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NUMERICAL MODELLING FOR HYDRAULIC ASSESSMENT OF BRIDGES AGAINST DEPLETING DISCHARGING CAPACITY OF EASTERN RIVERS

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By:

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ABSTRACT

Afflux at bridges can be a source of flood as they cause elevated water levels. The presence of bridges in the rivers cause obstruction to flow of water in the river, due to which there is are increased water levels on the upstream side of the bridges increasing severity and extent of the floods. If we don't consider the effect of bridges, the elevated water levels will cause surprise damages and property losses. The bridges in the river also cause the increase in the velocities of the flow near or at the bridge piers causing scouring. Bridge scour is major causes of bridge failure. This study envisages one dimensional study of the effects of bridges on the flow of the channel. The study area chosen is as our case study is River Sutlej near Bahawalpur. One dimensional study is chosen as the depth to width ratio in the tributary is not considerable, nor the slope is incredible. So the longitudinal flow study will constitute most of the flow characteristics Hydraulic modelling is used to analyze the hydraulic behavior of the system and simulating the river flows.Further, due to sedimentation in Sutlej river, the depleting discharging capacity for various return period floods is also simulated. According to simulations, afflux and scour corresponding to various return period floods have been computed. Further it is concluded that three soffit of the three bridges in nearby vicinity at safe height to avoid even 100-year flood event.

Keywords: Afflux, scour, HECRAS, Hydraulic Modelling etc

1. INTRODUCTION

Due to the presence of bridges, the river cross sections undergoes alteration of the natural geometry of the cross sections because it induces obstruction. A major effect is the water surface elevation on the upstream side of the bridges in comparison to normal water levels i.e. by considering no bridge in the river. Piers can cause an afflux.

The dashed line in the Fig.-1 below is showing the normal water surface level (undisturbed).when a structure is present, water surface level is shown by solid line. Maximum increase of water level is shown by afflux.

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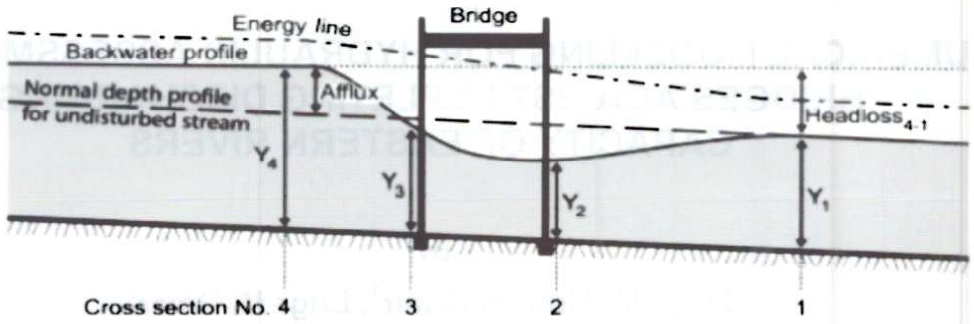


Fig 1: Side elevation at a bridge contraction

Water levels elevated on the upstream of bridges and culverts are a possible source of flood risk. If we increase the flow rate then afflux increases and similarly if we increase the degree of obstruction, afflux increases. In urban areas even, a small increase in water level above a threshold may cause flooding.

Scour is another important phenomena due to the back water effect which results in removing of sediments or gravel around the piers of the bridge. Scour has resulted in many disasters in the past.

The objectives of our research are One dimensional study of the impact of bridges on each other. The parameters under consideration include Water Surface Profiles (Backwater effect is the impact of heading up of water due to some obstruction) Froude number, Head losses Energy and Grade lines. Comparison are carried-out under different scenarios of bridges, their mutual interactions and the corresponding afflux.

2. LITERATURE REVIEW

Backwater effect is reckoned to be an unavoidable event, but the affects can be made less severe by adopting economical procedures including structural and non-structural strategic planning. Nonstructural measures include modeling and flood hazard mapping. Digital modelling techniques using computers have been recently used to overcome the abrasive effects of backwater and afflux.

A major effect consists in an increase of water surface elevation. On the upstream side of the bridge structure water levels increases above the normal water surface profile (no bridge). Backwater at bridges can be investigated in steady flow analysis.

