Flood Inundation Modelling Using Arc GIS and HEC-RAS of Godavari Reach, Nanded District

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Abstract— Godavari river catchments get flooded frequently when there is heavy rainfall and cause adverse effects to the people and property. So, flood forecasting should be done for flood warning and flood protection. The study presents a straightforward approach for processing output of Arc GIS and HEC RAS hydraulic model, to enable one and two-dimensional modelling and floodplain mapping in Arc GIS. The methodology is applied to Nanded reach of Godavari river, located in Maharashtra. From the digital elevation model of the study area, the river cross section details are extracted using Arc GIS. The cross-section details, Manning's value and observed 35-year flow data of Purna station (upstream cross section) are the input for the HEC RAS and unsteady flow simulation have been done. The output from the simulation is water surface elevation. These results were exported to Arc GIS and floodplain modelling have been done. The validation have been done by comparing the observed and simulated water surface elevation of downstream cross section (Yelli). Two-dimensional modelling is also done using HEC RAS. Using observed flow data of Purna station, expected flood have been forecasted using Gumbel's Distribution Method for 2,5,10,25,50,100-year return periods. Using these data, the steady flow analysis was done and the output was exported to Arc GIS and flood inundation mapping have been done for each return periods.

Keywords— flood inundation, Arc GIS, HEC-RAS, Godavari, Nanded, heavy rainfall, flood forecasting.

1 INTRODUCTION

Godavari river catchments get flooded frequently when there is heavy rainfall and cause adverse effects to the people and property. So, flood forecasting should be done for flood warning and flood protection. The study presents a straightforward approach for processing output of Arc GIS and HEC RAS hydraulic model, to enable one and two-dimensional modelling and floodplain mapping in Arc GIS. The methodology is applied to Nanded reach of Godavari river, located in Maharashtra. From the digital elevation model of the study area, the river cross section details are extracted using Arc GIS. The cross-section details, Manning's value and observed 35-year flow data of Purna station (upstream cross section) are the input for the HEC RAS and unsteady flow simulation have been done. The output from the simulation is water surface elevation. These results were exported to Arc GIS and floodplain modelling have been done. The validation has been done by comparing the observed and simulated water surface elevation of downstream cross section (Yelli). Two-dimensional modelling is also done using HEC RAS. Using observed flow data of Purna station, expected flood have been forecasted using Gumbel's Distribution Method for 2,5,10,25,50,100-year return periods. Using these data, the steady flow analysis was done and the output was exported to Arc GIS and flood inundation mapping have been done for each return periods.

Need for study

Hydrological risks have gotten more regrettable as of late because of worldwide environmental change. Break situations, floodplain outline, flood determining, and stream steering are a couple of the examinations that HEC-RAS has been utilized for up until now. Dam break situations are seemingly the most vital investigations that HEC-RAS can perform, since they can expect and stay away from serious debacles. In a flood situation, floodplain depiction is helpful for assessing water levels and extent. Floodplain outlines are likewise utilized when settling ashore use in territories, assessing where there is water in a waste bowl, and deciding how to disseminate water in the bowl. Flood estimating decides the rises at which a waterway arrive voluntarily fluctuate for different tempest extents.

2. LITERATURE REVIEW

Normal water engineering principles were used to construct the HEC-RAS model. To estimate and understand occurrences in channels, river system models have been developed using HEC-RAS and other programmes. A user's manual for HEC-RAS was published in 2010, and it describes the equations used in each phase of the results process.

When looking for instabilities in a model, it's important to understand the method for measuring the effects, which include water surface levels, velocities, and flows at each river mile. During the development of stable unsteady models for this research, this manual was carefully read.

