Dam Break Analysis of Peringalkuthu Dam, Thrissur Using HEC-RAS

Sophy James[1], Parvathi P Nair[1], Liya Varghese[1], Arjun Anilkumar[1], Hanna Paulose[2]

[1]*Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India*
[2]*Professor, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India*

Abstract - *A Dam break analysis is performed to model the flow of flood waves downstream of a dam in the event of a dam break. It involves field data collection and computer simulation to evaluate the dam failure and the impact of dam break on downstream area.*

Studies conducted to analyze the flood zoning and inundation mapping of different dams such as Idukki, Hidkal, Pulichinathala[1]–[3] *etc., prove to be crucial for disaster management in the event of a dam breach. After the literature review, we identified that Peringalkuthu Dam in Thrissur district hasn't been considered for such studies, despite being an aged dam (65+ years) whose safety has come under question during the August 2018 floods.*

The aim of this project is to conduct a Dam Break Analysis of Peringalkuthu Dam using HEC-RAS to find inundation maps showing depth, velocity and water stage elevation in the event of a dam breach. Input parameters like Design Flood Hydrograph, Manning's Roughness Coefficient, breach Parameters, and Elevation Storage relationship to draw results. The population under risk is also identified. Dam breach studies and inundation maps are important in preparing Emergency Action Plans and proper warning systems.

Key Words: Dam breach, HEC-RAS RAS (Hydrologic Engineering Centre's River Analysis System), Disaster management, Flood zoning, Inundation mapping, 2D Unsteady flow

1. INTRODUCTION

Dams are built for a variety of reasons, including electricity generation, irrigation, and flood control. Despite all of the advantages, dam failure might result in massive losses by causing unforeseen floods in the downstream area. To mitigate these risks, dam break analysis is required to forecast inundation levels and flood-prone zones in the Dam's downstream area.

The recent unpredictable rainfall (Oct 2020, Aug 2018) opened up discussions regarding the safety of this Dam. According to the KSEB, Peringalkuthu is a dam with a storage capacity of only 32 million cubic metres(MCM), while the upstream dams are huge. The Upper Sholayar Dam, Tamil Nadu, has a storage capacity of 153 MCM, while Lower Sholayar also has a similar storage capacity. The Parambikkulam Dam has a storage capacity of 505 MCM, while the maximum storage of Thoonakkadavu is 15 MCM. If these three dams are opened, the quantity of water reaching Peringalkuthu will be 3,882 cubic metres per second. The discharge capacity of Peringalkuthu is only 2,265 cubic metres per second, and the Dam will start overflowing within two hours. Heavy inflow from upstream dams will lead to a situation similar to the 2018 mid-August flood, and Chalakudy will be inundated within three hours. To ensure the protection of life and property of people living in Chalakudy, Peringalkuthu Dam should be reviewed and studied.

This project involves conducting Dam Break Analysis for Peringalkuthu Dam, Thrissur. It covers the prediction of breach parameters and the Dam break model setup in general. Implementation of Dam break analysis can benefit the people living downstream of the Dam against floods with the help of inundation maps which can be generated by incorporating results from dam break analysis with GIS.

1.1 AIM

To perform dam break analysis of Peringalkuthu dam using HEC-RAS (Hydrologic Engineering Center's River Analysis System) software and preparation of flood inundation map.

1.2 OBJECTIVES

- Predict velocity, flow depth and water stage elevation of flood waves in the event of dam failure.
- Predict peak of flood waves downstream between points of interest, time of travel of peak flood, and maximum water stage at point of interest.
- Predict dam-break flood for planning purposes and controlling downstream development.

2. STUDY AREA

The Peringalkuthu reservoir was created by building a dam over the Chalakudy river in Kerala's Thrissur district. The Dam's construction was completed in 1957. The Dam is a masonry gravity dam. The spillway has seven falling-type gates measuring 11.58 metres by 5.94 metres each and four sluice gates measuring 2.44 metres by 5.77 metres each. To generate hydropower, water from the reservoir is diverted via a tunnel. The total installed capacity of the project is 48 MW. The average annual generation of the power station is around 244 MU. The amount of water used to generate electricity is 36 cumec. When the reservoir's WL is at EL 422.40 m, a diversion to the Idamalayar reservoir with a discharge capacity of 39.43 cumecs is supplied. The overall catchment area at the Peringalkuthu dam site is 1007 sq km, out of which 512 sq. km is considered a free catchment.

3. METHODOLOGY

Using HEC-RAS to perform 2D modelling or combined 2D modelling is very straightforward. The following are the basic steps performed in 2D modelling within HEC-RAS [4]:

1. In HEC-RAS Mapper a Horizontal Coordinate Projection was created, using a projection file from an ESRI shapefile.

2. A terrain model, which is necessary for 2D modelling was created. For executing any inundation mapping in RAS Mapper, a terrain model is needed.

3. Added an additional mapping layer, for visualization.

4. Drew a boundary polygon for each of the 2D Flow Areas to be modelled in the HEC-RAS Mapper. Created the 2D computational mesh for each 2D Flow Area using the 2D Flow Area editor.

