Comparison of Water Level of Natural and Modified Section of Vishwamitri River using HEC-RAS

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Abstract *— The flood coming within the city has many primary effect such as loss of life, damage to buildings and other structures, including bridges, sewerage systems, roadways, and canals. As a result of which the study of flood for the river passing through the city is very important and so the study area of the present study is as follows. The study area includes Vishwamitri River, which is been located within the heart of the Vadodara city. The specific area to be studied of the Vishwamitri River is from chainage 15200 metre to 0 metre starting from NH-8 Crossing beyond Atladra Bridge. The objective of the study is to analyse the water surface elevation of natural river reach and then modifying the natural river reach cross-section into trapezoidal cross-section for 805 cumecs discharge, which was maximum flood observed by Vadodara city in 2005. After modifying the natural river reach section to trapezoidal section its maximum discharge carrying capacity is been found out and all this analysis and modification is done using the software HEC-RAS. Then by using Gumble's method flood frequency analysis is done to find the flood of specific return period for which modified river reach is safe. For maximum discharge carrying capacity of trapezoidal section and For maximum flood of 805 cumecs discharge observed by Vadodara city, Clearance between bottom of deck and water surface elevation available at all the bridges within the reach is been analysed for natural as well as modified trapezoidal section.*

Keywords — *Water level, flood, cross-section, river reach and HEC-RAS.*

I. INTRODUCTION

A flood is an overflow of water that submerges land, which is usually dry. The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water. Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry. During last 12 years Vadodara city have faced three major floods, which were in the year 2005, 2006 and 2013. And the peak flood was observed in the year 2005 which was of 805 cumecs. So the analysis of water level for different value of discharge is been carried out in this study over vishwamitri river and the required modification of the cross-section of natural river reach is carried out using HEC-RAS.

- Following are the limitations of the study.
  - Only one-dimensional analysis is done.
  - Only hydraulically best section of the modified section is computed.

- Following are the objectives of the study.
  - To identify affected cross-section of natural river reach using HEC-RAS for 805 cumecs discharge and then finding maximum discharge carrying capacity of it.
  - To modify the cross-sections of Natural River reach to trapezoidal cross-sections, to increase the discharge carrying capacity of the river and finding maximum discharge carrying capacity of trapezoidal river reach.
  - Compare water surface elevation of natural and modified section at 805 cumecs discharge.
  - To find the flood of a specific return period for which trapezoidal river reach is safe.
  - Comparing water surface elevation of trapezoidal section with its bank station elevation for its maximum discharge carrying capacity.
  - To find the difference between elevation of bottom of deck and water surface elevation and over topped portion at every bridges for different discharges.

- To compare natural and modified cross-section to identify the area of dredging and filling.

II. STUDY AREA & DATA COLLECTION

The study area includes Vishwamitri River which is been located within the heart of the Vadodara city. The specific area to be studied of the Vishwamitri River is from chainage 15200 metre to 0 metre starting from NH-8 Crossing beyond Atladra Bridge The map of Vadodara city is shown in Fig.1. In the map, Vishwamitri River is shown with blue colour.

Fig.1 Map of Vadodara City showing Vishwamitri River

Vishwamitri River which passes through the city, is meandering type of river with total stretch 70 km with a varying size of cross section of 30-60 m. About 25 km of river stretch passes through the Vadodara city and bisects the city. In recent years with fast pace urban and industrial growth of the city Vishwamitri River faces major pressure of sewage and waste dumping of the city, which not only obstructing the natural flow but experiencing floods and inundation of low-lying areas.

The Vadodara city is located in the southern part of the Gujarat state of India, and lies between 21°49”19’N and 22°48”37’ N latitude and 72°51”05’ E and 74°16”55’ E longitude.

Particularly for this study different data were collected which are been listed below.

- Geometric Data of a river.
- Geometric Data of bridges.
- Inflow at the upstream of the Vishwamitri River located within the city.
- Boundary conditions for the steady flow analysis.

The geometric data of river includes the cross sections of the Vishwamitri River, 152 cross-sections were taken, while the geometric data of bridge includes its location within the river, details of deck and details of piers, there are 15 bridges within the reach. The inflow at the upstream of the Vishwamitri River is taken 805 cumecs, which is the maximum value of inflow at the upstream of the Vishwamitri River calculated by Vadodara Municipal Corporation and it is the highest flood faced by Vadodara city during 2005.

