Final Report

Ministry of Forests, Lands and Natural Resource Operations

Surface Water Allocation in a Changing Climate:

Data Gaps, Needs, and Priorities

Prepared by ESSA Technologies Ltd. in partnership with WaterSmith Research Inc.

Surface Water Allocation in a Changing Climate:

Data Gaps, Needs, and Priorities

Prepared for:
BC Ministry of Forests, Lands and Natural Resource Operations

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Peace River Valley, British Columbia (Dave Marmorek, 2013)

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Executive Summary

To be better positioned to manage water supplies into the future, British Columbia water managers and other water professionals require support and a clearer understanding of data and modelling needs and actions to address those needs. To support collection of such information, a Climate Action Planning process is underway by the BC Ministry of Forests, Lands and Natural Resource Management (MFLNRO). This scoping study was conducted to assess the needs, information gaps, and priority options to better support surface water allocation decisions in the context of climate change, focusing on improving decision-making around: (1) new water licenses/authorizations; (2) environmental flow needs; and (3) regulatory restrictions for managing water in times of scarcity/drought. To do so, this research involved a combination of email inquiries, interviews, desktop research, structured surveys, and group discussions with various water professionals across British Columbia. Through this research we identified the following priorities:

Short-term (1-2 years)

- Deliver training in existing/new approaches to inform water allocation decisions
- Enhance existing tools available for each region
- Implement statistical analyses using historical streamflow data
- Develop generalized hydrologic indices for understanding environmental flow needs
- Enhance existing operational systems for in-season forecasting

Either short or long-term

- Improve harmonization of hydrometric data from multiple organizations with existing data portals
- Collect continuous hydrometric data at new locations

Long-term (>3 years)

- Extend existing tools to other regions/hydrological contexts
- Develop water allocation/management plans
- Account for future climate in existing/new approaches for assessing environmental flow needs

This list represents a “bottom-up” perspective on the key issues that need to be addressed. Interestingly, these priorities focus on addressing current challenges and not exclusively on addressing future climate impacts. Though the level of support for this list of priorities was very strong among the group, the number of individuals involved in identifying these priorities was relatively small, and as such these results should be interpreted with that constraint in mind. Nonetheless, the hope is that this information will be helpful in providing guidance and an initial framework for decision makers who are planning and implementing actions to improve British Columbia’s preparedness for future climate.

1 Introduction

Analyses of historic conditions over the last century and projections outward suggest that climate impacts on British Columbia's waterways could be significant (Pike et al. 2008; 2010; Rodenhuis et al. 2009; Tohver et al. 2014). Climate-induced changes in precipitation and air temperature are expected to have a strong influence on runoff dynamics as mediated by changes in water storage in the short (through changes in snowpack) and long term (through changes in glaciers). Where winter air temperatures are continuously below zero, rates of snow accumulation may increase with increasing precipitation. In locations where winter air temperature oscillates around freezing, the form of precipitation (snow vs. rain) is expected to change. Warmer air temperature can delay the accumulation of snowpack in the fall and advance the timing of snowmelt in the spring. For glacier influenced watersheds, increasing summer air temperature increases annual ablation and glacial retreat, thus altering summer streamflow. Moreover, decreasing summer and fall precipitation can exacerbate summer low flows, particularly for rainfall-dominated watersheds. In watersheds heavily influenced by groundwater, surface water-groundwater interactions can also change along the longitudinal profile of a river. Impacts on precipitation and air temperature can also influence evapotranspiration rates in forests, which affect the soil water balance and, thus, soil wetness and runoff responsiveness. All of these changes to runoff can influence the quantity, timing, duration, and frequency of streamflows.

Underlying these potential changes is evidence of increasing variability in hydroclimatic conditions (Milly et al. 2008; NRC 2011) and observations that these patterns can be synchronous across large landscapes (Stewart et al. 2005). These observations imply daunting challenges for water managers if the past cannot be reliably used to predict the future, and if key patterns of change will be common across large landscapes. Moreover, the current management system is based on a monitoring network designed under a different hydroclimatic regime (M. Miles and Associates Ltd. 2003; OAG 2010), with emerging pressures from increasing human demands for water, a new regulatory requirement for environmental flow needs, and increasing development from other resource uses that can have direct and/or indirect impacts on water resources. Future allocations will also be constrained by residual flows from past allocations.

To be better positioned to manage water supplies into the future, British Columbia water managers and other water professionals require support and a clearer understanding of data and modelling needs and actions to address those needs. Positioning can focus on areas where water conflicts have occurred and recent analyses or mapping of flow sensitivity indicate problems will continue into the future (Rodenhuis et al. 2009; Ptolemy 2009). A path forward can also be informed by other research around policy recommendations (TRCA and ESSA 2012) and development of tools for understanding climate impacts on water resources (Nelitz et al. 2013), yet this research is not specific to the needs of British Columbia. To support collection of such information, a Climate Action Planning process is underway by the BC Ministry of Forests, Lands and Natural Resource Management (MFLNRO).

This scoping study was conducted to assess the needs, information gaps, and priority options to better support surface water allocation decisions in the context of climate change, focusing on improving decision-making around: (1) new water licenses/authorizations; (2) environmental flow needs; and (3) regulatory restrictions for managing water in times of scarcity/drought. Other decisions/information needs, such as flood protection, works in/about a stream, groundwater licensing, and water quality were identified as important, but excluded from the scope for a variety of reasons.

While multiple modes of engagement were used to gather information and identify information gaps, this study was not intended to provide an exhaustive list of all information that might be relevant to water allocation decisions. Rather, it was intended as a first approximation of the perceived needs and priorities as informed by a sample of water allocation staff from across the province. With these constraints in mind, the information in this report is intended to be used to inform priorities and future investment decisions by provincial government decision makers.

2 Approach

This study involved a combination of desktop research and participatory engagement of water professionals across British Columbia. In particular, we completed five tasks which formed the basis of collecting the information contained in this report:

Task 1 – Email Inquiry: The research of others in climate adaptation planning indicates that the current "state of readiness" is an important consideration when deciding on opportunities to address future challenges related to climate change (Ford and King 2013). We distributed a set of questions to regional water managers and staff in Victoria to (1) gather some baseline information on the current "state of readiness" around water allocation decision-making to understand current data and/or models being used, (2) identify critical information/decision support needs, and (3) understand possible options to better address climate change in water allocation decisions. These questions included:

What data are currently used to support water allocation decisions in your region?

What models/analyses are currently used to support water allocation decisions in your region?

How well are the impacts of climate change integrated in water allocation decisions/models in your region?

What are the priority data/modelling needs to better address climate change in water allocation decisions in your region?

Are you aware of any good examples/case studies from elsewhere or models/approaches that integrate climate change into water allocation decisions?

Task 2 – Phone Interviews: Based on a synthesis of findings from Task 1, we convened a conference call with an advisory group and conducted a limited set of phone interviews with water managers and other technical experts to supplement our understanding of current data/models and future information/decision support needs.

Task 3 – Desktop Research: Using this baseline understanding and drawing upon the research team's collective knowledge/experience, we organized our understanding of the current situation to identify six categories of decision support needs: policy framework, awareness, data quantity/quality, water supply and demand analysis, environmental flow needs, and drought conditions. Next, we developed a draft list of options to address those needs based on the range of input and considerations that had been provided (see Appendix A). We then conducted focused desktop research to provide supporting details around these options and identify examples of how these options have been applied in BC or elsewhere, focusing on

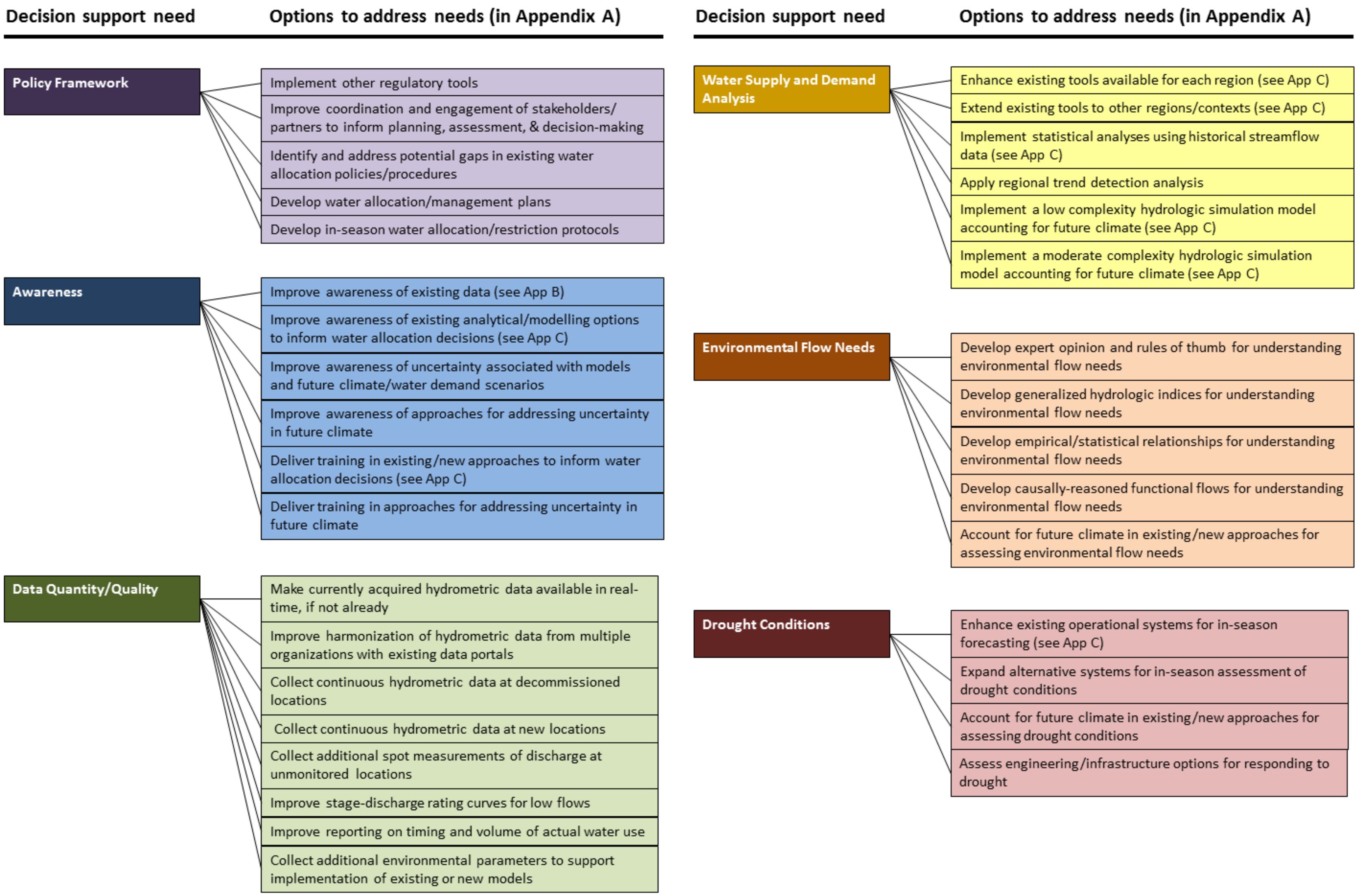

Figure 1. Overview of the decision support needs and options to address these needs (described in Appendix A). Some options reference Appendix B (summary of existing data) or Appendix C (summary of alternative approaches) to elaborate on more detailed considerations.

examples where climate change considerations have been included. We also conducted research to summarize currently available data (see Appendix B) and models/analytical approaches that are either currently being used in BC or could be used to support water allocation decision-making (see Appendix C). Based on this research we revised the list of options to address the decision support needs and summarized them for use in subsequent tasks (Figure 1). Before being finalized, this list of options was also reviewed by members of the advisory group.

Task 4 – Manager Survey: Drawing upon this list of options, we developed a web-based survey to engage provincial water managers and individuals in a provincial water allocation community of practice for their opinions on priority options to address moving forward. The survey addressed both individual decision support categories and cross-cutting issues. A background document was distributed as a companion to the survey, which described the survey options in more detail. The survey included 12 questions. Questions asked respondents to select from a list of options to identify those items they thought were the MOST important to address, as well as those items that were the LEAST important to address. The survey remained open for 10 days (see Appendix D). Responses to each question were summarized in bar charts, and the top 10 options across all categories were identified to inform further discussions (see Section 3).

