International Journal of Technical Innovation in Morden Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2584
Volume 3, Issue 4, April-2017

FLOOD FORECASTING UPTO GARUDESHWAR WEIR IN LOWER NARMADA BASIN USING HEC-RAS

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Abstract— ***There are many dam construct on Narmada river. Sardar Sarovar Dam(SSD) is One of the largest multipurpose dam on Narmada river. During the monsoon period, when the SSD is full at its Maximum Reservoir Level (MRL) and still the surplus flow is approaching, which is released from the dam to avoid the overtopping. This will result into wastage of valuable water into sea which can be used during low inflow in the dam. Garudeshwar weir has been proposed to construct at the downstream of dam which will create tail storage for running RBPH turbine a thought year. Garudeshwar weir will lead to increase water level due to back water flow flood situation will arise between Garudeshwar weir and SSD.***

With the advent of modern technology, the use of sophisticated software in flood modelling helps in getting an idea of extent of flood at its submergence. Hence, to facilitate in getting an idea of extent of flood and its submergence flood forecasting study at Garudeshwar weir which is 12 km downstream of SSD is consider for the modelling using HEC-RAS software. In this present study river reach of 12 km between weir and SSD including 28 cross sections and submersible bridge is selected for modelling.

Keywords— Flood modelling, Narmada river, Garudeshwar weir, Statue of unity, HEC-RAS, Return Period.

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,

- It is to store the water released from RBPH during peak hour power generation. This water stored in the Garudeshwar weir is then to be pumped back to the SSP reservoir during off peak hours.
- 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 for getting an idea of extent of water and its submergence in the study area.

II. OBJECTIVE OF STUDY

To study the HEC-RAS (v5.3) software.
To generate the River cross section at the key locations in between SSD and Garudeshwar weir.
To study peak discharge of different recurrence interval release from SSD to Garudeshwar weir.
To develop a Flood Forecasting Model in HEC-RAS.
To predict the water levels and velocity for discharge of different recurrence interval using the Flood Forecasting Model.

III. STUDY AREA

The study reach, located between 21.50'N ,73.45' E (SSD) and 21052'57" N, 73039'35" 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 and proposed statue of unity at middle reach and downstream reach is proposed Garudeshwar weir are shown in fig. 1.

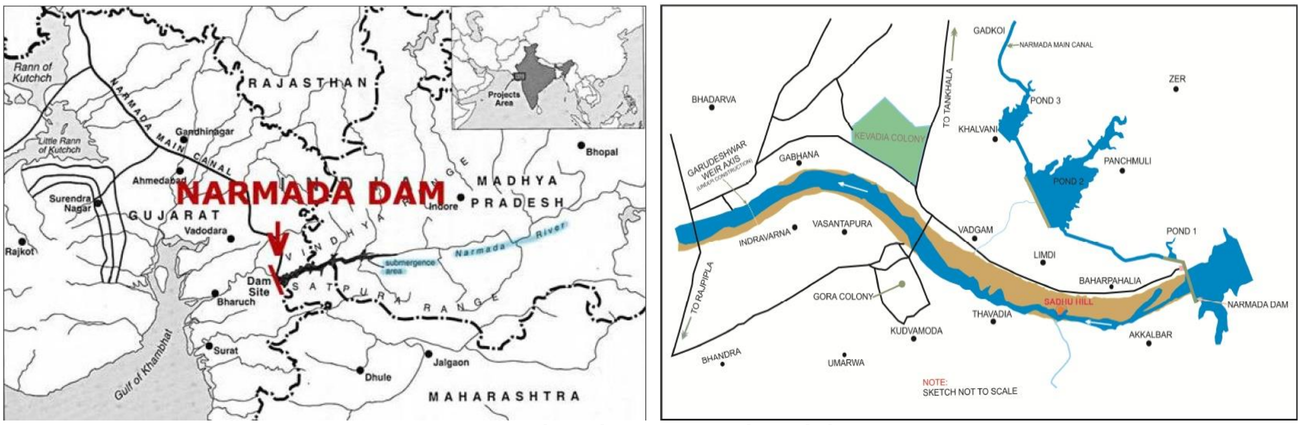


Fig. 1 River reach area between SSD and Garudeshwar site (Source : SSNNL)

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 Centre 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 and water temperature analysis.

