



Two-level modeling of dike breach scenarios: from GPU-accelerated 2D hydrodynamics to a simplified real-time modeling chain

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Dike breaches along navigation canals can lead to rapidly evolving flood dynamics, posing significant risks to populations and critical infrastructures. This contribution presents a two-level modeling framework for assessing the hydrodynamic consequences of dike failures. It builds upon previous developments in real-time flood mapping and breach modeling by extending them to both detailed scenario analysis and long-term risk assessment under changing hydroclimatic conditions.

The first component of the methodology relies on a computationally efficient chain of simplified models combining: (i) a 1D shallow-water hydraulic model of the waterways network, (ii) a lumped, semi-empirical breach-growth model accounting for the multi-scale processes governing dike failure, and (iii) a simplified floodplain representation based on pre-computed inundation maps. This framework is applied both for short-term forecasting and for long-term assessments under future climate conditions. The latter uses ensembles of climate projections (seven climate models under three emission scenarios) to evaluate the evolution of breach likelihood and flood hazard up to 2100.

The second component of the methodology consists of detailed “what-if” simulations based on a GPU-accelerated 2D hydrodynamic model (WolfGPU) solving the full shallow-water equations and coupled with the same breach-growth model as in the simplified approach. This technique provides high-resolution predictions of inundation depth, arrival time, and flow velocity fields for selected breach scenarios, enabling a refined characterization of local impacts.

The overall framework is demonstrated through applications to dike-breach scenarios along the Albert Canal in Belgium. Results from both approaches are compared in terms of predicted flood extent, maximum water depth, and warning lead times. The complementarity between fast simplified modeling for real-time support and high-resolution 2D simulations for scenario exploration is highlighted. The study further demonstrates the operational relevance of the framework for waterway managers, particularly in evaluating preventive measures such as anticipatory drawdown of the waterways.

Overall, this work delivers an integrated multi-scale modeling strategy for dike-breach hazard

assessment under both present and future hydrological conditions, combining efficiency, physical consistency, and operational applicability.

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