Dam Break Analysis of Idukki Dam Using FLDWAV River Mechanics

Afsal K P[1], Anjali Peter[2], Peter Jobe[3] , Vinaya S M[4] , Binoy Alias M.[5]

[1]B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India
[2]B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India
[3]B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India
[4]B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India
[5]Professor, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India

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Abstract - When a dam fails, a large quantity of storage water is released to downstream, producing a flood wave which is capable of creating disastrous damage to the downstream people and property. Pre-determination of flood wave characteristics along the downstream river reach is very much essential in mitigating such disasters. The present study aims to predict the characteristics of the flood wave like peak flood stage, peak flood discharge and their times of occurrence at different locations downstream in the river due to dam-breach for the Idukki dam built across the Periyar River in Kerala State, India. The National Weather Service FLDWAV model has been used for the study and the results are discussed in terms of outflow hydrographs.

Key Words: Dam Break Analysis, NWS FLDWAV, Idukki dam.,Periyar River, Kerala

1.INTRODUCTION

Dams provide many benefits to our society, but floods resulting from the failure of constructed dams have also produced some of the most devastating disasters of the last two centuries. A dam break may result in a flood wave up to tens of meters deep traveling along a valley at quite high speeds. The impact of such a wave on developed areas can be very devastating. Such destructive force comes as an inevitable loss of life, if advance warning and evacuation was not possible.

Dam break failures are often caused by overtopping of the dam due to inadequate spillway capacity during large inflows into the reservoir from heavy rainfall-generated runoff. Dam failure may also be caused by seepage or piping through the dam or along internal conduits, earthquake and landslide generated waves in the reservoir. For a cascade of dams, the breaking of one dam may cause subsequent damage to other dams located downstream due to their overtopping. Partial or catastrophic failure of a dam leading to uncontrolled release of water causes severe damages to lives and properties of people situated downstream. The effect of such a flood disaster can be mitigated to a great extent, if the resultant magnitude of flood peak and its time of arrival at different locations downstream of the dam can be estimated, facilitating planning of the emergency action measures. The most suitable instruments for analysis and prediction of a dam break flood are mathematical hydrodynamic simulation models. These models can be used for prediction of dam breach flood hydrograph and its routing through downstream valley to obtain the time series of discharge and water level at different locations of the valley. FLDWAV River mechanics is a widely used software for the same.

2. METHODOLOGY

For routing unsteady flood waves, a particular hydraulic method, known as the dynamic wave method based on the complete one-dimensional Saint-Venant unsteady flow equations, is chosen as the basic hydraulic routing algorithm for the FLDWAV model. This choice is based on its ability to provide more accuracy in simulating the unsteady flood wave than that provided by the hydrologic methods, as well as, other less complex hydraulic methods such as the kinematic-wave and the diffusion-wave methods. Of the many available hydrologic and hydraulic routing techniques, only the dynamic wave method accounts for the acceleration effects associated with the dam-break wave and the influence of downstream unsteady backwater effects produced by channel constrictions, dams, bridge-road embankments, and tributary inflows. Also, the dynamic wave method is computationally feasible, i.e., the computational time can be made rather insignificant if advantages of certain "implicit" numerical solution techniques are utilized.
The dynamic wave method is based on the complete one-dimensional equations of unsteady flow (Saint-Venant equations) which are used to route flood hydrograph(s) through a designated channel or floodplain and its tributaries.

The NWS FLDWAV model is based on an expanded version of the original equations developed by Barré de Saint-Venant (1871) which consists of equations of mass and momentum.

3. CASE STUDY

For this, Idukki dam has been selected for the study. Since this is the most important and discussed dam. The Idukki Dam is a double curvature arch dam constructed across the Periyar River in a narrow gorge between two granite hills in Kerala, India. At 167.68 meters, it is one of the highest arch dams in Asia. It was constructed and is owned by the Kerala State Electricity Board. It supports a 780 MW hydroelectric power station in Moolamattom, which started generating power on 4th October 1975. Technically, the dam type is a concrete double, curvature parabolic, thin arc dam.