III. METHODOLOGY

The methodology includes the development of the model of Vishwamitri River using HEC-RAS 4.1.0 and making analysis of water surface level at different cross-sections of the river for different inflow of flood at the upstream of Vishwamitri River and analysing the cross-sections which are been overtopped by the flood and making changes in the cross-sections and developing new mathematical model of the Vishwamitri River which can accommodate the flood.

Following steps are been carried out in HEC-RAS

- Start a New HEC-RAS Project
- Set up the River Reach
- Enter Cross-Section Data
- Add the Road Deck
- Add the Bridge Data
- Input Steady Flow Data
- Run Model, View Output

The steps involved in the methodology to prepare mathematical model of Vishwamitri River is briefly described below.

- First of all the river reach is selected.
- After selecting the river reach, the data of cross-sections were collected.
- Then the data of bridge coming in the river reach are collected.
- Finally other geometric data such as Manning's roughness coefficient value and slope of the river were taken.
- Using all these data, the river reach was developed.
- Then for maximum flood discharge of 805 cumecs which was observed in 2005, the simulation of river model prepared is carriedout.
- Then the maximum dicharge carrying capacity of the vishwamitri river for natural reach is found by trial and error in HEC-RAS.
- Then Constricted, Rectangular and Trapezoidal section river reaches were prepared which can atleast carry maximum flood discharge of 805 cumecs which was observed in 2005 and their maximum discharge carryiny capacity is also computed using HEC-RAS.
- Then the flood of which return period the new river reaches can accommodate is been found using Gumble's method.
- Water surface elevation at different sections of the reaches and their bank station elevation are compared for maximum discharge computed from all the reaches and from that best section of the river reach is selected.
- The free board at different bridges within the river reach is also calculated from water surface elevation and elevation of the bottom of the deck of bridge.

IV. RESULT & ANALYSIS

The natural and the modified trapezoidal cross-section of the river reach made using HEC-RAS are shown in Fig.2 and Fig.3 respectively.

The maximum flood observed by Vadodara city was 805 cumecs discharge, with this discharge Vishwamitri river was flooded. As a result of which the natural river reach is modified in constricted,

trapezoidal and rectangular section which can safely carry 805 cumecs discharge.The graphical comparison of water surface elevation of natural and modified trapezoidal section is shown in Fig.4 below.