5. Using the SA/2D Area Hydraulic Connection feature, added internal hydraulic structures, a dam as the connection between the 2D flow area and the Storage Area.

6. Connected the 2D Flow Areas to 1D Hydraulic elements (Storage Area)

7. Drew external boundary condition lines along the perimeter of the 2D flow areas using the Geometric Data editor.

8. Filled all of the boundary and initial condition data for the 2D flow areas in the Unsteady Flow data editor. Set necessary computational choices and settings for the 2D flow areas in the Unsteady Flow Simulation window.

9. Ran the simulation of unsteady flow.

10. Output is taken as map layers including Depth, velocity, and water surface elevation.

11.Found affected areas and inundation area is found

12.Population of most affected areas is found.

13.Rehabilitation cost is calculated based on the previous data available.

4. INPUT DATAS

4.1 RESERVOIR DATA

It is important to know an elevation-storage relationship for the reservoir in order to anticipate the flood hydrograph. The input data received from Dam Safety Authority, Pallom, and Kottayam is shown in **Table -1**. The storage elevation curve can be drawn from the data.

Table -1: Storage-Elevation Data

Storage	Elevation
399.4	0
401.73	230
404.77	1100
407.82	2720
410.87	5470
413.92	9490
416.97	14730
420.01	21410
423.06	29420
423.98	32000

4.2 TOPOGRAPHIC DATA

Digital Elevation Model was created by obtaining a shapefile of the interested area from Google Earth Pro. The shape file was uploaded into USGS Earth Explorer in order to obtain the Digital Elevation Model of the proposed river basin. The DEM was input into the software to get the terrain features and Storage-Elevation relationship.

4.3 BREACH PARAMETERS

The construction of a concrete gravity dam involves a number of concrete monoliths. Peringalkuthu being a concrete dam, USACE suggests using an average breach width of multiple monoliths (2007), while FERC (1988) and NWS (Fread, 2006) suggest using an average breach width of less than or equal to half of the entire length of the Dam. USACE, FERC, and NWS all suggest using a vertical breach side slope since monoliths are typically rectangular in shape and therefore have vertical sides. Figure 1 illustrates the monolith failure width (B), the breach depth (H), and the vertical side slope of 0:1 (**Fig -1**) [5]. The range of possible failure times for modelling purposes is 0.1 hours to 0.5 hours.

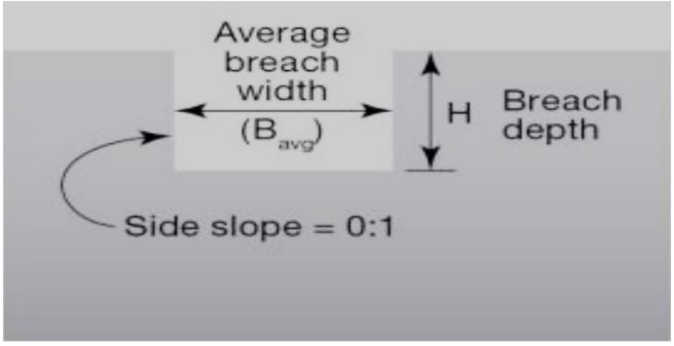

Fig -1: Breach mechanism of a concrete dam from FEMA Guidelines[5]

4.4 BOUNDARY CONDITIONS

There are four types of external boundary conditions that can be linked directly to the boundary of 2D Flow Areas; these are:

- Flow Hydrograph
- Stage Hydrograph
- Normal Depth
- Rating Curve

5. RESULT AND OBSERVATION

Flood inundated areas in the event of a breach of Peringalkuthu Dam were considered and maps showing Depth, velocity and water stage elevation at various affected areas were obtained. Time-plot series for any point downstream of the dam for the above-mentioned parameters was also obtained incorporating results from dam break analysis with GIS.

5.1 DEPTH

The maximum depth of water is around 15-18 m represented in the map in dark blue color and is observed in the immediate downstream of the Dam as well as in other areas further downstream, as shown (**Fig -2)** in the inundation map.

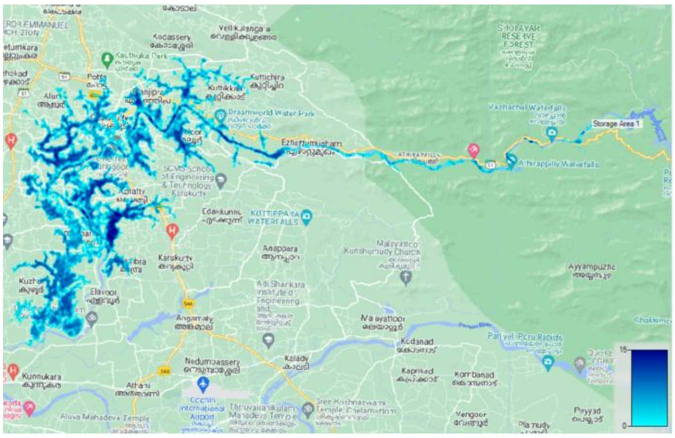

Fig -2: Depth map layer

5.2 VELOCITY

Velocity varies from 10-15 m/s, and maximum velocity is observed at the immediate downstream of the river reach, which is shown in red. Velocity reduces as we move further downstream with the lower velocities represented by blue (**Fig -3**).

