RIVER PREDISPOSITION TO ICE JAMS: A GEOSPATIAL MODEL

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1. Introduction

When dynamic breakup occurs on rivers, ice moving downstream may eventually stop at an obstacle when the volume of ice exceeds the transport capacity of the river, resulting into an ice jam. The suddenness and unpredictability of these ice jams are a constant danger to local populations. Therefore forecasting methods are necessary to provide an early warning to these populations.

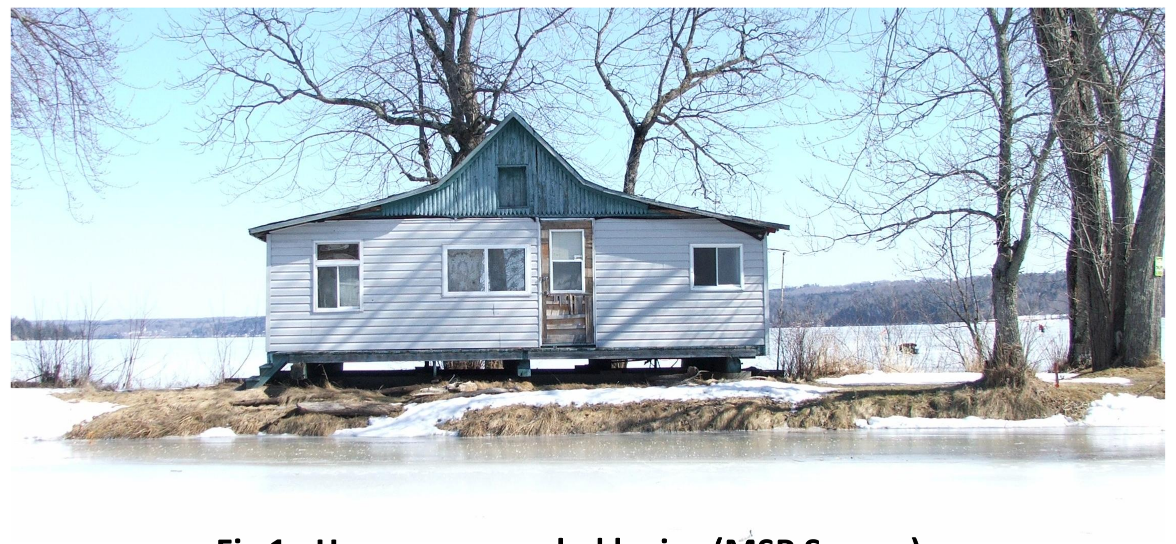

Fig 1 : House surrounded by ice (MSP Source)

2. Objectives

The morphological and hydrological factors controlling where and how the ice will jam are numerous and complex. The aim of this project is to develop a simplified geospatial model that would estimate the predispositions of any river to ice jams. The question here is not to predict when the ice will break up but rather to know where the released ice will be susceptible to jam.

3. Study Area

- Chaudiere River, south of Quebec city (Canada).
- Flows south to north from Megantic Lake to the Saint-Lawrence River.
- History of ice jams and frequent flooding of riverside municipalities.
- 185 kilometers long, 6682 squared kilometers watershed.
- 180.000 inhabitants along the entire watershed.

