Dam Break Analysis using GIS Applications

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***Abstract*— This work describes the analysis of a dam break in the aspects of simulation and various parameters. The parameters and outflow predictions are mainly for the understanding of dam break mechanics, which is essential for the dam break analysis, and eventually determine the flood in each river station for a specific interval. In this work I use USACE HEC-RAS model tightly coupled with the ArcGIS based on available geometry data by considering neyyar dam as study area. It was modeled using ArcGIS and analyzed using these. HEC-RAS is a 1-D steady flow hydraulic model designed to aid hydraulic engineers in channel flow analysis and flood plain determination. Here, parameters associated to specific spatial features having coordinates are located on object classes and connected its corresponding features like by means of database relationships. The information content in HEC-RAS input and output files along with coordinate time (t) is recreated in a geodatabase data model to promote model interface and take advantage of GIS spatial analysis and visualization capabilities which gives an animated effect .Here I model this based on a limited geometric data**

Keywords*— DEM, HEC-GeoRAS, HEC-RAS, Dam Breach, Unsteady Data,Water Surfuce profile, Model

I. INTRODUCTION

In 1979 the Central Water Commission (CWC) Of India Establish Dam Safety Organization taken up measures for ensuring dam safety in their respective jurisdiction. Dam provides many benefits for our society, but floods resulting from the failure of constructed dams also produced some of the most devastating disasters. Simulation of such dam break events and the resulting floods can reduce threats due to potential dam failures. A breached dam releases large volumes of water very rapidly we can't predict dam-break floods using observations of natural floods. Most of the dam-break models were complex, tricky and time consuming Dam break was modeled and analyzed using USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) model based on available geometry data. HEC-RAS can incorporate both steady and unsteady, one dimensional flow computations using the same set of geometry data for either analysis. Unsteady flow computations use the full equations of motion

II. LITERATURE REVIEW

A large number of numerical models are available for computation of dam break flows like Simplified Numerical Model, ID Model , 2D Model and Integrated 1D-2D Model that include Dam failure analysis models developed by National Weather Service (NWS) such as DAMBRK, SMPDBK, and FLDWAV are widely used in the aspect of dam break flood routing. The Simplified Dam-Break (SMPDBK) was developed by the National Weather Service (NWS) for predicting downstream flooding produced by a dam failure. SMPDBK does not provide time varying results for a dam break simulation. This method is useful for situations where reconnaissance level results are adequate, and when data and time available to prepare the simulation are sparse FLDWAV Model is used for unsteady flow analysis using the full equations of motion. The FLDWAV [3] program is a combination of two popular NWS programs: the Dynamic Wave Operation Network Model (DWOPER) and the Dam-Break Forecasting Model (DAMBRK). The NWS developed DAMBRK specifically for simulating the failure of a dam and the resulting flood wave through the downstream valley. The model has been used in numerous dam break simulations to determine the maximum crest height to be expected and the warning time available for downstream inhabitants. The model has been used in numerous dam break simulations to determine the maximum crest height to be expected and the warning time available for downstream inhabitants. Another type model called BREACH is a physically based mathematical model to predict the breach characteristics (size, time of formation) and the discharge hydrograph from a breached earthen dam [8]. The Full Equations (FEQ) computer program simulates flow in a stream system by solving the full equations of motion for one-dimensional, subcritical unsteady flow [10]. FEQ uses the continuity and momentum equations to determine the flow and depth throughout the stream system following the specification of initial flow and boundary conditions

Another type model is ISIS Flow [11], which is a full hydrodynamic simulator for modeling flows and levels in open channels. ISIS Flow is able to model complex looped and branched networks, and is designed for simulating flood plain flows. ISIS Flow incorporates both unsteady and steady flow solvers, with options that include simple backwaters, flow routing and full unsteady simulation. A key strength of ISIS Flow is the ability to model a wide range of hydraulic structures including all common types of bridges MIKEFLOOD model [12] developed by DHI Group, Denmark, It is a commercially available integrated tool for detailed floodplain studies. It is an integration of two numerical hydrodynamic models MIKE 11 (1-D) and MIKE 21 (2-D) with a unified user interface and gives you the best of both steady and unsteady flow computations , but the disadvantage is that the detailed spatial modeling where needed, plus the speed of 1-D calculations where appropriate. MIKE FLOOD is ideal for many types of analyses such as flooding, storm surge, dam break, embankment failure, and more.

