# OCCURRENCE OF EXTREME HYDROLOGIC EVENTS IN THE KELANI RIVER BASIN AND IMPACT OF CLIMATE CHANGE ON RIVER FLOW REGIME

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Climate change is a severe and growing issue with visible and disproportionate impacts in many parts of the world. Recent studies state that climate change is occurring at a relatively faster and even more critical rate than previously expected. Climate consequences such as harsher heat waves, longer droughts, more frequent floods, increased sea level rise, and storm surges are already experienced worldwide. Climate change is expected to impact Sri Lanka through changes in rainfall patterns, sea level rise, and increased temperature. Climate change-related variations in temperature and rainfall patterns can result in more prolonged droughts and frequent floods. The IPCC's 6$^{th}$ Assessment Report on Climate Change states that the average global surface temperature is anticipated to increase, ranging from 1.1-1.8 °C, 2.3-3.6 °C, 3.3-4.7 °C, and 3.3-6.7 °C, 4.3-7.8 °C under SSP1, SSP2, SSP3, SSP4, and SSP5 scenarios, respectively, relative to 1986-2014 (IPCC, 2022). The Kelani River basin, which experiences yearly flooding, is one of Sri Lanka's most vulnerable basins (Dissanayaka & Rajapakse, 2019).

The study aims to evaluate how climate change may affect river flow change and the occurrence of extreme hydrologic events in the Kelani River basin. This study uses a hydraulic model to analyse river flow and precipitation data to identify extreme hydrological events and simulate river flow while considering the effects of extreme rainfall. The study also aims to determine future trends in river flow variation caused by climate change. Observed rainfall, streamflow, and Simulated Future Streamflow using GCM data were used to identify future trends of river flow variation due to climate changes based on the HEC-HMS hydrological modeling process.

The results revealed that the Hanwella sub-basin exhibits a variation in the range of -35.2% to 37.46% in the annual mean streamflow percentage under assumed climate change scenarios. This study also aims at developing quantitative estimates to handle the impacts of these extreme hydrological events, and flood events become more frequent when considered for SSP5 scenarios than SSP2 scenarios. The model results can be used to understand better catchment characteristics and its hydrologic response to rainfall under the impact of climate change scenarios. The return periods for floods in the Kelani River basin were calculated using the projected future data for both SSP2 and SSP5 scenarios. The results indicated a significant decrease in return periods, particularly in the SSP5 scenario, indicating that future flood events will occur more frequently. Applying the Gumbel distribution is appropriate for the frequency analysis of the Kelani River basin. This statistical method permits the analysis of extreme events and provides valuable insights into the frequency and magnitude of particular hydrological phenomena within the basin.

**Keywords: HEC-HMS modeling, Runoff elasticity, Frequency analysis**

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## Introduction

- Climate change involves long-term temperature and weather variations, accelerating faster and more critically than anticipated
- Sri Lanka experiences altered rainfall, higher temperatures, leading to increased frequency of floods and droughts

## Significance of Research

- Climate change causes more frequent floods and longer droughts, damaging infrastructure and risking lives
- Predicting extreme events helps proactive solutions for basic needs of community. Quantitative studies are vital for addressing river flow impacts
- Kelani River basin is highly vulnerable for frequent annual floods in Sri Lanka

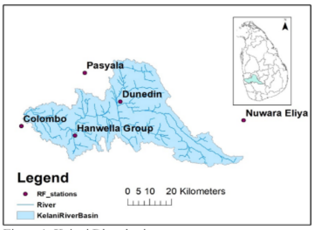


Figure 1: Kelani River basin

## Objectives

To identify the impacts of extreme hydrologic events and identify mitigation measures in the Kelani River basin on river flow impending climate changes. for that following specified objectives were addressed

- To identify extreme hydrologic events related to river flow or precipitation
- To use a hydraulic model to simulate river flow with the effect of extreme rainfall
- To identify future trends of river flow variation due to climate change

## HEC-HMS Model

- Governing equation in the HEC-HMS model is the water mass balance equation
- The HEC-HMS model is a versatile tool that can be utilized for a variety of flood-related investigations

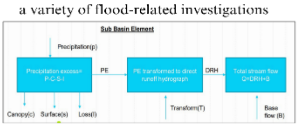


Figure 2: Governing equation in the HEC-HMS model

## Frequency Analysis

- Flood frequency analysis utilizes historical data and statistical distributions such as Gumbel, Log-Normal, and Weibull to estimate future flood probabilities and magnitudes
- Gumbel distribution is preferred for extreme value analysis due to its accurate match with observed values

## General Circulation Models (GCMs)

- General Circulation Models (GCMs) are computer-based mathematical models
- GCMs are essential tools for understanding past climate changes, studying present climate conditions, and making projections about future climate scenarios
- At every grid cell, GCMs resolve respective equations to compute temperature, precipitation etc.

