Integrated Modelling Program for Canada (IMPC)

Kick-Off Workshop Report

September 14-15, 2017
National Hydrology Research Centre
11 Innovation Boulevard, Saskatoon, SK

Integrated Modelling Program for Canada
Global Water Futures

Executive Summary

The Integrated Modeling Program for Canada, IMPC, aims to provide an integrated platform for forecasting, prediction and decision making under uncertainty to address outstanding local- to national-scale challenges for the current and future quality and quantity of water in Canada's major river basins. IMPC received its $1.6 million funding under the Global Water Futures (GWF) program in Canada and officially commenced in June 2017.

IMPC held its kick-off workshop on September 14-15th, 2017 at National Hydrology Research Centre, Saskatoon. The aim of the workshop was to plan for large-scale modelling activities for forecasting, prediction, and water resources management and decision support over the next three years, until August 2020. Integrating the core Global Water Futures (GWF) modelling group into IMPC as well as engaging users and collaborators at the outset of the program were also key objectives in this workshop.

Nearly 70 people from 16 academic, regulatory, and industrial sectors attended the workshop in-person or online to present and discuss their objectives, plans, and perspectives. Distinguished Professor Eric Wood from Princeton University also participated in this workshop as one of the international advisors to the program.

The workshop began with an overview of the GWF and IMPC programs, followed by presentations and discussions by investigators, collaborators, and stakeholders' representatives. Presentations covered topics related to each of the four Themes of IMPC, namely Theme A: Integrated Earth System Modelling, Theme B: Water Management Modelling, Theme C: Decision Making Under Uncertainty & Non-Stationarity, Theme D: User Engagement, Knowledge Mobilization, and Decision Support Systems. End-user community representatives had the opportunity to brief attendees on their organizational work and make connections to IMPC research. The IMPC program management team also provided an overview of the structure of the project, important dates and anticipated timelines.

Final concluding remarks of the workshop emphasized a need for:

- Right and clear directions from the management team for efficient and timely progress;
- A clear Inception Report that outlines explicit plans, timelines, and deliverables;
- A User Engagement Strategy that clearly outlines plans for engaging diverse stakeholders and partners; and
- Close coordination between IMPC and the core modelling team.

This report provides a list of participants, followed by a list of presentations and a synthesis of discussions under each section. The workshop agenda is provided in the appendix. A copy of the final report and all presentations can be found on the IMPC webpage at http://gwf.usask.ca/impc/resources/Meetings.php#KickOffWorkshop.

Thank you to all who participated and contributed to making this workshop a success!

Amin Haghnegahdar
IMPC Program Manager

Saman Razavi
IMPC Principal Investigator

Hayley Carlson
User Engagement Specialist

Approximately 70 individuals from 16 academic, regulatory and industrial organizations attended the IMPC Kick-Off Workshop, September 14-15th 2017 at the National Hydrology Research Centre in Saskatoon, Saskatchewan.

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List of Participants

Approximately 70 individuals from 16 academic, regulatory, and industrial organizations attended the workshop in-person or online via WebEx. Distinguished Professor Eric Wood from Princeton University, serving as one of the international advisors to the program, also attended the workshop to lend his expertise and experience.

- Laurie Tollefson (Agriculture and Agri-Food Canada)
- Anil Gupta (Alberta Environment & Parks)- WebEx
- Bernard Trevor (Alberta Environment & Parks)- WebEx
- Khaled Akhtar (Alberta Environment & Parks)
- Muluneh Mekonnen (Alberta Environment & Parks)- WebEx
- Tom Tang (Alberta Environment & Parks)- WebEx
- Andrew Huang (City of Calgary)- WebEx
- Sandy Davis (City of Calgary)- WebEx
- Bruce Davison (Environment and Climate Change Canada)
- Daniel Peters (Environment and Climate Change Canada)
- Vincent Fortin (Environment and Climate Change Canada) - WebEx
- Amin Haghnegahdar (Global Institute for Water Security)
- Chris DeBeer (Global Institute for Water Security)
- Daniel Princz (Global Institute for Water Security)
- Elvis Asong (Global Institute for Water Security)
- Fuad Yassin (Global Institute for Water Security)
- Hayley Carlson (Global Institute for Water Security)
- Jefferson Wong (Global Institute for Water Security)
- Kasra Keshavarz (Global Institute for Water Security)
- Leila Eamen (Global Institute for Water Security)
- Luis Morales Marin (Global Institute for Water Security)
- Mark Ferguson (Global Institute for Water Security)
- Mohamed Abdelhamed (Global Institute for Water Security)
- Mohamed Elshamy (Global Institute for Water Security)
- Prabin Rokaya (Global Institute for Water Security)
- Razi Sheikholeslami (Global Institute for Water Security)
- Seyedmohammad Ghoreishi (Global Institute for Water Security)
- Shervan Gharari (Global Institute for Water Security)
- Stacey Dumanski (Global Institute for Water Security)
- Stephanie Merrill (Global Institute for Water Security)
- Syed Mustakim Ali Shah (Global Institute for Water Security)
- André Bertoncini (GWF, Centre For Hydrology)
- Caroline Aubry-Wake (GWF, Centre For Hydrology)
- Chris Marsh (GWF, Centre For Hydrology)
- Diogo Costa (GWF, Centre For Hydrology)
- Dominique Richard (GWF, Centre For Hydrology)
- Holly Annand (GWF, Centre For Hydrology)
- Kevin Shook (GWF, Centre For Hydrology)
- Siquong Guo (GWF, Centre For Hydrology)
- Youssef Loukili (GWF, Centre For Hydrology)
- Zhibang Lv (GWF, Centre For Hydrology)
- Dominique Richard (GWF, Centre For Hydrology)
- Kevin Gawne (Manitoba Hydro)- WebEx
- Fisaha Unduche (Manitoba Infrastructure and Transportation)
- Paulin Coulibaly (McMaster University)- WebEx
- Mike Renouf (Prairie Provinces Water Board)
- Eric Wood (Princeton University)
- Tricia Stadnyk (University of Manitoba)
- Masoud Asadzadeh (University of Manitoba)
- Al Pietroniro (University of Saskatchewan)
- Amin Elshorbagy (University of Saskatchewan)
- Carl Gutwin (University of Saskatchewan)
- Graham Strickert (University of Saskatchewan)
- Howard Wheater (University of Saskatchewan)
- John Pomeroy (University of Saskatchewan)
- Karl-Erich Lindenschmidt (University of Saskatchewan)
- Pat Gober (University of Saskatchewan)
- Saman Razavi (University of Saskatchewan)
- Tim Jardin (University of Saskatchewan)
- Yanping Li (University of Saskatchewan)
- Bryan Tolson (University of Waterloo)- WebEx
- Hongren Shen (University of Waterloo)- WebEx
- Roy Brouwer (University of Waterloo)- WebEx
- Curtis Hallborg (Water Security Agency)
- John-Mark Davies (Water Security Agency)
- Richard Janowicz (Yukon Department of Environment)

