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Dam Break Analysis using HEC-RAS: A Case Study of Karjan Dam

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Abstract - *A dam is a structure constructed across river which stores water and supplies water for various purposes. Though the dams have many benefits, there is always a threat of dam break floods which are devastating in nature. Hence it becomes essential to analyze and simulate dam failure scenarios to understand the severity of dam break flood and identify areas under threat which helps in land use planning and developing emergency response plans. This study attempts to carry out dam break/breach analysis for the Karjan dam using a two-dimensional hydraulic model called Hydraulic Engineering Center's River Analysis System (HEC-RAS). RAS-Mapper tool is used to extract river geometry data from the Cartosat-1 digital elevation model (DEM) and to generate the inundation map to identify the areas affected. The study involves the prediction of breach parameters, breach flood hydrograph, peak flow, flood arrival time, and generation of inundation maps. The dam break model is simulated for unsteady flow conditions using Probable Maximum Flood (PMF) corresponding to different failure scenarios. HEC-RAS tool is utilized to determine the breach outflow hydrograph and hydraulic conditions at critical downstream locations. The outcome will assist the local government in making proper planning and development decisions.*

***Key Words*: Arc-GIS, Dam break analysis, Karjan dam, Flood Inundation, HEC-RAS**

1. INTRODUCTION

Dam is barrier constructed across the river to store the water. This stored water is useful for Domestic, Irrigation, Industrial, hydro electricity generation etc. Floods occur due to dam failure always dangerous for so it is necessary to analyse flood wave propagation at the downstream side of dam for evaluation of flooding disaster. Dam Break Analysis is useful to identify the inundation area, flood depth, flood velocity and travel time of flood waves. (Joshi M.,2017) Dams are the most basic frameworks for the general public that contribute to social progress and achievement. Dams have the potential to disappoint because of several specific security challenges and threats. Surges caused by dam failures can result in massive disasters with massive death tolls and property losses, especially in densely populated areas.

Past disasters caused by dam failures have been linked to the amount of time it takes for the water to clear after the dam has failed (Wahl, T.L, 1998). As a result, it's vital to appreciate the process of dam rupturing and, if possible, to consider key breaking criteria needed to visualize the process. Regardless, many existing dams continue to pose growing threats to downstream areas because to fundamental crumbling, lack of outline, flawed development, and poor activity and care. The breach development rate has a crucial effect on the pinnacle release from a dam failure, according to Hanson et al. (2005). The breach initiation and formation times must be tracked in order to determine the breach development rate.

HEC-RAS, MIKE FLOOD, MIKE 21, and MIKE11 are examples of software created for dam break modelling over the last two decades. Without a doubt, the quality and dependability of the counterfeit procedures for each component of the river flood improves the quality and authenticity of the river flood risk maps that are developed.

For this research, a DEM file for the study region is necessary. Aside from topographical data, satellite photos also provide precise information on the area of interest, as well as the various structures there. This is extremely important for determining the area that could be flooded if a dam on the upstream side of the river bursts (Qi, H., 2011).

Many scholars have studied in this area to determine the peak discharge from dams and link it to other characteristics [(SCS, 1981), Singh and Snorrason (1984), Froehlich (1995a and 2008)]. Froehlich (1995a) gathered data from 63 dam failure scenarios to determine the average breach width. He analyzed data from 21 real-life dam failures to estimate the time it takes for the breach to form. The majority of the research is focused on two parameters: average breach width and breach formation time, as they are more sensitive to failure peak during dam breaching.

Using HEC-RAS, a numerical simulation of the failure of the Karjan dam is carried out in this article (Product of Hydrologic Engineering Center, U S Army Corps of Engineer). The influence of overtopping failure is examined in this study using Saint-Venant equations. For breach evolution and analysis of the impact of dam break floods on downstream regions, a trustworthy and accurate mathematical model must be built (Dhiman S, 2018).

2. STUDY AREA

The Karjan Reservoir Project is located near Jitagadh village in the Nandod Taluka of Gujarat's Narmada District. River Karjan is left bank tributary of river Narmada. It is down stream of Sardar Sarovar Project. Through a left and right bank canal system, the project covers 51000 hectares of CCA. The project area lies on the western coast of the Indian continent, between 73̊.5' and 73̊.40' longitude east and 21̊.30' and 22̊.0' latitude north. The elevation of the project area varies between 18m to 120m above MSL.

