FLOOD VULNERABILITY ASSESSMENT THROUGH 1D & 2D MODELLING FOR BRAHMAPUTRA RIVER (GUWAHATI TO CHHAYGAON STRETCH) USING HEC RAS

A dissertation submitted in
Partial Fulfilment of the Requirement for the Award of the Degree of

MASTERS OF TECHNOLOGY
In
CIVIL ENGINEERING
(With Specialization in Water Resource Engineering) Of
ASSAM SCIENCE &TECHNOLOGY UNIVERSITY
SESSION 2020-22

By
ANUBHAV BARMAN
ROLL NO: 200620030001
ASTU REG. NO.: 156806220 of 2020-21

Under the Guidance
of
DR. BIPUL TALUKDAR
PROFESSOR
ASSAM ENGINEERING COLLEGE
DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE JALUKBARI,
GUWAHATI-781013

DECLARATION

I hereby declare that the work presented in the dissertation **"FLOOD VULNERABILITY ASSESSMENT THROUGH 1 & 2 D MODELLING FOR BRAHMAPUTRA RIVER (GUWAHATI TO CHHAYGAON STRETCH**) **USING HEC RAS "** in partial fulfillment of the requirement for the award of the degree of "MASTER OF TECHNOLOGY" in Civil Engineering (with specialization in Water Resource Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13 under Assam Science & Technology University,is a real record of my work carried out in the said college under the supervision of Dr. Bipul Talukdar, Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13.

Do hereby declare that this project report is solemnly done by me and is my effort and that no part of it has been plagiarized without citation.

Date: ANUBHAV BARMAN

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: Dr. BIPUL TALUKDAR

(Professor)

Civil Engineering Department

Assam Engineering College

CERTIFICATE FROM THE SUPERVISOR

This is the certified that the work presented in the project report entitled "FLOOD VULNERABILITY ASSESSMENT THROUGH 1 D & 2 D MODELLING OF BRAHMAPUTRA RIVER (GUWAHATI TO CHHAYGAON STRETCH) USING HEC RAS " is submitted by ANUBHAV BARMAN, Roll No 200620030001, a student of M.Tech 4th semester, Department of Civil Engineering, Assam Engineering College, to the Assam Science and Technology University in partial fulfillment of the requirement for award of the degree of Master of Technology in Civil Engineering with Specialization in Water Resource Engineering under my guidance and supervision.

Date:

DR. BIPUL TALUKDAR
(Professor)
Department of Civil Engineering
Assam Engineering College
Guwahati-781013

CERTIFICATE FROM HEAD OF THE DEPARTMENT

This is to certify that the project report entitled "FLOOD VULNERABILITY ASSESSMENT THROUGH 1 D & 2 D MODELLING OF BRAHMAPUTRA RIVER (GUWAHATI TO CHHAYGAON STRETCH) USING HEC RAS " has been submitted by ANUBHAV BARMAN, bearing Roll No: 200620030001, a student of M.Tech. 4th Semester, Water Resource Engineering (Civil Engineering Department), Assam Engineering College, in partial fulfillment of the requirements for the award of the degree of Master of Technology in Water Resource Engineering of Assam Science & Technology University.

Date:

Place:

DR. JAYANTA PATHAK
Professor & Head
Department of Civil Engineering
Assam Engineering College
Jalukbari,Guwahati-13

ACKNOWLEDGEMENT

At the very outset I would like to express my deepest gratitude and sincere thanks to my respected guide Dr. Bipul Talukdar , Professor ,Department of Civil Engineering ,Assam Engineering College for his invaluable supervision ,guidance and constructive suggestion throughout the course of my work .

I would like to express my deepest gratitude and sincere thanks to Dr. Jayshree Hazarika, Assistant Professor ,Department of Civil Engineering ,Assam Engineering College for her constant guidance, supervision , resourceful criticism, valuable time and encouragement throughout the course of my work.

I also express my sincere thanks and gratitude to Dr.Jayanta Pathak, Professor & Head of the Department of Civil Engineering, Assam Engineering College, for his kind co-operation while carrying out my work.

I extend my grateful thanks to all the faculty members of the Department Of Civil Engineering, Assam Engineering College for their free exchange of ideas and for lending their helping hand whenever I needed them.

I also like to thank all my classmates and well-wishers for their constant encouragement, valuable advice and inspiration throughout the work.

Lastly, I acknowledge my indebtedness to all my family members for their whole hearted moral support and constant encouragement.

ANUBHAV BARMAN
M.TECH 4th Semester
Department of Civil Engineering
Assam Engineering College
Jalukbari

ABSTRACT

Due to its location and numerous hydro-meteorological and topographical factors, Assam is particularly vulnerable to river bank erosion and flooding. Brahmaputra , the major river in the sstate of Assam, has experienced significant flooding and bank erosion and is regarded as a problematic river throughout Assam's history. The Brahmaputra rolls down the plain of Assam east to west for a distance of 640 km upto Bangladesh border. Through its course, the river receives innumerable tributaries coming out of the northern, north-eastern and the southern hill ranges. The mighty river with a well-knit network of tributaries drains an area of 56,480 sq. km. accounting for 72% of its total geographical area of the state. The Brahmaputra basin is characterised by extremely large floods and bank erosion, which cause widespread destruction. In the current work, a study along the Brahmaputra River has been conducted with a focus on the calculation of surface water elevations on downstream area of Guwahati for various discharge amounts and also involves determining the flooding area at various discharge amounts. As a result, it will intensify the flood scenario and its effects on the Brahmaputra River basin on the downstream side. A River Analysis System (HEC-RAS) model for the specified study area was created by the Hydrologic Engineering Center. Numerous cross sections will make up the study reach, based on the appropriate circumstance. River levels at various cross- sections have been simulated using the measured performance. The goal is to assist decision- makers, planners, and insurers in creating a solid strategy for the creation of flood mitigation strategies and plans to reduce disaster-related losses in the study region.

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 PROLOGUE

River flooding stands as the most catastrophic natural phenomenon, especially in urban areas, causing significant loss of life, property, and assets. It is crucial to conduct thorough research and develop swift public flood risk assessments to prioritize mitigation efforts. Flooding occurs when there's a rapid increase in water levels due to snowmelt, heavy rainfall in both upper and lower parts of a basin, or dam failure, putting lives and properties at risk. This natural, recurrent event for rivers is primarily observed during the monsoon months from June to September, with floods often resulting from the rivers' inability to handle the influx, leading to drainage issues and erosion of river banks. Excessive or prolonged rainfall exceeding the soil's absorption capacity and the river channels' flow capacity causes rivers to overflow, affecting surrounding areas. Despite the regular occurrence of floods in monsoon-prone regions, many areas lack flood risk maps, essential for preventing or minimizing damage. Thus, developing predictive models, monitoring tools, and establishing regulatory and contingency plans is imperative.

Flood risk assessment in river basins has long been a focus globally. Various flood mitigation strategies, including flood plain management and the application of technology and data, have been employed to reduce flood damages. Flood damage reduction strategies can be divided into structural and non-structural measures. Structural measures involve the construction of dams, levees, diversion channels, and other physical barriers. In contrast, non-structural measures aim to lessen flood impacts without relying on physical structures. For these measures to be effectively implemented, engineering tools like flood modeling must be utilized. Flood modeling is an engineering tool that offers precise flood profiles by considering parameters such as precipitation, runoff, catchment characteristics, and return periods. Floodplain studies, which provide water surface profiles and maps for land-use planning in flood-prone areas, often incorporate the analysis of historical floods for model calibration, ensuring the model can accurately replicate observed water surface heights during actual flood events. A successful river flood model needs an accurate representation of river channel and floodplain geometries and model parameters to precisely predict flow sizes and water levels. Computer models are essential in this analysis, helping determine water surface profiles for various flow conditions. Traditionally, water surface elevations are plotted on maps manually to delineate floodplains. However, software tools, continuously being developed and updated, facilitate the extraction of spatial features useful for hydraulic models from geographical data sources, in both GIS and non-GIS formats. The spatial and temporal data gathered are crucial for flood management and development planning. The use of software that offers a range of options for modeling hydraulic systems has proven successful in areas with medium mountains, leading to numerous international publications and research projects.

The Brahmaputra River in the Assam, marking its expansive journey across the northeastern part of India. This mighty river, originates near the Chemayungdung glacier near Mansarovar in Tibet, traverses through the rugged terrains of the Himalayas, entering India in Arunachal Pradesh, and further flowing into the plains of Assam, where it significantly broadens near Guwahati (91°44′E: 26°11′N). The Brahmaputra, revered as 'Luit' in local parlance (meaning 'blood of the son'), weaves through the Assam valley, shaping the region's socio-economic fabric.

Geographically, the Brahmaputra stretch in Guwahati to Chhaygaon via Palashbari is adorned with a variety of fluvial features. It hosts old meander loops, abandoned channels, and levees that narrate the river's ever-changing paths. The basin also presents multiple river terraces, evidencing ancient courses at varying elevations, with the current Brahmaputra channel residing at the lowest. Past riverine systems, now inactive and known as 'Dead Brahmaputra' channels, can be traced, offering insights into the river's geomorphological evolution.

This region is rich in agricultural and tea plantation areas situated on higher terrains, while the fertile lower plains are primarily used for paddy cultivation. The surrounding areas are endowed with lush forest reserves, such as the Amchang Wildlife Sanctuary near Guwahati, hosting diverse flora and fauna. The climate here is typified by a subtropical regime, experiencing warm, humid summers, heavy monsoonal downpours leading to widespread flooding, followed by dry autumns and chilly winters.

Given the Brahmaputra's history of recurrent flooding and erosion, it becomes imperative to explore and implement effective flood management and riverbank protection strategies. These measures are crucial for mitigating the adverse effects of floods, ensuring the safety and well-being of the local population, and preserving the region's rich cultural and environmental heritage.

The HEC-RAS hydraulic model could be a rearranged way to show a stream flow. Applying GIS strategies, flood visualization can be effortlessly produced which might be valuable for surge relief and arranging of the basin for conducting different sorts of studies including building flood estimating and flood immersion models, analyzing diverse surge control options, tending to social impacts of little dam evacuations, and creating a surge early caution framework. This study employment these devices to highlight the flooding potential for the study region as a result of urbanization and extraordinary precipitation occasions and assesses the potential of using wetlands as a moderation alternative. In this study, HEC-RAS illustrate a suitable examination and entertainment of hydraulic streams in water system arrange of Waterway system.

1.2 OBJECTIVE OF THE STUDY

The Objectives of the study are as given below:

i. The development of a hydrological model for Brahmaputra River (Guwahati To Chhaygaon Stretch) in Assam, India.
ii. Development of hydraulic/ hydrodynamic model for the river Brahmaputra for assessment of Flood Vulnerability.
iii. Development of Flood Plain map of the study area for a 100-year return period.
iv. To determine suitable embankment height to control flooding.

1.3 SCOPE OF WORK

The scope of work involves conducting a comprehensive flood vulnerability assessment of the Brahmaputra River in Assam. The primary objective is to evaluate the extent of flood risk and assess the effectiveness of existing embankments in mitigating inundation. The 2D model in HEC-RAS will provide detailed outputs including water surface elevations, inundation depths, and flow velocities across the study area. Comparisons will be made between scenarios with and without embankments to recommend optimal embankment heights for flood protection. The scope also includes proposing strategic measures for managing flood risks .

1.4 METHODOLOGY

- **Study Area Definition**: Define the geographical scope of the study covering the Brahmaputra River basin in Assam, including key hydrological and topographical features.
- **Data Collection**: Gather discharge data, basin characteristics (such as land use, soil type, and slope), and topographic maps necessary for modeling.
- **Synthetic Unit Hydrograph**: Develop a Synthetic Unit Hydrograph based on historical data and basin characteristics to represent a 100-year return period flood event.

- **1D and 2D Modeling**: Implement HEC-RAS for both 1D and 2D modeling to simulate flood scenarios, including peak discharge and flood hydrographs.
- **Scenario Analysis**: Evaluate flood extents, water surface elevations, inundation depths, and flow velocities under different scenarios (with and without embankments).
- **Mitigation Strategies**: Recommend optimal embankment heights and other flood mitigation measures based on modeling results to enhance resilience and manage flood risks effectively.

1.5 ABOUT BRAHMAPUTRA RIVER

The Brahmaputra River, originating as the Yarlung Tsangpo in Tibet and known as the Siang in Arunachal Pradesh before becoming the Brahmaputra in Assam, spans approximately 2,900 kilometers and covers a basin of 580,000 square kilometers. In Assam, it is a lifeline supporting agriculture, fishing, and transportation, vital for millions of people. The river's fertile sediments enrich the plains and sustain a unique ecosystem that includes river islands known as chars, shaped by its powerful currents.

Despite its role in sustaining livelihoods and biodiversity, the Brahmaputra is infamous for its devastating floods during the monsoon season, impacting Assam's socio-economic fabric. The river's banks are fortified with embankments to mitigate flood damage, alongside tea plantations and dense forests that enhance the region's natural beauty and economic productivity.

Culturally, the Brahmaputra is integral to Assamese identity, nurturing civilizations and traditions along its banks for centuries. Festivals and spiritual beliefs revolve around its waters, symbolizing its significance as the "son of Brahma" in Sanskrit mythology. Efforts to manage its water resources sustainably, balancing development with conservation, are ongoing to safeguard its role as a vital resource and cultural icon in Assam.

1.6 CHAPTERWISE PLANNING

- **Chapter 1**: Introduction-Overview of the Brahmaputra River: origin, flow path, and significance.Importance of flood vulnerability assessment in Assam.
- **Chapter 2**: Literature Review- Review of existing studies and Exploration of methodologies and models used for flood vulnerability assessments globally and regionally.

- **Chapter 3**: Study Area and Materials-Description of the study area: geographical extent, topography, and hydrological characteristics. Use of HEC-RAS software for 1D and 2D flood modeling.Data collection methods: discharge data, basin characteristics, and topographic maps.
- **Chapter 4** Methodology-Development of Synthetic Unit Hydrograph for 100-year return period. Detailed explanation of 1D and 2D modeling techniques in HEC-RAS.
- **Chapter 5**: Results and discussions-Analysis of flood extents, water surface elevations, inundation depths, and flow velocities.Analysis of flood extents, water surface elevations, inundation depths, and flow velocities.
- **Chapter 6**: Conclusion - Summary of findings and key conclusions drawn from the study.Future research directions: areas for further study and improvement in flood modeling and mitigation strategies.
- **Chapter 7**: References- Comprehensive list of sources cited throughout the report and literature review.Detailed technical data.

Fig1.1: Map showing the area of study on the Bank of River Brahmaputra in the Kamrup Metropolitan and Kamrup District of Assam.

CHAPTER 2

LITERATURE REVIEW

In continuation with endeavour of exploring the available works related to the topic, some literatures have been reviewed. These literature reviews demonstrate the familiarity of this topic and scholarly context. This study is an effort mainly to focus on the floodplain modeling using hydraulic models. Different researchers used different types of techniques and methods for flood control in order to protect the riverbank. A summary review of previous similar researches dealing with the floodplain modelling using hydrodynamic models is presented in this chapter.

Yi (Frank) Xiong (2011) has done a Dam Break Analysis Using HEC-RAS. Break parameters prediction, the understanding of dam break mechanics, top outflow expectation were shown as the fundamental for the dam break investigation, and inevitably decided the misfortune of the harms. As an application example, Foster Joseph Sayers Dam break was further modeled and analysed utilizing USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) model based on accessible geometry information. Combination of mechanics and case studies, reflection of overwhelming instruments of head cut erosion, more particular categorization of dam, judicious examination and induction of dam break prepare are required in creating a satisfactory dam break recreation model.

From this study it is known that the dam breaks due to piping elongates the time period of high-water surface level, which increments the term of chance. In any case, the dam break does not increment the down stream's most extreme water surface height (Max. W.S. Elev) significantly at past design "Probable Maximum Flood (PMF)". Foster Joseph Sayer dam break has more prominent effect on the downstream area which is closer to the dam in accordance with the comparison of the hydrographs at different areas.

Yongping Yuan et al. (2011) done a project on floodplain Modeling in the Kansas River Basin Using Hydrologic Engineering Center (HEC) Models. In this study, it focused on highlighting the flooding potential for Kansas River region and also for using wetlands as a mitigation option. Various tools such as Hydrologic Engineering center- Hydrologic Modeling system (HEC-HMS) and Hydrologic Engineering center- River Analysis System (HEC-RAS) which is used for various types of studies such as building flood forecasting, flood inundation models, to analyze various flood control, early flood warning system, etc.

A GIS device ICLUS's projections of urban land use densities for 2020 were adjusted to show expanding densification of urban regions, by converting low concentrated improvement to medium concentrated in 2030 and to high concentrated improvements in 2040. The paper concludes that there will be an increase in peak runoff and flood inundation for different storms from baseline scenario to 2040 which is about 15% increase in runoff for all the land use and design storm scenarios.

Ali M. F et al. (2013) has done Integration of HEC-RAS and geographical information system (GIS) in the hydrological study of peak flow response to deforestation on a small watershed in Malaysia. The geological informations were prepared utilizing geographical information system (GIS) to appear the lands utilize alters within the study range. The hydrological information was analyzed through relapse investigation, stream length bend, and soil conservation service (SCS) strategy for analysing runoff for land use change. The relapse investigations have found critical increment of r2 value from 3.1% between year 1990 to 1996, 7.5% between year 1997 to 2000, and 13.2% between the years of 2001 to 2006. The stream length bend has chosen streamflow information event on December 28 to 29, 1996 on the Kinta Stream at outlet of Kinta watershed result which has appeared volume of stream flow that was 2.209 × 106 cumecs.

From the study it is concluded that the precipitation was not the major contributing figure, hence when precipitation condition was kept consistent, the runoff varieties were primarily coming from land use alter of watersheds or land use periods, which too got to be further examined. Estimate of basin is too another factor. Little basins act in an unexpected way from the huge ones in terms of the relative significance of various stages of the runoff phenomenon. In small catchments the overland stream stages are fundamental over the channel stream. Hence, the land use and concentration of rainfall have a critical part within the peak flood.

Sunil Kute et al. (2014) has done a flood modeling of river Godavari using HEC-RAS. The flood discharged for Gangapur dam, which is built on upstream of Nashik city at 14 km separate is considered for the modeling. The surge release is based on the most exceedingly worst discharge of 1969 surge. The stream, 14 bridges over the stream and the flood plain were modeled. The demonstrate encourages to find the surge plain and its degree for compelling surge relief measures.

After giving all the input parameters to the program for the computation, the yield in terms of the table and the graphs is gotten which incorporates: value of ground elevation, velocity head, water surface elevation, total velocity, max channel depth, losses, average velocity, wetted perimeter etc. The rating curve and for the given release, the submergence at the given section is additionally shown which the level of flood appears.

Muhammad Shahzad Khattak et al. (2015) has done a case study on Kabul river using HEC-RAS and ArcGIS. Khyber Pakhtunkhwa Province, which experienced uncommon floods in July/August 2010 uncovering the helplessness of the area to this natural catastrophe were measured. The peak floods from recurrence investigation were input into HECRAS model to discover the corresponding surge levels expected along waterway reaches expanding through Warsak dam to Attock. Results found from HEC-RAS model were utilized in combination with ArcGIS to prepare floodplain maps for different return periods. Through floodplain maps, regions that are vulnerable to flooding dangers have been recognized.

Urban areas such as those of Nowshera are also vulnerable to flooding, which was also evident in July/August 2010 floods. It is clearly visualized from the floodplain maps that with one in 100-year return-period surge, the levels of inundation are generally four times that due to ordinary flow. Therefore, it is greatly vital to supply assurance to cities such as Charsadda and Nowshera on both banks of the stream mainly through raising of embankments.

Vieux Boukhaly Traore et al. (2015) has done a hydraulic analysis of the Kayanga River Basin, Senegal using HEC-RAS. In this paper, the river reach selected which is located between the Niandouba dam and Kounkane threshold and the flow characteristics to analyze the hydraulic behavior of this system is analyzed using HECRAS model. ArcGIS computer program is additionally utilized to extract the bathymetry for the separated cross segment and the distance between two adjoining cross sections which help in creating the river geometry in HEC-RAS.

The study concluded that the HECRAS model is utilized to analyze dynamic of stream in Kayanga waterway basin. The main stream characteristics along the study reach is being calculated which offer assistance the decision makers in finding the high, low and constant flow characteristics regions and also the expansive and contractive area regions. The above results too offer assistance the concerned parties for water assignment, water administration, hydraulic structure execution, natural planning and surge control ministration in Kayanga Stream.

Chandresh G. Patel et al. (2016) has done a case study on Surat city in which floodplain Delineation Using HECRAS Model is done. Stream area near Nehru Bridge is utilized as test case to recreate surge stream. Discharges rise to to food return period for 25 and 32 have been utilized for examination of surge situation. Result of the research clearly demonstrates that most of the zone of the Surat city is submerged for a depth of 2.5 to 4.0 m when the release discharged from Ukai dam rises to to return period of 32 a long time (25768.09 Cumecs).

A few stream cross areas have been recognized which can not contain release that's likely to come for return period of 25 years. It is additionally illustrated that most of the low lying region of the city is submerged at release breaks even with to return period of 32 years. Basic remedial measures have been recommended in arrange to anticipate surge impact in low lying region of Surat city up to a few degree. One of the foremost critical lessons learnt from the study is that the use of GIS for the undertaking of surge recreation can progress precision and can too demonstrate cost-saving for floodplain outline.

Uttam Aryal et al. (2016) have done a study on flood hazard assessment in Dhobi-Khola watershed (Kathmandu, Nepal) using hydrological model. In this study, the flood prone areas of the Dhobi-Khola watershed were identified and using HEC-RAS and GIS, the flood risk area was also delineated. With discharge data of Gaurighat and rainfall data of Sundarijal stations, the model was calibrated and validated in Bagmati river watershed and then transported to Dhobi-Khola watershed using hydrological data of Budhanilkantha station.

The flood risk evaluation makes a difference to decide the high flood risk zones in advance, which helps to require moderation measures effectively and productively. As expressed by diverse consider related to Bagmati, a few destinations that are close Anamnagar, Thapagaun, underneath Bhatkekopul, behind Sukedhara which fall beneath the High Danger, Exceptionally High Hazard, Extremely High Risk category. So, the levee height ought to be remade with detail hydro-engineering survey in arrange to avoid future immersion.