1) *STEADY FLOW WATER SURFACE PROFILE*: This component of the modelling system is intended for calculating water surface profiles for steady gradually varied flow. The system can handle a single river reach, a dendritic system, or a full network of channels. The steady flow component is capable of modelling subcritical, supercritical, and mixed flow regime water surface profiles. The basic computational process is founded on the outcome of one dimensional energy equation. Energy losses are calculated by friction (Manning’s equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions). The effects of various obstructions such as bridges, culverts, dams, weirs, and other structures in the flood plain may be considered in computations.

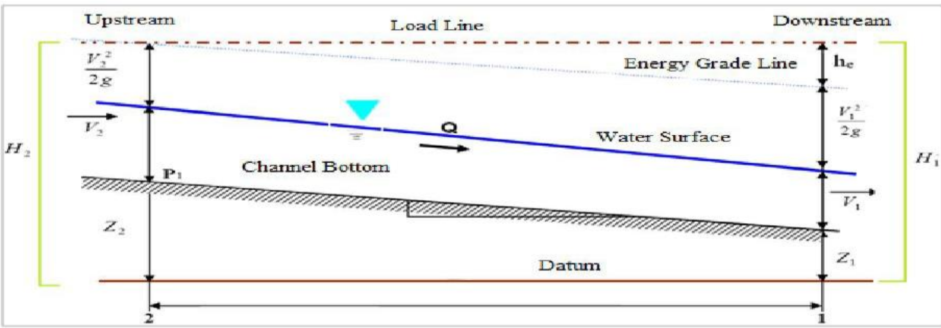
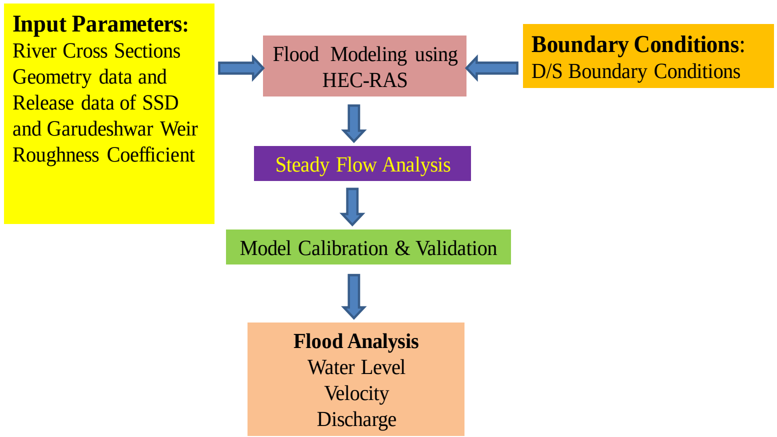


Fig. 2 Energy equation between two spots

$$Z_2 + Y_2 + \frac{\alpha_2 V_2^2}{2g} = Z_1 + Y_1 + \frac{\alpha_1 V_1^2}{2g} + h_e$$

Where,
Z1, Z2 = elevations of the main channel inverts in m;
Y1, Y2 = depths of water at cross sections in m;
V1, V2 = averages velocities (total discharge/total flow area) in m/s;
α1, α2= velocity weighting coefficients;
g = gravitational acceleration in m/s2;
he = energy head loss in (m);

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 for different recurrence interval

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 develops in HEC-RAS shown in fig. 4.

Fig. 3 Gora Bridge (source : /www.tripadvisor.in)

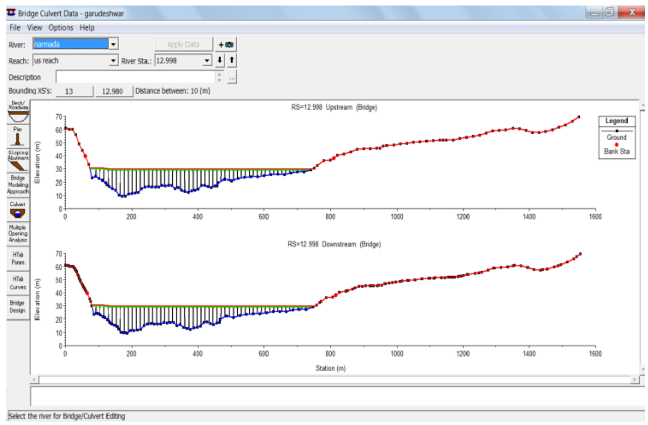


Fig. 4 Geometry of Gora Bridge in HEC-RAS

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 fig. 6.

