Presented at the international workshop on "Development Strategies to Adapt for the Natural Disasters due to Climatic Change in Asia" on September 2011.

Climate Change Impacts on Floods in Kelani River Basin and Adaptation Measures

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Outline of the presentation

- Background of the study
- Methodology
- Models used
- Calibration and validation of the models
- Results and discussion
- Next steps

Objectives of the Study

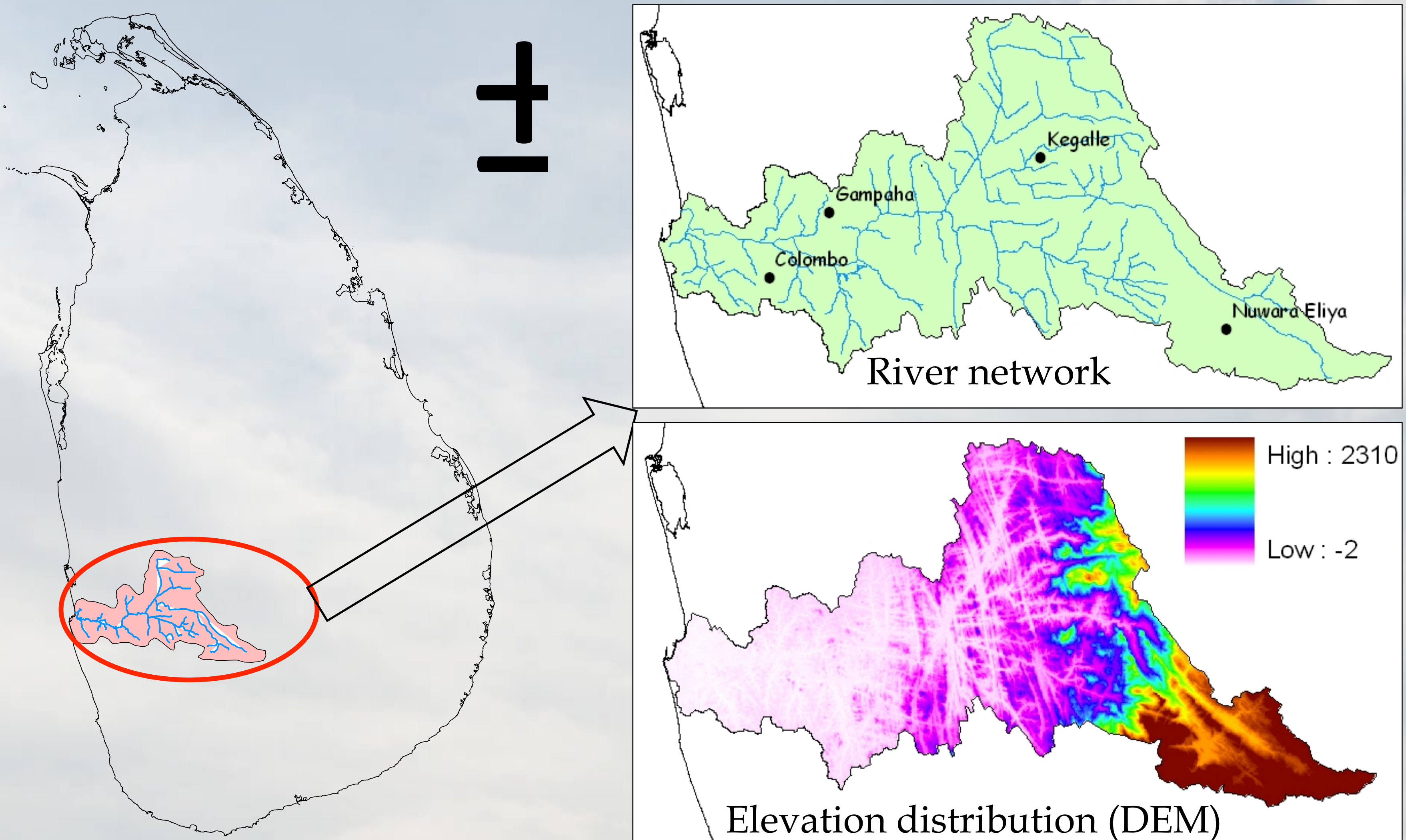
- Identify the future extreme rainfall and flood conditions and propose suitable adaptation measures to minimize the risks of damages and losses caused by the floods occur in lower Kelani catchment due to climate change

  - To identify extreme rainfall events occurred during recent past and predict the precipitation for future
  - To simulate flood under the past extreme rainfall and predict for future
  - To propose adaptation measures to minimize the risks of damages and losses and optimize the proposed measures

Background Problem

- There is ample evidence to suggest that Sri Lanka's climate has already changed (Eriyagama, 2010)
- Rainfall time series of Sri Lanka shows a trend of increased lengths of dry periods along with an increasing trend of rainfall intensity, especially after the late seventies (Ratnayake & Herath, 2005)
- Extremely heavy rainfall and annual total rainfall increased in Colombo area (Samarasinghe, Long-range forecast of climate change: Sri Lanka future scenario)
- Kelani catchment receives rain from both northeast and southwest monsoons and cause frequent floods
- Kelani river flows through the capital city and therefore, flood loss damage is high

Study Area

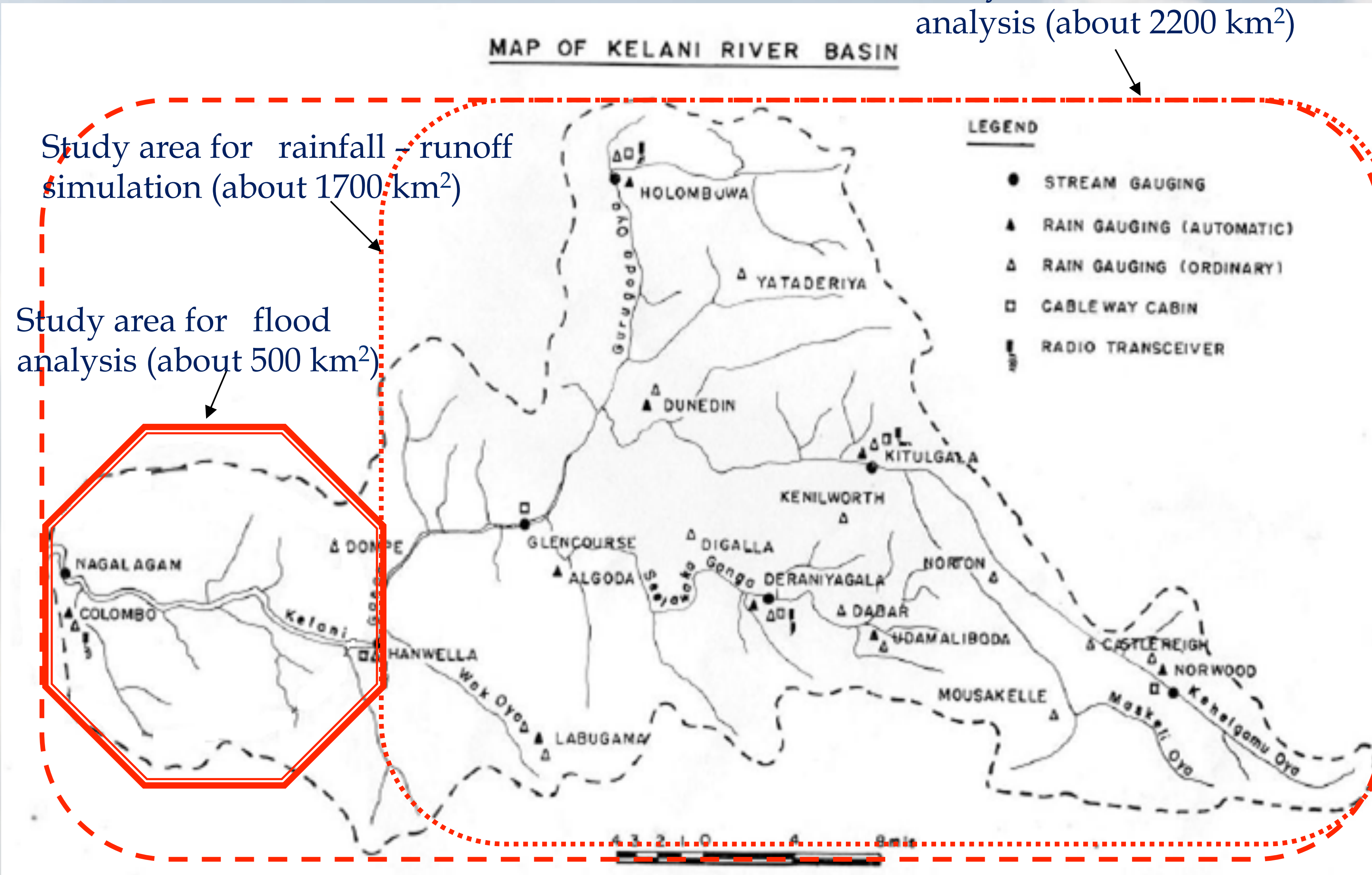

Kegalle
Gampaha
Colombo
Nuwara Eliya
River network
High : 2310
Low : -2
Elevation distribution (DEM)

Study Area

Study area for rainfall analysis (about 2200 km^2)

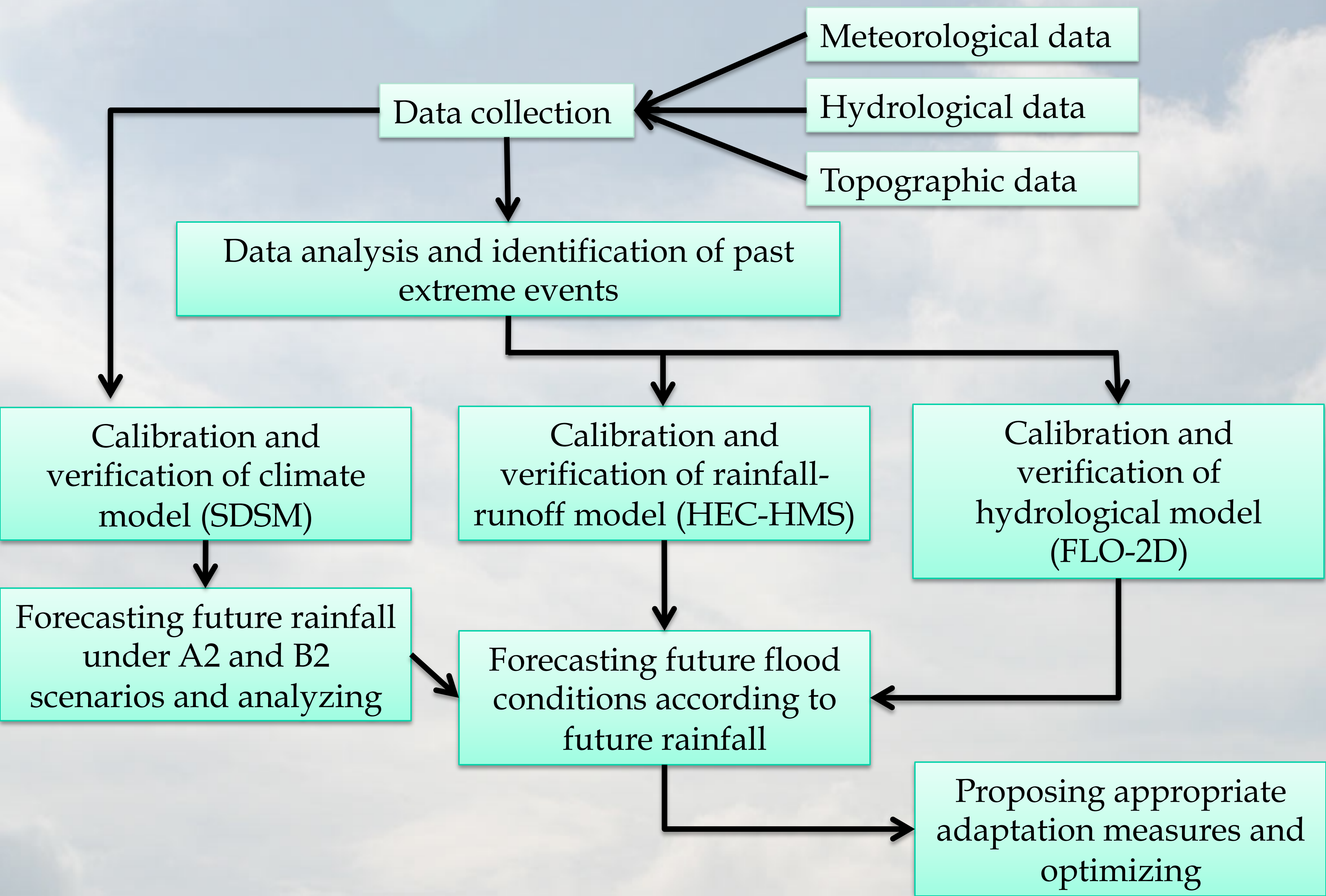
Study area for rainfall – runoff simulation (about 1700 km^2)

Study area for flood analysis (about 500 km^2)



Source: Department of Irrigation, Sri Lanka

Methodology

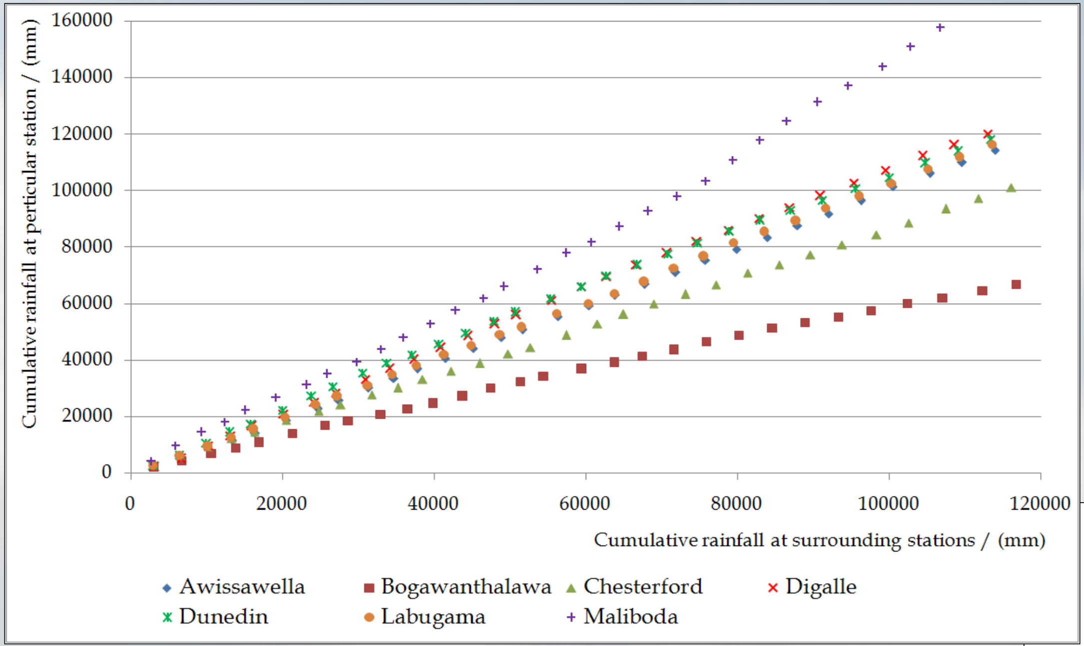


Models used

- Statistical Downscaling Model (SDSM) – for rainfall forecast under A2 & B2 scenarios
  - Calibration – 1961 to 1975
  - Validation – 1976 to 1990
- Hydrologic Engineering Center – Hydrologic Modeling System (HEC–HMS) – for rainfall runoff simulations at Hanwella gauging station
  - Calibration – November 2005
  - Validation – April, May & June 2008, May 2010 and 2005 to 2010
- FLO–2D – for flood and inundation analysis at lower catchment from Hanwella
  - Calibration – November 2005
  - Validation – April 2008, June 2008 and May 2010

Data preparation for climate model

Upper catchment

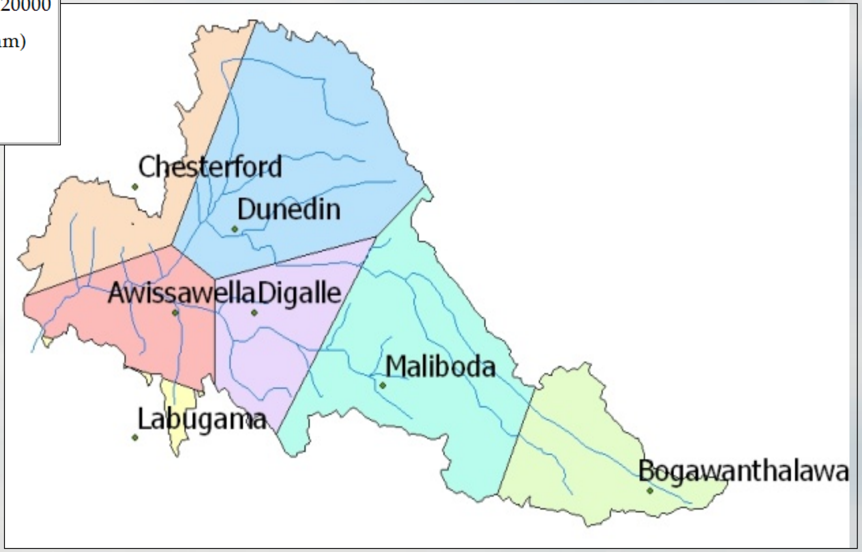


Double mass curves for all stations

Stations - upper catchment

- Awissawella
- Bogawanthalawa
- Chesterford
- Digalle
- Dunedin
- Labugama
- Maliboda

