FLOOD INUNDATION MAPPING OF KOPILI RIVER THROUGH 2D MODELLING USING HEC-RAS AT NAGAON DISTRICT, ASSAM

A dissertation submitted in

Partial Fulfilment of the Requirement for the Award of the Degree of

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In

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(With Specialization in Water Resource Engineering)

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DECLARATION

I hereby declare that the work presented in the dissertation **“FLOOD INUNDATION MAPPING OF KOPILI RIVER THROUGH 2D MODELLING USING HEC-RAS RIVER AT NAGAON DISTRICT, ASSAM”** in partial fulfillment of the requirement for the award of the degree of “MASTER OF TECHNOLOGY” in Civil Engineering (with specialization in Water Resource Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13 under Assam Science & Technology University, is a real record of my work carried out in the said college for 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.

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CERTIFICATE

This is the certification that the work presented in the project report entitled "**FLOOD INUNDATION MAPPING OF KOPILI RIVER THROUGH 2D MODELLING USING HEC-RAS RIVER AT NAGAON DISTRICT, ASSAM**" is submitted by KARTIK KALITA, Roll No: 230620061010, a student of M.Tech 3rd semester, Department of Civil Engineering, Assam Engineering College, to the Assam Science and Technology University in partial fulfillment of the requirement for award of the degree of Master of Technology in Civil Engineering with Specialization in Water Resources Engineering under my guidance and supervision.

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ABSTRACT

Assam is very prone to river bank erosion and flooding because of various hydro-meteorological and topographical characteristics. Kopili, one of the main rivers of Nagaon district results in extensive flooding and bank erosion and is also considered a problematic river in the history of Assam. That is the reason why it is important to study the flow pattern of this river. In this present work, a study has been done along the river Kopili which focuses on the calculation of peak runoff, delineating watershed boundaries, preparation of Land use and Landcover map followed by soil map , generation of intensity duration frequency curve and curve number, Lag time calculation for different subbasins and time of concentration depths in the downstream area of the Nagaon district and also includes the determination of flood inundation area for a discharge of 100-year return period. Hence, it will stimulate the critical situation of flood and its impact on the Kopili River basin on the downstream side. Hydrologic Engineering Centers' River Analysis System (HEC-RAS) model of the given study area was prepared.

The calibrated performance has been used to simulate the level of water in river at different cross-sections. The purpose is to give a hand to policymakers, planners and insurers, to develop a strong strategy for the development of flood mitigation measures and plans to minimize the losses associated with the disaster in the study area.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

River flooding has a reputation for being one of nature's most catastrophic wonders, especially in urban areas. One of the most catastrophic characteristic threats that can result in the loss of life, property, and money is flooding. As a result, it is crucial to conduct an efficient analysis and create an open surge risk architecture that gives priority to the effects of mitigation. Flooding is the process of submerging a region by a sudden surge in water brought on by snowmelt, intense precipitation concentrated in the top part of a basin and also within its lower part, or by the failure of a dam, putting people's lives and property in the affected area at risk. It might be a regular occurrence for a stream. Eighty percent of the precipitation falls between June and September, during the monsoon season. These, together with the rivers' low carrying capacity, are to blame for flooding, backed-up drainage systems, and erosion of riverbanks. It occurs when excessive or ongoing precipitation exceeds the ability of the soil to absorb water and the stream channel to transport it. This results in a stream overflowing its banks and flooding nearby land. Despite the fact that floods frequently occur in monsoon-affected areas, many places still require surge danger maps in order to prevent or lessen the damage. Therefore, it is essential to create and advance predictive models and observational tools, as well as to set up regulatory frameworks and contingency plans.

Flood Inundation Mapping (FIM) has significant importance for flood risk assessment and management specifically for the areas that are recurrently affected by the floods and are also of great magnitude of damages. Along with Kopili river, a sub-tributary of Brahmaputra, Nagaon district of Assam has been greatly affected by the flows. This area has suffered from the Monsoons submerging the geographic area along with its hydrological features. Since these floods bring destruction to the population, infrastructure and farmland, they also increase the need of comprehensive and predictive flood mapping in order to be able to handle disasters. The Hydraulic Engineering Center's River Analysis System HEC-RAS is widely used for simulating the riverine hydraulics which allows detailed modeling of flood stages and its extent thus making this task easier. The flood inundation maps of the Kopili river in Nagaon District are produced using HEC-RAS in this study. This involves using topography, handloading and meteorological data to predict the flooding scene particularly at extreme events. HEC-RAS has matured the modeling of floods thereby enhancing the visualization of flood filled zones and in turn resilience approaches towards flood are made easy. By using satellite imagery, GIS data, and HEC-RAS hydraulic simulations, this study effectively outlines the areas at risk of flooding and pinpoints high-risk zones that need immediate attention. Additionally, it takes into account the unique challenges posed by the Kopili River, such as its varying flow patterns and sediment levels, to enhance the accuracy and dependability of the findings. This research aligns with the broader objectives of sustainable development and resilience in Assam, providing a methodology that can be applied to other flood-prone areas. It also emphasizes the significance of incorporating modern technology into disaster risk reduction strategies, showcasing how HEC-RAS can revolutionize flood management in India and beyond.

The Hydrologic Modeling System (HEC-HMS), created by the U.S. Army Corps of Engineers, provides sophisticated tools for simulating hydrologic processes at the watershed scale. This study uses HEC-HMS to analyze and model flood inundation in the Kopili River basin, incorporating climatic, topographic, and hydrological data to simulate flood events and evaluate their impacts. By integrating precipitation data, land-use characteristics, and soil properties, HEC-HMS generates hydrographs that reflect the temporal and spatial variability of flood flows. These outputs are then used to pinpoint flood-prone areas, assess the extent of inundation, and guide risk mitigation strategies. The use of HEC-HMS in this research highlights its effectiveness in understanding flood hydrodynamics, especially in regions like Nagaon, where traditional methods often struggle to address the complexities of flood events. The combination of remote sensing and GIS technologies further improves the accuracy of the modeling process, enabling detailed floodplain mapping and risk assessments. The results of this study contribute to the formulation of evidence-based flood management policies, enhancing disaster preparedness, early warning systems, and sustainable development initiatives in Assam. Moreover, the research showcases the versatility of HEC-HMS in various hydrological contexts, providing a strong framework for hydrological modeling and flood risk assessment globally.

1.2 OBJECTIVES OF THE STUDY

Since the degree of immersion is depends on the terrain and changes over time, it is unclear how to estimate flood extent. When there is a bank of full stream depth during a flood event, water is no longer contained solely inside the main stream channel and spills onto nearby flood plains. These factors make preparing a flood forecast highly difficult and time-consuming. To assess the potential flood dangers brought on by floods, numerical modeling of the Kopili River Reach in the Nagaon district has been undertaken in this work. The stakeholders in the management of water resources would benefit from the study's findings. The numerical analysis program HEC-RAS (Hydrologic Engineering Centre-River Analysis System) provides the finer details of flood profiles. The computer programme is very easy to use and has accurate calibration. A GIS and HEC-RAS strategy for river modeling facilities is presented in this work. The method establishes a connection between the HEC- RAS hydraulic simulation and ArcView GIS, enabling improved showcase and evaluation of the research area's flood inundation data. The goal of the study is to use ArcMap, HEC-HMS, and HEC-RAS to create a flood inundation area map for the Kampur town area and Roha town area of the Nagaon district utilizing rainfall data obtained from the Nagaon Division Water Resource Department, Assam.

The present study has been undertaken with the following objectives,

- To Prepare Land Use and Land Cover map and Soil map of the study area.
- To simulate the peak discharge of Study area at Sink using the HEC-HMS model.

CHAPTER 2

LITERATURE REVIEW

The literature on this topic has been thoroughly explored, and several publications have been examined. These reviews highlight the prominence of the subject and its academic foundation. The main objective of this project is to create flood inundation maps using hydraulic models. To protect riverbanks from flooding, numerous researchers have utilized various strategies and methodologies. This chapter offers a summary of previous studies that focused on floodplain modeling through hydrodynamic models

Ahmad Shahiri Parsa et al. (2016) has done a study on Floodplain Zoning Simulation by Using HEC-RAS and CCHE2D Models in the Sungai Maka River. The purpose of this study is to focus on the investigation of HEC-RAS and CCHE2D in order to assess and anticipate the surge profundity and spatial degree of flood in the Sungai Maka floodplain. This will help the decision-makers, particularly the involved government's division, and developers make an appropriate arrangement for future advancement.

Anjusha K.K. (2021) has done a study on Flood Inundation Modelling Using Arc GIS and HECRAS of Godavari Reach, Nanded District In this study, the GIS data was first imported and then exported to the HEC-RAS, which prepared the output of the HEC-RAS and carried out the steady stream inquiry and hydraulic design evaluation. This current investigation's work incorporates territory demonstrating with ArcMap, water driven displaying with HEC RAS, and planning with ArcMap. The computerized height model assumes a significant part in improving the model's exhibition. It is suggested that a high-goal advanced spatial information base be utilized to improve the model's exactness. The stream release input controls the whole flood immersion measure.

Awu John et al. (2017) has done a case study of Oyun River, Nigeria where flood inundation simulations were done using HEC-RAS. The study location is around 20 kilometers from Kwara State's capital, Ilorin. In this study, an advance enquiry about the plan was received. A Digital Elevation (DEM) of the Oyun Stream Basin was used to create RAS Layers, stream layers centerlines, stream way centerlines, major channel banks, and cross-section cut-lines in Hec-GeoRAS. Using the RAS Layers, the HEC-RAS demonstration revealed the hydraulic parameters of an open channel stream moving downstream and mapped the flood immersion zone The water surface profile that was created using the findings from the Hec-Ras investigation revealed that the surge inundation area covered a range of 11.217 m2 inside the Oyun Waterway reach, while the depth of the immersion area varied from 0.6 m to 2.8 m, separately. It was also agreed that the results of this study will provide governments and other organizations with extensive data for better planning and decision-making regarding surge control and mitigation.

