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MAPPING INUNDATION DUE TO MAXIMUM PROBABLE FLOOD USING GIS AND HEC-RAS

A CASE STUDY OF DOWNSTREAM AREA OF SARDAR SAROVAR DAM

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Abstract — *A significant deficiency of most computer models used for stream floodplain analysis, is that the locations of structures impacted by floodwaters, such as bridges, roads, and buildings, cannot be effectively compared to the floodplain location. This research presents a straightforward approach for processing output of the HEC-RAS hydraulic model, to enable two- and three-dimensional floodplain mapping and analysis in HEC-RAS using ArcView geographic information system. The methodology is applied to a lower Narmada reach, located between Sardar Sarovar Dam and proposed Garudeshwar weir. Because Garudeshwar weir has been proposed to construct at the downstream of dam which will create tail storage for running RBPH turbine a thought year. Because of that it will lead to increase water level due to back water flow in flood situation will arise between Garudeshwar weir and SSD. Conventional flood frequency analysis, involving log-normal, Gumbel's, and log-Pearson type III (LP3) distributions, was used to calculate extreme flows with different return periods. The peak floods from frequency analysis were input into HEC-RAS model to find the corresponding flood levels expected along river reaches extending through SSD dam to proposed Garudeshwar weir. Results obtained with HEC-RAS model were used in combination with ArcGIS to prepare floodplain maps for different return periods. Through floodplain maps, areas that are vulnerable to flooding hazards have been identified.*

***Keywords*-:** *Flood modelling, Narmada river, HEC-RAS, Return Period, ArcGis, Flood plain map.*

I. INTRODUCTION

The Narmada, also called the Rewa, is a river in central India and the fifth longest river in the Indian. Many small and large dam is constructed on Narmada river. One of the largest multipurpose dam on Narmada river is SSD. At SSD site 6 units (each of 200 MW) Reversible type turbine are installed in RBPH(river bed power house) and water which is released from turbines after generating power is wasted to the sea. When irrigation development is reached to the maximum, the RBPH cannot be run to waste the water. The above operation would facilitate the production of power generation during peak demand period by recirculation of the same water. Thus, the use of RBPH can be continued without wasting the water to the sea. For this purpose, a tail pond is necessary in downstream of SSD which will be created by Garudeshwar Weir.
Basic function of Garudeshwar Weir,

1) It is to store the water released from RBPH during peak hour power generation. This water stored in the Garudeshwar dam is then to be pumped back to the SSP reservoir during off peak hours.
2) It is to create a reservoir surrounding Statue of Unity, being propagated as the world's highest statue on a small island

3) km downstream of the SSP Dam.

Garudeshwar weir is concrete weir which will be constructed 12.1 km downstream of SSD near Garudeshwar village which serve as the tail pond for reversible operation (RBPH). Construction of Garudeshwar weir will affect the water level condition on downstream side of SSD. So, in this study HEC-RAS software is used to develop hydraulic model and Results obtained with HEC-RAS model were used in combination with ArcGIS to prepare floodplain maps for getting an idea of extent of water and its submergence in the study area.

II. OBJECTIVE OF STUDY

To study the HEC-RAS (v4.1) software.
To generate the River and Approach channel cross section at the key locations in between SSD and Garudeshwar weir using survey data.
To study releases from SSD to Garudeshwar weir for different return period.
To develop a Flood Forecasting Model in HEC-RAS.
To predict the water levels and discharge using the Flood Forecasting Model.
To develop a Flood Plain Model in RAS Mapper by combination of Results obtained with HEC-RAS model and ArcGIS

III. STUDY AREA

The study reach, located between 21.50'N ,73.45' E,(SSD) and $21^{0}52'57''$ N , $73^{0}39'35''$ E (Garudeshwar site), approximately 12.10 km long with 28 cross sections. The river reach selected for present study because water level rise due to construction of proposed garudeshwar weir in future. Distance between cross-sections to cross-sections is 500m. Upstream reach is Sardar SSD, Gora submersible bridge at middle reach and downstream reach is proposed Garudeshwar weir are shown in figure 1.

