ASSESSING THE EFFICACY OF PHYSICS-INFORMED NEURAL NETWORKS FOR ENHANCED FLOOD ROUTING SIMULATION

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Master of Science (Major Component of Research)

Department of Civil Engineering
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Thesis submitted in partial fulfillment of the requirements for the degree

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DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 2025/10/29

The above candidate has carried out research for the ~~PhD/MPhil/~~Masters thesis~~/dissertation~~ under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Prof. R. L. H. L. Rajapakse

Signature of the Supervisor: Date: 2025/10/30

DEDICATION

This thesis is dedicated to all those who offered unwavering support and encouragement throughout my academic journey. This achievement is not mine alone; it is also a reflection of the compassion, guidance, and solidarity of the remarkable individuals who stood by me during this transformative period.

To my supervisor, Prof. Lalith Rajapakse, I express my heartfelt gratitude. Your insightful guidance, generous mentorship, and encouragement have been instrumental in shaping this research.

I lovingly dedicate this work to my family, whose constant encouragement and patience have been my greatest strength. To my parents and brother, thank you for your unconditional support and belief in me. A special tribute goes to my late mother, whose dream for my academic success continues to inspire and guide me every day.

I also dedicate this thesis to my friends and research colleagues for their motivation, support, and positivity throughout this endeavor. Finally, this work is for anyone passionate about learning and committed to the pursuit of knowledge through research.

ACKNOWLEDGEMENT

First and foremost, I extend my heartfelt gratitude to my supervisor, Prof. Lalith Rajapakse, from the Department of Civil Engineering at the University of Moratuwa, for his steadfast guidance, encouragement, and insightful mentorship throughout this research. His expertise, patience, and unwavering support have been pivotal in shaping the direction and quality of this thesis.

I also wish to sincerely thank the Progress Review Committee, especially Dr. Kasun De Silva, for their critical feedback, thoughtful suggestions, and consistent support, which helped enhance the depth and clarity of this work.

Special thanks are due to the Urban Water Management Division of the Sri Lanka Land Development Corporation (SLLDC). I am especially grateful to the General Manager (Planning and Design), Eng. (Mrs.) A.H. Thushari and all the staff members for their kind cooperation and timely provision of the necessary datasets. Their support was instrumental in the successful execution of this study.

I am also thankful to the academic staff of the Department of Civil Engineering, University of Moratuwa, including Prof. H.R. Pasindu, the Research Coordinator, and the lecturers and professors of the Hydraulics Division, for their continued academic guidance and encouragement throughout the MSc program.

My sincere appreciation also goes to the administrative staff of the Department of Civil Engineering, the University of Moratuwa, and the UNESCO Madanjeet Singh Centre for South Asia Water Management (UMCSAWM), including Ms. Vinu Kalanika and Ms. Janani Nisansala, for their support, which created a positive and enabling research environment.

To my fellow researchers and colleagues, thank you for your collaboration, encouragement, and knowledge-sharing that enriched this journey and made it a truly collective effort. Finally, I am deeply grateful to my family and friends for their constant motivation, patience, and unwavering belief in me. Their love and emotional strength carried me through every challenge I faced along this path.

ABSTRACT

Assessing the Efficacy of Physics-Informed Neural Networks or Enhanced Flood Routing Simulation

Flooding has emerged as one of the most destructive natural hazards, causing extensive damage to infrastructure, livelihoods, and ecosystems. The intensifying impacts of climate change, particularly altered rainfall patterns and increased frequency of extreme precipitation events, have further amplified the severity and recurrence of both riverine and localized urban flooding. These conditions often overwhelm existing channel capacities, highlighting the need for accurate flood modeling to support critical decisions related to urban resilience and disaster preparedness. While traditional hydrodynamic models such as HEC-RAS remain widely used for flood simulation, the recent advancement of data-driven methods, particularly Machine Learning (ML), offers promising alternatives. This study explores the application of Physics-Informed Neural Networks (PINNs) as a novel approach for 1D flood routing and peak flow prediction within urban canal networks, especially in data-scarce environments. The PINN framework integrates physical laws, as partial differential equations (PDEs), directly into the model, enhancing the ability to address data scarcities. The 1D Saint-Venant equations were used as the guiding PDE within this particular model. Observed water level data, canal cross sections and rainfall data from the Urban Water Management Division of the Sri Lanka Land Development Corporation (SLLDC) were used as model inputs. The methodology was implemented on three major canal systems in Colombo, Sri Lanka: Madiwela East Diversion, Dehiwala-Wellawatta-Kirulapone Canal System, and Parliament Lake-Kiththampahuwa-Kinda-Dematagoda Canal System. The performance of the PINN model was evaluated by comparing its predicted water levels against observed data at multiple water level monitoring stations along the mentioned canals, using Nash-Sutcliffe-Efficiency (NSE) and Root Mean Square Error (RMSE) as evaluation metrics. In parallel, HEC-RAS 1D hydraulic models were developed for each canal system using the same boundary and terrain data. These models served as a benchmark for comparison with the PINN approach. The results revealed that the PINN model consistently achieved higher accuracy, outperforming HEC-RAS at intermediate water level validation locations. PINN model predictions exhibited NSE values exceeding 0.98 at training locations and above 0.95 at validation points, with corresponding RMSE values below 0.10 m (10 cm). In comparison, while HEC-RAS also demonstrated acceptable performance with NSE values above 0.90 in most cases, its RMSE values were comparatively higher, ranging from 0.10-0.17 m in some locations. These findings highlight higher accuracy of the PINN model, particularly in predicting flood peaks and spatial water level profiles. The integration of physics-based constraints with machine learning allows PINNs to outperform traditional models like HEC-RAS, especially in urban flood scenarios with sparse data availability.

Keywords: Climate variability, data-scarce regions, flood peaks, flood modelling, HEC-RAS, PINN

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LIST OF ABBREVIATIONS

Abbreviation	Description
ANN	Artificial Neural Network
BC	Boundary Condition
CNN	Convolutional Neural Network
DP	Deep Learning
GNN	Graph Neural Network
HEC-RAS	Hydrologic Engineering Center - River Analysis System
IC	Initial Condition
LSTM	Long Short-Term Memory
ML	Machine Learning
NSE	Nash–Sutcliffe Efficiency
PDE	Partial Differential Equation
PINN	Physics-Informed Neural Network
RMSE	Root Mean Square Error
R-R	Rainfall–Runoff
SLLDC	Sri Lanka Land Development Corporation
SRM	Short-Term Runoff Modelling
CRM	Continuous Runoff Modelling
GS	Gaussian Software