Unsteady Flow Simulation Of Haripura Dam Using HEC-RAS

*Ankita Sawai, Assistant Professor, Civil Engineering Department, Glocal University, Saharanpur (U.P.), India.

Dr. (Mrs.) Jyothi Prasad, Professor, Civil Engineering Department, G. B. Pant University of Agriculture & Technology, Uttarakhand, India.

Abstract - **An analysis of unsteady flow simulation of hypothetical failure of Haripura dam at Udham Singh Nagar of Uttarakhand is done using HEC-RAS software. The study involves the prediction of breach parameters, flood hydrographs, time of arrival of peak stage and maximum discharge at selected locations including the dam site at 0 km, Govindpur at 5 Km, Narayanpur at 10 Km, Mahtosh at 20 Km, Lambakhera at 26 Km, Mehdipur at 30 Km, Ramnagar at 40 Km, Bilaspur at 45 Km and Khanpur which is located at the distance of 50 Km downstream from the dam. With the variation in height and width of breach, four scenarios are taken in the present study. Stage and flood hydrographs from all the four scenarios are studied and it has been concluded that maximum stage obtained among all the scenarios was 238.97 m, therefore people living very close to dam site in downstream area needs to build their houses above an appropriate level for their safety against high flood levels.**

Keywords — Breach formulation, Dam Break Analysis, HEC-RAS, Hydrograph, Manning's Roughness Coefficient, St. Venant's Equations.

I. INTRODUCTION

Dams are constructed across a river to serve numerous purposes such as irrigation, power generation, flood prevention, industrial use, etc. With all the benefits, constructions of dams may prompt to tremendous problems on the failure of the dam structure. Dam failure is generally catastrophic and may occur due to many reasons such as piping through the structure, overtopping, design error, heavy rainfall generated runoff, earthquake, etc. [1]. As dam break possess high hazards, dam break analysis is considered very important. Dam break analysis can be carried out by either Mathematical simulation using the computer or scaled physical hydraulic model [2]. The fundamental target of developing a dam break model is to simulate the flood wave along the downstream valley. There is an extensive literature review available about dam break modeling such as Johnson and Illes (1976) described failure shapes of arch dams, gravity dams, and earthen dams. He explicated trapezoidal and few triangular breach shapes particularly for earthen dams [3]. Petra Check and Sadler (1984) studied sensitivity of floods by changing breach parameters. They concluded that breach parameters have reasonable impact for locations close to the dam site [4]. Singh and Scarlatos (1988) analyzed 52 case studies and concluded that the ratio of top breach width to dam height was considerably scattered and found that the ratio of top and bottom breach widths were in the range of 1.06 to 1.74 having an average of 1.29 with the standard deviation of 0.18. They also deduced that most failure times were within 3 hours and 50% of the failures times were within 1.5 hours [5].

In the present study, Hydrologic Engineering Centre's River Analysis System (HEC-RAS) software has been taken up for analysis of dam breach by taking different scenarios [6].

1.1 Objectives of the study

(i) To estimate dam breach parameters using appropriate empirical formulae.

(ii) To determine outflow hydrograph and the peak discharge.

(iii) To estimate flood and flood arrival time at selected locations in the downstream area of Haripura Dam.

II. METHODOLOGY

The core of dam break modeling is hydrodynamic modeling which is based on two partial differential equations given by Barre De Saint Venant in 1871 [7]. These equations are:-

(i) Conservation of mass equation

$$\partial Q\, \partial X + \partial (A + A_o)\, \partial t - q = 0$$

(ii) Conservation of momentum equation

$$\partial Q \partial t + \partial (Q/A)/\partial X + gA\partial h \partial X + (S_f + S_c) = 0$$

 DOI : 10.35291/2454-9150.2019.0154

Where Q = discharge, A = active flow area, A_0 = inactive storage area, h = water surface elevation, q = lateral outflow, X = distance along waterway, t = time, S_f = friction slope, S_c = expansion contraction slope and g = gravitational acceleration.

2.1 Dam Break Simulation

2.1.1 About the software

HEC-RAS is Hydrologic Engineering Centre's, River Analysis System developed to focus on development and use of unsteady flow model for dam break studies. HEC-RAS requires precise depiction of the terrain data and the hydrologic inputs as boundary conditions. In order to have confidence in model outcomes in HEC-RAS, estimation and calibration of appropriate model parameters for terrain roughness and hydraulic structures must be done [8]. This software helps to perform one dimensional steady flow, unsteady flow calculations, sediment transport computations and water quality analysis.

