Assessment of inundation risk at Bhavani River (stretch from Sathyamangalam to Velliyampalayam) using HEC-RAS

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Abstract

Floods are natural disasters that cause losses and damages to lives, properties and the nature. The main objective of this study is to perform hydraulic analysis using HEC-RAS and to suggest measures to mitigate flood. The study area chosen for analysis is Vellayampalayam to Sathyamangalam stretch which is located along the Bhavani river. These areas are frequently affected due to flood. Field survey is carried out to determine cross section data (width, depth, elevation of the river stretch). Discharge is calculated using rational method.

These data are feed as input into HEC-RAS model for simulation. From the results, it was found that the areas around the stretch chosen as study area are greatly affected by the floods. As per field condition, the channel improvement plans were suggested to mitigate the effects of flood.

Keywords: Flood, HEC – RAS, Bhavani River, channel improvement plan.

Introduction

Rivers play important role in the human civilization since they are found to be the main source of fresh water, transportation and resources[1]. However, sometimes this relationship is often "troubled" because of change in river discharge which leads to flood or drought. Floods have been considered as one of the most devastating natural hazards which cause huge damage and loss to human activity, economic development of a society as well as on the environment.[4,5,17] The flood profile of a river can be done by flood modelling softwares. The parameters such as rainfall, return period, characteristics of a catchment and runoff play a major role in defining flood[2,3]. These parameters can be given as input variables and flood hydrograph can be got as output which can be used for flood mitigation measures.[10]

Many researchers have found that hydraulic modelling coupled with Remote Sensing (RS) and Geographic Information System (GIS) would give effective results.[2,9,14,16,18] With rapid advancement in computer technology and research in numerical techniques, various 1-D hydraulic models, based on hydraulic routing, have been developed in the past for flood for casting and inundation mapping. In this study, one dimensional hydraulic model HECRAS has been developed using geometric and past flood data of the Bhavani River[4-6].

The discharge (past flood data) and river stage (stations and elevations) are the most important variables in flood warning applications. In this study, the flood water levels along the Bhavani River in Erode were simulated using the HEC- RAS 1-D hydraulic model to prepare the people to survive during floods with minimum damages and to suggest river training works to manage flood.[7,8]

Study Area Description

Bhavani river is situated between latitude 11 ^{0}29' 2.13" N to 11^{0}30'17.57" N and longitude 77^{0}9'7.23" E to 77^{0}14'18.30" E, Erode district, Tamil Nadu. The index map of the study area is shown in figure 1.

The Bhavani river is the mmajor tributary of Cauvery river. It originates from Nilgiri Hills of the Western Ghats, enters the Silent valley National Park in Kerala and flows back towards Tamil Nadu. The Bhavani river basin is divided in two sub-basins namely: upper Bhavani basin (up to Gobichettipalayam) and lower Bhavani basin (up to Sathyamangalam). Erode district lies at a bend of the river Bhavani, where its course changes suddenly from the south-east to south-west. From the left bank of the river, ground rises slightly towards the north but the height above Mean Sea Level (MSL) is 215.75m. The city of Bhavani and its economy have been hit by a number of floods over the past few decades which were mainly during the years 2001 and 2018.

Floods occurred in river Bhavani after 17 years (July 2018), created lot of damage in residential as well as industrial areas since major portion of the city gets submerged[9,10]. Due to encroachment, silting and scouring, depth and width of the river get reduced day by day. Thus, modifying the channel would help in the preparation of flood mitigation plan as a curative measure for the control of flood in the river Bhavani.

This needs for a hydraulic analysis of the river. A stretch from Sathyamangalam to Velliampalayam has been chosen to carry out the analysis in order to manage flood entering agricultural lands and nearby villages.

