Chapter 11
Flood Modelling Using HEC-RAS for Purna River, Navsari District, Gujarat, India

Darshan J. Mehta and Yennam Varun Kumar

Abstract The small and medium river banks are seriously flooded due to high-intensity of rainfall in monsoon seasons. The floods threatened human safety, life and property. This paper presents a process of 1D steady flow analysis used Hydrologic Engineering Center River Analysis System software. The one-dimensional modelling is applied on research Purna River, this river is one of the non-perennial rivers in Gujarat. This work contains flood model in which station, elevation of each cross-section was assessed at a particular section of the study reach. Steady flow analysis and hydraulic design analysis were carried out and after providing slope and discharge (flood event) at particular cross section software will compute the water surface elevation, depth of water and velocity of the water. The result from the research analysis could be used by flood management authorities to mensurate the flood at various cross-section of the study region.

Keywords HEC-RAS · Purna River · Steady flow analysis

11.1 Introduction

Flooding may occur due to the overflow of water from the river and lake (Patel and Sanjay 2019). This event occurrence due to high-intensity of rainfall in the river catchment area (Khattak et al. 2016). Flash floods are caused by a steep slope and highly erodible mountains, especially in mountain ranges (Mehta et al. 2013a, 2021). Floods damage human lives and property. Most of the floods occurred suddenly those are natural and artificially, most of flood disasters naturally occurred, but some disasters caused due to dam and poor reservoir management (Kumara and Mehtab 2020). In India, flood affected area is about 98.8422 million acres or nearly one by eight of the countries geographical area is flood-prone (Mehta et al. 2013b, 2017). Flooding is a significant aggravation that impacts sea-going aquatic ecosystems and the ecosystem services that they provide. Anticipated expansions in worldwide

D. J. Mehta (✉) · Y. V. Kumar
Dr. S & S. S. Ghandhy Government Engineering College, Surat, Gujarat, India

P. Kumar et al. (eds.), *Water Resources Management and Sustainability*,
Advances in Geographical and Environmental Sciences,
https://doi.org/10.1007/978-981-16-6573-8_11

flood hazards because of land use change and water cycle intensification will likely only increase the frequency and severity of these impacts. Sometimes, cyclones and tsunamis also cause floods (Mehta and Yadav 2020; Mehta et al. 2020; Agrawal and Regulwar 2016).

The study area is located in Gujarat; the state average precipitation is 150 cm. The most of the rivers are floods occur during rainy seasons. Purna River is an important west-flowing seasonal river; this river watershed is located at south east part of Gujarat and north west part of Maharashtra (Mehta et al. 2021; Kumara and Mehtab 2020). This river originates from Western Ghats; this river is frequently flooded and carries huge flood water due to heavy rains in monsoon, but this river has inadequate capacity to carry the peak flood discharge (Kumara and Mehtab 2020). For flood forecasting is used 1D steady flow model in HEC-RAS. This model gives approximate flood water depth at short time by computation. The 1D steady flow model is used for hydraulic structure, inundation canal and flood wall design (Ahmad et al. 2016; Demir and Kisi 2016). This paper presents the use of a HEC-RAS approach for river modelling facilities.

11.1.1 Objectives of Study

Objectives of this study is to examine and assess the adequacy of a part of Purna River reach of Navsari region which is nearly 13.5 km and to carry out 1D steady flow analysis using Hydrologic Engineering Center River Analysis System software.

11.2 Study Area

Purna River is the non-perennial river in Gujarat state. This river originated from Saputara hill ranges in near the Chinchai village in Maharashtra. Zankhri River is the main tributary of this river. Navsari town is situated at the left bank of the Purna River, this river delta ends into the Arabian Sea (Mehta et al. 2021).

The Purna River is westside flowing river and has its rises in the Sahyadri ranges of the Western Ghats in Dang district and its total length 180 km before joining with Gulf of Khambhat (Arabian Sea). This river watershed lies between 20° 43′–21° 05′ N latitudes and 72° 43′–73° 57′ E longitudes. This river watershed area is 2435 km^2, out of which is nearly 2377 km^2 lies in Gujarat and 58 km^2 lies in Maharashtra. The river catchment is bounded by Western Ghats separating Purna and Tapi rivers in east, the ridge separating Purna and Ambica rivers in south, Arabian Sea in west and the ridge separating Purna and Mind Hola on north. Important tributaries are Girra River, Zankhari River and Damas khadi. The maximum, minimum temperatures observed at CWC site in Mahuva it varies from 34 to 44 °C and 26 to 10 °C, respectively. The average precipitation 122 cm in this region (Mehta et al. 2021; Kumara and Mehtab 2020).

