HEC-RAS Based Hydraulic Modeling of Pus River for Flood Management

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Abstract

Floods are among the most devastating natural disasters, particularly in regions like Maharashtra, India, where river systems such as the Pus River play a critical role in both ecology and local economies. This study applies HEC-RAS and HEC-HMS to simulate hydraulic behaviour of the Pus River under various flow conditions. Utilizing digital elevation models (DEMs), rainfall data, and river cross-section profiles, this research identifies vulnerable flood zones and provides actionable strategies for flood risk mitigation. Simulations under increased runoff conditions showed flood impacts expanding over 2,000 hectares, affecting key towns and infrastructure. The study proposes structural and non-structural flood management strategies and emphasizes integrating modeling tools into regional planning frameworks.

(**Keywords:** *Flood Management, HEC-RAS, Hydraulic Modeling, Floodplain Mapping, Pus River Basin, Hydrology, GIS*)

Introduction:

The Pus River, located in Vidarbh Region, Maharashtra, is an important river that serves multiple functions, including providing water for irrigation, hydropower generation, industrial processes, and domestic use. It is also home to diverse ecosystems and is an important socio-economic resource for the communities along its banks. However, like many rivers, the Pus River faces various hydrological challenges, particularly during periods of extreme weather conditions, such as heavy rainfall, leading to river flooding.

Flooding presents recurring challenges in many parts of India. The Pus River basin, a tributary of the Penganga River in Maharashtra, regularly experiences seasonal floods that disrupt lives, agriculture, and infrastructure. This paper explores the application of the Hydrologic Engineering Centre's River Analysis System (HEC-RAS) to model the hydraulic behaviour of the river and simulate flood scenarios. Accurate hydrological modeling is crucial for infrastructure planning, risk mitigation, and sustainable river management.