The US Army Corps of Engineers HEC RAS is a 1-D model which cooperate both steady and unsteady flow computation and can model it based on available geometric data. The main advantage over other models mentioned above is that it comprises of GUI, separate hydraulic components, data storage and management capabilities and graphics and reporting capabilities [4].

III. METHADOLOGY Neyyar Dam Break Simulation

A. *Study Area.*

To predict the flood hydrograph from the reservoir, it is necessary to have either of the following along with details of typical flow through the reservoir and normal retained water level. For the analysis it is necessary the data requirements for the reservoir. Reservoir data includes Maximum water level, Full reservoir level and Length of reservoir, its location, purpose, Dam height etc. Neyyar Dam is located at the longitude of 77º 09'E at the latitude of 8º 32'N in Thiruvananthapuram district mainly used for the irrigation purpose.

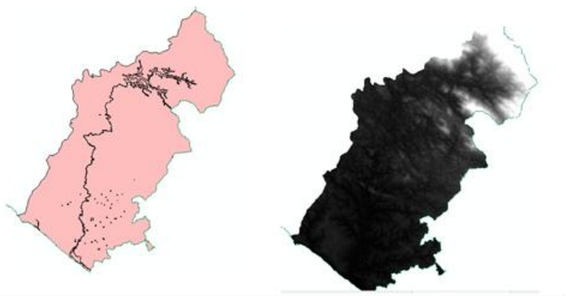


Fig 1. Neyyar Reservoir and DEM

B. *Dam Break Simulation Using HECRAS Overview*

Using GIS for hydrologic/hydraulic modeling usually involves three steps: 1) pre-processing of data, 2) model execution and 3) post-processing/visualization of results. Extraction of geometric data from a Digital elevation Model (DEM) using Arc GIS for use in the HEC-RAS model. Further, develop the HEC-RAS model by adding flow data. Run unsteady-state simulations to generate water surface profiles. Exporting the HEC-RAS model results into ArcGIS to create and represent floodplain maps

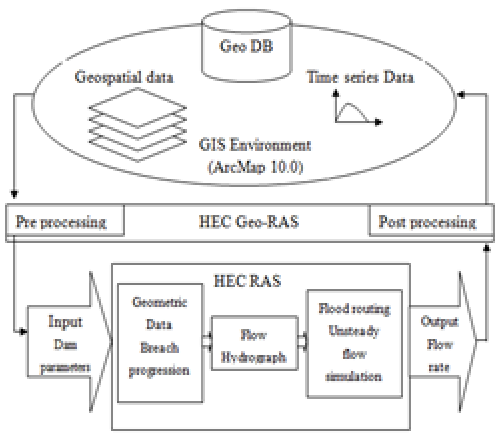


Fig 2. Dam Break Analysis using HECRAS Overview

C. *Preprocessing*

The pre-processor is used to process the geometric data into a series of hydraulic properties tables and rating curves. This is done in order to speed up the unsteady flow calculations. Instead of calculating hydraulic variables for each cross-section during each iteration, the program interpolates the hydraulic variables from the tables. The process is divided in three steps

First prepare the poly line themes defining stream centerline, stream banks, flow path lines and cross-sections. Second step is to use of the HEC-GeoRAS preRAS menu functions to extract 3-D spatial data from the Grid to develop 3-D polyline Z themes of the previously defined stream centerline, stream banks, flow path lines and cross-sections in order to generate the HEC RAS Import file which is the final step

