NSERC CONNECT Workshop on environmental flows in Canada held in Montreal, Quebec, January 31 to February 1, 2018: Abstracts and proceedings

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Abstract

According to the Brisbane Declaration (2007), Environmental flows (E-Flows) are “the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems, and the human livelihoods and well-being that depend on these ecosystems”. E-Flows are an important component of sustainable water management frameworks. Numerous methods and models exist to estimate E-Flows needs. However, significant knowledge gaps remain. To help fill these knowledge gaps, a workshop was convened to bring together E-Flows experts representing various sectors from across the country and internationally to provide the base for a national research network focused on E-Flows research. The workshop brought together 42 academic researchers and representatives from federal and provincial governments, non-government organizations, Canadian water users, and the Centre for Indigenous Environmental Resources. The information gathered in the workshop is providing the critical foundation for an application for a NSERC Strategic Partnership Grant for Networks proposal. A national E-Flows research network will formalize idea exchange and collaboration opportunities, and be a key tool for Canada's water resources management community, as well as for Canadian water users.

A series of presentations highlighted the history of E-Flows research, current methodologies, and water users, indigenous, and regional perspectives in implementing the use of E-Flows in resource management, and identified current E-Flows research priorities. Breakout sessions enabled all workshop participants to contribute their knowledge of E-Flows, discuss research priorities, and help design the future E-Flows research network. Subsequently, a working group convened to discuss the steps forward to create the national E-Flows research network. The working group will guide and further develop the national network based on the discussions and priorities identified during the workshop. The objective of the network is to enable a transformation from concepts to E-Flows practice by identifying and validating ecological and social responses to managed flows, and how to achieve these flows while maximising the economic, social and cultural benefits from water. Outcomes of this research network (i.e. knowledge, tools, methods, highly qualified personnel) will make a significant contribution to national, provincial, and territorial ecosystem-based water management planning.

This brief report highlights key conclusions from the workshop and documents the priority recommendations put forth by the participants.

Introduction

With growing global pressures, increasing climatic variability, and land-use changes, the development of new knowledge, tools, and standardised methods to support integrated water management is critical to sustaining biodiversity and water resources. Environmental flows (E-Flows), defined as the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems, and the human livelihoods and well-being that depend on these ecosystems, offer an important mechanism and toolset to support the development of sustainable water management frameworks. Many provincial and territorial governments in Canada have developed policies and regulations to support the development and implementation of E-Flows frameworks. Numerous methods and models exist to estimate E-Flows needs. For example, recent research within Canada has focused on the comparison of hydrologic methods or the development of new tools, such as habitat models. However, significant knowledge gaps remain including: (i) a comprehensive assessment of existing ecohydrological indicators, including critical field validation to identify future research needs; (ii) the expansion of the E-Flows concept to incorporate underrepresented habitats (e.g. cryosphere and wetland habitats); (iii) the explicit incorporation of future climate change impacts in E-Flows strategies; and (iv) the direct inclusion of ecosystem services in E-Flows frameworks.

On January 31st and February 1st, 2018, the NSERC CONNECT Workshop on Environmental Flows in Canada was convened in Montreal, Quebec. The workshop was comprised of academic researchers and non-academic partners with representatives from federal and provincial governments, non-government organizations, industry (Hydro, Oil & Gas), and the Centre for Indigenous Environmental Resources. Workshop participants contributed their knowledge from an array of scientific sub-disciplines, including ecology, hydrology, hydraulics, sociology, and biology.

The objectives of the workshop were:

- To convene a meeting of multi-sectoral partners interested in research and research outcomes related to E-Flows in Canada.
- Provide the foundation for an application for a NSERC Strategic Partnership Grant for Networks (SPG-N) proposal.
- Identify core research priorities for E-Flows in Canada and internationally.
- Build a working group to execute the workshop's participants vision for a national E-Flows research network (the Network).

The Network will enable a transformation from concepts to E-Flows practice by identifying and validating ecological responses to managed flows, and how to achieve these flows without compromising economic objectives for water. Bringing a measure of certainty into water allocations paired with ecological objectives will support water users, governments, stakeholders

and rights holders in future planning in water resources management. Ultimately, a national E-Flows research network will be a key tool for Canada's water resources management community and Canadian water users. This report summarizes the workshop and discussions.

Welcome & Opening Remarks

The workshop began with an opening ceremony by elder Timothy Anderson. André St-Hilaire welcomed the participants and introduced the workshop facilitator Michelle Sault (Minokaw Consulting). M. Sault distributed blank cards that participants were instructed to use to list and rate the research priorities outlined by each speaker. The participants were asked to rate how important they think each research priority is based on what they know, their intuition, and their intellect. The rating cards were to be used by the working group to help formulate the core research priorities for the Network.

The workshop proceeded with presentations addressing the general themes of the practitioners' perspectives and research needs. The transverse themes were other aquatic ecosystems (e.g. wetlands), governance, and groundwater extraction. All presenters outlined what they believe are current research priorities for E-Flows within that research area.