Until determining the floodplain boundary, geometric data is used to construct an interpolation surface to allocate water surface level all over the area, and the river centre line is used to locate bank stations. River cross sections should have bank lines, river centre lines, and flow path lines listed. Boundary conditions are applied along the interpolation region's edge. The distance along the line of boundary cross sections is used to determine boundary conditions. (Ackerman et al.,2009)

Floodplain zoning and land use planning are essential for protecting houses, infrastructure, and property in floodplains. Floodplain zoning has become very successful thanks to advances in GIS (Geographic Information Systems), the advancement of computational facilities and applications, and the availability of spatial data such as DEM (Digital Elevation Model). Software such as Hydrologic Engineering Centers River Analysis System (HEC RAS) and another software Geo-RAS are used to assess the effect of flooding on a specific location or region by getting water level surface profiles. The HEC RAS simulation provided the water surface elevation and flood extent, which was mapped in a GIS and different zones were determined. GIS was used to determine the depth of flood level and velocity of flow along the river and inundation region. Due to absence of high-resolution earth terrain data, the floodplain topography differs from the Digital Elevation Model(DEM). Accurate terrain data is needed for hydrologic modelling precision. (Pathak et al., 2016). Cross parts, topographical details, roughness coefficient for river bed, and flow hydrograph of the specified section are all inputs to HEC RAS. After simulation, HEC RAS provides the elevation of water surface in each and every cross section.

Based on the data obtained, we can build a contour- map and identify flooded areas, as well as prepare a flood risk map using maximum discharge. Flood hazard maps and flood risk maps, which display the negative effects of various flood occurrences, are needed for flood risk management. Because of the flooding, we need to be mindful of the sources of contamination in the environment. (Beilicci et al.,2014). Guides of flood peril were made with the assistance of a GIS (Geographic Information System) and the Hydrologic Engineering River Analysis System in this paper (HEC RAS). Planning of a DEM (Digital Elevation Model), reenactment of flood profundity at different return periods utilizing HEC-RAS, and advancement of flood hazard maps by consolidating the first and second steps are completely remembered for this examination. For return times of 10, 25, 50, and 100 years, 3-dimensional peril maps were created. (Demir et al.,2016).

During the rainy season, the dam fills up to its Maximum Reservoir Level (MRL), and water is discharged from the dams to prevent submersion. This could result in flooding on the downstream end. The programme HEC RAS is used to model floods in order to prevent catastrophe in the cities downstream. The model aids in the positioning of the floodplain and the implementation of flood warning and mitigation measures. Flood profiles are formed at any river crossing with varying intensities and return times. (Kute et al.,2014)

The current channel bathymetric data, cross section data, DEM (Digital Elevation Model) data and Lidar data are all combined to create the channel cross section. The original data is derived using different vertical and horizontal datums as well as spatial forecasts. The data is translated to a standard datum and estimates to prevent distortions. The results can vary due to variations in the consistency of tributary flow and lateral inflow estimates. (Adams et al.,2010)

Flood immersion guides can be produced utilizing HEC-RAS and HEC-GeoRAS. HEC-RAS is a free, easy to understand free programming for gathering water surface rise and profiles from different sorts of streams. The HEC-RAS yield is changed over into polygon type documents that show the flood region for a given stream release that causes flooding utilizing GeoRAS.These creation outlines are utilized in civil arranging, crisis the executive’s plans, flood protection rates, and biological investigations. For looking at changed flood recurrence occasions, a few floodplain polygons can be overlaid on a similar setting. Since consistent stream, one-dimensional demonstrating is time free and eliminates the impacts of stream constriction and slack time in water surface profiles, it was picked for this examination. Manual estimations of stream lessening and parallel inflows were taken. In the aftereffects of a one-dimensional consistent stream model, the water profundity of each cross area doesn't fluctuate along its length. (Goodell, C. et.al,2006).

3 METHODOLOGIES

3.1 Study area

Godavari river basin is 2nd largest river basin of India, occupying approximately 9.5 percent of the country's total land area. It includes the states of Andhra Pradesh, Maharashtra, Odisha and Chhattisgarh as well as smaller portions of Karnataka, Madhya Pradesh, and the U.T. of Puducherry. Figure 1 depicts the basin's geographical setting.