Rahul Agarwal et al. (2016) unsteady flow analysis in lower Dudhana river using HEC-RAS. Calculation of surface water elevations on downstream side of upper catchment of Dudhana Stream for diverse sum of releases additionally incorporates assurance of flooding zone at distinctive amount of the discharge for different time arrangement from dam. Consequently, stimulate the basic circumstance of flood and its affect on Dudhana River basin on downstream side. Study reach consists of 21 cross sections.

Steady and Unsteady flow was effectively run for Dudhana Stream and 3D view of discerning plot for single discharge for given study zones. The execution of calibrated show has been confirmed for previous discharges from dam in last year records. Moreover, model can be geo-referenced with Google earth and flooding can be highlighted on Google map.

Adebayo Kehinde John (2017) has done a case study on Eleyele catchment area. He determined the flood plain map and run off computation using Geographic information system (GIS). Five maps which includes topography map were generated i.e land use map, digital elevation model (DEM) map, Hydrology map, Triangulated irregular network (TIN) map which finally gives us the flood plain area.

The taking after conclusions were made based on the discoveries from this study that the geographical and DEM maps of Eleyele catchments appear that there's notable lower of heights within the southern portion of the catchment outline which has influenced the hydrological design of the catchment, the hydrological maps of Eleyele catchment appears streams were amassing within the lower locale of the catchment range, the surge plain outline created from the TIN of the study region appears that 50% of the Eleyele catchment region are inclined to surge and these ranges are strikingly of moo elevation.

Azhar Husain (2017) has done a Flood Modeling by using HEC-RAS. Right now steady and unsteady streams are available and silt transport is beneath improvement. A key element is that all three components will utilize a common geometric information representation and common geometric and hydraulic computation schedules. In addition to the three hydraulic investigation components, the framework contains a few hydraulic design features that can be conjured once the fundamental water surface profiles are computed. The main objective is to supply an surge control system in which all computations made by the different territorial included in river training.

The output from the HEC-RAS model was utilized to decide the degree of overtopping of bridges/barrages within the study reach when subjected to surge of a given magnitude. With increased stream flows at distinctive areas within the future, the vulnerability of the basin to high magnitude flooding events is likely to extend beneath future climatic change within the River basin framework.

Thet Hnin Aye et al. (2017) has developed a Flood Inundation Map for Bago River Basin, Myanmar. In arrange to perform waterway flood risk mapping, HECHMS and HEC-RAS were utilized as hydrological and hydraulic models, individually. Three flood events were connected to calibrate and approve the come about. The most elevated profundity of immersion can seriously affect the upper portion of Bago city zones and downstream country ranges counting the paddy areas.

In this study, the investigation embraced illustrated that the model is right now at the restrain of prescient capacity for flood immersion, but the results of calibration and approval indicated acceptable comes about in recreating the surge occasions. The results of the hydrologic demonstrate may be encourage moved forward by installing a thick arrange of gaged stations. They accept the data inferred from this study can contribute to evaluating the plausibility of surge harm for the neighborhood population and for those locations where information is constrained, such as in Myanmar.

Amina Azouagh et al. (2018) has done a study on Integration of GIS and HEC-RAS in Floods Modeling of Martil River (Northern Morocco) using HEC-RAS. This investigation, therefore, presents flood mapping and classification of hazard regions utilizing the Hec-GeoRas and Hec-Ras hydraulic demonstrating devices integrated into the Arcgis information framework. The outcome demonstrate that the utilize of aerial photographs provides a great information of the morphology and physical characteristics of the waterway, which is able offer assistance choice creators to prevent flooding in the urban range of Tetuan, Morocco.

The overall outcomes permitted to find flood zones, velocities and heights of water, etc. These results are dependable and are steady with the morphology of the field. The study region has experienced significant rebuilding amid the last twenty a long time in parallel with the improvement of mindfulness of the flood issue: bridges, dams, tunnels, recovery of the river and its tributaries have been built, however it only takes a stormy day for the roads and neighborhoods to be submerged in water permitting panic to set in again.

Shayannejad M et al. (2018) has done an analysis on open channel networks using HEC-RAS. In this paper, an illustration was solved in unsteady stream utilizing HEC-RAS. In this procedure, the energy and duration equations are chosen for consistent, gradually differing stream by the Newton–Raphson procedure and the advertised technique is utilized to tree-type and looped-channel systems.

Results obtained from HEC-RAS model were connected in compound with ArcGIS to provide floodplain maps for variation return cycles. Hydrologic procedures are strategies that clarify the computation of flow circumstances in a channel reach. Routed hydrographs for standard and composed channels are at that point contrasted with a river analysis system model (HEC-RAS). Those output obtained shows that the recommended model (HEC-RAS) procedure is useful in directing a organize hydrograph.

Avanti Waghchaure et al. (2020) have done a flood modeling and flood forecasting using HEC-RAS. The flood prediction of Mutha Stream utilizing HEC-RAS has talked about in this paper. In Maharashtra, Pune city faces issues of floods and harms amid rainstorm. Forecast of stage of stream amid the surge requires scientific modeling of the river. The study speaks to the significance of 2D modeling of surge issues which makes a difference to create administration techniques to handle the likely future occasions by employing flood chance reducing measures.

This paper presents a technique for modeling and forecasting of surge caused due to numerous reasons like heavy rainfall, destitute stream basin, and need of space for water flow in riverbed due to urbanization. The result table of hydraulic properties and all profile plots can too be utilized in future arranging of developmental works. Display circumstance of stream basin shows that it will not be able to carry tremendous surge. So it is very critical to extend estimate of waterway.

Raymond Diedhiou et al. (2020) has done a case of Senegal River Estuary Downstream Diama Dam. The study carries out the hydraulic modeling of the estuary of Senegal stream downstream of the Diama Dam in transitory mode by the HEC-RAS computer program. The primary geometric model, of which the regions of Senegal stream downstream Diama Dam have been represented by cross-section, is one-dimensional. The second one is also one dimensional in which the region of the Senegal Stream estuary downstream Diama Dam is presented as water capacity zones.

The outcomes obtained from HEC-RAS simulations are the varieties of the water levels, the transient variations of the flow rates for each segment, the most extreme stream velocities and the engendering times of the flood waves. These results are solid and steady with the morphology of the estuary. To oversee flood circumstances amid water discharges at the Diama dam, real-time water level checking and estimation gear should be introduced upstream of the dam. This demonstrates may be at that point can be utilized as a decision instrument by the concerned authorities.

CHAPTER 3

STUDY AREA and MATERIALS

3.1 STUDY AREA

The study area of interest spans from the iconic Umananda Island, through the serene town of Palashbari, to the picturesque area of Chhaygaon along the majestic Brahmaputra River in Assam, India. Situated at approximately 26°10′N latitude and 91°41′E longitude, this segment of the Brahmaputra epitomizes a harmonious blend of natural beauty, cultural heritage, and economic activity, contributing significantly to the region's identity and livelihoods.

Climatically, this stretch of the Brahmaputra River basin shares characteristics with its neighboring areas, falling under the humid subtropical climate regime. Summers are warm and humid, with average temperatures around 24°C, while winters bring milder, drier conditions with temperatures dropping to approximately 15°C. This climate nurtures a rich biodiversity and lush vegetation along the riverbanks, enhancing the area's scenic charm and ecological importance.

The topography surrounding this river segment is diverse, featuring hills, plains, and occasional riverine islands, offering a varied landscape that adds to the region's natural allure. Palashbari, located to the west of Guwahati city, serves as a tranquil retreat amidst the urban sprawl, boasting verdant surroundings and a serene ambiance that attracts visitors seeking solace in nature.

Compared to the bustling urban center of Guwahati, the population density in this area, particularly around Palashbari and Chhaygaon, is relatively lower, providing a peaceful rural atmosphere. However, like other areas along the Brahmaputra, flooding remains a concern during the monsoon season due to the river's fluctuating water levels and susceptibility to inundation.

Spanning approximately 60 kilometers from Umananda Island to Chhaygaon , this section of the Brahmaputra River holds both natural beauty and historical significance. Beyond its role as a vital transportation artery, the Brahmaputra in this stretch also serves as a cultural and recreational hub, hosting activities such as boating, fishing, and religious ceremonies along its banks.

In summary, the stretch of the Brahmaputra River from Umananda Island via Palashbari to Chhaygaon encapsulates a harmonious fusion of natural splendor, cultural heritage, and economic activity, shaping the socio-economic fabric of the region and offering diverse experiences to residents and visitors alike.

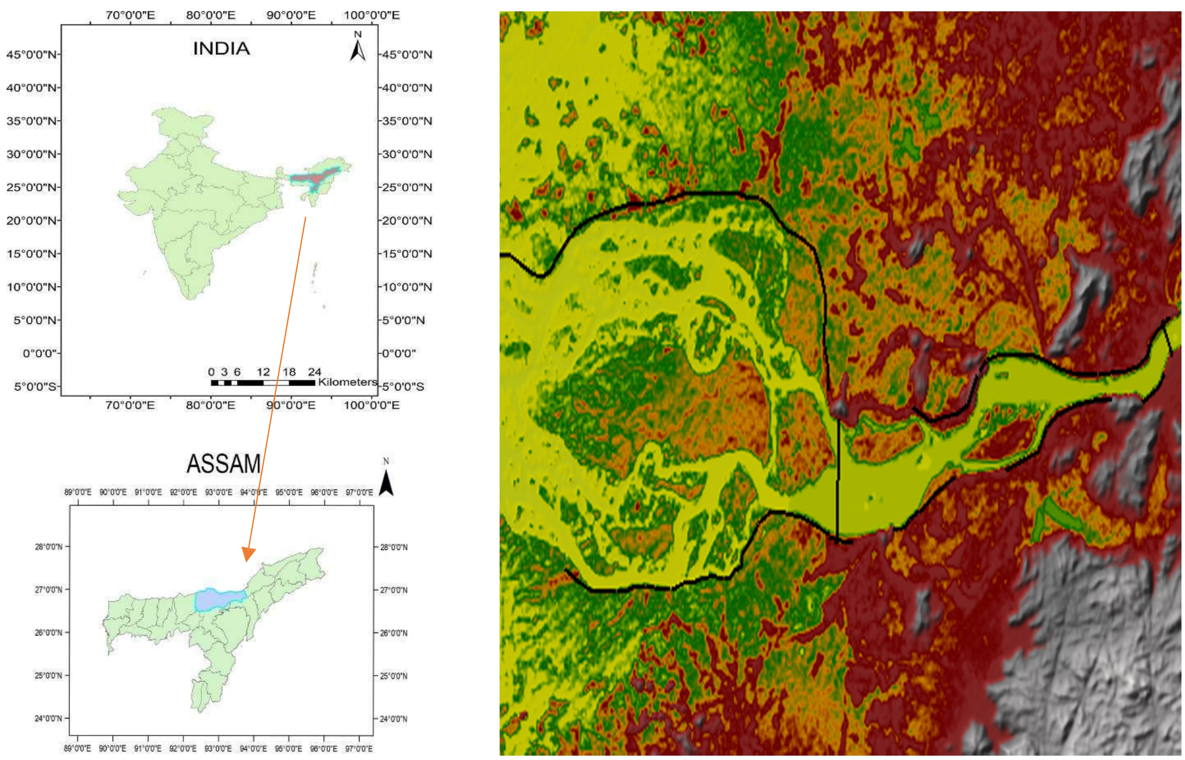


Fig 3.1: Brahmaputra River Basin Map

Fig 3.2: Study Area

3.2 MATERIALS:

3.2.1 Google Earth Pro- It is a free geospatial desktop application that allows you to see the world and create highly detailed maps. With Google Earth Pro, all users are now allowed to access high-quality and high-resolution aerial photography and ground images. Included with the bird's eye view of the planet, Google Earth Pro also provides a number of different tools and layers for exploring our green planet. Overall, we can say that Google Earth Pro is a competent and professional application that is easily available in the market. In this study, we will select the study area and determine the river centre lines which are then exported to ArcGIS for further use.

3.2.2 HEC-RAS– This software is developed by U.S Federal Government resources and is therefore in the public domain. HEC-RAS is a hydraulic model created by the Hydrologic Engineering Centre. The primary adaptation of HEC-RAS was created in 1990 and evolved from a steady flow model called HEC-2, first created in 1966. As computer capabilities moved forward, the HEC-2 computer program was changed over to the windows-based HEC-RAS computer program to assist water powered displaying with a graphical user interface (GUI). HEC-RAS is a coordinate framework of program, outlined for interactive utilization in a multi- tasking environment. The system is comprised of a GUI, separate investigation components, information capacity and administration capabilities, graphics and reporting facilities. It may be used, copied, distributed or redistributed freely. However it is requested that HEC should be given appropriate acknowledgement in any subsequent use of this work.

The fundamental computational strategy is based on the solution of the one- dimensional energy equation. Energy losses are assessed by friction (Manning's condition) and contraction and expansion. The Momentum equation is used in circumstance where the water surface profile is rapidly varied and Energy equation is only valid for gradually varied. These circumstances incorporate mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and assessing profiles at stream confluences (stream intersections).

HEC-RAS models can viably utilize to improve and simplify the forecasts of regions likely to be immersed beneath a given flood. The HEC-RAS model was at first utilized for calculating water surface profiles for 1D steady state flow. It provides the modeler with an option to utilize either the steady flow or unsteady flow option. Along with the unsteady and steady flow choices, the HEC-RAS model too gives the various capabilities such as modeling of open channel systems and single streams (both unsteady and steady flow alternatives), analysis of bridges, weirs, and culverts (unsteady and steady stream choices), displaying capacity zones, route dams, tunnels, pumping stations, and levee failures (unsteady flow option only), handling of subcritical, supercritical, and mixed-flow administrations (steady flow option only). In this study, the stream geometry has been imported from ArcGIS to HEC-RAS and after that it'll be further utilized to consider the stream characteristics for both steady and unsteady conditions such as finding discharge at distinctive cross section of the river, velocity of the river at distinctive areas, etc which can offer assistance in flood mapping.

3.2.3 Synthetic Unit Hydrograph- For formation of unit hydrograph (UH) the information about rainfall and the flood hydrograph is necessary. But , when catchment is at a remote location, the availability of such data is very rare. To construct UH for those regions empirical methods are used. The UH derived from these empirical equations is called Synthetic Unit Hydrograph (SUH). Such hydrographs are unique to specific regions only. There are various methods like CWC dimensionless approach, Synder method, Two parameter Gamma distribution method and Hybrid model. In this project the traditional method that is Synder's has been used .

3.2.4 Synder's Method- Synder had studied many catchments in United states of America (USA) and provided some empirical equations. The important characteristic of hydrograph at a catchment is basin lag. It is the time duration between centroid of the rainfall excess and the peak of the direct runoff hydrogaraph (DRH) this is dependent upon the size,shape, stream density length of main stream, slope and land use and land cover.

Here

L:Basin length measured along the water course from the basin divide to the basin length in km.

L_{ca} : Distance along the main water course from the gauging station to a point opposite to watershedcentroid.

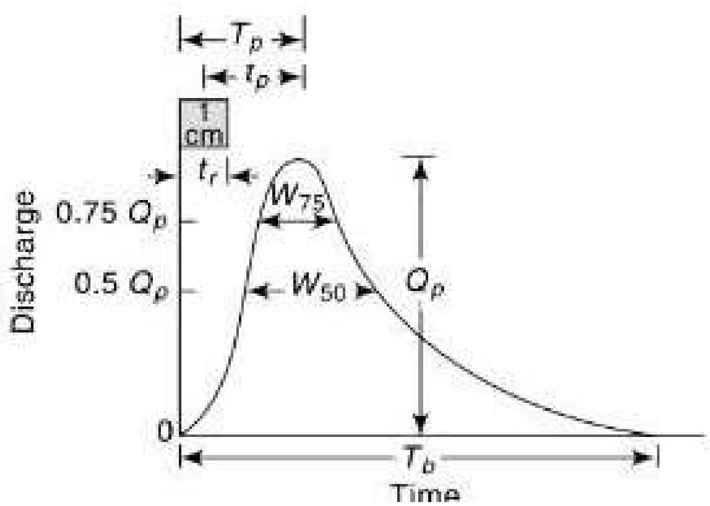


Figure 3.3: Rough sketch of SUH

The following equations are used to as per North Brahmaputra Subzone report be Central water Commission (CWC) compute the synthetic unit hydrograph with known values of A, L & S

(I) $q_p = 2.272(L*L_c/S)^{-.409}$:

(II) $t_p = 2.164(q_p)^{-.940}$:

(III) $W_{50} = 2.084(q_p)^{-1.065}$:

(IV) $W_{75} = 1.028(q_p)^{-1.071}$:

(V) $W_{R50} = .856(q_p)^{-.865}$:

(VI) $W_{R75} = .440(q_p)^{-.918}$:

(VII) $T_B = 5.428(t_p)^{.852}$:

(VIII) $t_m = t_p + t_r/2$:

(IX) $Q_p = q_p * A$:

Where q_p= Peak discharge of unit hydrograph per unit area in m^s/s per sq. km

t_p= Time from the centre of unit rainfall duration to the centre of unit hydrograph (hrs).

W_{50}= Width of the U.G measured at 50% peak discharge ordinate (Q_p) in hrs.

W_{75}= Width of the U.G measured at 75% peak discharge ordinate (Q_p) in hrs.

W_{R50} = Width of the rising side of U.G measured at 50% of peak discharge ordinate (Q_p)in hrs.

W_{R75} = Width of the rising side of U.G measured at 75% of peak discharge ordinate (Q_p)in hrs.

T_B = Base width of unit hydrograph in hrs.

T_m = Time from the start of rise to the peak of unit hydrograph in hrs.

Q_p = Peak discharge of unit hydrograph in cubic metres per second.

From the empirical formulas a some points of the unit hydrographs will be available. Plotting thosepoints in the graph paper and joining them through a smooth curve will provide the Synthetic Unit Hydrograph (SUH). The discharge ordinates available from the SUH for rainfall excess of t_r durationwhen multiplied it will provide the volume of water in the catchment. For the calculation of the volume another standard method is to multiply the area with the depth of flow. From the available area and the calculated volume the depth of flow will be calculated.

3.2.5 Estimation Of Design Storm

Design Storm Duration

The design storm in this work has been formulated as per the North Brahmaputra subzone report by CWC. As per section 3.1.0 the design storm T_D is taken as the T_B that is base width of the unit hydrograph. The design storm is the duration of the storm rainfall which cause the maximum discharge in a drainage basin .The design storm duration T_D which is equal to T_B is rounded off to nearest full hour for any specific site study.

Effective rainfall

The effective rainfall (ER) is that part of the rainfall that becomes direct runoff at the outlet of the watershed. It is that rainfall which is neither retained on the land surface nor infiltrated. This can be calculated by deducting the losses to rainfall due to initial storage, infiltration, etc. The report suggests that the As per cl. 2.3.0 report a design loss rate of 0.24cm/hr has to be adopted. The reduction of the loss rate from the hourly rainfall increment provides the effective rainfall for the basin.

Base flow

The base flow is the flow of water that comes from below the surface of the earth due to presence of some water sources. The report suggests a design base flow rate of $0.05cm^3/s/km^2$.

Critical Sequencing

To determine the peak discharge the effective rainfall units are arranged against the 1 hr synthetic unithydrograph ordinates such that the maximum value of effective rainfall comes against the peak discharge of synthetic unit hydrograph. The next lower value of effective rainfall units come against the next lower discharge ordinate and so on upto T_D hour duration. The sequence of effective rainfall then reversed so as to obtain the critical sequence of the effective rainfall.

The SUH then convoluted against the reversed effective rainfall and this provides direct surface runoffhydrograph (DSRO) for required return period. The DSRO with addition of base flow rate provides theflood hydrograph .

3.2.6 Gumbell's Distribution Method- Gumbel method is a consistent and exact flow forecasting method. It is a probability distribution function for extreme value in hydrologic and meteorological studies for prediction of flood peaks, maximum rainfalls, maximum wind speed etc.

The data of maximum flood peak of Brahmaputra River from 1990 to 2019 is available from from Water Resource Department.

.

3.2.7 Discharge Data: The discharge data of Brahmaputra River from 1990 to 2019 collected from Water Resource Department are shown in table 3.1

Table3.1: Discharge data of Brahmaputra River from 1990 to 2019 collected from Water Resource Department

YEAR	MAX FLOW IN cms
1990	48365.09
1991	43918.73
1992	37934.82
1993	44900
1994	31885.24
1995	45656.43
1996	39300
1997	42900
1998	54100
1999	38982.45
2000	32755.67
2001	35240.87
2002	38645.8
2003	32648.09
2004	36124.13
2005	45405.96
2006	40235.5
2007	32096
2008	38199.5
2009	46707.5
2010	28570.72
2011	26487.6
2012	33219.6
2013	31195.2
2014	33290.2
2015	36915.8
2016	35645.87
2017	31595.52
2018	32125.56
2019	26790.69

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION: The methodology used for preparation and assessment of Model is illustrated through the following FLOW CHART.