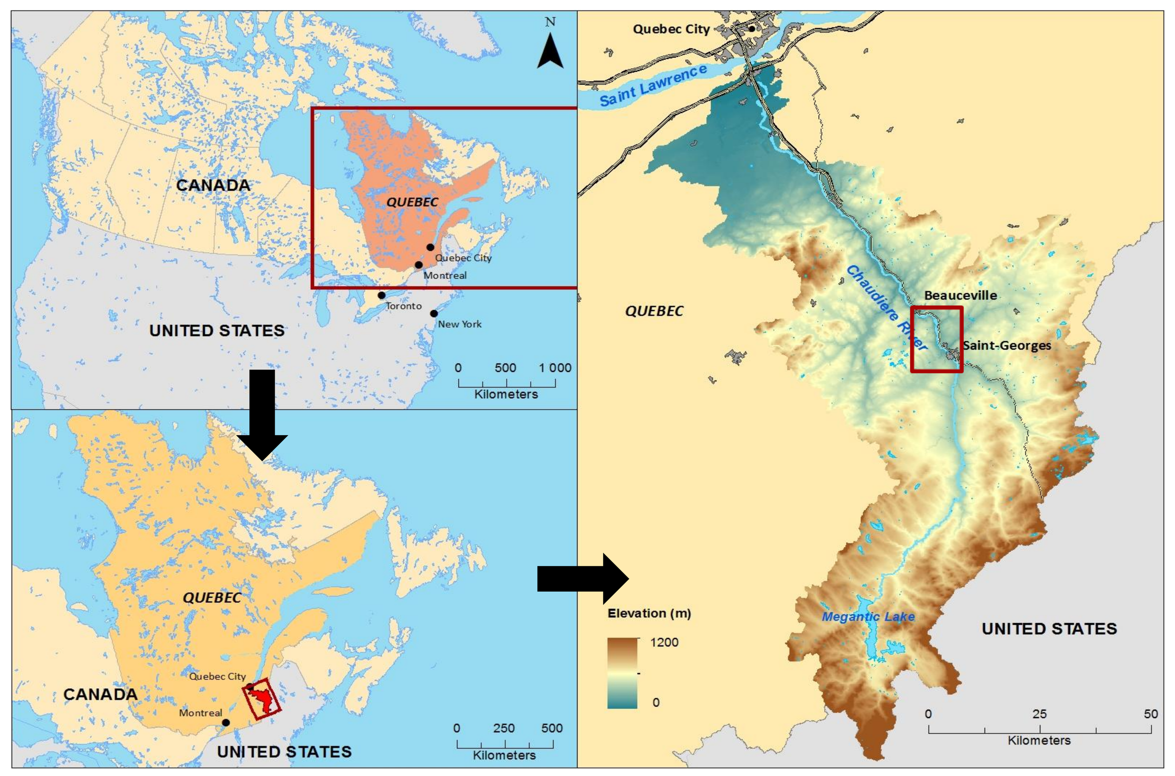

Fig 2 : Chaudiere River watershed situation

4. Methodology

A. Geospatialization

The six following factors have been selected in the literature as a main potential cause of ice jams:

1	Presence of an island	4	High sinuosity of the channel
2	Presence of a bridge	5	Confluence
3	Narrowing of the channel	6	Slope break

Input data comes from the National Hydrographic Network (NHN), the National Topographic Database (NTDB), and the Quebec Topographic Database (BDTQ).

Geospatialization is the spatial representation of a physical characteristic of the channel and its transformation into a potential ice jamming factor. Tools from the GIS-based FRAZIL system (developed at INRS) have been used to generate the river channel centerline, its segmentation into equal length sections, calculation of the width, and calculation of channel sinuosity along the axis (Fig 3). This information was derived from readily available geospatial data over 250 m regular-spaced segments along the entire channel.

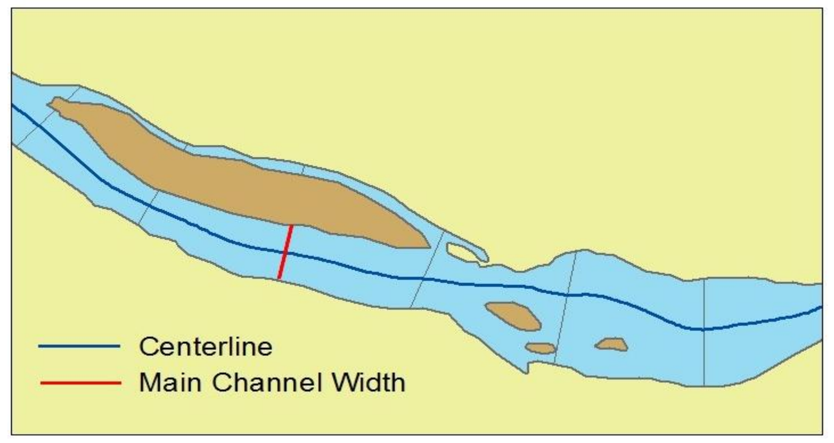

Fig 3 : Spatial representation of the FRAZIL outputs, channel centerline, width and sinuosity

1/2. Correction of the segment width

Island ⇒ Main channel width is kept

Bridge ⇒ Half of width is kept (difficulty to estimate numbers of pillars)

3. Narrowing Index (Fig 4) : $NI = \frac{Wi}{Wmax}$ **PARAMETER 1**

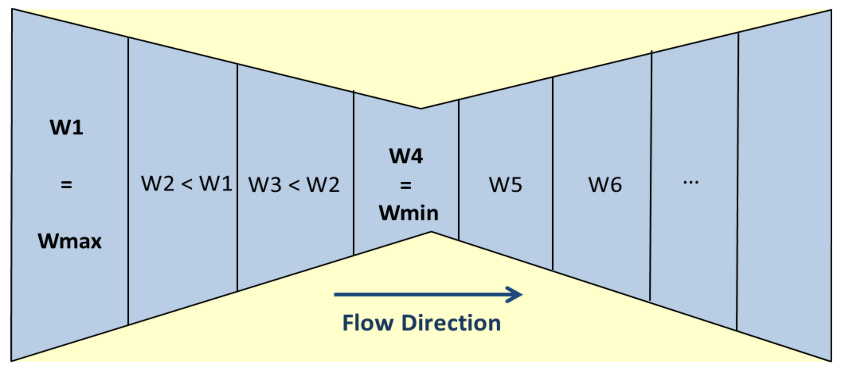

Fig 4 : Narrowing index algorithm, calculated by dividing the segment width by the upstream maximum width