Summary of Presentations

Environmental flows in a non-stationary world: Research challenges and strategies to achieve ecological resilience
N. LeRoy Poff, Colorado State University and University of Canberra

N. L. Poff began his presentation with a description of the history of E-Flows research. Over time, the study of E-Flows has evolved from foundations in applied conservation and statistical characterization of rivers to involve more engagement by non-scientists (stakeholders and policy makers) and managing rivers at a regional scale. E-Flows standards are now being decided based on both the science and social objectives.

Last year was the 10th anniversary of the Brisbane Declaration that formally defined E-Flows. Since the Brisbane Declaration, there has been a lot of global activity focused on E-Flows, including:

- Environmental flow standards developed at the state-level
- National scale objectives (e.g. Australia - Murray-Darling Basin Plan)

- Books: *Environmental Flows: Saving Rivers in the Third Millennium* (2012) and *Water for the Environment: from Policy and Science to Implementation and Management* (2017)

He noted several future global challenges to E-Flows determination:

- Climate change shifting flow regimes
- Population growth increasing water demands
- Resource depletion shifting social expectations and needs

He defined the term non-stationarity, which refers to the changing environment due to anthropogenic influences. As a result, researchers and practitioners must consider that rivers may not be able to return to baseline conditions with a changing climate. Hydrologic baselines will shift and alter previously determined "reference" flow regimes. He illustrated this point with the fact that half of the 2010 snowmelt-driven streams could become pluvial-driven streams in the future. Additionally, introductions of non-native and invasive species will have disruptive interactions on native species and have strong implications for ecosystem management. He emphasized that hydro-ecological non-stationarity must be considered when thinking about e-flow management. Ultimately, if only the historical conditions are considered for restoration projects, we may be trying to restore the river to a condition that cannot be sustained.

N. L. Poff concluded his presentation with the following research priorities:

- Develop dynamic modelling of hydro-ecological relationships based on mechanistic understanding.
- Incorporate non-flow environmental factors into E-Flows studies to understand where flow interventions are likely to achieve desired ecological outcomes.
- Develop insight into how vulnerable species and ecosystems are to hydrologic change projected from global warming, and collaborate with water resource engineers and public/policy-makers to manage for long-term resilience.
- Broadening the hydro-ecological foundation to reflect multiple ecological response variables and their scaling relationships, and how to transfer information across scales.

Socialising the environmental flow process: A frontier for innovation

Rebecca Tharme, Riverfutures Ltd. and the Australian Rivers Institute at Griffith University

R. Tharme described how the definition of E-Flows is being revised to include thinking around culture and economy, and trying to restore the social benefits of healthy rivers systems. When engaging with stakeholders, consideration should be given to their different values, knowledge systems and expectations. She detailed three views of the river as economic, cultural, and environmental values. The process of E-Flows determination should begin with a clear vision

and a set of objectives on the desired future state of the river system. She suggested the process should begin with societal values and finish with measurable scientific endpoints.

Social factors are not included in the majority of E-Flows methods, which are predominantly based on hydrological or ecological relevance. However, holistic environmental flow methods, which involve multidisciplinary teams, are more comprehensive. These methods consider the whole ecosystem, flow regime (e.g. key low and high flow events, timing and variability), structure and function, and source to sea.

She proposed that e-flow methods should consider the social components alongside and intertwined with the ecological components. The social dimension of E-Flows is still an under-appreciated element of E-Flows implementation. The knowledge of social institutions is weakly developed and poorly connected. She believes there is still a lot of potential to bring in the understanding of the social aspect.

R. Tharme concluded her presentation with the following research priorities:

- Consolidate, synthesis and strengthen knowledge base on E-Flows social aspects - concepts, lexicon, methods and applications.
- Explore human relationships with flow regimes, links to ecohydrology and impacts of flow alteration on cultures (e.g. intangible links, cultural connectivity).
- Develop framing and content for key area of E-Flows process - socio-ecological context (e.g. ethics, belief systems, trust building, historical legacies, positions and politics, drivers of E-Flows process).
- Advance management procedures and tools for environmental water allocation, trade-offs analyses, and optimizations with infrastructure design/operation.
- Analyse institutional arrangements and participatory models for water resource use and E-Flows management, and identify most appropriate cultural, economic and biogeographic contexts for their use.
- Develop new generation desktop E-Flows methods that incorporate social factors (e.g. typologies of governance, socio-ecological setting).
- Establish E-Flows data to track progress on water-related Sustainable Development Goals (SDGs) and indicators to demonstrate ecological, economic and societal benefits of E-Flows and healthy aquatic ecosystems.

BC Hydro's Water Use Plan: Past, present and future
Guy Martel, BC Hydro

The objective of G. Martel's presentation was to provide an industry perspective on E-Flows. His presentation focused on the BC Hydro Water Use Plan (WUP) process, which is a 13-step process that involves consultation, regulatory review and follow-up review. Within this process

the values and objectives of regulators, stakeholders and First Nations are considered. The goal is to gain consensus from all stakeholders and come up with the best compromise. This process is consensus-based and not mandatory. Anyone from the community is welcome to participate and provide their aspiration objectives (e.g., the want for a better environment or more vegetation). The structure of the decision making is to clarify the decisions, define the objectives, model the alternatives, estimate consequences, and evaluate trade-offs. The WUP process has led to over 300 monitoring studies and physical works.