Fig. 5 Under construction Garudeshwar weir site

Fig. 6 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. 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 fig. 8.

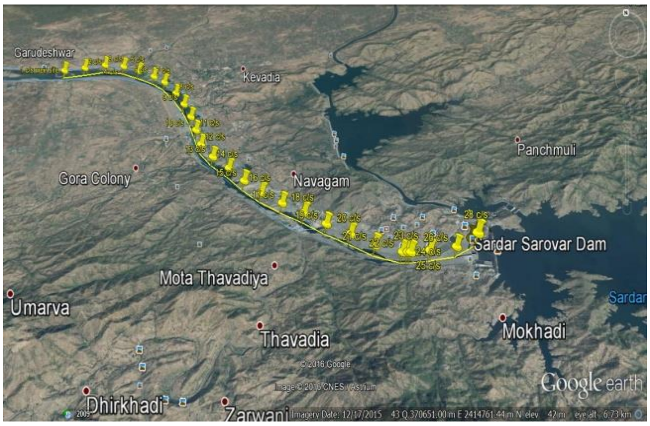


Fig. 7 Google earth image of study river reach

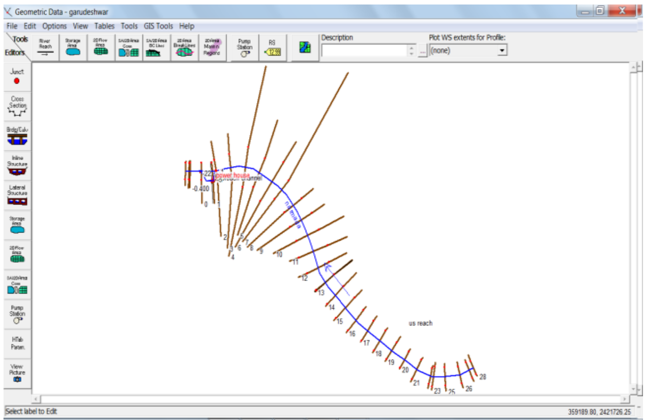


Fig. 8 Geometry of study river reach in HEC-RAS

D. 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 fig. 9 to calculate water level for discharge of different recurrence interval. 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 fig. 10. 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.