As backwater effect can bring upstream flooding, due to the presence of geometry of the bridge and the characteristics of the floodplain backwater effect varies

Decision is required to be taken depending on the type of method of computation and the amount of topographical data that is required .1-D models are very popular because of reduction in the computational time. One dimensional hydrodynamic flood modelling is based on the following three Assumptions are:

i) There is no remarkable variation in the density of water, i.e. Water is incompressible and homogenous.

ii) The stream shape is in such a shape that length is considerably larger than the depth of the water. I.e. the acceleration in the vertical dimension is insignificant, The bottom slope is exceptionally small, Pressure distribution is hydrostatic and there are no sharp curvatures.

iii) Flow velocity is uniform across the channel

The 1D model use following equations to calculate bridge energy loss are Standard steep energy method and Momentum Equation

Software we used for 1 D modeling is HEC-RAS. The computational procedure of HEC-RAS is based on the one-dimensional energy equation. By friction and contraction / expansion Energy losses are evaluated. The momentum equation used where WSL are changing rapidly

The capabilities of HEC-RAS are, It has attractive and user friendly User Interface, It uses Hydraulic Analysis various Components, Much better data storage and Can also incorporate Graphics.

Water flows in the main channel during normal flow periods and overtops during flood discharges resulting in a compound channel flow section. Compound sections are those having different flow properties. However, we take the Manning's roughness coefficient to be 0.02 to calibrate our model which is within the range value for our Sutlej River bed and it gave us fair results due to 1D flood modeling.

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3. DESIGN APPROACH AND METHODOLOGY:

- Modeling tools used to obtain required results using AutoCad. It provides elevation profile of the river bed as well as cross sections as shown in Fig 2, which is in turn used in HEC-RAS to run simulations. Since the project was based on a software, HEC RAS, and a software can run a data in a specific format so in this step data is brought in a specific format so that it can be executed by HEC RAS.
- We used this AutoCAD drawing as a acquired data from Authentic source, this drawing were consisted of elevation data of our case study river i.e., River Sutlej.
- To analyze the area under consideration i.e., area surrounding the bridges, we take a total reach length of 2200m and drawn total 21 number of cross sections on the AutoCAD drawing at 100 meters, according to the requirement considering the contraction and expansion lengths.

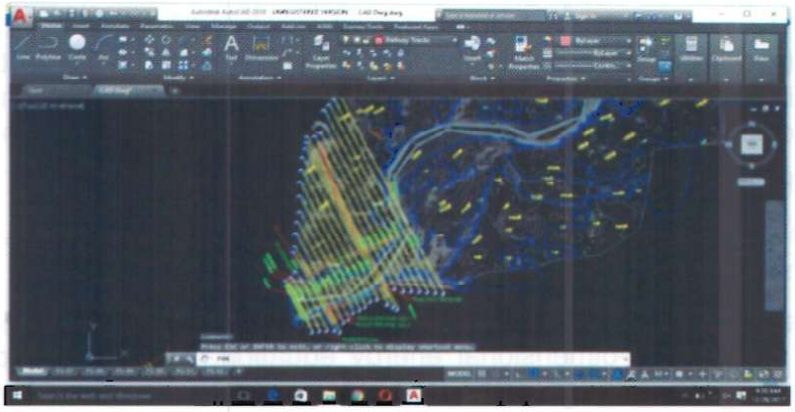


Fig 2 : Elevation profile of River bed and cross sections

- Conversion of .dwg into Excel Format of cross sectional data
- Establishment of river reach as shown in Fig 3.