Fig -1: Location of Idukki dam

Table -1: Salient features of Idukki dam

Location	Idukki, Kerala, India 9° 50′ 34″ N, 76° 58′ 34″ E
Type of dam	Concrete double curvature parabolic, thin arch
Impounds	Periyar River
Height	168.91m
Length	365.85m
Dam volume	450000 m^3
Spillways	Nil
Reservoir total capacity	1996 x 10^6 m^3
Active reservoir capacity	1459 x 10^6 m^3
Inactive capacity	536 x 10^6 m^3
Catchment area	649.3 km^2
Surface area	60 km^2
Normal elevation	732.62

Fig -2: Downstream view of Idukki dam

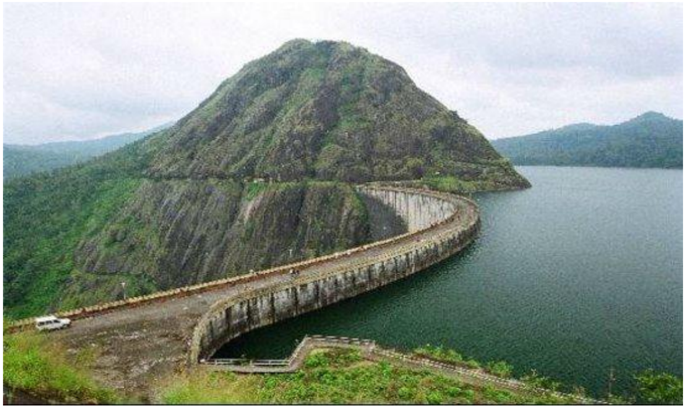

Fig -3: Upstream view of Idukki dam

4. INPUT DATA

The following data were required for the analysis:

- Salient features of dam and other hydraulic structures in study reach of the river.
- Rating curves of all the hydraulic structures in the study reach of the river
- Design flood hydrograph.
- Spillway rating curve.
- Cross-sections of the river from dam site to the most downstream location of interest.
- Elevation - storage/area relationship of the reservoir.
- Stage-discharge relationship at the last river cross-section of the study area, if available.
- Manning's roughness coefficient for different reaches of the river under study.
- Topographic map of the downstream area at a scale of 1:15000 to 1:25000, with a contour interval of 2 to 5 m for preparation of inundation map for dam break flood.

- Breach Geometry.
- Time taken for Breach formation.
- Reservoir elevation at start of failure and initial water elevation.
- Description of d/s flow condition, i.e. subcritical and super-critical.

Several sections were taken along the downstream valley of the dam until plain terrain was encountered as shown in figure 4.The details of sections given includes the width of the valley at various elevations.
The initial flow in the channel was also entered as input to the software.

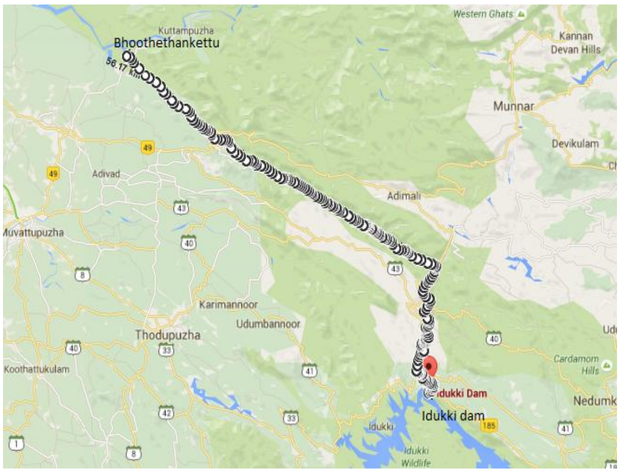

Fig -4: Sections along downstream channel

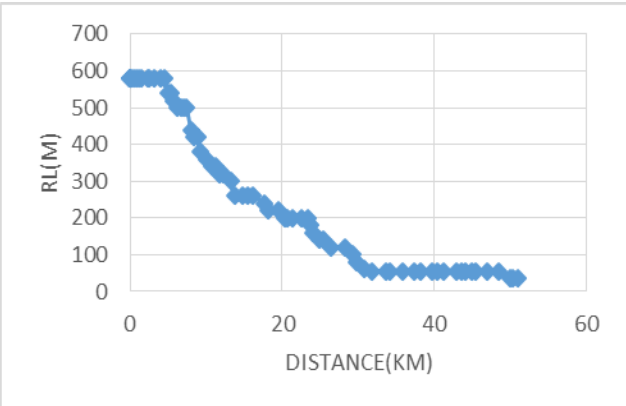

Chart -1: Longitudinal profile of the downstream channel bottom

The values of the above required input data were included in the input file.

