THESIS

ON

“DAM BREAK ANALYSIS AND FLOOD INUNDATION MAPPING USING HEC-RAS FOR ADWA DAM, MIRZAPUR”

Submitted in partial fulfilment of the requirement for the award of degree of

MASTERS OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING
(SOIL AND WATER CONSERVATION ENGINEERING)

SUBMITTED BY:

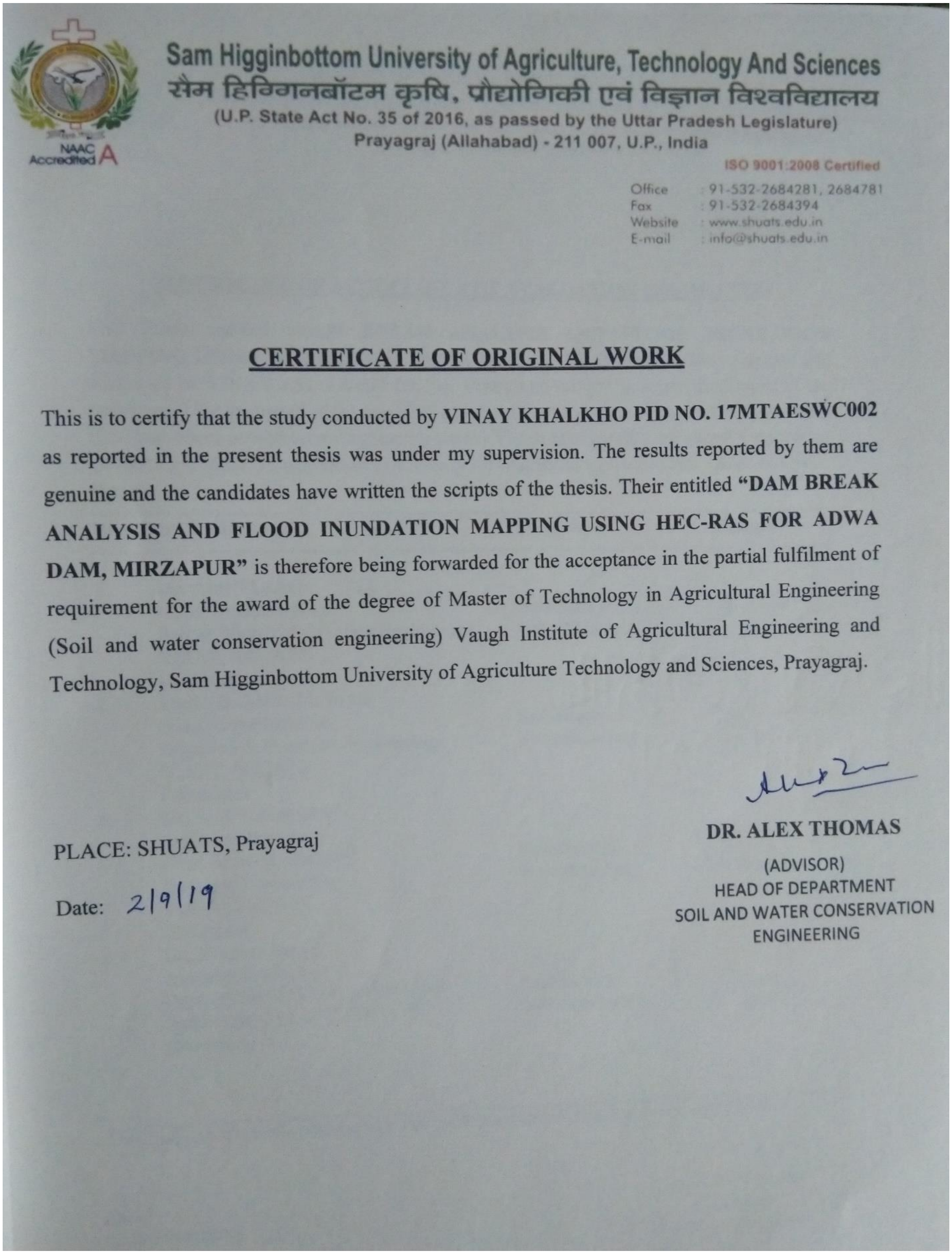
VINAY KHALKHO

17MTAESWC002

VAUGH INSTITUTE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
SAM HIGGINBOTTOM UNIVERSITY OF AGRICULTURE TECHNOLOGY AND SCIENCES

Prayagraj-211007 (UP),INDIA

2019



Sam Higginbottom University of Agriculture, Technology And Sciences
सैम हिग्गिनबॉटम कृषि, प्रौद्योगिकी एवं विज्ञान विश्वविद्यालय
(U.P. State Act No. 35 of 2016, as passed by the Uttar Pradesh Legislature)
Prayagraj (Allahabad) - 211 007, U.P., India
NAAC Accredited A
ISO 9001:2008 Certified
Office : 91-532-2684281, 2684781
Fax : 91-532-2684394
Website : www.shuats.edu.in
E-mail : info@shuats.edu.in

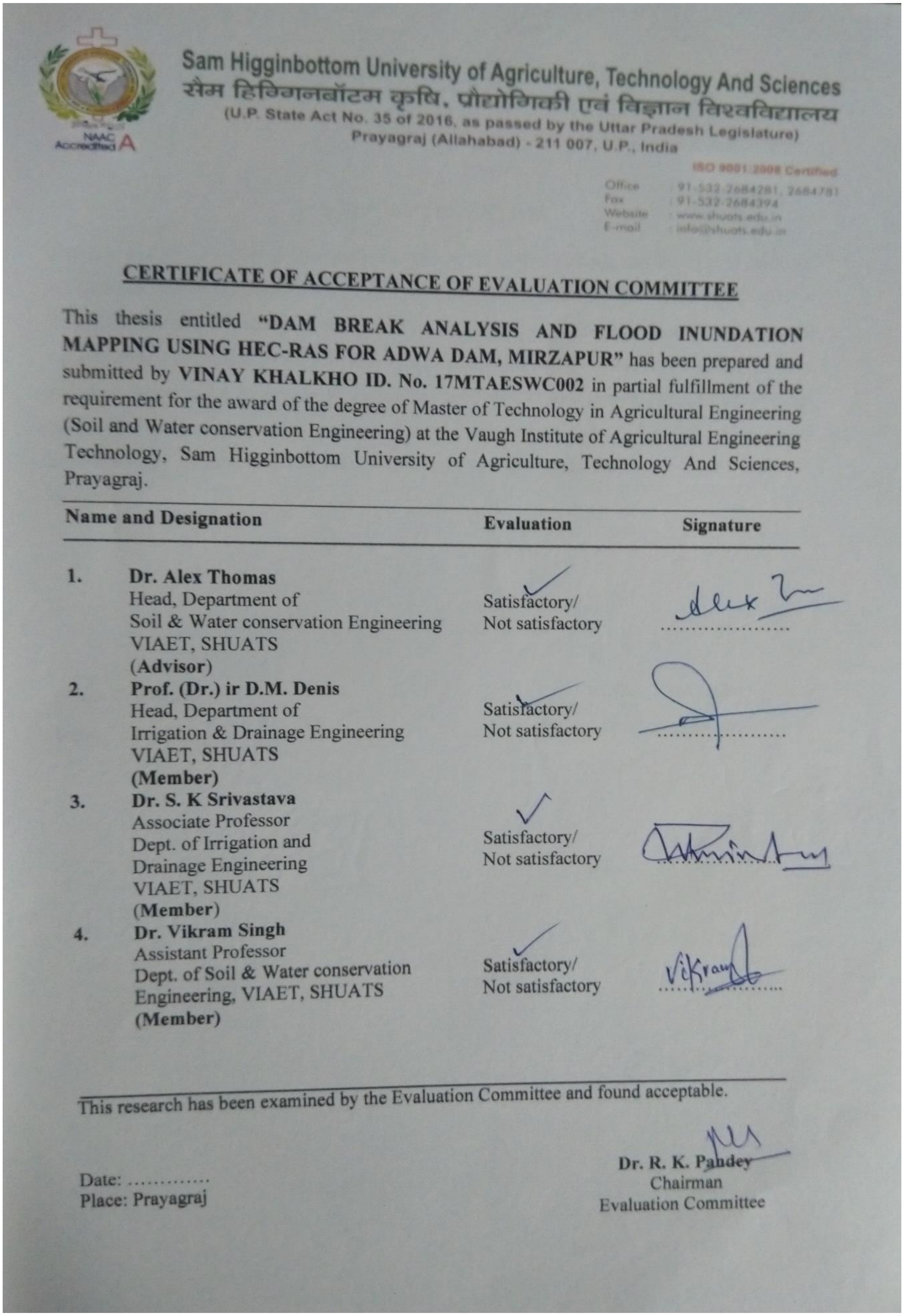
CERTIFICATE OF ORIGINAL WORK

This is to certify that the study conducted by **VINAY KHALKHO PID NO. 17MTAESWC002** as reported in the present thesis was under my supervision. The results reported by them are genuine and the candidates have written the scripts of the thesis. Their entitled **"DAM BREAK ANALYSIS AND FLOOD INUNDATION MAPPING USING HEC-RAS FOR ADWA DAM, MIRZAPUR"** is therefore being forwarded for the acceptance in the partial fulfilment of requirement for the award of the degree of Master of Technology in Agricultural Engineering (Soil and water conservation engineering) Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj.

PLACE: SHUATS, Prayagraj

Date: 2/9/19

DR. ALEX THOMAS
(ADVISOR)
HEAD OF DEPARTMENT
SOIL AND WATER CONSERVATION
ENGINEERING



Sam Higginbottom University of Agriculture, Technology And Sciences
सैम हिग्गिनबॉटम कृषि, प्रौद्योगिकी एवं विज्ञान विश्वविद्यालय
(U.P. State Act No. 35 of 2016, as passed by the Uttar Pradesh Legislature)
Prayagraj (Allahabad) - 211 007, U.P., India

NAAC Accredited A

ISO 9001:2008 Certified

Office : 91-532-2684281, 2684781
Fax : 91-532-2684394
Website : www.shuats.edu.in
E-mail : info@shuats.edu.in

CERTIFICATE OF ACCEPTANCE OF EVALUATION COMMITTEE

This thesis entitled **"DAM BREAK ANALYSIS AND FLOOD INUNDATION MAPPING USING HEC-RAS FOR ADWA DAM, MIRZAPUR"** has been prepared and submitted by **VINAY KHALKHO ID. No. 17MTAESWC002** in partial fulfillment of the requirement for the award of the degree of Master of Technology in Agricultural Engineering (Soil and Water conservation Engineering) at the Vaugh Institute of Agricultural Engineering Technology, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj.

	Name and Designation	Evaluation	Signature
1.	**Dr. Alex Thomas** Head, Department of Soil & Water conservation Engineering VIAET, SHUATS **(Advisor)**	[✓ Satisfactory]/ Not satisfactory	Alex …………………
2.	**Prof. (Dr.) ir D.M. Denis** Head, Department of Irrigation & Drainage Engineering VIAET, SHUATS **(Member)**	[✓ Satisfactory]/ Not satisfactory	…………………
3.	**Dr. S. K Srivastava** Associate Professor Dept. of Irrigation and Drainage Engineering VIAET, SHUATS **(Member)**	[✓ Satisfactory]/ Not satisfactory	…………………
4.	**Dr. Vikram Singh** Assistant Professor Dept. of Soil & Water conservation Engineering, VIAET, SHUATS **(Member)**	[✓ Satisfactory]/ Not satisfactory	Vikram …………………

This research has been examined by the Evaluation Committee and found acceptable.

Date: ………….
Place: Prayagraj

Dr. R. K. Pandey
Chairman
Evaluation Committee

SELF ATTESTATION

This is to certify that, I have personally worked on the research thesis entitled **“DAM BREAK ANALYSIS AND FLOOD INUNDATION MAPPING USING HEC-RAS FOR ADWA DAM, MIRZAPUR”** The data mentioned in this report were obtained during the unfeigned work done and collection by myself. Any other data or information in this report which has been collected or borrowed from outside agency has been duly acknowledged. None of the findings information pertaining to work has been concealed. The results embodied in this project report have not been submitted to any other universities or institute for the award of any degree or diploma.

Place- Prayagraj **VINAY KHALKHO**

Date- **17MTAESWC002**

CONTENTS

ABSTRACT

The study was conducted on Adwa dam, situated at Mirzapur Uttar Pradesh.The dam failures can cause immense damage and loss of life and properties when they occur. The study consider Complete hydraulic simulation and analysis for a hypothetical dam break of Adwa dam was performed using United States Army Corps of Engineers (USACE), Hydrologic Engineering Center's River Analysis System (HEC-RAS) computer model with DEM (Digital Elevation Model). The average breach width and breach development time of dam is calculated by using the geometric information of the Adwa dam through regression equation of the Froehlich (2008). The flood inundation map was generated by HEC-RAS and imported into Q-GIS to delineate the areas flooded under the assumed dam break scenario. The details of water surface elevations, depth of flood, flood arrival time and velocity of flood wave at different locations of downstream gives an idea about extent of flooding. Study showed total 52 villages are affected by the flood, the maximum discharge flows out from the breached dam is 4358.5044 m^3/s (CMS) noted at 5:00 hours after dam breached due to overtopping and 4436.9175m^3/s (CMS) at 5:30 hours after dam breached due to piping mode of failure. The maximum volume of water accumulated is 281885.53 1000m^3 and 273305.68 1000m^3 due to overtopping and piping failure respectively at end of simulation time. The results of the modelling showed that in the event of failure of Adwa dam, some areas which include residential, agricultural and industrial areas were identified to have very high risk of being inundated due to the significant difference in the value of water surface elevation and ground elevation. Emergency evacuation should be undertaken within 41 minutes of the dam breach.

Keywords:- HEC-RAS, Q-GIS, DEM, Dam Breach

ACKNOWLEDGEMENT

All praises to Lord JESUS Almighty

I would like to express my gratitude to **Dr. Alex Thomas,** Associate Professor and Head, Department of Soil and Water conservation Engineering and my research supervisor for all his guidance, comments and unconditional help and suggesting me this topic and valuable suggestions are spread in this work. Thanks are extended for providing me the valuable suggestion, timely guidance, encouragement and providing all kind of help and support throughout the research work. His deep interest and dedication towards the improvement of my research thesis will always be remembered.

I want to express my sincere thanks to all the faculty members of **SHUATS** who directly or indirectly helped me in the successful completion of my course structure.

Special thanks to Chairman **Prof. (Dr.) R. K. Pandey** Department of Civil engineering and member **Prof. (Dr.) ir D.M. Denis** Head, Dept of Irrigation and Drainage Engineering and **Dr. S.K. Siravastava** Dept of Irrigation and Drainage Engineering and **Dr. Vikram singh,** Department of Soil and Water conservation Engineering for his valuable suggestions and constant guidance.

I am very thankful to Mr. Ronit De for valuable suggestion.

I am truly thankful to God for giving me enough strength and courage and for confronting all the obstacles and evincing that I can overcome them. Finally, I would like to express my heartfelt gratitude to **my Parents and friends** for their eternal support, encouragement, motivation and blessings; this led to successful completion of this thesis.

Place:- Prayagraj VINAYKHALKHO

Date:-

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION AND SYMBOLS

mm : millimeter

hr : hour

min : minute

e.g : for example

et al : and other

fig. : figure

Ha : Hectare

HEC-RAS : Hydrologic Engineering Centre-River analysis system

DEM : Digital Elevation Model

USGS : United States Geological Survey

1-D : One dimensional

2-D : Two dimensional

WSE : Water Surface Elevation

CHAPTER-I

INTRODUCTION

Water is one of the vital natural resources available on earth. The growth process, increase in population and expansion of economic activities which would lead to increase in demand of water for diverse purposes such as domestic requirement, irrigation, industrial uses, power generation, aquaculture, navigation, recreation and other uses. It is estimated that the demand for water use for these diverse purposes may be of the order of 105 million- hectare meters by the year 2050 A.D.

India is the seventh largest country in the world, with a total area of 3.287 million Km^2 and it is a semi-arid country, hence overall National planning and resource management in respect of water if necessary. Water storage is the major limiting factor for many purposes most of the countries around the world. Nearly 3200 major / medium dams and barrages had been constructed in India by the year 2012. Tehri dam on Bhagirathi river is the biggest, highest and tallest dam in India, it is the eight highest dam in the world, located at Uttarakhand. Hirakud Dam is the longest major earthen dam in India. It is situated at sambalpur odisha, constructed across the Mahanadi river.

Dam is a barrier constructed across the river to store the water or restrict the water. Dams have been constructed for thousands of years around the world for different purposes like flood control, electricity generation, irrigation, water supply, domestic purposes, recreation and etc. Dams provide many benefits to civilisation, but floods resulting from the failure of constructed dams have also produced some of the most devastating disasters of the last two centuries.

Two major consequences of a dam failures are :-

Life loss: Because of heavy flood resulting from dam-break this loss may occurs if the villages and the residing families are washed away.

Economic loss: This loss is calculated in terms of revenue which will be required to rebuild the washed away villages in terms of infrastructure, and other allied facilities. The dam break analysis will make possible to predict the flood and areas affected by flood at downstream due to breach. This helps in estimation of cost in case of rehabilitation. The study predicts the potential of precautionary measures which can be taken to completely avoid the dam break which avoid or minimize damage.

On august 2018, severe floods affected the south Indian state of kerela, due to high rainfall. Over 483 people died and 14 are missing. The climate change that causes extreme rainfall, has increased the frequency of floods, landslides, and increasing disaster risks caused by a dam failure. Modeling the dam failure and the impact of the flood is necessary to reduce losses from the potential for dam failure. A numerical model is often used to predict the flood propagation due to a dam failure, but the model used is generally still 1-D, so the distribution of inundation can not be predicted accurately. However the 1-D model approach can be used for certain cases, mostly used in channel planning, but it has limitations on runoff analysis. At the time the water starts to overflow to surface, 2-D phenomenon occurs. Therefore, it is necessary to have the calculation of the area of inundation, water level inundation, and rapid flood flooding (flood travel time). By conducting such analysis, the disaster risk of the affected area can be known.

Dam failure results from eternal force and internal erosion. The case studies show that dam failure may arise due to different reasons ranging from seepage, piping (internal erosion), overtopping due to insufficient spillway capacity and insufficient free board and to settlement due to slope slides on the upstream shells and liquification due to earthquakes. USACE
(United States Army Crops of Engineers) Hydrologic Engineering Center (HEC) Research Document 13 lists a list of more complete causes as follows: 1) Earthquake, 2) Landslide, 3) Extreme storm , 4) Piping, 5) Equipment malfunction, 6) Structure damage, 7) Foundation, failure, 8) Sabotage. Regardless of the reason, almost all failures begin with a breach formation. Basically, breach is defined as the opening formed in the dam body that leads the dam to fail and this phenomenon causes the concentrated water behind the dam to propagate towards downstream regions. Despite the fact that the main modes of failure have been identified as piping or overtopping, the actual failure mechanics are not well understood for either earthen or concrete dams. This paper consider dam failure due to overtopping failure and piping failure.

Overtopping Failure: A general description of overtopping failure of an earthen dam, a head cut erosion process will first start on the downstream side of the dam embankment. While water is going over the dam crest, the dam crest acts like a broad crested weir. The head cut will erode back towards the center of the dam and widen over time. As the head cut begins to cut into the dam crest, the weir crest length will become shorter, and the appropriate weir coefficient will trend towards a sharp -crested weir value. When the head cut reaches the upstream side of the dam crest, a mass failure of the upstream crest may occur, and hydraulic control section will act very much like a sharp crested weir. The head cut will continue to erode upstream through the dam embankment, as well as erode down through the dam and widen at the same time.