Azaz khan I. Pathan et al. (2015) conducted a study on River Flood Modeling Using GIS, HEC-GeoRAS, and HECRAS for the Purna River, Navsari District, Gujrat, India. In this study, the GIS data was first imported and then exported to the HEC-RAS, which prepared the output of the HEC-RAS and carried out the steady stream inquiry and hydraulic design evaluation. Additionally, HEC-RAS will provide the height of the water's surface elevation after receiving the slope and top release of a given cross region. By providing Bank, surge divider, and other tools, we are able to predict the surge from this work.

The study demonstrates the value of combining ArcGIS and HECRAS to assess flooding at various cross segments and predict the probability of flooding at particular cross segments that will provide the water surface elevation after applying top discharge so that future opportunities lie in forming bank close rivers and preparing floodplain mapping of streams as well as creating surge hazard outline for Navsari area under changing scenarios.

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 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 streams cross areas have been recognized which cannot 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 degrees. 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 to demonstrate cost-saving for floodplain outline.

Darshan J. Mehta et al. (2014) made a study on the use of the 1D HEC-RAS model in the design of canals in Surat city. Surat city and the surrounding districts are particularly impacted by river Tapi surges. Since a long time back, the city has seen countless floods. The years 1883, 1884, 1942, 1944, 1945, 1949, 1959, 1968, 1994, 1998, 2002, 2006, 2007, and 2012 all had significant floods. In this investigation, the necessity for surge entryways on the storm channels is moreover assessed relying on the HEC-RAS water surface elevation computation for distinct surge releases. Existing storm routes are not stamped as it were. The recommendations are done based on this study are either to extend height of bank or develop a holding wall at certain areas along the study reach.
The study area is heavily impacted by the surge, so it is important to develop a surge reducing plan for the study area that will help to prevent a major calamity in the near future. It is strongly advised to increase the carrying capacity of the Tapi stream in order to reduce the surge in the Surat city's surrounding area in light of previous surge events. According to the analysis of the surge event of 2006, the West and South West zones are most likely to flood, whilst the East zone is least likely. In a dangerous flood occurrence in 2006, Surat city was submerged to a degree of 90–95 percent.

Hakim Farooq Ahmad et al. (2016) has done a study the application of HEC RAS Model using 1D steady flow analysis for flood studies in the river Jhelum in Kashmir valley. The HEC-RAS model used peak flood records to determine the resulting anticipated flood levels. The first focus of the investigation was on assessing the suitability of the HEC-RAS model for simulating the water surface profiles of the Jhelum River, which is the waterway most responsible for flooding the whole Kashmir valley. The results obtained from the use of one-dimensional steady flow analysis using the HEC RAS model sows that the area under study was found to get inundated to a greater extent for 100- year & 50-year floods and the left bank of the river is more vulnerable to get inundated than the right bank.

Prabeer Kumar Parhi (2018) has done a Flood Management in Mahanadi Basin using HECRAS. In this study, the return period is calculated using the peak flood levels at several sites along the Mahanadi River reach between the Hirakud dam and Naraj, the river's delta head. The analysis was done using surges from the past 25 years because it is considered that these surges are the most critical and fall under changing climatic conditions. This study came to the conclusion that the left and right banks of the river's existing embankments system are insufficient to protect the low-lying portions of the Mahanadi delta from flooding and to withstand floods of 25 years return period. As an alternative to moderate floods channel, clearance may be taken up to decrease the ruin of surges in the deltaic locales of Mahanadi Stream.

Praful Kumar V. Timbadiya et al. (2011) has done a study on Calibration of HEC-RAS Model on Prediction of Flood for Lower Tapi River, India. Through simulation of surges using HEC- RAS for the years 1998 and 2003, together with images of canal reaches taken during the field visit of the lower Tapi Stream, it has been demonstrated the necessity of various channel roughness coefficient Manning's 'n' values along the waterway. The surge for the year 2006 in the river has been replicated using the calibrated model in terms of channel roughness. By recording the flood peaks of observed and simulated surges and computing the root mean square error (RMSE) for the intermediate gauging stations on the lower Tapi Stream, it has been possible to access the execution of the calibrated HEC-RAS-based model.

A value of n = 0.035 up to Kakrapar weir and n = 0.025 downstream of Kakrapar weir might be suitable for recreation of future flood in the lower Tapi Stream, according to simulation of the previously described surge for various values of Manning's unpleasantness coefficient along the river reach. In order to advance the results, a two-dimensional hydrodynamic model of the lower Tapi River, including its flood plain region, is necessary.

Somaiyeh Khaleghi et al. (2015) has done a study on the integrated use of HEC-RAS, GIS, and RS for flood risk assessment in the Lighvan Chai River. GIS and the HEC-RAS model were used to determine the surge inclined area with different return times throughout the 16 km length of the Lighvan Chai Stream, and satellite images were used to extract land use changes over the last 10 years (2000–2010).

The outcomes of Lighvan Chai surge zoning appear that the proportion of overflowed zone by 25-year to the flooded area by 200-year return period is proportionate to 67%. This issue shows that roughly 67% of the total area of flooding is caused by 25-year or less. According to the study of the Lighvan basin, the percentages of thick pasture, desert land, and irrigated farming have decreased by 44%, 54.3%, and 0.5%, respectively. In any case, the private region, the fragile field, and the rained cultivating have all increased by, respectively, 88.9%, 45.5%, and 38.6%. Thus, flooding causes damage to productive rural areas and private range in the studied region.

Sudha Yerramilli (2012) has done a Hybrid Approach of Integrating HEC-RAS and GIS towards the Identification and Assessment of Flood Risk Vulnerability in the City of Jackson, MS. To reveal the vulnerability of the current foundation of the area whose formative codes are tied to a 100-year magnitude flood event, a 200-year size flood occasion that the research area experienced in 1979 was replicated. The outcomes demonstrated the effectiveness of the developed half-breed approach in illustrating the surge condition, visualising the geographical degree, and assessing the location's helplessness. The City of Jackson is exposed to an increased risk due to its key transportation corridors (I-55, Highway 80) and other essential infrastructure being affected by surge waters, according to the defencelessness appraisal from the 1979 surge event simulated by the HEC-RAS model.

Arc GIS and the HEC-RAS 1-D flood simulation model work together to show how well they can simulate flood events and spatially represent how vulnerable a location is to a risk occurrence in terms of the depth and size of the inundation. The HEC-RAS rebuilt water level depth at Pearl Stream at Jackson coordinated with the only immersion depth data at that time with just 4.75% of under estimation. The majority of I-55 and Highway 80, two of the state's main thoroughfares, are expected to be under water, causing the paralysis of the capital city of Mississippi.

Thaileng Thol et al. (2016) has done a flood study of a river reach in Cambodia using HEC- RAS. The Lower Mekong Stream in Cambodia, which is 50 km long, was chosen to represent the surge pattern from 2000 to 2013. An outline of a ten-year return period flood was too set up. The investigation is based primarily on the observed information of water level of 8 years, 18 river cross-sections and digital elevation model (30 m x 30 m). DEM is in a low resolution hence it cannot detail each height changing; fewer cross sections cannot make accurate stream bathymetries such as expansion and compression.

The yields for the flood research from 2000 to 2013 and the 10-year return period flood included the stream as well as flood depth and degree. The total affected areas on both sides of these 50 km-long streams, excluding the river area, which is approximately 4600 ha, were increased from 1,400 to 7,400 ha and consisted of various arrive uses, including residential, rice field, and mechanical zone, while the surge profundity ranged from zero to almost 10 m on both sides of the stream.

CHAPTER 3
STUDY AREA AND MATERIALS

3.1 STUDY AREA

Kopili Basin has a total geographical area (TGA) of about 1,355,600 hectares. It is between 91–93º E long. and 25–27ºN lat. Kopili River is one of the principal south bank tributaries 297 km in length contributing the flow into Brahmaputra River and it originates from the south-western slope of the Shillong Peak (Kusre et al. 2010). The elevation of the basin ranges from 74 to 1967 m (Kumar et al. 2014). The area of the basin lies between Assam and Meghalaya states and is mostly inundated by frequent floods due to high precipitation and rising water levels of Kopili River and accumulation of flow in its low-lying areas. The basin has a moderate and sub-humid climate with the annual rainfall of the study area ranging from 980 to 1700 mm. The average annual runoff of the basin is 600 mm approximately, more than 80% of the runoff occurs in monsoon season. The area receives its maximum rainfall during the months of June to September. Varied climatic zones are experienced owing to the study area's differential topography.

3.2 ABOUT KOPILI RIVER

The Kopili River begins at the Meghalaya Plateau, with a source of approximately 800 meters above sea level. Originating in India, the river is 290 kilometers in length and has significant cultural connotations for the local people. In its journey, it traverses through the northeastern regions of Assam and Meghalaya, eventually pouring into the powerful Brahmaputra River. The Kopili River is classified as an integral source for agriculture in the region by providing irrigation systems. The inadequate drainage carrying capacity of the tributaries compounded by evacuation of rain water and as well as spills of sub-tributaries further worsens the flood situation. Moreover, due to the Kopili Hydro Electric Project, it is evident that the river has the potential for hydroelectric power as well. However, the local rivers pollution caused by industrial waste and deforestation have greatly harmed the river and in turn, the plants and animals dwelling in the catchment areas. As a result, sustainable management would be needed to protect the wildlife in the area. Despite the growing issues, the river's scenic beauty is unparalleled, with alluring landscapes, mesmerizing valleys, and magnificent waterfalls to enjoy from. Overall, the nephology of the area alongside the unique ecosystem would attract countless of tourists from around the globe.