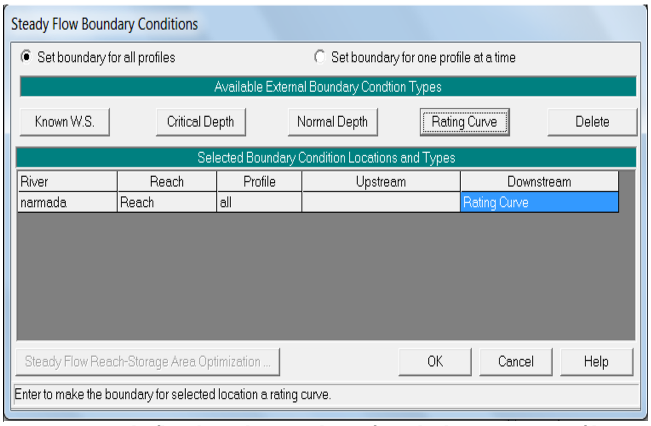


Fig. 9 Steady flow boundary condition for calculating water profile

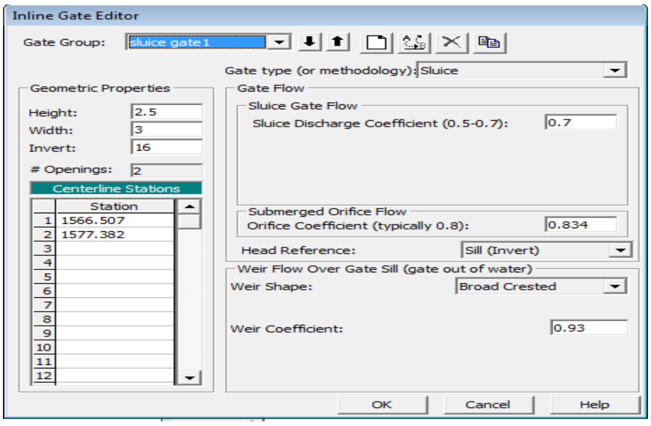


Fig. 10 Gate opening data of Garudeshwar weir

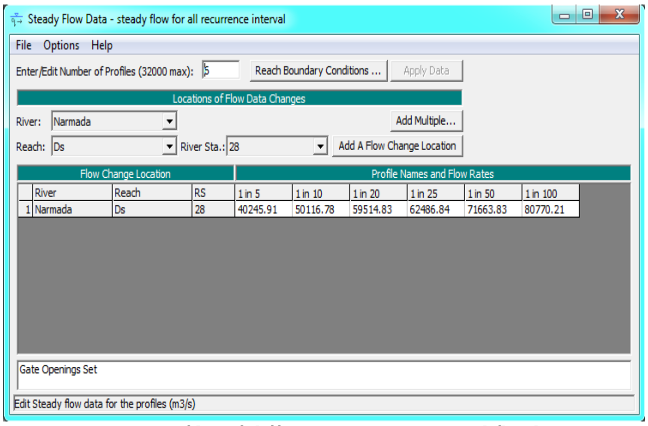


Fig. 11 Profiles of different recurrence interval floods

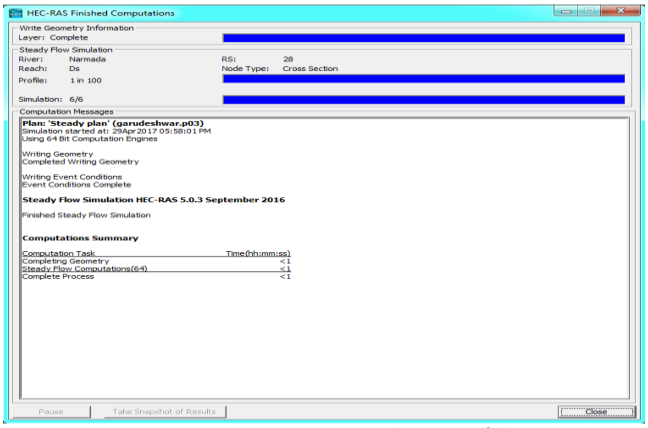


Fig. 12 Run HEC-RAS model successfully

VII. RESULTS

In present study, Model is calibrated and validated against Manning's Roughness of the river reach. The manning's 'n' value used for Simulation of model are justified as the prototype river bed condition indicated presence of rock outcrops, rocky boulders, vegetation, etc. in the river regime. This also matched with the 'n' values assigned for different river bed conditions as mentioned in the book "open channel Hydraulics" by Chow Ven. Te. (1959).

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, 5.

The Water and Velocity Profile plot between SSP and Garudeshwar weir for different Recurrence interval is shown in Fig. 13 and Fig. 14.

The water surface elevations are obtained at the key locations in the river reach. The outputs generated for different recurrence interval at important cross sections are shown in Fig. 15 to 19