❖ Rainfall is averaged over the catchment according to Thiessen polygon method

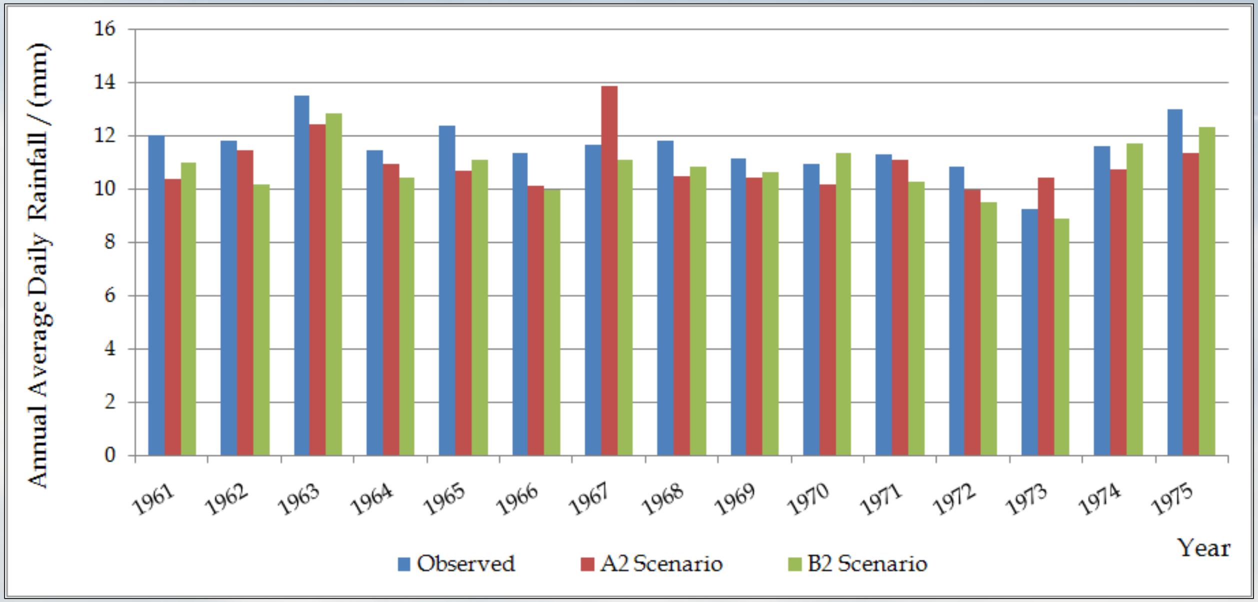


Thiessen polygon arrangement

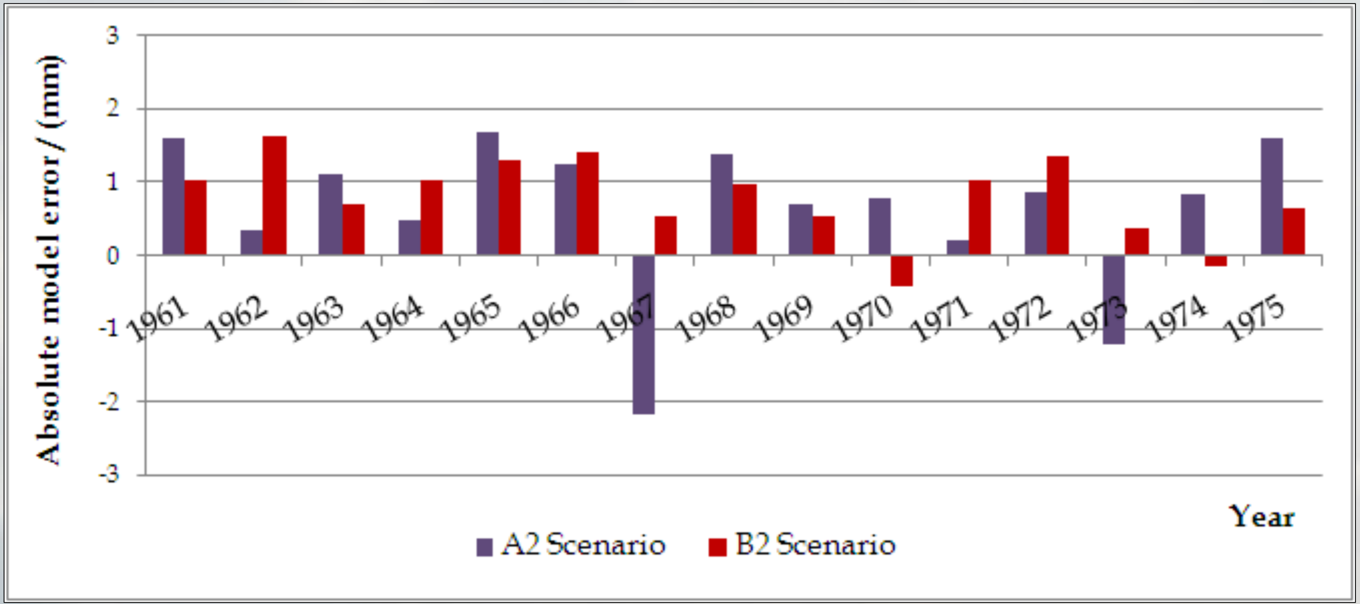
Lower catchment – Colombo meteorological station

