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Case Report

Dam Break Analysis Using HEC-RAS and HEC-GeoRAS – A Case Study of Ajwa Reservoir

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Abstract: The paper initially describes about the details of the Ajwa Dam and further about the scenario of breaking of Ajwa Dam. The Ajwa Reservoir is located 20 km north-east of Vadodara city with waste weir and outlet works. The major reason of Vadodara being flooded in heavy rains is due to the release of water from Ajwa Reservoir. The attempt is made to study the disaster effect in the event of breaking of Ajwa Dam. Software ArcGIS, HEC-GeoRAS and HEC-RAS are used for the dam break analysis. Prediction of outflow hydrograph at various river station is generated with the help of USACE Hydrologic Engineering Center's River Analysis System software i.e. HEC-RAS. Maximum water surface elevation, velocity in the channel and discharge for a particular station of river in the downstream is described as a result of dam break. Floodplain inundation map is generated for the downstream tail reach.

Keywords: HEC-RAS, HEC-GeoRAS, Dam Break, Hydrograph

1. Introduction and Study Area

Vadodara is the third largest city in the state of Gujarat, with an area of 149 sq. km (vmc.gov.in) and a population of 17 lakh, (vmc.gov.in) located between Ahmedabad and Surat. Post-independence, the city has experienced rapid population growth and significant metamorphoses. Though the existence of Vadodara can be traced back to the 2nd century B.C. its existence as a city dates back to 1816 when it came under British Rule. The modernisation of the city began in 1882 with Late Shrimant Maharaja Sayajirao Gaekwad - III ascending the throne of the Baroda State. Ajwa Reservoir having an earthen embankment is used as an application purpose for the whole study.

1.1. Ajwa Reservoir (Sayaji Sarovar)

Ajwa Sarovar is an earthen dam built by Late Shrimant Maharaja Sayajirao Gaekwad - III. A survey of this project was undertaken by Mr. Sadashivaji in 1883. The scheme was sanctioned on 26th November 1884 and the work was commenced in January 1885 and completed in 1891. The reservoir is located in Lower Mahi basin on Surya River.

Table 1. Salient features of Ajwa Dam.

Salient features of Ajwa Dam	
Construction Year	1892
Operation & Maintenance	Vadodara Municipal Corporation (VMC)
Type of Dam	Earthen
Height of Dam	17.00 m
Length of Dam	4390 m
Top width of Dam	4.87 m
Gross Storage Capacity	63.43 Mm^3
Catchment Area of Dam	95 km^2
Waste weir length	243.84 m
Seismic Zone	III

1.2. Waste Weir

The waste weir is 244 m in length and 30.50 m in width. There are 62 shutter, each 3.05 m and 0.91 m in height. The shutters are fixed with chains at two points. The chains are carried over pulleys and tied to the floats. The floats are circular each 0.91 m in diameter and 1.82 m in height. All of them are filled with sand, gravel. The quantity of sand for each float is manipulated according to the requirements. The width of the paving is 28.65 m and made of concrete. The waste weir is automatically operated and the overflow level is 64.31 m.

(VMSS)

1.3. Data Collection

Table 2. Data Collected and Source.

Type of Data	Name of Organization
Salient features of Dam and Volume-Elevation data for Ajwa Reservoir	Water Works Department, VMC
River Cross-section details for every 500 m on downstream of dam	Water Works Department, VMC
Highest water level of the Dam reached from year 1967-2014	Water Works Department, VMC
Discharge from waste weir for different water level in Ajwa Reservoir	Water Works Department, VMC
DEM of area of interest	http://srtm.csi.cgiar.org/selection/inputCoord.asp

2. Methodology

2.1. Use of Software

HEC-RAS 4.1.0 (Product of Hydrologic Engineering Center, U S Army Corps of Engineer)[5]

HEC-GeoRAS 10 (Product of Hydrologic Engineering Center, U S Army Corps of Engineer)[6]

ArcGIS 10.1 (Product of Environmental System Research Institute)

2.2. Making of Geometry in ArcGIS

Table 3. Details of Digital Elevation Model (DEM) used in study.

	Latitude	Longitude	
Min	20 N	70 E	SRTM 90m DEM version 4
Max	25 N	75 E	
Center Point	22.50 N	72.50 E	

The DEM is loaded in ArcMap (a part of ArcGIS) and converted into TIN (Triangulated Irregular Network) using ArcToolbox.