2.1.2 Study area

Haripura dam is built on the Bhakra river in Udham Singh Nagar district of Uttarakhand has latitude and longitude 29° 8' N and 79° 20' E respectively and comes under seismic zone IV. The Major Rivers on which dam is built are Bhakra and Khajia. It is an Earthen dam of height 10.98 meters and length 7,980 meters. The main purpose of construction of the dam is irrigation. Dam is designed for total discharge of 877.82 cumecs. The total live storage capacity of Haripura reservoir is 27.61 MCM. The full reservoir level is 242.38 m. Total dead storage capacity of the reservoir is 0.72 MCM and gross storage capacity of the reservoir is 28.32 MCM. Downstream river of Haripura spillway is taken in the present study up to the downstream of Bilaspur City which is located 51 km away from dam site.

2.2 Model Setup

2.2.1 Cross-sections of the downstream river

The downstream river of Haripura Dam is represented in the model by cross-sections at different intervals. Cross-sections are taken with the help of Google Earth at the interval of 1 km up to the distance of 51 km. As nature of dam break flood is highly unsteady, firmly divided cross-sections are taken, particularly at places where the geometry of river is changing rapidly.

2.2.2 Breach Formulation

Depending on the height (H_D) and capacity of Haripura dam, National Weather Service (NWS, Fread, 2006) guidelines are adopted [9]. For the present study, four different scenarios are taken depending on the variation of breach parameters and its calculations are shown in Table No.1. Failure time is taken in the range of 0.1 to 1 hour, side slope (H:V) is taken 1 in all the four cases.

Table 1. Calculation of Breach Parameter

Scenarios	1	2	3	4
Height of breach (m)	1	1	1	0.51
Average Breach Width B_{avg} (m)	2 x H_D = 21.96	3 x H_D = 31.94	4 x H_D = 43.92	2 x H_D = 21.96

2.3 Flow Hydrograph

Flow Hydrograph generated for four different scenarios mentioned above depending on the adopted guidelines is shown in Figure 1.

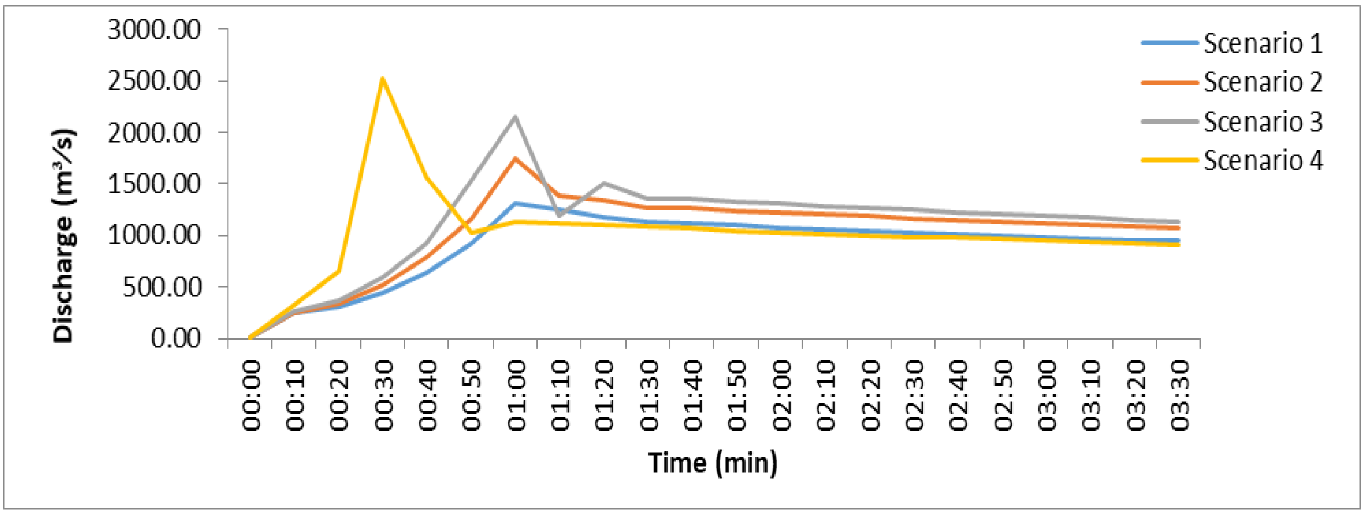

Figure 1. Flow Hydrograph for different scenarios

 DOI : 10.35291/2454-9150.2019.0154

2.2.4 Roughness Coefficient

Downstream river of Haripura reservoir consists of rocky river bed and is surrounded by vegetation therefore on the basis of guidelines given by Chow (1959), manning's roughness coefficient is taken 0.035 throughout the length of the river under study area [10]. The value of roughness coefficient is taken slightly higher than usual as breach flood will exceed the normal flood level.