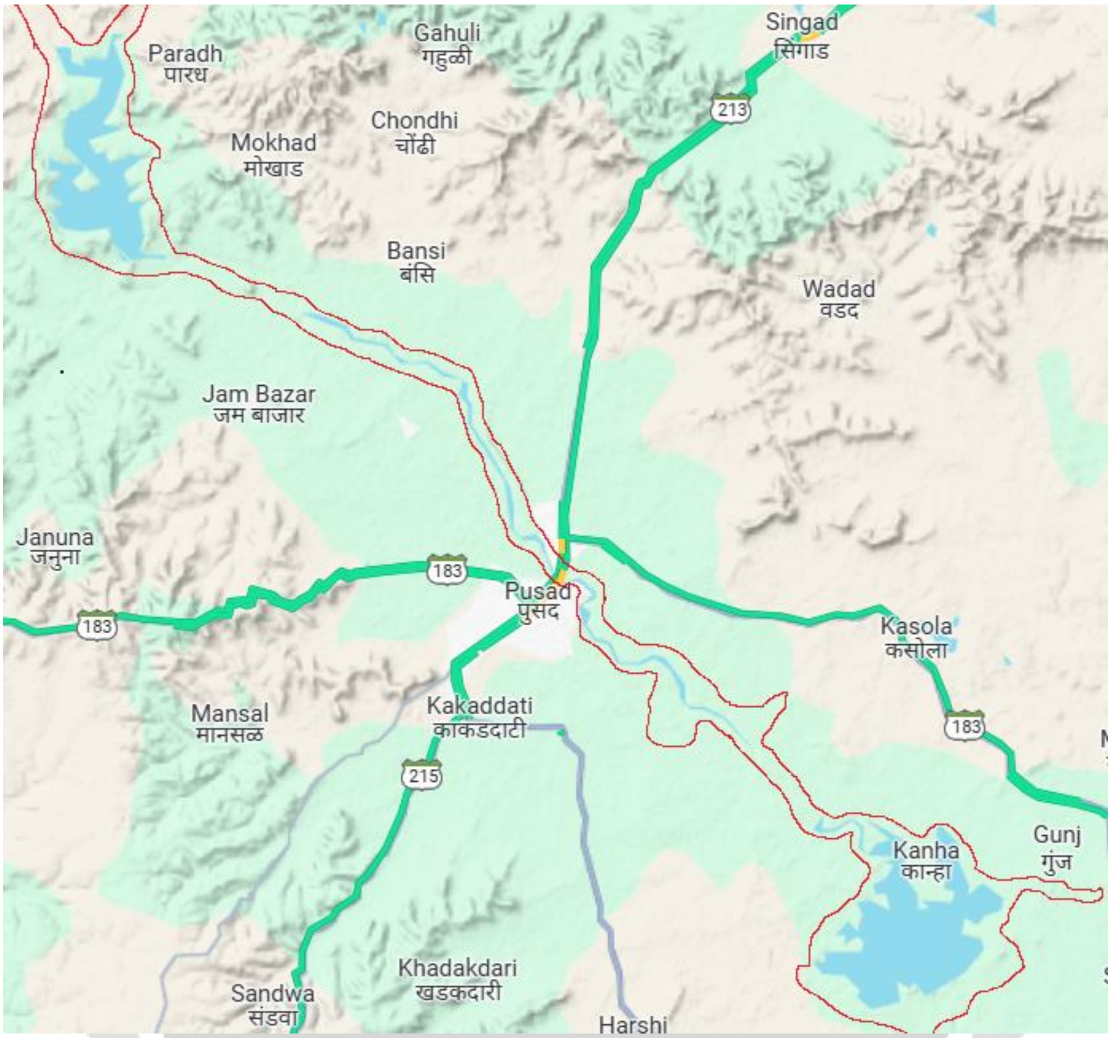

Fig. River Map of Pus River (Source: Google Earth)

Objectives:

The objectives of this study are as follows:

1. To develop a hydrological model of the Pus River using HEC-RAS, incorporating available hydrologic, topographic, and hydraulic data to simulate river flow and water surface profiles.
2. To simulate the hydraulic behaviour of the river under various flow conditions, such as base flow, moderate floods, and extreme flood scenarios.
3. To analyse flood risk and assess the extent of floodplains under different flow conditions, identifying areas most vulnerable to flooding.
4. To assess the model's accuracy by comparing its predictions with available field data or observations.
5. To provide recommendations for flood management strategies, land-use planning, and infrastructure development based on the modeling results.

Literature Review:

Previous studies underscore the importance of integrating Geographic Information Systems (GIS) and Digital Elevation Models (DEMs) in hydrodynamic modeling. Rao and Ghosh (2014) emphasized that topographic accuracy directly influences hydraulic simulation results. Several researchers have utilized HEC-RAS in combination with HEC-HMS to predict flood extents and design mitigation strategies. Notably, Williams and Green (2018) showed how channel geometry and terrain variations influence flood propagation. The literature supports using a combined approach for flood modeling and risk assessment.

Methodology:

This study followed a structured approach involving data collection, model setup, calibration, and result analysis:

Data Collection:

Topographic Data: DEMs and surveyed cross-sections were used to model river geometry.

Hydrological Data: Historical discharge, precipitation records, and soil characteristics were sourced from local irrigation departments.

Hydraulic Structures: Data for existing dams, bridges, and weirs were integrated into the model.

Model Setup:

The river was divided into multiple reaches.
Boundary conditions were defined using hydrographs and stage-discharge relationships.
HEC-RAS was used to input geometry, cross-sections, and flow regimes.

Calibration and Validation:

Calibration involved comparing simulated water levels with historical flood data.

Validation was performed using separate datasets to assess the model's predictive accuracy.

Flow Simulations:

Scenarios included base flow, moderate floods, and extreme rainfall-induced events.

Sensitivity analyses were conducted to understand the impact of varying Manning's coefficients and flow rates.

Result & Discussion:

- This map is likely used as base input for developing a river reach model in HEC-RAS. Once geometry is set up, hydrologic input (from HEC-HMS or manual calculation) can drive the hydraulic simulation to evaluate:
  - Water surface profiles
  - Flood inundation areas
  - Impact of structures like bridges, culverts, or dams

Table Area Statement of Pus River and its tributaries

AREA STATEMENT				
Sr. No.	Nallah	Length (m)	Width (m)	Area Calculation (sqm)
1	R1	14965	800	11972000
2	R2	2000	200	400000
3	R2	2000	200	400000
4	R3	3499	200	699800
5	R4	1530	200	306000
6	R5	2000	200	400000
7	R6	3139	200	627800
8	R7	3999	200	799800
9	R8	3999	200	799800
10	R9	3317	200	663400
11	R10	2000	200	400000
12	R11	2500	200	500000
13	R12	4000	200	800000
14	L4	2520	200	504000
15	L5	4030	200	806000
16	L6	10595	200	2119000
17	L7	4005	200	801000
18	L8	1500	200	300000
19	L9	5000	200	1000000
20	L10	1000	200	200000
			Total Area in Sqm.	24498600
			Total Area in Ha.	2449.86

- This is likely part of a 2D mesh or terrain input for a HEC-RAS 2D simulation.
- It's used to simulate overland flow, water depth, flood extent, etc., by tracking how water moves over this topography.
- It can be connected to inflows from HEC-HMS or other hydrological models.