HEC-GeoRAS plugin is installed into Arc-GIS.

With the help of editing feature the river from the discharge-weir is drawn up to Pingalwada (the last cross section used location) for a distance of 83 km.

Similarly the reservoir, dam and few cross sections on downstream of dam are drawn in ArcGIS.

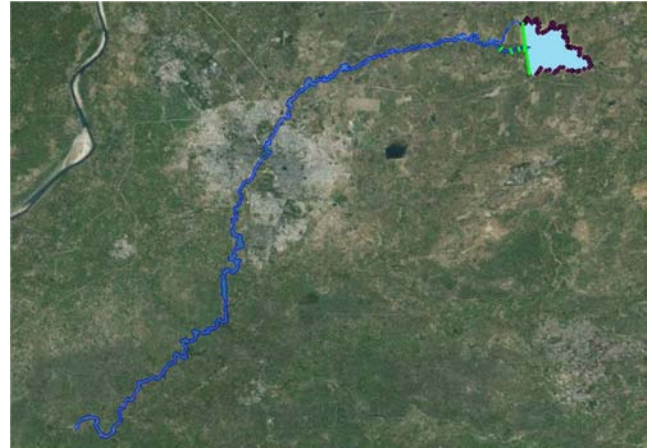Then all these features drawn are digitized using HEC-GeoRAS.

Figure 1. Drawn features in ArcMap.

The river up to 55 km flows within city Vadodara.

Then using export feature in HEC-GeoRAS the features are converted in HEC-RAS format

2.3. Dam Break Analysis in HEC-RAS

The converted data from ArcMap with help of HEC-GeoRAS is loaded into HEC-RAS with the help of import feature available in HEC-RAS.

For the Reservoir, elevation and volume data is incorporated in HEC-RAS.

The cross-section data is entered into HEC-RAS from start of river at discharge weir up to 83,258.794 km and the manning's coefficient is taken as 0.04 for the whole model. The cross-section plot for a station 3000 m downstream of waste weir is shown in figure below.
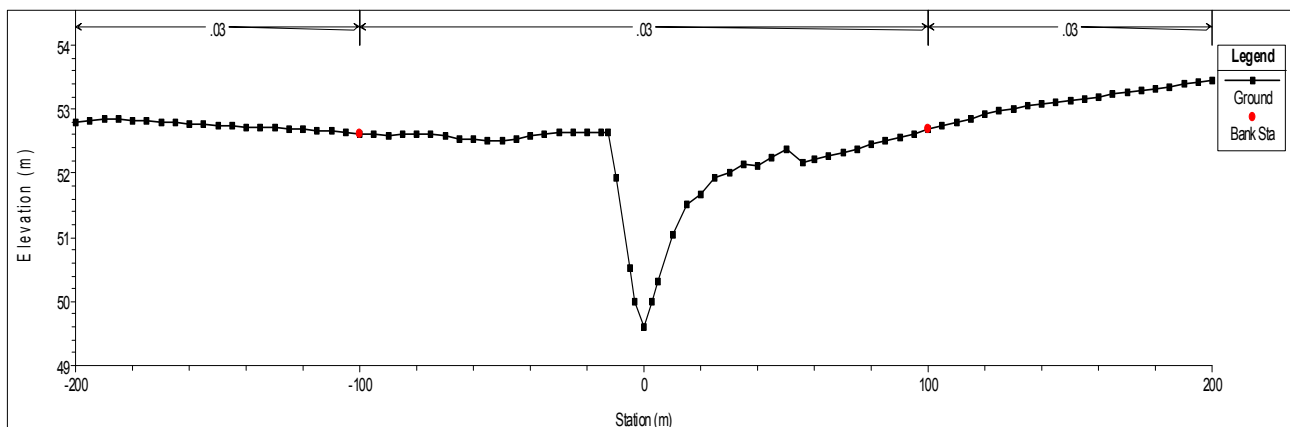

Figure 2. Cross section view of river in HEC-RAS.

