Bridge-Stream Network Assessments to Identify Sensitive Structural and Hydraulic Parameters for Planning Flood Mitigation

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Abstract

The interactions between rivers, bridges and the surrounding hydrogeological features are not well-understood at the river network scale. Previous studies are limited to steady state analyses focused on a specific structure and impacts occurring up- and downstream are often not considered. Complications can arise when perturbations to specific structural or hydrogeological features attenuate and/or intensify hazards on the network scale. By attempting to quantify the dynamic interactions along a river under transient conditions we can develop a framework for assessing risks associated at the bridge-stream network scale.

Study Areas

Otter Creek
- Low Gradient
- 12 road and 8 rail bridges

Black Creek
- Low – Medium Gradient
- 3 road and 2 rail bridges

Mad River
- Medium – Very High Gradient
- 16 road bridges

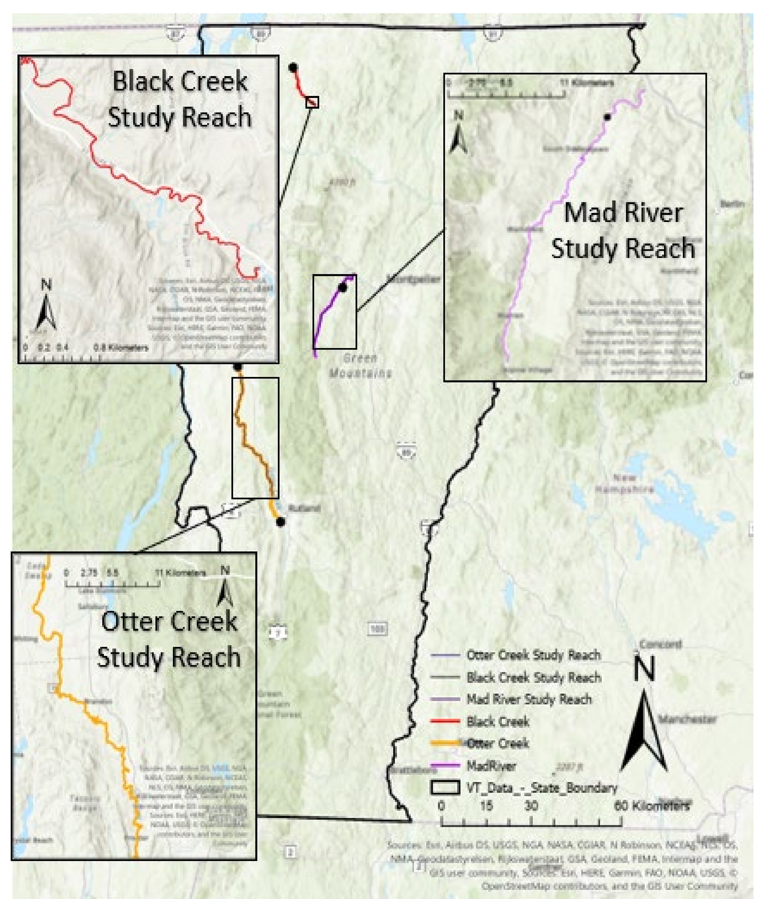

Figure 1. Map showing location of 3 study areas.

Computer Model

- 2D unsteady HEC-RAS models
- Calibrated to gauged Tropical Storm Irene (~Q500)
- Verified fidelity for several additional flood events (Q2, Q25, Q50, Q100)