Piping Failure: General description of piping failure occxurs when water is seeping through the dam at a significant enough rate, such that it is internally eroding material and transportation it out of the dam. As the material is eroded, a large hole is formed, thus able to carry more water and erode more material. The movement of water through the dam during this process is modelled as a pressurized orifice type of flow. During the piping flow process, erosion and headcutting will begin to slough off and fall into the moving water. The headcutting and material sloughing process will continue to move back towards the upstream side of the dam, while the piping hole continues to grow simultaneously. If the piping hole is large enough, the weight of the material above the hole may be too great to be maintained, and a mass caving of material will occur. This will result in a large rise in the outflow through the breach and will accelerate the breaching process and also at this point, the hydraulics of the flow transition from a pressure/orifice type flow to an open air weir type flow. The headcutting and erosion process then continues back through the dam, as well as downward. Additionally, the breach will be widening. Depending on the volume of water behind the dam, the breach may continue to cut down and widen until the natural channel bed is reached. Then the breach will go into a widening phase.

It is necessary to estimate the geometric description of a dam break to simulate the resulting flood wave and downstream effects. Some easily accessible computer models used to perform dam breach hydrograph computation and downstream routing are HEC-RAS, HEC-HMS, NWS-BREACH model, NWSDAMBRK, NWS-FLDWAV and a few others. These models involve estimating the prospective features of the violation outside of the model. Also available or being created are several "process" models that try to simulate the development of a dam failure using sediment transport equations to estimate erosion rates and soil mechanics relationships to predict mass slope failures. The availability of terrain data has enhanced the ability to develop hydraulic models capable of simulating a dam failure situation and assessing the resulting flood wave using geographic information systems (GIS).

Flood is an overflow of water that overflows soil, causes damage to agricultural property, villages, metropolitan regions, and leads to loss of life. Floods can also be described as surplus flows exceeding the transportation ability of river channels, lakes, ponds, reservoirs, drainage system, dam and any other water bodies, whereby water inundates regions outside water bodies. Flash flood is an integrated impact of high-intensity rainfall, unexpected failure of lakes, collapse of check dams, and very steep topography. It has an effect on human life causing serious financial loss owing to damage. It is difficult to avoid hazards or deter their occurrence, but it is credible to work on reducing their impacts.

Flood Inundation Mapping is an important tool for engineers, planners, and government agencies used for municipal and urban growth planning, emergency action plans, flood insurance rates and ecological studies. By understanding the extent of flooding and floodwater inundation, decision makers are able to make choices about how to best allocate resources to prepare for emergencies and to generally improve the quality of life (Warren, c. et al 1994). Inundation mapping is a way to represent flooding for use in determining current flooding extent or areas forecasted to flood. This is useful information for emergency managers, rescue workers, and citizens who would be impacted by possible evacuations. This is commonly performed by linking GIS and hydrologic/hydraulic models, which then can be used to display the flood extent. Current engineering practice is to use a rainfall-runoff model to simulate a design storm of a given recurrence interval and to convert the peak flow to stage using a steady state hydraulic model, assuming the design storm and the generated water level will have the same return period, which may not be true depending on other environmental or storm-specific conditions. This peak stage is used to determine water levels which are used to generate a map of flooding for the design event (Abshire, k.e.et al 2012).

Flood maps are effective tools for assisting flood hazard management. The requirement and classification of flood maps depends on the purpose of their use. Flood hazard maps can be defined as maps showing inundated area or different parameters such as flood depth and flood velocity. Several important parameters are required for performing hydraulic flood modelling such as topographic data, discharge data to provide model inflow and outflow as boundary conditions, estimation of the roughness coefficient and validation data.

In recent years, flood hazard assessment has considerably improved especially due to the use of geo-potential dam break flood magnitudes and assessing the associated downstream hazard by integrating HEC-RAS and GIS technologies. This approach, which allows visualizing and analysing the results in geospatial environment.

HEC-RAS is developed by the U.S. Army Corps of Engineers. HEC-RAS water surface profile model used for modeling both steady and unsteady, one-dimensional, gradually varied flow in both natural and man-made river channels. HEC-RAS is used for dam break analysis. HEC-RAS is also used for sediment transport/mobile bed computations and water temperature modelling. HEC-RAS is designed for interactive use in a multi-tasking environment. This system consists of a graphical user interface (GUI), separate analysis components, data storage and management capabilities, graphics and reporting facilities.

The study presented herein aims at designing and implementing a systematic approach for predicting potential dam break flood magnitudes and assessing the associated downstream hazard by integrating HEC-RAS and GIS technologies. This approach, which allows visualizing and analysing the results in geospatial environment, was used to study the potential dam break flooding of Adwa dam, earthen dam located in Mirzapur in the North of India.

Objective

- To determine depth of water at different station along the downstream channel.
- To determine peak outflow hydrograph when dam break occurs by either overtopping or piping mode of failure.
- Mapping of the flood prone area on the left and right bank of downstream channel after dam break along with disaster management procedure.

CHAPTER-II

REVIEW OF LITERATURE

The following studies evaluate the multiple impacts of dam failure using different software and various failure conditions. In the current research, HECRAS is used to perform the assessment of the Dam Break. Digital elevation model is used to obtain the topographical function for dam break assessment Probable Maximum Flood (PMF) is estimated using QGIS / ArcGIS.

Duressa J. N. and Jubir A. K. (2018), calculated breach parameters by Von Thun and Gillette Regression equation are selected as input data into the HEC-RAS model for dam break analysis. The general objective of the study is to analyze Dam break by using hydraulic models (Hydraulic Engineering Center's River Analysis system). For this study the failure location is assumed to be at the center of the dam due to presence of high hydrostatic pressure and develop equally in both sides. From the result of dam break simulation the peak discharge formed by overtopping mode of failure is more devastating than the piping mode of failure. The effect of dam breach parameters on discharge is more pronounced than that of the water level. Dam break has greater impact on the downstream location where is closer to the dam in accordance with the hydrograph at downstream locations. The created river network was exported to HEC-RAS model for further dam break analysis by addition of different geometric data including dam information, calculated breach parameters, initial condition, upstream and downstream unsteady boundary condition. After full computation the model result were exported to integrated Arc-GIS and HEC- GeoRAS model for mapping flood inundation. Developed inundation map guides the dam owners and emergency management authority to give emergency action plan for the highly affected area by flooding and used for planning future economic development activities.

Yakti B. P. *et al* (2018), simulated the flooding induced by the failure of Way Ela Natural Dam. A two-dimensional (2D) numerical model, HEC-RAS v.5, is used to simulate the overland flow. The dam failure itself is simulated using HECHMSv.4. The results of this study, the flood inundation, flood depth, and flood arrival time are verified by using available secondary data. These information are very important to propose mitigation plans with respect to possible dam break in the future.

Balogun O.S. and Ganiyu H.O. (2017), studied and analyzed a hypothetical dam break scenario using Hydrologic Engineering Center's River Analysis System computer model. Unsteady flow simulation was performed using geometric data obtained from Digital Terrain Model with 100-year, 24 hr flow event. The HEC-RAS was used in concert with HEC-GeoRAS to assess the flood hazard along the river channel. The simulated water surface elevations were exported to Arc GIS to produce an inundation map that graphically indicates the extent of the flood hazard. The results show that some important locations such as industrial, residential, motor parks, recreational and places of worship along the river length are prone to significant flood impact. This map serves as an input for emergency preparation programme in the event of the dam break.

Basheer T. A. *et al* (2017), stated that dams breach geometry prediction is crucial in dam break studies. The characteristics of flood hydrographs resulting from a dam breach essentially depend on the breach geometry and the required time for breach formation. To investigate the impact of breach parameters on maximum breaching outflows, five breach prediction approaches were implemented to calculate the flood hydrographs using HEC-RAS model. Numerous reservoir water levels for each approach were considered. Sensitivity analysis was carried out to evaluate the effect of each parameter on the resulting flood hydrographs. The time and value of peak discharge for each scenario were analysed and discussed. Results show that the most suitable method for estimating breach parameters is Froehlich approach. Furthermore, the sensitivity analysis shows that the breach side slope does not affect the peak discharge time and has a minor influence on peak outflow values. Meanwhile, the required time for the breach to develop was highly sensitive to both peak discharge and peak discharge time.

Bhandari M. *et al* (2017), study used two dimensional flow routing capabilities of Hydrologic Engineering Center's River Analysis System (HEC-RAS) for flood inundation mapping in lower region of Brazo River watershed subjected to frequent flooding. For analysis, river reach length of 20 km located at Richmond, Texas, was considered. Detailed underlying terrain information available from digital elevation model of 1/9-arc second resolution was used to generate the two-dimensional (2D) flow area and flow geometrics. The water surface elevation and velocity distribution obtained after 2D hydraulic simulation were used to determine the extent of flooding. For this, RAS mapper's capabilities of inundation mapping in HEC-RAS itself were used. Mapping of the flooded areas based on inflow hydrograph on each time step were done in RAS mapper, which provided the spatial distribution of flow. The results from this study can be used for flood management as well as for making land use and infrastructure development decisions.

Husain A. ***et al*** **(2017),** found that HEC-RAS is an integrated system of software, designed for interactive use in a multitasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The HEC-RAS system will ultimately contain three 1-dimensional hydraulic analysis components for: (1) Steady flow water surface profile computations; (2) unsteady flow simulation; (3) Movable boundary sediment transport computations. Currently steady and unsteady flows are available and sediment transport is under development. A key element is that all three components will use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the three hydraulic analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed including bridge scour computations, uniform flow computations, stable channel design, and sediment transport capacity.

Kane S. ***et al*** **(2017),** compare two junction models for subcritical flows. In channel branches, we solve numerically the Saint-Venant hyperbolic system by combining Preissmann scheme and double sweep method. We validate our results with HEC-RAS using Nash and Sutcliffe efficiency. In junction models, equality of water stage and complete energy conservation equation from HEC-RAS are compared. Outcome of the research clearly indicates that the complete conservation energy model is more suitable in flow through junction than equality of water stage model in serious situations.

Mao J. ***et al*** **(2017),** found out that application of Geographic Information System technology integrated with hydrological modeling for mapping flood-inundated areas and depth can play a momentous role in further minimizing the risk and possible damage. In the present study, base terrain data, hydrological data, and dam engineering data were integrated using the MIKE-21 dam-break model to analyze flood routing under the most serious scenarios. A deterministic approach was used to calculate the hydraulic elements of dam breakage during a flood. Additionally, the hydraulic elements generated by the MIKE-21 dam-break model (a modeling system for estuaries, coastal waters, and seas)—including flood depth, submersion time, and flow direction—were integrated with a digital elevation model of the site downstream of the dam in order to map the possible affected areas. Using an empirical model in addition to using the superimposition of dam flood calculation results and the social and economic survey data, dam damage assessment was implemented. In accordance with a relevant standard, the flood risk mapping guidelines and a set of client/server structures were developed for a management system for dam-break hazard mapping of the Foziling reservoir.

Anjana K.T.K. *et al* (2016), described how dam break analysis can be performed using HEC-RAS. This involves prediction of dam break parameters, flood hydrograph, time of arrival of flood wave, peak flow. HEC RAS offers user control over the parameters. HEC-RAS can be used to model both overtopping as well as piping failure breaches for earthen dams and concrete dams. The resulting flood wave is routed downstream using unsteady flow equations.

Lyu H. M. *et al* (2016), conducted a study to analyze the influential factors of the flooding, the topographical characteristics were mapped using Digital Elevation Model (DEM) by the Geographical Information System (GIS) and meteorological conditions were statistically summarised at both the whole city level and the district level (Guangdong Province, China). To analyze the relationship between flood risk and urbanization, GIS was also adopted to map the effect of the subway system using the Multiple Buffer operator over the flooding distribution area. Based on the analyses, one of the significant influential factors of flooding was identified as the urbanization degree, e.g., construction of a subway system, which forms along flood-prone areas. The total economic loss due to flooding in city centers with high urbanization has become very serious. Based on the analyses, the traditional standard of severity of flooding hazards (rainfall intensity grade) was modified. Rainfall intensity for severity flooding was decreased from 50 mm to 30 mm in urbanized city centers. In order to protect cities from flooding, a “Sponge City” planning approach is recommended to increase the temporary water storage capacity during heavy rainstorms. In addition, for future city management, the combined use of GIS and Building Information Modelling (BIM) is recommended to evaluate flooding hazards.

Patel C. G. and Gundaliya P. J. (2016), Presented a study that describes the application of HEC-RAS model with integration of GIS for delineation of flood plain. Digital Elevation Model (DEM) of Surat city is used as main input for flood inundation mapping. River section near Nehru Bridge is used as sample case to simulate flood flow. Discharges equal to flood return period for 25 and 32 (worst flood year) have been used for investigation of flood scenario. Outcome of the research clearly indicates that most of the area of the Surat city is submerged for a depth of 2.5 to 4.0 m when the discharge released from Ukai dam equals to return period of 32 years (25768.09 Cumecs).

Georgea A. C. and Nair B.T. (2015), presented a study which 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.

Traore V. B. *et al* (2015), shown that in many developing countries food safety became a top priority for authorities and water resources managers. It is directly related to human's life and economic development. Due to this necessity, the government of Senegal has selected the valley of Anambe of 16000 ha, to develop irrigated agriculture through rice cultivation. Two dams (Niandouba and Confluent) have been built to reinforce water availability due to climate change and variability effect on the rainfall. For a better management of this hydraulic system, the knowledge of flow dynamic is required. In this paper, author have used HEC-RAS model to describe the hydraulic behavior of this system. The river reach selected, is located between the confluence dam and Kounkane threshold. From an image LANDSTAT of this area, we have divided the river reach into 24 cross sections perpendicular to flow direction and numbered from 1 to 24. ArcGIS software is used to extract bathymetry for each cross section. This allows creating the river geometry with HEC-RAS. Four stream flows have successively fixed as upstream boundaries. For each stream flow, HEC-RAS calculate the flow characteristics. The high and low flow characteristics areas have been located. The most of these flow parameters decreases from upstream to downstream.

Ostad-Ali-Askari K. and Shayannejad M. (2015), show that employment of delayed Rockfill dams without impermeable membrane is an appropriate tool for controlling flood. For this purpose first hydraulic currents should be discerned from the Rockfill dams so that we can obtain the stage discharge relation for them. Secondly the unsteady currents in the open channels should be fully analyzed. This can be performed through solving the Saint-Venant equations. Since solving such equations, especially for a network of open channels with various cross sections is very complex and time-consuming, appropriate software should be used. This research the HEC-RAS has been employed. Results obtained for the discharge-gauge relation of Rockfill dam is used in this software. Data required for employing this software including blueprint of the network of channels, mapping results of various network sections, roughness coefficient of various network, distances between the mapped sections, and hydrograph of a definite flood, location and specifications of Rockfill dam. Output of this software includes water level profile and the inflow hydrographs at various points of the network and hydrograph of the outflow flood the Rockfill dam.

Chandrabose G. and Nair T. (2014), analyzed that dams are considered as structures containing dangerous forces. Even though dam failures are comparatively rare, they can cause immense damage and loss of life and properties when they occur. This study deals with dam break analysis of a gravity dam using HEC-RAS with the river geometry derived from SRTM Digital elevation model. The preparation of inundation map is done by HEC-GeoRAS. For the analysis, of maximum probable flood was determined using GIUH based clark's method. The area of inundation for probable maximum flood, time travel etc., were computed by conducting dam break analysis.

Xiong Y. (2011), described the dam break in the aspects of theories and models. Break parameters prediction, the understanding of dam break mechanics, peak outflow prediction were shown as the essential for the dam break analysis, and eventually determined the loss of the damages. Secondly, as an application example, Foster Joseph Sayers Dam break was further modeled and analyzed using USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) model based on available geometry data. The results show that dam break is a complicated and comprehensive process involving lots of principles. Combination of mechanics and case studies, reflection of predominant mechanisms of head-cut erosion, more specific categorization of dam, prudent investigation and inference of dam break process are needed in developing a satisfactory dam break simulation model. Foster Joseph Sayers Dam break due to piping elongates the time period of high water surface level, which increases the duration of risk. However, the dam break does not increase the downstream maximum water surface elevation (Max. W.S. Elev) significantly at previously designed Probable Maximum Flood (PMF). Dam break has a greater impact on the downstream location where is closer to the dam in accordance with the comparison of the hydrographs at different downstream locations. Sensitivity analysis demonstrates that the changes of dam break parameters had no much influence on the downstream Max. W.S. Elev.

Timbadiya P.V. *et al* (2011), found out that Channel roughness is a sensitive parameter in development of hydraulic model for flood forecasting and flood inundation mapping. The requirement of multiple channel roughness coefficient Mannnig's 'n' values along the river has been spelled out through simulation of floods, using HEC-RAS, for years 1998 and 2003, supported with the photographs of river reaches collected during the field visit of the lower Tapi River. The calibrated model, in terms of channel roughness, has been used to simulate the flood for year 2006 in the river. The performance of the calibrated HEC-RAS based model has been accessed by capturing the flood peaks of observed and simulated floods; and computation of root mean squared error (RMSE) for the intermediated gauging stations on the lower Tapi River.

Cameron A.T. *et al* (2006), have done a Dam break analysis of Hawaii dam. Dam break study consists of precipitation analysis, hydrologic modeling, dam break flood routing and inundation mapping of resultant flood. Hydrologic modeling was performed with the HEC-HMS. Dam breach analysis and flood routing flood wave was performed with HEC-RAS software. Inundation mapping was prepared using HECgeoRAS.

Hicks F. E. & Peacock T. (2005), studied that, at present, most river flood forecasts are conducted using a two-step procedure. First, flood routing is conducted, normally using hydrological models. The resulting flood peaks are then converted to water level forecasts using a steady flow hydraulic model, such as HEC-RAS. Recently, the HECRAS model has been extended to facilitate unsteady flow analyses, and while the numerical scheme is not robust enough to handle dynamic events (such as ice jam release floods) or supercritical flows, it does have the capability to route simple open water floods and produce water level forecasts at the same time. Here, the viability of the HEC-RAS unsteady flow routine for flood forecasting is examined through an application to the Peace River in Alberta and it is shown that accuracy comparable to more sophisticated hydraulic models can be achieved. Since many agencies already have HEC-RAS models established for floodplain delineation purposes, it would be a simple matter to extend them to the flood forecasting application. An ancillary advantage would be that flood forecasting accuracy could potentially be improved and simplified into a one-step process, without necessitating a time-consuming transition to unfamiliar models.

CHAPTER-III

MATERIAL & METHODS

This chapter deals with the methodology adopted to achieve the objectives given in Chapter I. It explains the procedures and process and adapted to achieve the result to be presented in the next chapters.

3.1 DESCRIPTION OF THE STUDY AREA

The study was conducted at Adwa dam which is situated Ahungi Kalan village, lalganj Tehsil, Mirzapur district, Uttar Pradesh, northen part of India. It is located at 24º45'15" North latitude and 82°18'40" East longitude. The altitude of the place above main sea level is 94.00 meter. The study area falls in Sub-tropical region having arid and semiarid weather conditions . The average rainfall 1072 mm , the average annual temperature in Mirzapur is 26.0º c. May is the warmest month of the year. The temperature in May averages 34.4º c. In January, the average temperature is 16.5º c. Adwa dam is constructed across the Adwa river which comes under Irrigation & water resources Department (Uttar Pradesh). The main purposes of constructing Adwa dam is Irrigation. The Adwa reservoir has a total capacity 57.7 million cubic meters and the dam has a length of 7906 m and the maximum height of 20.48 m above the ground. There are total 8 gates to discharge the water from the reservoir. The catchment area of Adwa reservoir extends over 1029.9776 sq. km.

