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Calibration of an Ice Jam Flood forecasting System for the Lower Red River, Manitoba

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Background

The lower reach of the Red River in Manitoba, between Winnipeg and Lake Winnipeg has been an area often afflicted by ice jam events and the severity and frequency of these events have increased in recent decades (Lindenschmidt et al. 2010). Severe jams of this nature attribute to extensive property damage, economic loss, and sometimes even loss of life. Hence, there is a need for an ice jam flood forecasting system for this site to help provide flood managers and government agencies with information essential for better flood mitigation strategies.

Model Setup and Calibration

RIVICE, a one-dimensional ice hydraulic model embedded with river ice processes was utilized to simulate actual ice jam events.

- **Upstream Boundary Condition**: Volumetric flow readings recorded at the Water Survey of Canada gauge station, Red River at Selkirk Bridge (Gauge 4)
- **Downstream Boundary Condition:** Water levels recorded on Lake Winnipeg (Gauge 6).

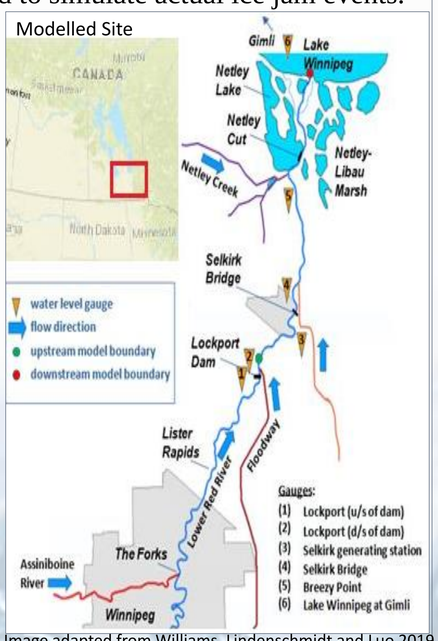


Image adapted from Williams, Lindenschmidt and Luo 2019

Widths of outflows were introduced to simulate water leaving the main channel during ice jam flood events.

RIVICE was used to simulate ice jam events that occurred during three different years during the spring break up period in order to calibrate how much water was lost from the main channel due to overbank flow and leakage into the floodplain.

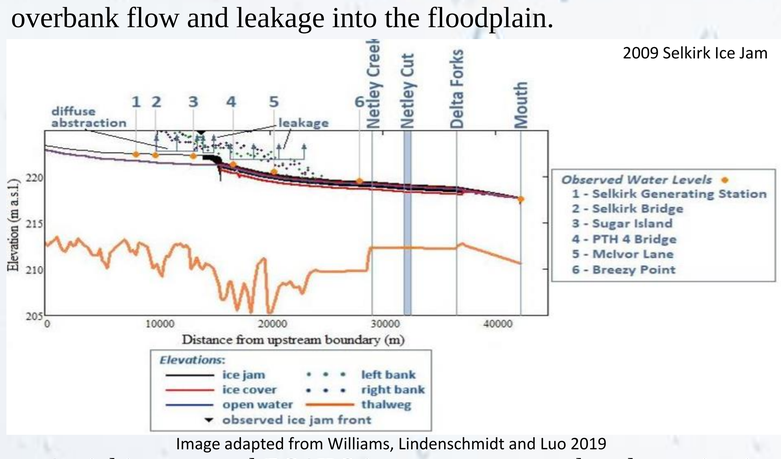
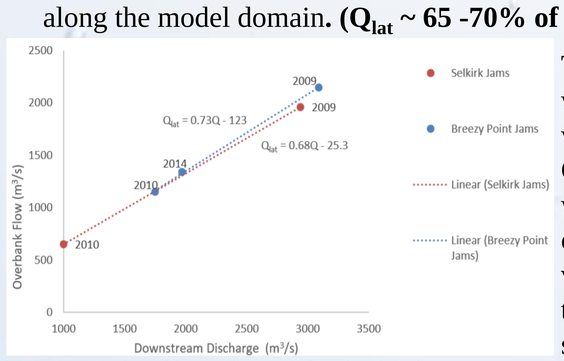


Image adapted from Williams, Lindenschmidt and Luo 2019

- Aerial images and RSAT-2 imagery were used to determine ice jam toe and front locations during events.
- Ice volumes and widths of outflows were adjusted until simulated ice jam fronts and water levels agreed with observations.
- Five ice jam events were simulated, where a relationship between flow and overbank flow for two different stretches along the model domain. **(Q_{lat} ~ 65 -70% of Q)**



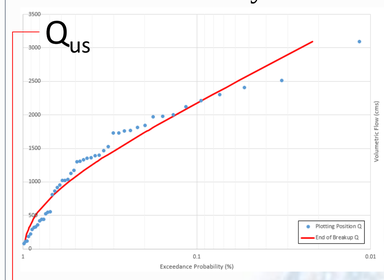
This relationship was then setup within a Monte Carlo frame-work in order to calibrate the volume of ice in the two separate stretches.