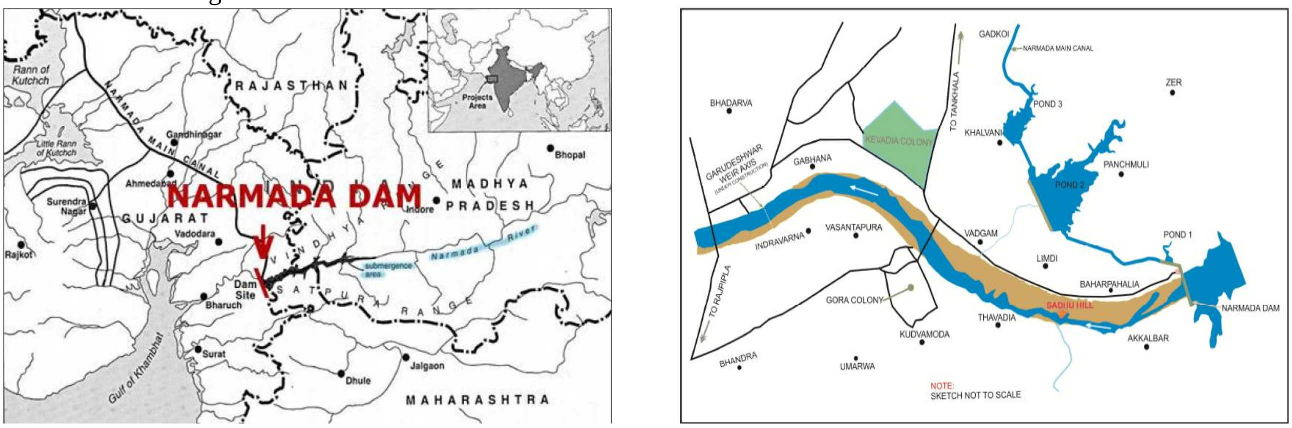
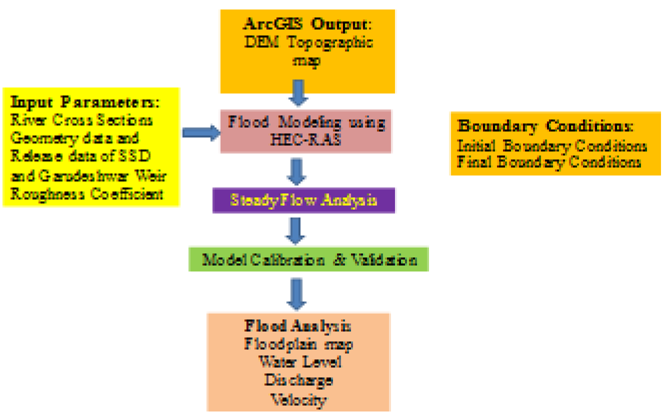


Figure 1. River reach area between SSD and Garudeshwar site
Source : SSNNL

IV. OVERVIEW OF HEC-RAS SOFTWARE

HEC-RAS is an integrated system of software for one-dimensional water surface profile computations and is designed for interactive use in multi-tasking, multiuser network environment. HEC-RAS (Hydrologic Engineering Center River Analysis System) was developed by U.S. Army Corp of Engineers in 1995 which is a part of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers. HEC-RAS is “software that allows you to perform 1-D steady and unsteady flow river hydraulics calculations, sediment transport capacity, uniform flow computations, two- and three-dimensional floodplain mapping and water temperature analysis. The latest HEC-RAS version is available free-of-charge under a public domain license from the website of the U.S. Army Corps of Engineers.

V. METHODOLOGY



VI. HEC-RAS INPUT PARAMETERS

HEC-RAS uses a number of input parameters for hydrodynamic analysis of the river stream channel geometry and water flow. These parameters are used to establish a series of cross-sections along the stream. In each cross-section, the locations of the stream banks are identified and used to divide into segments of left floodway (overbank), main channel and right floodway (overbank). The function of HEC-RAS is to determine water surface elevations at all location of interest. Following are the data required for carrying out 1-D hydrodynamic modelling using HEC-RAS:
- Geometric Data of Cross-sections, Bridge and Weir between SSD and Garudeshwar weir.
- Boundary condition of Downstream reach
- Calibrated Manning 'n' value
- flood summary
- DEM Topographic Map

A. Bridge

Gora Bridge had been situated 6m Downstream of SSD, with total length 740 m and width 7.9 m. It is having 59 pier and height of bottom deck of bridge is 29 m. Due to lower height of deck it is submersible during high flood in river. The necessary data for calculating the weir flow under or above the Bridge is Deck width, weir coefficient, weir submergence, crest shape and Pier data and it is used for schematic diagram, flow calculations and submergence criteria. Schematic diagram of Gora bridge develop in HEC-RAS shown in figure 3.