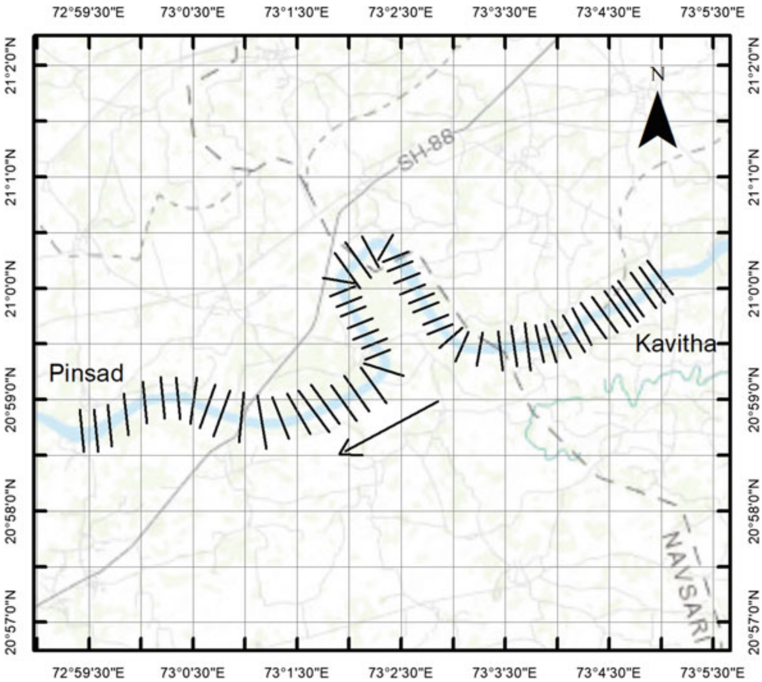

Fig. 11.1 Study area

In this study area, Purna River near Navsari is taken to carry out one-dimension steady flow analysis of Purna river basin of the Navsari region using HEC-RAS. This project work represents a process of one-dimensional steady flow analysis of the river by using computation. This study reach consists of 55 cross-sections, distance between two cross section 250 mitres at stream line. Approximately, 13.5 km length of Purna River is covered which is shown in Fig. 11.1. The upstream village is Kavitha and downstream village is Pinsad (Mehta and Yadav 2020).

11.3 Data Collection

The Hydrological data of Purna River at site Mahuva of is collected from Irrigation Department (Navsari) which include.

Table 11.1 Past flood data

Sr. No.	Year	Discharge (cumecs)
1	2004	8836
2	2005	5437
3	2006	3273
4	2007	3058
5	2008	1853
6	2014	1543

11.3.1 Cross Sectional Data

This spacing between each cross section is 250 m. It consists of 55 cross-sections. Approximately, 13.5 km length of Purna River is covered. The cross-section data consist of station-elevation. In addition to this, it also consists of data of left bank and right bank R.L.

11.3.2 Past Flood Event

As discussed in previous section, peak discharge was used for analysis of flood. The data were collected from Irrigation Department, Navsari. Details of six flood events is shown in Table 11.1.

11.4 Methodology

The methodology taken in this study has been shown through the flowchart which is shown in Fig. 11.2.

11.4.1 HEC-RAS Analysis Procedure

The Geometric data are added to cross section details which contain station, elevation, right over bank, left over bank and channel length, Manning's constant, left bank and right bank (Ingale and Shetkar 2017; Parhi et al. 2012).

Then from steady flow analysis menu, apply boundary condition and peak discharge parameters. After that save steady flow analysis file. Then, from hydraulic design function apply peak discharge and slope then after applying geometry it gives directly the water surface elevation height (Timbadiya et al. 2011, 2014).