https://doi.org/10.25303/1610da024029

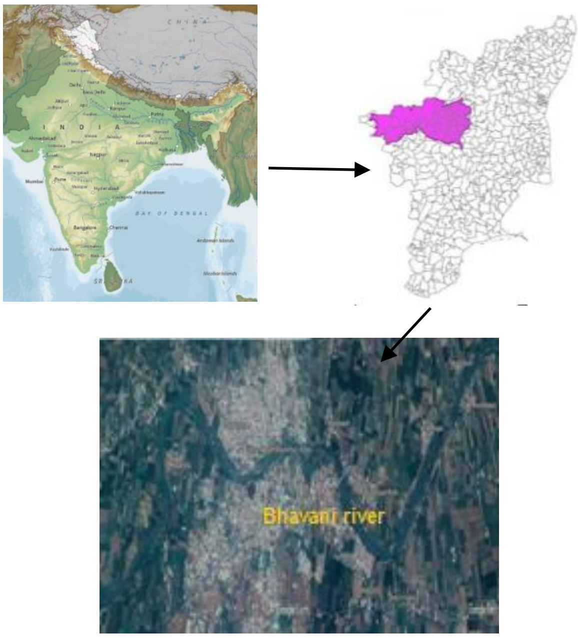

Fig. 1: Index map of the study area

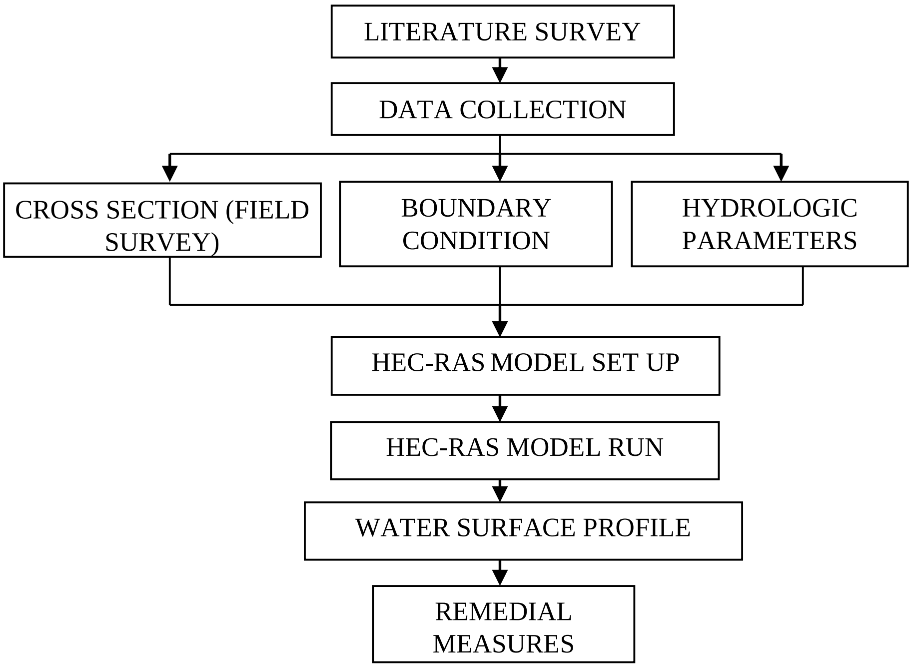

Fig. 2: Methodology flow chart

Material and Methods

A reconnaissance survey has been carried out in the study area to observe existing width, ground level, flood affected areas, cross sections and bridge elevation. The main inputs needed to analyze flood characteristics are geometric data (cross section, elevation, bank station and reach length), steady flow data (boundary condition and initial condition) and hydrologic parameters (rainfall data). The methodology flow chart is depicted in figure 2.

The study reach was subdivided into 42 cross sections. The details like station number, elevation, Manning's roughness coefficient (n = 0.03 for left and right bank and n = 0.025 for the center of the river stretch) were entered in geometric data window of HEC-RAS software[11,12]. Then, the ssteady flow data like number of profiles to be computed, flow data and the river system boundary conditions are entered. In order to calculate the carrying capacity of the river, discharge data must be entered for all profiles. Discharge is calculated using the rational formula shown in equation 1:

$$Q = 0.278\ CIA\ (m^3/s) \tag{1}$$

where Q = peak storm water runoff rate from the drainage area, C = runoff coefficient for drainage area (dimensionless), I = intensity of the design storm (mm/hr) and A= area of the watershed (ha).

https://doi.org/10.25303/1610da024029

The runoff coefficient is based on type of soil and land use as shown in table I.