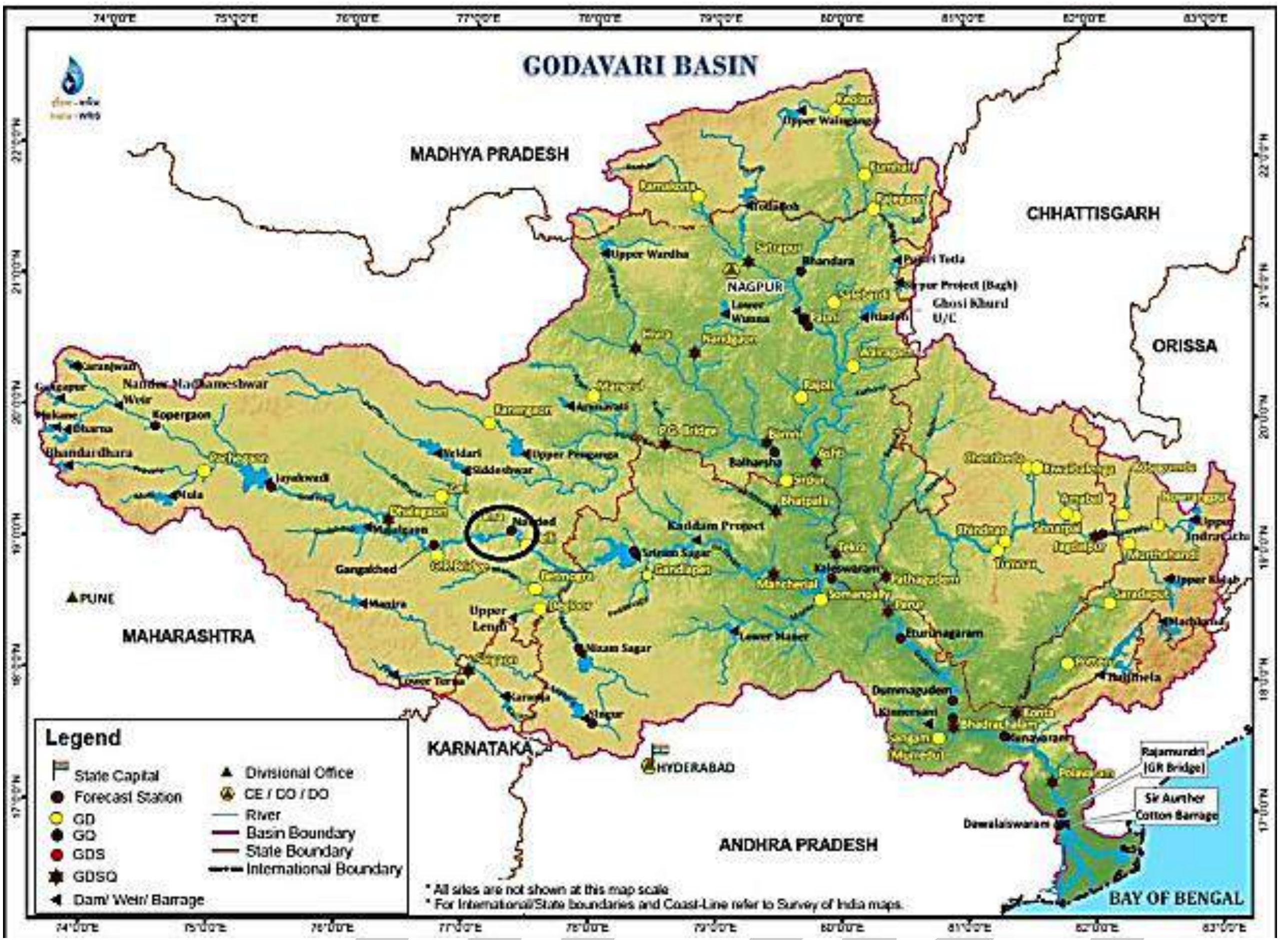

Fig.1 Hydrological observation station maps along Godavari basin.

The canal is divided into two sections: All canals that flow into the Bay of Bengal and the Regional Rivers lead to the Bay of Bengal, which is characterized mainly by river flow to the outlet. The basin receives an average annual rainfall of 1096.92 mm. Southwest rainfall begins in July and lasts until September, accompanied by heavy rainfall of the year.

River and Reach under study

The river length from Purna to Yelli is the study location. Nanded is located halfway between these two stations. The study area for this project is Nanded (19.1383° N, 77.3210° E), which is located in Maharashtra. Nanded is situated on the banks of the Godavari River. Nanded is the state's eighth largest urban agglomeration and 81st most populous city of India. Because of its proximity to a variety of schools, the Nanded flood plain is of importance.

