Mapping the impact of levee failure on flood risks: A Toronto case study

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NH1.4
EGU23-3616

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1 - Research background

Earthen levees are part of flood defense systems as the levee in Etobicoke Creek (EC), Toronto, Canada (Fig.1). Although in good condition, a levee may fail during flood events [1]. In this research, we investigate the impact of levee failure due to backward erosion on flood risk.

2 – Method

2.1 – Hydraulic model

We used HEC-RAS to model a 350-yr return period event (Fig.2). Our hydraulic model is based on: a bathymetry survey for cross-sections, a high resolution DTM, and historical flow data. The flood extent is shown in Fig.3. We simulated two breaches (A, B in Fig.4, Fig.5) at different locations [2] to study the impact of levee failure on flood risk.

Fig.1: Earthen levee in yellow, EC river in blue

EC river flowing southwards

Crest of the levee with a walking path

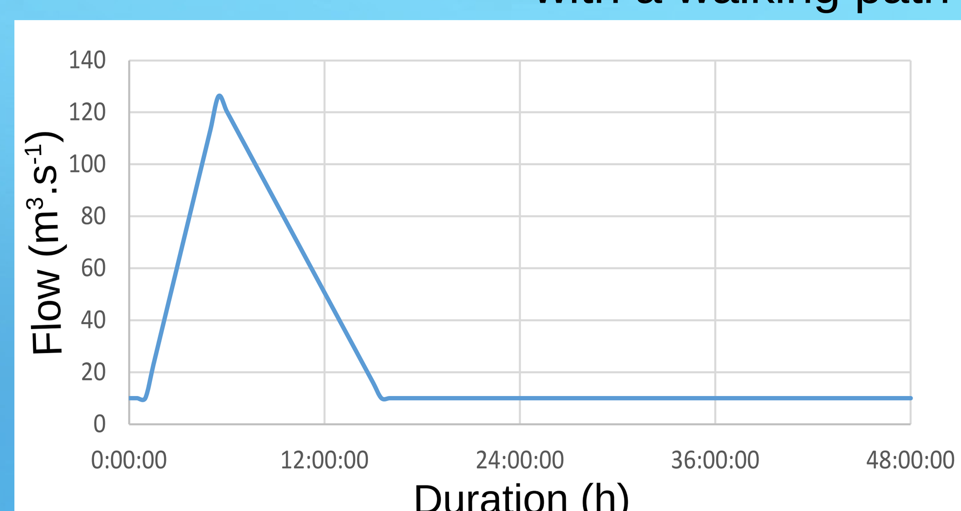

Fig.2: Hydrograph of a 350-yr simulation in EC

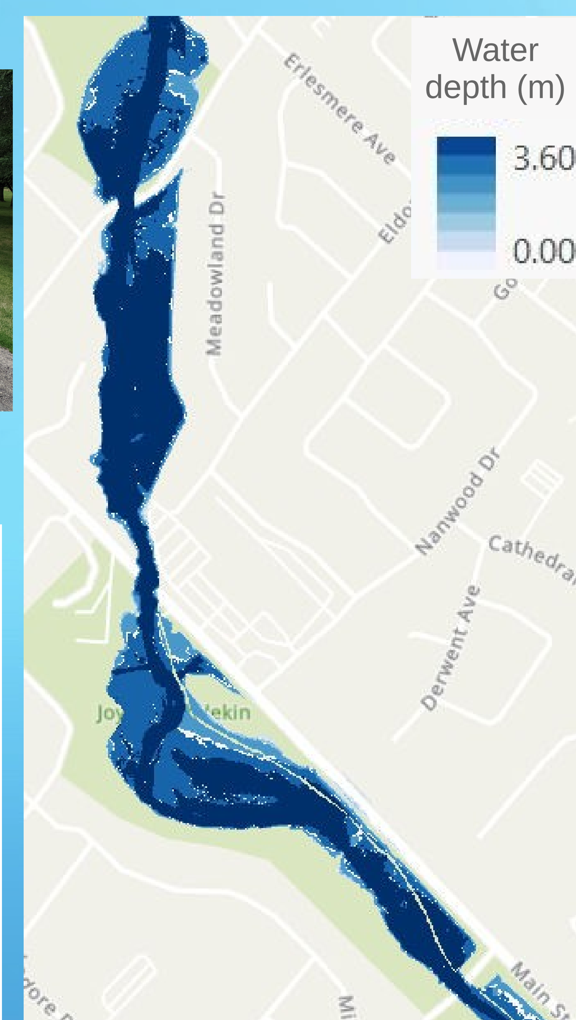

Fig.3: Max water depth for 350-yr return period

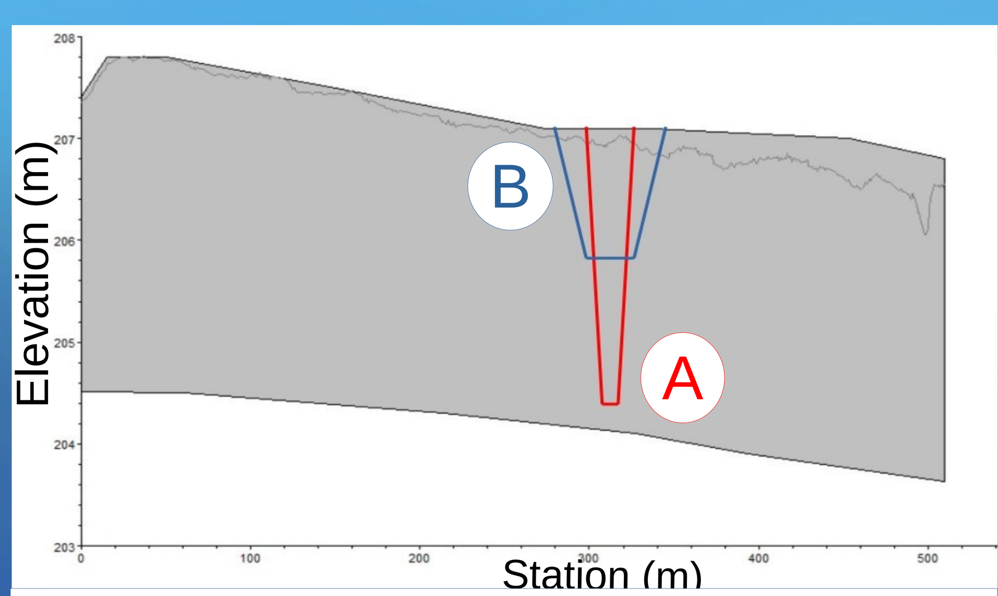

Fig.4: Example of two breaches tested

Fig.5: Flow through a breach

2.2 – Flood risk mapping