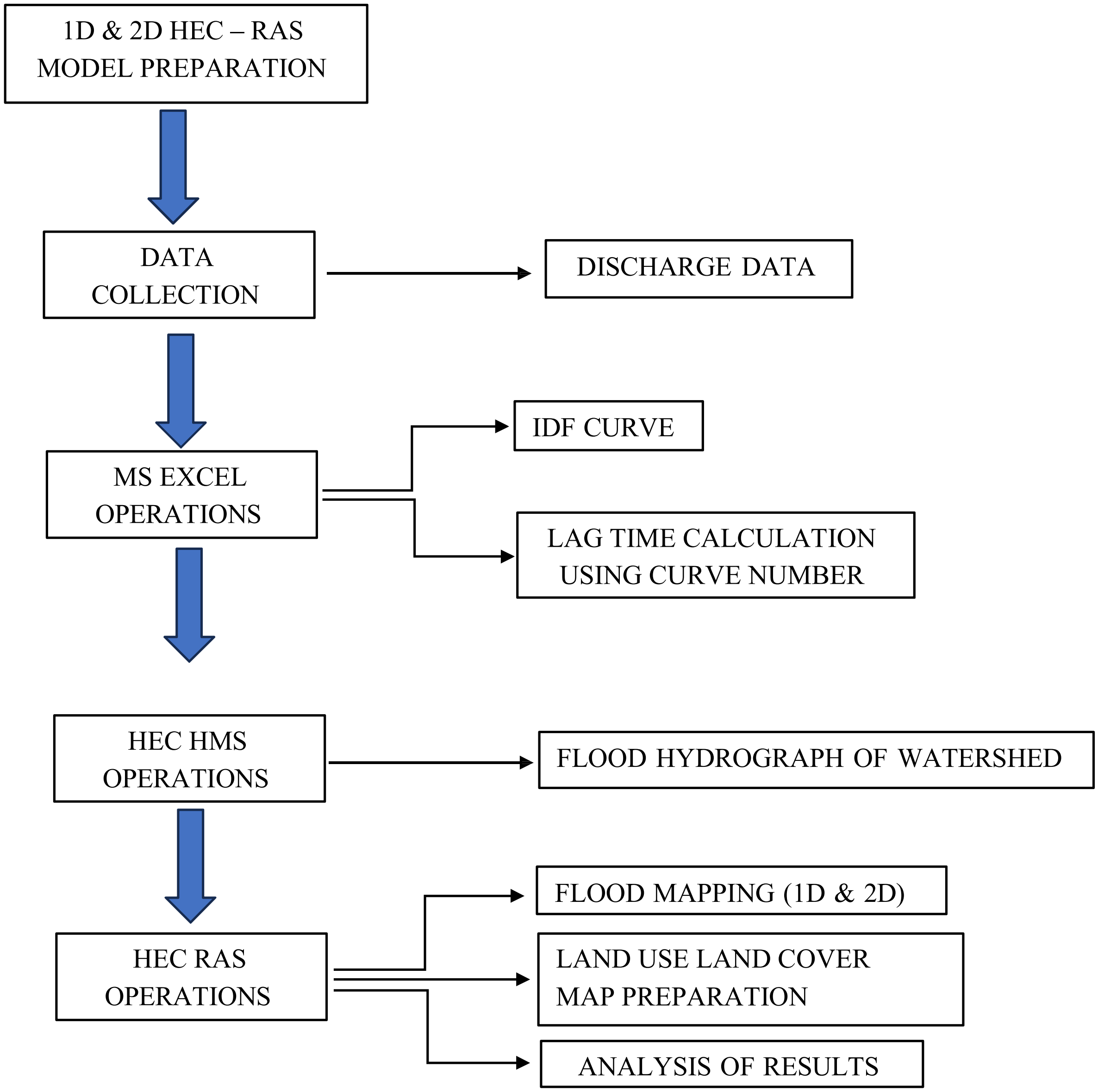


Fig 4.1: Operational Flowchart

4.2 OPERATIONS IN GOOGLE EARTH PRO:

By using Google Earth Pro software, the study area is selected and the center line of the river is marked.

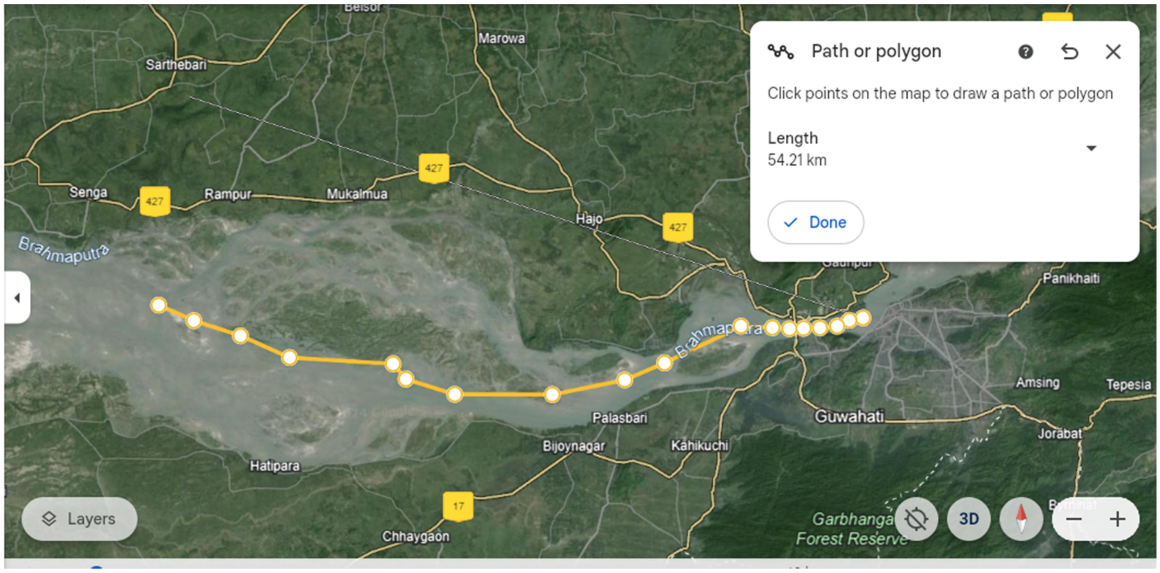


Fig 4.2: Centre Line of Brahmaputra River in Google Earth Pro

4.3 LAND USE LAND COVER:

Land use and land cover are terms used in geography and environmental studies to describe the way land is utilized by humans and the type of natural and artificial features that cover the Earth's surface.

1. **Land Use**: This refers to the human activities and purposes that land is designated for. It includes various categories such as residential, commercial, industrial, agricultural, recreational, and more. Land use helps us understand how different areas are developed and utilized based on societal and economic needs.

2. **Land Cover**: This term describes the physical and biological material found on the Earth's surface, including both natural and artificial elements. Examples of land cover categories are forests, grasslands, water bodies, urban areas, barren land, and more. Land cover data helps us understand the extent of various types of surfaces on the planet.

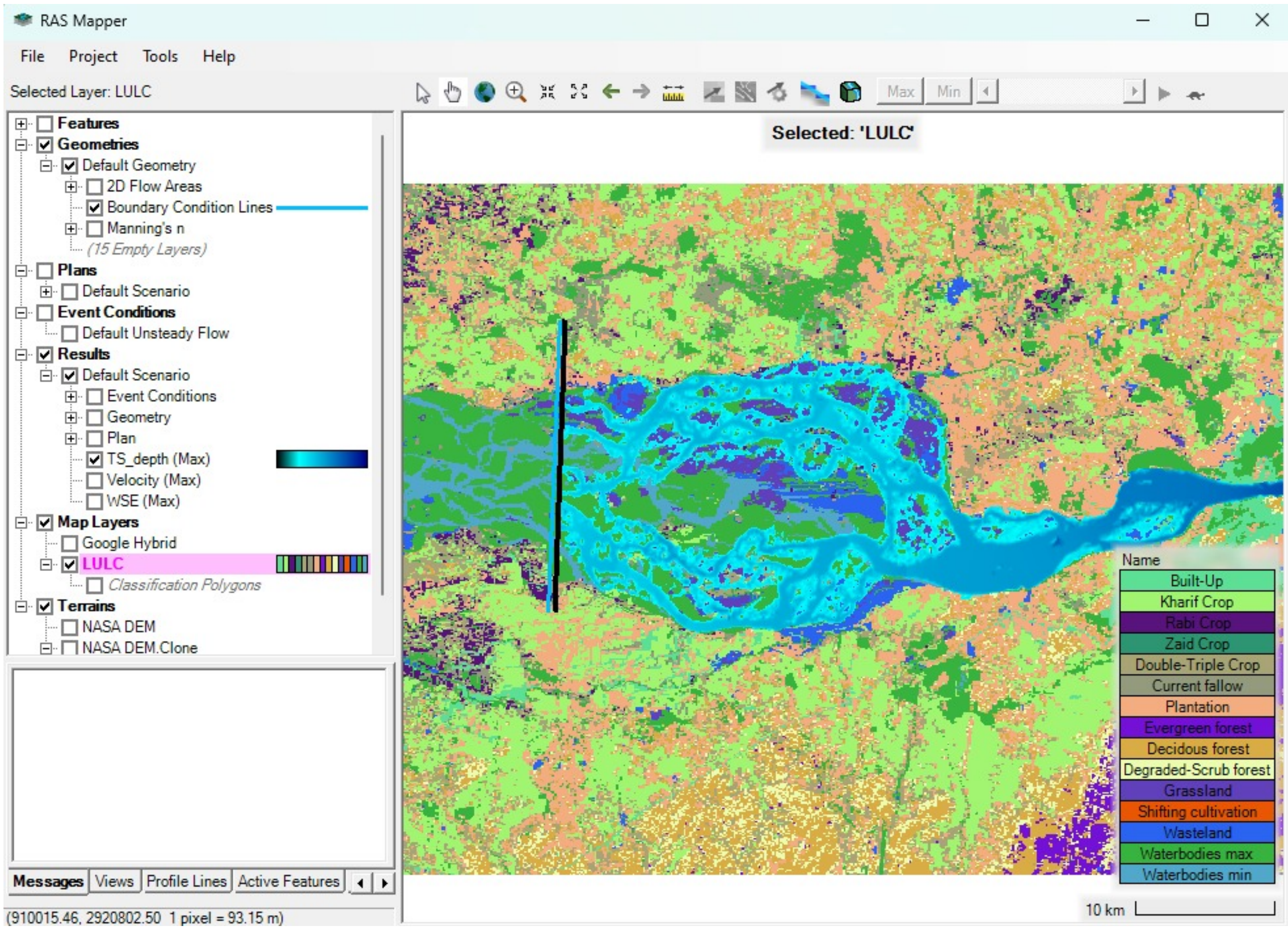


Fig 4.3: Land Use Land Cover Map Obtained From HEC-RAS

4.4 OPERATION IN MS EXCEL:

1) Gumbel Method for Flood Frequency Analysis:

The 2D hydrodynamic simulation provides information on hydraulic parameters such as water surface elevation, velocity, and flow depth at a different location in the computational domain. The flood frequency analysis is done by using Gumbel's method for the annual peak streamflow data for a period of 1956-2017, to calculate the discharges at three different return periods, mainly 25 years, 50 years, and 100 years. It is also known as the Generalized Extreme Value distribution method. The discharge corresponding to the above mentioned return periods are calculated using frequency analysis. The observed data is fitted to Gumbel's distribution and the discharge is calculated using the general equation of frequency analysis, given by

$$x_T = x + K_T \times S \quad \text{---- Eqn no 4.1}$$

Where, x_T = Design intensity for a particular duration and a particular return period

x = Mean of the annual maximum for a particular duration

S = Standard Deviation of the annual maximum for a particular duration

K_T = Frequency factor

Extreme value type I (EV-I) distribution, also known as Gumbel's distribution, is a limiting probability distribution which is used to model the maximum or minimum values from a sample of independent, identically distributed random variables, as the size of the sample increases. Frequency factor (K_T) is determined by the standard equation derived from Gumbel's distribution function as,

$$K_T = -\frac{\sqrt{6}}{\pi}\left\{0.5772 + \ln\left(\ln\left(\frac{T}{T-1}\right)\right)\right\} \quad \text{---- Eqn no 4.2}$$

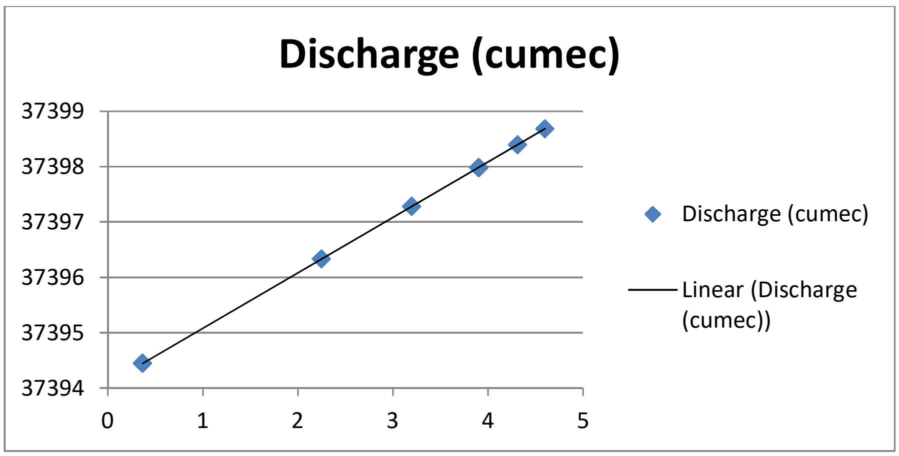
The K_T values are a function of return period only as can be observed from equation 2. The K_T for the return periods is calculated as mentioned in Table 2.1. To Obtain Flood Hyetograph and IDF curve for different return Period.

Table 4.1 Frequency factor (K_T) values for different return periods.

	2 YEAR	10 YEAR	25 YEAR	50 YEAR	75 YEAR	100 YEAR
Y_T	0.366513	2.250367	3.198534	3.901939	4.310784	4.600149
K_T	-0.15254	1.540963	2.393325	3.025655	3.39319	3.653316

Table 4.2: GUMBEL DISTRIBUTION

Time (years)	Reduced Mean	Reduced Standard Dev	Mean	Standard Dev	YT	K	Discharge (cumec)
2	0.5362	1.1124	39394.6	6746.414975	0.366513	-0.15254	39394.4483
10	0.5362	1.1124	39394.6	6746.414975	2.250367	1.540963	39396.3322
25	0.5362	1.1124	39394.6	6746.414975	3.198534	2.393325	39397.2803
50	0.5362	1.1124	39394.6	6746.414975	3.901939	3.025655	39397.9837
75	0.5362	1.1124	39394.6	6746.414975	4.310784	3.39319	39398.3926
100	0.5362	1.1124	39394.6	6746.414975	4.600149	3.653316	39398.6819



2) Design Flood By Synthetic Unit Hydrograph (SUH) Approach

Derivation of 1 hour synthetic unit hydrograph parameters

For the formation of synthetic unit hydrograph, already available data are area (A), Basin length measured along the water course from the basin divide to the gauging station in km (L), Basin slope(S).

As per cl. 3 of North Brahmaputra subzone 2(a) report by Central Water Commission, To estimate an 1 hr unit hydrograph in this zone following relationships will be used

Table 4.3: Available data for developing synthetic Unit hydrograph

Available Data		
Parameter	Value	Unit
L	49	km
Lc	25.08	km
Slope	10.33	m/km
Area	2896.1	sq km

Table 4.4: Determination of parameters of SUH

Sl. No	Parameter	Formula	Value	Value considered
1	q_p	$2.272\left(\frac{L \times L_c}{S}\right)^{-0.409}$	0.49	0.49
2	t_p	$2.164(q_p)^{-0.940}$	4.42	4.42
3	W_{50}	$2.084(q_p)^{-1.065}$	4.45	4.5
4	W_{75}	$1.028(q_p)^{-1.071}$	2.21	2.2
5	W_{R50}	$0.856(q_p)^{-0.865}$	1.59	1.6
6	W_{R75}	$0.440(q_p)^{-0.918}$	0.85	0.9
7	T_B	$5.428(t_p)^{0.852}$	23.89	24
8	t_m	$t_p + \frac{t_r}{2}$	4.92	5
9	Q_p	$q_p \times A$	1419.1	1420

Where

q_p= Peak discharge of unit hydrograph per unit area in m^3/s s per sq. km

t_p= Time from the centre of unit rainfall duration to the centre of unit hydrograph (hrs).

W_{50}= Width of the U.G measured at 50% peak discharge ordinate (Q_p) in hrs.

W_{75}= Width of the U.G measured at 75% peak discharge ordinate (Q_p) in hrs.

W_{R50}= Width of the rising side of U.G measured at 50% of peak discharge ordinate (Q_p) in hrs.

W_{R75}= Width of the rising side of U.G measured at 75% of peak discharge ordinate (Q_p) in hrs.

T_B= Base width of unit hydrograph in hrs.

T_m= Time from the start of rise to the peak of unit hydrograph in hrs. Q_p= Peak discharge of unit hydrograph in cubic metres per second.

Table 4.5 : Ordinates of SUH

TIME IN HOURS	ORDINATES OF SUH(CUMEC)
0	0
1	452
2	810
3	1188
4	1372
5	1420
6	1393
7	1299
8	1205
9	1104
10	1046
11	943
12	815
13	725
14	590
15	475
16	362
17	285
18	212
19	186
20	130
21	103.2
22	75
23	35
24	0

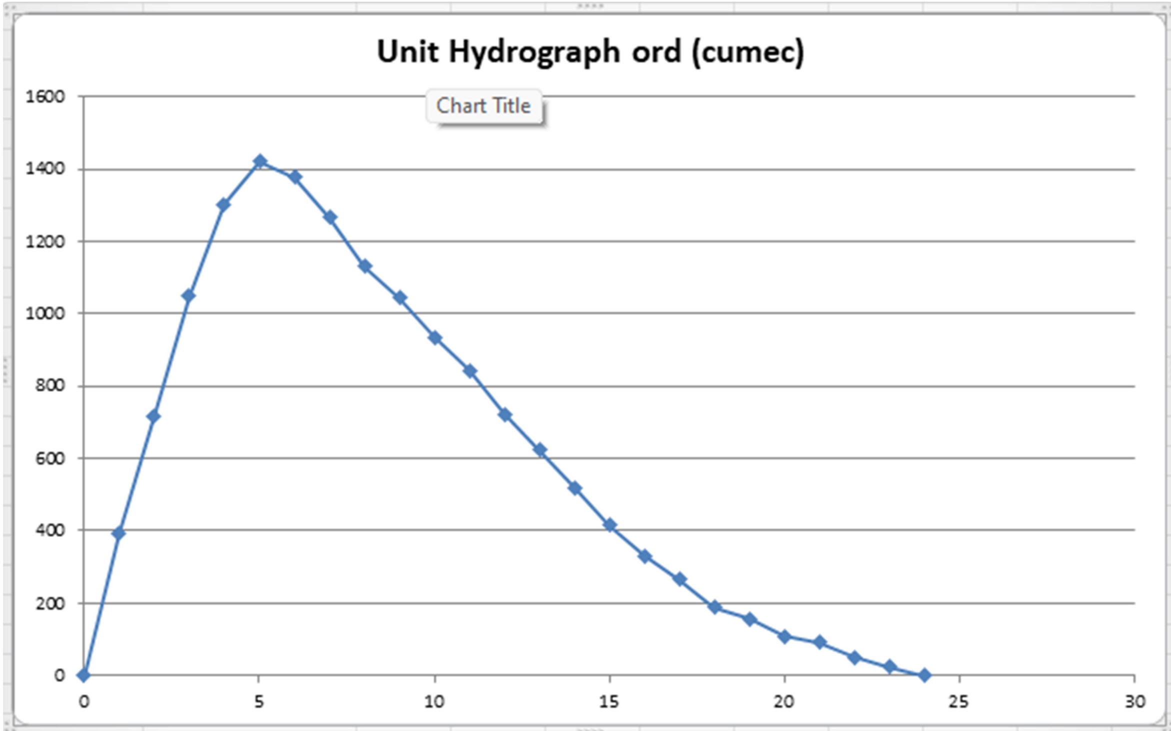


Figure 4.4: Synthetic unit Hydrograph of Brahmaputra watershed

2.1) 100 Years Of Flood Estimation

i. **Calculation of Point rainfall to areal rainfall**

As per Cl. 3.1.1 of North Brahmaputra subzone report the $T_D = T_B$, which is equal to 24 hours.T_D= 24 hour. Based on subzone report

100 years 24 hr point rainfall = 36 cm (as per plate 9 of North Brahmaputra subzone report)

Table 4.6: Calculation to determine Hourly rainfall increment Estimation of effective rainfall unit

As per cl. 2.3.0 North Brahmaputra subzone 2(a) report a design loss rate of 0.20 cm/hr has been adopted.

Duration of Rainfall (hr)	Distribution factor	24 Hr Rainfall (C=cm)	Areal rainfall (cm)	Hourly rainfall Increment (cm)
1	0.13	36	4.68	4.68
2	0.25	36	9	4.32
3	0.32	36	11.52	2.52
4	0.4	36	14.4	2.88
5	0.47	36	16.92	2.52
6	0.52	36	18.72	1.8
7	0.56	36	20.16	1.44
8	0.61	36	21.96	1.8
9	0.65	36	23.4	1.44
10	0.69	36	24.84	1.44
11	0.73	36	26.28	1.44
12	0.76	36	27.36	1.08
13	0.79	36	28.44	1.08
14	0.81	36	29.16	0.72
15	0.84	36	30.24	1.08
16	0.86	36	30.96	0.72
17	0.88	36	31.68	0.72
18	0.9	36	32.4	0.72
19	0.92	36	33.12	0.72
20	0.93	36	33.48	0.36
21	0.95	36	34.2	0.72
22	0.97	36	34.92	0.72
23	0.98	36	35.28	0.36
24	1	36	36	0.72
			TOTAL	**31.32**

The design loss rate of 0.20 cm/hr is subtracted from the 1 hr rainfall increment to obtain the 1 hr effective rainfall.

Table 4.7: Determination of 1 hour effective rainfall

Time	Hourly rainfall Increment (cm)	Design loss rate (cm/hr)	1 hr effective rainfall(cm)
1	4.68	0.2	4.48
2	4.32	0.2	4.12
3	2.52	0.2	2.32
4	2.88	0.2	2.68
5	2.52	0.2	2.32
6	1.8	0.2	1.6
7	1.44	0.2	1.24
8	1.8	0.2	1.6
9	1.44	0.2	1.24
10	1.44	0.2	1.24
11	1.44	0.2	1.24
12	1.08	0.2	0.88
13	1.08	0.2	0.88
14	0.72	0.2	0.52
15	1.08	0.2	0.88
16	0.72	0.2	0.52
17	0.72	0.2	0.52
18	0.72	0.2	0.52
19	0.72	0.2	0.52
20	0.36	0.2	0.16
21	0.72	0.2	0.52
22	0.72	0.2	0.52
23	0.36	0.2	0.16
24	0.72	0.2	0.52

3)Estimation of base flow: As per cl. 2.4, North Brahmaputra subzone 2(a) report a designbase flow of 0.05 $cm^3/s/km^2$ has been adopted.