The Mirzapur District lies between the parallels of 23.52 & 25.32 North latitude and 82.7 and 83.33 East longitude. The district extends between the middle Gangetic plain basin in the north and the Vindhyan ranges in the south. On the north and north-east it is bounded by the Varanasi district, on the south bounded by Sonbhadra district, on the north-west by Allahabad district (Prayagraj) . The shape to the north and west is totally regular. In no direction, except for about 13 km. in the north-east where the Ganges separates the Tehsil of Chunar from the district of Varanasi, has Mirzapur a natural frontier. The Chanvar fields, considered to be one of the most fertile lands tracts in India, are located on Gangetic flood plains of the district. Also, Indian Standard Time is calculated on the basis of 82.5° E longitude, from a clock tower in Mirzapur. According to Central Statistical organisation the district of Mirzapur had an area of 4521 km^2.

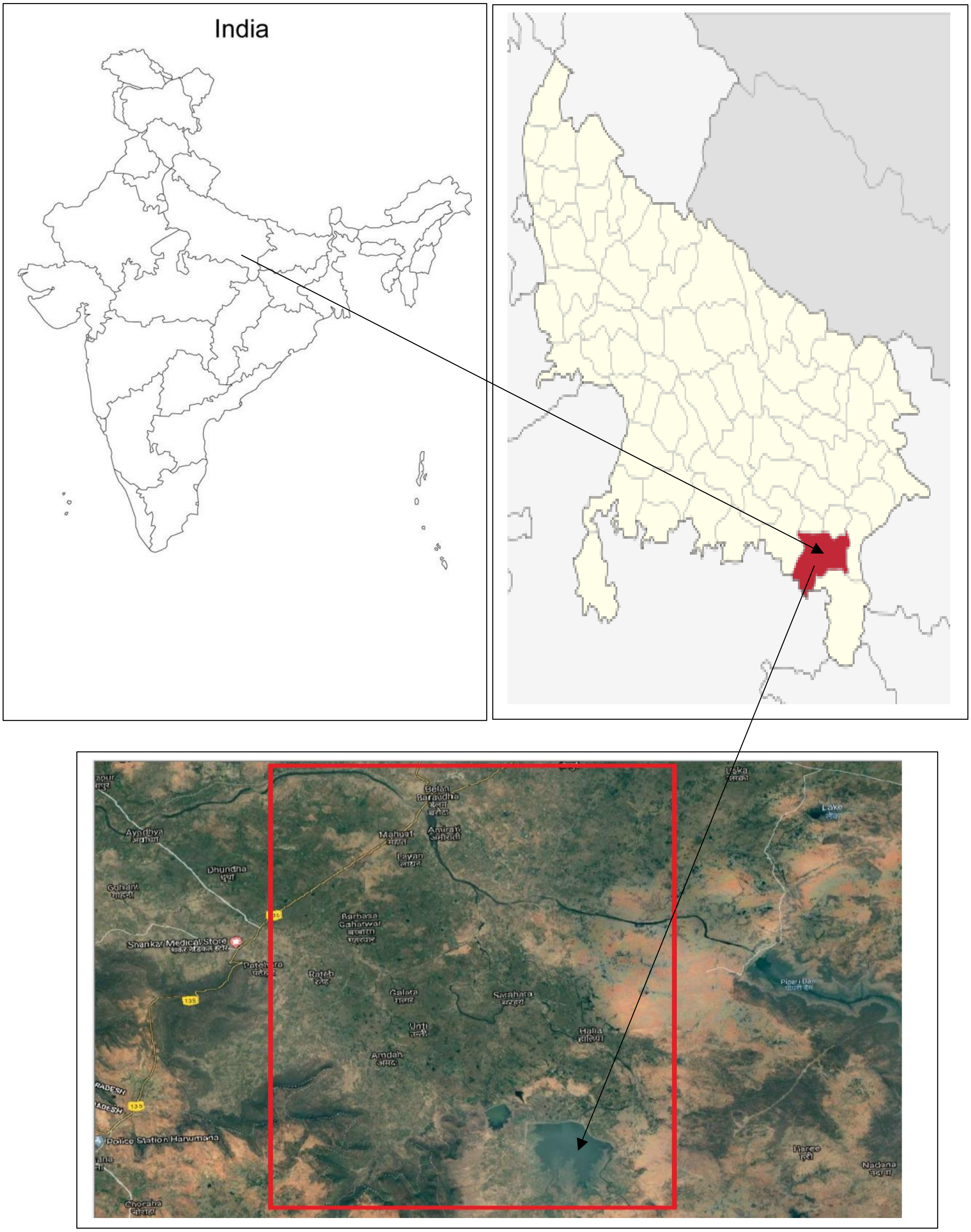


Fig 3.1 Location of study area

3.2 Demography of study area

Mirzapur district of Uttar Pradesh has total population of 2,496,970 as per the Census 2011. Out of which 1,312,302 are males while 1,184,668 are females. In 2011 there were total 394,925 families residing in Mirzapur district. The Average Sex Ratio of Mirzapur district is 903. As per Census 2011 out of total population, 13.9% people lives in Urban areas while 86.1% lives in the Rural areas. The average literacy rate in urban areas is 75.5% while that in the rural areas is 67.3%. Also, the Sex Ratio of Urban areas in Mirzapur district is 877 while that of Rural areas is 907. The population of Children of age 0-6 years in Mirzapur district is 410621 which is 16% of the total population. There are 215841 male children and 194780 female children between the age 0-6 years. Thus, as per the Census 2011 the Child Sex Ratio of Mirzapur is 902 which is less than Average Sex Ratio (903) of Mirzapur district. The total literacy rate of Mirzapur district is 68.48%. The male literacy rate is 65.98% and the female literacy rate is 47.51% in Mirzapur district (www.censusindia.co.in)

3.3 Climatic Parameter of Study Area

The district experiences the tropical climate divisible into winter season (Mid November to February), the summer season (Mid March to Mid June) and the rainy season (Mid June to Mid October) that is common in the plain of North India. About 9 months of the year are dry and 3 months are moist. During the peak summer, the air is generally very dry and hot and the atmosphere becomes dusty due to very high wind velocity, severe fog in extreme winter (January) resulting in massive traffic and travel delays.

3.3.1 Rainfall:

The Major source of rainfall of Mirzapur district is southwest monsoon (summer monsoon) which is generally lies from mid-June to mid-October. July, August and September being wettest months receiving about 279 mm, 340 mm and 193 mm rainfall respectively. The average annual rainfall of district varies between 850 mm to 1350 mm.

3.3.2 Temperature:

The maximum mean monthly temperature 41.8^{o}C has been recorded during the month of May and minimum 9.3^{o}C in January. The average annual maximum temperature being 34.4^{o}C in May and minimum temperature being 16.5^{o} in January. The average annual temperature in Mirzapur is 26.0^{o} c. May is the warmest month of the year. The temperature in May averages 34.4^{o} c. In January, the average temperature is 16.5^{o} c.

3.4 Geomorphology & Soils Types

Agro climatically, the Mirzapur district falls under two zones viz. indo-Gangetic plains covering 30-40% of total area and Vindhyan zone covering remaining area. Area under Gangetic plains is endowed with rich alluvial and fertile soil and good irrigation facilities while Vindhyan zone has meagre resource of water and land is mostly degraded. Mirzapur district is drained by two river i.e: Ganga and Belan. After its confluence with Yamuna at Allahabad, Ganga drains the Lower Kaimur sandstones, in east west direction, across the Mirzapur District towards Varanasi. Later it is joined by its north south tributary Belan River. The land in the district is mostly uneven. The landscape is dotted with hills, mountains, plateaus, waterfall and river. The soil is generally rocky and there are wide variations in the soil type of district comprising of alluvial, red, and black soils.

The terrain in Mirzapur district is hard rocky and the soil are residual, well drained entisols and alfisols, derived from recent alluvium and kaimur sandstones, sand to sandy loam texture and reddish to reddish brown in colour (Singh et al.,2002). The land use of the district is categorized into nine categories of land use pattern and recognized by State Planning Institute, Lucknow. These categories are forest, cultivable wasteland, present fallow land, other fallow land, non-cultivable land, other land excluding agriculture, pasture land, groves and gardens and net sown area. Out of the above, net sown area, forest and other land excluding agriculture, form the three major land use. The net sown area, covers about 191240 hectares (42.26% of total land use), followed by forest 109236 hectares (24.14% of the total land use) and other land excluding agriculture covers 50097 hectares (11.07% of total land use) covered more than three-forth (77.5%) of the total land use reported area for the district in 2010-11. Forest play an important role in the economy of Mirzapur district which is proved by a large portion of population engaged in forest based activities.

3.5 Land use pattern

Land use is man made dynamic process in which human uses land resource to fulfill their various economic, social and culturable needs and the same time also provides a base for development. The proper management, for sustainable development of land, can improve the eco system and its productivity in a particular region. The study is an effort to identify the current pattern of land use in Mirzapur district of Uttar Pradesh. The land holding of Mirzapur 72.65% people having less than 1 Ha, 1-2 Ha for 15.01% and >2 Ha for 12.34%.

Table No.3.1 Land use pattern of Mirzapur

YEAR	**2010**	
Land use	**Area (Hectares)**	**(%)**
Forest	109236	24.14
Cultivable Waste Land	13493	2.99
Present Fallow Land	40142	8.87
Other Fallow Land	10487	2.31
Non -Cultivable Land	8666	1.91
Other Land Excluding Agriculture	50097	11.07
Pasture land	514	0.11
Groves & Gardens	28633	6.32
Net sown Area	191240	42.26

Total Reported Area	452508	100

Source: Compiled from Sankhikiya Patrika, District Mirzapur, 2012 (www.updes.up.nic.in/spatrika)

3.6 Data Collection

Geometry data of Dam and daily rainfall data of catchment area are collected from the Irrigation Department Uttar Pradesh, Division Office Mirzapur, the DEM (Digital Elevation Model) of study area is downloaded from the Earth Explorer portal (earthexplorer.usgs.gov) of United States Geological Survey (USGS) and Projection file (UTM zone based prj.file) of study area have downloaded from spatial references (spatialreference.org).

3.7 Software Used

3.7.1 HEC-RAS 5.0.3

HEC-RAS software is developed by Hydrologic Engineering Centre (HEC), it is the division of Corps of Water Resources (IWR), US Army Corps of Engineering. The software was mainly designed by Mr. Gary W Brunner. He is the leader of HEC-RAS development team. The main features are: HEC-RAS system contain one dimensional river analysis components for steady flow water surface profile computations, unsteady flow simulation (one-dimensional and two-dimensional hydrodynamics), movable boundry sediment transport computations and water quality some additional features are dam breach analysis, bridge and culvert design and analysis, levee studies and channel modification studies.

The study focused on HEC-RAS, river analysis hydraulic model requires an accurate representation of the terrain data and the hydraulic inputs used as boundary conditions. The model parameters for terrain roughness and hydraulic structures should be estimated and and then calibrated in order to the model results. The research paper focused on the development and use of unsteady flow models for the study of Dam Break.

For unsteady flow, HEC-RAS solves the full, dynamic, 1-D Saint Venant Equation using an implicit, finite difference method.

St. Venant's Equations

Continuity equation

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \qquad \text{...3.1}$$

Momentum equation

$$\frac{1}{A}\frac{\partial Q}{\partial t} + \frac{1}{A}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + g\frac{\partial y}{\partial x} - g\left(S_0 - S_f\right) = 0 \qquad \text{...3.22}$$

Where

x = space coordinate along the channel axis.

t = time

A = cross-sectional area of the flow at location x

Q = discharge

g = acceleration due to gravity

S_o = bed slope

S_f =friction slope

3.7.2 ArcGIS: ArcGIS is a geographic information system (**GIS**) for working with maps and geographic information. ArcGIS is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database.

3.7.3 QGIS 2.18: QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data. QGIS functions as geographic information system (GIS) software and allowing the users to analyze and edit spatial information, in addition to composing and exporting graphical maps. QGIS supports both raster and vector layers, vector data is stored as either point line, or polygon features. Multiple formats of raster images are supported by the software.

3.8 Methodology

The methodology involves field and desk works. The field work involves carrying out reconnaissance survey to have first-hand information about the site condition, identification of physical features of the study area (dam, river and downstream area) and the type of failure to which the dam is prone to as a result of the repeated high intensity rainfall. Collection of geometry data of dam and terrain information for the main channel and overbank flood plain areas such as dam body volume, catchment area, reservoir volume and height of dam from foundation, height of the dam from river bed, daily discharges, and spillway capacity. Desk works involves the simulation of dam break event using HEC-RAS and preparation of flood inundation maps using Q-GIS software. The following paragraphs describe the methodologies used in performing the two-dimensional flow calculations within HEC-RAS.

3.9 Working with HEC-RAS

3.9.1 Procurement of Digital Elevation Model (DEM) file:

Digital Elevation Model (DEM) is a representation of a terrain's surface. It is a raster layer which contains elevation values of the terrain of our area of interest. DEM file is necessary to conduct 2D dam break analysis using HEC-RAS DEM file (Entity_ID-ASTGDEMV2_0N24E082) has been downloaded from the Earth Explorer portal (earthexplorer.usgs.gov) of United States Geological Survey (USGS), NASA/METI. Then, the DEM file is clipped for our area of interest using spatial analyst tool of Arc Toolbox in ArcGIS.

3.9.2 Dam Break Analysis using HEC-RAS: RAS Mapper is a GIS extension within HEC-RAS. A projection file is set(prj.) and insert DEM file (tif, file) in RAS-MAPPER. Satellite imagery (Google Hybrid) layer should be loaded for reference in RAS-MAPPER.

Fig3.2 Visualization of Google hybrid in HEC-RAS

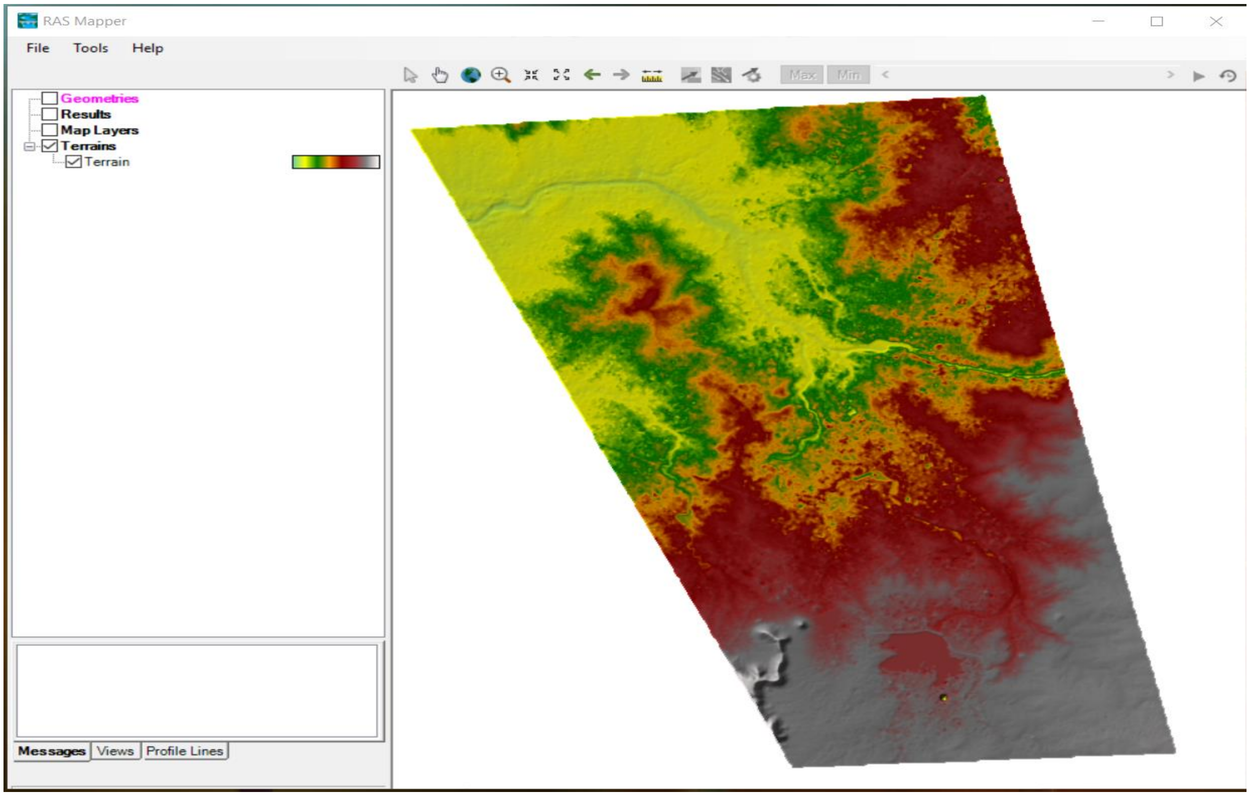


Fig3.3 visualization of DEM in HEC-RAS

3.9.3 Putting geometric data: Geometric data such as location of reservoir, downstream and dam are specified. Insert Elevation v/s volume curve of reservoir as a input data in Geometric data. The downstream area is divided into 45809 cells with a cell size of 150m x 150m.

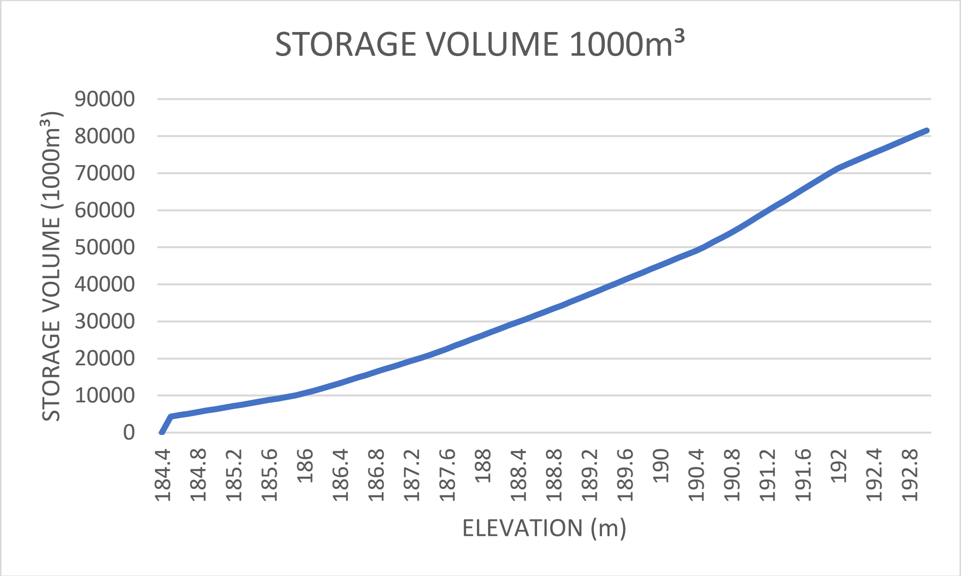


Fig3.4 Volume V/S Elevation Relationship of Reservoir

3.9.4 Gate Parameters: Gate specification of the dam such as height, width, invert, type of gate, number of gates, location of gate and user defined curves or discharge coefficient are specified.