The basin contains mixture of land use and various types of soils, then runoff coefficient is determined using equation 2:

$$C = \frac{C_1A_1 + C_2A_2 + \ldots + C_nA_n}{A_1 + A_2 + \ldots A_n} \qquad (2)$$

As per the equation, the value of C is calculated as 0.483. Then, a boundary condition must be established at the most downstream cross section for a critical flow profile and at the most upstream cross section for a critical flow profile[13]. Based on this input data, HEC RAS will generate the results in the form of water profile curves and hydrographs.

Developing HEC – RAS model: Creating a Hydraulic model with HEC-RAS involves five major steps. They are:

- Creating a new project
- Geometric data entry
- Flow data and boundary conditions entry
- Performing hydraulic calculation
- Viewing and printing result

A project is created in HEC –RAS window. The geometric data is developed by digitizing the river system schematic. This is accomplished by pressing the river reach button and then drawing the river reach from upstream (u/s) to downstream (d/s)[14-16].

As soon as the reaches are connected, junctions are formed automatically by the interface. Cross section details and hydraulic structure data are entered. Geometric details of study area such as flow path, xs cut lines, banks, river are shown in the figure 3. Boundary conditions are required in order to perform the calculation. The upstream and downstream conditions are entered by pressing the reach boundary condition button from the steady flow data entry form. As soon asthe geometric data and flow data are entered, the hydraulic calculations are performed[17].

Table I
Runoff coefficient (as per BIS IS 8835: 1978)

S. N.	Type of Soil Based on Land Use	Run off Coefficient
1	Loam, lightly cultivated or covered	0.40
2	Loam, largely cultivated and suburbs with garden, lawns, macadamized roads	0.30
3	Sandy soils, light growth	0.20
4	Parks, lawns, meadows, gardens, cultivated area	0.05- 0.20
5	Plateaus lightly covered	0.70
6	Clayey soils stiff and bare and clayey soil and light covered	0.55

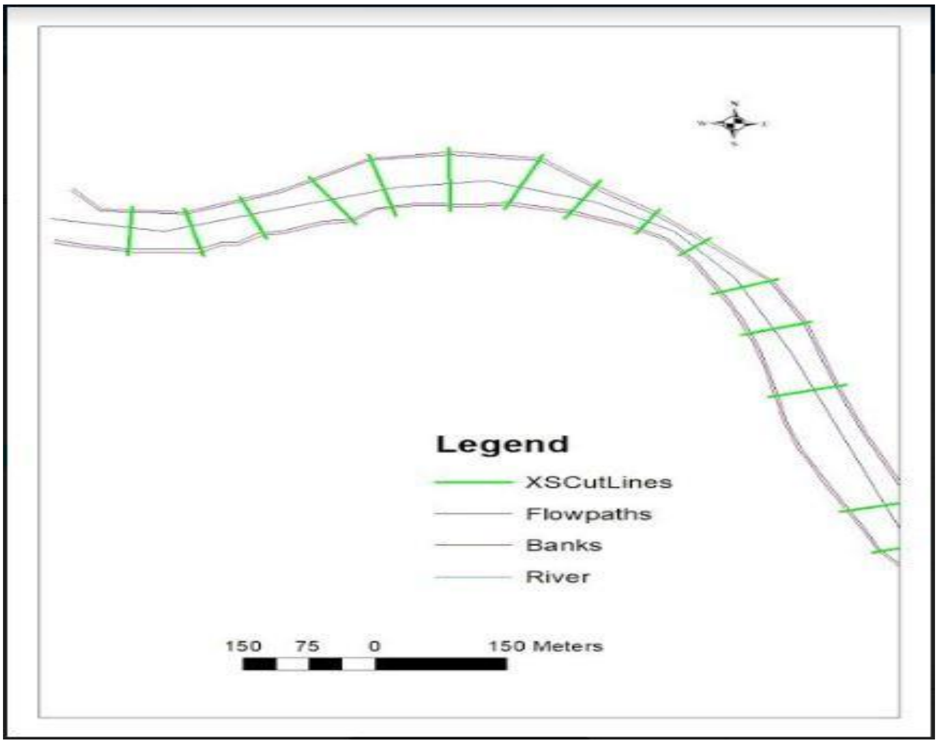

Fig. 3: Geometric detail of the study area

Results and Discussion

The results can be viewed after the computation from the view option. These options include: cross section plots, profile plots, rating curve plots, XYZ perspective plots, tabular output at specific locations (detailed output tables) and tabular output for many locations (profile summary tables). The results indicate that the left bank, right bank and centre of the channel meet high velocity profile between 10000 to 20000 ft and the lowest point of the velocity profile is between 0 to 10000 ft. Figure 4 represents the final output of the flood level (due to rainfall), energy line and water surface profile. Figure 5 depicts profile for boundary condition.