Task 5 – Final Prioritization: A final conference call was convened among the advisory group and survey respondents (15 individuals in total). The purpose of the call was to discuss results of the survey, assess the group's level of support for the top 10 emerging options, identify any critical gaps, and develop a shorter list of priorities from this list (see Agenda in Appendix E). Three questions were posed during the conference call to inform discussions and identify emerging priorities (see Final Prioritization Survey in Appendix E).

3 Survey Results

As noted, a web-based survey was deployed to provincial water managers for their opinions on priority options to address (see questions in Appendix D). The options that were presented in the survey are summarized in Appendix A. A summary of results from the survey is provided on the following pages. The survey was completed by 18 respondents. These respondents included individuals from MFLNRO and MOE, both headquarters (Victoria) and all regions of the province with the largest proportion being located in the Thompson/Okanagan or Victoria (Figure 2). A large majority of respondents indicated that climate change impacts are "not integrated at all" in current decision making, with a small number indicating that "integration is in progress" or "partially integrated" (Figure 3).

Water allocation decision-making was generally rated as "weakly supported" in the areas of awareness of data/models and tools for assessing drought conditions. Decision-making is, on average, seen as "weakly" to "somewhat supported" in the areas of environmental flow needs assessment and water supply and demand analyses, while being "somewhat supported" in the area of data quantity/quality and "somewhat" to "strongly supported" in the area of policy frameworks (Figure 4). Accompanying this assessment is an illustration of the relative importance of addressing the six categories of decision support needs based on the current situation (Figure 5). Opportunities to improve water supply and demand analysis received a strong and consistent level of support across respondents. Environmental flow needs also received a strong level of support as being one of the most important areas to address. There was moderate positive support for addressing data quantity/quality. Drought conditions, policy framework, and awareness were rated (in decreasing importance) as the least important categories to address by the largest number of respondents, and most important by the fewest respondents. These results provide an aggregate measure of the relative importance of a category of actions, within which many individual options are embedded. As such, they do not provide an indication of the relative importance of individual options across categories (i.e., they cannot be used to compare importance of individual options across categories).

Figure 6 provides a breakdown of the relative importance of all options within each category of need (i.e., the full list of options in Appendix A). The rank order of options is based on sorting by the number of times it was identified as most important. Another way of sorting could use the overall level of positive or negative support, calculated by subtracting the negative from the positive support. This approach leads to a slightly different rank order for only a few options (bottom three options in data quantity/quality). The list of top 10 options identified as most important to address across all six categories is presented in Table 1. This list includes the options receiving the most votes across all categories, which includes the top three options from water supply and demand analysis, top two options from environmental flow needs and data quantity/quality, as well as the top options related to drought conditions, policy framework, and awareness.

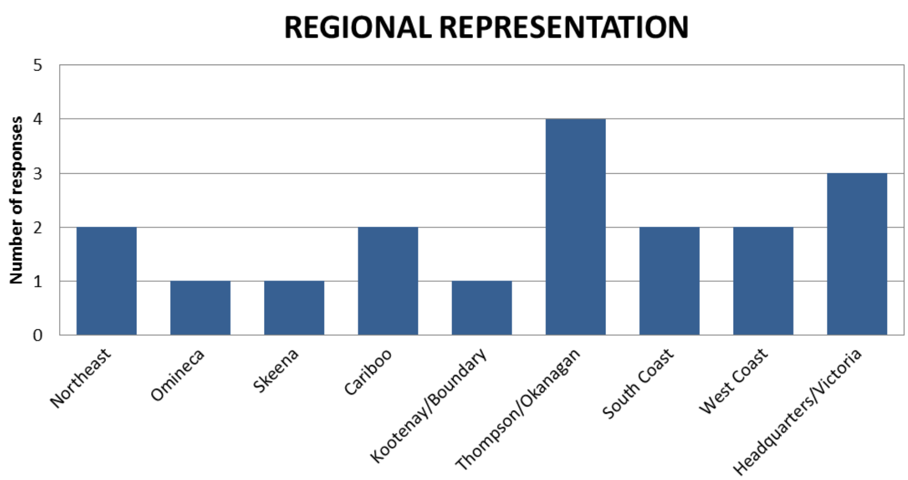

Figure 2. Representation of survey respondents across FLRNO regions (18 responses in total).

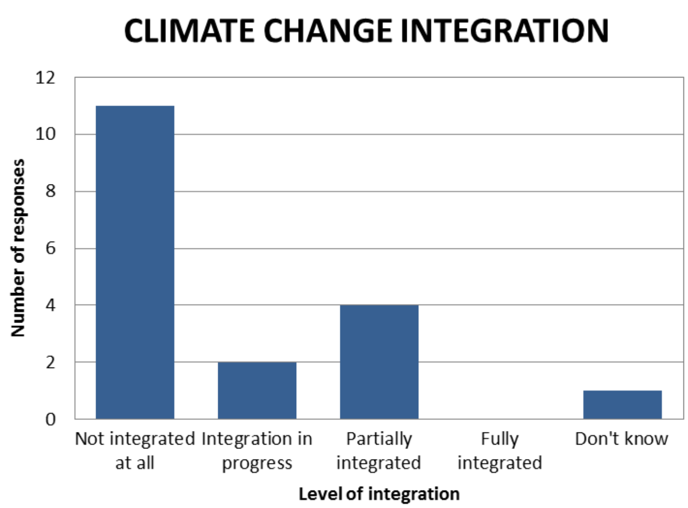

Figure 3. Level of integration of climate change impacts in current decision-making.

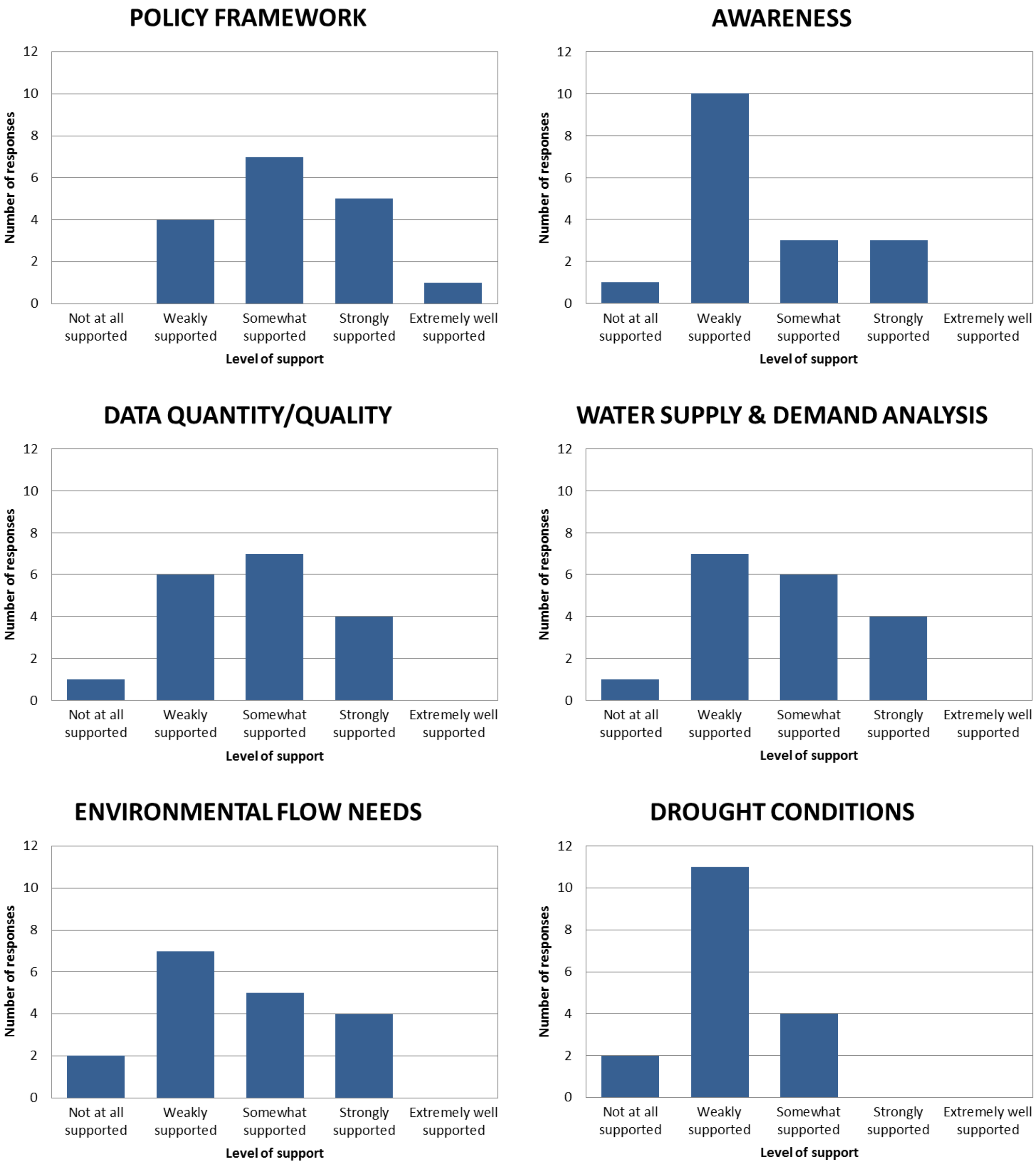

Figure 4. Level of support in decision-making as related to six areas.

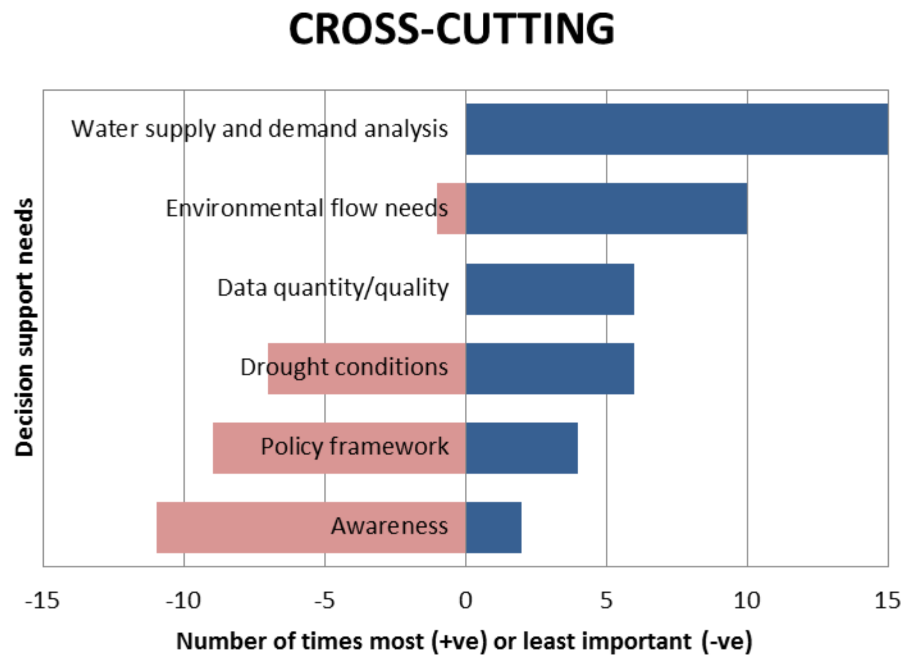

Figure 5. Relative importance of six areas with decision support needs based on a sorting by number of times identified as most important.