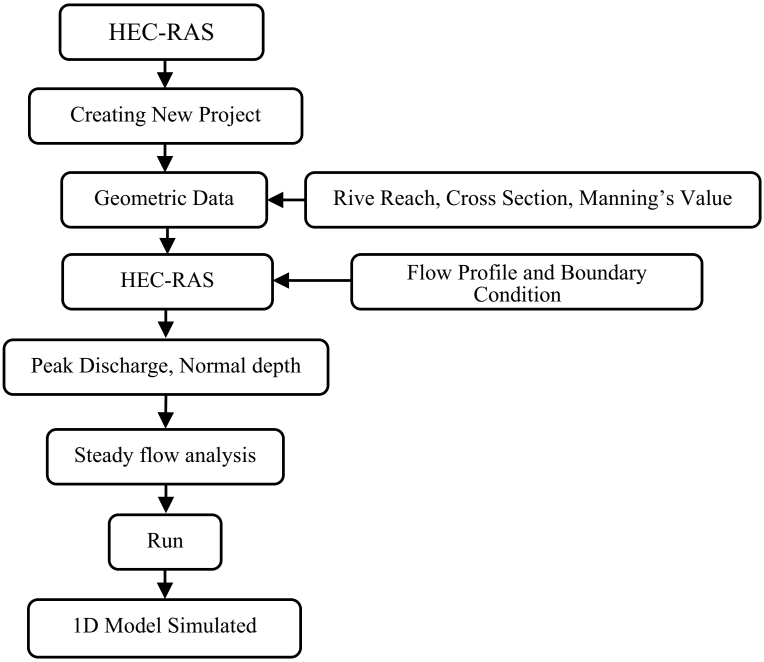

Fig. 11.2 Flowchart of methodology

- Create a new HEC-RAS project. Create a new river geometry editor window. Give name of the Project as shown in Fig. 11.3.
- Create a new cross section. Paste the surveyed station/elevation points into the new cross section and then add the location of the left and right bank station.
- Enter the Manning's value for upstream reach. In this paper, value of '*n*'. The value of '*n*' can be taken according to bed material of the river reach as 0.03 or 0.04.

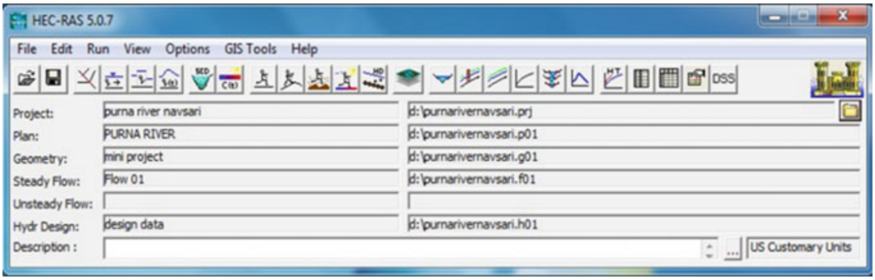

Fig. 11.3 Main window of HEC-RAS

11.5 Result and Discussion

After giving imputes discharge for the years 2004, 2005, 2006, 2007, 2008 and 2014, the computed sections are obtained. Figures 11.4 and 11.5 indicate that the water is overtopped from the left bank and right bank of cross section after applying peak discharge. So, the chances of flooding are more in these cross sections. The water surface elevation obtained after the steady flow analysis is compared with existing left side and right side RL of Purna river basin. Based on this comparison analysis, water level to decide the flow condition is critical or not for all cross sections of river. If the discharge water overtops from particular cross-section, then the flow condition is high critical. If the discharge water remains in particular cross-section with sufficient remaining carrying capacity of basin, then the flow is considered as moderately critical. For all year, the condition of flow is different which depends on water discharge of that particular year. The energy gradient line and water surface line is obtained after computing the analysis.

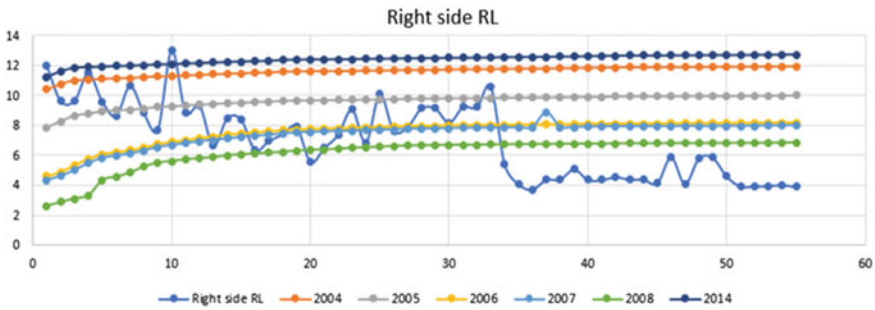

Fig. 11.4 Graphical representation between existing and computed levels for flood events (right bank) of Purna River

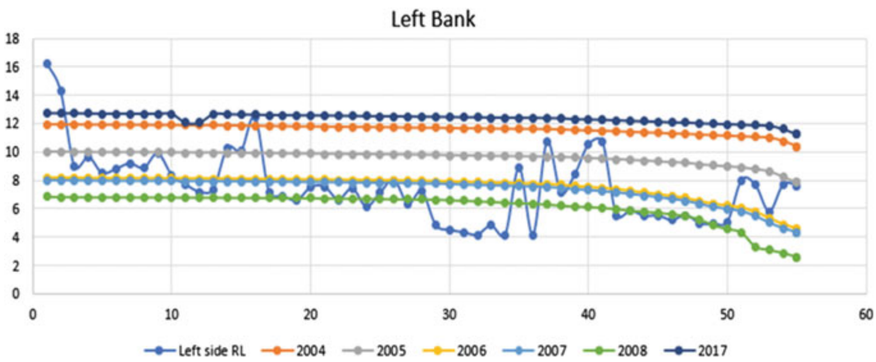

Fig. 11.5 Graphical representation between existing and computed levels for flood events (left bank) of Purna River

By the analysis, it is found that cross-section no. 34–55 have less carrying capacity as compared to other cross-sections.

