FLOOD VULNERABILITY ASSESSMENT THROUGH 1D & 2D MODELLING FOR JIA BHARALI RIVER USING HEC RAS

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2021-23

DECLARATION

I hereby declare that the work presented in the dissertation **"FLOOD VULNERABILITY ASSESSMENT THROUGH 1 & 2 D MODELLING FOR JIA BHARALI RIVER USING HEC RAS "** in partial fulfillment of the requirement for the awardof the degree of "MASTER OF TECHNOLOGY" in Civil Engineering (with specialization inWater 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: AKHOURI ASHISH PRASAD

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

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ABSTRACT

Due to its location and numerous hydro-meteorological and topographical factors, Assam is particularly vulnerable to river bank erosion and flooding. Jia-Bharali, the major river in the Sonitpur district, has experienced significant flooding and bank erosion and is regarded as a problematic river throughout Assam's history. One of the main branches of the river Brahmaputra, the Jia-Bharali, enters the North Brahmaputra Plain at Bhalukpung in Arunachal Pradesh in North Eastern India after flowing from the lower Himalayas. The Jia-Bharali basin is characterised by extremely large floods and bank erosion, which cause widespread destruction. In the current work, a study along the Jia Bharali River has been conducted with a focus on the calculation of surface water elevations on downstream area of Tezpur 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 Jia-Bharali 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.

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CHAPTER 1

INTRODUCTION

1.1 PROLOGUE

River flood has been known as the foremost disastrous marvels particularly in urban zones. Flood is one of the most devastating characteristic risks which lead to the misfortune of lives, properties and assets. It has therefore necessary to be imperative to make effective study, quick open surge risk layout, which will prioritize the mitigation impacts. Flooding signifies the method of immersion of an area by sudden rise of water due to snow-melt, extreme precipitation concentrated in the upper portion to as well within the lower portion of a basin or due to dam disappointment in which life and property in the influenced range are beneath chance. It could be a normal and repeating occasion for a stream. Eighty percent of the precipitation takes place within the monsoon months from June to September. These coupled with lack of carrying capacity of the rivers are dependable for causing floods, drainage congestion and disintegration of river-banks. It is a result of overwhelming or persistent precipitation surpassing the absorptive capacity of soil and the conveyance capacity of stream channel. This causes a stream to flood its banks on to the adjacent lands. In spite of the fact that floods happen most for a long time in monsoon-affected areas, numerous areas still need surge hazard maps to avoid or moderate the harm. Hence, it is vital to develop and progress prescient models and observing devices, and establish regulatory measures and possibility plans.

Stream surge chance appraisal has been considered after a long time around the world. However, diverse strategies of surge relief have being connected, floodplain administration and the utilization of science and information can decrease flood harms. Management measures to diminish flood harm which can be wiped out in two parts: structural and nonstructural measures. Structural flood administration application includes damming, trenches, the diversion of stream flooding, and other physical flood relief structure constructions. The nonstructural surge administration approach includes reducing the damaging impacts of surge without constructing physical structures. To optimize the surrounding lands, the foremost fundamental apparatus is to anticipate the dangers of flood in waterways and decide their boundaries. The waterway zoning maps are certainly one of the foremost essential and vital data required in respectful designing ventures and ought to be taken into consideration a few times recently or operational improvement within the ventures. As the waterway zoning maps allow profitable data, such as the depth and zone of flood prevention in flood zones, it is significant to supply the maps in the first place.

The relief measures are possible in development only in case the engineering apparatuses such as flood modeling are embraced. The flood modeling is one of the designing apparatuses which give exact data of the flood profile. The precipitation, runoff, catchment characteristics, and return period are the parameters which oversee the flood. Floodplain studies give water surface profiles and floodplain maps for land-use arranging for flood inclined regions. Floodplain studies regularly incorporate the examination of memorable surges which are utilized in model calibration to create beyond any doubt by which the model can reproduce noteworthy water surface heights recorded amid real surge occasions. Hydrological modeling which could be a disentangled representation of the genuine circumstance could be a challenging task especially for regions with constrained information and hydrologic models ought to be well calibrated.

An effective waterway flood demonstrate requires an adequate representation of the waterway channel and floodplain geometries, with an exact portrayal of the show parameters, to make it conceivable to anticipate the stream size and water levels along the reach precisely. Computer models play a pivotal role in these analyses by aiding in the determination of water surface profiles associated with different flow conditions. Often the computed water surface elevations are manually plotted on paper maps in order to delineate floodplains. Computer program apparatuses have been (and are being) created and overhauled to extricate spatial highlights that are valuable for hydraulic models, from geographical information sources, both in GIS and non-GIS situations. These simulations empower us to pick up an understanding of the impacts of past human exercises within the stream framework and examine the important impacts of changes in arrive utilization on the performance of the waterway through time. This spatial and temporal data could be a vital input for surge administration and formative arranging. These softwares which offers a wide assortment of choices for modeling water powered frameworks has been effectively utilized in comparable ranges of medium mountains and has been the subject of a few universal distributions and proposition work.

The Jia-Bharali river catchment is bounded by longitudes 92°00′–93°25′E and latitudes 26°39′–28°00′N in the North Brahmaputra Plain of north eastern India. The Jia-Bharali, one of the major tributaries of the river Brahmaputra, flows down from the lower Himalayas in Arunachal Pradesh in the north eastern India and enter the North Brahmaputra Plain at Bhalukpung (92°65′E: 27°01′N) where it takes the name of Jia-Bharali (Jia meaning alive in local language). Jia-Bharali catchment is made up of two tectonic blocks being separated by the river itself. The western block is tectonically active with continued release of strain and the eastern block is a zone of strain accumulation. The structural features of the Jia-Bharali basin include a system of faults dividing the basin into a number of blocks within the Brahmaputra valley. A zone of weakness or a graben between the Rangapara block to the west and Charali block to the east is noted, along the Jia-Bharali river catchment is bounded by longitudes 92°00′–93°25′E and latitudes 26°39′–28°00′N in the North Brahmaputra Plain of north eastern India. The Jia-Bharali, one of the major tributaries of the river Brahmaputra, flows down from the lower Himalayas in Arunachal Pradesh in the north eastern India and enter the North Brahmaputra Plain at Bhalukpung (92°65′E: 27°01′N) where it takes the name of Jia-Bharali (Jia meaning alive in local language). Jia-Bharali catchment is made up of two tectonic blocks being separated by the river itself. The western block is tectonically active with continued release of strain and the eastern block is a zone of strain accumulation. The structural features of the Jia-Bharali basin include a system of faults dividing the basin into a number of blocks within the Brahmaputra valley.

It is dotted with numerous meander scars, remnant channels, misfit streams, inactive floodplains and natural levee. The Jia-Bharali catchment shows the presence of a number of river terraces at different topographic levels with the present Jia-Bharali channel system occupying the lowest level. The course of this palaeo river system is known as Mara Bharali (Mara meaning dead) and is well discernible on the ground. Subsequently, Mara Bharali has attained a graded condition with respect to the local base as the Brahmaputra River at Tezpur, 92°53′E: 26°39′N and developed a wide meander belt (Khound etal. 2013). The region has extensive tea-plantations on the higher topographic surfaces and paddy fields generally occupying the lower topographic planes. The northern portion along the foothills of Arunachal Himalaya is made up of reserve forests (e.g., Chariduar, Balipara reserve forests) and sparsely populated forest-villages. The region abounds in biodiversity with evergreen and deciduous trees of many types. The climate of the study area is sub-tropical in nature with hot and humid summer (average temperature 29°C), heavy monsoon rain (May–September) followed by inundation of almost the entire area, dry autumn and cold winter (November–February, average temperature 16°C). The Jia-Bharali River basin experiences 4–5 major floods annually during the monsoon periods (Jain etal. 2007), frequently occurred flood creates great havoc in the physical and cultural landscapes

Jia- Bharali, the main river of Tezpur locale has long been considered as a tricky river within the history of Assam due to re-current and extensive flooding and bank disintegration. Therefore it is important to understand suitable methods by which local people would have used to mitigate and to protect river bank erosion and flood and to suggest some suitable measures. Frequently occurred flood creates great havoc in the physical and cultural landscapesof the study area. Sometimes, water level rises to 3 feet from the actual land surface which can create unhealthy and unhygienic environment by spreading up diseases, scarcity of food etc.

Therefore, it is important to understand suitable methods by which local people would have used to mitigate and to protect river bank erosion and flood and to suggest some suitable measures.

Program frequently utilized in combination with HEC-RAS is ArcGIS. The essential inputs to HEC-RAS in this study incorporate the waterway release, channel, floodplain geometry, and channel resistance. 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. This is often a primary reason we have utilized it in this study.

1.2 OBJECTIVE OF THE STUDY

The Objectives of the study are as given below:

i. The development of a hydrological model for river Jia Bharali on the Northern bank of Brahmaputra River in Assam, India.
ii. Development of hydraulic/ hydrodynamic model for the river Jia Bharali 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 ABOUT JIA BHARALI RIVER

The Bharali or Jia Bharali is a tributary of the Brahmaputra River in the Indian state of Assam. The Bharali river originates in the hills of Arunachal Pradesh and flows through the heart of Tezpur before its confluence with the Brahmaputra River. Jia Bharali in Assam is also known as Kameng river in Arunachal. The name Bharali or Bharalu originate from Boro goddess name – Bhollobri. In the eastern Himalayan mountains, originates in Tawang district from the glacial lake below snow-capped Gori Chen Mountain 27°48′36″N 92°26′38″E, elevation 6,300 metres (20,669 ft), on the India-Tibet border and flows through Bhalukpong circle of West Kameng District, Arunachal Pradesh and Sonitpur District of Assam, India. It becomes a braided river in its lower reaches and is one of the major tributaries of the Brahmaputra River, joining it at Tezpur, just east of the Kolia Bhomora Setu bridge. The Kameng River is about 264 kilometres (164 mi) long. Its drainage basin is about 11,843 square kilometres (4,573 sq mi) large. The Kameng forms the boundary between East Kamemg District and West Kameng Districts and is also the boundary between the Sessa and Eaglenest sanctuaries to its west and the Pakke Tiger reserve to the east. The Dafla Hills are east and the Aka Hills (home of Aka tribe) are west of the Kameng River. The entire stretch of forest along the Bhalukpong–Bomdila highway on the west bank of the river in West Kameng has vanished in the last few years though the forest across the river continues to be in a healthy state.

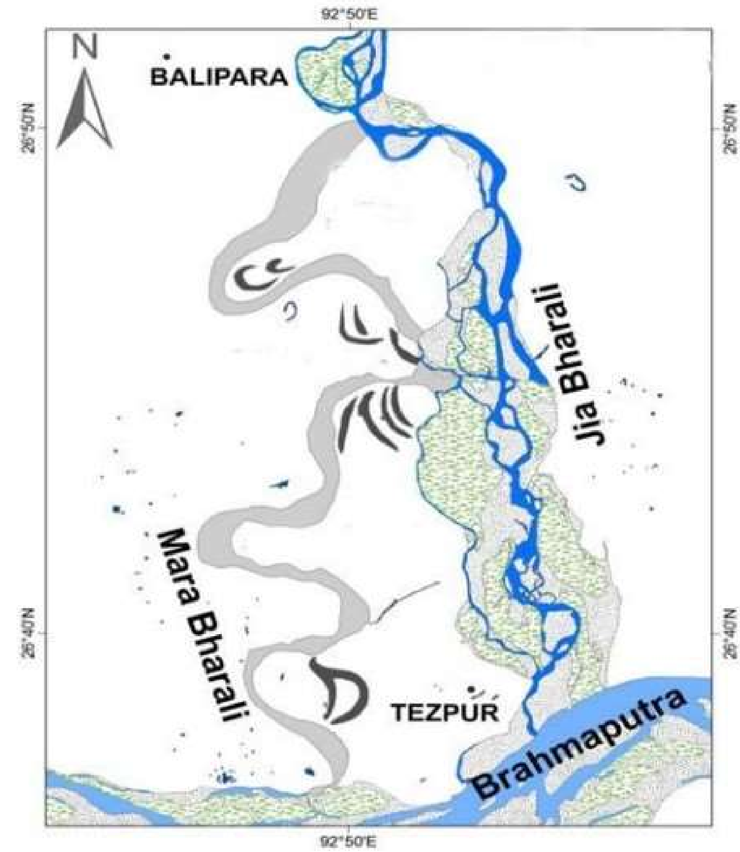


Fig1.1: Map showing the area of study on the Bank of River Jia Bharali (Tezpur) in the Sonitpur District of Assam.

<u>**CHAPTER 2**</u>

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 & MATERIALS

3.1 STUDY AREA

The area under study is located within the North bank of the mighty river Brahmaputra. Tezpur, the Cultural Capital of Assam, lies between 26º 38′ north latitude and 92 º 48′ east longitudes with an area of about 40 km^2 and bounded by Rangapara in the north, Jamugurihat in the east, Dhekiajuli in the west and Nagaon in the south. Climatically, the study area falls under sub-tropical monsoonal type of climate with an average temperature of 21ºC and around 10ºC during summer and winter seasons respectively. This beautiful town of northern bank of mighty river Brahmaputra is dotted with a range of lower hills and hillocks like Agnigarh, Auguri, Bamuni hills with luxuriant growth of ever-green and semi-deciduous forests. Along with this lower hills and hillocks Tezpur town is also decorated with some different geometric shapes low-lying areas which are abandoned channel of the river JiaBharali. With the density of 2,600 persons / km^2 the total population of this beautiful town is 102,505 (2011 census). The issue of flooding gets to be more complicated within the lower reach for which this study will be centering in those zones.

The river reach length of the study area is about 12kms. It started from the Mansiri Village of Sonitpur District flowing through Tezpur town to where the river finally meets the mighty Brahmaputra.

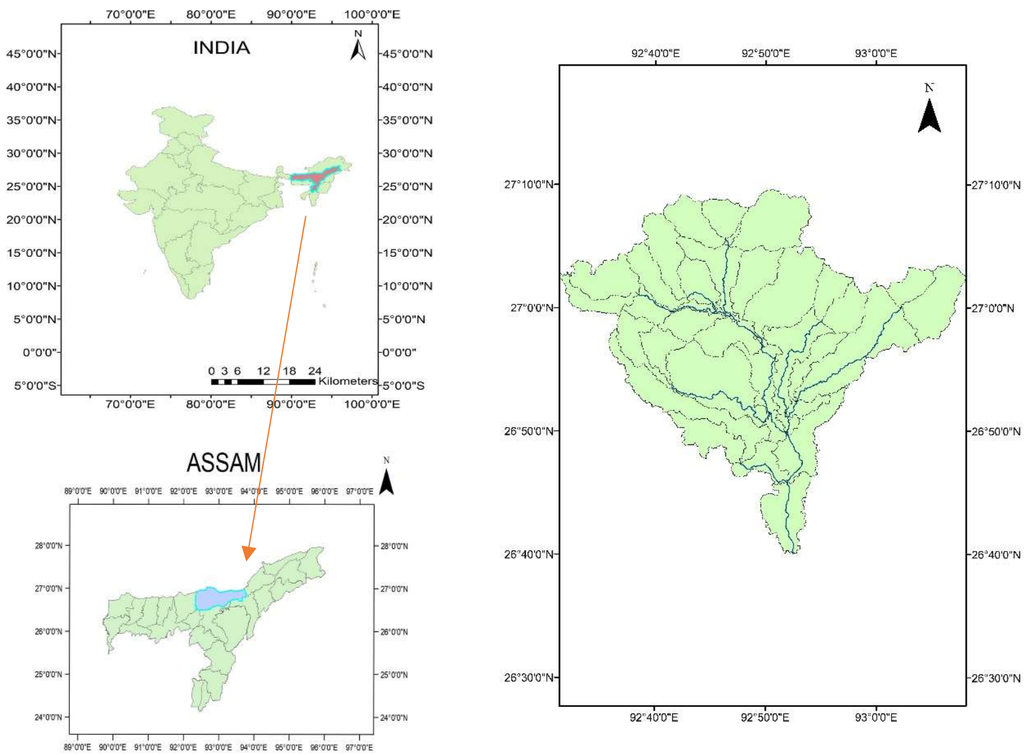


Fig 3.1: Jia-Bharali River Basin Map

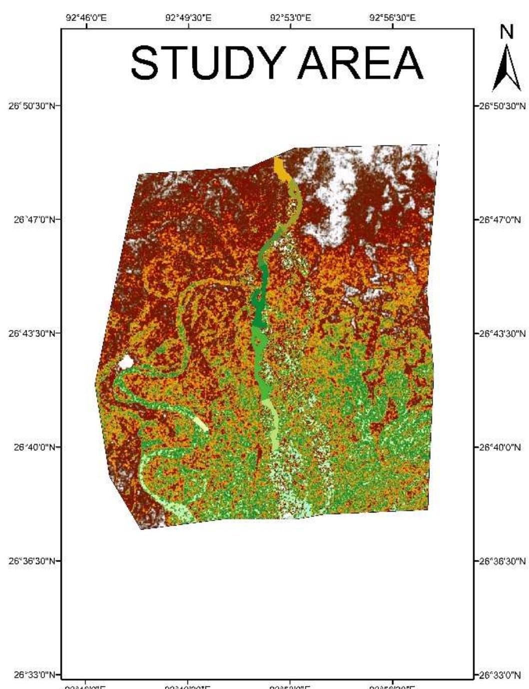


Fig 3.2: Study Area

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 ArcMAP- It is a geographic information system (GIS) which works with maps and geographic information maintained by the Environmental Systems Research Institute (ESRI). It can also be use for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database. In this study ArcGIS is use to delineate the river basin and also delineate only the study area basin map using DEM which is downloaded using "www.opentopgraphy.org". We can also find the river bathymetry from the downloaded DEM.

3.2.3 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 HEC-HMS (Hydrologic Engineering Center's Hydrologic Modelling System) is a software developed by the Hydrologic Engineering Center (HEC) of the United States Army Corps of Engineers. It is a powerful and widely used tool for hydrological modelling, specifically designed for simulating the hydrologic processes within a watershed. HEC-HMS is used by engineers, hydrologists, and researchers to analyse and predict the behaviour of watersheds and river systems under various hydrological conditions.

HEC-HMS allows users to simulate various hydrological processes, including rainfall, runoff, evapotranspiration, snowmelt, and more. The software provides a comprehensive platform for building watershed models and assessing the impact of different factors on the water cycle.

3.3 DATA:

3.3.1 Rainfall Data:

The Rainfall data of the Study Area in obtained from the website of India water Resource Information System.

Table 3.1: Rainfall Data from year 2005 to 2020

Year	Maximum Rainfall (mm)
2005	90.4
2006	107
2007	120
2008	75
2009	115.6
2010	70
2011	180
2012	77
2013	81.4
2014	140
2015	91.6
2016	140.8
2017	115.2
2018	180.2
2019	180.4
2020	72.6

3.3.2 Discharge Data: The discharge data of Jia Bharali River from 2005 to 2020 collected from Water Resource Department are shown in table 3.1

Table3.2: Discharge data of Jia Bharali River from 2005 to 2020 collected from Water Resource Department

Year	Max. Flow in cms
2005	2622
2006	2431
2007	3100
2008	2469
2009	2564
2010	2597
2011	2492
2012	2266
2013	2266
2014	2966
2015	2347
2016	2346
2017	2333
2018	3091
2019	2318
2020	3455

CHAPTER 4

METHODOLOGY

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

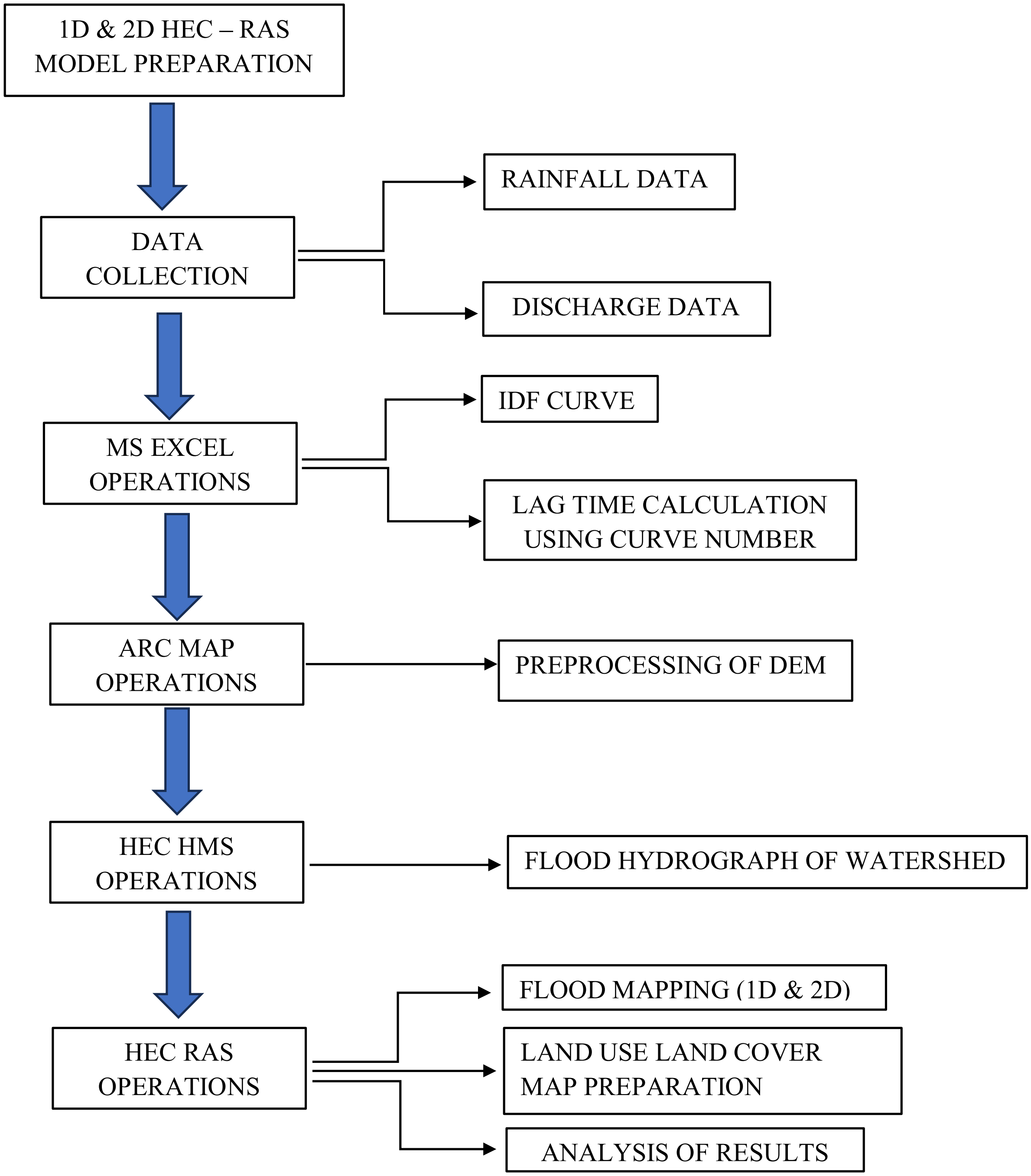


Fig 4.1: Operational Flowchart

4.2 OPERATIONS IN GOOGLE EARTH PRO:

Firstly, the DEM is downloaded from www.opentopography.org. After that, 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 Jia Bharali River in Google Earth Pro

4.3 OPERATIONS IN ARC MAP:

1) The Downloaded DEM is imported in ARC Map using the add data feature of the software.

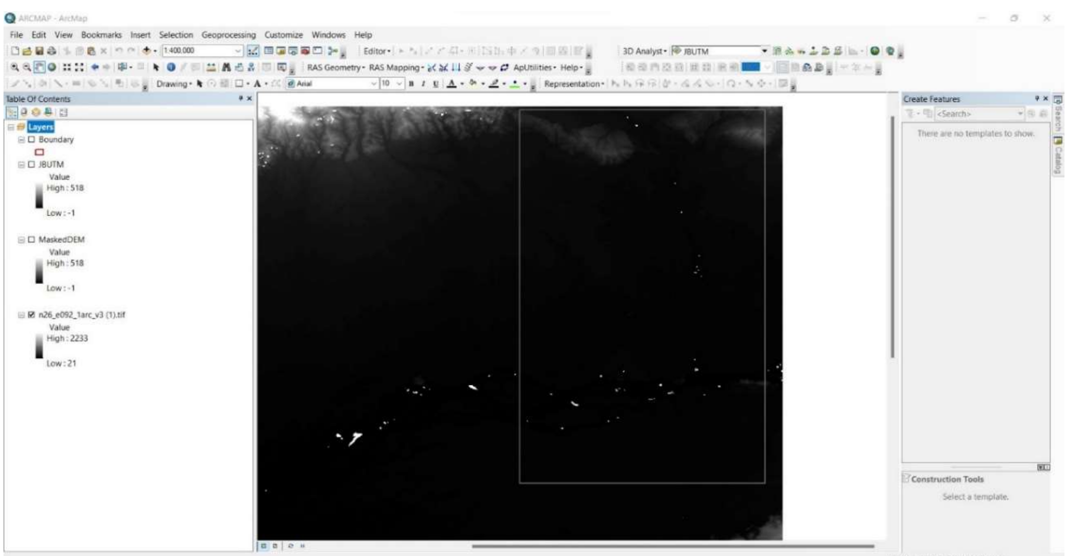


Fig 4.3: Arc Map Window displaying DEM

2) To clip a digital elevation model (DEM) in ArcMap, we have followed these steps:

I. Open ArcMap and add the DEM layer that you want to clip.
II. Add the layer that you want to use as the clip feature. This can be a polygon, a shapefile, or any other feature layer.
III. Make sure that the two layers have the same projection.
IV. Click on the "Geoprocessing" menu and select "Clip."
V. In the Clip tool dialog box, select the input raster layer (the DEM layer) and the clip feature layer.
VI. Choose the output raster location and name, and make sure that the "Use Input Features for Clipping Geometry" option is selected.
VII. Click OK to run the tool.
VIII. Once the clip operation is completed, you will have a new clipped DEM layer.