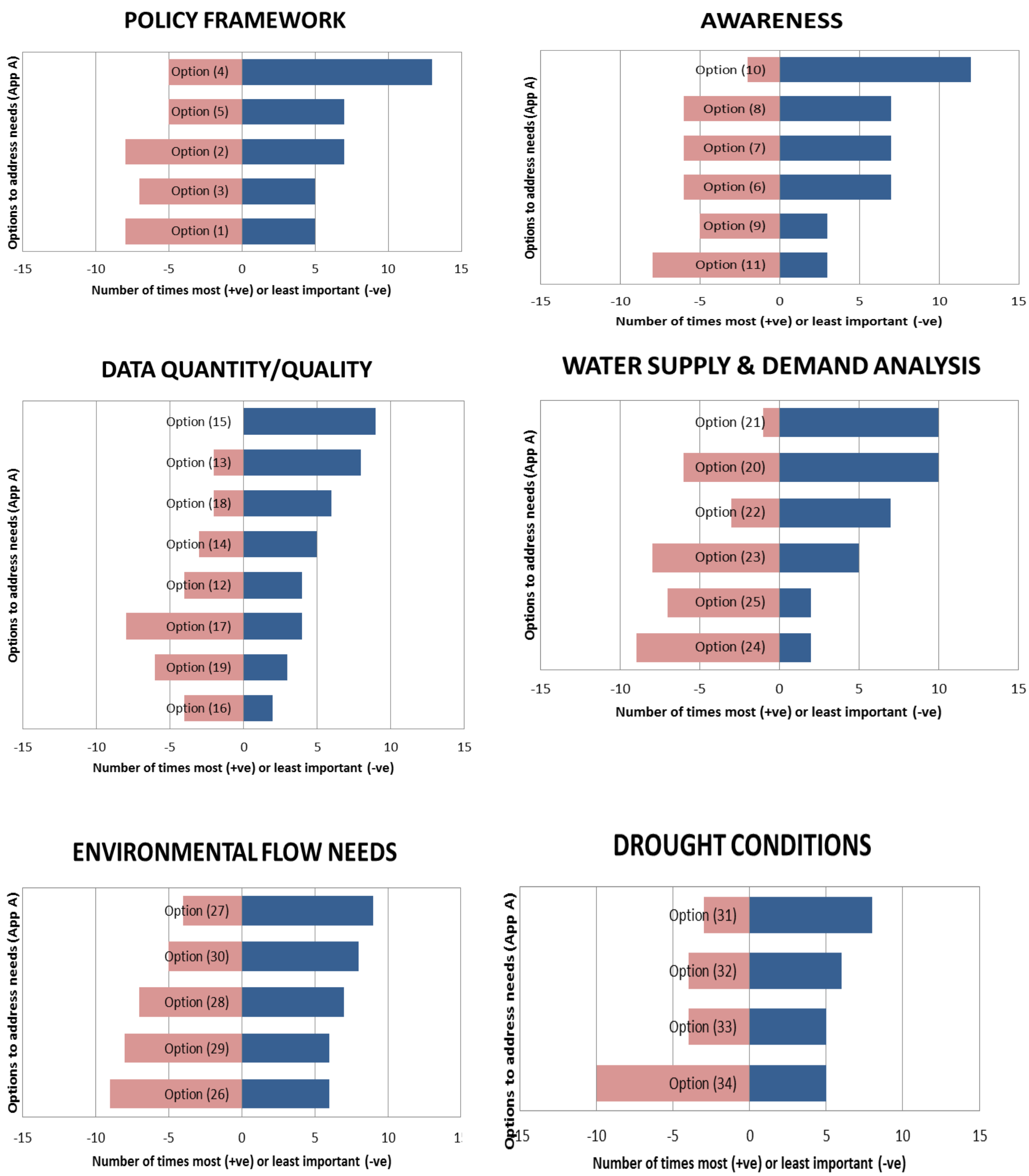

Figure 6. Relative importance of different options to address decision support needs across different areas based on sorting by number of times identified as most important. See Appendix A for a full description of these options.

4 Emerging Priorities

A final conference call was convened to review the results of the survey and identify a short-list of priorities based on a longer list of candidate priorities that emerged from the manager survey (options in Table 1). The conference call was attended by 15 individuals, which included a relatively equal mix of representatives from the advisory group and survey respondents. After a presentation of the survey results (from Section 3), people were asked to respond to three questions using a web-based survey:

What is your general level of support for this list of top 10 options as representative of provincial priorities?

Which of these priorities are short-term (1-2 years) versus long-term (3 or more years) actions?

What are the top 3 options to pursue based on a consideration of feasibility, cost, and impact?

Responses to these questions were immediately reviewed with the group. Overall the group was supportive of the top 10 priorities with a majority indicating strong support (four or five fingers in Figure 7). The ratings relating to whether options are short-term vs. long-term opportunities are summarized in Figure 8. A tally of the number of times an option was identified as being most important is provided in Table 1. When considering both the level of support and timeliness, short-term priorities receiving top ranked support include: (10) Deliver training in existing/new approaches to inform water allocation decisions, and (27) Develop generalized hydrologic indices for understanding environmental flow needs, while long-term priorities receiving top ranked support include: (4) Develop water allocation/management plans, and (21) Extend existing tools to other regional/hydrological contexts.

Table 1. Ranking of top 10 options emerging from a manager's survey. These options are described in more detail in Appendix A.

Short title of option	Area of decision support need	Vote tally	Short or long term
Option (10): Deliver training in existing/new approaches to inform water allocation decisions	Awareness	7	Short-term
Option (27): Develop generalized hydrologic indices for understanding environmental flow needs	Environmental flow needs	7	Short-term
Option (4): Develop water allocation/management plans	Policy framework	6	Long-term
Option (13): Improve harmonization of hydrometric data from multiple organizations with existing data portals	Data quantity/quality	5	Equally short or long term
Option (21): Extend existing tools to other regions/ hydrological contexts	Water supply & demand analysis	4	Long-term
Option (15): Collect continuous hydrometric data at new locations	Data quantity/quality	3	Equally short or long term
Option (20): Enhance existing tools available for each region	Water supply & demand analysis	3	Short-term
Option (22): Implement statistical analyses using historical streamflow data	Water supply & demand analysis	3	Short-term
Option (30): Account for future climate in existing/new approaches for assessing environmental flow needs	Environmental flow needs	2	Long-term
Option (31): Enhance existing operational systems for in-season forecasting	Drought conditions	2	Short-term

A number of important issues were raised as a result of the roundtable discussion that provide some cautionary notes for interpreting the emerging priorities and implementing next steps:

- The number of survey respondents (18) and attendees on the conference call (15) was relatively small. As well, the conference call had little representation of people who make water allocation decisions. As such, the emerging priorities should be viewed as preliminary and cautiously interpreted in terms of how well they represent the priorities of a broad group of water allocation decision-makers. It was also seen as important to engage individuals from the regions to work on clarifying details around and implementing any of these priorities.
- Training was identified as a top priority. Prior to developing and implementing a training program it was acknowledged that there needs to be a reasonable understanding of the landscape units where historic fish-flow conflicts have arisen and the reasons for these conflicts. Within that context there needs to be careful consideration of which data and approaches around water supply and demand analysis, environmental flow needs, and drought conditions are being presented through training since all approaches will be designed for specific applications, and have strengths and weaknesses. Training in any approach implies its endorsement by the province. So although training is seen as an important prerequisite for addressing the implications of climate change there needs to be careful thought provided to what is contained in any training module.
- On several occasions it was noted that work is currently underway around a number of these options and that these results reinforce the importance of those efforts (e.g., training, improved harmonization of data, developing or implementing existing hydrologic indices for understanding environmental flow needs, enhancing/extending existing tools, enforcement of Water Sustainability Act). The implication is not that the priorities in Table 1 are irrelevant, but that there is an existing knowledge base and capacity from which to implement some of these options.
- Although this scoping study began with a focus on climate change, the emerging priorities place more emphasis on addressing current challenges in decision-making than addressing future climate change impacts and related challenges.
- In terms of the criteria for prioritizing (feasibility, cost, and impact), it was recognized that there will be resource constraints (money and technical expertise) when pursuing some of these options which may be difficult to overcome. As such, it was also seen as important to avoid delays by focusing on things in the near-term (without compromising quality) to address some of the current challenges that will provide benefits for adapting to future climate. Although short-term and long-term priorities can be mutually supportive, a comment was made that the distinction between short-term and long-term opportunities may be a function of available resources. For instance, some options may not be possible for provincial staff to implement in the near-term, but with outside capacity and additional financial resources could be completed in short order.
- There were also some concerns that the emerging priorities did not sufficiently capture the interdependence of options that might be required to address some of the priority needs. For instance, it was expressed developing water allocation/management plans was identified as a top ranked priority, yet there was an inconsistency with the lower ranking of the tools and strength of data that would be required to support development of those plans. Development of management plans require strong tools and good quality data so their ranking was seen as needing to be somewhat inseparable. Further exploration of this potential inconsistency seems warranted as to the reasons for it and how to respond to it.

5 Closing Thoughts

Overall, this scoping study was successful in identifying priorities that would help improve water allocation decision-making across the province. It represents a “bottom-up” perspective on the key issues that need to be addressed and potential solutions that could be implemented. We acknowledge, however, that the emphasis of these priorities is on addressing current challenges and not exclusively on addressing future climate impacts. This outcome is consistent with the views of others conducting climate adaptation research who have noted that the current situation and “state of readiness” is an important factor to consider when preparing for future climate. Although we had a reasonable level of response to the manager survey and engagement on the final conference call, the number of individuals involved in identifying these emerging priorities is a relatively small sample of water practitioners across the province. These results should therefore be interpreted with that constraint in mind. Nonetheless, the hope is that this information will be helpful in providing guidance and an initial framework for decision makers who are planning and implementing actions to improve British Columbia’s preparedness for future climate.

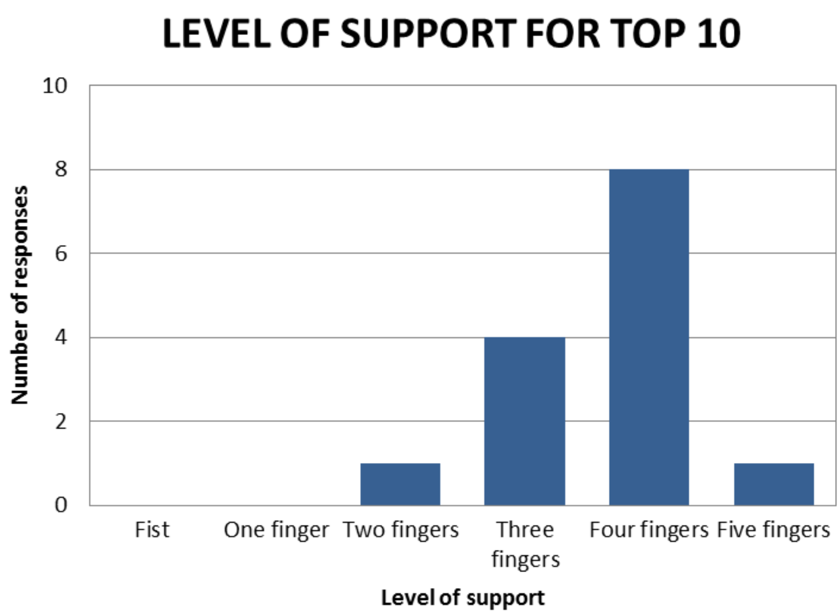

Figure 7. Level of support for the top 10 options in Table 1 on a scale ranging from no support (fist) to strong support (five fingers).

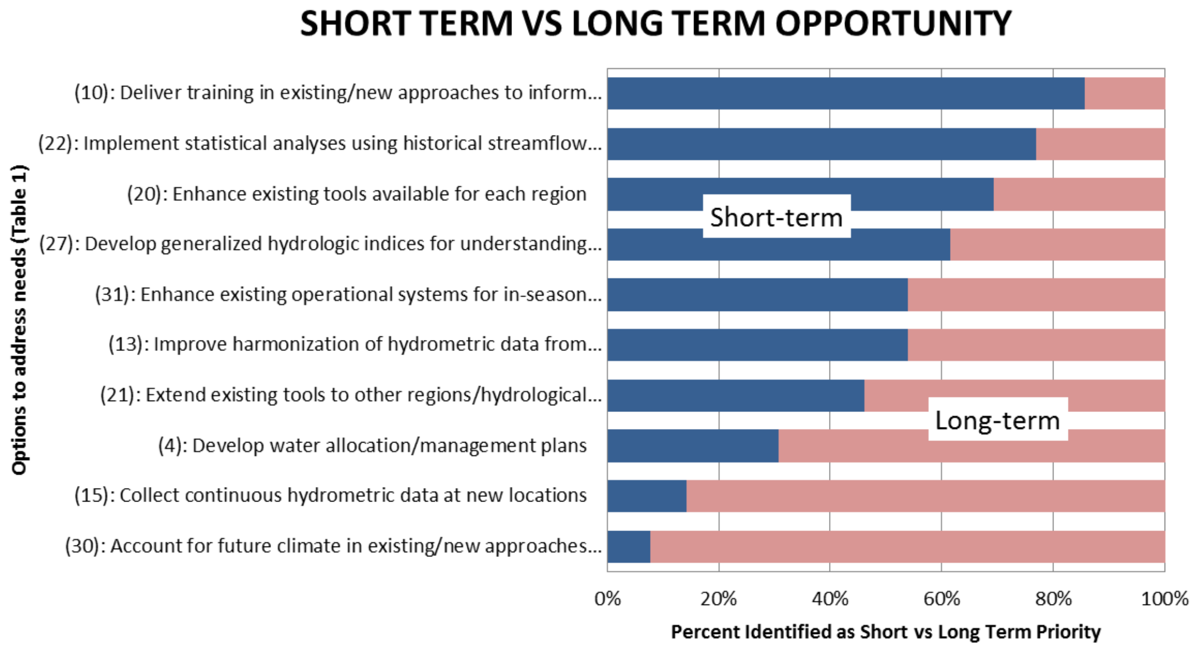

Figure 8. Responses from the group on whether the top 10 options are short-term (1-2 years) or long-term (3 or more years) opportunities. Rank order of options based on the percentage of time that the option was identified as being a short-term opportunity (i.e., with highest percentage being highest ranked).