Table-1: Salient features of Karjan Dam

Type	Masonry and Concrete
Maximum Height	100 m
Length at the Top of the dam	903 m
Top width of dam	7.77 m
Full Reservoir Level	115.25 m
Maximum Reservoir Level	116.10 m
Area at Full Reservoir Level	36.77 Km^2
Gross Storage Capacity	630 Mm^3
Effective Storage Capacity	581 Mm^3
Mean annual rainfall	1209 mm

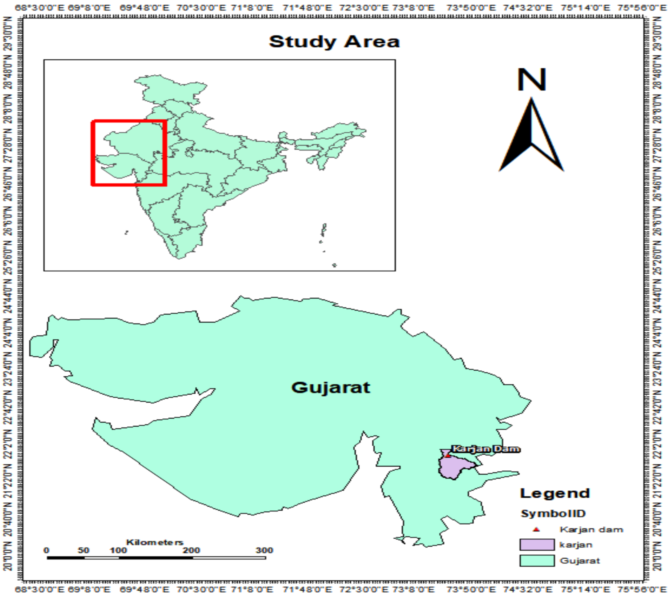

Figure-1: Study Area

3. METHEDOLOGY

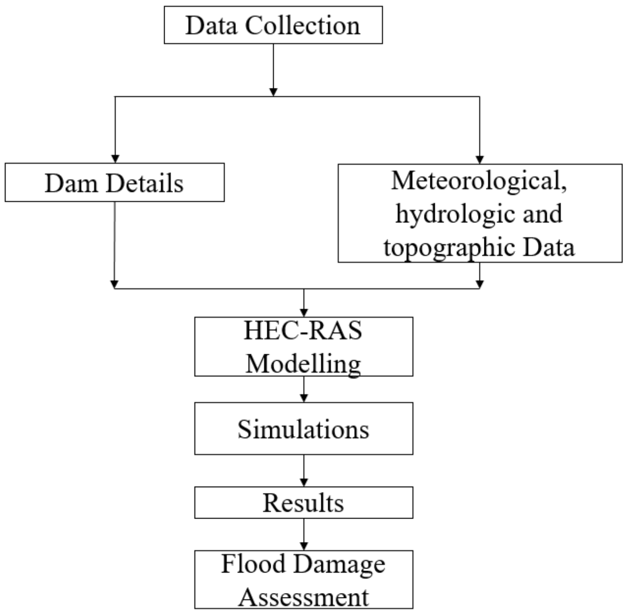

Chart-1: Methodology Chart

For dam break analysis research of Karjan dam in Narmada district, Gujarat, India, the US Crops Army's Hydrologic Engineering Center's River Analysis System (HEC-RAS) simulation model was utilized. The HEC-RAS two-dimensional model is a powerful

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yet user-friendly tool for calculating water depth, discharge, inundation area, flood wave velocity, and water surface profile in two dimensions.

