaculture	The demand for fish and other seafood has exceeded the capacity of natural sources and the growing demand of aquaculture production increases the impacts of phosphorus and dissolved oxygen issues in lakes.	• **Status –** The impacts of most interest relate to phosphorus supply to the water column, and waste deposits on the lake bed as they affect benthic invertebrate communities, and dissolved oxygen supply via Carbonaceous Biochemical Oxygen Demand. • **Key Needs –** How much production may be acceptable within a given site lacks clarity; Broader issues such as how to manage cumulative effects across sites in some proximity to each other is even less clear. • **Going Forward** – Efforts to better understand aquaculture-environmental interactions are continuing, but are also lagging behind the increases in the number of production sites and quantities.
Forest change	Forests dominate much of Canada's landscape and are a critical source of freshwater. Forests are undergoing unprecedented change due to natural and anthropogenic	• **Status** – Forests are undergoing extensive change due to multiple stressors (e.g., harvesting, wildfire, insect and disease, urbanization and climate change); Changes to forested landscapes are having direct and indirect impacts on various forest-water issues such as increasing flood risk, threatening drinking water supply, and altering critical aquatic habitats. • **Key Needs** – Better understanding on how forests are changing and the impacts of these changes on freshwater supply and habitat; Need for rigorous forest-water science

Key Stressor or Theme	Concern/Issue	Synthesis of the Science – Early Observations
	stressors and this is having direct impacts on freshwater.	to better inform effective forest and water management of these interdependent resources. • **Going Forward** – Suggest coordinated support for advancing science on forest-water issues to address current and emerging issues; Focus on building dialogue and collaboration between forest and water scientists, managers, and stakeholders to establish a national strategy on forest-water management; Improve the linkages between dynamic terrestrial models and hydrological and biochemistry models to allow for effective, science-based management strategies in order to ensure critical forest-sourced freshwater is sustained in a changing world.
Multiple Stressors (MS) and Cumulative Effects (CE)	Stressors and their impacts on aquatic environments are studied and treated in isolation from each other. Real-world interactions with other stressors and cumulative effects are not well understood.	• **Status** – Current science most often involves single substance toxicity testing on lab-reared, individual species, which does not reflect real-world conditions where MS and CE can alter the impacts of these substances; Important MS and CE research has been conducted on streams, rivers, lakes, and wetlands in Canada, but the North remains understudied; Government of Canada is currently involved in several ground breaking coordinated initiatives and programs involving MS/CE, including Living Laboratories and the Oil Sands Operational Framework Agreement (OFA); The new Impact Assessment Act (2019) includes understanding existing or potential cumulative effects on the rights and interests of Indigenous peoples as one of its key objectives. • **Key Needs** – Interdisciplinary, co-developed research into MS and CE to effectively assist in evidence-based decision making; Groundwater research in this area would benefit from greater integration and support, particularly as groundwater is an important source of drinking water for millions of Canadians. • **Going Forward** – Continue research into mixtures of substances, prioritize MS/CE monitoring networks, and establish reference monitoring sites; Use existing data and causal frameworks for further study and model development to link impacts of MS and CE between surface and groundwater; Promote a holistic approach to watershed and environmental management and studies; Work to establish collaboration with universities, Indigenous Peoples, and communities.
Chemical Mixtures	Real-world mixtures contain combinations of existing pollutants, contaminants of emerging concern, and vast	• **Status** – The science on how chemical mixtures of concern for freshwater systems are defined, identified and investigated has evolved significantly over the past decade; Effects-based approaches to detect mixtures of concern in monitoring programs have

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	quantities of unknown substances. Mixtures exert real-world effects in freshwater ecosystems in Canada and around the world.	been pioneered by Canadian researchers, shifting away from purely single-chemical monitoring. • **Key Needs** – Regulatory agencies around the world, including in Canada, are recognizing the need to address issues such as cumulative exposures and effects; Combined effects from multiple chemicals and sources have not been routinely or adequately assessed; Strong need to enhance chemical, toxicological, and ecological understanding of environmental chemical mixtures. • **Going Forward** – Science is rapidly developing the tools and approaches to address the risks posed by the universe of unknown substances present in environmental samples, and guide management options; Challenges to implement such tools holistically and broadly within existing regulatory and policy frameworks remain.
Ecosystem Services	Freshwater ecosystems in Canada provide a multitude of ecosystem services such as food, filtered water, and clean air. Canadians rely on these services to support their health and well-being. Protection of ecosystems and their services is essential to provide environmental and economic sustainability.	• **Status** – Canada's freshwater ecosystem services are impacted by climate change, contaminant emissions, harmful algal blooms, invasive species, waterborne pathogens, and nutrients; Many of these services remain unrecognized or poorly studied despite being threatened by pressures from human activity. • **Key Needs** – Case studies involving cross-departmental, cross-disciplinary projects which place ecosystem services at its centre, focusing on nature-based solutions for delivery of a One-Health approach; Co-development mechanisms to build ecosystem services research with indigenous communities and other stakeholders; Greater effort to incorporate ecosystem services in strategic thinking; Infrastructure and tools for monitoring that supports environmental protection. • **Going Forward** – Recognition that implementing total ecosystem protection, including freshwater, traverses mandates requiring a whole-of-government solution; Strengthened identification and quantification of strategic ecosystem services provided by Canada's freshwaters, and the use of ecosystem services data and information to guide monitoring assessment needs and protection requirements.
Management of Environmental Flows	Global freshwater resources are under increasing threat from human activities and increasing societal demands for water have led to	• **Status** – Development of holistic framework to include linkages between flow and ecology at the watershed scale is ongoing; The establishment and management of optimal environmental flows in a cold-region country is done through recognizing unique flow regimes and incorporating the effects of ice on flows, water levels, and habitat plus the understanding of the increased statistical uncertainties that this can bring to