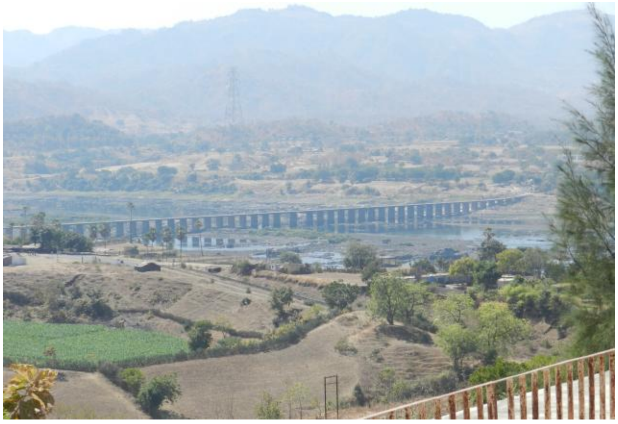


Figure 2. Gora Bridge (source:SSNNL)

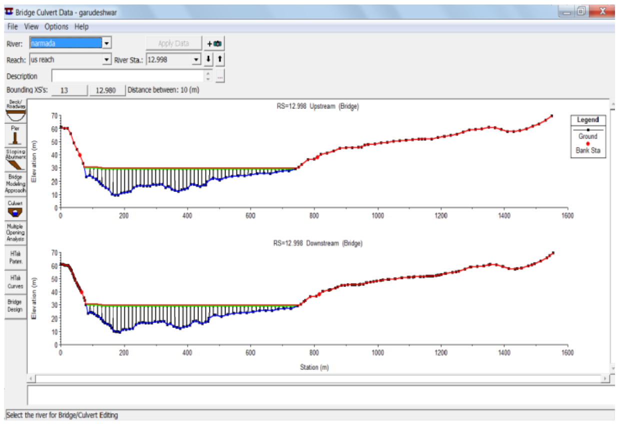


Figure 3. Geometry of Gora Bridge in HEC-RAS

B. Inline Structure Data

Garudeshwar weir is having total length 1187 m out of which 609 m is length of overflow spillway section. Height of overflow section is 31.75 m. Eight sluice gates having maximum opening height 2.5 m are provided on 16 m invert level with 105 Cusecs discharge capacity of each sluice gate. The necessary data for calculating the weir flow is weir width, weir coefficient and crest shape and it is used for schematic diagram, flow calculations and submergence criteria. Schematic diagram of Garudeshwar weir develop in HEC-RAS shown in figure 5.

Figure 4. Under construction Garudeshwar weir site

Figure 5. Geometry of Garudeshwar weir in HEC-RAS

C. Geometric Data

In present study, the geometric data i.e. cross section data between SSD and Garudeshwar weir is entered which includes the cross section of river Narmada and the adjoining contours at that section. Also cross section of approach channel is entered which carrying water to the powerhouse of weir. This data will give the horizontal spread of the water at the particular discharge in the adjoining area. The data to be entered is from upstream to downstream direction of the river in geometric data editor of HEC-RAS as shown in figure 7.

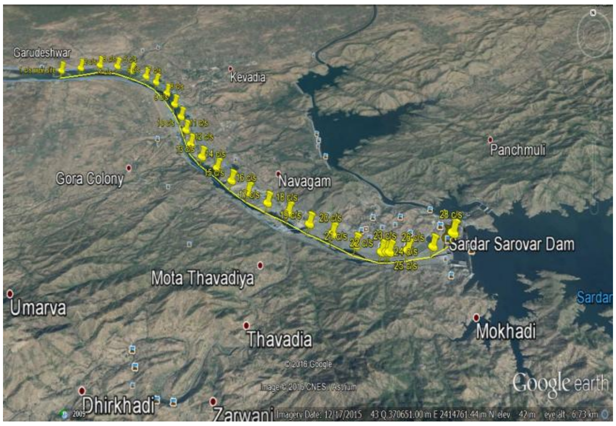


Figure 6. Google earth image of study river reach

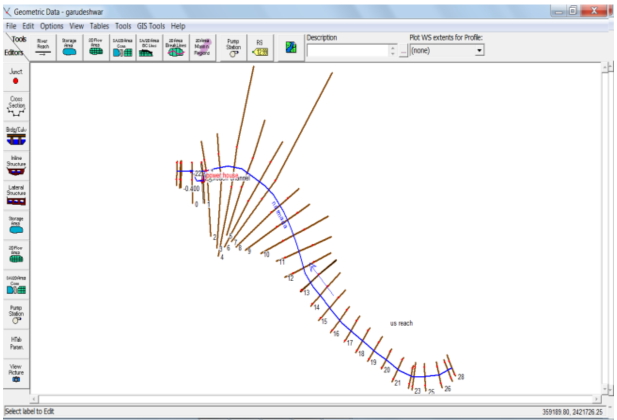


Figure 7. Geometry of study river reach in HEC-RAS

D. Dem Topographic Map

DEM is Required for Flood plain mapping**.** The 30 m DEM to a manageable size to reduce processing time Which is shown in figure 8. DEM (.tif) file converting into the TIN File using Arc GIS which is shown in figure 9.

