Rainfall-runoff modelling for the Beas basin, India using HEC-HMS: Prediction of peak flow

Supervisor:
Dr. Vijay Shankar
Associate Professor
(CED), NIT Hamirpur HP

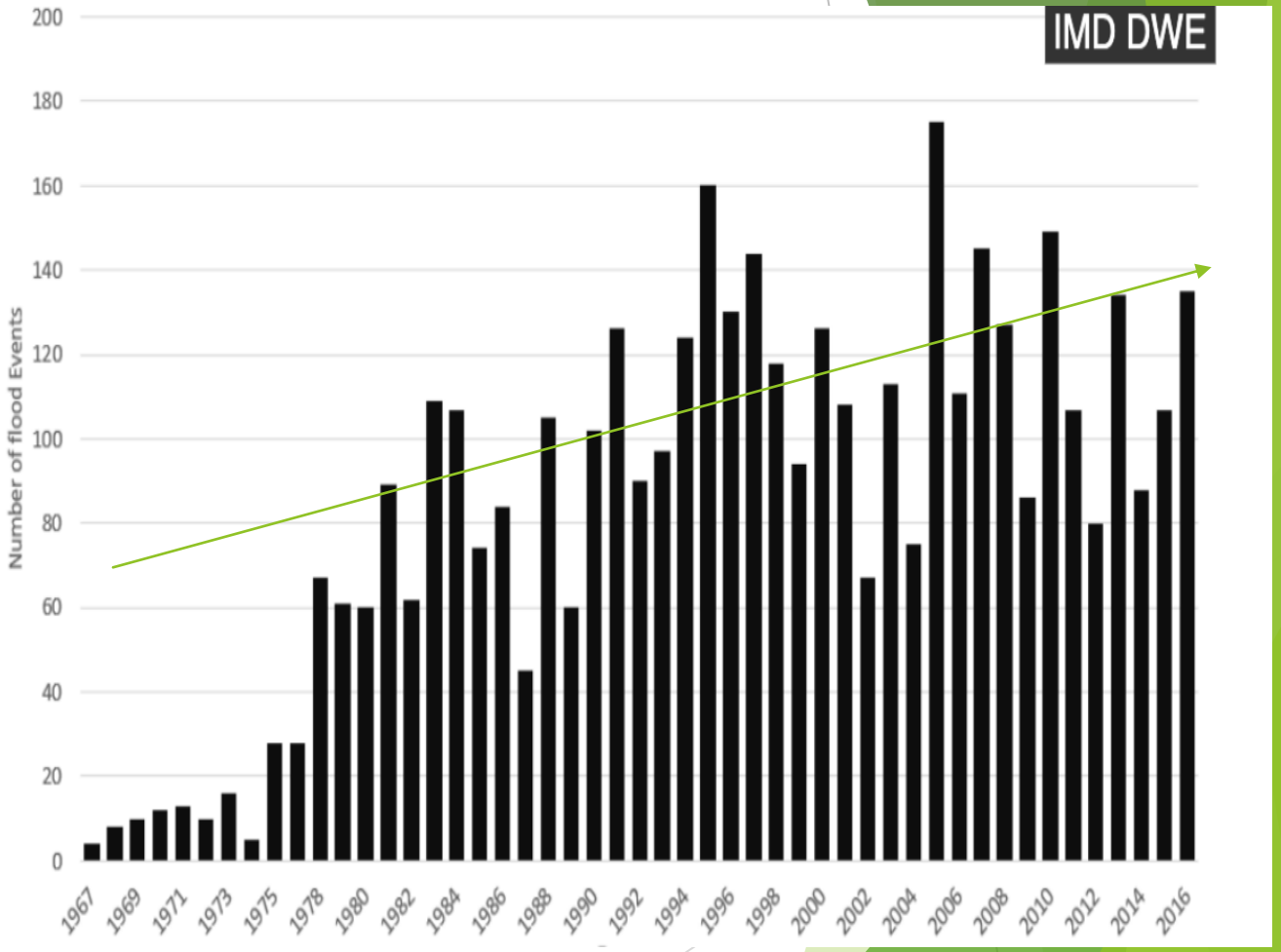
By:
Abhishek Sharma
Research Scholar (PhD)
CED, NIT Hamirpur HP

Introduction

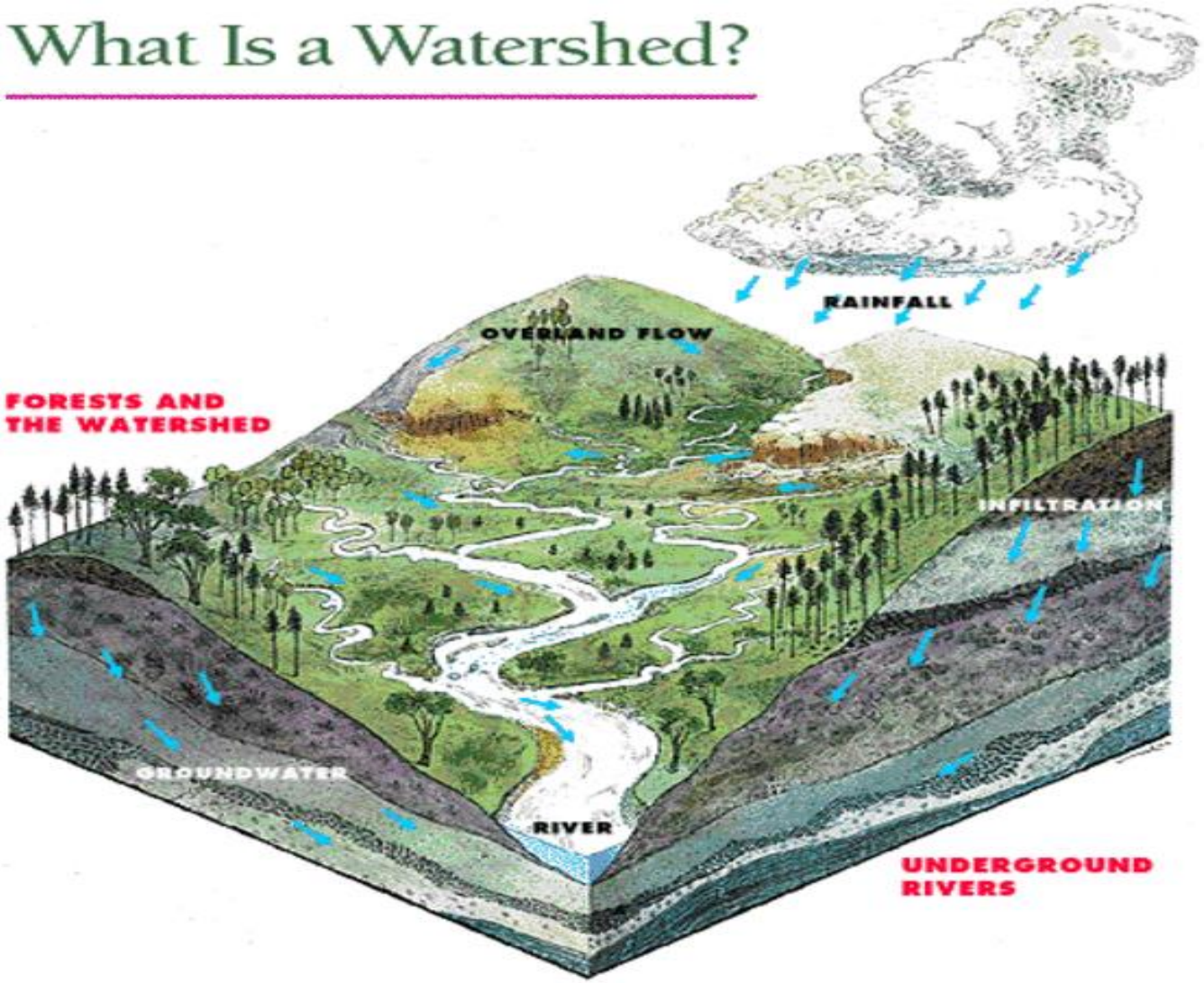
- Owing to urbanization, unplanned socio-development and climate change, there is increased vulnerability to extreme events i.e., floods and droughts across the globe Being a first-ranked natural disaster, floods impacted the lives of more than 32 million people all over the world between 1995 to 2015 (Guha-Sapir et al., 2015)
- Accurate estimation of peak discharge from a storm event is essential to make forecasts along with appropriate control and extenuation measures.
- To predict catchment flow, Rainfall-Runoff (RR) models use a variety of approaches, by using observable data or mathematical and analytical techniques to determine river discharge.