SDSM model – Calibration

For upper catchment

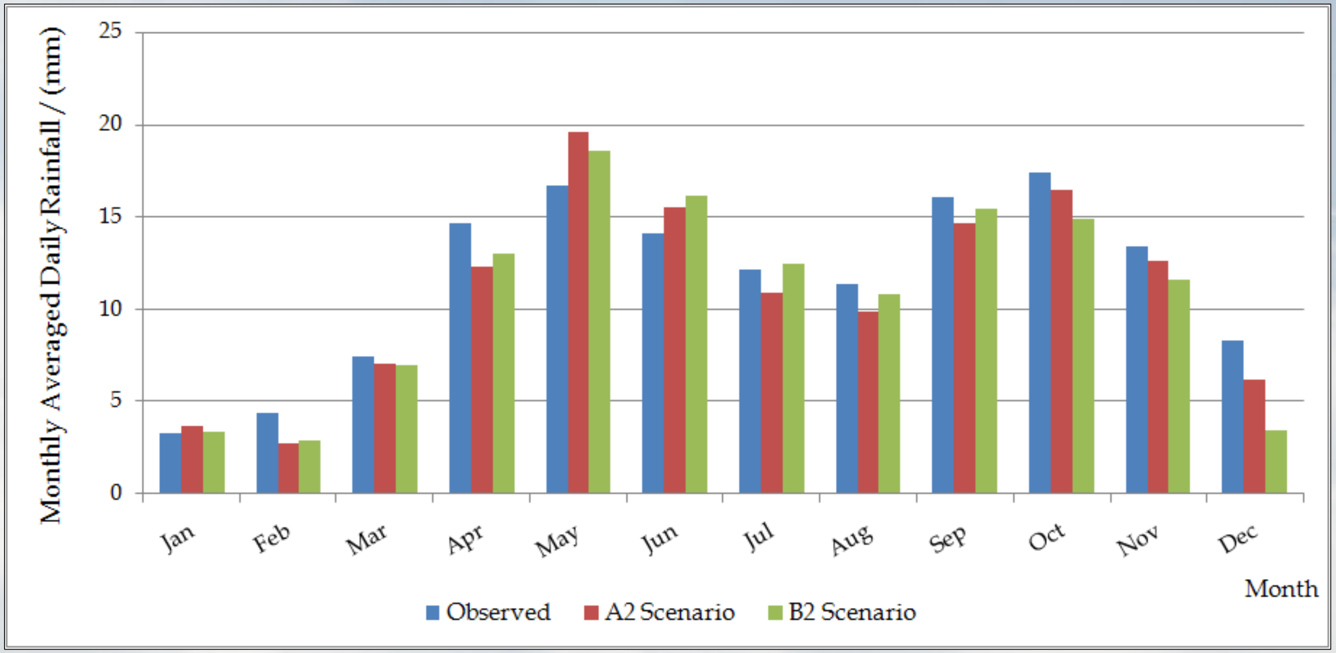


Variation of annual average daily rainfall

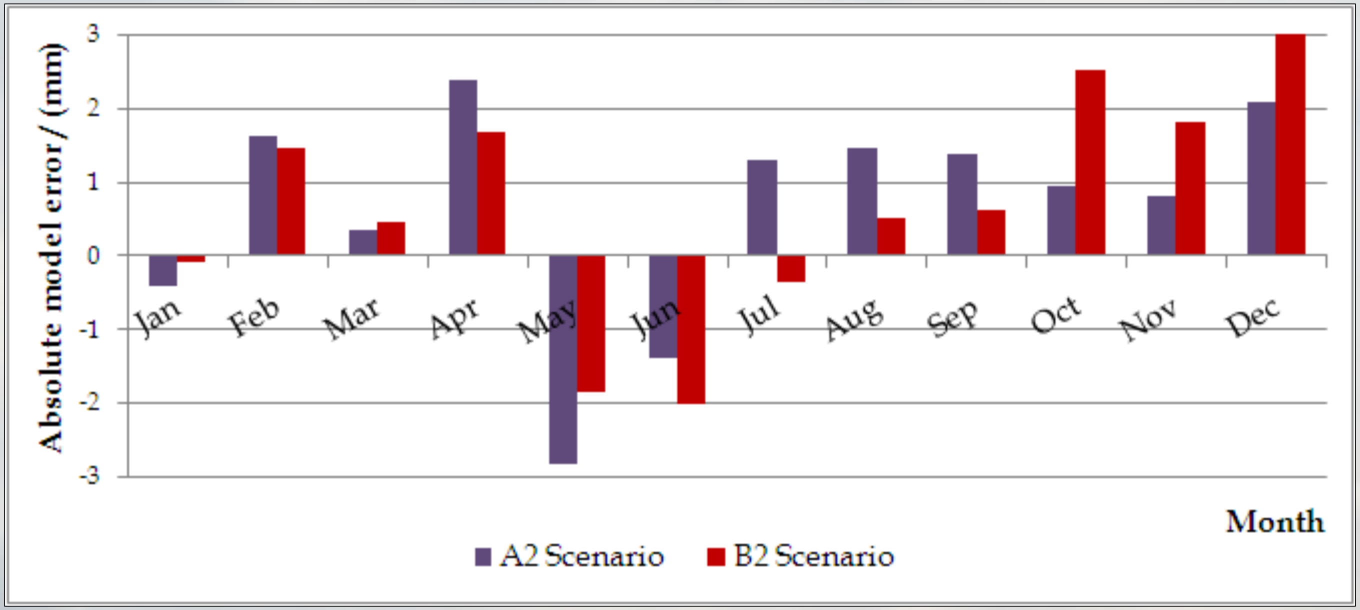


Annual mean absolute model error

For upper catchment

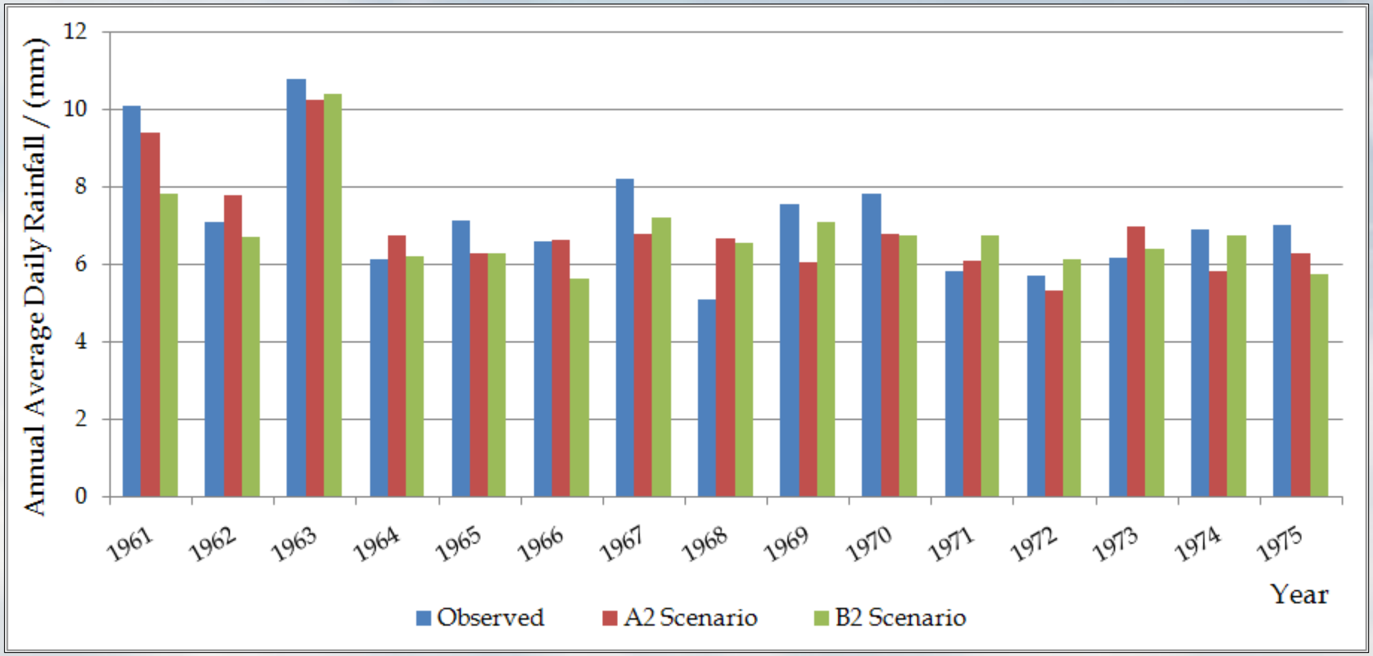


Variation of monthly average daily rainfall

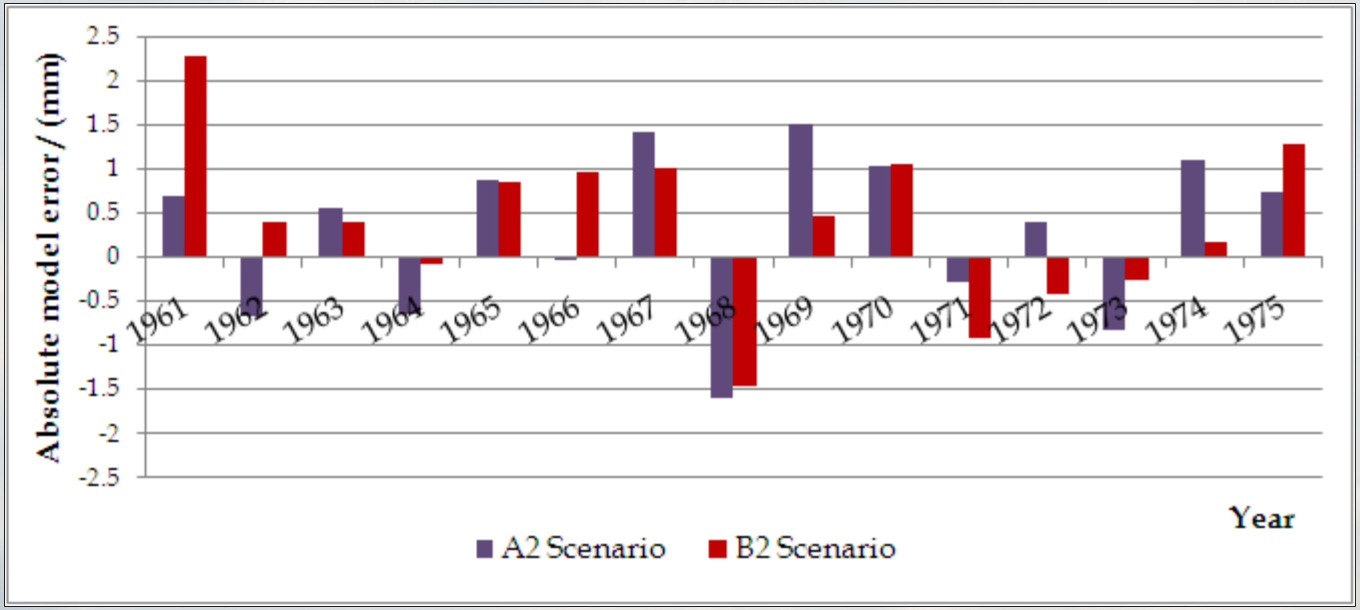


Monthly mean absolute model error

For lower catchment

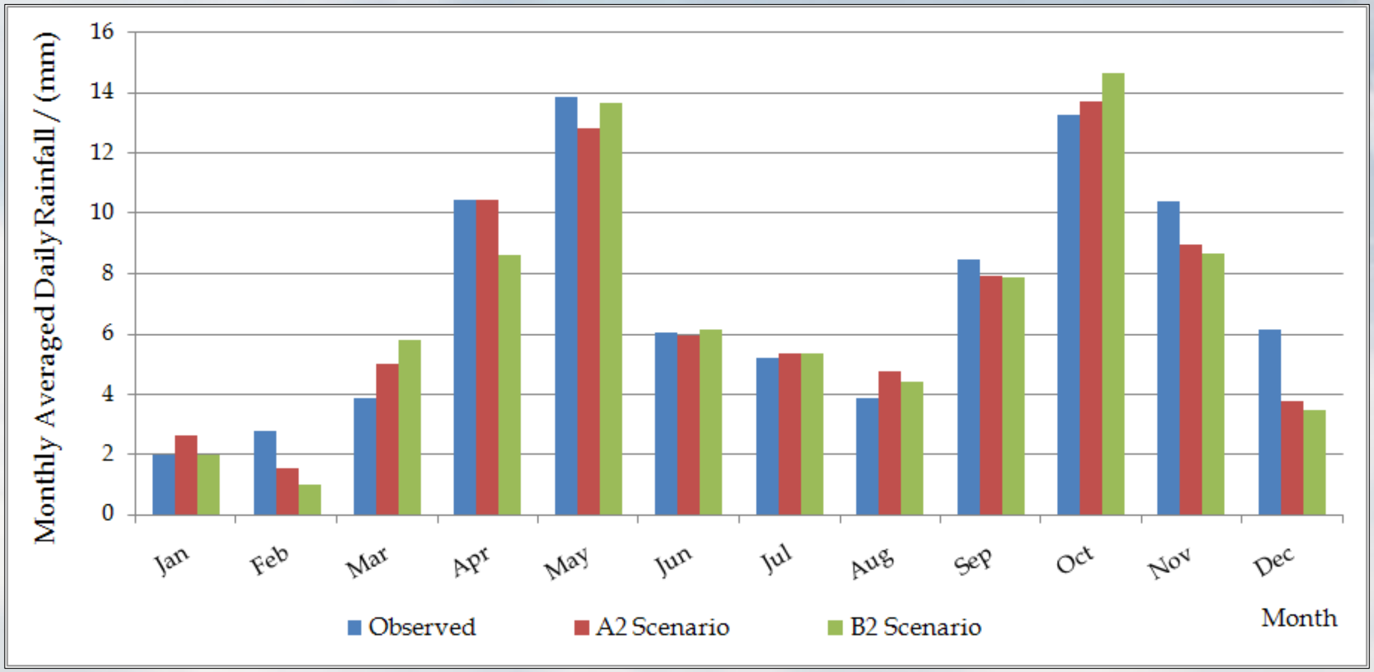


Variation of annual average daily rainfall

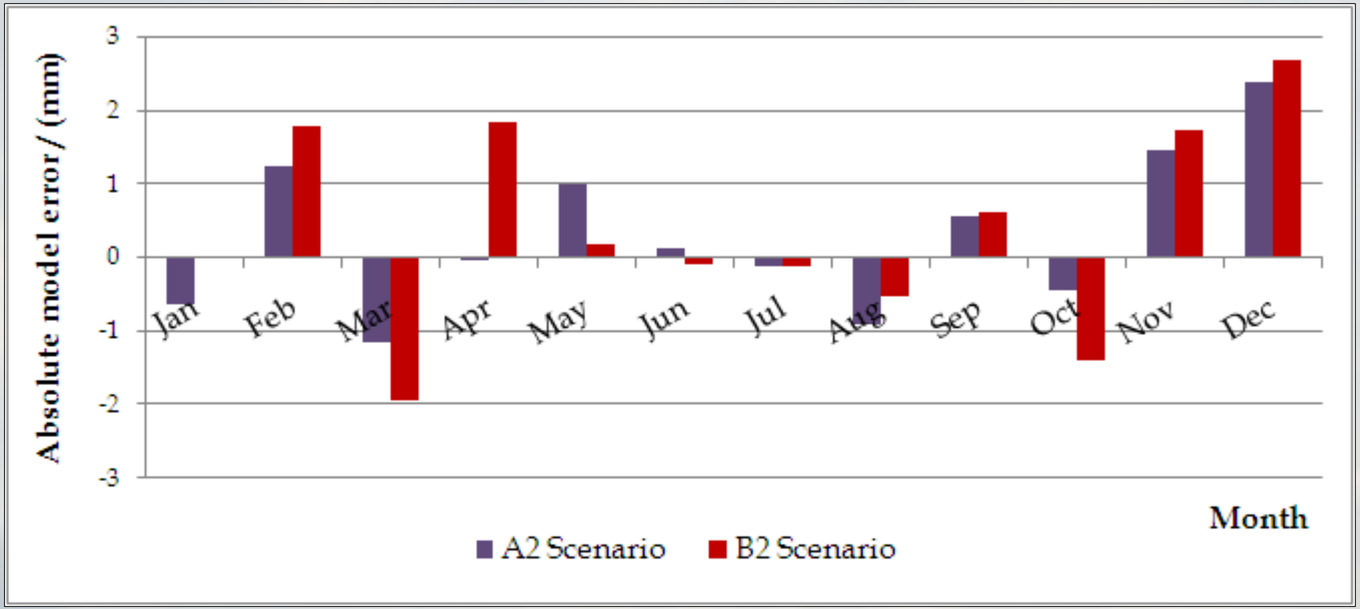


Annual mean absolute model error

For lower catchment



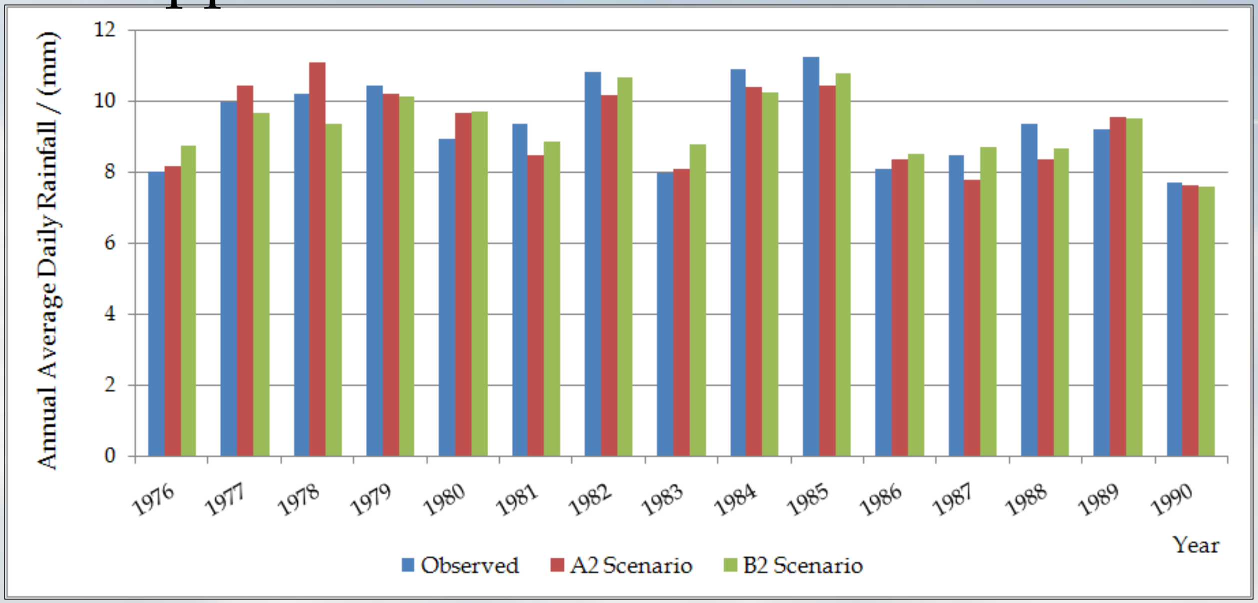
Variation of monthly average daily rainfall