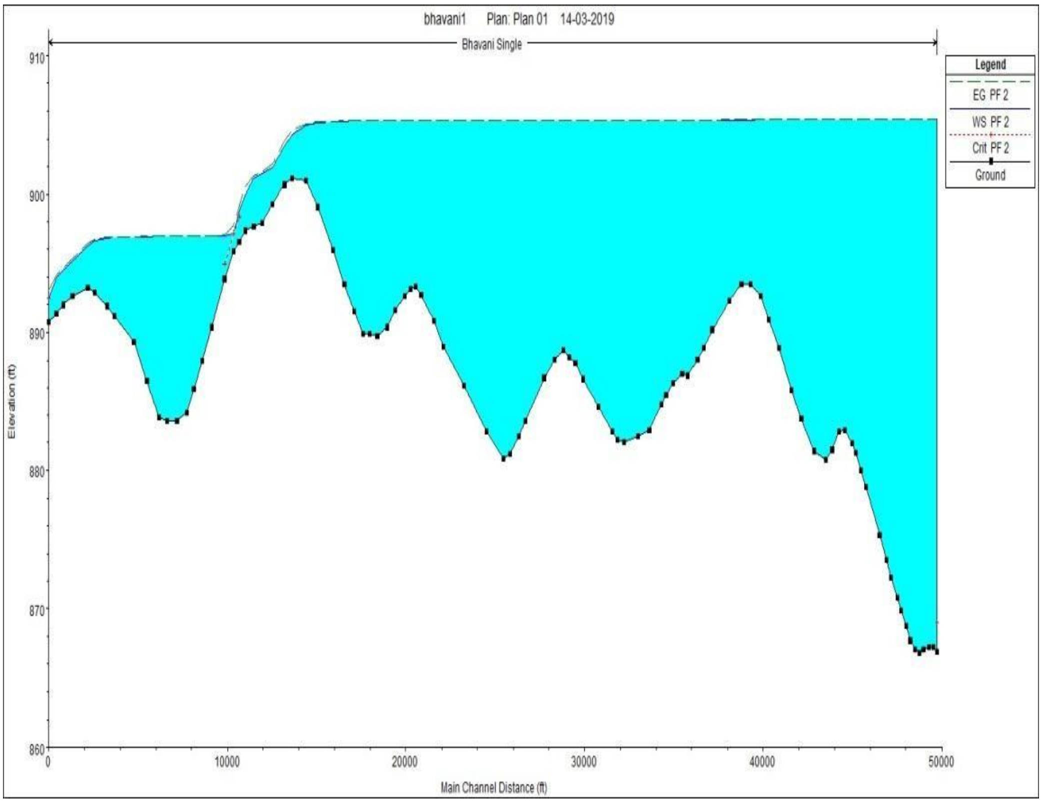

Fig. 4: Water surface profile

Plan: Plan 02 Bhavani Single RS: 15245.08 Profile: PF 1

E.G. Elev (ft)	905.29	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.030	0.025	0.030
W.S. Elev (ft)	905.29	Reach Len. (ft)	204.36	234.19	269.39
Crit W.S. (ft)	868.96	Flow Area (sq ft)	844.68	9598.36	874.08
E.G. Slope (ft/ft)	0.000000	Area (sq ft)	844.68	9598.36	874.08
Q Total (cfs)	3181.00	Flow (cfs)	111.41	2951.93	117.65
Top Width (ft)	299.02	Top Width (ft)	21.98	253.58	23.46
Vel Total (ft/s)	0.28	Avg. Vel. (ft/s)	0.13	0.31	0.13
Max Chl Dpth (ft)	38.46	Hydr. Depth (ft)	38.43	37.85	37.26
Conv. Total (cfs)	6930523.0	Conv. (cfs)	242740.5	6431449.0	256333.9
Length Wtd. (ft)	234.58	Wetted Per. (ft)	60.44	253.58	60.67
Min Ch El (ft)	866.90	Shear (lb/sq ft)	0.00	0.00	0.00
Alpha	1.13	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	511.53	5110.92	524.86
C & E Loss (ft)	0.00	Cum SA (acres)	34.33	358.05	38.05