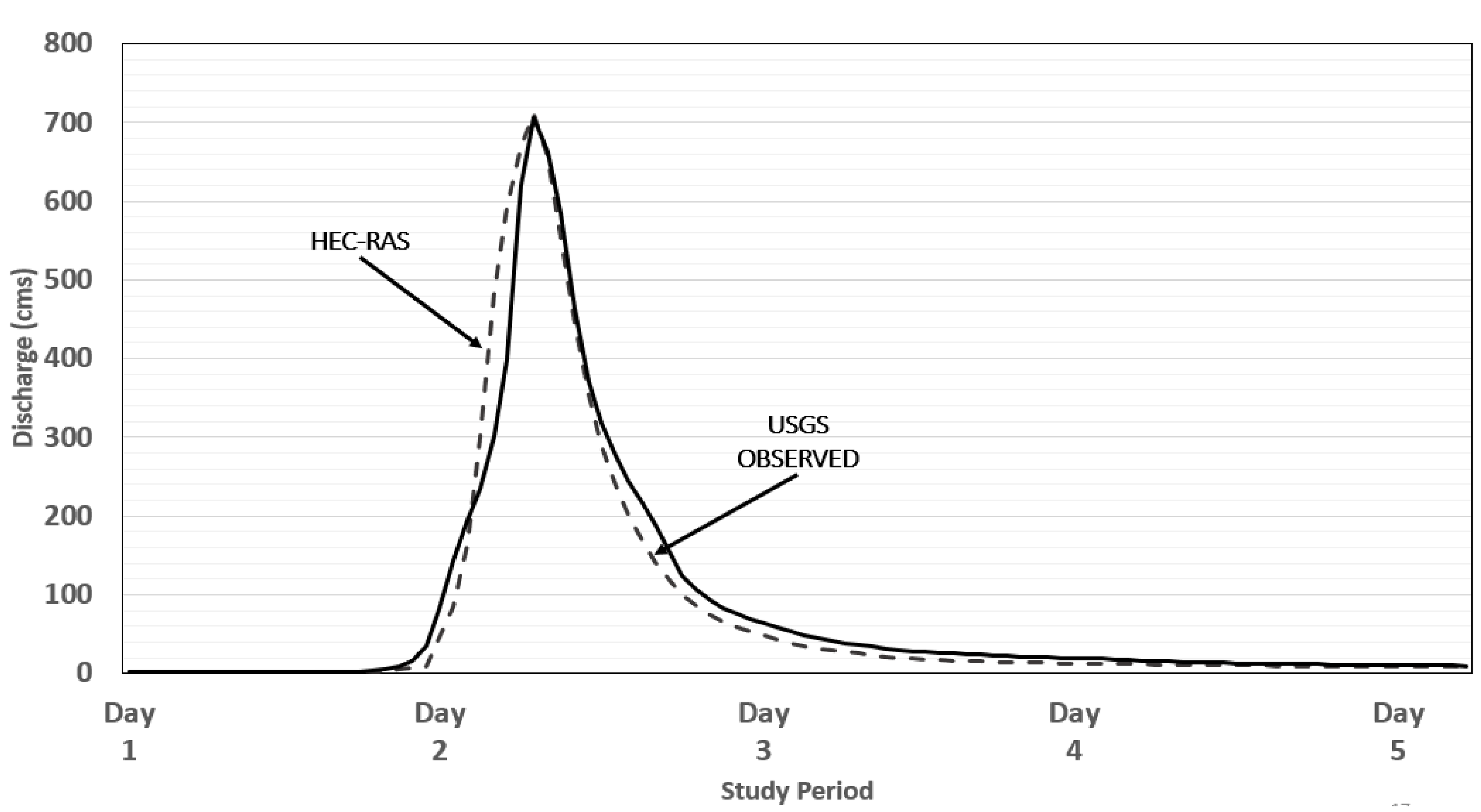

Figure 2. Comparison hydrographs showing Mad River HEC-RAS output compared to the USGS observed hydrograph during Tropical Storm Irene. This achieved a Nash-Sutcliffe Efficiency value of 0.94.

Analysis

Using the calibrated HEC-RAS model results a framework was developed to identify structures or locations in a river network that would be best suited for flood mitigation interventions based on specific stream power, channel gradient and noticed adverse flood impacts. Each bridge was and flood event was then categorized using this framework. Bridge's and culverts were then selected to be modeled for intervention (bridge deck elevation increase, flood plain reconnection, and culvert addition) and the intervention results throughout the river were compared to the original baseline HEC-RAS models. Each river was then compared to observe how interventions might impact rivers of varying gradients differently,

