Bridge-Stream Network Modeling for Bridge Risk Assessment and Flood Mitigation

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Abstract

Due to the severe damages to structures, particularly bridges, that Tropical Storm Irene brought, many stakeholders became concerned with transportation infrastructure durability for current and future projects. There became a need to better understand the interactions between rivers, hydraulic structures and the surrounding hydrogeological features which are currently not well-established or understood at the river network scale. Studies often focus on a singular structure, and do not consider cascading impacts up- and downstream. Complications can arise when specific structural or hydrogeological features attenuate and/or intensify hazards on the network scale. Quantifying the dynamic interactions in a bridge-stream network under transient conditions can provide a framework for risk assessment and flood mitigation.

Study Areas

Study areas in Vermont - Otter Creek, Black Creek and Mad River (Fig 1) are selected to capture a range of gradients (low to very high). A range of road and rail bridges are featured in 2D unsteady HEC-RAS models for each area. Each model is calibrated to Tropical Storm Irene (Q500) as well as several other storm events (Q25, Q50, Q100).

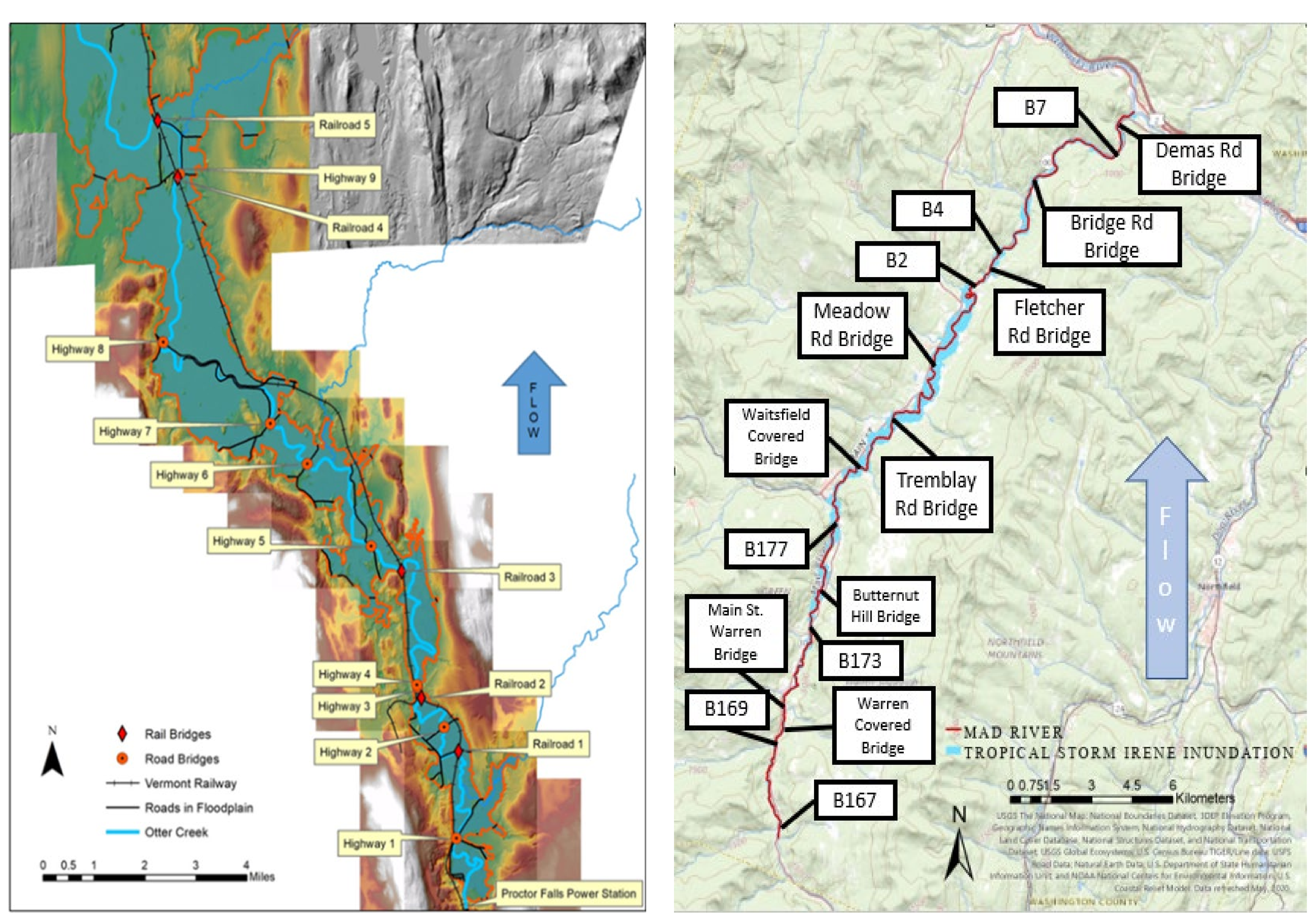

Fig 1. Maps showing Otter Creek (Left) and the Mad River (Right) and their associated infrastructure observed in 2D HEC-RAS models

