J. Indian Water Resour. Soc.,
Vol. 39, No. 4, Oct., 2019

BAUR DAM BREACH ANALYSIS USING 2D HEC-RAS

Meenakshi Ramola[1], Jyothi Prasad[2*], H. J. Shiva Prasad[2]

ABSTRACT

Dam is a very essential part of our society. It provides power supply, irrigation water, tourism, navigation and many other benefits. Dam structure is very crucial and lack of strategy, maintenance, structure design can cause high level of flood devastation to the adjacent area. It affects at high level interms of loss of lives of people, loss of economy, environment degradation etc. Dam breach process may be instantaneous or gradual, depending on type of dam. In this paper hypothetical breach of earthen dam has been analysed by using HEC-RAS, which is a computer program and used for dam breach modelling. Methodology adopted during modelling is summarised in this paper. Dam breach analysis is important, it provides detail knowledge about flood characteristics with the help of flow,depth, water surface elevation values and also about inundated areas by using inundation maps. These maps are useful for local administration and other stakeholders at the time of emergency, so that local people can be saved by providing emergency warning. The results of modelling show that overtopping failure causes more flood with respect to piping failure in earthen dam, however the difference is meagre. This paper presents a case study based on limited data of Baur dam (Uttarakhand) analysed using HEC-RAS modelling breach guidelines. The results of HEC-RAS analysis shows that worst scenario is pool reservoir level with overtopping failure pattern of Baur dam.

Keywords: *Breach parameter, HEC-RAS, Dam breach analysis, Inundation map,Flood analysis*

INTRODUCTION

Dam breach analysis is very important because failure of dam causes massive or uncontrolled release of water, which causes loss of flora and fauna, structure, environment, human lives. Dams are structure constructed across river to store water for different purposes. Their site survey detail, structure detail, foundation property, type of dam, natural vegetation and terrain plays key role to prevent dam breach. Failure of dam can be instantaneous or gradual, depending on type of construction material. Concrete dam may fails instantaneously whereas earthen dam failure can be gradual due to overtopping of water over crest or due to piping. Failure of any dam poses most of the disaster to the nearby area or locality of that dam. According to report "Guidelines for Mapping Flood Risk Associated with Dams" Jan 2018, Central Water Commission, Government of India, the Machuchu Dam failure in Gujarat was a calamity, claiming lives more than, 2000 persons and upto 2018, 36 large dam failure cases recorded in India [2]. Recently on late night 2nd June, 2019, Tiware dam fails in Ratnagiri district of Maharashtra in which 7 villages and 20 people swept away. Major causes of dam failure that were identified in Costa report (1985) are overtopping due to insufficient spillway capacity (34%), piping and seepage (28%), and foundation defects (30%) [3]. Embankment dam failure analysis can be observed as a two-step process. First is the analysis of actual breach of dam, and second is the dam breach outflow must be routed properly to the downstream of dam so that resulting flood at population centre area can be properly determined [8].With the advancement in techniques the dam break modelling can be easily simulated. Some of them are HEC-RAS, MIKE 11, MIKE 21, DAMBRK etc are very helpful for dam break modelling. This paper reviews about the 2D HEC-RAS simulation process, breach parameter selection criteria, generated result and inundation maps with inundated area detail for two different scenarios.

1. *M. Tech. Student & [2]Professor, Dept. of Civil Engg., College of Technology.*
2. *G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand)*
Email[*] (corresponding author: profjyothiprasad@gmail.com)
Manuscript No. 1523

OBJECTIVES

- The key objective is to plot an inundation map for the downstream areas of Baur dam.
- To simulate dam breach flow to the downstream side of dam.
- Evaluation of risk
- To give an idea about the time and flood level at which the flood strike at populated areas.

METHODOLOGY

In this work, two scenarios are considered to estimate the flood characteristics. The study is performed on Baur dam, Uttarakhand having latitude 29°08'N and longitude of 79°20'E using HEC-RAS model. In dam breach analysis, breach parameters play important role to decide failure pattern as shown in Table 1. In this work trapezoidal shape of breach is considered, and the modelling is conducted at two different scenarios which are based on two different failure patterns of dam.

Scenario 1: Pool reservoir level with overtopping failure

Scenario 2: Pool reservoir level with piping failure.