Data collection and analysis.

The Central and State Governments also perform hydrological observations in the basin. In the basin, the Central Water Commission operates 48 gauge-discharge locations. Sediment observations are made at 16 of the sites, and water quality monitoring is performed at 18 of them. In the basin, the Central Water Commission operates 18 flood forecasting stations. The most popular data types Offer a rundown of the area's physical features. The geographic data is based on a 30 m resolution DEM (Digital Elevation Model) obtained from the USGS Earth Explorer.

Godavari river's daily discharge has been documented for 35 years in the flood observatory data base. We have daily discharge data for each station upstream station is Purna, and downstream station is Yelli, according to Geographic Information System research. By processing main meta data given for each DEM, the Arc GIS assigns the position.

These meta data serve as the basis for extracting cross sections, elevations, and other diagrams. The Arc GIS specifies the correct order of station placement based on the elevation difference. The chainage values are given by the DEM. The downstream side should have a lower chainage value, such as 417.0963, while the upstream side should have a higher chainage value, such as 86768.24. A total of 1287.45 km2 of land has been chosen for this analysis.

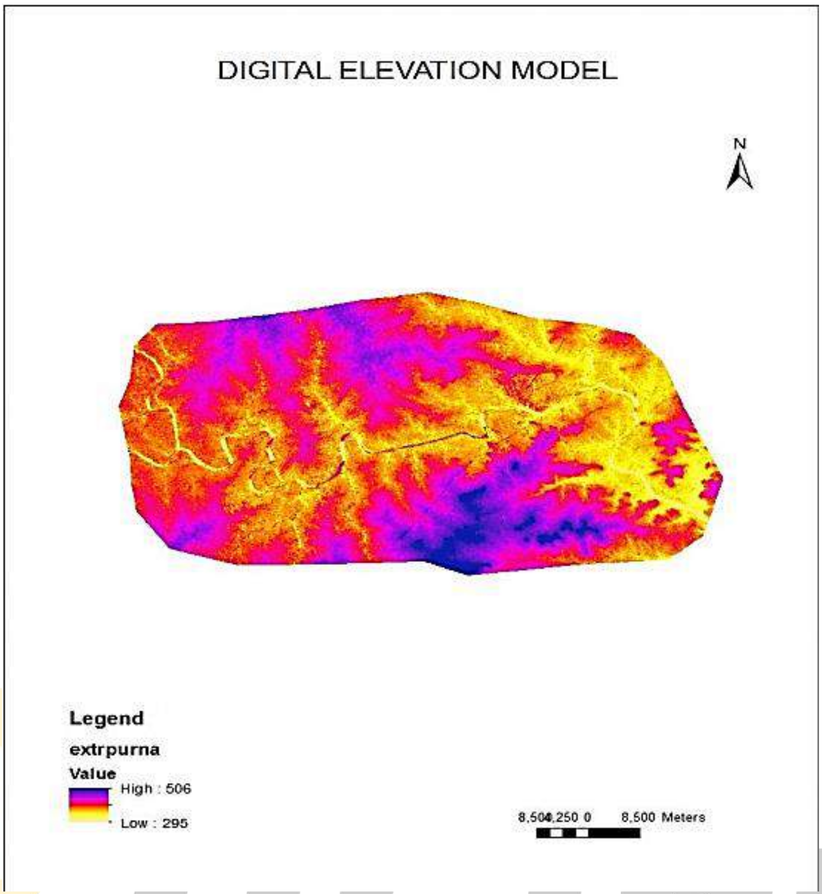

Fig 2: The flood event was simulated using the new HEC-RAS-v5 model developed by the USACE.