Motivation

- United Nations sustainable development goals (SDGs) namely, climate action, affordable and clean energy, clean water and sanitation and building resilient infrastructure
- Increase in number of extreme events.

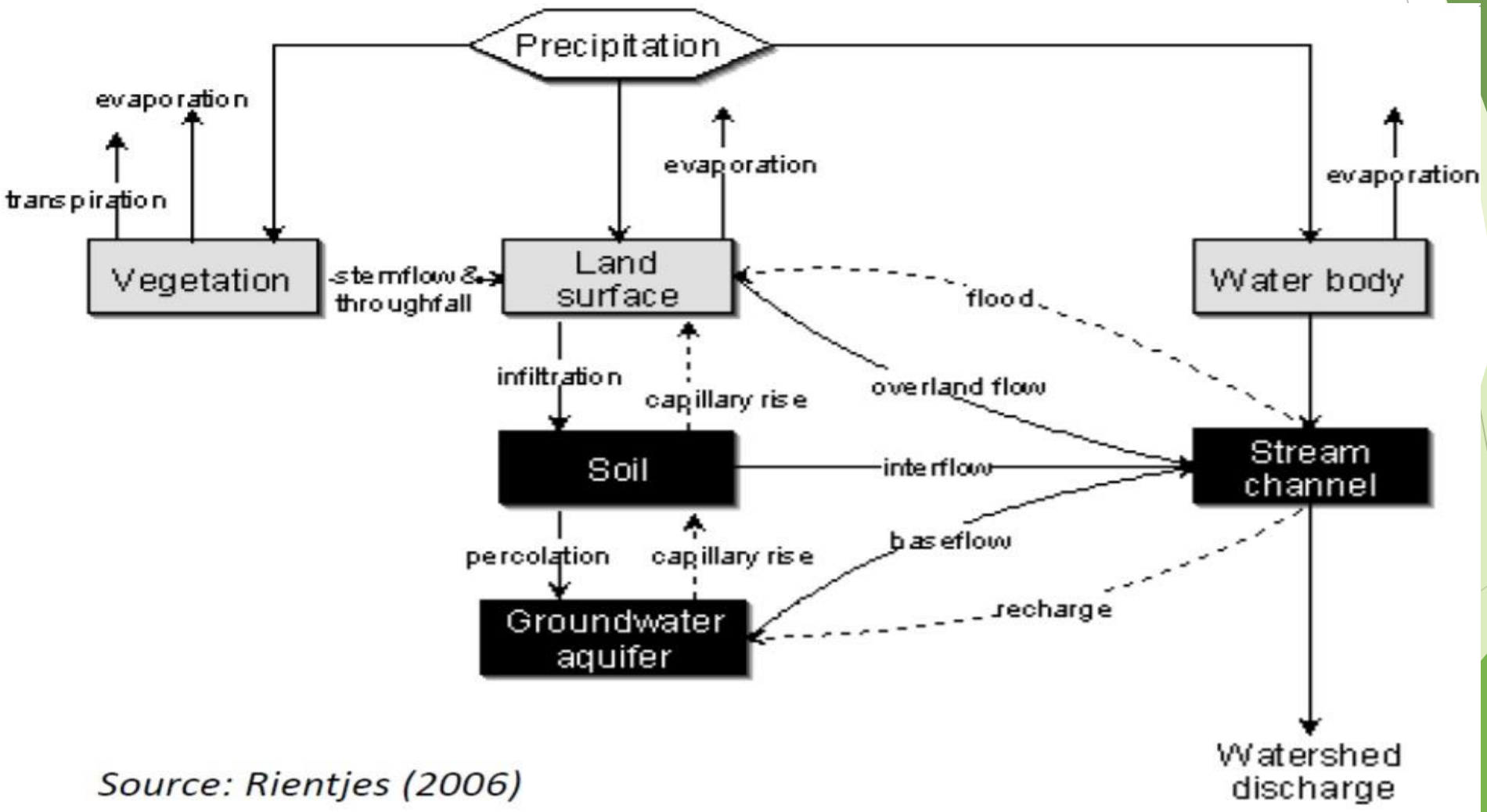


What Is a Watershed?