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Appendix A: Options to Address Decision Support Needs

Option to address decision support need	Description/rationale	Examples
POLICY FRAMEWORK		
(1) Implement other regulatory tools	Various types of regulatory tools, other than water licensing, may be necessary to deal with the increasing complexity of water management, especially in situations with significantly changing availability and timing of water and/or in high demand areas. These other tools could include penalties, incentives for water efficiency, and/or zoning based on hydrological or environmental parameters (e.g., fisheries/temperature sensitive watersheds).	• Comparative analysis of tools for water use management (Nelitz et al. 2009) • Negotiated agreements through multi-stakeholder bodies in times of water scarcity (e.g., through Water Use Plans, BC Hydro has agreed voluntarily to reduce its water allocation at many hydroelectric facilities to provide more flows for fish (BC Hydro. 2015)
(2) Improve coordination and engagement of stakeholders/partners to inform planning, assessment, and decision-making	Water allocation planning (as described in above option) is usually one of a number of planning activities within a basin. It is critical that water allocation is consistent with the objectives and activities prescribed by other plans. Collaborative water planning (e.g., considering surface and groundwater supply/demand, incorporating land use effects on instream flows) is considered good planning practice, as well as having multiple stakeholders participate. There is no single approach to designing a multi-stakeholder process; however, a broad set of good practices can contribute to successful outcomes of collaborative decision-making. Establishing clear roles for regional and local stakeholders, advisory groups (e.g., Watershed Management Boards), and opportunities for them to engage and collaborate along the process will improve outcomes of decision-making.	• Multi-stakeholder discussion on the implications of climate change for water management in the Okanagan basin (Cohen et al. 2004) • Recommendations for Improving Alberta's Water Management and Allocation (Minister's Advisory Group on Water Management and Allocation 2009) • Principles and guidance on collaborative water management and multi-stakeholder processes (Fraser Basin Council 2011) • Criteria and best practices for collaborative planning (Frame et al. 2004)
(3) Identify and address potential gaps in existing water allocation policies/ procedures	There may be other gaps in policy and procedures that could possibly be addressed to improve decision-making and better incorporate changing availability and timing of water due to climate change (i.e., more or less water at different times of year).	• Policy requiring storage capacity for all new water authorizations in certain areas • Policy requiring consideration of 1 in 15 year 7-day low flows instead of the current 1 in 5

Option to address decision support need	Description/rationale	Examples
(4) Develop water allocation/management plans	Water allocation plans are a means of identifying water demands and ensuring that longer term water use is compatible with the goals of a sustainable environment. Such a planning process involves defining problems, formulating strategies to address them, and understanding trade-offs among competing objectives (as described in above option) to inform decision-making. Water allocation planning processes have been undertaken in various areas of the province by local governments and community groups, and the resulting plans provide some guidance to water managers when they make decisions about issuing new licenses.	• Examples of water allocation and water management plans developed in the province are available at the MFLNRO website[1] (E.g., Cowichan Water Management Plan, Okanagan Basin Water Management Plan, Township of Langley Water Management Plan) • Rethinking Our Water Ways (Fraser Basin Council. 2011) provides an overview of a variety of planning processes that are available to communities in BC, including recommendations on how to incorporate climate change considerations into water supply and demand planning • BC Water Use Plan Guidelines (Province of British Columbia 1998) • An overview of international best practice on water allocation management and planning (Speed et al. 2013) • Vancouver Island region provides water resource information and maps to indicate times when water is available for diversion to storage and when water cannot be taken from a river • Reports describing the hydrology, water use and conservation flows for various fish species throughout B.C. such as the Okanagan Lake Basin (NHC and Ptolemy 2001) and Fraser River Action Plan (Rood and Hamilton 1994).

[1] Water Allocation and Water Management Plans. Ministry of Forests, Lands, and Natural Resource Operations. Available online: http://www.env.gov.bc.ca/wsd/water_rights/wap/

Option to address decision support need	Description/rationale	Examples
(5) Develop in-season water allocation/ restriction protocols	Management protocols are important for establishing consistent and defensible approaches to addressing water supply constraints, including in-season shortages. Developing in-season protocols would involve clarifying the steps/criteria for managing restrictions on water withdrawals during drought periods. Protocols would specify important data/systems and analytical option(s) for assessing water availability, consumption requirements, environmental flow needs, and uncertainty, and would outline options and priorities for drought response. Relating protocols to timing of supply vs. demand would help address seasonal variability.	• Identify important indicator streams, landscape units, and/or snowpack monitoring stations in region, coupled with key streamflow/snowpack thresholds for defining levels of concern and/or restrictions • Accurately report on stream flow during droughts while being mindful of potential confusion when reporting around flow augmented streams • Prioritize the regional water supplies with regards to severity of restrictions at various levels of concern • Utilize in-season hydrologic forecasting information (snow bulletin, streamflow predictions) provided by River Forecast Centre (link to these data in Appendix B) • Utilize protocols outlined in the BC Drought Response Plan (Econnics 2010)

Option to address decision support need	Description/rationale	Examples
AWARENESS		
(6) Improve awareness of existing data	There are various data sets and maps across the province generated and maintained by different agencies, at the federal, provincial and regional levels (e.g., Water Survey of Canada, MFLNRO, MoTI), yet there may be limited awareness about them. Local knowledge and experience can also be very valuable. Raising awareness through various means (community of practice, training, etc) might aid in related analyses and decision-making by staff with the existing technical capacity to apply these data.	• See list of available data sources in Appendix B
(7) Improve awareness of existing analytical/ modelling options to inform water allocation decisions	Various technical approaches are currently being used/ developed to support water allocation decisions across MFLNRO's regions. Decision-making may be improved with increased awareness and application of these tools to those staff with the existing technical capacity to apply them.	• North West Water Tool (NWWT) and North East Water Tool (NEWT) are in use, Omineca Hydrology Model is under development/testing, and Okanagan Water Allocation Tool (OWAT) is under review • Mapping of flow-sensitive landscapes (Ptolemy 2009) • See list of analytical/modelling options in Appendix C
(8) Improve awareness of uncertainty associated with models and future climate/water demand scenarios	Uncertainties can include an imperfect knowledge about a river, natural variation across watersheds and years, errors in human observation, varying assumptions in the way data could be used to provide broader inferences, and a lack of clarity about how a system should be managed. There are uncertainties today and will continue to be when making future projections under a different climate. Further, uncertainties can be associated with the output generated by any model. It is important to understand, estimate, and document uncertainties so regulators and decision-makers are aware of the limitations and can make more informed decisions. For instance, there are uncertainties with existing tools (NWWT/NEWT) and their use of mean monthly flows to represent timing of critical periods which can vary across months and years that do not coincide with timing of mean monthly low flows.	• Supply and demand uncertainty considerations in the Okanagan Water Allocation Tool Plan (Wester Water Associates Ltd. 2014) • Systematic analysis of uncertainty management in model-based decision support (Walker et al. 2003) • Approach to qualitatively incorporate climate change assessment into water management decision-making by ranking decisions based on their climate sensitivity, significance, and stakeholder support (Purkey et al. 2007)

Option to address decision support need	Description/rationale	Examples
(9) Improve awareness of approaches for addressing uncertainty in future climate	Uncertainties are a necessary consideration when making water allocation decisions in the context of climate change. There are unknowns in terms of the analytical/modelling approach and uncertainties in terms of which climate forcings (model and emissions scenario). It can be a challenge to coherently incorporate these uncertainties and interpret results into the water allocation decisions. Hence, there may be benefits of raising awareness of options for addressing uncertainties among staff with the existing technical capacity to apply them.	• Systematic analysis of uncertainty management in model-based decision support (Walker et al. 2003) • Supply and demand uncertainty considerations in the Okanagan Water Allocation Tool Plan (Wester Water Associates Ltd. 2014) • Uncertainty assessment of climate change impacts on the hydrology of small prairie wetlands (Zhang et al. 2011) • Guide for Assessment of Hydrologic Effects of Climate Change in Ontario (EBNFLO Environmental and AquaResource Inc. 2010) • Guidance as applied to water management is currently being developed by the Canadian Council of Ministers of the Environment
(10) Deliver training in existing/new approaches to inform water allocation decisions	For staff needing stronger technical skills, capacity, or experience, there may be benefits of investing in training in the use of existing/new approaches to address specific needs in water allocation decision-making. Training could include teaching of approaches ranging from low to moderate technical complexity.	• Trend detection analysis, determination of ecologically based flows, application of existing water allocation tools (e.g., NEWT), water balance calculations, use of various data to support decision-making • See list of analytical/modelling options in Appendix C
(11) Deliver training in approaches for addressing uncertainty in future climate	For staff that currently have the technical skills to undertake analyses/modelling to support water allocation decision-making, there may be value in providing additional training in approaches for incorporating uncertainties and interpreting results from analyses involving a range of future climate projections.	• Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning (Water Utilities Climate Alliance 2010) • Guide for Assessment of Hydrologic Effects of Climate Change in Ontario (EBNFLO Environmental and AquaResource Inc. 2010)

Option to address decision support need	Description/rationale	Examples
DATA QUANTITY/QUALITY		
(12) Make currently acquired hydrometric data available in real-time, if not already	Hydrometric data are currently stored in an online database, though only a subset of hydrometric stations provide real-time reporting. Improvements can be made if more measurements are made available in real-time.	• Environment Canada's real-time hydrometric data portal (Available online: http://wateroffice.ec.gc.ca/google_map/google_map_e.html?searchBy=p&province=BC&doSearch=Go)
(13) Improve harmonization of hydrometric data from multiple organizations with existing data portals	Most current hydrometric data are acquired and consolidated through Environment Canada's Wateroffice. Other hydrometric data (e.g., collected by other agencies and/or water users) may be available and worth consolidating with this station network. Protocol outlined in the Manual of British Columbia Hydrometric Standards (Ministry of Environment 2009) can be used to evaluate and rate data quality.	• Environment Canada's federal-provincial-territorial hydrometric data portal (Available online: http://wateroffice.ec.gc.ca/search/search_e.html?sType=h2oArc) • PCIC data portal for aggregation of meteorological data (see Appendix B) • Cataloging of others' data (e.g., Aquarius software) • See partnerships of others: Okanagan Basin Water Board and Regional District of Nanaimo • See data portal in the Northeast (Appendix B)
(14) Collect continuous hydrometric data at decommissioned locations	Most watersheds in province have experienced a reduction in the number of hydrometric stations since the 1980s and 90s and there is a need to improve the existing monitoring network. Re-establishing stations at previously decommissioned locations with longer term data leverages historical records, which can be informative for trend detection analysis and future forecasting.	• Network deficiencies documented by others with a recognition of the value and need for long term monitoring at decommissioned sites to detect future regional changes in climate (M. Miles and Associates Ltd. 2003; OAG 2010)
(15) Collect continuous hydrometric data at new locations	Most watersheds in the province have experienced a reduction in the number of hydrometric stations since the 1980s and 90s. There is a recognized need to strengthen the existing long term monitoring network. Identified gaps where new stations could be established include small streams, under-represented hydrologic zones, and areas with high pressure/demand.	• Network deficiencies documented by others (M. Miles and Associates Ltd. 2003; OAG 2010), which can include under-represented ecoregions in which most people live in and use water and focus on areas of high fish-flow conflicts
(16) Collect additional spot measurements of discharge at unmonitored locations	Most watersheds in the province have experienced a reduction in the number of hydrometric stations since the 1980s and 90s. There is a recognized need to improve the availability of flow data. Identified gaps include small streams, under-represented hydrologic zones, and areas with high pressure/demand. Spot measurements in these systems can be valuable for	• Network deficiencies documented by others (M. Miles and Associates Ltd. 2003; OAG 2010) • Manually measure winter low flows under ice cover