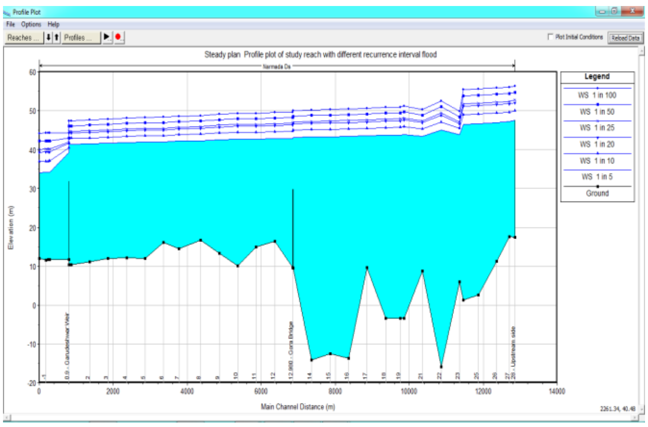


Fig. 13 Water profile plot for different recurrence interval

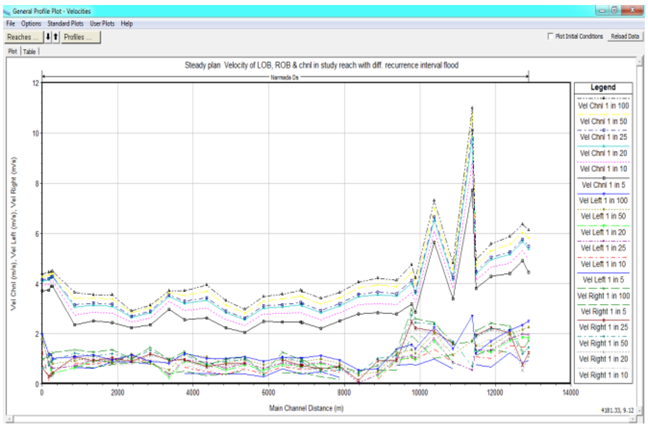


Fig. 14 Velocity profile plot for different recurrence interval

The profile plot (Fig. 13 & 14) displays the water surface and velocity profile for different Recurrence interval. The profile plot has been obtained for the subcritical flow regime. It is a good way to get a quick overview of the entire study area. Sudden changes to the water surface and Velocity 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.

Individual cross section shows a Steep slope at right side is observed at Ch 28 (U/S cross section) and Ch 12.998(bridge site) shown in Fig. 15 & 17. Similarly, at Ch 0.9 (weir site) and Ch -2 (D/S cross section) steep slope at left side is observed which is shown in Figure 18 & 19.

Water levels in the river near the proposed statue of unity site is shown in Fig. 16.

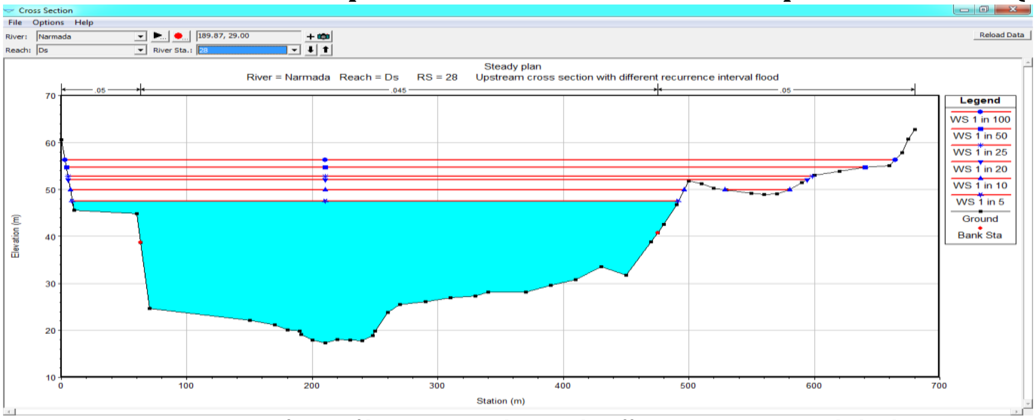


Fig. 15 Water Surface Profile at U/S C/S (Ch 28) with Different recurrence interval Floods

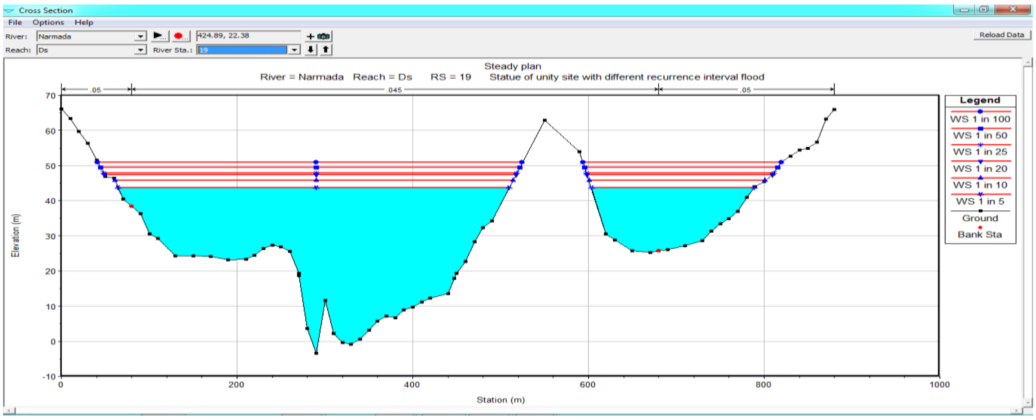


Fig. 16 Water Surface Profile at statue of unity C/S (Ch 19) with Different recurrence interval Flood