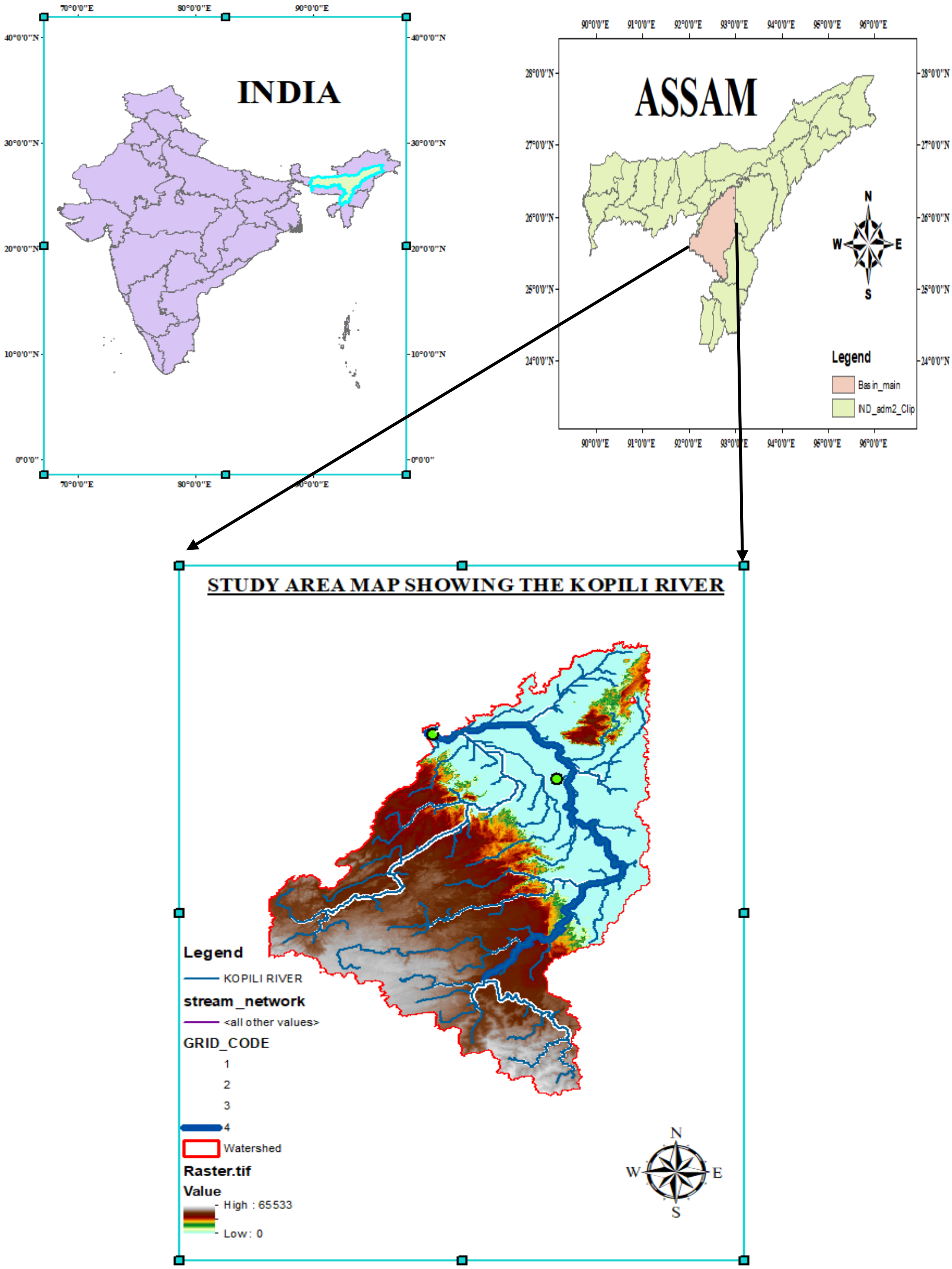

Figure 3.1: Geographical location of the Kopili River Basin

3.3 MATERIALS

3.3.1 Google Earth Pro: We can make extremely detailed maps with this geospatial desktop application, which is free. All users now have access to high-quality, high-resolution aerial photographs and ground photographs thanks to Google Earth Pro. Google Earth Pro offers a variety of tools and layers for exploring our green globe in addition to the aerial view of the earth. In conclusion we can say that Google Earth Pro is a capable and expert application that is easily accessible in the market. The study area is chosen, and the river centre lines are established and exported to ArcGIS for further use.

3.3.2 ArcMap: It is a geographic information system (GIS) which utilises maps and geographic data maintained by the Environmental Systems Research Institute (ESRI). Additionally, it can be used for making and using maps, gathering geographic data, evaluating information that has been mapped, sharing and discovering geographic information, utilising maps and geographic data in a variety of applications, and maintaining geographic data in a database. In this study, the river basin is identified using ArcGIS, and a basin map identifying solely the study region is identified using a DEM that was acquired using "USGS Earth Explorer."

3.3.3 HEC-HMS: 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.

3.4 DATA COLLECTED

3.4.1 Rainfall Data

The rainfall data of Nagaon area from 2004 to 2023 is collected from Nagaon Division of Water Resource Department" are shown in table 3.1

Table3.1: Rainfall data of Nagaon area from 2004 to 2023 collected from Nagaon Division of Water Resource Department, Assam

YEAR	Maximum Daily Rainfall(mm)
2004	116.3
2005	129.7
2006	41.1
2007	84.1
2008	104.39
2009	94.5
2010	100.6
2011	94.5
2012	369.8
2013	285.7
2014	291
2015	151
2016	305
2017	250
2018	225
2019	105.93
2020	105.6
2021	146.99
2022	81.48
2023	215.77

3.4.2 Digital Elevation Model data

Digital Elevation Models (DEMs) served as a representation of the research area's topological features. Depiction of the topographic surface of the Earth's bare ground of any surface structures, trees, or other items. A Digital Elevation Model (DEM) was generated from the shuttle Radar Topography Mission (SRTM) where 90 m resolution was used in this study and downloaded from USGS.

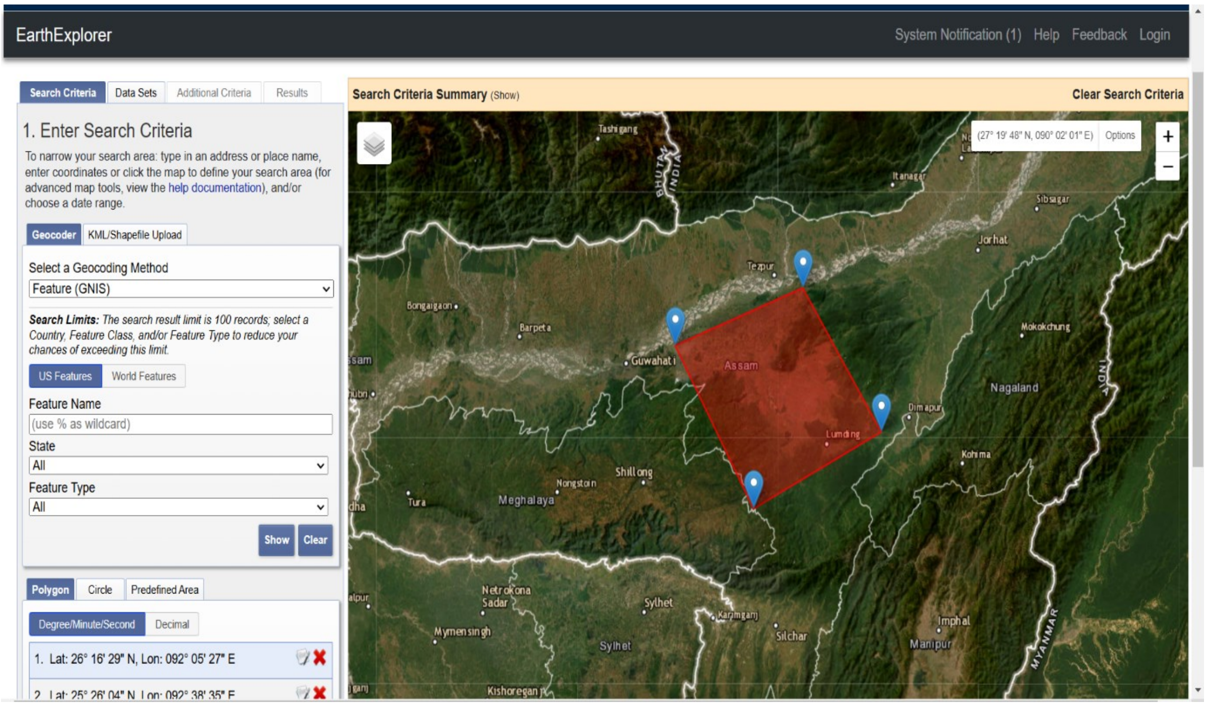

Figure 3.2: DEM of the study area

3.4.3 DMSW data:

In order to further evaluate and classify the types of soil data that was collected using a scale of 1:500000 from the International Food and Irrigation Organization (FAO).