The development of a stream centerline, cross-sections, stream banks, and flow path lines as shape files are required for preprocessing. Digitizing polylines creates these themes while in the edit mode. It is helpful to have a visual data source to identify the centerline, banks, and flow paths[4] . For this analysis, we will use the grid (DEM) and/or the drain.shp file, as the visual source

While Select the Create Stream Centerline command from the preRAS menu. Digitize river reaches one by one from upstream to downstream. The river centerline is used to establish the river reach network for HEC-RAS . Similarly Digitize the Bank lines and Flow path lines from the preRAS menu. The Flow Path Centerlines theme is used to identify the hydraulic flow path in the left overbank, main channel, and right over bank. The flow paths are used to derive downstream reach lengths in HEC-RAS. All flow paths (left overbank, main channel, and right overbank) are drawn from upstream to downstream. This will create a RAS GIS Import File in HEC-RAS import format containing terrain elevation extracted from the grid

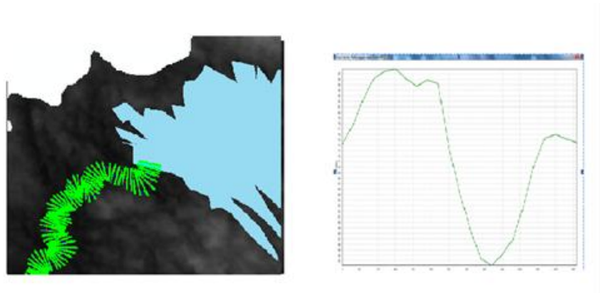


Fig 3. (a) Cross Section Cutline (b) Plot of Xs

D. *Model Execution- Running HECRAS*

The model execution of Dam Break Analysis can be done with Import RAS GIS Import File into HEC-RAS. This is accomplished from the Geometric Data Editor by selecting Import Geometry Data file in GIS Format. and Complete the hydraulic structure data, if any.

The main goal to develop the HEC-RAS model for our study area, using the geometric data extracted from the Grid using GeoRAS. The process is divided in two steps: Complete the geometry and unsteady flow data. Run the unsteady flow simulation and export the results of the simulation into Arc view

Geometric Data: The Geometric data is mainly for establishing the connectivity of the river system. Entering cross sectional data defining the entire necessary junction Information and adding hydraulic structural data. The HEC-RAS geometric file for use in dam break analysis is the same format that is used for all HEC-RAS studies. Cross-sections are formulated and described in the same way regardless of the flow regime being modeled

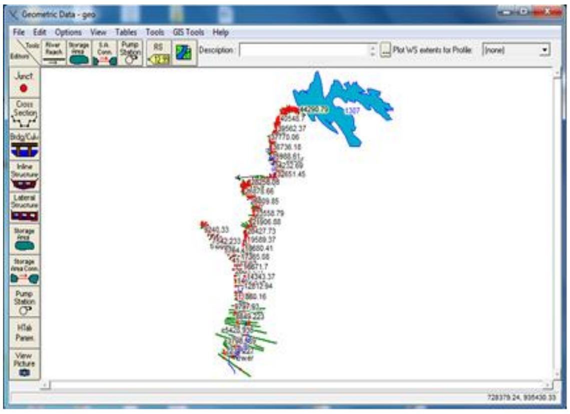


Fig 4. Geometric Data

Breach Geometry: To model a dam failure in RAS, we must enter the failure mode, breach size, and breach time. HEC-RAS supports both overtopping and piping failure modes with the failure trigger being a target water surface, water surface and duration, or specific time. The breach size is defined by a trapezoid and the duration over which the breach occurs. Lastly, RAS allows the user to customize progression of the breach over the full formation time.