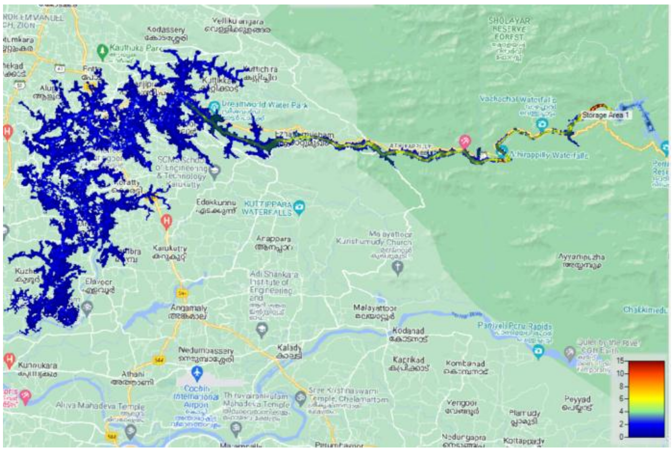

Fig -3: Velocity map layer

5.3 WATER SURFACE ELEVATION

The maximum observed water stage elevation of 412 m is observed at the immediate downstream of the Dam, represented by orange (**Fig -4**). The WSE reduces further downstream.

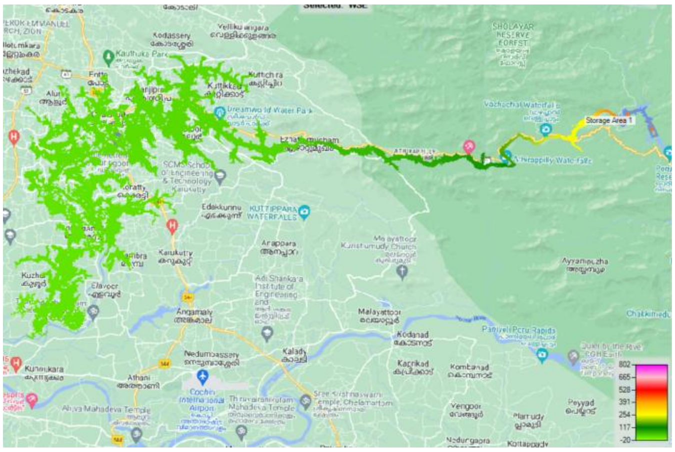

Fig -4: Water surface elevation map layer

5.4 OBSERVATION

Table -2: Result table

Places most affected	Depth max m)	Velocity max(m/s)
Poringalkuthu	44.96	15.93
Athirappilly	8.17	2.96
Konnakuzhi	13.45	0.5
Kuttikkadu	10.37	0.38
Melur	16.32	0.62
Elanjipra	16.8	0.87
Potta	11.36	0.11
Chalakkudi	12.41	1.17
Mampra	11.56	0.29
Valoor	18.22	0.30
Muringoor	15.01	0.5
Aloor	11.55	0.26
Kottatt	13.76	0.41
Koratti	17.43	0.26
Thruthiparambu	16.91	1.6
Annalloor	22.28	0.25
Cheruvaloor	18.12	0.23
Vynthala	12.26	0.33
Annamanada	8.59	0.19

Total Area under risk: 160 square km.

Table -3: Area-Population table

Area	Population
Chalakudy	49525
Melur	22678
Annamanada	1925
Potta	17876
Elanjipra	3883
Koratty	17463
Muringoor	6683
Annalloor	6254
Athirappilly	9216

Total Population under risk: 196503.

The population of the villages aforementioned is obtained from the internet. Average no. of people in a typical family in Kerala is assumed to be 4. Therefore, the total no. of families affected is 49,125. Based on the history of flood inundation, the compensation given to each family for land, construction and infrastructure is 5 lakhs by the government. Therefore, the total cost for rehabilitation comes up to 2000 crore rupees. Thus, periodic inspection must be done in major dams situated in hazard-prone areas in-order to avoid such occurrences. However, the value of the emotional and psychological damages caused to people living near dam sites is immeasurable. Unsteady flow

6. CONCLUSION

HEC-RAS is an updated software which gives the flood inundation map of a potential dam breach. It also facilitates routing the resultant flood through downstream valleys to get the time series of discharge and water level at different locations of the valley. For the purpose of this analysis, overtopping mode of failure of the structure is considered.

The parameters of breach selected based on already established research is reasonable for the dam break flood generation. The depth of flow at different locations within the river reach of 50.1 km, varies from 66.91 m (just below Peringalkuthu dam site) to 0.61 m at the end of the reach. The total area of inundation is 160 square kilometres. The details of water surface elevations and velocity of maximum flow at different locations of the valley gives an idea about the extent of flooding. The authorities should give sufficient warnings to the downstream inhabitants as it is observed that about 1,90,000 inhabitants are at risk.

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