

# DAM BREAK ANALYSIS USING BOSS DAMBRK

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## Abstract

Dams are constructed to serve a variety of purposes such as supply of drinking and irrigation water, generation of electric power, flood protection etc... However a dam break may result in high flood waves traveling along a valley at quite high speed. The intensity of the catastrophic failure of dams varies depending on the extent of inundated area, size of the population under risk and the warning time available. The present study deals with the Dam Break Analysis of Thenmala Dam of Kerala State, India. As a part of the work, the maximum precipitation and maximum flood have been evaluated using the Gumbel's and Clark's method respectively. The final analysis is done using the software BOSS DAMBRK for evaluating the extent of inundation, travel time and velocity of downstream progressing water.

**Keywords:** BOSS DAMBRK; maximum precipitation; maximum flood; Gumbel's method; Clark's method

## 1. INTRODUCTION

Catastrophic flash flooding occurs when a dam is breached and the impounded water escapes to the downstream valley through the breach leading to its uncontrolled release and can have large impacts on the land and communities downstream of the dam. The failure of a dam may result in flood waves travelling at quite high speeds. With such destructive forces in action, there will be inevitable loss of lives and destructions caused to the infrastructure. Along with these factors, there will be increased movement of sediments and debris mainly causing spreading of pollutants. In the below sections, a brief overview of the software, methodology used in the dam break analysis and the analysis results are discussed.

## 2. METHODOLOGY AND MATERIALS

For the study, estimation of maximum precipitation and maximum flood forms the base. Maximum precipitation is evaluated using the Gumbel's Method and the corresponding flood is evaluated using the Clark's method. The maximum flood is then routed using the reservoir routing method known as Modified Pul's method to finally obtain the time – elevation – flood outflow relation which helps in understanding the sufficiency of the provided spillway.

The next step is the analysis of the problem using the BOSS DAMBRK software. This portion of the study makes use of breach description values; reach description values; reservoir description values; inflow hydrograph values and boundary conditions as inputs. DAMBRK simulates the failure of the dam together with the movement of the dam-break flood wave through the downstream channel.

### 2.1 Study Area

Thenmala dam, together with the adjoining Kallada river

basin of Kerala state, India is selected as the study area. The study area is approximately 542.1 square kilometers in area and lies between latitude of  $8^{\circ}9'$  to  $9^{\circ}17'$  and a longitude of  $76^{\circ}16'$  to  $77^{\circ}24'$ .

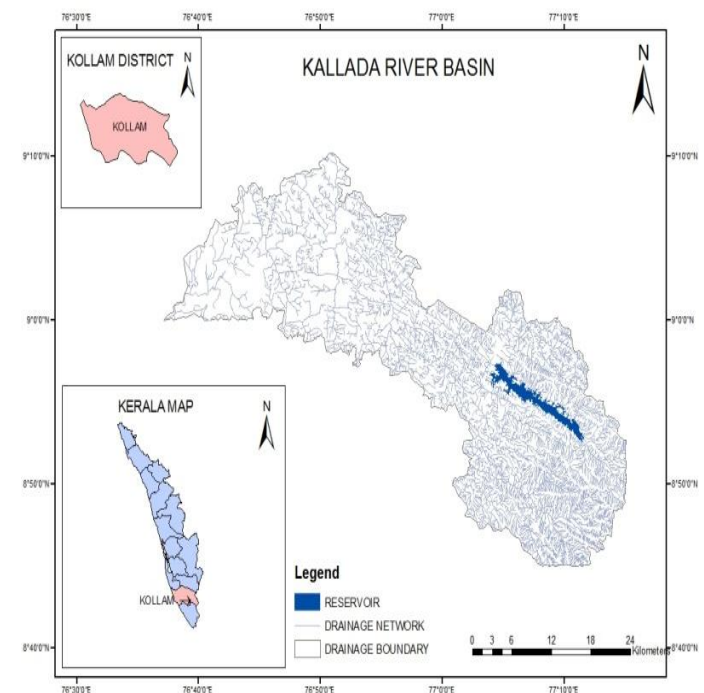


Fig. 1: Kallada River Basin

The dam characteristics include:

- FRL = 115.82 m
- MWL = 116.73 m
- Spillway crest level = 106.68 m
- Top of dam crest level = 118.87 m
- Height of dam = 85.35 m

- Length of dam = 335 m
- Live storage capacity = 487.9 Mm<sup>3</sup>

## 2.2 Data Used

The data collected for the study includes the daily rainfall data for the past 30 years (1982 – 2011) from the Indian Meteorological department. Survey of India toposheets (58 G4, 58 H2, 58 D9, and 58 C16) are also made use for digitizing the boundary as well as for identifying the drainage network of the study area. ASTER digital elevation model is also used to obtain the river cross sections.