Dynamic Breach geometry (breach depth and width, breach side slope factor), timing (breach initial time, breach formation time, etc.), failure mode, breach progression, flow conditions, material, geometry and type of the dam can affect peak hydrograph estimation [1]

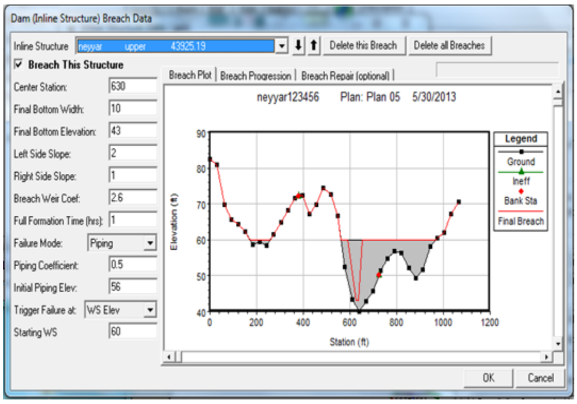


Fig 5. Breach Geometry

Dam Break mechanisms and impacts, some dam breach parameters were adjusted to simulate the dam break and analyze the sensitivities. The main breach parameters which include mainly the breach depth and width then Breach Slide slope factor and finally the time taken for Breach Formation, which include the Breach initial time and Breach formation time[7]

Unsteady Flow Simulation and simulation Manager: In this work we put together an unsteady flow data. When developing an unsteady model, however we always put together a steady flow model to evaluate the river system under a range of flows. But the unsteady flow is more complicated than the steady flow. We should always put together a steady flow analysis to iron out issues with your model to prior to modeling in unsteady flow. Also the boundary conditions must be established at all ends of the river system: The user is required to enter boundary conditions at all of the external boundaries of the system, as well as any desired internal locations, it may include Flow Hydrograph, Stage Hydrograph or Flow/Stage Hydrograph at upstream and also include Rating curve or Normal depth at the downstream and also set the initial flow and storage area conditions in the system at the beginning of the simulation period [4]. Similarly the initial conditions must be established for the entire system: Specify flows and perform a steady flow backwater analysis. Initial conditions flow data is used to calculate a water surface profile at the beginning of the simulation. Initial flows and stages are required to begin the unsteady flow calculations. Once we have been entered all of the geometry and unsteady flow data, the user can start to performing the unsteady flow calculations. For dam break type flows, the conservative form of the equations should be used for computation

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \tag{1}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial\left(\frac{\beta Q^2}{A}\right)}{\partial x} + gA\left[\frac{\partial h}{\partial x}\right] = gA(S_b - S_f) \tag{2}$$

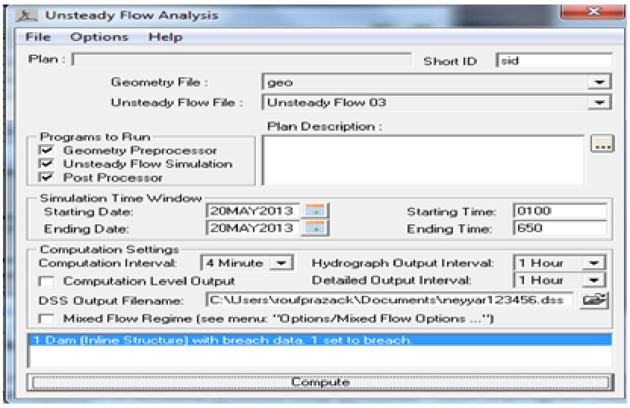


Fig 6: Simulation Manager window

The unsteady flow simulation is actually a three step process. First a program called RDSS (Read DSS data) runs. This software reads data from a HEC-DSS file and converts it into the user specified computation interval. Next the UNET program runs. This software reads the hydraulic properties tables computed by the preprocessor, as well as the boundary conditions and flow data from the interface and the RDSS program. The program then performs the unsteady flow calculations. And the final step is a program called TABLE.

