2D Flood Route Analysis of Girna River by Using Hec-Ras Software

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***Abstract*—Floods are more frequent in our country because of changing climatic patterns and irregular rainfall. Flood is an event that occurs when water overflows and submerges the surrounding areas. Flooding in Nashik to Jalgaon region of Girna river is a major problem. It has various devastating effects on the livelihood and infrastructure in the particular area. The people residing near the banks are frequently facing the hazard of flooding. The major flooding events in recent years are 2006,2019 and 2025 flood events impacting the locality. Moderate flooding events have a return period of 2 to 3 years. Various bridges get submerged due to which communication is disrupted. In consideration with the above, it is necessary to model such flood events to determine the extent, frequency and flow pattern of water for effective execution of flood mitigation measures. The present paper describes the development of a 2D hydrodynamic model based on HEC-RAS (Hydrological Engineering Centre's River Analysis System) – modelling system developed by Hydrological Engineering Centre at the United States Army Cops of Engineers for the flood route analysis of Girna river in Nashik to Jalgaon segment. HEC- RAS 6.7 Beta 4a is used for modelling and analysis of flow pattern of the water in Girna river for the simulation of 2019 floods. This study indicates the efficiency of 2D modelling of flood problems in implementation of flood mitigation strategies.**

***Index Terms:* 2D Hydrodynamic Modelling, Climatic Patterns, Flood Mitigation, Flood Route Analysis, Girna River, HEC-RAS**

I. INTRODUCTION

Flood is a hazardous event which is in the form of surface runoff due to excessive rainfall. Undoubtedly, the process of flood management in India is very complex due to the influence of several socio-hydro climatological factors, such as climate change, sea level rise, and socio-economic dynamics. (Mohit Prakash Mohanty et. Al., October 2020) [1]. Flood risk increases with climate change, population growth and the increase of economic assets, and that risk is dynamic, constantly changing with underlying surface condition changes (Hallegatte et al., 2013; Lai et al., 2020) [2] [3].Given the complexity of nonlinear hydro meteorological and hydro climatological processes, so that it is essential to use modern scientific research and technical advancements to increase our understanding of hydrological hazards and our capacity to respond to droughts and floods (Pu et al. 2021) [4].

Various flood methods have been implemented across the world for effective and efficient flood mitigation and management. Lihong Wang et. Al., used the literature review method to survey the changing trends of flood management strategies according to development trends over time (2022 Nov 25) [5].The Mike software suite, created by DHI Group, is extensively utilised for managing and forecasting water systems, such as river and coastal flooding. Complex flood occurrences can be accurately simulated due to their complexity in hydraulics. (Peigen Wang, Xiaoxu Wu, Yichen, 2025, 100752) [6]. GIS modelling is done in conjunction with HEC-HMS was carried out using the Soil Conservation Service Curve Number (SCS-CN), SCS Unit Hydrograph (SCS-UH), and Muskingum routing techniques. These approaches effectively integrated rainfall and watershed morphology details like slope, land use, soil properties, and climatic conditions. The model's accuracy in predictions was enhanced through model calibration. (Priyanka Sharad Jawale et. al., December 2025) [7]. Tate and Maidment presented a methodology based on HEC-RAS for the two- and three-dimensional floodplain mapping using Arc GIS [8]. Sharif et al. Investigated trends in magnitude and timings of flows in the Upper Indus basin – a climatically sensitive basin in the Himalayan region [9].

Darshan Mehta, Yennam Varun Kumar published a work in which steady flow analysis and hydraulic design analysis were carried out in Purna river and after providing slope and discharge (flood event) at particular cross section software computed the water surface elevation, depth of water and velocity of the water (February 2022) [10]. Prafulkumar V Timbadiya et. Al., calibrated HEC-RAS based model and its performance has been accessed by capturing the flood peaks of observed and simulated floods in the years 2003 and 2006; and computation of root mean squared error (RMSE) for the inter-mediated gauging stations on the lower Tapi River (March 2014) [11].

1.1 Software used: - HEC-RAS

HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. In the present study HEC-RAS version of 6.7 Beta 4a is used.

HEC-RAS software is used because it has several benefits. These include the ability to simulate 2D flow, create accurate floodplain maps, integrate with real terrain data, simulate dam releases and barrages, perform scenario analysis, and help with flood risk management.