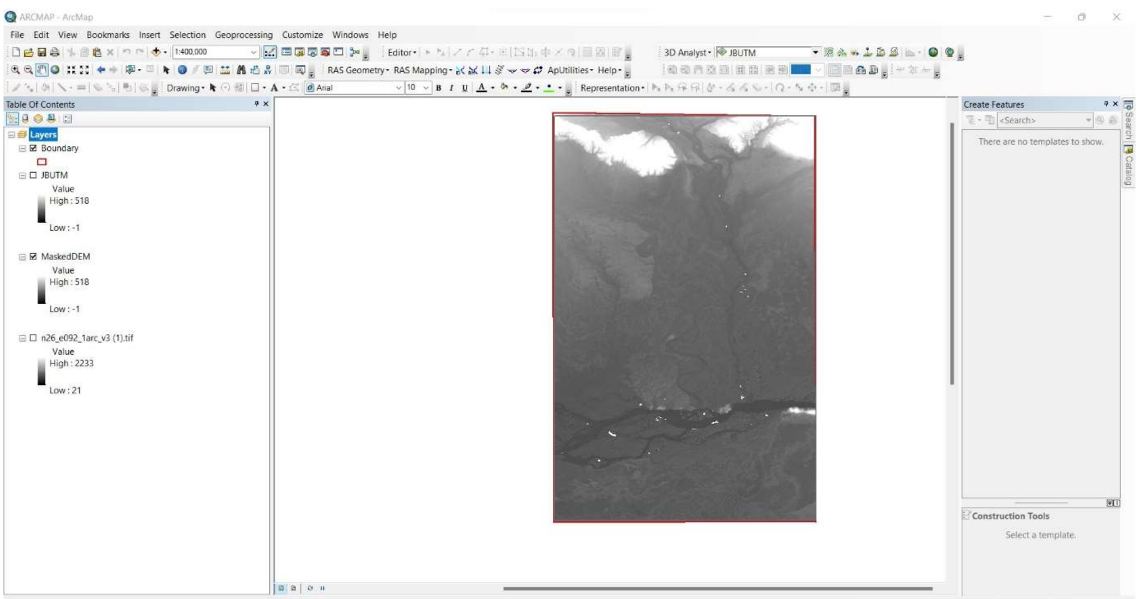


Fig 4.4: Clipped DEM

3) 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 46N

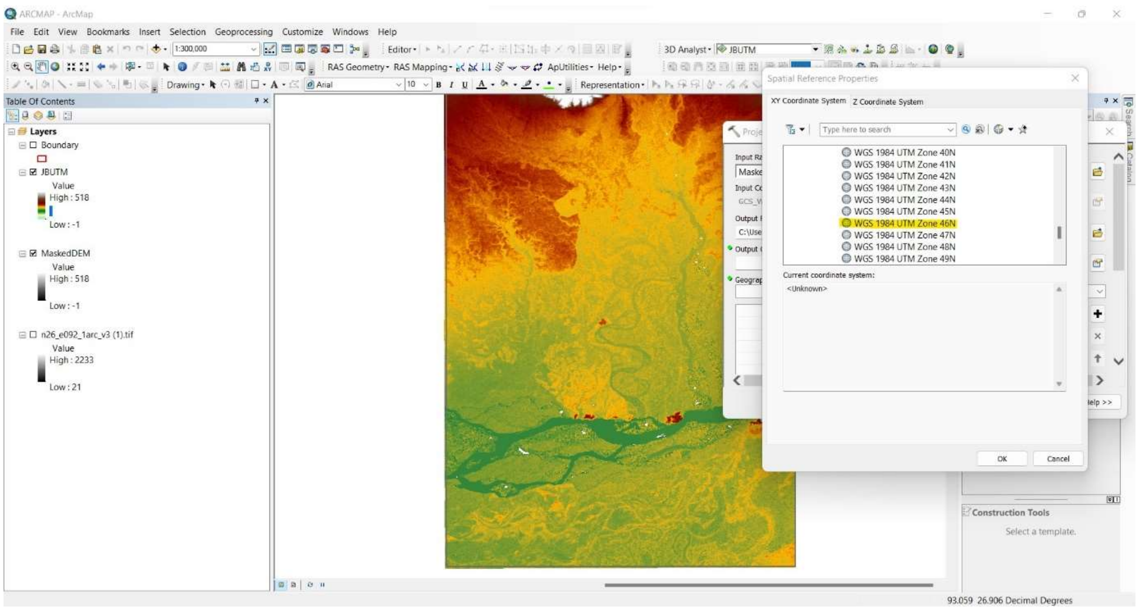


Fig 4.5: Assigning projection to the DEM

4) The converted DEM having the required projection is saved.

4.4 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.

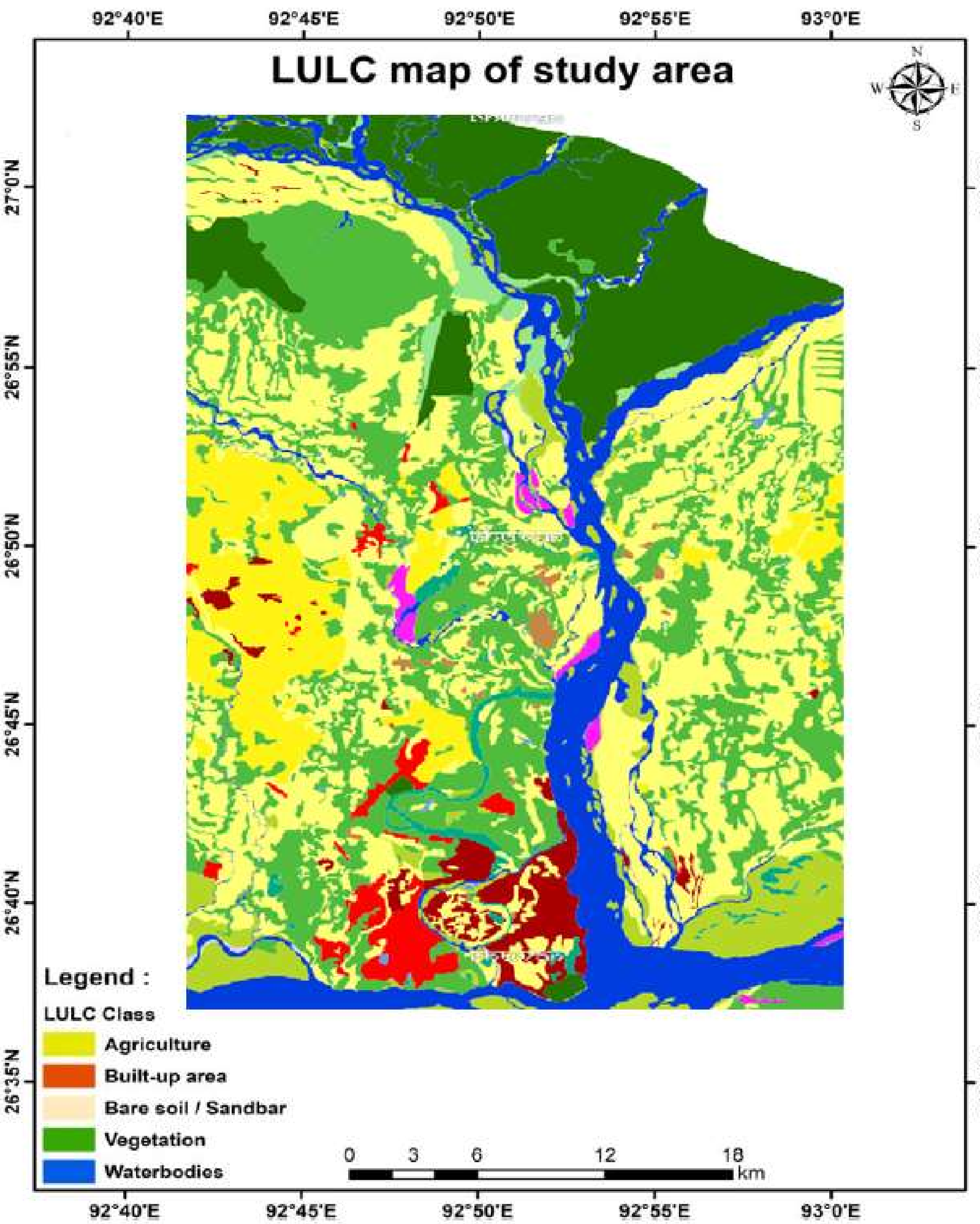


Fig 4.6: Land Use Land Cover Map Obtained From ARC MAP

4.5 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

$$x_T = x + K_T \times S$$

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,

$$K_T = -\frac{\sqrt{6}}{\pi}\{0.5772 + ln\,(ln\,(\frac{T}{T-1}))\}$$

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	0.366512921	2.250367327	3.198534261	3.901938658	4.310784111	4.600149227
K_T	-0.15479	1.5031	2.33753	2.95656	3.31636	3.57102

Table 4.2: GUMBEL DISTRIBUTION

Year	Maximum Rainfall (mm)	PRECIPITATION							
		5 min	10 min	15 min	30 min	60 min	120 min	720 min	1440 min
2005	90.4	13.68898	17.2470	19.7429	24.8745	27.3780	39.4858	71.7505	90.4000
2006	107	16.20266	20.4141	23.3683	29.4422	32.4053	46.7366	84.9260	107.0000
2007	120	18.17121	22.8943	26.2074	33.0193	36.3424	52.4148	95.2441	120.0000
2008	75	11.35700	14.3089	16.3796	20.6370	22.7140	32.7593	59.5275	75.0000
2009	115.6	17.50493	22.0548	25.2465	31.8086	35.0099	50.4930	91.7518	115.6000
2010	70	10.59987	13.3550	15.2877	19.2612	21.1997	30.5753	55.5590	70.0000
2011	180	27.25681	34.3414	39.3111	49.5289	54.5136	78.6222	142.8661	180.0000
2012	77	11.65986	14.6905	16.8164	21.1874	23.3197	33.6328	61.1149	77.0000
2013	81.4	12.32613	15.5300	17.7774	22.3981	24.6523	35.5547	64.6072	81.4000
2014	140	21.19974	26.7100	30.5753	38.5225	42.3995	61.1506	111.1181	140.0000
2015	91.6	13.87069	17.4760	20.0050	25.2047	27.7414	40.0100	72.7030	91.6000
2016	140.8	21.32088	26.8626	30.7500	38.7426	42.6418	61.5001	111.7530	140.8000
2017	115.2	17.44436	21.9785	25.1591	31.6985	34.8887	50.3182	91.4343	115.2000
2018	180.2	27.28709	34.3796	39.3548	49.5839	54.5742	78.7096	143.0248	180.2000
2019	180.4	27.31738	34.4177	39.3985	49.6390	54.6348	78.7970	143.1836	180.4000
2020	72.6	10.99358	13.8510	15.8555	19.9767	21.9872	31.7110	57.6227	72.6000

MEAN	17.3876	21.9070	25.0772	31.5953	34.7751	50.1544	91.1367	114.8250
STANDARD DEVIATION	5.9657	7.5163	8.6040	10.8403	11.9313	17.2080	31.2690	39.3964

Table 4.3: Rainfall Intensity for Different Return Period

Time (hours)	Time (minutes)	Mean	Standard Deviation	2 YEARS		10 YEARS		25 YEARS		50 YEARS		75 YEARS		100 YEARS	
				Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)
0.08	5.00	17.39	5.97	16.46	197.57	26.35	316.25	31.33	375.99	35.03	420.31	37.17	446.06	38.69	464.29
0.17	10.00	21.91	7.52	20.74	124.46	33.20	199.23	39.48	236.86	44.13	264.78	46.83	281.00	48.75	292.49
0.25	15.00	25.08	8.60	23.75	94.98	38.01	152.04	45.19	180.76	50.52	202.06	53.61	214.44	55.80	223.21
0.50	30.00	31.60	10.84	29.92	59.83	47.89	95.78	56.93	113.87	63.65	127.29	67.55	135.09	70.31	140.61
1.00	60.00	34.78	11.93	32.93	32.93	52.71	52.71	62.67	62.67	70.05	70.05	74.34	74.34	77.38	77.38
2.00	120.00	50.15	17.21	47.49	23.75	76.02	38.01	90.38	45.19	101.03	50.52	107.22	53.61	111.60	55.80
12.00	720.00	91.14	31.27	86.30	7.19	138.14	11.51	164.23	13.69	183.59	15.30	194.84	16.24	202.80	16.90
24.00	1440.00	114.83	39.40	108.73	4.53	174.04	7.25	206.92	8.62	231.30	9.64	245.48	10.23	255.51	10.65

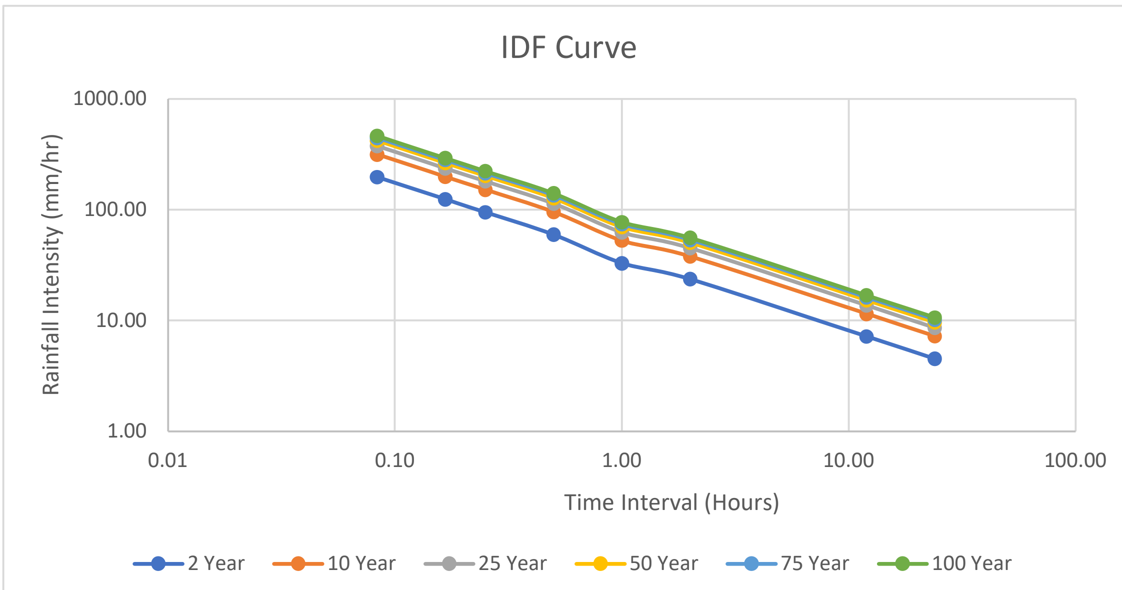


Fig 4.7: IDF Curve

2) Lag Time Calculation: LAG Time is computed for different Sub Basins using Curve Number

Table 4.4: Lag Time Calculation

Sub Basins	Hydraulic Length (l) m	Average Basin Slope (S) m/m	Average Basin Slope (Y)%	Curve Number (CN)	S=[(1000/CN)-10] inch	Lag Time (L) hour	Lag Time (L) min
Sub-1	4549.8	0.1908336	19.08336	80	2.50	0.63	37.94
Sub-2	17355.18	0.04321077	4.321077	90.58	1.04	2.66	159.47
Sub-3	7902.86	0.44198	44.198	70.02	4.28	0.86	51.72
Sub-4	239.18	0.36863	36.863	80	2.50	0.04	2.59
Sub-6	12737.71	0.4249661	42.49661	70.08	4.27	1.29	77.15
Sub-12	4192.37	0.28684	28.684	80	2.50	0.48	28.99
Sub-16	9959.66	0.4009483	40.09483	70.97	4.09	1.06	63.67
Sub-17	12911	0.1645085	16.45085	71.59	3.97	2.00	120.29
Sub-18	19780.06	0.2219509	22.19509	72.6	3.77	2.36	141.67
Sub-19	3279.51	0.05488846	5.488846	80	2.50	0.91	54.44
Sub-20	1267.2	0.03889964	3.889964	80	2.50	0.50	30.22
Sub-21	1828.82	0.05138712	5.138712	80	2.50	0.59	35.26
Sub-22	17180.08	0.2124788	21.24788	70.36	4.21	2.29	137.56
Sub-23	18246.98	0.1115267	11.15267	77.57	2.89	2.71	162.38
Sub-24	192.95	0.08127	8.127	80	2.50	0.08	4.64
Sub-25	19586.91	0.2200293	22.00293	70.7	4.14	2.48	148.75
Sub-27	14065.91	0.08452096	8.452096	82.28	2.15	2.18	130.74
Sub-28	3099.48	0.04936728	4.936728	80	2.50	0.91	54.87
Sub-30	12111.53	0.07849011	7.849011	79.15	2.63	2.22	132.93
Sub-31	17654.06	0.1078417	10.78417	78.82	2.69	2.58	154.86
Sub-32	18032.93	0.0632777	6.32777	70.2	4.25	4.39	263.17
Sub-33	29713.56	0.1425963	14.25963	76.22	3.12	3.68	220.76
Sub-34	23816.85	0.07579782	7.579782	74.48	3.43	4.45	266.75
Sub-35	9779.08	0.02525426	2.525426	86.22	1.60	2.60	156.15
Sub-36	30144.04	0.05983186	5.983186	81.32	2.30	4.92	294.97
Sub-37	5836.01	0.03205052	3.205052	91.24	0.96	1.25	75.29
Sub-38	6206.62	0.03215779	3.215779	88.01	1.36	1.50	89.98
Sub-39	16844.75	0.03227832	3.227832	85.15	1.74	3.70	221.70
Sub-40	22473.25	0.02944811	2.944811	86.73	1.53	4.60	276.17
Sub-41	11895.41	0.03020459	3.020459	85.85	1.65	2.82	169.25
Sub-42	16918.29	0.5150657	51.50657	70.53	4.18	1.45	86.87
Sub-43	15522.51	0.4154714	41.54714	70.56	4.17	1.50	90.21
Sub-44	16490.51	0.0391276	3.91276	82.94	2.06	3.56	213.52
Sub-45	39934.71	0.03354001	3.354001	85.21	1.74	7.22	432.95
Sub-46	13744.71	0.4297728	42.97728	70.86	4.11	1.33	79.82
Sub-48	11206.89	0.3501486	35.01486	70.3	4.22	1.27	76.26
Sub-49	11559.71	0.2915115	29.15115	70.16	4.25	1.43	86.00
Sub-50	15755.75	0.2870535	28.70535	70.72	4.14	1.82	109.36

Formulae used for Lag Time Calculation:

$T_c = 1.67L$

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1900Y^{0.5}}$$

Where,

L= Lag time (Hrs)

l=Hydraulic Length

S= (1000/CN) – 10

CN = Curve Number

4.6 OPERATION IN HEC-HMS:

Developing a flood study model with HEC-HMS (Hydrologic Engineering Center's Hydrologic Modeling System) involves several steps to simulate rainfall-runoff processes and analyze the resulting hydrographs. HEC-HMS is commonly used for hydrologic modeling to estimate streamflow in watersheds. Here's a general outline of the process:

1. Data Collection and Preparation:
    - Obtain topographic data: You will need Digital Elevation Models (DEMs) or other elevation data to define the watershed boundaries and flow directions. (Source: NASA SRTM 30m resolution)
    - Gather meteorological data: Obtain rainfall data, such as observed precipitation records or design storm data for various return periods. (Source: India-WRIS)
    - Acquire land use and soil data: Collect information on land cover types and soil properties within the watershed.
    - Land Cover Source: Bhuvan-Thematic Services of the National Remote Sensing Centre (NRSC), Indian Space Research Organization (ISRO)
2. Set Up the Project:
    - Launch HEC-HMS: Open the HEC-HMS software and create a new project.
    - Define the watershed: Digitize or import the watershed boundary based on the topographic data.
    - Divide the watershed into sub-basins: Define sub-basins within the main watershed based on hydrologic characteristics and flow patterns.

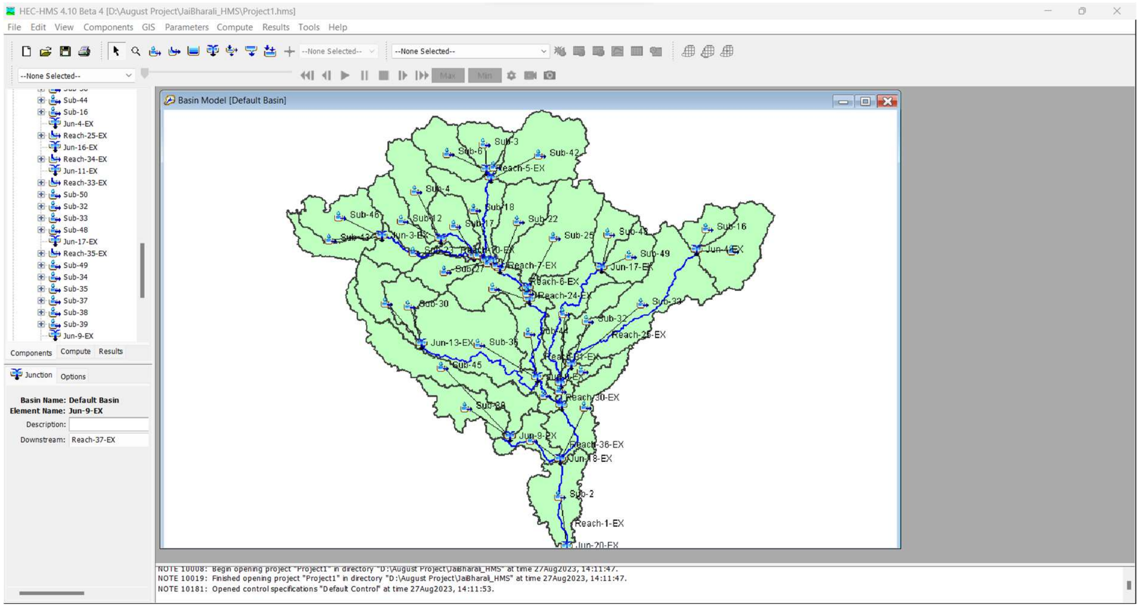


Fig 4.8: HEC HMS interface showing Sub Basin & Junctions

- Delineate hydrologic response units (HRUs): Divide each sub-basin into smaller HRUs representing distinct land use and soil combinations.

3. Hydrologic Model Setup:
    - Select a hydrologic method: Choose an appropriate hydrologic method, such as SCS-CN (Soil Conservation Service Curve Number) or SCS Unit Hydrograph, to estimate runoff.
    - Assign land use and soil data: Assign the appropriate land use and soil data to each HRU.
    - Set up rainfall data: Input the rainfall data for the simulation period, including rainfall depths and durations.
4. Model Calibration and Parameters:
    - Calibrate the model: Adjust the model parameters (e.g., CN values, time to peak, lag time) to match observed streamflow data from gauged locations within the watershed.
    - Validate the model: Verify the model's performance by comparing simulated results with independent observed data.
5. Run the Simulation:
    - Configure simulation settings: Set the simulation duration and time step, as well as any other relevant simulation parameters.

- Initiate the simulation: Run the HEC-HMS model to compute the rainfall-runoff process for the selected events or storm periods.

6. Post-Processing and Analysis:
   - Review the results: Analyze the output hydrographs generated by HEC-HMS for each sub-basin or outlet point in the watershed.
   - Assess flood characteristics: Examine the peak flow rates, hydrograph shapes, and other relevant parameters to understand the hydrologic response.
7. Communicate Findings:
   - Prepare reports and summaries: Document the modeling process, input data, calibration results, and conclusions.
   - Share the results: Communicate the findings and hydrograph outputs with relevant stakeholders, such as government agencies, communities, or decision-makers.

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

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

1) Create a new project in HEC-RAS: 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) Assigning Projection to the DEM: Projection File is also downloaded from spatialreference.org and applied in the terrain model.

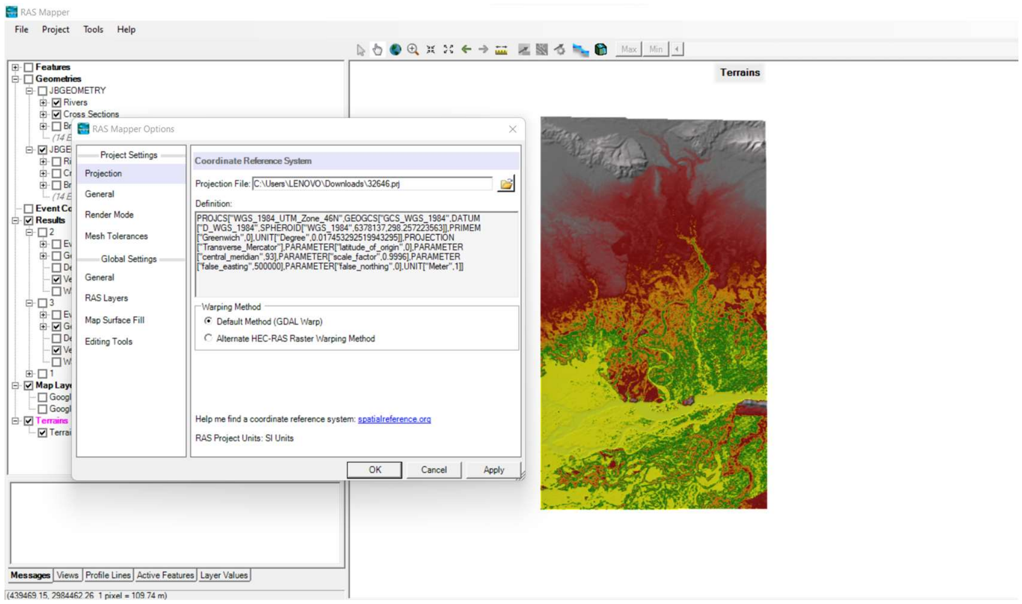


Fig 4.9: Applying Projection to the Terrain in RAS Mapper

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.