The soil map was created as a vector layer in a GIS system. For reclassification of the soil map, user soil database was referred from Map Windows SWAT 2012 interface. There are only 3 HSGs are found, dominated by soil C. The nature of the soil is shown in the figure itself in figure 3.3

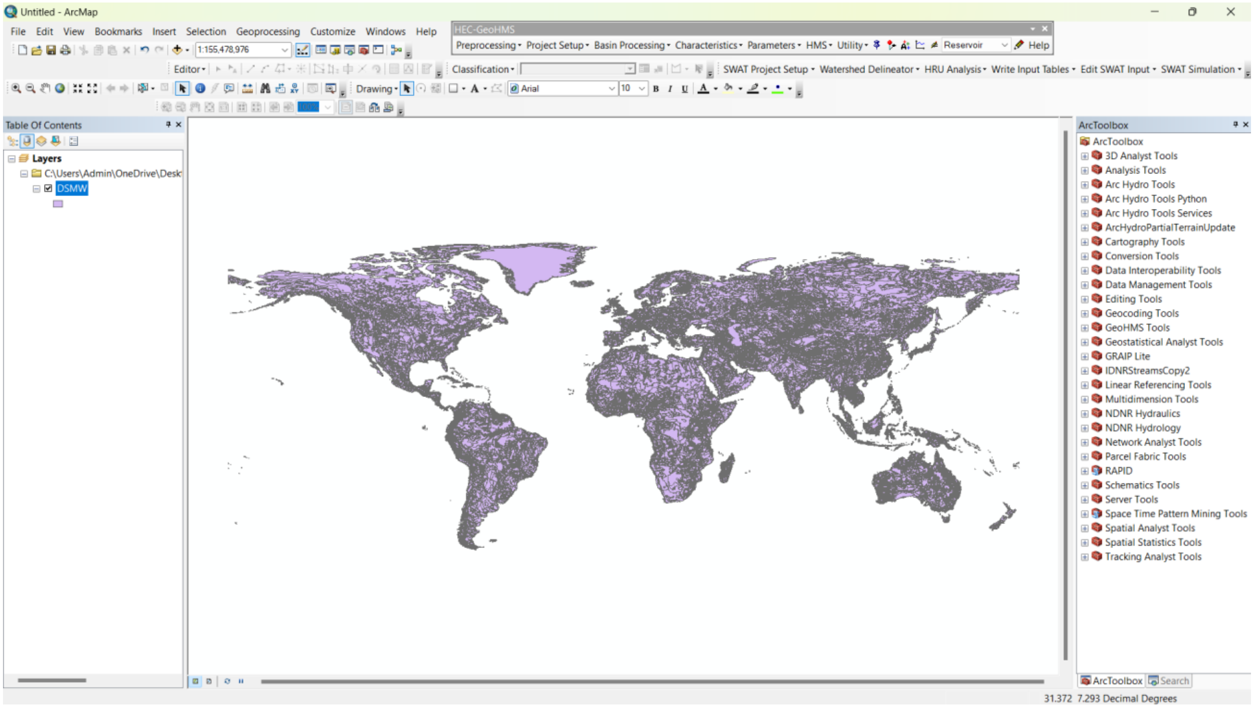

Figure 3.3: Showing FAO world soil map

CHAPTER 4
METHODOLOGY

4.1 INTRODUCTION

The methodology used for preparation and assessment of model is illustrated through the following flow chart.

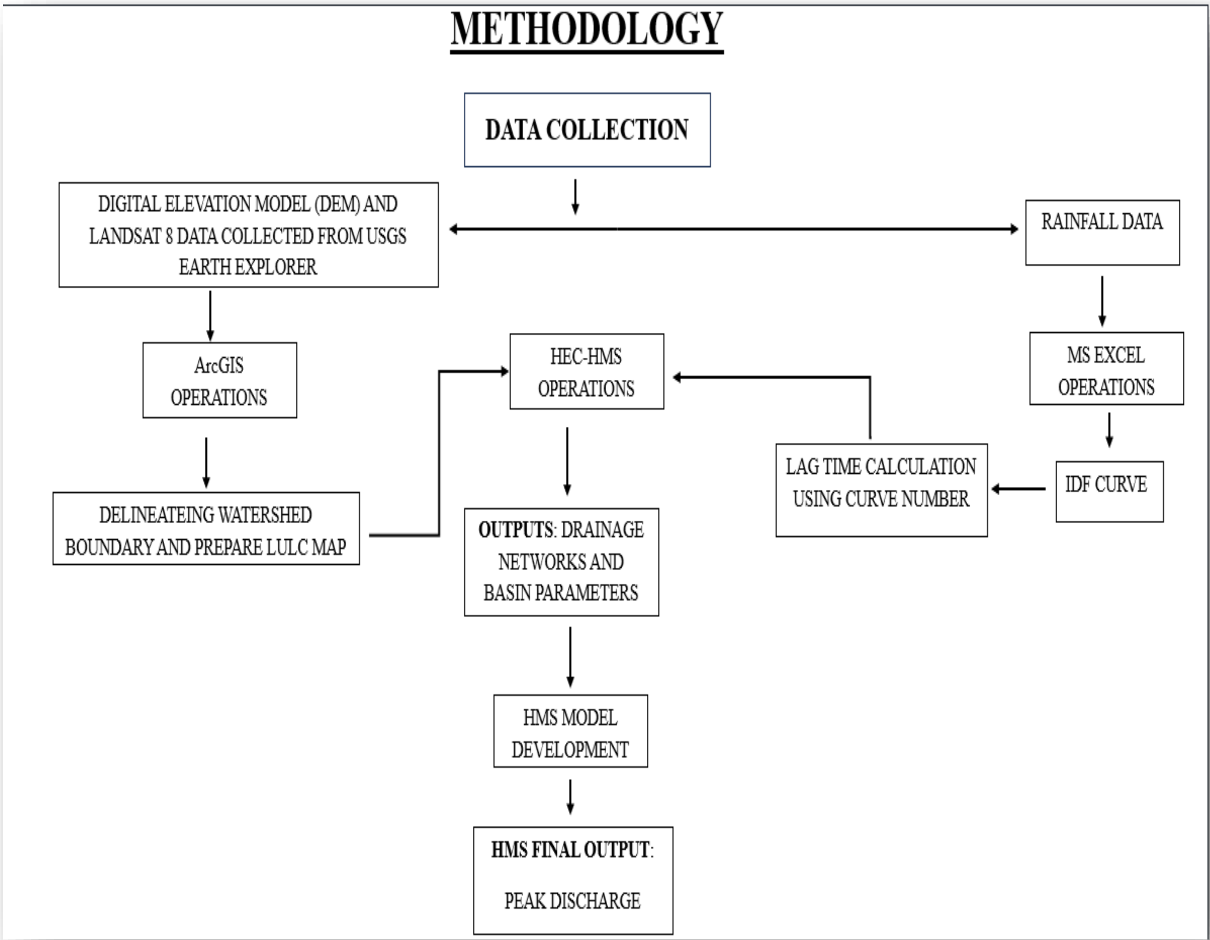

Fig 4.1: Flow Chart of Study Area

4.2 OPERATIONS IN ARCMAP

1. Firstly, the DEM is downloaded from USGS earth explorer. The downloaded DEM is imported to the ArcMap using the add data feature of the software.

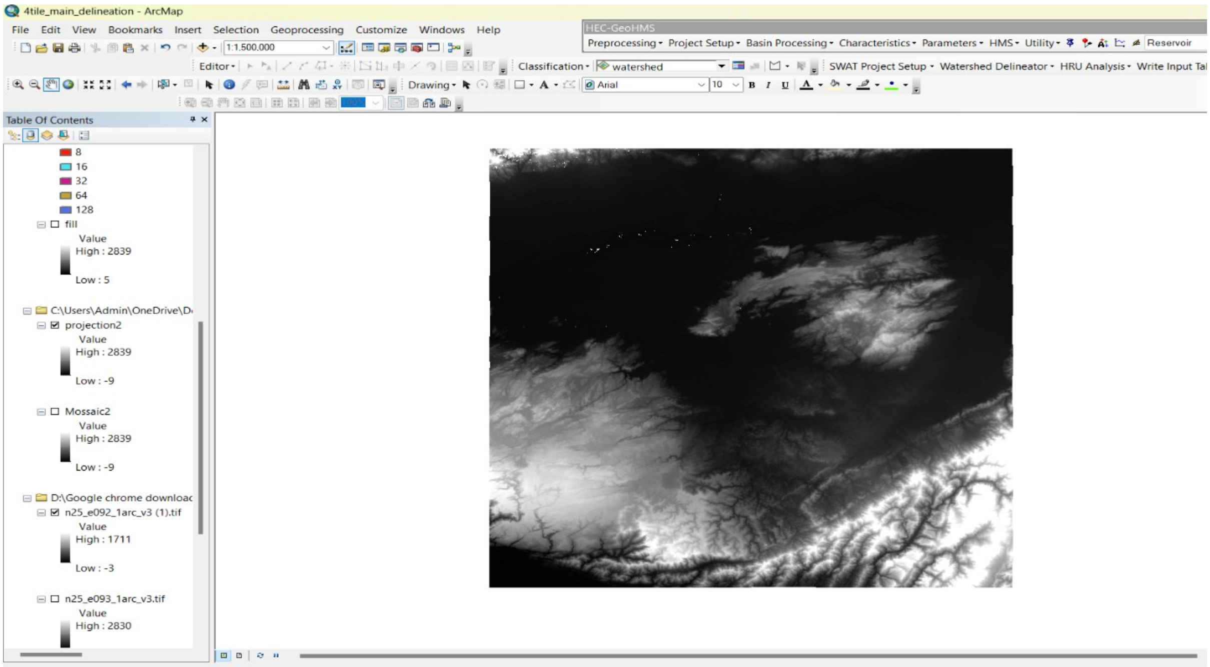

Fig 4.2: Importing DEM to ArcMap

2. To clip a DEM in ArcMap, we have followed these following steps:

A. First, we open ArcMap and add the DEM layer that we want to clip.

B. Add the layer that we want to use as the clip feature. This can be a polygon, a shape file, or any other feature layer.

C. Make sure that the two layers have the same projection.

D. Click on the "Geoprocessing" menu and select "Clip."

E. In the Clip tool dialog box, select the input raster layer (the DEM layer) and the clip feature layer.

F. Choose the output raster location and name, and make sure that the "Use Input Features for Clipping Geometry" option is selected.