Option to address decision support need	**Description/rationale**	**Examples**
	supplementing continuous data sets. Spot measurements might also be helpful for filling in specific gaps (e.g., winter low flows under ice cover). Manual streamflow measurements at a range of flow levels, particularly critical low flows (e.g., late summer, winter), would enhance the spatial coverage of information for allocation decision-making. Manual measurements can be used to relate streamflows among neighboring watersheds.	
(17) Improve stage-discharge rating curves for low flows	Accurate manual discharge measurements at extreme low flows are necessary for full calibration of hydrometric stations and, thus, acquisition of accurate, continuously recorded low flows. Many hydrometric stations (including Water Survey of Canada stations) have limited calibration measurements at extreme low flows due to a historical focus on moderate and high flows. Moreover, technical challenges exist with making low flow measurements using conventional velocity-based methods due to low velocities and due to low water levels relative to substrate sizes. Improving rating curves for low flows is particularly important with increasing drought related to climate change.	• Deploy monitoring teams during extreme low flows to capture more calibration observations • Employ tracer-based measurements (e.g., salt dilution gauging) to measure low flows more accurately (Moore 2004; Moore 2005; Hudson and Fraser 2005)
(18) Improve reporting on timing and volume of actual water use	Reliable information on current status of water use and licensing across BC is limited. Information on historic patterns and current volumes of water use, as well as information on future pressures would benefit decision-making. A priority may be to focus on streams in which current flows are highly degraded.	• BC Water Use Reporting Centre is a web-based system that is being piloted to help utilities and large water users regularly record water use (Okanagan Basin Water Board 2012)[2]
(19) Collect additional environmental parameters to support implementation of existing or new models	While there is a recognized need to improve existing streamflow monitoring networks, the spatial coverage is generally more sparse for other environmental variables that are also useful for water supply analysis. Increasing the quantity and representation of watersheds that have hydrometric gauges paired with other environmental monitoring would enhance options for analyses, including calibration and testing of hydrologic models and prediction of climate impacts.	• Snowpack, stream temperature, precipitation, air temperature • Other meteorological variables, particularly global radiation and wind speed • Lower, middle, and upper elevations within watersheds

[2] Okanagan Basin Water Board. BC Water Use Reporting Centre. See: http://www.obwb.ca/tools/bc-water-use-reporting-centre/

Option to address decision support need	Description/rationale	Examples
WATER SUPPLY AND DEMAND ANALYSIS (WSDA)		
(20) Enhance existing tools available for each region	Several useful tools have been developed for individual regions that are designed to facilitate WSDA analyses. These tools are easy to use, require limited data inputs, and concisely summarize water supply and demand volumes for a location of interest. However, the water supply output tends to be limited to average conditions without indication of inter-annual variability, trends, and/or climate impacts. Moreover, because they are based on statistical modelling of historical streamflows, they represent moderate and large watersheds much better than small watersheds due to the greater availability of data from larger watersheds. Opportunities exist to enhance the functionality and/or utility of these tools for decision-making in the regions for which they were developed.	• Northeast (NEWT), Northwest (NWWT), Okanagan Water Allocation Tool (OWAT) and Omineca water tools (see Appendix C). Potential enhancements include extreme low flows (e.g., 5, 10, 20 year return periods), greater certainty for small streams, historical trends in flow rates, projections of climate change impacts on supply • Incorporate the environmental risk framework of the Environmental Flow Needs Policy (approved and signed off) • Consider linking to the FISH Habitat Wizard (include stream assessment report) • Consider integrating water supply analyses that have a focus on fish and environmental flows (e.g., Rood and Hamilton 1994) • Consider integrating landscape analyses of flow sensitive regions (Ptolemy 2009) to inform determinations of environmental flows • Develop ensemble forecasting to examine seasonal flood and/or low flow risks (currently under development by River Forecast Centre for flooding)
(21) Extend existing tools to other regions/hydrological contexts	The existing tools (discussed above, see Appendix C) have proven utility and functionality, and provide a template for being extended throughout the province.	• Extend to southern interior and coastal regions • Adapt to smaller watersheds (e.g., NEWT does not represent small streams well due to limited availability of historical data for small streams)
(22) Implement statistical analyses using historical streamflow data	Flow thresholds can be developed by applying frequency analysis using historical streamflow data from a particular watershed or region. These thresholds can form the basis for estimating water availability. Requires several years of continuous flow data and can be limited by availability of data for extending to the watershed of interest. Requires training in advanced statistical techniques.	• The British Columbia Streamflow Inventory (Coulson and Obedkoff 1998) is currently being updated (Ahmed and Jackson. 2013) • Landscape analyses of flow sensitive regions (Ptolemy 2009) • Low flow frequency analysis to quantify low flow thresholds (e.g., 5, 10, 20 year return periods)

Option to address decision support need	Description/rationale	Examples
		• Hydrologic Engineering Center-Statistical Software Package (HEC-SSP, see Appendix C)
(23) Apply regional trend detection analysis	Investigate regional trends in historical streamflows (low flows, peak flows, annual yields) as a first approximation of potential climate impacts. Approaches can range from relatively straightforward to complex. The different types of data requirements are minimal (i.e., flow data are sufficient); however, a long period of record (e.g., >50 years) is necessary to separate climate impacts from other influences (e.g., Pacific Decadal Oscillation). Moreover, rates of historical changes do not necessarily represent rates of future changes.	• Plot annual maximum, mean, and minimum (7-day mean) flows over the period of record for a hydrometric station to investigate stationarity and inter-annual variability. Examine the data (visually and statistically) for step changes, trends, and shifts in trends
(24) Implement a low complexity hydrologic simulation model accounting for future climate	Low complexity water balance models can be useful for estimating water supply at annual and, potentially, monthly time-steps. They require minimal data inputs (e.g., monthly air temperature, precipitation) and training, but typically perform better at predicting relative changes in water supply than absolute changes. Most are not suitable for estimating water supply at short time-steps (e.g., sub-annual or sub-monthly). Consider for watersheds where regionally derived tools like NEWT are not available.	• WRENSS (WinWrnsHyd and ECA-AB) • Thornthwaite Monthly Water Balance Model • Distributed monthly water balance model for prediction of stream flow regime and annual runoff for ungauged basins in BC (Moore et al. 2012) • See list of modelling options in Appendix C
(25) Implement a moderate complexity hydrologic simulation model accounting for future climate	Moderate complexity runoff models provide a relatively high degree of accuracy in predicting water supply and the impacts of climate change, particularly for short time-steps (sub-monthly). In general, they represent hydrological processes in greater detail than low complexity models and, thus, are more suitable for predicting climate impacts. The data needs are also relatively minimal (e.g., hourly or daily air temperature, precipitation); however, they require advanced training to implement. Consider for watershed studies where investment in significant training and set up costs are worthwhile.	• Models supported by National Research Council Canada through Green Kenue – Raven, HBV-EC, UBC Watershed Model, WATFLOOD • SRM (Snowmelt-Runoff Model) • See list of modelling options in Appendix C

Option to address decision support need	Description/rationale	Examples
ENVIRONMENTAL FLOW NEEDS (EFN)		
(26) Develop expert opinion and rules of thumb for understanding environmental flow needs	Desktop methods for EFN estimation are based on expert opinion, usually a group of specialists in aquatic biology/ecology, fluvial geomorphology and related disciplines. Although these methods have the benefit of being simple to use, quick and inexpensive, environmental flows generated using these methods are more heuristic, opinion-based and more difficult to test. Only hydrological data are required for these methods.	• Tennant Method recommends stream flows based on percentages of Mean Annual Discharge (MAD) (Tennant 1976) • Quantified Mean Annual Discharge (MAD) values/thresholds alongside empirical surveys and fish responses (Ptolemy and Lewis 2002) • Instream flow thresholds as guidelines for reviewing proposed water uses (Hatfield et al. 2003) • Alberta Desktop Method (Locke and Paul 2011) • BC Instream Flow Needs thresholds for fish and fish habitat, developed primarily for small hydropower, is a two-tiered approach based on expert opinion requiring reliable flow records and a good understanding of fish distribution (Hatfield et al. 2003). Limited use since derived thresholds are seen as too conservative. • See BC Environmental Flow Needs Policy • Extensive reviews of EFN methods have been done by others, for British Columbia (Hatfield et al. 2003; 2013), Canada (Linnansaari et al 2013), and an international perspective (Annear et al. 2004; Tharme 2003; Hirji and Davies 2009a; 2009b)
(27) Develop generalized hydrologic indices for understanding environmental flow needs	These methods use natural flow characteristics (e.g., wetted width, depth) or hydrological indices as a surrogate for an ecological target such as habitat availability for a species of interest. Assessing EFN with these methods involves comparing the selected hydrological indices pre- and post-regulation/ withdrawal. There is no requirement to characterize target species habitat requirements or its life-history consequences to flow alteration. The rationale underlying these methods is that biological responses to different types of flow alteration are difficult to predict, and preserving key aspects of the natural hydrograph is a good way to maintain the physical aspects of	• Ecological Limits Of Hydrologic Alteration (ELOHA) (Poff et al. 2010) • Studies examining relationship between flows and hydraulic geometry (e.g., Hogan and Church 1989; Reid et al. 2010) • Indicators of Hydrologic Alteration (IHA) is an early formation of the concept (Richter et al. 1996)

Option to address decision support need	Description/rationale	Examples
	streams on which fish and other ecosystem components depend.	
(28) Develop empirical/ statistical relationships for understanding environmental flow needs	These methods establish a relationship between flow (or other explanatory variables) and target species abundance or habitat availability. The relationship is not established through cause-effect prediction, but based on statistical relations of the studied variables. These approaches may incorporate models (e.g., PHABSIM) that simulate habitat availability and suitability under different flow regimes, usually for a single species.	• Effect of water withdrawal on fish winter habitat (Hatfield 2012) • Physical Habitat Simulation (PHABSIM) (Hatfield and Bruce 2000) • An empirical assessment of PHABSIM using long-term monitoring of coho salmon smolt production in Bingham Creek, Washington (Beecher et al. 2010)
(29) Develop causally-reasoned functional flows for understanding environmental flow needs	These methods are developed for specific species and/or habitats in specific river reaches. They are based on cause-effect conceptual models linking flow and other variables with changes in habitats or life-history survival mechanisms of target species. These approaches are data and resource-intensive, requiring site and aquatic species data, as well as physical habitat measurements and modelling. In some cases, multiple functional flows can be derived from a suite of representative species, allowing for more a more holistic EFN decision framework.	• Okanagan Fish Water Management Tool (Hyatt et al. 2015) • Reviews of these types of approaches summarized by others (Alexander et al. 2013) • BC Hydro Water Use Planning studies[3] • Some environmental assessment studies to support small hydro project development[4]
(30) Account for future climate in existing/new approaches for assessing environmental flow needs	Future climate may lead to either increased or reduced flows at different times of year. These changes will have implications on environmental flow needs and habitat access/availability for various fish species, ultimately requiring greater flexibility in EFN decisions to address changing conditions (WWF-Canada 2011). The above described EFN assessments can be improved by accounting for changes in future climate conditions and flow which are linked to methods to support WSDA that incorporate future climate.	• Evaluation of changes in flow under future climate with an assessment of changes to instream habitats for several fish species in Central Interior of BC (Nelitz et al. 2010) • The Okanagan Water Stewardship Council has formed the Environmental Flows Committee[5] to study the legal, ecological, and economic aspects of Environmental Flows in the Okanagan • Expected changes in flow and EFN under climate change were analyzed in the Northeastern BC (Hatfield et al. 2013)

[3] BC Hydro. Coquitlam-Buntzen WUP: http://www.bchydro.com/about/sustainability/conservation/water_use_planning/lower_mainland/coquitlam_buntzen.html
[4] Project Information Centre. Kokish River Hydroelectric Project. See: http://a100.gov.bc.ca/appsdata/epic/html/deploy/epic_project_home_332.html
[5] Okanagan Basin Water Board. Environmental Flows. See: http://www.obwb.ca/environmentalflowswups/