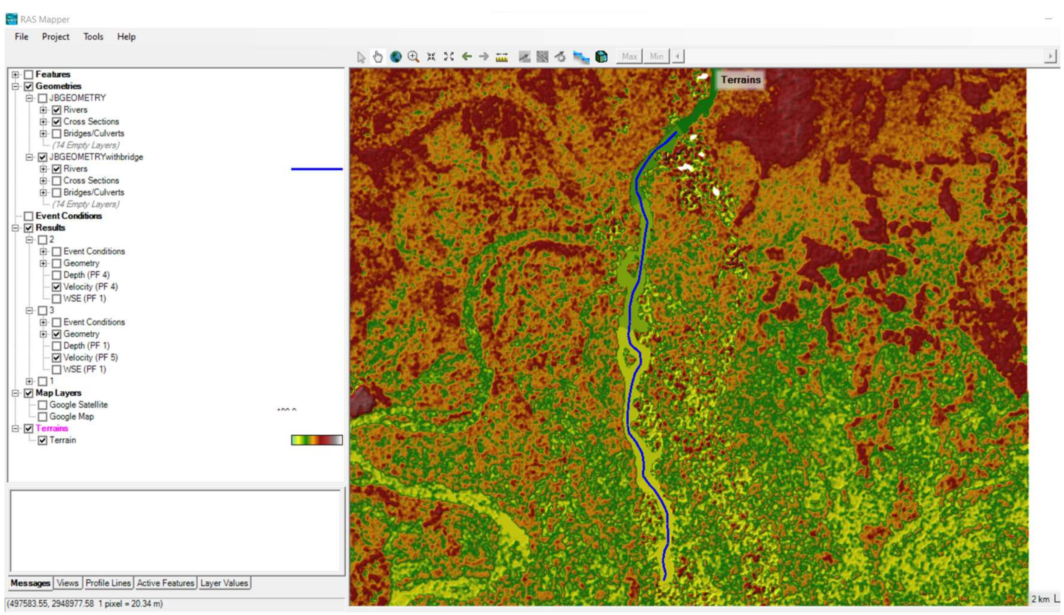


Fig 4.10: Marking centreline of the river in RAS Mapper

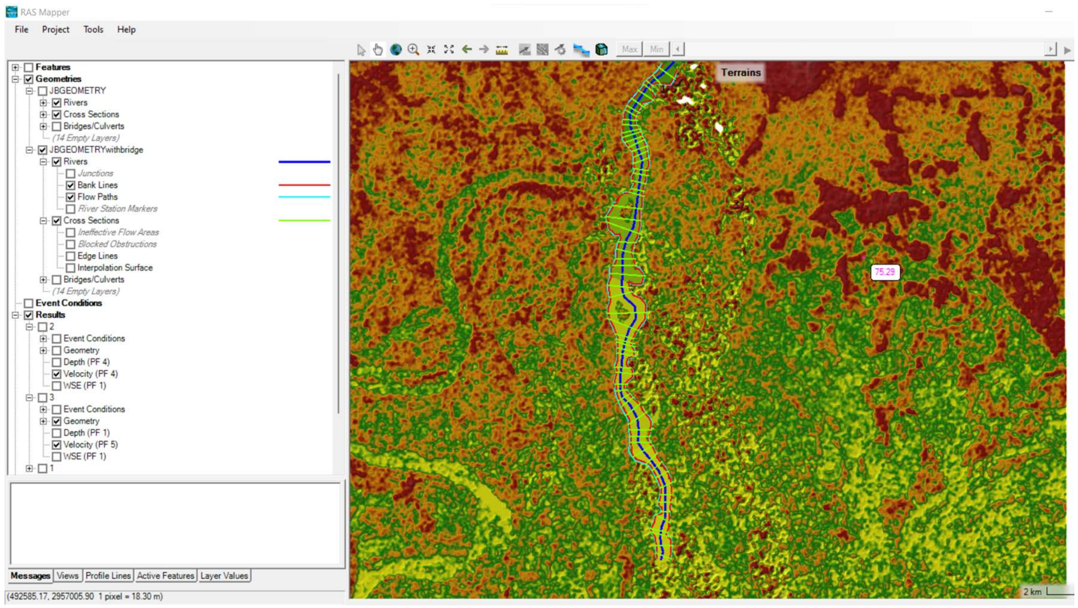


Fig 4.11: Marking Bank Lines, Flow Paths and cross sections in the RAS Mapper

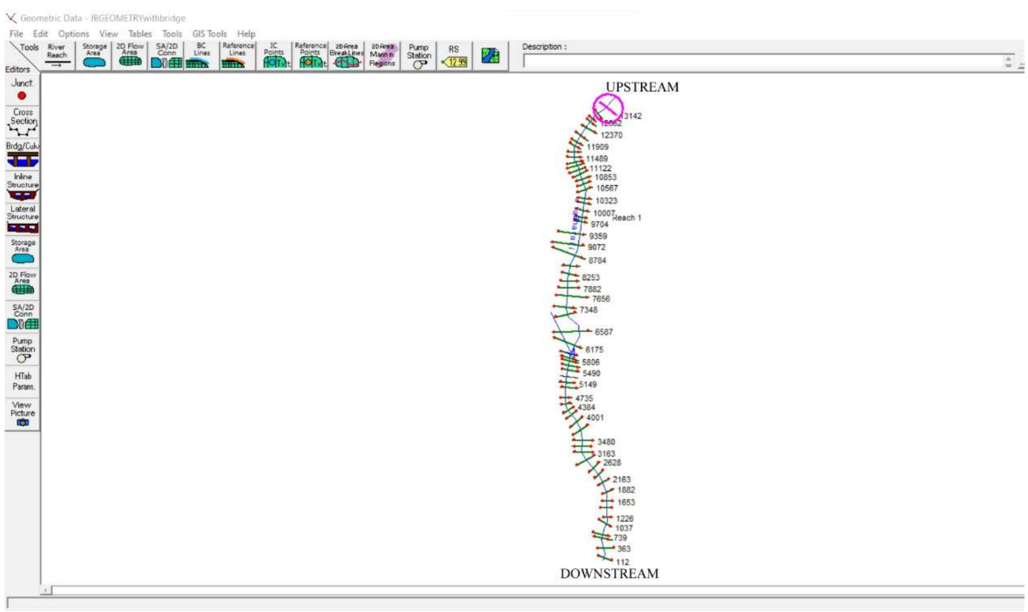


Fig 4.12: Cross Section Window of HEC RAS

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 (0.04)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.

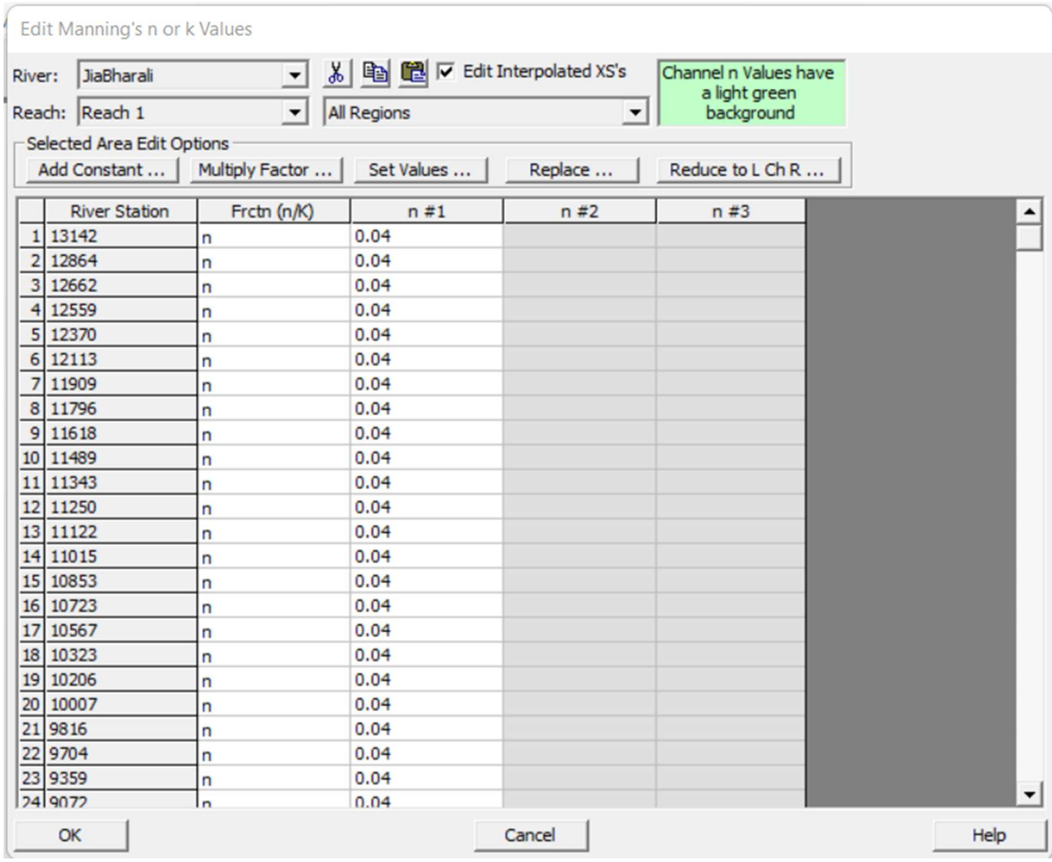


Fig 4.13: Applying Manning's n value

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.

$$Z_2 + Y_2 + \alpha_2 \frac{V_2^2}{2g} = Z_1 + Y_1 + \alpha_1 \frac{V_1^2}{2g} + h_e$$

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.

4.7.1 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 4.5: Discharge Data for steady flow analysis

Minimum Value (PF1)	Maxmimum Value (PF2)	Average of Maximum (PF2)	10% of maximum (PF4)	20% of maximum (PF5)
0.6292	4710	2646.92	5181	5652

The discharge data of Jia-Bharali River from 2005 to 2020 collected from Water Resource Department".

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 2005 to 2020.

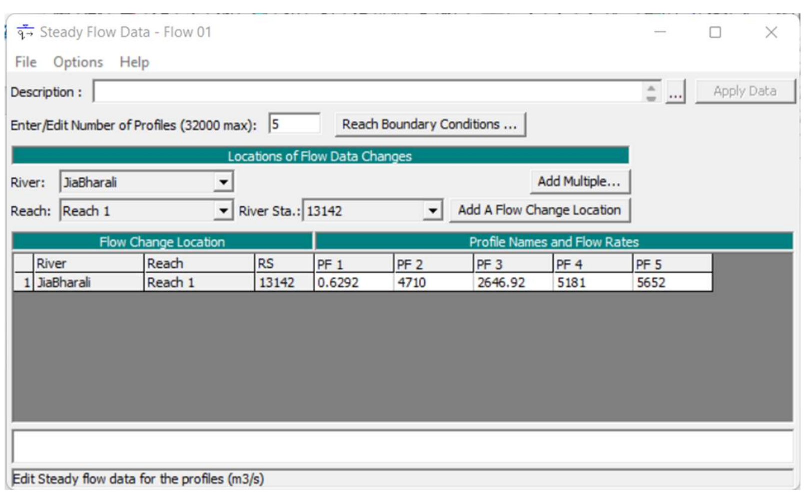


Fig 4.14: Entering Steady Flow Data

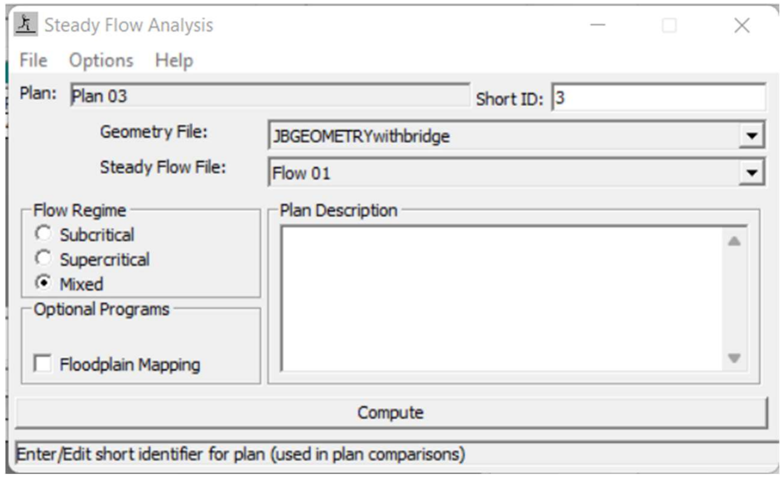


Fig 4.15: Steady Flow Analysis

4.8 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.

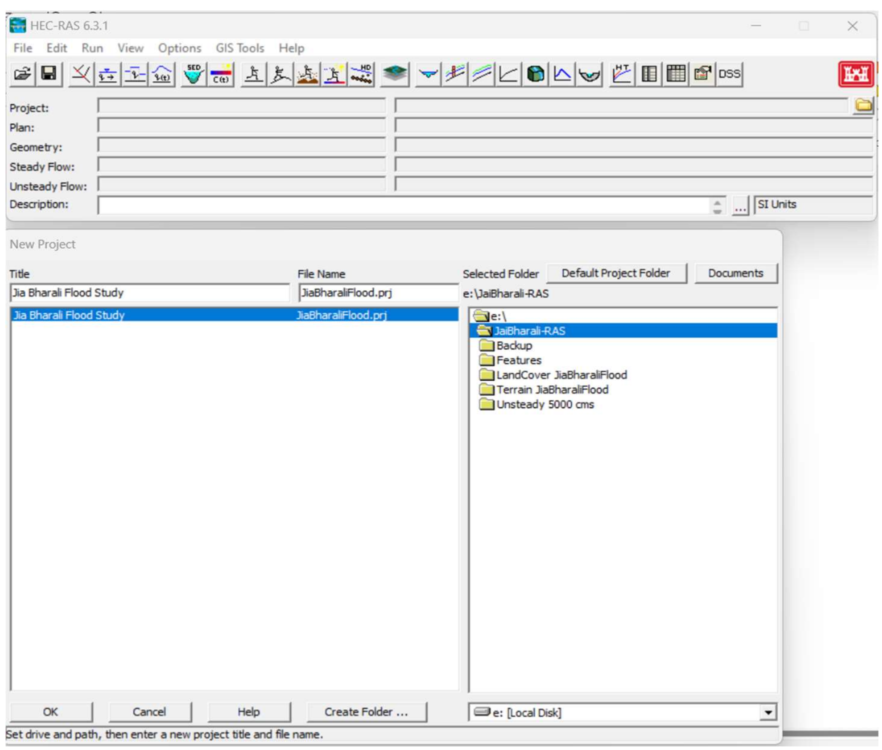


Fig 4.16: Creating a new project

▪ Define the project's geographical location and coordinate system.

▪ Set up a 2D modeling analysis by selecting the "2D Flow Area" option.

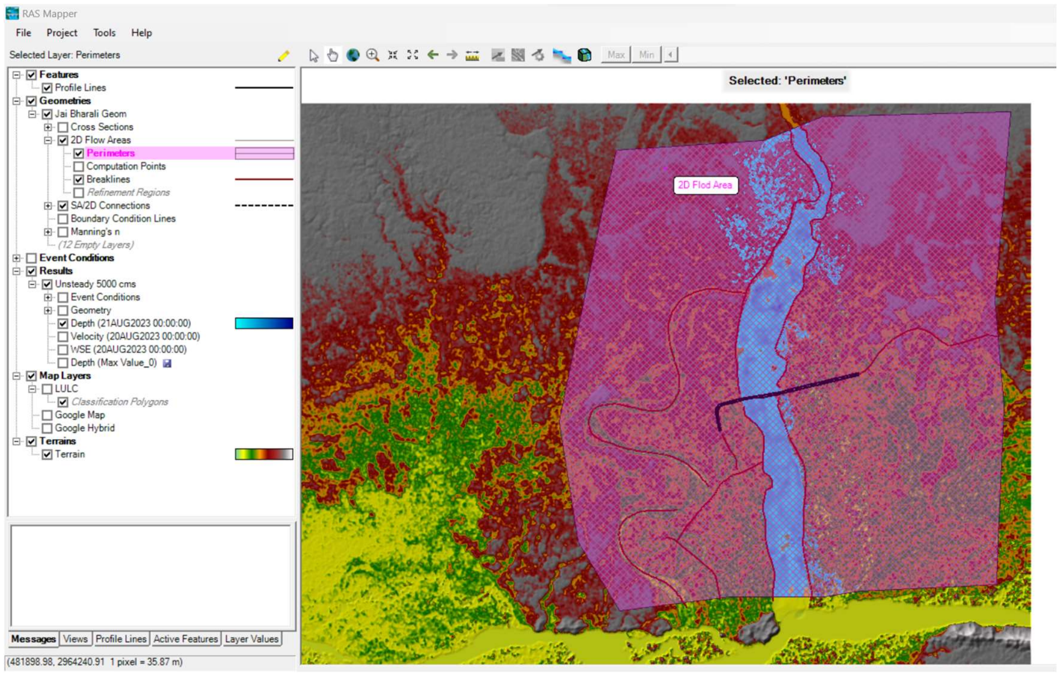


Fig 4.17: Setting up of 2D Flow Area

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.

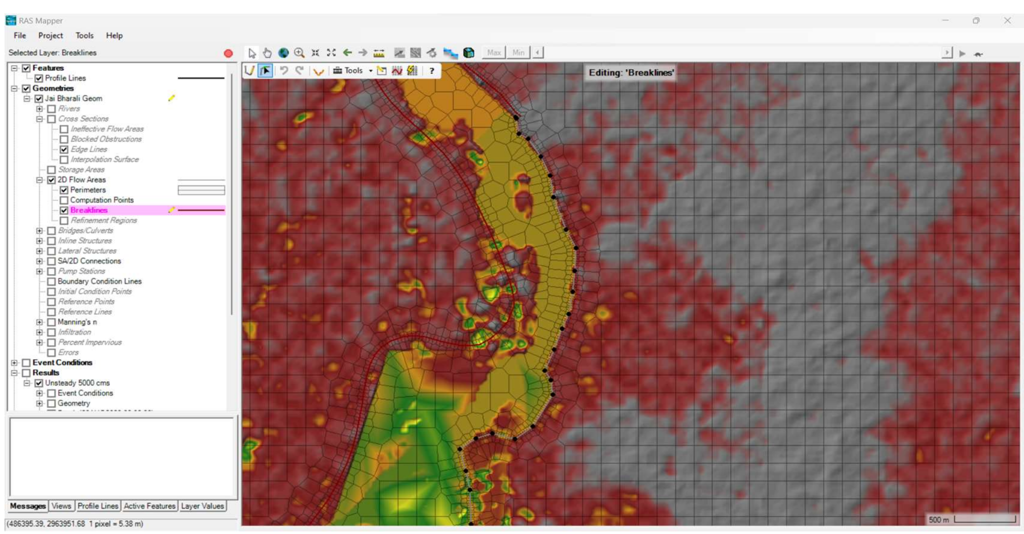


Fig 4.18: Defining the Left and Right Over Banks

3. **Define Hydraulic Structures:**

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

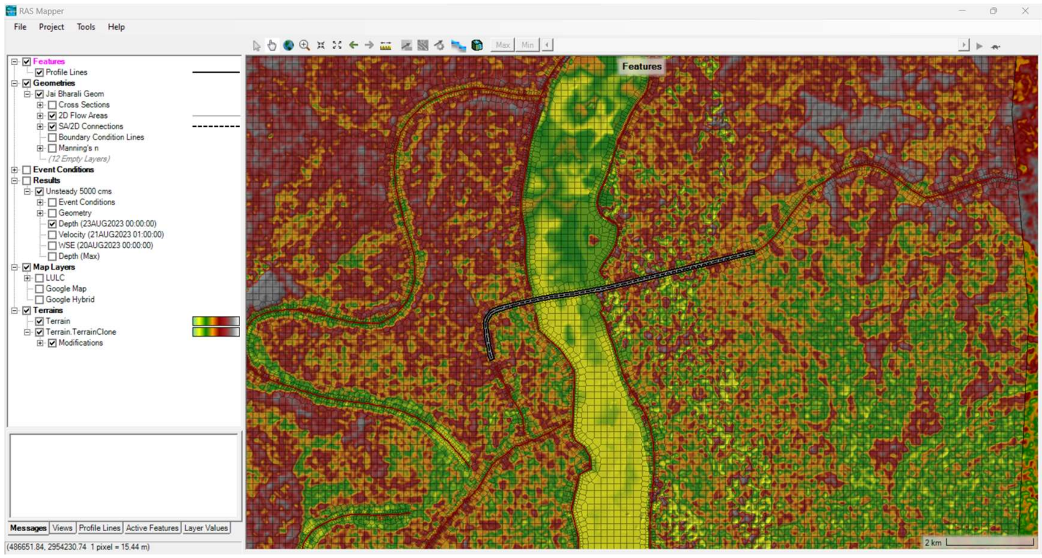


Fig 4.19: Setting up of Bridge

- 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.

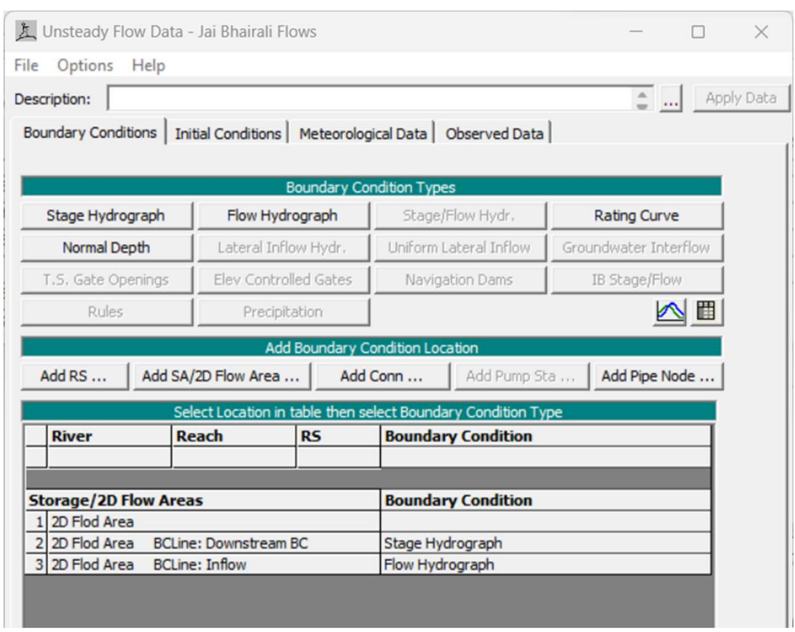


Fig 4.20: Defining Boundary Conditions

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.

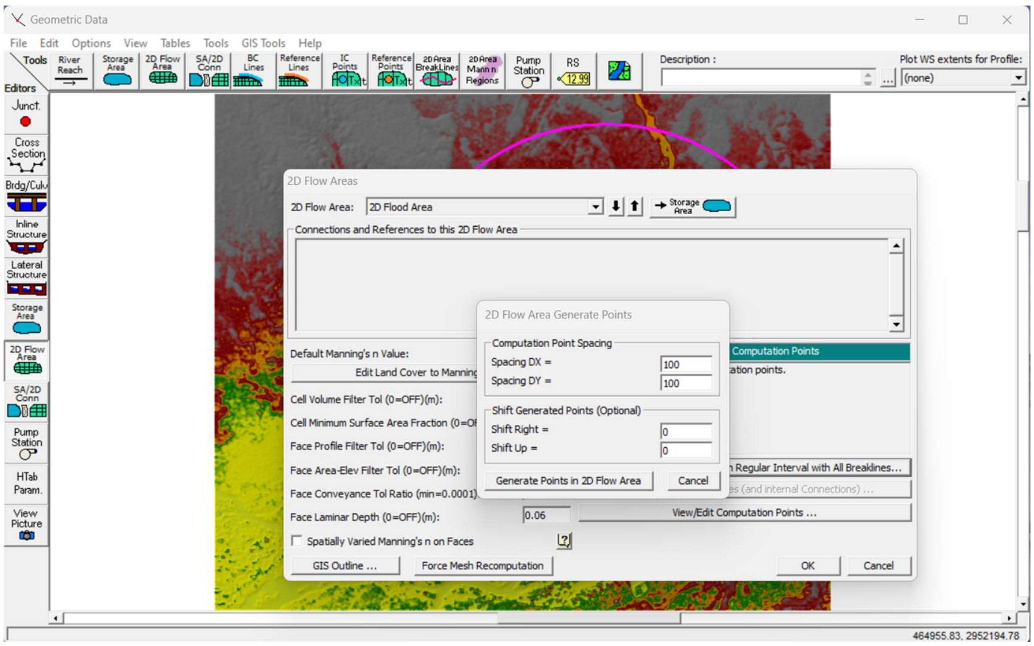


Fig 4.21: Generation of Mesh

- 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.