Presentations and Synthesis of Discussions

The first day of the workshop was allocated to Theme A, the largest IMPC theme containing seven sub-projects. Day 1 also included one presentation on the project management structure. The other three Themes and their corresponding seven sub-projects (3, 2, and 2, for Themes B, C, and D, respectively) were discussed on Day 2. Select collaborators and end-user community representatives had the opportunity to present their works and needs under each related theme throughout both days. Howard Wheater, Saman Razavi, and Al Pietroniro provided some conclusions and final remarks.

Opening Remarks

Saman Razavi opened the workshop by welcoming participants and providing an overview of the workshop agenda and plans for each day. Then, Howard Wheater presented an overview and updates of the Global Water Future (GWF) program as well as its links to IMPC, followed by an overview of the objectives and research themes of IMPC by Saman Razavi.

Theme A: Integrated Earth Systems Modelling

I. Atmospheric and Hydrologic Modelling: Projects A1, A2 and A5

During the discussion period, Howard Wheater emphasized the obvious importance of an agreed-upon strategy and plan to conduct the model inter-comparison project (A5) to avoid wasting time and resources. He also highlighted the need to include the significant amount of work that has been completed in Western Canada on this subject and recommended inclusion of uncertainty analysis in this work by accounting for input uncertainty, feasible parameter sets for different models, and use of different levels of data assimilation. Eric Wood questioned the usability of such inter-comparison projects based on his past experience with similar work, particularly in the context of providing meaningful decision-making metrics at the end for end-users. Saman Razavi highlighted that evaluating models in a decision making context is part of theme C that will be discussed on day 2. Trish Stadnyk

Presentations

- **Welcome, Introduction, and Overview of the Agenda** (*Saman Razavi and Al Pietroniro)*
- **Global Water Futures: Overview, Updates and Links to IMPC** (*Howard Wheater and John Pomeroy)*
- **Overview of IMPC Objectives and Research Themes** (*Saman Razavi)*
- **Overview of Theme A: Integrated Earth Systems Modelling** (*Al Pietroniro)*
- **High-Resolution Atmospheric Modelling** (*Yanping Li)*
- **Advancing Modelling Strategies for Canada: MESH/VIC/CHM** (*John Pomeroy and Al Pietroniro)*
- **GEM-Hydro** (*Vincent Vionnet and Vincent Fortin)*
- **HYPE Experience** (*Trish Stadnyk)*
- **Model Inter-Comparison and Multi-Model Analysis** (*Bryan Tolson)*
- **User Perspective: State of Hydrologic Forecasting in Manitoba** (*Fisaha Unduche)*
- **User Perspective: State of Hydrologic Forecasting in the Yukon** (*Richard Janowicz)*

commented that it would be a huge step backward if model inter-comparison is done at sub-basin scale because the goal and scope of GWF/IMPC is to address trans-boundary issues, water management, and climate change impact that all happen on larger scales. She recommended that GEM-Hydro is already applied in the Great Lakes Basin can be a good candidate for application to the Nelson-Churchill RB in this context.