Option to address decision support need	Description/rationale	Examples
DROUGHT CONDITIONS		
(31) Enhance existing operational systems for in-season forecasting	The River Forecast Centre (RFC) and BC Hydro conduct in-season operational streamflow forecasting. RFC also issues bulletins estimating seasonal runoff volumes, and publishes low flow advisories (i.e., drought ratings). A BC Drought Response Plan is updated on an ad-hoc basis that incorporates low flow forecasts from the RFC. However, forecasts are more-or-less qualitative assessments of anticipated flow levels (i.e. not derived from operational hydrologic simulation modelling) and do not account for climate change. Opportunities exist to enhance in-season forecasting to support short-term allocation decisions and in-season drought response, both in terms of the technical forecasting and dissemination of information.	• Provincial forecasting systems are currently being updated to utilize more advanced models (River Forecast Centre: WARNS to CLEVER, BC Hydro: UBC Watershed Model to Raven, see Appendix C) • Develop/implement operational hydrologic simulation modelling for forecasting low flows • Develop/implement ensemble forecasting of low flows using historical and future climate scenarios (currently being developed by River Forecast Centre for flood forecasting) • Develop a task force/group to improve information sharing among agencies involved with forecasting, monitoring, allocation decisions , drought response
(32) Expand alternative systems for in-season assessment of drought conditions	In-season systems other than operational forecasting can be used to assess the severity and/or timing of critical drought conditions based on regional real-time environmental data (e.g., precipitation indices, streamflow levels). Data requirements are relatively minimal and, once developed, these approaches are relatively straightforward to apply and require minimal training. However, they are not forward looking in terms of predicting future drought frequencies or severity related to climate change.	• Identification of drought indicator streams and landscape units (Ptolemy 2009) • Develop threshold values for drought conditions based on precipitation and/or streamflow data • Assessments being done by the Provincial Technical Drought Working Group
(33) Account for future climate in existing/new approaches for assessing drought	Any of the above methods/approaches can be improved by explicitly accounting for a range of future climate forcings and examining how they affect predictions.	• Drought Preparedness Plan in Saskatchewan (Rowan et al. 2011) • Uncertainty in low flows (Wilby and Harris 2006) • Trends, indices, and approaches for projecting drought conditions provided by others (Dai 2011; Jeong et al. 2014; Gobena and Gan 2013)
(34) Assess engineering/ infrastructure options for responding to drought	A variety of engineering/infrastructure measures could assist in responding to drought – e.g., alternative technologies for pumping, conveyance, storage, and irrigation, techniques for managing stormwater, and/or approaches to water conservation. Assessments of these alternatives could inform the range of drought response options available to decision makers.	• Drought Proofing Australian Cities (Isler et al. 2010) • An Okanagan Homeowner's Guide to Using Rain as a Resource (Okanagan Basic Water Board 2011)

Appendix B: Subset of Available Data Sources

Data	Data description	Source	Data provider
Hydrometric data	Wateroffice provides real-time (daily, hourly, and sub-hourly) hydrometric data and historical data collected at stations across Canada. The HYDAT database provides historical data and station information, which can also be accessed using Environment Canada's Data Explorer (ECDE) to browse and extract HYDAT hydrometric information online, filtering station information, water level, discharge and sediment data.	http://wateroffice.ec.gc.ca/index_e.html http://ec.gc.ca/rhc-wsc/default.asp?lang=En&n=894E91BE-1 https://www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=0A47D72F-1	Environment Canada
Water resources data	BC Water Resources Atlas (BCWRA) is an iMapBC application with enhanced query functionality to enable drilling down to water related data. The Atlas displays information related to the water resources of British Columbia, such as watersheds, water quantity and quality monitoring sites, aquifers, water wells and flood protection works.	http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html	Ministry of Environment
Water resources data	The Water Portal is a map-based water information tool designed to provide public access to a wide range of water-related data and information in northeast B.C.	http://www.bcogc.ca/public-zone/water-information	BC Oil and Gas Commission
Water allocation restrictions	Province-wide layer showing streams having a water allocation restriction. Available in iMapBC (see layer of water resources management, water allocation restrictions).	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=34251&recordSet=ISO19115 https://arcmaps.gov.bc.ca/ess/sv/imapbc/ http://www.data.gov.bc.ca/dbc/geographic/view_and_analyze/imapbc/index.page	Data BC
Streamflow inventory	Hydrologic characteristics compiled into a series of standardized tables and charts and regionalized provincial graphs and maps to enable the estimation of various streamflow parameters at ungauged sites in the province. Analyses available for the late 1990s with updates to some regions more recently.	http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2227 http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=40801 http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=16063	Ministry of Environment
Streamflow analysis	Streamflow Return Periods and 7-Day Average Streamflow Compared to Historic Median Streamflow are available for select locations across the province from the River Forecast	http://bcrfc.env.gov.bc.ca/freshet/ALL_WSC_GoogleMap.html http://bcrfc.env.gov.bc.ca/bulletins/watersupply/7DayFlowGoogle.ht	Ministry of Forests, Lands and Natural Resource

Data	Data description	Source	Data provider
	Centre.	ml	Operations
Water use	The vision of the Okanagan Basin Water Board is to have a fully-integrated water reporting system to meet the needs of residents and agriculture while supporting wildlife and natural areas. This requires water use reporting since managers can be more responsive to water shortages with greater availability of accurate data.	http://www.obwb.ca/tools/bc-water-use-reporting-centre/	Okanagan Basin Water Board
Snow data	River Forecast Centre provides archived and real-time information from automated snow pillows and manual snow surveys.	http://bcrfc.env.gov.bc.ca/data/index.htm http://bcrfc.env.gov.bc.ca/data/survey/	Ministry of Forests, Lands and Natural Resource Operations
Snow data and in-season water supply forecast	Snow survey and water supply bulletin provides a commentary on the flood risk and water supply outlook leading into the freshet and summer season.	http://bcrfc.env.gov.bc.ca/bulletins/index.htm http://bcrfc.env.gov.bc.ca/bulletins/watersupply/current.htm	Ministry of Forests, Lands and Natural Resource Operations
Future projections of hydrology	Modelled hydrologic data at over 120 sites located in the Peace, upper Columbia, Fraser and Campbell River watersheds. Projections available as daily time series from 1950 until 2098.	http://www.pacificclimate.org/data/station-hydrologic-model-output	Pacific Climate Impacts Consortium
Historical meteorological data	BC station data portal includes a consolidation of observation weather stations across different data holders from 1870 to present day.	http://www.pacificclimate.org/data/bc-station-data	Pacific Climate Impacts Consortium
Historical trends in climate	Maps for all months from 1972 onward using data collected by Environment Canada. Monthly maps of maximum and minimum temperature departures as well as total precipitation departures are provided on a monthly average and a seasonal average basis.	http://www.pacificclimate.org/analysis-tools/seasonal-maps	Pacific Climate Impacts Consortium
Historical reconstruction and future climate data	High-resolution climatology of temperature and precipitation, including historical hindcast (1901-2012) and projections to 2100 (2011-2040, 2041-2070 and 2071-2100). Available for different areas (ClimateBC, ClimateWNA, and Climate NA) and in different formats (Hectares BC). Other tools to access similar data are also available, though provide information at a coarser spatial/temporal resolution (e.g., PLAN2ADAPT and Regional Analysis Tool).	http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/#ClimateBC http://climatewna.com/climatena_map/ClimateBC_Map.aspx http://climatewna.com/climatena_map/ClimateWNA.aspx http://climatewna.com/climatena_map/default.aspx http://www.hectaresbc.org/app/habc/HaBC.html http://www.pacificclimate.org/anal	UBC Centre for Forest Conservation Genetics AND Pacific Climate Impacts Consortium

Data	Data description	Source	Data provider
		ysis-tools	
Groundwater data	Observation well network comprised of 145 active observation wells in the network covering major groundwater areas of the province. Some data available in real-time. Network collects, analyzes and interprets groundwater hydrographs and groundwater quality data from various developed aquifers. Observation wells are equipped with automatic water level recorders or data loggers that monitor water level fluctuations on a continuous basis. Also available is a statistical analysis of long-term trends in groundwater levels recorded at 119 observation wells that have been monitored for ten years or more and were active as of 2004.	http://www.env.gov.bc.ca/wsd/data_searches/obswell/map/obsWells.html http://www.env.gov.bc.ca/soe/indicators/water/wells/index.html http://www.env.gov.bc.ca/wsd/data_searches/obswell/map/obsWells.html	Ministry of Environment
Groundwater data	Aquifer classification database.	http://www.env.gov.bc.ca/wsd/data_searches/wells/ https://a100.gov.bc.ca/pub/wells/public/common/aquifer_report.jsp	Ministry of Environment
Climate change adaptation resources	A variety of resources to help prepare for the impacts of climate change (e.g., tools/resources for local gov't, First Nations and natural resource sector). As well, agriculture is a major water user and water can be used more efficiently. Various resources are available to inform actions in this sector.	http://www.retooling.ca/ http://www.agf.gov.bc.ca/emergency/Drought/Drought.htm	Fraser Basin Council Ministry of Agriculture

Appendix C: Subset of Alternative Analytical/Modelling Approaches

Model name	Description (purpose, scope, utility, and ease of use)	Climate awareness	Spatial/ temporal scale	Citation/source/ availability
NEWT/NWWT	The Northeast Water Tool (NEWT) and Northwest Water Tool (NWWT) are both GIS-based hydrology tools specifically developed to support decision-making for short term water allocation approvals in Northern B.C. The output includes hydrology data (30-year average) for rivers and lakes throughout the region, with a summary of short term water use approvals and water licenses issued through the BC Water Act. They are driven in the background by statistical water balance models that account for monthly and annual precipitation and temperature grids from the ClimateWNA program, evapotranspiration, land cover, and hydrometric data from Water Survey of Canada (WSC); however, user input is limited to location coordinates.	Based on the design of the statistical models running in the background, NEWT/ NWWT could potentially be enhanced to incorporate climate change scenarios by adjusting the precipitation and temperature data utilized internally within the models.	Point location / Monthly and annual	Hydrological modelling and decision-support tool development for water allocation in Northeastern British Columbia (Chapman et al. 2012) Available from the BC Oil & Gas Commission:http://www.bcogc.ca/public-zone/water-information and Ministry of Forests, Lands and Natural Resource Operations: http://bcwatertool.ca/nwwt/
Thornthwaite Monthly Water Balance Model	The Thornthwaite model is a monthly water balance model developed by the US Geological Survey. The amount of monthly precipitation that is rain, snow, or mixed rain/snow are estimated for a specific location based on temperature thresholds. Direct runoff from impervious surfaces is modelled as infiltration-excess overland flow. Total monthly runoff is calculated as direct runoff and runoff generated from surplus.	Can be used in studies of climate change impacts on water resources.	Point location / monthly	Software and documentation: http://wwwbrr.cr.usgs.gov/projects/SW_MoWS/Thornthwaite.html

Model name	Description (purpose, scope, utility, and ease of use)	Climate awareness	Spatial/ temporal scale	Citation/source/ availability
WRENSS (WinWrnsHyd and ECA-AB)	WinWrnsHyd is a lumped parameter hydrologic model based on the Water Resources Evaluation of Non-Point Silvicultural Sources (WRENSS) handbook. It provides changes in average streamflows under different forest management scenarios (Beckers et al. 2009b). ECA-AB, also based on WRENSS, incorporates many components of the WinWrnsHyd model, but does not explicitly simulate evapotranspiration (Nelitz et al. 2013). These models are mainly used to estimate changes in average annual flows (yield) for evaluating the effects of existing and future forest management on water resources (Beckers et al. 2009b). These tools are considered low complexity.	Was classified as having a low climate change functionality in a recent review of hydrological models (Beckers et al. 2009a).	Watershed / annual	Documentation: http://www.westernsnowconference.org/sites/westernsnowconference.org/PDFs/2005Swanson.pdf While detailed model descriptions for ECA-AB were found online, no information was found regarding user documentation and support. Information about ECA-AB can be obtained from Dr. Silins at the U of Alberta: http://rr.ualberta.ca/StaffProfiles/AcademicStaff/Silins.aspx
HEC-SSP	HEC-SSP is used for performing statistical analysis on hydrological data, including flow and volume frequency analysis, and duration analysis (i.e. percent of time that a hydrologic variable is likely to equal or exceed some specific value of interest). Input data are flows (e.g. annual low flow series). Model outputs include frequency curve plots, data plots, and raw data. Outputs can be linked to a watershed map.	Can be used to estimate the flow levels corresponding to a range of low flow return periods (e.g. 5, 10, 20 year return period low flows) after adjusting hydrologic data to account for climate change scenarios.	Point location / flow frequencies at various time scales	Available from the US Army Corps of Engineers: http://www.hec.usace.army.mil/software/hec-ssp/
Distributed monthly water balance model (Moore et al. 2012)	Moore et al. developed a simple distributed water balance model that can run using existing spatial datasets for predicting monthly mean runoff from each grid cell in a digital elevation model, which can be summed for an entire watershed. It accounts for variable forest canopy effects, glacier melt, snowmelt, soil moisture storage, and evaporation.	Can be used to evaluate the effect of a changing climate on monthly runoff and snow cover.	Point location or watershed / monthly	Documentation see Moore et al. 2012