Flood risk maps combine flood hazard (depth and velocity) with social (Tbl.1) and economical exposure [3]. In Tbl.2, we associated a qualitative vulnerability level (1-5) to the economical criterion based on land-use and to the percentage of population per social exposure criterion. We used ArcGIS Pro to overlay with equal weight each raster (Fig.6, Fig.7).

Tbl 1: Social exposure criteria

Social Indicators	Criterion
Age	75-yrs and older
	25 to 40-yrs
Language proficiency	No English nor French, French only
Income	Low Income Measure after tax
Population	Population density per km²

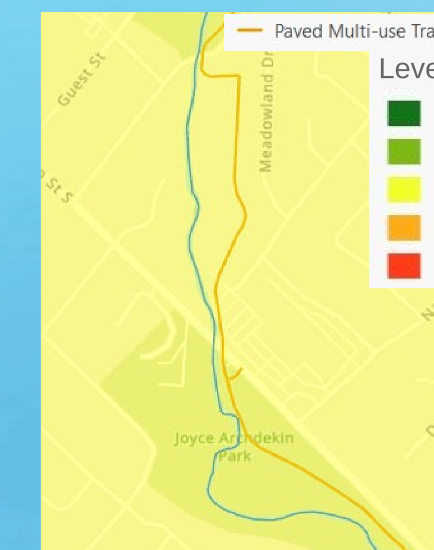

Fig.6: Social vulnerability

Fig.7: Economical vulnerability

Tbl 2: Economical and social vulnerability levels

Level	Economical	Social
5 Very high	Industrial	> 80 %
4 High	Commercial, residential buildings	61 - 80 %
3 Medium	Government and institutional	41 - 60 %
2 Low	Pervious build up areas	21 - 40 %
1 Very low	Forest and recreational open areas	≤ 20 %

3 – Results

Breach A, showed that low bottom elevation leads to longer duration of breach flow and steep side slopes increase the velocity through the breach. Velocity depends on breach location as shown in Fig.8.
Breach B do not produce any noticable water velocity variation and behaves like overflow.
Overall computed risk maps show that a larger area is at risk due to breaching as in Fig.9. However, the social vulnerability data set has a significant lower resolution than water depth&velocity map (Fig.10) and the economical vulnerability map, affecting the resolution of the risk. Hence, Fig.11 shows risk without social vulnerability.