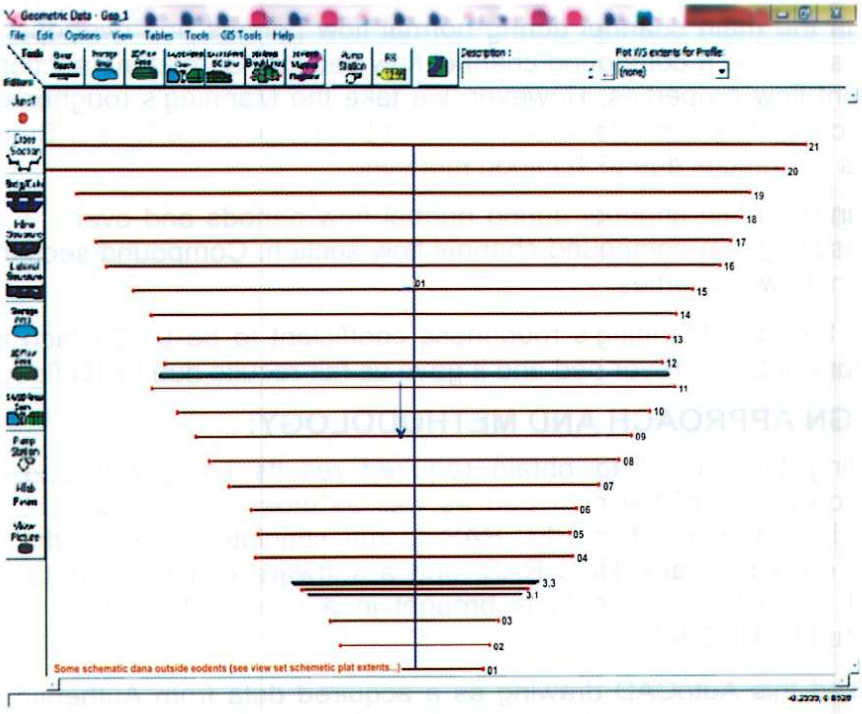


Figure-3 : Establishment of river reach in HECRAS

- It is required to locate the cross sections at regular intervals. Cross sections should be perpendicular to the flow line. Cross section spacing also depends upon size of the stream and longitudinal slope.
- Data are required for each cross section as shown in Fig-4 are Cross section coordinates, River station, Channel bank stations, Reach lengths on downstream direction. Roughness coefficients. Contraction and expansion coefficients.

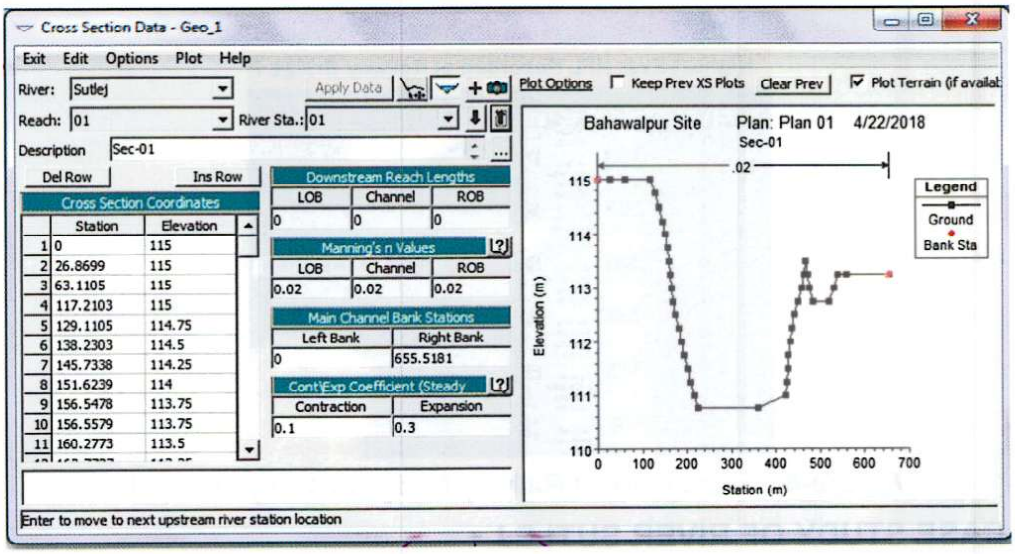


Figure-4 : Cross sections imported in HECRAS.

- The bridge routines in HECRAS enables analysis of bridge hydraulics by using different methods so the distance between the cross sections must be within expansion and contraction lengths/coefficients as shown in Fig-5.