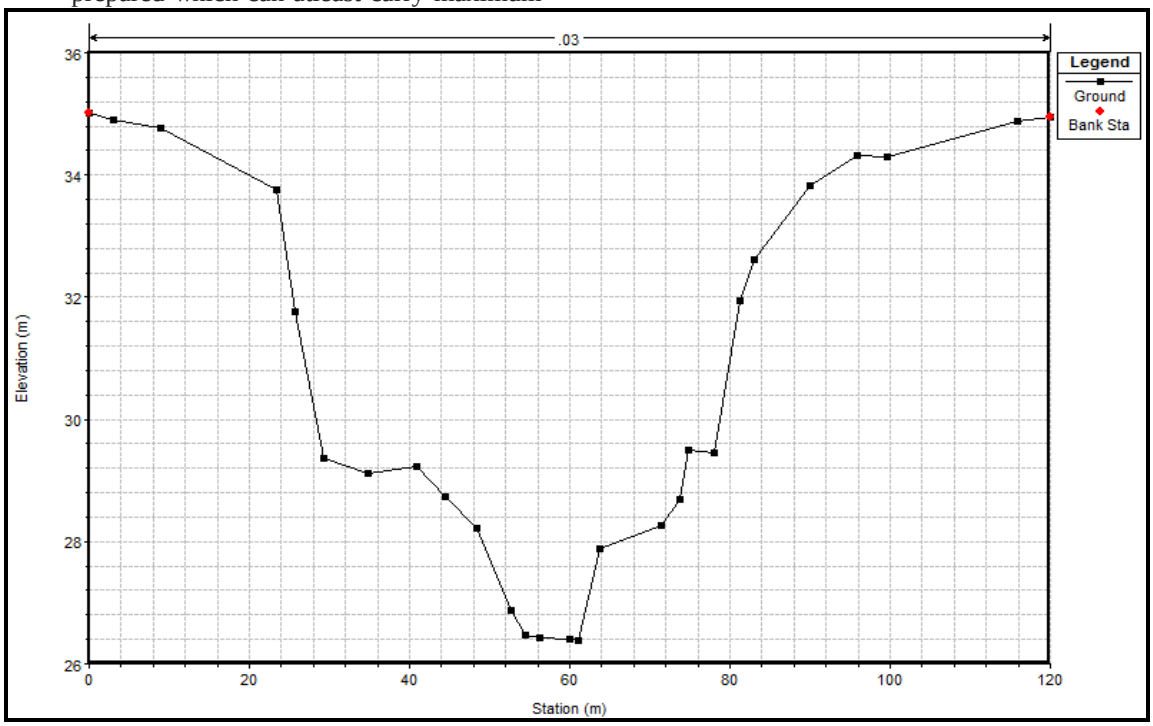

Fig.2 Cross-Section of Natural River Reach.

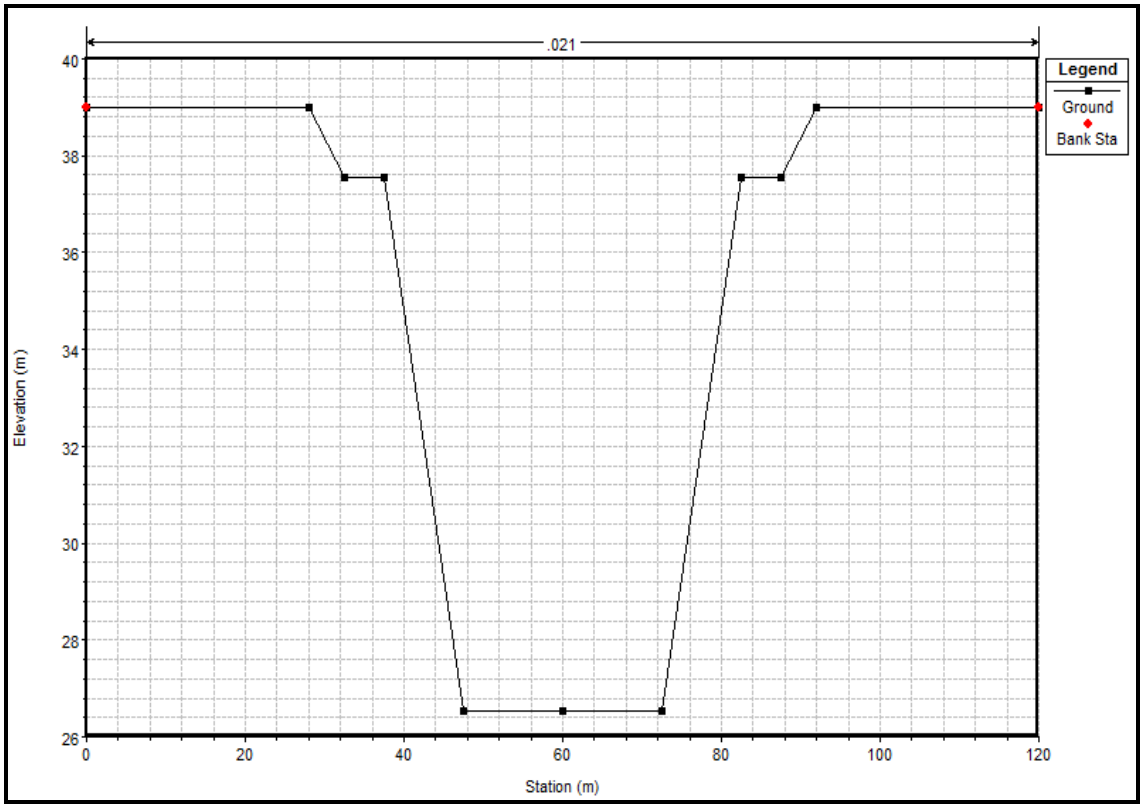

Fig.3 Cross-Section of trapezoidal River Reach.

