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CONTENTS

Baur dam breach analysis using various Manning's roughness values

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ABSTRACT: This paper describes the importance of flood mapping in terms of saving downstream agricultural land. Flood can cause high impact on the productivity of nearby crops which further affects the country's economy. The Baur dam is situated in Udham Singh Nagar district of Uttarakhand State of India. It has a Culturable Command Area of 65.72 km^2 for Uttarakhand and 314.53km^2 for Uttar Pradesh state. Present study key focus is on describing the importance of Manning's roughness value in dam breach analysis. In this work hypothetical breach modelling of Baur dam is performed by using Hydrologic Engineer's Centre-River Analysis System (HEC-RAS 5.0.3) model. Details about study area, breach parameters, modelling procedure, and outflow flood values are also described. Flow hydrographs are plotted at different Manning's roughness value for the populated downstream areas of dam and it has been observed from the results that as roughness value increases, flow decreases which justifies Manning's theory. Inundation maps with varying Manning's values are plotted. The Manning's roughness value of 0.030 leads to 37.75km^2 inundated area in the downstream of dam.

Key words: Dam breach analysis, HEC-RAS, inundation map, Manning's theory, roughness parameter

It is well known that dam is very beneficial to our society as it is valuable for power production, tourism, irrigation, water supply for households, and navigation, etc**.** Baur dam is an irrigation dam located at Uttarakhand with a Culturable Command Area of 65.72 km^2 for Uttarakhand and 314.53km^2 for Uttar Pradesh. It also has some negative side, such as if it fails due to any reason may cause high level of devastation in terms of life, economy, social and environmental aspects, etc. The main purpose of this dam is to provide irrigation water to the nearby areas. In case of dam failure due to any reason, it can not only effect the nearby areas, but also the irrigation water supply will also get affected badly. Recently in 2017, Central Water Commission circulated a report stating that about 1, 07,487 casualties took place in India due to floods and in last 64 years between 1953 to 2017, one-fifth of global death had occurred only due to floods (http:// indiaenvironmentportal.org.in). This data shows the importance of present work as dam breach is one of the main cause of flood. Dam can fail because of various reasons such as: overtopping, piping, earthquake, high precipitation on upstream places, foundation failure, structure failure, landslide, etc. Earthen dam fails mainly because of overtopping and piping. In this work, Baur dam breach analysis is considered which is an earthen dam and for analysis overtopping failure is considered at five different roughness values in the range of 0.030 to 0.040. HEC-RAS is an example of semi-physical model and useful for flood planning and management. Methodology used for dam breach analysis in this work is presented in Figure 1. According to Manning's theory, roughness coefficient is denoted by 'n' and this roughness value represent resistance to the flood flow in channels and in flood plains. Flow resistance can be defined as "the force to overcome or the work required to be done to counter the action of the rigid, flexible or moving boundary on the flow". The present breach analysis is performed with the objective of plotting an inundation map for the downstream areas, to assess the impacts of different Manning's values on the flood flow parameters as well as to present risk analysis for the flooded area of Baur dam with the flow value of flooded water

MATERIALS AND METHODS

Baur dam is an Earthen dam and constructed on Baur and Kahrala rivers in Udham Singh Nagar district of Uttarakhand state with latitude 29°08'N and longitude 79°20'E. Dam is having 17.98 meters height and 9500 meters length with the reservoir capacity of 103.37 Mcum. It's main purpose is irrigation for the areas of Udham Singh Nagar district of Uttarakhand and areas of Rampur district of Uttar Pradesh. The neighbouring cities of Baur dam are Nainital, Haldwani, Rudrapur, Bazpur and Gadarpur. The study area comes in the hilly and Tarai region of Uttarakhand, for which five different Manning's roughness value were considered including 0.030, 0.033, 0.035, 0.038, 0.040 from the data provided by Chow (1959).
In this work dam breach modelling is performed for assessing the impacts of different Manning's value on flow

value of flood generated by dam breach. Selection of modeling totally depends on the usefulness and requirement of work. For dam breach analysis accurate detail knowledge of dam and its hydraulic structure, prediction of breach parameters are required. In this work data is collected from Irrigation Department, Rudrapur, Uttarakhand. The data requirement changes according to modeling prospects. The detail of data required in this two dimensional work is as given below:

- Digital Elevation Model (D.E.M.) of the Baur dam site (Bhuvan portal).
- Salient features of dam and its hydraulic structures (Irrigation department).
- Design flood hydrograph or probable maximum flood as upstream boundary condition.
- Manning's roughness coefficient value of site (Chow, 1959).
- Normal depth at downstream of dam as downstream boundary condition.