Total base flow= Area x Rate of base flow ---- Eqn no 4.3

= 2896.1x 0.05

= 144.805 cm^3/s

4)**Critical sequencing of 100 years for Brahmaputra**

To determine the peak discharge the effective rainfall units are arranged against the 1 hr synthetic unit hydrograph ordinates such that the maximum value of effective rainfall comes against the peak discharge of synthetic unit hydrograph. The next lower value of effective rainfall units come against the next lower discharge ordinate and so on upto T_D hour duration. The sequence of effective rainfall then reversed so as to obtain the critical sequence of the effective rainfall.

Table 4.8: Critical sequencing of 100 years flood

Time	U.G ordinate (m^3/s)	1hr.effective rainfall (cm)	Reversed Effective rainfal (cm)	Direct runoff (m^3/s)
1	452	2.32	0.52	1048.64
2	810	2.68	0.52	2170.8
3	1188	2.68	0.52	3183.84
4	1372	4.12	0.52	5652.64
5	1420	4.48	0.52	6361.6
6	1393	4.12	0.88	5739.16
7	1299	2.68	0.88	3481.32
8	1205	2.68	0.88	3229.4
9	1104	2.32	0.88	2561.28
10	1046	2.32	1.24	2426.72
11	943	1.6	1.24	1508.8
12	815	1.6	1.24	1304
13	725	1.24	1.6	899
14	590	1.24	1.6	731.6
15	475	1.24	2.32	589
16	362	0.88	2.32	318.56
17	285	0.88	2.68	250.8
18	212	0.88	2.68	186.56
19	186	0.88	4.12	163.68
20	130	0.52	4.48	67.6
21	103.2	0.52	4.12	53.664
22	75	0.52	2.68	39
23	35	0.52	2.68	18.2
24	0	0.52	2.32	0
			TOTAL	41985.864
			Base flow	144.805
			TOTAL FLOW	42130.669

TIME	UG ORDINATES	0.52	0.52	0.52	0.52	0.52	0.88	0.88	0.88	0.88	1.24	1.24	1.24	1.6	1.6	2.32	2.32	2.68	2.68	4.12	4.48	4.12	2.68	2.68	2.32	TOTAL DSRO	BASE FLOW	TOTAL FLOW
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**
0	0	0																								0	144.805	**144.805**
1	452	235.04	0																							687.04	144.805	**831.845**
2	810	421.2	235.04	0																						1466.24	144.805	**1611.045**
3	1188	617.76	421.2	235.04	0																					2462	144.805	**2606.805**
4	1372	713.44	617.76	421.2	235.04	0																				3359.44	144.805	**3504.245**
5	1420	738.4	713.44	617.76	421.2	235.04	0																			4145.84	144.805	**4290.645**
6	1393	724.36	738.4	713.44	617.76	421.2	397.76	0																		5005.92	144.805	**5150.725**
7	1299	675.48	724.36	738.4	713.44	617.76	712.8	397.76	0																	5879	144.805	**6023.805**
8	1205	626.6	675.48	724.36	738.4	713.44	1045.44	712.8	397.76	0																6839.28	144.805	**6984.085**
9	1104	574.08	626.6	675.48	724.36	738.4	1207.36	1045.44	712.8	397.76	0															7806.28	144.805	**7951.085**
10	1046	543.92	574.08	626.6	675.48	724.36	1249.6	1207.36	1045.44	712.8	560.48	0														8966.12	144.805	**9110.925**
11	943	490.36	543.92	574.08	626.6	675.48	1225.84	1249.6	1207.36	1045.44	1004.4	560.48	0													10146.56	144.805	**10291.365**
12	815	423.8	490.36	543.92	574.08	626.6	1143.12	1225.84	1249.6	1207.36	1473.12	1004.4	560.48	0												11337.68	144.805	**11482.485**
13	725	377	423.8	490.36	543.92	574.08	1060.4	1143.12	1225.84	1249.6	1701.28	1473.12	1004.4	723.2	0											12715.12	144.805	**12859.925**
14	590	306.8	377	423.8	490.36	543.92	971.52	1060.4	1143.12	1225.84	1760.8	1701.28	1473.12	1296	723.2	0										14087.16	144.805	**14231.965**
15	475	247	306.8	377	423.8	490.36	920.48	971.52	1060.4	1143.12	1727.32	1760.8	1701.28	1900.8	1296	1048.64	0									15850.32	144.805	**15995.125**
16	362	188.24	247	306.8	377	423.8	829.84	920.48	971.52	1060.4	1610.76	1727.32	1760.8	2195.2	1900.8	1879.2	1048.64	0								17809.8	144.805	**17954.605**
17	285	148.2	188.24	247	306.8	377	717.2	829.84	920.48	971.52	1494.2	1610.76	1727.32	2272	2195.2	2756.16	1879.2	1211.36	0							20137.48	144.805	**20282.285**
18	212	110.24	148.2	188.24	247	306.8	638	717.2	829.84	920.48	1368.96	1494.2	1610.76	2228.8	2272	3183.04	2756.16	2170.8	1211.36	0						22614.08	144.805	**22758.885**
19	186	96.72	110.24	148.2	188.24	247	519.2	638	717.2	829.84	1297.04	1368.96	1494.2	2078.4	2228.8	3294.4	3183.04	3183.84	2170.8	1862.24	0					25842.36	144.805	**25987.165**
20	130	67.6	96.72	110.24	148.2	188.24	418	519.2	638	717.2	1169.32	1297.04	1368.96	1928	2078.4	3231.76	3294.4	3676.96	3183.84	3337.2	2024.96	0				29624.24	144.805	**29769.045**
21	103.2	53.664	67.6	96.72	110.24	148.2	318.56	418	519.2	638	1010.6	1169.32	1297.04	1766.4	1928	3013.68	3231.76	3805.6	3676.96	4894.56	3628.8	1862.24	0			33758.344	144.805	**33903.149**
22	75	39	53.664	67.6	96.72	110.24	250.8	318.56	418	519.2	899	1010.6	1169.32	1673.6	1766.4	2795.6	3013.68	3733.24	3805.6	5652.64	5322.24	3337.2	1211.36	0		37339.264	144.805	**37484.069**
23	35	18.2	39	53.664	67.6	96.72	186.56	250.8	318.56	418	731.6	899	1010.6	1508.8	1673.6	2561.28	2795.6	3481.32	3733.24	5850.4	6146.56	4894.56	2170.8	1211.36	0	40152.824	144.805	**40297.629**
24	0	0	18.2	39	53.664	67.6	163.68	186.56	250.8	318.56	589	731.6	899	1304	1508.8	2426.72	2561.28	3229.4	3481.32	5739.16	6361.6	5652.64	3183.84	2170.8	1048.64	41985.864	144.805	**42130.669**
25			0	18.2	39	53.664	114.4	163.68	186.56	250.8	448.88	589	731.6	1160	1304	2187.76	2426.72	2958.72	3229.4	5351.88	6240.64	5850.4	3676.96	3183.84	1879.2	42045.304	144.805	**42190.109**
26				0	18.2	39	90.816	114.4	163.68	186.56	353.4	448.88	589	944	1160	1890.8	2187.76	2803.28	2958.72	4964.6	5819.52	5739.16	3805.6	3676.96	2756.16	40710.496	144.805	**40855.301**
27					0	18.2	66	90.816	114.4	163.68	262.88	353.4	448.88	760	944	1682	1890.8	2527.24	2803.28	4548.48	5398.4	5351.88	3733.24	3805.6	3183.04	38146.216	144.805	**38291.021**
28						0	30.8	66	90.816	114.4	230.64	262.88	353.4	579.2	760	1368.8	1682	2184.2	2527.24	4309.52	4945.92	4964.6	3481.32	3733.24	3294.4	34979.376	144.805	**35124.181**
29						0	0	30.8	66	90.816	161.2	230.64	262.88	456	579.2	1102	1368.8	1943	2184.2	3885.16	4686.08	4548.48	3229.4	3481.32	3231.76	31537.736	144.805	**31682.541**
30						0	0	0	30.8	66	127.968	161.2	230.64	339.2	456	839.84	1102	1581.2	1943	3357.8	4224.64	4309.52	2958.72	3229.4	3013.68	27971.608	144.805	**28116.413**
31						0	0	0	0	30.8	93	127.968	161.2	297.6	339.2	661.2	839.84	1273	1581.2	2987	3651.2	3885.16	2803.28	2958.72	2795.6	24485.968	144.805	**24630.773**
32						0	0	0	0	0	43.4	93	127.968	208	297.6	491.84	661.2	970.16	1273	2430.8	3248	3357.8	2527.24	2803.28	2561.28	21094.568	144.805	**21239.373**
33						0	0	0	0	0	0	43.4	93	165.12	208	431.52	491.84	763.8	970.16	1957	2643.2	2987	2184.2	2527.24	2426.72	17892.2	144.805	**18037.005**
34						0	0	0	0	0	0	0	43.4	120	165.12	301.6	431.52	568.16	763.8	1491.44	2128	2430.8	1943	2184.2	2187.76	14758.8	144.805	**14903.605**
35						0	0	0	0	0	0	0	0	56	120	239.424	301.6	498.48	568.16	1174.2	1621.76	1957	1581.2	1943	1890.8	11951.624	144.805	**12096.429**
36						0	0	0	0	0	0	0	0	0	56	174	239.424	348.4	498.48	873.44	1276.8	1491.44	1273	1581.2	1682	9494.184	144.805	**9638.989**
37						0	0	0	0	0	0	0	0	0	0	81.2	174	276.576	348.4	766.32	949.76	1174.2	970.16	1273	1368.8	7382.416	144.805	**7527.221**
38						0	0	0	0	0	0	0	0	0	0	0	81.2	201	276.576	535.6	833.28	873.44	763.8	970.16	1102	5637.056	144.805	**5781.861**
39						0	0	0	0	0	0	0	0	0	0	0	0	93.8	201	425.184	582.4	766.32	568.16	763.8	839.84	4240.504	144.805	**4385.309**
40						0	0	0	0	0	0	0	0	0	0	0	0	0	93.8	309	462.336	535.6	498.48	568.16	661.2	3128.576	144.805	**3273.381**
41						0	0	0	0	0	0	0	0	0	0	0	0	0	0	144.2	336	425.184	348.4	498.48	491.84	2244.104	144.805	**2388.909**
42						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	156.8	309	276.576	348.4	431.52	1522.296	144.805	**1667.101**
43						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144.2	201	276.576	301.6	923.376	144.805	**1068.181**
44						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93.8	201	239.424	534.224	144.805	**679.029**
45						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93.8	174	267.8	144.805	**412.605**
46						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81.2	81.2	144.805	**226.005**
47						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144.805	**144.805**

Figure 4.9: Determination of 100 years flood Hydrograph

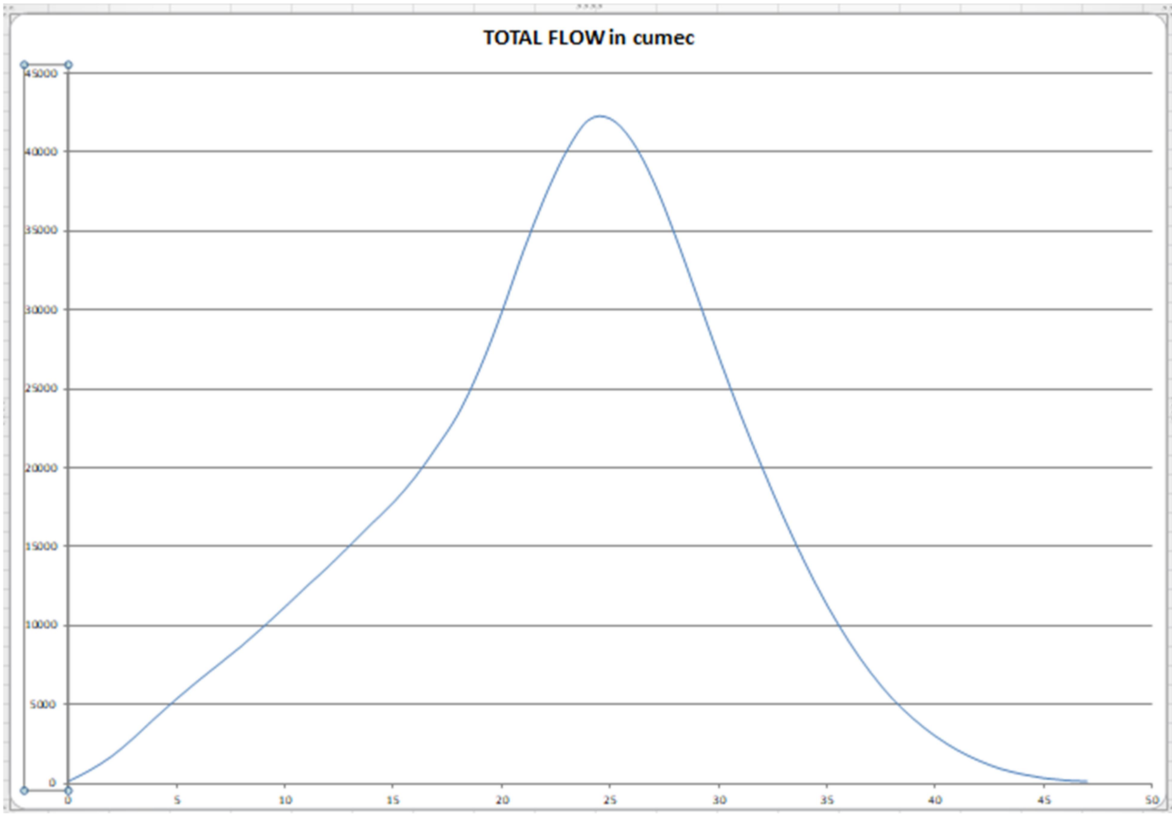


Figure 4.5: 100 years flood and Hydrograph

From the Unit hydrograph method and the Gumbell's Distribution the Maximum flood in m3 is found out for return period of 100 years. The Unit hydrograph method starts with the development of synthetic unit hydrograph SUH. The design storm is selected based on CWC report on North Brahmaputra Basin (subzone 2a). The limitation of the SUH method is the selection of design storm is not based on observed data and rather on the basis of isohytal map of CWC. The Gumbel distribution method is based on observed discharge data of the Brahmaputra Riverriver from 1990 to 2019.

Return period	Unit hydrograph method	Gumbel Extreme value method
100 years	42130.71 cumec	39398.68cumec

Since, unit hydrograph method provided the highest value amongst the three methods, therefore, 42130.71 m3/s may be considered for 100 year return period flood respectively for planning and design purpose of the project.

4.5 OPERATIONS IN HEC-RAS (1D MODEL):

The following are the general steps for performing a one-dimensional (1D) hydraulic modelling using HEC-RAS:

1) <u>Create a new project in HEC-RAS</u>: Launch the HEC-RAS program and create a new project. Select SI units of measurement. We then digitize the river centreline, and specify the river reach that we want to model. The DEM which is saved using ARC Map is imported in HEC RAS using the RAS Mapper feature of the software.
2) <u>Downloading and Assigning Projection to the DEM:</u> Digital elevation Models (DEM) file was downloaded from NASA SRTM 30 m Resolution . Projection File is also downloaded from spatial reference .org and applied in the terrain model. The Clipped DEM is now given a suitable projection based on the location of the river i.e. WGS 1984 having a UTM Zone of 46 N . .

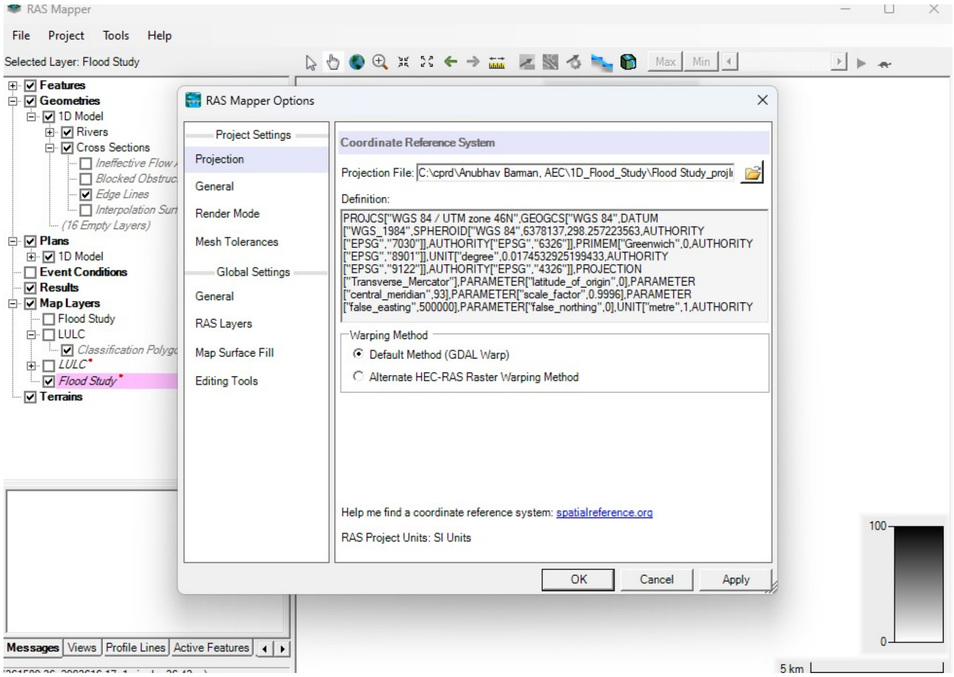


Fig 4.6: Applying Projection to the Terrain in RAS Mapper

3) <u>Define the geometry of the river</u>: The RAS Mapper of HEC-RAS allows us to define cross-sections, banks, and floodplains for your river. After defining the cross-sections, we can set the channel shape, bank stations, and the floodplain geometry.

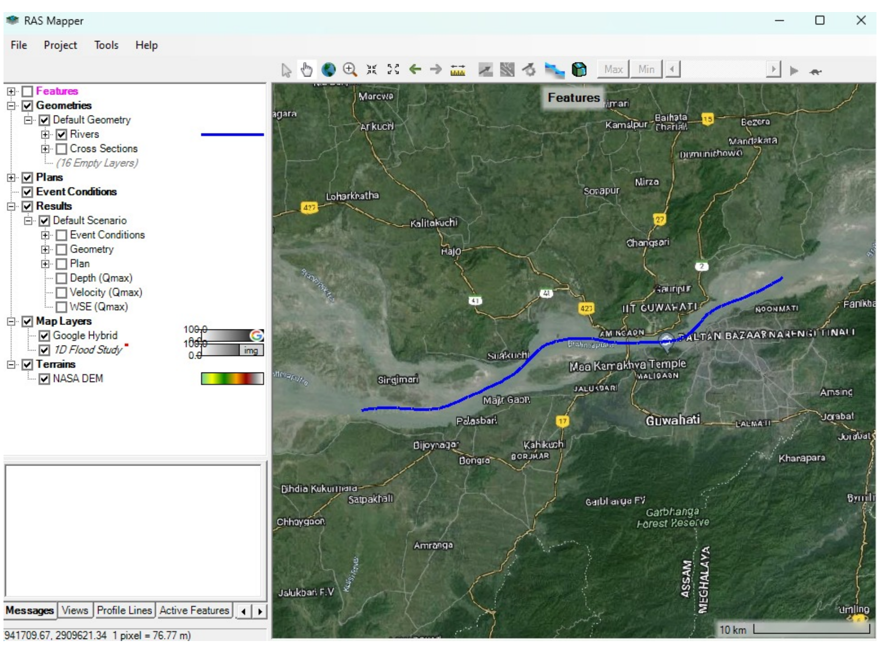


Fig 4.7: Marking centreline of the river in RAS Mapper

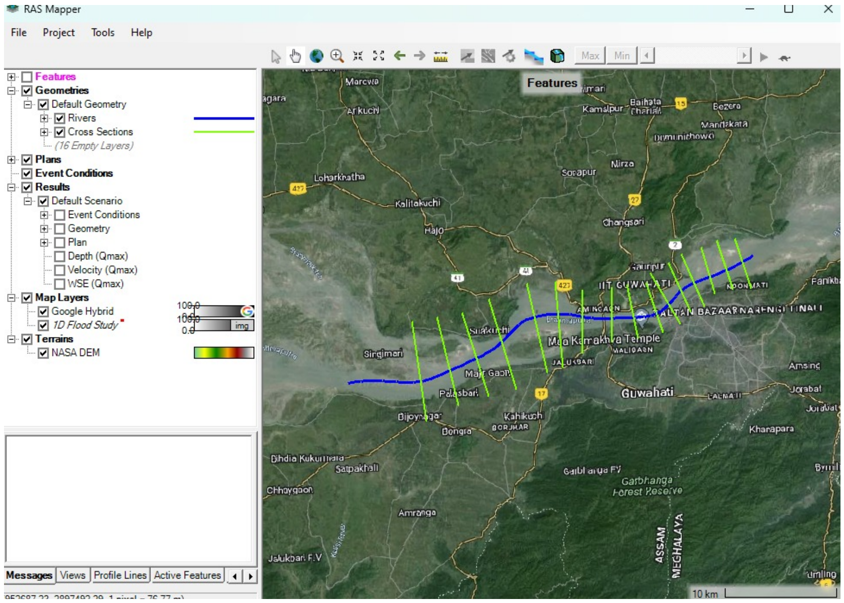


Fig 4.8: Marking Bank Lines, Flow Paths and cross sections in the RAS Mapper

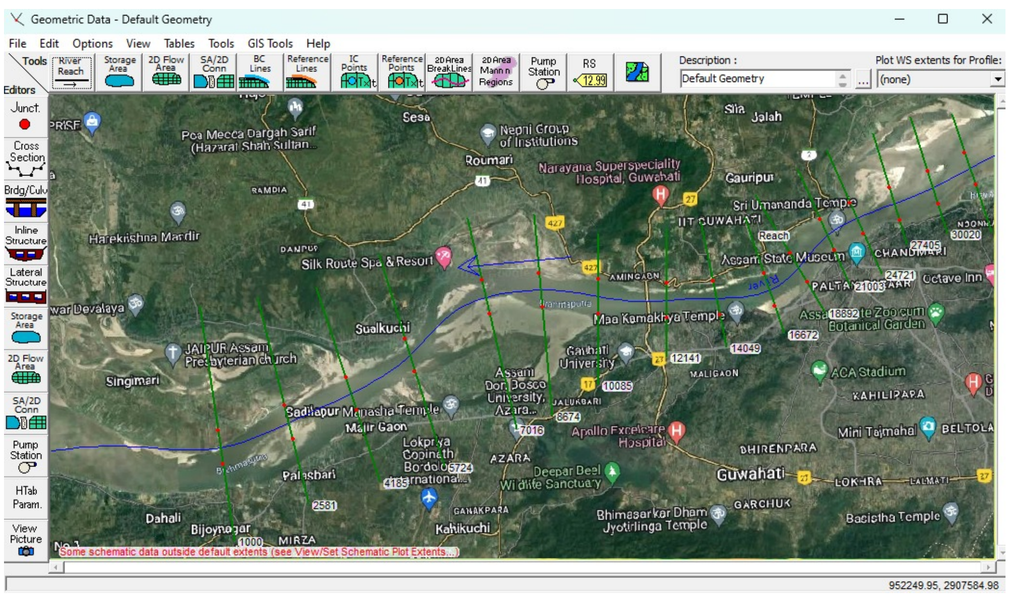
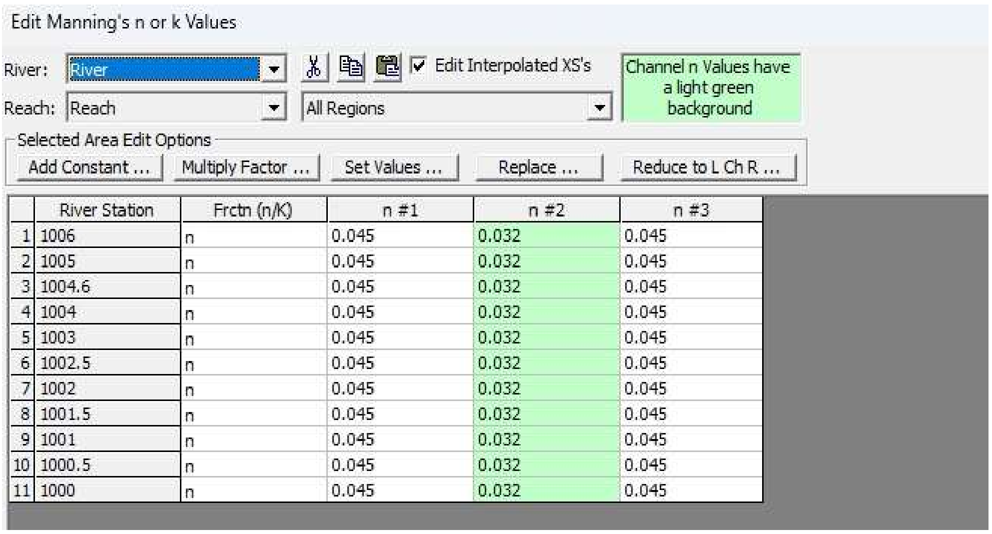


