Design Flood Hydrology for BC Natural Resource Professionals Event

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British Columbia's hydrological cycles are changing and many resource professionals are grappling with the implications for design of bridges, culverts and other structures. Design flood hydrology is complex as it is and is made more so by climate change.

To discuss these issues, APEGBC hosted a continuing professional development event this March 28th on Design Flood Hydrology for BC's natural resource professionals. Funded by Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) and supported by the Association of BC Forest Professionals, the workshop's objective was to discuss climate change-induced variations in precipitation patterns, resulting flood hydrology, and steep creek processes. Professional engineers, geoscientists, foresters, and members of other professional associations explored issues relating to terrain stability, design of natural resource infrastructure, and maintenance to discuss strategies for improving the robustness of natural resource infrastructure in a changing climate. In addition to presentations by climate scientists, provincial government staff and the consulting community, case studies and group discussions engaged the audience.

More than 140 people participated in person and via the web. Through the engagement of the climate scientists and practitioners, participants gained insight into current understanding of changes to future hydrology, impacts to natural resource infrastructure, and current practices in the resource industry.

A question considered was "Are traditional methods of design flood hydrology such as the rational and regional method appropriate under a changing climate?" Current requirements for design flood hydrology in the *Forest Planning and Practices Regulation* (FPPR) were outlined, along with tools and resources to understand future hydrologic projections. A discussion on bottom-up approaches to building resilience to crossing structures in the context of climate change also took place. This set the stage for further discussion on hydrology and peak flow design periods.

Current Practices

Current methods of determining design flood hydrology are difficult to calibrate and their accuracy is called into question; they are estimates at best, and results may be variable. A range of approaches are currently used to consider climate change in design flood hydrology practices in the resource industry:

1. minimal considerations (i.e., status quo)
2. considerations for larger permanent structures
3. designing permanent structures to be more resilient to debris flows/floods (i.e., Q_{200} instead of Q_{100})
4. adding an arbitrary factor to increase design peak flow estimates, (i.e., 10 –20%)
5. adding "freeboard" clearance for floating debris and Head Water to Diameter ratio (HW/D) for culverts at the discretion of the Professional of Record.

Current practices include using a longer return period design flood estimate than required in the design of crossing structures (e.g., fords, bridges, portables) and designing these structures to improve their resilience.

Climate Change and Hydro-Geomorphic Processes

The presentation about climate change and hydro-geomorphic processes such as debris floods, debris flows, bank erosion and scour stressed that the correct identification of process type is more important than consideration of climate change, as getting the process wrong may make orders of magnitude difference in the prediction of peak flows and sediment volumes.

The presenter Dr. Matthias Jakob, P.Geo., then explained that sediment movements are indirect consequences of global warming. Uncertainties thus compound and become difficult to quantify reliably.

It was noted that land use, and land cover (e.g., forest fires, forest harvesting) changes occur concurrently with climate changes and may have more dramatic impacts on watersheds than the direct consequences of precipitation changes. One of the principal challenges is to identify the geomorphic thresholds that may be exceeded more often in a future climate.

Future Climate in British Columbia

Despite the inherent uncertainties of future greenhouse emissions, information emerged about future hydrology. The information shared was based on best available science and will likely continue to evolve impacted by the loss of stationarity (the fact that past climate is no longer a reliable indicator of the future climate) and informed by the collection of latest hydrologic and climatic monitoring data:

- Global distribution, magnitude, type, timing and intensity of precipitation is changing;
- Information specific to a particular stream that may be relevant to design decisions is dependent on availability of historic stream flow data;
- These data are only available for certain locations in the province;
- General trends that help with a higher level understanding, including hydrologic projections at a large watershed or regional level, are available. These include:
    - Station observations, including precipitation climatology and cumulative precipitation of weather and climate variables in BC from 1870 to present day;
    - Canada-wide transient climate projection data for precipitation and temperature at a ~10-km resolution
    - Projected gridded model output for four basins in BC at a resolution of 1/16-degree from 1955 to 2098 (roughly 35 km^2 projections of hydrologic states and fluxes for the four watersheds in BC)
    - Projected streamflow data for more than 120 sites in four basins in BC as daily time series from 1955 to 2098
- Many aspects of major floods are changing and many rain-generated and rain-on-snow–generated precipitation events are observed in BC's Fraser, Columbia, Campbell and Peace river basins:
    - Snow dynamics respond strongly to the warming temperature signal with reduced snow accumulation and shorter snow season.