III. RESULTS AND DISCUSSION

Results are based on four scenarios depending on the sensitivity of breach parameters are given in above Table 1. Downstream Stage and flow routing downstream area has been divided into nine different locations for all the four scenarios.

Table 2. Comparison of Maximum Water Surface Elevation, Time of Arrival and Velocity of Flow for all the scenarios

Place	Location from Dam (Km)	Maximum Water Surface Elevation (m)				Time of Arrival (min)			
		Scenario				Scenario			
		1	2	3	4	1	2	3	4
Dam site	0	238.7	238.9	236.3	236.2	70	60	80	60
Govindpur	5	230.3	230.4	230.5	230.3	180	170	160	140
Narayanpur	10	219.9	220.0	220.1	221.2	260	240	230	210
Mahtosh	20	208.7	208.8	208.8	208.7	540	520	510	520
Lambakhera	26	203.5	203.6	203.7	203.5	720	680	670	700
Mehdipur	30	201.2	201.3	201.3	201.2	840	780	780	790
Ramnagar	40	196.3	196.4	196.4	196.3	1210	1110	1090	1160
Bilaspur	45	192.2	192.2	192.2	192.2	1330	1240	1210	1270
Khanpur	50	189.3	189.4	189.9	189.8	1440	1370	1320	1380

In the first scenario, peak discharge obtained in the downstream area was 1314.4 m³/s after 60 minutes of breach initiation. The maximum stage observed was 238.73 m with the arrival time of 70 minutes. The maximum velocity at the time of peak was 1.34 m/s. In the second scenario, peak discharge of 1743.6 m³/s was obtained after 60 minutes of breach initiation with the velocity of 1.44 m/s at the average breach width of 32.94 m. Maximum water surface elevation was observed to be 238.97 m.

In the third scenario, maximum stage observed was 236.3 m with the arrival time of 80 minutes. Maximum discharge obtained was 1418.75 m³/s after 80 minutes of dam break with the velocity of 1.54m/s. In the fourth scenario, maximum discharge obtained was 1283.01 m³/s after 60 minutes of breach initiation with the velocity of 1.58 m/s. The maximum stage obtained for this scenario was 236.23 m with arrival time of 60 minutes. Table 3 shows the comparison of maximum discharge and time of arrival for different scenarios at selected locations.

Table 3. Comparison of Maximum Discharge, Time of Arrival and Velocity of flow for all the scenarios

Place	Location from Dam (Km)	Maximum Discharge (m³/s)				Time of Arrival (min)			
		Scenario				Scenario			
		1	2	3	4	1	2	3	4
Dam site	0	1314.4	1743.6	1418.7	1283	60	60	80	60
Govindpur	5	1055.5	1211.8	131s0.4	1070.3	180	170	160	140
Narayanpur	10	1042.5	1195.3	1289.9	1058.2	250	240	230	200
Mahtosh	20	876.3	995.1	1062.1	874.5	540	520	500	510
Lambakhera	26	831.2	929.7	989.3	826.7	710	680	660	690
Mehdipur	30	804.4	905.8	958.2	808.5	820	780	770	780
Ramnagar	40	710.8	791.8	832.1	716.7	1190	1110	1090	1140
Bilaspur	45	695.9	770.4	807.0	700.3	1320	1240	1210	1270
Khanpur	50	682.9	753.5	785.6	686.4	1440	1370	1320	1380

Comparison of results for four scenarios shows that scenario 2 is the most critical case. Maximum stage obtained in scenario 2 is 238.9 and maximum discharge is 1743.6 **m³/s.** The longitudinal bed profile of main channel and maximum

 DOI : 10.35291/2454-9150.2019.0154

water surface elevation due to the flood generated by hypothetical dam breach for scenario 2 is shown in Figure 2. A 2D view of downstream area inundated due to dam break flood for scenario 2 is shown in Figure 3. Cross-section of downstream river after dam break with maximum water level at the distance of 0 Km, 5 Km, 10 Km, 20 Km, 26 Km, 30 Km, ,40 Km 45 Km and 50 Km from the dam site are shown in figure 4 to 12.