He outlined the following challenges with the WUP process:

- In many cases decision requirements exceeded available information
- The opportunity to take the adaptive process is there, but rarely used
- Performance measures were rarely developed
- Transparency led to anyone in the community being able to participate, which can be a challenge when some are more vocal than others

He described the following as benefits of the WUP:

- Regulatory certainty
- Remissible costs
- Great relationships with agencies and First Nations
- Legacy of evidence-based structure

G. Martel concluded his presentation with the following research priorities:

- Develop appropriate performance measures: Relation flow - icthyofauna.
- Develop appropriate performance measures: Relation flow - salmonid recruitment.
- Develop appropriate performance measures: Biological significance.
- Offsetting measures to mitigate effects of variable flows.

A provincial perspective on environmental flows
Robert Metcalf, Ontario Ministry of Natural Resources and Forestry

The objective of R. Metcalf's presentation was to provide a regional perspective on E-Flows. He highlighted the importance of a national E-Flows research network to engage with provincial agencies and have provincial-level advocates. The majority of approvals associated with E-Flows are under provincial jurisdiction, and even where federal approvals apply, the federal representatives typically defer to their provincial colleagues. He believes those involved in the provincial approval processes would favour research efforts that:

- Streamline the process (e.g. information requests linked to clear assessment criteria).
- Ensure management decisions are based on sound science.
- Ensure that any required effects/effectiveness monitoring results in useful information for decision making.

References to E-Flows are increasing in provincial legislation, policy, strategies, and technical guidance. Some resources have been developed to assist staff implementing E-Flows as part of the approval process. Several provinces also contributed to DFO's *Framework for assessing the ecological flow requirements to support fisheries in Canada.*

R. Metcalf concluded his presentation with the following research priorities:

- More effort has focused on the development of methods to prescribe environmental flows for altered flow regimes or on criteria to assess possible impacts of a proposed alteration and less on developing and implementing monitoring programs to test the effects of an alteration or effectiveness of mitigation strategies. Therefore, no basis for adaptive management.
- The experimental design and monitoring effort required to link management actions to specific ecosystem responses, in the presence of confounding influences, is impractical for individual projects.
- Lack of scientific evidence that links environmental flows to desired ecosystem responses.
- Field staff responsible for the approvals process lack information on environmental flow methods and or framework to effectively implement policy when it exists.
- Better understanding of lake processes for managing lakes using environmental water level regimes.
- The range of flow and level alterations (large instream developments, small instream diversions, water takings, groundwater withdrawals) potentially makes science needs very broad.
- Often there is no clear policy statement on the desired state for a river ecosystem (this precludes the use of 'standards' and 'benchmarks')
- National regionalisations are not always the same as provincial regionalisations

Speaking to the Water (online video)
Pat McCabe, Diné/Navajo and Lakota activist, artist, and ceremonial leader

In this online video, P. McCabe discusses her spiritual connection with water. The Lakota belief is that water is life, and water has consciousness. She tells a story about communicating and praying with water. She calls for respect for water and recognition that it is extraordinary and sacred.

Aboriginal Research Needs
Marrell-Ann Phare, Centre for Indigenous Environmental Resources

The objective of M.-A. Phare's talk was to highlight Aboriginal E-Flows research needs. She highlighted that Indigenous communities are not a part of the stakeholder groups that include the

public. Rather, Indigenous communities should be considered as a government and nation. As such, they should be engaged in research as early as possible and invited to co-design projects with researchers if the research has anything to do with their lands, territories, or people. She emphasized that they are government, not public, and indigenous government have rights.

She recommended that E-Flows researchers need to start thinking about their work in the context of Indigenous people creating their own role. She suggested when working with Indigenous communities that the research should be co-designed to be of interest and use to both the researchers and the communities. Also, when working with First Nations you need to be aware of Treaty Boundaries. Ultimately, the focus should be on how we can do this together from the beginning.

Hydrologic/Hydraulic approaches to environmental flows
Daniel Caissie, Fisheries and Oceans Canada

The objective of D. Caissie's presentation was to discuss the hydrological and hydraulic approaches to E-Flows. His talk focused on historical and river hydraulics methods. Historical stream flow methods rely on hydrometric data (based on gauge information) and assume that if you protect some of the flow then you protect some of the instream habitat. These methods focus on stream hydrology by looking at flow metrics (mean annual flow, flow duration statistics, and low flow frequency analyses).