Al Pietroniro explained the work of Water Survey Canada and challenges related to measuring and using flows at gauges. He described the process of quality control of data that might take over a year. He highlighted that flow measurements are not perfect and subject to uncertainty; it would be beneficial if this uncertainty were reflected in modelling. In response to a question by Graham Strickert, Al mentioned that cameras are used in some gauges but this is hard and expensive to maintain.

Howard Wheater strongly emphasized the immediate need for discussions and coordination of plans and activities between the core modelling team and the IMPC team. He also highlighted the need for a bigger mapping of all the GWF modelling plans regarding who is doing what, where, and when.

Eric Wood advised that the next big breakthrough in modelling efforts is to account for the existing intersectoral feedbacks (e.g. between agriculture, mining, industries, etc.) using an integrated modelling approach for a more robust study of the impact of climate change. Al Pietroniro confirmed this approach for the core of GWF team. Saman Razavi also explained that this challenging task is a main goal for IMPC and described how we are working towards this approach by coupling MESH with water management and irrigation.

Fisaha Unduche asked if these more research-based models will have a user-interface to bring all of their results together for end-users to access for operational forecasting, among other purposes. Al Pietroniro pointed that this is a goal for the core modeling team to develop platforms like FEWS. He also explained that in Canada flood forecasting is a provincial issue and thus, we can have a national flow forecasting system that can inform the provincial agencies for flood forecasting purposes. However, to do this all groups would have to be involved; the FEWS system might be one way forward.

Presentations

- **Non-Point Source Modelling: HYPE and the Future of MESH/CHM** (*Diogo Costa)*
- **Water Quality Modelling: Land Surface and In-Stream** (*Karl Lindenschmidt)*
- **River Ice Modelling** (*Karl Lindenschmidt)*

II. Water Quality and River Ice Modelling: Projects A3 and A4

Howard Wheater provided an overview of the strategy for Water Quality modelling using multiple models at multiple scales for various purposes. SPARROW, a quasi-steady state empirical model, is a good starting point as it has already been applied to South Saskatchewan, Red River, Assiniboine, and Qu'Appelle River basin in Western Canada and the Great

Lakes in Eastern Canada. Next, we need to move to more dynamic models like HYPE and learn from its water quality simulation modules for our purposes. It was suggested that Ilias Pechlivanidis (Howard's former student) with Diogo and Trish lead this effort. The next step may be to explore implementing sediment and nutrient transport in MESH at large scales. At a fine resolution, Diogo is developing new algorithms for CRHM that can be then upscaled for representation in MESH. Thus, there is a reasonable spread of tools but there is a need to work up a plan for our project and potential learnings between models.

Saman Razavi explained how ideally everything can be integrated into one model like MESH that already has a good hydrology and added representation of water management. MESH can also benefit from improved efficiency as Bruce Davison mentioned. In response, Howard Wheater explained that while MESH remains a focus, due to its complexities and computational and data demand, particularly for running future scenarios, simpler and more efficient models such as HYPE are useful especially for pan-Canadian applications. He also highlighted the importance of developing improved algorithms at fine scales suitable for the cold region processes (like Diogo's work with CRHM) that can later be implemented in MESH. Howard insisted that a multi-model water quality capability would be very useful for IMPC and the GWF core modelling team.

Karl Lindenschmidt, in response to a question from Fisaha Unduche on the forecasting mechanism in his river ice modelling, explained how he adapts a Monte-Carlo approach using randomly generated parameter sets from a distribution to account for uncertainty in predicting the location of the toe of the ice jam, which is the most challenging factor. He also mentioned, with regards to the water quality modelling, that a multi-model approach allows for a cross-model validation and comparison.

Amin Haghnegahdar raised a question about potential issues with not having enough resources to complete all this work in a timely manner. Karl argued that a lot is already happening and that he expects the MESH-WQ will be tested by Spring 2018. Moreover, he emphasized that he still wanted to do methodological research on water quality as well.

User community representatives also shared their perspectives and requirements around water quality modelling. Mike Renouf (PPWB) highlighted that, from a broad perspective, nutrients and nutrient transport is the number one water quality issue across all the three provinces, and any tool that can support understanding and managing of the process and identifying sources in terms of natural vs. anthropogenic, and non-point vs point source pollutions is much needed. Additionally, there are also more specific issues such as metals on a basin-by-basin basis. John-Mark Davies (WSA & PPWB) also emphasized the same point and added that there are also concerns around emerging contaminants with unknown risks such as metals mainly associated with sediment loads.

Pharmaceuticals, personal care items, and pesticides are also among other contaminants with impacts on water quality. Fisaha Unduche (MI) expressed that end-users shouldn't be forgotten in such modelling activities. The models developed should be simple enough to use and efficient to run for operational purposes. Saman re-iterated this point by emphasizing the concept underlying IMPC is that the work and its outcomes should be useful for decision making purposes.

Howard concluded the Water Quality discussions by highlighting that land surface processes and water quality modelling are very complex and very uncertain. Therefore, it is good to have different models and approaches if resources can be afforded.