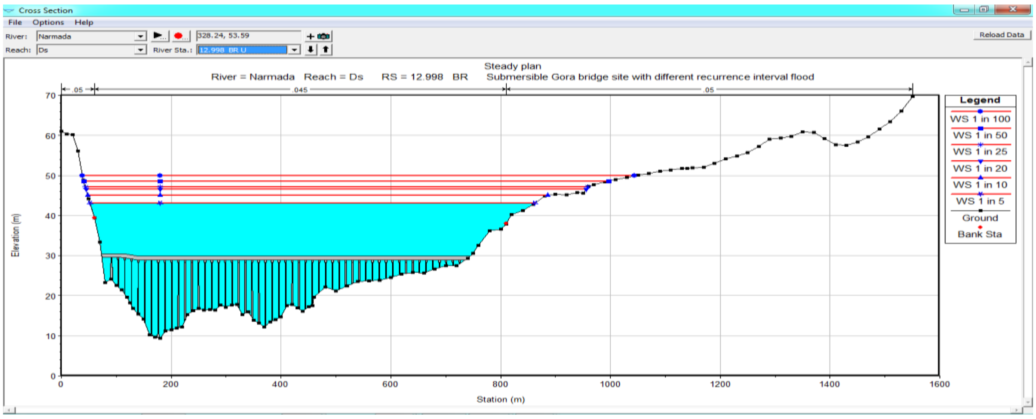


Fig. 17 Water Surface Profile at Gora Bridge (Ch 12.998) with Different recurrence interval Floods

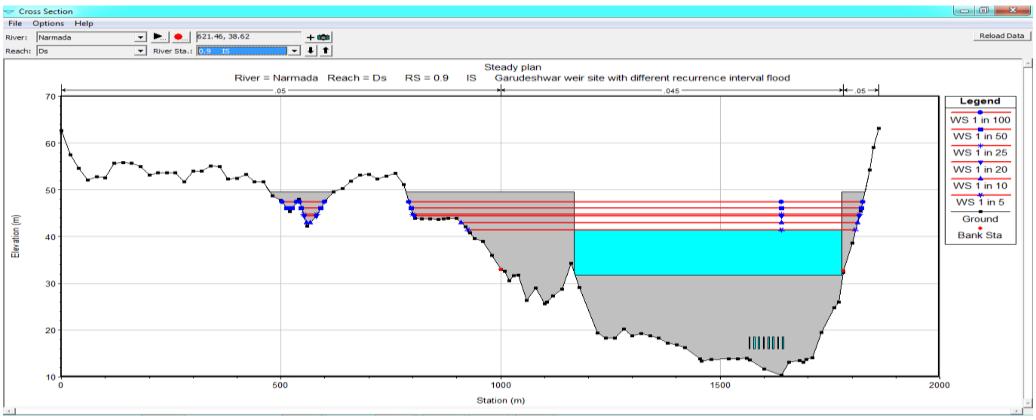


Fig. 18 Water Surface Profile at Garudeshwar Weir (Ch 0.9) with Different recurrence interval Floods