The system includes a graphical user interface, analysis tools, data storage and handling features, graphics, mapping, and reporting tools.

HEC-RAS includes four main river analysis components: one-dimensional steady flow water surface profile calculations; one-dimensional and/or two-dimensional unsteady flow simulations; quasi unsteady or fully unsteady flow calculations for movable boundaries and sediment transport (1D and 2D); and one-dimensional water quality analysis. All four components use the same geometric data and common hydraulic computation routines. In addition to these components, the system has several hydraulic design features that can be used after computing water surface profiles. HEC-RAS also includes a comprehensive spatial data integration and mapping system called HEC-RAS Mapper. HEC-RAS is designed to perform one-dimensional and two-dimensional hydraulic calculations for a full network of natural and man-made channels, overbank areas, floodplains, levee-protected areas, and more.

Fig. No. 1.1.1: HEC-RAS software

1.2 Research Background

Every year during monsoons (June to September) the Girna river which is a major tributary of Tapi river experiences flooding. Due to which the Nashik, Malegaon and Jalgaon region surrounding the banks of Girna river are adversely affected which is harmful to the locality. If there is excessive rainfall then the water is released from the reservoirs which in turn causes troubles. During these seasons many bridges and roads along the route of the river are submerged, damaging the communication facilities and the surrounding areas become waterlogged. The return period of these flood events is 2-3 years. In this study 2D flood route analysis of Girna river is performed by using HEC-RAS software in order to analyse the flow pattern and to simulate the 2019 flood. Conventionally flood route analysis was carried out by using one-dimensional hydraulic models, but they have problems in simulating complex flow patterns, especially in urban areas or areas having wider flood plains where water flow of water is multidirectional. On the other hand, two-dimensional analysis is more accurate as it represents the flow of water in both longitudinal and lateral directions. The inputs required for the model are Digital Elevation Models(DEM), terrain data, boundary conditions, water surface elevation and storage areas for the simulation. It is much suited for complex flood route analysis and inundation mapping. This approach is beneficial for development of flood inundation mapping for the prediction of vulnerable areas.

II. STUDY AREA

The area for present study is Girna river. It is a seasonal river and is a major tributary of Tapi river in Maharashtra. It originates from the Western Ghats, Nashik, Maharashtra. The coordinates of Girna river are 21°08′30″N to 75°19′00″E and it’s total length is 241 km. The climate in the study area is semi-arid. The main tributaries of Girna river are Jhiri from the left and Titoor from right. The average basin elevation is approximately 143 m above from the mean sea level. There is hilly terrain in the upper reach and flat alluvial terrain in the lower reach and the soil type is alluvial soil which is fertile in nature. The study area from Chankapur dam (20.4988632°N 73.8834431°E) to Girna Dam (20.48° N 74.72° E) is spread across 130 km stretch. Chankapur Dam (20.48° N 74.72° E) useful storage of 2427 million cubic ft. And Girna Dam (20.48° N 74.72° E) useful water storage capacity of 11800 million cubic ft. Are two major structures along the study route. Minor structures and hydraulic features across the route include Sarpganga–Girna Confluence(20.49° N 73.90° E), Abhona / Kalwan KT Weirs (20.50° N 73.95° E), Small Check Dams near Vani–Kalwan (20.47° N 74.05° E), Punad Nadi Confluence (20.528° N 74.069° E), Dabhadi Diversion Weir (20.53° N 74.60° E), Minor Canal Headworks (Girna Irrigation System)(20.48° N 74.45° E), Village Bandharas between Niphad–Malegaon (20.50° N 74.30° E).