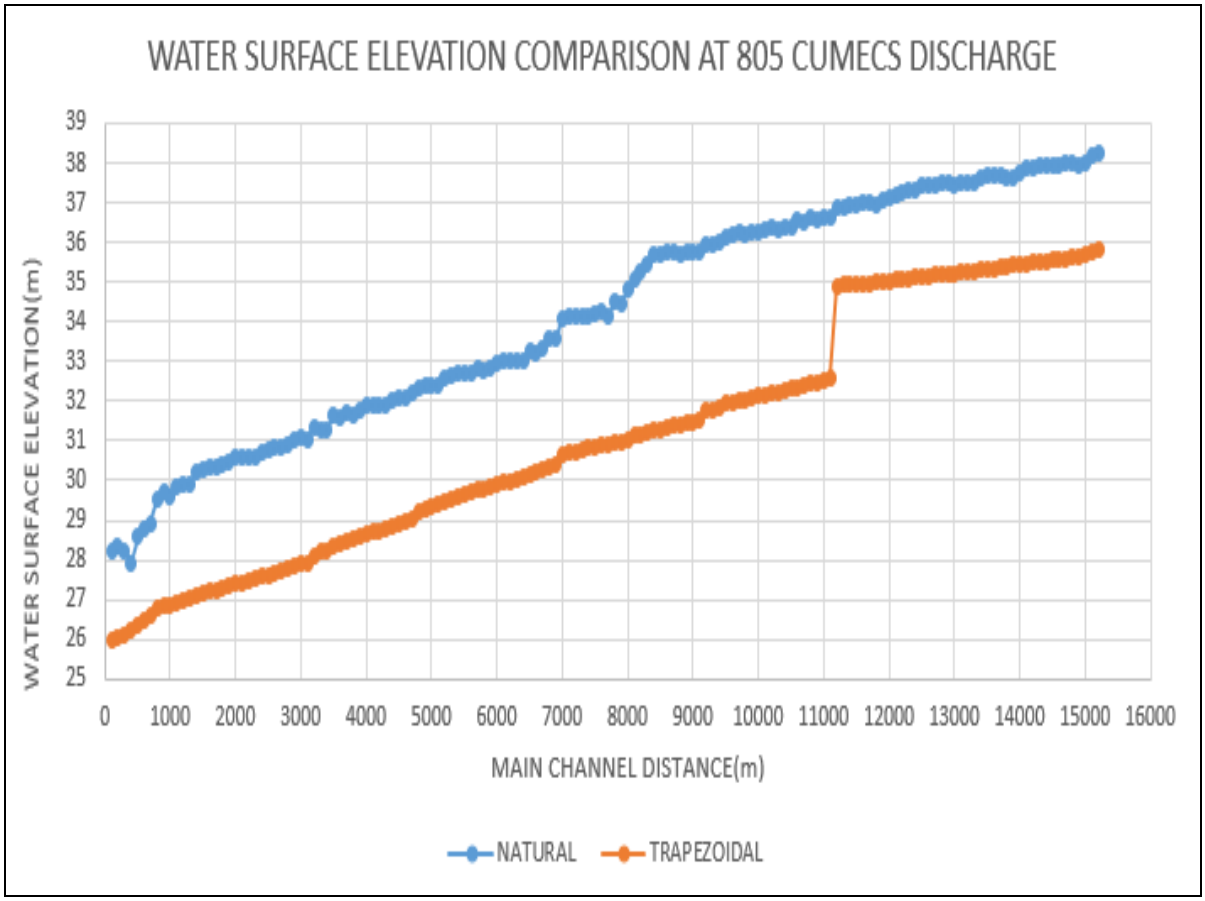

Fig.4 Graphical Comparison of Water Surface Elevation of Natural and Trapezoidal Section at 805 Cumecs Discharge

Now the maximum discharge carrying capacity of natural and trapezoidal section is been found by trial and error in HEC-RAS and it is found that the maximum discharge carrying capacity of natural and trapezoidal section is 25 cumecs and 880cumecs respectively.

The return period for which the trapezoidal section can safely carry the discharge equal to their maximum discharge carrying capacity is found from the Table 1 below,which is obtained using Gumble's method.