The analysis of a dam failure is a two-step procedure. 1) Examination of the dam's actual breach. 2) The breach's discharge must be routed via the downstream valley to estimate the flood's impact on population centers.

a) Overtopping Failure

In the event of an overtopping failure, water rushes over the dam's crest. The erosion of the head cut begins on the dam embankment's downstream side. When the cut reaches the dam's upstream side, it will cause mass failure.

b) Breach Parameters

Breach width, breach depth, side slope angles, and breach time are all characteristics to consider. Dam break analysis is carried out in this study for worst-case scenarios to estimate flooding areas on the downstream side of the dam, therefore breach parameters are used to achieve maximum dam breaching and peaked out flow from broken dams is calculated using full reservoir discharge.

c) Data Collection

The Karjan Dam is situated near Jitagadh village of Nanded Taluka, Dist. Narmada of Gujarat State across river Karjan. Digital Elevated Model (DEM) from Indian Geo-platform of ISRO, Bhuvan (www.nrsc.gov.in) with 30m resolution and WGS 84 datum and UTM projection. The Karjan dam's discharge data were obtained from the State Water Data Center (SWDC). The Karjan dam's Rainfall data was also obtained from the State Water Data Center (SWDC). HEC-RAS 5.0.6 (2D) Model is used to create simulation for analyzing flood susceptible area of Jitagadh village of Nanded Taluka, Dist. Narmada of Gujarat State. For Dam break analysis and to determine the following flood on the downstream side of the Dam, a two-dimensional unsteady flow analysis is used. The Implicit Finite Volume methodology and Wave Diffusion equations were employed with the Unsteady Flow Analysis approach.

d) Dam Break Analysis for Karjan Dam

Digital Elevation model (DEM) from Indian Geo-platform of ISRO, Bhuvan (www.nrsc.gov.in) with 30m resolution and WGS 84 datum and UTM projection 43N is used. From DEM Terrain Model was created in RAS Mapper.

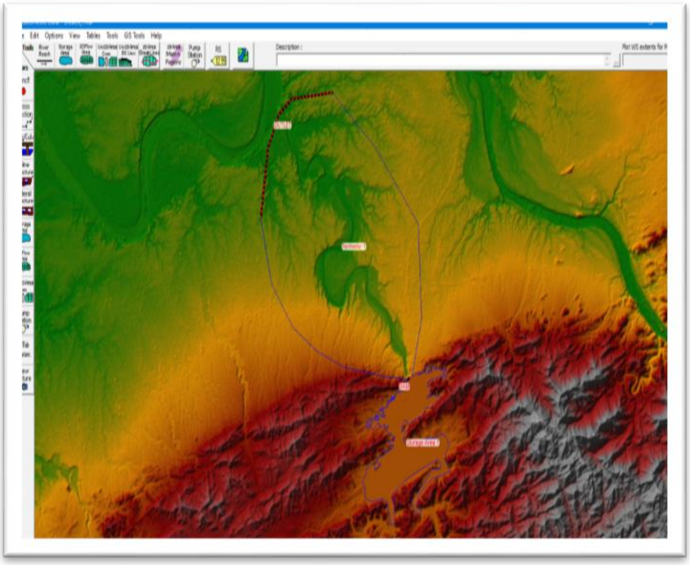

Figure-2: Geometric Data of Karjan Dam

The 2D flow area boundary and the Storage area boundary were marked after the Terrain model was created, and then mesh generation was completed.

Boundary conditions- 1) Storage area- 2d Flow area connection 2) Exit boundary- Normal Depth 3) Lateral Flow.