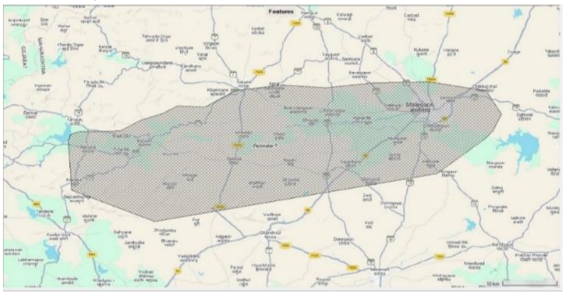

Fig 2.1 Study Area (Map Layer)

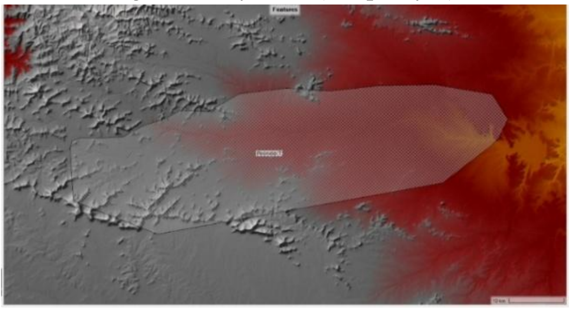

Fig 2.2 Study Area (Terrain Layer)

III.METHODOLOGY

The methodology adopted for the present study focuses on developing a two-dimensional (2D) hydraulic model using HEC-RAS to simulate flood routing and inundation characteristics of the Girna River. The approach integrates geospatial data processing, hydrological inputs, and numerical modelling techniques to accurately represent flood behaviour under unsteady flow conditions. Compared to conventional one-dimensional models, the 2D approach provides better representation of lateral flow spread, floodplain interaction, and spatial variation of depth and velocity.

3.1 Overall Methodological Framework

The study follows a systematic workflow consisting of:

- Data collection and preparation
- DEM processing and terrain generation
- Development of 2D computational mesh
- Assignment of hydraulic parameters
- Boundary condition definition
- Unsteady flow simulation
- Model calibration and validation
- Flood inundation mapping and analysis

3.2 Data Collection and Preparation

The datasets required for the study were collected from reliable sources:

- Digital Elevation Model (DEM): Bhuvan (ISRO), 30 m resolution (Cartosat-1, CartoDEM)
- Discharge Data: IMD/CWC flood hydrographs
- Land Use/Land Cover (LULC): For Manning's roughness values
- Projection System: WGS 84 UTM Zone 43N
- Historical Flood Data: For calibration and validation

3.3 DEM Tiles Acquisition and Processing

The DEM data for the study area was downloaded from Bhuvan geoportal in the form of multiple raster tiles. The primary source used on the Bhuvan Geoportal for downloading terrain tiles (Digital Elevation Models) is the Cartosat-1 satellite, which produces the CartoDEM dataset. The tiles covering the Girna River basin include:

Cdnf43w, cdnf43v, cdnf43u, cdnf43t, cdnf43q, cdnf43p, cdnf43o, cdne43e, cdne43d, cdne43c

These tiles represent grid-based elevation data required to cover the entire study area.

Processing Steps:

1. DEM Tile Downloading from Bhuvan:

Digital Elevation Model (DEM) tiles were downloaded from the Bhuvan geoportal, which is developed by Indian Space Research Organisation. The required tiles covering the Girna River study area were selected and downloaded in raster format.

2. Mosaicking:

The downloaded DEM tiles were merged (mosaicked) using the built-in merging tools available in the Bhuvan platform/associated utilities to create a continuous terrain dataset of the study area.

3. Projection:

The merged DEM was projected into WGS 84 UTM Zone 43N coordinate system to ensure spatial accuracy and compatibility with hydraulic modeling.

4. Clipping:

The DEM was clipped according to the defined study area boundary of the Girna River basin to reduce data size and improve computational efficiency.

5. Preprocessing:

Sink filling was performed to eliminate artificial depressions in the terrain

Errors and voids in the DEM were identified and corrected to improve data quality

6. Import into HEC-RAS:

The processed DEM was imported into RAS Mapper in HEC-RAS to generate the terrain model.

This step is very important because the accuracy of terrain data directly affects the reliability of flood simulation results.

