FLOOD MODELLING OF RIVER AMBICA USING HEC-RAS

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Abstract : A natural hazard like flood is being an integral part of civilization since ages, turning out to be a disaster for society. It results in damage to human life, deterioration of environment and infrastructure facilities through inundation of low lying areas. In some of the last decades frequent flooding condition have been generated in Ambica river and major flood event has occurred in the years of 1981, 1984, 1994, 1997, 2001, 2003, 2004, 2006, 2013 & 2014. However Navsari city is located at the bank of river Ambica, which is being frequently affected by floods and the maximum discharge, was observed at Gadat i.e. 2989 cumec in the year 2004. In order to know the submergence of area in nearby location of Ambica River due to extreme flood, present study aims to prepare a 1D-Hydrodynamic model by using HEC-RAS. This model will analyse the steady flow of river in 1D and based on this study it is strongly recommended to construct flood wall or either increase the height of the existing wall at a particular cross-section.

***IndexTerms* - Ambica River, Flood modelling, HEC-RAS-1D, ArcGIS, steady flow.**

1. Introduction:

India is riverine country which is very much prone to flooding, where flooding occurrences are most significant natural hazards that cause loss of properties and lives, especially in the less heighted region. Flood is excess of water outside its normal course. Flash flood, river flood, coastal flood, urban flood and flooding due to the opening or breaking of dam or reservoir are the various types of flood.

Due to excessive human interference, rainfall, snowfall and tsunami increases the risk of flooding. The outcome of flood, when a stream is flushed out, with too much water encloses and overflow nearby areas. However, various methods of flood mitigation have been applied such as structural and non-structural methods. In which structural measures includes Channel Improvement, Diversion of Flood Waters and Reservoirs whereas non-structural measures includes flood forecasting and warning, mass evacuation, watershed management etc. One dimensional (1D) river flow modelling and computation of flood inundation became easier after the rapid advancement in computer technology. Hydraulic modelling and flood overflow mapping are performed in order to predict important data from a flood event involving the scope of submergence and water surface elevation at that particular part of river Ambica which is located in Navsari. This paper presents a model developed for the Ambica river from Kachh oli to Dhamdachha village using a HEC-RAS to predict flood levels along the river.

2. Aim of the study:

The aim of this study is to obtain flood inundated area near river Ambica basin using hydrological model.

3. Objectives of study:

- To evaluate the water heights at various section.
- To simulate the critical situation of flood.
- To enumerate the cross section by using HEC-RAS.
- To allocate preventive measures so flood risk can be prevented.

4. Study area and data collection:

4.1. Study Area:

The river Ambica rises from Saputara hills and meets in Arabian Sea. The catchment area of Ambica basin is lying in Gujarat and Maharashtra. The total length of the river from its origin to Arabian Sea is 164 km. The river basin lies between 20°31´ - 20°57´ N latitudes and 72°48´ - 73°52´ E longitudes. The total catchment area of the basin is 2830 km², of which 102 km² lies in Maharashtra and the remaining 2583 km² in Gujarat. Khapri, Valam, Kaveri and Kharear are important tributaries of the Ambica River.

The study reach with 133 cross-section details. Following are the details of study area: Length of river reach is 4 km (4000 m), Red lines indicates cross-section of river reach with the interval of 30 meters.

4.2. Data collection:

The Navsari Drainage department provided the topographic data of the study reach in the form of contour and Cross-sections of reach in the Auto CAD (.dwg file) format. The cross-section data at 30 m intervals exceeding over a length of 4000 m has been provided. Data includes the station and elevation coordinates, reach length and channel width at the section. It also include past flood peak discharge data. The Central Water Commission (CWC) Surat, provided river discharge data and water surface elevation measured at Gadat Gauge station.