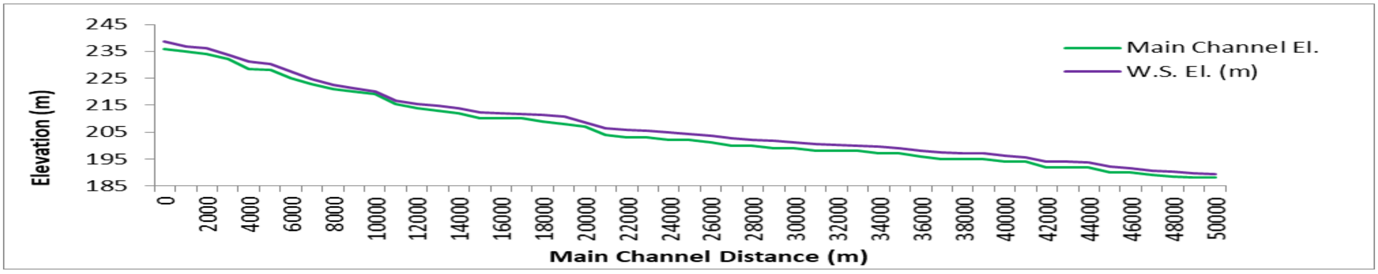

Figure 2. Longitudinal Profile of Downstream River for Scenario

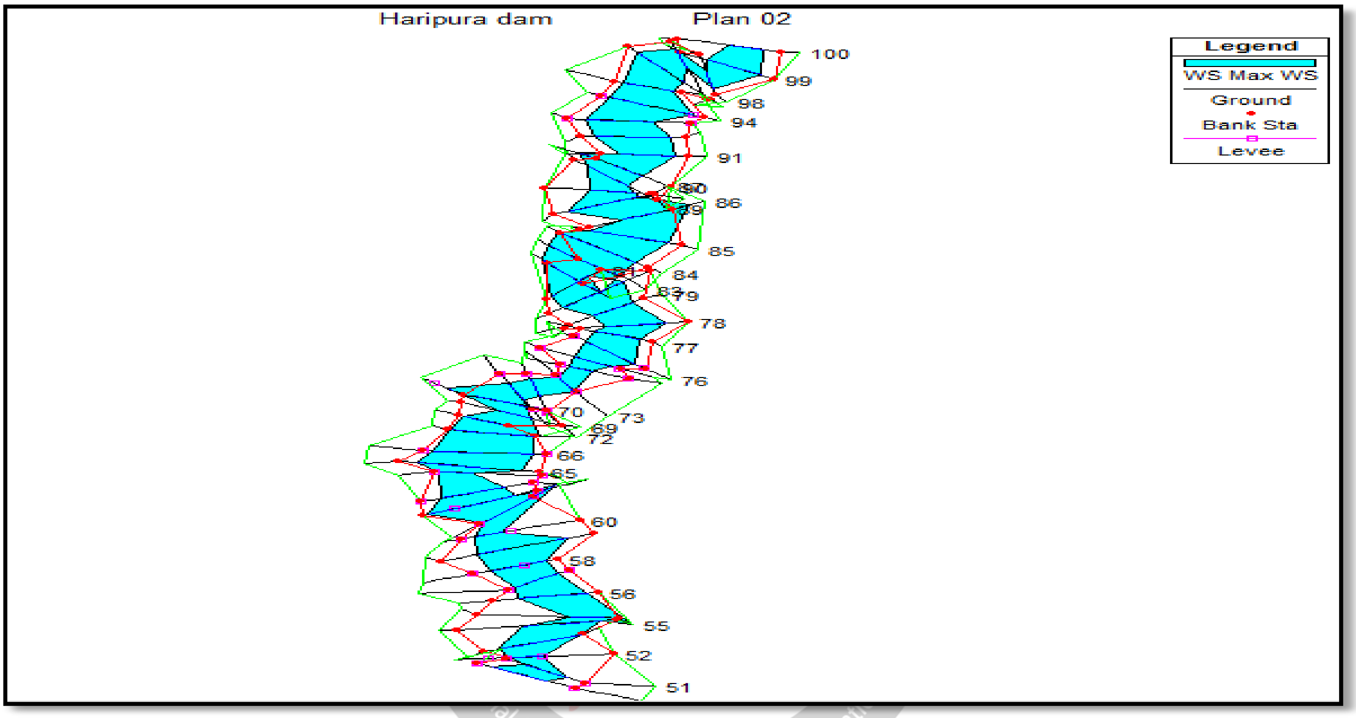

Figure 3. X-Y-Z Perspective Plot of Downstream River for Scenario 2

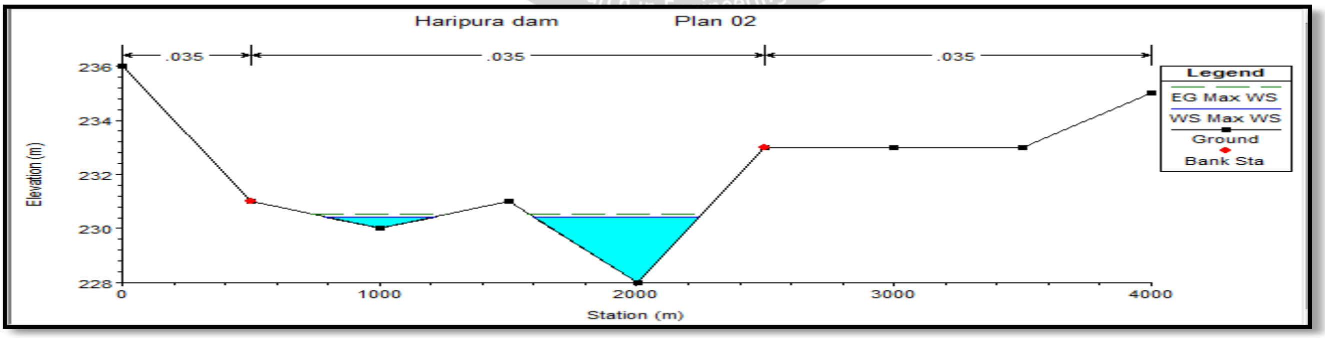

Figure 4. River cross-section at Dam Site for Scenario 2

 DOI : 10.35291/2454-9150.2019.0154

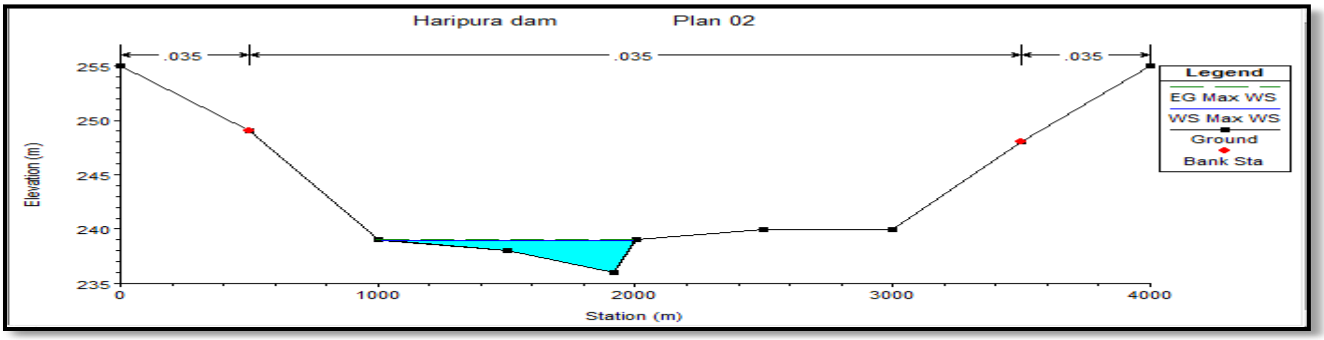

Figure 5. River cross-section at 5 Km d/s from Haripura Dam

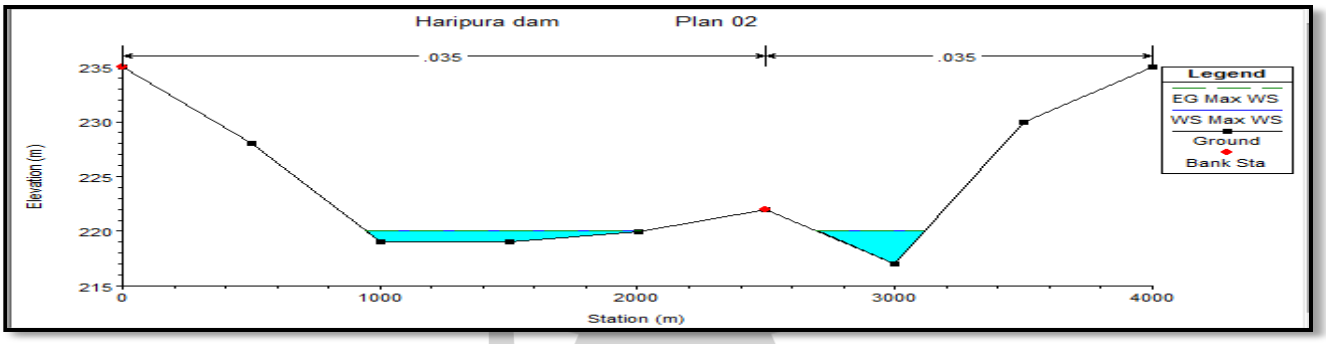

Figure. 6 River cross-section at 10 Km d/s from Haripura Dam

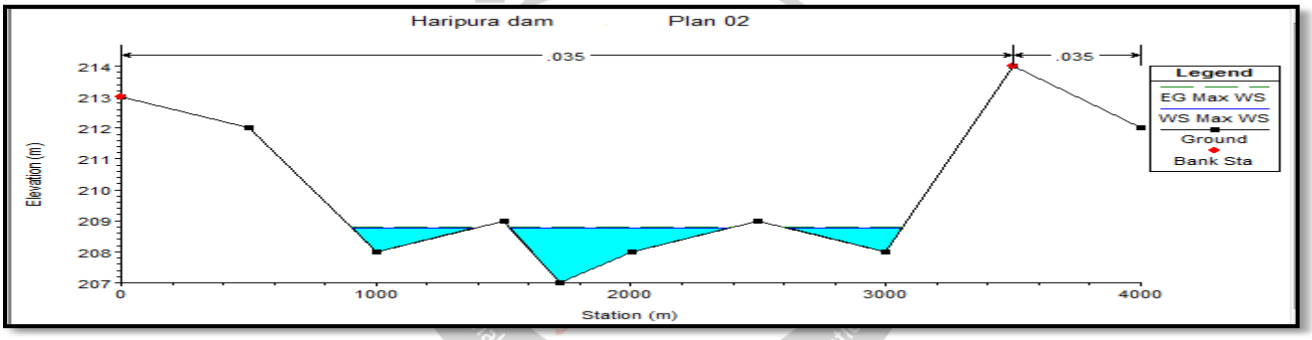

Figure 7. River cross-section at 20 Km d/s from Haripura Dam

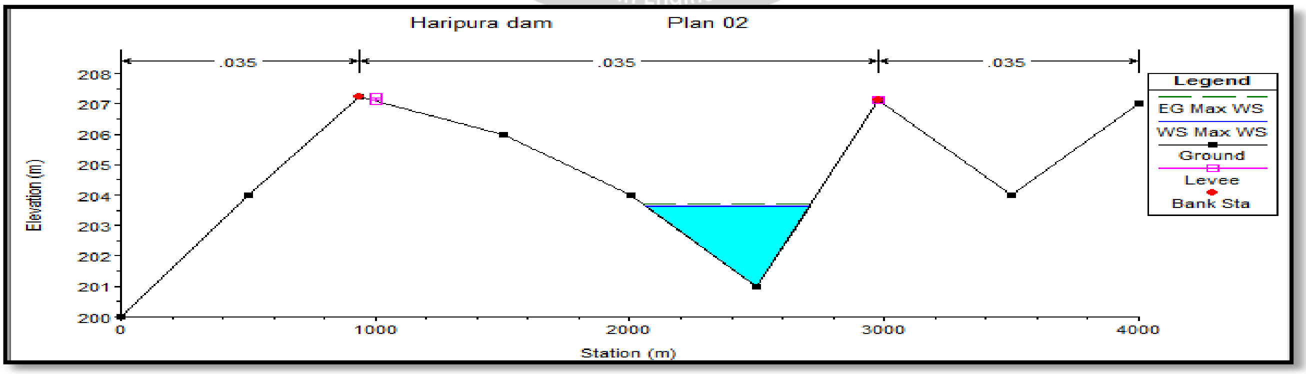

Figure 8. River cross-section at 26 Km d/s from Haripura Dam