## 2.3 Software Used

- ArcGIS 9.1
- BOSS DAMBRK

## 3. DETERMINATION OF MAXIMUM PRECIPITATION AND FLOOD

Rainfall data is required for the computation of maximum precipitation and the corresponding peak discharge. Also, ASTER digital elevation model is been made use to obtain the downstream channel cross sections.

### 3.1 Maximum Precipitation

The daily rainfall values are analysed using the Gumbel's method to obtain the maximum precipitation. The cumulative rainfall values are found out for 1-, 2-, 3-days respectively and the maximum value for each month are considered. Mean and standard deviation for each time period is calculated in order to find out maximum intensities of rainfall for different durations. Intensity – Duration – Frequency curves are then plotted for different return periods to find out the maximum precipitation corresponding to the time of concentration. The time of concentration ( $T_c$ ) used above was calculated using the Kirpich's equation and is obtained as 1.5 hours.

$$T_c = 0.0195 L^{0.77} S^{-0.385} \quad (1)$$

where L is the length of the main water course upstream of the dam in kilometers (44.78 km) and S is the slope of the study area (1 in 33). The obtained IDF curves for the basin are shown in Figure 2.

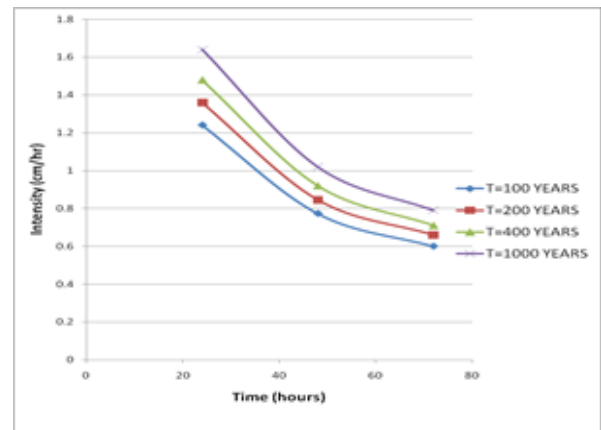


Fig. 2: IDF curves for Kallada River basin

### 3.2 Maximum Flood

Clark's method is used to determine the maximum flood. This method involves the preparation of isochrones as in Figure 3. Isochrones are lines that connect points of equal time of travel. The inter-isochronal areas ( $A_r$ ) are then determined using the GIS software and the corresponding inflows are obtained using equation 2.

$$I = (2.78 \times A_r) / t \quad (2)$$

Where 't' represents time of travel and is dependent on the obtained time of concentration and number of inter-isochronal areas. The inflows are then routed using the Muskingum's method to obtain the maximum flood value. The Muskingum's method is based on equation 3.

$$Q = C_0 I_1 + C_1 I_0 + C_2 Q_0 \quad (3)$$

Where  $C_0$ ,  $C_1$  and  $C_2$  are constants and take the values 0.27, 0.57 and 0.17 respectively and are dependent on two factors, i.e., storage constant (K) and a dimensionless factor (x). Value of 'K' is taken as 0.2 (for natural channels) and 'x' as 0.15 day. 'I' represents inflow to the reservoir and 'Q' represents outflow.