3.9.5 Estimation of Dam Breach Parameters: The estimation of the breach location, size, and development time are critical in order to make accurate estimate of the outflow hydrographs and downstream inundation. Once the breaching parameters are estimated, the HEC-RAS can be used to compute the outflow hydrograph from the dam breach and perform downstream routing. The user must be required to enter the information like: failure location, failure mode, breach development time, breach shape, weir and piping coefficient and trigger mechanism into HEC-RAS model to define a dam breach. To numerically reproduce the progression, two main parameters have to be determined: breach geometry (width) and breach formation time. Due to high number of parameters involved, the formation of a breach is a complex process, hardly describe with mathematical tools (Froehlich 2008). There are several equation given by scientists to estimate breach parameters like MacDonald et al, Froehlich, Von Thun & Gillete, Xu & Zhang but this paper considers Froehlich(2008). The reason being that values generated by Froehlich are suitable earthen dam , Training Document 39.HEC-RAS

Froehlich(2008):

Froehlich’s regression equations for average breach width and failure times are

$$B_{ave} = 0.27K_0\, V_w^{0.32} h_b^{0.004} \qquad \text{...3.3}$$

$$tf = 63.2\sqrt{\frac{V_w}{gh_b^2}} \qquad \text{...3.4}$$

Where:

B_{ave}= average breach width (meters)

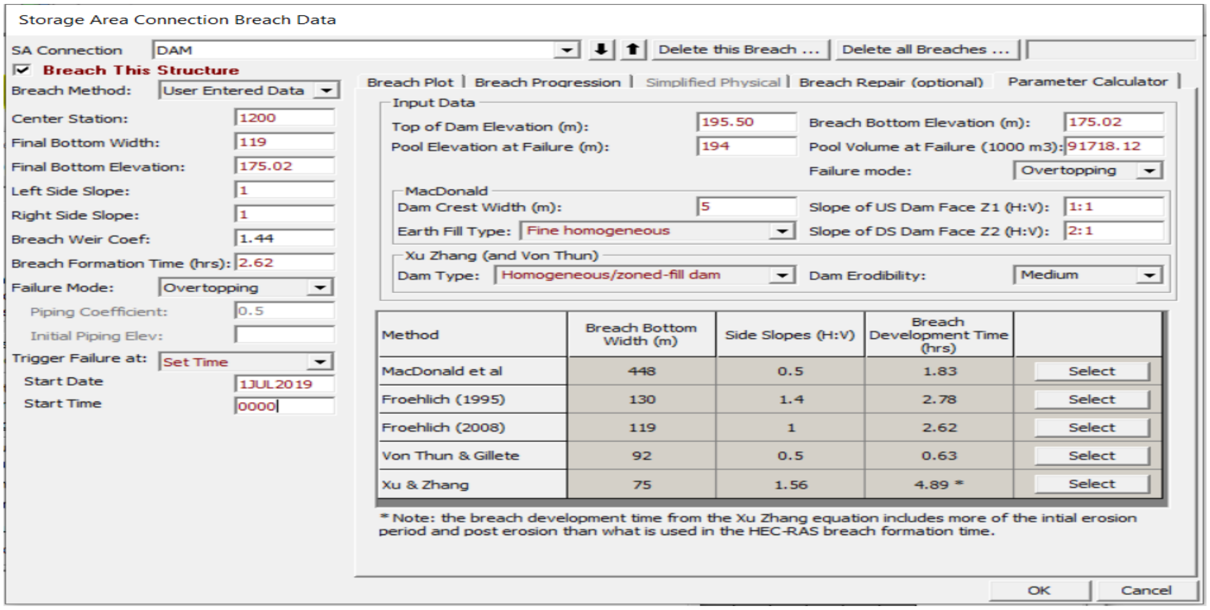
K_0= constant (1.3 for overtopping failures, 1.0 for piping)

V_w = reservoir volume at time of failure (cubic meters)

h_b= height of the final breach (meters)

g =gravitational acceleration (9.80665)

tf =breach formation time (seconds)


Storage Area Connection Breach Data

SA Connection: DAM

☑ **Breach This Structure**

Breach Method: User Entered Data
Center Station: 1200
Final Bottom Width: 119
Final Bottom Elevation: 175.02
Left Side Slope: 1
Right Side Slope: 1
Breach Weir Coef: 1.44
Breach Formation Time (hrs): 2.62
Failure Mode: Overtopping
Piping Coefficient: 0.5
Initial Piping Elev:
Trigger Failure at: Set Time
Start Date 1JUL2019
Start Time 0000

Input Data
Top of Dam Elevation (m): 195.50
Pool Elevation at Failure (m): 194
Breach Bottom Elevation (m): 175.02
Pool Volume at Failure (1000 m3): 91718.12
Failure mode: Overtopping

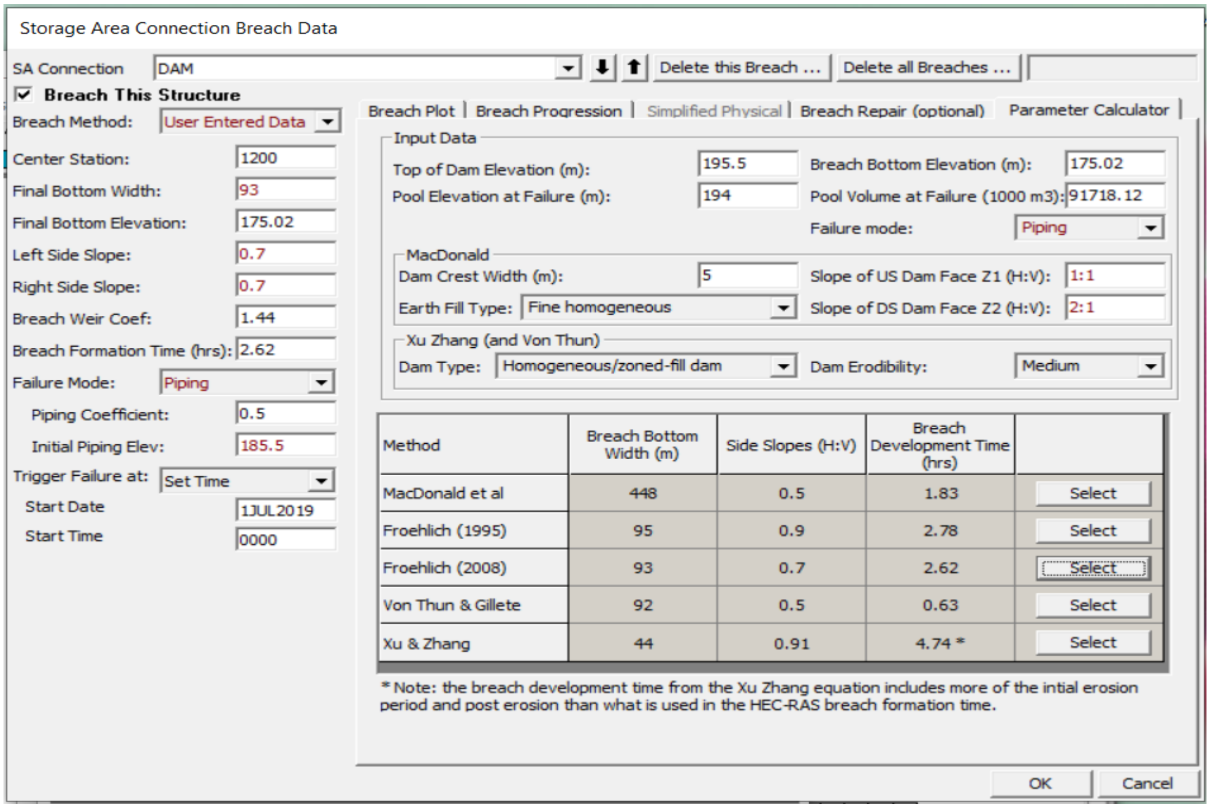
MacDonald
Dam Crest Width (m): 5
Earth Fill Type: Fine homogeneous
Slope of US Dam Face Z1 (H:V): 1:1
Slope of DS Dam Face Z2 (H:V): 2:1

Xu Zhang (and Von Thun)
Dam Type: Homogeneous/zoned-fill dam
Dam Erodibility: Medium

Method	Breach Bottom Width (m)	Side Slopes (H:V)	Breach Development Time (hrs)	
MacDonald et al	448	0.5	1.83	Select
Froehlich (1995)	130	1.4	2.78	Select
Froehlich (2008)	119	1	2.62	Select
Von Thun & Gillete	92	0.5	0.63	Select
Xu & Zhang	75	1.56	4.89 *	Select

* Note: the breach development time from the Xu Zhang equation includes more of the intial erosion period and post erosion than what is used in the HEC-RAS breach formation time.

Fig.3.5 Calculation of Dam Breach Parameter Due to Overtopping Failure


Storage Area Connection Breach Data

SA Connection: DAM

☑ **Breach This Structure**

Breach Method: User Entered Data
Center Station: 1200
Final Bottom Width: 93
Final Bottom Elevation: 175.02
Left Side Slope: 0.7
Right Side Slope: 0.7
Breach Weir Coef: 1.44
Breach Formation Time (hrs): 2.62
Failure Mode: Piping
Piping Coefficient: 0.5
Initial Piping Elev: 185.5
Trigger Failure at: Set Time
Start Date 1JUL2019
Start Time 0000

Input Data
Top of Dam Elevation (m): 195.5
Pool Elevation at Failure (m): 194
Breach Bottom Elevation (m): 175.02
Pool Volume at Failure (1000 m3): 91718.12
Failure mode: Piping

MacDonald
Dam Crest Width (m): 5
Earth Fill Type: Fine homogeneous
Slope of US Dam Face Z1 (H:V): 1:1
Slope of DS Dam Face Z2 (H:V): 2:1

Xu Zhang (and Von Thun)
Dam Type: Homogeneous/zoned-fill dam
Dam Erodibility: Medium

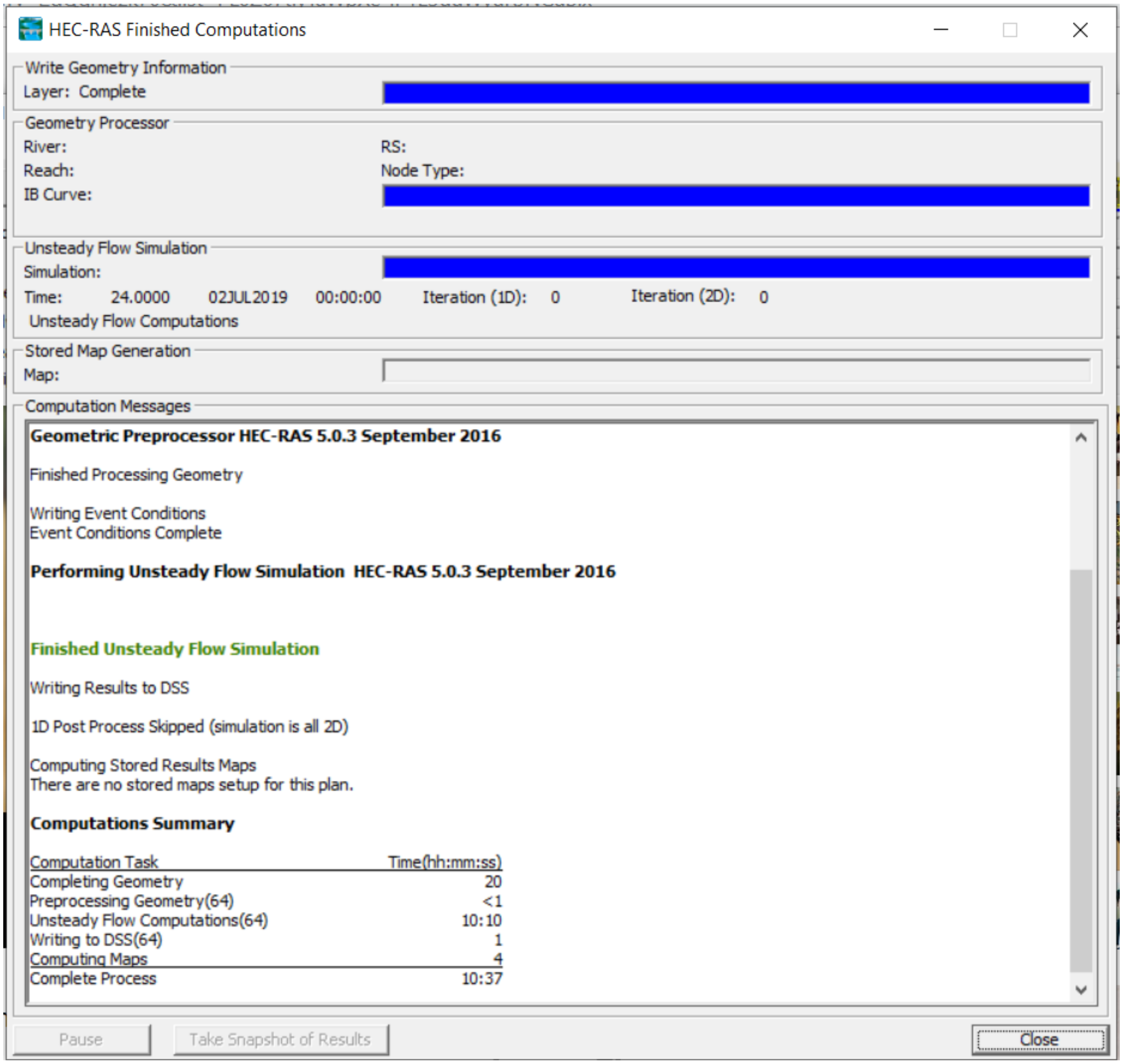
Method	Breach Bottom Width (m)	Side Slopes (H:V)	Breach Development Time (hrs)	
MacDonald et al	448	0.5	1.83	Select
Froehlich (1995)	95	0.9	2.78	Select
Froehlich (2008)	93	0.7	2.62	Select
Von Thun & Gillete	92	0.5	0.63	Select
Xu & Zhang	44	0.91	4.74 *	Select

* Note: the breach development time from the Xu Zhang equation includes more of the intial erosion period and post erosion than what is used in the HEC-RAS breach formation time.

Fig.3.6 Calculation of Dam Breach Parameter Due to Piping Failure

3.9.6 Unsteady flow data. Lateral inflow hydrograph data of reservoir and hourly precipitation data was collected from Irrigation Department Uttar Pradesh, Division Office Mirzapur. It was put as unsteady flow data in HEC-RAS. Initial level of water parameters related to control of gates were also specified.

3.9.7 Unsteady Flow Simulation. Dam breach analysis is simulated as an unsteady flow simulation with a computational interval of 5 seconds and mapping interval of 5 minutes for 24 hours.



Write Geometry Information
Layer: Complete

Geometry Processor
River:
RS:
Reach:
Node Type:
IB Curve:

Unsteady Flow Simulation
Simulation:
Time: 24.0000 02JUL2019 00:00:00 Iteration (1D): 0 Iteration (2D): 0
Unsteady Flow Computations

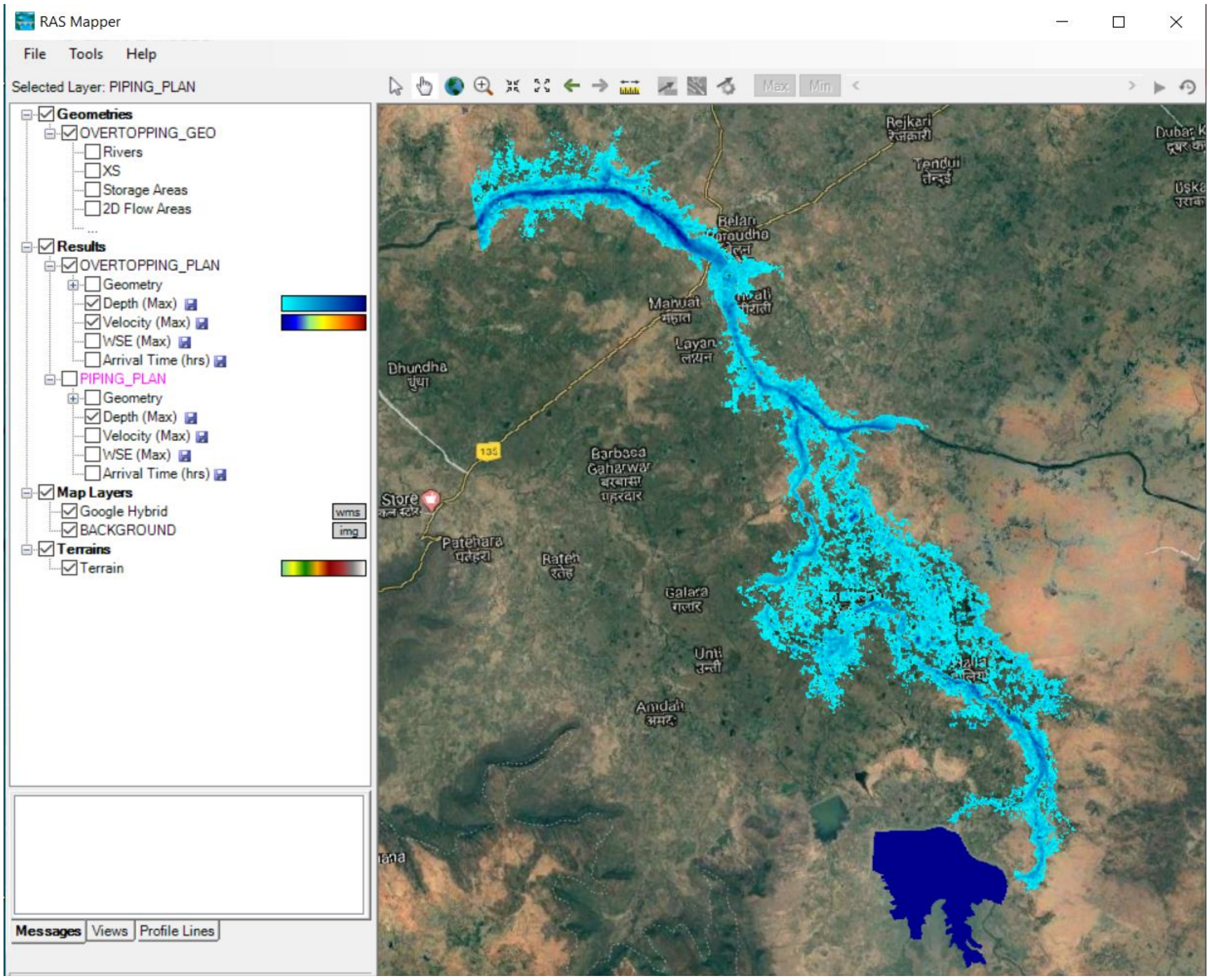
Stored Map Generation
Map:

Computation Messages

```
Geometric Preprocessor HEC-RAS 5.0.3 September 2016

Finished Processing Geometry

Writing Event Conditions
Event Conditions Complete

Performing Unsteady Flow Simulation  HEC-RAS 5.0.3 September 2016


Finished Unsteady Flow Simulation

Writing Results to DSS

1D Post Process Skipped (simulation is all 2D)

Computing Stored Results Maps
There are no stored maps setup for this plan.

Computations Summary

Computation Task                          Time(hh:mm:ss)
Completing Geometry                                   20
Preprocessing Geometry(64)                            <1
Unsteady Flow Computations(64)                     10:10
Writing to DSS(64)                                     1
Computing Maps                                         4
Complete Process                                   10:37
```

Fig. 3.7 Simulation of Dam Break in HEC-RAS

3.9.8 Result visualization in RAS Mapper. Flood progression in the downstream area can be visualized as an animation in RAS Mapper. Maximum water depth, Water surface elevation, Velocity of water Arrival time can be exported as a raster layer for further processing in GIS software.



☑ Geometries
  ☑ OVERTOPPING_GEO
    ☐ Rivers
    ☐ XS
    ☐ Storage Areas
    ☐ 2D Flow Areas
☑ Results
  ☑ OVERTOPPING_PLAN
    ☐ Geometry
    ☑ Depth (Max)
    ☑ Velocity (Max)
    ☐ WSE (Max)
    ☐ Arrival Time (hrs)
  ☐ PIPING_PLAN
    ☐ Geometry
    ☑ Depth (Max)
    ☐ Velocity (Max)
    ☐ WSE (Max)
    ☐ Arrival Time (hrs)
☑ Map Layers
  ☑ Google Hybrid
  ☑ BACKGROUND
☑ Terrains
  ☑ Terrain

Fig. 3.8 Simulation of Dam Break in HEC-RAS

3.10 Flood Inundation mapping using QGIS: Raster layers of water depth imported from RAS Mapper are again exported into QGIS. Village boundary, roads and railways maps of study area are downloaded from Open Street Map and loaded as shapefile. Web imagery (Google Hybrid) is also added as background reference. Then, depth-based flood hazard maps are created for different conditions for our area of interest.