- **Stream Channels**
- **Upland area or Hills**
- **Flat area or Valley**

Rainfall-Runoff process

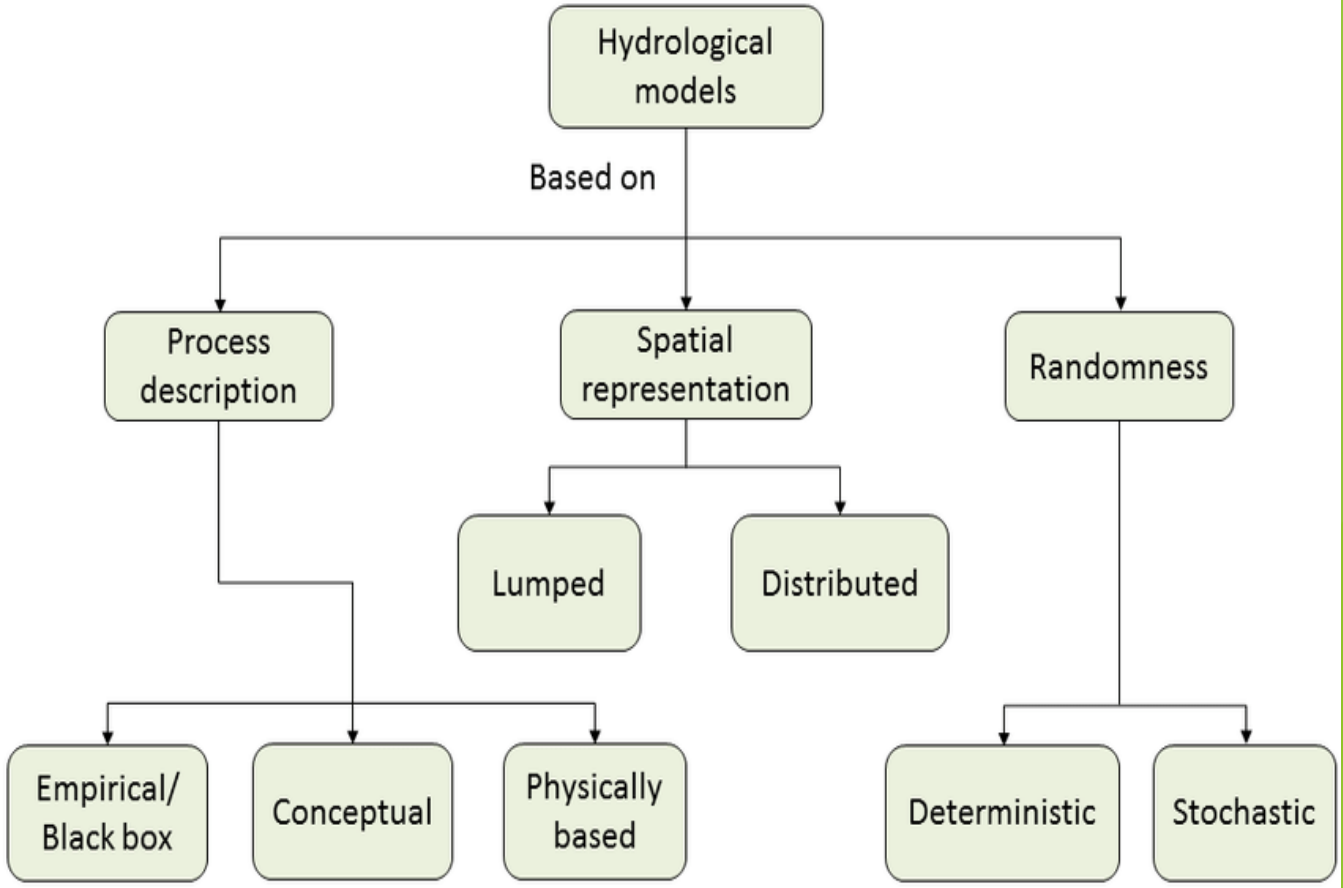


Source: Rientjes (2006)

Hydrological models

- A hydrologic model is a simplification of a real-world system that aids in understanding, predicting, and managing water resources

- Hydrological modelling involves the application of mathematical expressions that define quantitative relationships between inputs(e.g.flow-forming factors) and outputs (e.g.flow characteristics)



HEC-GeoHMS model

- HEC-GeoHMS uses ArcGIS and the Spatial Analyst extension to develop a number of hydrologic modeling inputs for the Hydrologic Engineering Center's Hydrologic Modeling System, HEC-HMS.

- The program allows users to visualize spatial information, document watershed characteristics, perform spatial analysis, and delineate subbasins and streams. Working with HEC-GeoHMS through its interfaces, menus, tools, buttons, and context-sensitive online help allows the user to expediently create hydrologic inputs for HEC-HMS.

Literature Review

Author Name	Tittle	Key Findings
Mandal and Chakrabarty (2016)	Flash food risk assessment for upper Teesta river basin: using the hydrological modeling system (HEC-HMS) software	The peak discharge and volume from an excess rainfall event in the upper Teesta basin in the Darjeeling region were computed. The drainage pattern and delineation of the basin and sub-basin were acquired from DEM. The runoff in the basin was calculated from the NRCS curve number, a function of land use land cover and hydrologic soil group of the basin
Martin et al. 2012	Application of HEC HMS / RAS and Gis tools in food modeling: a case study for river Sironko–Uganda.	A food modeling study in Uganda for the Sironko catchment was undertaken by using HEC-HMS hydrological modeling. The study developed the expected and observed runoff volumes in the catchment for various rainfall events.

Literature Review

Author Name	Tittle	Key Findings
Ramly and Tahir (2016)	Application of HEC-Geo-HMS and HECHMS as rainfall-runof model for food simulation	To delineate the basin and its catchment characteristics in flood-prone upper Klang–Ampang urban basin of Malaysia, the DEM was processed in GIS and further extended with HEC-GeoHMS to develop the hydrologic parameters of the river basin. Further, this data had been used for the estimation of runoff in the HEC-HMS model
Natarajan and Radhakrishanan (2019)	Simulation of extreme event-based rainfall–runof process of an urban catchment area using HEC-HMS	The study aims to develop a rainfall–runof simulation model by generating peak fow and volume of the extreme rainfall event that occurred on 22 November 1999 in the ungauged Koraiyar basin located south of Tiruchirappalli City in South India. Using SCS method, the peak fow and volume prepared from the model are compared with the standard Nash–Sutclife values and found to be in acceptable range.