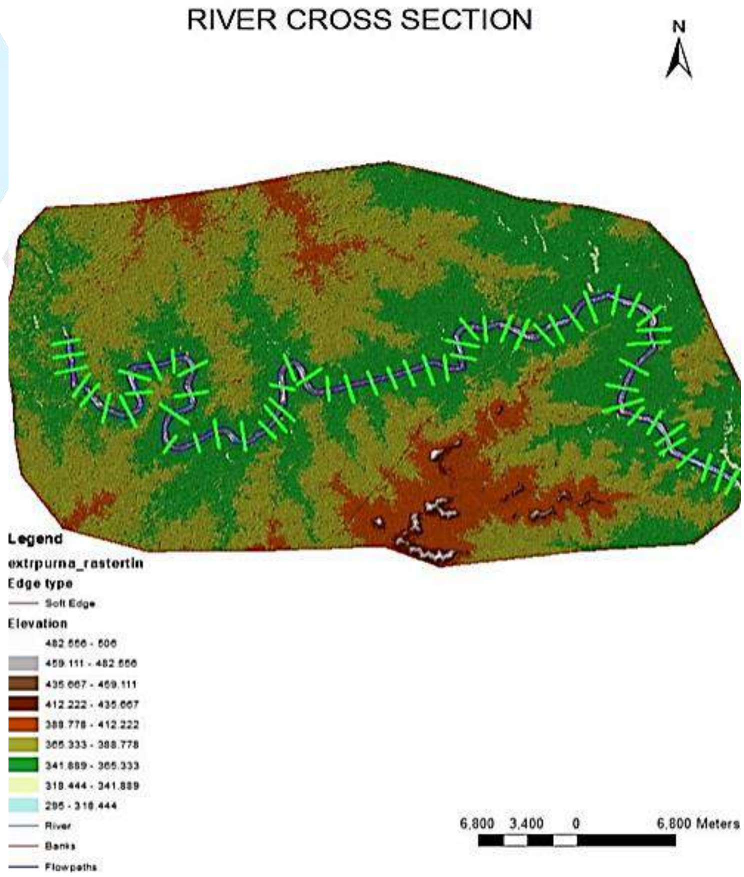

Fig. 3: The output from Arc Map (cross section extracted)

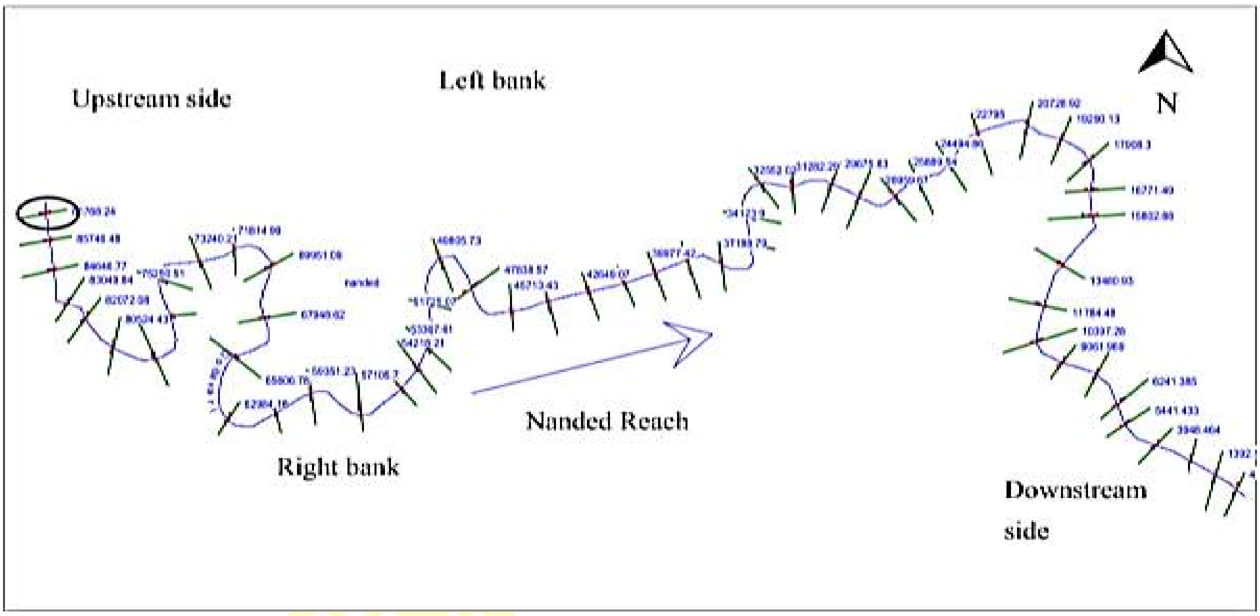

Fig. 4: River centerline and cross section cut lines

RESULTS & DISCUSSION

The downstream side, i.e. Yelli, is calibrated and validated by comparing simulated and observed values. This research presents the effects of one-dimensional(1-D), two-dimensional(2-D), and forecasting of flood.