Fig. 5: Profile for boundary condition

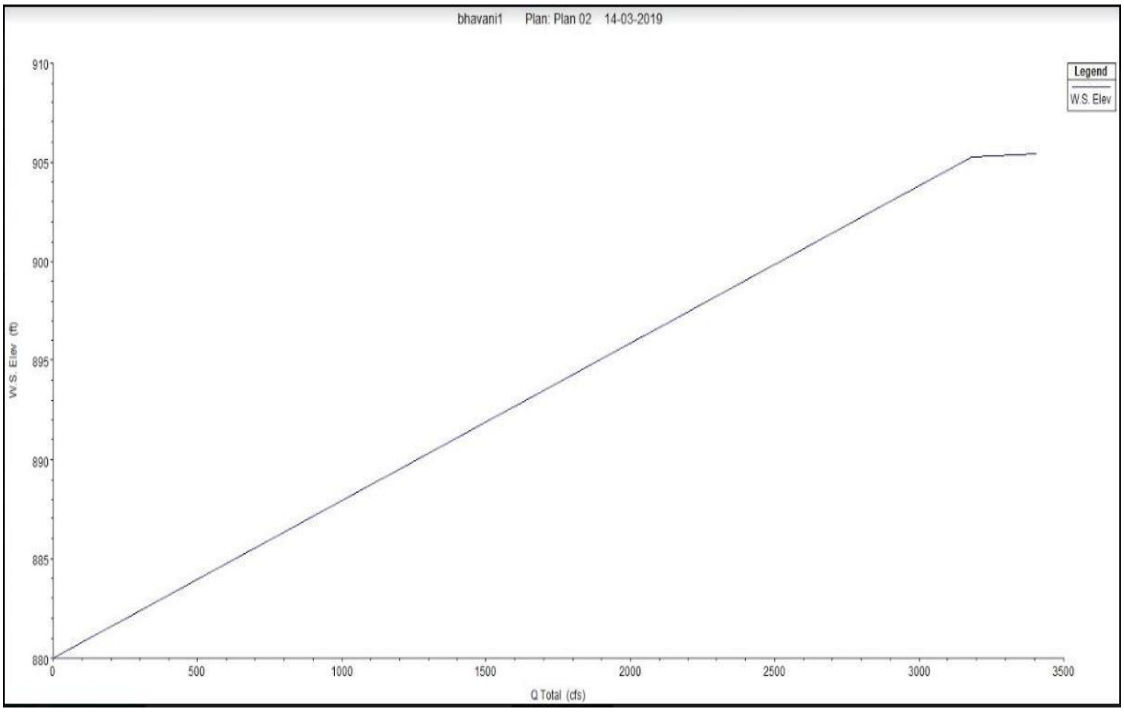

Fig. 6: Rating Curve

The rating curve depends on the hydraulic characteristics of the stream channel and floodplain and will vary over time at almost every station. Figure 6 represents the rating curve of normal flow. The graph varies linearly so both the discharge and elevation are directly proportional to each other[18].

Remedial Measures

Structural solutions to flood problems are one of the best ways to mitigate flood. Construction of spur, retaining wall, revetments and embankments based upon the site conditions has the tendency to alter the hydraulic characteristics of the river. Spur are man - made hydraulic structures to protect against erosion. Retaining walls are built to support about vertical (steeper than 70°) or vertical slopes of earth masses[19,20]. Revetments are sloping structures which are constructed on banks or cliffs to absorb the energy of incoming water. The embankment can be adopted along the stretch of the river to reduce the flood damage.

Conclusion

Due to heavy and frequent flooding in the Bhavani River especially along Vellayampalayam to Sathyamangalam, stretch detailed analysis is done using HEC-RAS a hydraulic modeling software. Modeling is done for a stretch of about 12 kms (which is a flood prone zone selected as a study area). Various factors like discharge, intensity of flood, rate of flow etc. are used to analyze the flood characteristics. River training works can be constructed as a flood control measure.

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(Received 25th May 2023, accepted 28th July 2023)