5. Overview of HEC-RAS:

HEC-RAS is open source software which is designed by U.S. Army Corps of Engineers in 1995. Hydraulic models were built using the software HEC-RAS (Hydrologic Engineering Centre-River Analysis System). HEC-RAS is based on the U.S. army team of engineers. HEC-RAS water surface profile model used for modeling. The model contains,

- A steady and unsteady flow modeling.
- The unsteady flow element can be used to performed subcritical, supercritical and mixed pattern (subcritical, supercritical, hydraulic jumps and drawdowns) calculations in the unsteady flow computations.
- 1 dimensional model in which river and floodplain flow is modeled in 1D.
- Where as in a combined 1D-2D model, river flow is modeled in 1D and floodplain flow is modeled in 2D
- In a refined 2D model, river and floodplain flow is modeled in 2D.

It require three types of component for every HEC-RAS project namely the geometry data, flow data and plan data. The geometry data includes description of the size, shape and connectivity of stream cross-section. Likewise the flow data consists discharge rates. Finally, plan data contains information relevant to the run specifications of the model, including a detail of the flow effect.

The river and the surrounding floodplains are represented by a set of cross sections, in which the flow is modeled only in 1D models. HEC-RAS hydraulic model has been widely used in connection with Environmental System Research Institute (ESRI) ArcGIS software. The HEC has developed an ArcGIS extension called HEC-GeoRAS, which was specifically designed to process geospatial data for use with HEC-RAS. The HEC-GeoRAS software allows to write geometric data to a file in the required format for HEC-RAS.

HEC-RAS uses the energy equation to compute the water surface profiles between one cross-sections to next cross-section. The energy equation is written as:

$$Z_2 + Y_2 + \frac{a_2 v_2^2}{2g} = Z_1 + Y_1 + \frac{a_1 v_1^2}{2g} + h_e$$

Where Z_1, Z_2 = elevations of the main channel
Y_1, Y_2 = depths of water at adjacent cross-sections
V_1, V_2 = velocities (total discharge/ total flow area)
a_1, a_2 = velocity weighting coefficients
g = gravitational acceleration
h_e = energy head loss

The energy head loss term is defined in the form of Equation,

$$h_e = L\bar{S_f} + C\left|\frac{a_2 v_2^2}{2g} - \frac{a_1 v_1^2}{2g}\right|$$

L = discharge weighted reach length,
$\bar{S_f}$ = friction slope between cross-sections, and
C = expansion or contraction loss coefficient

The representative distance weighted reach length are defined as:

$$L = \frac{L_{lob}\bar{Q}_{lob} + L_{ch}\bar{Q}_{ch} + L_{rob}\bar{Q}_{rob}}{\bar{Q}_{lob} + \bar{Q}_{ch} + \bar{Q}_{rob}}$$

Where L_{lob}, L_{ch}, L_{rob} = cross-section reach lengths for flow in the left over-bank, main channel, and right over-bank, respectively

$\bar{Q}_{lob}, \bar{Q}_{ch}, \bar{Q}_{rob}$ = arithmetic average of the flows between sections for the left over-bank, main channel, and right over-bank, respectively

For situations when the flow may be rapidly varied, the momentum equation is used to solve the water surface profiles. These situations includes hydraulics of bridges, river confluences, and mixed flow regimes such as hydraulic jumps. The momentum equation used in HECRAS is shown in Equation

$$\frac{Q_2\beta_2}{gA_2}+A_2\bar{Y}_2+\left(\frac{A_1+A_2}{2}\right)LS_0-\left(\frac{A_1+A_2}{2}\right)L\bar{S}_f=\frac{Q_1\beta_1}{gA_1}+A_1\bar{Y}_1$$

Where β = momentum coefficient that accounts for a varying velocity distribution in irregular channels
Y1, Y2 = depths measured from the water surface to the centroid of the cross-sectional area at CS1 and CS2
Q1, Q2 = discharge at locations CS1 and CS2
A1, A2 = wetted area of the cross-section at locations CS1 and CS2
L = distance between sections CS1 and CS2 along the channel
S*o* = slope of the channel based on mean bed elevations, and
f = slope of the energy grade line

Limitations in the HEC-RAS steady flow simulation include the assumptions that the flow is steady, the flow is gradually varied, the flow is one-dimensional, and the river channels have small slopes.