CROSS SECTION OUTPUT

In the results, each cross section has a cross section with water surface elevation, as well as an energy head line (E.G Max W.S, in the figure) and a critical maximum water surface.

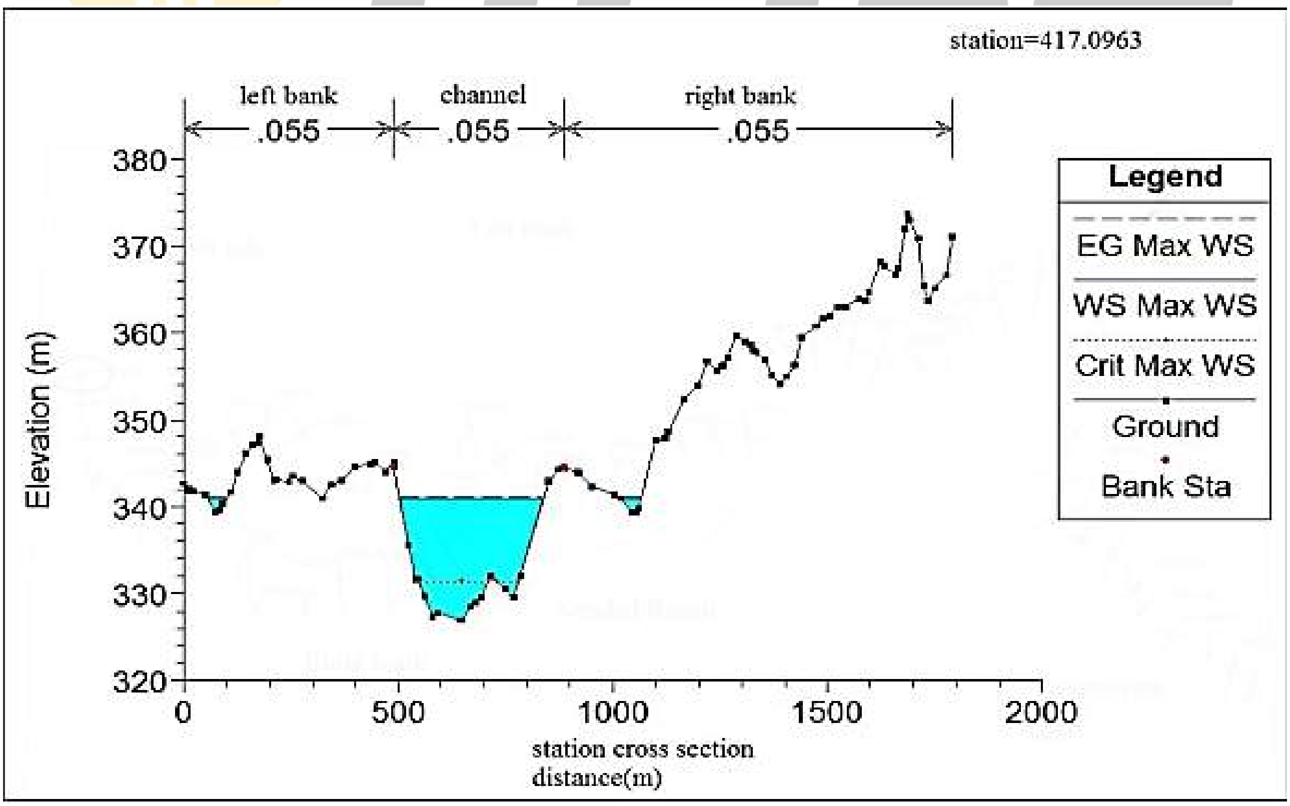

Fig. 5: Information of the station 417.0963(cross section)

X Y Z PERSPECTIVE PLOT

It's a pseudo(false) three-dimensional plot. The bank stations, ground level and highest water surface elevation have all mentioned in this.