Model name	Description (purpose, scope, utility, and ease of use)	Climate awareness	Spatial/ temporal scale	Citation/source/ availability
Snowmelt runoff model (SRM)	SRM has been widely used for simulating and forecasting streamflow in snow-dominated mountainous basins. SRM uses snow cover information and meteorological data as input variables and generates daily streamflow. It has low data requirements and is computationally simple, resulting in being implement for applications with sparse data (Abudu et al. 2012).	Can be used to evaluate the effect of a changing climate on seasonal snow cover and runoff (Rango et al. 2008).	Watershed / daily	Documentation: ftp://hydrolab.arsusda.gov/pub/srm/srm4.pdf
HBV-EC	The HBV-EC is a conceptual hydrological model that was adapted from the original HBV (developed in the early 1970s at the Swedish Meteorological and Hydrological Institute) by Environment Canada and UBC (Moore 1993) to better represent glacier and forest cover processes. The model has been applied in small to medium watersheds, in mountainous settings with a predominant snowmelt / glacial melt component. Required climate inputs are temperature and evaporation, and precipitation. HBV-CA is considered a moderate complexity model. HBV-EC is supported by the National Research Council Canada through Green Kenue (see description below).	Can be used for climate studies, including modelling glacier and streamflow response to future climate scenarios (Stahl et al. 2008).	Watershed / daily	Available through the Green Kenue platform: http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/green_kenue_index.html
University of British Columbia Watershed Model (UBCWM)	UBCWM is a hydrologic model designed for forecasting runoff from mountainous watersheds. The model divides watersheds into elevation bands (up to eight), and model parameters can be individualized for each band. Inputs include maximum and minimum daily air temperature, and daily precipitation. Outputs include daily discharge, and discharge from rainfall-runoff, glacial melt, and snow melt. UBCWM has been used for operational flow forecasting by BC Hydro (Beckers et al. 2009b). UBCWM is considered a moderate complexity model. UBCWM is supported by the National Research Council Canada through Green Kenue (see description below).	Can be used to model several hydrological processes (e.g. glacier melt) and components (e.g. lakes, groundwater) relevant for climate change. The model is considered to have a medium functionality for climate change applications (Beckers et al. 2009a). The input can be adjusted for a range of scenarios.	Watershed / daily	Documentation see Quick et al. 1995 Available through the Green Kenue platform: http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/green_kenue_index.html

Model name	Description (purpose, scope, utility, and ease of use)	Climate awareness	Spatial/ temporal scale	Citation/source/ availability
WATFLOOD	WATFLOOD is a distributed hydrology model that integrates a set of computer programs to forecast flood flows for watersheds having response times ranging from one hour to several weeks. It is also used for climate change studies and includes a model component for glacier melt. WATFLOOD is considered a moderate complexity model. WATFLOOD is supported by the National Research Council Canada through Green Kenue (see description below).	Used by Manitoba Hydro to model climate change impacts in the Nelson River. It has also been applied to climate change studies in cold environments (Werner and Bennett 2009).	Watershed / hourly to monthly	Software and documentation: http://www.watflood.ca/ Available through the Green Kenue platform: http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/green_kenue_index.html Introduction to WATFLOOD (Kouwen et al. 2011)
Raven	Raven is a flexible modelling framework that can be used as a lumped, semi-distributed, or fully distributed model. It does not contain assumptions on the functioning of the watershed. Rather, it allows the operator to construct a model that is tailor-made to fit the data availability, watershed characteristics, and operational application of interest by customizing the selection of algorithms and the watershed discretization. Raven is considered a moderate complexity model. Raven is supported by the National Research Council Canada through Green Kenue (see description below).	Can be used to understand the hydrological behavior of a watershed and assess the potential impacts of land use, climate, and other environmental change upon watershed properties such as low flows, flood potential, or groundwater recharge (Raven Development Team no date).	Point location or watershed / hourly or daily Highly customizable	Available from the University of Waterloo: http://www.civil.uwaterloo.ca/jrcraig/Raven/Main.html Available through the Green Kenue platform: http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/green_kenue_index.html A modified version is expected to be freely available in the near future from BC Hydro. Other citations (Craig and Snowdon 2011; Craig et al. 2014)
Green Kenue	Green Kenue is an advanced data preparation, analysis, and visualization tool to assist hydrologic modelers with surface hydrological modelling, forecasting, and event simulation. A user-friendly interface integrates environmental databases and geospatial data with numerical models and simulation data. It provides complete pre- and post-processing for the WATFLOOD, Raven, UBC Watershed Model, and HBV-EC.	Changes over 3D space and time can be viewed and analyzed, including lake level rise, flood inundation, climate change influences, weather forecasts, and hydrological predictions.	Specific to the hydrologic model being implemented through Green Kenue	Available from National Research Council Canada: http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/green_kenue_index.html

Appendix D: Manager Survey

BC Water Allocation Needs & Options Survey

INTRODUCTION

Demands for water are increasing rapidly and water allocation decisions are currently being made without adequate understanding of the future availability of water in a changing climate. To support the Climate Action Planning process underway for the BC Ministry of Forests, Lands and Natural Resource Management (MFLNRO), a scoping study is underway to assess the needs, information gaps, and priority options to better support surface water allocation decisions in the context of climate change.

This study focuses on understanding options to improve decision-making in the following areas:

(1) Water allocation decisions related new water licenses/authorizations;
(2) Water allocation decisions in the context of understanding environmental flow needs; and
(3) Decisions around regulatory restrictions related to managing water in times of scarcity/drought.

Work to-date has involved gathering information from senior water managers to understand the current "State of Readiness" around water allocation decision-making to identify a range of decision support needs, both to address current gaps/challenges and future challenges related to climate change. This information has been supplemented by interviews with other provincial staff, data partners, and external technical experts, as well as some desktop research. A background document has been sent to you by email which summarizes our understanding of the needs and describes options to address those needs in more detail (supported by examples of what is happening in BC and elsewhere).

The survey that follows is centered around the broad decision support needs and more detailed options described in the background document. In the survey you will be asked to select from a list of options that you believe are the MOST important to address to improve water allocation decision making across the province, as well as those items that are the LEAST important to address. The primary goals of this exercise are to strengthen the effectiveness and defensibility of today's water allocation decisions in the context of future climate with the least additional administrative burden on provincial decision makers.

The survey includes 12 questions. It will take approximately 1-1.5 hours to both review the background document and complete the survey. IT IS IMPORTANT THAT YOU READ THE BACKGROUND DOCUMENT BEFORE COMPLETING THE SURVEY TO ENSURE YOU UNDERSTAND THE QUESTIONS.

The DEADLINE to complete the survey is 12:00 PM on Monday, March 23, 2015.

BC Water Allocation Needs & Options Survey

OVERVIEW

Below is an overview of the broad categories of decision support needs and options to address these needs as described in Table 1 of the survey backgrounder. These categories of needs and options form the basis of the questions that we would like you to consider in the survey that follows.

Decision support need	Options to address needs (in Table 1)
Policy Framework	Implement other regulatory tools
	Improve coordination and engagement of stakeholders/ partners to inform planning, assessment, & decision-making
	Identify and address potential gaps in existing water allocation policies/procedures
	Develop water allocation/management plans
	Develop in-season water allocation/restriction protocols
Awareness	Improve awareness of existing data (see Table 2)
	Improve awareness of existing analytical/modelling options to inform water allocation decisions (see Table 3)
	Improve awareness of uncertainty associated with models and future climate/water demand scenarios
	Improve awareness of approaches for addressing uncertainty in future climate
	Deliver training in existing/new approaches to inform water allocation decisions (see Table 3)
	Deliver training in approaches for addressing uncertainty in future climate
Data Quantity/Quality	Make currently acquired hydrometric data available in real-time, if not already
	Improve harmonization of hydrometric data from multiple organizations with existing data portals
	Collect continuous hydrometric data at decommissioned locations

- Collect continuous hydrometric data at new locations
- Collect additional spot measurements of discharge at unmonitored locations
- Improve stage-discharge rating curves for low flows
- Improve reporting on timing and volume of actual water use
- Collect additional environmental parameters to support implementation of existing or new models

Water Supply and Demand Analysis

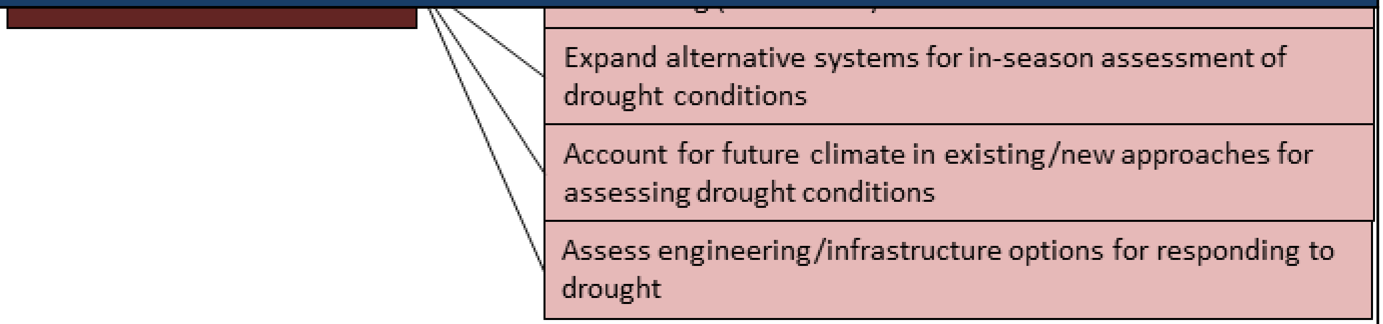
- Enhance existing tools available for each region (see Table 3)
- Extend existing tools to other regions/contexts (see Table 3)
- Implement statistical analyses using historical streamflow data (see Table 3)
- Apply regional trend detection analysis
- Implement a low complexity hydrologic simulation model accounting for future climate (see Table 3)
- Implement a moderate complexity hydrologic simulation model accounting for future climate (see Table 3)

Environmental Flow Needs

- Develop expert opinion and rules of thumb for understanding environmental flow needs
- Develop generalized hydrologic indices for understanding environmental flow needs
- Develop empirical/statistical relationships for understanding environmental flow needs
- Develop causally-reasoned functional flows for understanding environmental flow needs
- Account for future climate in existing/new approaches for assessing environmental flow needs

Drought Conditions

- Enhance existing operational systems for in-season forecasting (see Table 3)


Expand alternative systems for in-season assessment of drought conditions
Account for future climate in existing/new approaches for assessing drought conditions
Assess engineering/infrastructure options for responding to drought

POLICY FRAMEWORK

1. From the list of options below related to POLICY FRAMEWORK, select the two (2) items requiring the MOST attention, and two (2) items requiring the LEAST attention for strengthening water allocation decision-making across the province.

	Least attention required	Most attention required
Implement other regulatory tools	◯	◯
Improve coordination and engagement of stakeholders/partners to inform planning, assessment, and decision-making	◯	◯
Identify and address potential gaps in existing water allocation policies/procedures	◯	◯
Develop water allocation/management plans	◯	◯
Develop in-season water allocation/restriction protocols	◯	◯

AWARENESS

2. From the list of options below related to AWARENESS, select the two (2) items requiring the MOST attention, and two (2) items requiring the LEAST attention for strengthening water allocation decision-making across the province.

	Least attention required	Most attention required
Improve awareness of existing data	◯	◯
Improve awareness of existing analytical/modelling options to inform water allocation decisions	◯	◯
Improve awareness of uncertainty associated with models and future climate/water demand scenarios	◯	◯
Improve awareness of approaches for addressing uncertainty in future climate	◯	◯
Deliver training in existing/new approaches to inform water allocation decisions	◯	◯
Deliver training in approaches for addressing uncertainty in future climate	◯	◯

DATA QUANTITY/QUALITY

3. From the list of options below related to DATA QUANTITY/QUALITY, select the two (2) items requiring the MOST attention, and two (2) items requiring the LEAST attention for strengthening water allocation decision-making across the province.