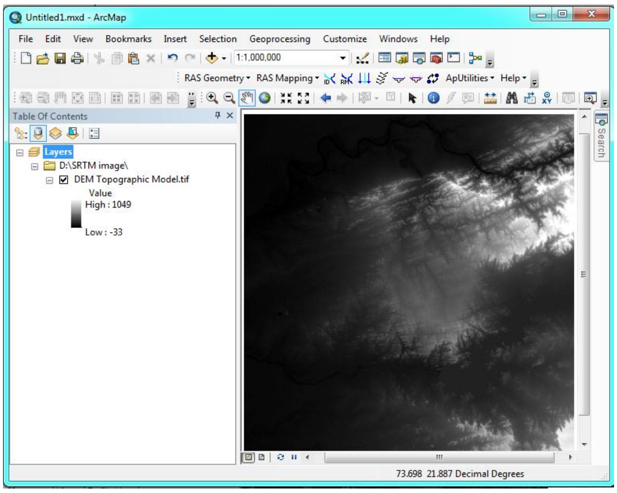


Figure 8. Digital Elevation Model (Raster Image) (https://www.usgs.gov)

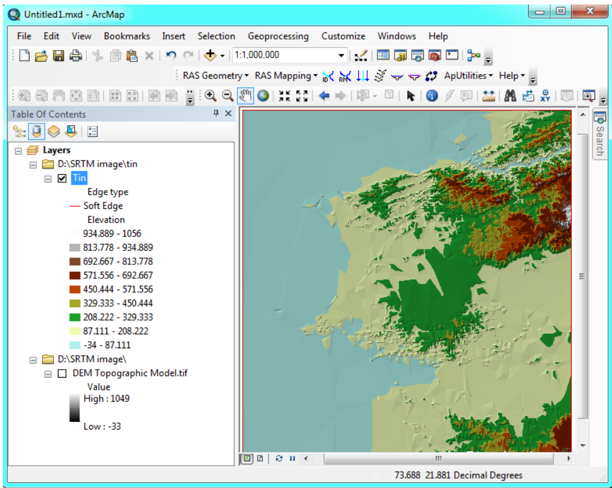


Figure 9. DEM Convert into TIF to TIN file

Flood plain mapping using RAS Mapper in HEC-RAS. It is required DEM (.flt) file to Export DEM (.tin) file in RAS Mapper. DEM(.tin) file convert to DEM(.flt) using Grass GIS which Export in to RAS Mapper is shown in figure 10. Geometry of HEC-RAS is Export on Flt file in RAS mapper is shown in figure 11.

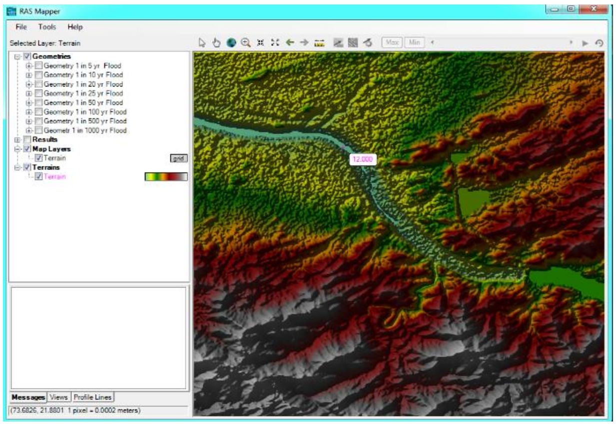


Figure 10. Import DEM (.flt) file into Ras Mapper

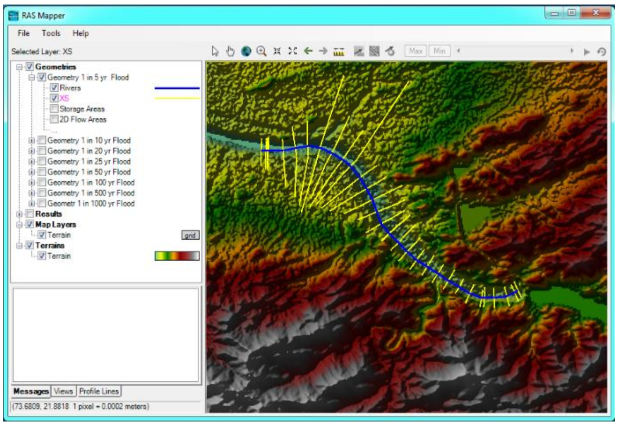


Figure 11. Geometry on DEM(.flt) file in Ras Mapper

E. Entering Flow Data And The Boundary Conditions

The type of flow data entered depends upon the type of analysis to be performed in the project. In present paper, the steady flow analysis is performed to determine the water level for recurrence year flood. The discharge of 1 in 5, 1 in 10, 1 in 20, 1 in 25, 1 in 50 and 1 in 100 considered. It includes the flow data, number of profiles computed and river system boundary conditions.