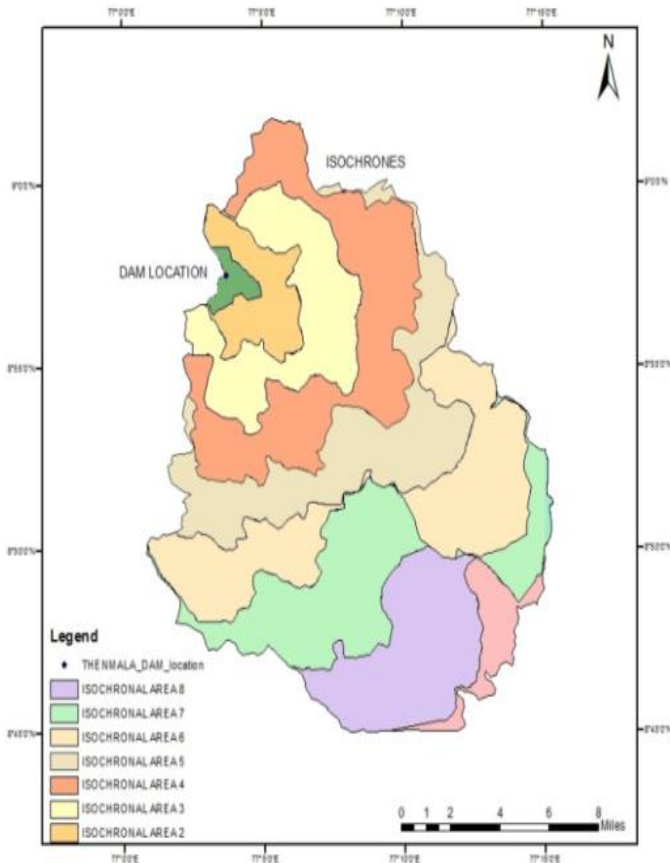


Fig. 3: Isochrones

3.3 Flood routing

Modified Pul’s method is a flood routing technique to determine the peak flow attenuation that a hydrograph undergoes. To perform the routing, a relation between storage and outflow is calculated and plotted and is solved at each time step using the equation 4.

$$\frac{S_2}{\Delta t} + \frac{O_2}{2} = \left( \frac{S_1}{\Delta t} + \frac{O_1}{2} \right) - O_1 + \left( \frac{I_1 + I_2}{2} \right) \tag{4}$$

Where ‘S’ represents storage of the reservoir, ‘O’, the outflow and ‘I’, the inflow.

3.4 Analysis

Upon providing the various inputs required by the software for the execution of the analysis, the software solves the unsteady flow equations as in Eqn. 5 and Eqn. 6 iteratively and generates a series of results including reservoir depletion values, water surface elevations corresponding to each sections, flood wave velocity, travel time, depth and area of inundation.

$$A \frac{\partial V}{\partial x} + VT \frac{\partial V}{\partial x} + T \frac{\partial y}{\partial t} - q = 0 \tag{5}$$

$$\frac{\partial y}{\partial x} + \frac{V}{g} \frac{\partial V}{\partial x} + \frac{1}{g} \frac{\partial V}{\partial t} = S_0 - S_f \tag{6}$$

In this study, 43 cross sections are specified which upon interpolation is increased to 272. Cross section of the channel together with the corresponding flood plain sections are obtained from the ASTER digital elevation model using the ArcGIS software. The surface area of the reservoir is provided as reservoir description along with the respective elevations. The inflow hydrograph values obtained previously by Muskingum’s method are given as inputs together with the various boundary conditions for the analysis.

4. RESULTS AND DISCUSSIONS

4.1 Maximum Precipitation

The magnitudes of maximum values of 24 hrs, 48hrs and 72 hrs rainfall values are computed for each year during the data period of 1982-2011 and are shown in Table 1. The maximum intensities are then found out and are tabulated in Table 2. Also the time of concentration was found out to be 1.5 hrs. Using these values and adopting a return period of 1000 years (as for large hydraulic structures), the maximum precipitation is found as 396 mm with the help of the IDF curves that are plotted as shown in Figure 2.

Table 1: Maximum rainfall values

Year	Maximum precipitation (mm)		
	24 hours	48 hours	72 hours
1982	107.4	128	154.2
1983	145.4	154.6	155.8
1984	86.8	134.1	165.5
1985	87.2	120.6	173
1986	80.8	120.8	146
1987	99.4	173	197.2
1988	84.6	131.2	138.4
1989	112.2	119.4	169.8
1990	97.4	152.4	167.6
1991	147.2	201.2	319.6
1992	268.6	345.4	357.6
1993	131.6	192.4	274
1994	162.4	214	251.4
1995	97.2	147	161.4
1996	99.2	151	215.4
1997	131.6	130	159.2
1998	174.8	282.2	330.4
1999	123.2	181.4	244.2
2000	201.4	222.7	264.2

2001	128	147.6	187
2002	153.2	212.6	231
2003	73.4	95	134.6
2004	66.8	121	149
2005	79.4	120.8	132
2006	134.2	162.4	191.4
2007	160.2	170.4	177.8
2008	95.2	119.6	136
2009	112.6	160.2	181.8
2010	180	260.4	283.8
2011	106	107.2	114.4

Using equation 2, the inflows to the reservoir are found out. These inflows as in table 3 are routed using equation 3 to get the instantaneous unit hydrograph ordinates. These IUH ordinates are first converted to 1 hour unit hydrograph ordinates by S-curve technique and are then converted to direct runoff ordinates, which is in turn converted to flood hydrograph ordinates by accounting the base flow. For the tabulations, an initial loss of 10mm is assumed as per the Kallada irrigation report (1966) and the base flow rate is taken equal to 0.15 cumecs/ sq.km as per the Central Water Commission's flood estimation report and is obtained as 79 cumecs. Figure 4 shows the obtained flood hydrograph and the value of the maximum flood entering the reservoir is found as 4589.42 cumecs.