The dam data is inserted using the inline structure feature in HEC-RAS and thus the upstream slope, downstream slope, crest width, length of dam, dimensions of weir and elevation of dam is entered.
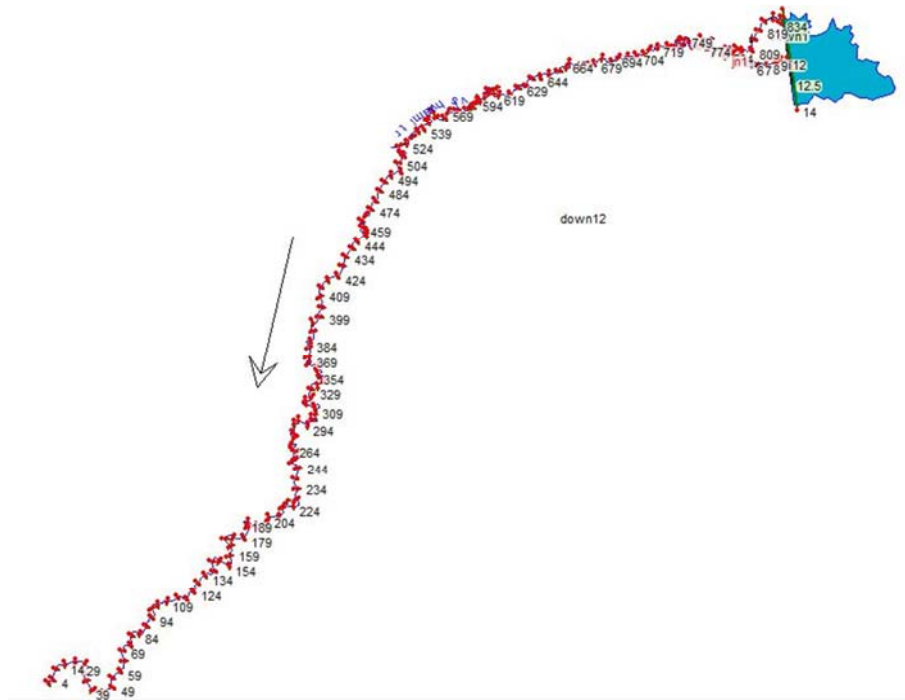

Figure 3. Geometrical view of data entered in HEC-RAS.

Then unsteady flow analysis is done for the mixed flow regime with the boundary conditions incorporated as discharge of 600 m³/s, normal depth as 0.0006 and starting water surface elevation in the reservoir as 65.83 m.

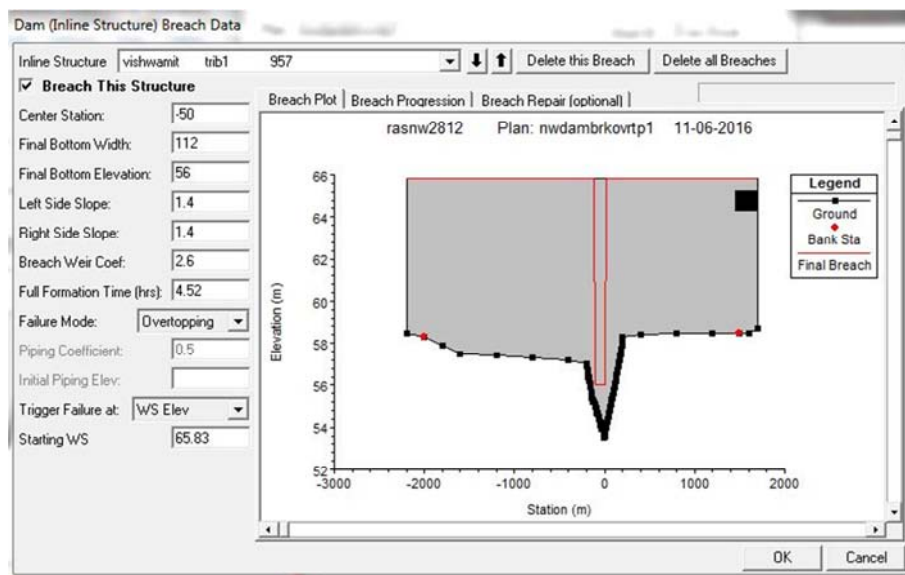Then same unsteady flow analysis file is copied to run for breach of dam.

Figure 4. Breach parameters for overtopping failure.

Then the model is run one by one for the unsteady flow analysis file without breach data entered and the unsteady flow analysis file with the breach feature ON.

While entering breach data once the failure mode overtopping is selected and once piping. The starting elevation for piping is taken as 63. Thus the model is run for both types of failure.