CHAPTER – IV

RESULTS AND DISCUSSIONS

Dam break analysis was performed using HEC-RAS for two major types of dam breach cases, i.e. overtopping and piping. Overtopping dam failure is the most common type of dam failure in the earthen dam. A head-cut is formed on the top of the earthen dam due to a large amount of water inflow in the reservoir. Water erodes a part of dam gradually and it creates a devastating situation. Piping dam failure occurs due to seepage of water inside the dam. The dam erodes from the inside and gradually, pipe-like structures are formed inside it which leads to failure.

4.1 Breach Width and Time Development

The average breach width and breach development time of dam is calculated by using the geometric information of the Adwa dam through regression equation of the Froehlich (2008). The breach bottom width and breach development time calculated by Froehlich (2008) are 119 m and 2.62 hr for overtopping and 93m and 2.62 hr for piping mode of failure respectively. The bottom breach elevation of the dam which is used as input for HEC-RAS model is 175.02 m for both mode of failure.

Table no. 4.1 Breach parameter for Overtopping and Piping.

Parameter	Overtopping	Piping
Centre station (M)	1200	1200
Breach bottom elevation (M)	175.02	175.02
Dam crest width (M)	5	5
Slope of upstream (H:V)	1:1	1:1
Slope of downstream (H:V)	2:1	2:1
Top dam elevation (M)	195.5	195.5
Pool elevation at failure (M)	194	178194
Pool volume at failure (1000M^3)	91718.12	91718.12
Breach bottom width (M)	119	93

Breach formation time (Hr.)	2.62	2.62
Side slope (left and right both)	1	0.7

4.2 Flood Hydrograph of breached dam

The maximum discharge flows out from the breached dam is 4358.5044 m^3/s (CMS) noted at 5:00 hours after dam breached due to overtopping and 4436.9175m^3/s (CMS) at 5:30 hours after dam breached due to piping mode of failure. The peak discharge rate of piping mode of failure is greater than that the overtopping mode of failure shown in figure 4.1. Further, the peak of overtopping failure occurs after peak of piping failure. Finally, we can say that the overtopping failure is more dangerous than piping failure.

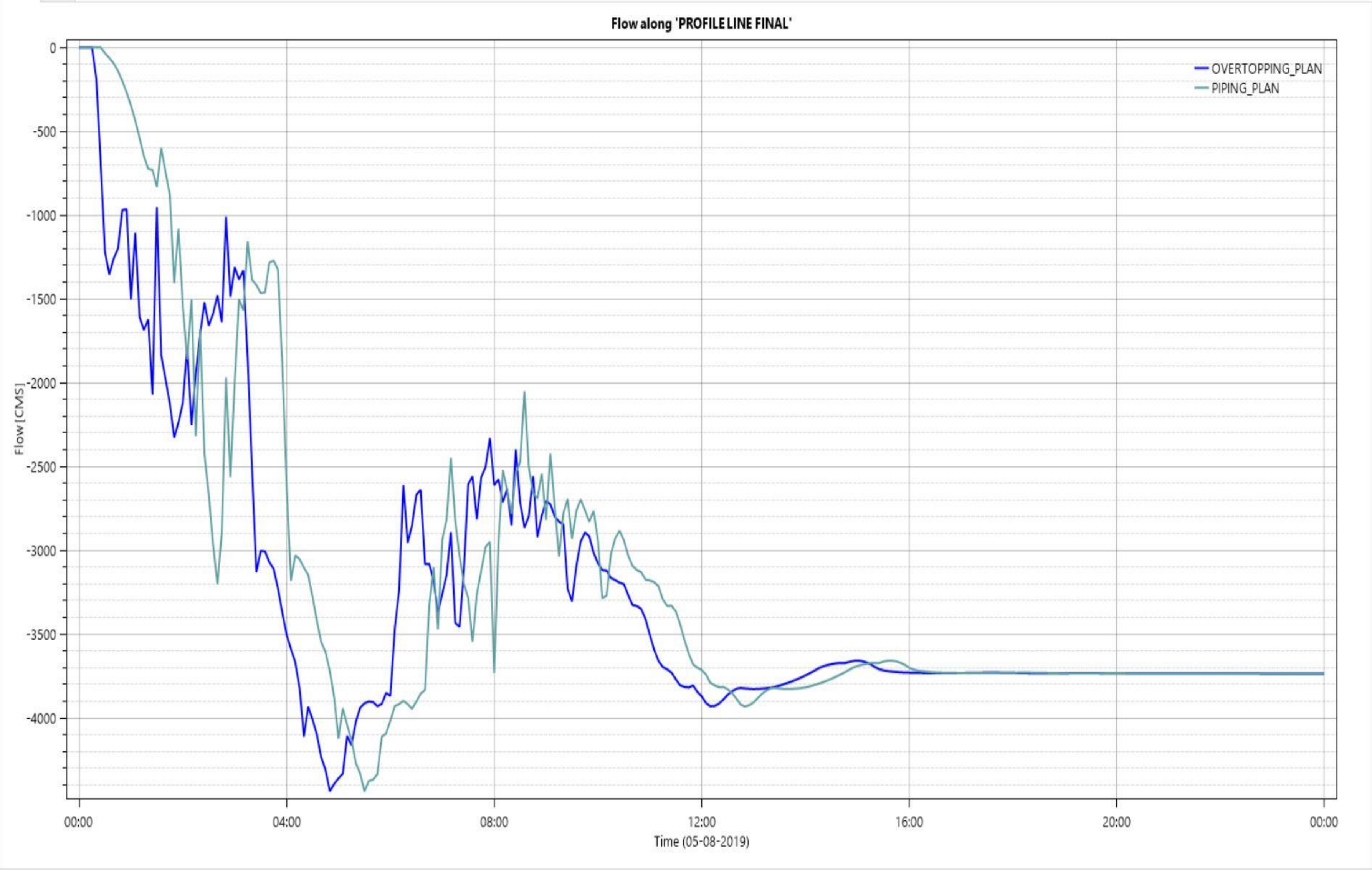


Fig.4.1 Outflow hydrograph of breached dam by overtopping failure and piping failure

4.3 Volume of water accumulation at downstream river

The maximum volume of water accumulated is 281885.53 1000m^3 and 273305.68 1000m^3 due to overtopping and piping failure respectively at end of simulation time. The flood volume accumulation along a profile line (downstream river) with respect to time is simulated by RAS mapper, a tool included in HEC-RAS.

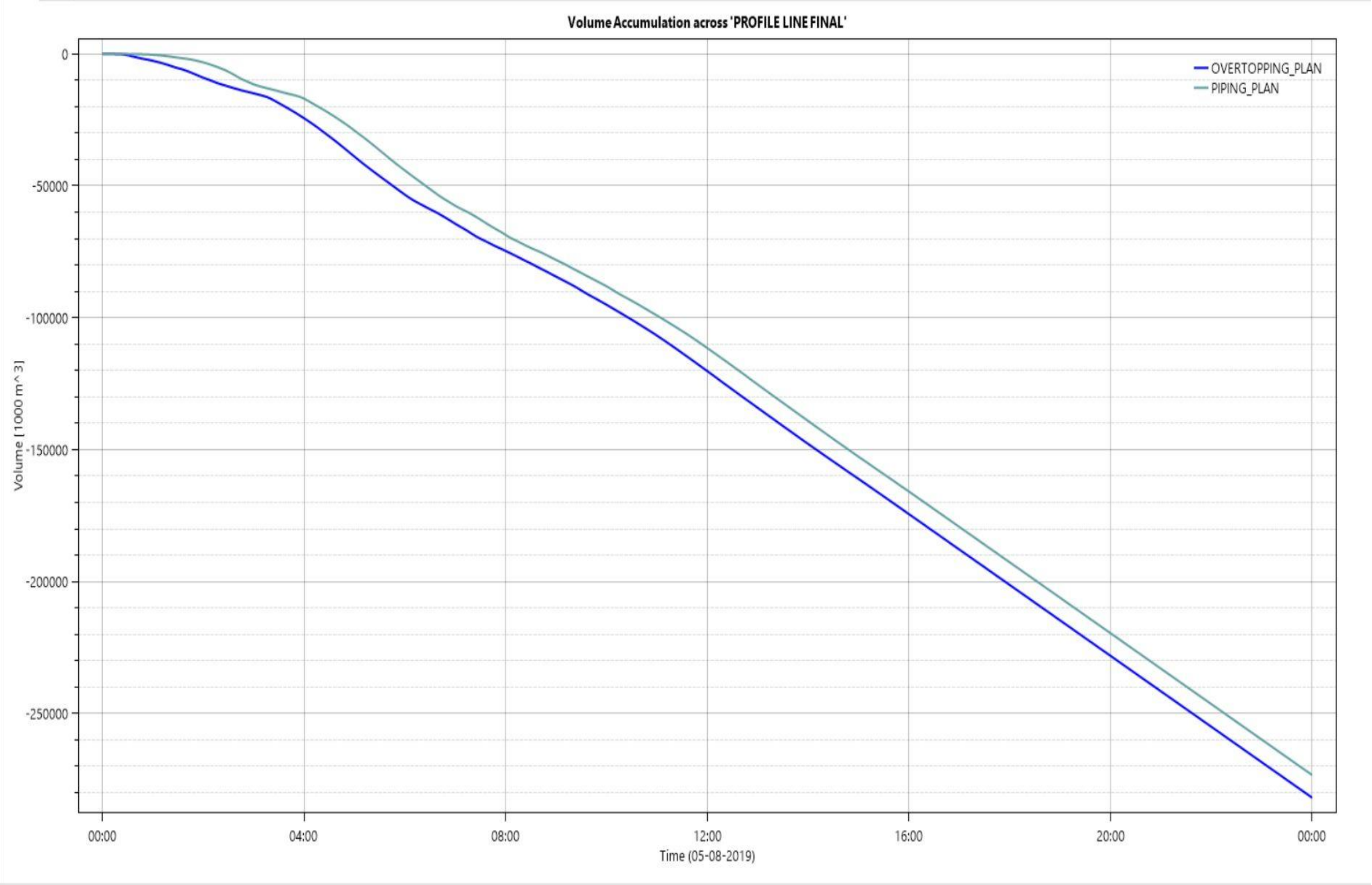


Fig 4.2 Volume of water accumulation after dam breached with respect to time.

4.4 Flood depth

Maximum depth of water accumulated in different stations along the profile line find by RAS Mapper and plotted it in graphical form. The depth of water accumulated over the downstream area is the difference between terrain elevation and water surface elevation (WSE).

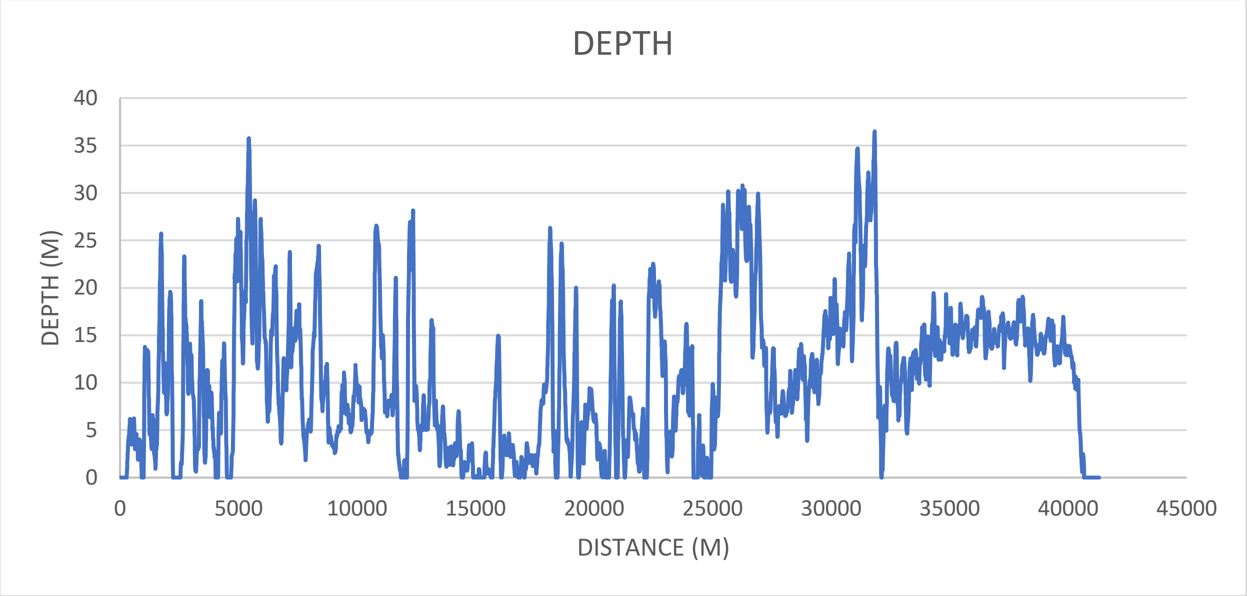


Fig 4.3 Depth of water accumulated over the downstream area due dam failure by overtopping.

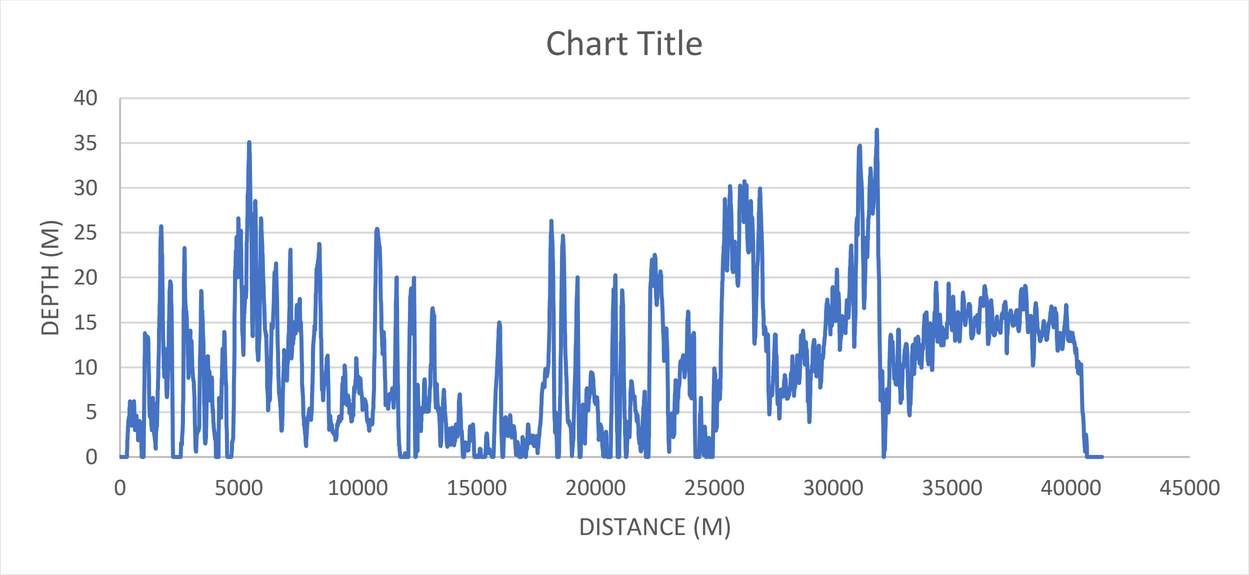


Fig 4.4 Depth of water accumulated over the downstream area due dam failure by piping.

\

4.5 Water Surface Elevation (WSE) at Downstream side

The water surface elevation (WSE) find by RAS Mapper for different station along the profile line and plotted it in graphical form. The Water Surface Elevation at the downstream side is the sum of actual elevation of different station and water depth.

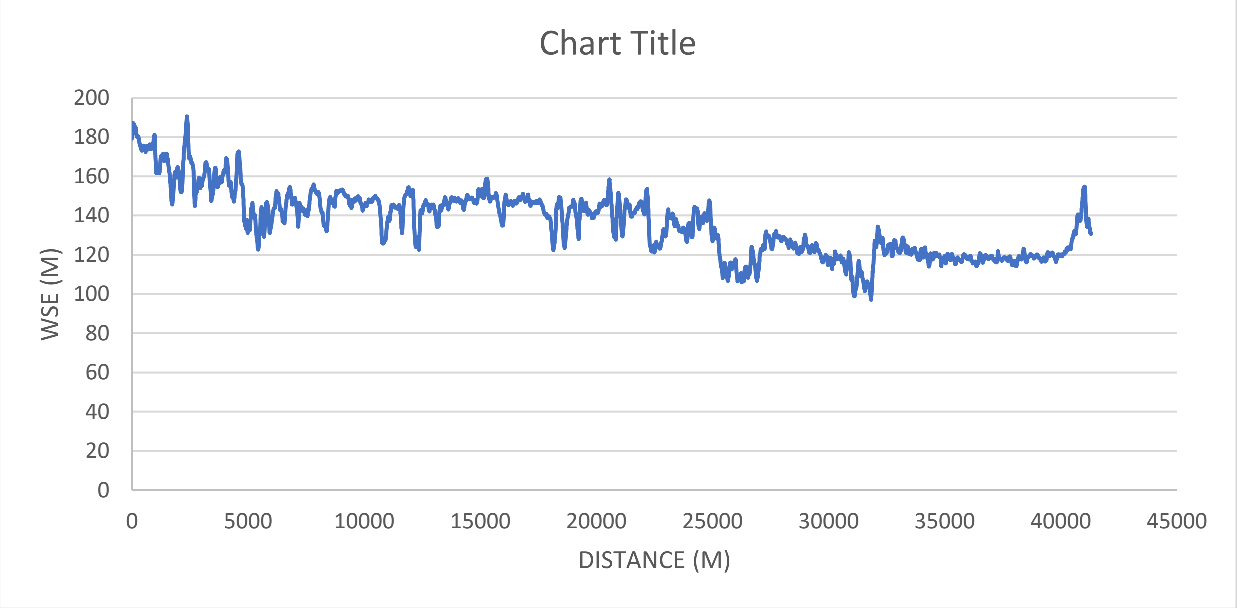


Fig4.5 WSE with respect to distance over the downstream area due dam failure by overtopping.

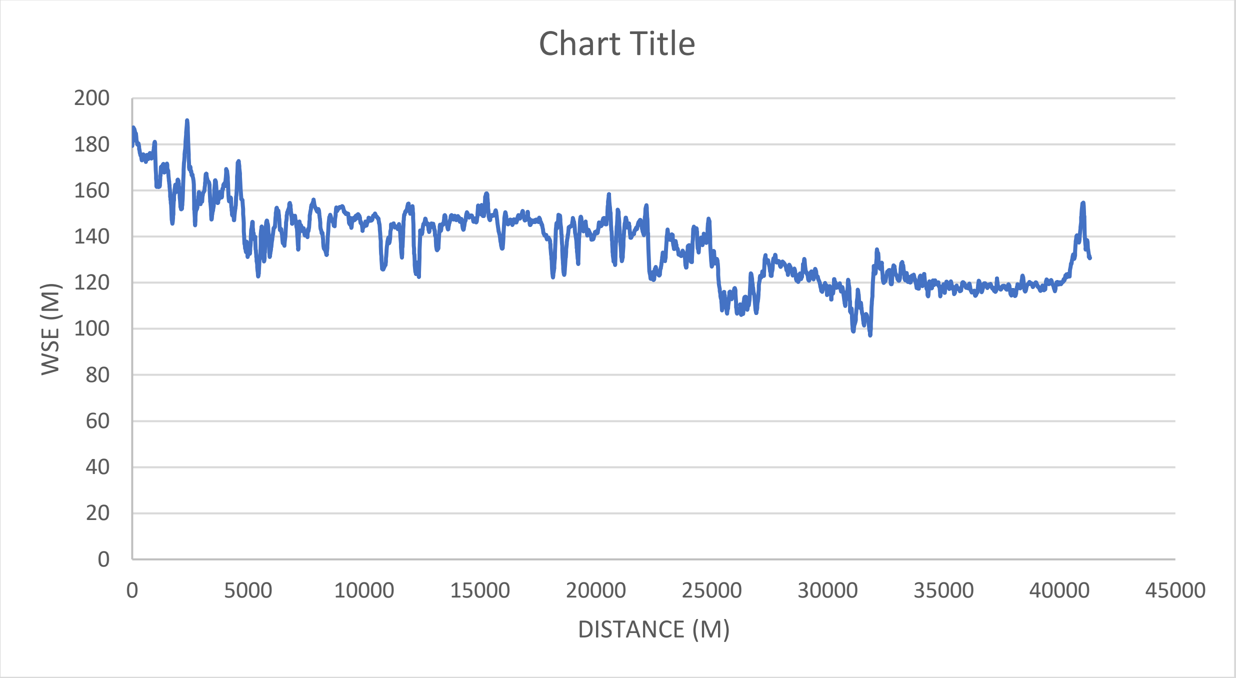


Fig4.6 WSE with respect to distance over the downstream area due dam failure by piping.