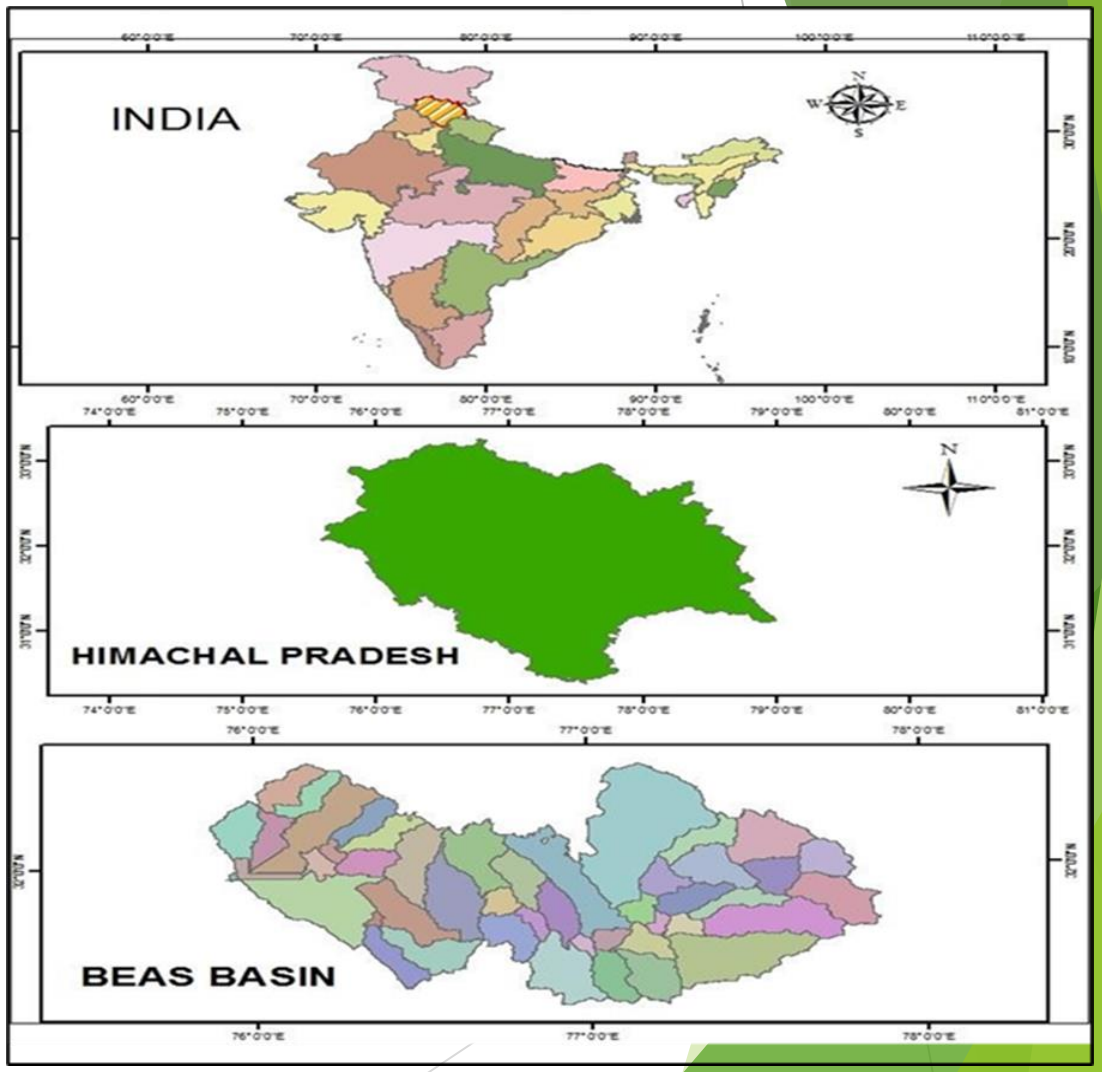
Objectives of Study

The main objectives of study are:

1) to extract the hydrological parameters of Upper Beas river basin;
2) to develop and evaluate the performance of Rainfall-Runoff (RR) model using integrated HEC-GeoHMS program.

STUDY AREA

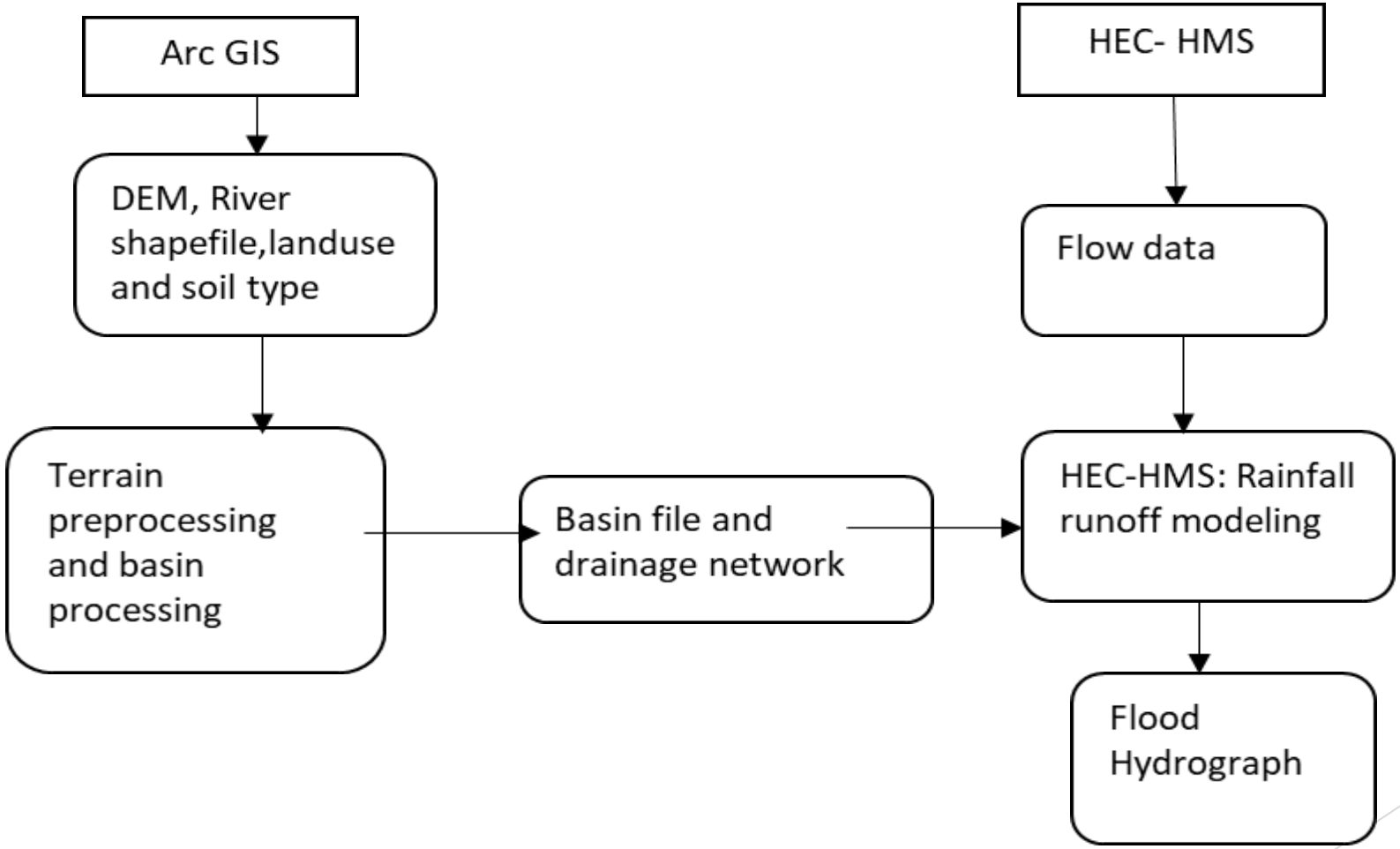
- The study area comprises the Beas Basin (BB) located between 32 21' 59.2" – 30.8 16' 09" N latitude & 77 5' 08.3" E - 74 57' 31.2" E longitude in NWH.
- The Beas is a perennial river that rises 4,361 metres above mean sea level (MSL) on the southern face of Rohtang Pass in Kullu at Beas Kund.
- The temperature changes from temperate to sub-tropical along the downstream of the river course with deciduous subtropical mixed forests i.e., Deodar, Fir, Spruce, Alder, Poplar, and Walnut.
- The catchment's soils are rather thin and young, becoming thicker in valleys and areas with gentle slopes