6. HEC-RAS Input Parameters:

6.1. Geometric Data:

The basic geometric data consists of establishment of the river reach which is connected (River System Schematic). The geometric data in the form of cross section data, reach lengths, friction parameter in the form of Manning's n values and contraction/expansion coefficient across each cross-section. These data and other relevant data such as contour map of study area are provided by Navsari Drainage Department.

6.2. Cross sectional Data:

Boundary geometry for analysis of flow in river reach is specified in terms of ground surface profiles (cross-sections) and the measure distance between them (reach length). Cross sections should be perpendicular to the anticipated flow lines and should extend across the entire flood plain. Cross sections are required throughout the locations of a stream reach and at locations where changes occur in discharge, slope, shape, or roughness, at locations where levees begin or end, bridges, weirs, etc.

6.3. Steady flow Data:

Steady flow data are required to perform steady water surface profile calculation. Steady flow data consisting flow regime, boundary conditions and discharge information. Flow regime conditions are assumed that subcritical flow for upstream side & supercritical flow for downstream side. Boundary conditions are necessary to establish the starting water surface at the ends of the river system (upstream and downstream). The upstream boundary condition and downstream boundary condition should be known water surface elevation, critical depth, Normal Depth, or Rating Curve.

6.4. Flood Summary:

For evaluation of flood performance, past flood data collected from the SWDC, Gandhinagar were used. Major flood events took place in the year 1981, 1984, 1994, 1997, 2001, 2003, 2004, 2006, 2013 and 2014.

7. Methodology:

The steps required for steady flow simulation in HEC-RAS are as follows:

- Create a new HEC-RAS project
- Enter geometric data and add all the cross sections
- Entering the river and reach information, the right and the left banks of the cross sections, distance of the main channel and the left and the right bank from the downstream section, Manning's roughness coefficient in the main channel and the left and the right banks are "0.030".
- River network geo-referenced using HEC-GeoRAS and GIS.
- After adding all data and geo-referencing the river network we get Geometric cross-sections (Fig. 2) in HEC-RAS which is same as that collected from Navsari Drainage Department.
- Once the geometric data is entered, the necessary steady flow data for different flood peak discharge can be entered subsequently. Steady flow data consists of the number of profiles are 5 and the flow data inputted PF 1 as 11000 m^3/s, PF 2 as 6500 m^3/s, PF 3 as 5000 m^3/s, PF 4 as 3200 m^3/s, PF 5 as 1765 m^3/s and PF 6 as 930 m^3/s.
- Determine the boundary conditions in steady flow window (There are four boundary conditions such as rating curve, normal depth, critical depth and water surface level. Here, downstream boundary condition of normal depth 0.00418 (river bed slope) is considered).
- Finally, after entering all of the data, open run windows and the simulation was carried out and the water surface profiles were extracted.