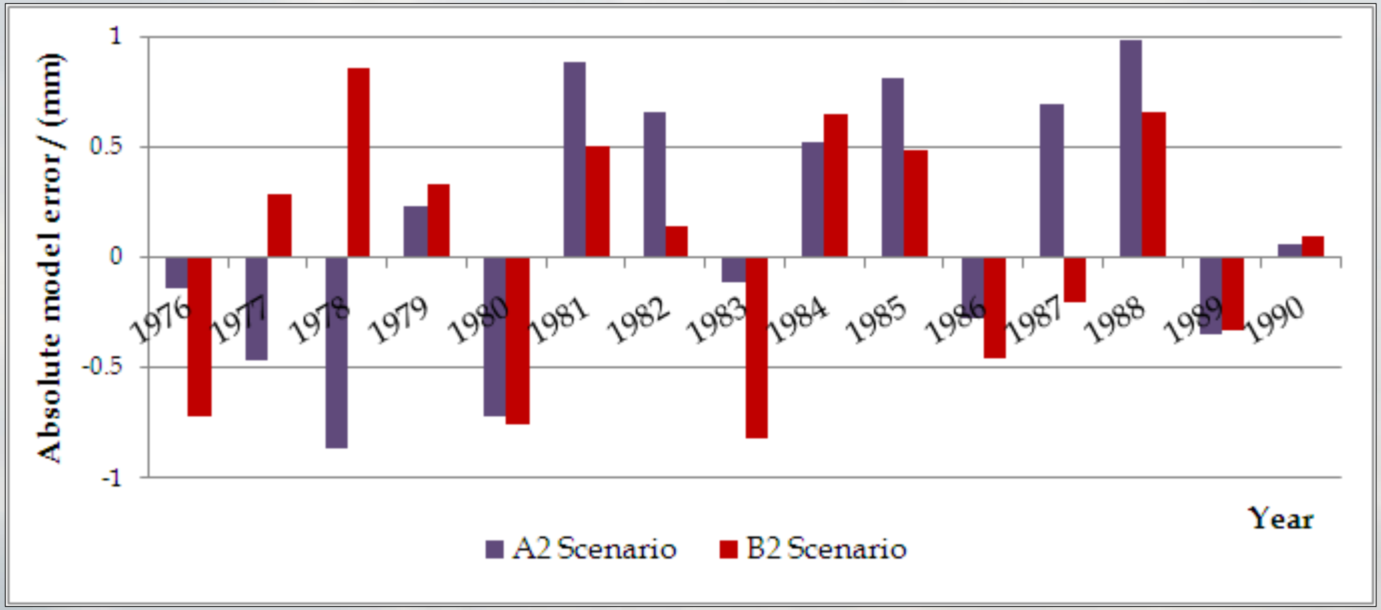
Monthly mean absolute model error

SDSM model – Validation

For upper catchment

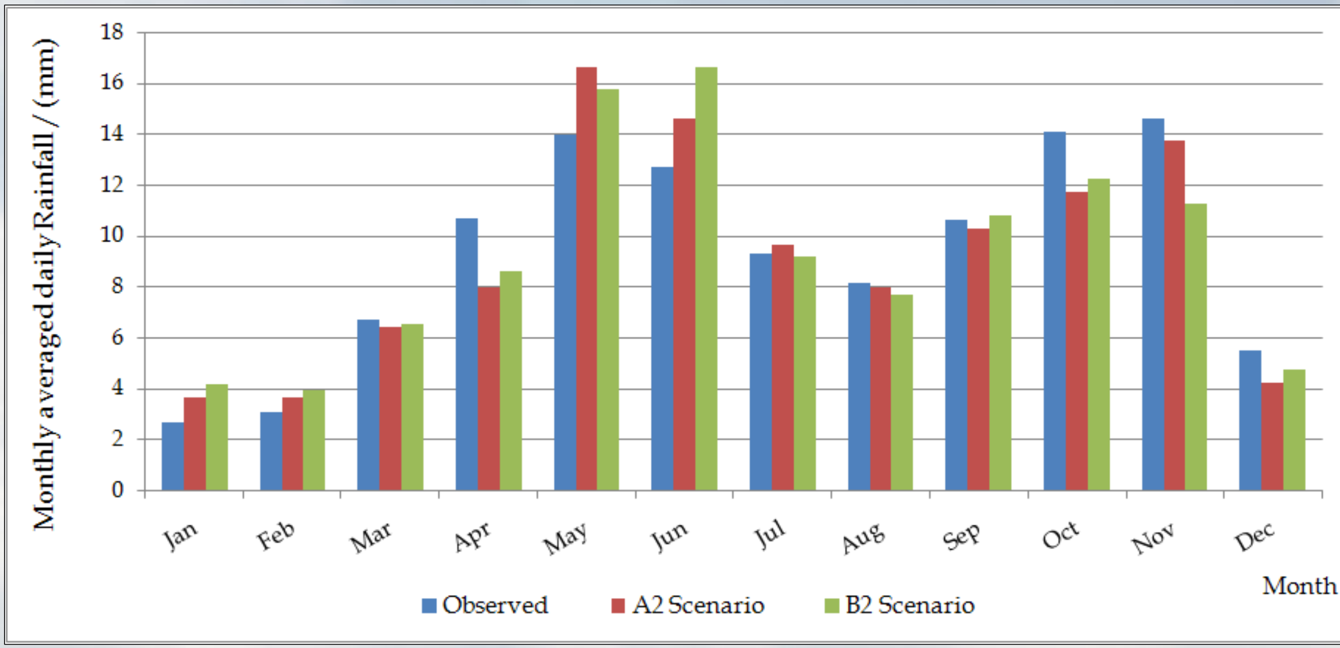


Variation of annual average daily rainfall

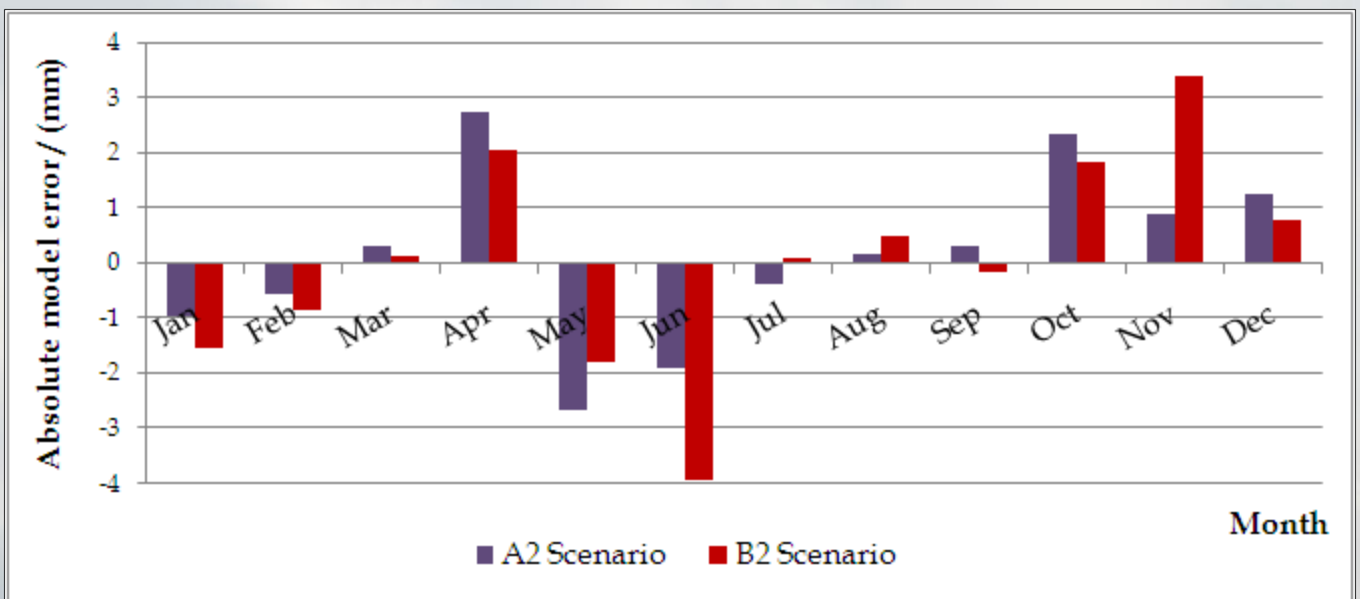


Annual mean absolute model error

For upper catchment

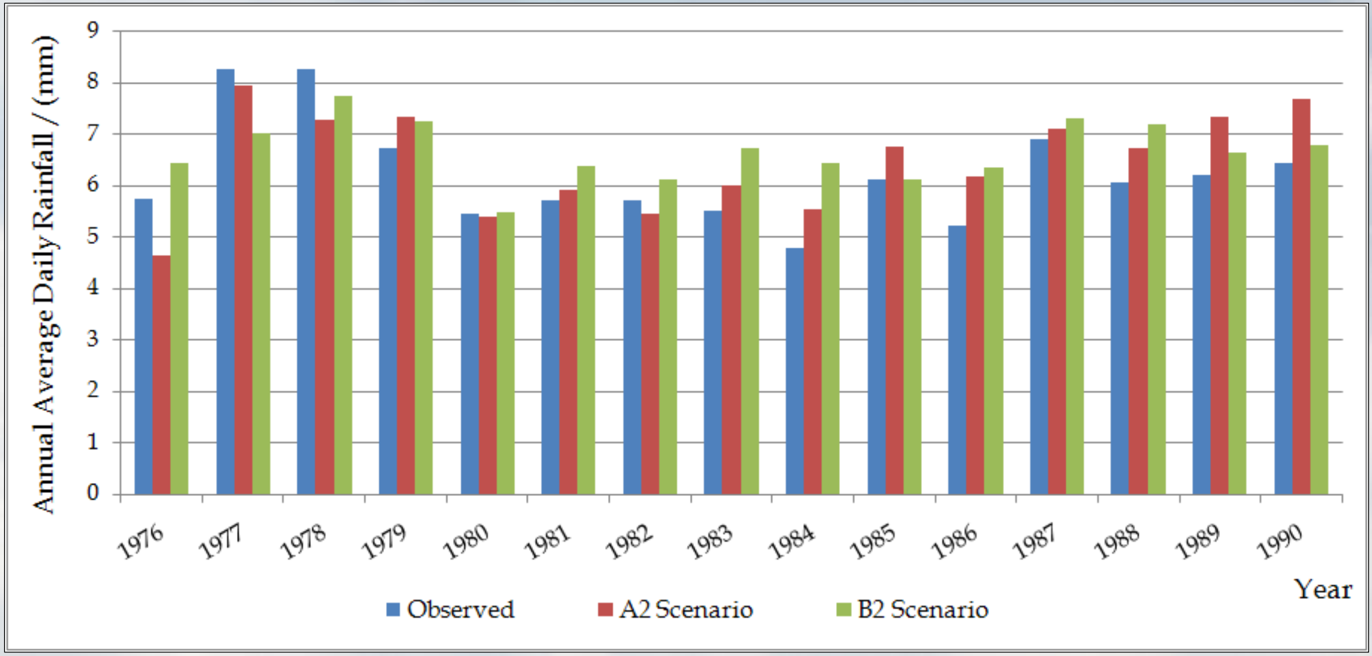


Variation of monthly average daily rainfall

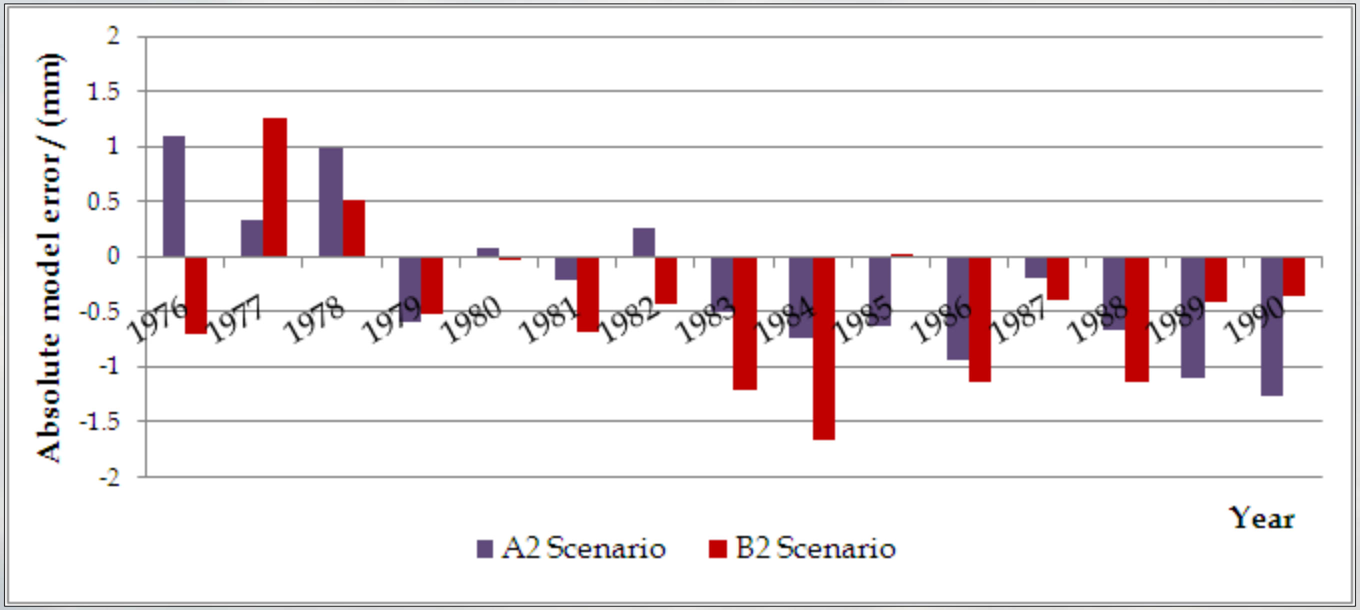


Monthly mean absolute model error

For lower catchment

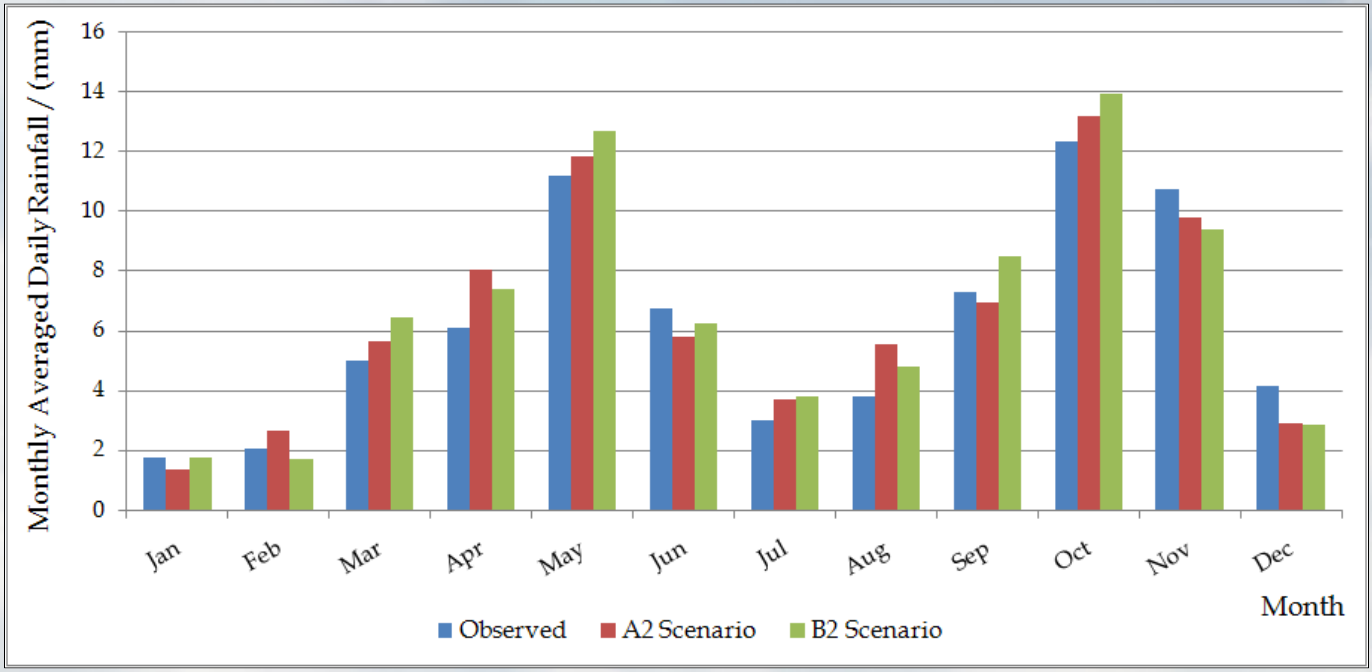


Variation of annual average daily rainfall

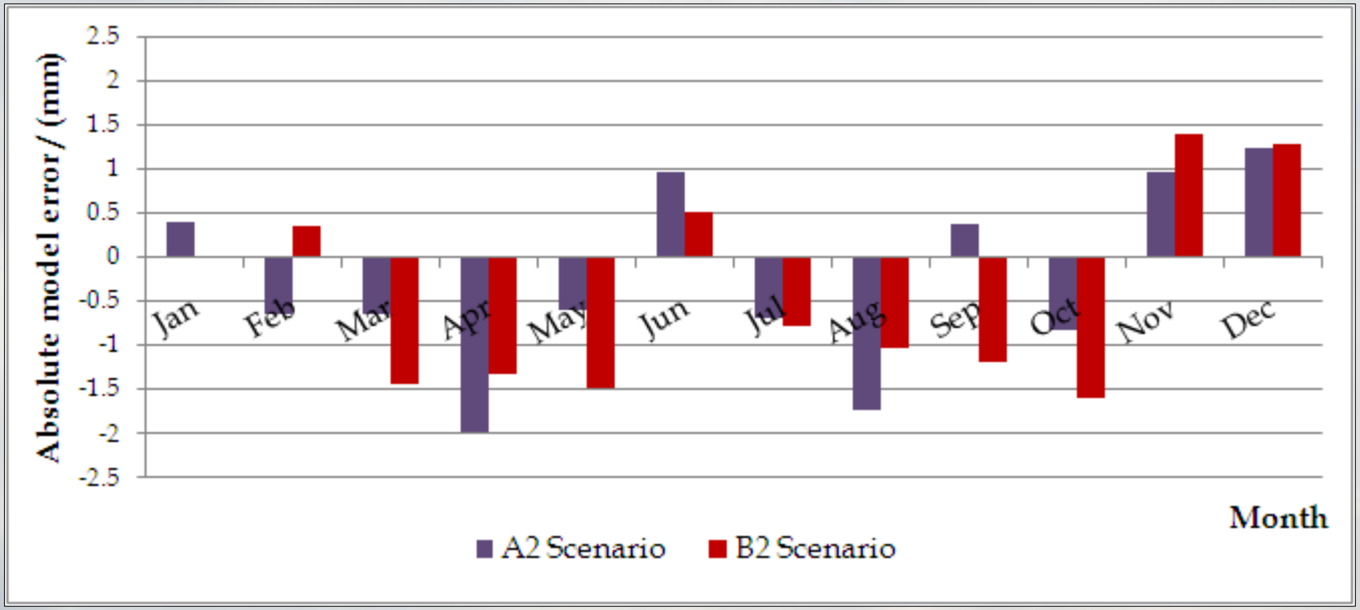


Annual mean absolute model error

For lower catchment

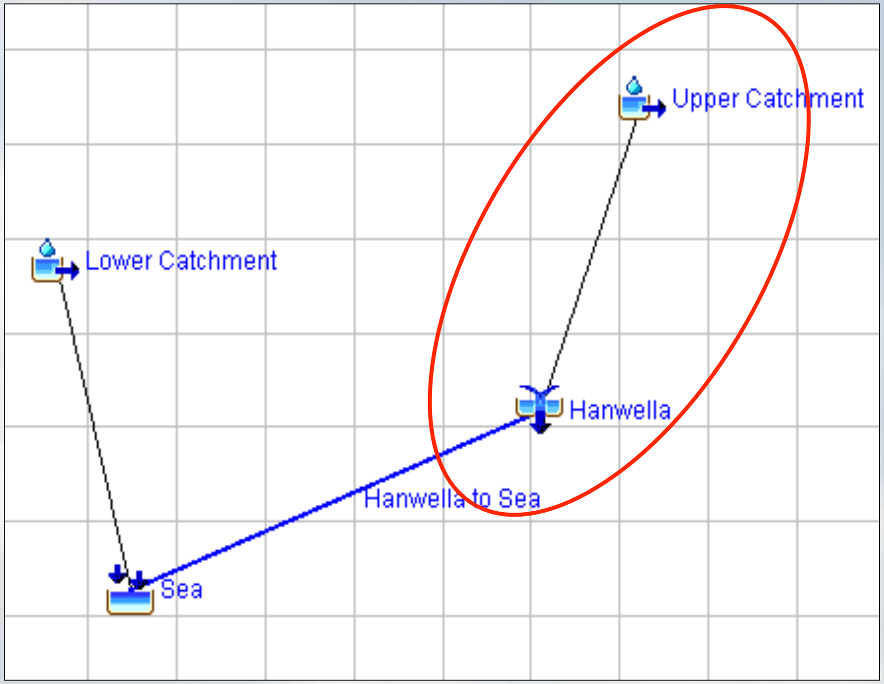


Variation of monthly average daily rainfall



Monthly mean absolute model error

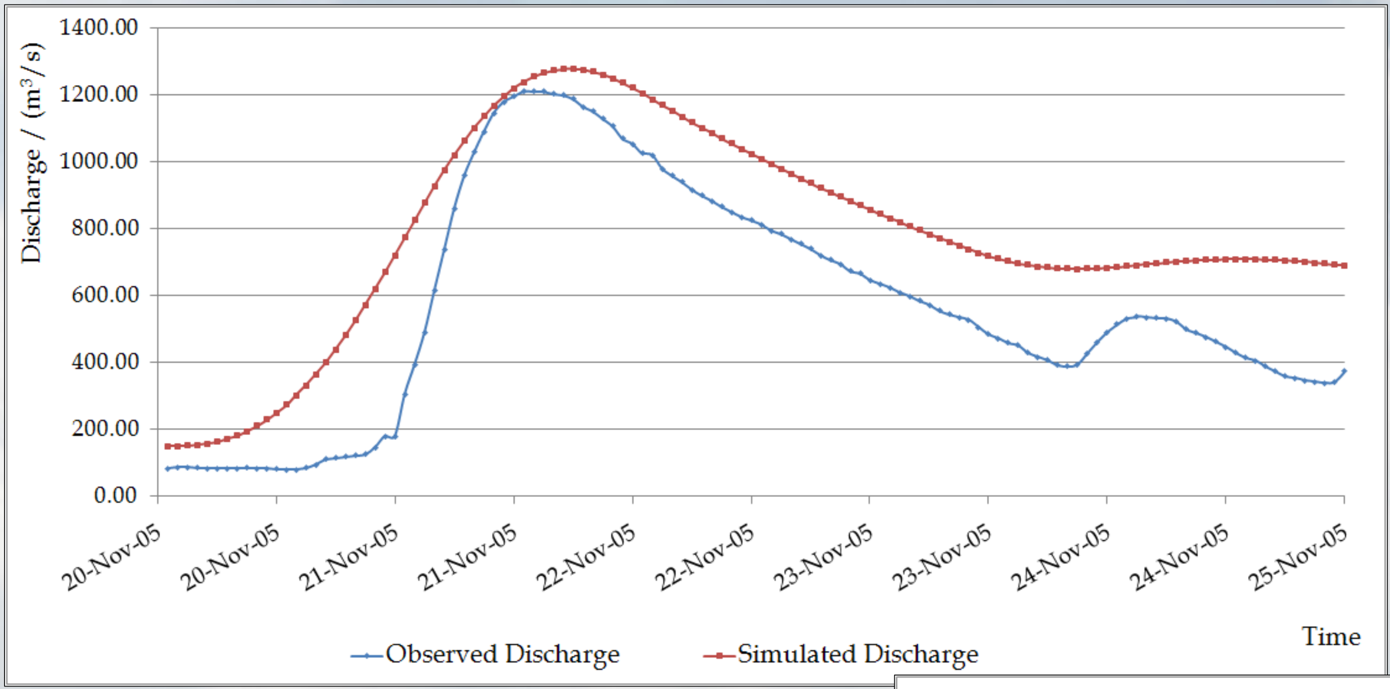
Rainfall – Runoff model



Upper Catchment

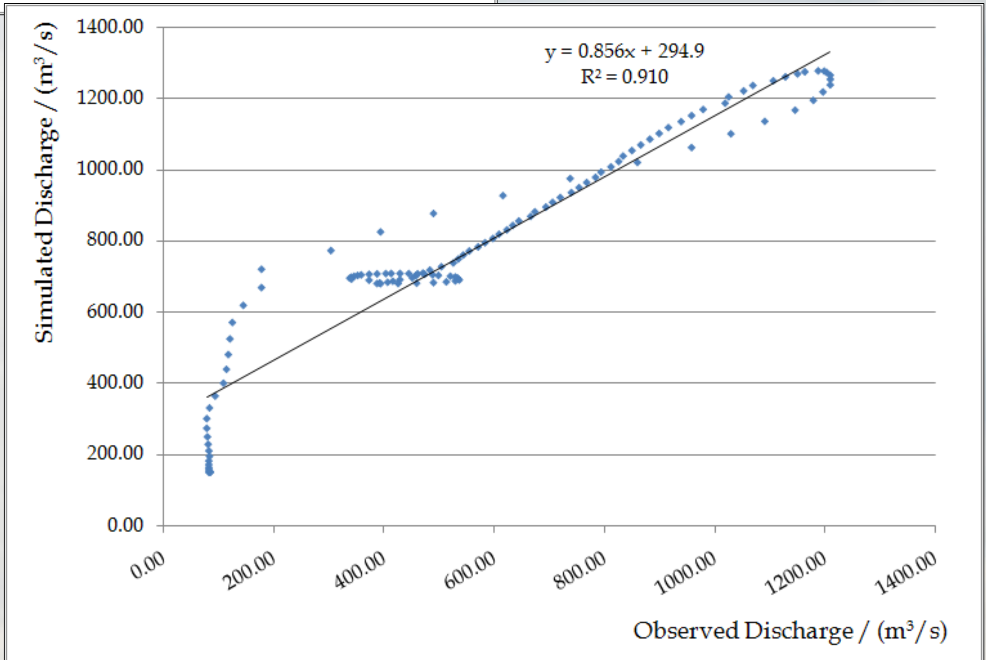
- Area – 1740 km^2
- Loss Method – Soil moisture accounting
- Transform method – Clerk unit hydrograph
- Baseflow method – Recession

HEC – HMS model – Calibration

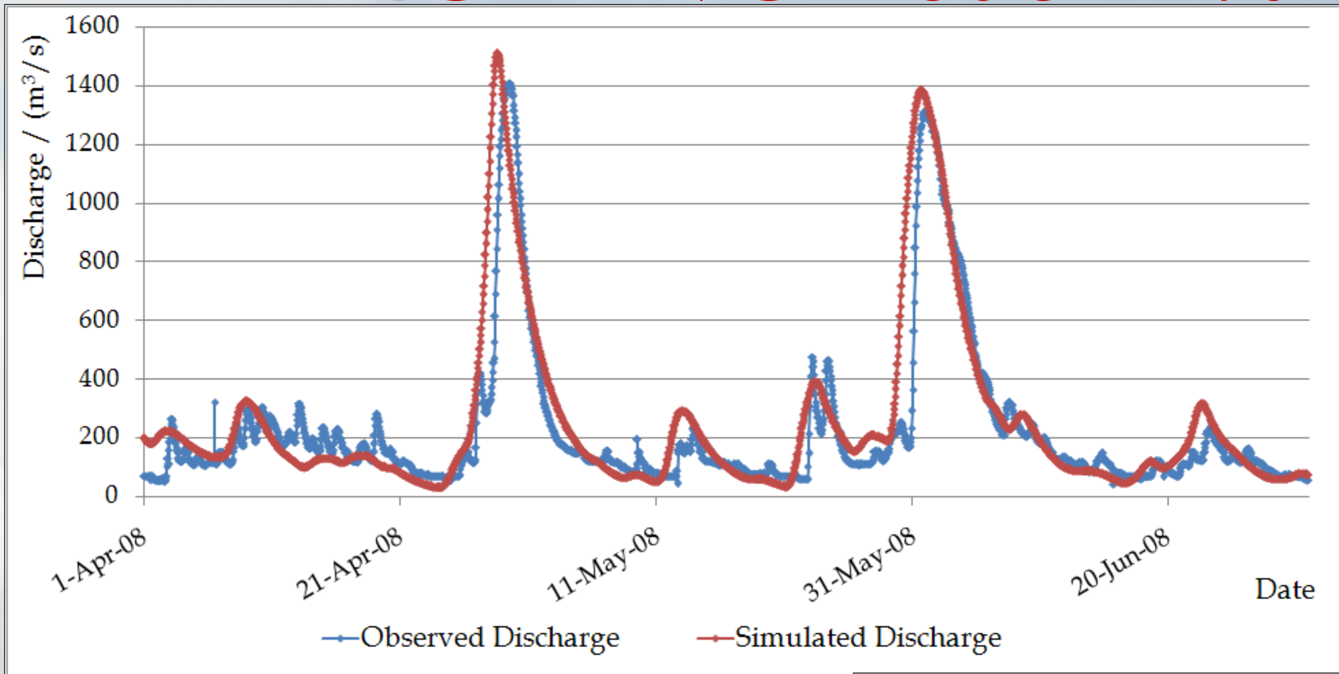


Variation of observed and simulated discharge at Hanwella gauging station during November 2005 flood event