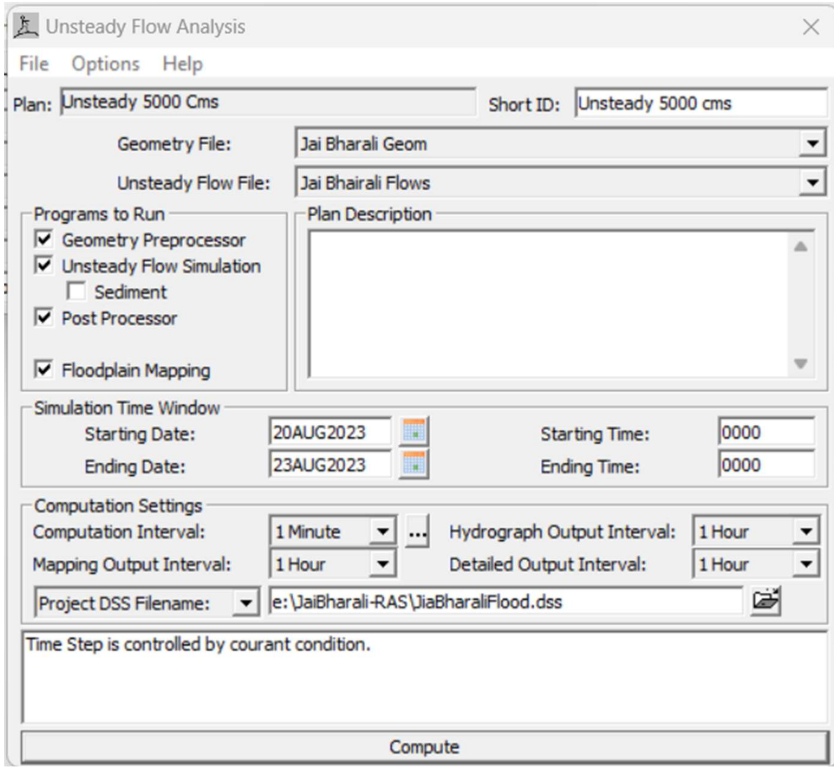


Fig 4.21: Simulation Run

CHAPTER 5

RESULTS AND DISCUSSION

5.1: RESULTS FROM HEC HMS: Time Series Plot of 3days at 5 min interval is obtained from HEC HMS

Table 5.1: Time Series Plot

Date	Time	Inflow from Reach-1-EX (M3/S)	Inflow from Sub-2 (M3/S)	Outflow (M3/S)
20-Aug-23	0:00	0	0	0
20-Aug-23	0:05	0	0	0
20-Aug-23	0:10	0	0	0
20-Aug-23	0:15	0	0	0
20-Aug-23	0:20	0	0	0
20-Aug-23	0:25	0	0	0
20-Aug-23	0:30	0	0	0
20-Aug-23	0:35	0	0	0
20-Aug-23	0:40	0	0	0
20-Aug-23	0:45	0	0	0
20-Aug-23	0:50	0	0	0
20-Aug-23	0:55	0	0	0
20-Aug-23	1:00	0	0	0
20-Aug-23	1:05	0	0	0
20-Aug-23	1:10	0	0	0
20-Aug-23	1:15	0	0	0
20-Aug-23	1:20	0	0	0
20-Aug-23	1:25	0	0	0
20-Aug-23	1:30	0	0	0
20-Aug-23	1:35	0	0	0
20-Aug-23	1:40	0	0	0
20-Aug-23	1:45	0	0	0
20-Aug-23	1:50	0	0	0
20-Aug-23	1:55	0	0	0
20-Aug-23	2:00	0	0	0
20-Aug-23	2:05	0	0	0
20-Aug-23	2:10	0	0	0
20-Aug-23	2:15	0	0	0
20-Aug-23	2:20	0	0	0
20-Aug-23	2:25	0	0	0

Continued in Appendix I

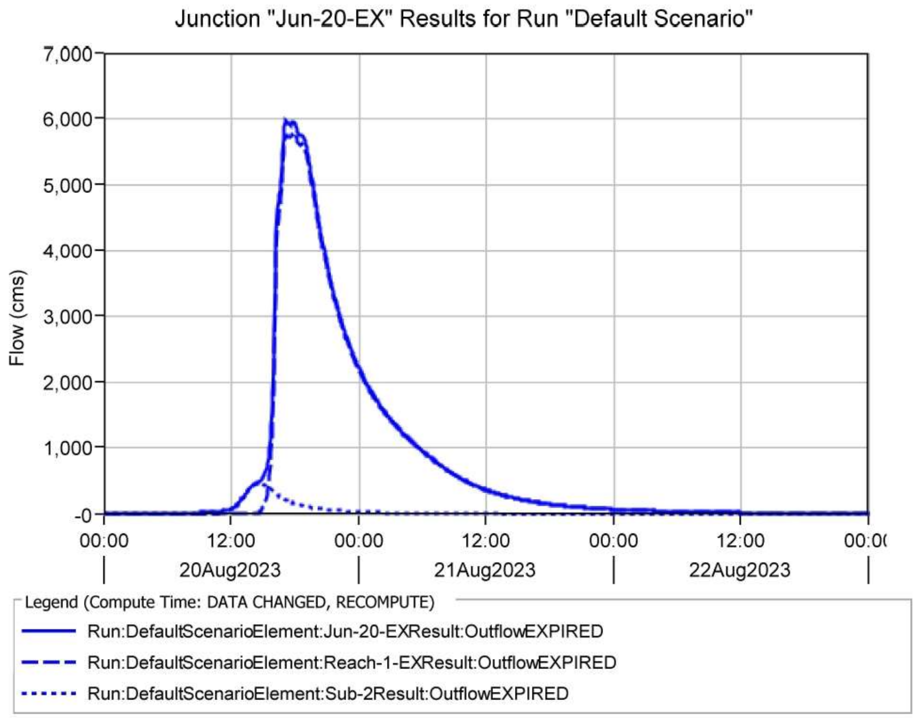


Fig 5.1: Hydrograph of Downstream obtained from HEC HMS

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

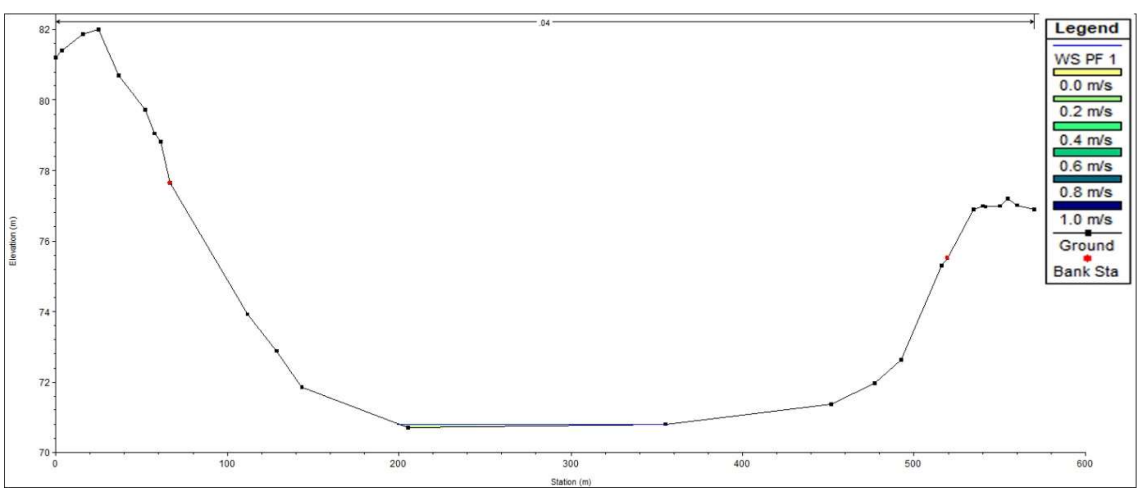


Fig 5.2: Upstream Elevation Depth Graph for PF1(Q_{min})

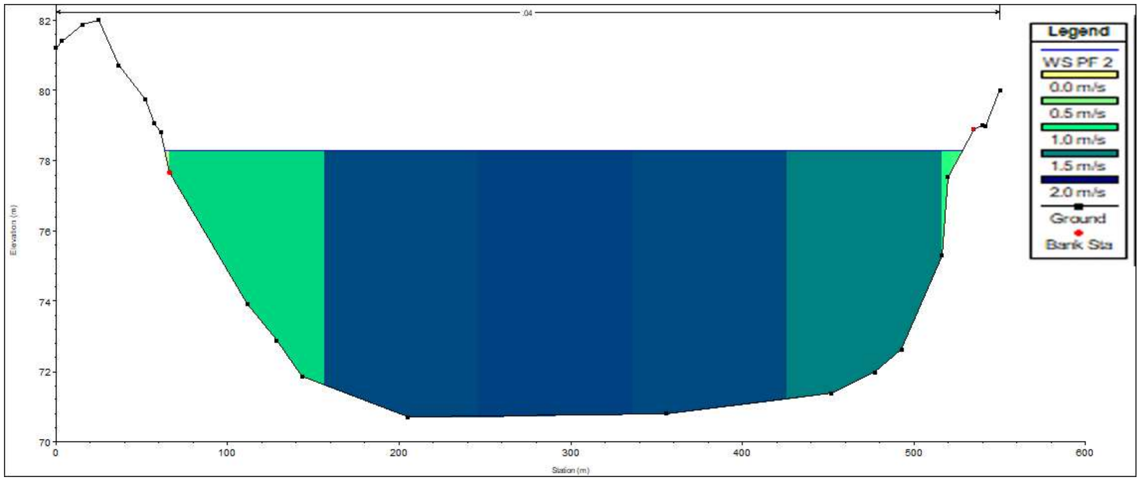


Fig 5.3: Upstream Elevation Depth Graph for PF2(Q_{max})

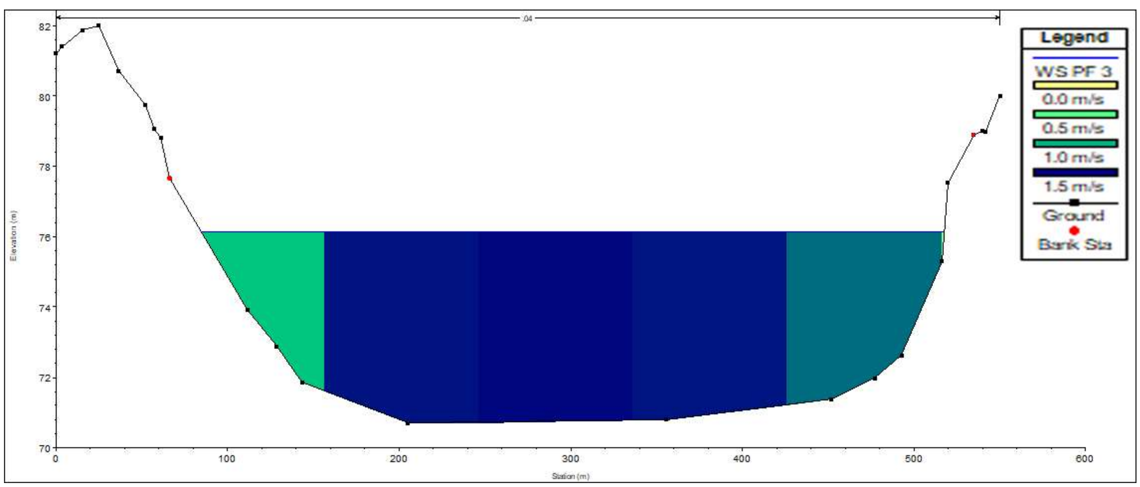


Fig 5.4: Upstream Elevation Depth Graph for PF3(Q_{maxavg})

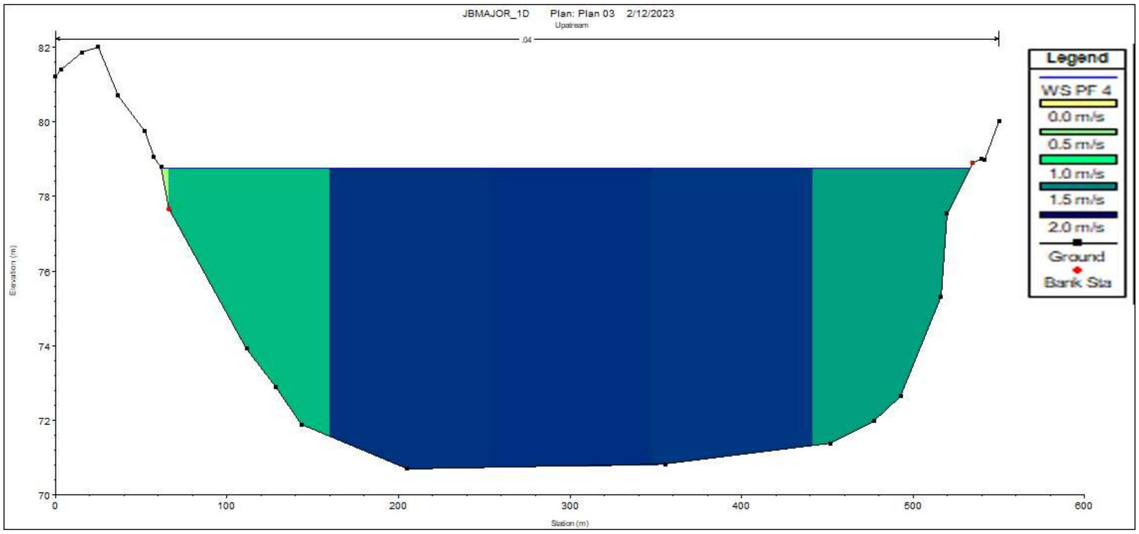


Fig 5.5: Upstream Elevation Depth Graph for PF4($1.1Q_{maxavg}$)

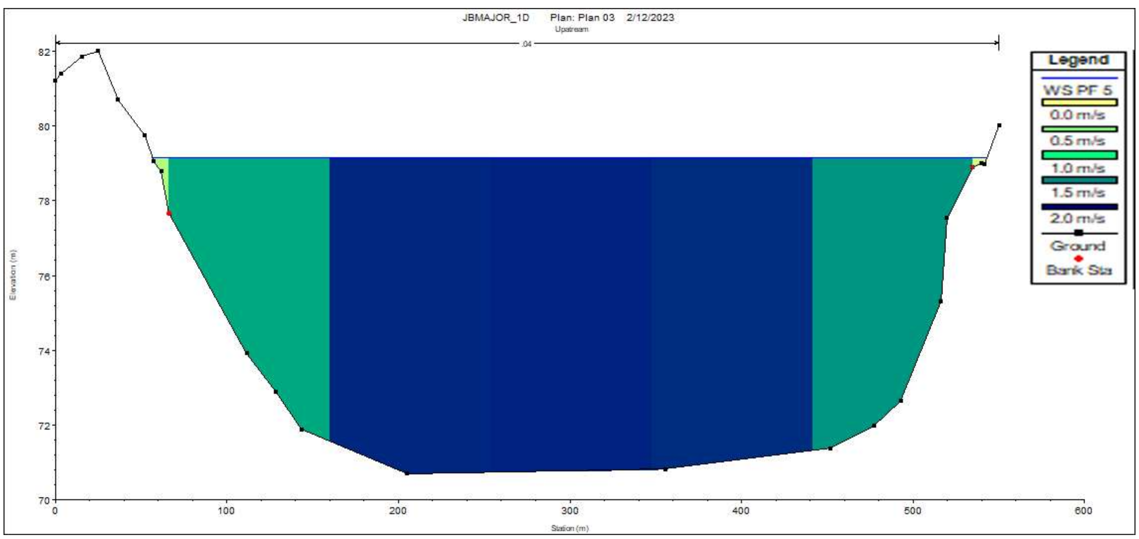


Fig 5.6: Upstream Elevation Depth Graph for PF5($1.2Q_{maxavg}$)

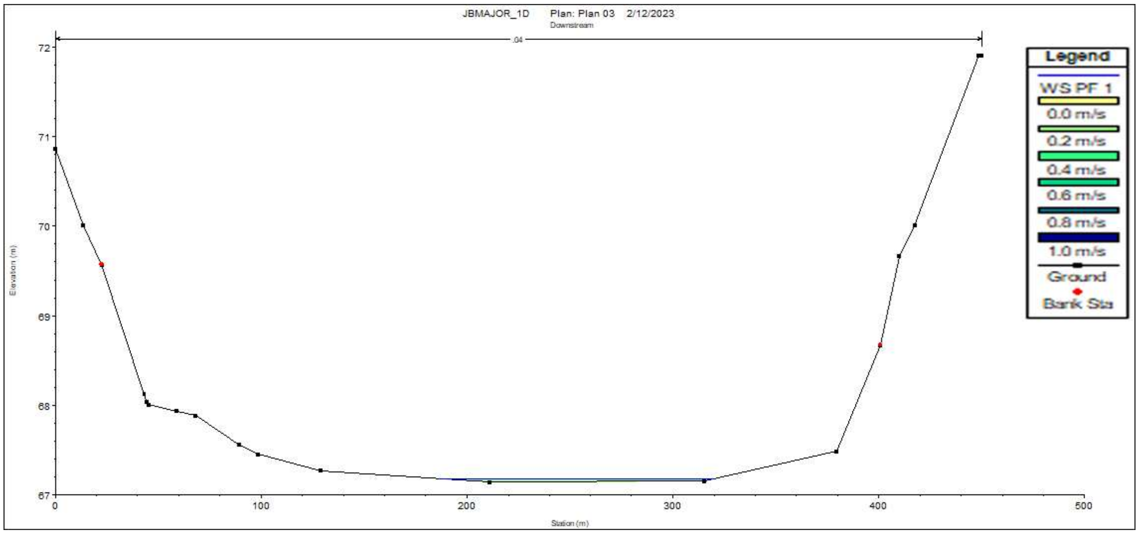


Fig 5.7: Downstream Elevation Depth Graph for PF1(Q_{min})

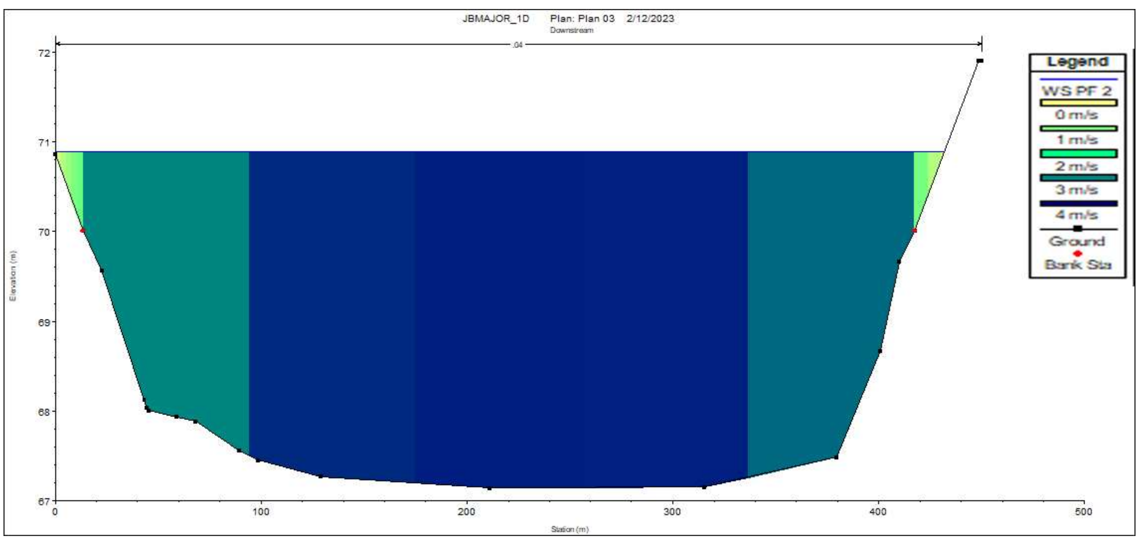


Fig 5.8: Downstream Elevation Depth Graph for PF2(Q_{max})

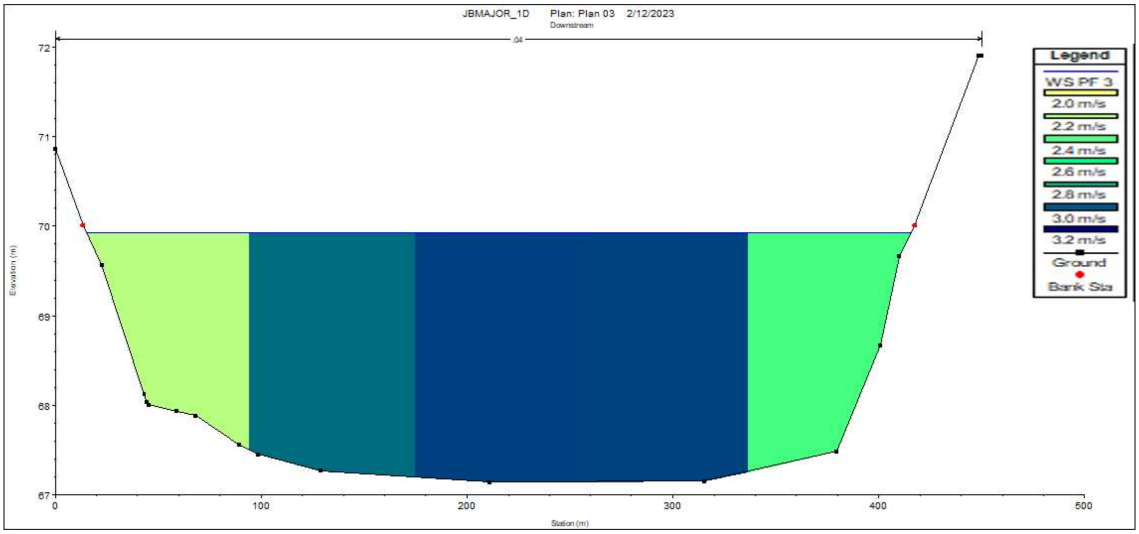


Fig 5.9: Downstream Elevation Depth Graph for PF3(Q_{maxavg})

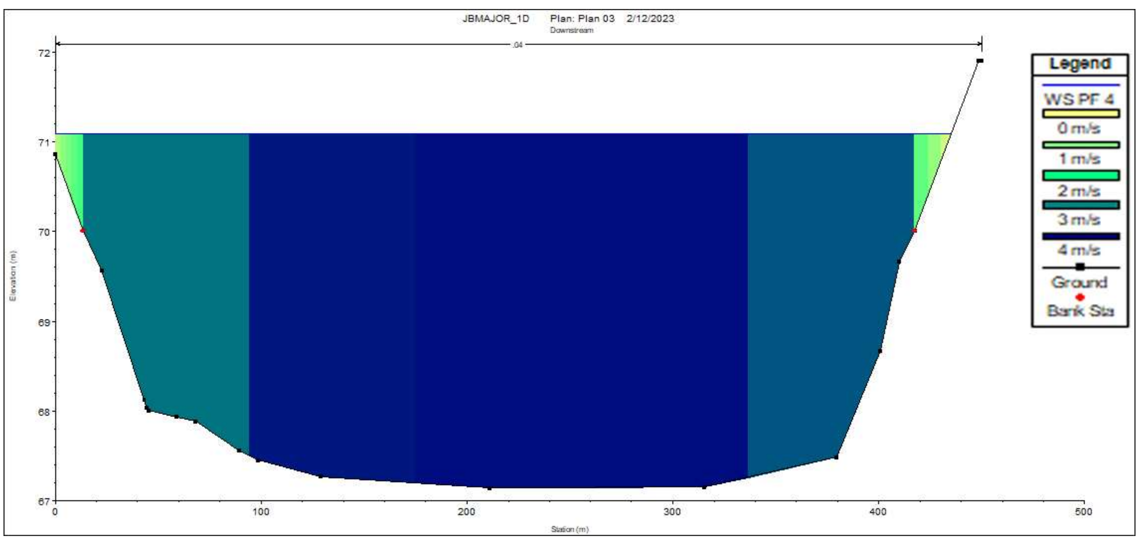


Fig 5.10: Downstream Elevation Depth Graph for PF4(1.1Q_{max})

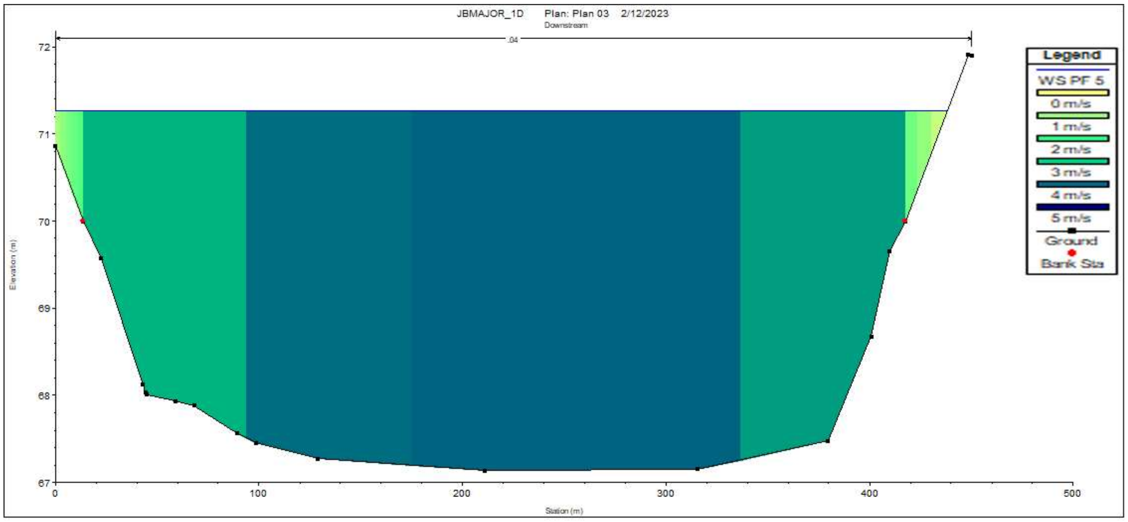


Fig 5.11: Downstream Elevation Depth Graph for PF5(1.2Q_{max})