4.6 Developing the Flood Inundation Map

Dam break flood inundation map is a graphic display that can be used to indicate areas that may be flooded as a result of dam failure. For this study, flood inundation map was generated using HEC-RAS and QGIS. Water depth at different points of downstream area after arrival of flood is exported as a raster layer from the RAS Mapper and shape file of settlement of study area is added in QGIS, then it is used to prepare flood hazard map. These maps can be used to identify areas, important roads and railways as a potential hazardous area due to dam failure. These maps are also extensively used by dam authorities to prepare Emergency Action Plan (EAP) for disaster management.

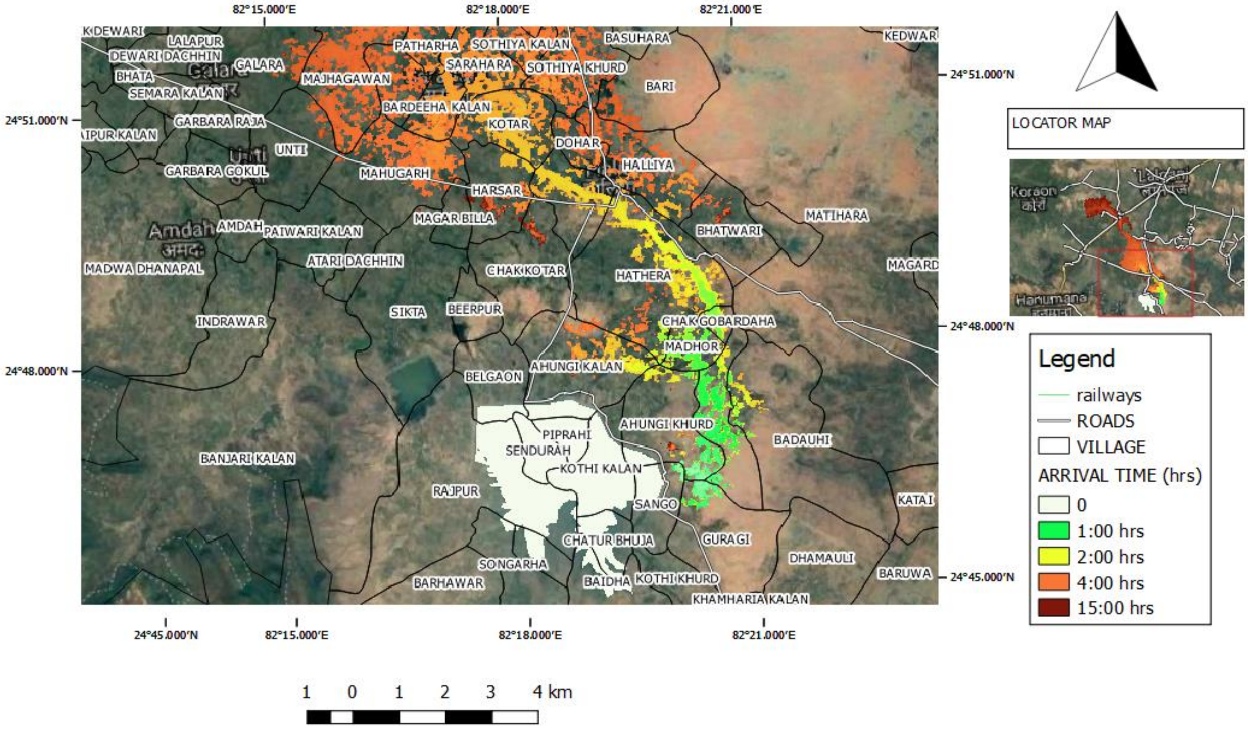


Fig. 4.7 Arrival time (hr) flood inundation map of Adwa dam (Overtopping failure)

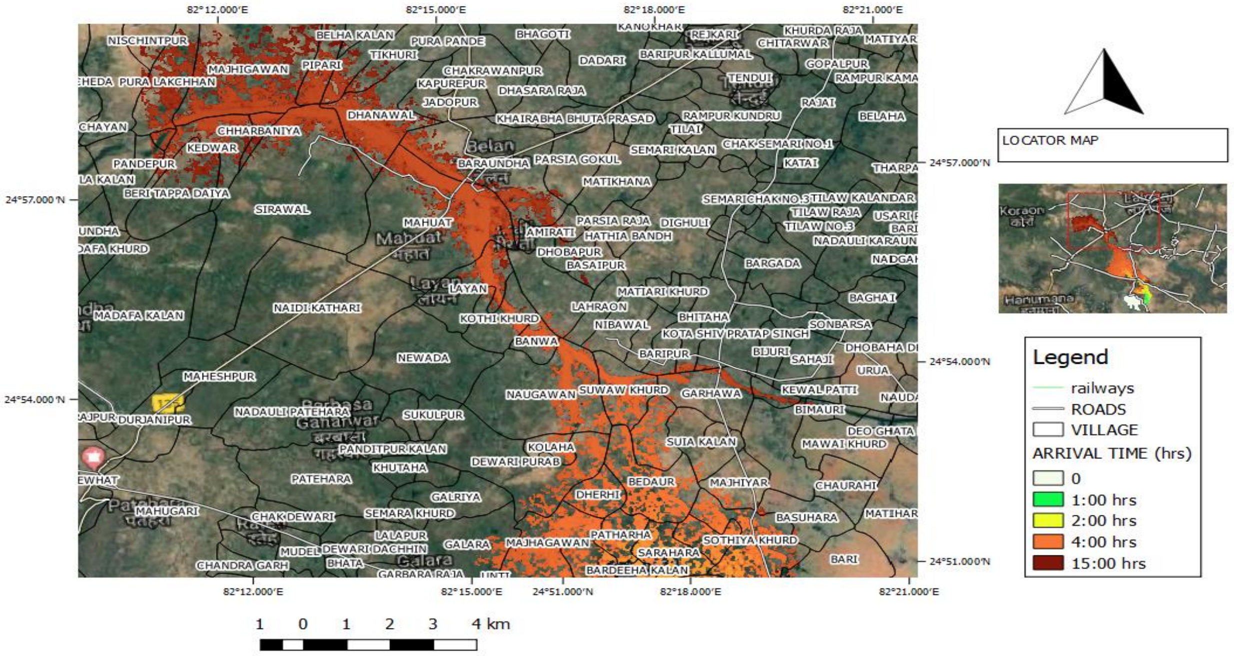


Fig. 4.8 Arrival time (hr) flood inundation map of Adwa dam (Overtopping failure)

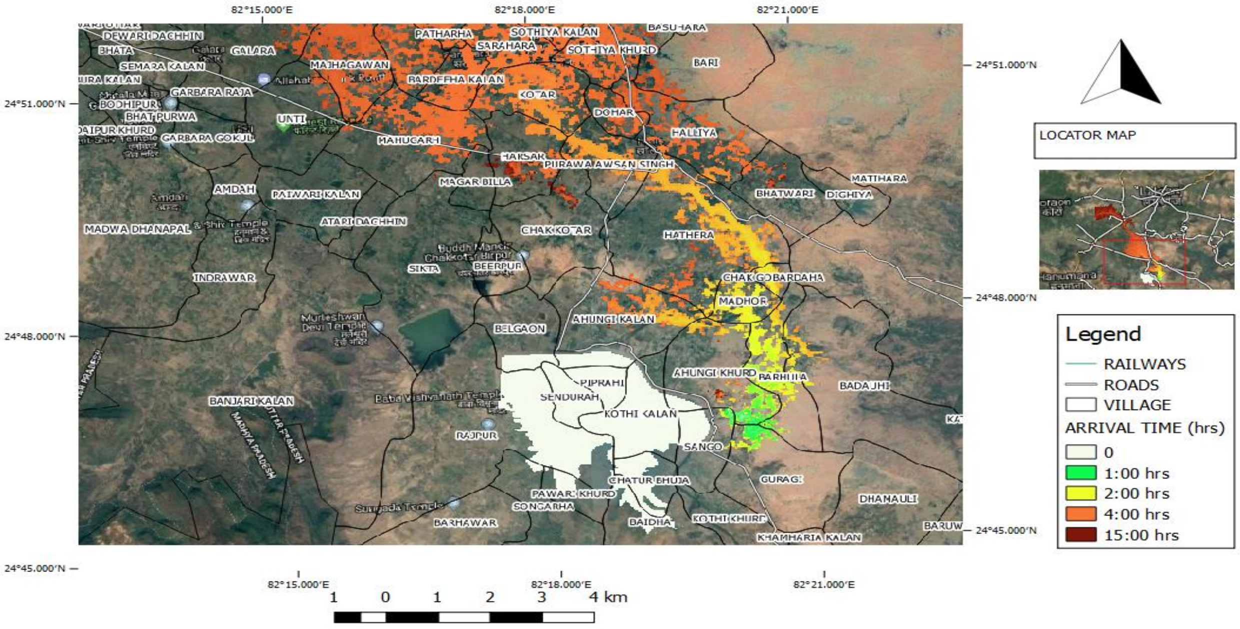


Fig4.9 Arrival Time (hr) flood inundation map of Adwa dam (Piping failure)

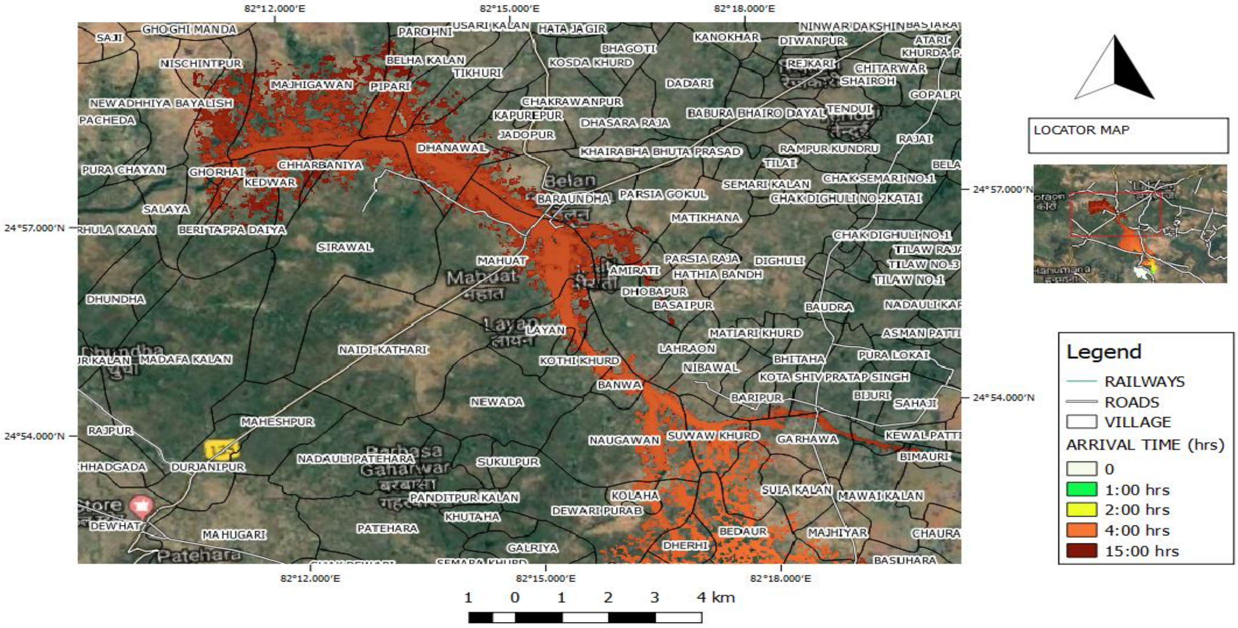


Fig4.10 Arrival Time (hr) flood inundation map of Adwa dam (Piping failure)

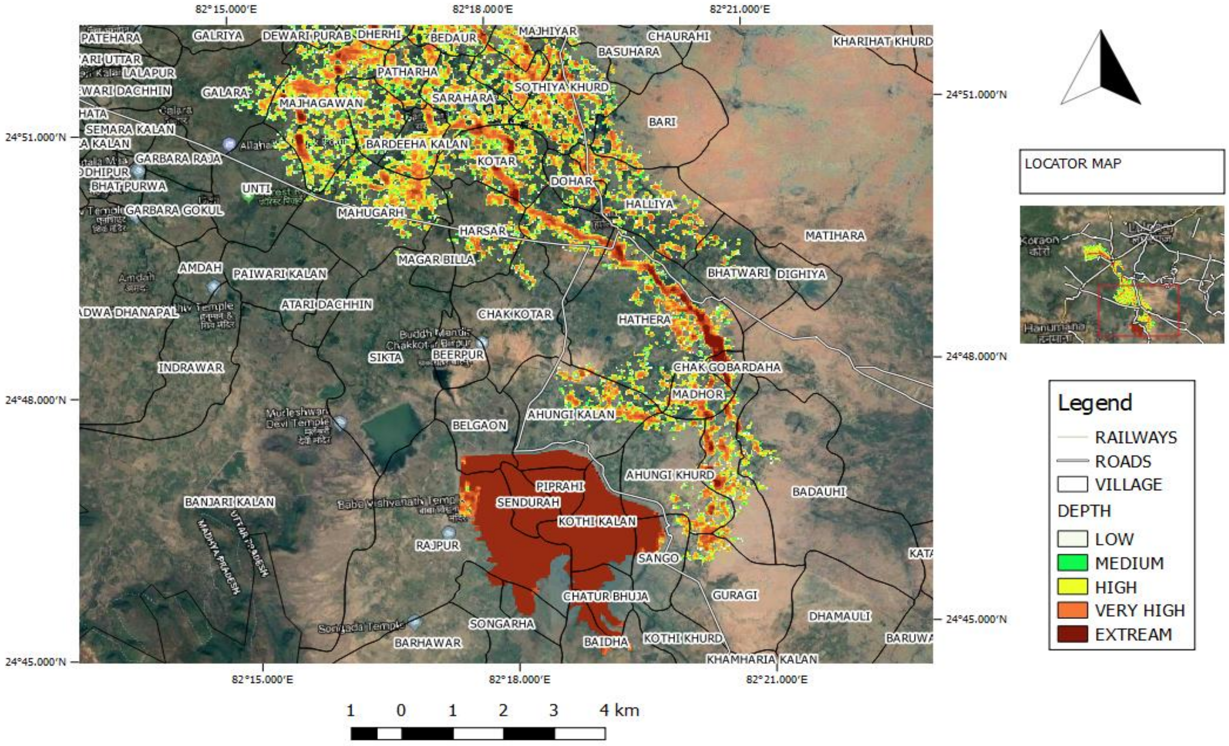


Fig 4.11Depth based flood inundation map of Adwa dam (Overtopping failure)

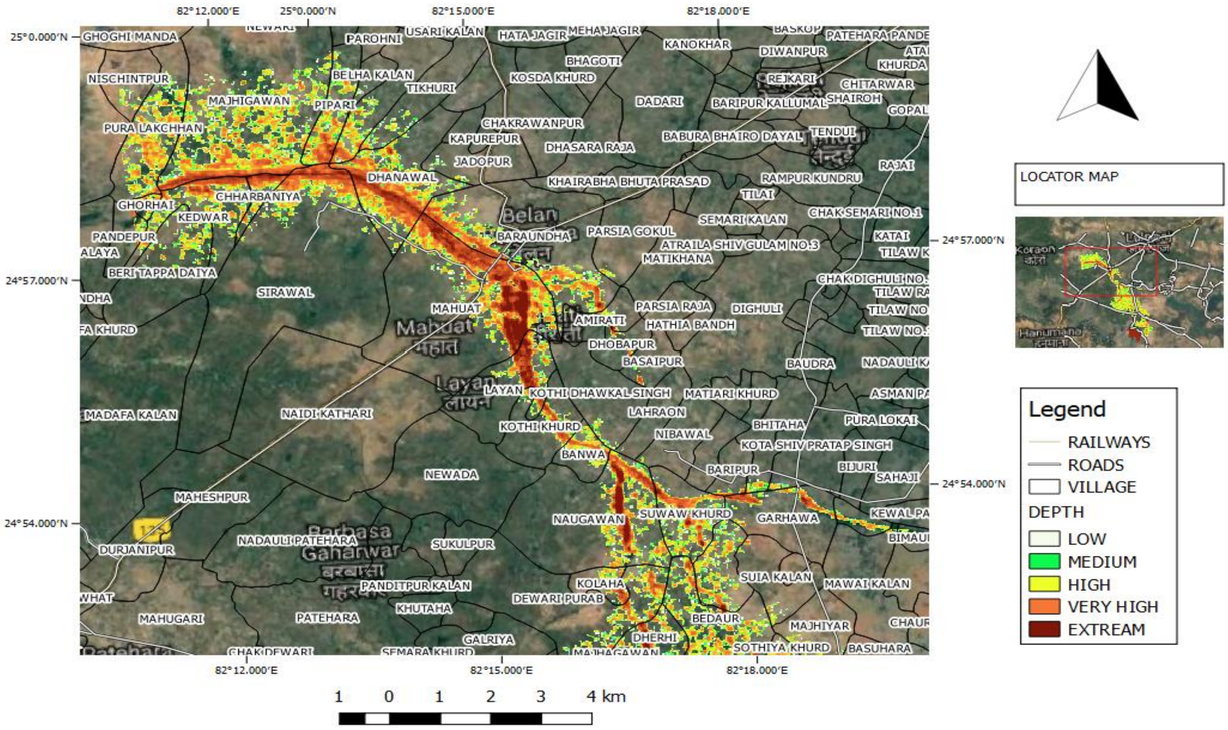


Fig4.12 Depth based flood inundation map of Adwa dam (Overtopping failure)