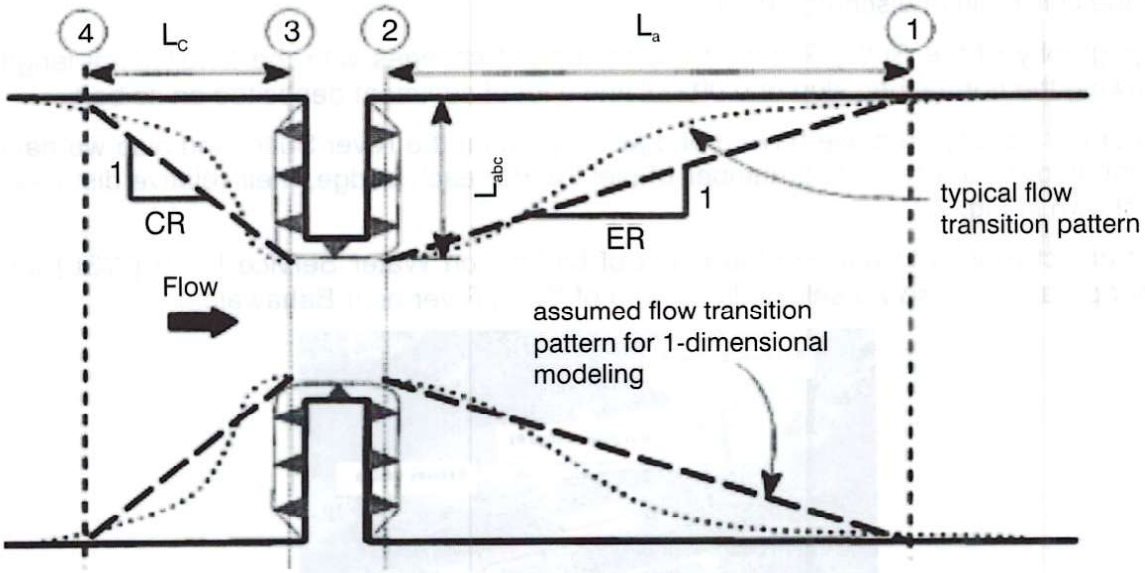


Figure-5 : Expansion and contraction lengths overview

- Model CALIBRATION by using Manning's 'n' Values and Contraction and expansion coefficients. The manning's coefficient we selected is 0.02 for our case study according to the flood mark as shown in Fig-6 .we have avoided a section by section calibration of 'n' values, since to calibrate the 'n' values in this way would produce a model where all the parameter effects are marked.

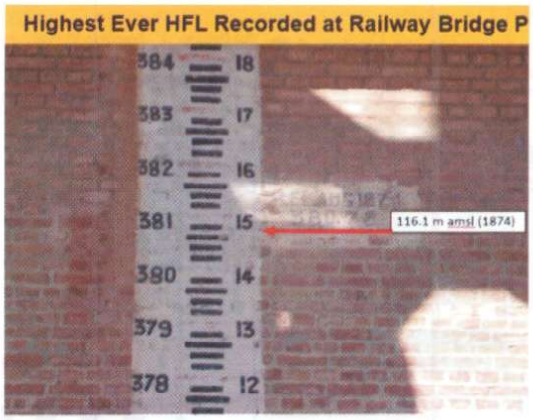


Figure-6 : Flood mark at Railway Bridge of 100 year flood.

4. CASE STUDY OF RIVER SUTLEJ

The Sutlej River is the most extensive of the five rivers of Pakistan. The Sutlej River has a length of 1,450 km (900 miles) long. The Sutlej River is a eastern most branches of the Indus River. hen in Punjab, it merges with Beas and further into Chenab. Total length of the river Sutlej in Pakistan is 329 miles .We use Dipalpur, Suleimanki Barrage and Islam Barrage which are constructed on the main river stream for Irrigation purposes and also for the collection of discharge data

Topography of the Sutlej Riverbed shows a mind changes with the longitudinal length showing the normal bed slop of 0.00227 and a lot of sediment deposited on its bed.

In our case study area, we have 3-bridges located on the River Sutlej and also we have all the information regarding number of piers under each bridge, their relative distances as shown in Fig.-7.