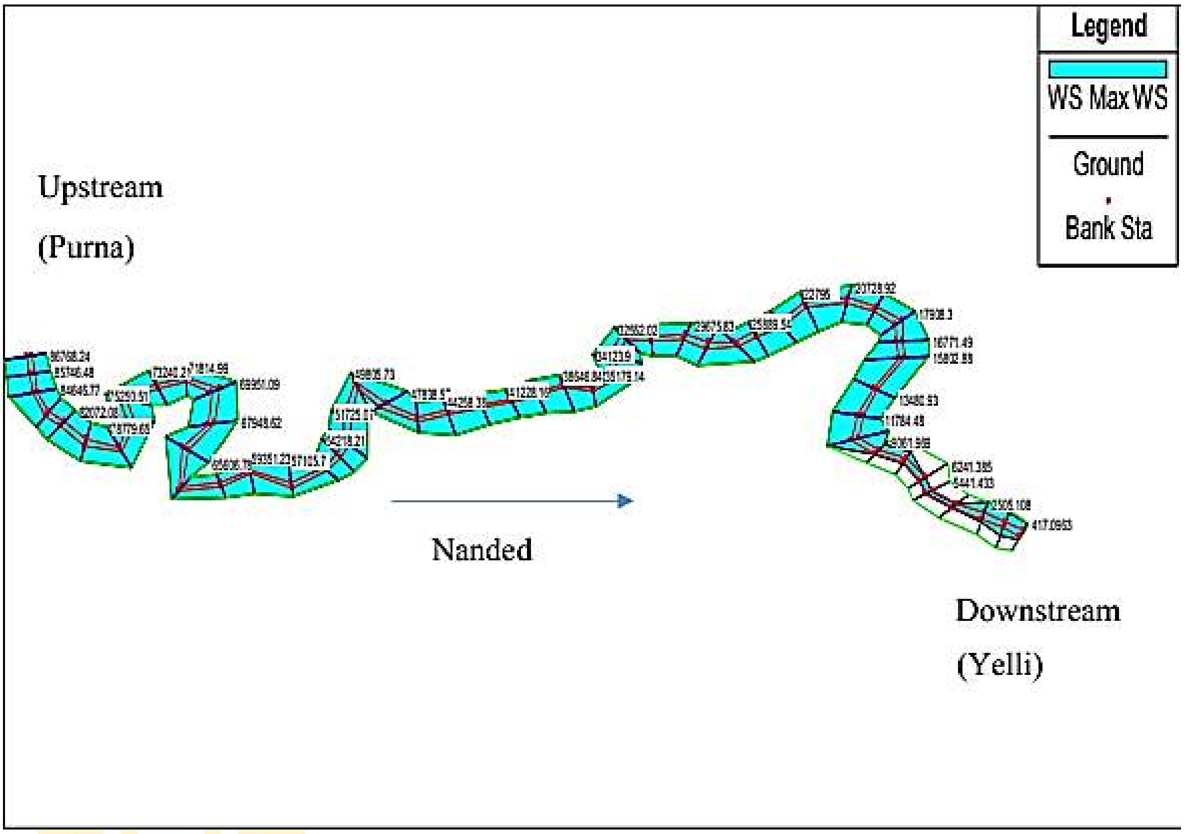

Fig. 6: Pseudo(false) three-dimensional plot

- To get a different viewpoint of the river reach, the plot area can be rotated right or left, down or up. The cross-section data can be overlaid with the computed water surface profiles. The maximum water surface elevation is shown in this graph.
- We have the option of rotating.
- This diagram has a useful rotation angle and azimuth angle. We can make the plot more interesting by using its time. The elevation of the water surface changes over time.

Water surface elevation profiles

The program will see the water surface rise, energy grade line height, and basic profundity rise in profile plots (otherwise called long parts or longitudinal profiles) of the HEC-RAS consistent stream and flimsy stream computational information.