Fig 4.9: Cross Section Window of HEC RAS

4) <u>Define the boundary conditions</u>: We need to specify the upstream and downstream boundary conditions for our model, including the flow rate, water surface elevation, and boundary geometry. We can also add hydraulic structures such as bridges, culverts, and weirs.

5) Assigning roughness values: We need to specify the Manning's n values for each cross-section to define the channel roughness. The Manning's n values can be assigned based on the channel material, vegetation, or other factors that influence the channel roughness. There is a guideline in HEC-RAS website for assigning the values of Mannings n.



	River Station	Frctn (n/K)	n #1	n #2	n #3
1	1006	n	0.045	0.032	0.045
2	1005	n	0.045	0.032	0.045
3	1004.6	n	0.045	0.032	0.045
4	1004	n	0.045	0.032	0.045
5	1003	n	0.045	0.032	0.045
6	1002.5	n	0.045	0.032	0.045
7	1002	n	0.045	0.032	0.045
8	1001.5	n	0.045	0.032	0.045
9	1001	n	0.045	0.032	0.045
10	1000.5	n	0.045	0.032	0.045
11	1000	n	0.045	0.032	0.045

Fig 4.10: Applying Manning’s n value

6) Run the HEC-RAS model: After setting up your geometry, boundary conditions, and roughness values, you can run the model to calculate the water surface elevation, velocity, and other hydraulic parameters for each cross-section. The HEC-RAS model uses the Saint Venant equations to simulate the hydraulic behavior of the river.

HEC-RAS model use the energy equation to compute a water solution based on given discharge.

$$Z_2 + Y_2 + \alpha_2 \frac{V_2^2}{2g} = Z_1 + Y_1 + \alpha_1 \frac{V_1^2}{2g} + h_e \quad \text{---- Eqn no 4.4}$$

Where: Z1 and Z2 are the elevation of the main channel invert, h1 and h2 are depth of water at cross section, V1 and V2 are average velocities, α1 and α2 are the velocity weighting coefficient, g and he are gravitational acceleration and head loss respectively.

The head loss between two cross sections is comprised of friction losses and contraction or expansion losses.

7) Review the results: After running the HEC-RAS model, you can review the results to ensure that they are reasonable and make any necessary adjustments to the model inputs or parameters. We can visualize the results using graphs, tables, and maps.

i) STEDY FLOW ANALYSIS

At first, we analyse the results for steady flow of the river. For that the steady flow option is selected. Five discharge values are selected which will appears in different names as Q_{min}, Q_{max}, Q_{avg}, $1.1Q_{max}$ and $1.2Q_{max}$.

Table 4.10: Discharge Data for steady flow analysis

Minimum Value (PF1)	Maxmimum Value (PF2)	Average of Maximum (PF2)	10% of maximum (PF4)	20% of maximum (PF5)
144.805	42130.71	15458.68	46343.70	50556.85

In table 3.1, three discharge values are selected for this study i.e.Q_{min},Q_{max}, Q_{avg} and two values are selected as 10% and 20% of maximum discharge value of the available data from HEC-HMS.

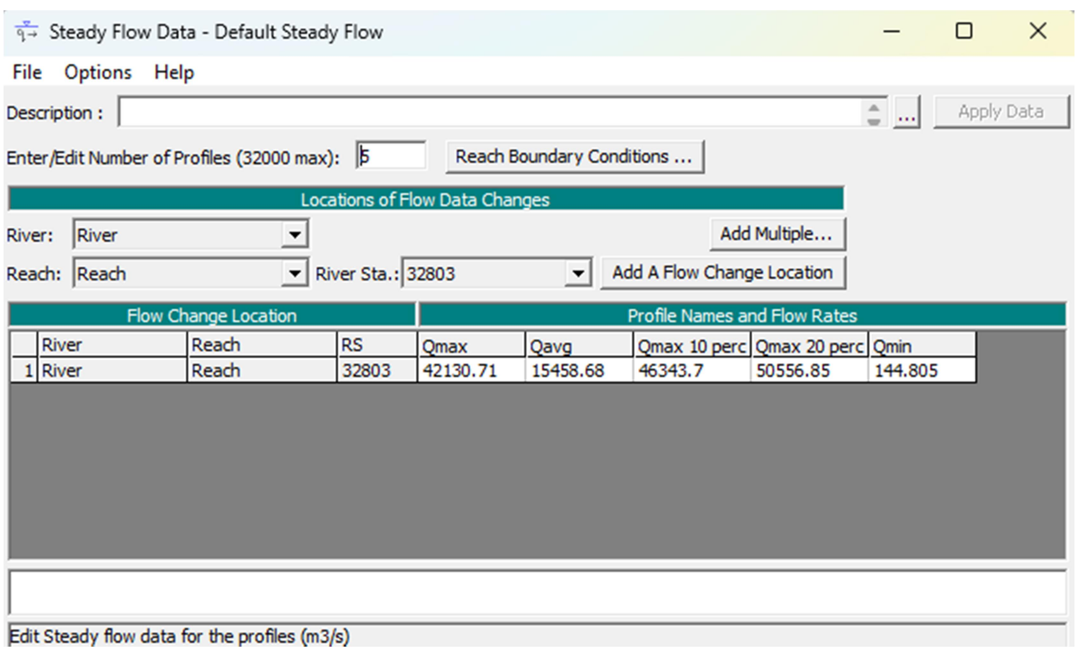


Fig 4.11: Entering Steady Flow Data

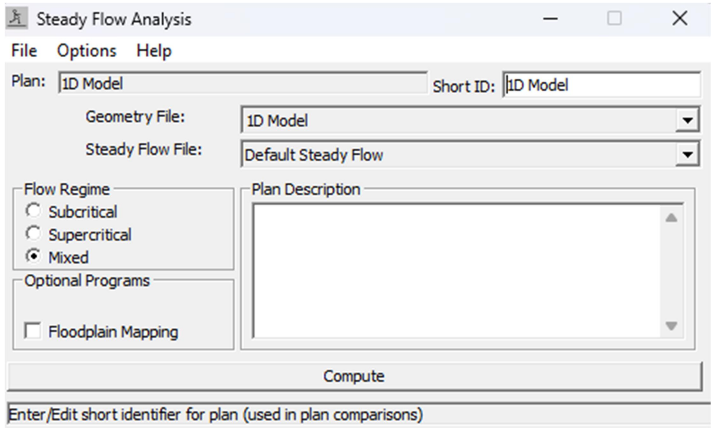


Fig 4.12: Steady Flow Analysis

4.6 OPERATIONS IN HEC-RAS (2D MODEL):

The 2D modeling capability of HEC-RAS allows for more accurate representation of complex hydraulic conditions, such as flow patterns, water levels, and velocities. Here's a step-by-step guide to performing a HEC-RAS 2D modeling analysis:

1. **Project Setup:**
   - Launch HEC-RAS and create a new project.

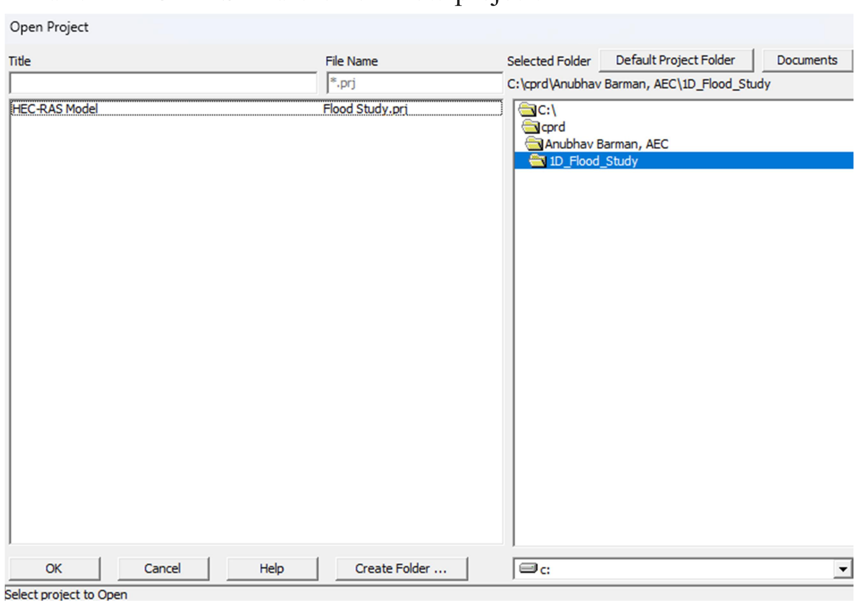


Fig 4.13: Creating a new project

   - Define the project's geographical location and coordinate system.
   - Set up a 2D modeling analysis by selecting the "2D Flow Area" option.

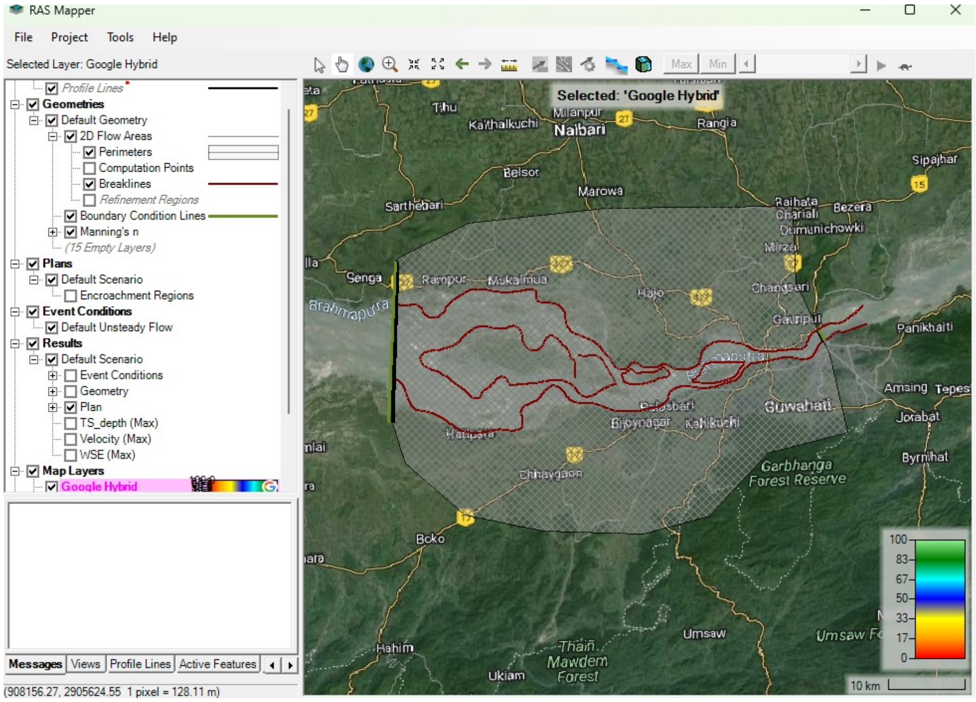


Fig 4.14: Setting up of 2D Flow Area

2. Define Geometry:

- Import or create a terrain elevation dataset (e.g., Digital Elevation Model or DEM) that represents the topography of the study area.
- Define cross sections and banks to create the geometry of the river or channel.

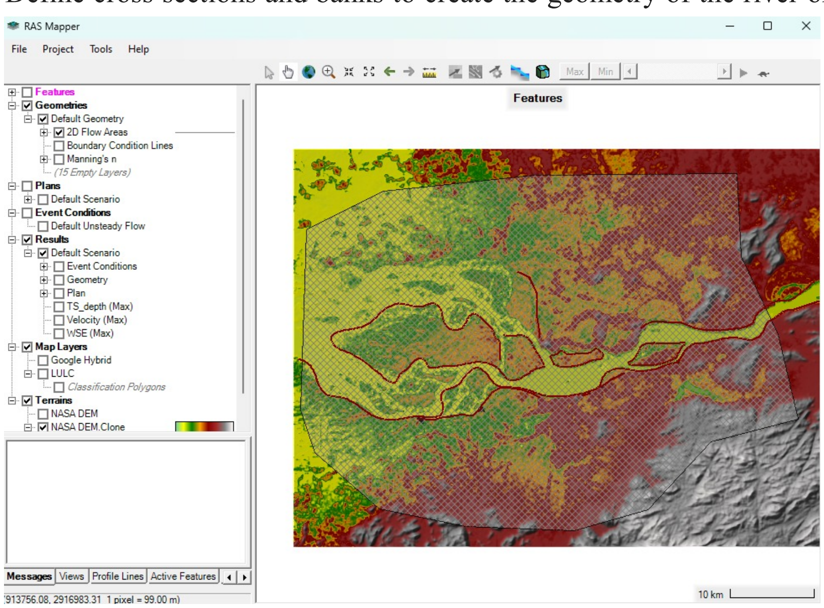


Fig 4.15: Defining the Left and Right Over Banks

3. **Define Hydraulic Structures:**

▪ Add any structures that impact the flow, such as bridges, culverts, weirs, and levees.

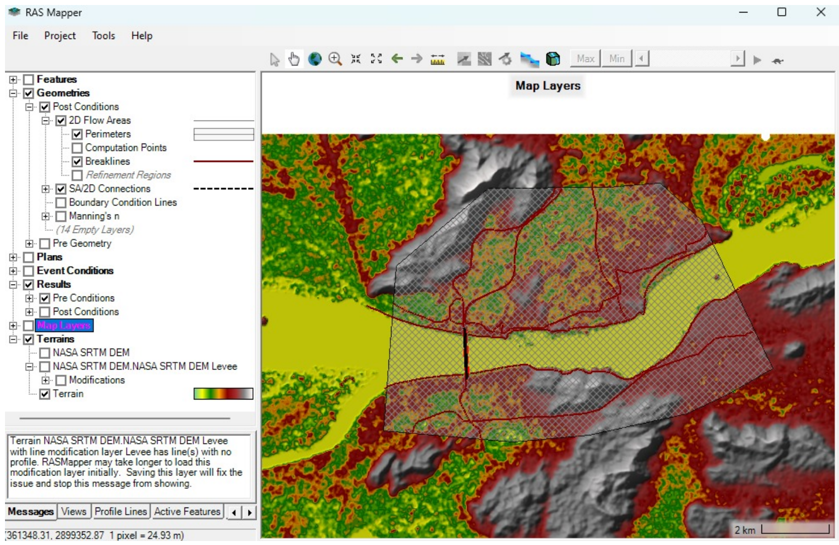


Fig 4.16: Setting up of Bridge

▪ Specify the characteristics of these structures, including dimensions, openings, and flow behavior.

4. **Define Boundary Conditions:**

▪ Set up upstream and downstream boundary conditions by specifying water levels, discharges, or hydrographs.

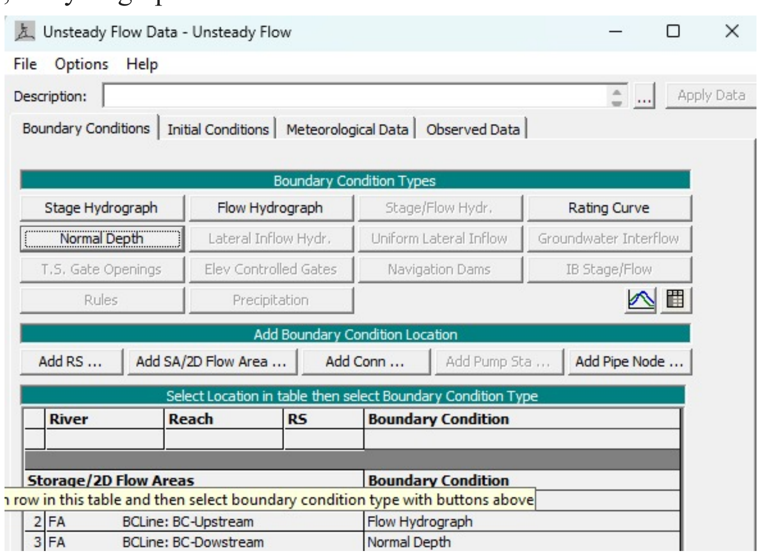


Fig 4.17: Defining Boundary Conditions

5. Define Initial Conditions:

- Specify the initial water surface elevations within the modeling domain.
- This step is crucial to provide a starting point for the analysis.

6. Mesh Generation:

- Create a mesh or grid that discretizes the 2D modeling area.

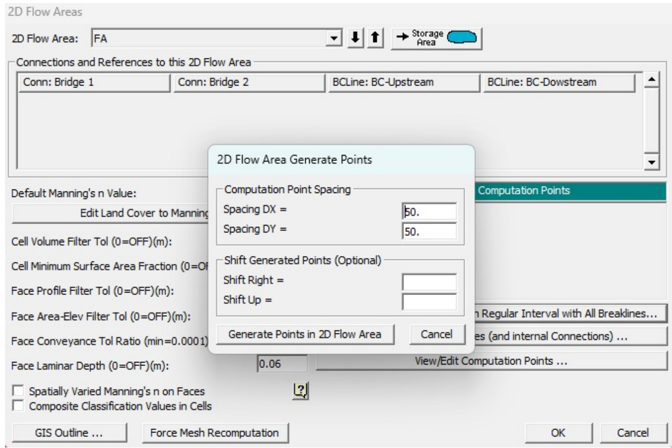


Fig 4.18: Generation of Mesh

- HEC-RAS uses this mesh to solve the governing equations for flow.

7. Run the Simulation:

- Configure simulation settings: Set simulation parameters such as the simulation duration and time step.
- Run the 2D simulation: Initiate the simulation and allow HEC-RAS to calculate the flood flows and water levels.