River hydraulic methods look at how you use the river hydraulics to help with instream processes. The wetted perimeter is the most common method where river width is a function of discharge. This method gives a feel for how habitat can change with a reduction in flow.
His conclusions were that all approaches should provide similar results if applied correctly. E-Flows are best applied as an integrated approach that uses multiple methods. There is no E-Flows method that is entirely scientifically defensible, so no method is better than the other. Researchers should apply methods with the best knowledge they have to make a decision. Ultimately, the prescribed flow regime should make sense.

D. Caissie concluded his presentation with the following research priorities:

- Comparison of various hydrological approaches being applied across Canada under different regional hydrologic characteristics.
- More research into hydraulic rating methods (e.g. changes in river width) as a reduction of flow.
- More research of population responses during drought events. How does it influence growth, fish density, distribution of fishes, fish passage, etc.?

Linking flows and ecology: Current understanding and directions with examples from the Mactaquac Aquatic Ecosystems Study

Allen Curry, Canadian Rivers Institute and the University of New Brunswick

The objective of A. Curry's presentation was to describe some ecological approaches to E-Flows. He provided examples of review papers that discuss flow-ecology relationships, and described the current state of the science. These reviews were unable to generate quantitative flow-ecology relationships from the published literature. There is a call for experimental work to assess the effect of flow on biological component of the ecosystem. Essentially, we do not really know what those connections are yet, but we are pretty sure they exist.

He described the research in the Mactaquac Aquatic Ecosystem Study (MAES). The MAES approach is to:

- Establish a baseline to understand natural variability in the St. John River downstream of Mactaquac Dam (N.B.) and to develop metrics to help quantify this variability.
- Model the current state; predict flow outcomes from different reservoir management scenarios (including decommissioning) on sediment, temperature, water quality.
- Develop an Ecological Limits of Hydrological Alteration (ELOHA) framework for E-Flows on the St. John River.

There is growing literature on flow-ecology relationships. There is a lot of good flow and biological data for our streams that still needs to be looked at. Models can predict flows and biological responses.

A. Curry completed his presentation with the following research priorities:

- Increase awareness of process-based ecological responses.
- Address the unlinked or not apparent flow-ecology relationships.
- Moving beyond predicting the current state or past "reference" or expectations. It is a changing world: landscapes, climate, and social values.
- Moving beyond "model cells" to whole ecosystem modelling.

Research needs for holistic environmental flows frameworks in a changing world

Wendy Monk, Environment and Climate Change Canada, University of New Brunswick, and the Canadian Rivers Institute

The objective of W. Monk's presentation was to describe the holistic approaches to E-Flows research. She described holistic approaches as the aim to match the scale of protection and recovery with the scale of water resource development. The scale is not always at the site-level, but often watershed and regional scale. There is a growing number of approaches and applications and she highlighted the ELOHA approach, which considers scientific and social

processes. The scientific process incorporates hydrological foundation, flow alteration, and flow-ecology relationships. The social process considers societal values and adaptive management. This approach involves long-term monitoring, which is why it is a dynamic process rather than static.

She emphasised that from the start scientists need to co-create with aboriginal communities and stakeholders. Co-creating conservation or restoration objectives to reflect social values and socio-ecological goals. Knowledge from the social sciences, aboriginal communities, and stakeholders should be directly integrated into the descriptions of flow-ecology and flow-social relationships.

W. Monk concluded her presentation with the following research priorities:

- Incorporate non-stationarity - dynamic baselines.
- Moving towards mechanistic understanding.
- Expand beyond watershed boundaries.
- Prioritize aboriginal and stakeholder engagement for water vision - links to sustainable governance structure.

Statistical tools in E-Flows determination
Taha B. M. J. Ouarda, INRS

Statistical techniques are typically used for the assessment and management of E-Flows. Typically, E-Flows are estimated using observation data from a given site. However, problems are encountered where there is little data available for the site of interest. The solution is to estimate the E-Flows using regional information from a similar basin. There is a need for non-linear models, as hydrological processes are typically non-linear. He presented the Generalized Additive Models (GAM), which are not restricted by linearity. He outlined several advantages to GAM over linear models:

- More flexible due to the smoothing functions used to model the predictor-predictand relationship
- Allow for precise identification of the effect of each explanatory variable of the response variable
- The response variable could have a distribution other than normal

Regionalization methods build relationships between flow quantiles and physiographic/climate metrics based on selected homogenous sites. He described homogenous regions as geographically contiguous regions, geographically non-contiguous regions, or as hydrological neighbourhoods. Hierarchical cluster analysis can be used to partition basins into fixed geographically non-contiguous regions.

Ultimately, better estimations are achieved with regional models using GAM rather than using linear models. Smooth curves improve the understanding of the true relationship between response and explanatory variables. A delineation of homogenous regions method used along with GAM improves the estimations.

T. Ouarda concluded his presentation with the following research priorities:

- How do we efficiently combine statistical techniques with other approaches commonly used to estimate E-Flows (hydraulic, ecological, holistic, etc.). Is it possible to bootstrap between approaches to combine their advantages and strengths while avoiding their limitations? Would this help develop models that can cover wider temporal and spatial scales?
- How can we develop universal (not specific to a given region) e-flow estimation approaches, that can address all specific (solvable and useful in practice) issues?
- How do we integrate all the components of risk analysis (risk, reliability, resiliency, vulnerability) in E-Flows management decisions?
- What additional variables should we include to improve our e-flow models (physiographic: drainage network type, junction angle, etc.; or other such as root zone storage)?