Presentations

- **Floodplain and Flood Risk Analysis: A SaskRB Perspective (**Amin Elshorbagy)
- **Floodplain and Flood Risk Analysis: Great Lakes RB perspective and FloodNet Experience (***Paulin Coulibaly)*

III. Flood Mapping and Risk Analysis: Project A6

Howard Wheater pointed out that copulas are neat ideas and suggested that the models that have already been set up or will be set up by the core team can be very useful for this work. Al Pietroniro also mentioned that MESH is already applied to the Great Lakes and Nelson-Churchill basin and can potentially be used for this work. Amin Elshorbagy explained how the statistical methodology derives annual flood peaks from the continuous time series and highlighted that how they can use model simulations to also generate Probability Distribution Functions (PDFs) for other variables such as annual snow depth. He also mentioned that the model results are particularly useful for studies on climate change scenarios. Howard highlighted that future climate forcing data for MESH is expected to be generated soon for up to year 2100 that can potentially be used in this work.

Eric Wood suggested that focusing on flood mapping might be a better path given a huge interest by flood insurance companies. Al Pietroniro also mentioned that the government of Canada cut their flood insurance coverage after 2012 and now there is a big challenge for flood insurance companies because 1) flood maps are outdated and they struggle to update them, and b) nobody knows how to handle climate change. Paulin Coulibaly highlighted how complex this problem can become and suggested that there needs to be a limit on what level of complexity we consider this issue at, but at the same time we should ensure we can clearly communicate results in simple ways for stakeholders and decision making.

In response to Curtis Hallborg question about consideration for ice influence flooding like freeze-up periods, mid-winter or spring break-up periods, in this flood risk analysis, Amin Elshorbagy mentioned that these factors are not explicitly included but highlighted a related work by Karl Lindenschmidt's on modelling ice jam floods and hoped that his results can eventually integrate into models. Amin E. also mentioned there could be various ways to relate this work to the bigger IMPC project, which has a broad scope; for example, how the change in management and reservoir operations affect flood mapping and risk assessment, or how this flood mapping relates to stakeholders and to flood insurance.

In conclusion, Howard Wheater once again alerted that this work, similar to the water resources component, is currently under-resourced and suggested a need to grow this in future.

IV. Uncertainty Characterization: Project A7

Presentations

- **Characterization & Attribution of Uncertainty in Modelling (***Saman Razavi)*

Amin Elshorbagy raised the issue of a large computational demand of uncertainty analysis (UA), especially with integrated modelling approaches that consider climate to watershed to hydraulics, and highlighted what is called compartmentalized UA as a possible solution some researchers are adopting to reduce the computational burden. In such UA approach, the critical factors in the chain of the models that has the highest impact on the peaks, for example, are identified and UA is conducted around those factors only and not the entire chain. Saman Razavi also mentioned for problems with deep uncertainty we need to think around concepts such as "sparsity of factors" in statistics, which states that in complex systems normally only a handful of factors dominate a system's behavior.

Howard Wheater pointed out that it is quite difficult but important to find a common agreed methodology for UA, for everyone in the group to ideally use. He does not believe in optimization but supports a framework by which a set of feasible parameter sets consistent with the conditioning data is identified. He believed the sensitivity analysis (SA) tools we have are powerful enough for application to hydrological models; however, we need to recognize that as we move to a decision support context the issue becomes how to frame uncertainty in relation to the decisions that should be made.

Trish Stadnyk's team has applied Saman's SA/UA tool, VARS (Variogram Analysis of Response Surfaces), and found that it is very efficient for application to complex models. Saman agreed, suggesting that his research shows that VARS can be two orders of magnitude more efficient than similar SA tools.

In response to Saman's inquiry about some SA works with CRHM, Kevin shook explained that they try to use measured data and inform the model as much as possible to avoid calibration. However, he recognized that often there is no way around calibration and there is always uncertainty. In fact, there are factors that cannot be measured or poorly understood that are calibrated in CRHM such as overland flow velocities in prairies or underground parameters, which are all calibrated. Howard discussed the challenge with hard-wiring of parameters in complex models such as MESH and CRHM and how they are trying to reengineer and unwire them in CRHM.

Saman closed the discussion by remarking that SA is essentially different than optimization and these two should not be misunderstood and there is a lot that can be gained from this type of analysis.

Theme B: Water Management Modelling, Coupling Human-Driven and Natural Systems

V. Water Resources Modelling: Projects B1, B2 and B3

In response to Howard Wheater's question on the data demand for valuation of environmental impacts, Roy pointed out that the relationship between the activity and the environmental flow is crucial. It is also a large challenge to find, for example, what is the exact value of something like wetlands and then use that information. Trish Stadnyk mentioned dependency of this hydro-economic analysis on markets in US and Canada and that it is very complex and depends on many factors like climate change, especially with respect to the future regulation for example. Roy discussed it depends on the available knowledge and information about the market demand. And that the complex system should be decomposed into simpler components which can then be controlled and evaluated separately to identify the main sources of uncertainty. The value of the economic activity is subject to price volatility. One process to explore this is scenario building or stochastics models. Roy suggested his preference is to do a modular coupling approach and not a fully integrated one. He also highlighted that it is also very important to ensure the right level of complexities are considered and there is always a tradeoff when building hydro-economic models.