## Climate Scenarios

- The Shared Socioeconomic Pathways (SSPs) are a set of scenarios developed by the scientific community to explore different future trajectories of greenhouse gas emissions, land use, and socio-economic development (IPCC, 2022)

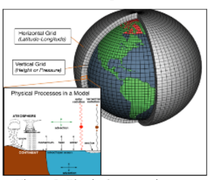


Figure 3: Physical process in a GCM (NOAA (climate.gov))


Figure 4: SSP scenarios (IPCC, 2022)

## Result and Analysis

### Calibration of HEC-HMS Model

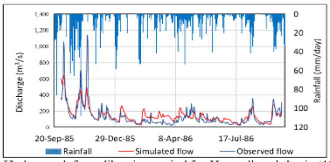


Figure 5: Hydrograph for calibration period for Hanwella sub-basin (1985/1986)

### Validation of HEC-HMS Model

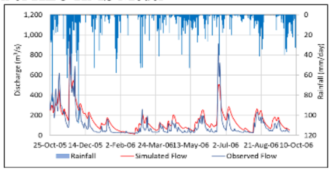


Figure 6: Hydrograph for validation period for Hanwella sub-basin (2005/2006)

### Frequency Analysis for Future Predicted Data

- The future period is divided into short-term (2025-2040), midterm (2041-2070), and long-term (2071-2100)
- Frequency analysis was performed for precipitation and streamflow data. For the SSP5 scenario, discharge values were much higher than observed, while for SSP2, they were slightly higher

### Frequency Analysis for Discharge Under SSP2 and SSP5 Scenarios

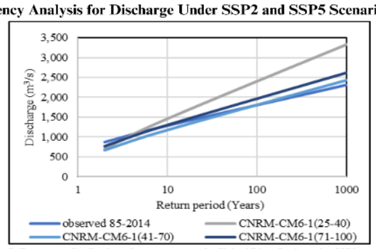


Figure 7: Frequency distribution of extreme events for Kelani River Basin under SSP2 scenario

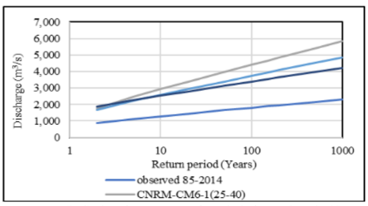


Figure 8: Frequency distribution of extreme events for Kelani River Basin under SSP5 scenario

- Return periods for floods in the Kelani River basin were calculated using future data for SSP2 and SSP5 scenarios. Results suggest an increased frequency of future flood events

Table 1: The Return Periods for the extreme events under SSP2 and SSP5 scenarios

| Date of Flood | Discharge ($m^3/s$) | Return Period in Years According to Observed Data | Return Period in Years According to the SSP2 Scenario | Return Period in Years According to the SSP5 Scenario |
|---|---|---|---|---|
| 06/05/1992 | 1,076 | 4 | 4 | 1 |
| 04/21/1999 | 1,282 | 10 | 7 | 1 |
| 11/22/2005 | 1,209 | 7 | 6 | 1 |
| 04/29/2008 | 1,408 | 17 | 9 | 1 |
| 06/01/2008 | 1,308 | 11 | 7 | 1 |
| 01/05/2016 | 1,630 | 25 | 12 | 2 |

## Conclusions

- Flood frequency analysis shows that different climate change scenarios have distinct variations in precipitation and streamflow values according to there severity
- The Gumbel distribution is suitable for frequency analysis in the Kelani River basin, allowing analysis of extreme events
- Flood events are expected to increase under the SSP5 scenario compared to SSP2

## References


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