E-Flows and Climate Change

André St-Hilaire, INRS and the Canadian Rivers Institute

The objective of A. St-Hilaire's presentation was to describe the E-Flows research needs related to climate change. He defined the main options for studying climate change as looking at historical trends and inferring what may happen (requires long time series) and modelling the physics of the atmosphere and interactions with land and oceans. Future greenhouse gas concentrations must be included in the models. The primary source of information in climate change impact studies are global climate models, which have demonstrated their utility in predicting average temperature, but not precipitation.

In North America, the average available water is increasing during the winter and decreasing in the summer. The optimistic climate change scenarios predict an increase in groundwater recharge. There will likely be an increase in the number of days with water temperatures at stressful limits for cold-water species, such as Atlantic Salmon. Thermal refugia for cold-water species will become increasingly important and these species may depend more on tributaries that are not predicted to have the same temperature increases as mainstems.

Ultimately, summer flows will decrease in many places across Canada. Groundwater recharge and discharge will change regionally. A shift in spring floods will impact water availability and river sensitivity to withdrawals. Water temperature will change with potential important

increases during the summer months. Thermal refugia will become more important for many fish species.

A. St-Hilaire concluded his presentation with the following research priorities:

- What are the likely shifts not only in low flows, but in all characteristics of the hydrograph:
    - Amplitude, frequency, duration, variability
    - Variability of impacts across regions (e.g. North)
- Identify aquifers that are connected and may be most sensitive to climate change.
- Standardized approach? Tools?
- Do we need to re-think some of the hydrological methods currently used in Canada in the context of non-stationarity?
- Shift in species distribution: implication for ecological approaches?

eFlows in the North (aka Cold Regions)
Daniel Peters, Environment and Climate Change Canada

The objective of D. Peter's presentation was to describe E-Flows research needs related to environmental flows in the north. He began with an overview of the history of E-Flows. He explained that a significant next step in E-Flows research is to explicitly consider processes in cold regions. Temperature-controlled processes govern the hydrology of watersheds. These processes influence the timing, duration, and magnitude of flows and water levels related to the formation and growth of annual snow and ice cover. Canada has a range of flow regimes that are influenced by latitude and altitude. These flow regimes may be altered by the predicted changes in climate and human development. Canada is generally a cold region, and its large size can make it difficult to monitor. In particular, the northern regions in Canada have a low density of gauging.

Rapid assessments of E-Flows were developed to address the vast geography of Canada, range of flow regimes, and lack of high density data. The National Agri-Environmental Standards Initiative (AAFC) began this work, which has been continued under the Climate Change Adaptation Program by Environment and Climate Change Canada. A suite of hydrological indicators was developed specifically for cold regions. These indicators are used to assess change in ecological flow assessments. He outlined examples of ice effects on hydrology, hydraulics and ecology, including reductions in solar radiation, flow velocity and dissolved oxygen concentrations. He concluded that it is critical for E-Flows guidelines to consider the impacts of climate variability/change on the timing and magnitude of flows and water levels. Caution is required when using hydrological models for the development of E-Flows, as there is a need to assess that ability of the model to replicate the important hydrological indicators.

D. Peters concluded his presentation with the following research priorities:

- Higher density and co-location of hydrometric, ecological, water quality monitoring/sampling sites.
- National database water temperature with indicators.
- Explicitly recognize cold region processes in E-Flows.
- Develop novel monitoring framework(s) that capitalize on remote sensing approaches and DNA approaches.
- Integrated community based monitoring.
- Integrated watershed management to protect riverine and floodplain ecosystems (e.g. reservoir flow releases to offset effect climate change?).
- Develop software tools for rapid assessment of hydrological and ecological indicators.

Breakout Sessions

A. St-Hilaire began with presenting the objective of the Network: *The proposed work will enable a transformation from concepts to E-Flows practice by identifying and validating ecological responses to managed flows, and how to achieve these flows without compromising the economic objectives for water. Bringing a measure of certainty into water allocations paired with ecological objectives will support industry, governments, stakeholders and rights holders in forward future planning in water resources management.*

Andre asked if anyone is in disagreement with the objective. Summary of the responses include:

- Need to allow for economic compromise
- Need to consider social aspect and not just the economic
- When referring to ecological responses to flow - do you mean pure ecological or social as well? Should correct objective to read: ecological and social responses
- Need cultural as well

The objective was revised to: *The proposed work will enable a transformation from concepts to E-Flows practice by identifying and validating ecological* ***and social*** *responses to managed flows, and how to achieve these flows* ***while maximising*** *the economic,* ***social and cultural benefits from*** *water****. The work will support future ecosystem-based water planning from industry, governments, stakeholders and rights holders.***

The six breakout session groups were comprised of representatives from academia, industry, NGOs, and provincial and federal government agencies. M. Sault facilitated the breakout session by asking all groups to consider several questions regarding research priorities for the network, and the structure, function and purpose of the Network's working group. Each group shared their

responses with the entire group, and lists of the responses were created (Table 1). The information collected from the breakout session was used the following day by the working group to develop a path forward for the Network.