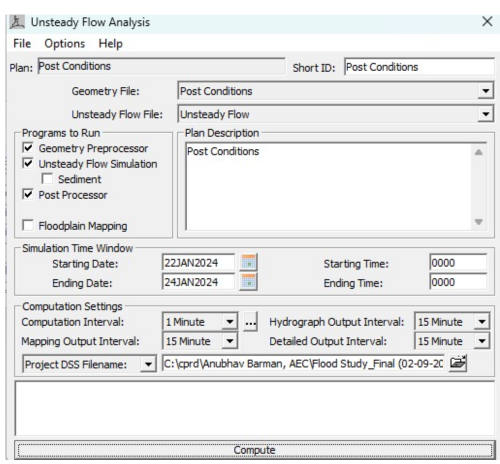


Fig 4.19: Simulation Run

CHAPTER 5

RESULTS AND DISCUSSION

5.1 : RESULTS FROM HEC RAS (1D MODEL):

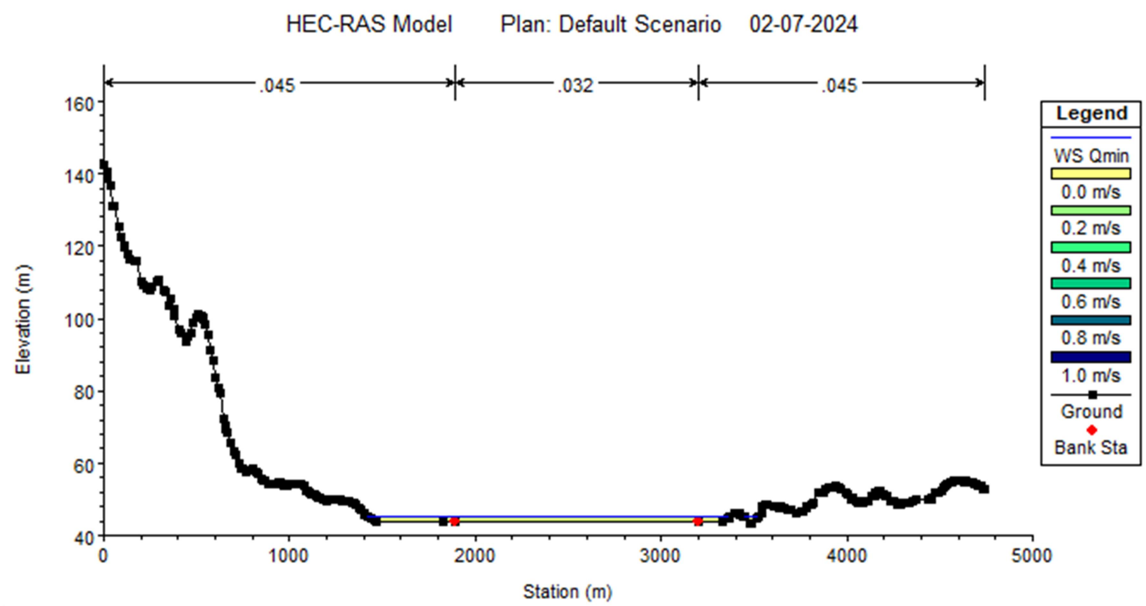


Fig 5.1: Upstream Elevation Depth Graph for PF1(Q_{min})

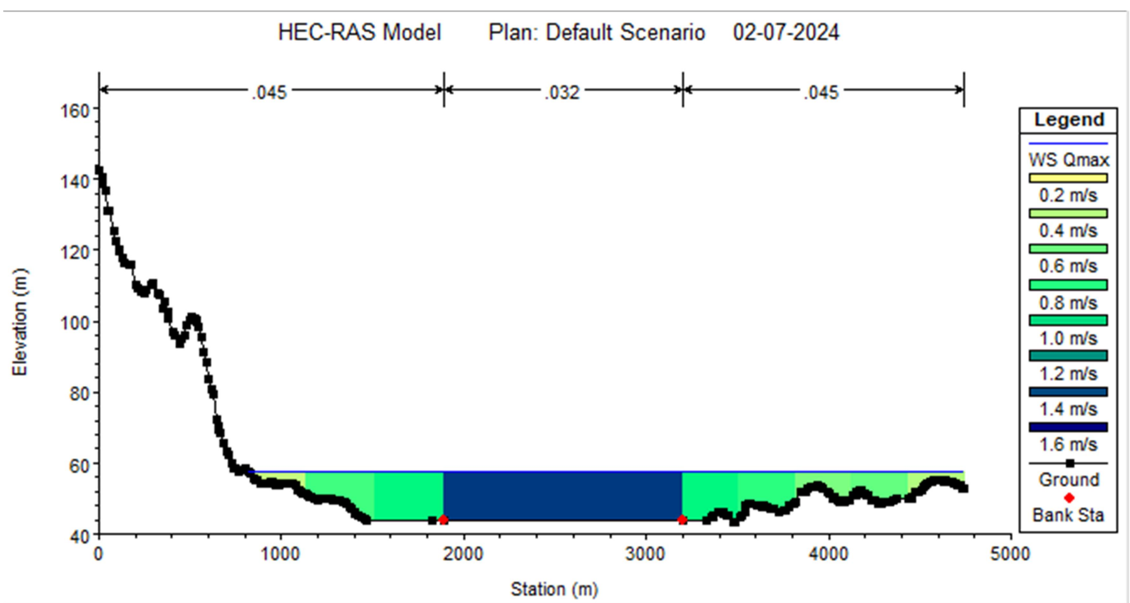


Fig 5.2: Upstream Elevation Depth Graph for PF2(Q_{max})

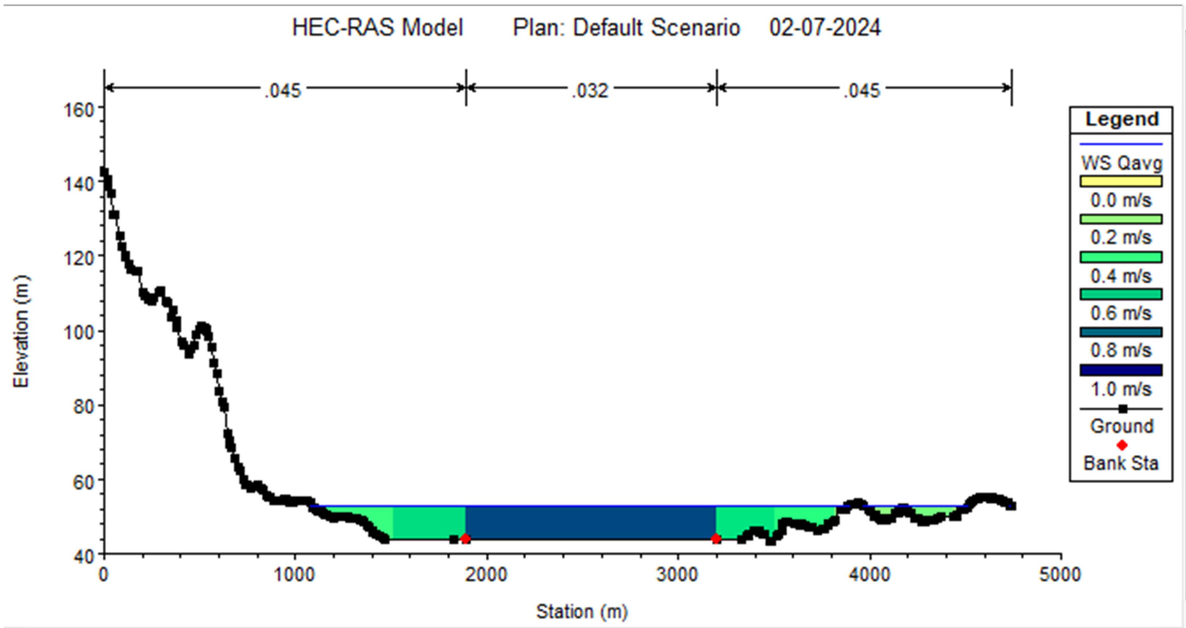


Fig 5.3: Upstream Elevation Depth Graph for PF3(Q_{avg})

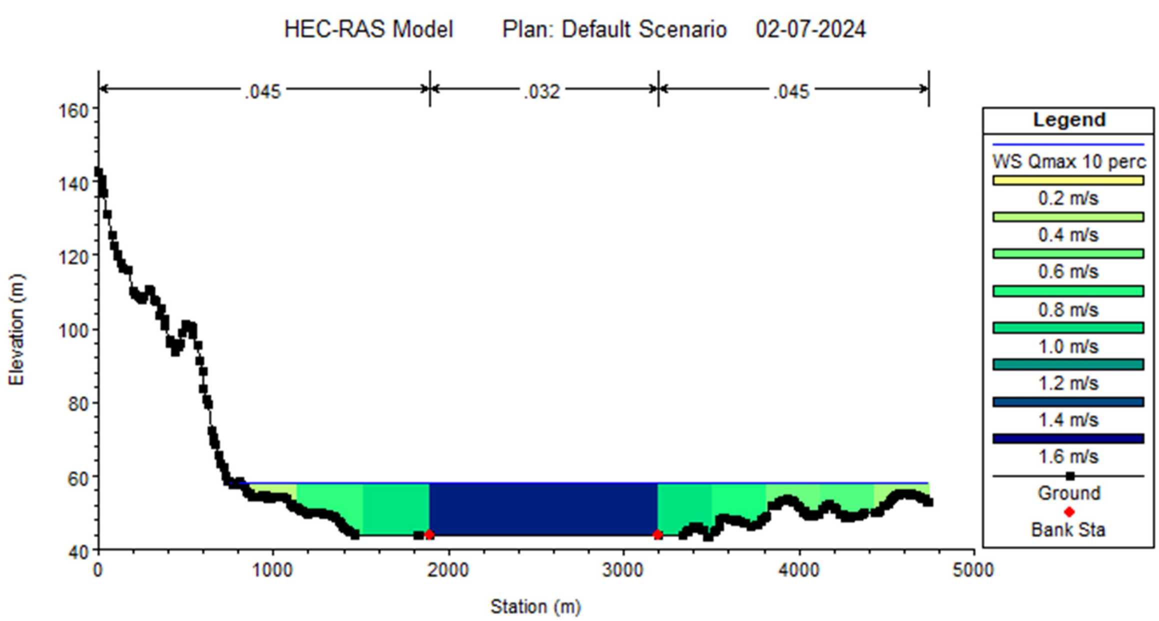


Fig 5.4: Upstream Elevation Depth Graph for PF4($1.1Q_{maxavg}$)

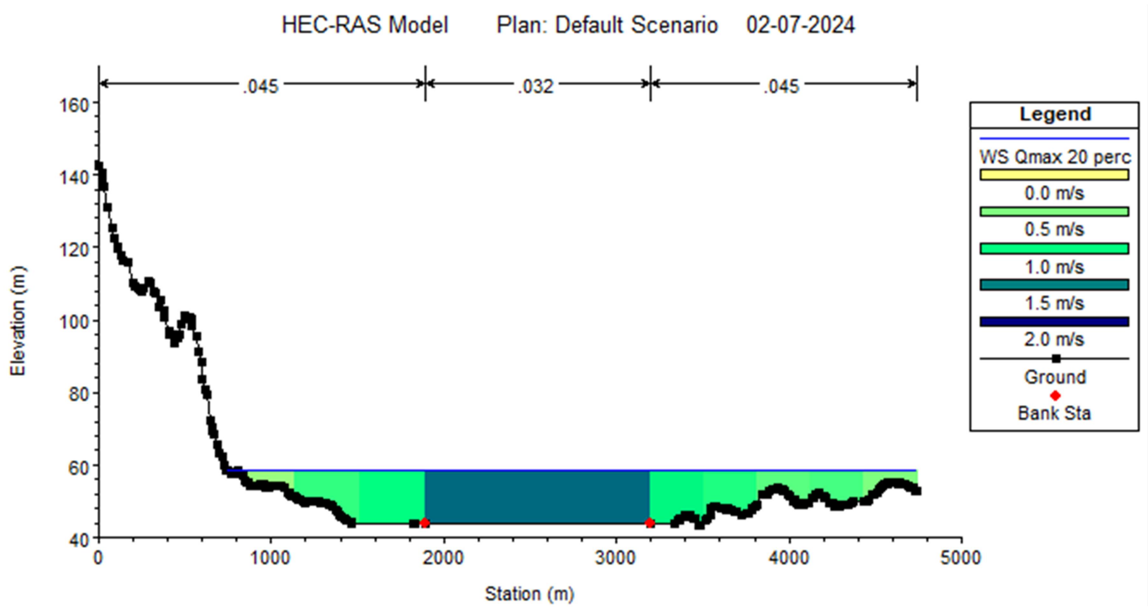


Fig 5.5: Upstream Elevation Depth Graph for PF5($1.2Q_{maxavg}$)

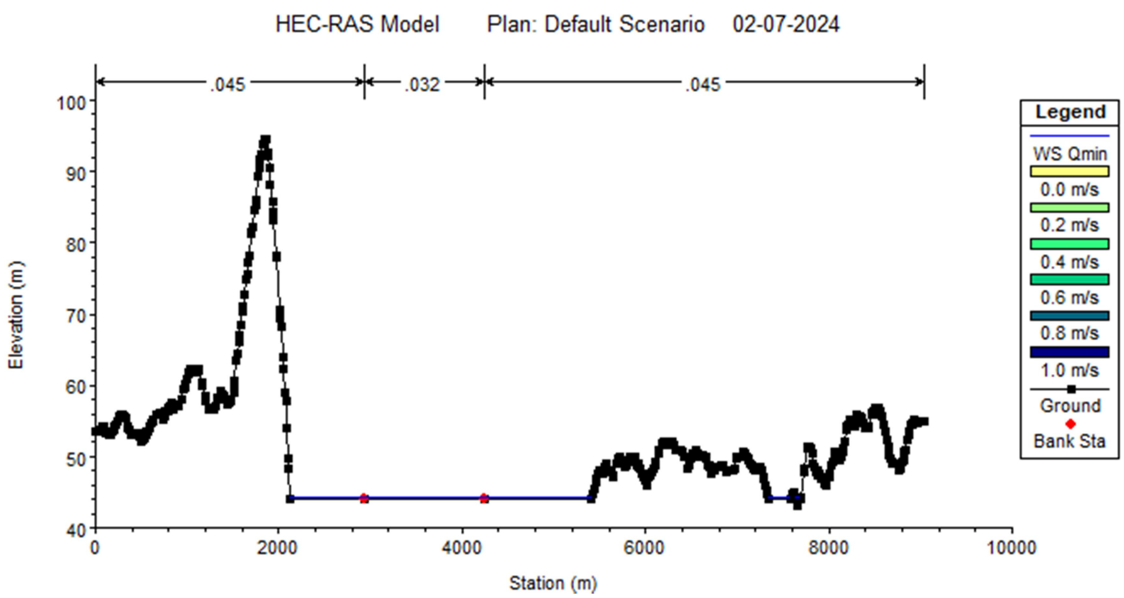


Fig 5.6: Downstream Elevation Depth Graph for PF1(Q_{min})

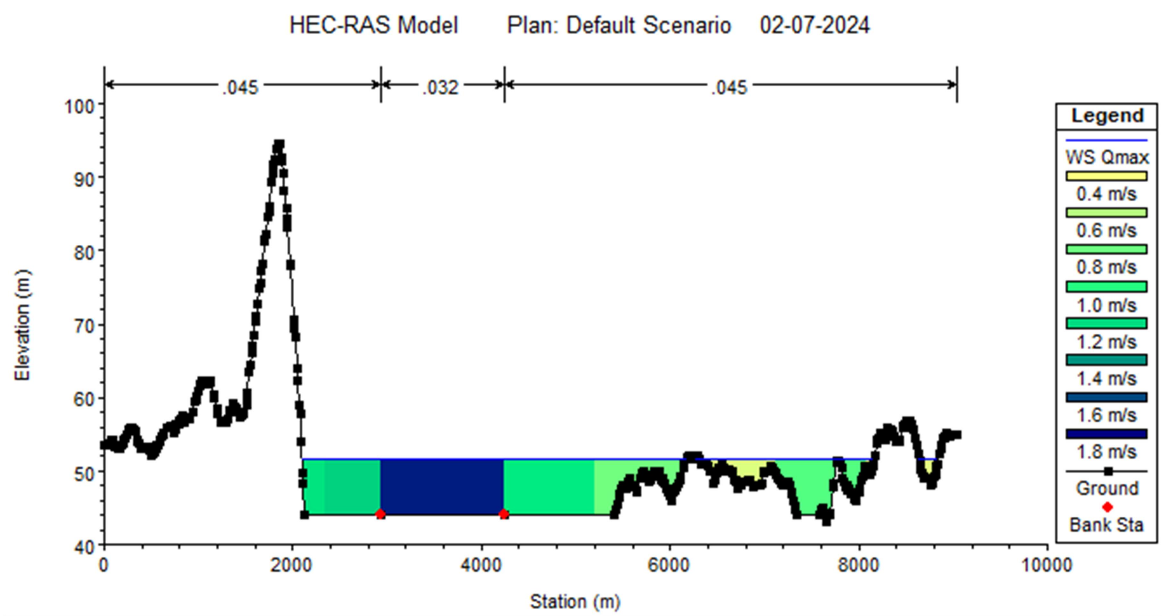


Fig 5.7: Downstream Elevation Depth Graph for PF2(Q_{max})

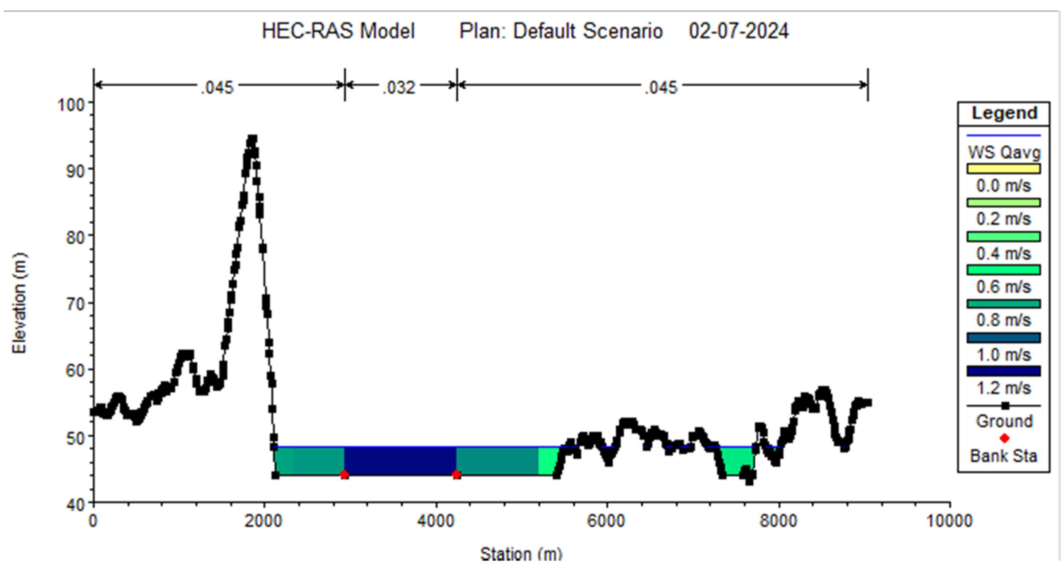


Fig 5.8: Downstream Elevation Depth Graph for PF3(Q_{avg})

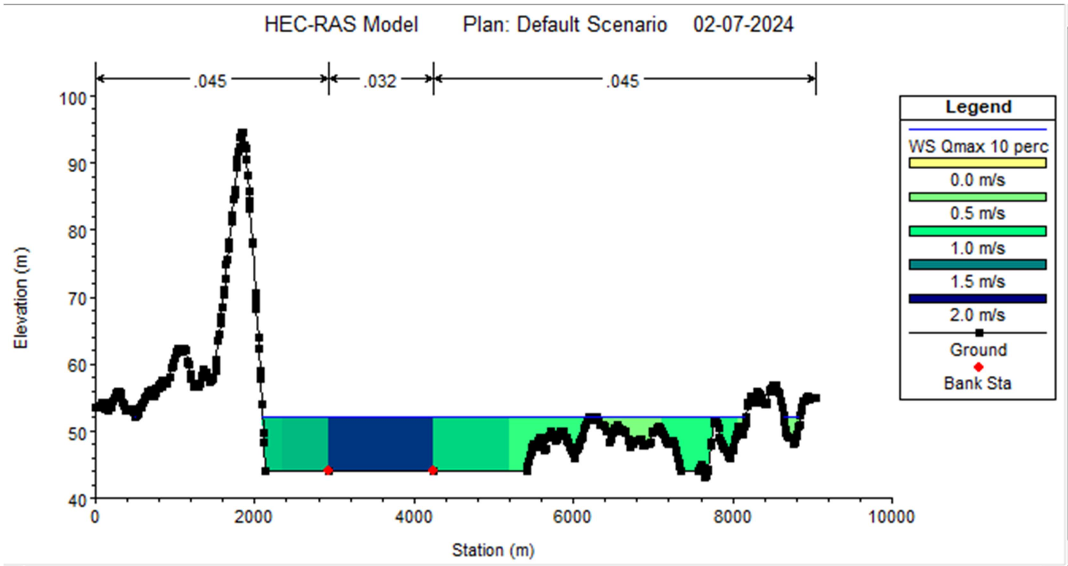


Fig 5.9: Downstream Elevation Depth Graph for PF4(1.1Q_{max})

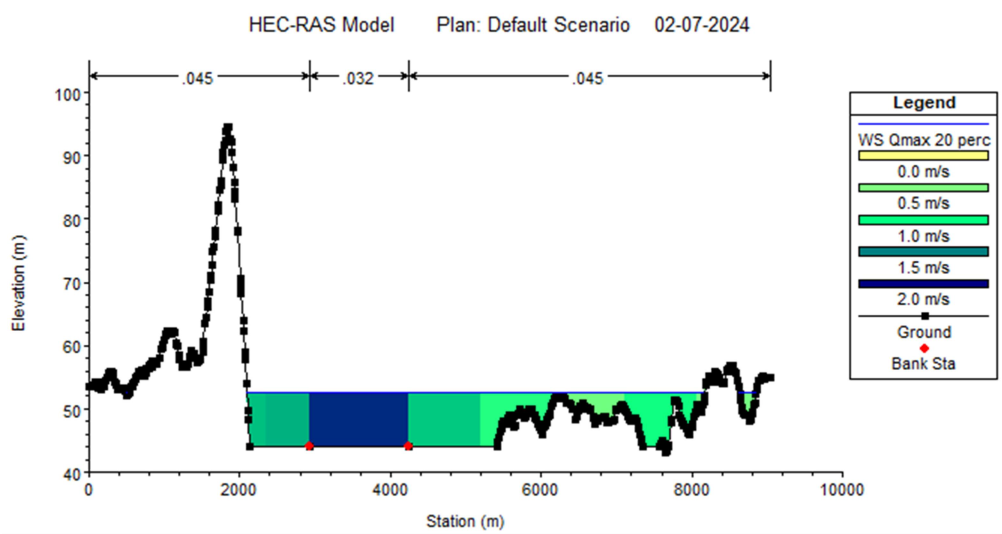


Fig 5.10: Downstream Elevation Depth Graph for PF5(1.2Q_{max})