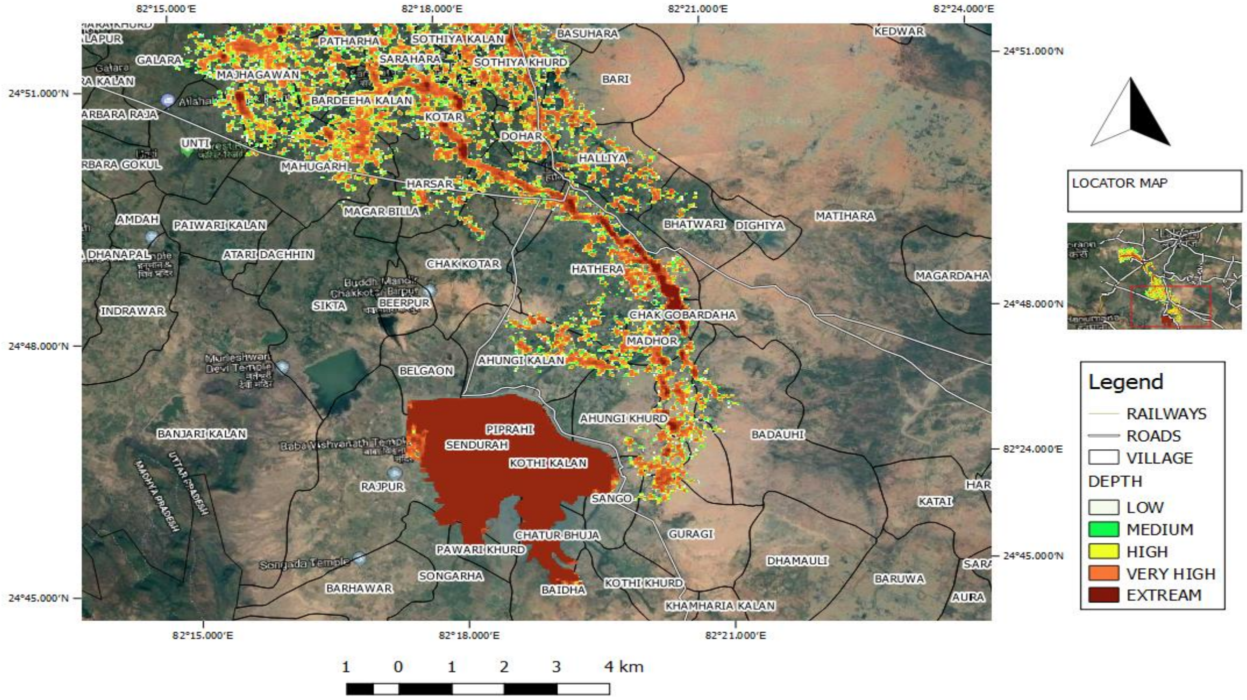


Fig4.13 Depth based flood inundation map of Adwa dam (Piping failure)

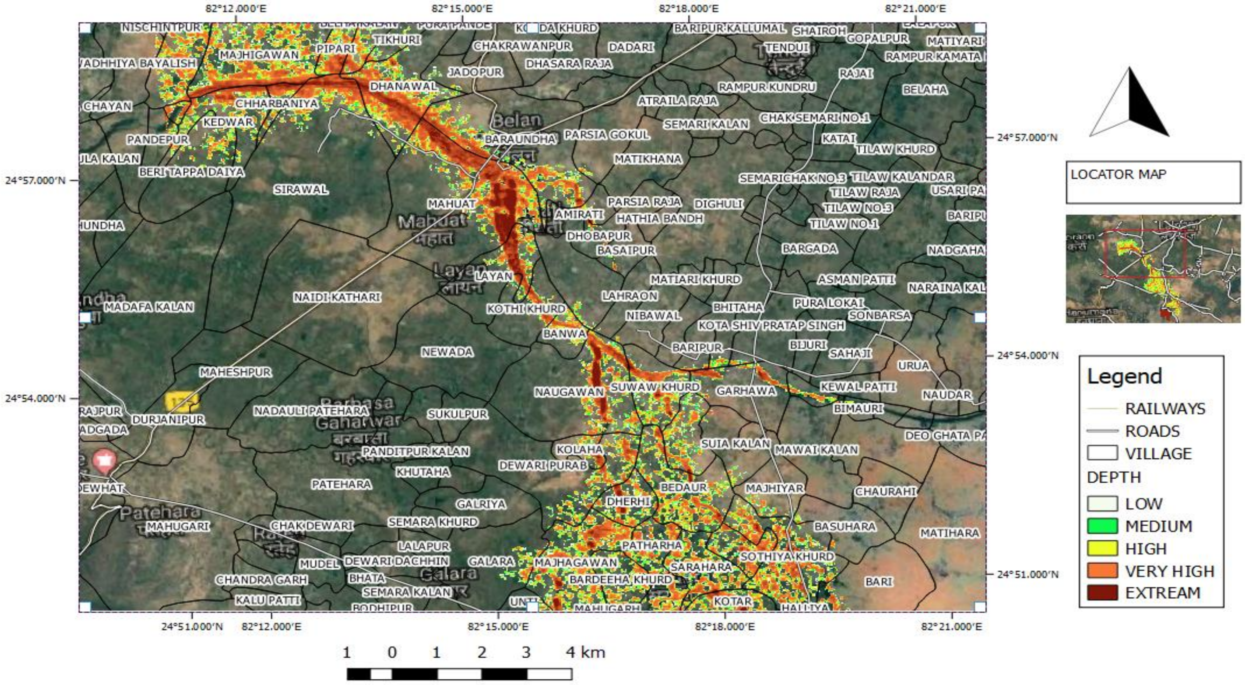


Fig4.14 Depth based flood inundation map of Adwa dam (Piping failure)

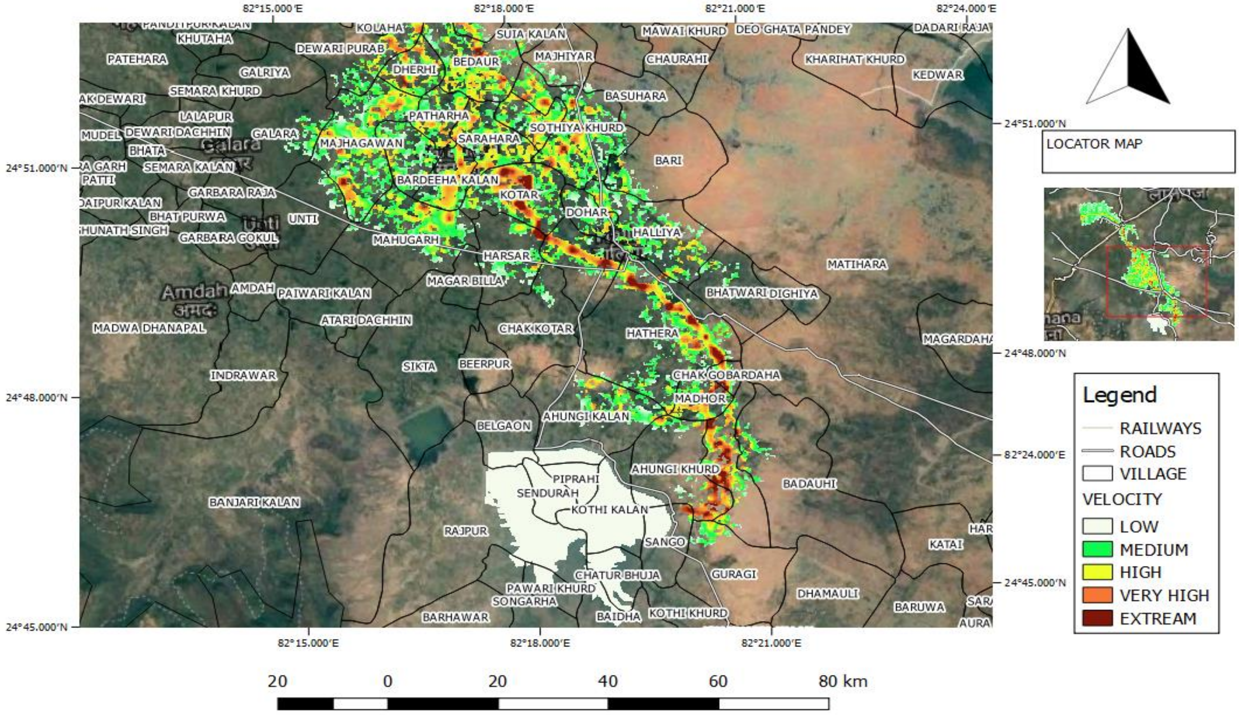


Fig4.15 Velocity based flood inundation map of Adwa dam (Overtopping failure)

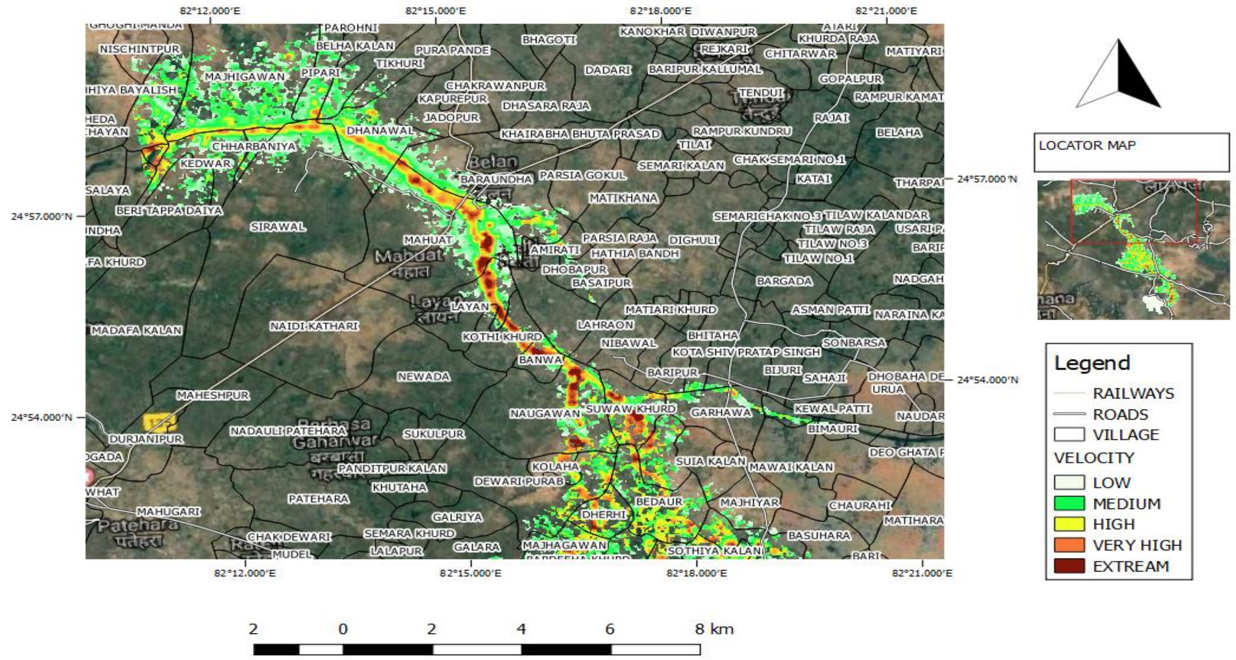


Fig4.16 Velocity based flood inundation map of Adwa dam (Overtopping failure)

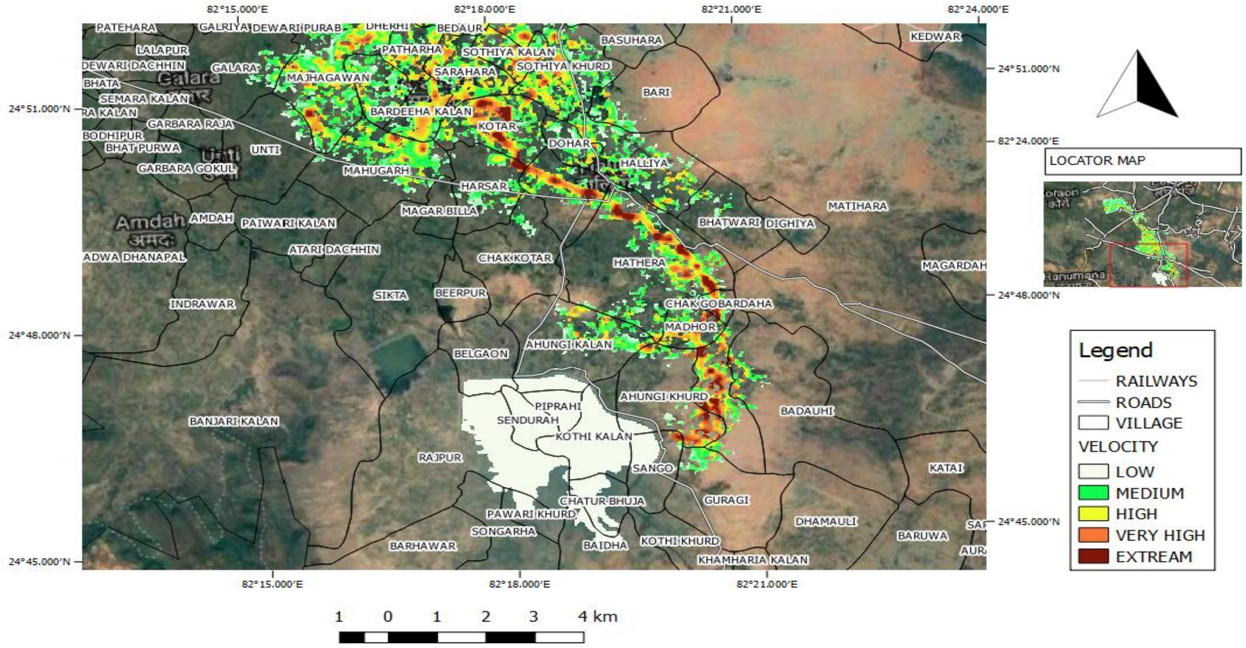


Fig4.17 Velocity based flood inundation map of Adwa dam (Piping failure)

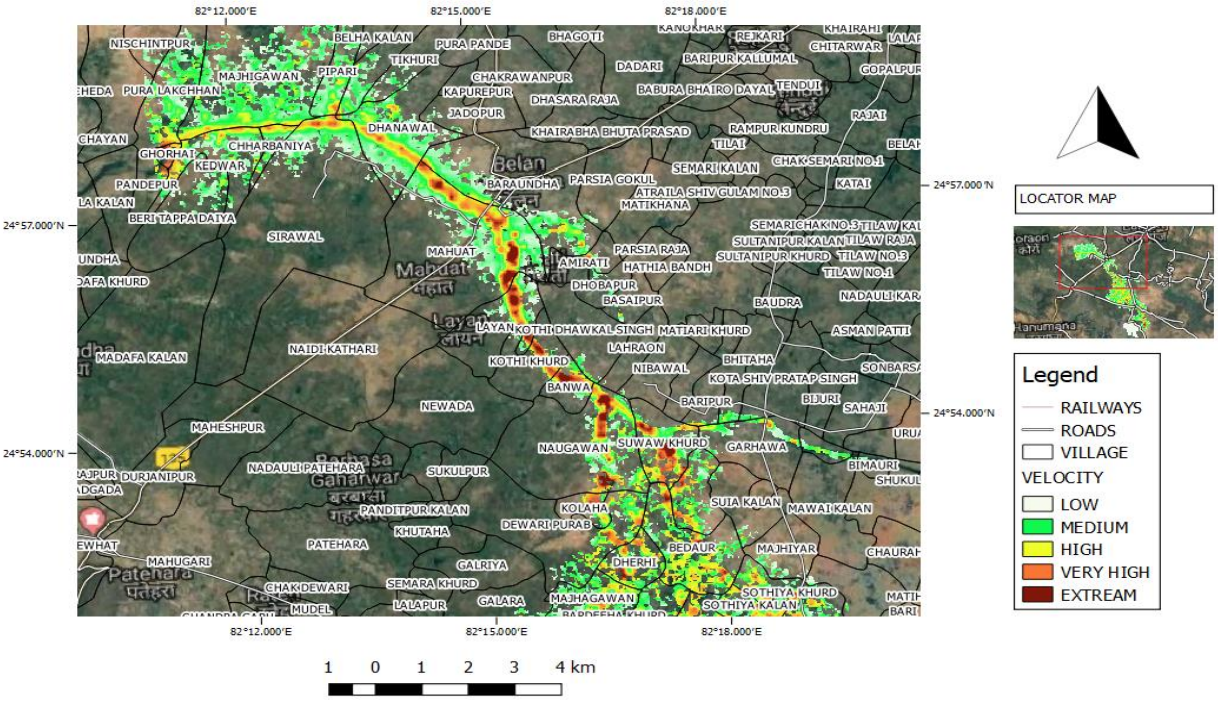


Fig4.18 Velocity based flood inundation map of Adwa dam (Piping failure)

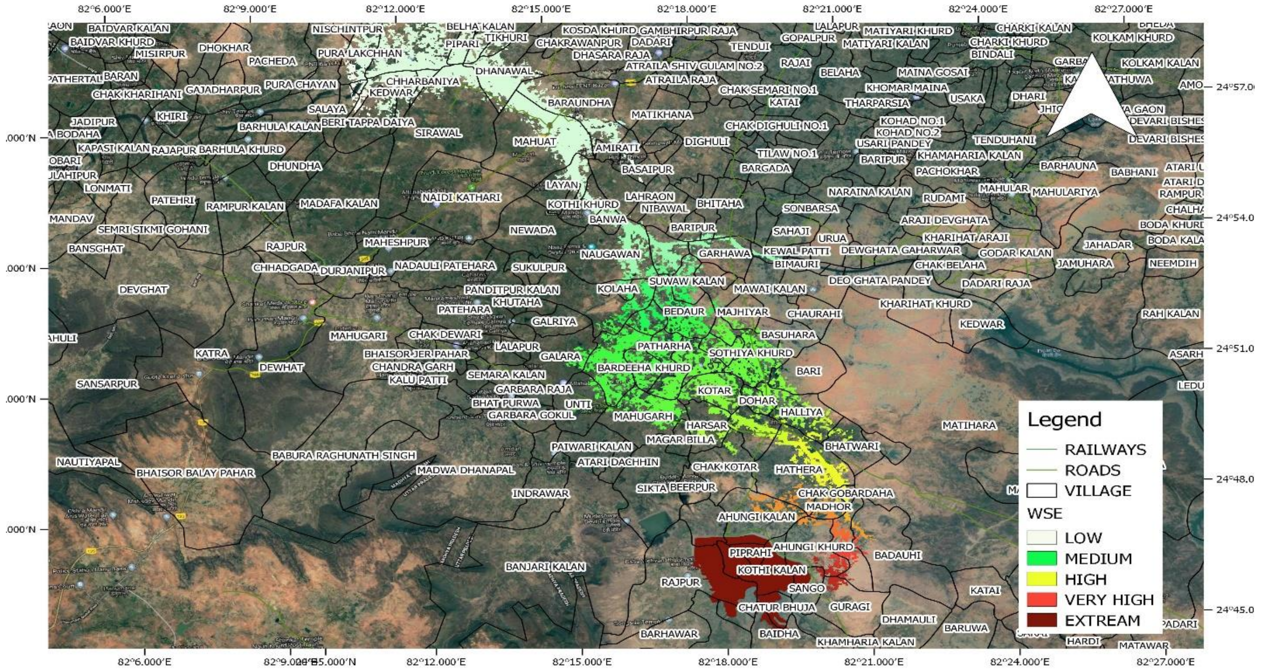


Fig 4.19 WSE based flood inundation map of Adwa dam (Overtopping failure)

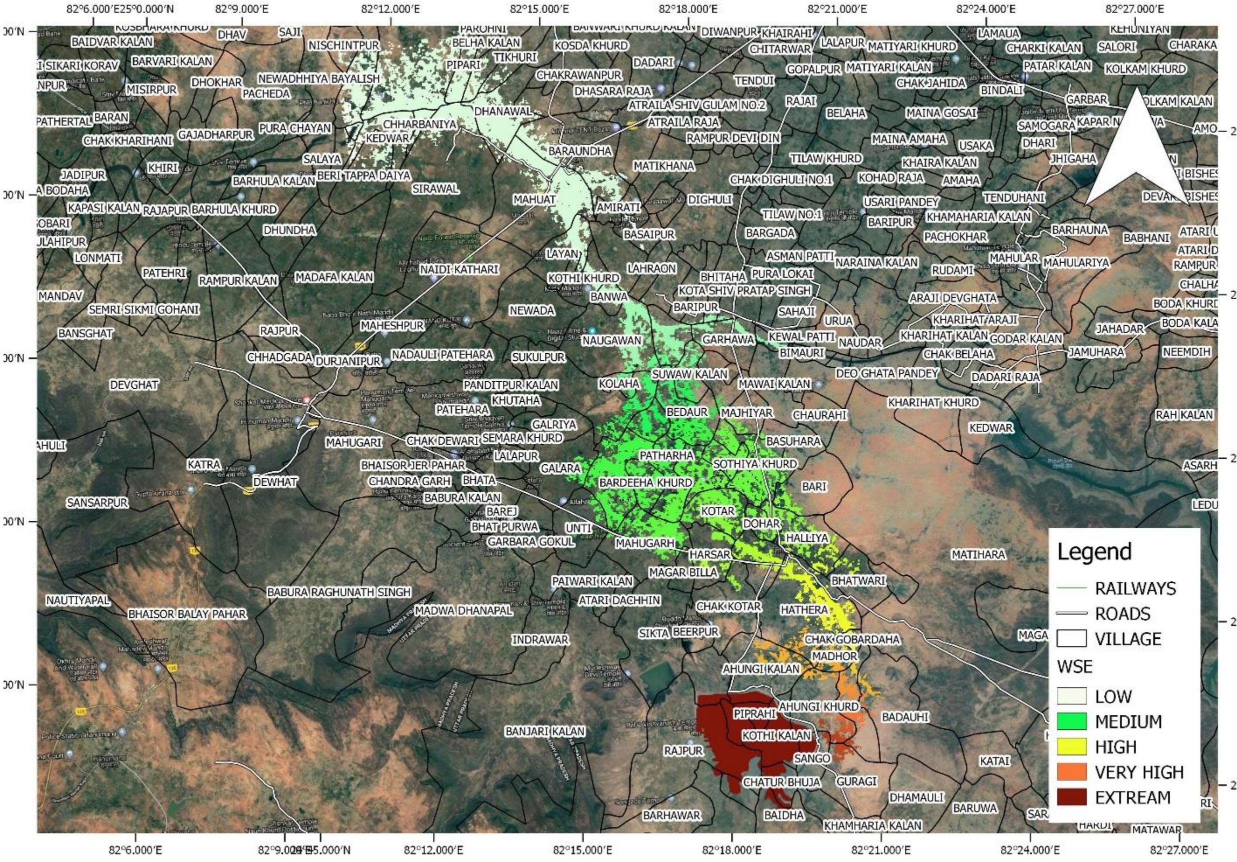


Fig4.20 WSE based flood inundation map of Adwa dam (Overtopping failure)

List of villages situated on the left and right side of the stream channel situated at the downstream end of the dam break is given below. It is observed that the flooding occurs 41 minutes after dam break. Emergency evacuation of people should be completed within the time Table 4.2

Table no.4.2 List of villages situated at the downstream side of the dam.