This software takes the results from the UNET unsteady flow run and writes them to a HEC-DSS file

E. GeoRAS Post processing

The Post Processor is used to compute detailed hydraulic information for a set of user specified time lines during the unsteady flow simulation period. In general, the unsteady flow solver only computes stage and flow hydrographs at user specified locations. By running the Post Processor, the user will have all of the available plots and tables for unsteady flow that HEC-RAS normally produces for steady flow

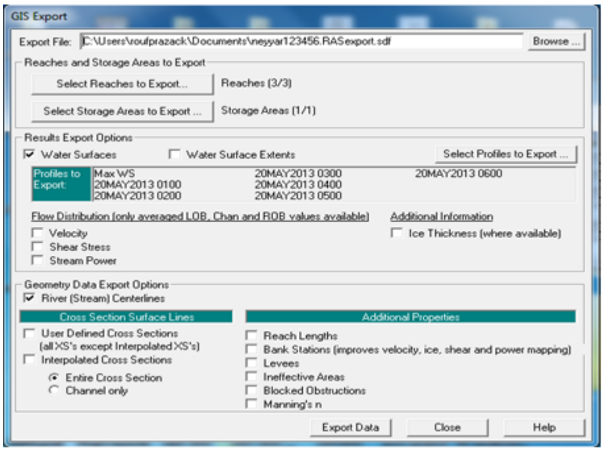


Fig 7. GIS Export Files

When the Post-Processor runs, the program reads from HEC-DSS the maximum water surface profile (stages and flows) and the instantaneous profiles. These computed stages and flow are sent to the HEC-RAS steady flow computation program SNET. Because the stages are already computed, the SNET program does not need to calculate a stage, but it does calculate all of the hydraulic variables that are normally computed. This consists of over two hundred hydraulic variables that are computed at each cross section for each flow and stage.

Post-processing using GeoRAS incorporates the water surface profiles derived from the HEC-RAS model into the spatial environment of GIS. The water surface profile data is used to develop a water surface TIN, and the intersection of the water surface TIN with the terrain model TIN provides flood visualization. The results can be shown in 2-D or 3-D view

Import RAS Data: This process is mainly for HECRAS imported results into feature classes. Here the feature class is created with the bounding polygons, cut lines and storage areas. The cutline feature class will hold the cross sections locations attributed with a water surface elevation for each cross section for each profile the bounding polygon layer having a bounding polygon feature for each water surface profile. Point feature class will be created for velocities and bank point locations as shown in the result

F. Floodplain Mapping

Floodplain mapping is accomplished in the GIS using HEC-GeoRAS. GIS information is exported from HEC-RAS and read into the GIS with GeoRAS. The geo-referenced cross sections are imported and water surface elevations attached to the cross sections are used to create a continuous water surface [5]. The water surface is then compared with the terrain model and the floodplain is identified where the water surface is higher than the terrain. HEC-GeoRAS produces inundation maps for flood extent and depth and, as shown in Figure, when displayed with imagery can be used to identify the area impacted during a dam failure scenario