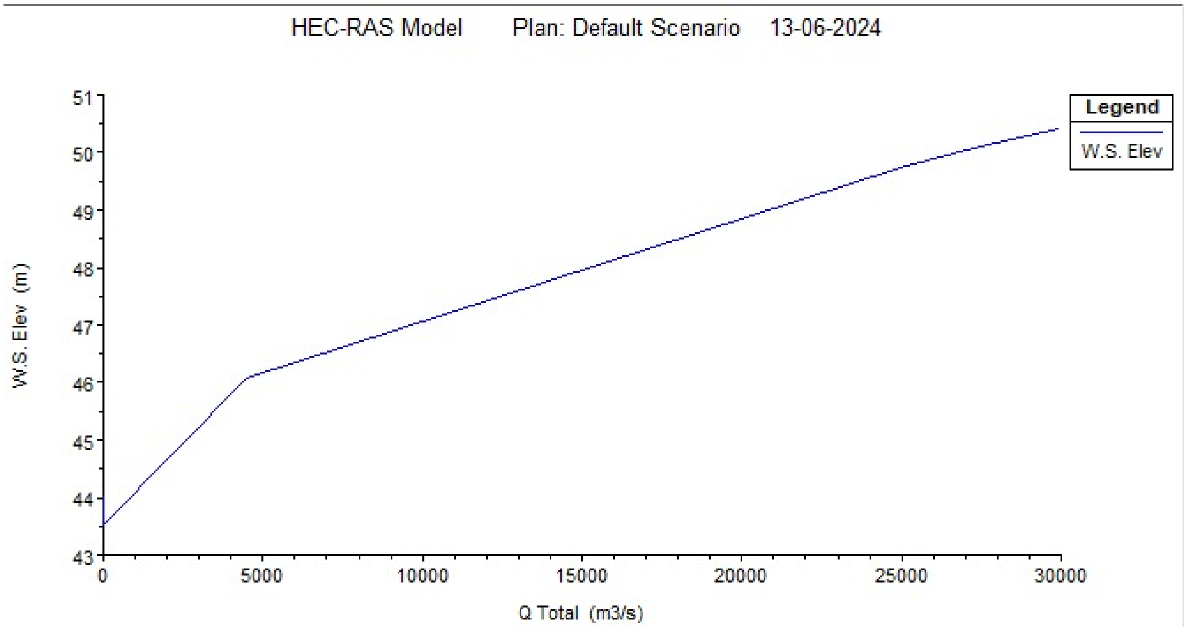


Fig 5.11: Rating Curve of Upstream

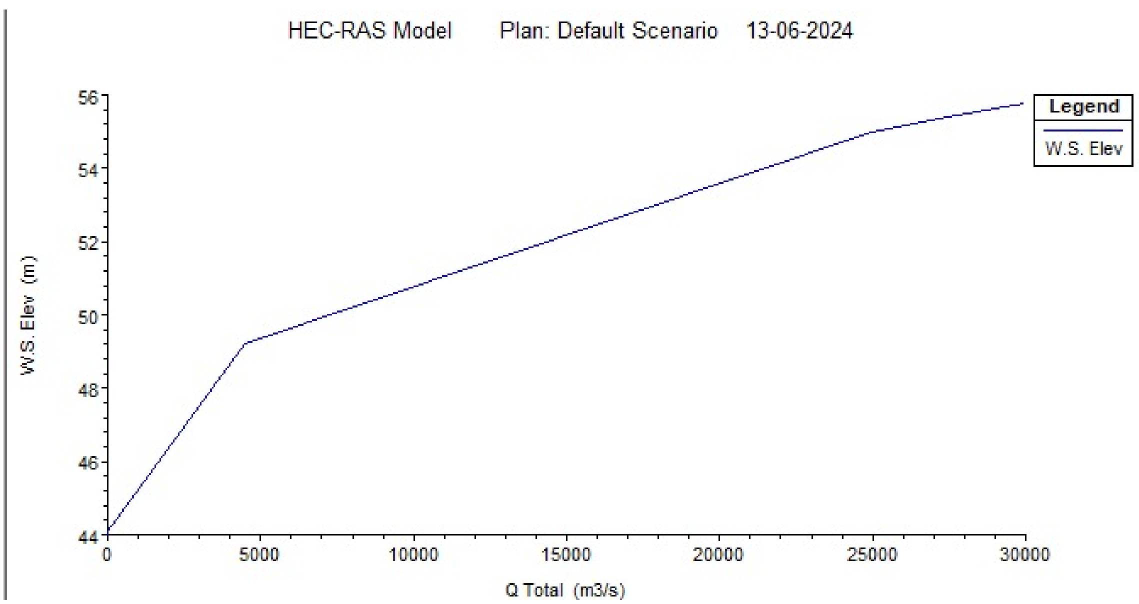


Fig 5.12: Rating Curve Downstream

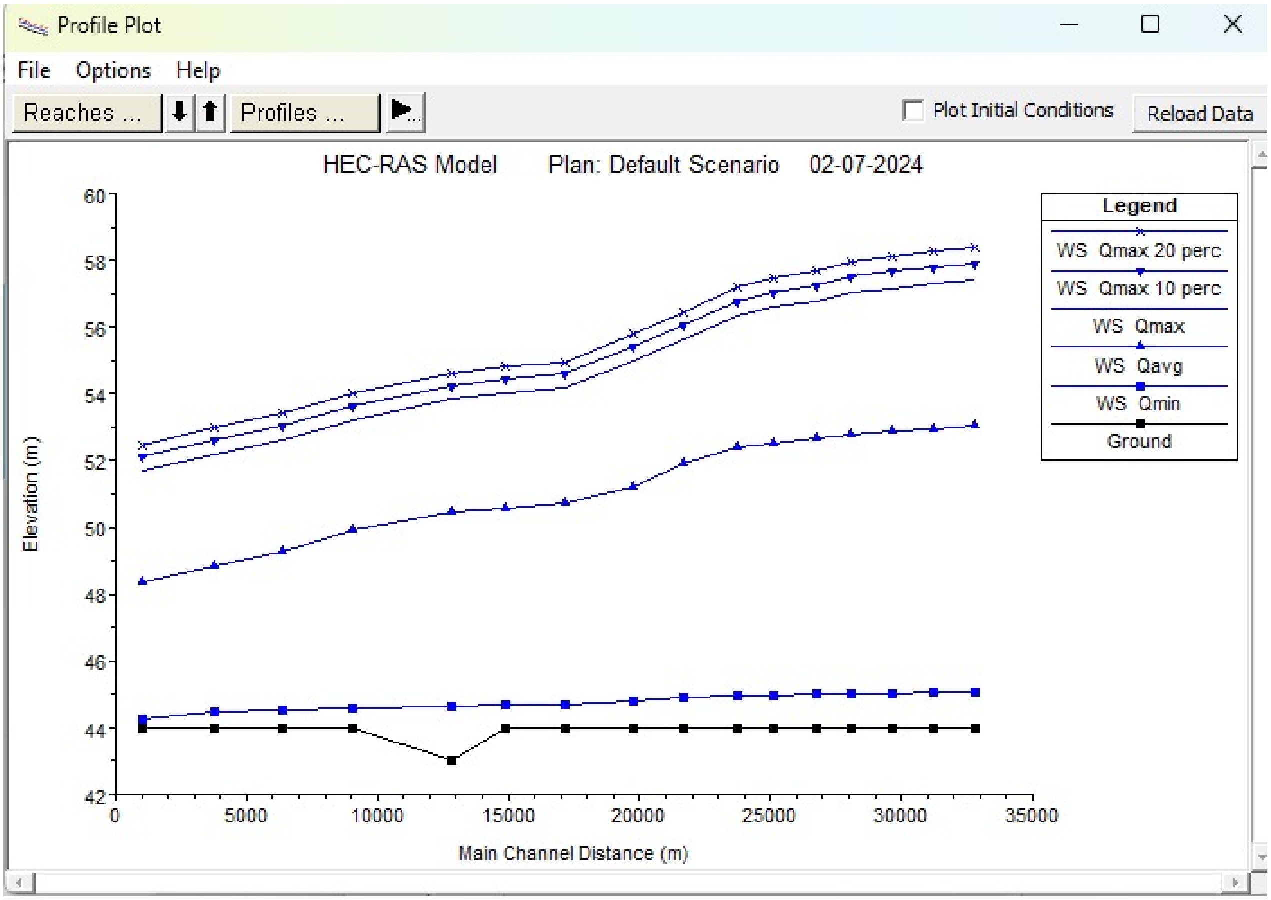


Fig 5.13: General Profile Plot

After providing all the input parameters to the software for the computation, various outputs in terms of the table and the graphs are obtained such as the value of ground elevation, velocity head, water surface elevation, total velocity, max channel depth, losses, average velocity, wetted perimeter, etc. The rating curve is also determined i.e. graph between water surface height and discharge at the given surge at a given cross area. This gives the approximate idea about the water level at different release values.

The profile output table of the steady flow analysis are shown below:

Table 5.1- Profile output table for steady flow analysis for Qmax

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach	32803	Qmax	42130.71	44.00	57.42		57.50	0.000067	1.44	39715.45	3920.99	0.13
Reach	30020	Qmax	42130.71	44.00	57.31		57.39	0.000071	1.47	38657.94	3897.26	0.13
Reach	27405	Qmax	42130.71	44.00	57.17		57.26	0.000086	1.57	36368.20	3806.70	0.14
Reach	24721	Qmax	42130.71	44.00	57.04		57.13	0.000083	1.58	36005.97	3913.93	0.14
Reach	21003	Qmax	42130.71	44.00	56.77		56.97	0.000157	2.13	24956.76	3565.26	0.19
Reach	18892	Qmax	42130.71	44.00	56.58		56.73	0.000126	1.89	28960.51	4055.40	0.17
Reach	16672	Qmax	42130.71	44.00	56.33		56.52	0.000165	2.08	25232.21	3382.69	0.19
Reach	14049	Qmax	42130.71	44.00	55.65		56.00	0.000396	2.95	19478.20	3107.52	0.29
Reach	12141	Qmax	42130.71	44.00	54.97		55.22	0.000387	2.57	23654.00	4641.64	0.28
Reach	10085	Qmax	42130.71	44.00	54.16		54.38	0.000266	2.36	23894.21	4078.06	0.24
Reach	8674	Qmax	42130.71	44.00	54.01		54.06	0.000070	1.21	52059.02	7583.52	0.12
Reach	7016	Qmax	42130.71	43.00	53.83		53.88	0.000097	1.35	48465.94	7980.32	0.14
Reach	5724	Qmax	42130.71	44.00	53.22		53.34	0.000239	1.97	33472.71	6911.12	0.22
Reach	4185	Qmax	42130.71	44.00	52.63		52.74	0.000209	1.87	34021.80	6449.83	0.21
Reach	2581	Qmax	42130.71	44.00	52.19		52.26	0.000152	1.57	39424.46	6899.13	0.17
Reach	1000	Qmax	42130.71	44.00	51.69	46.44	51.78	0.000200	1.72	35128.60	6151.16	0.20

Continued in Appendix II

5.2 : RESULTS FROM HEC RAS (2D MODEL):

- **Water Surface Profiles**: The most fundamental result is the water surface profile, which shows how the water level changes along the length of the river or channel.
- **Flood Extent Maps**: HEC-RAS 2D modelling allows us to generate floodplain maps that illustrate the extent of flooding for various water levels. These maps can be useful for emergency planning, land-use decisions, and risk assessment.
- **Velocity and Flow Distribution**: The model can provide information about flow velocity and direction across the study area. This can be important for assessing the potential for erosion, sediment transport, and habitat changes.
- **Inundation Depth**: HEC-RAS can calculate the depth of inundation at various locations within the floodplain. This information is useful for understanding the potential impact of a flood event on structures and infrustructure.
- **Animation**: Some visualization tools within HEC-RAS allow you to create animations of the simulated flow, which can be useful for presentations and conveying the results to stakeholders.

