STEVENS
INSTITUTE OF TECHNOLOGY
1870

Ph.D. DISSERTATION DEFENSE

Candidate: Berina Mina Kilicarslan
Degree: Doctor of Philosophy
School/Department: Charles V. Schaefer, Jr. School of Engineering and Science / Department of Civil, Environmental & Ocean Engineering

Date: Tuesday, December 3rd, 2024
Time/Location: 02:00 p.m. / UCC-206
Title: Enhancing Hydrological Models to Support Flood Inundation Mapping and Water Resources Management

Chairperson: Dr. Marouane Temimi, Department of Civil, Environmental & Ocean Engineering

Committee Members: Dr. Reza Marsooli, Department of Civil, Environmental & Ocean Engineering
Dr. Philip Orton, Department of Civil, Environmental & Ocean Engineering
Dr. Philip Odonkor, Department of Systems and Enterprises

ABSTRACT

This dissertation explores innovative approaches to enhancing hydrological modeling by addressing critical challenges in flood inundation mapping (FIM) and water resources management practices. The initial phase involves developing a high-resolution FIM framework based on the Weather Research and Forecasting Model Hydrological modeling system (WRF-Hydro), the computational engine of the National Water Model (NWM), and a conceptual FIM method called Height Above the Nearest Drainage (HAND). This framework was designed to support an existing regional flood advisory system using lumped hydrological modeling approach for urban areas. The suggested approach showed superior performance in streamflow estimations and FIM representation, in the flood advisory domain with a focus on highly urbanized watershed. To improve the fidelity of HAND-based FIM in capturing hydrodynamic flood behavior, the second phase of this work incorporates a surrogate modeling approach that bridges the HAND method with the Hydrologic Engineering Center River Analysis System (HEC-RAS). This integration significantly reduces the false alarm rate by 18% compared to the baseline HAND method, while maintaining computational efficiency and demonstrating its transferability to other regions. The study also addresses challenges posed by ice induced flooding in U.S northern watersheds. A synergic approach leveraging remote sensing observation and numerical models was used to enhance streamflow estimation in ice prone regions. Here, river ice climatology datasets derived from satellite observations were employed. A scalable methodological framework is introduced, coupling the NWM with the 2D HEC-RAS hydrodynamic modeling. This ice-informed modeling approach integrates streamflow estimates from the NWM Retrospective dataset with a 2D HEC-RAS model, improving streamflow estimates and capturing temporal variations by incorporating river ice information into channel properties. This dissertation achieves accurate streamflow and FIM estimates across scales, demonstrating significant advancements in hydrological modeling. By integrating high-resolution models, surrogate techniques, and remote sensing data, this work showcases effective approaches to enhance streamflow estimation and flood inundation modeling in challenging settings such as

highly urbanized watersheds and cold regions. These findings contribute to the field of operational hydrology by addressing research and operational gaps in FIM and water resource management practices.