From the analysis of maximum discharge, the maximum discharge carrying capacity of the trapezoidal river reach is 880 cumecs and from the Table 1, the return period for which the trapezoidal river can carry the flood of magnitude 880 cumecs safely is 25 years.

Table 1 Magnitude of Flood for Different Return Period

Return Period (years)	Flood Discharge in cumecs
15	752.69
20	820.00
22	843.95
25	872.69
30	915.80
35	951.73
37	966.10
40	982.87

Graphical comparison of water surface elevation of trapezoidal section with its bank station elevation for its maximum discharge carrying capacity is shown in Fig.5 below.

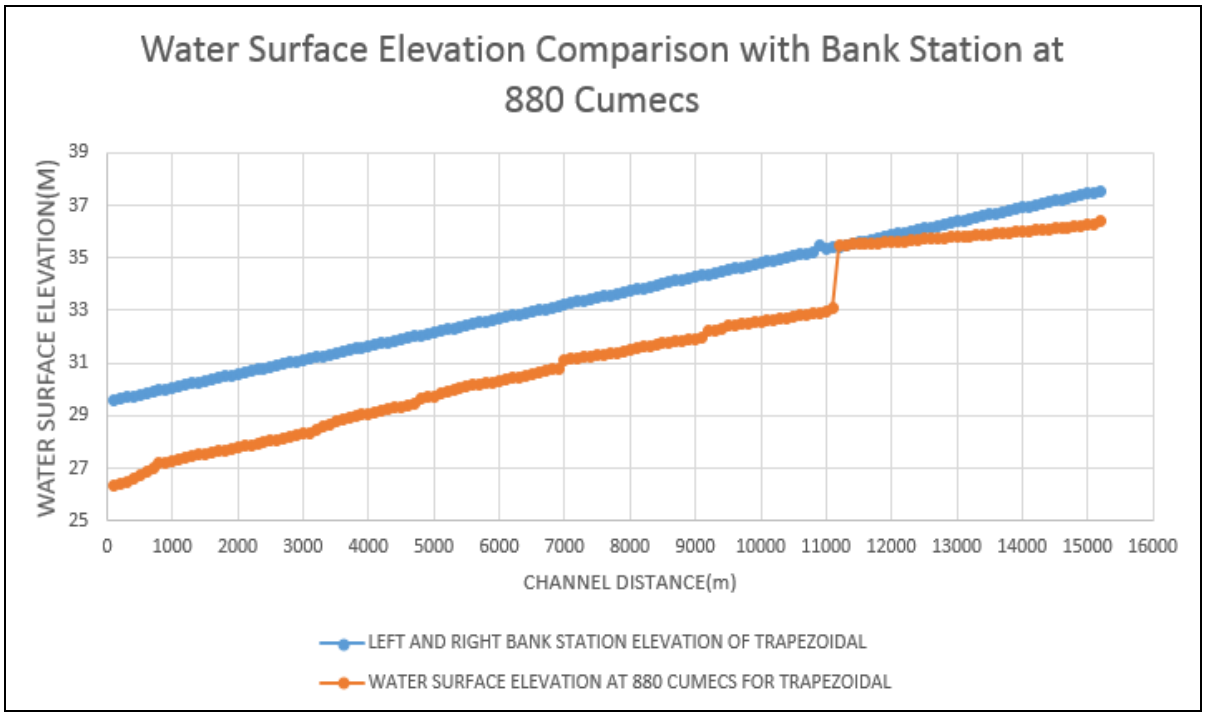

Fig.5 Water Surface and Bank Station Elevation Comparison of Trapezoidal Section at 880 Cumecs Discharge

Table 2 Clearance between Water Surface Elevation and Bottom of Deck (m) and Overtopped Portion (m)

Name of Bridge	Bottom of Bridge	Top of Bridge	At 880 cumecs water surface elevation (m)		Clearance between water surface elevation and bottom of deck (m)		Overtopped portion (m)	
			Natural	Trapezoidal	Natural	Trapezoidal	Natural	Trapezoidal
NH-8(UP)	41.39	43.84	38.5	36.22	2.89	5.17	5.34	7.62
NH-8(DOWN)	41.2	43.81	38.41	36.23	2.79	4.97	5.4	7.58
PIPE BRIDGE	35.77	36.53	37.56	35.63	-1.79	0.14	-1.03	0.9