Data requirements and Sources

Sr No	Data classification	Data Type	Source
1	Meteorological Data	Precipitation (daily)	IMD Shimla
		Evapotranspiration (daily)	NASA Power
2	Watershed Data	DEM @ 30x30m resolution	Bhuvan
		LULC @ 30x30m	ESRI
		HSG @250m	USDA
3	Observed Flow Data	Discharge (Daily)	BBMB

Methodology

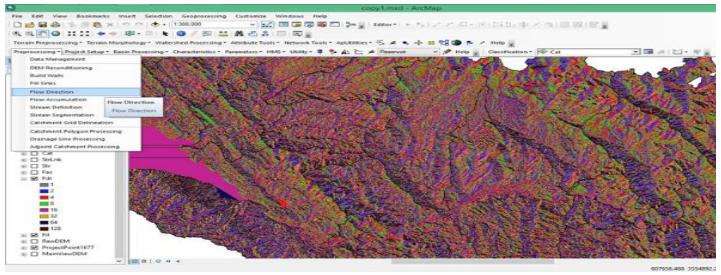


Components in HEC-GeoHMS modeling

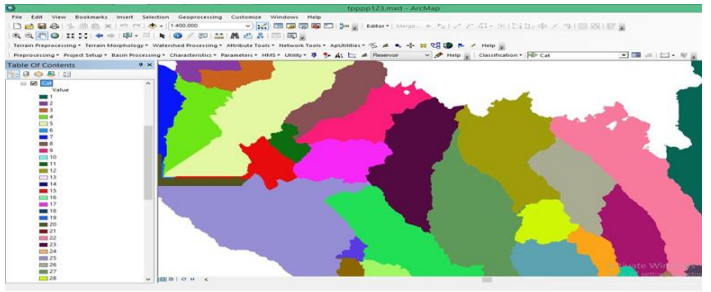
It consists of the following key components:

- Terrain Preprocessing
- HMS Project Setup
- Basin Processing
- Stream and Watershed Characteristics
- Hydrologic Parameters
- HMS Model Files

1. Creation of basin model



(a)



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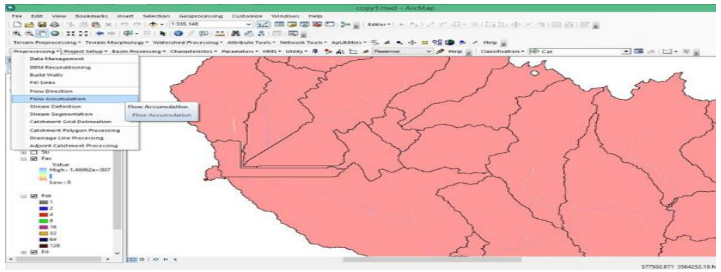

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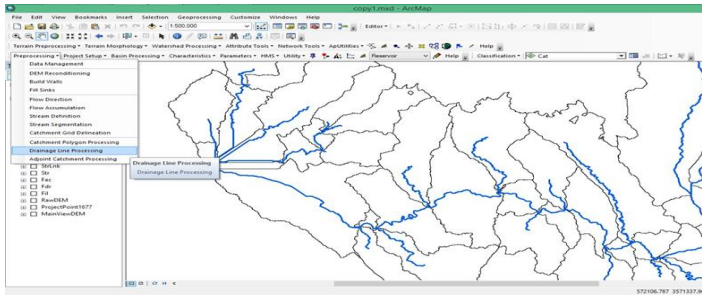
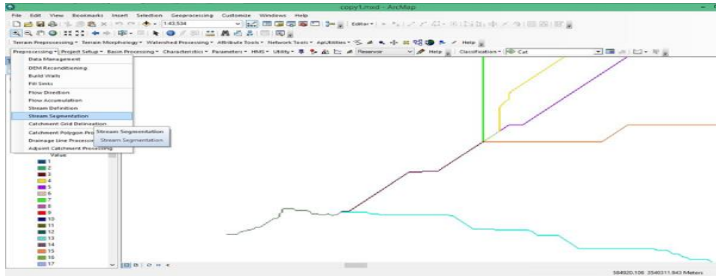


(e)



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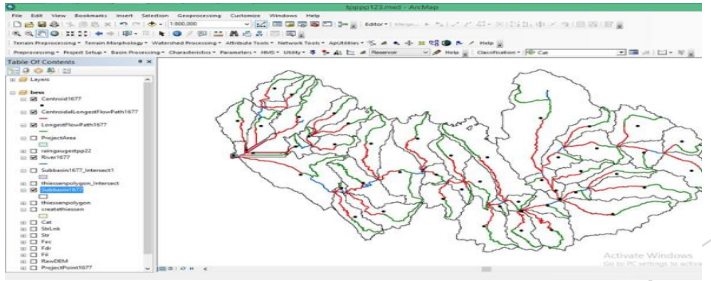


(f)

Figure 3. Various steps involved in basin creation: a) flow direction b) flow accumulation c) stream segmentation d) catchment Grid delineation e) drainage preprocessing f) basin characteristics

2. Development of hydrological Model

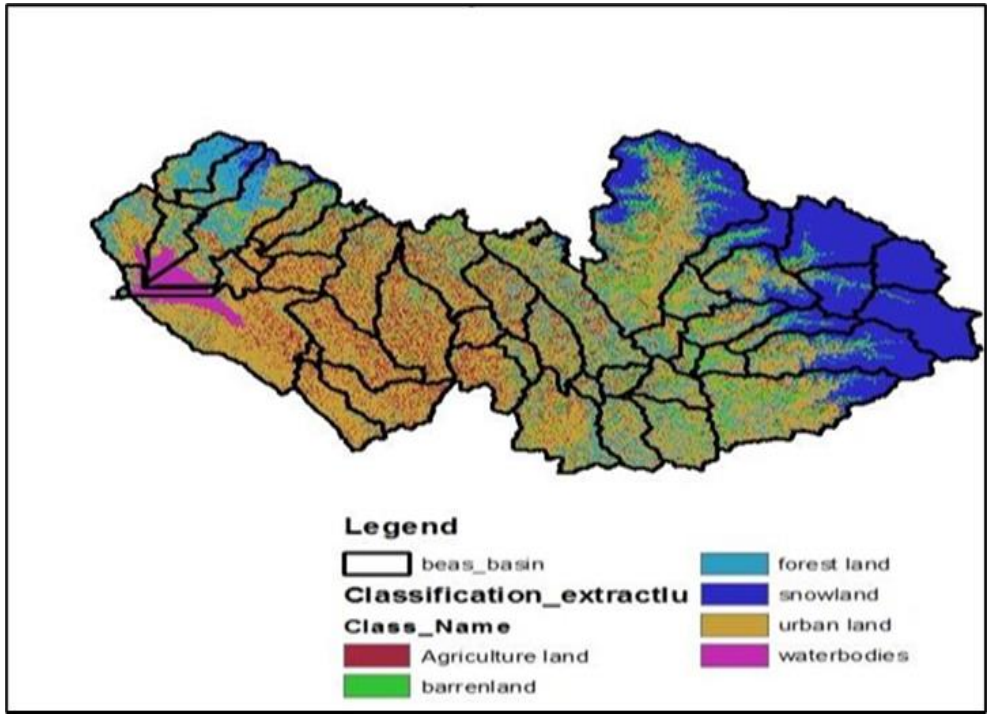
- The basin is divided into 45 sub basins , junctions, reaches and sink make up the basin model. The hydrological factors for each sub-basin are calculated using LULC and soil data. To determine the hydrologic loss rate Soil Conservation Service (SCS) curve number (CN) is used. The SCS-CN model is given by (USDA, 1972)

