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Dam Break Analysis of Mullaperiyar Dam using HEC-RAS

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Abstract: Mullaperiyar dam, with an active capacity of 2,99,13,00,000 m3 is constructed on the Periyar River in Kerala. It is a controversial issue between two states Kerala and Tamil Nadu. Even though the dam is situated in Kerala but the benefits of the dam is being enjoyed by Tamil Nadu. The age of the dam is 119 years which is more than its design period i.e. 50 years. As it is an old dam, there is a threat for a dam to fail, Hence the dam is taken for the present study. This paper presents a case study of Dam Break Analysis of Mullaperiyar Dam using HEC-RAS software which involves the prediction of a dam break, River reach, Discharge, unsteady flow equation, etc.
Keywords: Mullaperiyar Dam, Dam Break Analysis, HEC-RAS, Periyar River. Etc

I. INTRODUCTION

A dam is a barrier that impounds water that plays important role in the economy of the country. The water stored in dams is generally used for irrigation, aquaculture, industrial use, human consumption, etc. However, in the rare event of their failure, this may cause disastrous flooding in the downstream area which may lead to huge loss and damage to human life and property. In this study, the dam break analysis of the Mullaperiyar dam is done with the help of HEC-RAS. Hydrologic Engineering Centre's River Analysis System (HEC-RAS) modeling made by the U.S. Army Corps of Engineers, a standard for dam breach flood inundation models, is used to work steady flow simulations to model the dynamic nature of the flood wave produced by a dam breach summary. The dam is constructed on the Periyar river from which the name is formed 'Mullaperiyar Dam.

II. SCOPE AND OBJECTIVE

The prediction of the dam break is the major purpose of planning and plan and choice-making concerning dam safety, controlling downstream developments, evacuation planning, and actual period flood forecasting. For analyzing the flood damage due to the chances and type of a dam failure, but also the flood hydrograph of discharge from the dam breach and the generation of flood waves. Dam failure can potentially lead to loss of life and property damage. The main significance of the study is to deeply study the particular site and analyze it through HEC-RAS and possibly predict a resulting flood wave and chances of failure of a dam.
Following are the objectives of the study:
Study the particular dam site deeply, Input data in HEC-RAS and analyze it, predict the failure chances of the dam as per the studies.

III. METHODOLOGY

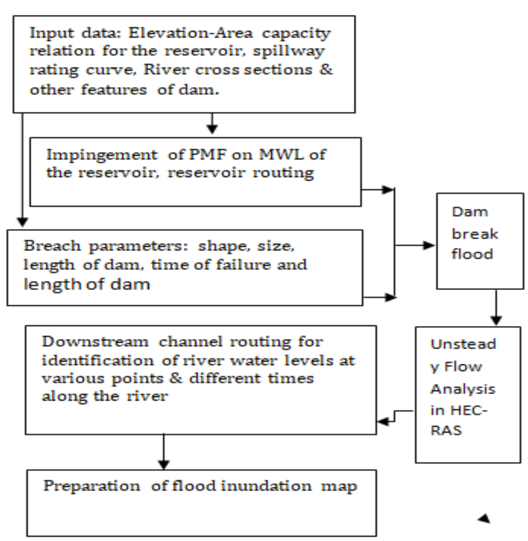

Fig. 1 Flow chart explaining the process of dam break analysis

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The process of dam break analysis starts with the collection of data. As mentioned in the literature review by some of the papers, the modeling process requires large and accurate data of the reservoir, dam sites, and its detailed structures. The Flow chart shows the step of the methodology. Firstly the chart starts with the collection of data and further steps.
Let us discuss more details about the data required for analysis.

A. Dam break Modelling and Discussion

Following are the input used as data for modelling:
1) Cross section details of particular reach of site.
2) Catchment area of the site.
3) Maximum Flood intensity.
4) Details of river and dam.
5) Contour details at a particular reach of river cross section.

B. Data Requirement

Necessary data requires for the analysis is:
1) Reservoir/Storage Area Data
2) Topographic data of the particular area
3) Catchment Hydrology
4) Structure Data.

C. Reservoir Data

To predict the flood hydrograph mainly two types of data is required as shown below. The data available should also have the details of flow and normal retained water level.
1) Elevation- storage relationship for the reservoir, or
2) Bathymetric data of the reservoir

The availability of the above-mentioned data limits the extent of modeling for the prediction of flood flow out of the reservoir, but the time for the flow to escape the reservoir cannot be considered. It's just like simple flat pond modeling. Time taken for the flow to escape the reservoir may be important if the reservoir is large in length, narrow, and has many branches.