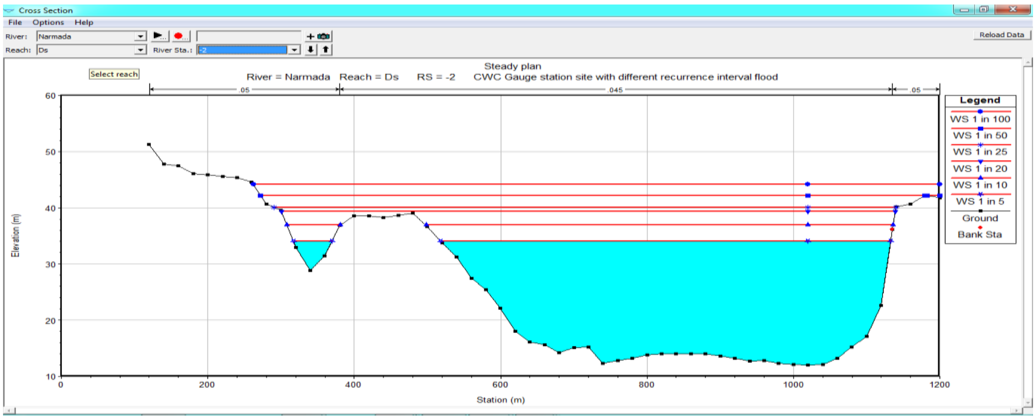


Fig. 19 Water Surface Profile at D/S C/S (Ch -2) with Different recurrence interval Floods

TABLE 1
DETAIL OUTPUT OF U/S C/S (CH 28) FOR DIFFERENT RECURRENCE INTERVAL FLOODS

Profile Output Table - Standard Table 1

HEC-RAS Plan: Steady Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Vel Left (m/s)	Vel Right (m/s)
Narmada	Ds	28	1 in 5	40245.91	17.39	47.56	48.56	0.000679	4.44	9212.13	482.87	0.30	0.91	1.14
Narmada	Ds	28	1 in 10	50116.77	17.39	49.98	51.21	0.000733	4.95	10417.29	540.68	0.32	1.45	1.22
Narmada	Ds	28	1 in 20	59514.82	17.39	52.12	53.56	0.000769	5.36	11631.16	588.64	0.33	1.84	1.11
Narmada	Ds	28	1 in 25	62486.84	17.39	52.77	54.27	0.000776	5.47	12018.07	593.25	0.34	1.95	1.25
Narmada	Ds	28	1 in 50	71663.82	17.39	54.72	56.38	0.000794	5.80	13210.03	636.33	0.34	2.26	1.46
Narmada	Ds	28	1 in 100	80770.21	17.39	56.34	58.19	0.000824	6.13	14276.35	661.46	0.35	2.52	1.72

Total flow in cross section.

TABLE 2
DETAIL OUTPUT OF STATUE OF UNITY C/S (CH 19) FOR DIFFERENT RECURRENCE INTERVAL FLOODS

Profile Output Table - Standard Table 1

HEC-RAS Plan: Steady Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Vel Left (m/s)	Vel Right (m/s)
Narmada	Ds	19	1 in 5	40245.91	-3.36	43.76	44.25	0.000339	3.18	13232.08	631.47	0.21	0.79	1.92
Narmada	Ds	19	1 in 10	50116.77	-3.36	45.73	46.37	0.000404	3.63	14497.07	653.42	0.23	1.05	2.17
Narmada	Ds	19	1 in 20	59514.82	-3.36	47.42	48.20	0.000460	4.01	15620.89	679.60	0.25	1.05	2.41
Narmada	Ds	19	1 in 25	62486.84	-3.36	47.92	48.75	0.000476	4.13	15965.07	684.09	0.25	1.13	2.49
Narmada	Ds	19	1 in 50	71663.82	-3.36	49.46	50.42	0.000521	4.45	17029.00	696.86	0.27	1.36	2.74
Narmada	Ds	19	1 in 100	80770.21	-3.36	50.92	52.00	0.000559	4.74	18054.83	708.95	0.28	1.57	2.96

Total flow in cross section.