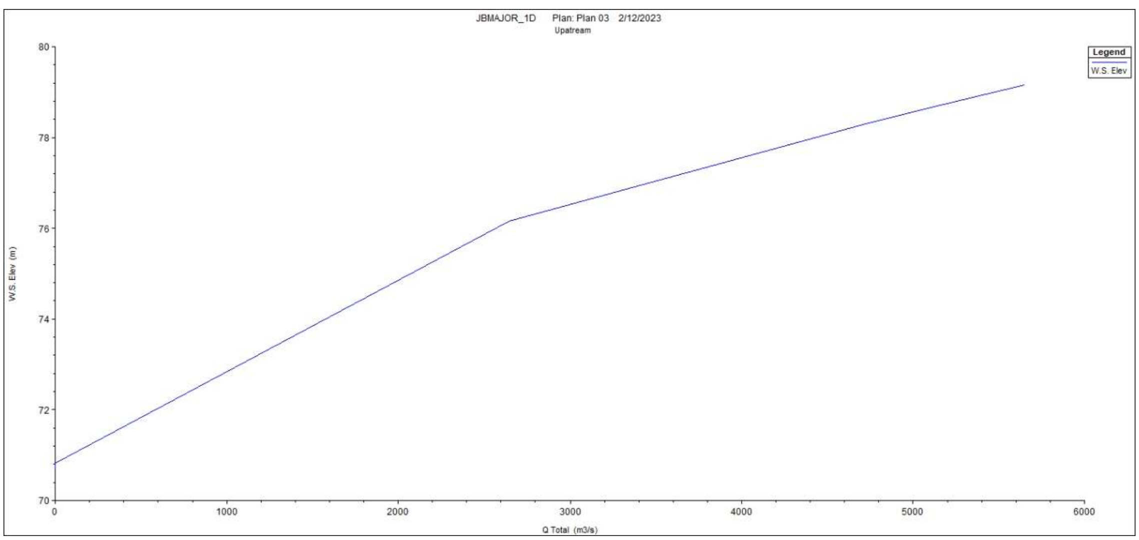


Fig 5.12: Rating Curve of Upstream

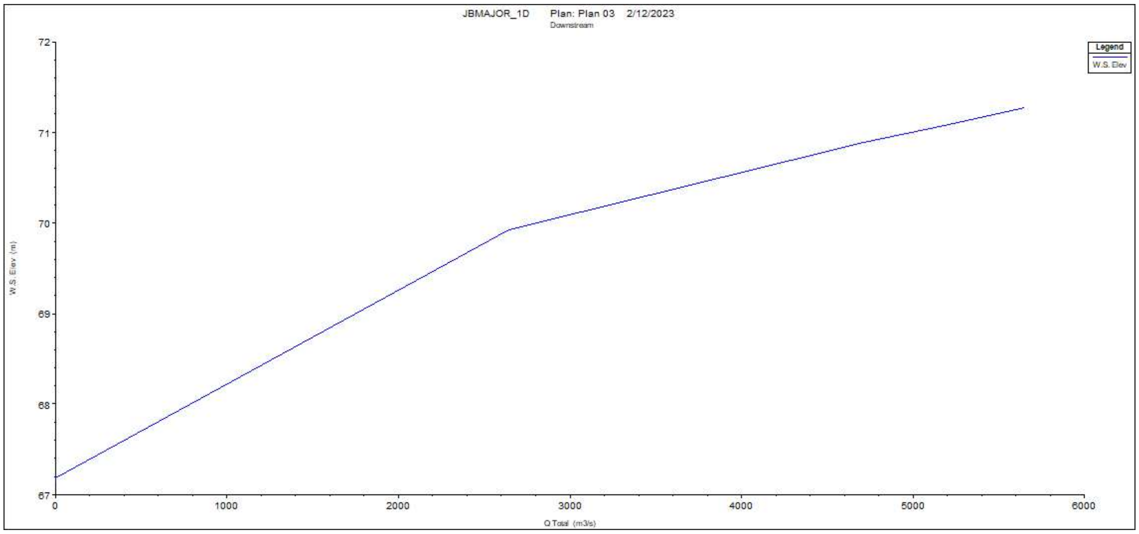


Fig 5.13: Rating Curve Downstream

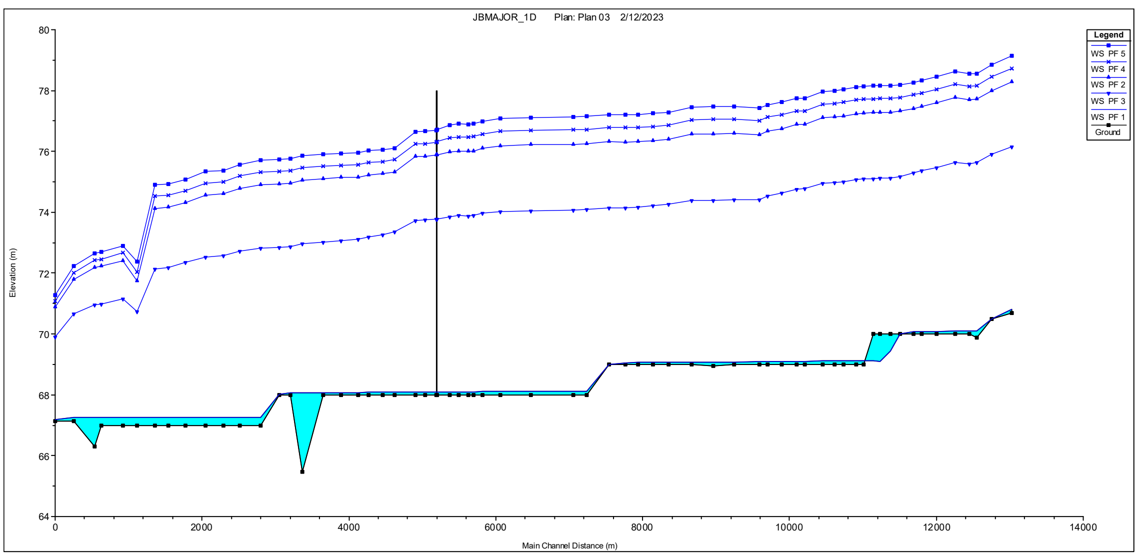


Fig 5.14: General Profile Plot

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 5.2- Profile output table for steady flow analysis for Qmax

Reach	River Station	Profile	Q Total	Min Ch Elevation	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude No. of Channel
		Qmax	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	13142	PF 2	4710	70.7	78.29	73.73	78.42	0.000359	1.62	2914.7	464.33	0.21
Reach 1	12864	PF 2	4710	70.49	78		78.28	0.000647	2.36	2092.98	345	0.28
Reach 1	12662	PF 2	4710	69.87	77.72		78.11	0.000958	2.96	1762.57	277.8	0.35
Reach 1	12559	PF 2	4710	70	77.69		77.99	0.000726	2.52	2006.29	312.48	0.3
Reach 1	12370	PF 2	4710	70	77.77		77.86	0.000204	1.4	3540.36	499.9	0.16
Reach 1	12113	PF 2	4710	70	77.59		77.77	0.000466	1.92	2542.09	410.86	0.24
Reach 1	11909	PF 2	4710	70	77.47		77.67	0.000469	2.05	2432.27	388.96	0.24
Reach 1	11796	PF 2	4710	70	77.41		77.62	0.000501	2.11	2380.65	362.6	0.25
Reach 1	11618	PF 2	4710	70	77.33		77.53	0.00052	2.07	2430.15	395.7	0.25
Reach 1	11489	PF 2	4710	70	77.29		77.45	0.00043	1.85	2642.73	415	0.23
Reach 1	11343	PF 2	4710	70	77.28		77.39	0.00027	1.51	3189.25	478.3	0.18
Reach 1	11250	PF 2	4710	70	77.28		77.36	0.000201	1.32	3633.92	515.1	0.16
Reach 1	11122	PF 2	4710	69	77.26		77.34	0.000156	1.24	3912.35	511.7	0.14
Reach 1	11015	PF 2	4710	69	77.24		77.32	0.000154	1.26	3845.57	486	0.14
Reach 1	10853	PF 2	4710	69	77.16		77.28	0.000255	1.6	3124.43	460.7	0.18
Reach 1	10723	PF 2	4710	69	77.13		77.25	0.00025	1.58	3085.46	424	0.18

Reach	River Station	Profile	Q Total	Min Ch Elevation	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude No. of Channel
		Qmax	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	10567	PF 2	4710	69	77.1		77.21	0.000225	1.49	3286.32	460.3	0.17
Reach 1	10323	PF 2	4710	69	76.88		77.11	0.000534	2.18	2272.89	378.16	0.26
Reach 1	10206	PF 2	4710	69	76.88		77.04	0.000356	1.84	2705.59	407.38	0.21
Reach 1	10007	PF 2	4710	69	76.75		76.95	0.000502	2.04	2417.78	405.39	0.25
Reach 1	9816	PF 2	4710	69	76.66		76.86	0.000448	2.03	2438.01	354.5	0.24
Reach 1	9704	PF 2	4710	69	76.53		76.79	0.000671	2.32	2164.53	403	0.28
Reach 1	9359	PF 2	4710	69	76.58		76.64	0.000139	1.03	4645.94	721.49	0.13
Reach 1	9072	PF 2	4710	68.94	76.58		76.6	0.000064	0.73	6444.06	907.48	0.09
Reach 1	8784	PF 2	4710	69	76.56		76.59	0.000055	0.71	6780.47	957	0.08
Reach 1	8468	PF 2	4710	69	76.4		76.54	0.000337	1.7	2856.84	433.62	0.2
Reach 1	8253	PF 2	4710	69	76.36		76.46	0.000248	1.47	3264.72	487.3	0.17
Reach 1	8053	PF 2	4710	69	76.32		76.41	0.000214	1.37	3550	512.6	0.16
Reach 1	7882	PF 2	4710	69	76.31		76.38	0.000164	1.18	4106.79	606	0.14
Reach 1	7656	PF 2	4710	69	76.31		76.34	0.000062	0.74	6470.18	902.8	0.09
Reach 1	7348	PF 2	4710	68	76.25		76.31	0.000116	1.09	4431.89	583.48	0.12
Reach 1	7167	PF 2	4710	68	76.24		76.29	0.000106	1.03	4703.63	624.1	0.12
Reach 1	6587	PF 2	4710	68	76.21		76.24	0.000054	0.64	7165.91	1053.2	0.08
Reach 1	6175	PF 2	4710	68	76.18		76.21	0.000061	0.79	6133.8	822.54	0.09
Reach 1	5928	PF 2	4710	68	76.1		76.18	0.000162	1.27	3816.58	525.5	0.14
Reach 1	5806	PF 2	4710	68	76.02		76.15	0.000286	1.68	2997.88	451.28	0.19
Reach 1	5736	PF 2	4710	68	76.01		76.13	0.000294	1.61	3115.95	488.32	0.19
Reach 1	5609	PF 2	4710	68	76.01		76.09	0.000152	1.23	3894.11	502.5	0.14
Reach 1	5490	PF 2	4710	68	75.97	70.54	76.07	0.000204	1.38	3538.6	507.07	0.16
Reach 1	5310		Bridge									
Reach 1	5149	PF 2	4710	68	75.84		75.96	0.000254	1.57	3121.8	439.8	0.18
Reach 1	5019	PF 2	4710	68	75.84		75.92	0.00019	1.36	3635.37	497.4	0.15
Reach 1	4735	PF 2	4710	68	75.33		75.78	0.001099	3.02	1654	316.43	0.37
Reach 1	4576	PF 2	4710	68	75.27		75.59	0.000843	2.58	1912.03	312.3	0.32
Reach 1	4384	PF 2	4710	68	75.23		75.43	0.000495	2.08	2392.12	375.9	0.25

Reach 1	4235	PF 2	4710	68	75.15		75.36	0.000518	2.04	2366.17	376.14	0.25
Reach 1	4001	PF 2	4710	68	75.14		75.24	0.000258	1.48	3283.43	483.8	0.18
Reach 1	3760	PF 2	4710	68	75.09		75.18	0.000216	1.35	3601.32	544.2	0.16
Reach 1	3480	PF 2	4710	65.47	75.06		75.12	0.000153	1.13	4182.65	591.4	0.14
Reach 1	3311	PF 2	4710	68	74.95		75.08	0.000371	1.63	2970.7	510.67	0.21
Reach 1	3163	PF 2	4710	68	74.92		75.02	0.000258	1.42	3422.51	557.7	0.18
Reach 1	2912	PF 2	4710	67	74.91		74.97	0.000131	1.11	4391.38	619.7	0.13
Reach 1	2628	PF 2	4710	67	74.78		74.91	0.000272	1.61	3028.29	433.69	0.19
Reach 1	2404	PF 2	4710	67	74.6		74.82	0.000513	2.12	2323.44	351.15	0.25
Reach 1	2163	PF 2	4710	67	74.55		74.7	0.000326	1.73	2810.29	386.1	0.2
Reach 1	1882	PF 2	4710	67	74.31		74.56	0.000603	2.26	2143.09	318.04	0.27
Reach 1	1653	PF 2	4710	67	74.17		74.42	0.000648	2.3	2154.82	346.2	0.28
Reach 1	1475	PF 2	4710	67	74.13		74.31	0.000442	1.93	2510.27	360	0.23
Reach 1	1226	PF 2	4710	67	71.75	71.75	73.82	0.0097	6.38	743.55	182.94	0.99
Reach 1	1037	PF 2	4710	67	72.42	69.49	72.66	0.000842	2.22	2175.04	424.91	0.31
Reach 1	739	PF 2	4710	67	72.22		72.41	0.000699	1.98	2468.3	503	0.28
Reach 1	644	PF 2	4710	66.3	72.18		72.34	0.00059	1.83	2689.36	545	0.26
Reach 1	363	PF 2	4710	67.14	71.79		72.08	0.001313	2.43	1975.25	465.2	0.37
Reach 1	112	PF 2	4710	67.14	70.89	69.97	71.52	0.004001	3.51	1350.4	431.9	0.62

Continued in Appendix II

5.3: 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 infrastructure.
- **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.

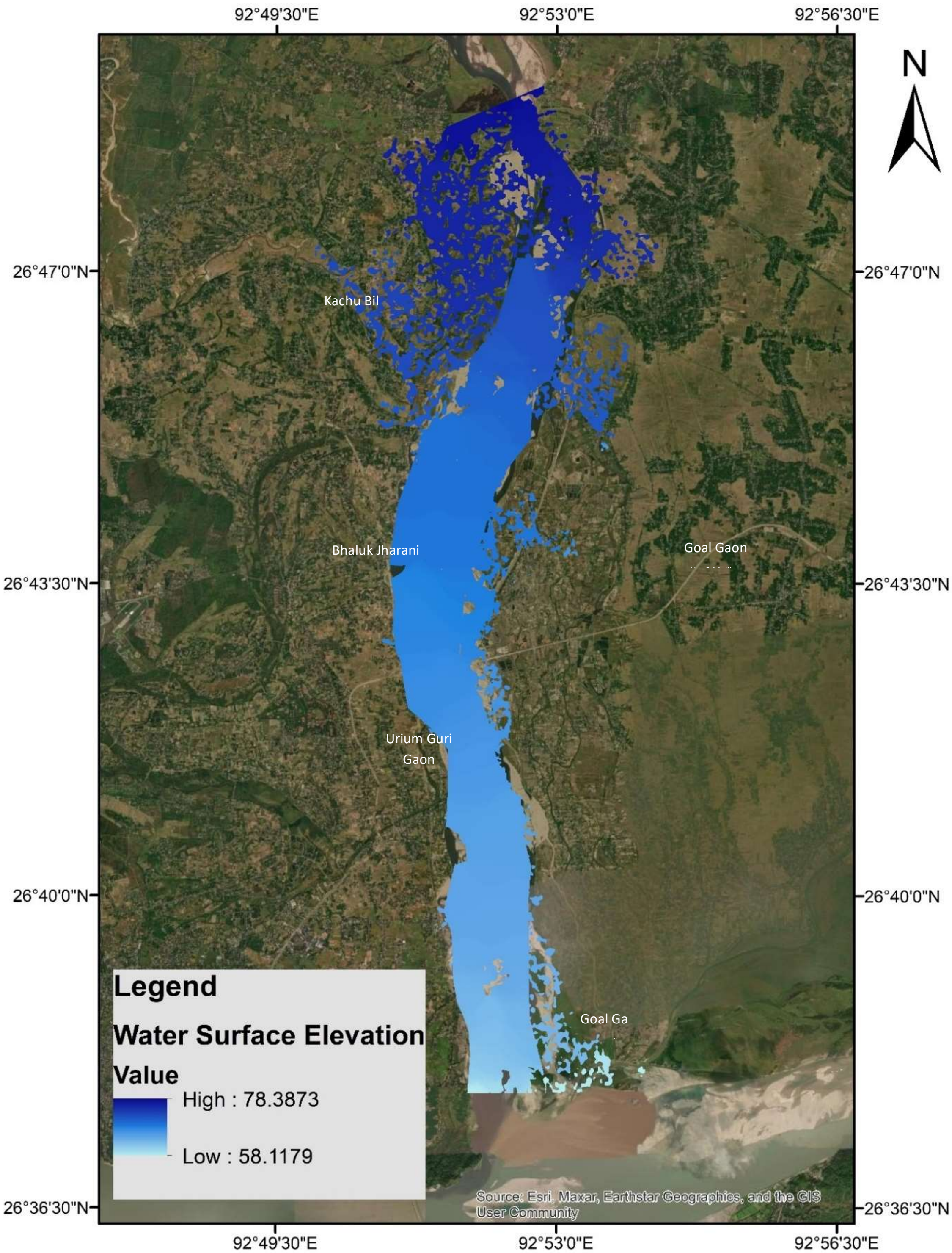


Fig 5.15: Water Surface Elevation without Embankment

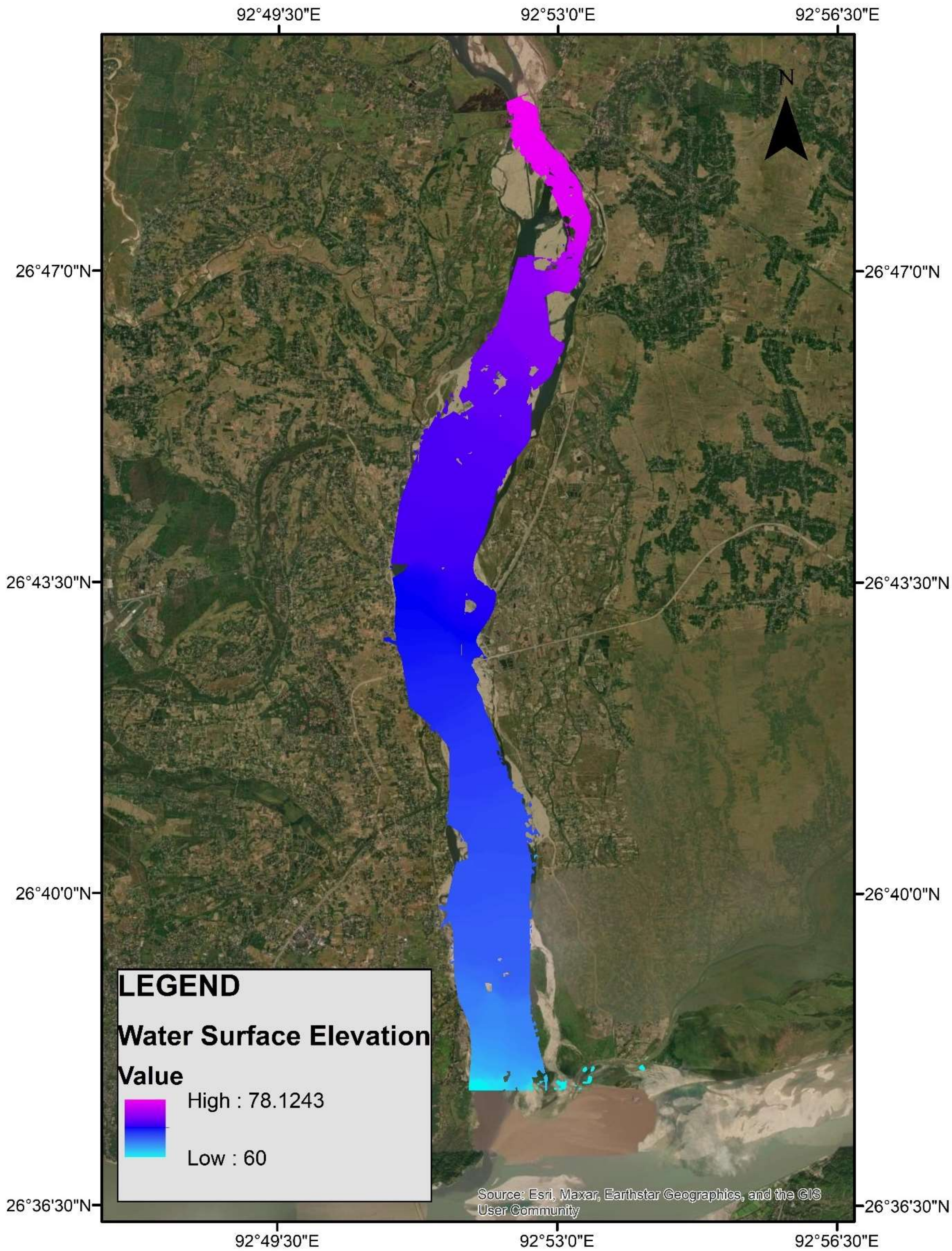


Fig 5.16: Water Surface Elevation with Embankment

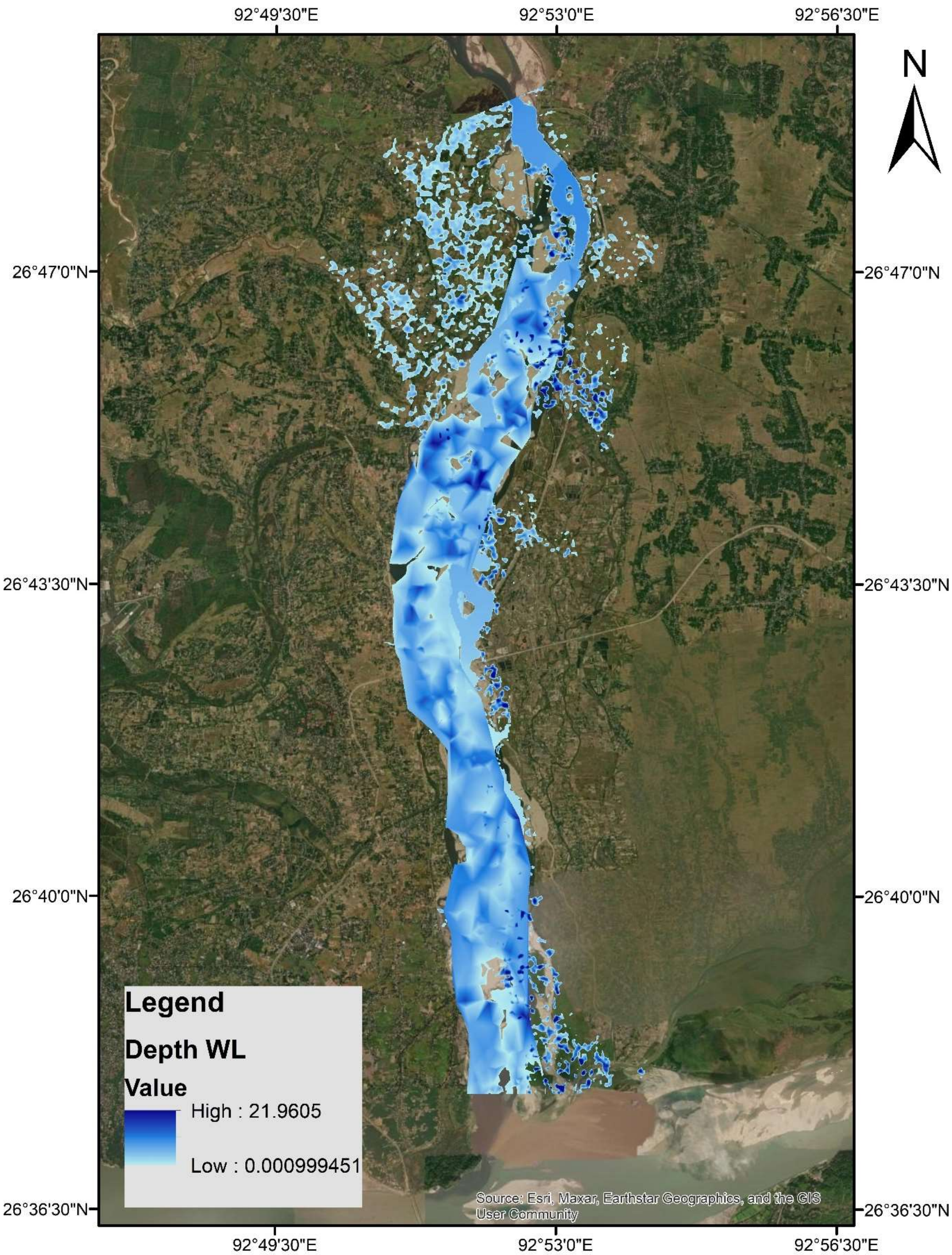
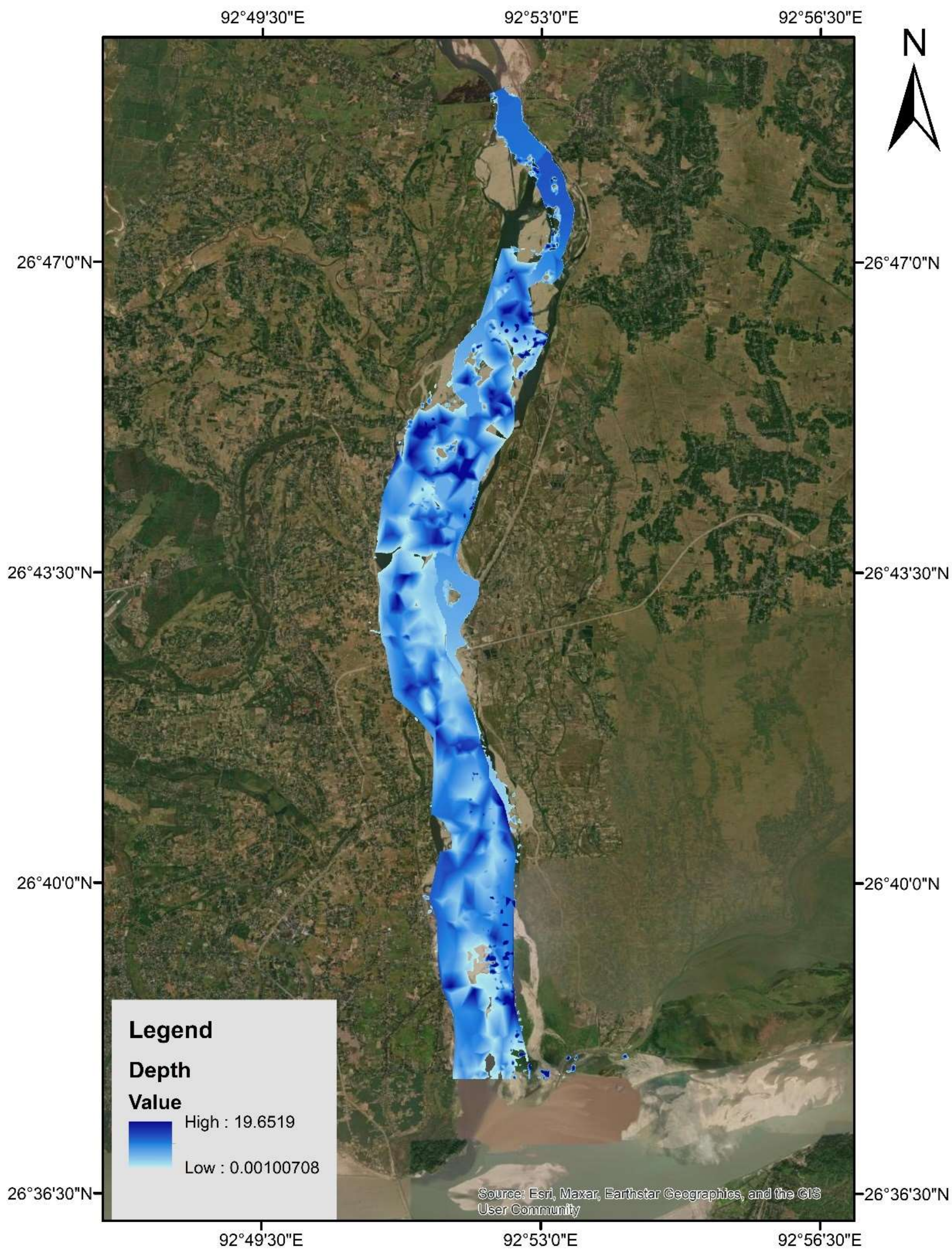