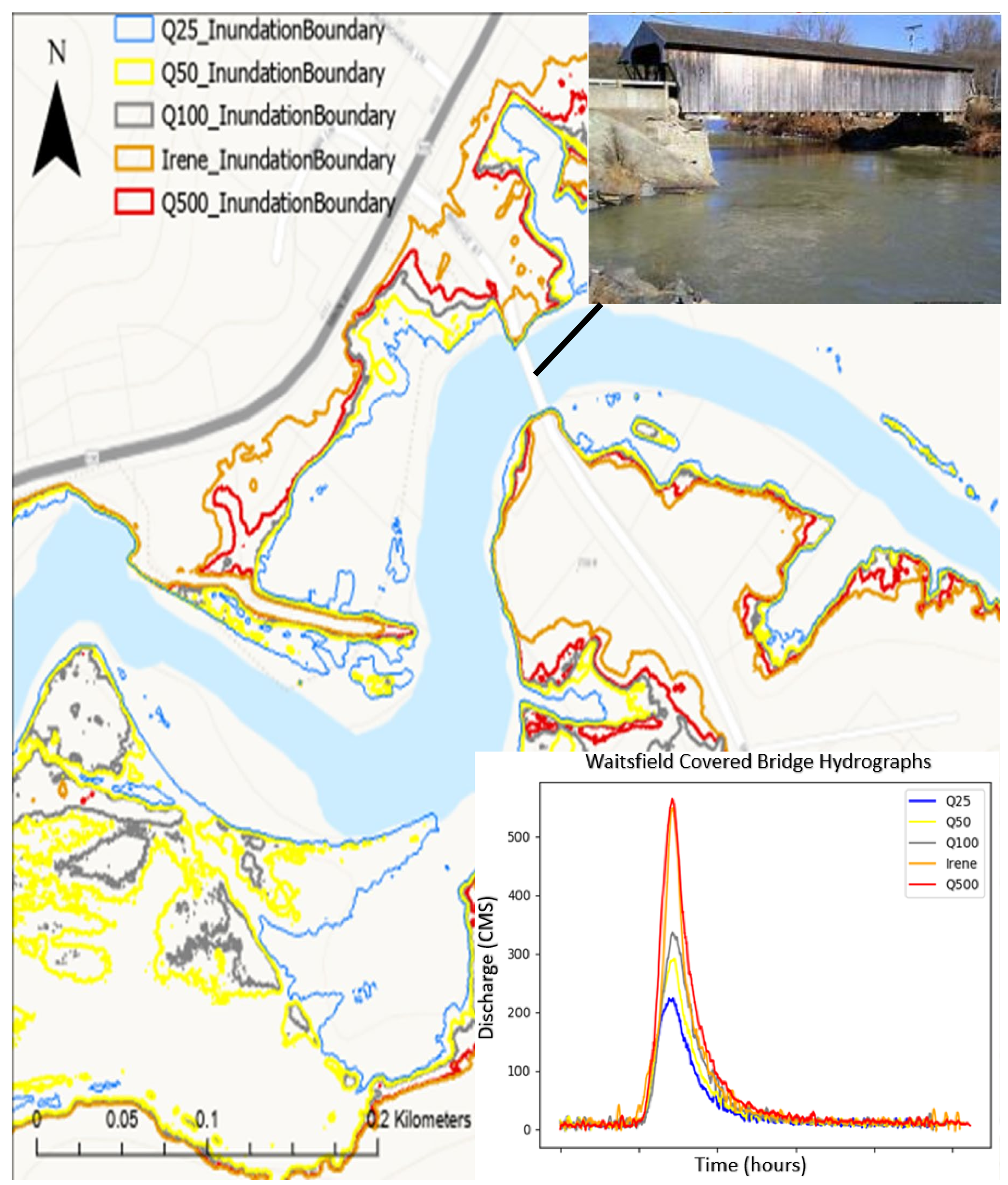

Fig 2. Flood inundation map at the Waitsfield Covered Bridge, showing the flood extents for five storm events with corresponding hydrographs.

Analysis

Sensitivity analyses are being performed on infrastructure within the hydrologic models to assess the bridge-stream network response (Fig 2). Transportation infrastructure is altered by removing, adding and elevating structures within the models, to observe the cascading impacts (e.g., the inundation area, velocity and stream power) along the river corridor and associated infrastructure (Fig 3).