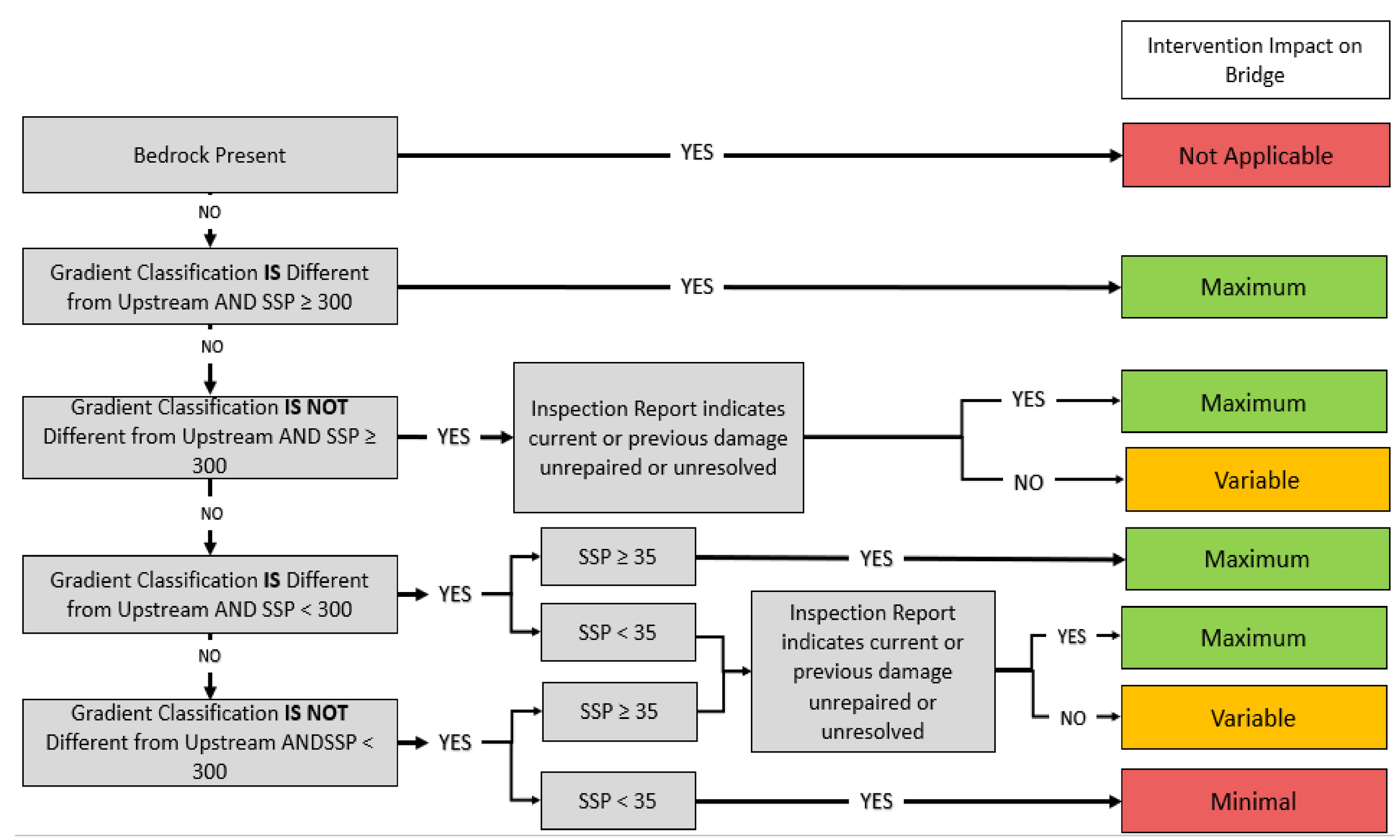

Figure 3. Developed framework used to identify structures or locations in a river network that would be best suited for flood mitigation interventions.