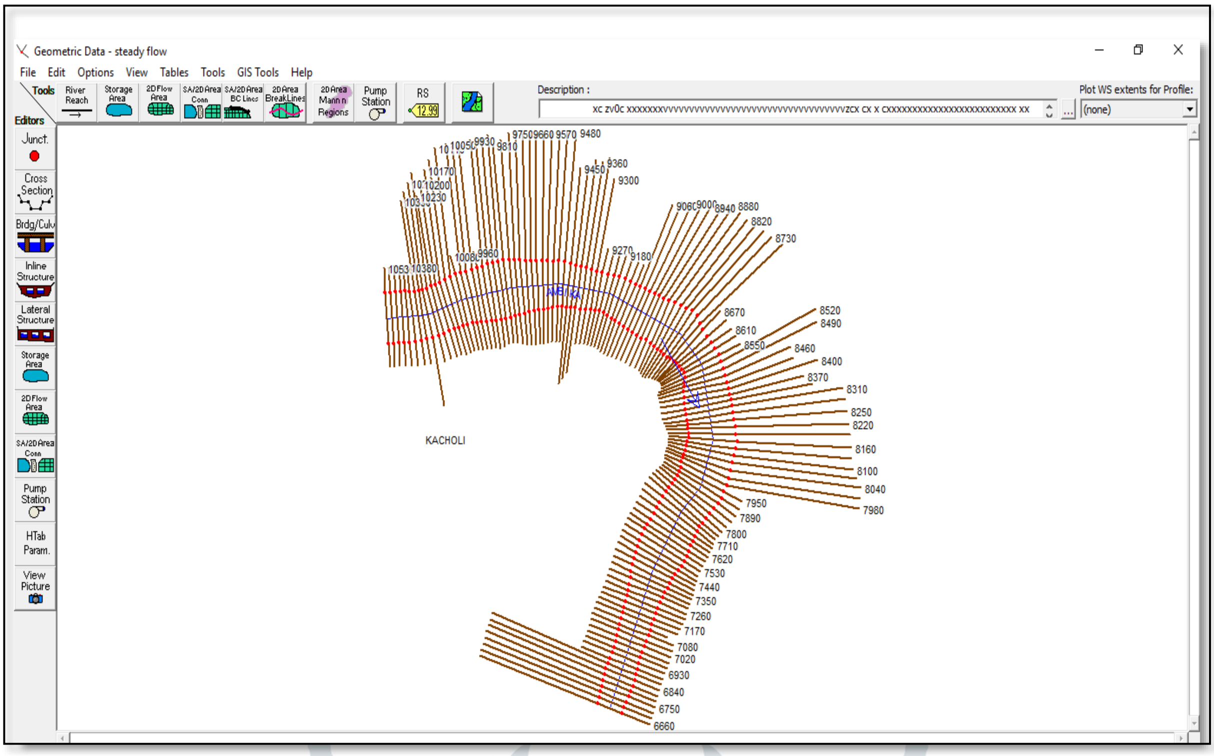

Figure 1: Georeferenced River Network

8. Results:

In present study, the hydrodynamic flood model for the Ambica River from Kachholi to Dhamdachha was performed using the HEC-RAS version 5.0.6 for the one dimensional steady flow analysis. After inputting all data, model was run for one dimensional steady flow water surface profile computations for river Ambica and the water surface profile for each cross sections are generated by the software. These graphs represents the elevation of water at a particular cross section and also give the over flow depth of water surface for both left and right bank river reach. It also give full profile plot throughout reach for 4000m. The water surface profile for two and three dimensional view shown in figure below.