In present study, Rating curve is used as a Downstream boundary condition in a steady flow analysis is shown in figure 12 to calculate water level for discharge of different Return period. However, steady flow data and gate opening schedule is entered. physical description and required coefficient of gate is entered in HEC-RAS as shown in figure 13. Return period 1 in 5, 1 in 10, 1 in 20, 1 in 25, 1 in 50 and 1 in 100 is considered in the present modelling.

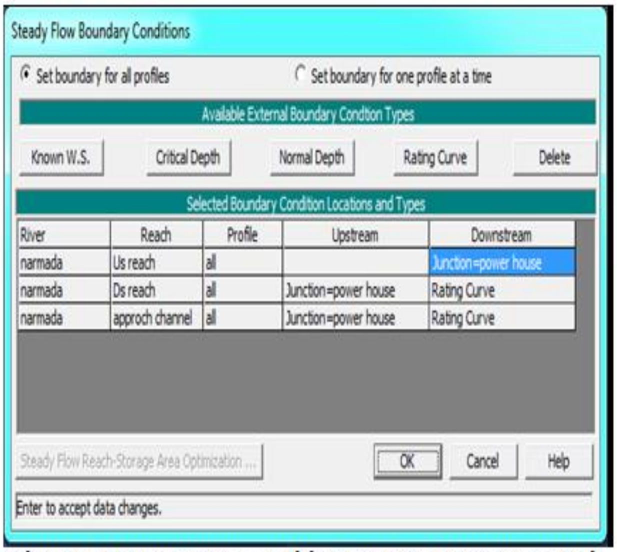


Figure 12. boundary condition for Steady flow analysis

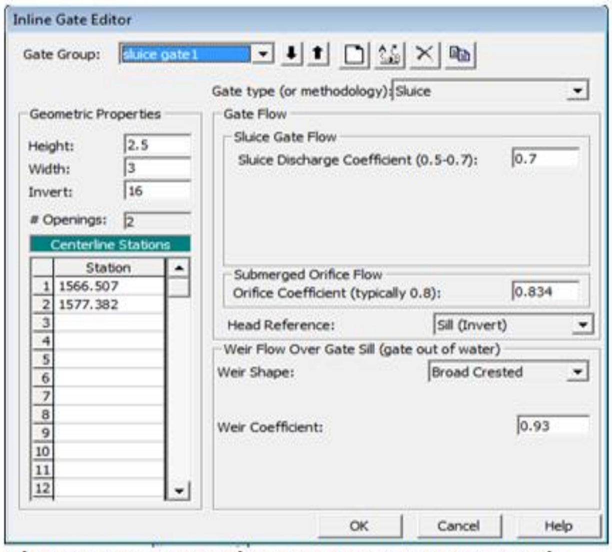


Figure 13. Gate opening data of Garudeshwar weir

VII. RESULTS

After giving compute manning ‘n’ value and other input parameters to the software for the computation, the output in terms of the table and the graphs is obtained which includes:

In the cross section output the value of ground elevation, velocity head, water surface elevation, total velocity, Energy elevation, Energy slope, Top width, Flow area, Froud number, wetted perimeter, Sluice coefficient, Gate discharge etc at the key locations in the river reach are shown in Table 1 ,2 ,3 & 4.

The Profile plot between SSP and Garudeshwar weir for minimum (5 yr) and maximum (100 yr) Recurrence interval is shown in Figure 14 and Figure 15.

The water surface elevations are obtained at the key locations in the river reach. The outputs generated for different return periods at important cross sections are shown in Figure 16 to 19

