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Preventive Ice Cover Weakening in a Hanging Dam at St. Raymond, QC

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1 Context

Recent flooding events along the St. Anne River at the Town of St. Raymond, QC (50 km West of Quebec City, QC) led to the deployment of an unprecedented effort to reduce the risks related to the 2015 breakup (Turcotte and Morse, 2015). Proactive ice weakening interventions were applied in March and April 2015, based on the experience from past years and in other rivers (e.g. Beltaos et al, 2007a; Beltaos et al, 2007b; Topping et al., 2008). The objective was to improve the channel conveyance capacity through a large hanging dam (Vergeynst et al., 2015) prior to breakup. A standard excavator and amphibious excavator were used. This poster presents the results of a field survey that had for objective to evaluate the efficiency of these ice-weakening interventions.

2 Mechanical ice cover weakening measures

In winter spring of 2015, the ice cover in the St. Anne River consisted of a 2.5-km long floating ice cover section followed upstream by a 9.5-km long frazil hanging dam or frazil jam. Ice weakening interventions were applied between Chute-Panet Dam (km 0.0) and the Ice-Control Structure (km 6.2). Many photographs and videos were taken to monitor the progress and the result of each mechanical weakening technique.

2.1 Standard excavator

The standard excavator (backhoe with a 1.5 m^3 bucket) created channels into the thick hanging dam starting from upstream (km 6.0) to downstream (km 4.2). The excavator could work directly on the ice where the hanging dam was grounded and the resulting channel was locally as wide as 27 m (i.e., 27% of the channel width). However, for security, operational and limited access reasons (floating ice cover, presence of bridges and private properties), the excavated channel was not continuous (combined length of 1.2 km) and it was only 14-m wide on average. About 30 250 m^3 of ice were withdrew from the river and deposited on the bank forming impressive (5-m high) ice and snow dikes (Figure 1). The progression speed of the excavator was about 13 m/h. The complete data for the standard excavator is shown in Table 1.

Figure 1. Standard Excavator working at km 5.8 in the St. Anne River (looking upstream with the ICS in the background)

Table 1. Data relative to the field work made by the standard excavator and the amphibious excavator in the St. Anne River in March and April 2015

	Standard Excavator	**Amphibious Excavator**
Location	Between km 4.21 to 6.09	km 0.23 to km 5.13
Operating days	11 days (96 hours)	5 days / 4 nights (99 hours)
Operating weight	35 000 kg	25 000 kg
Type of ice cover	Frazil hanging dam	Floating / Frazil hanging dam with grounded reaches
Total distance covered	1240 m	5110 m
Mean excavated width	14.3 m (up to 27.5 m)	13.7 m
Mean ice thickness	120 cm (up to 315 cm)	60 cm
Excavated/broken volume of ice	30 250 m^3	39 650 m^3
Mean progression speed	113 m/d or 12.9 m/h	1022 m/d or 51.6 m/h
Volumetric flux of broken ice	2750 m^3/d or 315 m^3/h	9600 m^3/d or 400 m^3/h
Cost by unit volume	0.54 \$/m^3	1.42 \$/m^3
Cost by unit distance	13.15 \$/m	12.90 \$/m

2.2 Ice weakening process by the Amphibex

The amphibious excavator ("Amphibex", Eco Technologies, New-Brunswick, Canada) was launched on the floating ice cover at km 0.2. It broke through the floating ice cover (from km 0.2 up to km 2.5) and then continued to break the cover that overlaid the frazil hanging dam up to km 5.1. This 5000-m long, narrow channel connected one 320-m long ice-free channel segments excavated by the backhoe. Table 1 presents the data about the Amphibex work.

Due to the low channel discharge and the presence of an intact ice cover between km 0.0 and 0.2, the channel was still occupied by broken ice and slush and the Amphibex was not able to use its rear propellers. Instead, it was using its arm and bucket to pull its platform forward (Figure 2A). Broken ice "blocks" were deposited on the intact ice cover on the side. Its progression up to km 2.5 was slower than usual (broken ice pieces are normally transported downstream by the current) and it was even slower upstream of km 2.5 through the hanging dam. Table 2 shows how the type of ice cover affected the Amphibex progression. Its velocity was reduced by 29% in the non-grounded frazil hanging dam and down to 43% in the grounded reach of the dam. As a consequence the cost of ice cover weakening operations by unit of distance was significantly higher in the hanging dam. This result compares with observations from Beltaos et al (2007).