SR. NO	**VILLAGE NAME**	**ARRIVAL TIME (hr)**	**VELOCITY (m^3/s)**	**WSE (water surface elevation) In m**	**VILLAGE ELEVATI-ON (m)**	**DISTANCE B/W DAM TO VILAAGE (km)**	**VILL DISTANCE FROM RIVER (m) (RIGHT+ LEFT)**
1	AHUNGI KHURD	0.41	7.13	177.71	174.11	0.81	
2	GURAGI	0.66	0.83	177.53	175.50	0.72	350.90 (R)
3	BARULA	0.91	8.31	170.84	168.88	1.47	
4	MADHOR	1.33	6.39	165.33	164.38	3.11	
5	CHAK GOBARDAHA	1.41	5.78	159.28	140.57	4.02	
6	HATHERA	1.66	3.64	152.20	150.46	4.32	
7	BADAUHI	1.75	1.57	158.54	156.58	2.08	520.36 (R)
8	AHUNGI KALAN	2.25	1.14	158.14	165.55	2.40	1550 (L)
9	PURWA AWSAN SINGH	2.66	2.51	156.46	156.06	7.60	
10	HALLIYA	2.75	2.73	155.64	152.35	6.63	434.90 (R)
11	HARSAR	2.91	2.11	152.20	149.01	6.81	
12	BARDEEHA KALAN	3.41	2.51	149.70	148.30	9.85	

13	KOTAR	3.50	3.28	152.14	150.50	8.36	
14	DOHAR	3.58	2.11	152.03	147.21	7.06	472.08 (R)
15	SOTHIYA KHURD	3.58	3.88	150.37	149.36	8.57	639.39 (R)
16	SOTHIYA KALAN	3.83	1.22	150.31	149.53	9.72	787.51 (R)
17	PATHARA	3.83	1.79	149.97	140.86	10.35	1930 (R)
18	BARDEEHA KHURD	3.85	1.48	148.26	144.89	9.87	687.23 (R)
19	SARHARA	3.91	1.96	149.96	148.17	9.32	
20	MAHUGARH	4.25	1.39	149.22	147.13	8.27	
21	DHERHI	4.75	2.95	143.98	139.93	11.67	
22	SUWAW KALAN	5.08	2.69	143.84	143.22	12.40	1660 (R)
23	MAJHAGAWAN	5.16	1.33	148.57	146.45	10.12	
24	BEDAUR	5.32	1.74	143.93	142.17	10.93	1180 (R)
25	BHATWARI	5.33	0.48	155.73	154.16	5.64	565.86 (R)
26	SUWAW KHURD	5.58	2.25	137.06	132.58	13.85	695.67 (R)
27	DEWARI PURAB	5.66	2.52	143.70	141.47	12.38	
28	BARI	5.75	1.42	152.03	147.86	7.84	1860 (R)
29	UNTI	6.16	0.34	148.57	148.07	10.42	383.21 (L)
30	GALARA	6.33	1.11	148.07	147.51	11.94	267.80 (L)
31	KOLHA	6.41	2.37	142.52	141.51	13.32	
32	NAUGAWAN	6.66	1.55	137.80	133.84	14.20	

33	BANWA	7.00	2.17	136.38	135.38	16.38	
34	KOTHI KHURD	7.25	1.11	134.46	133.33	17.11	
35	GARWAHA	7.25	1.14	137.00	133.47	14.50	2190 (R)
36	KOTHI DHOWAL SINGH	7.41	0.25	135.92	135.56	16.71	561.71 (R)
37	LAYAN	7.91	0.92	133.70	132.50	18.09	
38	BARIPUR	7.91	0.96	137.00	135.13	14.83	1920 (R)
39	MAHUAT	8.31	1.12	133.65	130.58	19.41	
40	DHANWAL	8.83	0.92	133.54	131.60	23.05	
41	SIRAWAL	8.91	0.68	133.47	131.45	23.99	
42	BARAUNDA	9.33	0.68	133.65	131.41	19.56	249.56 (R)
43	SON BARSA	9.33	0.50	133.48	131.56	25.24	298.75 (R)
44	PIPARI	9.58	0.43	133.47	132.24	25.48	338.59 (R)
45	GHORHAI	9.83	1.85	131.37	129.59	25.95	
46	CHHAR BANIYA	10.58	0.98	133.41	132.55	25.07	
47	MAJHIGAWAN	10.91	1.45	133.33	132.82	25.55	
48	AMIRATI	11.50	1.98	133.65	130.12	18.46	1530 (R)
49	KEDWAR	11.50	0.93	133.29	130.17	24.87	
50	BERI TAPPA DAIYA	12.58	0.55	133.29	132.03	24.79	658.46 (L)
51	PURA LAKCHAN	13.66	0.66	133.16	132.12	26.56	136.25 (R)
52	DHOBAPUR	13.83	1.35	133.65	132.20	19.29	1530 (R)

Note:- R denotes village situated right side of the river and L denote village situated lest side of the river.

4.6 Emergency Action Plan

Developing effective emergency action plans involves a precise forecast of flood levels and the duration of flood wave arrival at a place where infrastructure and population are at risk. In the HEC-RAS model, the arrival time for flood wave to reach the critical place along the flood route needed for emergency action plans is determined by calculated velocity and water surface elevation. Figure 4.7,4.8 and 4.9,4.10 shows arrival time based inundation map of Adwa dam break by overtopping and piping mode respectively which is used for planning effective and urgent emergency action. Figure 4.19 displays WSE-based flood inundation map of Adwa dam break by overtopping mode and figure 4.20, showing WSE-based flood inundation map of Adwa dam by piping mode.

CHAPTER -V

SUMMARY AND CONCLUSIONS

In this study, complete hydraulic simulation and analysis were performed using the U.S. Army Corps of Engineers (USACE), the computer model of the River Analysis System (HEC-RAS) of the Hydrologic Engineering CenteR (HEC-RAS). HEC-RAS public domain software for the implementation of mixed flood routing and flood level forecasting. The flood inundation map was generated by HEC-RAS and imported into QGIS to delineate the areas flooded under the presumed dam break scenario. Details of water surface altitudes, flood depth, flood arrival time and flood wave velocity at various downstream places give an understanding of the extent of flooding. The result of the modelling showed that in the case of Adwa dam failure, some regions including residential, agricultural and industrial fields were recognized as having a very high risk of inundation owing to the important difference in the value of water surface elevation and ground elevation.

Because of the scenario described above, it was established that there will be displacement of people from residential homes and commercial establishments located along the study area, such as business centers, recreational areas, industrial areas and places of worship. The flood map was developed based on the extent of the water spread along the channel. Proper assessment of the risks associated with dam failure will assist in land use planning and the development of emergency reaction plans to help mitigate disastrous losses to human lives and property, and the authorities should also offer adequate warnings to the downstream side residents.

In an region such as the downstream region of the Adwa dam where a dam failure would endanger life, agricultural land and other assets either by overtopping or piping mode. Dam breach simulation provides valuable information on the area most likely to be affected. The simulation HEC-RAS output also helps the user to estimate when flood waves will first arrive and when flows will be at the maximum at required places downstream of the dam after a failure. This data may prove to be of excellent significance when generating an emergency action plan for the unfortunate case of a dam break.

One of the most significant lessons learned from the research is that using GIS for flood simulation can enhance precision and can also demonstrate cost-saving for floodplain delineation.

Some concluding remarks from the study are given below

- Overtopping failure mode tends to provide sharper and greater peak discharge relative to the piping failure mode.
- Carry out an inquiry into the practical application of the outcomes of this research to assist in the preparation of an emergency evacuation plan.
- The time of travel of flood wave at the farthest point of the study area is 13.66 hours.
- It is feasible that very extremely high rainfall could happen due to climate change. Under this situation, all Uttar Pradesh dams must be prepared for the dam-break assessment and emergency action plan.

REFERENCES

Abdulrahman, D. Z. (2014). Case study of the Chaq-Chaq dam failure: Parameter estimation and evaluation of dam breach prediction models. Journal of Engineering Research and Applications, 109-116.

Abshire, K. E. (2012). Impacts of hydrologic and hydraulic model connection schemes on flood simulation and inundation mapping in the Tar River basin. *Diss. Duke University*.

Ackerman, C. T. (2005). HEC-GeoRAS; GIS Tools for support of HEC-RAS using ArcGIS. United States Army Corps of Engineers, Davis.

Apte, N. Y. (2009). Urban Floods in context of India, India Meteorological Department, New Delhi. Proceedings of Innovative-ways-of-managing-Urban-Floods.

Arnold, J. G., Srinivasan, R., Muttiah, R. S., & Williams, J. R. (1998). Large area hydrologic modeling and assessment part I: model development 1. JAWRA Journal of the American Water Resources Association, 34(1), 73-89.

Balogun, O. S., & Ganiyu, H. O. (2017). Development of Inundation Map for Hypothetical Asa Dam Break using HEC-RAS and ARC GIS. Arid Zone Journal of Engineering, Technology and Environment, 13(6), 831-839.

Bao, W. M., Zhang, X. Q., & Qu, S. M. (2009). Dynamic correction of roughness in the hydrodynamic model. Journal of hydrodynamics, 21(2), 255-263.

Basheer, T. A., Wayayok, A., Yusuf, B., & KAMAL, M. (2017). Dam Breach parameters and their influence on flood hydrographs for Mosul Dam. Journal of Engineering Science and Technology, 12(11), 2896-2908.

Boussekine, M., & Djemili, L. (2016). Modelling approach for gravity dam break analysis. Journal of Water and Land Development, 30(1), 29-34.

Butt, M. J., Umar, M., & Qamar, R. (2013). Landslide dam and subsequent dam-break flood estimation using HEC-RAS model in Northern Pakistan. Natural hazards, 65(1), 241-254.

Cameron, A. T., Gary, W., & Brunner, P. E. (2006). Dam failure analysis using HEC-RAS and HEC-GeoRAS. In Proceedings of the Third Federal Interagency Hydrologic Modeling Conference, April (pp. 2-6).

Cook, A. C. (2008). Comparison of one-dimensional HEC-RAS with two-dimensional FESWMS model in flood inundation mapping. Graduate School, Purdue University, West Lafayette.

Dincergok, T. (2007, March). The Role of Dam Safety in Dam-Break Induced Flood Management. In Proceedings of International Congress on River Basin Management" (pp. 682-697).

Dincergok, T. (2007, May). The Role of Dam Safety in Dam-Break Induced Flood Management. In *Proceedings of International Congress on River Basin Management"* (pp. 682-697).

Dodge, R. A. (1988). Overtopping Flow on Low Embankment Dams--Summary Report of Model Tests. *Available from the National Technical Information Service, Springfield VA 22161, as PB 89-174833. Price codes: A 03 in paper copy, A 01 in microfiche. Report*.

Duressa, J. N., & Jubir, A. K. (2018). Dam Break Analysis and Inundation Mapping, Case Study of Fincha'a Dam in Horro Guduru Wollega Zone, Oromia Region, Ethiopia. Science Research, 6(2), 29.

Earles, T. A., Wright, K. R., Brown, C., & Langan, T. E. (2004). LOS ALAMOS FOREST FIRE IMPACT MODELING 1. JAWRA Journal of the American Water Resources Association, 40(2), 371-384.

Gee, D. M., & Brunner, G. W. (2005). Dam break flood routing using HEC-RAS and NWS-FLDWAV. In *Proceedings of the 2005 World Water and Environmental Resources Congress. EWRI 2005: Impacts of Global Climate Change* (p. 2005).

George, A. C., & Nair, B. T. (2015). Dam break analysis using BOSS DAMBRK. Aquatic Procedia, 4, 853-860.

HEC-RAS 5.0 reference manual,TD-39 using HEC-RAS for dam break studies, August 2014.

Hicks, F. E., & Peacock, T. (2005). Suitability of HEC-RAS for flood forecasting. Canadian Water Resources Journal, 30(2), 159-174.

http://www.hec.usace.army.mil/software/hecras/downloads.aspx

Husain, A., Sharif, M., & Ahmad, M. L. (2018). Simulation of Floods in Delhi Segment of River Yamuna Using HEC-RAS. American Journal of Water Resources, 6(4), 162-168.

Iosub, M., Minea, I., Hapciuc, O., & Romanescu, G. H. (2015). The use of Hec-Ras modelling in flood risk analysis. *Aerul si Apa. Componente ale Mediului*, 315.

Kane, S., Sambou, S., Leye, I., Diedhiou, R., Tamba, S., Cisse, M. T., ... & Sane, M. L. (2017). Modeling of unsteady flow through junction in rectangular channels: impact of model junction in the downstream channel hydrograph. Computational Water, Energy, and Environmental Engineering, 6(03), 304.

Knebl, M. R., Yang, Z. L., Hutchison, K., & Maidment, D. R. (2005). Regional scale flood modeling using NEXRAD rainfall, GIS, and HEC-HMS/RAS: a case study for the San

Antonio River Basin Summer 2002 storm event. Journal of Environmental Management, 75(4), 325-336.

Kute, S., Kakad, S., Bhoye, V., & Walunj, A. (2014). Flood modeling of River Godavari using HEC-RAS. Int J Res Eng Technol, 3(09), 81-87.

Lyu, H. M., Wang, G. F., Shen, J., Lu, L. H., & Wang, G. Q. (2016). Analysis and GIS mapping of flooding hazards on 10 May 2016, Guangzhou, China. Water, 8(10), 447.

Mao, J., Wang, S., Ni, J., Xi, C., & Wang, J. (2017). Management System for Dam-Break Hazard Mapping in a Complex Basin Environment. ISPRS International Journal of Geo-Information, 6(6), 162.

Modak, S., & Nagarnaik, P. (2006). Flood Control And Prediction of Flood Using HEC-RAS–A Review. ingeniería civil, 2, 18-23.

Ostad-Ali-Askari, K., & Shayannejad, M. (2015). Usage of rockfill dams in the HEC-RAS software for the purpose of controlling floods. American Journal of Fluid Dynamics, 5(1), 23-29.

Pappenberger, F., Beven, K., Horritt, M., & Blazkova, S. (2005). Uncertainty in the calibration of effective roughness parameters in HEC-RAS using inundation and downstream level observations. Journal of Hydrology, 302(1-4), 46-69.

Parhi, P. K. (2013). HEC-RAS Model for Mannnig's Roughness: A Case Study. Open Journal of Modern Hydrology, 3(03), 97.

Patel, C. G., & Gundaliya, P. J. (2016). Floodplain Delineation Using HECRAS Model—A Case Study of Surat City. Open Journal of Modern Hydrology, 6(01), 34.

Patro, S., Chatterjee, C., Mohanty, S., Singh, R., & Raghuwanshi, N. S. (2009). Flood inundation modeling using MIKE FLOOD and remote sensing data. *Journal of the Indian Society of Remote Sensing*, *37*(1), 107-118.

Sarhadi, A., Soltani, S., & Modarres, R. (2012). Probabilistic flood inundation mapping of ungauged rivers: Linking GIS techniques and frequency analysis. *Journal of Hydrology*, *458*, 68-86.

Scarlatos, P. D., & Singh, V. P. (1988). Analysis of Gradual Earth-Dam Failure.

Sharkey, J. K. (2014). Investigating Instabilities with HEC-RAS Unsteady Flow Modeling for Regulated Rivers at Low Flow Stages.

Sharma, P., & Mujumdar, S. (2017). Dam Break Analysis Using HEC-RAS and HEC-GeoRAS–A Case Study of Ajwa Reservoir. *Journal of Water Resources and Ocean Science*, *5*(6), 108.

Singh, V. P., & Scarlatos, P. D. (1988). Analysis of gradual earth-dam failure. *Journal of hydraulic engineering*, *114*(1), 21-42.

Subramanya, K. (2013). Engineering Hydrology, 4e. Tata McGraw-Hill Education.

Timbadiya, P. V., Patel, P. L., & Porey, P. D. (2011). Calibration of HEC-RAS model on prediction of flood for lower Tapi River, India. Journal of Water Resource and Protection, 3(11), 805.

Traore, V. B., Bop, M., Faye, M., Malomar, G., Gueye, E. H. O., Sambou, H., ... & Beye, A. C. (2015). Using of Hec-ras model for hydraulic analysis of a river with agricultural vocation: A case study of the Kayanga river basin, Senegal. American Journal of Water Resources, 3(5), 147-154.

Warren, C. J., & Reardon, E. J. (1994). The solubility of ettringite at 25 C. *Cement and Concrete Research*, *24*(8), 1515-1524.

Wahl, T. L. (1998). Prediction of embankment dam breach parameters: a literature review and needs assessment.

Xiong, Y. (2011). A dam break analysis using HEC-RAS. Journal of Water Resource and Protection, 3(06), 370.

Yakti, B. P., Adityawan, M. B., Farid, M., Suryadi, Y., Nugroho, J., & Hadihardaja, I. K. (2018). 2D Modeling of Flood Propagation due to the Failure of Way Ela Natural Dam. In MATEC Web of Conferences (Vol. 147, p. 03009). EDP Sciences.

Zhou, R. D., Eng, P., & Donnelly, C. R. (2005, October). Comparison of HEC-RAS with FLDWAV and DAMBRK models for dam break analysis. In CDA Annual Conference (pp. 1-12).

Zope, P. E., Eldho, T. I., & Jothiprakash, V. (2016). Impacts of land use–land cover change and urbanization on flooding: A case study of Oshiwara River Basin in Mumbai, India. Catena, 145, 142-154.