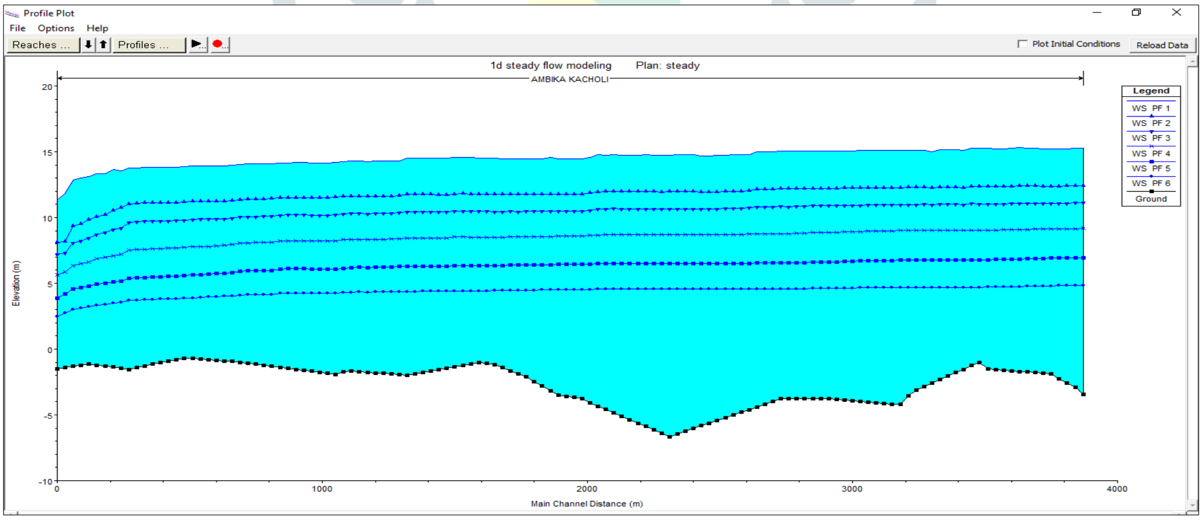

Figure 2: Profile plot of river Ambica

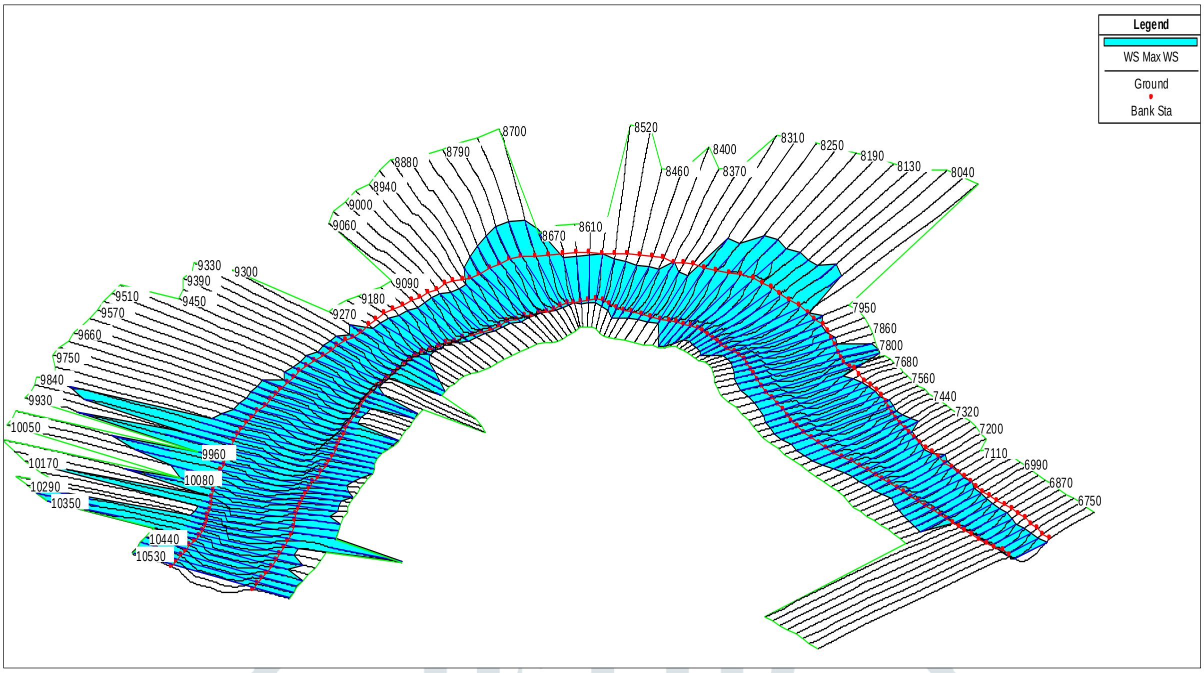

Figure 3: 3D Profile Plot of Ambica River

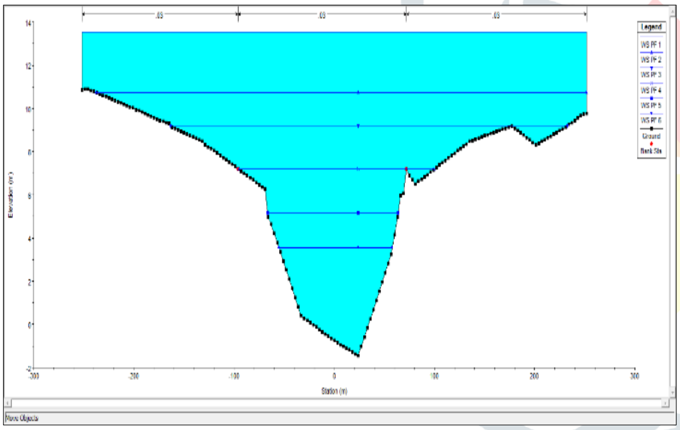

Figure 4: water surface profile at cross-section 6660

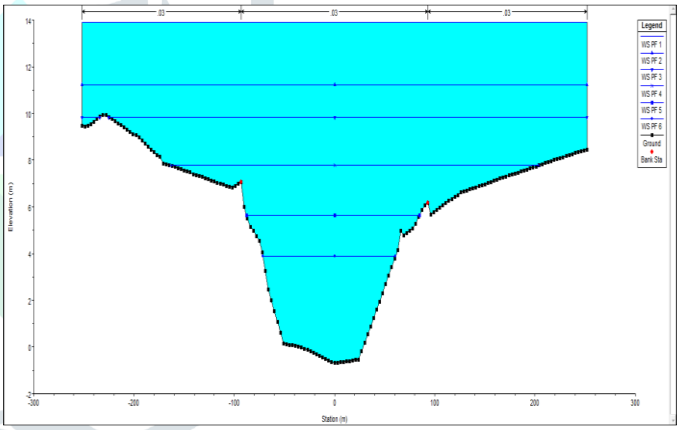

Figure 5: water surface profile at cross-section 7170

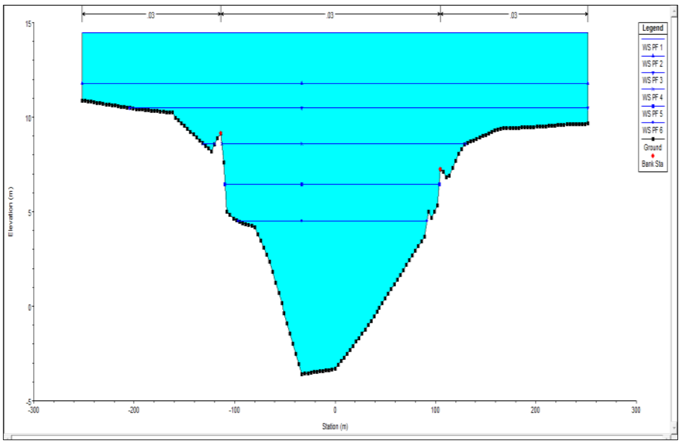

Figure 6: water surface profile at cross-section 8580