G. Click OK to run the tool.

H. Once the clip operation is completed, we will have a new clipped DEM layer.

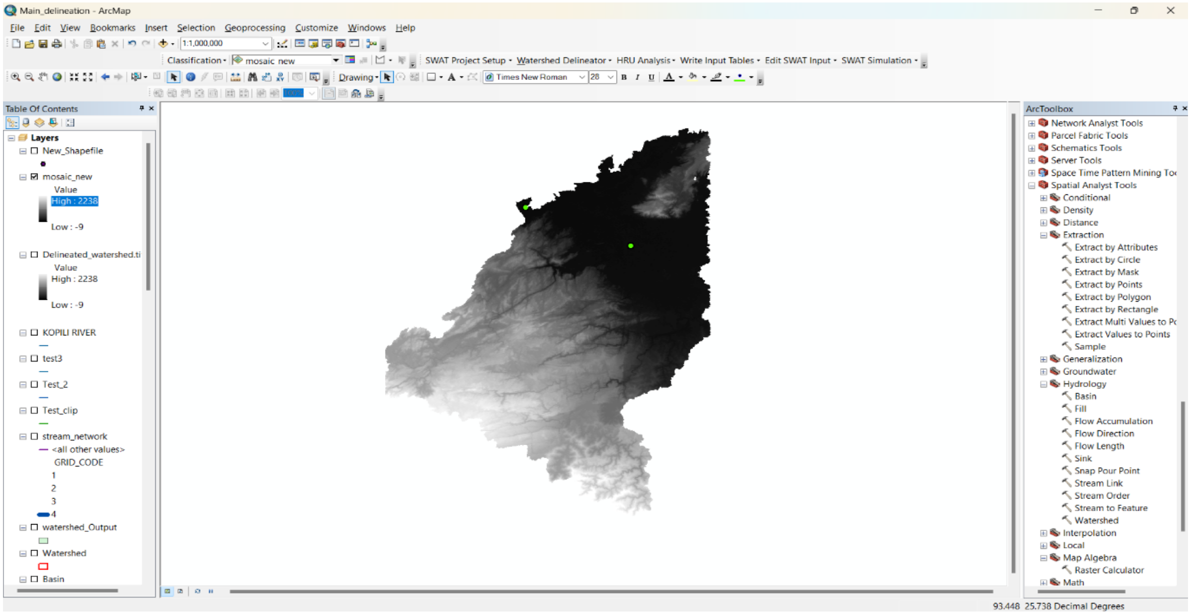

Fig 4.3: Clipped DEM

3. The clipped DEM is now given a suitable projection based on the location of the river. In the present study WGS 1984 having a UTM Zone 46 is used.

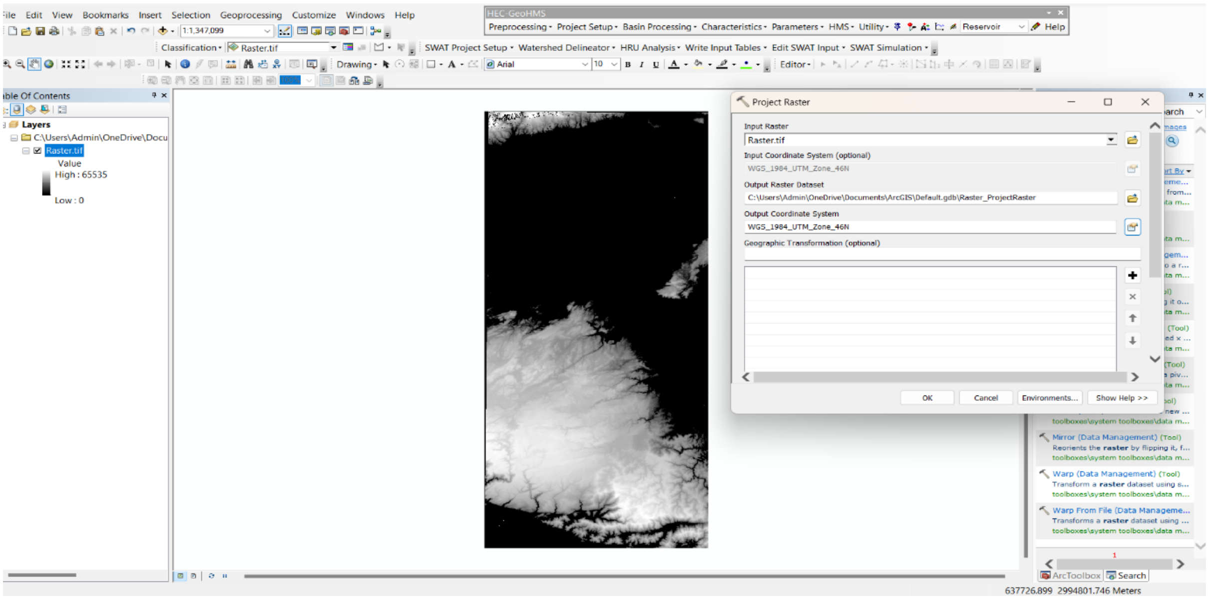

Fig 4.4: Assigned projections to the DEM

4.3 LAND USE AND 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.

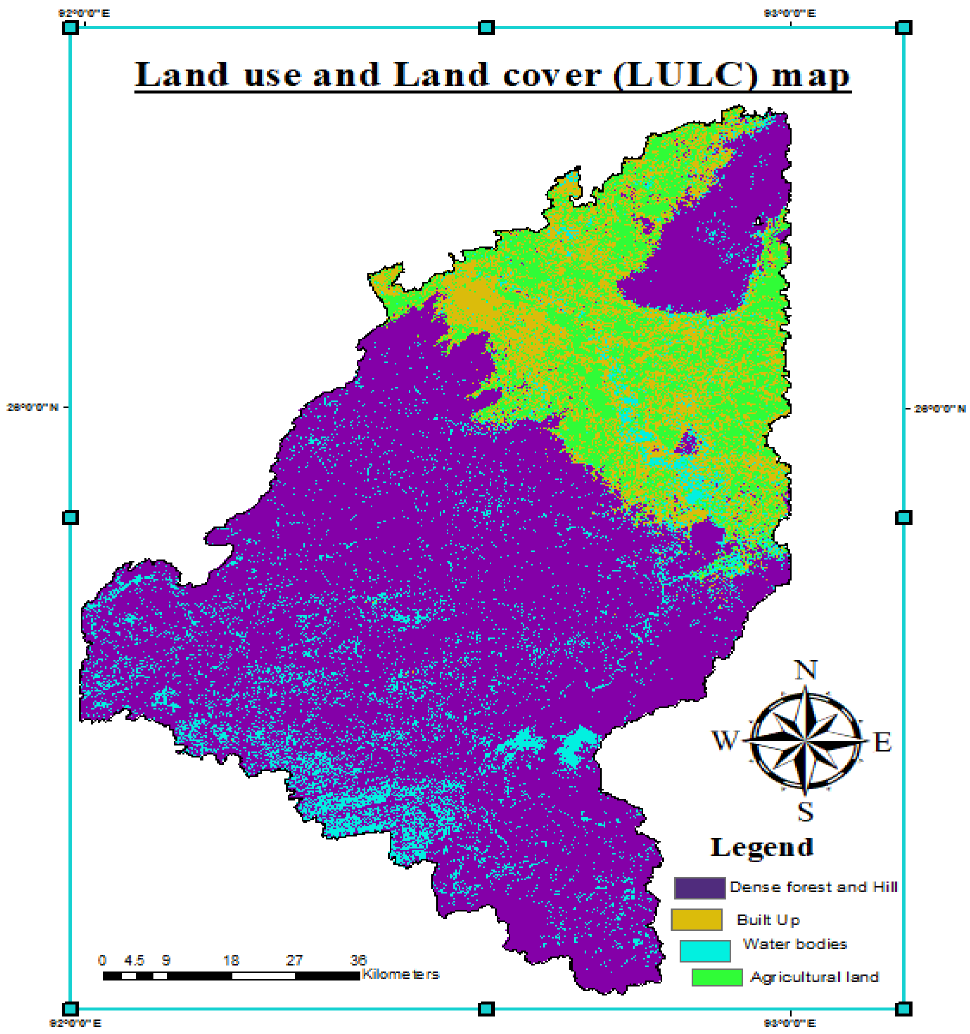

Fig 4.5: Land use and land cover map of Study area

4.4 OPERATIONS IN MS EXCEL

4.4.1 Gumbel Method of 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 2004-2023, to calculate the discharges at six different return periods, mainly 2 years ,10 years ,25 years, 50 years,75 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

$$\mathbf{x_T = X + K_T \, x \, S}$$

Where,

x_T= Design intensity for a particular duration and a particular return period x

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 (KT) is determined by the standard equation derived from Gumbel's distribution function as,

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

$$K_T = \frac{(Y_T - \tilde{y}_n)}{\sigma_n}$$

$$Y_T = \ln(\ln(\frac{T}{T-1}))$$

$\tilde{y}_n$ and σ_n values are obtained from the table under for different numbers of n (n=20 in our case as we have 20 years of rainfall data)