DOI : 10.35291/2454-9150.2019.0154

ISSN : 2454-9150 Vol-05, Issue-02, May 2019

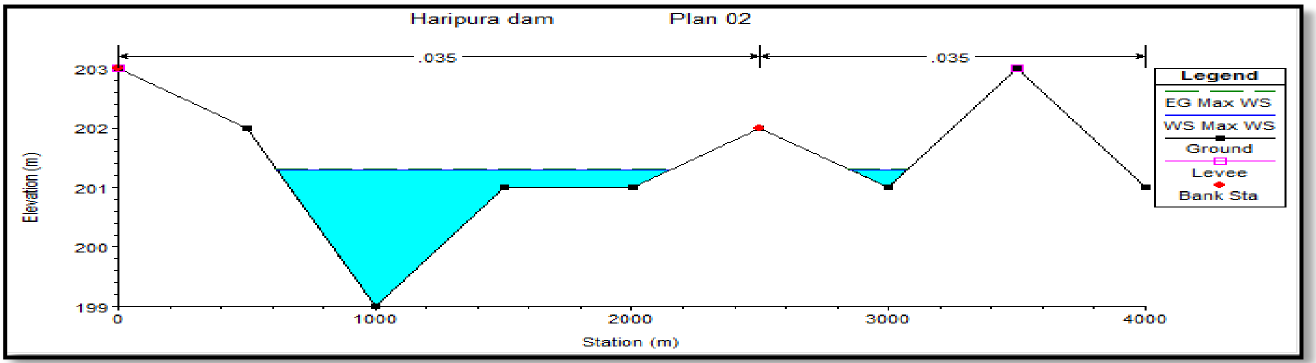

Figure. 9 River cross-section at 30 Km d/s from Haripura Dam

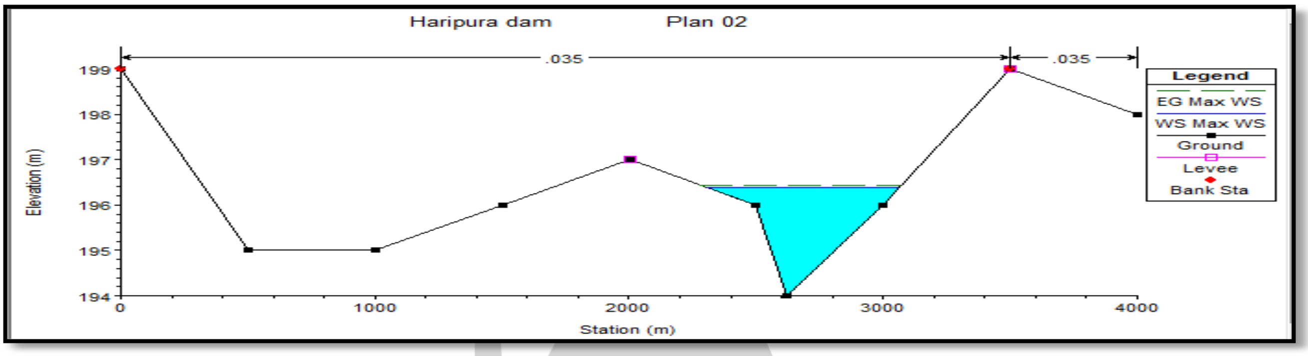

Figure 10. River cross-section at 40 Km d/s from Haripura Dam

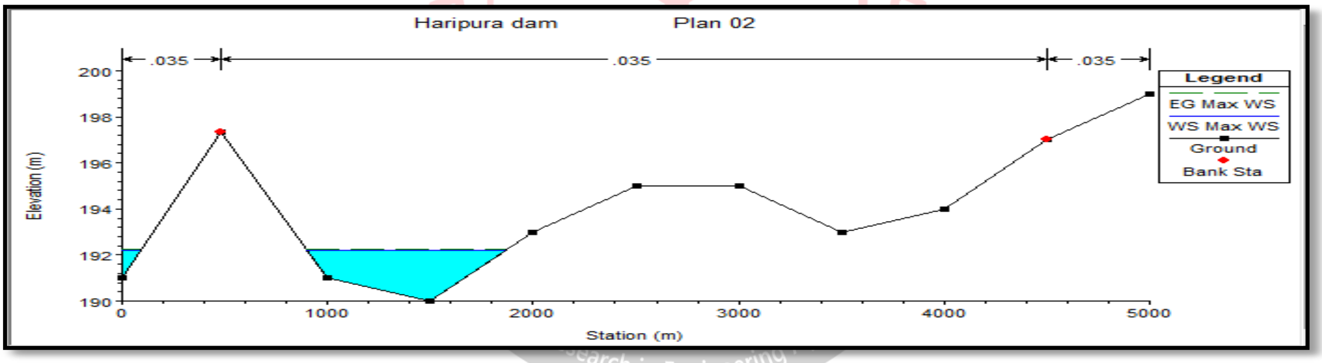

Figure 11. River cross-section at 45 Km d/s from Haripura Dam

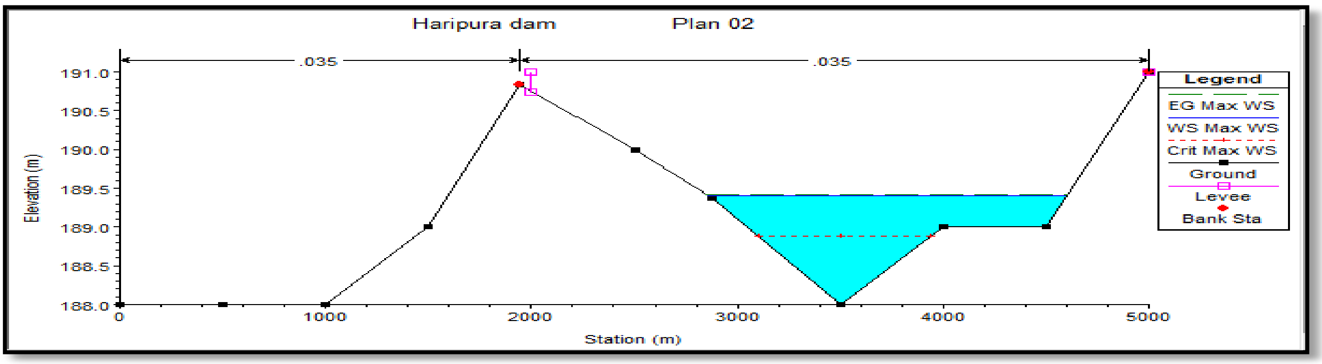

Figure 12 River cross-section at 50 Km d/s from Haripura Dam

IV. CONCLUSION

From the present study, it has been concluded that:-

(i) Breach parameters hold a significant role in dam break study of Haripura Dam using HEC- RAS therefore selection of breach parameters is needed to be done with high precision.

(ii) It is also observed that Places such as Govindpur,