$R^2 = 0.91$

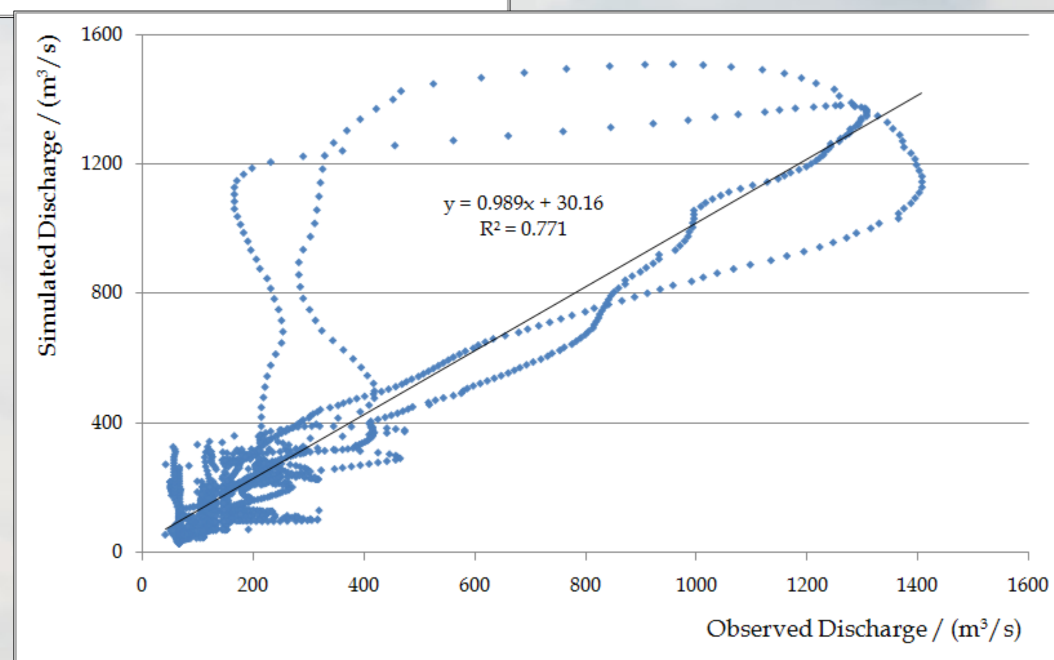


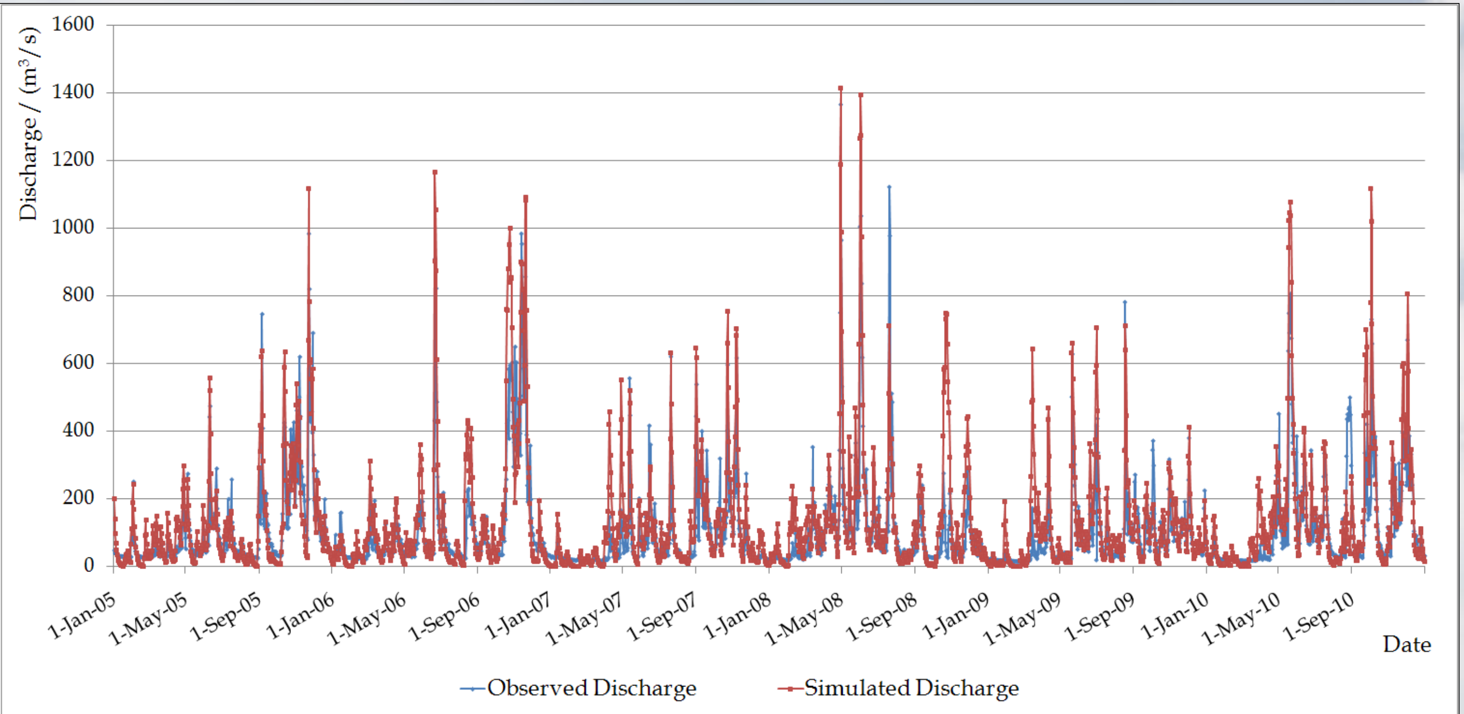
HEC – HMS model – Validation



Variation of observed and simulated discharge at Hanwella gauging station from April to June 2008 flood events

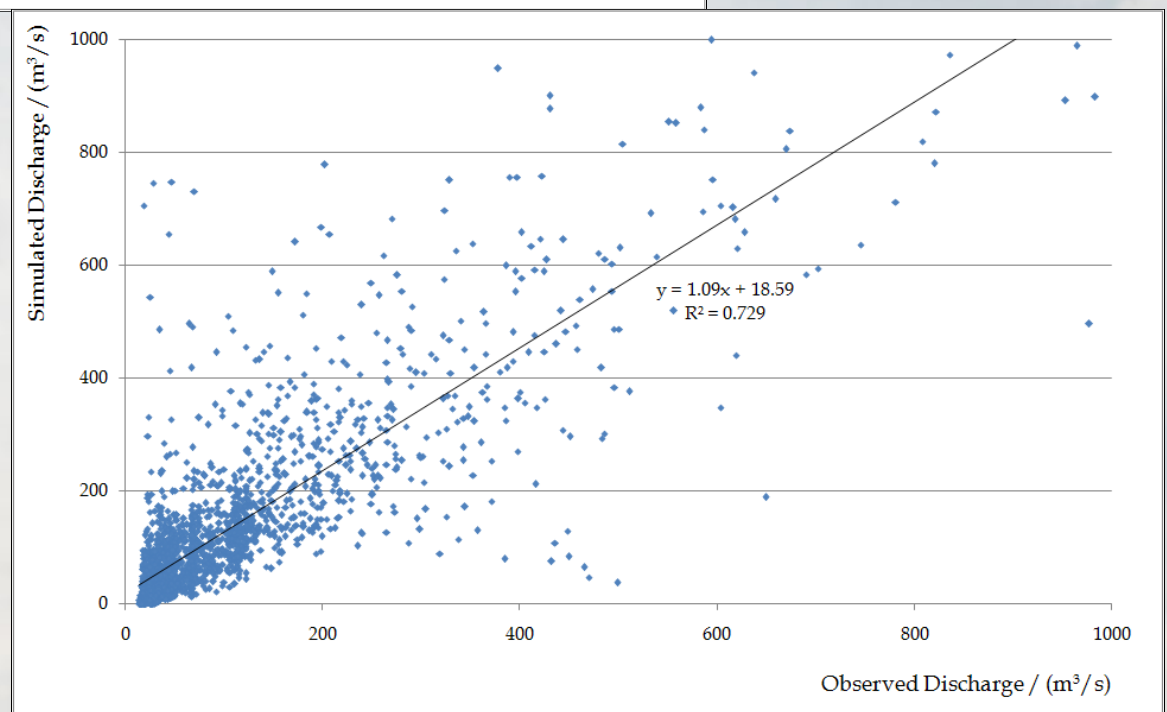
$R^2 = 0.77$



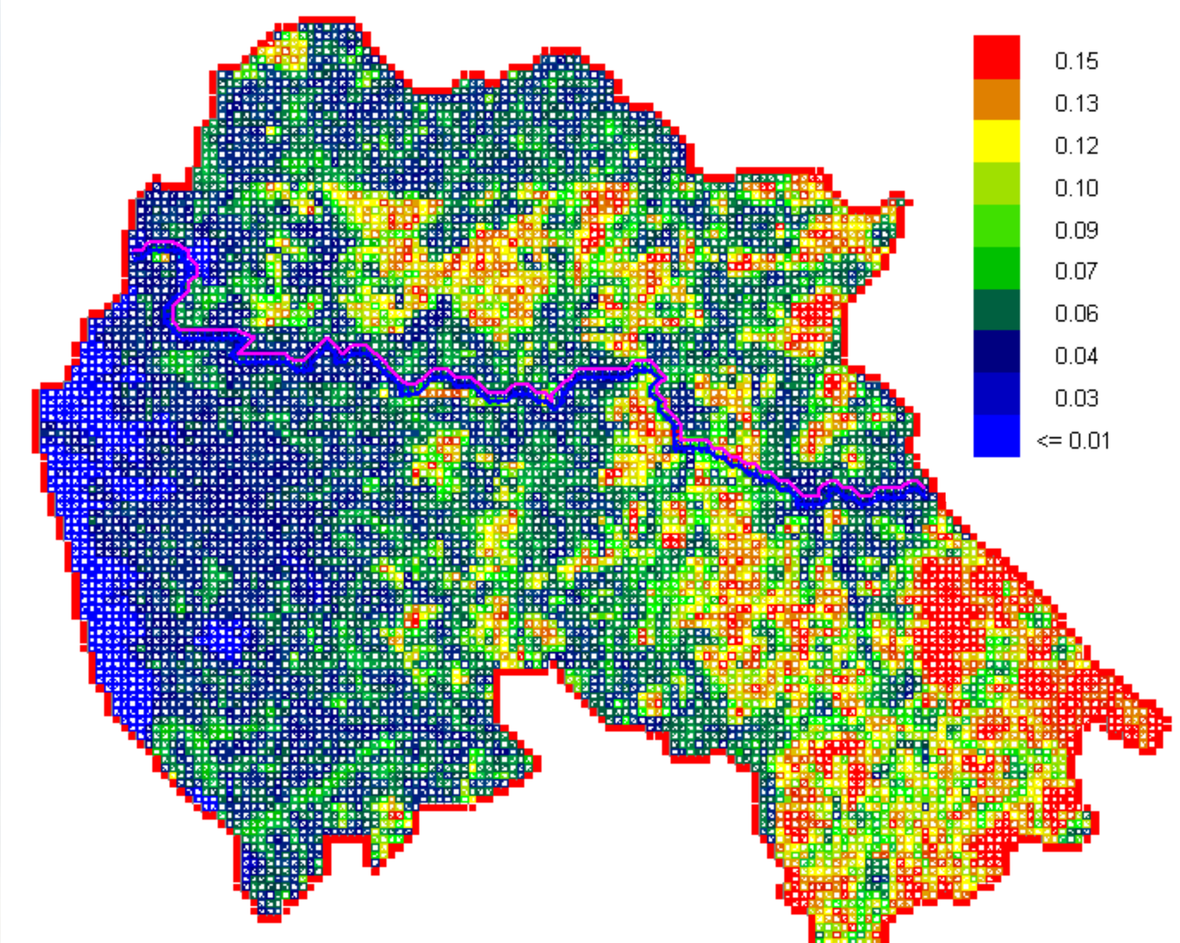


Variation of observed and simulated daily discharge at Hanwella gauging station from 2005 to 2010

$R^2 = 0.73$



Flood inundation model (FLO-2D)

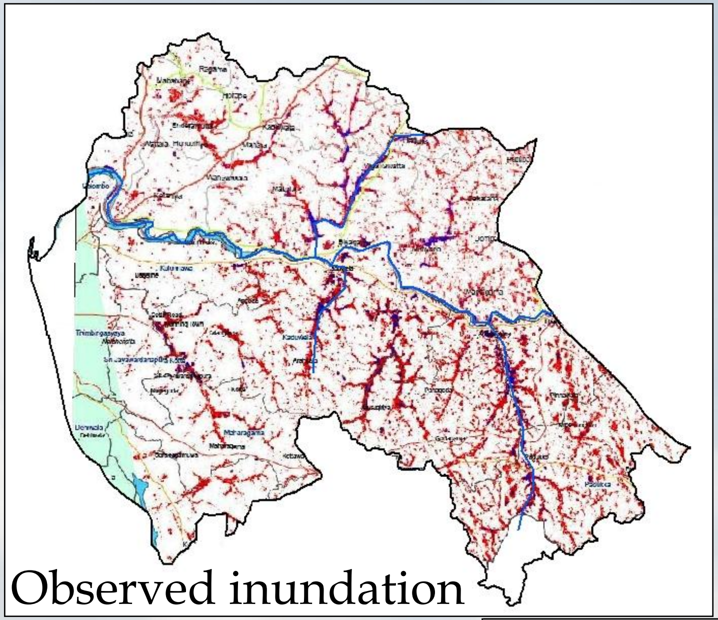


Manning's coefficient according to land use

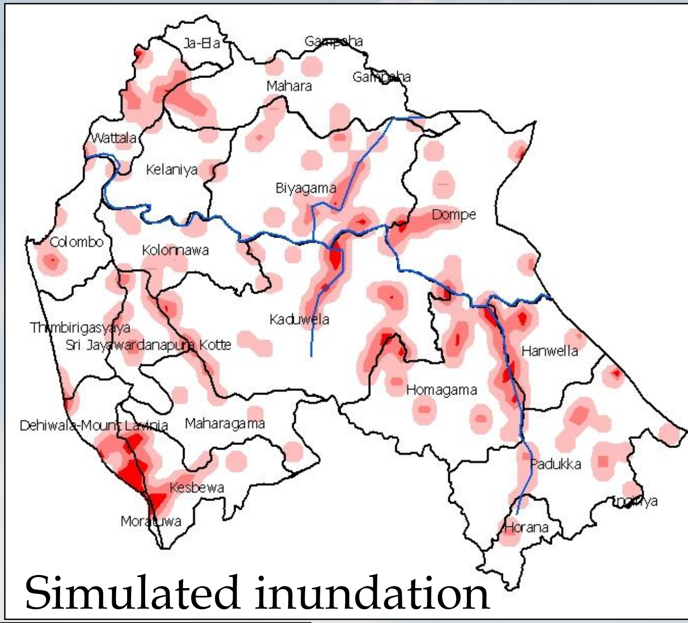
Parameters

- Channel and catchment characteristics such as,
  - Infiltration
  - Manning's coefficient
  - Channel roughness
  - Channel shape and dimensions