TABLE 3
DETAIL OUTPUT TABLE OF BRIDGE C/S (CH 12.998) FOR DIFFERENT RECURRENCE INTERVAL FLOOD

Profile Output Table - Bridge Only

HEC-RAS Plan: Steady Locations: User Defined

River	Reach	River Sta	Profile	E.G. US. (m)	Min El Prs (m)	BR Open Area (m2)	BR Open Vel (m/s)	Q Total (m3/s)	Min El Weir Flow (m)	Q Weir (m3/s)	Delta EG (m)	BR Sel Method
Narmada	Ds	12.998	1 in 5	43.40	29.58	5323.01	2.50	40245.91	29.81	26930.46	0.19	Press/Weir
Narmada	Ds	12.998	1 in 10	45.37	29.58	5323.01	2.82	50116.77	29.81	35086.14	0.23	Press/Weir
Narmada	Ds	12.998	1 in 20	47.07	29.58	5323.01	3.09	59514.82	29.81	43050.94	0.26	Press/Weir
Narmada	Ds	12.998	1 in 25	47.59	29.58	5323.01	3.17	62486.84	29.81	45603.35	0.27	Press/Weir
Narmada	Ds	12.998	1 in 50	49.16	29.58	5323.01	3.40	71663.82	29.81	53554.20	0.30	Press/Weir
Narmada	Ds	12.998	1 in 100	50.66	29.58	5323.01	3.60	80770.21	29.81	61604.75	0.33	Press/Weir

Total flow in cross section.

TABLE 4
DETAIL OUTPUT TABLE OF WEIR C/S (CH 0.9) FOR DIFFERENT RECURRENCE INTERVAL FLOODS

Profile Output Table - Inline Structure

File Options Std. Tables Locations Help

HEC-RAS Plan: Steady Locations: User Defined — Reload Data

River	Reach	River Sta	Profile	E.G. Elev (m)	W.S. Elev (m)	Q Total (m3/s)	Q Weir (m3/s)	Gate Area (m2)	Gate Invert (m)	Gate Open Ht (m)	Gate Submerg	Q Gates (m3/s)
Narmada	Ds	0.9	1 in 5	41.69	41.41	40245.91	39479.36	7.50	16.00	2.50	0.71	766.56
Narmada	Ds	0.9	1 in 10	43.32	42.94	50116.77	49547.64	7.50	16.00	2.50	0.77	569.13
Narmada	Ds	0.9	1 in 20	44.80	44.33	59514.82	59050.28	7.50	16.00	2.50	0.82	464.54
Narmada	Ds	0.9	1 in 25	45.26	44.75	62486.84	62037.64	7.50	16.00	2.50	0.83	449.20
Narmada	Ds	0.9	1 in 50	46.69	46.10	71663.82	71254.87	7.50	16.00	2.50	0.86	408.95
Narmada	Ds	0.9	1 in 100	48.09	47.43	80770.21	80401.70	7.50	16.00	2.50	0.88	368.50

Energy gradeline for given WSEL.

TABLE 5
DETAIL OUTPUT TABLE OF D/S C/S (CH -2) FOR DIFFERENT RECURRENCE INTERVAL FLOODS

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Steady Locations: User Defined — Reload Data

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Vel Left (m/s)	Vel Right (m/s)
Narmada	Ds	-2	1 in 5	40245.91	12.03	34.01	34.71	0.000618	3.71	10965.97	667.49	0.28	1.00	
Narmada	Ds	-2	1 in 10	50116.77	12.03	36.92	37.70	0.000594	3.93	12968.72	710.94	0.28	1.33	0.21
Narmada	Ds	-2	1 in 20	59514.82	12.03	39.35	40.19	0.000683	4.10	14826.17	838.38	0.30	1.79	0.59
Narmada	Ds	-2	1 in 25	62486.84	12.03	40.07	40.93	0.000663	4.14	15436.42	849.22	0.30	1.76	0.67
Narmada	Ds	-2	1 in 50	71663.82	12.03	42.17	43.08	0.000616	4.27	17299.85	924.21	0.29	1.85	0.63
Narmada	Ds	-2	1 in 100	80770.21	12.03	44.18	45.14	0.000575	4.37	19174.06	937.84	0.29	1.99	0.98

Total flow in cross section.

VIII. CONCLUSIONS

- The HEC-RAS provides the flood profile for the worst flood intensity. This profile will facilitate to adopt appropriate flood disaster mitigation measures.
- 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.
- Flood modeling using HEC-RAS is effective tool for hydraulic study, handling of disaster management measures.
- Inundation maps can be prepared by using HEC-RAS result so that submergence area can be found.

ACKNOWLEDGEMENTS

The execution of this paper has been possible due to help and guidance of Dr. Suvarna. D. Shah and of Superintending Engineer of SSNNL are thankfully acknowledged. The authors are thankful to Rajendra R Shah. Due to her constant help and association in field work and soft computing, this work has taken a shape.

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