#### 4.2 Maximum flood

**Table 2** : Maximum rainfall intensities

Maximum rainfall intensities (cm/hr)				
Return period	100 years	200 years	400 years	1000 years
Duration				
24 hours	1.240	1.360	1.480	1.64
48 hours	0.773	0.846	0.920	1.02
72 hours	0.600	0.660	0.710	0.79

**Table 3**: Reservoir inflow

Time (minutes)	Interisochronal areas(km <sup>2</sup> )	Inflow (cumecs)
0	0	0
10	5.449	90.880
20	26.657	223.319
30	61.440	341.606
40	97.570	406.867
50	110.108	273.912
60	91.402	254.097
70	79.423	189.253
80	52.941	133.317
90	17.818	33.023

#### 4.3 Reservoir Routing

The modified Pul's method makes use of equation 4 for the routing process and a time – elevation - flood outflow relation is obtained, from which it can be understood that the spillway provided is sufficient.

#### 4.4 Dam Break Analysis

For the analysis using BOSS DAMBRK software, several inputs are given which includes the reach description which is obtained from ASTER DEM, the various boundary conditions which involve several factors like time to dam failure, routing period, slope of channel downstream etc..., reservoir description as surface areas corresponding to different elevations and breach description which includes breach width, breach side slope, final breach elevation etc...

After the analysis using the software, a number of outputs are obtained. Table 4 shows water surface elevations at various selected cross sections.

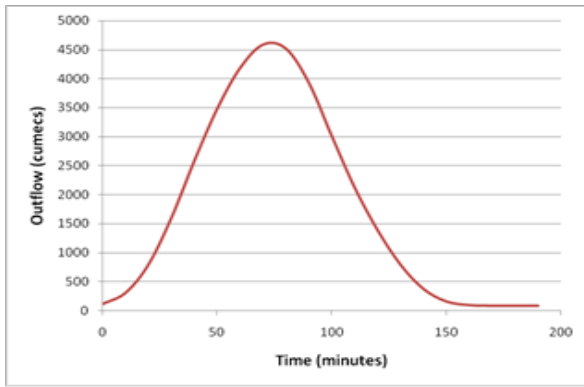


Fig. 4: Flood hydrograph

Table 4: Water surface elevations

River cross section location (km)	Water surface elevation (m)
0	85.09
0.437	68.40
0.560	65.00
0.630	64.750
0.840	63.730

0.980	61.370
2.800	51.400
.313	42.010
5.192	36.150
5.875	32.880
6.813	30.770
8.833	29.660
11.200	27.740
13.588	19.310
14.000	18.110
38.000	10.840
69.000	7.470

Table 5 briefs about the flood wave velocity, travel time and area of inundation, which are the required outputs of the dam break analysis. The maximum velocity of 1.72 m/s occurred at a distance of 11.2 km and a minimum velocity of 0.06 m/s at a distance of 14 km downstream of the dam section.

Table 5: Results of dam break analysis

River cross section location(m)	Flow velocity (m/s)	Channel flow area (sq.m)	Left flood plain area (sq.m)	Right flood plain area (sq.m)	Time (minutes)
0	0.9	39	0	0	0
0.437	1.38	25	0	0	5.277
0.560	1.54	18	1	4	1.33
0.630	1.49	15	1	8	0.783
0.700	1.44	13	1	11	0.81
0.770	1.40	10	1	14	0.833
0.840	1.36	8	1	16	0.857
0.910	1.32	6	2	19	0.883
0.980	1.29	5	2	21	0.904
2.800	1.46	24	0	0	20.77
4.313	1.13	21	0	0	22.31
5.192	1.68	21	0	0	8.72
5.875	1.35	26	0	0	8.432
6.813	0.98	36	0	0	15.952
8.833	0.89	21	0	19	37.82
11.200	1.72	20	0	0	22.93
13.588	1.35	25	0	1	29.48
14.000	0.06	304	0	237	114.44
38.000	0.48	73	0	0	833.33
69.000	0.50	70	0	0	1033.33

### 5. CONCLUSIONS

The dam break analysis of Thenmala Dam is carried out

using BOSS DAMBRK software. The maximum precipitation is found out to be 396mm and the corresponding flood to be 4589.42m<sup>3</sup>/s. The spillway

provided is also found out to be adequate. The total time of travel of dam break flood wave is found out to be 35.98 hours. Various other outputs such as flood wave velocity, area and depth of inundation etc... are also obtained so that adequate warnings can be provided to the public during emergencies like flood.

## 6. REFERENCES

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