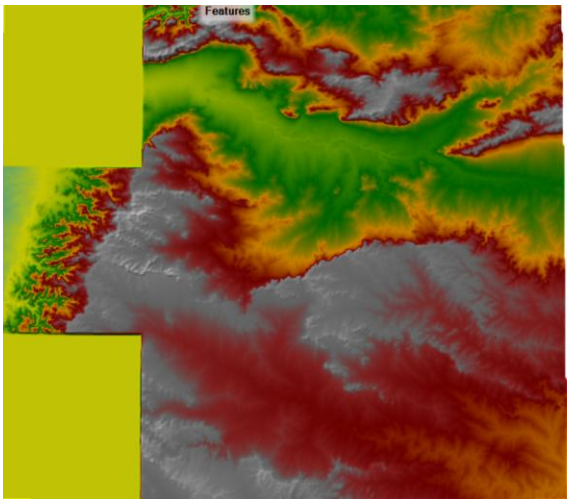

Fig No 3.3.1 Terrain Layer

3.4 Terrain Modelling

Terrain modelling was carried out in RAS Mapper, where the processed DEM was used to generate a high-resolution terrain surface. This terrain serves as the base for hydraulic computations and floodplain representation.

3.5 Development of 2D Flow Area (Mesh Generation)

A 2D flow area was defined to represent the river channel and adjoining floodplain. The area was discretized into computational grid cells (mesh) of 100*100 and total of 147562 cells are formed inside mesh.

Fine mesh used near river channel and settlements

Coarser mesh used in less critical regions

Mesh size selected based on accuracy and computational efficiency

This mesh enables simulation of flow in both longitudinal and lateral directions.

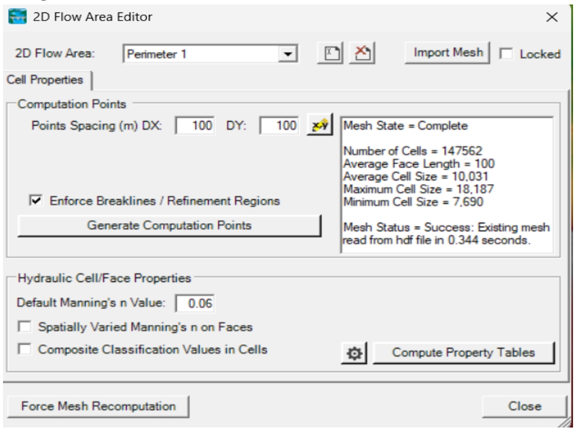

Fig No 3.5.1 Computational Mesh Points

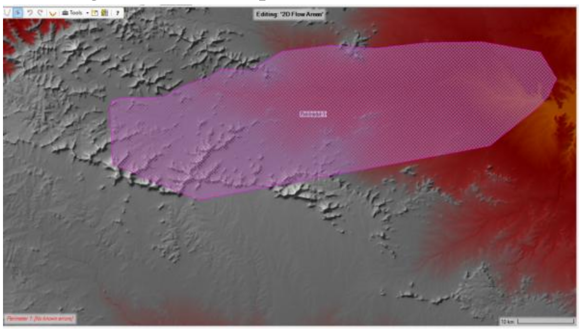

Fig No 3.5.2 Generated Mesh

3.6 Assignment of Manning's Roughness Coefficient

Manning's roughness coefficient (n) was assigned using LULC data:

- River channel: low roughness
- Agricultural land: moderate roughness
- Urban areas: higher roughness
- Vegetation: variable roughness

This parameter significantly affects velocity and water depth.

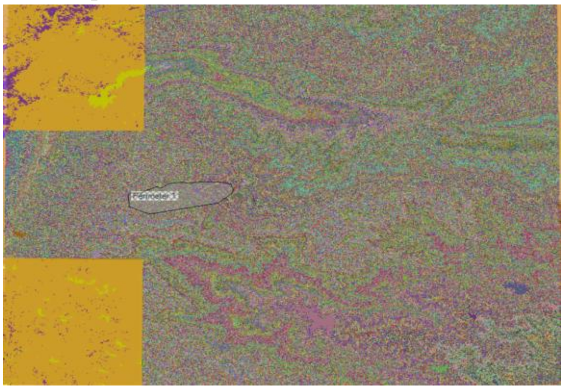

Fig no 3.6.1 LULC Terrain Layer

3.7 Boundary Conditions

Boundary conditions were defined to simulate real flow conditions:

- Upstream Boundary named as Inlet and assigned Flow hydrograph of discharge through changapur dam on flood days from 9 july 2019 to 11 august 2019.
- Downstream Boundary named as outlet an assigned normal depth on slope of 0.002.
- Additional Inputs: Precipitation of 9 july 2019 to 11 august 2019