Table 1. Breakout Session Responses

Topic	Responses
Research priorities: Honouring those in the room who have additional ideas or input	• Science and evidence for policy and decision-making. • Designing with Indigenous communities from the outset rather than waiting for a project for engagement. • E-Flows as pre-project planning and design, not just a tool for mitigation. • Broad social aspect, including psychology and human behaviour, role of citizen science. • Research capacity to build knowledge and understanding around E-Flows at the community and technical levels. • Tools and frameworks to break down the barriers to proper stakeholder engagement and Indigenous community involvement. • Ethics component that explicitly identifies and articulates values. • E-Flows and fish passage. Informing dam operations, and implications for movement of non-native species. • Groundwater-surface water interactions. Assessing the value of groundwater and understanding its role in base flows and creating refugia. • Models to look at impact of land use. • Risk modelling. • Operationalising E-Flows from small water withdrawals to large scale hydro. Scaled from small to large streams. • Implementing E-Flows science. Translate knowledge to management and policy. How to take the science of E-Flows and make it simple enough so it can be used. • Adaptive monitoring and how to appropriately monitor E-Flows (moving away from classical). Tools and frameworks for adaptive management. • Impacts of ice ecology and dynamics on E-Flows, and implications for hydrology, habitat, and temperature. • Cumulative impacts of water withdrawals. • Restoration: how to decide what is the best baseline? • Information on water consumption vs allocation. • Integrating wetlands. • Climate change impact on E-Flows. • Provincial differences. • Systematic reviews and analyses of data that is already out there. • Developing a standardized monitoring program similar to environmental effects monitoring. • National hydrologic characterization to look for transferability across watersheds. • Hydro issues and E-Flows.
Guiding principles for the working group	• Adaptive and flexible to respond to changing conditions. • Applied: Ensure outcomes have impact that is measurable and verified.

	• Driven by users and stakeholders. • Use integrated approaches and interdisciplinary research. • Inclusive. • Multidisciplinary and comprehensive representation. • Accountable and transparent. • Meaningful research that supports decision-making.
Statements of purpose for the working group	• Promote novel interdisciplinary collaborations among the network. • Ensure research initiatives stay on track and consistent with overall objectives. • Reflect common values of the network and society. • Improve the effectiveness of E-Flows programs and activities in protecting and maintaining aquatic ecosystems in Canada • Allocate funds, maintain project focus, and disseminate new knowledge. • Coordinate emerging Network and select priorities and strategic direction. • Develop a research program that is useful and applied. • Promote and raise profile of E-Flows in Canada and internationally. • Frame research within short-term objectives and long-term fundamental research objectives. • To see effective uptake of E-Flows in decisions making and implementation on the ground.
Roles and Responsibilities of the working group	• Not temporary and has lasting potential. • Small and functional that communicates ideas to the larger group. • Representation by industry/user, indigenous, government (local, regional, provincial, territorial, national), researchers, NGOs, and practitioners (consultants). • Emphasis on good management with good administration. • Social and ecological representation. • There are not enough seats at the table for representatives from all sectors, so find people that are trusted and can represent multiple sectors. • Good geographical representation. • Eight people, including 2 academics (social and aquatics). • People with good organizational skills. • People that are well-networked. • Consensus-based decision making.

Working Group Meeting

A subset of workshop participants convened after the workshop to use the knowledge gained from the workshop to plan a path forward for the network and design the future working group. The working group meeting was comprised of academics, federal government representatives, and a practitioner.

Discussion on working group leadership & membership

The group was unanimous in its decision that A. St-Hilaire is the best person to lead the working group. The group then discussed who should be invited to join the Network's working group, which included:

- Provincial representation, including one representative from eastern Canada and one from western Canada
- The group discussed the need to be cautious to not favour one industry over others. Representatives from all applicable industries (e.g., Oil & Gas, Agriculture, Hydro) will be approached. Those that are interested in participating in the Network will be invited to join the working group.
- Involve Aboriginal representatives in the Network from the start and ask for their input in drafting research priorities. Will reach out to representatives from First Nations, Metis and Inuit communities.

Research Priorities - Themes

The group looked at the ratings of the research priorities that were outlined in the workshop presentations. Below is a list of the priorities that received the overall highest ratings:

- Incorporate non-flow environment factors into E-Flows studies to understand where flow interventions are likely to achieve desired ecological outcomes.
- Develop insight into how vulnerable species and ecosystems are to hydrologic change projected from global warming and collaborate with water resource engineers and public/policy makers to manager for long-term resilience.
- Advance management procedures and tools for environmental water allocation trade-off analyses and optimizations with infrastructure
- Offsetting measures to mitigate effects of variable flows
- Population responses during drought events. How does it influence growth, fish density, distribution of fishes, fish passage, etc.?
- Moving beyond predicting current states or past "reference" or expectation. It is a changing world: landscapes, climate, and social values.