DAM BREACH SIMULATION

Study area

Baur dam comes under the category of earthen dam and constructed on Baur and Kahrala rivers in Udham Singh Nagar district of Uttarakhand state. The location of dam have latitude 29°08'N and longitude of 79°20'E. It has height of 17.98 meters and length of 9500 meters. Its main purpose is irrigation and used to irrigate the area of Udham Singh Nagar district of Uttarakhand and areas of Rampur district of Uttar Pradesh.

About the model used

HEC-RAS is Hydrologic Engineering Centre's River Analysis System computer program developed by U. S. Army Corps of Engineers. It is a software easily accessible to public domain. The software helps to perform one dimensional, two dimensional and coupling of both 1D and 2D flow analysis, sediment transport computation and water quality modeling [1]. Recently in March, 2019 HEC-RAS Version 5.0.7 is released.

Dam breach analysis using 2D HEC-RAS

Two Dimensional Unsteady flow modelling is prepared for dam breach analysis with plotting of flood inundation map with the help of RAS Mapper feature in HEC-RAS in collaboration of QGIS. In this work 2D HEC-RAS modelling performed. The two-dimensional flow means third dimension (depth) is considered shallow as compared to other two directions. In which Navier-Stokes's equation is helpful to solve the 2D Saint Venant's Equations which represent mass and momentum conservation in plane. HEC-RAS has the ability to solve either the 2D full Saint Venant shallow water equations or the 2D Diffusion Wave equations, as chosen by the user.

Below are the basic 2D Saint Venant's Equation used over floodplain.

- **Conservation of mass:**

$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial x}=0$$

- **Conservation of momentum:**

$$\frac{\partial (hu)}{\partial t}+\frac{\partial (hu^2+0.5gh^2)}{\partial x}+\frac{\partial (hv)}{\partial y}=0$$

$$\frac{\partial (hv)}{\partial t}+\frac{\partial (hv^2+0.5gh^2)}{\partial x}+\frac{\partial (hu)}{\partial y}=0$$

Breach parameter selection criteria

A careful evaluation and understanding of breach parameters is necessary so that the vagueness of every aspects of dam failure can be reduced. Breach parameters depends on several factors such as soil characterstics, upstream discharge of dam, degree of compaction and geometry of fill material [4]. According to Dam Safety Report, Breach parameters include breach geometry i.e breach width, breach depth, breach side slope factor and breach initiation and formation time.

Table 1: General Guidelines for Assuming Breach Geometry

Dam type	Breach width (expressed as dam height)	Side slope of breach Z(H):1(V)	Failure time in hours	Agency
Earthfill dam	(0.5-3.0) H.D.	0-1.0	0.5-4.0	USACE 1980
	(1.0-5.0) H.D.	0-1.0	0.1-1.0	FERC
	(2.0-5.0) H.D.	0-1.0	0.1-1.0	NWS
	(0.5-5.0) H.D.	0-1.0	0.1-4.0	USACE 2007

Where, H.D. = Height of dam & L = Length of dam crest

Steps of dam breach Modelling using 2D HEC-RAS

The steps followed in developing two- dimensional modelling using HEC-RAS as shown:

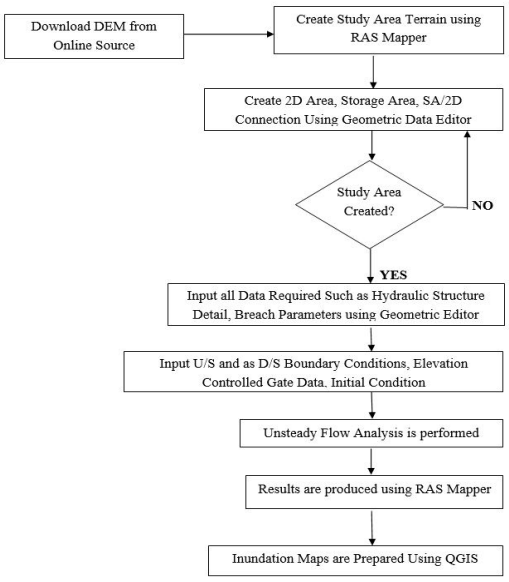

Figure 1: Steps of dam breach Modelling using 2D HEC-RAS

RESULTS AND DISCUSSION

The Baur dam breach results are simulated using HEC-RAS model. The results show the data of peak discharge of flow, maximum water surface elevation, time of arrival of flood at four different downstream areas named as Kelakhera, Gadarpur, Bosena, Milakkhanam for modelling.