5. OUTPUT OBTAINED

The output obtained from the software gave details of 74 sections along the downstream channel. Out of these 74 sections, those sections near to economically important places like townships, hydraulic structures etc. are selected and the output corresponding output is tabulated in table 2.

Table -2: Output obtained at selected sections

Section No.	Location (km)	Bottom RL (m)	Time Max WSEL (Hour)	Max WSEL (m)	Time Max Flow (Hour)	Max Flow (cumec)	Max Velocity (m/s)
1	0.00	580.00	4.22	585.67	1.001	10000	5.64
28	13.30	440.00	5.724	447.25	5.505	9729	3.66
60	28.65	120.00	8.800	128.77	6.000	240	1.62
74	36.00	50.00	10.185	80.69	4.222	240	1.50

The output obtained consist of hydrographs at various stations along the downstream channel. Chart 2 shows the hydrograph obtained at 0km from the nose of the dam (dam section itself).It is clear from the hydrograph that the discharge suddenly rises to very high value of 10000 cubic-meter/second when the failure happens. Then, it is seen that the discharge reduces at the section as the water flows through the downstream channel simultaneously.

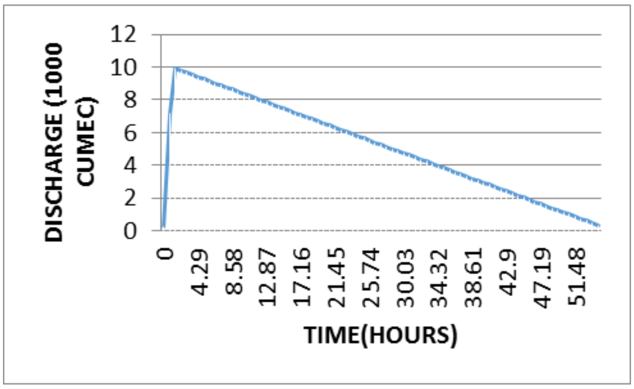

Chart -2: Hydrograph obtained at location 0 km from the dam

Chart 3 reveals that discharge at that section (13 km from the nose of the dam) is almost constant (due to initial flow in the channel) until the flood wave reaches the section. When the flood wave reaches the section, it adds to the initial flow in the channel and as a result discharge suddenly increases to a very high value as shown in Chart 3.

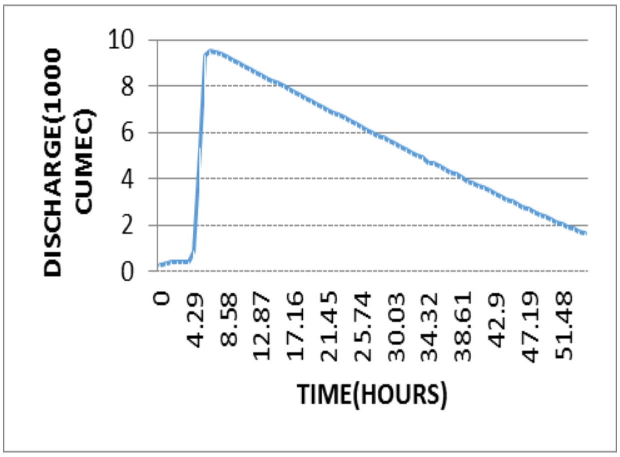

Chart -3: Hydrograph obtained at location 13 km from the dam

6. CONCLUSION

From the study, it can be concluded that the failure of Idukki dam can cause severe destruction on health and property of the people living on the banks of the downstream channel (Periyar River).

From the output obtained, it is very clear that even at a distance of 36 kilometers from the nose of the dam, the water level can rise about 30 meters from the channel bottom. It is to be also noted that the flood wave can hit various stations within few hours from the time of dam breach at high velocities. This can cause severe destruction along the flood wave path.

The Periyar River flows through areas of high economic importance and population. Thus it can cause severe floods on a large areas in the central Kerala.

Hence, it is very necessary for the authorities to take necessary steps like flood forecasting and sufficient warnings especially during the monsoons in flood prone areas to reduce the impact on life and properties due to dam failure.

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