The model is simulated to run for 24 hours from 00:00 'o clock 08th September 2008 to 24:00 'o clock 08th September 2008 and hydrograph for 1 hour interval output is obtained.

Further the detailed output table can be viewed in view section and the velocity in channel, water surface elevation,

discharge, and energy gradient level and be observed for each station.

The RAS Mapper is opened and the result layer is loaded within it, then the coordinate system is assigned to the file by selecting the float file of the study area. Here the DEM obtained from SRTM site is loaded as float file and background file for mapping.

Then floodplain layer is generated by RAS Mapper.

These layers are then loaded into ArcGIS to get the real time view of the results.

Thus the shape file of floodplain area can be viewed on map and more hazardous zone can be recognized.

3. Results

The model is simulated for 24 hours and the vulnerable cross sections are obtained with their peak discharge, maximum water surface elevation and channel velocity. Dam break analysis is done for various water surface elevations in the reservoir and for the case of maximum water surface elevation results are shown in table 4.

Table 4. Dam Break Analysis.

Location	Distance from Dam (m)	Peak Disch-arge (m³/s)	Without Dam Break		Dam Break	
			Max. W.S. Elev. (m)	Channel Velocity (m/s)	Max. W.S. Elev. (m)	Channel Velocity (m/s)
Just u/s of dam	10	599	66.06	0.02	66.06	0.02
Just d/s of dam	100	776	57.22	0.41	57.29	0.49
Rasulabad village	5500	661	52.44	0.87	52.60	0.88
Gujarat State Highway 63	7500	649	51.74	0.67	51.87	0.69
Rahkui Village	11500	640	49.64	0.64	49.70	0.67
Kotambi Village	15000	594	47.69	0.46	47.83	0.45
Vadodara Halol Highway	18500	580	46.97	0.37	47.16	0.35
Bhaupura Village	19500	577	46.04	0.37	46.30	0.35
Kotali village	25000	537	44.31	0.21	44.69	0.20
Harni-virod Road	27500	510	44.01	0.21	44.41	0.20
State highway 158	30000	423	37.94	0.73	38.07	0.68
Urmi School over-bridge	34500	508	35.98	0.95	35.98	0.95
Vadsar, kalali	45000	558	31.34	0.55	31.34	0.55

The stage and flow hydrographs for all the cross sections are also obtained within HEC-RAS as a part of result. In the figures below the legend Dam Break denotes results for Dam Break due to overtopping.
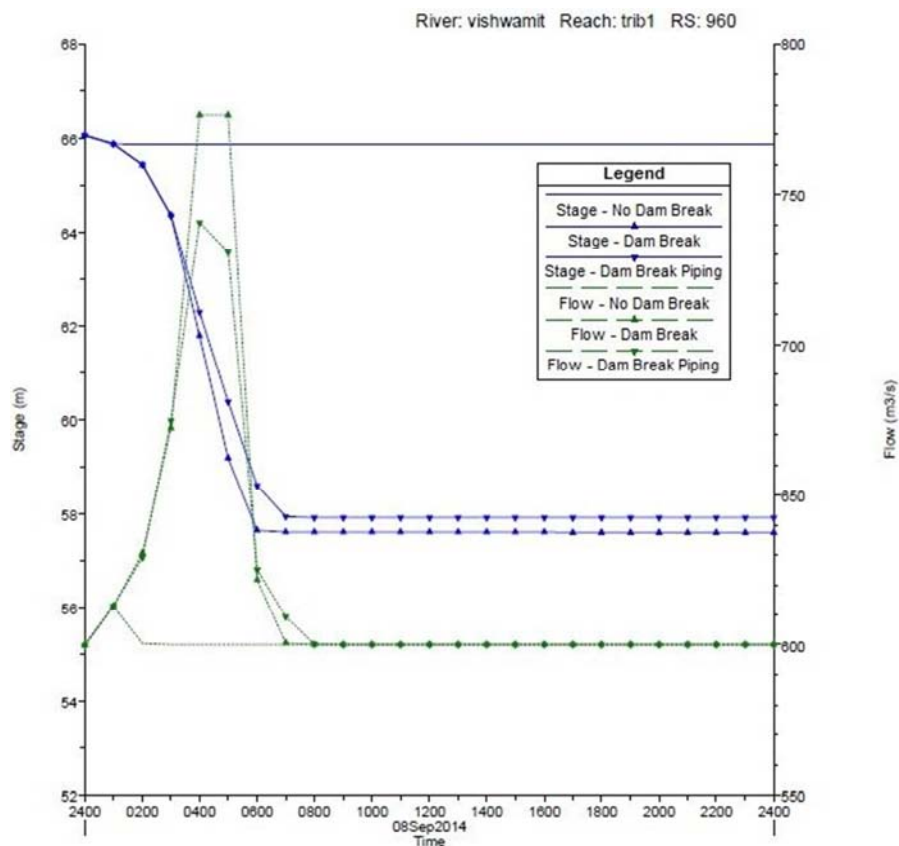