The methodology adopted in this work is two dimensional using HEC-RAS 5.0.3 model. HEC-RAS was developed by U. S. Army Corps of Engineers. This model can perform in one dimension (1D), two dimension (2D)s and coupling of both 1D and 2D. The software is easily downloadable and available to all researchers. HEC-RAS uses data provided by the user and simulate it for different flow results and also provide animation video of flow in the downstream of dam. The video clearly gives the details of flood generated due to dam failure and the user can analyse the flood devastation. The model simulate the resulting flood wave generated based on consequences of an upstream event and models downstream effect based on result of dam breach. Embankment dam failure analyses can be viewed as two-step process. First, the actual dam breach must be analysed, second the breach outflow must be routed to the downstream to determine the downstream resulting flood. The simulation process used in 2D HEC-RAS for dam breach modeling is presented in Figure 1.

The simplest approach of breach parameter prediction modeling is by estimating the breach parameter using various empirical formulas as given by many researchers Froelich (1995), Froelich (2008), Von Thun and Gillete (1990) and MacDonald *et al.* (1984) and then compare their result with guidelines given by different agencies such as United State Army Corps of Engineers (USACE), National Weather Service (NWS), Federal Energy Regulatory Commission (FERC) After complete analysis and calculation Von Thun & Gillette breach parameters are considered and USACE 2007 guidelines are used in this work. According to them, breach width range comes out to be 8.9916m to 89.916m, and the final breach parameters considered are: breach bottom width = 66m, side slope = (0.5:1.0), and breach development time is 0.36 hours.

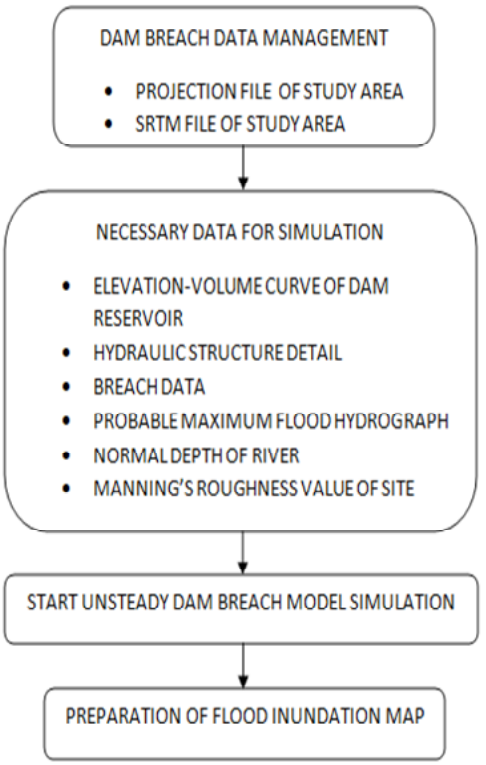

Fig. 1: Flowchart used for 2D dam break modelling using HEC-RAS

HEC-RAS is a computer program developed by U. S. Army Corps of Engineers for modeling natural river flows and other channels. Recently, in March, 2019 HEC-RAS Version 5.0.7 is released. Implicit Finite Volume algorithm solves the unsteady flow equation. For the development of inundation maps some key steps are processed: (a) Extraction of SRTM 30m DEM file (b) creating study area (c) applying structure detail and breach parameters (d) computation of hydrograph (e) producing flood inundation map**.** Flood inundation maps are helpful during relief operation at the time of flood so that loss of life can be minimized.

RESULTS AND DISCUSSION

The results are developed after hypothetical breach modeling of Baur dam by using 2D HEC-RAS at different Manning's value and then their flow hydrographs are

Table 1. Flow Values at Two Places for Five Different Manning's value

Place	Flow for n_1 = 0.030 Cumec	Flow for n_2= 0.033 Cumec	Flow for n_3= 0.035 Cumec	Flow for n_4= 0.038 Cumec	Flow for n_5= 0.040 Cumec
Kelakhera	562.74	359.41	319.89	304.45	261.57
Bosena	313.18	312.99	309.87	305.66	301.31

Table 2. Details of Inundated Area

Manning's value	n_1 = 0.030	n_2 = 0.033	n_3 = 0.035	n_4 = 0.038	n_5 = 0.040
Inundated Area(Km^2)	37.75	36.78	36.51	35.46	35.35

compared. Variation of flow is observed at highly populated downstream areas of Baur dam named as Kelakhera and Bosena which are 10 km and 20 km respectively from dam location. Table 1 provides the detail of flow variation at different manning's values. Different Manning's roughness values are taken as: n_1=0.030, n_2=0.033, n_3=0.035, n_4=0.038, n_5=0.040 and their inundated area details are shown in Table 2 which proves the Manning's theory which states that as Manning's roughness value increases the flood flow value decreases also noticed in Figures 2 and 3. Inundation map of Baur dam study area is shown in Figure 4 which is plotted with the help of QGIS.