4. Standardized Sinuosity Coefficient : $S = \sqrt{1 - \frac{1}{Ks^2}}$ **PARAMETER 2**

5. Average Affluent Slope : $ASlope = \frac{\text{Global difference in elevation}}{\text{Main stream length}}$

6. Slope Break Index

DEM ⇒ Upstream points elevation ⇒ Percent slope ⇒ Slope Break Index

$$Slope = \frac{H_i - H_{i-1}}{L} \times 100$$

$$\text{Slope Break Index (SBI)} = (Slope_i - (A)Slope_{i-1})$$ **PARAMETER 3**

B. Conceptual Model

The conceptual model integrates these three parameters to establish the potential occurrence of ice jams along the river, the ''Ice Jam Predisposition Index''. This is the second version of the model (De Munck et al, 2011).

1. Parameters values standardisation

For each parameter, values are divided into four classes : 1 is given to the weakest, 4 to the strongest. Threshold values are found according to ''Natural Breaks''. Natural Breaks classes are based on natural groupings inherent to the data, maximizing the difference between classes (Fig 5).

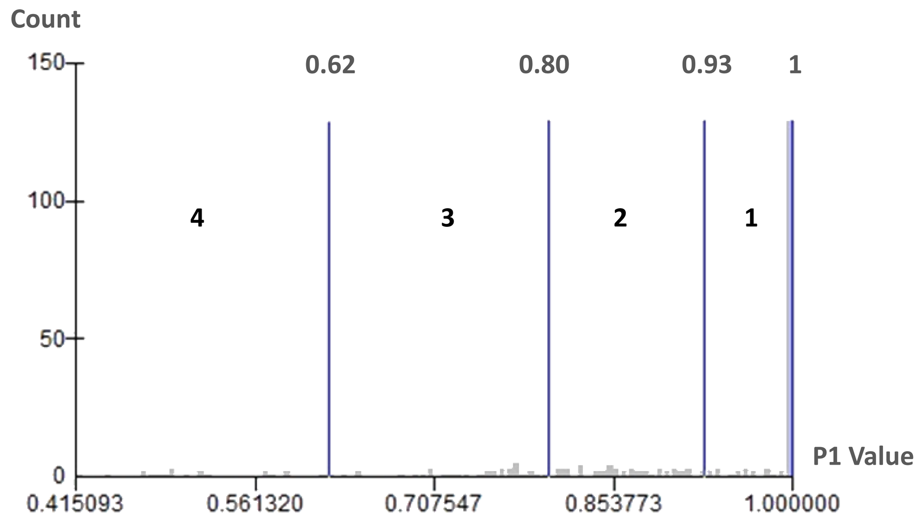

Fig 5 : Parameter 1 classes establishment, 4 corresponds to stronger narrowing, 1 to weaker

2. Parameters relative importance

Each parameter have a different degree of importance in the jamming process. According to literature, we gave weights from minimum 1 to maximum 9 (Fig 6).

3. Parameters weight

By calculating the priority vector, the normalized main eigenvector, we found a different weight for each parameter. Sum of weights is equal to 1 (Fig 6).

Parameter	1	2	3	Priority Vector
1	0	3	5	0.65
2	1/3	0	2	0.23
3	1/5	1/2	0	0.12

Fig 6 : Parameters relative importance and parameter weights (priority vector)

4. Ice Jam Predisposition Index

The class value attributed to each parameter is multiplied by the weight factor. Sum of weighted values is divided by sum of weighted maximal values.

$$\text{Ice Jam Predisposition Index} = \frac{\sum_{k=1}^{3} V_k W_k}{\sum_{k=1}^{3} V_{max} W_k}$$

C. Validation

- Validation is still in progress and the model is currently validated upon historical observations and local knowledge, collected in partnership with the Ministry of Public Security.
- Observations are listed in an intern journal software by ministry terrain agents from 2005 to nowadays.
- Often recurrent accuracy issues : if the break up point is well documented, often, it is not the case for the congestion point.

5. Preliminary Results

The river section south of Beauceville is used to compare the model and the historical data. This section is well documented with information on ice jams and also contains all the jamming factors selected for the study.