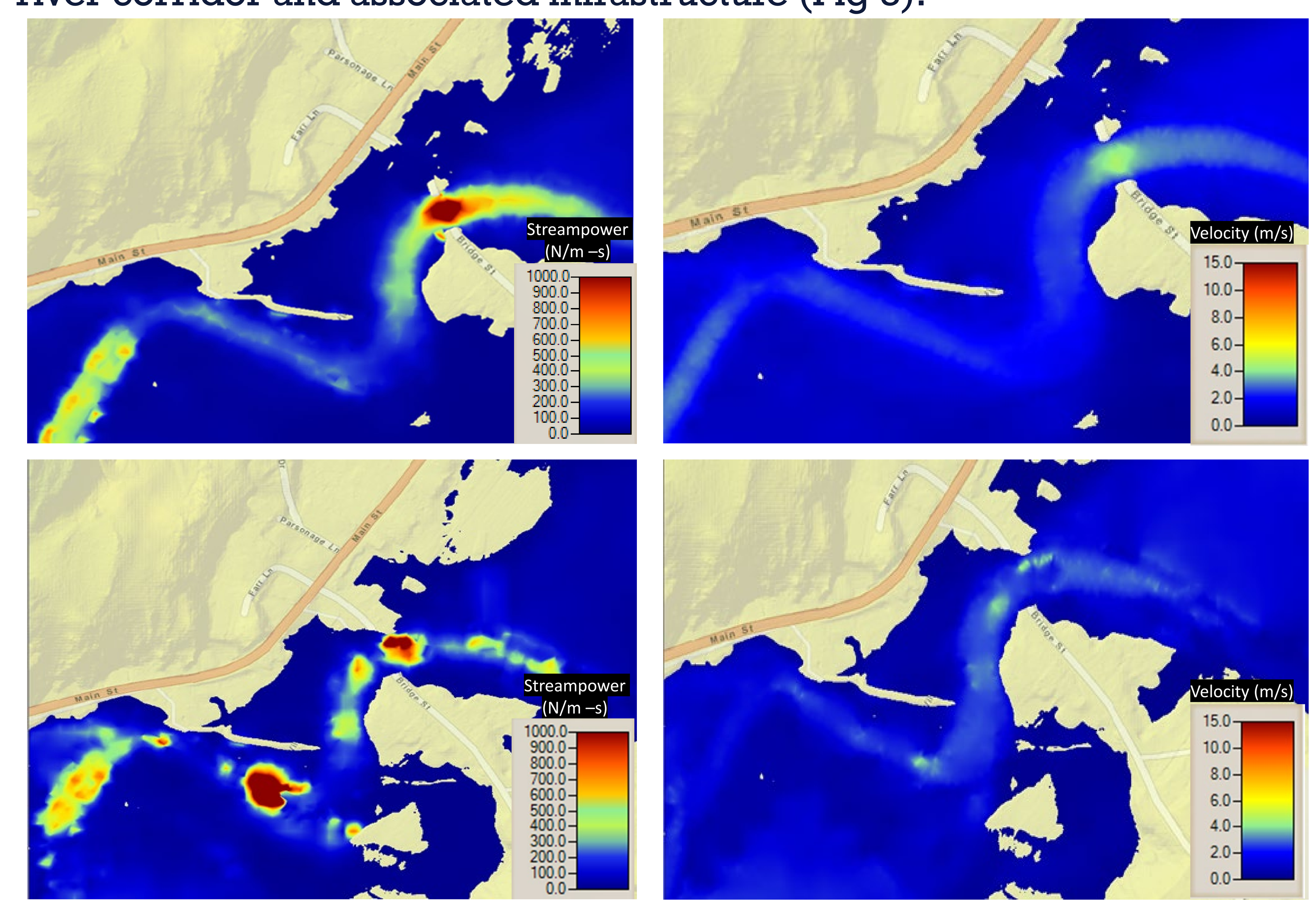

Fig 3. 2D HEC-RAS stream power with the Waitsfield Bridge in place (Top Left), and removed (Bottom Left); velocity with the bridge in place (Top Right), and removed (Bottom Right)

Conclusions and Ongoing Research

- Development of an optimization wrapper is underway, which will automate the sensitivity analyses to run hundreds of mitigation scenarios (e.g., lengthening a bridge, lowering an approach road, adding culverts) to optimize a desired set of user-defined outcomes.
- The three HEC-RAS models will be compared to frame a simplified risk assessment. The results are expected to be applicable to other stream-bridge networks with similar geographic and climatic conditions within New England and else where.

VERMONT AGENCY OF TRANSPORTATION

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Funding for this research is provided, partially or entirely, by the Transportation Infrastructure Durability Center at the University of Maine under grant 69A3551847101 from the U.S. Department of Transportation's University Transportation Centers Program. Matching funds from the Vermont Agency of Transportation are also gratefully acknowledged.

Acknowledgements

The authors are grateful to Cassidy Cote, Jaron Borg, Nick Wark and Drs. Emily Parkany, Ian Anderson and Dryver Huston for their valuable feedback. Special thanks to Matthew Trueheart, Lindsay Worely, Dr. Kristen Underwood, Nicholas Vartanian, Eliza Jobin-Davis and Eric Romero for their help and contribution to the HEC-RAS models.

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