Our objective was to analyze the effect of bridges on Water Service Level (WSL) and other parameters, so we selected this area of Sutlej River near Bahawalpur.

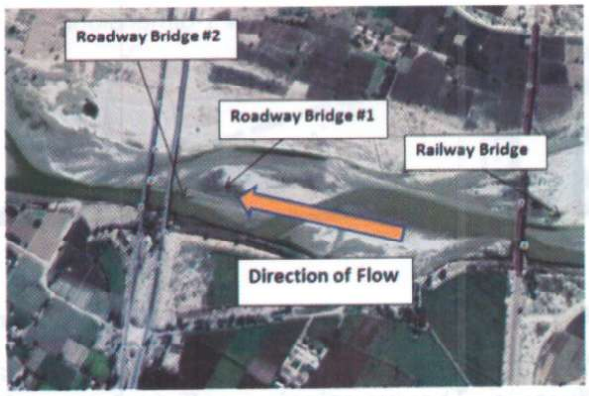


Figure-7 : Location of bridges in our case study.

We used the discharge data of the Islam Barrage since it was closest to our case study area during our analysis as shown in Table-1.

Table 1: Discharge data on different barrages on the Sutlej river.

Return Period (Years)	Suleimanki Barrage (1963-2014) (cusecs)	Islam Barrage (1963-2014) (cusecs)	Mailsi Syphon (1973-2014) (cusecs)
5	151,291	112,939	84,970
10	213,705	160,026	130,238
25	292,565	219,520	187,433
50	351,068	263,656	229,865
100	409,138	307,466	271,983

Road Bridge # 1 data :

Bridge # 1 exists 356m from downstream Total deck width is 8 m. Total length of the bridge is 585.22m. Depth of slab of bridge is 2m .Total number of piers are 11. Width of pier is 1m. Spacing between piers is 50m. Total number of bays are 12.

When all this data were fed into the HECRAS bridge modeling, HECRAS plotted the bridge as shown in Fig-8.

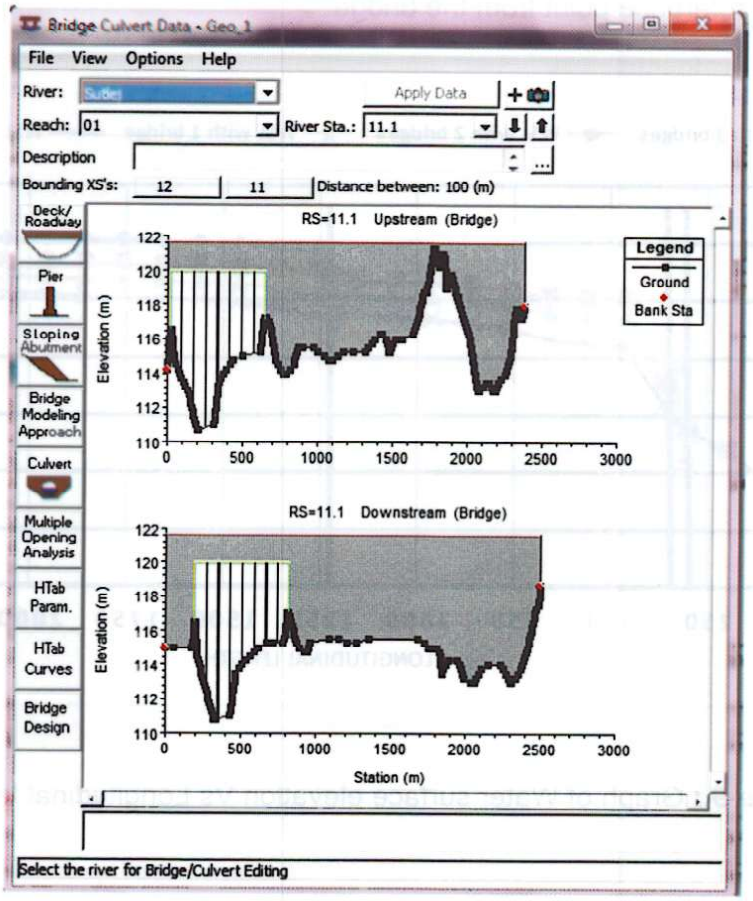


Figure-8 : Bridge in HECRAS.