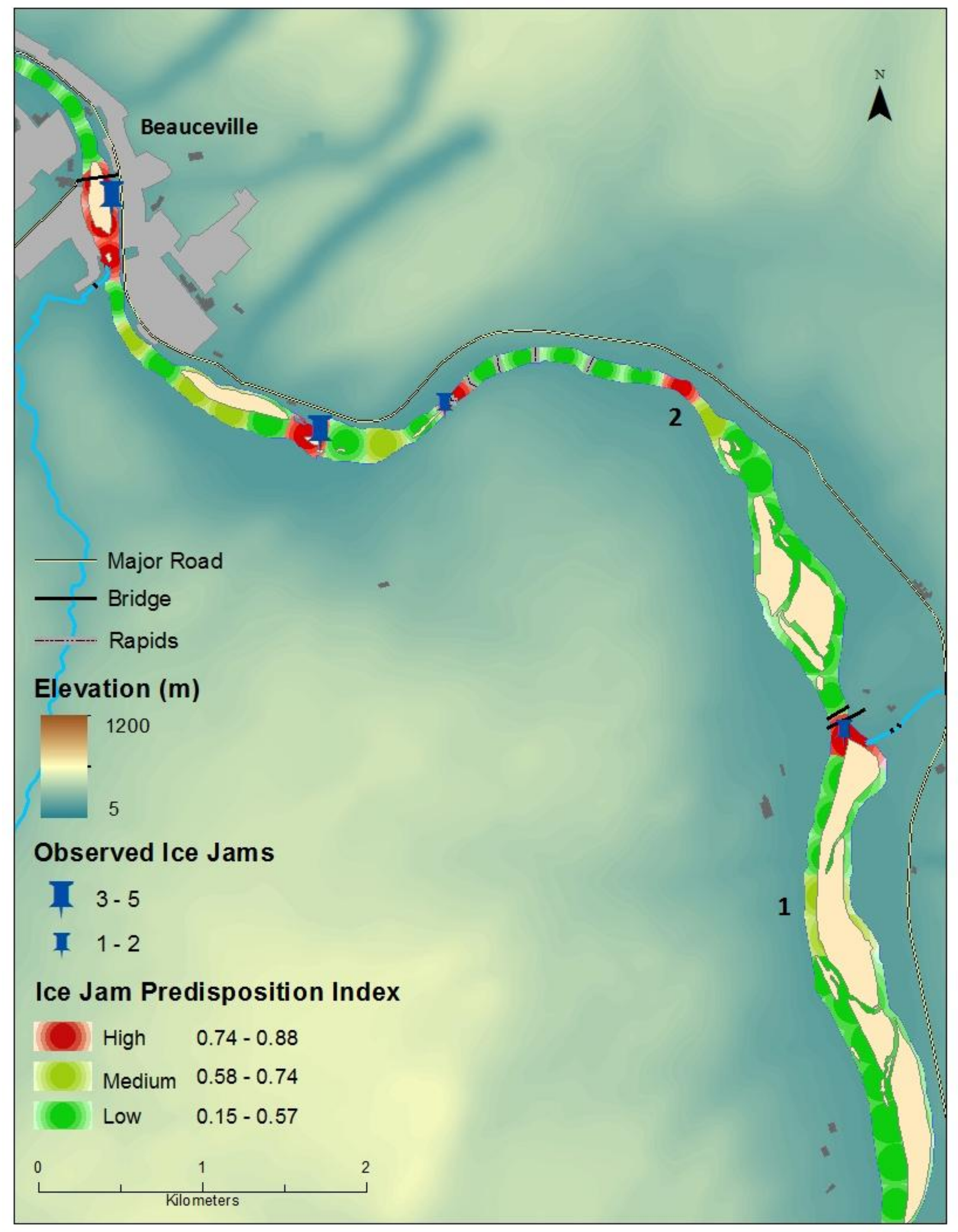

Fig 7 : Model results and observed ice jams (2005-2012) near Beauceville

- Three risks of jamming classes based on Natural Breaks.
- Ice Jam Predisposition Index tend to overestimate values in the high class, as on points 1 and 2 (Fig7).
- Parameter 1 (natural narrowing, islands and bridges) weight is too strong in the model.
- Still better to have more false-positive errors, in order to minimize false-negative error, which can result into a lack of warning.

6. Perspectives

The preliminary results presented here are encouraging. High risk in the model corresponds with ice jams known sites. However the geospatial model still presents certain limitations because of some positive errors (false ice jam predisposition). To be approved the model will be tested on two other rivers, the Saint-François River and the Assomption River, also in southern Quebec. This structural model might be an input in further studies which would take into account hydrological and meteorological conditions.

7. References

De Munck, S., Gauthier, Y., Bernier, M., Poulin., J., Chokmani., K, 2011, *Preliminary development of a geospatial model to estimate a river channel's predisposition to ice jams*, CRIPE 16th Workshop on River Ice.