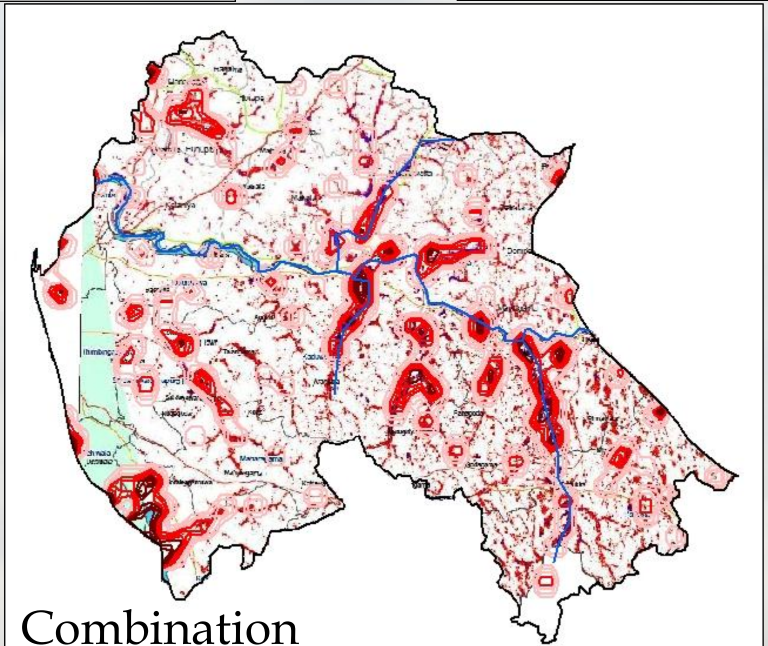
Inundation areas



Observed inundation



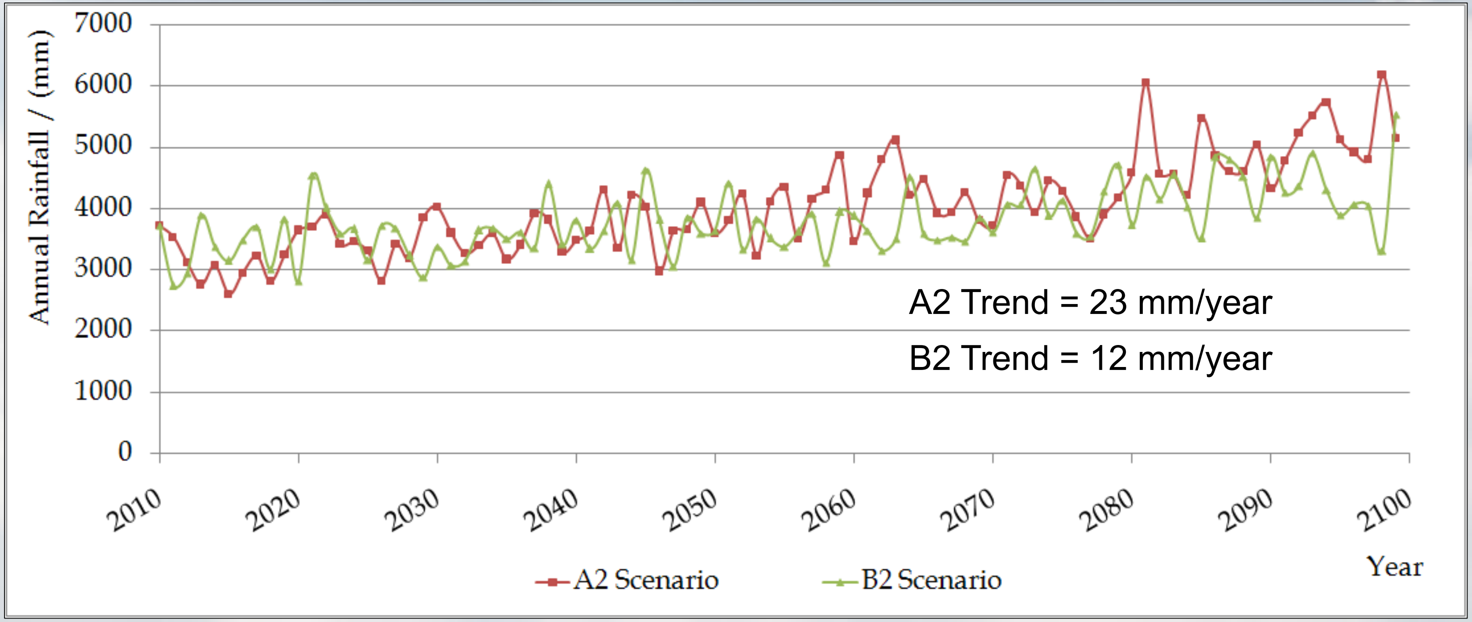
Simulated inundation



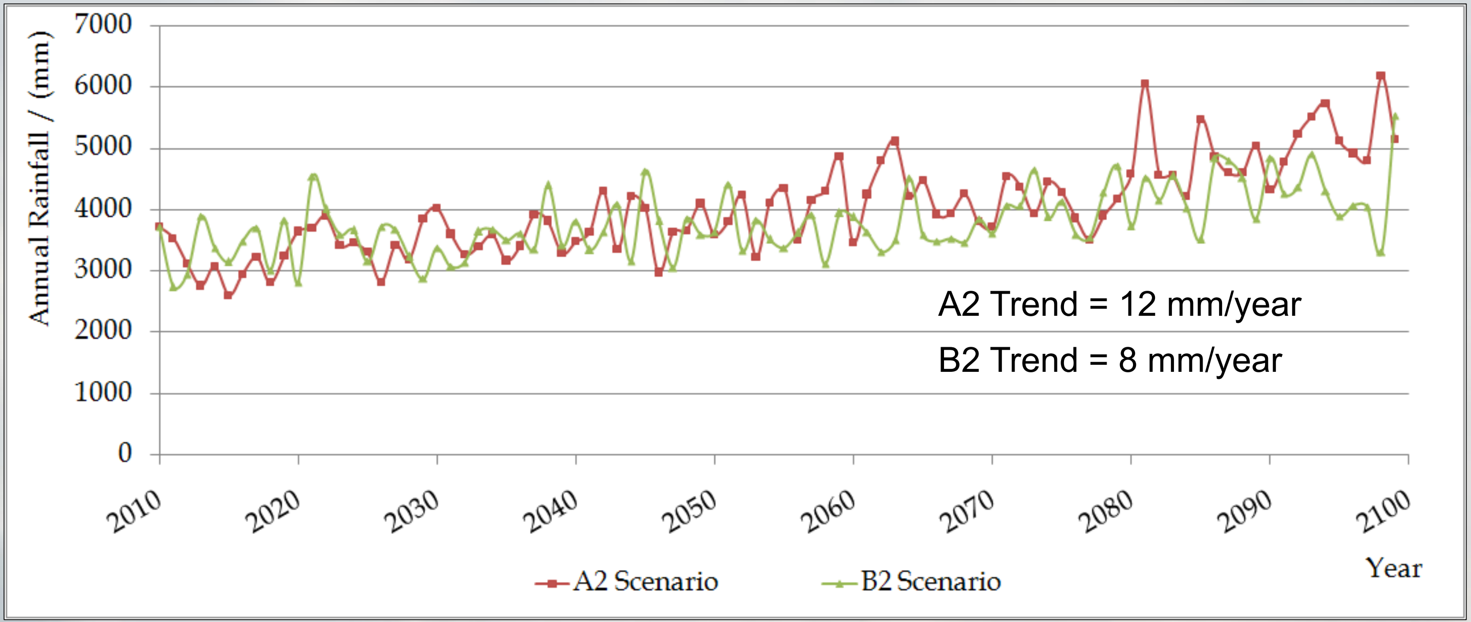
Combination

Results

Future climate forecasts



Annual total rainfall at upper catchment



Annual total rainfall at lower catchment

Extreme value analysis

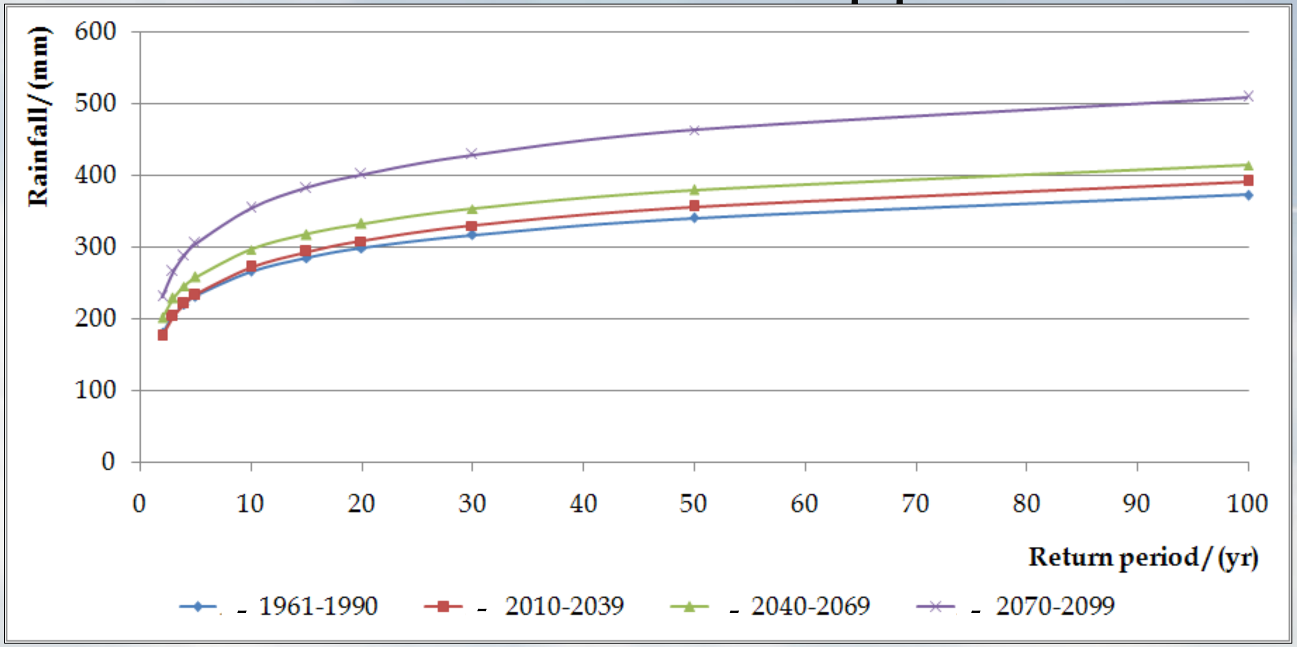
Upper Catchment

- 3 day total rainfall according to
  - Gumbel distribution
  - Generalized Extreme Value (GEV) distribution

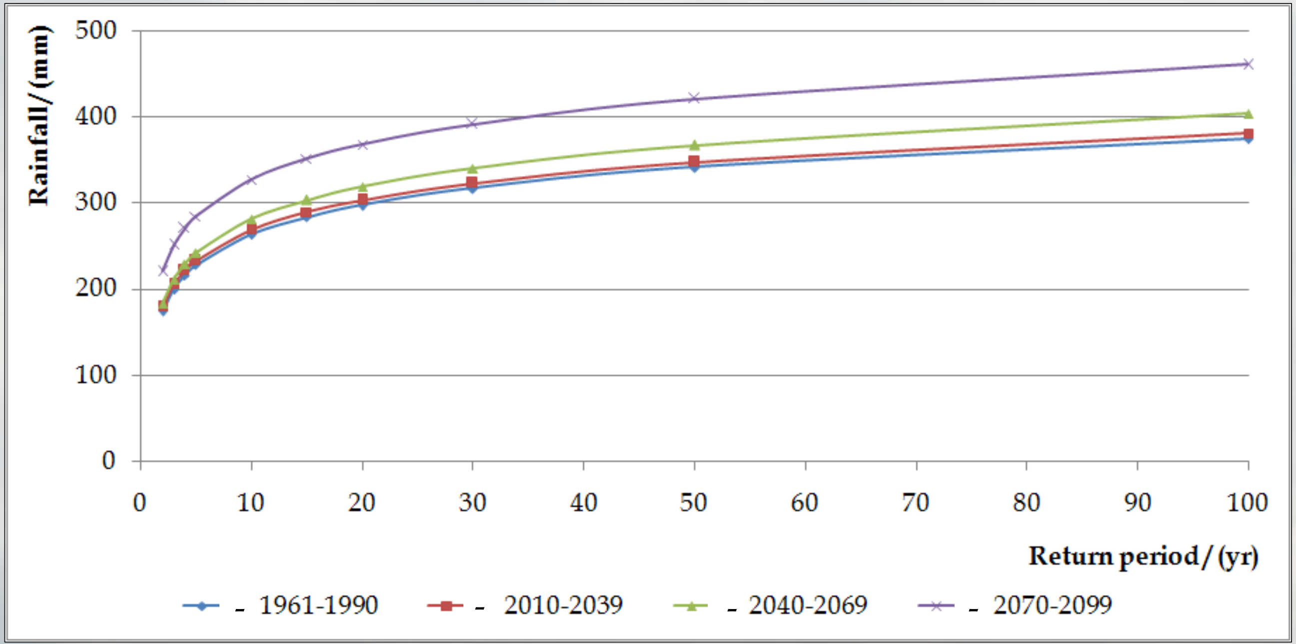
Lower Catchment

- Daily rainfall according to
  - Gumbel distribution
  - Generalized Extreme Value (GEV) distribution