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \qquad (1)$$

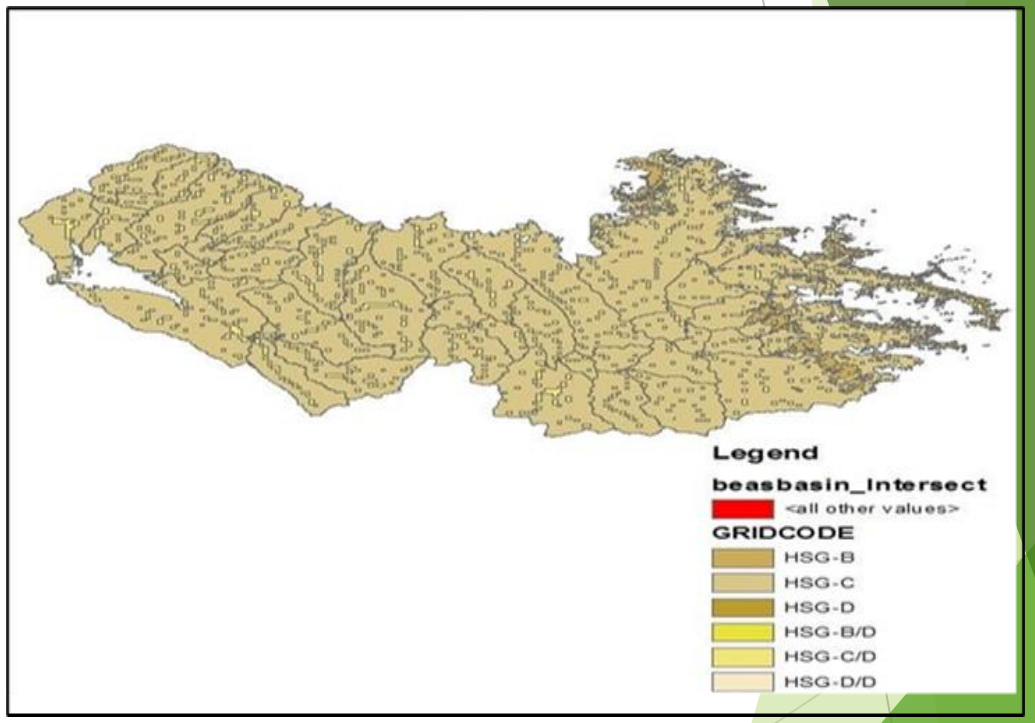
$$S = \frac{25400 - 254CN}{CN} \qquad (2)$$

where Q is the runoff value (mm); P is the precipitation (mm); I_a is the initial abstraction (mm); S is the potential maximum retention. In the present study, the CN value is based on land use–land cover and hydrological soil group (USDA-SCS, 1974)