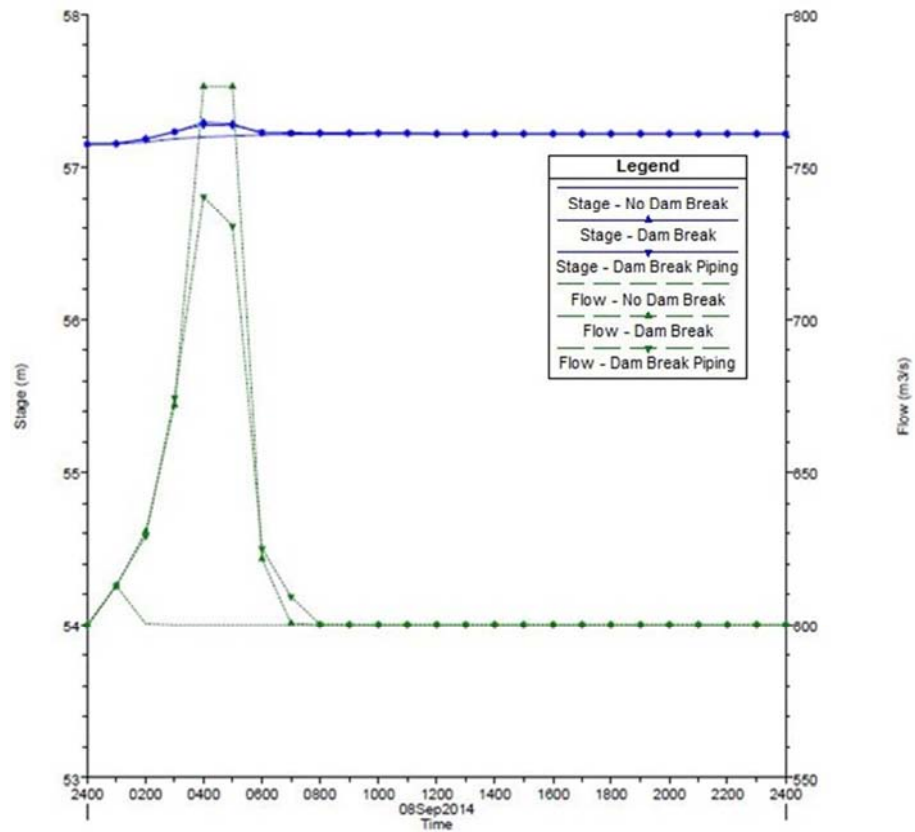*Figure 5. Stage and Flow Hydrograph just u/s of dam.*