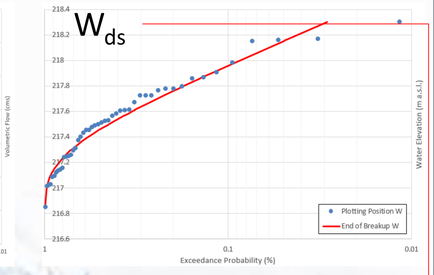
Image adapted from Williams, Lindenschmidt and Luo 2019

Stochastic Model Calibration

First, frequency distributions for boundary conditions are needed.

- 48 years of upstream flow and downstream water level records were available for spring breakup periods
- Staging at the end-of-breakup was considered to be the water level recorded at the last B-flag.
- The following day's flow recording was taken as the flow at the end of the breakup period.
- Gumbel distributions were created from the 48 years of data for both boundary conditions.





- Now is time to calibrate the frequency distribution for the volume of ice forming the actual ice jams, where the frequency distributions above are used as input.
- The distribution of the location of the ice jam toe is uniform because the lodgment of the ice jam can occur anywhere between a range of places.
- It is assumed volume of ice will follow a General Extreme Value distribution so, a Gumbel Distribution is first used to estimate its frequency distribution.

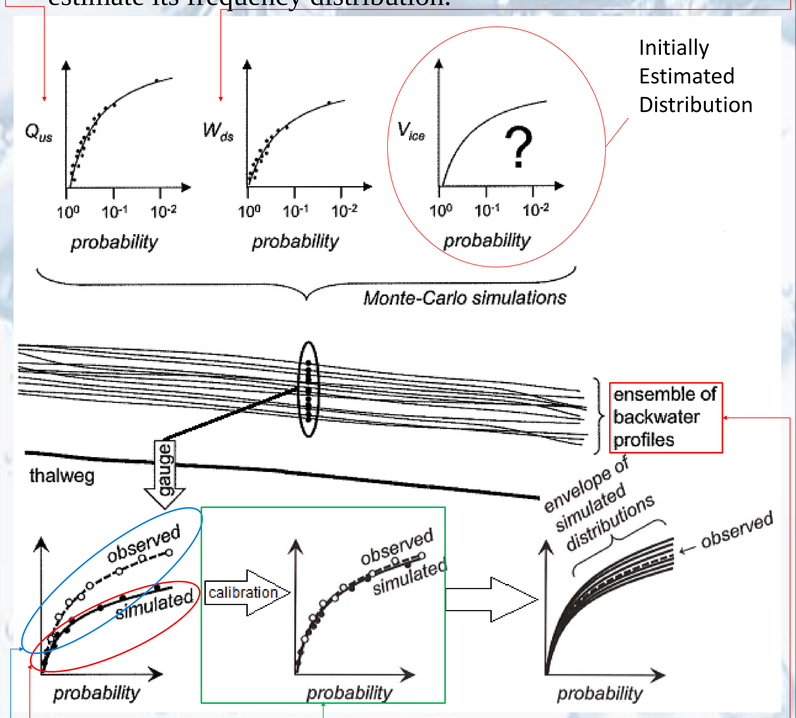
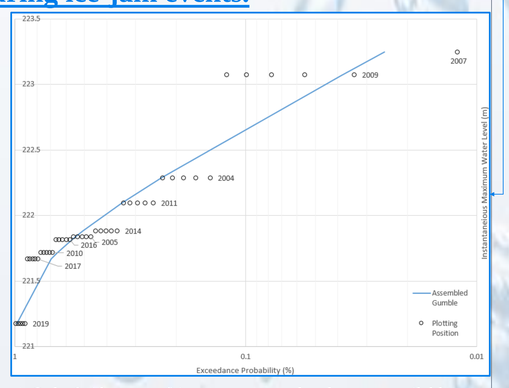


Image adapted from Lindenschmidt (In review)

- Random values are drawn from these distributions for multiple runs to yield an **ensemble of backwater level profiles.**
- Water levels are extracted from the ensemble at gauge locations where a **simulated ice-jam stage frequency distribution** is created.
- The simulated distribution is compared to an **observed frequency distribution – instantaneous maximum water levels experienced during ice-jam events.**
- Location and scale parameters of V-ice distribution altered, and runs reiterated until observed and simulated agree.
- Many model runs ran to obtain an envelope of ensembles. The observed distribution should run through median of envelope.