After giving imputes discharge for the years 2004, 2005, 2006, 2007, 2008 and 2014, the computed sections are obtained.

11.6 Conclusion

From flood analysis, the sections at which water overtop the existing level are found critical so it require restoration work and needs to be raised. With increased stream flows at different cross-sections of Purna river basin in the future, the chances of high magnitude flooding events are likely to increase under future climatic change in the river basin system. So, it is recommended that construction of levees, embankment and necessary flood gates in floodplain area. It is strongly recommended that no new construction is allowed in floodplain area. In our analysis, we found that in the year 2004, 2005 and 2014 the highest flood level has been reached. It is recommended that the storm drain outlets should be provided with flood gates to prevent entry of flood water in the study area. It is also recommended that there should be restriction in encroachment of width of the river because river sections are sensitive to high floods, encroachment will result in flooding of study region. It is strongly recommended that the sections, which water overtop over the existing embankment or retaining wall need to be raised. This study also recommends improving carrying capacity of Purna River so that it will minimize flood effects.

Acknowledgements Authors are thankful to the Navsari irrigation department for providing data of Purna River and Principal, Dr. S. & S. S. Ghandhy Government Engineering College, Surat for granting permission to carry out research work.

References

Agrawal R, Regulwar DG (2016) Flood analysis of Dhudhana river in upper Godavari basin using HEC-RAS. Int J Eng Res 1:188–191

Ahmad HF, Alam A, Bhat MS, Ahmad S (2016) One dimensional steady flow analysis using HECRAS–a case of River Jhelum, Jammu and Kashmir. Eur Sci J 12:340–350

Demir V, Kisi O (2016) Flood hazard mapping by using geographic information system and hydraulic model: Mert River, Samsun, Turkey. Adv Meteorol

Ingale H, Shetkar RV (2017) Flood analysis of Wainganga River by using HEC-RAS model. Int J Sci Eng Technol 6(7):211–215

Khattak MS, Anwar F, Saeed TU, Sharif M, Sheraz K, Ahmed A (2016) Floodplain mapping using HEC-RAS and ArcGIS: a case study of Kabul River. Arab J Sci Eng 41(4):1375–1390

Kumara YV, Mehtab DJ (2020) Water productivity enhancement through controlling the flood inundation of the surrounding region of Navsari Purna river, India. Water Prod J. https://doi.org/10.2203/WPJ.2021.264752.1024

Mehta DJ, Yadav SM (2020) Hydrodynamic simulation of River Ambica for riverbed assessment: a case study of Navsari Region. In: Advances in water resources engineering and management. Springer, Singapore, pp 127–140
Mehta DJ, Ramani MM, Joshi MM (2013a) Application of 1-D HEC-RAS model in design of channels. Methodology 1(7):4–62
Mehta D, Yadav SM, Waikhom S (2013b) Geomorphic channel design and analysis using HEC-RAS hydraulic design functions. Paripex Int J Glob Res Anal 2(4):90–93
Mehta DJ, Yadav SM, Waikhom SI (2017) HEC-RAS flow analysis in the River Tapi. In: Proceedings of the 37th IAHR world congress, Kuala Lumpur, Malaysia, vol 16
Mehta D, Yadav SM, Waikhom S, Prajapati K (2020) Stable channel design of Tapi River using HEC-RAS for Surat region, vol 91. Springer, Cham, pp 25–36
Mehta DJ, Eslamian S, Prajapati K (2021) Flood modelling for a data-scare semi-arid region using 1-D hydrodynamic model: a case study of Navsari Region. Model Earth Syst Environ 1–11
Parhi PK, Sankhua RN, Roy GP (2012) Calibration of channel roughness for Mahanadi River, (India) using HEC-RAS model. J Water Resour Prot 4(10):847–850
Patel KB, Sanjay Y (2019) One dimensional unsteady flow analysis using HEC-RAS modelling approach for flood in Navsari City. In: Proceedings of recent advances in interdisciplinary trends in engineering & applications (RAITEA)
Timbadiya PV, Patel PL, Porey PD (2011) Calibration of HEC-RAS model on prediction of flood for lower Tapi River, India. J Water Resour Prot 3(11):805
Timbadiya PV, Patel PL, Porey PD (2014) One-dimensional hydrodynamic modelling of flooding and stage hydrographs in the lower Tapi River in India. Curr Sci 708–716