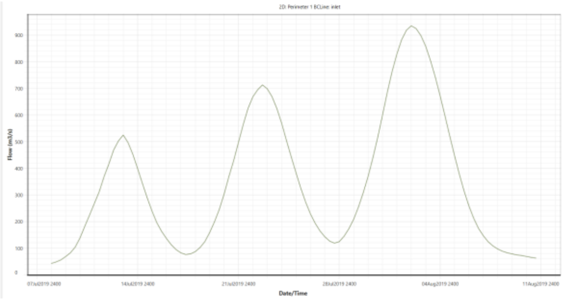

Fig no 3.7.1 Inflow hydrograph

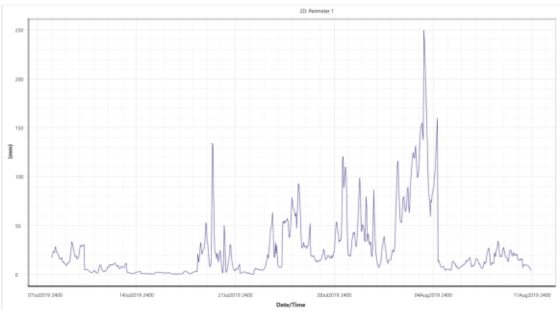

Fig no 3.7.2 Precipitation data

These conditions control the movement of water through the model domain.

3.8 Unsteady Flow Simulation

The model was simulated under unsteady flow conditions using HEC-RAS 2D solver.

- Governing equations:
- Continuity equation
- Diffusion wave momentum equation

Time step selected based on Courant stability condition

Simulation period defined based on flood hydrograph

This allows dynamic simulation of flood propagation over time.

3.9 Model Execution

The simulation was executed in HEC-RAS:

- Computations performed iteratively with 10 minutes interval to ease in computation
- Stability and convergence checked
- Errors corrected by adjusting parameters

3.10 Flood Inundation Mapping

Results were analyzed using RAS Mapper, generating:

- Flood extent maps
- Water depth distribution
- Velocity maps
- Water surface elevation

3.12 Analysis of Results

The results were used to:

- Identify flood-prone areas
- Analyze depth and velocity variation
- Understand flood propagation behaviour
- Assess impact on settlements and agriculture

IV. RESULT AND DISCUSSION

The HEC-RAS 2D simulation was executed for the Girna River basin under the design flood event. The model produced spatial maps of maximum water depth, flow velocity, and water surface elevation (WSE) across the study domain extending from [upstream boundary near Chankapur Dam] to [downstream boundary near Girna dam]. The results are presented as maximum envelope maps extracted from RAS Mapper. The simulation indicates extensive floodplain inundation across the Girna basin. The inundation spreads significantly on both banks of the river, affecting agricultural land, settlements, and infrastructure across Kalwan, Satana, and Malegaon talukas. The white (dry) areas on the depth map correspond to elevated terrain such as hills and upland areas that remain above the flood level. Certain maps are generated from simulation,

A) Maximum Water Depth Distribution

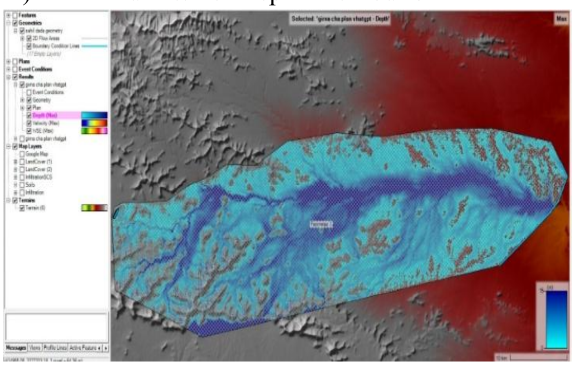

Fig No 4.1 Maximum Depth

B) Maximum Flow Velocity Distribution

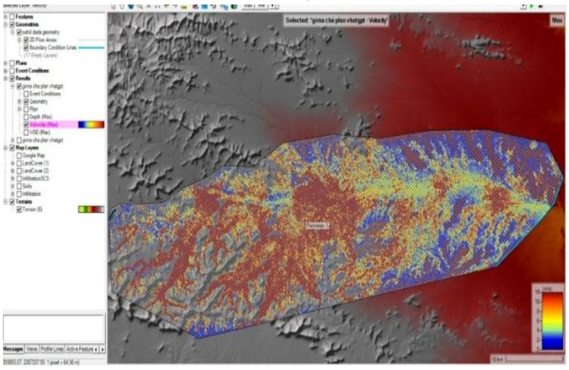

Fig No 4.2 Maximum Velocity

C) Maximum Water Surface Elevation (WSE)

