ANALYSIS OF THE EFFECT OF CLIMATE CHANGE IMPACTS ON FLOODS IN KELANI RIVER BASIN, SRI LANKA

S.P.S.P. Kulathunga

(179239C)

Degree of Master of Science

Department of Civil Engineering

University of Moratuwa
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Supervised by

Prof. R. L. H. L. Rajapakse

Degree of Master of Science
Water Resources Engineering and Management

Thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Water Resources Engineering and Management

UNESCO Madanjeet Singh Centre for
South Asia Water Management (UMCSAWM)

Department of Civil Engineering
University of Moratuwa
Sri Lanka

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DECLARATION OF THE CANDIDATE AND SUPERVISOR

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Date

S.P.S.P. Kulathunga

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The above candidate has carried out research for the Master's Thesis/Dissertation under my supervision.

2023-06-30

Date

Prof. R. L. H. L. Rajapakse

ABSTRACT

Analysis of the Effect of Climate Change Impacts on Floods in Kelani River Basin, Sri Lanka

Sri Lanka is highly vulnerable to climate change impacts, including rising land and sea temperatures, changing precipitation patterns, more extreme weather events, and sea-level rise. Notably, climate change has been observed to increase flood frequency, expand flood areas, and intensify flood damages. Previous research in Sri Lanka has mainly focused on rainfall estimation using weather models and examining climate change scenarios. This study aims to improve flood forecasting by analyzing climate change-induced changes in rainfall depths from Intensity-Duration-Frequency (IDF) curves and considering design sea levels. The objective is to gain insights into future flood characteristics, specifically the projected increases in discharges and water levels.

The HEC-HMS Hydrological modelling tool was selected for the hydrological modelling of the entire Kelani Basin, while the HEC-RAS model was used for flood modelling in the Lower Kelani Basin which is downstream from Glencourse. HEC-HMS simulating discharges from rainfall inputs that served as boundary conditions for the HEC-RAS model. The verified models are utilized to simulate the 50-year design rainfall dataset lasting 3 days, incorporating published IDF equations from selected rain gauge locations along with the calibrated models. Rainfall depth multipliers of 1.100, 1.122, and 1.140 were applied to the design rainfall dataset for the RCP4.5, RCP6.0, and RCP8.5 projections, respectively. Simulations also considered sea-level rise values of 0.47 m, 0.48 m, and 0.63 m corresponding to the respective climate change projection scenarios.

Calibration and validation of the three HEC-HMS models (Kelani Upper, Kelani Middle, and Kelani Lower) and the HEC-RAS Flood model for Lower Kelani (downstream to Glencourse) Basin were successfully calibrated using 2016 May and validated using 2017 May flood event data. The Nash Efficiency values during calibration were 0.79, 0.95, and 0.85 for the Kelani Upper, Kelani Middle, and Kelani Lower models, respectively. During validation, the Nash Efficiency values were 0.87, 0.85, and 0.25, respectively. The calibration Nash Efficiency values for the HEC-RAS model were 0.57, 0.56, and 0.52, and the validation Nash Efficiency values were 0.80, 0.57, and 0.53 for the respective models considering Hanwella Discharges, Hanwella Water Levels and Nagalagama Street Water levels, respectively.

The research concluded that, under climate change projections, the Glencourse Peak Discharge is projected to increase by approximately 13.3% to 16.2%. Similarly, at Hanwella, the peak discharge is expected to increase by approximately 6.4% to 8.8%, while the maximum water level is anticipated to rise by approximately 3.1% to 4.2%. Moreover, the maximum water level at Nagalagama Street is likely to experience an increase of around 16.2% to 21.7% under climate change projections.

Keywords: Design Rainfall, HEC-HMS, HEC-RAS, Hourly Data, IDF

DEDICATION

This thesis work is dedicated to my wife Champika, and my two sons Ihansa, and Mihinsa who have been a constant source of support and encouragement during the challenges of academic commitments and life. I am truly thankful for having you in my life. This work is also dedicated to my parents, Nimal and Ranjani, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

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LIST OF ABBREVIATIONS

1D	One Dimensional
2D	Two Dimensional
ALOS	Advanced Land Observing Satellite
AMC	Antecedent Moisture Condition
ANN	Artificial Neural Network
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
CanESM2	Canadian Earth System Model, version 2
CC	Climate Change
CHIRPS	Climate Hazards Group Infrared Precipitation with Station Data
CMIP	Coupled Model Inter-Comparison Project
CN	Curve Number
CO2	Carbon Dioxide
CRIP	Climate Resilient Improvement Project
CS	Cross Section
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DIAS	Data Integration and Analysis System
GCM	General Circulation Models
GIS	Geographic information system
HadCM3	Hadley Centre Coupled Model version 3
HEC	Hydrological Engineering Center
HMS	Hydrological Modelling System
ID	Irrigation Department
IDF	Intensity Duration Frequency
IPCC	Intergovernmental Panel on Climate Change
iRIC	International River Interface Cooperative
ITCZ	Intertropical Convergence Zone
LiDAR	Light Detection and Ranging
MCM	Million Cubic Meters
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NEX-GDDP	NASA Earth Exchange Global Daily Downscaled Climate Projections
NSE	Nash-Sutcliffe model efficiency
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PPM	Parts Per Million
R^2	Coefficient of Determination
RAS	River Analysis System
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RF	Rainfall
RRI	Rainfall-Runoff-Inundation
SCS	Soil Conservation Service
SD	Survey Department

SDSM	Statistical Downscaling Model
SDSM	Statistical Downscaling Model
SHER	Similar Hydrologic Element Response
SPI	Standard Precipitation Index
SRTM	Shuttle Radar Topography Mission
UH	Unit Hydrograph
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
WEB-RRI	Water Energy Budget-based Rainfall-Runoff-Inundation model
WL	Water Level
WRF	Weather Research and Forecasting
Yr.	Year