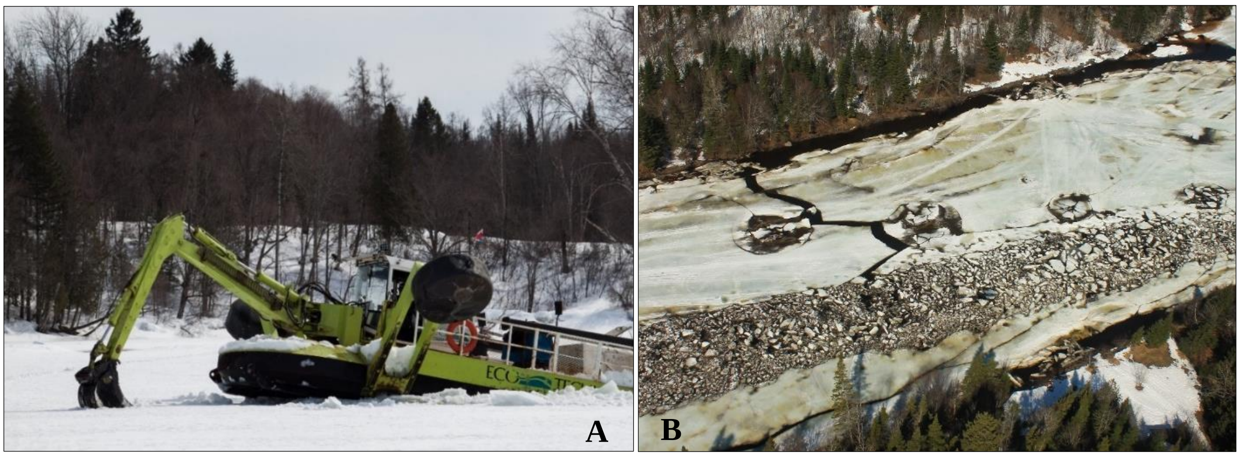

Figure 2. (A) Amphibex at work at km 0.3 on the St. Anne River and (B) channel made by the Amphibex at km 1.3, 8 days after the end of the ice weakening measure. The ice cover depicted presents several signs of advanced deterioration (cracks and open spots) even on the side of the channel. Of interest in the picture is the presence of artificial islands (old rafting boxes).

Table 2. Progression and cost of the amphibious excavator affected by the type of ice cover. (The comparaisons in percent are compared with the floating ice cover).

Parameters	**Floating ice cover**	**Frazil hanging dam**	**Grounded hanging dam**
Time in each ice cover (h)	38.75	60.25	
Distance covered (m)	2 270	2 840	
Ice cover thickness (m)	0.36	0.60	Up to 2.9
Mean channel width (m)	19	12	
Broken ice volume (m³)	15 300	24 350	
Progression speed (m/h)	58.6	41.8 (**-29%**)	33.6 (**-43%**)
Cost by unit distance ($/m)	9.70	12.00 (**+19%**)	16.90 (**+43%**)

Table 1 reveals that:

- The total distance covered by the Amphibex was 4 times longer than the standard excavator although their respective costs by unit distance are similar.
- The cost in $ per unit of excavated ice volume is 2.5 times cheaper with the standard excavator but its applicability is mostly limited to the grounded hanging dam reach.

3 Discussion

The 2015 thermal breakup event in the St. Anne River only partially contributed to validate the efficiency of these two mitigation measures. The standard excavator intervention was limited by the type of ice cover and by the presence of private properties and bridges, and its overall progression (only 100 m/d) was slow. Though the backhoe removed significant amounts of ice, there still remained a lot of ice in the excavated channel. The efficiency of the channel to prevent an ice jam is unknown because the type of breakup in 2015 was thermal. Given the amount of time that the channel was excavated before the ice finally cleared, there was significant melting and degradation of the ice in the River and the channel became wider under sunny conditions.

For some unknown reason, the Amphibex did not break the ice cover between km 0.0 and 0.2. This, in our view, was a fundamental error that prevented broken ice pieces from being evacuated. As a consequence, progress was very slow and solar radiation had to melt the ice and slush in the channel over several days after the Amphibex operation had ended (Figure 2B). The excavated channel was very narrow and sinusoidal. Moreover, the presence of the hanging dam decreased dramatically the cost-benefit ratio of this intervention (Table 2).

Both the standard excavators and Amphibex provide some benefits for St. Raymond but the suddenness of some historical mid-winter and spring flooding events, the logistics involved, and the fact that the hanging dam was grounded lead to the conclusion that the ice jam flood risk cannot be adequately mitigated using these two weakening measures only.

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