	Least attention required	Most attention required
Make currently acquired hydrometric data available in real-time, if not already	◯	◯
Improve harmonization of hydrometric data from multiple organizations with existing data portals	◯	◯
Collect continuous hydrometric data at decommissioned locations	◯	◯
Collect continuous hydrometric data at new locations	◯	◯
Collect additional spot measurements of discharge at unmonitored locations	◯	◯
Improve stage-discharge rating curves for low flows	◯	◯
Improve reporting on timing and volume of actual water use	◯	◯
Collect additional environmental parameters to support implementation of existing or new models	◯	◯

WATER SUPPLY AND DEMAND ANALYSIS

4. From the list of options below related to WATER SUPPLY AND DEMAND ANALYSIS, select the two (2) items requiring the MOST attention, and two (2) items requiring the LEAST attention for strengthening water allocation decision-making across the province.

	Least attention required	Most attention required
Enhance existing tools available for each region	◯	◯
Extend existing tools to other regions/hydrological contexts	◯	◯
Implement statistical analyses using historical streamflow data	◯	◯
Apply regional trend detection analysis	◯	◯
Implement a low complexity hydrologic simulation model accounting for future climate	◯	◯
Implement a moderate complexity hydrologic simulation model accounting for future climate	◯	◯

ENVIRONMENTAL FLOW NEEDS

5. From the list of options below related to ENVIRONMENTAL FLOW NEEDS, select the two (2) items requiring the MOST attention, and two (2) items requiring the LEAST attention for strengthening water allocation decision-making across the province.

	Least attention required	Most attention required
Develop expert opinion and rules of thumb for understanding environmental flow needs	◯	◯
Develop generalized hydrologic indices for understanding environmental flow needs	◯	◯
Develop empirical/statistical relationships for understanding environmental flow needs	◯	◯
Develop causally-reasoned functional flows for understanding environmental flow needs	◯	◯
Account for future climate in existing/new approaches for assessing environmental flow needs	◯	◯

DROUGHT CONDITIONS

6. From the list of options below related to DROUGHT CONDITIONS, select the one (1) item requiring the MOST attention, and one (1) item requiring the LEAST attention for strengthening water allocation decision-making across the province.

	Least attention required	Most attention required
Enhance existing operational systems for in-season forecasting	◯	◯
Expand alternative systems for in-season assessment of drought conditions	◯	◯
Account for future climate in existing/new approaches for assessing drought	◯	◯
Assess engineering/infrastructure options for responding to drought	◯	◯

CROSS-CUTTING IMPORTANCE

Having just considered options to improve water allocation decision-making across six broad categories of decision support needs (POLICY FRAMEWORK, AWARENESS, DATA QUANTITY/QUALITY, WATER SUPPLY AND DEMAND ANALYSIS, ENVIRONMENTAL FLOW NEEDS, and DROUGHT CONDITIONS), please consider the following questions to help us understand the relative importance of actions across these different categories.

7. How well supported are water allocation decisions today in your region by the following areas (or across the province if more relevant to you)?

	Not at all supported	Weakly supported	Somewhat supported	Strongly supported	Extremely well supported
Existing policy frameworks	◯	◯	◯	◯	◯
Awareness of data/models	◯	◯	◯	◯	◯
Data quantity/quality	◯	◯	◯	◯	◯
Water supply and demand analyses	◯	◯	◯	◯	◯
Environmental flow needs assessments	◯	◯	◯	◯	◯
Tools for assessment of drought conditions	◯	◯	◯	◯	◯

8. From the broad categories of decision support needs below, select the two (2) categories that are the MOST important, and two (2) categories that are the LEAST important for strengthening water allocation decision-making across the province.

	Least attention required	Most attention required
Policy framework	◯	◯
Awareness	◯	◯
Data quantity/quality	◯	◯
Water supply and demand analysis	◯	◯
Environmental flow needs	◯	◯
Drought conditions	◯	◯

9. How well are the impacts of climate change integrated in water allocation decisions in your region or technical area of practice?

◯ Not integrated at all

◯ Integration in progress

◯ Partially integrated

◯ Fully integrated

◯ Don't know

10. Is there anything else you would like to share?

CLOSING

11. Please provide the information below. Note that your answers will be anonymous and we would only use this information if we need to follow up.

Name: ____________

Position/Title: ____________

Agency: ____________

City/Town: ____________

Email Address: ____________

Phone Number: ____________

12. In which region of the province do you work?

- [ ] Northeast
- [ ] Omineca
- [ ] Skeena
- [ ] Cariboo
- [ ] Kootenay/Boundary
- [ ] Thompson/Okanagan
- [ ] South Coast
- [ ] West Coast
- [ ] Headquarters/Victoria

Thank you for providing your input!

Your answers will be anonymously combined with the views of others. This information will be summarized and presented on a conference call involving survey respondents and others before the end of March. It will also be included in a climate action report to be delivered to the Ministry of Forests, Lands, and Natural Resource Operations.

If you have any questions about this study or the survey please contact Kathy Hopkins with MFLNRO (Kathy.Hopkins@gov.bc.ca, 604-594-9568 or 250-387-2112) or Marc Nelitz with ESSA (mnelitz@essa.com, 604-677-9554).

Appendix E: Agenda and Final Call Survey

Data & Models to Support Water Allocation Decisions Conference Call Agenda

Day/Time: Thursday, March 26, 2015
11:00 – 12:00

Conference Details:

Phone Number: 1-877-353-9184
Participant ID: 316-1010#

Desktop Sharing:

Please join the conference line and click on the GoTo link below a few minutes early so we can start on time.

Click on the following GoTo link to see my computer and follow the prompts:
https://global.gotomeeting.com/join/898463333

or if you have problems with the above link, enter the Meeting ID here:
http://www.joingotomeeting.com/fec/?locale=en_US&set=true
Meeting ID: 898-463-333

Project Leads: Kathy Hopkins, MFLRNO
Kathy.Hopkins@gov.bc.ca
604-594-9568 OR 250-387-2112

Marc Nelitz, ESSA Technologies Ltd.
mnelitz@essa.com
604-677-9554

Goal of the Conference Call:
To identify a short-list of priorities to address that will ultimately improve water allocation decision-making in BC in the context of future climate.

Meeting Objectives:
(1) Discuss results of the survey;
(2) Identify critical gaps and priorities; and
(3) Discuss reporting and review process.

Requested Protocol:
Please state your name each time you speak
One voice at a time (use a speakers list)
Stick to the topic
Share opportunities for air time

Agenda:

Approximate times	Topic	Presenter
11:00–11:05	Welcome and purpose of call	Kathy
11:05–11:10	Overview of agenda and protocol	Marc
11:10–11:20	Presentation of survey results	Marc
11:20–11:45	Roundtable discussion about survey results. Guiding question: *What are the enablers/barriers that need to be addressed before addressing these top ranked options?*	Group
11:45–12:00	Final questions on priority options using survey monkey: https://www.surveymonkey.com/s/WaterAllocationFinalPriorities *(1) What is your general level of support for this list of top ranked options as representative of provincial priorities? Use fist-to-five (see next page).* *(2) Which priorities are shorter-term (1-2 years) versus longer-term actions to complete?* *(3) What are the top 3 options to pursue, based on a consideration of the following criteria:* Feasibility: Options that are the most feasible/practical to implement given the current situation. Cost: Options that are the least costly to implement (in relative terms) across the province. Impact: Options providing the greatest benefits to improve the current situation or prepare us for the future.	Marc/ Group
Last few minutes	Next steps: - Draft report available on March 27 - Who can review the draft report?	Kathy

Fist-to-Five Vote:

We will be using a fist-to-five voting system to gauge the group's level of agreement/support for the priority list of options. It is often used to build or gauge consensus, so it includes language that implies a need for consensus from a group. Our intent is not to develop a consensus agreement here, but this tool can be useful for gauging the level of agreement among a group and helping focus on critical issues of concern.

Fist: No support – will work to block proposal

"I need to talk more about the proposal and require changes for it to pass."

1 - Finger1: No support - won't block

"I still have strong reservations and want to discuss certain issues and suggest changes that should be made."

2 - Fingers: Minimal support - willing to work for it

"I am moderately comfortable with the proposal but would like to discuss some minor issues."

3 - Fingers: Neutral

"I'm not in total agreement but feel comfortable to let this decision or proposal pass without further discussion."

4 - Fingers: Solid support – clear intent to work for it

"I think it's a good idea/decision and will work for it."

5 - Fingers: Strong support - willing to lead proposal

"It's a great idea and I will be one of the leaders in implementing it."

1. What is your general level of support for the presented list of top 10 ranked options as being representative of provincial priorities? Use fist-to-five (see description below).

- Fist
- One finger
- Two fingers
- Three fingers
- Four fingers
- Five fingers

2. If you are not generally supportive of this list, which options do you think SHOULD NOT be included and which other options do you think SHOULD be included (if easy, use numbers from Table 1 in survey backgrounder)?

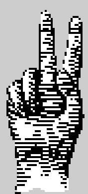
Below is a description of a fist-to-five voting system. It is often used to build or gauge consensus, so it includes language that implies a need for consensus from a group. Though the intent is not to develop consensus here, this tool can be useful for gauging the level of agreement among a group and helping focus on critical issues of concern.

Fist: No support – will work to block proposal

"I need to talk more about the proposal and re

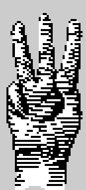
1 - Finger: No support - won't block

"I still have strong reservations and want to
changes that should be made."



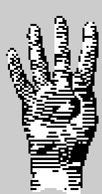
2 - Fingers: Minimal support - willing to work for

"I am moderately comfortable with the propo
minor issues."



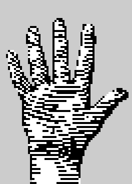
3 - Fingers: Neutral

"I'm not in total agreement but feel comforta
pass without further discussion."



4 - Fingers: Solid support – clear intent to work fo

"I think it's a good idea/decision and will wor



5 - Fingers: Strong support

"It's a great idea and I will be one of the leade

3. Which of the top 10 ranked options are short-term (1-2 years) versus longer-term actions to complete?

	Shorter-term (1-2 years)	Longer-term (3 or more years)
(4): Develop water allocation/management plans	◯	◯
(10): Deliver training in existing/new approaches to inform water allocation decisions	◯	◯
(13): Improve harmonization of hydrometric data from multiple organizations with existing data portals	◯	◯
(15): Collect continuous hydrometric data at new locations	◯	◯
(20): Enhance existing tools available for each region	◯	◯
(21): Extend existing tools to other regions/hydrological contexts	◯	◯
(22): Implement statistical analyses using historical streamflow data	◯	◯
(27): Develop generalized hydrologic indices for understanding environmental flow needs	◯	◯
(30): Account for future climate in existing/new approaches for assessing environmental flow needs	◯	◯
(31): Enhance existing operational systems for in-season forecasting	◯	◯

BC Water Allocation Needs & Options: Final prioritization

For the question that follows, please consider the following criteria when making your selections:

(A) Feasibility: Options that are the most feasible/practical to implement given the current situation.
(B) Cost: Options that are the least costly to implement (in relative terms) across the province.
(C) Impact: Options providing the greatest benefits to improve the current situation or prepare us for the future.

*4. What are the top 3 options to pursue moving forward?

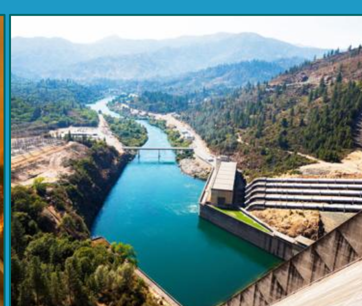
- [ ] (4): Develop water allocation/management plans
- [ ] (10): Deliver training in existing/new approaches to inform water allocation decisions
- [ ] (13): Improve harmonization of hydrometric data from multiple organizations with existing data portals
- [ ] (15): Collect continuous hydrometric data at new locations
- [ ] (20): Enhance existing tools available for each region
- [ ] (21): Extend existing tools to other regions/hydrological contexts
- [ ] (22): Implement statistical analyses using historical streamflow data
- [ ] (27): Develop generalized hydrologic indices for understanding environmental flow needs
- [ ] (30): Account for future climate in existing/new approaches for assessing environmental flow needs
- [ ] (31): Enhance existing operational systems for in-season forecasting

Project Report

ESSA 35 YEARS

Environmental & Cumulative Effects Assessment

Climate Change Adaptation & Risk Reduction



Aquatic Species at Risk & Water Resource Management

Terrestrial Ecology & Forest Resource Management