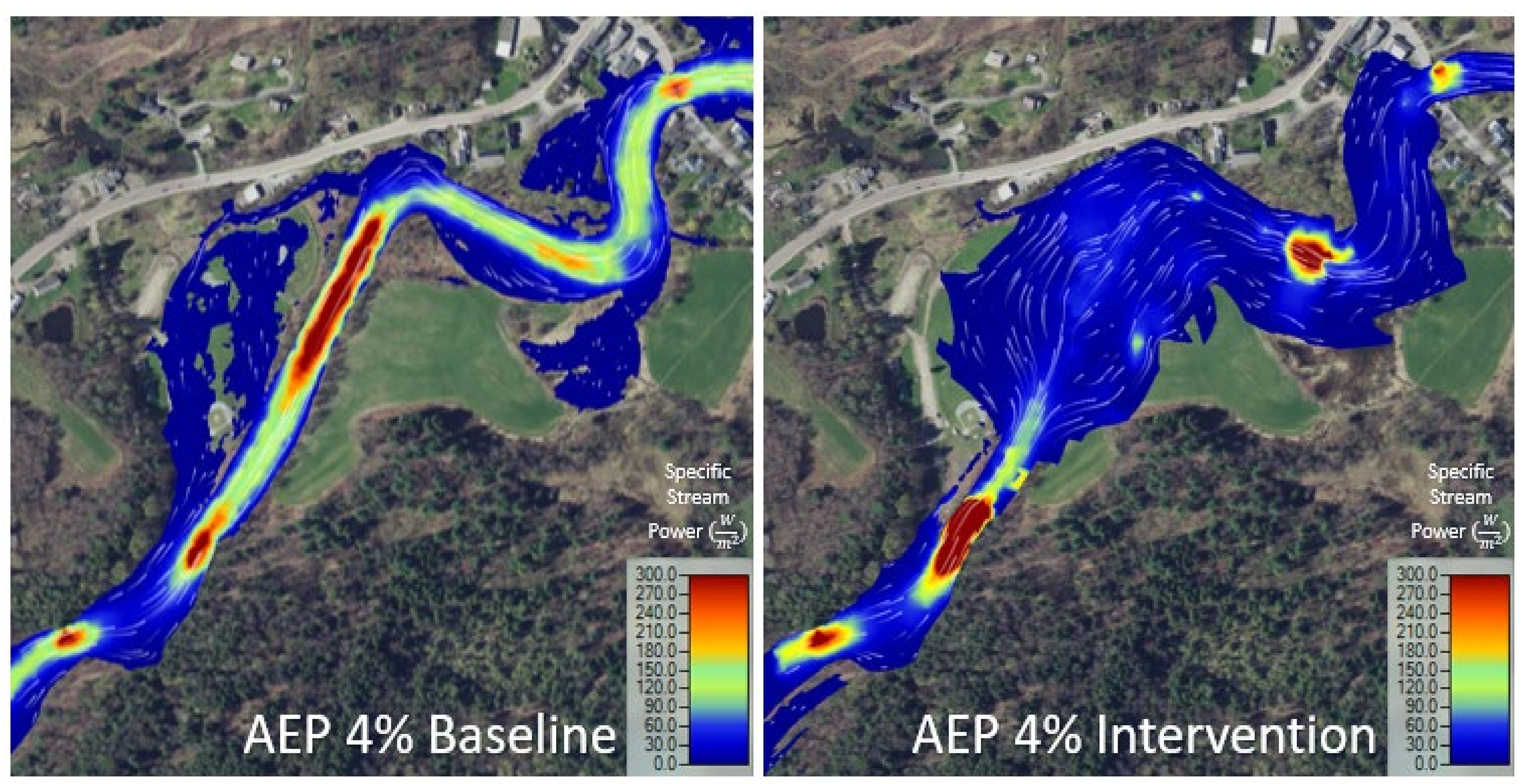

Figure 4. The Mad River's Waitsfield Covered Bridge HEC-RAS results showing the specific stream power results for the Q25 flood event (Annual Exceedance Probability 4%). Baseline Results (Right), Intervention Results (Left)

Conclusions

- The modeling results showed that interventions in a moderate or high gradient river will have less intuitive cascading up and downstream effects compared to a low gradient river.
- Given a site-specific intervention, the benefit of reducing stream power is more pronounced and varying in moderate to higher gradient rivers.
- The calibrated model showed how site-specific interventions have cascading consequences throughout the study reach, which were often counterintuitive, something that would not be captured through 1D modeling. Overall, this demonstrated the value of 2D transient modeling.
- Longitudinal cascading impacts appear to be more extensive in low gradient rivers, but are highly dependent on bridge-river physical characteristics.
- The screening framework proved more useful in moderate to high gradient rivers where changes in gradient are more dramatic and frequent. However, the screening framework may be successfully applied to low to moderate gradient rivers, if supporting data are available.

Acknowledgments

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