Scenario 1:

In the first scenario of Dam Breach Simulation, Pool Reservoir Level is considered with overtopping failure of earthen dam. This type of failure can take place by various reason such as heavy rainfall for several days and it exceeds the value of maximum capacity of reservoir,

Dam breach results for flood routing:

Routing of flood is plotted at four different places. All the required detail is shown in Table 2 with the variation of depth with time at all four places is shown in Figure 2 and Figure 3 shows variation of flow with time. The maximum depth at Kelakhera, Gadarpur, Bosena, and Milakkhanam are 2.76 m, 5.71 m, 4.44 m, and 22.19 m respectively. The maximum water surface elevation at Kelakhera, Gadarpur,

Bosena, Milakkhanam are 203.48 m, 199.46 m, 189.62 m, 192.25 m respectively.

Scenario 2:

In the second scenario of Dam Breach Simulation, Pool Reservoir Level is considered with piping failure of earthen dam. This type of failure starts from toe of dam and move towards the upstream side and a pipe network forms inside the dam. It's a process of erosion of soil material which results failure of dam.

Dam breach results for flood routing:

Routing of flood is plotted at four different places. All the required detail is shown in Table 3 with the variation of depth with time at all four places is shown in Figure 4 and Figure 5 shows variation flow with time. The maximum depth at Kelakhera, Gadarpur, Bosena, and Milakkhanam are 2.55 m, 2.62 m, 2.30 m, and 7.55 m respectively. The maximum water surface elevation at Kelakhera, Gadarpur, Bosena, Milakkhanam are 203.48 m, 200.36 m, 189.60 m, 192.25 m respectively.

Inundation map

Figure 6 and 7 shows the inundated map for both the scenarios. Inundated area value calculataed with the help of QGIS and it has been noted that the total area inundated for scenario 1 is more than for scenario 2, however the difference is less, but in respect of flood devastation small

Table 2: Maximum Discharge, Maximum Water Surface Elevation (WSE), Maximum Depth and Time of Arrival of Flood at Four Places for Scenario 1

Place	Distance from dam (Km)	Maximum Discharge Q_{max} (cumec)	Time & day of arrival of Q_{max} (Hours)	Maximum WSE (m)	Maximum Depth (m)
Kelakhera	10	74.5879	23:00 (day 3)	203.48	2.76
Gadarpur	10.5	40.9619	23:10 (day 1)	199.46	5.71
Bosena	20	162.1485	08:00 (day 2)	189.62	4.44
Milakkhanam	22	290.1153	16:10 (day 2)	192.25	22.19