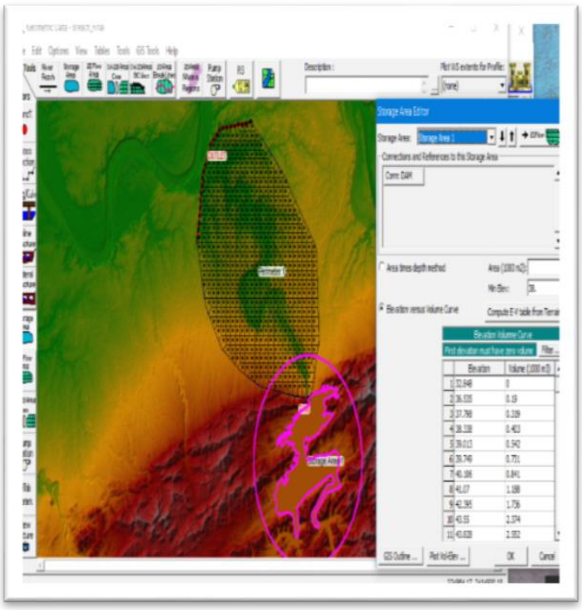

Figure-3: Elevation Volume Curve- Karjan Dam

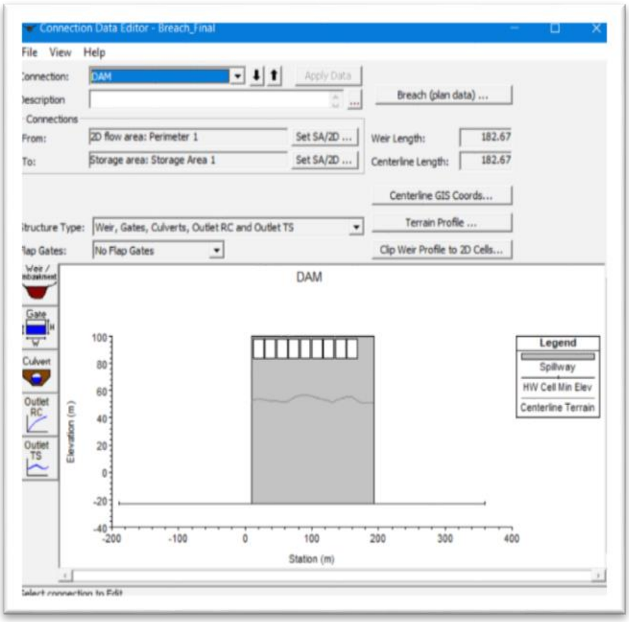

Figure-4: Karjan dam- Gate details

e) Breach Parameters

Breach width- 50 m

Breach Bottom Elevation- 20 m

Left Side Slope- 2

Right Slid Slope- 2

Breach time- 0.5

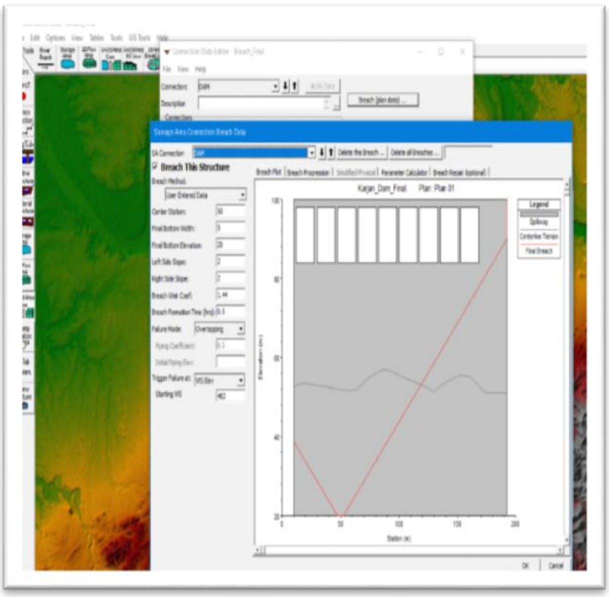

Figure-5: Breach Details- Karjan Dam

4. RESULT

For the dam breach research, an unsteady flow simulation is used. The output interval for the hydrograph was set to one hour, and the computational interval was set to one minute. At a lateral flow discharge of 17500 m^3/sec, the Karjan dam failed. The following area is flooded.