$\tilde{y}_n$ = 0.5236

σ_n = 1.0628

Table 4.1: $\tilde{y}_n$ and σ_n values for different numbers of observation n

n	$\bar{y}_n$	σ_n	n	$\bar{y}_n$	σ_n	n	$\bar{y}_n$	σ_n
8	0.4843	0.9043	35	0.5403	1.1285	64	0.5533	1.1793
9	0.4902	0.9288	36	0.5410	1.1313	66	0.5538	1.1814
10	0.4952	0.9497	37	0.5418	1.1339	68	0.5543	1.1834
11	0.4996	0.9676	38	0.5424	1.1363	70	0.5548	1.1854
12	0.5035	0.9833	39	0.5430	1.1388	72	0.5552	1.1873
13	0.5070	0.9972	40	0.5436	1.1413	74	0.5557	1.1890
14	0.5100	1.0095	41	0.5442	1.1436	76	0.5561	1.1906
15	0.5128	1.0206	42	0.5448	1.1458	78	0.5565	1.1923
16	0.5157	1.0316	43	0.5453	1.1480	80	0.5569	1.1938
17	0.5181	1.0411	44	0.5458	1.1499	82	0.5572	1.1953
18	0.5202	1.0493	45	0.5463	1.1519	84	0.5576	1.1967
19	0.5220	1.0566	46	0.5468	1.1538	86	0.5580	1.1980
20	0.5236	1.0628	47	0.5473	1.1557	88	0.5583	1.1994
21	0.5252	1.0696	48	0.5477	1.1574	90	0.5586	1.2007
22	0.5268	1.0754	49	0.5481	1.1590	92	0.5589	1.2020
23	0.5283	1.0811	50	0.5485	1.1607	94	0.5592	1.2032
24	0.5296	1.0864	51	0.5489	1.1623	96	0.5595	1.2044
25	0.5309	1.0915	52	0.5493	1.1638	98	0.5598	1.2055
26	0.5320	1.0961	53	0.5497	1.1653	100	0.5600	1.2065
27	0.5332	1.1004	54	0.5501	1.1667	150	0.5646	1.2253
28	0.5343	1.1047	55	0.5504	1.1681	200	0.5672	1.2360
29	0.5353	1.1086	56	0.5508	1.1696	250	0.5688	1.2429
30	0.5362	1.1124	57	0.5511	1.1708	300	0.5699	1.2479
31	0.5371	1.1159	58	0.5515	1.1721	400	0.5714	1.2545
32	0.5380	1.1193	59	0.5518	1.1734	500	0.5724	1.2588
33	0.5388	1.1226	60	0.5521	1.1747	750	0.5738	1.2651
34	0.5396	1.1255	62	0.5527	1.1770	1000	0.5745	1.2685

The K_T values are a function of return period only as can be observed from the above equation. The K_T for the return periods is calculated as mentioned in Table 4.2.

Table 4.2 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	-0.147804855	1.624733722	2.516874294	3.178715657	3.563402333	7.785616883

Table 4.3: Gumbel Distribution

YEAR	Maximum Rainfall(mm)	Precipitation (mm)							
		5 min	10 min	15 min	30 min	60 min	120 min	720 min	1440 min
2004	116.3	17.6109	22.18838	25.39935	32.00118	40.31896	50.7987	92.30737	116.30
2005	129.7	19.6400	24.74491	28.32585	35.68833	44.96448	56.65169	102.943	129.70
2006	41.1	6.2236	7.841293	8.976039	11.3091	14.24857	17.95208	32.62109	41.10
2007	84.1	12.7350	16.04508	18.36703	23.14101	29.15584	36.73406	66.75021	84.10
2008	104.39	15.8074	19.91612	22.79827	28.72402	36.18999	45.59653	82.8544	104.39
2009	94.5	14.3098	18.02925	20.63834	26.00268	32.76132	41.27668	75.0047	94.50
2010	100.6	15.2335	19.19304	21.97055	27.68116	34.87607	43.9411	79.84627	100.60
2011	94.5	14.3098	18.02925	20.63834	26.00268	32.76132	41.27668	75.0047	94.50
2012	369.8	55.9976	70.55255	80.76251	101.7544	128.2025	161.525	293.5105	369.80
2013	285.7	43.2626	54.50748	62.39548	78.61338	99.04666	124.791	226.7602	285.70
2014	291	44.0652	55.51864	63.55298	80.07174	100.8841	127.106	230.9669	291.00
2015	151	22.8654	28.80864	32.97766	41.54925	52.34878	65.95533	119.8488	151.00
2016	305	46.1851	58.18964	66.61051	83.92398	105.7376	133.221	242.0787	305.00
2017	250	37.8567	47.69643	54.59878	68.79015	86.67016	109.1976	198.4251	250.00
2018	225	34.0710	42.92678	49.1389	61.91114	78.00314	98.2778	178.5826	225.00
2019	105.93	16.0406	20.20993	23.13459	29.14776	36.72388	46.26919	84.0767	105.93
2020	105.6	15.9907	20.14697	23.06252	29.05696	36.60948	46.12505	83.81478	105.60
2021	146.99	22.2582	28.04359	32.1019	40.44586	50.95859	64.2038	116.666	146.99
2022	81.48	12.3382	15.54522	17.79483	22.42009	28.24754	35.58967	64.67072	81.48
2023	215.77	32.6733	41.16583	47.12311	59.3714	74.80328	94.24623	171.2568	215.77

MEAN	24.974	31.465	36.018	45.380	57.176	72.037	130.899	164.923
STD. DEVIATION	14.033	17.681	20.239	25.500	32.128	40.479	73.555	92.673

Table 4.4: Rainfall Intensity for Different Return Period

Time (hours)	Time (minutes)	Mean	Standard Deviation	2 Year		10 Year		25 Year		50 Year		75 Year		100 Year	
				Rainfall (mm)	Rainfall (mm/hour)	Rainfall (mm)	Rainfall (mm/hour)	Rainfall (mm)	Rainfall (mm/hour)	Rainfall (mm)	Rainfall (mm/hour)	Rainfall (mm)	Rainfall (mm/hour)	Rainfall (mm)	Rainfall (mm/hour)
0.08	5	24.974	14.033	22.900	274.799	47.774	573.287	60.293	723.520	69.581	834.971	74.979	899.751	134.230	1610.755
0.17	10	31.465	17.681	28.852	173.110	60.192	361.152	75.966	455.795	87.668	526.007	94.470	566.817	169.122	1014.735
0.25	15	36.018	20.239	33.027	132.107	68.901	275.604	86.957	347.828	100.352	401.408	108.138	432.551	193.591	774.364
0.5	30	45.38	25.5	41.611	83.222	86.811	173.621	109.560	219.121	126.437	252.875	136.247	272.494	243.913	487.826
1	60	57.176	32.128	52.427	52.427	109.375	109.375	138.038	138.038	159.302	159.302	171.661	171.661	307.312	307.312
2	120	72.037	40.479	66.054	33.027	137.805	68.902	173.918	86.959	200.708	100.354	216.280	108.140	387.191	193.595
12	720	130.899	73.555	120.028	10.002	250.406	20.867	316.028	26.336	364.709	30.392	393.005	32.750	703.570	58.631
24	1440	164.923	92.673	151.226	6.301	315.492	13.145	398.169	16.590	459.504	19.146	495.154	20.631	886.439	36.935

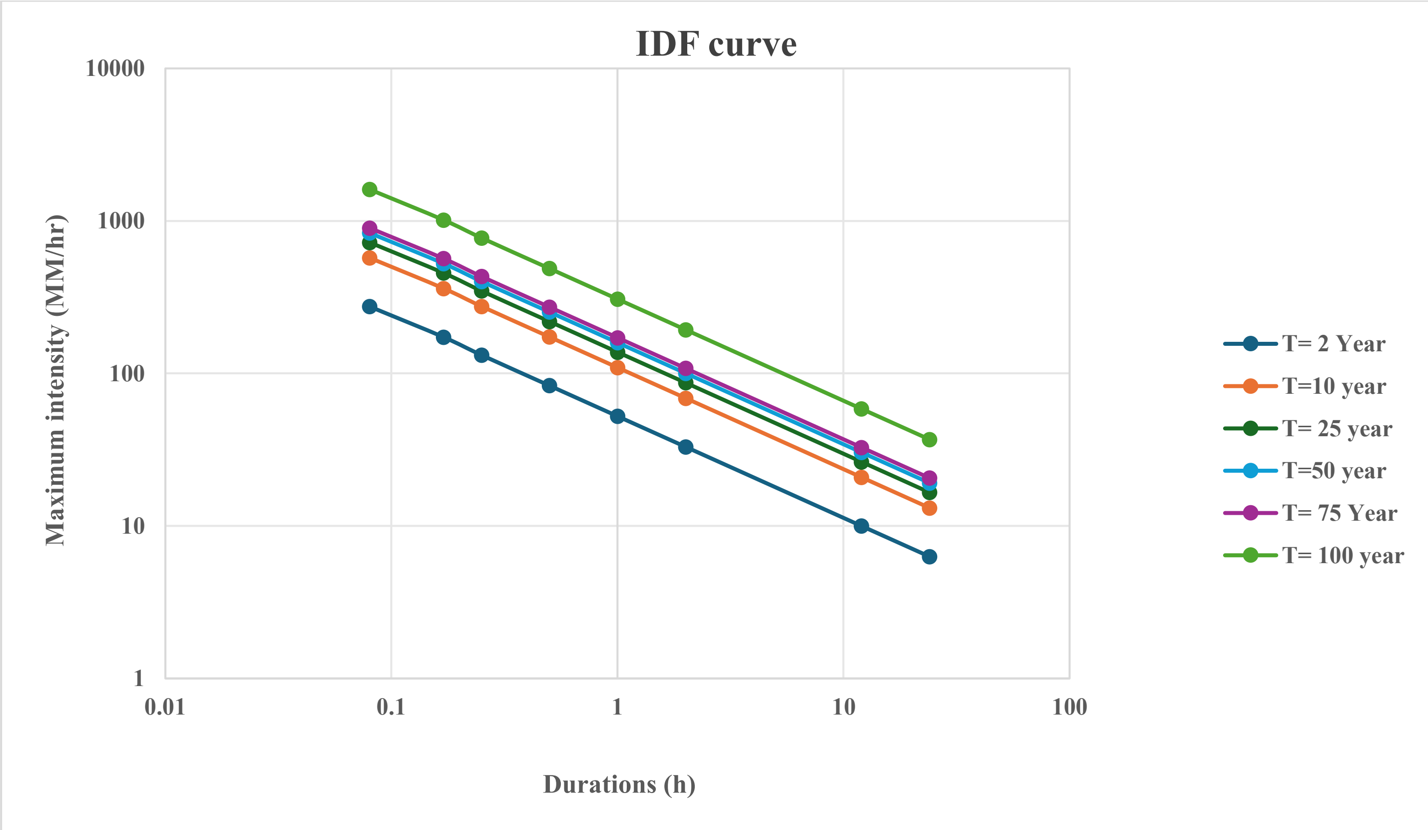

Fig 4.6: IDF Curve for various return periods

4.4.2 Lag Time calculation

Lag time is calculated for different sub-basins using Curve Number Method.