* Only 9-10 years of inst. max water levels were available, so the observed distribution had to be assembled from multiple values of the lower observations and a lone max observation.

Breakup and Model Forecasts

- Once the V_{ice} distribution is calibrated, the model should be tested for forecasting purposes.
- The same stochastic framework can be used for operational ice jam flood forecasting, **however**, in real time as more information is determined about possible ice jam locations and boundary conditions, **frequency distributions can be constrained!**
- Only random values between the constrained ranges of the distributions will be used in the Monte Carlo simulations.

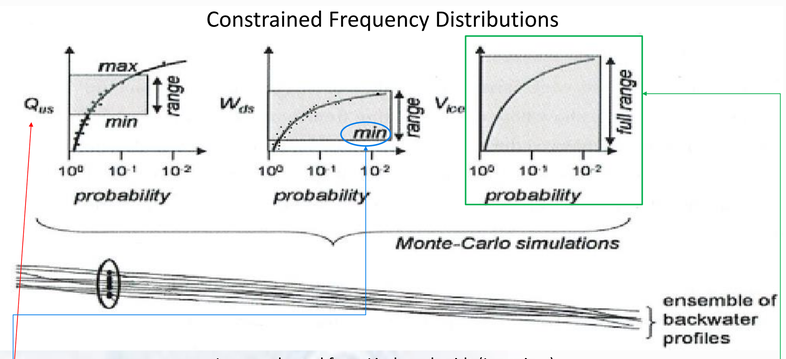
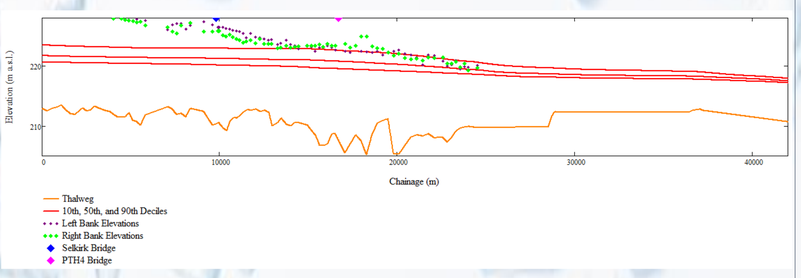


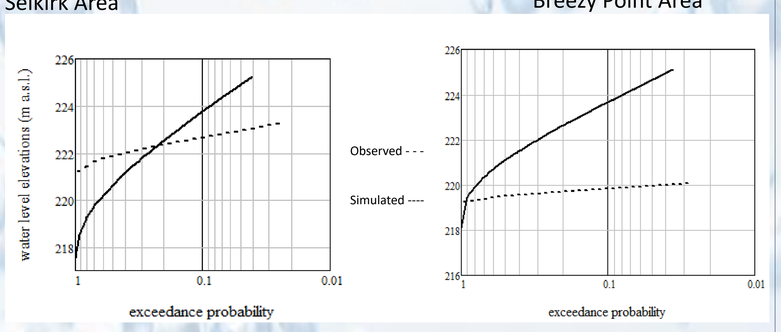
Image adapted from Lindenschmidt (In review)

- Flow forecasts for the Red River are based off of empirical relationships and are used to constrain a range of probable flows
- Water levels from the downstream gauge can be used to set a minimum value for the downstream water distribution.
- It is recommended to use the whole unconstrained V_{ice} distribution, because ice thickness estimates are often quite uncertain and far upstream ice may contribute to ice jam volume later than the initial jam.
- Monte Carlo simulations are executed hundreds of times to create an ensemble of backwater profiles.
- Flood probability maps or profiles showing probability of flooding along the river channel can be produced such as the example below



Current Project Status

Right now, the V_{ice} frequency distribution for two different areas are being calibrated for the Lower Red River site.



Once the model has been stochastically calibrated, validation will be conducted by hindcasting the breakup events of the 2019 season.

References

Lindenschmidt, K.-E., Syrenne, G., & Harrison, R. (2010). Measuring Ice Thicknesses along the Red River in Canada using RADARSAT-2 Satellite Imagery. Journal of Water Resource and Protection, 2-11, 923-933.