Presentations

- **Overview of Theme B** (Saman Razavi)
- **Water Resources Modelling: SaskRB** (Saman Razavi)
- **Water Resources Modelling: Manitoba and the Nelson-Churchill** (Masoud Asadzadeh)
- **In-Stream Flow Demand: Aquatic Ecosystem Health Indicators** (Tim Jardine and Daniel Peters)
- **Hydro-Economic Modelling** (Roy Brouwer)

Eric Wood mentioned a series of reports on water accounting at water district level in British Columbia but was not sure about other parts of Canada and how useful it might be for the project. Roy was aware of this Okanagan project and also one at Brock University. He also explained that Statistics Canada and the International Joint Commission (for Great Lakes) are very interested in this, but sufficient efforts have not been made. Khaled Akhtar also pointed to a research in University of Western Ontario by Professor Simonovic where they integrated hydrologic, climate, and economic models.

Laurie Tollefson explained that irrigation expansion in Saskatchewan can have various scenarios and this type of hydro-economic analysis can help to decide which scenarios are better. Trish brought up again the dependency on the scale of the problem; Manitoba cares about what happens in Saskatchewan and Alberta, but maybe Alberta doesn't. The great challenge for the project is how to reconcile various groups of users for the project. Mohammad Ghoreishi named software program, AnyLogic, allowing to link sociology, economy, and hydrology etc. together, considering the difference in their temporal scales.

While Al Pietroniro was sceptic about the utility of such models, Carl Gutwin pointed out that AnyLogic has been used in a study at the computer science department very successfully for the past 10 years where multiple stakeholders (e.g. Police, Community Services, etc.) are brought together to essentially have a discussion about what is important.

Presentations

- **User Perspective: PPWB** (Mike Renouf)
- **User Perspective: Irrigation Demands in the Prairie and Irrigation Expansion** (Laurie Tollefson)
- **User Perspective: WSA issues, Lake Diefenbaker, and More** (Curtis Hallborg)
- **User Perspective: WRMM and Alberta** (Tom Tang)
- **User Perspective: Manitoba Hydro's Perspective on WRMM** (Kevin Gawne)

VI. Water Resources: The User Perspective

In response to a question by Curtis Hallborg, Tom Tang explained that that graphical version of the water-user interface will be available as a beta version next year for internal use for testing and that currently, they are extensively testing the migration of WRMM model into what is called WMPSM modelling platform. Curtis also highlighted that Water Security Agency (WSA) in Saskatchewan works on a lot of similar issues to Alberta, and uses similar models and tools. He also pointed out how WSA is interested in seeing, for example, how Potash mine demands is influenced by climate and hydrological changes and how this can possibly be integrated into water management and water quality modellings.

In response to Howard Wheater's question on the Prairie Provinces Water Board's (PPWB) user engagement strategies, Mike Renouf described that PPWB does not have a direct mandate to engage users, but it has realized the importance of this issue over the recent years. PPWB has been working with people from Partners for the Saskatchewan River Basin as being the primary vehicle to carry messages from the board, and has been using their workshops to reach to communities. Amin Haghnegahdar posed a general question on user engagement strategies in other organizations such as Manitoba Hydro and Alberta Environment and Parks. Kevin Gawne from Manitoba Hydro highlighted that his organization reaches out to the stakeholders who are impacted by their operation. They went through a major hearing with operating licenses and thus, looking at modern means for answering the questions and find alternative operational strategies. They would like to answer many questions on understanding the impact of reservoir operations on stakeholders. Laurie Tollefson explained that in Agri-Food and Agriculture Canada they work closely with producers and Producer Associations in Saskatchewan and Alberta. In Saskatchewan, stakeholders are part of board of directors that helps to drive research programs for irrigation projects. In Alberta, they work closely with end-users at Bow River council, Oldman River Council, and Canadian Mill River in terms of modelling and technical support.

Fisaha Unduche described a user-engagement process within Manitoba Infrastructure in which they allocate funding to answer these types of questions to advance both the research and public engagement. Stakeholders have representatives on their committees and they meet mostly based on demand and often on a weekly basis. Mike

Renouf highlighted that there are very effective NGOs such as Red River Basin Commission, Partners of Saskatchewan River Basin, and Assiniboine Basin Initiative that provide tremendous opportunities for engagement.

Theme C and Theme D: Decision Making Under Uncertainty, Knowledge Mobilization and User-Engagement

Carl Gutwin explained that if there is a model in the right format, then it is very easy to change inputs, run the model, and then visualize the output on a web server. However, converting something like source code of a model to run on a website is very challenging. In response to Amin Haghnegahdar's question about complications with long model runs, Carl suggested various strategies can be adopted to expedite the process of appearance of interactivity on the web; for example, pre-running all the possible combinations of the model which people might be more likely interested in. This process can always be optimized in a way that humans are expected to deal with it.

In response to Saman Razavi asking if this can be run on an end-user's computer browser or a server, Carl pointed out that the architecture is to set up a box to run a model or communicate with a super computer. As long as we can communicate with those computers, give them input and take the output, many things can be arranged and the web server only runs the front end and interactivities.