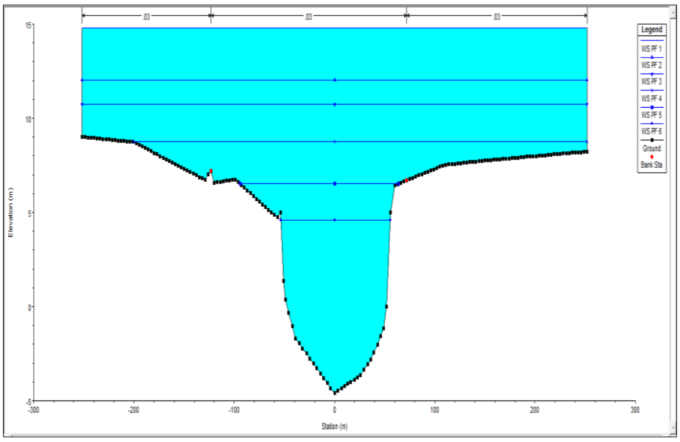

Figure 7: water surface profile at cross-section 9270

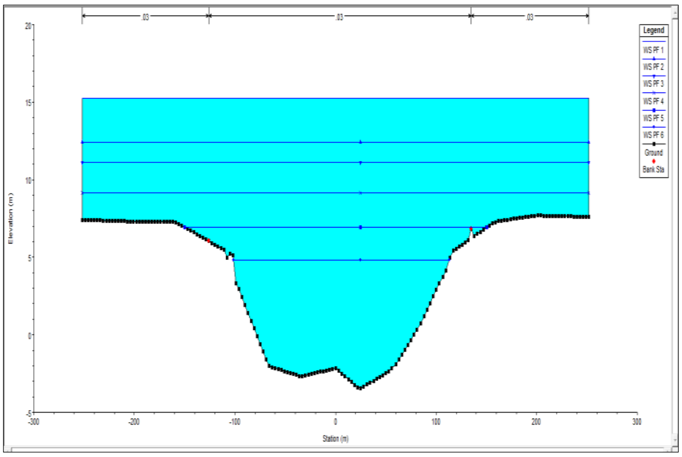

Figure 8: water surface profile at cross-section 10530

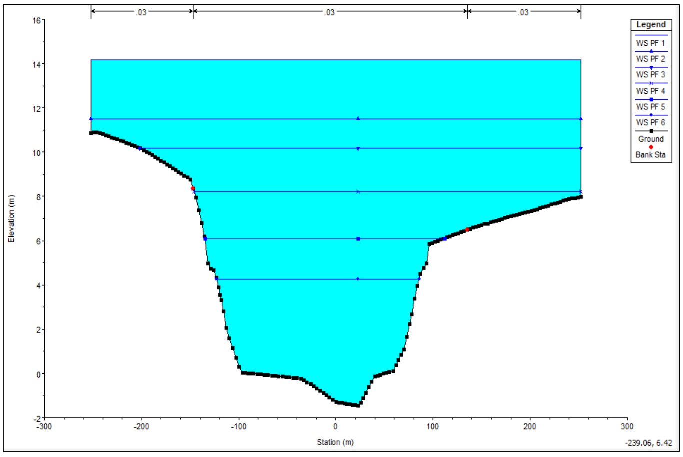

Figure 9: water surface profile at cross-section 7530

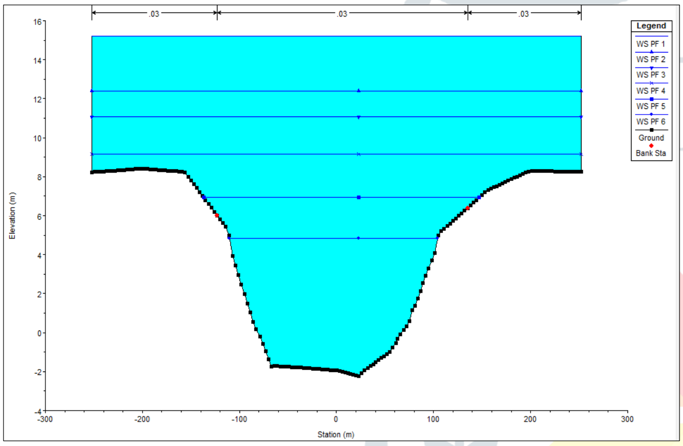

Fig. 10: water surface profile at cross-section 10440

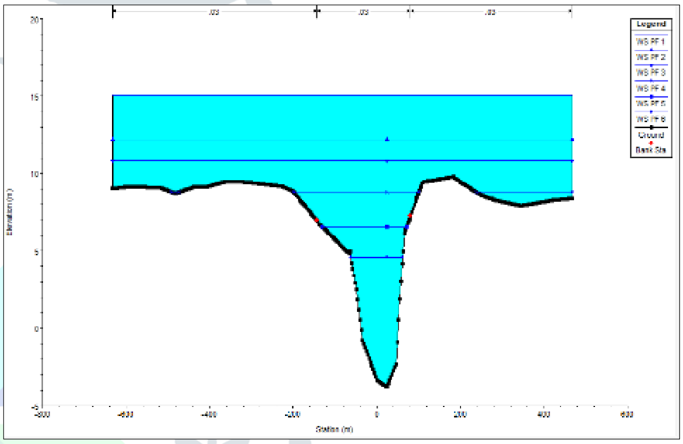

Fig. 11: water surface profile at cross-section 9450

9. Conclusion:

- The model developed by using HEC-RAS can be used to predict elevation of water for the river reach of Ambica from kachholi to Dhamdachha village to for the various discharge.
- As shown in result, almost all the cross sections are over flow during the discharge of 3200 m^3/s.
- The study area is highly affected by the flood so it is necessary to provide retaining wall throughout the reach length.

10. References:

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