D. Topographic Data

Necessary for flood inundation mapping:
1) General flood due to dam breaks are more than the natural floods. The areas which are in the safe zone from flooding may have a threat to get inundated. So the topographic data should be sufficiently more as the areal extent of data should not be underestimated.
2) Topographic data should increase widely across up– valley slopes and flood plains which are normal flood levels.
3) The major detail structure of road and railway embankments, and flood plains, which are above normal flood levels.
4) The data regarding smaller structures which may get completely flooded and then washes away may get avoided.

E. Catchment Hydrology

For an accurate prediction of outflow hydrograph, following data such as inflows into the reservoir, reservoir condition at the time of failure, and base flow conditions plays a major role in the river valley. For high-risk sites sensitivity analysis is a must. The flow conditions should be such that from normal low flow operating conditions to a probable maximum flood (PMF).

F. Structure Data

Estimation of breach parameters and potential flood flows, in case of structural failure of the dam, information required is as follows: Type of the structure, data requires for modeling, and levels of the dam. Also, details about gates, types of gates, and the number of gates, if partial modes of failure are to be considered valves and spillways are required. For estimation breach parameters, there are advanced techniques are available for the embankment of structure and then concrete or masonry structure. If the type of dam is of embankment type under analysis, the details of core, layer geometry with any surface protection along with particular material sizes are required. For masonry and concrete dam, failure mechanisms are based on potential maximum breach dimensions or failure of a single unit such as buttresses of spillways.

IV. STUDY AREA

A. Mullaperiyar Dam

The Mullaperiyar Dam is constructed on the Periyar river in Kerala, there is a controversial issue between the two states regarding the dam i.e. Kerala and Tamil Nadu. The dam is in Kerala but the benefits of the dam are being utilized by Tamil Nadu. There was an agreement made by a king of Kerala for 999 years. As the age of the dam is (119 years) which is more than its design period (50 years). There is a threat for the dam to fail. Hence this dam is taken for the present study.

B. Structure of Main Dam/Body of the Dam

The Mullaperiyar Dam is the first Surkhi concrete dam in a "V"-shaped gorge in the Western Ghats on the west-flowing Periyar River. It has a height of 47.28 m (155 feet) above the river bed of 0 (zero) feet and a length of 366 m (1200 feet). The total width including the original parapet is 3.66 m. The front and rear sides of the dam are made up of uncoursed rubble masonry along with lime surkhi combination mortar of proportion 2:1:3.

The proportion of lime surkhi mortar is two parts of lime, one part of surkhi and three parts of sand. The hearting, which holds more than 60% of the volume of the dam is made up of lime surkhi concrete with 3.125 parts of stone and 1 part of mortar. Later on, during the 1980s, a concrete backing of 10 m width was attached to the old dam on the downstream face as a measured strength to the old structure. After attachment of the concrete backing, strengthening has been increased to 6.4 m (21 feet). Hence it is a heterogeneous structure made up of rubble masonry upstream. Lime surkhi concrete hearting (which accounts for more than 60% of the volume of the dam), also rubble masonry on the downstream, an ungrouted open joint and 10 m concrete backing.

The Periyar River is a perennial river that rises from the Sivagiri group of hills in Kerala state and flows through this state and joins the Arabian Sea. Out of its total catchment of 5398 sq. km, 114 sq. km is present in Tamil Nadu far down the river from the Mullaperiyar Dam site and sq. km lies in Kerala. The maximum height of the main dam is 53.64 m (176 feet). On both sides of the main valley, there are small saddles, and the one on the left side was blocked by a Baby Dam of the same type with 73.15 m (240 feet) in length and has a height of 16.15 m (53 feet) is connected to the high ground by means of an Earthen Dam. The crest level of the spillway is 867041 m. Later on, 3 more spillway vents were added with the control gate each vent is of size 12.16 m x 4.88 m (40 feet x 16 feet).

C. Salient Features of Mullaperiyar Dam and Its Structure

Table - 4.2.1: Location of Mullaperiyar Dam

Location:	
State:	Kerala
Latitude:	9°31'30'' N
Longitude:	77°8'45''E

Table - 4.2.2: Reservoir Data of Dam

Reservoir:	
Catchment area:	624 sq. km
Full Reservoir level:	46.33 m (155 feet)
Maximum Water level:	47.24 m (155 feet)
Gross Capacity of Reservoir	443.23 MCM (15.662 TMC)
Gross storage at 104 feet:	144.19 MCM (5.092 TMC)
Gross storage at 136 feet:	317.43 MCM (11.210 TMC)
Gross storage at 155 feet:	470.54 MCM (16.617 TMC)
Probable Max Flood:	8676 cumecs(306399)
Recorded Max Flood:	8453 cumecs (298519 cusecs)