- Prioritise aboriginal and stakeholder engagement for water vision - links to sustainable governance structure.
- How do we integrate all the components of risk analysis (risk, reliability, resiliency, vulnerability) in E-Flows management decisions?
- Integrated watershed management (E-Flows) to protect riverine and floodplain ecosystems

Michael Van den Heuvel presented core themes that the group then expanded on to create a comprehensive list of themes for the Network.

Hydrological

- National hydrological characterization
- Climate Change/Non-stationarity, dynamic modelling (adapt with new information)
- Groundwater
- Connectivity to landscape (e.g., Peace-Athabasca Delta, wetlands, flood plains)

Ecology and E-Flows (site specific tests)

- Process-based relationships
- Data gathering/mining from national sources
- Connectivity to landscape (e.g., Peace-Athabasca Delta, wetlands, flood plains)
- Incorporating hydraulics with ecology
    - Geomorphology and Hydraulics
    - Food/life cycle connectivity (e.g., fish passage)

Non-flow environmental factors: Cumulative Effects Assessment

- Includes non-flow environmental factors (e.g., temperature, sediments, nutrients)
- Water quality and quantity
- Consideration of invasive species pathways

Decision Making Process

- Adaptive Management
- Decision making process
- Governance
- Ecosystems services
- Environmental management sciences - linked to Cumulative Effects Assessment
- Statistical models
- Multivariate, multi-objective approach
- Mitigation/offsetting
- Tool development (technical and feed into policy)

- Update regional guidelines or develop national guidelines
- Non-stationarity

Cross-cutting themes:

- Thread Indigenous theme into everything the Network does
- Meta or systematic analysis
- Raising profile of E-Flows in Canada
- New monitoring approaches/new and standardized variables

Outreach

The group discussed who should be sent invitations to become involved in the Network. It was also discussed what organizations may be interested in providing funds or in-kind support. The following are the groups that will be approached:

- Fisheries and Oceans Canada
- Environment and Climate Change Canada
- Parks Canada
- Transport Canada
- Hydro
  - Canadian Hydropower Association
  - Hydro Quebec
  - Association that deals with micro-Hydropower
  - Canadian Electricity Association
  - Ontario Water Power Association
  - BC Hydro
  - NB Power
  - Manitoba Hydro
  - SASK Power
  - NALCOR (Newfoundland)
  - Ontario Power Generation
  - Nova Scotia Power
- Agriculture
  - Cavendish Farms
  - Agriculture Canada
- Government representatives from the provinces and territories
- Oil & Gas companies
- Indigenous representatives
- NGOs
  - World Wildlife Fund

    - Trout Unlimited
    - Atlantic Salmon Federation
    - Fédération Québécoise pour le saumon atlantique
    - Nature Conservancy
    - Canadian Wildlife Federation
- The North
    - Territorial contacts
    - Inuit
    - Centre d'études nordiques
    - Quebec Nordique
    - ArcticNET

The group also discussed the need to have a science advisory committee where international collaborators can be involved. The description of the science advisory committee will be included in the Governance Section of the proposal. Individuals that will be invited to join the science advisory committee include:

- Rebecca Tharme, Riverfutures Ltd.
- LeRoy Poff, Colorado State University
- Angela Arthington, Griffith University
- Mike Acreman, Centre for Ecology & Hydrology
- A representative from the International Association of Hydrological Sciences (IAHS)
- A representative from the French National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA)
- A representative from the International Association for Hydro-Environment Engineering and Research (IAHR)

Path Forward

The group agreed to proceed and submit a proposal for an NSERC Strategic Networks Grant this spring. The Letter of Intent (LOI) is due in April. If successful, the group will have six months to write a full proposal. If the proposal is unsuccessful this year, the groups plans to continue organizing annual workshops/meetings to maintain group cohesion until approval for funding is received. If the group does not receive a NSERC Strategic Networks Grant this year, then other funding options, such as CRDs and provincial programs, will be explored. If the 2018 proposal is unsuccessful, the group will re-apply to the next available round of funding.

The group is a Category A, as it has never been funded through an NSERC grant. The group will need partner and international collaborator statements of interest. A. St-Hilaire will write a 1-

page document that can be sent to potential partners and international collaborators that includes the proposed Network's objectives, structure, themes, and examples of sub-themes. Additionally, the letters to potential collaborators will include a statement about the need for either financial or in-kind support. Also, an outline to why this research network is a priority for their organization.

The proposed name for the network is the Canadian Environmental Flows Research Network (CEFRN), with the short-form NSERC E-Flows Net.