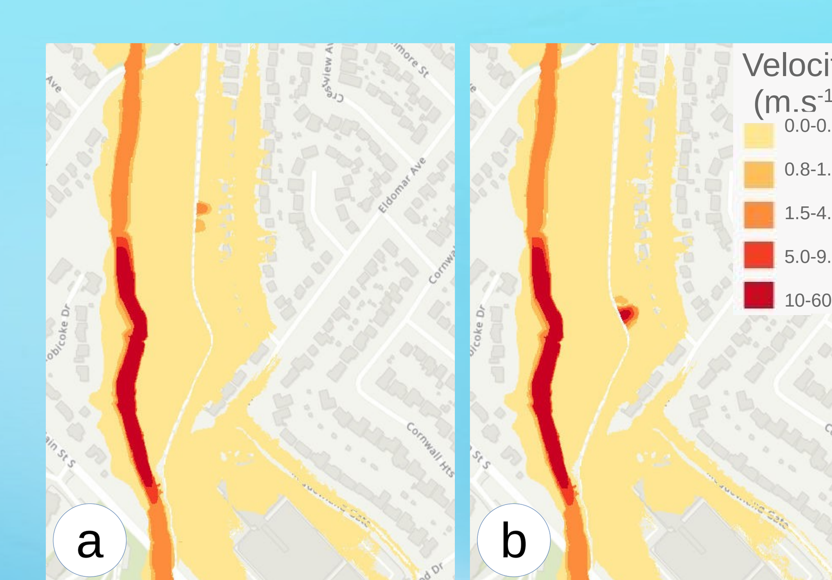

Fig.8: Breach velocity example for two breach location

Fig.9: Flood risk map for (a) no breach and (b) a breach

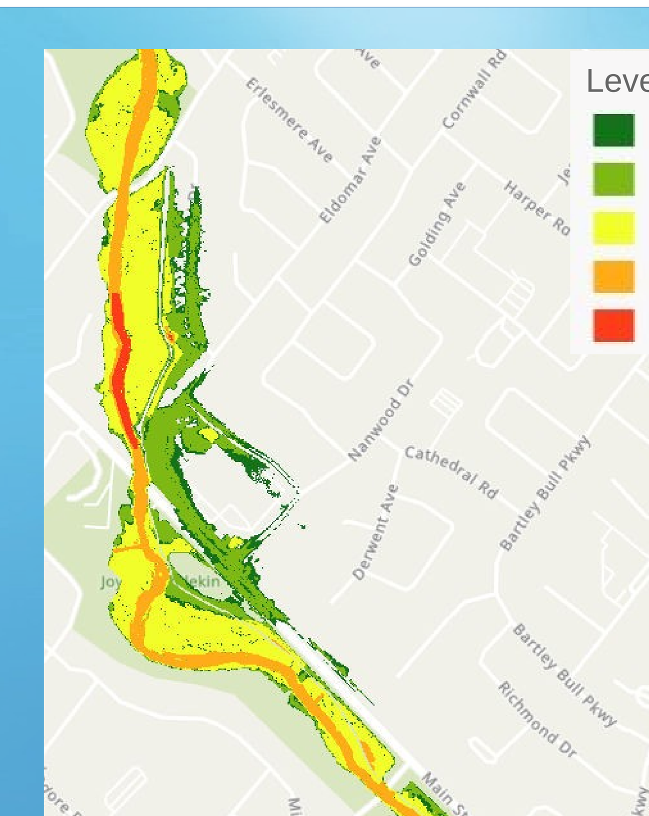

Fig.10: Overlay of depth and velocity hazard maps

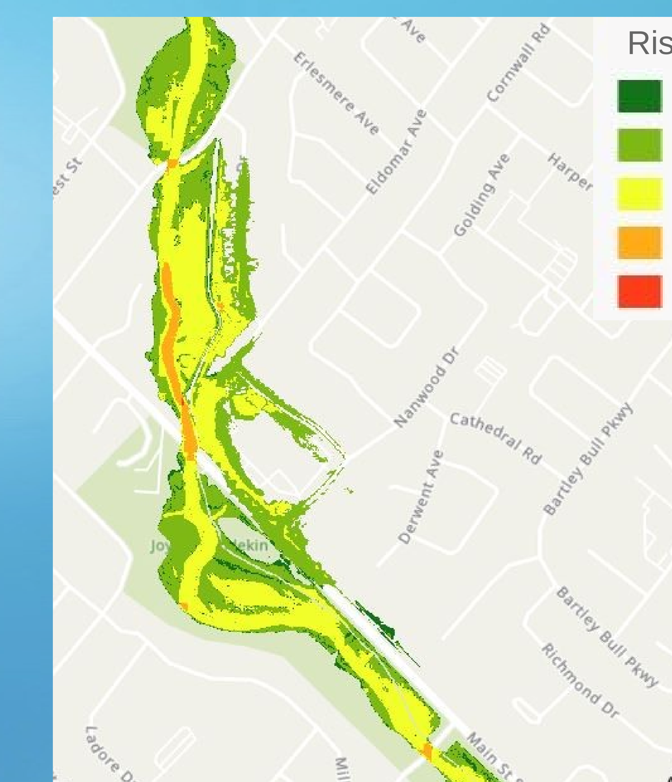

Fig.11: Risk map without social vulnerability

4 – Conclusions

We studied the breach impact for a 350-yr return period event in EC:

- breach location has a small effect on the maximal flood extent (Fig.8),
- breach shape B has similar effects to overflow in contrast to shape A,
- breaching leads to significant changes to risk maps (Fig.9),
- depth and velocity overlay (Fig.10) provides a better hydraulic hazard estimate than either depth or velocity alone.

Our research shows that integrating levee reliability in regular flood risk assessment is important because breaches increase flood risks.

References:

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Acknowledgements:
Environment Canada and TRCA for providing the hydraulic data; INRAE, Aix-Marseille University, and York University for the research fundings.