Presentations

- **Overview of Theme C: Decision Making under Uncertainty and Non-Stationarity** (*Saman Razavi, Pat Gober and Howard Wheater*)
- **Vulnerability Analysis of Environmental Change: Applications to Water Resource Futures for Saskatchewan** (*Howard Wheater*)
- **Exploratory Modeling and Decision Support** (Pat Gober)
- **GWF and IMPC Plans for Knowledge Mobilization** (*Graham Strickert, Pat Gober and* Stephanie Merrill)
- **Human-Computer Interface and Visualization** (*Carl Gutwin*)

Al Pietroniro suggested that having an app which can communicate flood risk is great. Carl explained that as long as data exists these things are relatively easy to implement and mentioned that Graham Strickert has done lots of work with app-based Citizen Science. Khaled Akhtar pointed out that Alberta's forecasting center has an app called Alberta River, where the users can, for example, send picture to report the water levels. John Pomeroy mentioned that there existed an app in UK for over a decade now that you enter the postal code and you can get the flood risk.

Mohammad Ghoreishi raised a question about visualizing model outputs in a way more suitable for social impact. Graham Strickert shared his experience where people did not like a scoring system, but rather those outputs which people care more about, such as water quality or recreational activities. Pat Gober explained a case study in Phoenix where they were really close to creating a map to display the security of water supply, but because of political implications it was not finalized.

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Core Modelling Strategy

Presentations

- **Overview of Core Modelling Positions** (*Al Pietroniro*)

Howard Wheater found it limiting that only 3 out of 28 core modelling positions are allocated to water resources management given the importance of transferring knowledge into a decision-making and intersectoral work; as Eric Wood brought up, there is a need to recognize and possibly reconsider this. Al Pietroniro suggested that the Knowledge Mobilization (KM) team can probably help with this aspect, and highlighted International Joint Commission (IJC) KM work as a successful example. He also suggested that partners and end-user communities can probably contribute in this regard as well. Bruce Davison, and then Al, pointed out that a critical feature of FEWS-type user interfaces should be simplicity and effectiveness.

Masoud Asadzadeh explained how in Manitoba, similar to Ontario, conservation districts make decisions at the sub-basin level, and that our models should be able to analyze these plans and produce relevant outputs. Al acknowledged that decisions are made at local scales but it is challenging to go to these details so at the end of the day a multi-model multi-scale multi-purpose approach seems more appropriate. Eric Wood advised that stakeholders will not tell you about which models to use, but they tell you about what metrics they require. Seven years passes quickly, and the program must consider milestones to interact at smaller time scales with stakeholders through students, post-docs, and HQPs. Curtis Hallborg raised a challenge on spatial variation of model performance at these large scales especially, in the model inter-comparison context. Al agreed and mentioned the importance of a multi-criteria approach for model assessment in this context and that it remains a challenge for KM team to engage people from the beginning.

Saman Razavi made it clear that IMPC's mandate is to start from decision context as opposed to Core Modelling team that deals with ground work model development. He pointed out that user-engagement and KM is key to IMPC and he really wants to involve users and expand IMPC users to tell us about decision problems as early as possible so IMPC can design its research and modelling to address these issues.

Howard Wheater mentioned that there is a small number of stakeholders interested in large scale and a very large number of stakeholders interested in small scales modellings. The modelling strategy for the core team should be at different scales because IMPC is one project and there are other GWF projects that deal with some smaller scale needs.

Eric Wood challenged Howard and the project to do some 1km Land Surface Modelling across all domains that can produce one consistent data set, which large and small scale projects can all use. Al suggested this was an excellent idea, and to consider it as a possible objective for the future. Howard explained how WRF atmospheric simulation is being carried out at 4 km. However, in terms of hydrological models, he was not sure if the assumption of going to hyper-resolution is a better strategy necessarily, given the issues with model structure, parametrization, and process representation at those scales. He pointed out that ultimately we are not sufficiently organized to do this at the moment, but is a promising avenue for the future through models such as CHM. Eric Wood acknowledged Howard's points but offered that some high-resolution data (e.g. Soil, DEM, and land cover) already exists that can be used as a testbed and learning tool.

Program Management

Presentations

- **Project Management and Planning** (*Amin Haghnegahdar, Howard Wheater, Saman Razavi*)

Howard Wheater raised quite a big issue to be resolved as a strategy to reach out and actively connect with stakeholders. Eric Wood described his experience with climate services in Europe where they segmented stakeholders and met them separately, which left them with an improved sense of participation and influence on the work. Amin Haghnegahdar thought some of this discussion are relevant to WP D1 that will be discussed on Day 2. Saman Razavi highlighted the need to plan a lot of individual meetings and come up with a list of potential users. However, he cautioned that due to the scale and scope of the needs we cannot reach all stakeholders. Thus far, the IMPC approach has been focused more on larger stakeholders. This is also an issue that should be discussed at the higher level of GWF. Trish Stadnyk suggested using "student internship" as a great opportunity to engage with stakeholders that has huge benefits for information exchange.