Gumbel distribution for upper catchment

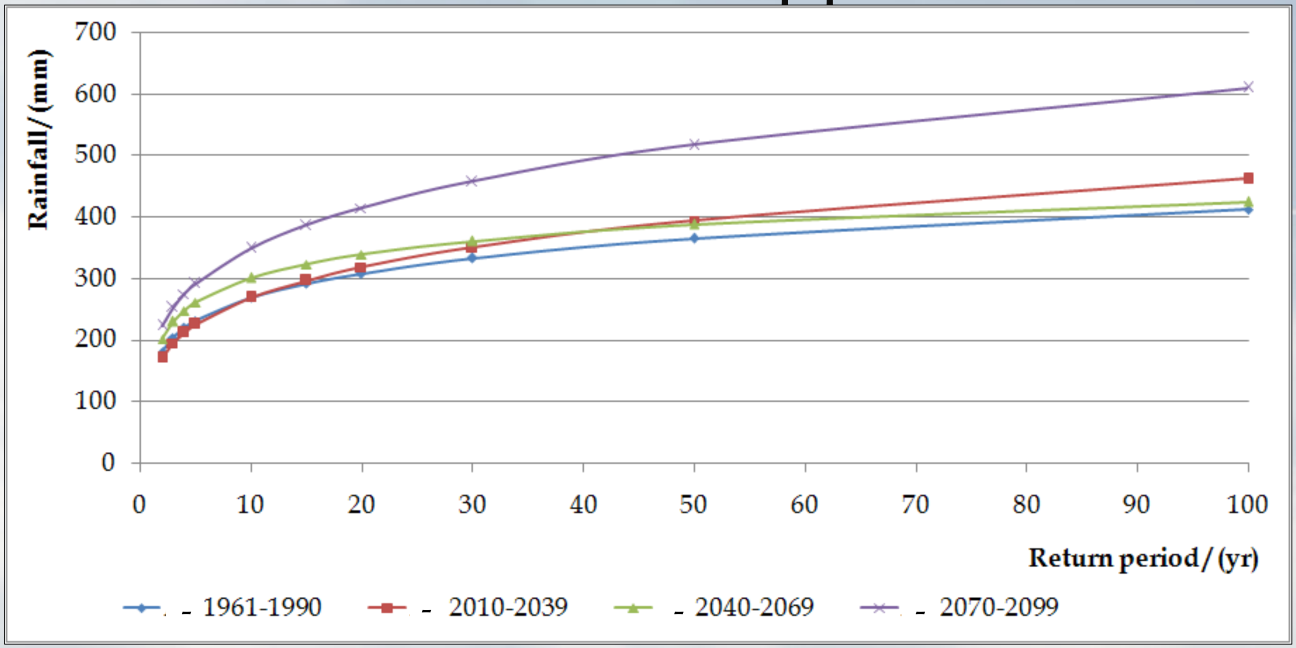


Frequency analysis according to A2 scenario

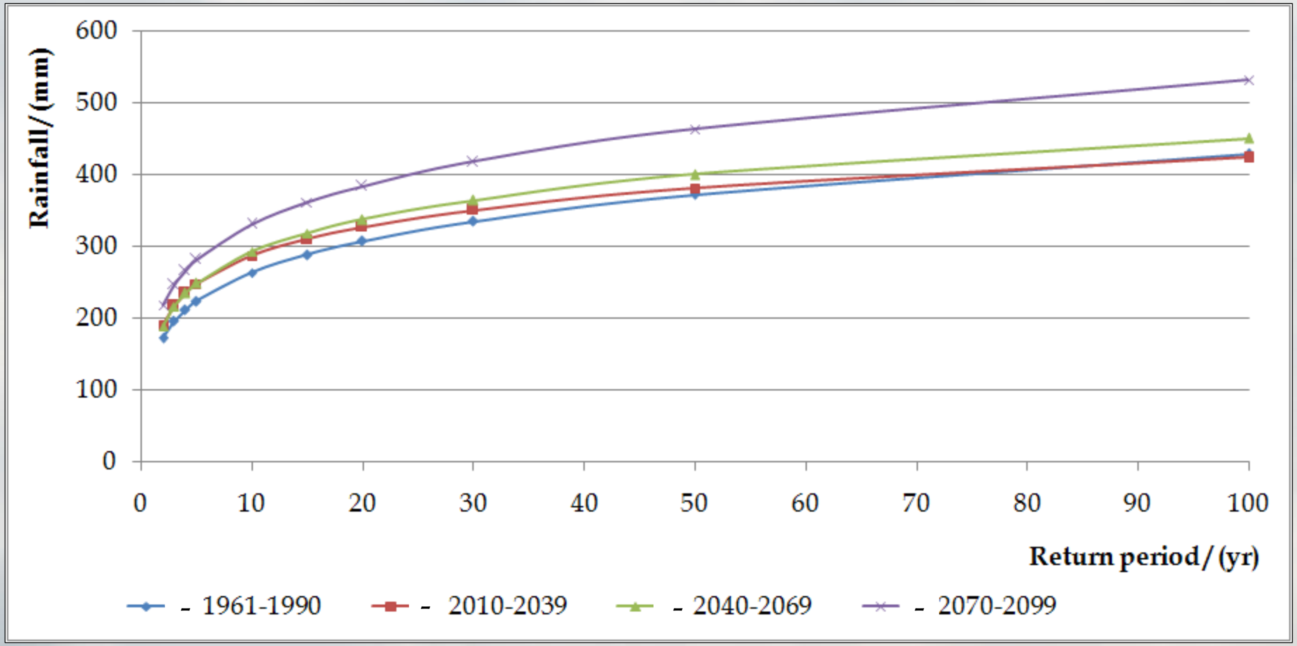


Frequency analysis according to B2 scenario

GEV distribution for upper catchment

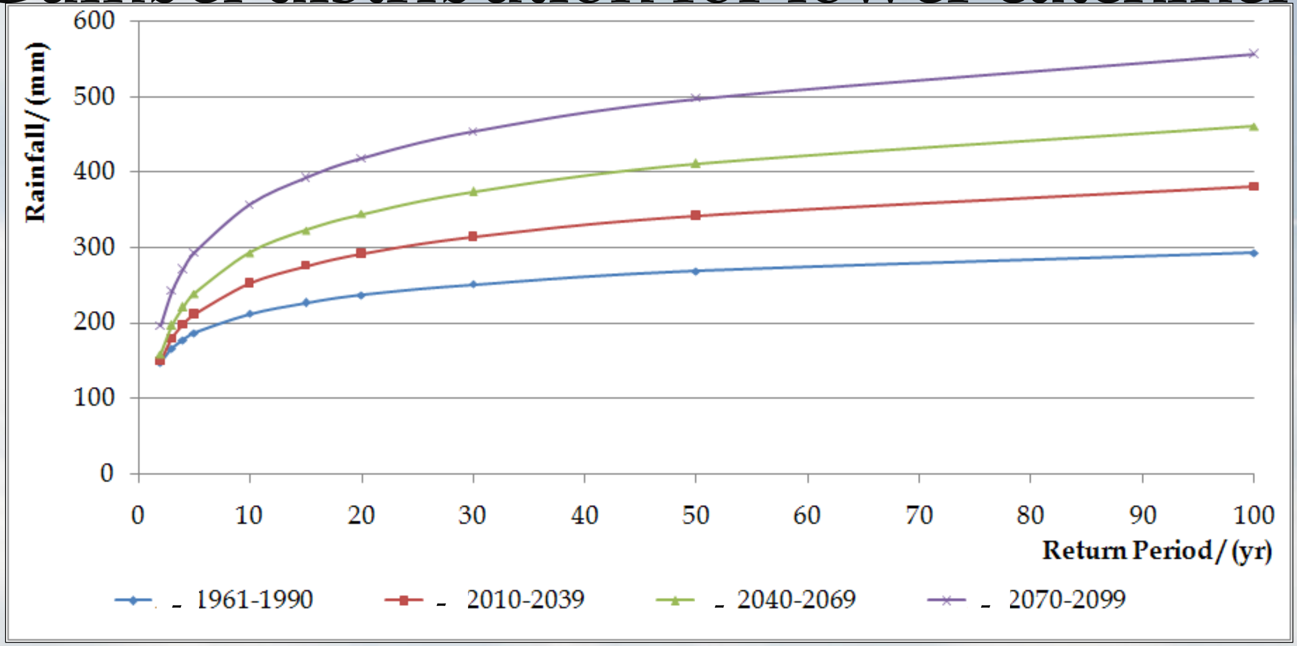


Frequency analysis according to A2 scenario

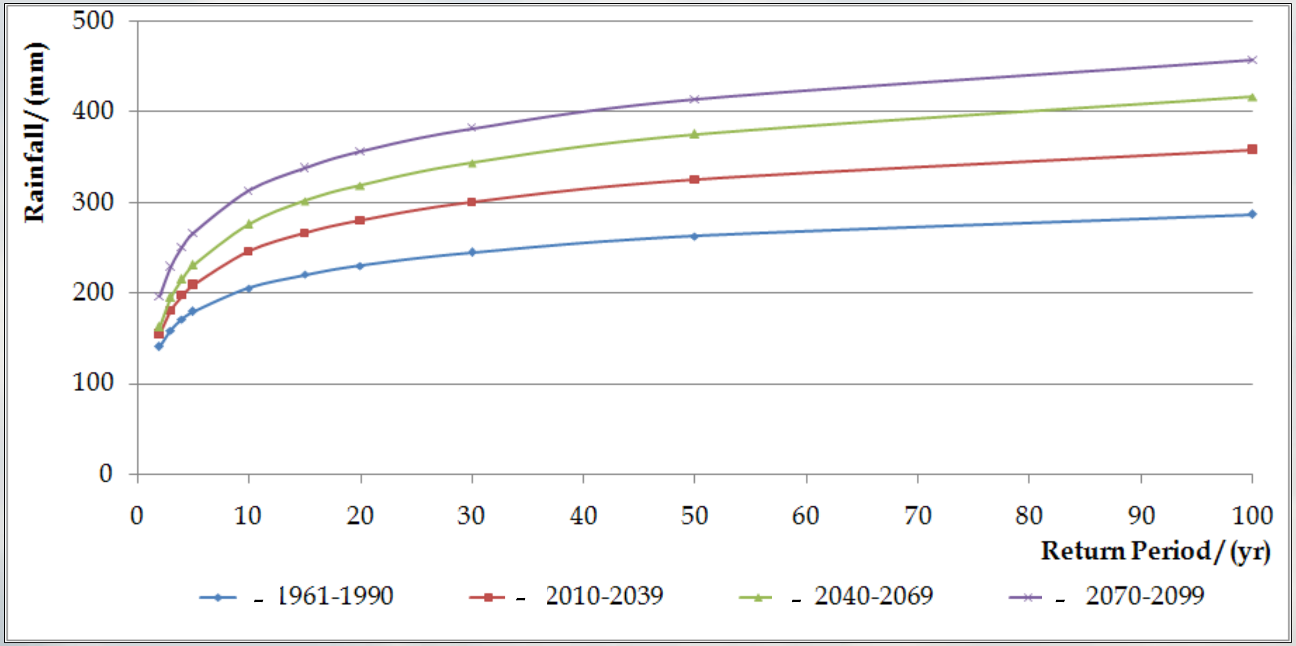


Frequency analysis according to B2 scenario

Gumbel distribution for lower catchment

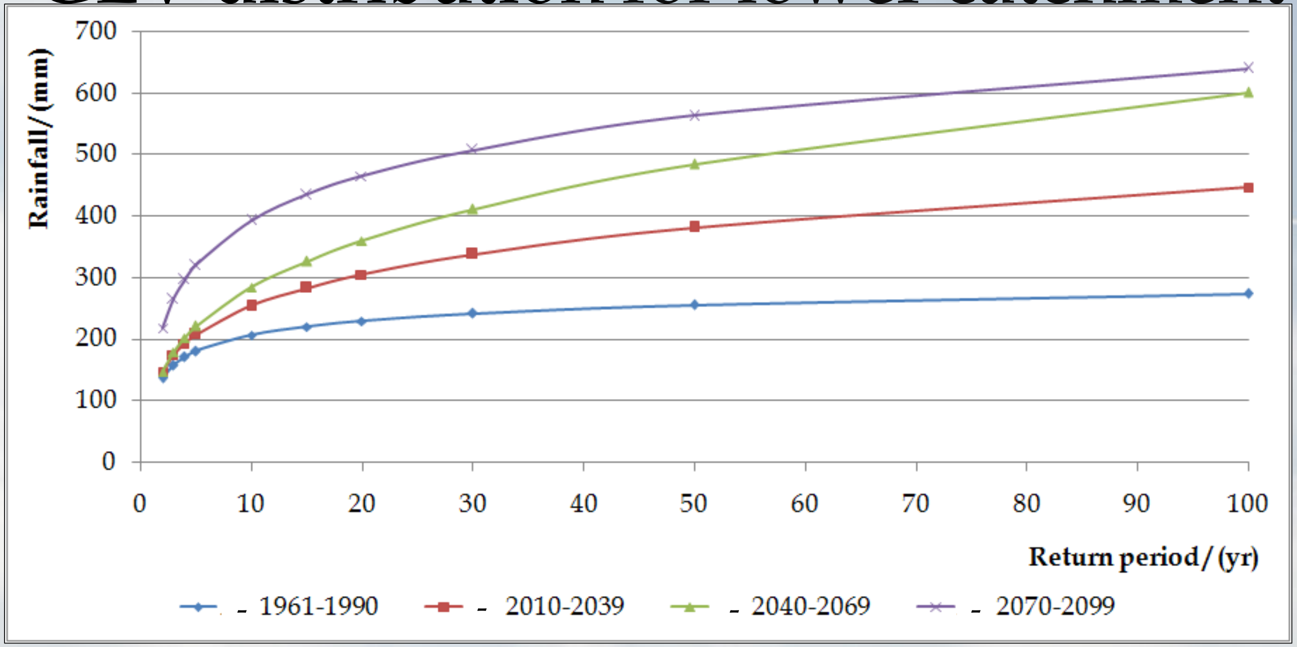


Frequency analysis according to A2 scenario

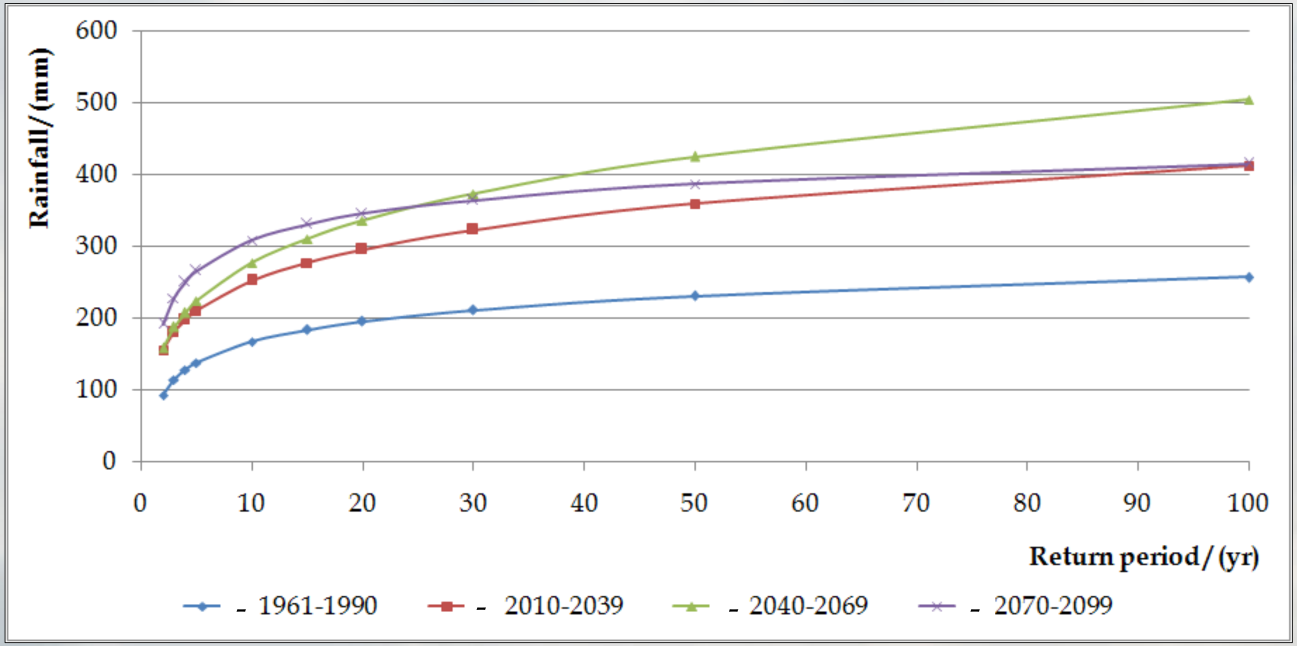


Frequency analysis according to B2 scenario

GEV distribution for lower catchment

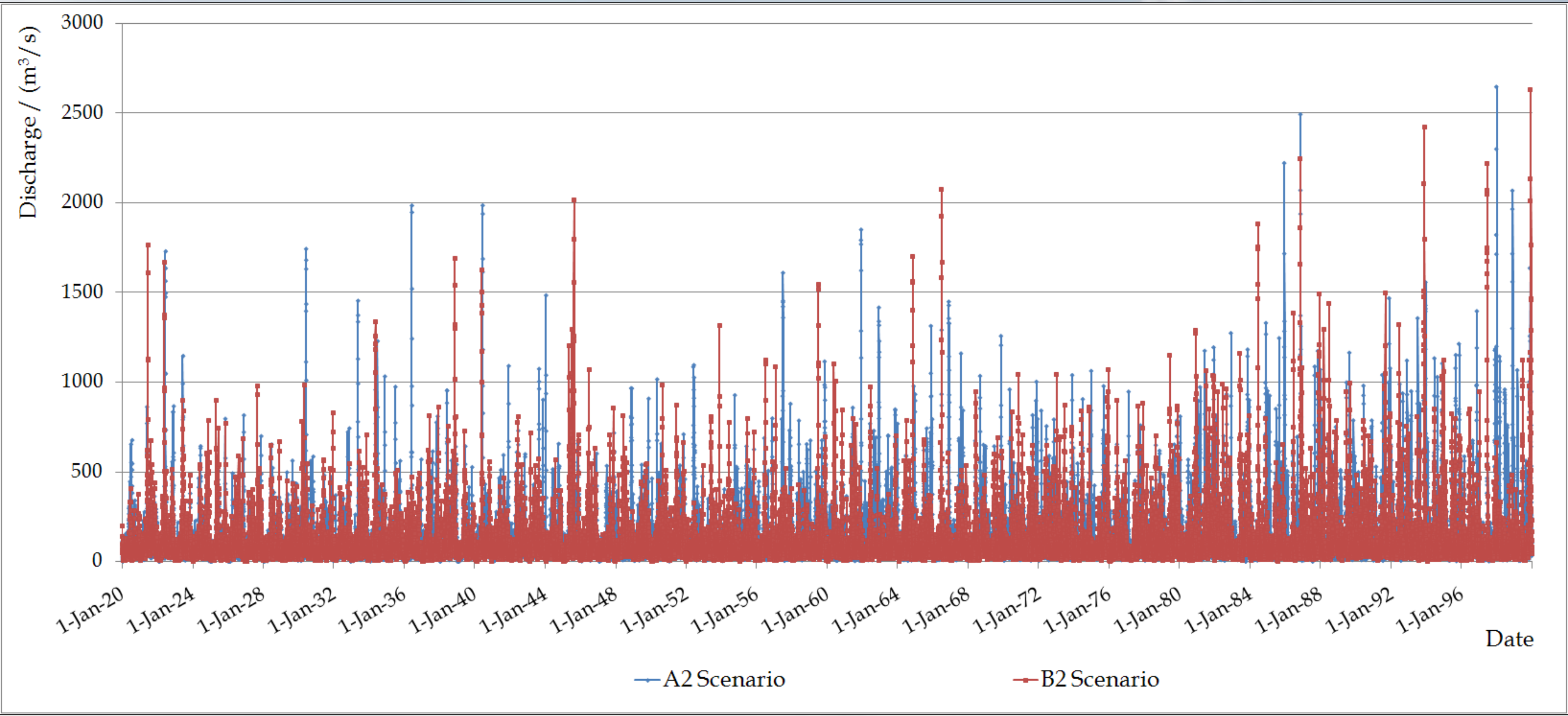


Frequency analysis according to A2 scenario

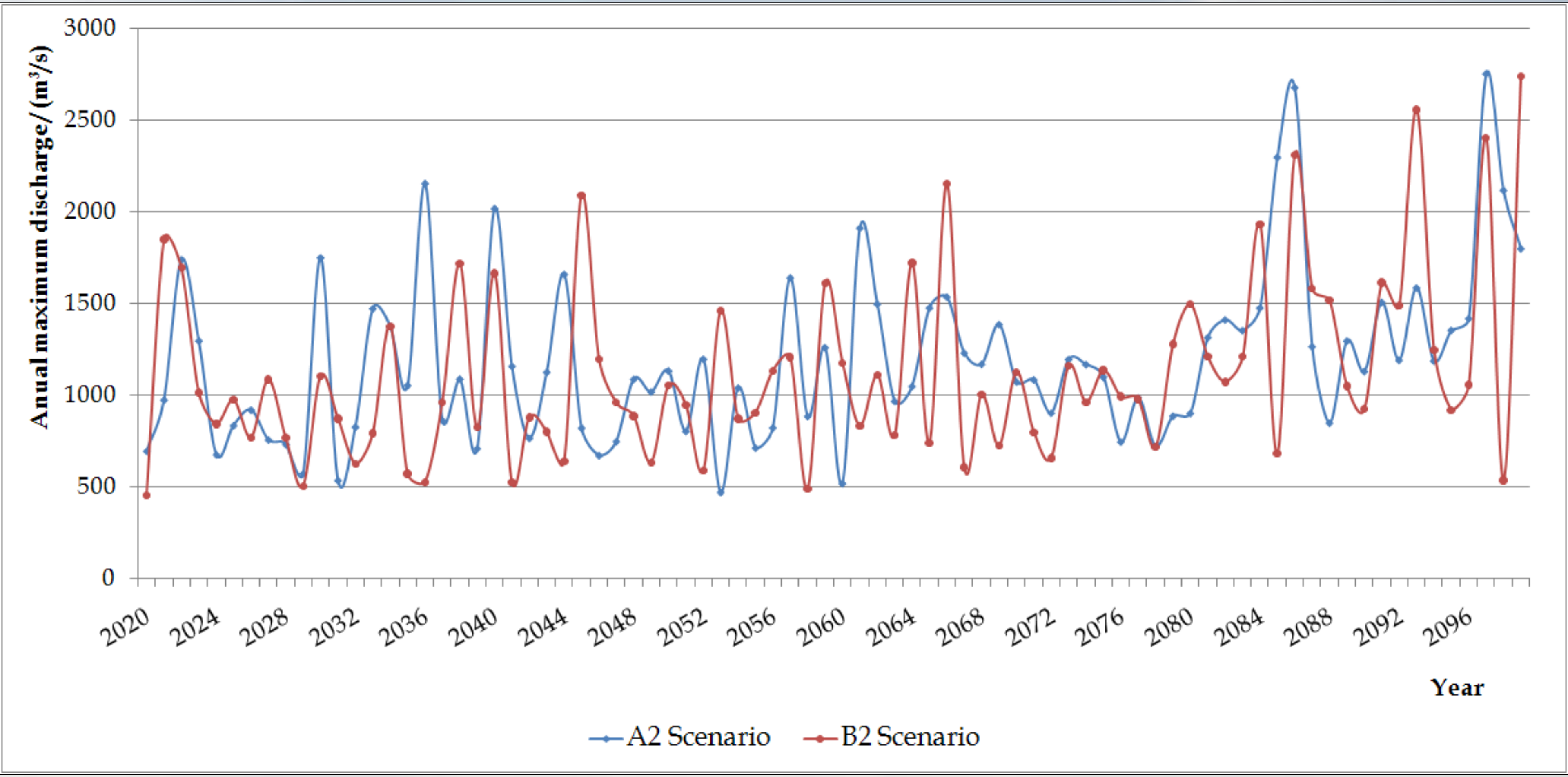


Frequency analysis according to B2 scenario

Future flow conditions of upper catchment

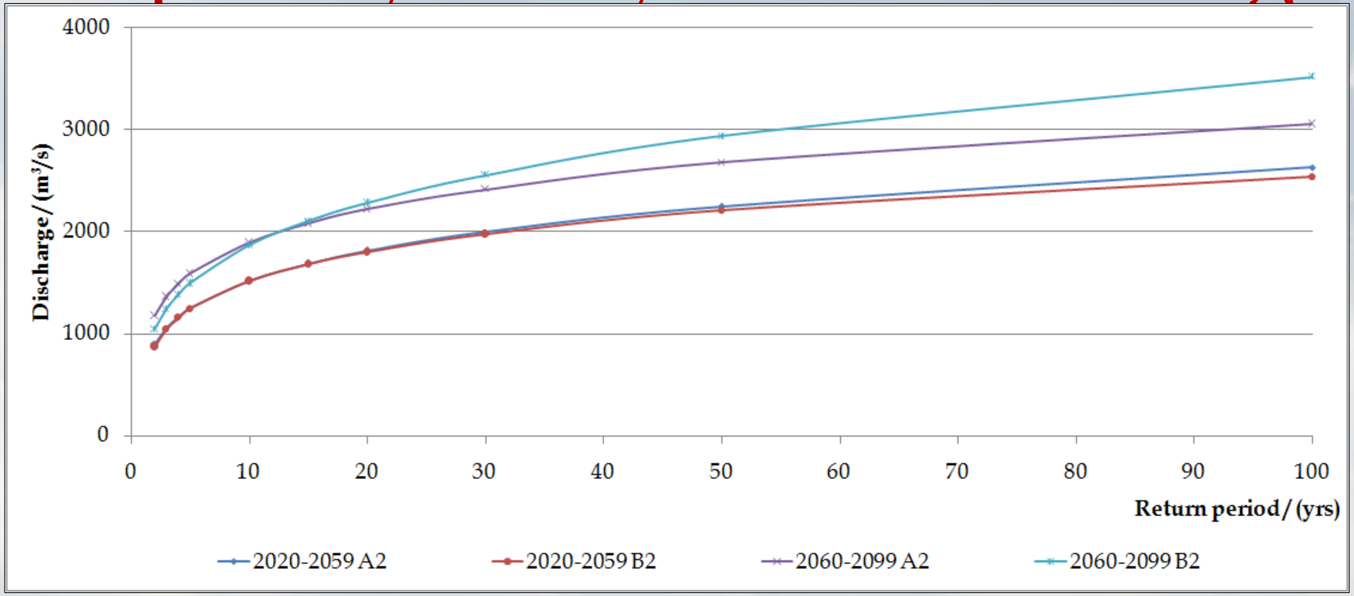


Variation of daily discharge at Hanwella gauging station from 2020 to 2099

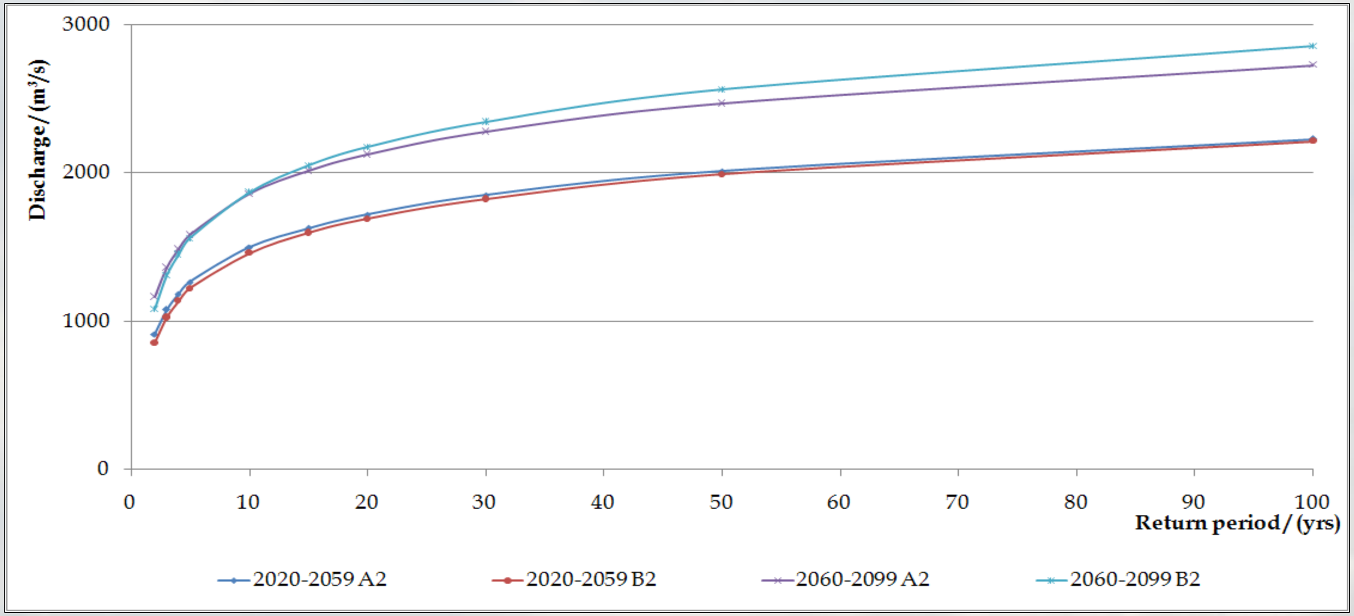


Variation of annual maximum daily discharge at Hanwella gauging station from 2020 to 2099