Road Bridge # 2 data:

Bridge # 1 exists 300m from downstream. Total deck width is 8 m. Width of pier is 1m.Total length of the bridge is 585.22m. Depth of slab of bridge is 2m. Total number of piers are 11. Total number of bays are 12. Spacing between piers is 49.3m

Railway Bridge:

Railway bridge exists 1214m from downstream. Total deck width is 10 m. Total length of the bridge is 635.20 m. Depth of slab of bridge is nearly 1.68m. Total number of piers are 7. Number of bays are 8. Width of pier is 1m. Spacing of piers are 78.3m.

5 RESULTS:

5.1 Analysis and Results of WSL

When we plotted the graph between WSL and number of bridges as shown in Fig-9.

It was concluded that if we increase the number of bridges the WSL on the upstream side of the bridges keep on increasing with the percentage depending on how much is the distance of a reference point from the bridge.

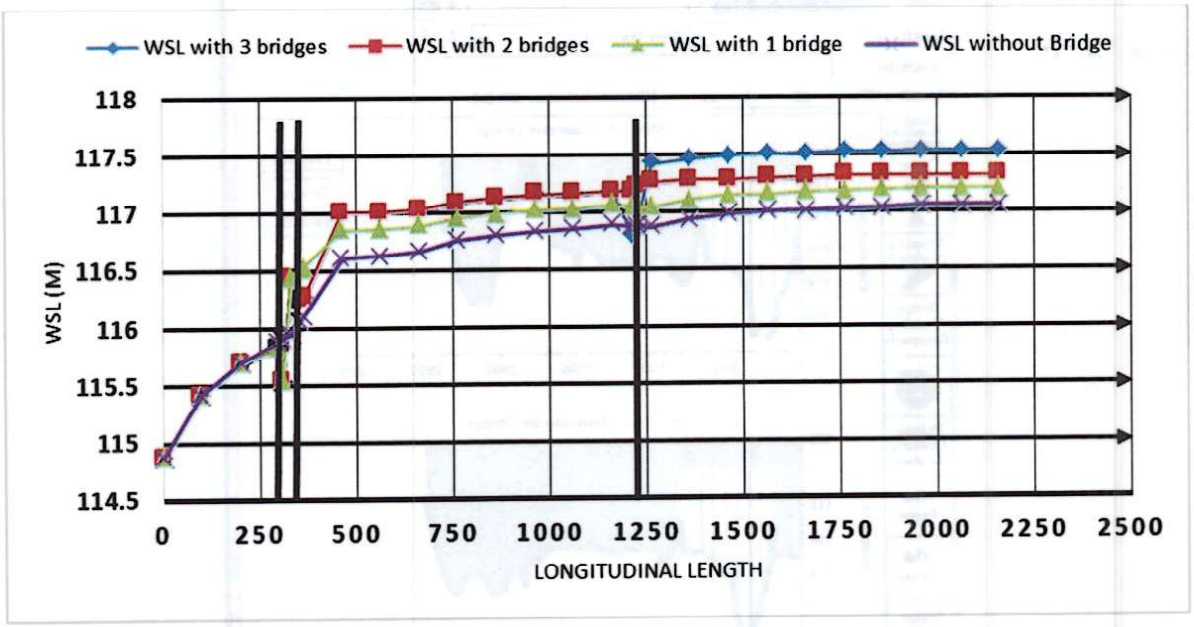


Figure-9 : Graph of Water surface elevation Vs Longitudinal length.

Table-2 : Water surface levels at upstream and downstream of three bridges.

Location	Min bed level	Water levels at 100 year floods				Change in WSL between with and without any bridge (m)
		without bridges	with 1 bridge	with 2 bridges	with 3 bridges	
U/S Railway Bridge	110.75	116.86	117.04	117.25	117.42	0.56
D/S Railway Bridge	110.75	116.87	117.05	117.17	116.8	-0.07
U/S Road Bridge #1	110.75	116.6	116.84	117	117	0.4
D/s Roadway Bridge #1	110.75	116.06	116.51	116.26	116.26	0.2
btw Roadway Bridge 1 & 2	110.75	115.94	116.43	116.43	116.43	0.49
U/S Roadway Bridge #2	110.75	115.94	116.43	116.43	116.43	0.49
D/s Roadway Bridge #2	110.75	115.88	115.83	115.83	115.83	-0.05

5.2 Analysis and Results of Froude's number:

When we analyzed the effect of bridges on the froude's number, We noticed that the froude's number suddenly increases near the bridges as shown in the Fig-10.