Formula used for lag time calculation

$T_c = 0.6$

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1140Y^{0.5}}$$

where,

L= lag time, hr

T_c= time of concentration, h

l = flow length, ft

Y= average watershed land slope, %

S= maximum potential retention, inch

Table 4.4: Lag Time Calculation

Sub-basin	Hydraulic length (l) KM	Hydraulic length (l) ft	Average basin slope (s) (m/m)	Average basin slope (Y)	Curve number (CN)	S=[(1000/CN) -10] inch	Time of concentration (Tc)	Lag time (L) hour	Lag time (L) min
S1	76.96	246944.27	0.0964	9.642	73.636	3.5803	16.89	10.14	608.16
S2	49.73	159567.37	0.2377	23.766	72.894	3.7186	7.75	4.65	278.90
S3	46.96	150676.54	0.1727	17.268	74.578	3.4088	8.68	5.21	312.52
S4	87.17	279712.53	0.1052	10.515	74.201	3.4769	17.59	10.55	633.21
S5	108.11	346905.86	0.2104	21.039	74.504	3.4221	14.65	8.79	527.22
S6	85.58	274597.45	0.2184	21.838	73.475	3.6101	12.28	7.37	441.92
S7	91.53	293690.78	0.2073	20.73	73.886	3.5344	13.14	7.89	473.12
S8	24.82	79638.76	0.1322	13.222	73.921	3.5280	5.79	3.47	208.34
S9	98.05	314621.24	0.1836	18.363	72.561	3.7815	15.31	9.19	551.25
S10	9.13	29299.60	0.0290	2.901	74.376	3.4452	5.48	3.29	197.30
S11	49.48	158777.41	0.1415	14.153	74.183	3.4802	9.64	5.79	347.15
S12	45.73	146734.70	0.1556	15.562	73.292	3.6441	8.85	5.31	318.73
S13	55.76	178923.44	0.1466	14.661	73.257	3.6506	10.70	6.42	385.22
S14	23.94	76806.15	0.1582	15.816	80	2.5000	4.29	2.58	154.53
S15	125.38	402323.85	0.1102	11.022	73.63	3.5814	23.35	14.01	840.68

4.5 OPERATIONS 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: USGS SRTM 30m resolution)
   - Gather meteorological data: Obtain rainfall data, such as observed precipitation records or design storm data for various return periods. (Source: Water Resource Department)
   - 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.

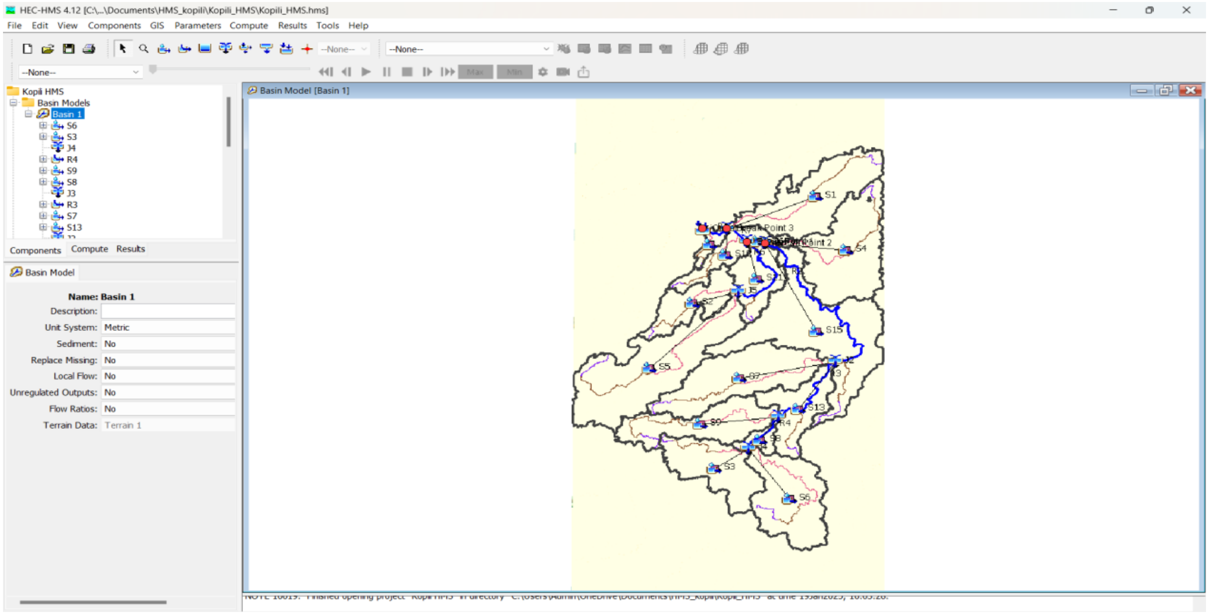

Fig 4.7: HEC-HMS interface showing sub-basins and junctions

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.
   - 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.

4. 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.

5. 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.

6. 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.

CHAPTER 5
RESULTS AND DISCUSSION

5.1 RESULTS FROM ArcGIS:

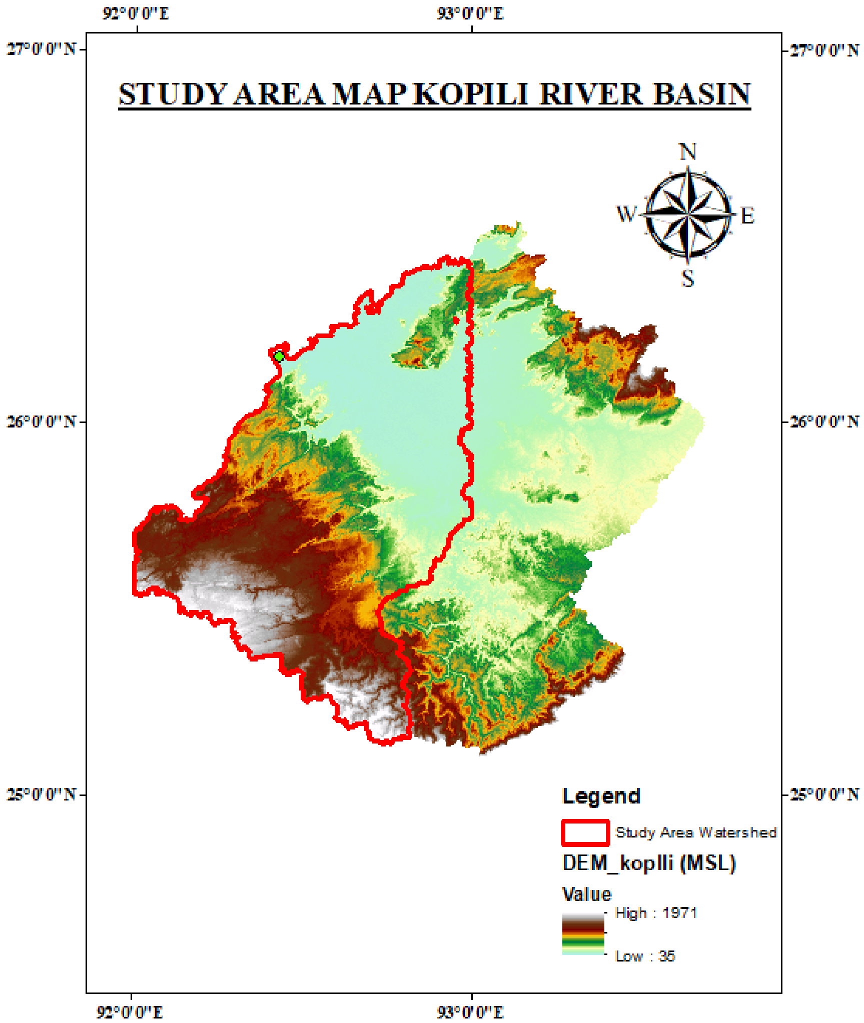

Figure 5.1: Delineated Watershed of Kopili River Basin

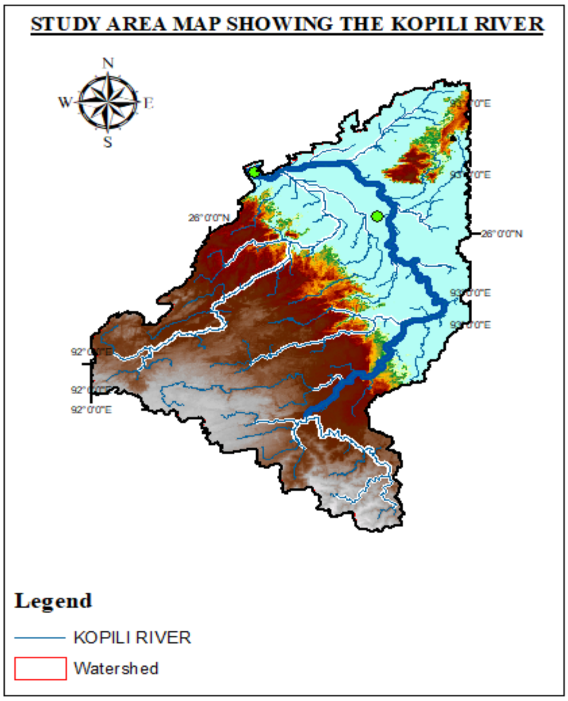

Figure 5.2: Clipped Watershed according to the study area.