Howard Wheater then brought up the next big challenge. IMPC is a complex program within a more complex program of GWF. This requires a lot of planning done, perhaps mainly by Amin, to ensure we are connecting to participants and people are aware of the work.

On the frequency and mechanism of interacting with partners, Mike Renouf pointed out that once a year in-person meeting and a nearly quarterly virtual meetings for an update seems reasonable. Trish Stadnyk discussed that this depends on the research project and it is best to do a survey to better find out their needs. Howard Wheater suggested a "road show" by Amin with KM team to go to different stakeholders although he cautioned not to get overloaded with in this. Saman Razavi highlighted how Graham explained to him challenges of engaging with communities like Cumberland House. Trish suggested if possible, it is important to have engagement at grassroots levels.

Pat Gober emphasized how in real Knowledge Mobilization researchers and end-user representatives are equal and the process is about trying to understand others perspective. She pointed out the importance of identifying venues of mutual benefits for creating opportunities to engage with partners and stakeholders. Youssef Loukili suggested a

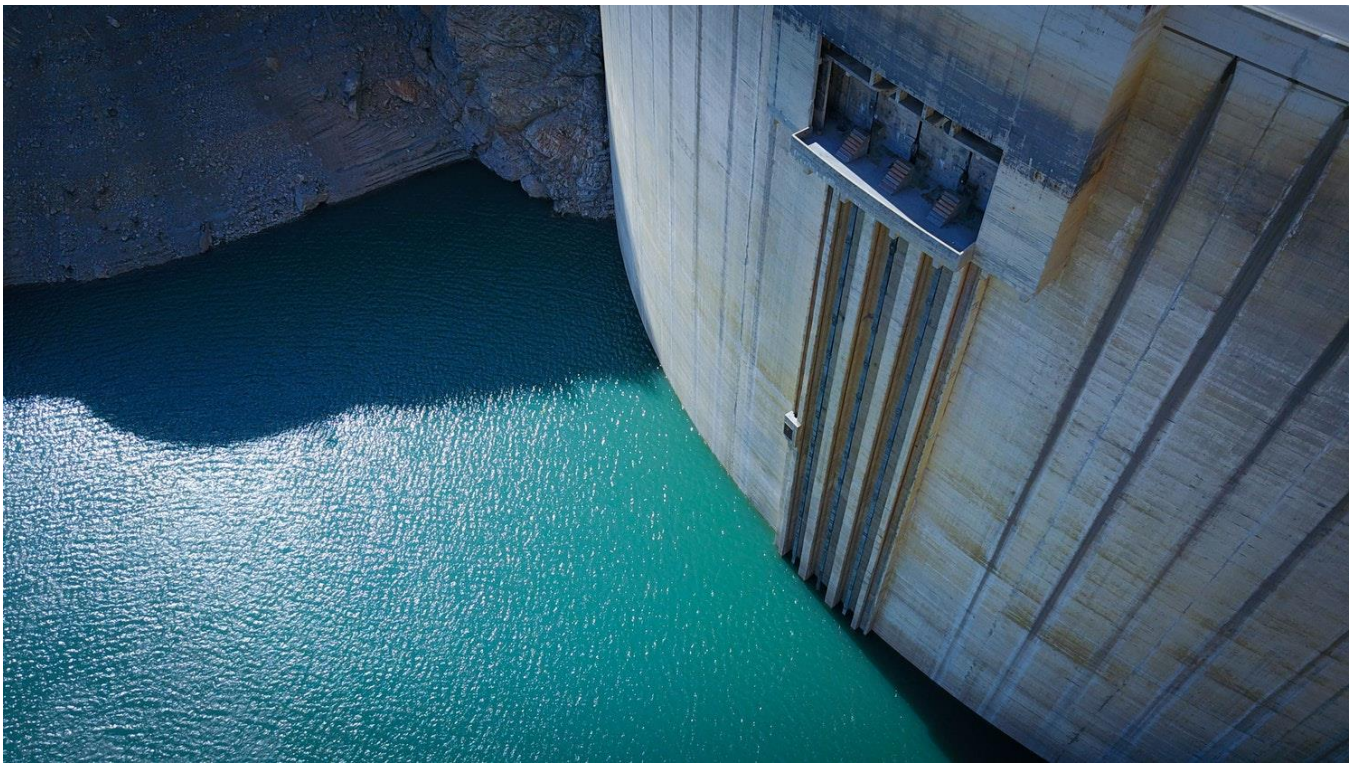
categorization of stakeholders and their needs to find the best way to involve them. Al Pietroniro followed up on this by suggesting that a good strategy for IMPC and GWF is perhaps to reach out to what is called “super-users” or “boundary organizations” such as PPWB or ECCC. Khaled Akhtar highlighted the possibility of learning from other projects such as FLOODNET in this respect.

A quick note by Khaled Akhtar on the timing of future meetings was that AEP forecasting group will be very busy during the forecasting season group May-June-July. Trish Stadnyk, however, pointed out that it is different in Manitoba where the busy forecasting season is March-April-June, so July is OK for them.