Table Elevation Zones

Sl. No.	Elevation (m)	Area (Sq. km)	% of Total Area
1	< 5	810.25	0.26
2	5-10	1374.58	0.44
3	10-50	2778.22	0.89
4	50-100	4711.13	1.51
5	100-200	27105.94	8.67
6	200-300	55928.81	17.88
7	300-400	54140.26	17.31
8	400-500	49345.60	15.77
9	500-750	101088.04	32.32
10	750-1000	12851.50	4.11
11	1000-1500	2677.72	0.84

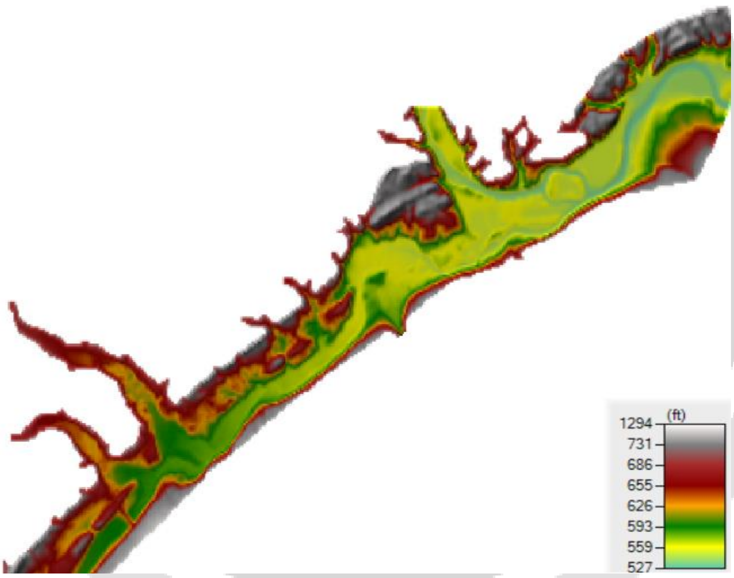

Fig. 2D elevation or terrain model

In a 2D velocity simulation output from HEC-RAS, show in **Fig.** how water flows through a river system and surrounding area.

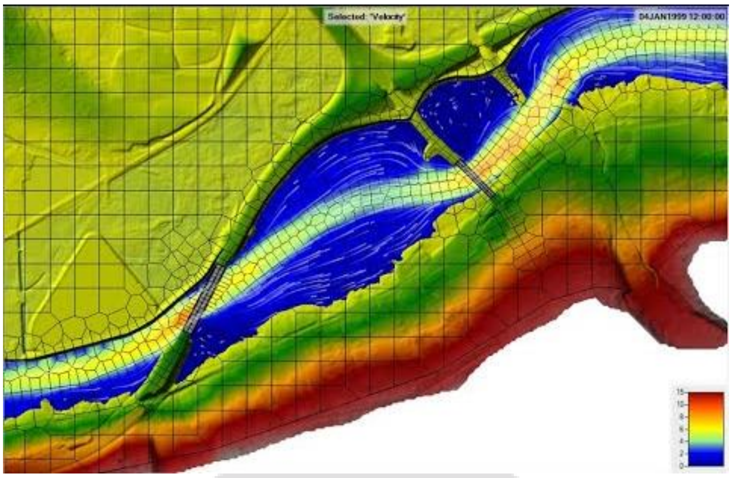

Fig. 2D velocity simulation output from HEC-RAS

Precipitation time series graph, likely used in HEC-HMS for hydrologic modeling input.

- If similar data were collected for the Pus River basin, it would be used in HEC-HMS to simulate how rainfall leads to streamflow, which then serves as input for HEC-RAS hydraulic modeling.