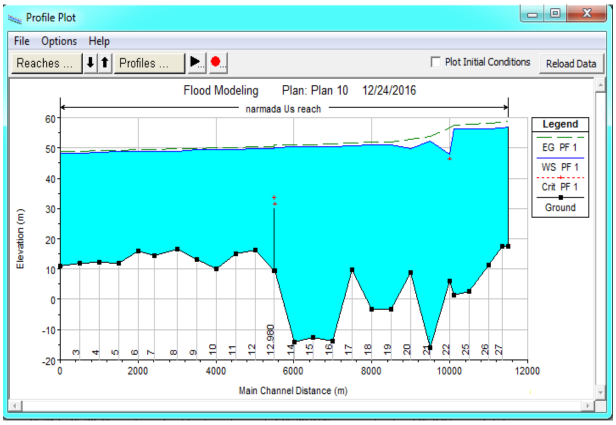


Figure 14. Water profile plot for 1 in 5 Year return period period

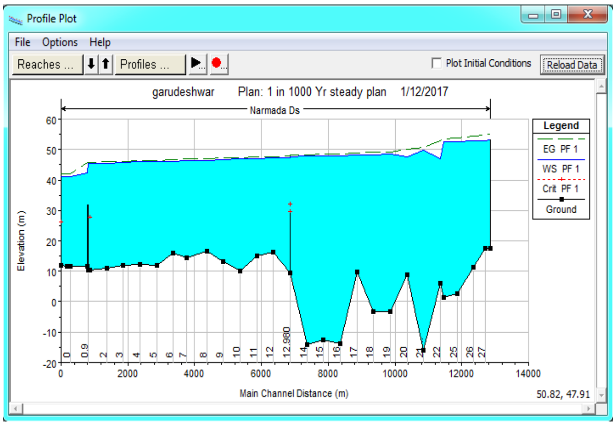


Figure 15. Water profile plot for 1in100 Year return

The profile plot (Figure 14 & 15) displays the water surface profile for the first cross section to the last cross section in the river reach for min (5 yr.) and max (100 yr.) Recurrence interval. The profile plot has been obtained for the mixed flow regime. It is a good way to get a quick overview of the entire study area. Sudden changes to the energy grade line and water surface should be given a special attention.

River profile shows a steep slope between Ch 22 to Ch 21. Also, a reverse slope in the river is observed between Ch 21 to Ch 20. Steep slope at right side is observed at Ch 28 (U/S cross section) and Ch 12.998(bridge site) shown in Figure 16 & 17. Similarly, at Ch 0.9 (weir site) and Ch 0 (D/S cross section) steep slope at left side is observed which is shown in Figure 18 & 19.

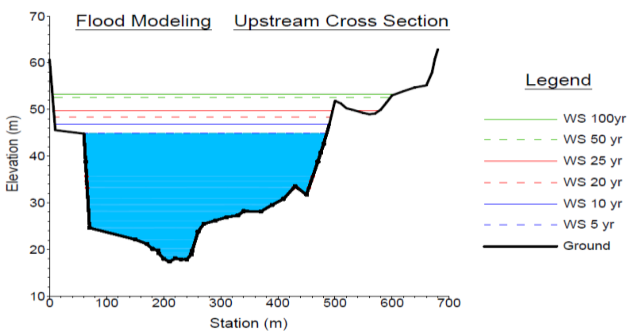


Table 1. Upstream cross section table

River	River Station	Profile	Q Total	Min ch El	W.S.Elev	E.G.Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Froud # chnl
			m^3/s	m	m	m	m/m	m/s	m^2	m	
Narmada	28	5 yr	28880.01	17.39	44.88	45.55	0.000668	3.65	7941.39	429.79	0.27
Narmada	28	10 yr	36035.99	17.39	46.83	47.69	0.000717	4.12	8858.80	480.93	0.29
Narmada	28	20 yr	42285.01	17.39	48.33	49.35	0.000736	4.50	9583.12	484.89	0.30
Narmada	28	25 yr	49105.01	17.39	49.79	51.00	0.000749	4.89	10317.49	532.76	0.32
Narmada	28	50 yr	62843.01	17.39	52.56	54.11	0.000750	5.56	11895.76	591.80	0.34
Narmada	28	100 yr	66610.00	17.39	53.30	54.93	0.000742	5.72	12332.75	601.59	0.35

Figure 16. Water Level at Ch 28 with Floods of Different Return Period

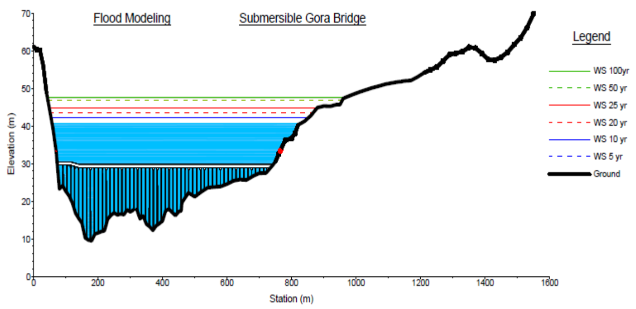


Table 2. Submersible Gora Bridge table

River	River st.	Profile	Q total	E.G.Up	Min El Prs	BR open area	Delta EG	Q Weir	BR Sluice Cof
			m^3/s	m	m	m^2	m	m^3/s	
Narmada	12.998	5 yr	28880.01	40.99	29.58	5323.01	29.81		0.03
Narmada	12.998	10 yr	36035.99	42.51	29.58	5323.01	29.81		0.04
Narmada	12.998	20 yr	42285.01	43.89	29.58	5323.01	29.81	28559.09	0.19
Narmada	12.998	25 yr	49105.01	45.17	29.58	5323.01	29.81	34227.53	0.22
Narmada	12.998	50 yr	62843.01	47.47	29.58	5323.01	29.81	45757.93	0.28
Narmada	12.998	100 yr	66610	48.07	29.58	5323.01	29.81	48948.32	0.29