Table - 4.2.3: Data of Main Dam

Main Dam:	
Length:	366 m (1200 feet)
Top of dam including	
Parapet:	48.16 m (158 feet)
Height of dam from	
Deepest foundation:	53.64 m (176 feet)
Top width of dam	
With parapet:	6.4 m (21 feet)
Downstream slope:	0.9276 to 1.0
Upstream slope:	1 to 20

Table - 4.2.4: Spillway Data of Dam

Spillway:	
Location:	Right Saddle
Crest level:	4.45 m (136 feet)
Number of vents (old):	10 in Nos. with size
	10.98 m x 4.88 m (36 ft. x 16 ft.)
Number of vents	
(Additional):	3 Nos. 12.16 m x 4.88 m
	(40 feet x 16 feet)

Table - 4.2.5: Data of Baby Dam

Baby Dam:	
Location:	Left Bank saddle
Type:	Composite gravity structure
Top of dam:	48.17 m (158 feet)
Length of dam:	73.15 m (240 feet)
Height of dam:	16.15 m (53 feet)

V. RESULTS AND DISCUSSION

This case study explained the advantages and disadvantages of using software to analyze dam breaches and determine the likelihood of dam failure. The HEC-RAS model is primarily set to run and getting resulting dam break flood hydrograph which is shown in fig. 5 below. The peak of the dam break flood is 15404.73 cumec. The probable maximum flood hydrograph's anticipated peak discharge is 8676 cumec. This demonstrates that the PMF is twice as projected.

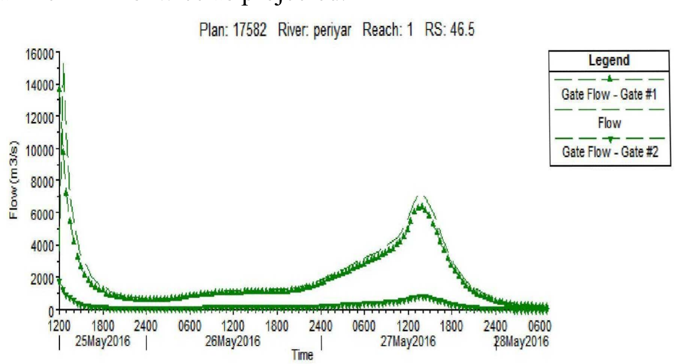

Fig. 2: - Outflow Hydrograph at the Dam Site

The maximum water surface level achieved by the dam flooding at different locations downstream of the dam.

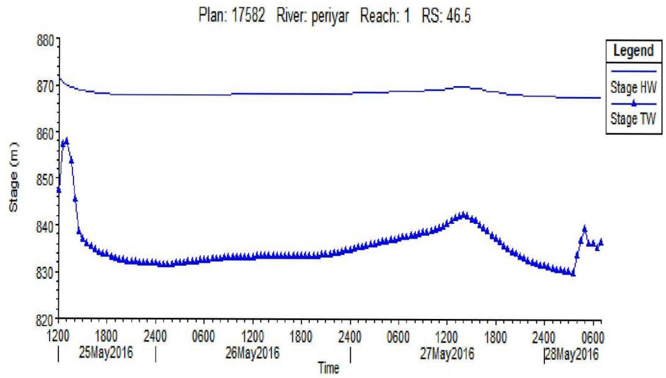

Fig. 3: - Stage Hydrograph at the Dam Site

The downstream floodwater is influenced by boundary conditions, which are an important input. These boundary constraints must be carefully chosen and should accurately reflect the real site characteristics. In this analysis, the upstream boundary condition is an inflow hydrograph; the dam authority provides a probable maximum flood (PMF) hydrograph. The downstream border condition is normal depth (friction slope value = 0.0004). The time series of gate opening is defined as the boundary condition at the inline structure, i.e., the spillway gate is kept open for 0.1 m during the simulation period, while the sluice gate is totally closed.

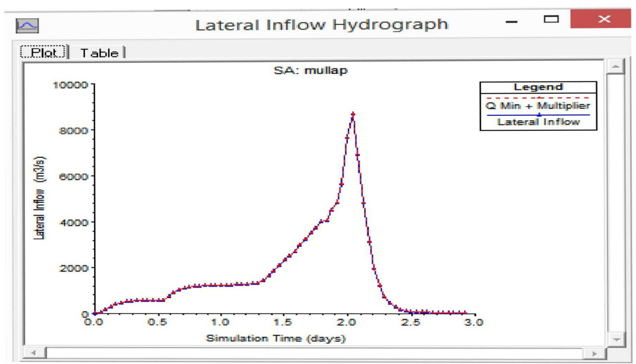

Fig. 4: - PMF Hydrograph (Upstream boundary condition – Lateral Inflow Hydrograph)