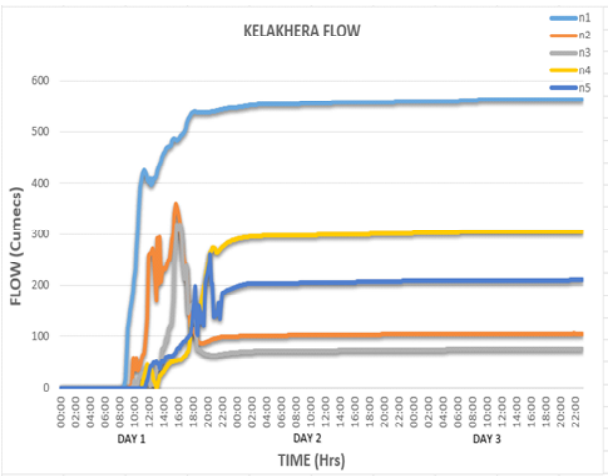

Fig. 2: Flow v/s Time for Kelakhera

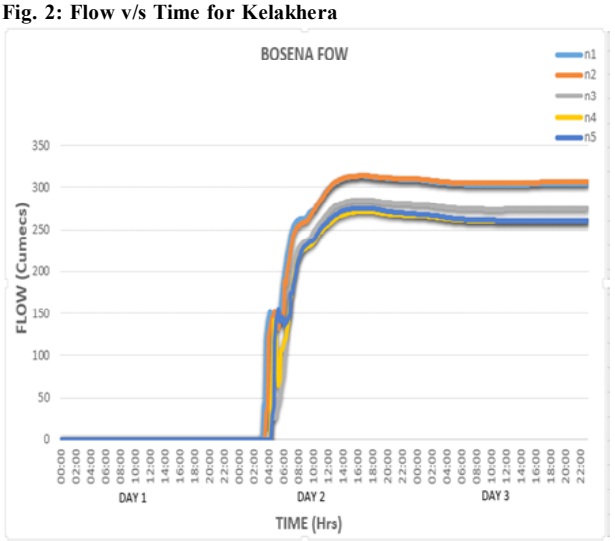

Fig. 3: Flow v/s Time for Bosena

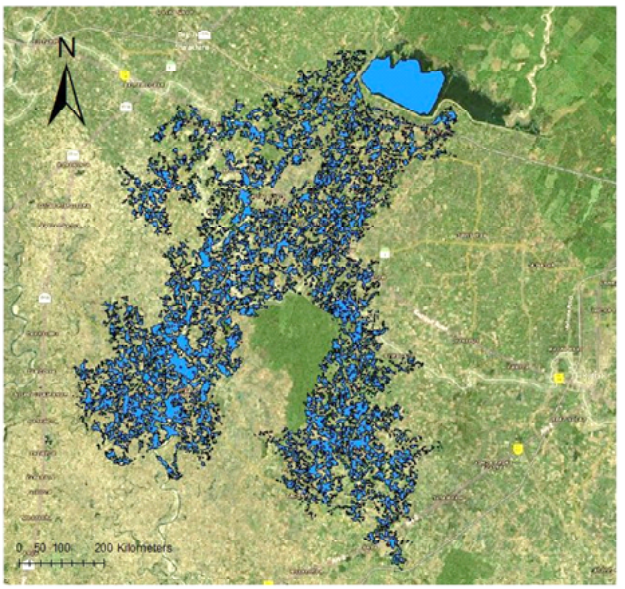

Fig. 4. Inundation map for downstream areas of Baur dam

Reservoir area of Baur dam is calculated as 11.23 Km^2 and the downstream inundated areas at different Manning's values are provided in the Table 2.

CONCLUSION

It has been concluded that as Manning's value increases for site, the flow value decreases simultaneously at any considered location at the downstream of Baur dam. Inundated area also includes the nearby irrigation area of dam site, and this detail will be helpful for the respected offices so that life and economic losses can be reduced. As roughness represents the resistance in channel, so when flow resistance increases as roughness coefficient increases, it produces retarding force on water and results in lower flow rate values. This theory is verified by the results shown in this paper. HEC-RAS 2D is a software that provides better understanding and analysis of flood

to the downstream areas of dam after dam breach.

REFERENCES

Chow. V.T. (1959). Open-channel hydraulics, New York: McGraw-Hill., 101-123.

Froelich, David C. (1995a). Peak Outflow from Breached Embankment Dam. *Journal of Water Resources Planning and Management*, 121 (1):90-97.

Froelich, David C. (1995b). Embankment Dam Breach Parameters Revisited. *Water Resources Engineering*, Proceedings of the 1995 ASCE Conference of Water Resource Engineering, San Antonio, Texas, 887-891.

Froelich, David C. (2008). Embankment Dam Breach Parameters and their Uncertainties. *Journal of Hydraulics Engineering*, 134 (12): 1708-1721.

India Environment Portal, Central Water Commission. (2017). National Register of Large Dam. Accessed November 12, 2018. http://indiaenvironmentportal.org.in

Macdonald, Thoma C., and Jennifer Langridge Monopolis (1984).Breaching Characteristics of Dam Failure. *Journal of Hydraulic Engineering*, 110 (5):567-586.

Thun, J. Lawrence and David R. Gillette. (1990). *Guidance on Breach Parameters*, unpublished internal document, U.S. Bureau of Reclamation, Denver, Colorado, March 13, 17p.

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