Figure 17. Water Level at Ch 12.998 with Floods of Different Return Period

Table 3. Garudeshwar Weir cross section table

River	River st.	Profile	Q total	E.G.Elev	W.S.Elev	Q Weir	Q Gates
			m^3/s	m	m	m^3/s	m^3/s
Narmada	0.9	5 yr	28880.01	39.75	39.57	27973.7	906.31
Narmada	0.9	10 yr	36035.99	40.96	40.72	35106.52	929.47
Narmada	0.9	20 yr	42285.01	42.03	41.73	41550.21	734.80
Narmada	0.9	25 yr	49105.01	43.15	42.78	48503.51	601.50
Narmada	0.9	50 yr	62843.01	45.29	44.78	62388.63	454.38
Narmada	0.9	100 yr	66610.00	45.86	45.32	66174.05	435.95

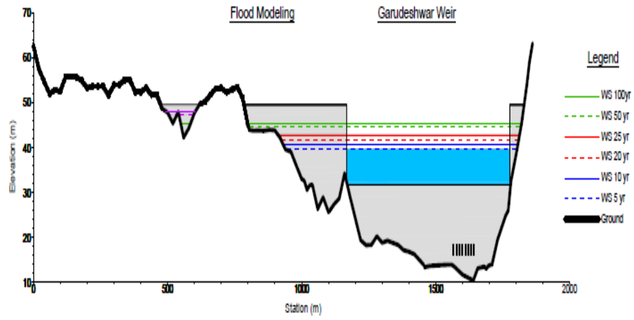


Figure 18. Water Level at Ch 0.9 with Floods of Different Return Period

Table 4. Downstream cross section table

River	River Station	Profile	Q Total	Min ch El	W.S.Elev	E.G.Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Froud # chnl
			m^3/s	m	m	m	m/m	m/s	m^2	m	
Narmada	0	5 yr	28880.01	11.69	30.59	31.21	0.00088	3.5	8253.95	574.38	0.29
Narmada	0	10 yr	36035.99	11.69	32.64	33.38	0.000863	3.81	9447.58	587.63	0.3
Narmada	0	20 yr	42285.01	11.69	34.65	35.45	0.000777	3.97	10638.13	600.33	0.3
Narmada	0	25 yr	49105.01	11.69	36.63	37.5	0.000805	4.13	11897.18	684.87	0.32
Narmada	0	50 yr	62843.01	11.69	40.16	41.11	0.000749	4.33	14582.76	888.53	0.32
Narmada	0	100 yr	66610	11.69	41.04	42.01	0.000695	4.37	15375.12	902.75	0.32

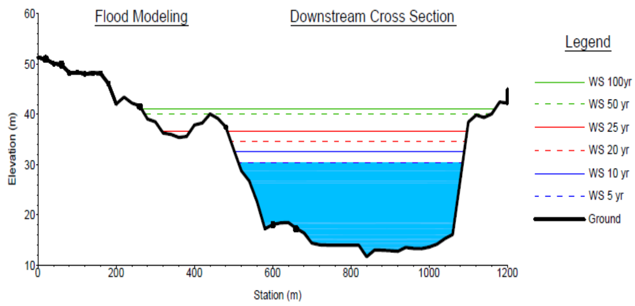


Figure 19. Water Level Ch 0 with Floods of Different Return Period

Flood inundation maps have been generated by exporting GIS data to the HEC-RAS for different recurrence interval. These maps show submergence area in plan/topo maps whichare shown in figure 20 to 25.