Fig 5.17: Depth Profile without Embankment



a

Fig 5.18: Depth Profile with Embankment

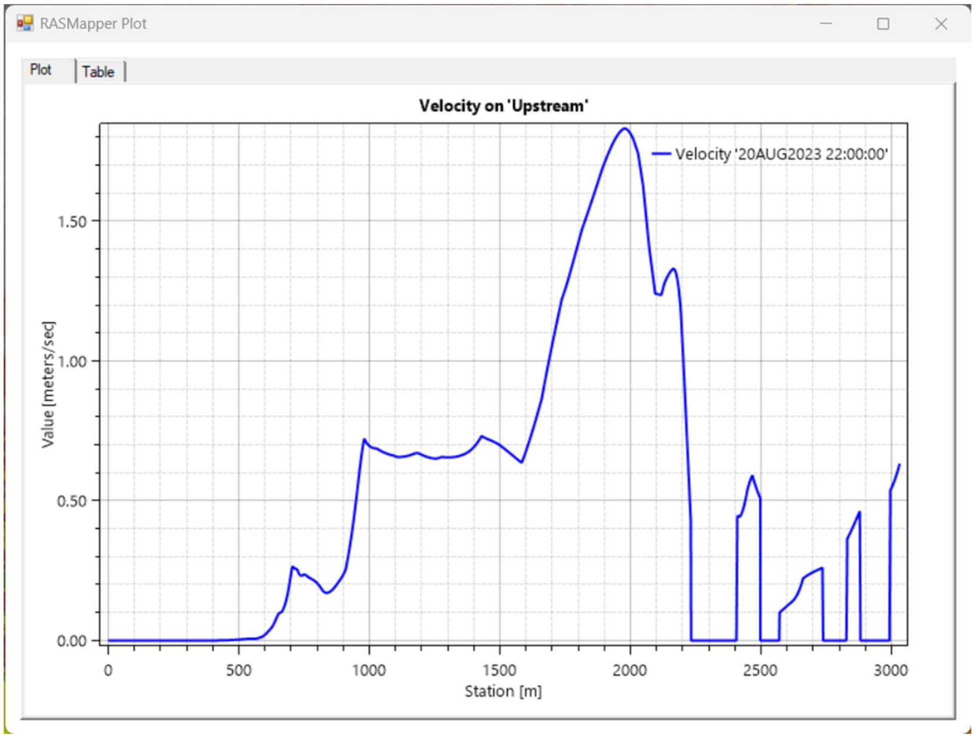


Fig 5.19: Velocity Profile on Upstream

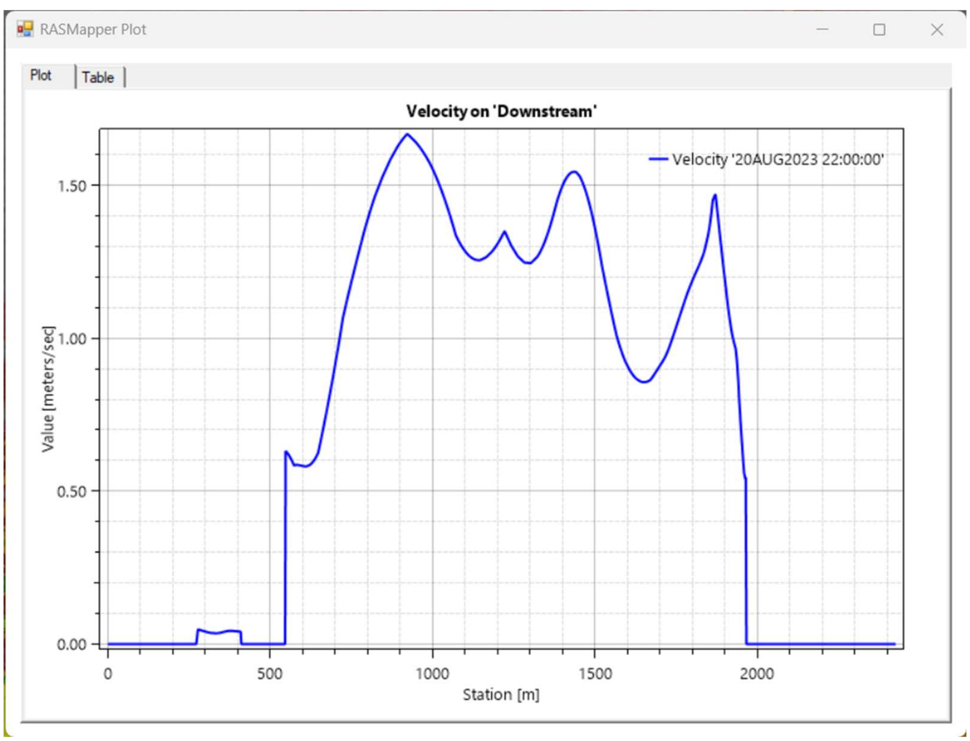


Fig 5.20: Velocity Profile on Downstream

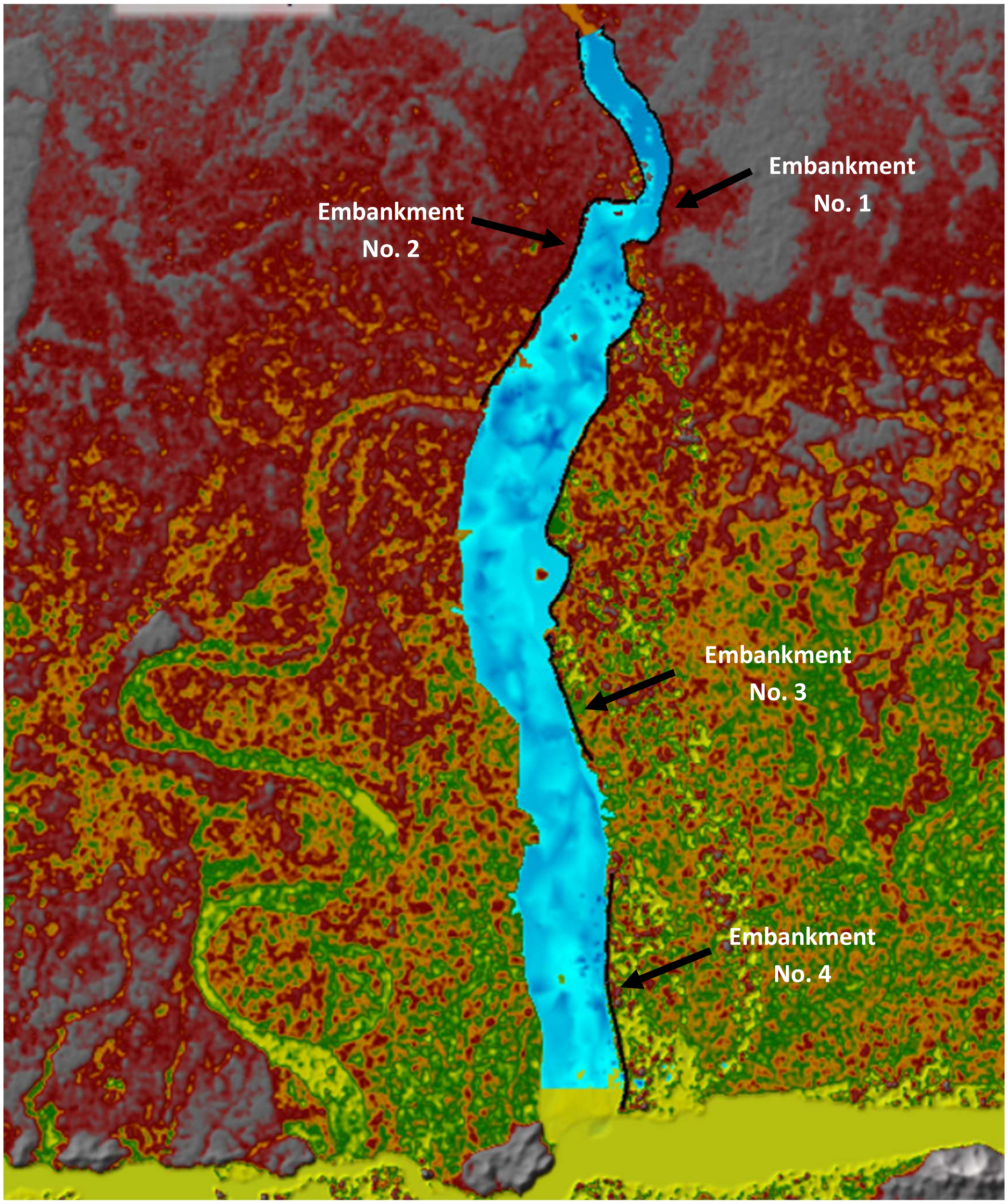


Fig 5.21: Probable suggested locations of embankments

5.4 SALIENT FEATURES:

Total Area inundated in the study area for the 100-year Return period: 4259 Hectare

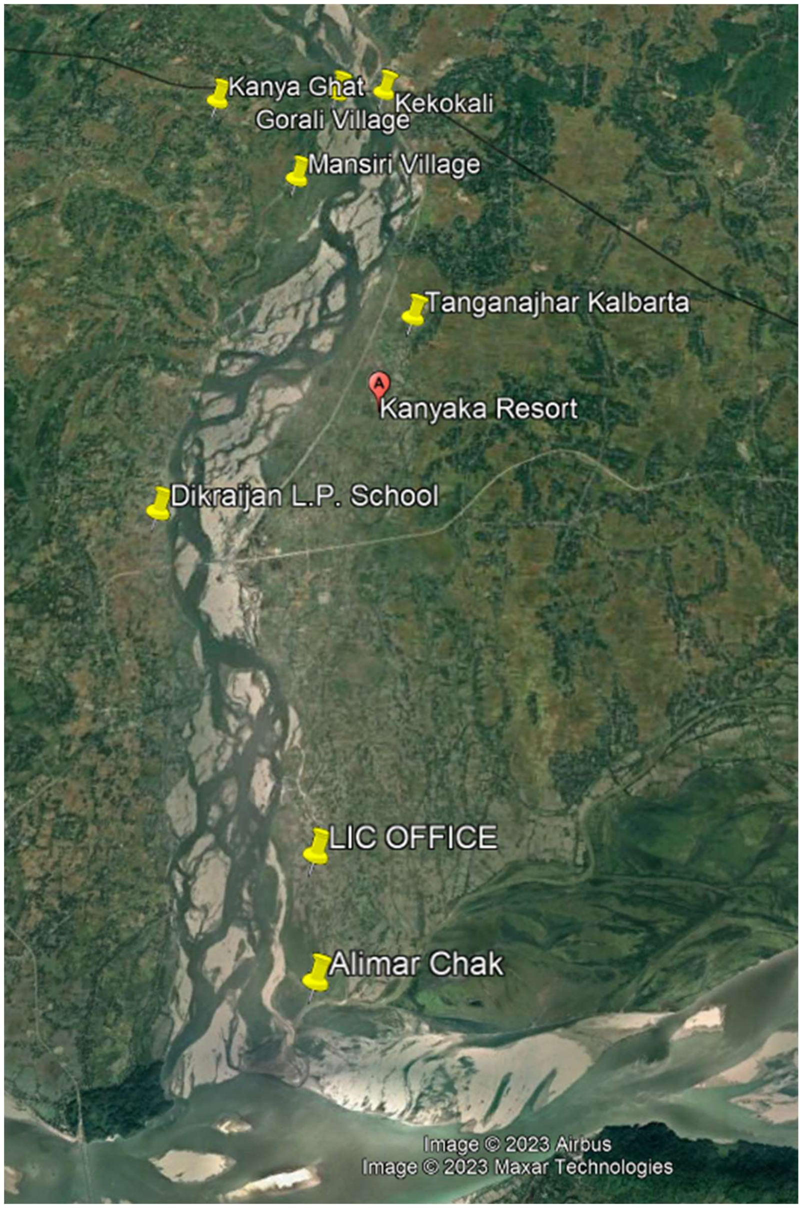


Fig 5.22: Prominent Locations of Flooding

Table 5.3: Coordinates of Various Prominent Locations

Prominent Points	Coordinates	Flood Inundation Depth (m)
Gorali Village	Lat: 26°48'27.99"N Long: 92°52'16.66"E	5.56
Kanya Ghat	Lat: 26°48'15.03"N Long: 92°50'44.12"E	2.51
Mansiri Village	Lat: 26°47'13.17"N Long: 92°51'54.92"E	2.35
Tanganajhar Kalbarta	Lat: 26°45'27.68"N Long: 92°53'35.56"E	3.6
Dikraijan L.P. School	Lat: 26°42'53.22"N Long: 92°50'51.49"E	1.43
LIC Office	Lat: 26°39'17.85"N Long: 92°53'11.07"E	2.4
Barbari Post Office	Lat: 26°24'20.53"N Long: 91°29'2.76"E	0.51
Alimar Chak	Lat: 26°38'4.51"N Long: 92°53'20.49"E	6.48

CHAPTER 6

CONCLUSION

The river Jia Bharali 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 Jia Bharali 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 HEC-HMS model was prepared using rainfall data to obtain a flood hydrograph of 72 hours for 100-year return period having a peak discharge of 5953 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 36856 hectares study area, 4259 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.

CHAPTER 7

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APPENDIX I

Table 5.1: Time Series Plot

Date	Time	Inflow from Reach-1-EX (M3/S)	Inflow from Sub-2 (M3/S)	Outflow (M3/S)
20-Aug-23	2:30	0	0	0
20-Aug-23	2:35	0	0	0
20-Aug-23	2:40	0	0	0
20-Aug-23	2:45	0	0	0
20-Aug-23	2:50	0	0	0
20-Aug-23	2:55	0	0	0
20-Aug-23	3:00	0	0.1	0.1
20-Aug-23	3:05	0	0.1	0.1
20-Aug-23	3:10	0	0.1	0.1
20-Aug-23	3:15	0	0.1	0.1
20-Aug-23	3:20	0	0.1	0.1
20-Aug-23	3:25	0	0.1	0.1
20-Aug-23	3:30	0	0.2	0.2
20-Aug-23	3:35	0	0.2	0.2
20-Aug-23	3:40	0	0.2	0.2
20-Aug-23	3:45	0	0.3	0.3
20-Aug-23	3:50	0	0.3	0.3
20-Aug-23	3:55	0	0.4	0.4
20-Aug-23	4:00	0	0.5	0.5
20-Aug-23	4:05	0	0.6	0.6
20-Aug-23	4:10	0	0.7	0.7
20-Aug-23	4:15	0	0.8	0.8
20-Aug-23	4:20	0	0.9	0.9
20-Aug-23	4:25	0	1	1
20-Aug-23	4:30	0	1.1	1.1
20-Aug-23	4:35	0	1.3	1.3
20-Aug-23	4:40	0	1.5	1.5
20-Aug-23	4:45	0	1.6	1.6
20-Aug-23	4:50	0	1.8	1.8
20-Aug-23	4:55	0	2	2
20-Aug-23	5:00	0	2.2	2.2
20-Aug-23	5:05	0	2.5	2.5
20-Aug-23	5:10	0	2.7	2.7
20-Aug-23	5:15	0	3	3
20-Aug-23	5:20	0	3.2	3.2
20-Aug-23	5:25	0	3.5	3.5

20-Aug-23	5:30	0	3.8	3.8
20-Aug-23	5:35	0	4.1	4.1
20-Aug-23	5:40	0	4.4	4.4
20-Aug-23	5:45	0	4.8	4.8
20-Aug-23	5:50	0	5.1	5.1
20-Aug-23	5:55	0	5.4	5.4
20-Aug-23	6:00	0	5.8	5.8
20-Aug-23	6:05	0	6.2	6.2
20-Aug-23	6:10	0	6.6	6.6
20-Aug-23	6:15	0	7	7
20-Aug-23	6:20	0	7.4	7.4
20-Aug-23	6:25	0	7.8	7.8
20-Aug-23	6:30	0	8.2	8.2
20-Aug-23	6:35	0	8.7	8.7
20-Aug-23	6:40	0	9.1	9.1
20-Aug-23	6:45	0	9.6	9.6
20-Aug-23	6:50	0	10.1	10.1
20-Aug-23	6:55	0	10.6	10.6
20-Aug-23	7:00	0	11	11
20-Aug-23	7:05	0	11.5	11.5
20-Aug-23	7:10	0	12	12
20-Aug-23	7:15	0	12.5	12.5
20-Aug-23	7:20	0	13.1	13.1
20-Aug-23	7:25	0	13.6	13.6
20-Aug-23	7:30	0	14.1	14.1
20-Aug-23	7:35	0	14.7	14.7
20-Aug-23	7:40	0	15.2	15.2
20-Aug-23	7:45	0	15.7	15.7
20-Aug-23	7:50	0	16.3	16.3
20-Aug-23	7:55	0	16.9	16.9
20-Aug-23	8:00	0	17.4	17.4
20-Aug-23	8:05	0	18	18
20-Aug-23	8:10	0	18.6	18.6
20-Aug-23	8:15	0	19.2	19.2
20-Aug-23	8:20	0	19.8	19.8
20-Aug-23	8:25	0	20.4	20.4
20-Aug-23	8:30	0	21	21
20-Aug-23	8:35	0	21.6	21.6
20-Aug-23	8:40	0	22.2	22.2
20-Aug-23	8:45	0	22.8	22.8
20-Aug-23	8:50	0	23.5	23.5
20-Aug-23	8:55	0	24.1	24.1
20-Aug-23	9:00	0	24.8	24.8

20-Aug-23	9:05	0	25.5	25.5
20-Aug-23	9:10	0	26.2	26.2
20-Aug-23	9:15	0	26.9	26.9
20-Aug-23	9:20	0	27.6	27.6
20-Aug-23	9:25	0	28.3	28.3
20-Aug-23	9:30	0	29.1	29.1
20-Aug-23	9:35	0	29.9	29.9
20-Aug-23	9:40	0	30.7	30.7
20-Aug-23	9:45	0	31.5	31.5
20-Aug-23	9:50	0	32.3	32.3
20-Aug-23	9:55	0	33.2	33.2
20-Aug-23	10:00	0	34.1	34.1
20-Aug-23	10:05	0	35	35
20-Aug-23	10:10	0	36	36
20-Aug-23	10:15	0	37	37
20-Aug-23	10:20	0	38	38
20-Aug-23	10:25	0	39.1	39.1
20-Aug-23	10:30	0	40.2	40.2
20-Aug-23	10:35	0	41.3	41.3
20-Aug-23	10:40	0	42.5	42.5
20-Aug-23	10:45	0	43.7	43.7
20-Aug-23	10:50	0	45	45
20-Aug-23	10:55	0	46.3	46.3
20-Aug-23	11:00	0	47.7	47.7
20-Aug-23	11:05	0	49.1	49.1
20-Aug-23	11:10	0	50.6	50.6
20-Aug-23	11:15	0	52.2	52.2
20-Aug-23	11:20	0	53.9	53.9
20-Aug-23	11:25	0	55.8	55.8
20-Aug-23	11:30	0	57.7	57.7
20-Aug-23	11:35	0	59.8	59.8
20-Aug-23	11:40	0	62.2	62.2
20-Aug-23	11:45	0	65	65
20-Aug-23	11:50	0	68.5	68.5
20-Aug-23	11:55	0	73.1	73.1
20-Aug-23	12:00	0	78.8	78.8
20-Aug-23	12:05	0	85.6	85.6
20-Aug-23	12:10	0	93.6	93.6
20-Aug-23	12:15	0	102.8	102.8
20-Aug-23	12:20	0	112.9	112.9
20-Aug-23	12:25	0	123.7	123.7
20-Aug-23	12:30	0	135.2	135.2
20-Aug-23	12:35	0	147.5	147.5

20-Aug-23	12:40	0	160.7	160.7
20-Aug-23	12:45	0	175	175
20-Aug-23	12:50	0	190.3	190.3
20-Aug-23	12:55	0	206.7	206.8
20-Aug-23	13:00	0	224.3	224.3
20-Aug-23	13:05	0	242.9	243
20-Aug-23	13:10	0	262.5	262.6
20-Aug-23	13:15	0.1	282.8	282.8
20-Aug-23	13:20	0.1	303.3	303.3
20-Aug-23	13:25	0.1	323.4	323.5
20-Aug-23	13:30	0.2	342.7	342.9
20-Aug-23	13:35	0.3	360.8	361.2
20-Aug-23	13:40	0.5	377.6	378.1
20-Aug-23	13:45	0.7	393	393.7
20-Aug-23	13:50	1.1	406.8	407.9
20-Aug-23	13:55	1.6	419.2	420.8
20-Aug-23	14:00	2.3	429.9	432.3
20-Aug-23	14:05	3.3	439.1	442.4
20-Aug-23	14:10	4.7	446.6	451.3
20-Aug-23	14:15	6.6	452.4	459.1
20-Aug-23	14:20	9.3	456.7	466
20-Aug-23	14:25	12.9	459.7	472.6
20-Aug-23	14:30	17.8	461.6	479.4
20-Aug-23	14:35	24.3	462.6	486.9
20-Aug-23	14:40	33	462.6	495.6
20-Aug-23	14:45	44.3	461.3	505.6
20-Aug-23	14:50	59.1	458.4	517.5
20-Aug-23	14:55	78.2	454	532.2
20-Aug-23	15:00	102.6	448.5	551.1
20-Aug-23	15:05	133.5	442.3	575.8
20-Aug-23	15:10	172.4	435.7	608
20-Aug-23	15:15	221	428.6	649.6
20-Aug-23	15:20	281.8	421.1	702.9
20-Aug-23	15:25	358.3	413.1	771.4
20-Aug-23	15:30	455.9	404.4	860.3
20-Aug-23	15:35	581.5	395.1	976.6
20-Aug-23	15:40	742.9	385.2	1128.1
20-Aug-23	15:45	945.9	374.5	1320.4
20-Aug-23	15:50	1193	363.1	1556
20-Aug-23	15:55	1493.2	351.1	1844.3
20-Aug-23	16:00	1887.8	338.6	2226.4
20-Aug-23	16:05	2461.8	326.2	2788
20-Aug-23	16:10	3230.9	314	3544.9