OLD SAMA BRIDGE	33.96	35.49	36.97	32.58	-3.01	1.38	-1.48	2.91
NEW SAMA BRIDGE	38.57	41.02	36.96	32.93	1.61	5.64	4.06	8.09
MANGAL PANDEY	32.58	35.19	36.28	32.27	-3.7	0.31	-1.09	2.92
FATEHGUNJ	33.68	35	36.3	31.78	-2.62	1.9	-1.3	3.22
BAL BHAVAN	34.97	36.15	35.17	31.4	-0.2	3.57	0.98	4.75
KALA GHODA	31.91	33.56	35.36	32.3	-3.45	-0.39	-1.8	1.26
BHIMNATH	31.92	32.91	34.93	32.27	-3.01	-0.35	-2.02	0.64
RAILWAY OVER	35.13	36.34	34.7	31.82	0.43	3.31	1.64	4.52
RAILWAY	33.73	35.67	34.16	31.12	-0.43	2.61	1.51	4.55
MUJMAHUDA	31.41	32.72	33.49	30.39	-2.08	1.02	-0.77	2.33
RAILWAY	30.45	32.11	32.99	29.96	-2.54	0.49	-0.88	2.15
RING ROAD	31.31	33.21	31.09	28.55	0.22	2.76	2.12	4.66

The clearance between bottom of deck and water surface elevation available at different bridges coming within the reach is been found out as shown in Table 2 for 880 cumecs discharge.

Fig.6 shows the graphical comparison of the water surface elevation at the bridges and the elevation of the bottom of the bridges.

The comparison of natural and modified section at chainage 14600 is shown in Fig.7 below, which gives the area that requires dredging and filling.