    - More rainfall in winter and fall and potential drought-like conditions in summer may occur;
- Large uncertainty in the modelling of future climate exist – coupled with natural climate variability projections of future climate, these should not be interpreted as precise calculations:
- The projected change in 20-year return event for 1-day precipitation in 2081–2100, relative to 1986–2005, assuming a 'business as usual' emissions trend or "representative concentration pathway (RCP) 8.5" shows that:
    - Magnitude of the 20-year event increases on average 22 percent in the 2081–2100 time horizon compared to the historical baseline;
    - Average return period for what is currently a 20-year event becomes seven years
- RCP 4.5 represents an optimistic reduction in emissions, while RCP 2.6 assumes, extremely optimistically, that global annual greenhouse gas emissions will peak between 2010 and 2020, with emissions declining substantially thereafter;
- Assuming an emissions scenario with aggressive greenhouse gas reductions (RCP 4.5), the projected change in 20-year return level for 1-day precipitation in 2081–2100, relative to 1986–2005, shows moderate changes to the size and average return period:
    - Magnitude of the 20-year event increases to approximately 10 percent for RCP 4.5 scenario; and,
    - Average return period for what is currently a 20-year event becomes 11 years.
- Infrastructure designed in consideration of the 2-, 5-, 10-, and up to the 100-year events may be affected.

Ministry of Transportation and Infrastructure Projects

The BC Ministry of Transportation and Infrastructure's technical circular on climate change (link: http://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/technical-circulars/2015/t06-15.pdf) requires the consideration of climate change in infrastructure design. Examples were presented of projects in which hydrologic data downscaled from the global climate models were used in conducting flood frequency analysis to determine peak flows to address climate change considerations in the design of stream crossings.

Discussing Adaptation

Audience members were asked to consider how hydrologic designs could take account changing climate. They were provided with summaries of climate projections for the 2020s and 2050s for various locations (coastal, inland, large and small watersheds, and varying societal impacts of infrastructure failure) and asked to consider how this might influence the design of structures such as bridge abutments, and road crossings. The following adaptation options were discussed to help professionals focus on climate change considerations:

- choice of the end of design life as the target date for the climate change analysis – this implies "overdesign" in the short term and appropriate design for the end of design life
- availability of downscaled climate change scenario ensembles and hydrological analysis relevant to the location

- investigation of the geomorphology and land use to determine the potential for debris floods or debris flows as those would dominate the infrastructure design rather than the inclusion of a climate change component to runoff
- understanding debris flow and debris flood hydroclimatic triggers and obtaining specific climate model outputs for the key variables to project changes
- availability of regional/local stream flow data
- consideration of a risk-based approach in the project and discussion of design alternatives

A discussion of resiliency afforded by the various design solutions for structures included gravel over steel portable, steel deck portable, concrete slab girders and log stringer bridges.

Next Steps

The audience identified a number of needs in terms of tools and guidance for addressing changing climate in their design of structures. These included more LiDAR data to understand the geomorphology, climate change-based Intensity Duration Frequency (IDF) curves, a tool for quantifying risk of debris floods, policy, practice guidelines and rules of thumb for scaling culvert designs, metrics for changes to run-off coefficients, information about experimental basins, and watershed models. Possible change to the design flow requirements under FRPA and how to deal with hydrologic non-stationarity were also discussed. The Chief Engineer of MFLNRO, Brian Chow, P.Eng. suggested that design flood hydrology in the context of climate change is very complicated and, at this time, no general guidance on approach exists, but efforts are being undertaken and a fuller understanding of types of events and their duration will be important in the future in terms of infrastructure design.

Several sources of information of benefit were noted at the event:

- The Water Survey of Canada is responsible for collection of standardized water resource information which provides real time and historical stream flow data (website: https://wateroffice.ec.gc.ca/);
- Climate change hazards information portal which helps integrate climate change impacts into planning and design of public infrastructure (paid website: http://www.ccinnovations.ca/clearinghouse/1132/cchip-predicting-the-impacts-of-climate-change-on-infrastructure/);
- The climate models and rainfall information provided by the Pacific Climate Impacts Consortium (website: https://www.pacificclimate.org/),
- Exploratory tools:
    - A recent add-on for Stormwater Management Model, the Climate Adjustment Tool,
    - University of Western Ontario's IDF CC Tool (website: https://www.idf-cc-uwo.ca/HelpFaqTOU)

It was evident from the event that even though there is still a lot we do not know and intricate system interactions we do not understand, best available science includes a great deal of climate information to help with the current understanding. Close collaboration between engineers, hydrologists, geomorphologists, meteorologists, climatologists, forest professionals, other resource professionals and owners of natural resource infrastructure is needed now more than ever to determine what design and operations and maintenance strategies might be useful in addressing risks, costs and benefits. Importantly, climate change will add one additional component in the uncertainty for the design of structures on small and typically steep creeks. The other uncertainties inherent in ungauged basins are at least as important in quantifying reliably. In this context, changes in hydroclimatic extremes (rather than annual means) are key.

Based on the information collated at the event, the APEGBC Climate change information portal (www.apeg.bc.ca/climateportal) has been updated to provide more resources for professionals in the natural resource sector actively involved in design flood hydrology. APEGBC's continuing professional development events can be accessed at www.apeg.bc.ca/events and practice guidelines at www.apeg.bc.ca/guidelines.