EVALUATING NON-STRUCTURAL INTERVENTIONS FOR DAM SAFETY: INSIGHTS FROM HYDRAULIC SIMULATION, STAKEHOLDER PERSPECTIVES, AND COMMUNITY-FOCUSED PROTOTYPES

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Master's by Research

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the Master of Science (Major Component of Research)

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DECLERATION

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).

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

Name of the Supervisors	**Signature of the Supervisor:**	**Dates**
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Prof. Menaha Thayaparan		01/01/2026
Dr. Sandun Dassanayake		01/01/2026
Dr. Chathura De Silva		01/01/2026

DEDICATION

I DEDICATE THIS STUDY TO ALL WHO WORK TO SAFEGUARD COMMUNITIES BY UNITING HUMAN INNOVATION WITH THE FORCES OF NATURE, TO MY PARENTS, TEACHERS, AND FRIENDS FOR THEIR UNWAVERING SUPPORT, AND TO THE CITIZENS OF SRI LANKA WHOSE RESILIENCE AND CONTRIBUTIONS INSPIRE THIS RESEARCH

ACKNOWLEDGMENT

I wish to express my deepest gratitude to my supervisors, Prof. Udayangani Kulatunga, Prof. Menaha Thayaparan, Dr. Sandun Dassanayake, and Dr. Chatura DeSilva, for their invaluable insights, guidance, encouragement, and constructive feedback throughout this research journey. Their perspectives and support were instrumental in shaping both the direction and the quality of this work.

I am also sincerely thankful to the officers of the Postgraduate Office, Faculty of Architecture, University of Moratuwa, for their kind assistance, timely clarifications, and excellent cooperation, which greatly facilitated the smooth progress of my academic work. My appreciation is further extended to the staff of the Department of Building Economics for their continued support and encouragement.

Special thanks are due to the Senate Research Grants, University of Moratuwa, for providing the financial assistance that made this research possible.

Finally, I wish to acknowledge with heartfelt gratitude the many individuals, friends, and colleagues who have supported me in countless ways during this educational journey. Although I am unable to mention each by name, their encouragement and companionship have been vital to the successful completion of this study.

ABSTRACT

Dam failures pose severe threats to both human life and socio-economic stability, often resulting in catastrophic losses. This study sets out to critically examine the socio-economic impacts of dam failures and to investigate innovative non-structural measures for risk reduction, with a focus on enhancing community preparedness. A mixed-methods approach underpinned by a pragmatist philosophy was adopted, integrating narrative and systematic literature reviews, hydraulic modelling, GIS-based analysis, agent-based modelling (ABM), stakeholder interviews, and gamification. Literature reviews synthesized global evidence on dam failure impacts and identified gaps in existing preparedness strategies. A case study of the Kantale Dam in Sri Lanka was conducted using 2D HEC-RAS modelling to simulate potential dam-break scenarios, producing detailed inundation maps and hazard parameters. These outputs were combined with socio-economic data and validated through semi-structured interviews, which provided insights into vulnerabilities and adaptive capacities of local communities. To translate complex risk information into accessible and participatory formats, the study developed a serious board game as a gamified non-structural intervention. Iteratively refined through pilot studies, the game successfully engaged participants, improved their knowledge of dam-related challenges, and fostered collaborative decision-making. The findings confirm that integrating technical modelling with community-based educational tools significantly enhances disaster preparedness. The research contributes to knowledge by advancing hybrid methodologies, demonstrating the value of ABM in simulating human behavior under disaster conditions, and pioneering a gamified approach to dam safety education. These contributions provide a replicable framework for policymakers and practitioners to strengthen dam safety management and reduce disaster risk in vulnerable regions.

Keywords: *Dam failures; Socio-economic impacts; Hydraulic modelling; Agent-Based Modelling (ABM); Non-structural measures; Gamification*

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LIST OF ABBREVIATIONS

Abbreviation	Description
ABM	Agent-Based Modelling
BIM	Building Information Modeling
CBEWS	Community-Based Early Warning System
CDA	Canadian Dam Association
DEM	Digital Elevation Model
DRIP	Dam Rehabilitation and Improvement Project
DRR	Disaster Risk Reduction
DSMP(s)	Dam Safety Management Plan(s)
EAP(s)	Emergency Action Plan(s)
EWS	Early Warning System(s)
FLUS	Future Land-Use Simulation
GISTM	Global Industry Standard on Tailings Management
GRCA	Grand River Conservation Authority
HEC-RAS	Hydrologic Engineering Centre's River Analysis System
ICMM	International Council on Mining and Metals
ICOLD	International Commission on Large Dams
MCDA	Multi-Criteria Decision-Making
MNRF	Ontario Ministry of Natural Resources and Forestry
OPG	Ontario Power Generation
PRI	Principles for Responsible Investment
RCC	Roller-Compacted Concrete
RSDHI	Remote Sensing-Based Dam Hazard Investigation
SAR	Synthetic Aperture Radar
TSF(s)	Tailings Storage Facility(ies)
UNEP	United Nations Environment Programme
USACE	United States Army Corps of Engineers

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