Calendar

- Draft one-pager to circulate to the working group — Feb 10
- Send letters to potential international collaborators — Feb 28
- Theme leaders will write their sections: — March 7
- Receive letter from collaborators — March 15
- Receive letters from provincial supporters — March 15
- Receive letters of support from practitioners — March 15
- Receive letters of support from industry — March 15
- Full draft of LOI sent to working group — March 15
- Full draft of LOI sent to network — March 20
- Submit LOI to NSERC — April 1
- Conference call to discuss next steps — April 16

Once the LOI is submitted, the group will continue to build the Network. The first project will be to create a manuscript comprised of a synthesis of the available E-Flows research across Canada. The group will also continue to gather information and metadata.

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Recommended Theme leaders

- Hydrological: Andrea Bradford
- Ecology: Wendy Monk or Allen Curry
- Non-Flows: Mike Van den Heuvel
- Decision-making: Simon Courtenay or Oliver Brandes

Conclusions

The workshop presentations and discussions can be summarized as follows:

- The workshop presentations covered the general themes of E-Flows research needs and perspectives of practitioners.

- Common topics discussed in the presentation include non-stationarity, aboriginal involvement and the need to consider social and cultural aspects.
- The presentations highlighted many research priorities, but with input from the whole group, a subset have been selected that encompass the most pressing issues for the future of E-Flows research.
- The objective for the Network is to enable a transformation from concepts to E-Flows practice by identifying and validating ecological and social responses to managed flows, and how to achieve these flows while maximising the economic, social and cultural benefits from water. Support future ecosystem-based water planning from industry, governments, stakeholders and rights holders.
- The need for a national E-Flows research network was agreed upon and steps will be taken to submit a proposal to NSERC this year.
- Regardless of the success of the 2018 proposal, the group will continue to work towards developing the Network.

Acknowledgements

The workshop was made possible by the financial support received from NSERC, the Trottier Family Foundation, and the Québec Ministère du Développement durable, de l'Environnement et de la Lutte contre les Changements Climatiques. The workshop organizers thank Michelle Sault for her facilitation that not only kept the workshop on task, but also enabled all workshop participants to contribute their knowledge and ideas. A big thank you to Timothy Anderson who opened and closed the workshop with traditional ceremonies, and also contributed his thoughts on water resource issues throughout the workshop. Finally, the organizers thank the workshop participants for taking the time to contribute to the workshop and share their knowledge.

List of Participants

Workshop Chairs: André St-Hilaire, Wendy Monk, Daniel Caissie, and Michael Van den Heuvel
Editor: Jess Kidd

Table 2. Workshop Participants

Name	Association
Bergeron, Normand	Institut national de la recherche scientifique (INRS)
Berthot, Laureline	INRS & Canadian Rivers Institute (CRI)
Blais, Daniel	Quebec Ministry of Sustainable Development, Environment and Parks (MDDELCC)
Bourgault, Marc-Andre	Université du Québec à Montréal (UQAM)
Bradford, Mike	Fisheries and Oceans Canada (DFO)
Brandes, Oliver	University of Victoria & POLIS Project on Ecological Governance
Burge, Leif	Stantec & CRI

Carroll, Greg	NB Power
Clarke, Keith	DFO
Cook, Steven	Carleton University
Curry, Allen	University of New Brunswick & CRI
Cyr, Jean-François	MDDELCC
Demers, Marc-André	Regroupment des Organisms de Bassins Versants du Québec (ROBVQ)
Duane, Calvin	Canadian Natural Resources Limited
Gorman, Mat	NB Power
Guay, Jean-Christophe	HQ
Guthrie, James	Imperial Oil
Imhof, Jack	Trout Unlimited
Janusz, Richard	DFO
Jardine, Tim	University of Saskatchewan & CRI
Jenkins, Rhys	Rio Tinto
Johnston, Patricia	Hydro Quebec (HQ)
Kirby, Judith	MDDELCC
Larocque, Marie	UQAM
Li, Qing	Government of Prince Edward Island
Linehan, Janice	Suncor
Martel, Guy	BC Hydro
Mass, Tony	Forum for Leadership on Water (FLOW)
Metcalfe, Robert	Ontario Ministry of Natural Resources and Forestry (OMNRF)
Mingelbier, Marc	Quebec Ministère des Forêts, de la Faune et des Parcs (MFFP)
Orlofske, Jessica	University of Wisconsin-Parkside & CRI
Ouarda, Taha	INRS
Peters, Daniel	ECCC
Phare, Merrell-Ann	Centre for Indigenous Environmental Resources (CIER)
Poff, LeRoy	Colorado State University
Porter, George	NB Power
Smokorowski, Karen	DFO
Tharme, Rebecca	Riverfutures Ltd.

Table 3. Working Group Participants

Name	**Association**
Berthot, Laureline	INRS & CRI
Burge, Leif	Stantec & CRI
Caissie, Daniel	DFO
Kidd, Jess	CRI
Monk, Wendy	ECCC & CRI
Ouarda, Taha	INRS
Peters, Daniel	ECCC
Smokorowski, Karen	DFO
St-Hilaire, André	INRS & CRI
Van den Heuvel, Michael	UPEI & CRI