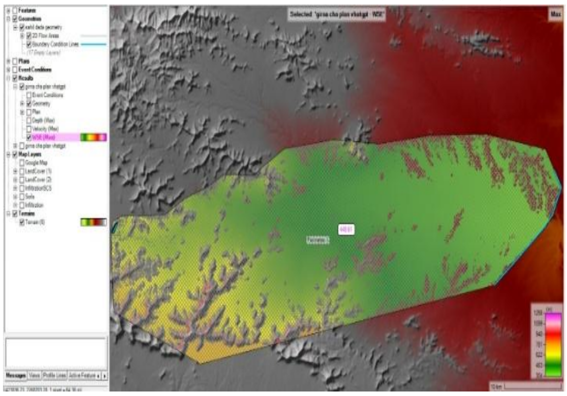

Fig No 4.3 Maximum Water Surface Elevation

4.1 At Inlet (Chankapur Dam):

A) Maximum depth

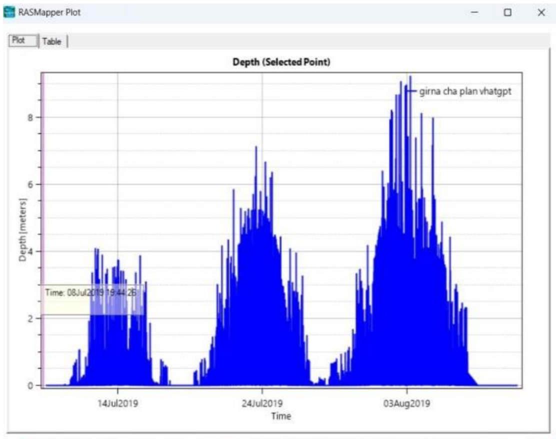

Fig No. 4.4 Depth of water at inlet

B) Maximum Water Surface Elevation

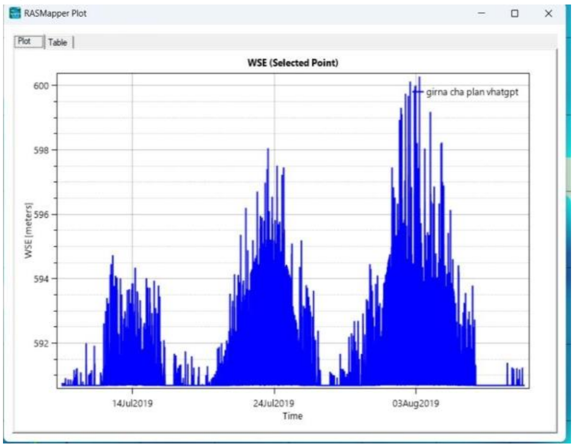

Fig No.4.5 Water Surface Elevation at inlet

C) Maximum velocity

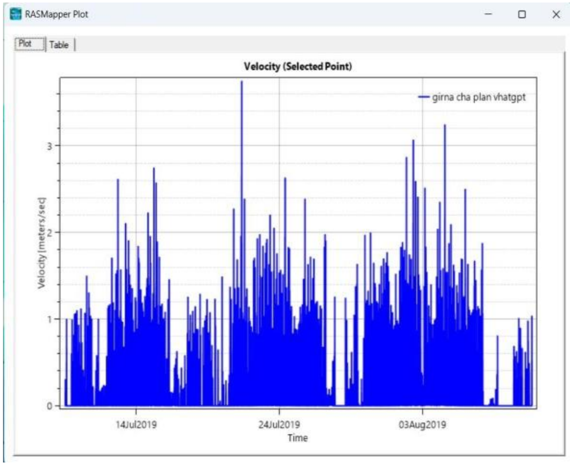

Fig No.4.6 Velocity of water at inlet

4.2 At Malegaon region,

A) Maximum depth

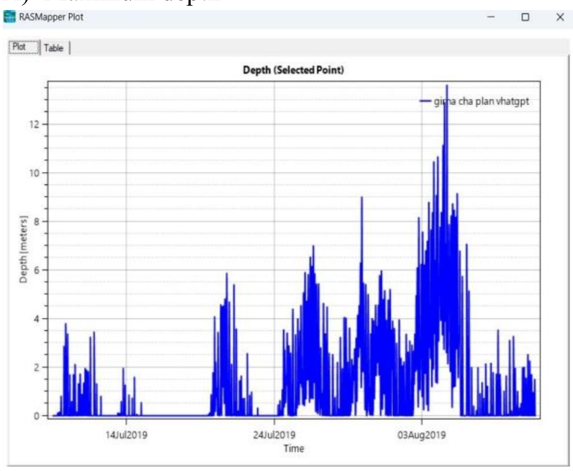

Fig No. 4.7 Depth of water

B) Maximum Water Surface Elevation

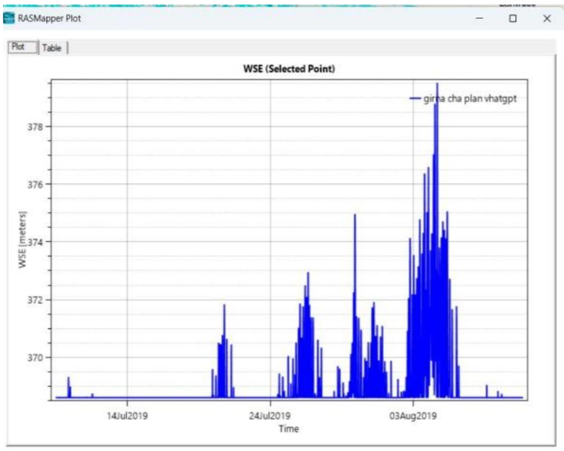

Fig No. 4.8 Water Surface Elevation

C) Maximum velocity

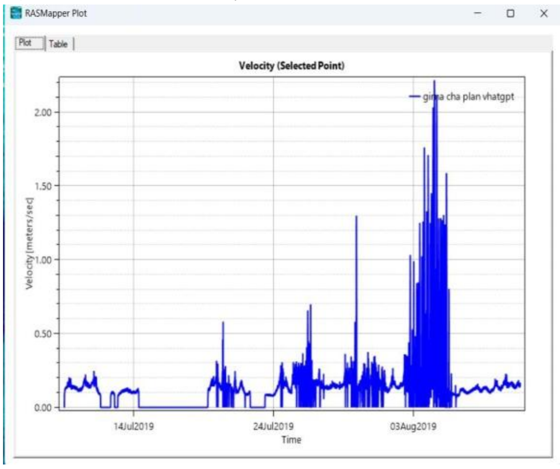

Fig No. 4.9 Velocity of water

4.3 Vulnerable villages in section 1 Upper Girna Basin (Kalwan – Satana reach)

Table no. 1 Maximum flood parameters, upper Girna basin.

Village	Distance from River	Max Depth (m)	Max Velocity (m/s)	Max WSE (m)	Risk Level	Remarks
Directly along main Girna channel						