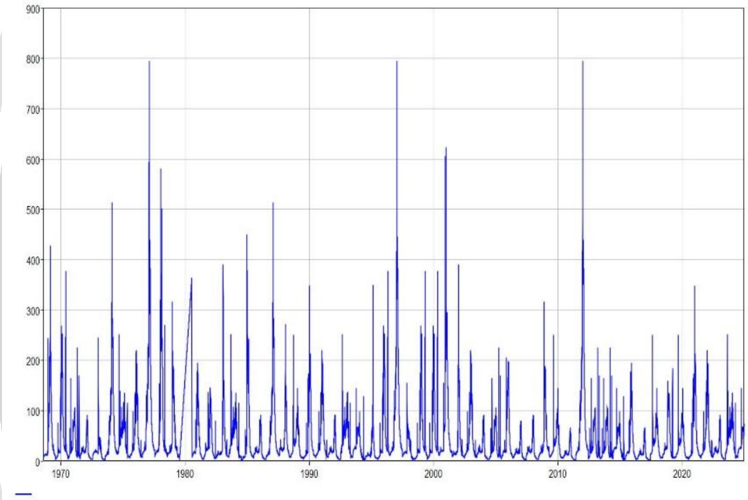

Fig. Precipitation Time Series Graph From HEC-DSS

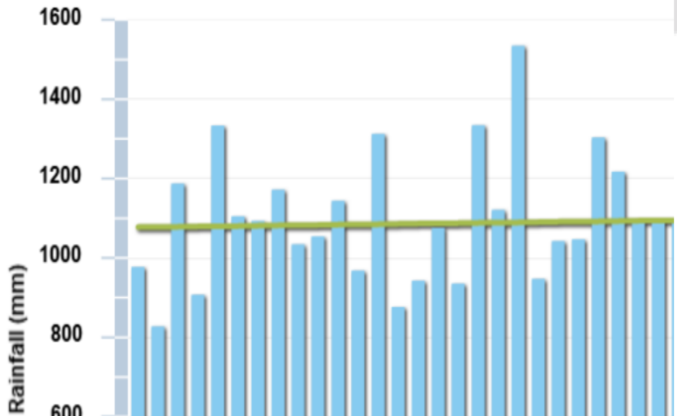

Fig. Precipitation Time Series Graph

Management Recommendations

- **Flood Defence Structures:** Construction of levees, embankments, or retention ponds in vulnerable zones.
- **Early Warning Systems:** Installation of real-time flood forecasting and alert systems, especially for downstream communities.
- **Watershed Management:** Implementation of soil conservation, and sustainable land use practices to reduce surface runoff.

Table Key Differences Observed

Aspect	Baseline Map	Modified Map (Red Zone)
Flood Area	No significant flood spread visible	Large, red-outlined zones indicate expanded flood-prone areas
Watershed Input	Existing flow based on current rainfall-runoff conditions	Increased runoff from 30-50% more watershed area
Flood Spread Direction	Localized near river channels	Flood spreads outward to Kanha, Kasola, Jam Bazar, etc.
Risk Level	Low to moderate	Significantly higher due to greater area under water

Conclusion:

The following conclusion are observed during study

1. The total flood-prone area, based on 2D modeling and area statement calculations, is approximately 2,449.86 hectares under current conditions.
2. The 2D flood simulations revealed that under current (baseline) conditions, flood spread is limited and mostly confined within the main river channel. However, when runoff was increased by 30–50%—simulating extreme rainfall events or upstream land use changes—the inundation area expanded significantly. Flood-prone zones increased by over 800 hectares, especially in downstream regions near Pusad, Kanha, and Kasola, affecting both settlements and productive agricultural lands.
3. Velocity outputs from the HEC-RAS model showed that flow velocities peaked near structural bottlenecks such as bridges and weirs, reaching speeds of up to 3.5 m/s, which indicates potential for erosion and infrastructure stress in high-flow scenarios. The model also identified low-lying areas with elevations between 527 to 600 feet as most vulnerable to flooding.
4. The precipitation time series from 1960 to 2010, used for hydrologic input, showed rainfall peaks aligning with historical flood years, validating the model setup.
5. Based on these findings, the following are strongly recommended:
   - Implementing structural flood defenses in high-risk zones.
   - Establishing floodplain zoning regulations.
   - Promoting watershed conservation to reduce peak runoff.
   - Deploying early warning systems to protect at-risk populations.

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