Frequency analysis for discharge at Hanwella



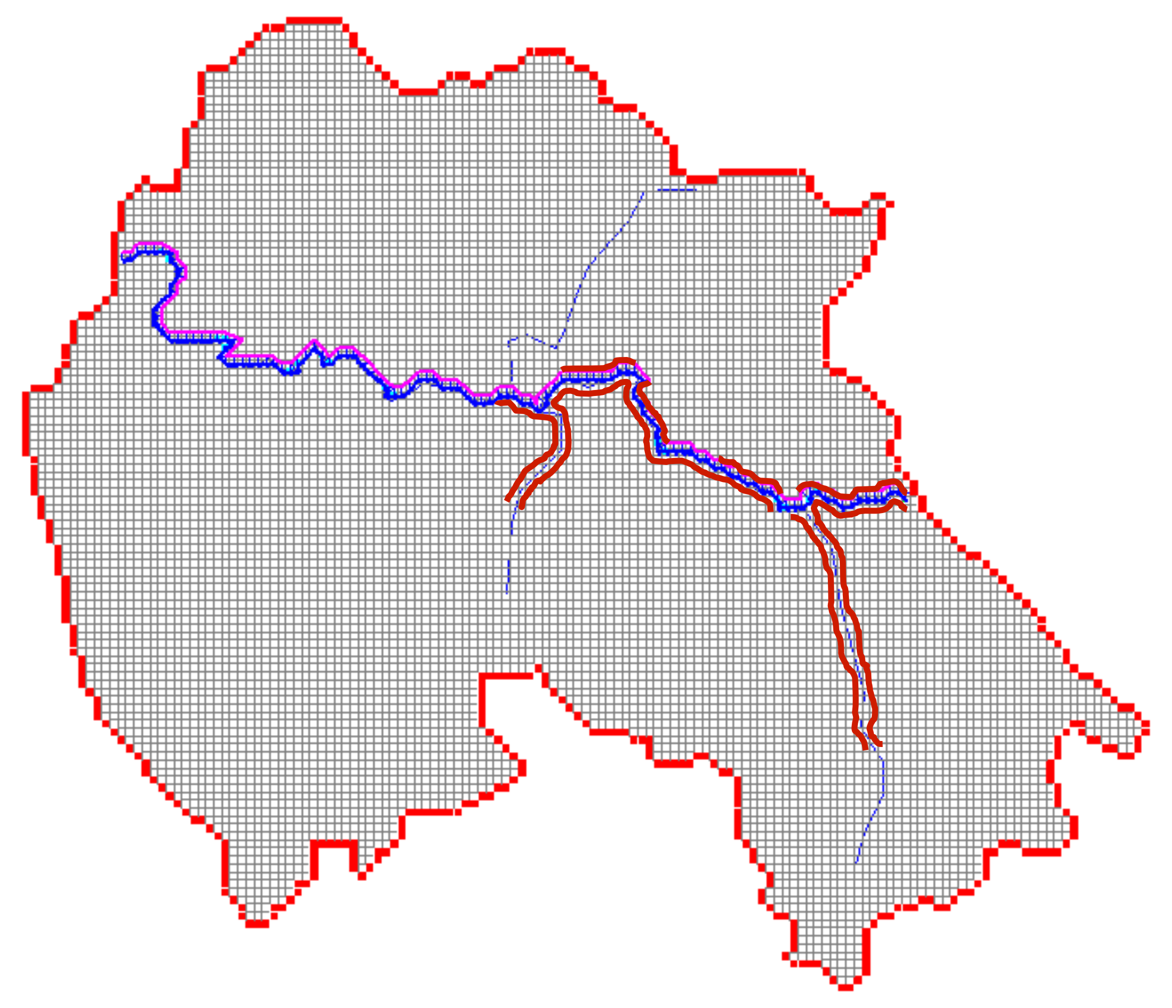
According to GEV distribution



According to Gumbel distribution

Discharge having an increasing trend from 2020-2059 period to 2060-2099 period

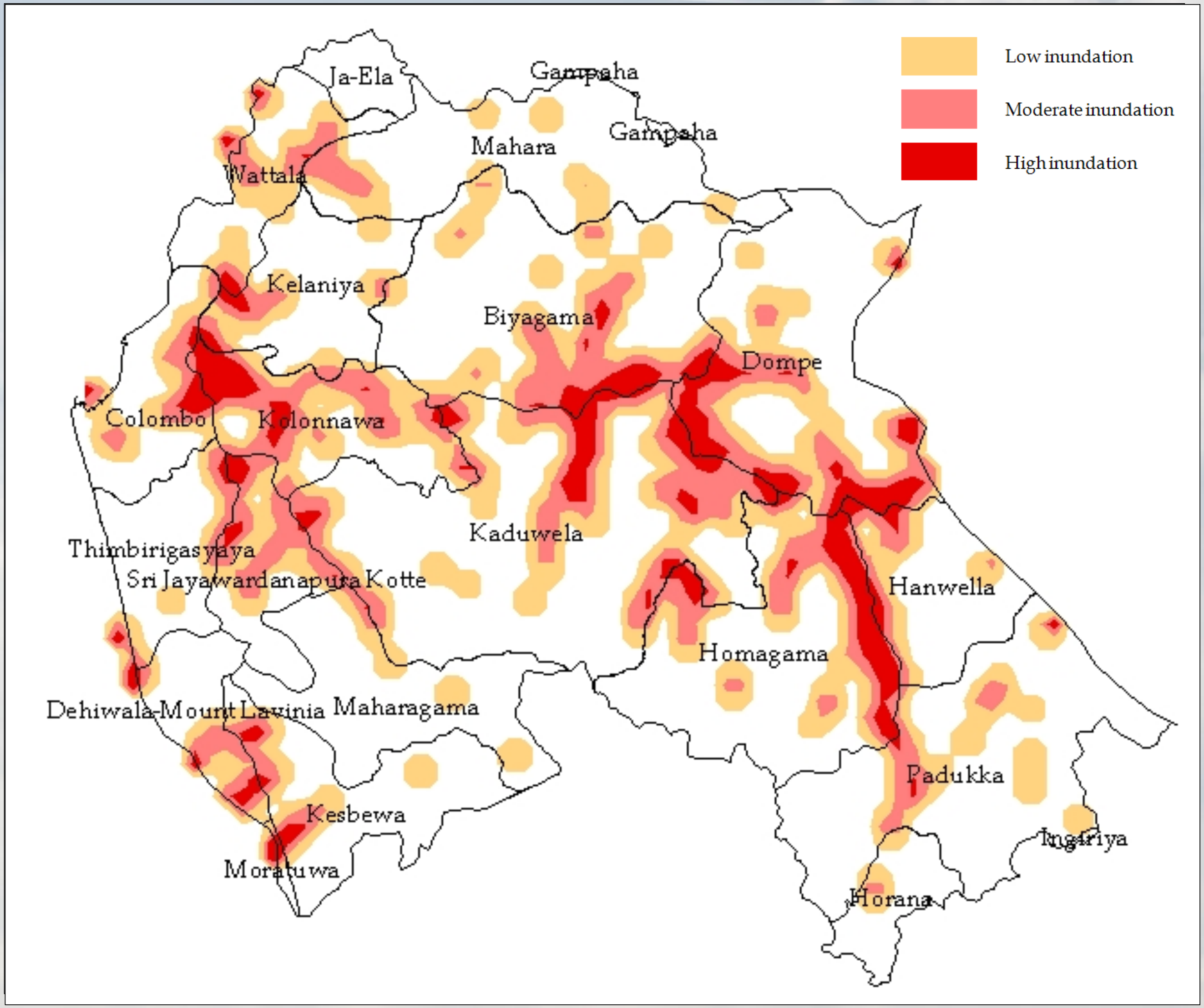
Inundation mapping and adaptation



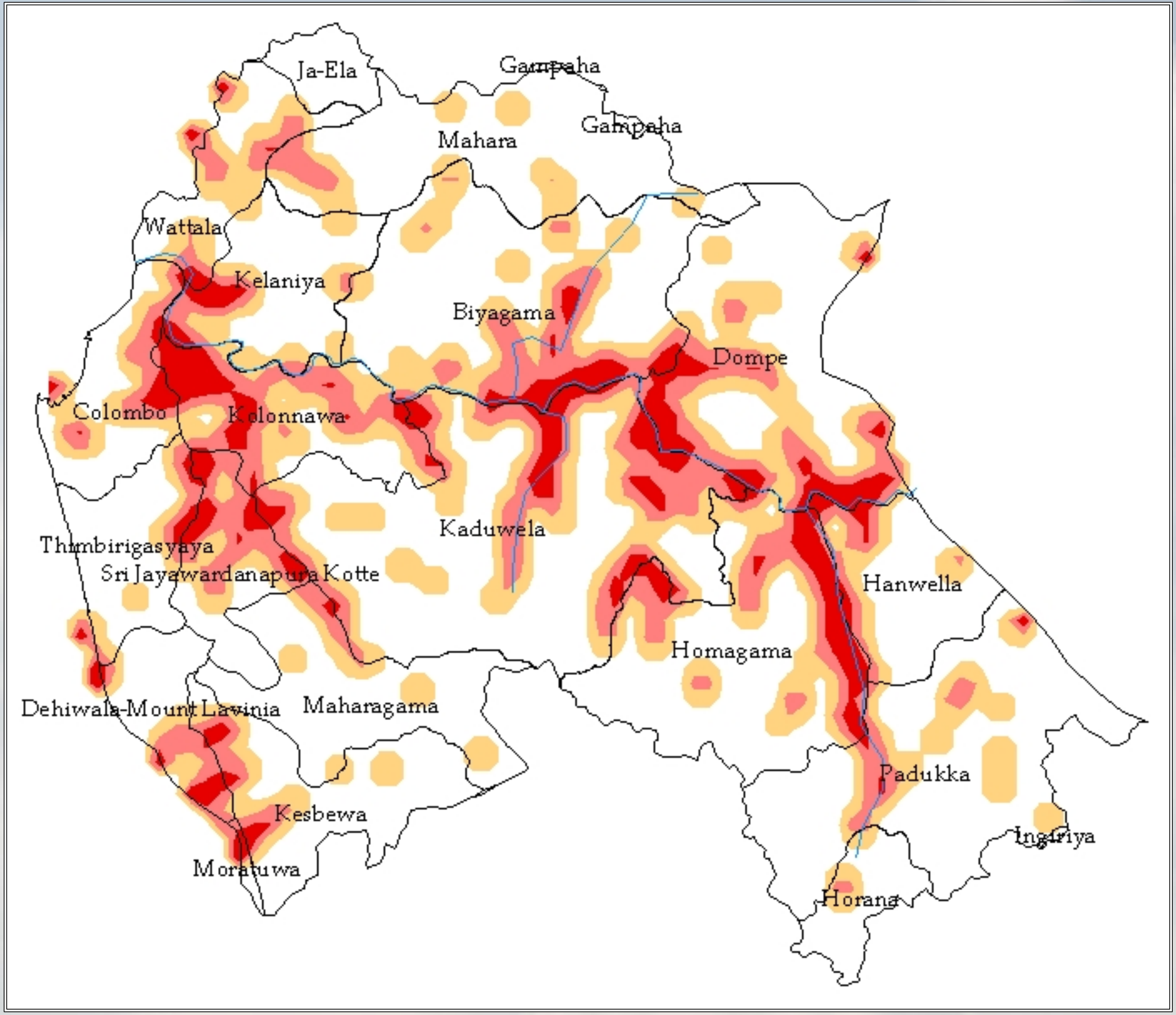
A levee along the river was introduce to minimize the area under flood in Hanwella, Homagama and Kaduwela areas.

Inundation mapping and adaptation

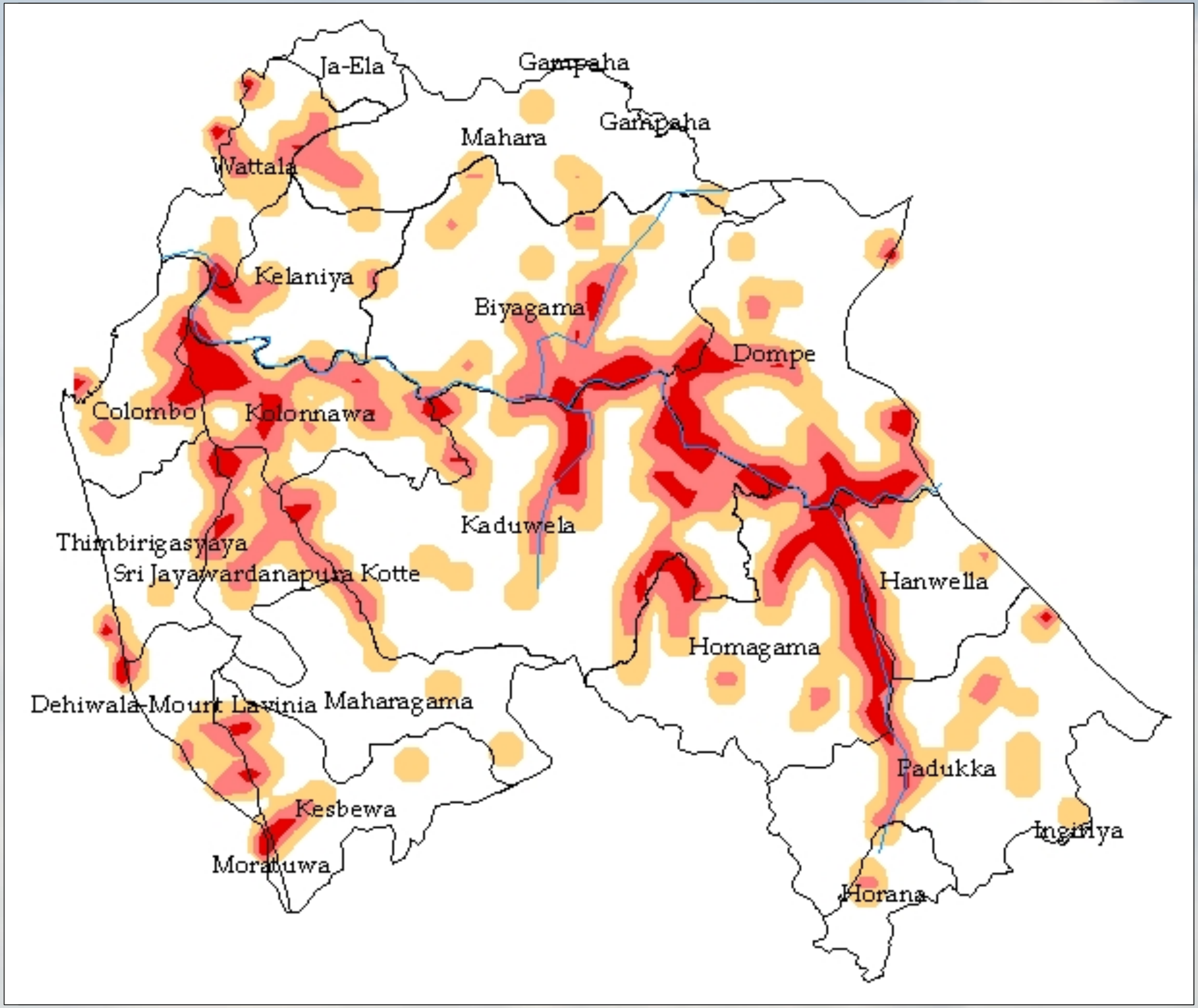
100 year return period rainfall (Gumbel distribution) according to 2040-2069 under A2 Scenario



100 year return period rainfall according to 2040-2069 under B2 Scenario

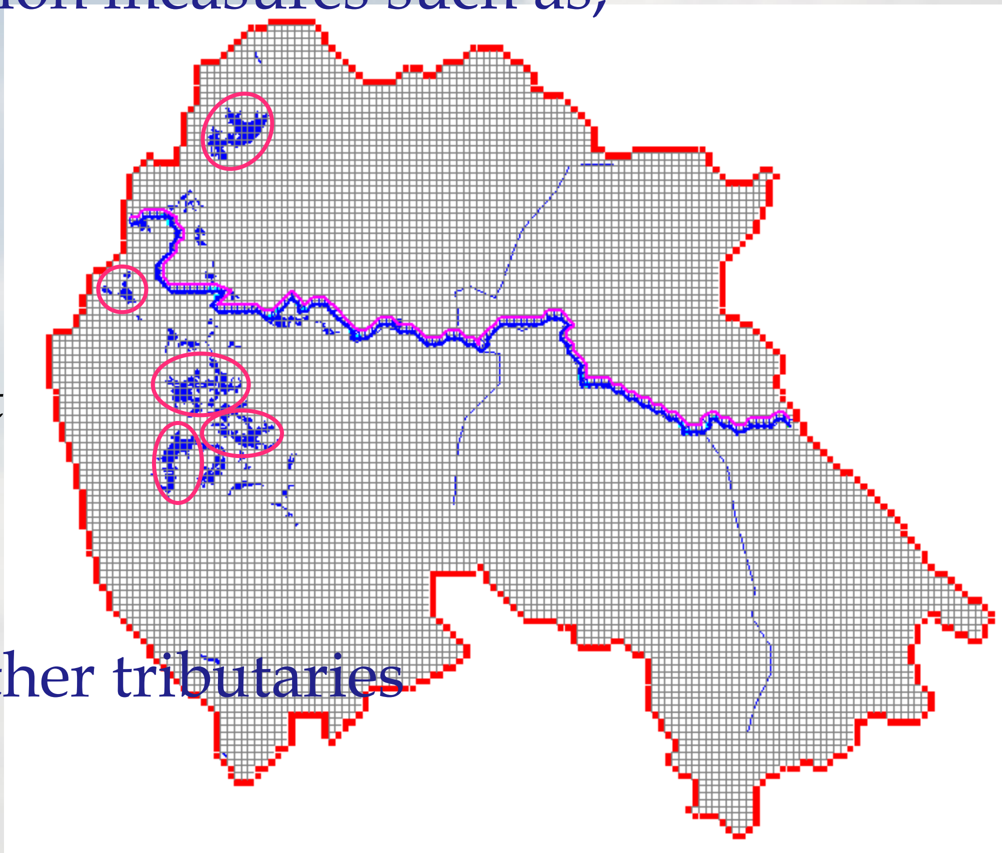


100 year return period rainfall according to 2070-2099 under A2 Scenario



Next steps

- Obtain inundation maps for more combinations of rainfall
- Consider alternative adaptation measures such as,
  - Develop flood warning system
  - Utilize flood control structures
  - Promote houses with basement
  - Introduce detention basins



- Model the catchment with other tributaries


Thank you