Kalwan	0–0.5 km (on channel)	8–12	6–10	620–680	High	Deep channel; dark blue depth core; red velocity zone
Bej	0.2–0.8 km	6–10	5–8	600–650	High	Confluence zone; high inundation extent
Bhendi	0.5–1.0 km	4–8	4–7	580–630	High	Wide floodplain; moderate to high depth
Manur	0.3–0.8 km	5–9	5–8	590–640	High	Adjacent to tributary; high velocity corridor
Wadi Bk.	0.5–1.5 km	4–7	3–6	570–620	High	Inundated by overbank flow; medium high depth
Moderate inundation zone (1–5 km from river)						
Athambe	1.5–3 km	2–5	2–4	560–590	Moderate	Floodplain spread; cyan depth zone
Shirasmani	2–4 km	1–4	1–3	550–580	Moderate	Light cyan; affected by sheet flow
Kurdane	2–4 km	1–4	1–3	545–575	Moderate	Overbank spread from Girna tributary
Warshi	1.5–3 km	2–5	2–4	555–585	Moderate	Mid-basin; moderate inundation depth
Kankapur	2–4 km	1–3	1–3	540–565	Moderate	Cyan fringe zone; shallow flooding
Peripheral / low-risk fringe (>4 km from river)						
Devala	4–6 km	0.5–2	0.5–2	530–560	Low	Light blue fringe; limited sheet flow