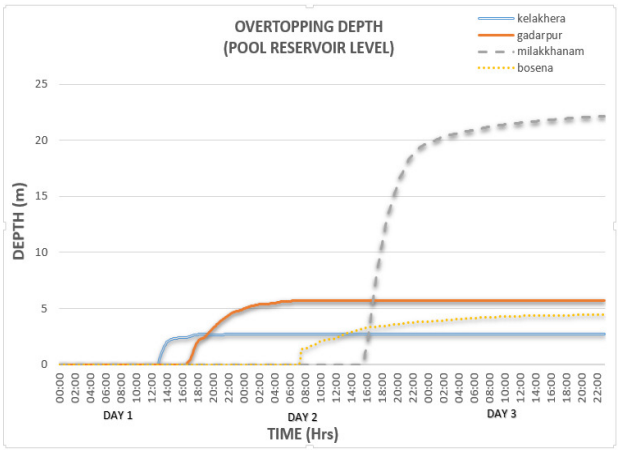

Figure 2: depth v/s time

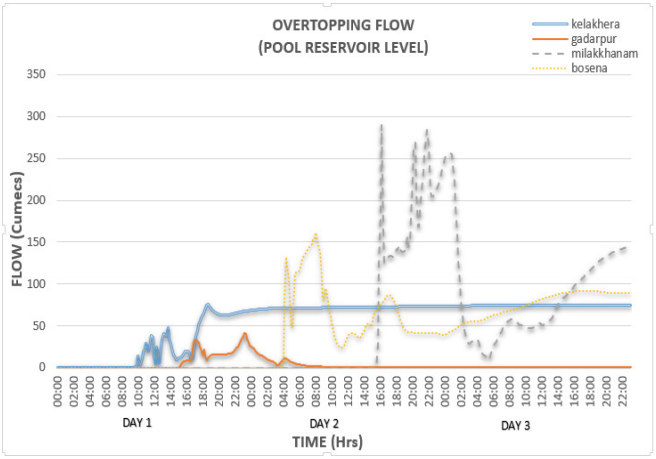

Figure 3: flow v/s time

Table 3: Maximum Discharge, Maximum Water Surface Elevation (WSE), Maximum Depth and Time of Arrival of Flood at Four Places for Scenario 2

Place	Distance from dam (Km)	Maximum Discharge Q_{max} (cumec)	Time & day of arrival of Q_{max} (Hours)	Maximum WSE (m)	Maximum Depth (m)
Kelakhera	10	135.9818	15:50(day 1)	203.48	2.55
Gadarpur	10.5	64.9816	22:30(day 3)	200.36	2.62
Bosena	20	292.2742	17:00(day 2)	189.60	2.30
Milakkhanam	22	352.1875	03:00(day 2)	192.25	7.55

area also counts much value because of human lives. So, the small difference regarding flooded area have to be noticed.

The inundated area values are shown in Table-4 with reservoir area of Baur dam is 11.231 km^2