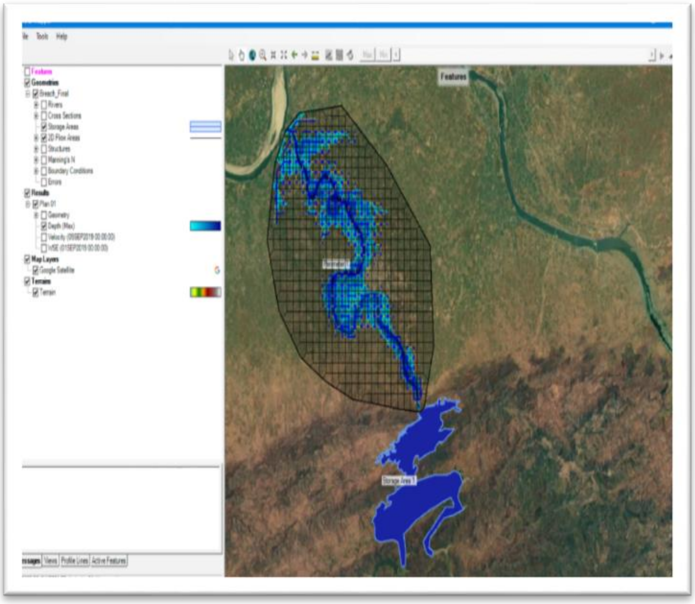

Figure-6: Flood Inundation Map

Flood inundation map of the area along the course of the river where the flood advances into the adjacent flooding plains, obtained from HEC-RAS. The inundation maps so generated show that around fourteen villages on the banks of 15 km stretch immediately downstream of Karjan dam are affected by the flood, among which some villages are severely affected. As the dam failure poses a significant threat to people and property downstream, the results of this study help to take precautions to protect people's lives and property by taking suitable measures to avoid catastrophes. This study also helps the authorities to develop an emergency response plan and flood mitigation measures.

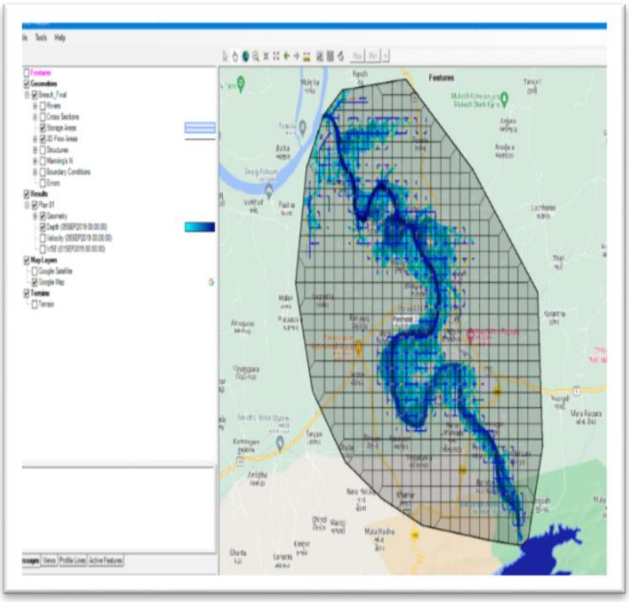

Figure -7: Inundation Map

Due to dam break Ramgadh, Rajpipla, Sundarpura, Sajva, Juna Kanvarpara, Chitrawadi, Bhacharwada, Hajarpara, Bhadaam, Torna, Bhuchhad, Dhanpor, Dhamnach, Juna Rundh area are under flooding.

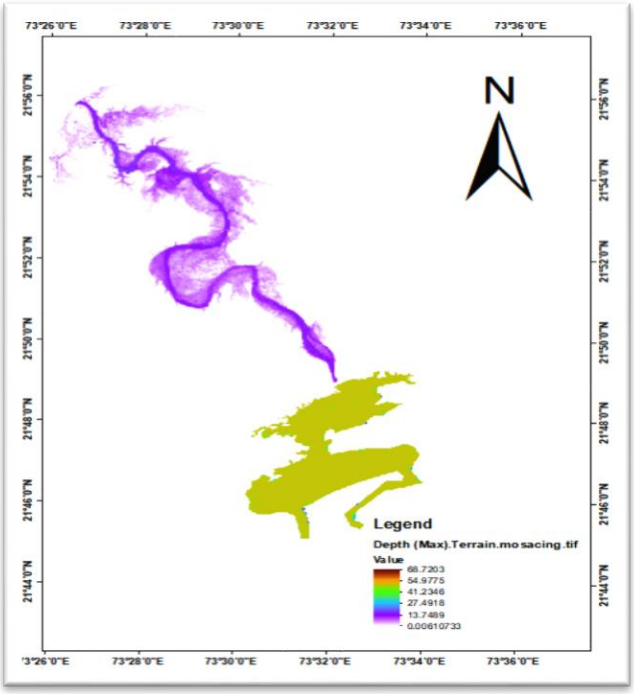

Figure -8: Depth Map

5. CONCLUSION

Flood defense planning has traditionally focused on safety standards, such as dike design levels or reservoir capacity requirements, in order to assure pre-defined protection levels for the population and economy. This approach to flood protection ignores the number of valuables protected by a defense system and, as a result, the effectiveness of flood protection measures. If the occurrence and magnitude of floods can be forecast and handled methodically, the negative consequences of floods can be minimized through effective planning and future development. As a result, our research will assist local planning authorities in making suitable decisions.

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