Gunjalnagar	4–7 km	0.5–2	0.5–1.5	525–555	Low	Near domain boundary; minor inundation
Nanduri	3–5 km	1–3	1–2	535–560	Low	Tributary floodplain; low-moderate depth

4.4 Vulnerable villages in Section 2 (Malegaon reach)

Table no. 2 — Maximum flood parameters, lower Girna basin

Village	Distance from River	Max Depth (m)	Velocity (m/s)	Max WSE (m)	Risk Level	Remarks
Malegaon — core	0–1 km (on Girna bank)	10–15+	8–12	460–510	Severe	Deep blue/black channel core; highest inundation in domain; city straddles both banks
Malegaon — Nayapura ward	0.3–1.5 km	6–12	5–9	450–495	Severe	Floodplain immediately east; dark blue depth; red-orange velocity zone
Yesgaon Bk.	0.5–2 km	5–10	4–8	445–490	High	Adjacent to Malegaon; heavily inundated downstream zone
Chandanpuri	1–3 km	4–8	3–7	440–480	High	Downstream reach; high flow depth from confined floodplain
Villages directly along lower Girna channel						
Pimpalgaon	0–1 km	8–14	6–11	455–505	Severe	Near Girna main channel; very deep inundation; dark core in depth map
Nandgaon	0.5–1.5 km	6–10	5–9	445–490	High	Wide inundation; high red zone along channel axis on velocity map
Dabhadi	0.5–2 km	5–9	4–8	440–485	High	Significant overbank flooding; medium dark blue depth
Dhavleshwar	1–2.5 km	4–8	3–7	435–475	High	Moderate-high depth; cyan to blue range in depth map
Aghar Bk.	1–3 km	4–7	3–6	430–470	High	Inundated by overbank flow; high velocity from tributary
Takali	1.5–3 km	3–6	2–5	425–460	Moderate	Mid-depth zone; affected by floodplain spread from main channel
Saundana	2–4 km	2–5	1.5–4	420–455	Moderate	Cyan zone; significant but not extreme inundation
Vake	2–4 km	2–5	1.5–4	420–450	Moderate	Moderate inundation; floodplain sheet flow

Peripheral / low-risk fringe (>4 km from river)						
Nimbole	3–5 km	1–3	0.5–2	410–440	Low	Light cyan fringe; shallow sheet flow only
Mungase	3–6 km	1–3	0.5–2	410–435	Low	Light inundation near domain boundary
Pandharun	4–6 km	0.5–2	0.5–1.5	405–430	Low	Fringe zone; minor overland flow
Varbane	4–6 km	0.5–2	0.5–1.5	405–428	Low	Peripheral zone; low impact

V. CONCLUSION

Two-dimensional flood routing simulation of the Girna River applying the HEC-RAS model for the 2019 flood was done, indicating that the model successfully captures the flow characteristics, floodplain flooding, and water surface profile in the river. The results from 2D flood routing analysis on the Girna River, obtained from HEC-RAS simulation for the year 2019, show that there is a high gradient hydraulic profile with water surface elevations of 304 m to 1258 m.

The upper basin (reach Kalwan-Satana) shows concentration of high velocity and high depth areas because of its hilly nature with peak depths of 12m and velocities of 10m/s at Kalwan along the river channel. On progressing to the lower basin (reach Malegaon-Jalgaon), there is increased hydraulic effects. The highest risk area in the study area is Malegaon which is described as severe with a peak depth of 10 to more than 15 m and velocities of 8–12 m/s.

Based on the analysis, there is a direct link between the distance from the channel and the intensity of flooding, such that high and severe flood risks will be prevalent in regions less than 1.5 km away from the riverbanks. Past this distance, flood risk decreases, becoming a moderate risk as flooding occurs further from the bank in overbank spread or sheet flow. This is evident in regions beyond 4 km, which experience low flood risk.

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