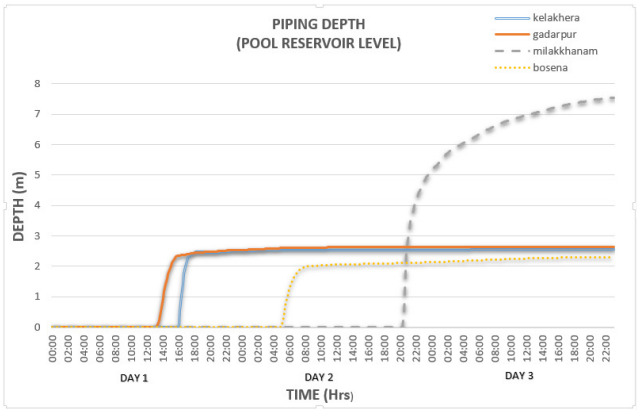

Figure 4: depth v/s time

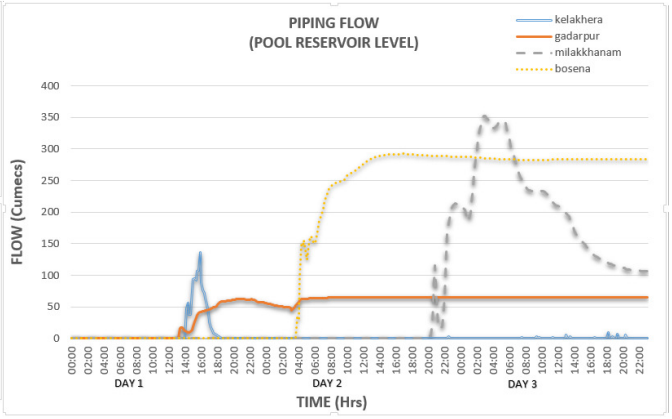

Figure 5: flow v/s time

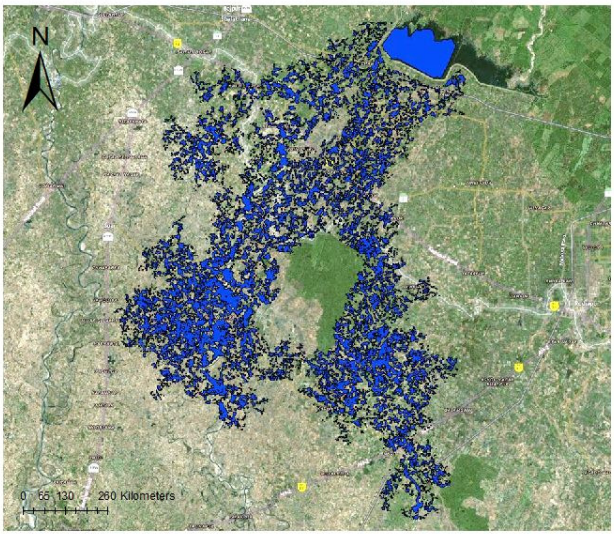

Figure 6: Inundation Map for Scenario 1

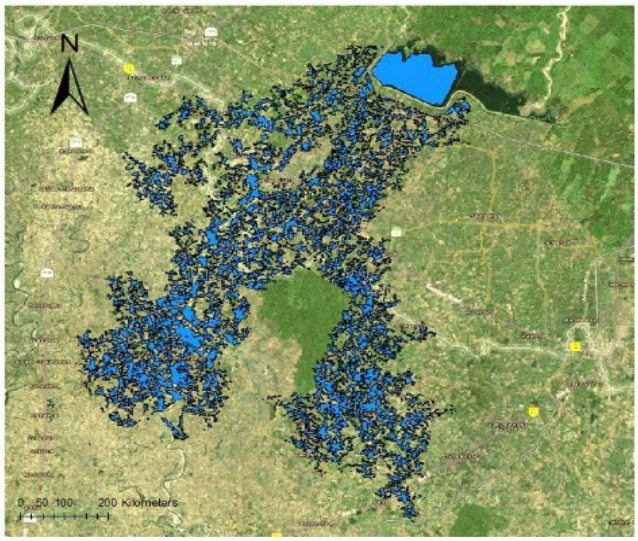

Figure 7: Inundation Map for Scenario 2

Table 4: Showing Details of Inundated Area

Scenario	1	2
Inundated area (km^2),	36.505544200 (36.51)	36.505503991 (36.51)

CONCLUSION

After the complete analysis of results for both scenarios, it has been concluded that 2D HEC-RAS gives better understanding of flood flow movement with various details such as discharge, depth, water surface elevation and the analyse of dam breach modelling becomes easy. The results show that overtopping failure is more devastating than the piping failure in earthen dam. Overtopping failure causes more flood in the downstream of dam. The total area inundated for scenario 1 was slighty more than scenario 2, however the difference found to be less and figures rounded off the final Table, but in respect of flood devastation small area also counts much value because of involvement of human lives. So, this paper emphasis to consider the small difference regarding flooded area. The Study of Water Surface Elevation detail gives the previous level of flood, which will helps authorities to suggest the people to build their houses above this level.

REFERENCES

1. Anjana K.T.K. , Dijo Joy, Revathy Manikuttan, Sachin Sas, Binou Alias M (2016). "Dam Break Analysis Using HEC-RAS". International Research Journal of Engineering & Technology (IRJET). Volume 3, Issue 3, pages 308-309.
2. Central Water Commission, (2018). "Guidelines for Mapping Flood Risk Associated with Dams", January, 2018, Central Water Commission, Ministry of Water Resources, Government of India. http://indiaenvironmentportal.org.in

3. Costa John E. (1985). "Flood from Dam Failure", United State Department of The Interior, Geological Survey Open File Report 85-560, Denver, CO.

4. Dam Safety Office (1998). "Prediction of Embankment Dam Breach Parameters", Water Resource Research Laboratory, pages 1-42.

5. Federal Energy Regulatory Commission (1987). "Engineering Guidelines for the Evaluation of Hydropower Projects", FERC 0119-1, Office of Hydropower Licensing, page 9.

6. Federal Energy Regulatory Commission (1988). "Notice of Revised Emergency Action Plan Guidelines".

7. Hydrologic Engineering Centre (HEC, 2016). "HECR-RAS River Analysis System, 2D Modelling User's Manual", Version 5.0, February 2016. Hydrologic Engineering Centre, Institute for Water Resources, U.S. Corps of Engineers, Davis, CA. http://www.hec.usace.army.mil/software/hec-ras.

8. Mrunal M.Joshi and S.S. Shahapure (2017)."Two Dimensional Dam Break Flow Study Using HEC-RAS for Ujjani Dam". International Journal of Engineering and Technology (IJET). Vol. 9, No. 4, pages 2923-2928.

9. U.S. Army Corps of Engineers (USACE, 2014). Using HECRAS for dam break studies", August 2014 Hydrologic Engineering Centre, Institute for Water Resources, U.S. Corps of Engineers, Davis. CA.