LULC and HSG mapping of the study area

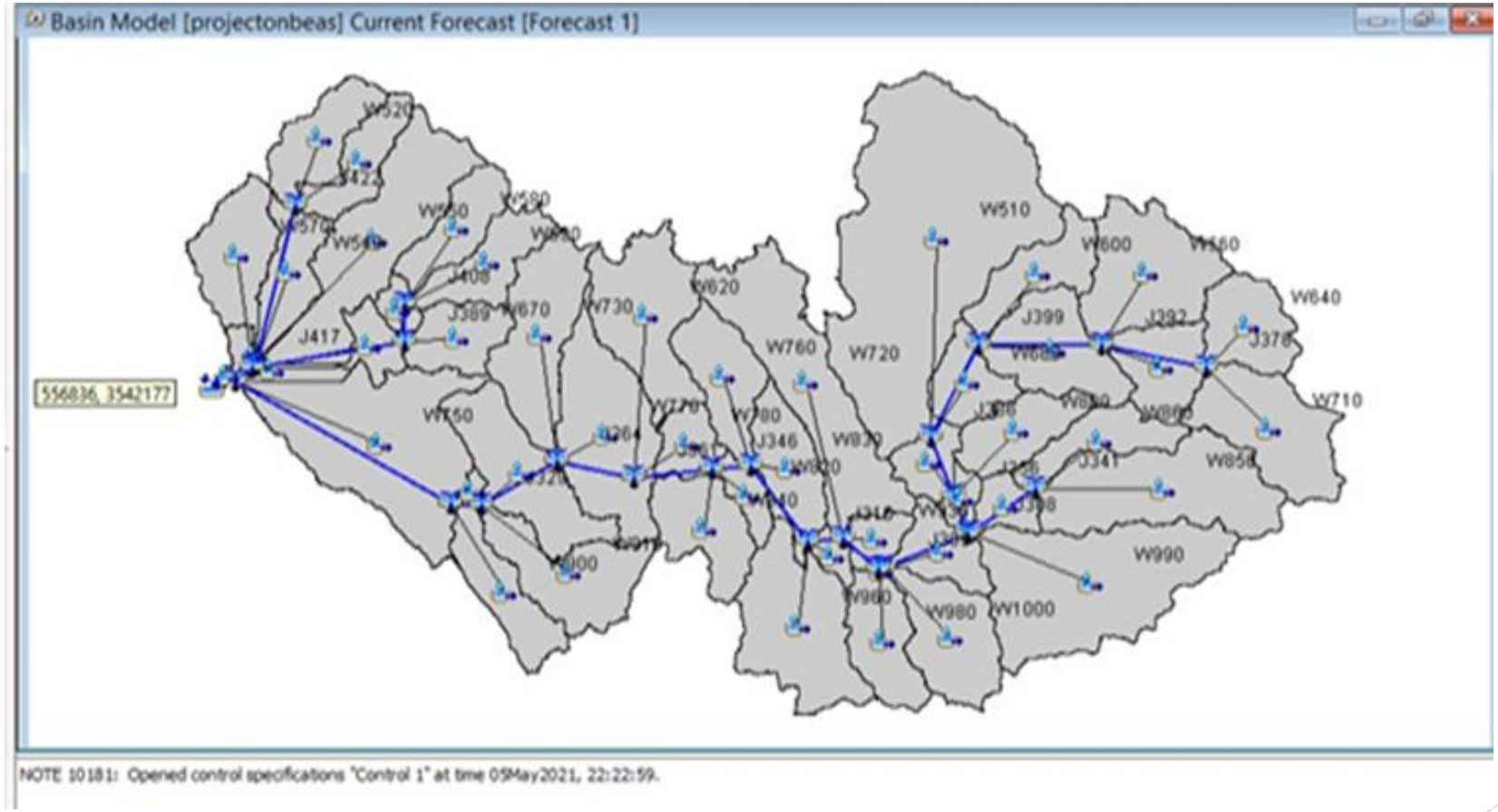


LULC mapping

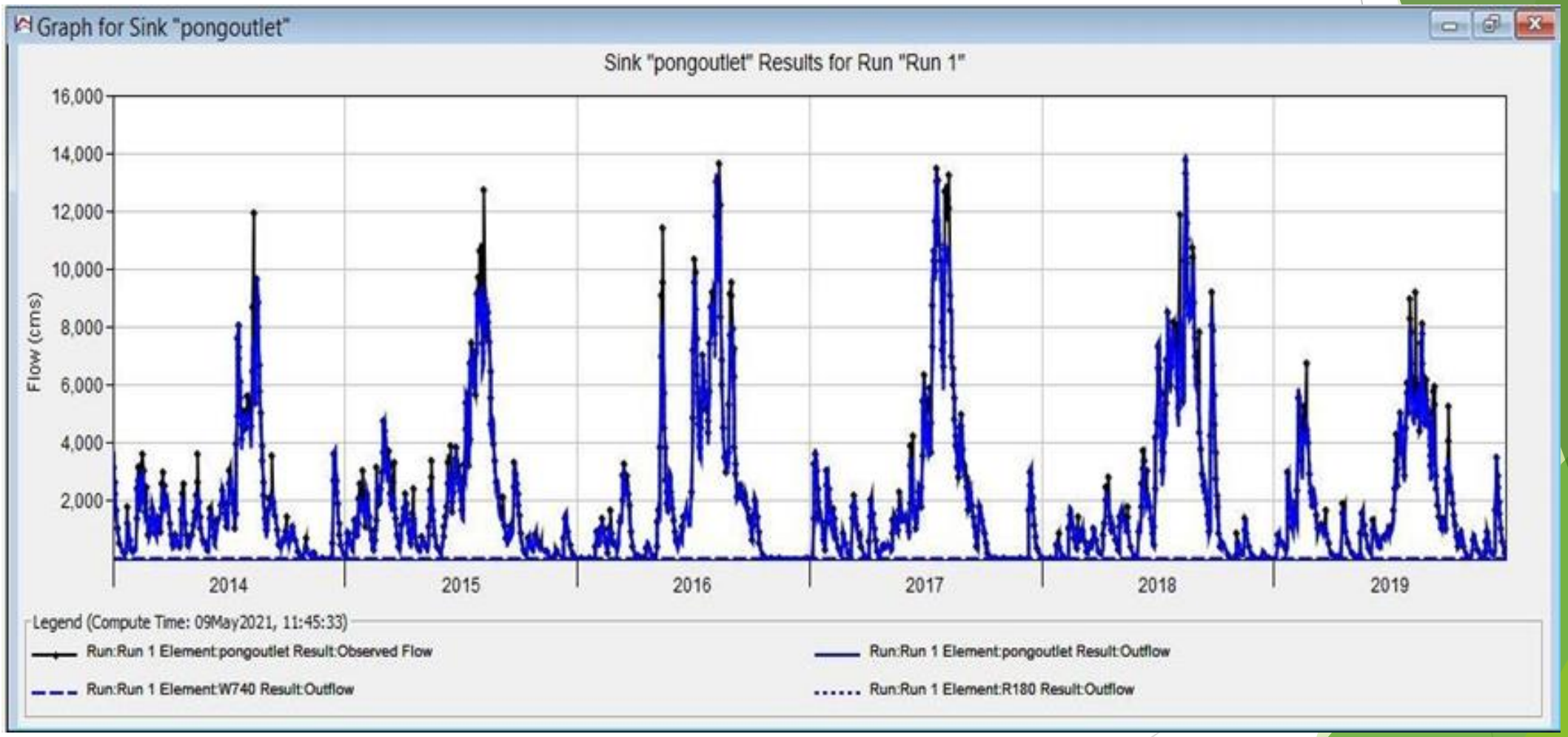


HSG mapping

Developed HEC HMS model of Beas Basin



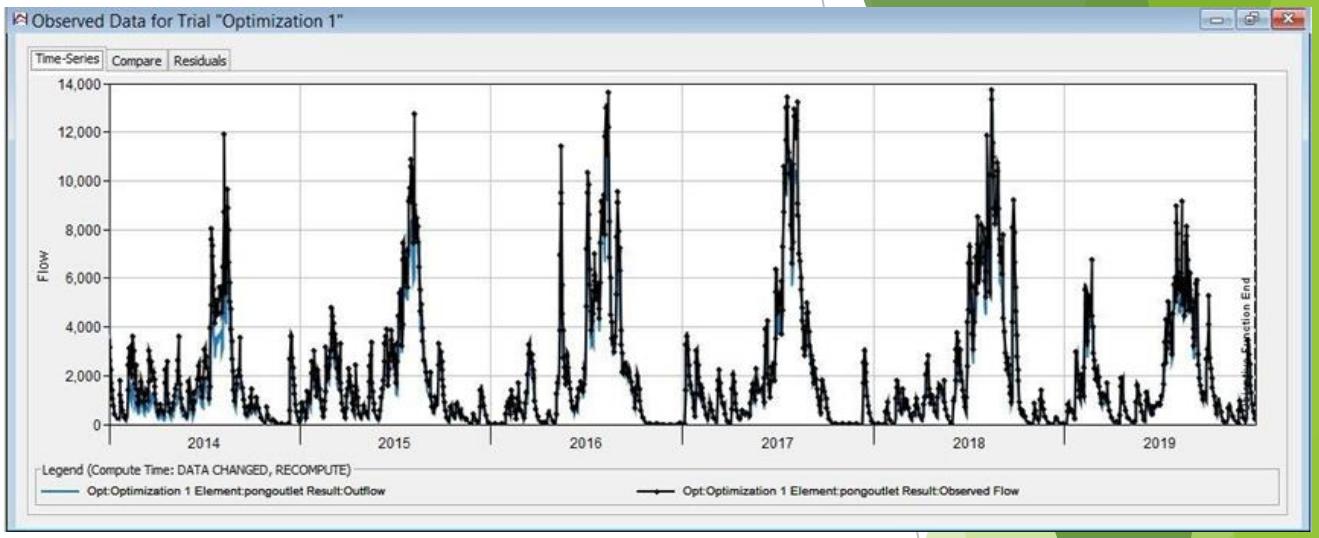
Results and discussion

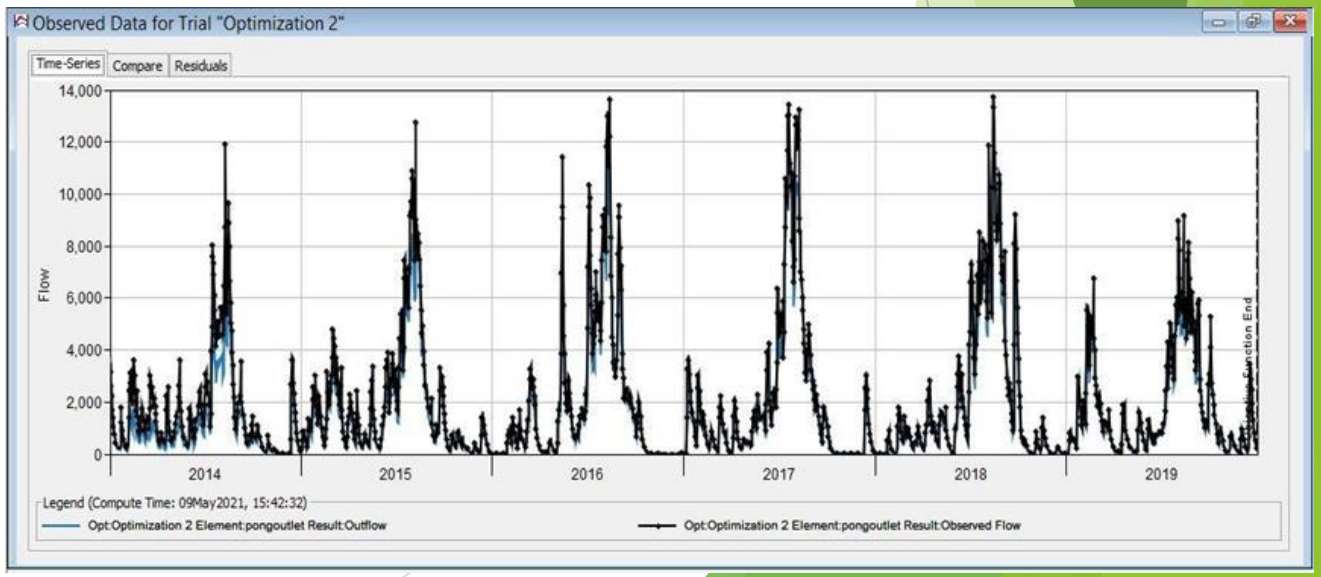


Results optimization under Trial 1,2

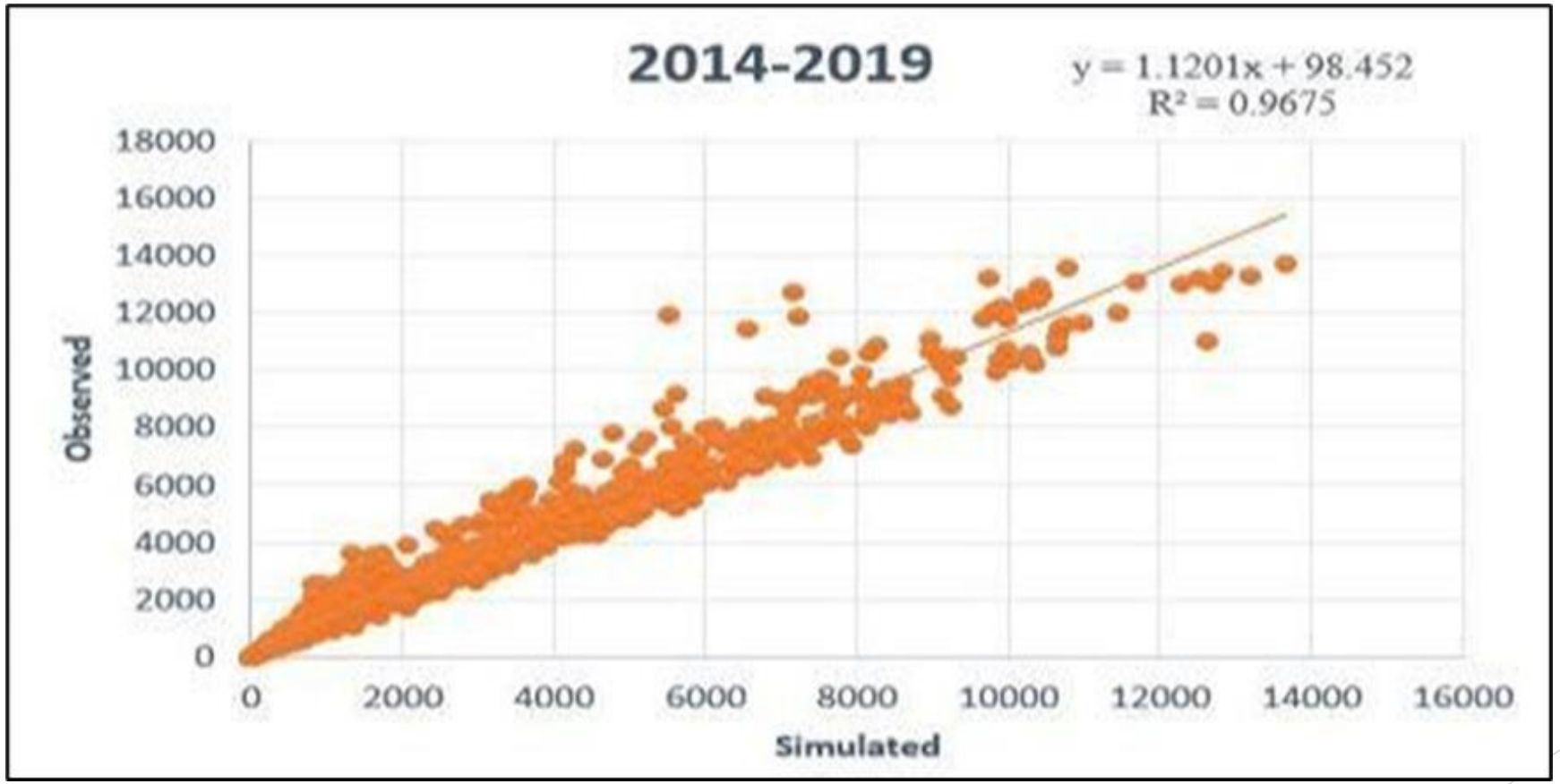
Results of optimization trials 1 and 2

Optimization	Element	Parameter	Units	Initial value	Optimized value
1	All subbasin	SCS CN scale factor		1.00	0.137
	R180	Lag-lag	Min	67.484	135.97
2	All subbasin	SCS CN scale factor		0.137	0.138
	R180	Lag-lag	Min	135.97	154.28





Model Performance



Conclusions

- The HEC HMS prototypical is used to generate acceptable simulated models and important method for reservoir storage control by predicting rainfall quantities.
- In this study, the RR model has been developed using HEC-GeoHMS. By calibrating the parameters for 2014-2019 and optimizing the flow, the outlet flow discharge of the Beas Basin was simulated and compared to the flow obtained from the discharge gauge located downstream of the basin.
- The findings indicate strong consistency between observed and simulated flows, with a calibration R2 of 0.9675
- The findings of this study may establish developing serious water policy and preparation policies could minimize the likelihood of flooding and aid in the maintenance and control of the reservoir outlet.

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Thank you