20-Aug-23	16:15	3938.2	302.5	4240.7
20-Aug-23	16:20	4326.6	291.7	4618.3
20-Aug-23	16:25	4486.5	281.6	4768.1
20-Aug-23	16:30	4576.7	272.2	4848.9
20-Aug-23	16:35	4667.5	263.4	4930.9
20-Aug-23	16:40	4796.3	255	5051.4
20-Aug-23	16:45	4988.3	247	5235.2
20-Aug-23	16:50	5231.6	239.1	5470.7
20-Aug-23	16:55	5470	231.6	5701.5
20-Aug-23	17:00	5638.5	224.3	5862.8
20-Aug-23	17:05	5720.7	217.4	5938.2
20-Aug-23	17:10	5743.9	210.9	5954.7
20-Aug-23	17:15	5738.1	204.6	5942.7
20-Aug-23	17:20	5723.4	198.7	5922
20-Aug-23	17:25	5712.2	193	5905.2
20-Aug-23	17:30	5712	187.6	5899.6
20-Aug-23	17:35	5725	182.3	5907.4
20-Aug-23	17:40	5747.7	177.2	5924.9
20-Aug-23	17:45	5771.3	172.3	5943.5
20-Aug-23	17:50	5785.8	167.4	5953.2
20-Aug-23	17:55	5784.3	162.6	5946.9
20-Aug-23	18:00	5765.2	158	5923.2
20-Aug-23	18:05	5732.2	153.5	5885.6
20-Aug-23	18:10	5692	149.1	5841.1
20-Aug-23	18:15	5652.8	145	5797.8
20-Aug-23	18:20	5622.5	141	5763.5
20-Aug-23	18:25	5606.1	137.3	5743.3
20-Aug-23	18:30	5603.4	133.7	5737.1
20-Aug-23	18:35	5608.1	130.3	5738.4
20-Aug-23	18:40	5610.4	127	5737.4
20-Aug-23	18:45	5602.2	123.9	5726.1
20-Aug-23	18:50	5581	120.9	5701.8
20-Aug-23	18:55	5546.8	118	5664.8
20-Aug-23	19:00	5501	115.1	5616.1
20-Aug-23	19:05	5445.1	112.3	5557.4
20-Aug-23	19:10	5381.1	109.7	5490.7
20-Aug-23	19:15	5310.6	107.1	5417.7
20-Aug-23	19:20	5235.4	104.6	5340
20-Aug-23	19:25	5156.9	102.2	5259.1
20-Aug-23	19:30	5076.2	99.8	5176.1
20-Aug-23	19:35	4994.4	97.6	5092
20-Aug-23	19:40	4912	95.4	5007.4
20-Aug-23	19:45	4829.6	93.4	4923

20-Aug-23	19:50	4747.7	91.4	4839.1
20-Aug-23	19:55	4666.5	89.5	4756
20-Aug-23	20:00	4586.2	87.6	4673.8
20-Aug-23	20:05	4507	85.8	4592.8
20-Aug-23	20:10	4429	84.1	4513.1
20-Aug-23	20:15	4352.3	82.5	4434.7
20-Aug-23	20:20	4276.9	80.9	4357.8
20-Aug-23	20:25	4203.1	79.3	4282.4
20-Aug-23	20:30	4130.7	77.8	4208.5
20-Aug-23	20:35	4059.8	76.4	4136.2
20-Aug-23	20:40	3990.4	74.9	4065.3
20-Aug-23	20:45	3922.5	73.6	3996
20-Aug-23	20:50	3856.1	72.2	3928.3
20-Aug-23	20:55	3791.1	70.9	3862
20-Aug-23	21:00	3727.6	69.6	3797.2
20-Aug-23	21:05	3665.6	68.4	3734
20-Aug-23	21:10	3605	67.2	3672.2
20-Aug-23	21:15	3545.8	66	3611.9
20-Aug-23	21:20	3488	64.9	3553
20-Aug-23	21:25	3431.6	63.8	3495.4
20-Aug-23	21:30	3376.5	62.7	3439.2
20-Aug-23	21:35	3322.6	61.7	3384.3
20-Aug-23	21:40	3270.1	60.7	3330.7
20-Aug-23	21:45	3218.7	59.7	3278.4
20-Aug-23	21:50	3168.5	58.7	3227.2
20-Aug-23	21:55	3119.5	57.8	3177.3
20-Aug-23	22:00	3071.6	56.9	3128.5
20-Aug-23	22:05	3024.7	56.1	3080.8
20-Aug-23	22:10	2979	55.2	3034.2
20-Aug-23	22:15	2934.2	54.4	2988.6
20-Aug-23	22:20	2890.4	53.6	2944.1
20-Aug-23	22:25	2847.6	52.9	2900.5
20-Aug-23	22:30	2805.8	52.2	2858
20-Aug-23	22:35	2764.8	51.5	2816.3
20-Aug-23	22:40	2724.8	50.8	2775.6
20-Aug-23	22:45	2685.6	50.2	2735.8
20-Aug-23	22:50	2647.3	49.5	2696.9
20-Aug-23	22:55	2609.8	48.9	2658.8
20-Aug-23	23:00	2573.2	48.4	2621.5
20-Aug-23	23:05	2537.3	47.8	2585.1
20-Aug-23	23:10	2502.1	47.2	2549.4
20-Aug-23	23:15	2467.8	46.7	2514.5
20-Aug-23	23:20	2434.1	46.2	2480.3

20-Aug-23	23:25	2401.1	45.7	2446.9
20-Aug-23	23:30	2368.9	45.2	2414.1
20-Aug-23	23:35	2337.2	44.8	2382
20-Aug-23	23:40	2306.2	44.3	2350.5
20-Aug-23	23:45	2275.8	43.9	2319.7
20-Aug-23	23:50	2246	43.4	2289.5
20-Aug-23	23:55	2216.8	43	2259.8
21-Aug-23	0:00	2188.1	42.6	2230.8
21-Aug-23	0:05	2160	42.2	2202.2
21-Aug-23	0:10	2132.4	41.8	2174.2
21-Aug-23	0:15	2105.3	41.4	2146.7
21-Aug-23	0:20	2078.6	41	2119.7
21-Aug-23	0:25	2052.5	40.6	2093.1
21-Aug-23	0:30	2026.8	40.2	2066.9
21-Aug-23	0:35	2001.5	39.7	2041.2
21-Aug-23	0:40	1976.7	39.3	2015.9
21-Aug-23	0:45	1952.2	38.8	1991.1
21-Aug-23	0:50	1928.2	38.3	1966.6
21-Aug-23	0:55	1904.6	37.8	1942.5
21-Aug-23	1:00	1881.4	37.3	1918.7
21-Aug-23	1:05	1858.6	36.8	1895.4
21-Aug-23	1:10	1836.1	36.2	1872.3
21-Aug-23	1:15	1814.1	35.6	1849.7
21-Aug-23	1:20	1792.4	35	1827.4
21-Aug-23	1:25	1771.1	34.4	1805.5
21-Aug-23	1:30	1750.1	33.8	1783.9
21-Aug-23	1:35	1729.5	33.1	1762.6
21-Aug-23	1:40	1709.3	32.4	1741.7
21-Aug-23	1:45	1689.4	31.7	1721.1
21-Aug-23	1:50	1669.9	30.9	1700.8
21-Aug-23	1:55	1650.7	30.1	1680.8
21-Aug-23	2:00	1631.8	29.3	1661.1
21-Aug-23	2:05	1613.3	28.5	1641.7
21-Aug-23	2:10	1595	27.6	1622.7
21-Aug-23	2:15	1577.1	26.8	1603.8
21-Aug-23	2:20	1559.4	25.9	1585.3
21-Aug-23	2:25	1542	25	1567
21-Aug-23	2:30	1524.9	24.2	1549
21-Aug-23	2:35	1508	23.3	1531.3
21-Aug-23	2:40	1491.4	22.4	1513.8
21-Aug-23	2:45	1475	21.6	1496.5
21-Aug-23	2:50	1458.8	20.7	1479.5
21-Aug-23	2:55	1442.8	19.9	1462.7

21-Aug-23	3:00	1427	19	1446
21-Aug-23	3:05	1411.3	18.2	1429.5
21-Aug-23	3:10	1395.9	17.4	1413.3
21-Aug-23	3:15	1380.5	16.6	1397.1
21-Aug-23	3:20	1365.3	15.9	1381.2
21-Aug-23	3:25	1350.2	15.1	1365.4
21-Aug-23	3:30	1335.3	14.4	1349.7
21-Aug-23	3:35	1320.5	13.7	1334.2
21-Aug-23	3:40	1305.8	13	1318.8
21-Aug-23	3:45	1291.2	12.4	1303.6
21-Aug-23	3:50	1276.8	11.8	1288.5
21-Aug-23	3:55	1262.5	11.1	1273.6
21-Aug-23	4:00	1248.4	10.6	1258.9
21-Aug-23	4:05	1234.4	10	1244.4
21-Aug-23	4:10	1220.6	9.5	1230.1
21-Aug-23	4:15	1207	9	1216
21-Aug-23	4:20	1193.5	8.6	1202.1
21-Aug-23	4:25	1180.2	8.1	1188.4
21-Aug-23	4:30	1167.1	7.7	1174.8
21-Aug-23	4:35	1154.2	7.3	1161.5
21-Aug-23	4:40	1141.4	7	1148.3
21-Aug-23	4:45	1128.7	6.6	1135.4
21-Aug-23	4:50	1116.3	6.3	1122.5
21-Aug-23	4:55	1103.9	6	1109.9
21-Aug-23	5:00	1091.7	5.7	1097.4
21-Aug-23	5:05	1079.6	5.4	1085.1
21-Aug-23	5:10	1067.7	5.1	1072.8
21-Aug-23	5:15	1055.9	4.9	1060.8
21-Aug-23	5:20	1044.1	4.6	1048.8
21-Aug-23	5:25	1032.5	4.4	1036.9
21-Aug-23	5:30	1021	4.2	1025.2
21-Aug-23	5:35	1009.6	4	1013.6
21-Aug-23	5:40	998.2	3.8	1002
21-Aug-23	5:45	986.9	3.6	990.5
21-Aug-23	5:50	975.7	3.4	979.1
21-Aug-23	5:55	964.6	3.2	967.8
21-Aug-23	6:00	953.5	3.1	956.5
21-Aug-23	6:05	942.4	2.9	945.4
21-Aug-23	6:10	931.4	2.8	934.2
21-Aug-23	6:15	920.5	2.6	923.2
21-Aug-23	6:20	909.6	2.5	912.1
21-Aug-23	6:25	898.8	2.4	901.2
21-Aug-23	6:30	888	2.3	890.3

21-Aug-23	6:35	877.3	2.1	879.4
21-Aug-23	6:40	866.6	2	868.6
21-Aug-23	6:45	856	1.9	857.9
21-Aug-23	6:50	845.4	1.8	847.2
21-Aug-23	6:55	834.9	1.7	836.6
21-Aug-23	7:00	824.4	1.7	826.1
21-Aug-23	7:05	814	1.6	815.6
21-Aug-23	7:10	803.6	1.5	805.1
21-Aug-23	7:15	793.3	1.4	794.7
21-Aug-23	7:20	783.1	1.3	784.4
21-Aug-23	7:25	773	1.3	774.2
21-Aug-23	7:30	762.9	1.2	764.1
21-Aug-23	7:35	752.9	1.1	754
21-Aug-23	7:40	742.9	1.1	744
21-Aug-23	7:45	733.1	1	734.1
21-Aug-23	7:50	723.3	1	724.3
21-Aug-23	7:55	713.7	0.9	714.6
21-Aug-23	8:00	704.1	0.9	705
21-Aug-23	8:05	694.6	0.8	695.4
21-Aug-23	8:10	685.2	0.8	686
21-Aug-23	8:15	675.9	0.7	676.7
21-Aug-23	8:20	666.8	0.7	667.5
21-Aug-23	8:25	657.7	0.7	658.4
21-Aug-23	8:30	648.7	0.6	649.4
21-Aug-23	8:35	639.9	0.6	640.5
21-Aug-23	8:40	631.1	0.6	631.7
21-Aug-23	8:45	622.5	0.5	623
21-Aug-23	8:50	614	0.5	614.5
21-Aug-23	8:55	605.5	0.5	606
21-Aug-23	9:00	597.2	0.5	597.7
21-Aug-23	9:05	589	0.4	589.5
21-Aug-23	9:10	581	0.4	581.4
21-Aug-23	9:15	573	0.4	573.4
21-Aug-23	9:20	565.1	0.4	565.5
21-Aug-23	9:25	557.4	0.3	557.7
21-Aug-23	9:30	549.8	0.3	550.1
21-Aug-23	9:35	542.2	0.3	542.5
21-Aug-23	9:40	534.8	0.3	535.1
21-Aug-23	9:45	527.5	0.3	527.8
21-Aug-23	9:50	520.3	0.3	520.6
21-Aug-23	9:55	513.2	0.2	513.5
21-Aug-23	10:00	506.2	0.2	506.5
21-Aug-23	10:05	499.4	0.2	499.6

21-Aug-23	10:10	492.6	0.2	492.8
21-Aug-23	10:15	485.9	0.2	486.1
21-Aug-23	10:20	479.3	0.2	479.5
21-Aug-23	10:25	472.9	0.2	473
21-Aug-23	10:30	466.5	0.2	466.6
21-Aug-23	10:35	460.2	0.1	460.4
21-Aug-23	10:40	454	0.1	454.2
21-Aug-23	10:45	447.9	0.1	448
21-Aug-23	10:50	441.9	0.1	442
21-Aug-23	10:55	436	0.1	436.1
21-Aug-23	11:00	430.2	0.1	430.3
21-Aug-23	11:05	424.4	0.1	424.5
21-Aug-23	11:10	418.8	0.1	418.9
21-Aug-23	11:15	413.2	0.1	413.3
21-Aug-23	11:20	407.7	0.1	407.8
21-Aug-23	11:25	402.3	0.1	402.4
21-Aug-23	11:30	397	0.1	397.1
21-Aug-23	11:35	391.7	0.1	391.8
21-Aug-23	11:40	386.6	0.1	386.6
21-Aug-23	11:45	381.5	0	381.5
21-Aug-23	11:50	376.4	0	376.5
21-Aug-23	11:55	371.5	0	371.5
21-Aug-23	12:00	366.6	0	366.7
21-Aug-23	12:05	361.8	0	361.8
21-Aug-23	12:10	357.1	0	357.1
21-Aug-23	12:15	352.4	0	352.4
21-Aug-23	12:20	347.8	0	347.8
21-Aug-23	12:25	343.3	0	343.3
21-Aug-23	12:30	338.8	0	338.8
21-Aug-23	12:35	334.4	0	334.4
21-Aug-23	12:40	330.1	0	330.1
21-Aug-23	12:45	325.8	0	325.8
21-Aug-23	12:50	321.6	0	321.6
21-Aug-23	12:55	317.5	0	317.5
21-Aug-23	13:00	313.4	0	313.4
21-Aug-23	13:05	309.4	0	309.4
21-Aug-23	13:10	305.4	0	305.4
21-Aug-23	13:15	301.5	0	301.5
21-Aug-23	13:20	297.6	0	297.6
21-Aug-23	13:25	293.8	0	293.8
21-Aug-23	13:30	290.1	0	290.1
21-Aug-23	13:35	286.4	0	286.4
21-Aug-23	13:40	282.8	0	282.8

21-Aug-23	13:45	279.2	0	279.2
21-Aug-23	13:50	275.7	0	275.7
21-Aug-23	13:55	272.2	0	272.2
21-Aug-23	14:00	268.8	0	268.8
21-Aug-23	14:05	265.4	0	265.4
21-Aug-23	14:10	262.1	0	262.1
21-Aug-23	14:15	258.8	0	258.8
21-Aug-23	14:20	255.5	0	255.5
21-Aug-23	14:25	252.3	0	252.3
21-Aug-23	14:30	249.2	0	249.2
21-Aug-23	14:35	246.1	0	246.1
21-Aug-23	14:40	243.1	0	243.1
21-Aug-23	14:45	240	0	240
21-Aug-23	14:50	237.1	0	237.1
21-Aug-23	14:55	234.2	0	234.2
21-Aug-23	15:00	231.3	0	231.3
21-Aug-23	15:05	228.4	0	228.4
21-Aug-23	15:10	225.6	0	225.6
21-Aug-23	15:15	222.9	0	222.9
21-Aug-23	15:20	220.2	0	220.2
21-Aug-23	15:25	217.5	0	217.5
21-Aug-23	15:30	214.8	0	214.8
21-Aug-23	15:35	212.2	0	212.2
21-Aug-23	15:40	209.7	0	209.7
21-Aug-23	15:45	207.1	0	207.1
21-Aug-23	15:50	204.7	0	204.7
21-Aug-23	15:55	202.2	0	202.2
21-Aug-23	16:00	199.8	0	199.8
21-Aug-23	16:05	197.4	0	197.4
21-Aug-23	16:10	195	0	195
21-Aug-23	16:15	192.7	0	192.7
21-Aug-23	16:20	190.4	0	190.4
21-Aug-23	16:25	188.2	0	188.2
21-Aug-23	16:30	186	0	186
21-Aug-23	16:35	183.8	0	183.8
21-Aug-23	16:40	181.6	0	181.6
21-Aug-23	16:45	179.5	0	179.5
21-Aug-23	16:50	177.4	0	177.4
21-Aug-23	16:55	175.3	0	175.3
21-Aug-23	17:00	173.3	0	173.3
21-Aug-23	17:05	171.3	0	171.3
21-Aug-23	17:10	169.3	0	169.3
21-Aug-23	17:15	167.4	0	167.4

21-Aug-23	17:20	165.5	0	165.5
21-Aug-23	17:25	163.6	0	163.6
21-Aug-23	17:30	161.7	0	161.7
21-Aug-23	17:35	159.9	0	159.9
21-Aug-23	17:40	158.1	0	158.1
21-Aug-23	17:45	156.3	0	156.3
21-Aug-23	17:50	154.5	0	154.5
21-Aug-23	17:55	152.8	0	152.8
21-Aug-23	18:00	151.1	0	151.1
21-Aug-23	18:05	149.4	0	149.4
21-Aug-23	18:10	147.7	0	147.7
21-Aug-23	18:15	146.1	0	146.1
21-Aug-23	18:20	144.5	0	144.5
21-Aug-23	18:25	142.9	0	142.9
21-Aug-23	18:30	141.3	0	141.3
21-Aug-23	18:35	139.8	0	139.8
21-Aug-23	18:40	138.3	0	138.3
21-Aug-23	18:45	136.8	0	136.8
21-Aug-23	18:50	135.3	0	135.3
21-Aug-23	18:55	133.8	0	133.8
21-Aug-23	19:00	132.4	0	132.4
21-Aug-23	19:05	130.9	0	130.9
21-Aug-23	19:10	129.5	0	129.5
21-Aug-23	19:15	128.2	0	128.2
21-Aug-23	19:20	126.8	0	126.8
21-Aug-23	19:25	125.4	0	125.4
21-Aug-23	19:30	124.1	0	124.1
21-Aug-23	19:35	122.8	0	122.8
21-Aug-23	19:40	121.5	0	121.5
21-Aug-23	19:45	120.2	0	120.2
21-Aug-23	19:50	119	0	119
21-Aug-23	19:55	117.7	0	117.7
21-Aug-23	20:00	116.5	0	116.5
21-Aug-23	20:05	115.3	0	115.3
21-Aug-23	20:10	114.1	0	114.1
21-Aug-23	20:15	112.9	0	112.9
21-Aug-23	20:20	111.8	0	111.8
21-Aug-23	20:25	110.6	0	110.6
21-Aug-23	20:30	109.5	0	109.5
21-Aug-23	20:35	108.4	0	108.4
21-Aug-23	20:40	107.3	0	107.3
21-Aug-23	20:45	106.2	0	106.2
21-Aug-23	20:50	105.1	0	105.1

21-Aug-23	20:55	104.1	0	104.1
21-Aug-23	21:00	103	0	103
21-Aug-23	21:05	102	0	102
21-Aug-23	21:10	101	0	101
21-Aug-23	21:15	100	0	100
21-Aug-23	21:20	99	0	99
21-Aug-23	21:25	98	0	98
21-Aug-23	21:30	97	0	97
21-Aug-23	21:35	96.1	0	96.1
21-Aug-23	21:40	95.1	0	95.1
21-Aug-23	21:45	94.2	0	94.2
21-Aug-23	21:50	93.3	0	93.3
21-Aug-23	21:55	92.4	0	92.4
21-Aug-23	22:00	91.5	0	91.5
21-Aug-23	22:05	90.6	0	90.6
21-Aug-23	22:10	89.7	0	89.7
21-Aug-23	22:15	88.9	0	88.9
21-Aug-23	22:20	88	0	88
21-Aug-23	22:25	87.2	0	87.2
21-Aug-23	22:30	86.4	0	86.4
21-Aug-23	22:35	85.5	0	85.5
21-Aug-23	22:40	84.7	0	84.7
21-Aug-23	22:45	83.9	0	83.9
21-Aug-23	22:50	83.1	0	83.1
21-Aug-23	22:55	82.4	0	82.4
21-Aug-23	23:00	81.6	0	81.6
21-Aug-23	23:05	80.8	0	80.8
21-Aug-23	23:10	80.1	0	80.1
21-Aug-23	23:15	79.3	0	79.3
21-Aug-23	23:20	78.6	0	78.6
21-Aug-23	23:25	77.9	0	77.9
21-Aug-23	23:30	77.2	0	77.2
21-Aug-23	23:35	76.5	0	76.5
21-Aug-23	23:40	75.8	0	75.8
21-Aug-23	23:45	75.1	0	75.1
21-Aug-23	23:50	74.4	0	74.4
21-Aug-23	23:55	73.7	0	73.7
22-Aug-23	0:00	73.1	0	73.1
22-Aug-23	0:05	72.4	0	72.4
22-Aug-23	0:10	71.7	0	71.7
22-Aug-23	0:15	71.1	0	71.1
22-Aug-23	0:20	70.5	0	70.5
22-Aug-23	0:25	69.8	0	69.8

22-Aug-23	0:30	69.2	0	69.2
22-Aug-23	0:35	68.6	0	68.6
22-Aug-23	0:40	68	0	68
22-Aug-23	0:45	67.4	0	67.4
22-Aug-23	0:50	66.8	0	66.8
22-Aug-23	0:55	66.2	0	66.2
22-Aug-23	1:00	65.7	0	65.7
22-Aug-23	1:05	65.1	0	65.1
22-Aug-23	1:10	64.5	0	64.5
22-Aug-23	1:15	64	0	64
22-Aug-23	1:20	63.4	0	63.4
22-Aug-23	1:25	62.9	0	62.9
22-Aug-23	1:30	62.3	0	62.3
22-Aug-23	1:35	61.8	0	61.8
22-Aug-23	1:40	61.3	0	61.3
22-Aug-23	1:45	60.8	0	60.8
22-Aug-23	1:50	60.2	0	60.2
22-Aug-23	1:55	59.7	0	59.7
22-Aug-23	2:00	59.2	0	59.2
22-Aug-23	2:05	58.7	0	58.7
22-Aug-23	2:10	58.2	0	58.2
22-Aug-23	2:15	57.8	0	57.8
22-Aug-23	2:20	57.3	0	57.3
22-Aug-23	2:25	56.8	0	56.8
22-Aug-23	2:30	56.3	0	56.3
22-Aug-23	2:35	55.9	0	55.9
22-Aug-23	2:40	55.4	0	55.4
22-Aug-23	2:45	55	0	55
22-Aug-23	2:50	54.5	0	54.5
22-Aug-23	2:55	54.1	0	54.1
22-Aug-23	3:00	53.6	0	53.6
22-Aug-23	3:05	53.2	0	53.2
22-Aug-23	3:10	52.8	0	52.8
22-Aug-23	3:15	52.3	0	52.3
22-Aug-23	3:20	51.9	0	51.9
22-Aug-23	3:25	51.5	0	51.5
22-Aug-23	3:30	51.1	0	51.1
22-Aug-23	3:35	50.7	0	50.7
22-Aug-23	3:40	50.3	0	50.3
22-Aug-23	3:45	49.9	0	49.9
22-Aug-23	3:50	49.5	0	49.5
22-Aug-23	3:55	49.1	0	49.1
22-Aug-23	4:00	48.7	0	48.7

22-Aug-23	4:05	48.3	0	48.3
22-Aug-23	4:10	47.9	0	47.9
22-Aug-23	4:15	47.6	0	47.6
22-Aug-23	4:20	47.2	0	47.2
22-Aug-23	4:25	46.8	0	46.8
22-Aug-23	4:30	46.4	0	46.4
22-Aug-23	4:35	46.1	0	46.1
22-Aug-23	4:40	45.7	0	45.7
22-Aug-23	4:45	45.4	0	45.4
22-Aug-23	4:50	45	0	45
22-Aug-23	4:55	44.7	0	44.7
22-Aug-23	5:00	44.3	0	44.3
22-Aug-23	5:05	44	0	44
22-Aug-23	5:10	43.7	0	43.7
22-Aug-23	5:15	43.3	0	43.3
22-Aug-23	5:20	43	0	43
22-Aug-23	5:25	42.7	0	42.7
22-Aug-23	5:30	42.4	0	42.4
22-Aug-23	5:35	42	0	42
22-Aug-23	5:40	41.7	0	41.7
22-Aug-23	5:45	41.4	0	41.4
22-Aug-23	5:50	41.1	0	41.1
22-Aug-23	5:55	40.8	0	40.8
22-Aug-23	6:00	40.5	0	40.5
22-Aug-23	6:05	40.2	0	40.2
22-Aug-23	6:10	39.9	0	39.9
22-Aug-23	6:15	39.6	0	39.6
22-Aug-23	6:20	39.3	0	39.3
22-Aug-23	6:25	39	0	39
22-Aug-23	6:30	38.7	0	38.7
22-Aug-23	6:35	38.5	0	38.5
22-Aug-23	6:40	38.2	0	38.2
22-Aug-23	6:45	37.9	0	37.9
22-Aug-23	6:50	37.6	0	37.6
22-Aug-23	6:55	37.4	0	37.4
22-Aug-23	7:00	37.1	0	37.1
22-Aug-23	7:05	36.8	0	36.8
22-Aug-23	7:10	36.6	0	36.6
22-Aug-23	7:15	36.3	0	36.3
22-Aug-23	7:20	36	0	36
22-Aug-23	7:25	35.8	0	35.8
22-Aug-23	7:30	35.5	0	35.5
22-Aug-23	7:35	35.3	0	35.3