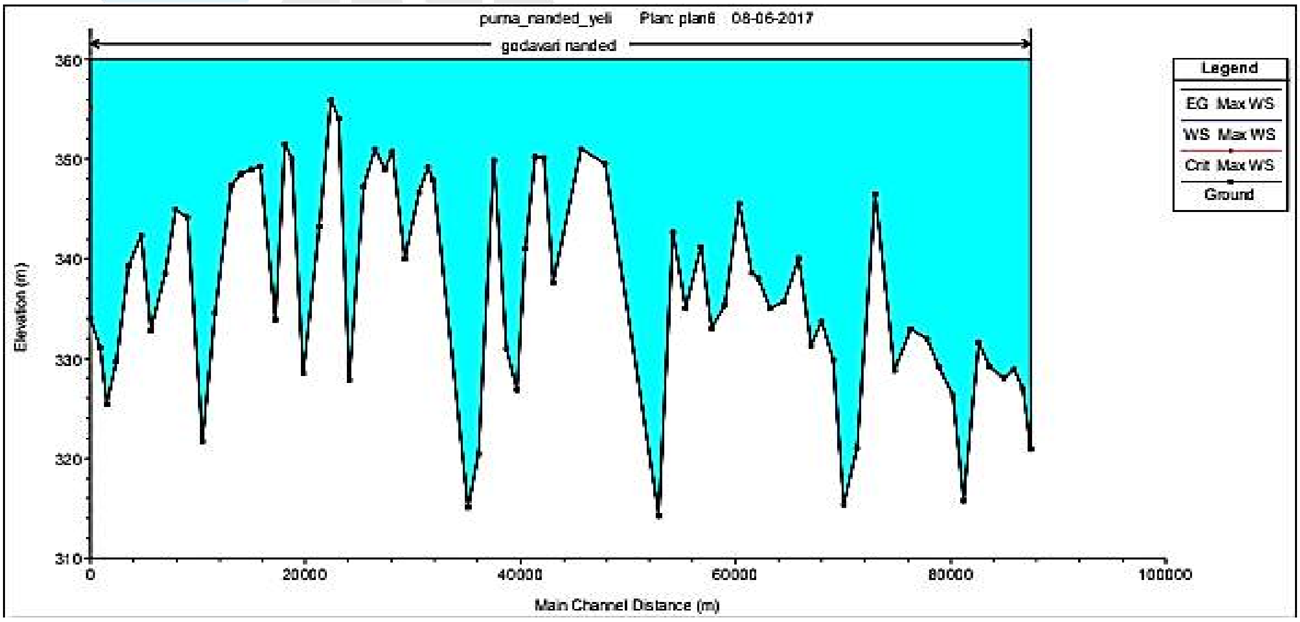

Fig. 7: Main channel distance and elevation graph

5. CONCLUSION

The investigation's essential objective is to demonstrate territory and outline floodplains. Immersion maps with precise gauges and a more extended lead time are expected to decrease flood harms. These flood immersion guides will help provincial networks discover variation ventures for their homes. These guides will assist neighborhood networks with getting aware of possible dangers and plan for them.

This current investigation's work incorporates territory demonstrating with ArcMap, water driven displaying with HEC RAS, and planning with ArcMap. The computerized height model assumes a significant part in improving the model's exhibition. It is suggested that a high-goal advanced spatial information base be utilized to improve the model's exactness. The stream release input controls the whole flood immersion measure.

Fusing irregularities coming about because of various components in the general interaction is perhaps the most troublesome parts of making dependable flood immersion maps. These vulnerabilities are mostly because of 1) stream gauge from a hydrologic-model or a rating bend of stage-release ; (2) input information, like topography(location) and land use region information; (3) demonstrating style (one-dimensional(1-D) or two-dimensional(2D)); (4) model setup and suppositions made (e.g., consistent or precarious state); (5) model boundaries (e.g., Manning's harshness coefficient); (6) Insufficient information for model outcome adjustment ; and (7) way to deal with flood immersion planning

Two kinds of limit conditions were utilized in this investigation: first, hydrograph and second, standard profundity limit condition. The hydrographic limit condition was set at the Godavari stream's upper end(upstream extreme).In expansion to the stream hydrograph, an energy incline should be indicated for conveying the release over the cells that incorporate the limit; the dissemination depends on the given slant and every cell's pre-prepared pressure driven properties.

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