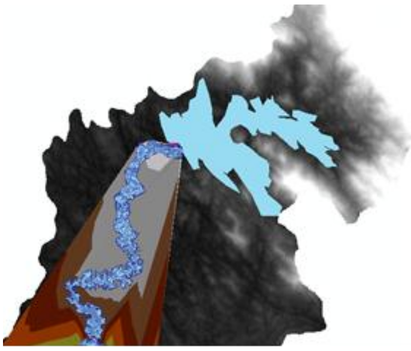
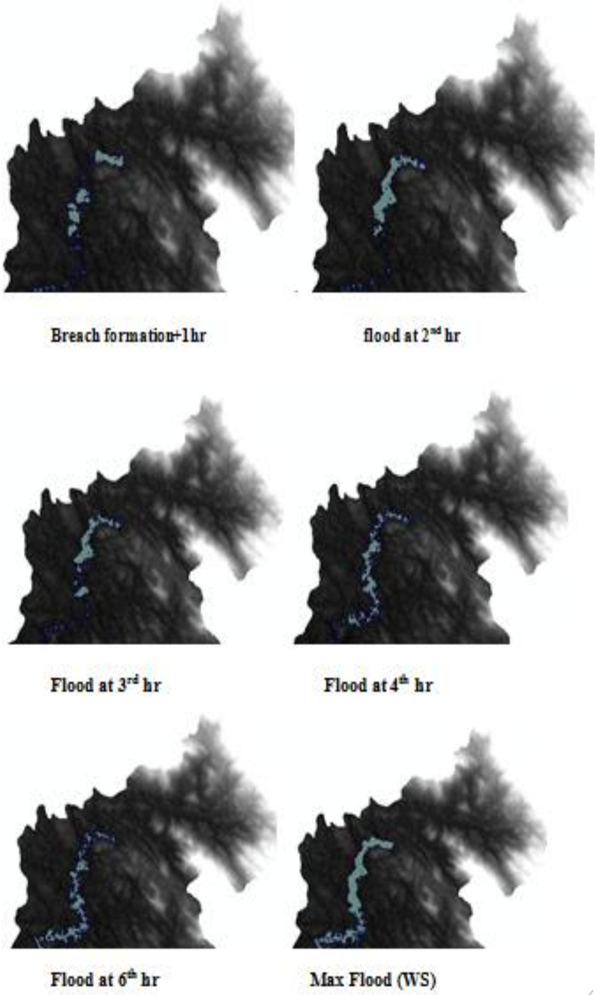


Fig 8. Floodplain Mapping

IV. EXPERIMENTAL RESULT

The results can be reviewed in the profile screen and they can be animated to show the change in water surface elevation throughout the entire analysis. The results can also be reviewed and animated in the three-dimensional screen. Although the program documentation indicates that results can also be viewed and animated in the cross-section review



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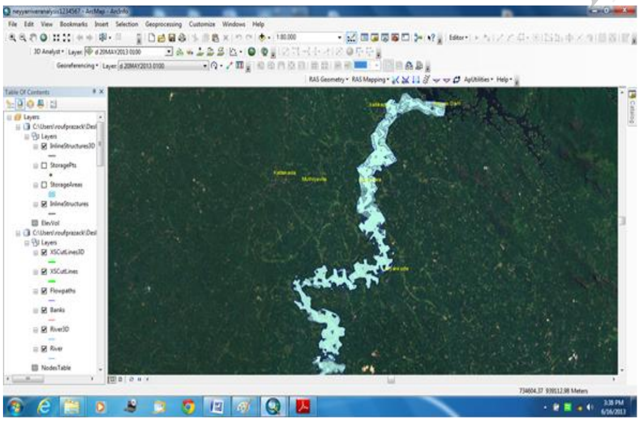

Fig 9. Max WS at Neyyar river

V. CONCLUSION

Dam break is a complicated and comprehensive process. Here the dam break tool in HEC-RAS was applied to Neyyar Dam at Thiruvananthapuram district. Dam break simulation and analysis based on given geometry data. Here the analysis result shows the maximum Water surface at each river stations after the dam breaks was animated with the help of Arc Map. HEC-RAS used in concert with HEC-GeoRAS provide the capabilities to create a river hydraulics model, simulate a dam failure, and map the resulting flood wave. Because of the availability of digital terrain data and processing capabilities, GIS is well suited to assist in performing dam failure analysis. The proper analysis of the hazards associated with dam failure will assist in land use planning and in developing emergency response plans to help mitigate catastrophic loss to human life and property.

VI. ▪ FUTURE WORK

For Dam Break Analysis detailed datas were necessary. Since these datas are highly confidential which was restricted for the commons? For this analysis the geometric data was generated with the help of available data only. So the accuracy may reduce More Accurate analysis can be done with the help of more input datas including the Land use information, ineffective areas...etc. are added to the geometric datas The analysis result can be improved by reducing the detailed output interval time at the time of unsteady flow simulation

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