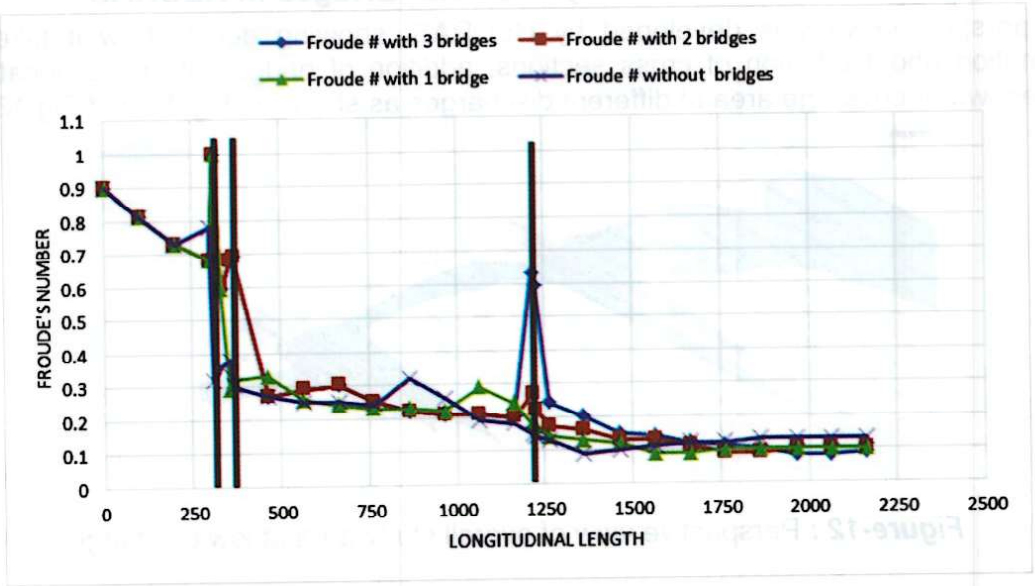


Figure-10 : Graph of Froude's number Vs Longitudinal length.

If we consider the Upstream side of the Railway Bridge, then we conclude that the froude number is changing depending upon the addition of more bridges on the downstream side

Considering our case study analysis the froude number under different scenarios of without considering the bridge, with 1 bridge, with 2 bridges and three bridges are increasing i.e., 0.14 , 0.17 , 0.22 and 0.59 respectively.

5.3 Analysis and Results of headloss:

HECRAS also contain the function to calculate the head losses caused by the application of different bridges as shown in Fig-11.