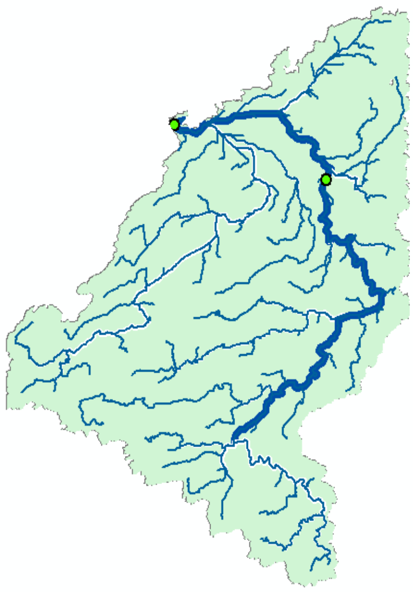

Figure 5.3: Watershed showing The Kopili River flow-path according to the study area.

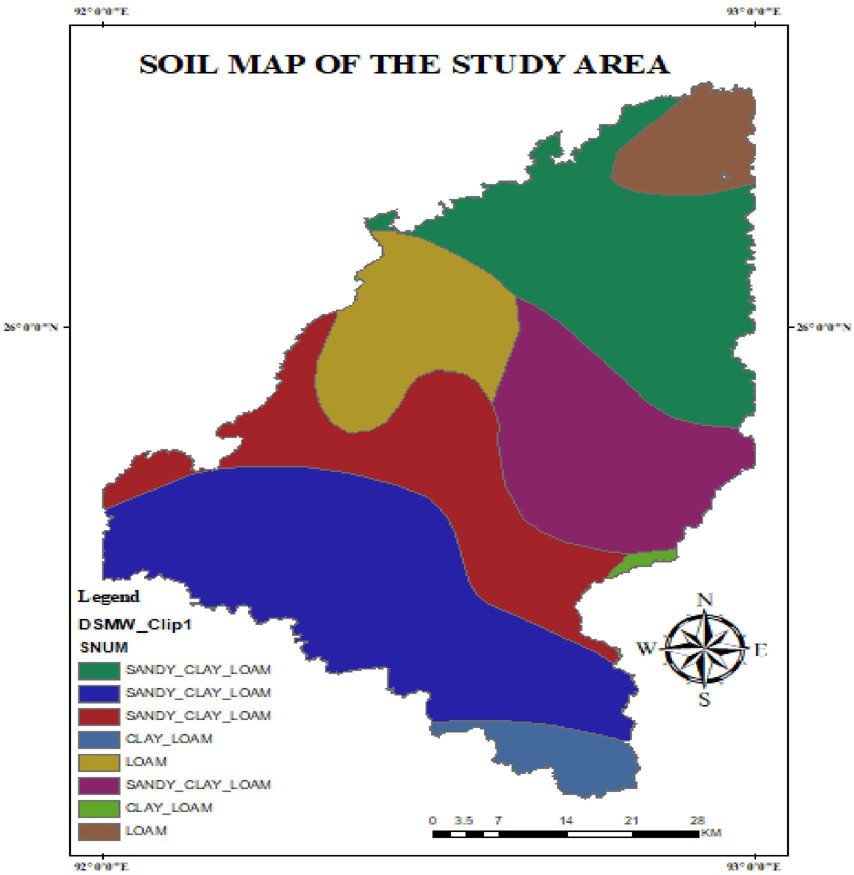

Fig 5.4: Study area soil map clipped from the FAO soil map

In order to further evaluate and classify the types of soil data that was collected using a scale of 1:500000 from the International Food and Irrigation Organization (FAO).

The soil map was created as a vector layer in a GIS system. For reclassification of the soil map, user soil database was referred from Map Windows SWAT 2012 interface. There are only 3 HSGs are found, dominated by soil C.

5.2 RESULTS FROM HEC-HMS:

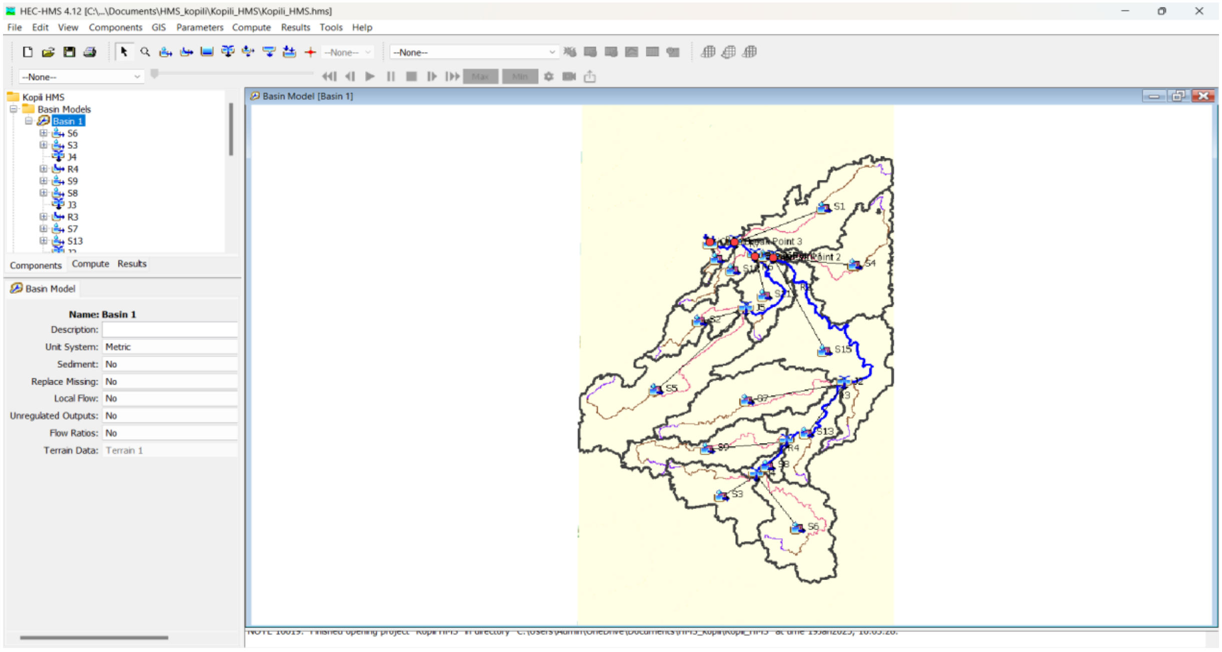

Figure 5.4: Dividing the watershed in to different subbasins, drainage parameters and watershed boundaries.

From the above map it has been observed that there is total 15 numbers of sub-basins.

Table 5.1: Longest flow path, basin slope, drainage density are obtained from HEC-HMS as output.

Subbasin Characteristics [Basin 1]

Filter: --None--

Subbasin	Longest Flowpath Length (KM)	Longest Flowpath Slope (M/M)	Centroidal Flowpath Length (KM)	Centroidal Flowpath Slope (M/M)	10-85 Flowpath Length (KM)	10-85 Flowpath Slope (M/M)	Basin Slope (M/M)	Basin Relief (M)	Relief Ratio	Elongation Ratio	Drainage Density (KM/KM²)
S6	85.57530	0.00862	56.60281	0.00345	64.18147	0.00570	0.21838	980.00000	0.01145	0.33917	39.40912
S3	46.95670	0.01353	14.69830	0.01527	35.21753	0.01475	0.17268	786.00000	0.01674	0.53973	39.01663
S9	98.04828	0.00918	40.04935	0.01036	73.53621	0.00871	0.18363	972.00000	0.00991	0.26805	38.85251
S8	24.81855	0.02637	11.69986	0.02073	18.61392	0.01441	0.13222	662.00000	0.02667	0.42544	39.08019
S7	91.52553	0.01303	44.15226	0.01142	68.64415	0.01247	0.20730	1219.00000	0.01332	0.34515	38.96565
S13	55.75954	0.01605	29.65565	0.00652	41.81965	0.01210	0.14661	900.00000	0.01614	0.40319	39.15033
S15	125.37984	0.00420	42.86670	0.00019	94.03488	0.00082	0.11022	990.00000	0.00790	0.31428	38.63993
S4	87.16936	0.00589	40.68311	0.00022	65.37702	0.00044	0.10515	802.00000	0.00920	0.37293	38.48321
S5	108.10943	0.01056	56.64910	0.01211	81.08207	0.00691	0.21039	1495.00000	0.01383	0.34735	39.19915
S2	49.72743	0.02017	20.64538	0.01858	37.29557	0.01685	0.23766	1040.00000	0.02091	0.41750	39.24764
S11	49.48125	0.00882	29.51397	0.00032	37.11094	0.00909	0.14153	628.00000	0.01269	0.40810	38.89926
S10	9.13090	0.00055	4.40318	0.00068	6.84817	0.00021	0.02901	9.00000	0.00099	0.32434	39.96353
S1	76.95749	0.00611	37.43113	0.00009	57.71812	0.00015	0.09642	801.00000	0.01041	0.39782	38.81037
S12	45.72827	0.01495	15.15731	0.00439	34.29621	0.01322	0.15562	697.00000	0.01524	0.38847	39.17046
S14	23.93580	0.02546	8.30121	0.00139	17.95185	0.02541	0.15816	651.00000	0.02720	0.38860	38.99281

Chapter 6
CONCLUSION

The Kopili River, which is the largest south-bank tributary of the river Brahmaputra, is the main cause of frequent floods in the Morigaon and Nagaon districts of Assam, an Indian state located in the northeastern part of the country. The movement of the river into the land due to erosion resulted in the breaching of existing embankments, which is perceived as a threat to the mainland. So, it is essential to examine the Kopili river's flood susceptibility.

From this work, following conclusion can be derived:

1) This works revealed that land use plays a significant role in determining flood vulnerability. Urbanized areas and agricultural lands, as shown in the map, were found to be more susceptible to flooding due to alternate runoff characteristics and reduce infiltration capacity.
2) The Soil map played a pivotal role in understanding the basin's hydrological behavior. Regions with clayey soils, characterized by low permeability, contributed to higher surface runoff.
3) The basin parameters will help to accurately simulating flood events within the HEC-RAS model.

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