VI. CONCLUSIONS

The generated peak of the dam break flood hydrograph is estimated as 15403 cumecs, which is almost 2 times the peak of the Probable Maximum Flood hydrograph. The depths of flows at different locations within the river reach of 36 km vary, from 45.33 m (just below the dam site) to 21.79 m at the end of the reach (chainage 36 km from dam sites). The process of a dam break is a very catastrophic event and a complex process, but the exact reason cannot be precisely determined with the help of software. Different types of dams constructed according to the usage and locality are studied. The new safety law for dams passed by the Indian government in 2021 is also studied, which involves many practical reasons regarding dam breaks.

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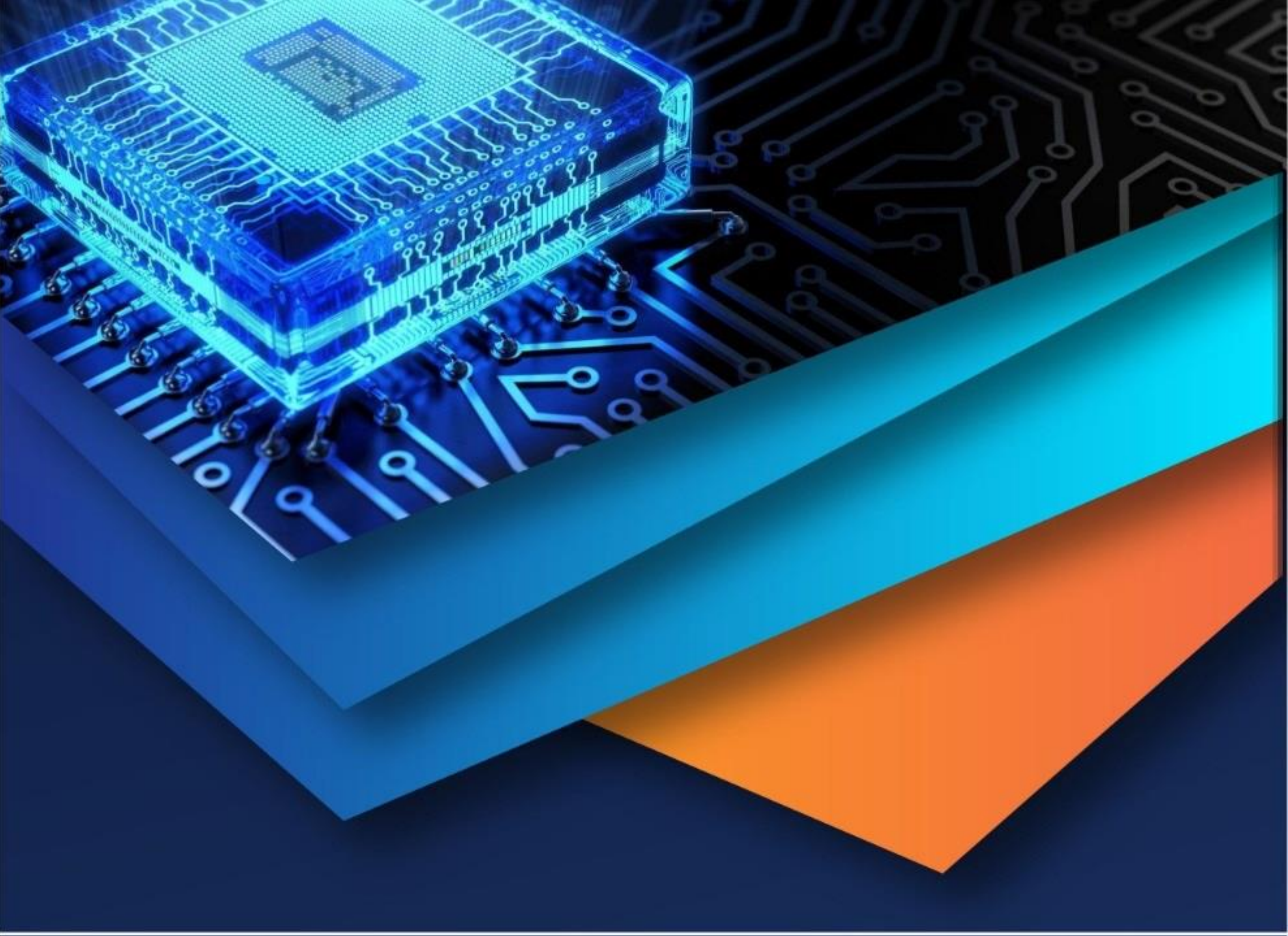

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