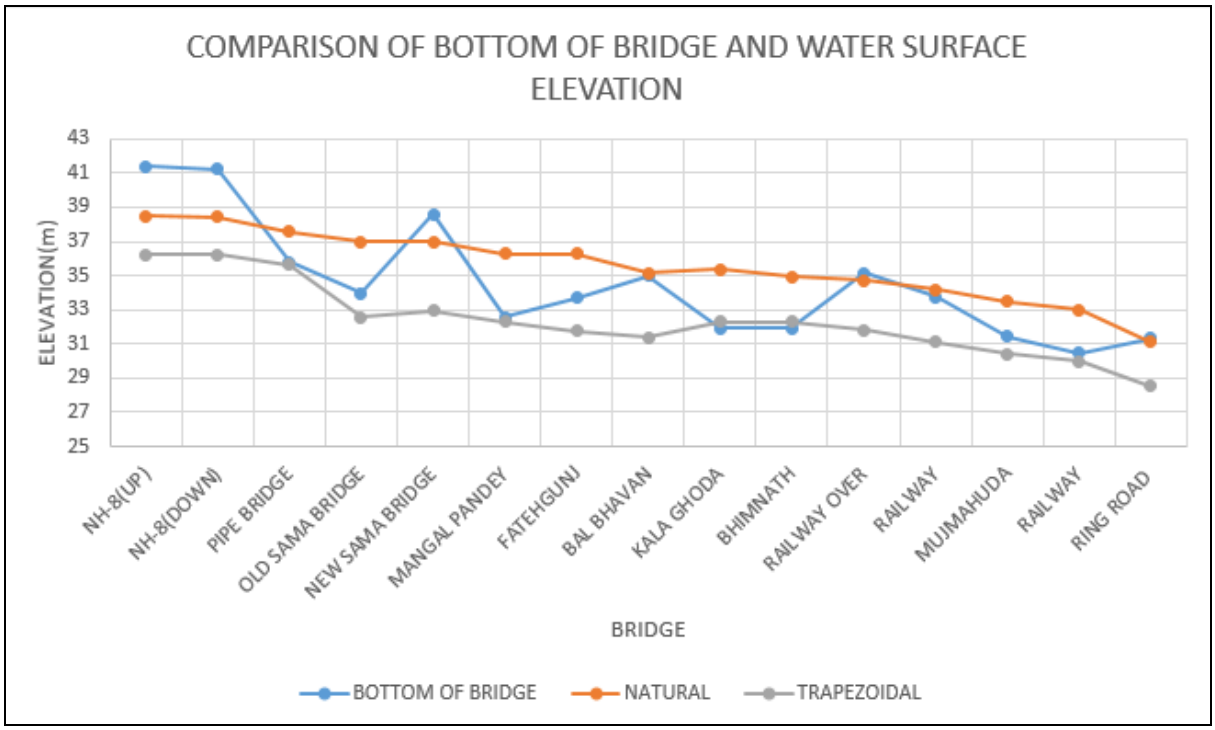

Fig.6 Graphical Comparison of the Water Surface Elevation at the Bridges and the Elevation of the Bottom of the Bridges.

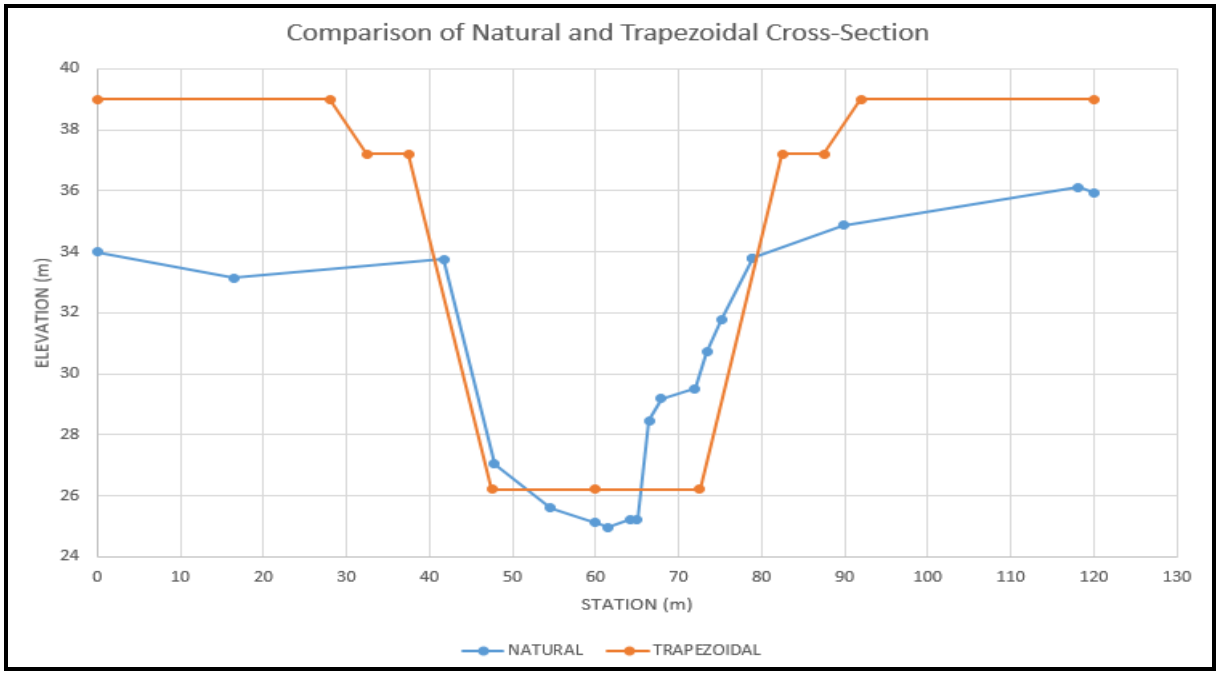

Fig.7 Comparison of Natural and Trapezoidal River Reach of Cross-Section 14600

V. CONCLUSIONS

- From the analysis of comparison of water surface elevation of natural, constricted, rectangular and trapezoidal river reach, it is concluded that the modified sections can carry safely the flood of discharge 805 cumecs.
- The maximum discharge carrying capacity of modified trapezoidal section is 880 cumecs discharge which is greater than 805 cumecs.
- In natural river reach Pipe, Old Sama, Mangal Pandey, Fatehgunj, Balbhavan, Kalaghoda, Bhimnath, Railway, Mujmahuda and Railway Bridges are affected and in trapezoidal river reach only Kalaghoda and Bhimnath Bridge is affected, so the natural section of river reach can be modified to trapezoidal section.

VI. REFERENCES

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