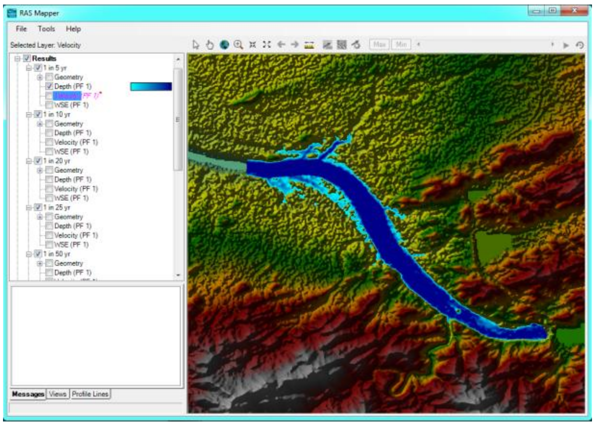


Figure 20. Inundation map having 1 in 5 year Flood

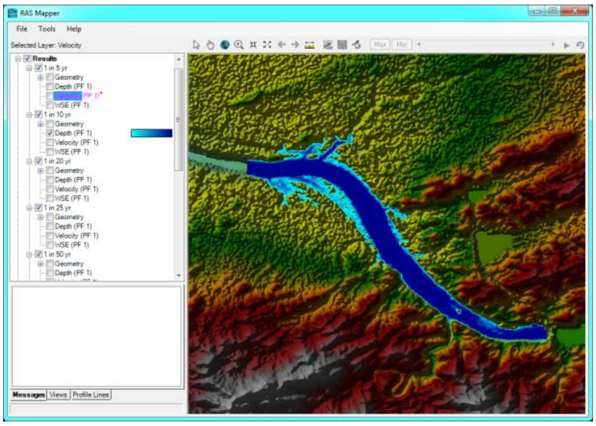


Figure 21. Inundation map having 1 in 10 year Flood

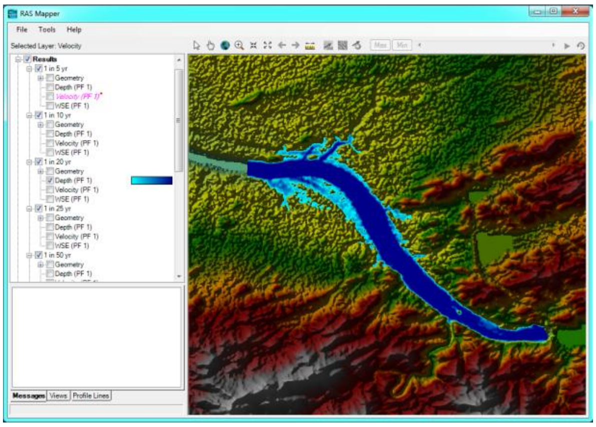


Figure 22. Inundation map having 1 in 20 year Flood

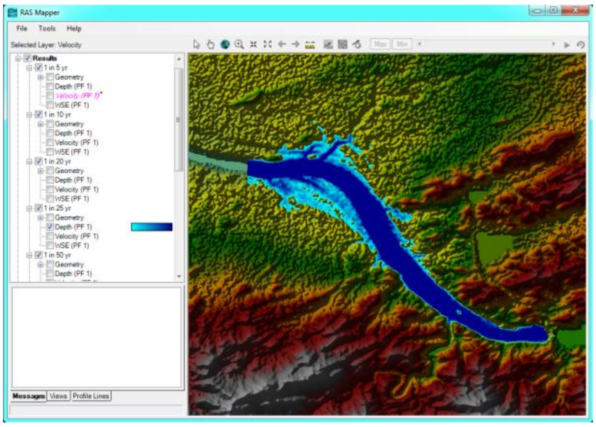


Figure 23. Inundation map having 1 in 25 year Flood

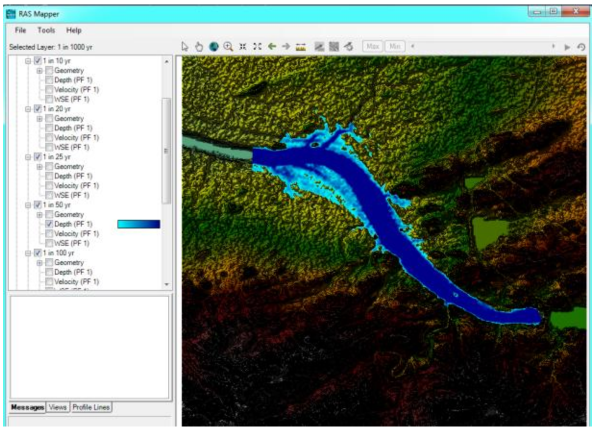


Figure 24. Inundation map having 1 in 50 year Flood

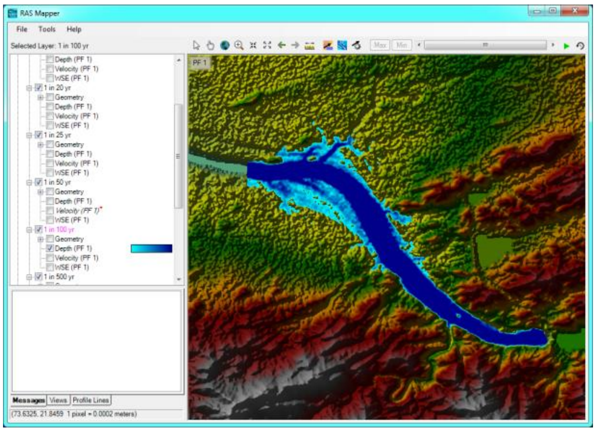


Figure 25. Inundation map having 1 in 100 year Flood

VIII. CONCLUSIONS

1) The HEC-RAS provides the flood profile for the worst flood intensity. This profile will facilitate to adopt appropriate flood disaster mitigation measures.
2) The flood profiles for different flood intensities with different return periods can be plotted at any given cross section of river. Also, such flood profile can be plotted for entire length of river reach.
3) Flood modeling using HEC-RAS is effective tool for hydraulic study, handling of disaster management measures.
4) From undulation maps, submergence area under different flood for various recurrence interval was found

ACKNOWLEDGEMENTS

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