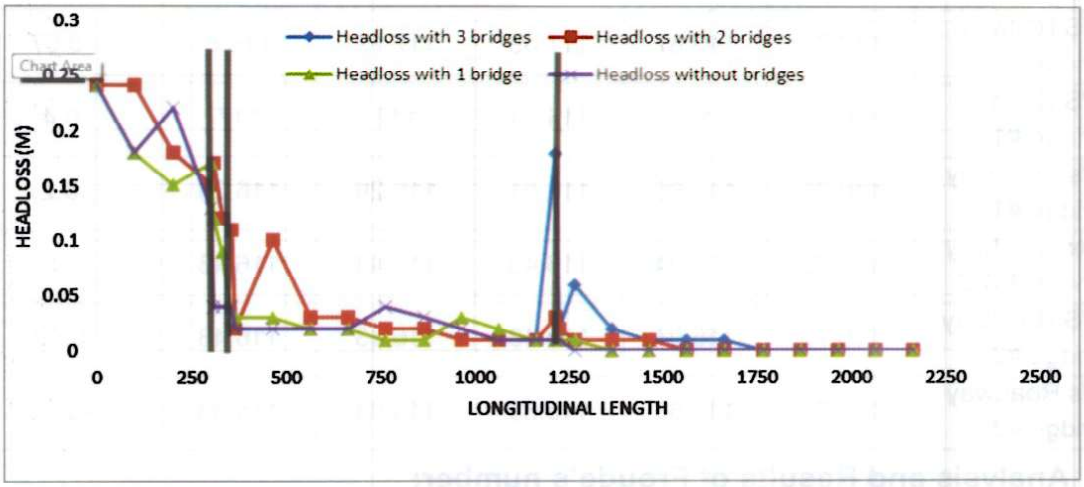


Figure-11 : Graph of Head loss Vs Longitudinal length

5.4 Perspective view of case study river with Bridges in HECRAS

This perspective view is developed by HECRAS, showing details how it takes the information about addition of cross sections, addition of bridges, its piers, location of bridges, water coverage area at different discharges as shown in Fig-12 and Fig-13.

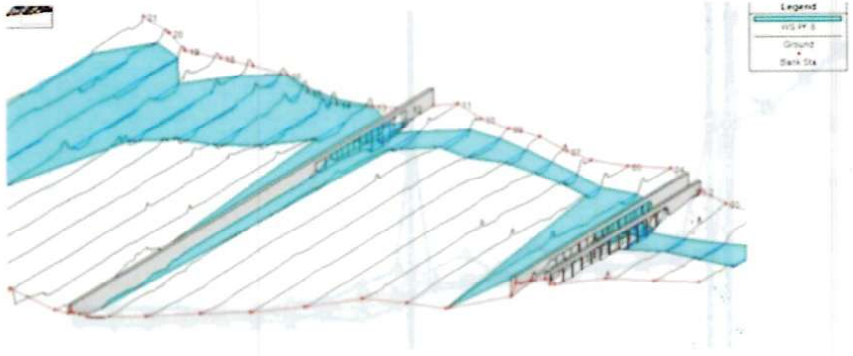


Figure-12 : Perspective view of overall study area at low discharge

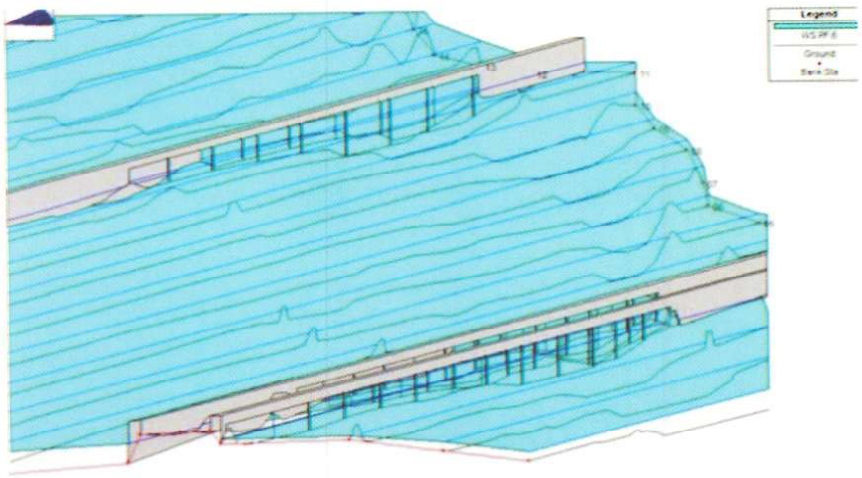


Figure-13 : Perspective view of overall study area at 100 year flood discharge

6. CONCLUSIONS

- The discharge at which we analyzed our case study was of 100 year return period.
- The maximum difference we got by comparing the scenarios of WSL without bridges and WSL with 3 bridges is only 0.56m.

However all three bridges are safe under flood discharge of 100 year return period.

- This model also gives those cross sections which were over topped during flow of flood discharge in the model and also give the height of overtopping water with respect to banks.
- According to our model, the areas surrounding those cross sections which overtopped are more likely to be suffered from floods. In our case study all the cross sections were overtopped except section number 3, 3.2, 4, 5 and 6.
- So there is a need to raise the levels of side leeves/embankment.

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