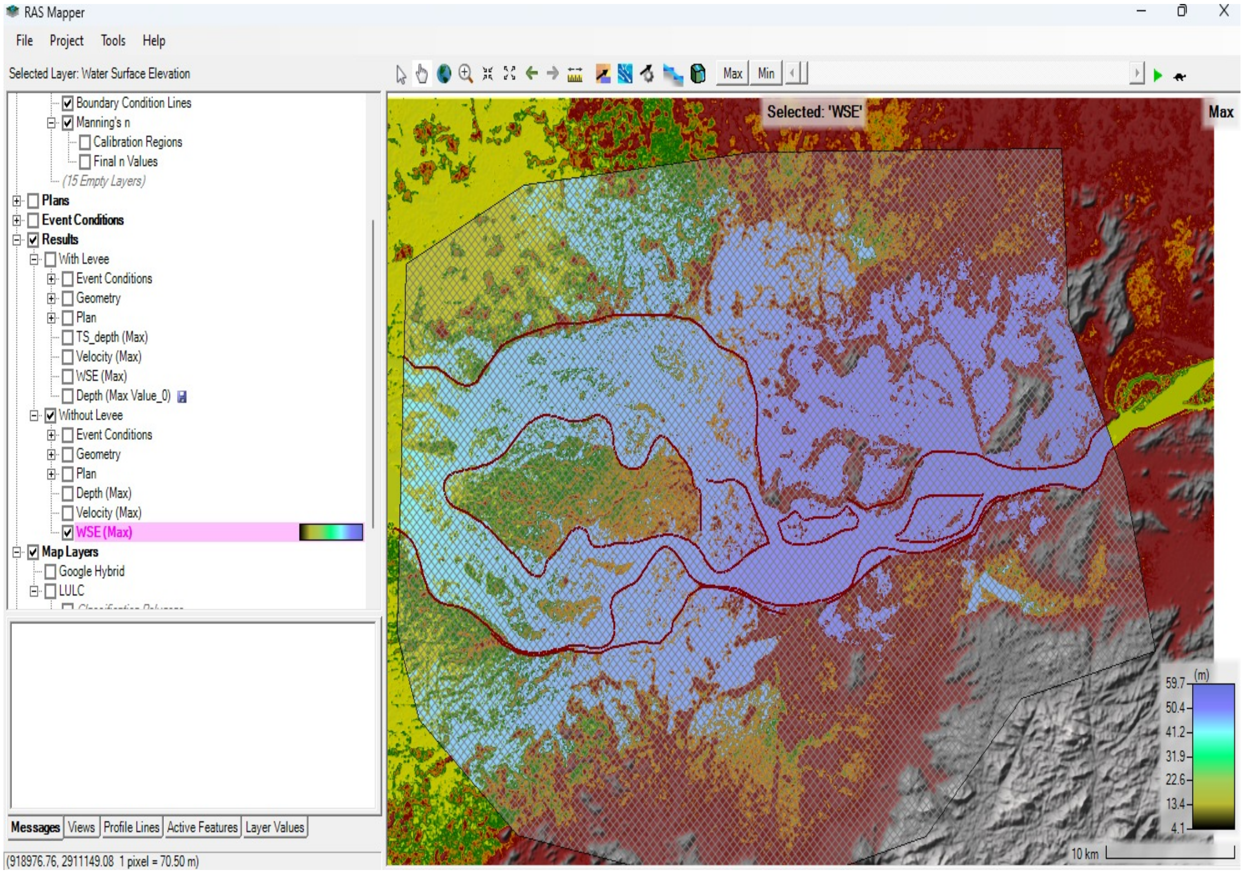


Fig 5.14: Water Surface Elevation without Embankment

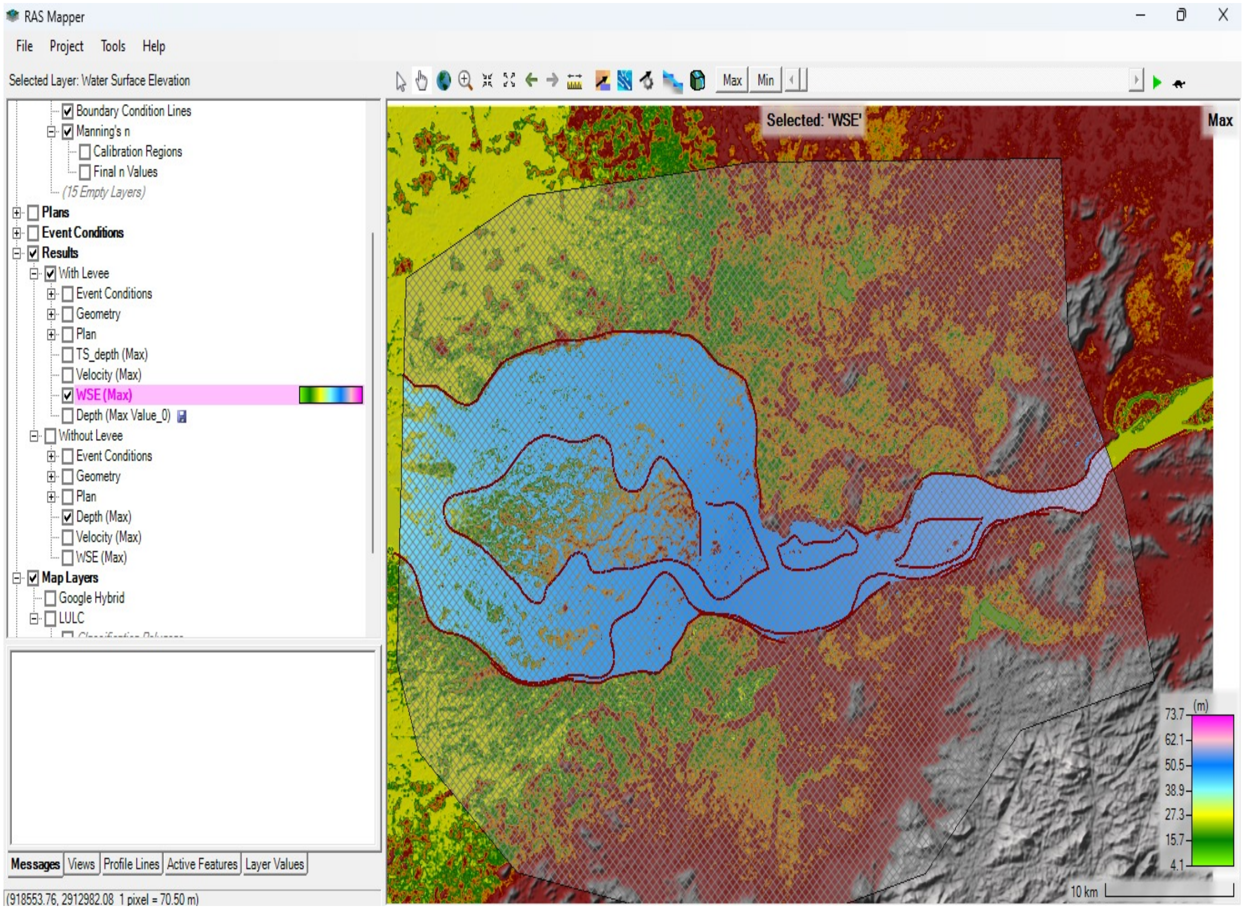


Fig 5.15: Water Surface Elevation with Embankment

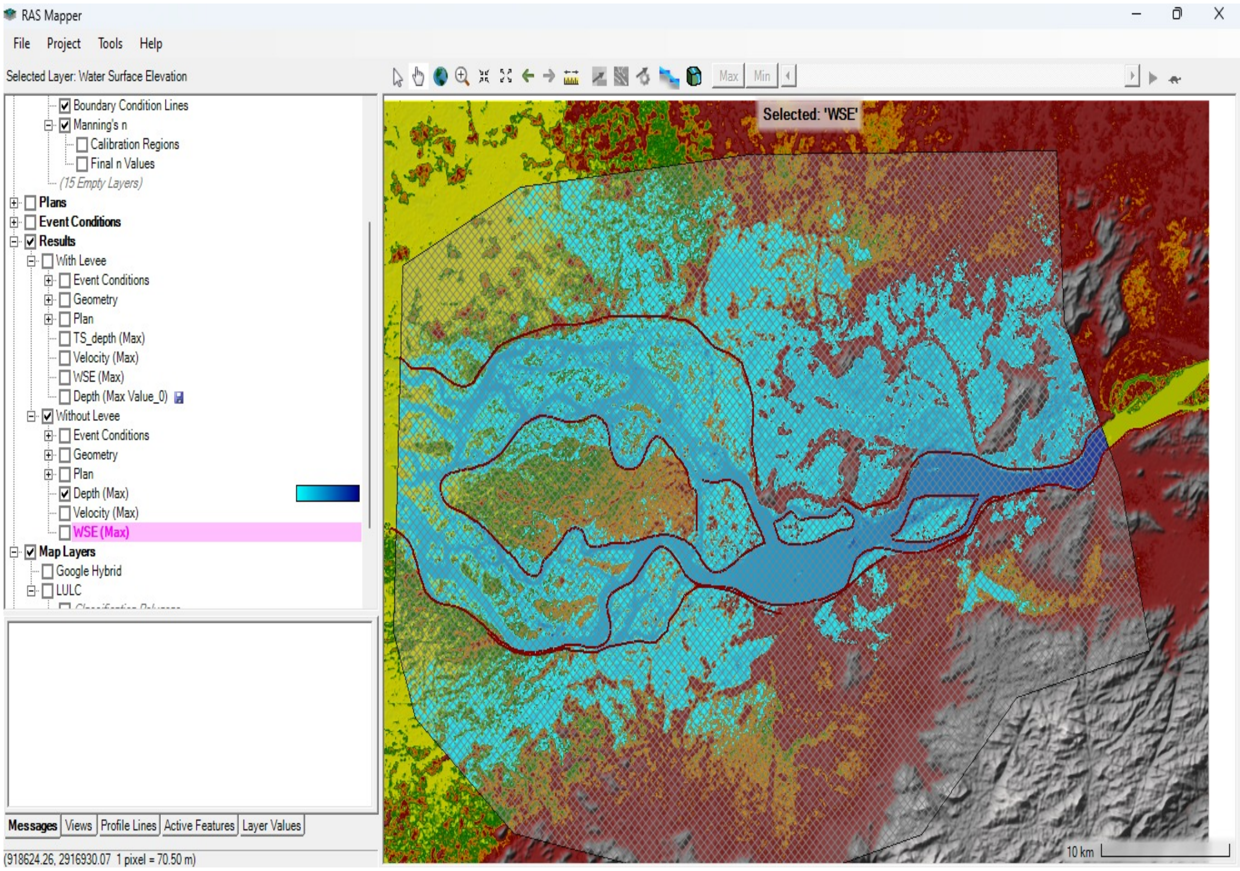


Fig 5.16: Depth Profile without Embankment

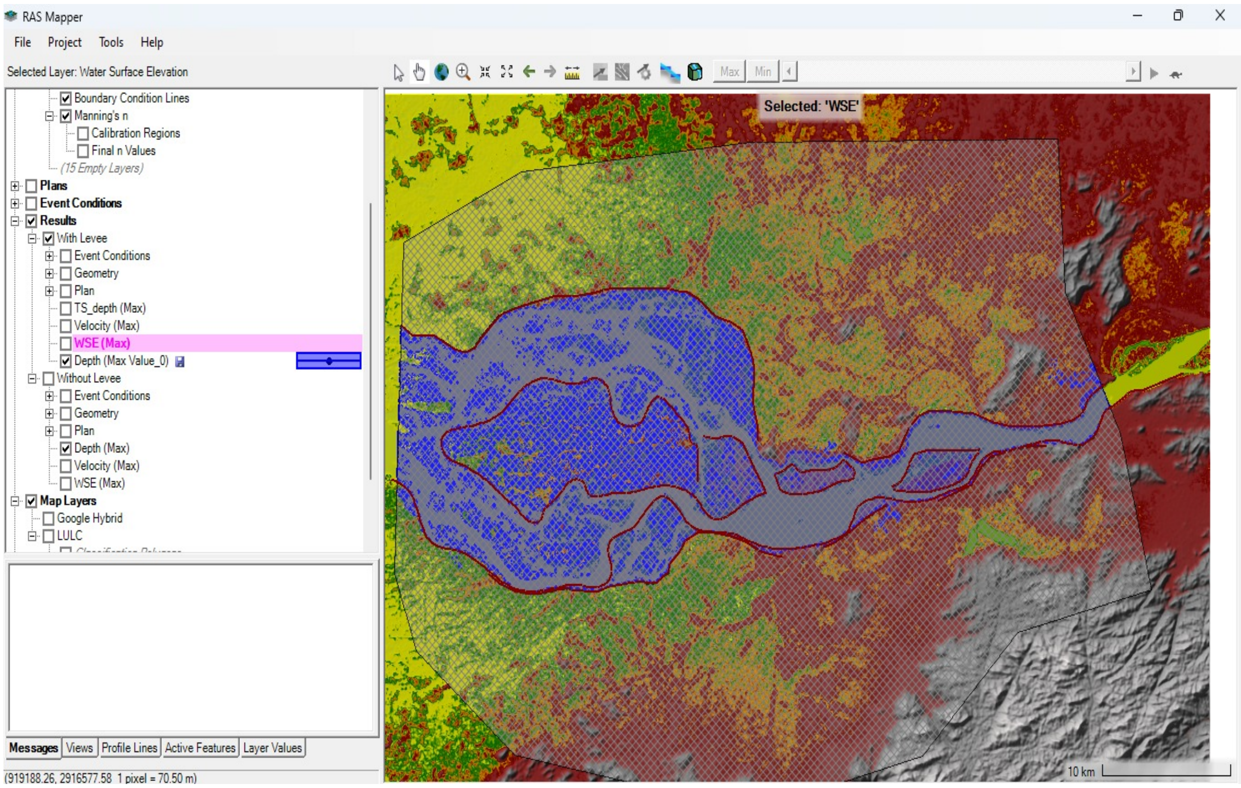


Fig 5.17: Depth Profile with Embankment

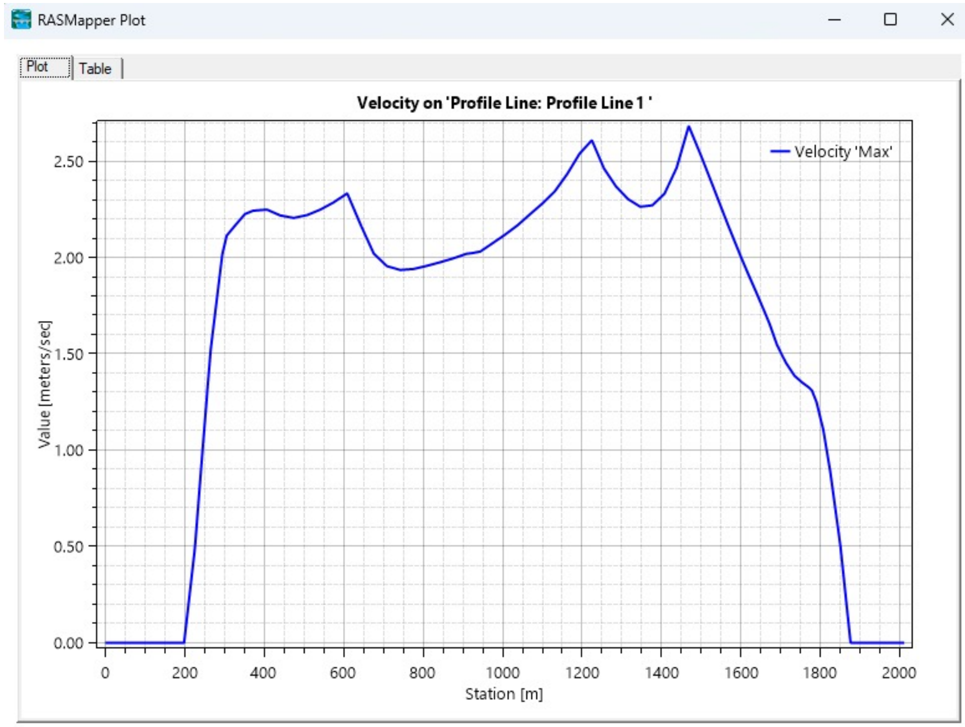


Fig 5.18: Velocity Profile on Upstream

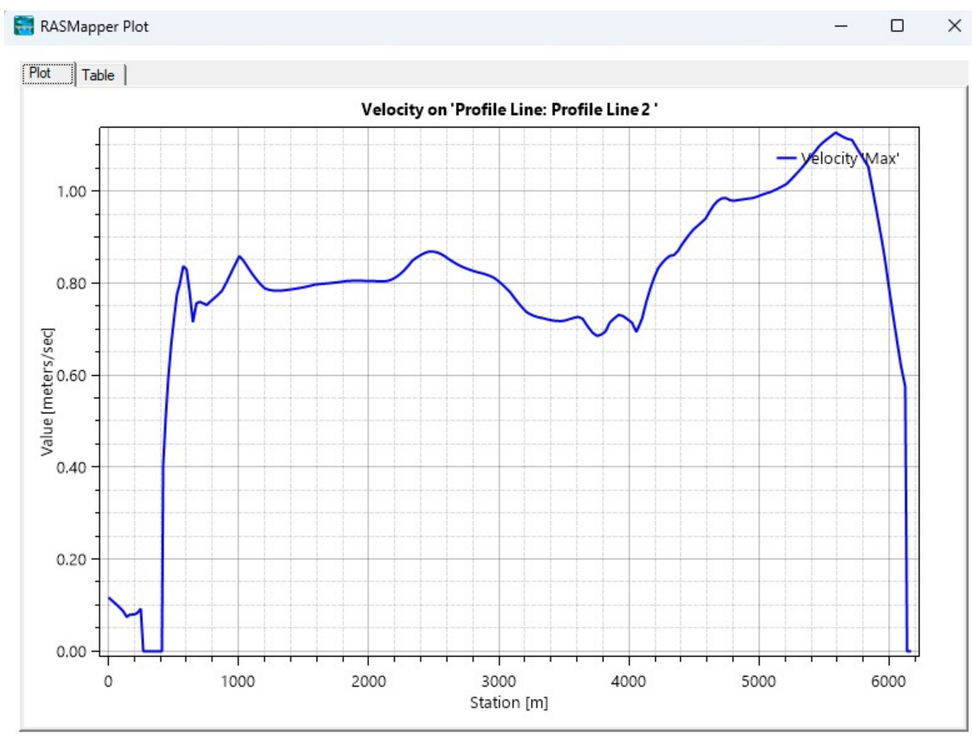


Fig 5.19: Velocity Profile on Downstream

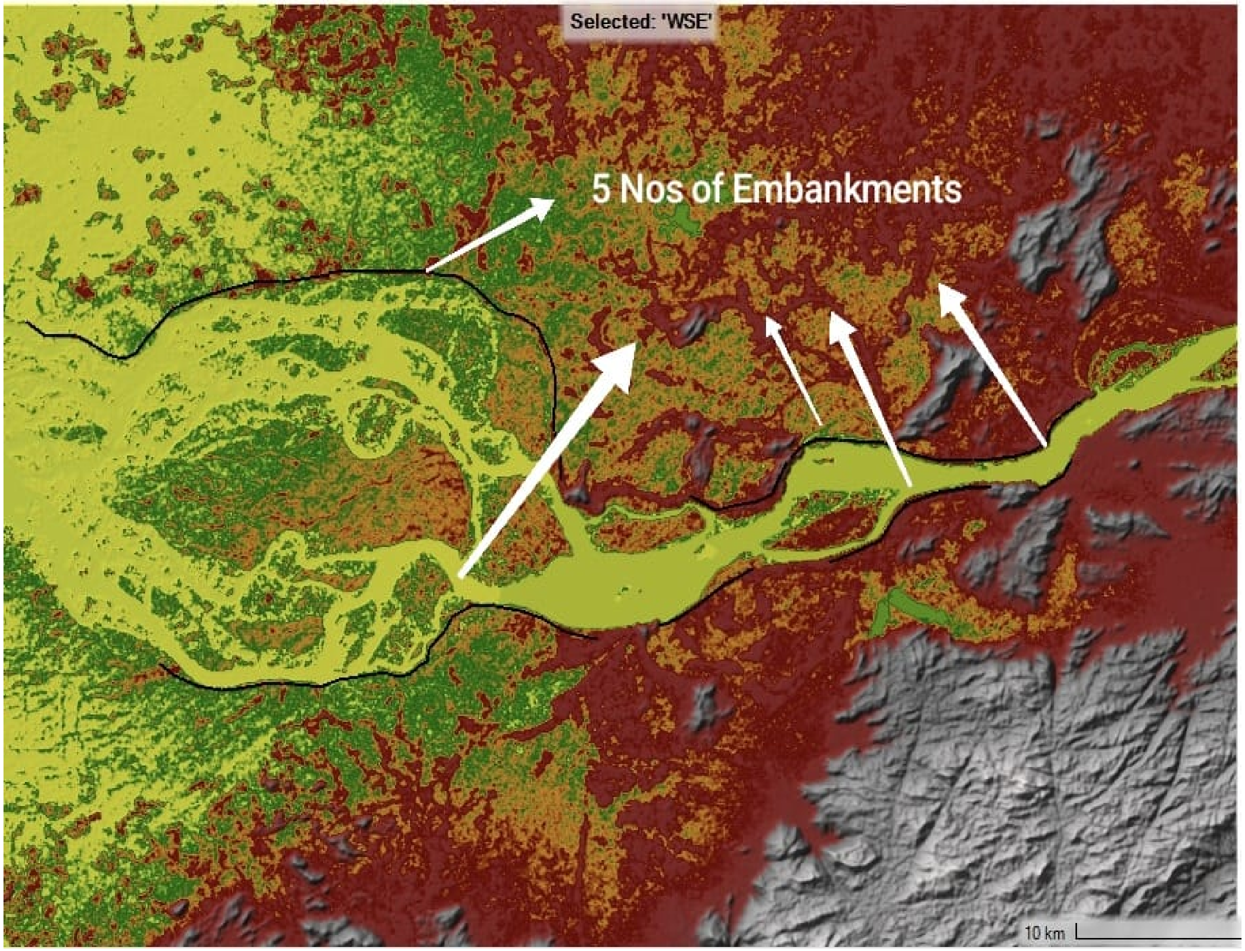


Fig 5.20: Probable suggested locations of embankments

5.3 SALIENT FEATURES:

Total Area inundated in the study area for the 100-year Return period: 95741.5 Hectares

Fig 5.21: Prominent Locations of Flooding

Table 5.2: Coordinates of Various Prominent Locations

Prominent Points	Coordinates	Flood Inundation Depth (m)
CHANGSARI	Lat: 26°16'03"N Long: 91°42'40"E	2.5
SESA	Lat: 26°14'41"N Long: 91°35'21"E	3.2
HAJO	Lat: 26°14'42"N Long: 91°31'34"E	3.54
HATIMURA	Lat: 26°12'00"N Long: 91°29'00"E	4.04
MUKALMUA	Lat: 26°16'27"N Long: 91°21'15"E	3.45
RAMPUR	Lat: 26°05'48"N Long: 91°26'26"E	2.8
CHHAYGAON	Lat: 26°03'05"N Long: 91°21'14"E	2.8
PALASHBARI	Lat: 26°07'04"N Long: 91°32'31"E	2.05

CHAPTER 6

CONCLUSION

The river Brahmaputra is one of the rivers in Assam to chronically suffer from losses due to flooding as well as streambank erosion and shifting of the channel. The movement of the river into the land due to erosion resulted in the breaching of an existing embankment, which was perceived as a threat to the mainland.

So, Flood Vulnerability Assessment of Brahmaputra River is imperative.

To study the flood vulnerability in the area a 1D & 2D model has been prepared using HEC-RAS Software which will allow to have a better visualization of the flooding scenario of the river.

This model is prepared to stimulate flood for 100-year Return Period with an objective of vulnerability assessment of flood and thereby suggest a protective measure to manage it and hence two models are prepared with and without embankments so that we can suggest an embankment of suitable height to protect the area from flooding and for achieving this a Synthetic Unit Hydrograph was prepared using discharge data and basin characteristics to obtain a flood hydrograph of 48 hours for 100- year return period having a peak discharge of 42301.7 cubic meter per second. This flood hydrograph is used to build the 2D model in HEC-RAS from which we obtained various results like water surface elevation, inundation depth and velocity at different locations in our study area. From the model we found that out of the total 210014.74 hectares study area, 95741.6 Hectares land gets inundated.

Hence to protect the area from flooding we can provide embankment of 5.0 m height so that flood water does not overtop the bank.

FURTHER STUDIES:-

Further studies on this project may include the following topics:-

- Validate hydraulic models used for accurate flood prediction.
- Assess climate change impacts on flood frequency and intensity in the Brahmaputra Basin.
- Evaluate economic and social impacts of flooding, including infrastructure damage and community displacement.

- Consider ecological consequences of flood control measures such as embankments on habitats and biodiversity.
- Engage local communities in flood risk management and resilience-building efforts.
- Adopt an integrated approach to flood risk management, combining structural and non-structural measures.
- Implement long-term monitoring programs to assess flood vulnerability and measure the effectiveness of mitigation strategies.

CHAPTER 7

REFERENCES

1. **“Application of 1-D HEC-RAS model in design of Channels”.International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 7 (August 2014)**: Darshan J. Mehta, Mr. Manthan Ramani, Mr. Maulik Joshi (2014)
2. **“Determination of floodplain map and runoff computation using geographic information system (GIS)”.** Department of Civil engineering, faculty of engineering the polytechnic, Ibadan. A. Kehinde John (2017)
3. **“Flood modeling and flood forecasting using HEC-RAS”. International journal of advance scientific research andf engineering trends, Volume 5 || Issue 6 || June 2020 || ISSN 2456-0774:** Avanti Waghchaure , Aarti Patil , Pragati Bachhav , Rajashri Bodhai .
4. **“Flood modeling of river Godavari using Hec-Ras”. International Journal of Research in Engineering and Technology, eISSN: 2319-1163 | ISSN: 2321-7308:**Muhammad Shahzad Khattak, Faizan Anwar, Tariq Usman Saeed, Mohammed Sharif, Khurram Sheraz, Anwaar Ahmed.
5. **“Flood Modelling by using HEC-RAS”. International Journal of Engineering Trends and Technology (IJETT) – Volume 50 Number 1 August 2017**:Azhar Hussain (2017).
6. **“Floodplain Delineation Using HECRAS Model—A Case Study of Surat City”, Open Journal of Modern Hydrology, 2016, 6, 34-42:** Chandresh G. Patel, Pradip J. Gundaliya
7. **“Floodplain Modeling in the KansasRiver Basin Using Hydrologic Engineering Center (HEC) Models Impacts of Urbanization and Wetlands for Mitigation”,** Y. Yuan Kamal Qaiser (2011): U.S. Environmental Protection Agency National Exposure Research Laboratory Environmental Sciences Division Landscape Ecology Branch Las Vegas, NV 89119
8. **“Floodplain Zoning Simulation by Using HEC-RAS and CCHE2D Models in the Sungai Maka River”,** Ahmad Shahiri Parsa, Mohammad Noori, Mohammad Heydari and Mahmood Rashidi**.**
9. **“GIS mapping algorithm for floodway modeling”. Journal of flood engineering Vol. 10 No. 1 (January-June, 2019)** : Sivasankkar Selvanathan and Randel L. Dymond
10. **“Integration of GIS and HEC-RAS in Floods Modeling of Martil River (Northern Morocco)”. European Scientific Journal April 2018 edition Vol.14, No.12 ISSN: 1857 –**

7881 (Print) e - ISSN 1857- 7431Amina : Azouagh, Rabei El Bardai, Ismael. Hilal, Jamal. Stitou el Messari, PhD (2018)

11. **"Integration of HEC-RAS and geographical information system (GIS) in the hydrological study of peak flow response to deforestation on a small watershed in Malaysia". International Journal of Water Resources and Environmental Engineering, Vol. 5(3), pp. 146-151, March, 2013 :**Ali M. F, Kamarudin A. F, Khalid K. and Abd Rahman N. F.
12. **"One Dimensional Steady Flow Analysis Using HECRAS – A case of River Jhelum, Jammu and Kashmir". European Scientific Journal November 2016 edition vol.12, No.32 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431:** Hakim Farooq Ahmad, Akhtar Alam, M. Sultan Bhat, Shabir Ahmad (2016):
13. **"River Flood Modeling Using GIS, HEC-GeoRAS And HECRAS For Purna River, Navsari District, Gujarat, India", International Journal of Scientific Development and Research (IJSDR) :** Azazkhan I.Pathan, 2Prof.B.M Vadher, 3Dr.P.G Agnihotri.

APPENDIX – I

Table 5.3- Profile output table for steady flow analysis for Qmin

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach	32803	Qmin	144.81	44.00	45.06		45.06	0.000006	0.08	2097.78	2012.21	0.02
Reach	30020	Qmin	144.81	44.00	45.05		45.05	0.000008	0.09	1720.61	1668.28	0.03
Reach	27405	Qmin	144.81	44.00	45.03		45.04	0.000015	0.12	1255.81	1464.85	0.04
Reach	24721	Qmin	144.81	44.00	45.02		45.02	0.000009	0.09	1683.06	1729.72	0.03
Reach	21003	Qmin	144.81	44.00	45.00		45.00	0.000012	0.11	1347.91	1361.77	0.04
Reach	18892	Qmin	144.81	44.00	44.99		44.99	0.000009	0.09	1637.22	1680.69	0.03
Reach	16672	Qmin	144.81	44.00	44.97		44.97	0.000011	0.10	1513.57	1573.93	0.03
Reach	14049	Qmin	144.81	44.00	44.93		44.93	0.000048	0.20	718.68	799.59	0.07
Reach	12141	Qmin	144.81	44.00	44.82		44.82	0.000072	0.23	637.91	805.62	0.08
Reach	10085	Qmin	144.81	44.00	44.71		44.71	0.000027	0.13	1232.61	1761.20	0.05
Reach	8674	Qmin	144.81	44.00	44.68		44.68	0.000008	0.07	2284.37	3119.06	0.03
Reach	7016	Qmin	144.81	43.00	44.66		44.66	0.000008	0.07	2016.12	2462.49	0.03
Reach	5724	Qmin	144.81	44.00	44.60		44.60	0.000062	0.17	959.01	1657.18	0.07
Reach	4185	Qmin	144.81	44.00	44.53		44.53	0.000014	0.08	1395.83	1842.24	0.03
Reach	2581	Qmin	144.81	44.00	44.47		44.47	0.000039	0.12	1487.43	3246.72	0.06
Reach	1000	Qmin	144.81	44.00	44.26	44.05	44.26	0.000200	0.18	958.89	3601.03	0.11

Table 5.4- Profile output table for steady flow analysis for Qavg

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach	32803	Qavg	15458.68	44.00	53.04		53.07	0.000040	0.86	23255.81	3382.19	0.09
Reach	30020	Qavg	15458.68	44.00	52.97		53.00	0.000048	0.94	21802.67	3815.20	0.10
Reach	27405	Qavg	15458.68	44.00	52.87		52.91	0.000062	1.00	20298.75	3563.65	0.11
Reach	24721	Qavg	15458.68	44.00	52.78		52.82	0.000055	0.99	20295.16	3497.63	0.11
Reach	21003	Qavg	15458.68	44.00	52.65		52.73	0.000096	1.28	13250.66	2307.12	0.14
Reach	18892	Qavg	15458.68	44.00	52.52		52.58	0.000074	1.12	16227.12	2434.13	0.12
Reach	16672	Qavg	15458.68	44.00	52.39		52.46	0.000092	1.22	13909.91	2101.69	0.14
Reach	14049	Qavg	15458.68	44.00	51.93		52.13	0.000329	2.04	9006.19	2434.25	0.25
Reach	12141	Qavg	15458.68	44.00	51.23		51.45	0.000381	2.14	8657.40	2665.89	0.27
Reach	10085	Qavg	15458.68	44.00	50.72		50.80	0.000156	1.36	12876.48	2440.50	0.17
Reach	8674	Qavg	15458.68	44.00	50.58		50.60	0.000050	0.78	28457.16	6284.74	0.10
Reach	7016	Qavg	15458.68	43.00	50.44		50.47	0.000081	0.93	23867.86	6038.32	0.12
Reach	5724	Qavg	15458.68	44.00	49.90		49.98	0.000232	1.50	13884.28	3951.08	0.20
Reach	4185	Qavg	15458.68	44.00	49.29		49.37	0.000227	1.40	14422.87	4745.28	0.20
Reach	2581	Qavg	15458.68	44.00	48.85		48.89	0.000145	1.08	19292.14	5072.66	0.16
Reach	1000	Qavg	15458.68	44.00	48.37	45.26	48.42	0.000200	1.18	16849.73	4574.15	0.18