 DOI : 10.35291/2454-9150.2019.0154

Narayanpur, Mahtosh and Lambakhera are in very close proximity to the downstream side of Haripura dam and are highly prone to flood from the dam break.

(iii) The maximum stage obtained among all the scenarios was 238.97 m, therefore people living very close to dam site in downstream area needs to build their houses above this level.

(iv) 'To achieve higher accuracy, the cross-sections of the downstream should be taken manually.

Acknowledgement

The authors are grateful for the support of Civil Engineering department, Glocal University, Saharanpur, U.P. and Civil Engineering department, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand.

References

[1] Hydrologic Engineering Centre, (2010a). "HEC-RAS River Analysis System, Hydraulic Reference Manual", CPD-69, U.S. Army Corps of Engineers, Hydrologic Engineering Centre, 609 Second Street, Davis, CA.

[2] Wahl, Tony L., (1988). "Prediction of Embankment Dam Breach Parameters", A Literature Review and Needs Assessment, Water Resources Research Laboratory, U.S. Department of the Interior, Bureau of Reclamation, Dam Safety Office, 1988.

[3] Johnson, F.A. and Illes, P., (1976). "A Classification of Dam Failures". Water Power and Dam Construction, 28(12), p. 43 – 45.

[4] Petra Check, A. W., and Sadler, P. A., (1984). "Routing of Dam Break Floods." International Water Power and Dam Construction, v. 36, p. 29-32.

[5] Singh, V.P., Scarlatos, P.D., Collins, J.G. and Jaurdan, M.R., (1988). "Breach Erosion of Earthfill Dams (BEED) Model". Natural Hazards, Volume 1, pages 161-180.

[6] Middlebrooks, (1952). T.A., Earth Dam Practice in the United States, ASCE Centennial Transactions Paper 2620, 1952, pp. 697-722.

[7] De Saint-Venant, Barre (1871). "Theory of Unsteady Water Flow with Application to River Floods and to Propagation of Tides in River Channels", Acad. Sci. (Paris) Comptes Rendus, 73, pp. 237-240.

[8] U.S. Army Corps of Engineers, (2007). Hydrologic Engineering Center, "Dam Breach Analysis using the Hydrologic Engineering Center's River Analysis System HEC-RAS", Training Manual, 2007.

[9] Fread, D. L. (2006). "Dam Failure Analysis", Advanced Technical Seminar, ASDSO, Burlington, VT.

[10] Chow, V. T., (1959). "Open Channel Hydraulics", Mc Graw-Hill Book Co., New York.

 DOI : 10.35291/2454-9150.2019.0154