Conclusion

Howard Wheater emphasized on some closing remarks that IMPC should consider after this “embryonic” meeting: The project requires an Inception Report, which reconsiders the IMPC’s strong proposal, identifies issues that need modification, and derives clear work plans. One area of complication is the interaction between all GWF the projects and the Core Modelling Team, which Al is overseeing. Details about the Core Modelling Team are not clear at this time, including team members and their roles. Similarly, details of IMPC members and roles are not finalized yet. It is not super urgent as the recruitments are still in progress, however, the management team, including Saman, Amin and Al need to meet in the next few weeks to build on these discussions and develop a more concrete plan that identifies human resources with timelines and deliverables. This is also a point that Eric Wood clearly made and we appreciate his time being here with his very clear and invariably incisive and insightful comments.

At the end, Howard invited Eric Wood to provide his final remarks. Eric Wood advised that this is a very challenging and exciting project - there is no room for sitting back. It is likely that after these two days people realize that the timeline and work plans are tighter than anticipated, and there is a real need for clear and right directions.



Appendix I: Workshop Agenda

Day 1: Thursday, September 14, 2017		
8:00-8:30	**Registration and Refreshment**	
8:30-8:40	Welcome, Introduction, and Overview of the Agenda	Razavi/Pietroniro
8:40-9:00	Global Water Futures: Overview, Updates and, Links to IMPC	Wheater/Pomeroy
9:00-9:15	Overview of the objectives of IMPC and research themes	Razavi
9:15-9:25	Overview of THEME A: Integrated Earth Systems Modelling	Pietroniro
9:25-9:40	High-resolution atmospheric modelling	Li
9:40-10:00	Advancing modelling strategies for Canada (MESH/VIC/CHM)	Pomeroy/Pietroniro
10:00-10:20	**Coffee Break**	
10:20-10:35	GEM-Hydro	Vionnet/Fortin
10:35-10:50	HYPE experience	Stadnyk
10:50-11:05	Model inter-comparison and multi-model analysis	Tolson (WebEx)
11:05-11:15	User perspective: State of hydrologic forecasting in Manitoba and issues	Unduche
11:15-11:25	User perspective: State of hydrologic forecasting in Yukon and issues	Janowicz
11:25-12:30	Hydrology Discussion - forecasting and prediction	Pietroniro (moderator)
12:30-13:30	**Lunch Break**	
13:30-13:40	Non-point source modelling (HYPE and future of MESH/CHM)	Pomeroy
13:40-13:50	Water Quality modelling (land surface and in-stream)	Lindenschmidt
13:50-14:00	River ice modelling	Lindenschmidt
14:00-14:30	Discussion - Water quality, ice	Pomeroy (moderator)
14:30-15:00	Core modelling positions overview and discussion	Pietroniro
15:00-15:20	**Coffee Break**	
15:20-15:30	Floodplain and flood risk analysis - SaskRB perspective	Elshorbagy
15:30-15:40	Floodplain and flood risk analysis - Great-Lakes RB perspective and FloodNet experience	Coulibaly (WebEx)
15:40-16:10	Discussion – Floods	Pietroniro (moderator)
16:10-16:20	Characterization & attribution of uncertainty in modelling	Razavi
16:20-17:30	Project management, planning, and discussion	Haghnegahdar/ Wheater/Razavi
Optional Dinner @ Boffins		

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Day 2: Friday, September 15, 2017		
8:00-8:30	**Registration and Refreshment**	
8:30-8:40	Overview of THEME B: Water Management Modelling, Coupling Human-driven and Natural Systems	Razavi
8:40-8:50	Water resources modelling – SaskRB	Razavi
8:50-9:00	Water resources modelling - Manitoba (Nelson-Churchill)	Asadzadeh
9:00-9:15	In-stream flow demand - Aquatic ecosystem health indicators	Jardine/Peters
9:15-9:30	Hydro-economic modelling	Brouwer (WebEx)
9:30-10:30	Discussion - Water management: modelling of operation, economy, environmental flows	Razavi (moderator)
10:30-10:50	**Coffee Break**	
10:50-11:00	User perspective: PPWB	Renouf
11:00-11:10	User perspective: Irrigation demands in the prairie and irrigation expansion	Tollefson
11:10-11:20	User perspective: WSA issues, Lake Diefenbaker, etc.	Hallborg
11:20-11:30	User perspective: WRMM and Alberta issues	Tang (WebEx)
11:30-11:40	User perspective: Manitoba Hydro's perspective on WRMM	Gawne (Webex)
11:40-12:30	Discussion - Water management: practical issues and stakeholder engagement	Renouf/Razavi (moderator)
12:30-13:30	**Lunch Break**	
13:30-13:45	Overview of THEME C: Decision Making under Uncertainty and Non-stationarity	Razavi/Gober/Wheater
13:45-13:55	Vulnerability analysis of environmental change – applications to water resource futures for Saskatchewan	Wheater
13:55-14:05	Exploratory Modeling and Decision Support	Gober
14:05-14:20	GWF and IMPC plans for knowledge mobilization	Strickert/Gober/Merrill
14:20-14:35	Human-computer interface and visualization	Gutwin
14:35-15:30	Discussion and Conclusions	Wheater/Pietroniro/ Razavi (moderator)