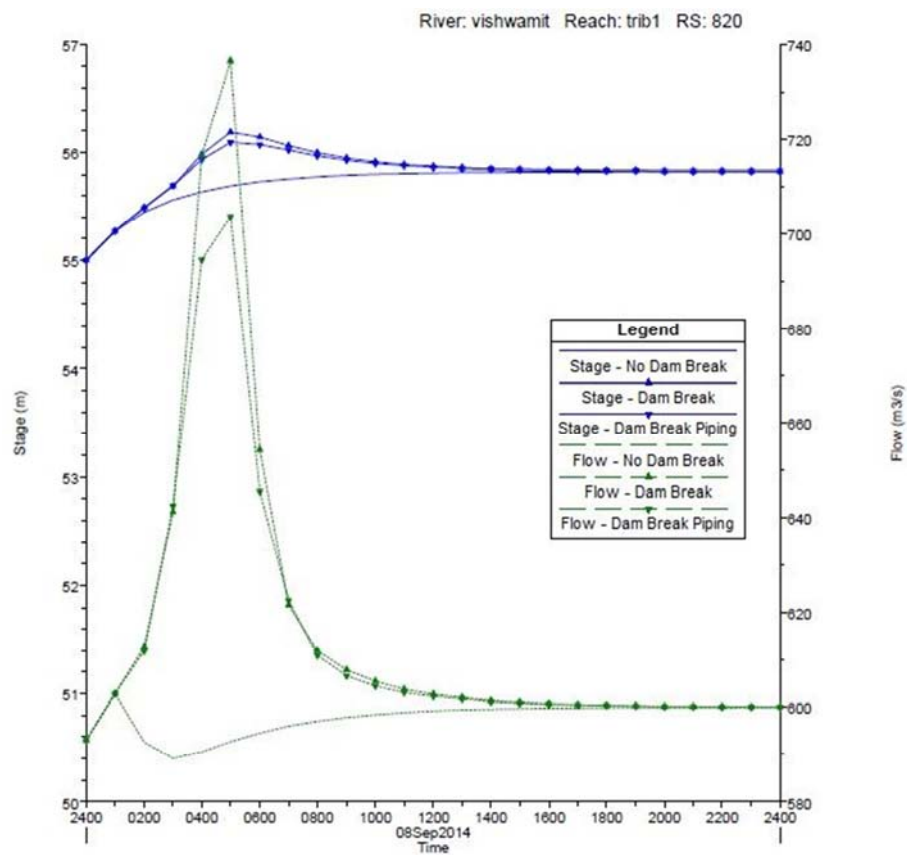*Figure 6. Stage and Flow Hydrograph just d/s of Dam.*

Figure 7. Stage and Flow Hydrograph at cross section 3000 m on downstream of Dam.

For the maximum water surface elevation the floodplain inundation map is obtained in ArcGIS as shown in figure 8. The shape file shown in blue colour indicates the floodplain affected area
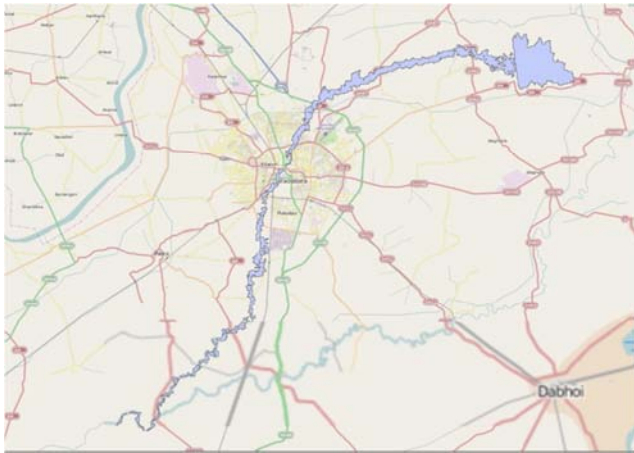

Figure 8. *Floodplain map.*

4. Conclusion

Dam break is a complex process so actual failure mechanics is not well understood, here we have used the regression equation Froehlich-1995a for overtopping and Froehlich-2008 for piping as suggested in training document 'Using HEC-RAS for Dam Break Studies' by U.S. Army Corps of Engineers[4]. With the help of Dam break analysis output as shown in table 4 the vulnerable cross section can be identified and modified to accommodate the maximum discharge it is facing during floods. The encroached area within floodplain zones can be vacated and remedial measures such as construction of retaining walls, channel modification, alertness for people, etc can be taken for future disaster. The river is having much turns so the average velocity is not more, the maximum velocity attained is 1.93 m/s at 36500 m on downstream of dam else for the entire flow the average velocity is 0.75 m/s. The attempt is made to study the disaster effect in the event of breaking of Ajwa Dam and compare it with effect of flooding without dam break for a constant discharge of 600 m³/s for 24 hours from the waste weir. The results are obtained for the above cases and compared in the tabular form in Table 4 for various reaches on downstream. The effect of dam break is observed more up to 18 km tail reach on downstream and further above 18 km the results

remain almost same for effect of dam break and without dam break. Thus with the flood plain map obtained further work can be carried out for delineating the zone of risk and marking it on actual ground site. With proper zone planning and management the future flood disaster effect can be minimized. Critical regions of high population density can be recognized and comparing it with flood plain map, levees and flood walls can be constructed in the regions as per the need.

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