22-Aug-23	7:40	35	0	35
22-Aug-23	7:45	34.8	0	34.8
22-Aug-23	7:50	34.5	0	34.5
22-Aug-23	7:55	34.3	0	34.3
22-Aug-23	8:00	34	0	34
22-Aug-23	8:05	33.8	0	33.8
22-Aug-23	8:10	33.6	0	33.6
22-Aug-23	8:15	33.3	0	33.3
22-Aug-23	8:20	33.1	0	33.1
22-Aug-23	8:25	32.9	0	32.9
22-Aug-23	8:30	32.7	0	32.7
22-Aug-23	8:35	32.4	0	32.4
22-Aug-23	8:40	32.2	0	32.2
22-Aug-23	8:45	32	0	32
22-Aug-23	8:50	31.8	0	31.8
22-Aug-23	8:55	31.5	0	31.5
22-Aug-23	9:00	31.3	0	31.3
22-Aug-23	9:05	31.1	0	31.1
22-Aug-23	9:10	30.9	0	30.9
22-Aug-23	9:15	30.7	0	30.7
22-Aug-23	9:20	30.5	0	30.5
22-Aug-23	9:25	30.3	0	30.3
22-Aug-23	9:30	30.1	0	30.1
22-Aug-23	9:35	29.9	0	29.9
22-Aug-23	9:40	29.7	0	29.7
22-Aug-23	9:45	29.5	0	29.5
22-Aug-23	9:50	29.3	0	29.3
22-Aug-23	9:55	29.1	0	29.1
22-Aug-23	10:00	28.9	0	28.9
22-Aug-23	10:05	28.7	0	28.7
22-Aug-23	10:10	28.5	0	28.5
22-Aug-23	10:15	28.3	0	28.3
22-Aug-23	10:20	28.2	0	28.2
22-Aug-23	10:25	28	0	28
22-Aug-23	10:30	27.8	0	27.8
22-Aug-23	10:35	27.6	0	27.6
22-Aug-23	10:40	27.4	0	27.4
22-Aug-23	10:45	27.2	0	27.2
22-Aug-23	10:50	27.1	0	27.1
22-Aug-23	10:55	26.9	0	26.9
22-Aug-23	11:00	26.7	0	26.7
22-Aug-23	11:05	26.6	0	26.6
22-Aug-23	11:10	26.4	0	26.4

22-Aug-23	11:15	26.2	0	26.2
22-Aug-23	11:20	26	0	26
22-Aug-23	11:25	25.9	0	25.9
22-Aug-23	11:30	25.7	0	25.7
22-Aug-23	11:35	25.6	0	25.6
22-Aug-23	11:40	25.4	0	25.4
22-Aug-23	11:45	25.2	0	25.2
22-Aug-23	11:50	25.1	0	25.1
22-Aug-23	11:55	24.9	0	24.9
22-Aug-23	12:00	24.8	0	24.8
22-Aug-23	12:05	24.6	0	24.6
22-Aug-23	12:10	24.5	0	24.5
22-Aug-23	12:15	24.3	0	24.3
22-Aug-23	12:20	24.2	0	24.2
22-Aug-23	12:25	24	0	24
22-Aug-23	12:30	23.9	0	23.9
22-Aug-23	12:35	23.7	0	23.7
22-Aug-23	12:40	23.6	0	23.6
22-Aug-23	12:45	23.4	0	23.4
22-Aug-23	12:50	23.3	0	23.3
22-Aug-23	12:55	23.1	0	23.1
22-Aug-23	13:00	23	0	23
22-Aug-23	13:05	22.8	0	22.8
22-Aug-23	13:10	22.7	0	22.7
22-Aug-23	13:15	22.6	0	22.6
22-Aug-23	13:20	22.4	0	22.4
22-Aug-23	13:25	22.3	0	22.3
22-Aug-23	13:30	22.2	0	22.2
22-Aug-23	13:35	22	0	22
22-Aug-23	13:40	21.9	0	21.9
22-Aug-23	13:45	21.8	0	21.8
22-Aug-23	13:50	21.6	0	21.6
22-Aug-23	13:55	21.5	0	21.5
22-Aug-23	14:00	21.4	0	21.4
22-Aug-23	14:05	21.3	0	21.3
22-Aug-23	14:10	21.1	0	21.1
22-Aug-23	14:15	21	0	21
22-Aug-23	14:20	20.9	0	20.9
22-Aug-23	14:25	20.8	0	20.8
22-Aug-23	14:30	20.6	0	20.6
22-Aug-23	14:35	20.5	0	20.5
22-Aug-23	14:40	20.4	0	20.4
22-Aug-23	14:45	20.3	0	20.3

22-Aug-23	14:50	20.2	0	20.2
22-Aug-23	14:55	20	0	20
22-Aug-23	15:00	19.9	0	19.9
22-Aug-23	15:05	19.8	0	19.8
22-Aug-23	15:10	19.7	0	19.7
22-Aug-23	15:15	19.6	0	19.6
22-Aug-23	15:20	19.5	0	19.5
22-Aug-23	15:25	19.4	0	19.4
22-Aug-23	15:30	19.3	0	19.3
22-Aug-23	15:35	19.1	0	19.1
22-Aug-23	15:40	19	0	19
22-Aug-23	15:45	18.9	0	18.9
22-Aug-23	15:50	18.8	0	18.8
22-Aug-23	15:55	18.7	0	18.7
22-Aug-23	16:00	18.6	0	18.6
22-Aug-23	16:05	18.5	0	18.5
22-Aug-23	16:10	18.4	0	18.4
22-Aug-23	16:15	18.3	0	18.3
22-Aug-23	16:20	18.2	0	18.2
22-Aug-23	16:25	18.1	0	18.1
22-Aug-23	16:30	18	0	18
22-Aug-23	16:35	17.9	0	17.9
22-Aug-23	16:40	17.8	0	17.8
22-Aug-23	16:45	17.7	0	17.7
22-Aug-23	16:50	17.6	0	17.6
22-Aug-23	16:55	17.5	0	17.5
22-Aug-23	17:00	17.4	0	17.4
22-Aug-23	17:05	17.3	0	17.3
22-Aug-23	17:10	17.2	0	17.2
22-Aug-23	17:15	17.1	0	17.1
22-Aug-23	17:20	17	0	17
22-Aug-23	17:25	16.9	0	16.9
22-Aug-23	17:30	16.8	0	16.8
22-Aug-23	17:35	16.8	0	16.8
22-Aug-23	17:40	16.7	0	16.7
22-Aug-23	17:45	16.6	0	16.6
22-Aug-23	17:50	16.5	0	16.5
22-Aug-23	17:55	16.4	0	16.4
22-Aug-23	18:00	16.3	0	16.3
22-Aug-23	18:05	16.2	0	16.2
22-Aug-23	18:10	16.1	0	16.1
22-Aug-23	18:15	16.1	0	16.1
22-Aug-23	18:20	16	0	16

22-Aug-23	18:25	15.9	0	15.9
22-Aug-23	18:30	15.8	0	15.8
22-Aug-23	18:35	15.7	0	15.7
22-Aug-23	18:40	15.6	0	15.6
22-Aug-23	18:45	15.5	0	15.5
22-Aug-23	18:50	15.5	0	15.5
22-Aug-23	18:55	15.4	0	15.4
22-Aug-23	19:00	15.3	0	15.3
22-Aug-23	19:05	15.2	0	15.2
22-Aug-23	19:10	15.1	0	15.1
22-Aug-23	19:15	15.1	0	15.1
22-Aug-23	19:20	15	0	15
22-Aug-23	19:25	14.9	0	14.9
22-Aug-23	19:30	14.8	0	14.8
22-Aug-23	19:35	14.8	0	14.8
22-Aug-23	19:40	14.7	0	14.7
22-Aug-23	19:45	14.6	0	14.6
22-Aug-23	19:50	14.5	0	14.5
22-Aug-23	19:55	14.5	0	14.5
22-Aug-23	20:00	14.4	0	14.4
22-Aug-23	20:05	14.3	0	14.3
22-Aug-23	20:10	14.2	0	14.2
22-Aug-23	20:15	14.2	0	14.2
22-Aug-23	20:20	14.1	0	14.1
22-Aug-23	20:25	14	0	14
22-Aug-23	20:30	14	0	14
22-Aug-23	20:35	13.9	0	13.9
22-Aug-23	20:40	13.8	0	13.8
22-Aug-23	20:45	13.7	0	13.7
22-Aug-23	20:50	13.7	0	13.7
22-Aug-23	20:55	13.6	0	13.6
22-Aug-23	21:00	13.5	0	13.5
22-Aug-23	21:05	13.5	0	13.5
22-Aug-23	21:10	13.4	0	13.4
22-Aug-23	21:15	13.3	0	13.3
22-Aug-23	21:20	13.3	0	13.3
22-Aug-23	21:25	13.2	0	13.2
22-Aug-23	21:30	13.1	0	13.1
22-Aug-23	21:35	13.1	0	13.1
22-Aug-23	21:40	13	0	13
22-Aug-23	21:45	12.9	0	12.9
22-Aug-23	21:50	12.9	0	12.9
22-Aug-23	21:55	12.8	0	12.8

22-Aug-23	22:00	12.8	0	12.8
22-Aug-23	22:05	12.7	0	12.7
22-Aug-23	22:10	12.6	0	12.6
22-Aug-23	22:15	12.6	0	12.6
22-Aug-23	22:20	12.5	0	12.5
22-Aug-23	22:25	12.4	0	12.4
22-Aug-23	22:30	12.4	0	12.4
22-Aug-23	22:35	12.3	0	12.3
22-Aug-23	22:40	12.3	0	12.3
22-Aug-23	22:45	12.2	0	12.2
22-Aug-23	22:50	12.2	0	12.2
22-Aug-23	22:55	12.1	0	12.1
22-Aug-23	23:00	12	0	12
22-Aug-23	23:05	12	0	12
22-Aug-23	23:10	11.9	0	11.9
22-Aug-23	23:15	11.9	0	11.9
22-Aug-23	23:20	11.8	0	11.8
22-Aug-23	23:25	11.8	0	11.8
22-Aug-23	23:30	11.7	0	11.7
22-Aug-23	23:35	11.6	0	11.6
22-Aug-23	23:40	11.6	0	11.6
22-Aug-23	23:45	11.5	0	11.5
22-Aug-23	23:50	11.5	0	11.5
22-Aug-23	23:55	11.4	0	11.4
23-Aug-23	0:00	11.4	0	11.4

APPENDIX - II

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

Reach	River Station	Profile	Q Total	Min Ch Elevation	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude No. of Channel
		Qmin	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	13142	PF 1	0.63	70.7	70.81	70.74	70.82	0.000312	0.07	9.35	157.21	0.09
Reach 1	12864	PF 1	0.63	70.49	70.5	70.5	70.51	0.069022	0.34	1.86	158.08	1
Reach 1	12662	PF 1	0.63	69.87	70.1	69.93	70.1	0.000033	0.04	14.98	95.03	0.03
Reach 1	12559	PF 1	0.63	70	70.1		70.1	0.00004	0.03	18.63	187.92	0.03
Reach 1	12370	PF 1	0.63	70	70.1		70.1	0.000014	0.02	32.76	350.22	0.02
Reach 1	12113	PF 1	0.63	70	70.09		70.09	0.000056	0.04	16.74	186.45	0.04
Reach 1	11909	PF 1	0.63	70	70.08		70.08	0.00004	0.03	21.6	272.18	0.03
Reach 1	11796	PF 1	0.63	70	70.07		70.07	0.000084	0.04	15.83	218.5	0.05
Reach 1	11618	PF 1	0.63	70	70.01	70.01	70.01	0.120174	0.34	1.84	234.2	1.23
Reach 1	11489	PF 1	0.63	70	69.43	69.18	69.43	0.000862		2.19	8.51	0
Reach 1	11343	PF 1	0.63	70	69.09	69.09	69.17	0.032947		0.51	3.36	0
Reach 1	11250	PF 1	0.63	70	69.12	68.7	69.12	0.000049		7.18	19.84	0
Reach 1	11122	PF 1	0.63	69	69.12		69.12	0.000024	0.03	22.86	217.12	0.03
Reach 1	11015	PF 1	0.63	69	69.11		69.11	0.000006	0.01	43.87	389.36	0.01
Reach 1	10853	PF 1	0.63	69	69.11		69.11	0.00001	0.02	34.95	311.11	0.02
Reach 1	10723	PF 1	0.63	69	69.11		69.11	0.000012	0.02	31.39	289.02	0.02
Reach 1	10567	PF 1	0.63	69	69.11		69.11	0.000008	0.02	37.77	345.07	0.02

Reach	River Station	Profile	Q Total	Min Ch Elevation	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude No. of Channel
		Qmin	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	10323	PF 1	0.63	69	69.11		69.11	0.00002	0.03	25.14	235.96	0.02
Reach 1	10206	PF 1	0.63	69	69.1		69.1	0.000016	0.02	28.12	269.31	0.02
Reach 1	10007	PF 1	0.63	69	69.1		69.1	0.00003	0.03	21.22	212.47	0.03
Reach 1	9816	PF 1	0.63	69	69.09		69.1	0.000028	0.03	22.88	242.04	0.03
Reach 1	9704	PF 1	0.63	69	69.09		69.09	0.000042	0.03	19.28	212.38	0.03
Reach 1	9359	PF 1	0.63	69	69.08		69.08	0.000019	0.02	31.04	385.67	0.02
Reach 1	9072	PF 1	0.63	68.94	69.08		69.08	0	0	121.06	575	0
Reach 1	8784	PF 1	0.63	69	69.08		69.08	0.000005	0.01	61.47	758.85	0.01
Reach 1	8468	PF 1	0.63	69	69.08		69.08	0.000036	0.03	23.05	295.84	0.03
Reach 1	8253	PF 1	0.63	69	69.07		69.07	0.000027	0.02	28.05	393.06	0.03
Reach 1	8053	PF 1	0.63	69	69.06		69.06	0.000047	0.03	22.84	354	0.03
Reach 1	7882	PF 1	0.63	69	69.06		69.06	0.000057	0.03	22.82	410.93	0.04
Reach 1	7656	PF 1	0.63	69	69.01	69.01	69.01	0.014416	0.11	5.65	791.45	0.42
Reach 1	7348	PF 1	0.63	68	68.11	68.01	68.11	0.000005	0.01	50.45	471.37	0.01
Reach 1	7167	PF 1	0.63	68	68.11		68.11	0.000005	0.01	51.41	483.55	0.01
Reach 1	6587	PF 1	0.63	68	68.11		68.11	0	0	338.4	617.46	0
Reach 1	6175	PF 1	0.63	68	68.11		68.11	0.000003	0.01	64.06	620.46	0.01
Reach 1	5928	PF 1	0.63	68	68.11		68.11	0.000007	0.01	43.63	418.9	0.01
Reach 1	5806	PF 1	0.63	68	68.1		68.1	0.000013	0.02	31.72	305.21	0.02

Reach	River Station	Profile	Q Total	Min Ch Elevation	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude No. of Channel
		Qmin	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	5736	PF 1	0.63	68	68.1	68.01	68.1	0.000017	0.02	28.07	274.22	0.02
Reach 1	5609	PF 1	0.63	68	68.1		68.1	0	0	123.36	424.73	0
Reach 1	5490	PF 1	0.63	68	68.1	68.01	68.1	0.00001	0.02	36.81	358.43	0.02
Reach 1	5310		Bridge									
Reach 1	5149	PF 1	0.63	68	68.1		68.1	0.000011	0.02	35.62	352.74	0.02
Reach 1	5019	PF 1	0.63	68	68.1		68.1	0.000002	0.01	50	394.09	0.01
Reach 1	4735	PF 1	0.63	68	68.1		68.1	0.000045	0.04	17.48	177.02	0.04
Reach 1	4576	PF 1	0.63	68	68.09		68.09	0.000061	0.04	16.03	177.64	0.04
Reach 1	4384	PF 1	0.63	68	68.08		68.08	0.000035	0.03	22.61	277.41	0.03
Reach 1	4235	PF 1	0.63	68	68.08		68.08	0.000042	0.03	21.78	287.95	0.03
Reach 1	4001	PF 1	0.63	68	68.07		68.07	0.00004	0.03	24.43	369.11	0.03
Reach 1	3760	PF 1	0.63	68	68.06		68.06	0.000049	0.03	24.25	428.67	0.03
Reach 1	3480	PF 1	0.63	65.47	68.06		68.06	0	0	126.25	476.34	0
Reach 1	3311	PF 1	0.63	68	68.06		68.06	0.000077	0.03	19.61	351.02	0.04
Reach 1	3163	PF 1	0.63	68	68.01	68.01	68.01	0.095493	0.26	2.39	379.85	1.06
Reach 1	2912	PF 1	0.63	67	67.26	67.01	67.26	0	0.01	119.26	467.95	0
Reach 1	2628	PF 1	0.63	67	67.26		67.26	0.000001	0.01	83.72	323.26	0
Reach 1	2404	PF 1	0.63	67	67.26		67.26	0.000002	0.01	44.33	181.48	0.01
Reach 1	2163	PF 1	0.63	67	67.26		67.26	0.000001	0.01	74.79	302.12	0.01
Reach 1	1882	PF 1	0.63	67	67.26		67.26	0.000001	0.01	60.3	244.31	0.01
Reach 1	1653	PF 1	0.63	67	67.26		67.26	0.000001	0.01	53.04	210.73	0.01
Reach 1	1475	PF 1	0.63	67	67.26		67.26	0.000001	0.01	72.88	269.58	0.01
Reach 1	1226	PF 1	0.63	67	67.25		67.25	0.000006	0.02	26.98	120.22	0.02
Reach 1	1037	PF 1	0.63	67	67.25		67.25	0	0	108.24	344.21	0
Reach 1	739	PF 1	0.63	67	67.25		67.25	0	0.01	94.04	375.61	0
Reach 1	644	PF 1	0.63	66.3	67.25		67.25	0	0	226.47	284.19	0
Reach 1	363	PF 1	0.63	67.14	67.25		67.25	0.000098	0.04	15.49	233.5	0.05

Table 5.5- Profile output table for steady flow analysis for Qavg

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Vel Channel	Flow Area	Top Width	Froude # Chl
		Qavg	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	13142	PF 3	2646.92	70.7	76.16	72.89	76.25	0.000391	1.35	1959.49	432.92	0.2
Reach 1	12864	PF 3	2646.92	70.49	75.91		76.1	0.000695	1.94	1389.35	317.59	0.28
Reach 1	12662	PF 3	2646.92	69.87	75.63		75.92	0.001055	2.5	1184.42	277.8	0.34
Reach 1	12559	PF 3	2646.92	70	75.6		75.8	0.000737	2.07	1369.17	295.97	0.29
Reach 1	12370	PF 3	2646.92	70	75.63		75.69	0.000203	1.12	2471.94	499.9	0.15
Reach 1	12113	PF 3	2646.92	70	75.48		75.6	0.000507	1.62	1710.89	378.34	0.23
Reach 1	11909	PF 3	2646.92	70	75.36		75.5	0.000486	1.67	1652.41	352.32	0.23
Reach 1	11796	PF 3	2646.92	70	75.29		75.44	0.000549	1.76	1613.38	362.6	0.25
Reach 1	11618	PF 3	2646.92	70	75.18		75.33	0.000642	1.8	1581.43	395.7	0.26
Reach 1	11489	PF 3	2646.92	70	75.13		75.25	0.000474	1.56	1759.14	400.78	0.23
Reach 1	11343	PF 3	2646.92	70	75.11		75.19	0.000283	1.22	2185.03	442.71	0.18
Reach 1	11250	PF 3	2646.92	70	75.1		75.16	0.000212	1.07	2515.39	515.1	0.15
Reach 1	11122	PF 3	2646.92	69	75.09		75.14	0.000148	0.97	2801	511.7	0.13
Reach 1	11015	PF 3	2646.92	69	75.07		75.12	0.000138	0.98	2791.94	486	0.13
Reach 1	10853	PF 3	2646.92	69	75		75.09	0.000252	1.3	2131.25	460.7	0.17
Reach 1	10723	PF 3	2646.92	69	74.98		75.05	0.000229	1.23	2200.88	394.41	0.16
Reach 1	10567	PF 3	2646.92	69	74.95		75.02	0.000216	1.18	2303.86	448.5	0.16
Reach 1	10323	PF 3	2646.92	69	74.77		74.93	0.00053	1.76	1547.75	322.56	0.24
Reach 1	10206	PF 3	2646.92	69	74.76		74.86	0.000357	1.48	1866.3	383.55	0.2
Reach 1	10007	PF 3	2646.92	69	74.63		74.77	0.000534	1.7	1612.45	351.97	0.24
Reach 1	9816	PF 3	2646.92	69	74.54		74.68	0.000457	1.64	1686.57	354.5	0.23
Reach 1	9704	PF 3	2646.92	69	74.41		74.6	0.000768	1.98	1376.15	314.38	0.29
Reach 1	9359	PF 3	2646.92	69	74.41		74.45	0.000155	0.87	3113.73	692.58	0.13
Reach 1	9072	PF 3	2646.92	68.94	74.4		74.42	0.000065	0.58	4485.76	892.15	0.08
Reach 1	8784	PF 3	2646.92	69	74.38		74.4	0.000056	0.57	4715.72	928.12	0.08
Reach 1	8468	PF 3	2646.92	69	74.26		74.35	0.000367	1.4	1944.38	420.08	0.2
Reach 1	8253	PF 3	2646.92	69	74.21		74.28	0.000255	1.18	2266.6	450.2	0.17

Reach	River Sta	Profile	Q Total	Min Ch Elev	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Vel Channel	Flow Area	Top Width	Froude # Chl
		Qavg	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	8053	PF 3	2646.92	69	74.17		74.23	0.000229	1.12	2445.85	512.6	0.16
Reach 1	7882	PF 3	2646.92	69	74.14		74.19	0.000182	0.97	2795.97	606	0.14
Reach 1	7656	PF 3	2646.92	69	74.14		74.16	0.000064	0.6	4508.51	902.8	0.08
Reach 1	7348	PF 3	2646.92	68	74.1		74.13	0.000105	0.84	3191.55	566.53	0.11
Reach 1	7167	PF 3	2646.92	68	74.08		74.11	0.000098	0.81	3357.98	616.83	0.11
Reach 1	6587	PF 3	2646.92	68	74.05		74.07	0.000053	0.51	4901.16	976.45	0.08
Reach 1	6175	PF 3	2646.92	68	74.02		74.04	0.000056	0.61	4415.39	787.27	0.08
Reach 1	5928	PF 3	2646.92	68	73.97		74.02	0.000148	0.99	2715.07	484.65	0.13
Reach 1	5806	PF 3	2646.92	68	73.9		73.99	0.000275	1.34	2063.47	431.14	0.18
Reach 1	5736	PF 3	2646.92	68	73.88		73.97	0.000291	1.34	2105.6	465.25	0.18
Reach 1	5609	PF 3	2646.92	68	73.89		73.93	0.000133	0.93	2837.63	485.86	0.12
Reach 1	5490	PF 3	2646.92	68	73.85	69.74	73.91	0.000197	1.1	2490.28	482.24	0.15
Reach 1	5310		Bridge									
Reach 1	5149	PF 3	2646.92	68	73.75		73.82	0.000241	1.24	2208.36	431.94	0.17
Reach 1	5019	PF 3	2646.92	68	73.73		73.79	0.00018	1.07	2589.79	497.4	0.14
Reach 1	4735	PF 3	2646.92	68	73.36		73.66	0.001109	2.43	1107.14	238.55	0.35
Reach 1	4576	PF 3	2646.92	68	73.25		73.48	0.000933	2.14	1282.91	312.3	0.32
Reach 1	4384	PF 3	2646.92	68	73.19		73.32	0.000507	1.68	1644.07	356.42	0.24
Reach 1	4235	PF 3	2646.92	68	73.11		73.25	0.000524	1.66	1627.86	356.01	0.24
Reach 1	4001	PF 3	2646.92	68	73.07		73.14	0.000267	1.2	2283.72	483.8	0.17
Reach 1	3760	PF 3	2646.92	68	73.02		73.08	0.000226	1.1	2475.53	532.33	0.16
Reach 1	3480	PF 3	2646.92	65.47	72.98		73.02	0.000152	0.89	2952.78	591.4	0.13
Reach 1	3311	PF 3	2646.92	68	72.88		72.97	0.000406	1.38	1966.28	456.92	0.21
Reach 1	3163	PF 3	2646.92	68	72.85		72.92	0.000289	1.17	2308.09	523.16	0.17
Reach 1	2912	PF 3	2646.92	67	72.82		72.86	0.000125	0.88	3101	616.63	0.12
Reach 1	2628	PF 3	2646.92	67	72.73		72.81	0.000245	1.25	2181.37	404.07	0.17
Reach 1	2404	PF 3	2646.92	67	72.59		72.73	0.000507	1.7	1625.58	341.54	0.24
Reach 1	2163	PF 3	2646.92	67	72.53		72.62	0.0003	1.35	2029.39	386.1	0.18
Reach 1	1882	PF 3	2646.92	67	72.35		72.5	0.000552	1.76	1533.17	303.3	0.25

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elevation	Critical W.S.	E.G. Elevation	E.G. Slope	Vel Channel	Flow Area	Top Width	Froude # Chl
		Qavg	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	1653	PF 3	2646.92	67	72.19		72.36	0.000686	1.89	1467.68	346.2	0.27
Reach 1	1475	PF 3	2646.92	67	72.13		72.25	0.000423	1.51	1792.91	360	0.22
Reach 1	1226	PF 3	2646.92	67	70.75		71.87	0.007095	4.69	565.43	173.23	0.82
Reach 1	1037	PF 3	2646.92	67	71.15		71.29	0.000649	1.63	1648.93	412.03	0.26
Reach 1	739	PF 3	2646.92	67	70.99		71.09	0.00057	1.49	1847.42	503	0.24
Reach 1	644	PF 3	2646.92	66.3	70.95		71.04	0.000477	1.37	2018.58	545	0.22
Reach 1	363	PF 3	2646.92	67.14	70.65		70.83	0.001147	1.86	1447.78	465.2	0.33
Reach 1	112	PF 3	2646.92	67.14	69.92	69.14	70.32	0.004002	2.8	944.63	400.4	0.58