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	substantial flow alterations in rivers impacting the physical and ecological attributes to sustain aquatic ecosystems.	environmental flows analyses; These analyses have started in Canada with the Lower Athabasca River, Wolastoq St. John River and Peace-Athabasca Delta. • **Key Needs** – Advanced knowledge on ecohydrological processes and the development of flow-level-ecology relationships; Explore methods to estimate streamflow and levels in ungauged rivers and lakes; Geospatial tools to access watershed scale water use and allocation; Continue to apply holistic environmental flows frameworks at watershed and regional levels; Develop and validate novel rapid assessment methods (e.g., DNA-based sampling approaches) • **Going Forward** – Develop high resolution data observations at different spatial and temporal scales; Co-create environmental flow frameworks for more cohesive flow management; Prioritize pan-Canadian remote sensing monitoring and assessment methods; Support open access data repositories for a variety of data types and information; Provide support for a national environmental flow network; Co-location of hydrometric, water quality, and ecological monitoring sites on rivers, lakes, and wetlands is necessary to support integrated modelling and management.
Groundwater Consumptive Issues	The amount of groundwater stored in Canadian aquifers and their sustainable yield and role in ecosystem functioning are poorly known. Impacts on groundwater may take many years or even decades to appear and it may take an extremely long time or be impossible to repair. This is a unique aspect of groundwater that requires management techniques different from those used for surface water.	• **Status** – Two distinct science challenges, the science of the natural system and the impact of anthropogenic changes on the system which could be labelled cumulative effects; As stated in the Council of Canadian Academies report on sustainable management of groundwater in Canada (2009), defining sustainable use of groundwater requires acknowledgement that “sustainability” involves judgment and is ultimately a societal decision that should be informed by scientific knowledge and sustainability principles, including the precautionary principle. • **Key Needs** – Mechanisms to assign value to water and to the ecosystem benefits are poorly understood and incomplete; Frameworks that identify and protect aquifers and groundwater flows vital to both humans and ecosystems (now and in the near future); Assessment of sustainability will usually require several independent indicators, which need further development. • **Going Forward** – Further develop and integrate key components (databases, geological framework, and quantitative hydrogeological characterizations) of hydrogeological models to inform decisions as to the sustainable use of groundwater from local to national scales; Models that couple atmosphere, land surface, hydrology, and groundwater need development to enable better assessment of the impacts of

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		land-use change, climate change, and variability; Hydrogeological studies, including aquifer mapping and characterisation to integrate groundwater concerns into the land-use management processes.
Freshwater Fish Habitat	Freshwater fish habitat is of economic, environmental, cultural and spiritual value to all Canadians. Habitat degradation and modification, aquatic invasive species, adverse effect of water quality due to pollution and climate change impacts to the characteristics and ecological function that support fish habitat are ongoing threats.	• **Status** – Protecting fish and fish habitat through the development of conceptual frameworks for understanding productivity-state response curves (risk and uncertainty); Metrics of productivity (quantity, quality and ecosystem transformation); Assessing offsets and developing effectiveness and functional monitoring. • **Key Needs** – Better understanding of cumulative effects of human activities on freshwater habitat; Assessment of the effectiveness of habitat management actions and individual stressors on fish habitat. • **Going Forward** – Coordination and cohesiveness at the national level for tools that help operationalize freshwater habitat science through the development of policy as well as regulatory tools that support the conservation and protection of fish and fish habitat; A freshwater habitat science approach with collaboration across federal departments and between federal, territorial, provincial and indigenous governments; An approach to data collection and standards for freshwater habitat monitoring.