Assessment of Flood Disaster and Strategies for Mitigation using Remote Sensing and GIS

A DISSERTATION

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

MASTER OF TECHNOLOGY
in
WATER RESOURCES DEVELOPMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the work presented in the dissertation entitled, "**Assessment of Flood Disaster and Strategies for Mitigation using Remote Sensing and GIS**", in partial fulfilment of the requirement for the award of the degree of **Master of Technology in Water Resources Development**, submitted in the Department of Water Resources Development and Management, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from July 2018 to May 2019 under the supervision of **Dr. Deepak Khare, Professor and Er. R.D. Singh, Visiting Professor,** Department of Water Resources Development and Management, Indian Institute of Technology, Roorkee, India.

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CERTIFICATE

This is to certify that the above declaration made by candidate is correct to the best of our knowledge.

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ABSTRACT

Floods are probably the most repeating, broad, grievous and frequently occurring natural hazards of the world. India is one of the most terrible flood-influenced nations. In India the Himalayan Rivers represent most extreme flood harm in the nation. The Kosi river in north Bihar, eastern India displays a challenge regarding long and repeating flood risk. In spite of a long history of flood control management in the basin for over five decades, the stream keeps on bringing a great deal of suffering through broad flooding. The fields of north Bihar are probably the most helpless regions in India, inclined to flooding. This Study addresses the flooding issue in the Kosi river basin and exhibits an in-depth investigation of flood hydrology. This study presents about the parameterization of hydrologic and hydraulic modelling for simulation of overflow and flood inundation zone mapping. SRTM-DEM of 90m pixel size is used to create the different maps (DEM) of Kosi Basin. Hydraulic and hydrological models such as SWAT model, SWAT-CUP along with HEC-RAS are utilized for runoff and flood inundation modelling. Average hydrological qualities of the Kosi waterway incorporate high discharge fluctuation, and high sediment motion. Yearly Peak discharge frequently surpasses the mean yearly flood and the low-lying regions of the alluvial fields are broadly immersed for seemingly endless amount of time after year.

Flood forecasting and warning, flood hazard mapping and flood risk zoning are very viable non-structural techniques in overseeing floods that diminishes the dangers and catastrophe of the floods. In perspective of this an effort has been made in the present study to simulate runoff and flood inundation for Kosi River Basin in Bihar, India. Results showed that for Kosi catchment, the observational runoff prediction model i.e. SWAT Model as presence of less data predicted discharge that can be considered in case of unavailability of accurate or sufficient data. The flood hazard map is approved with long term inundation maps and offers a practical answer for arranging mitigation measures in flood prone regions. The flood inundation for the Kosi River floodplain is completed utilizing HEC-RAS 1-D hydrodynamic model using steady flow as well as unsteady flow analysis shows give the results on which one can rely upon unless more accurate analysis is not happening.

Keywords: SWAT Model, HEC-RAS, Flood inundation mapping, Flood risk zoning

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Date:

Place: **Roorkee** **(Manish Kumar)**

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LIST OF ABBREVIATIONS

95PPU	95 Percent Prediction Uncertainty
1-D	One Dimensional
ASTER	Advanced Space borne Thermal Emission
CBA	Choose By Advantage
CWC	Central Water Commission
DEM	Digital Elevation Model
FAO	Food and Agricultural Organization
FMISE	Flood Management Improvement Support center
GIS	Geographical Information system
NASA	National Aeronautics and Space Administration
HEC	Hydrologic Engineering Corps
HEC HMS	Hydrological Engineering Center Hydrologic Modelling System
HEC RAS	Hydrologic Engineering Center River Analysis System
HRUs	Hydrological Response Units
HFL	High Flood Level
IMD	India Meteorological Department
KBCAT	Kosi breach Closure Advisory Committee
LU/LC	Land Use / Land Cover
MoI	Ministry of Irrigation
NATMO	National Atlas and Thematic mapping Organization
NS	Nash-Sutcliff
PC	Personal Computer
PMF	Probable Maximum Flood
SUFI	Sequential Uncertainty Fitting
SWAT	Soil and Water Assessment Tool
SWAT CUP	SWAT Calibration and Uncertainty Procedures
TIN	Triangulated Irregular Network
TOPSIS	Technique for Order Preference by Similarity to Ideal Solutions
UTM	Universal Transverse Mercator
WMO	World Meteorological Organization

CHAPTER 1
INTRODUCTION

1.1. GENERAL BACKGROUND

Water is a fundamental element of life. From the start of the presence of person, droughts and floods have influenced human exercises, properties and lives all over the world. Flood is a strangely high stage in a waterway, from the stage at which the stream floods its banks and immerses the bordering territory (Subramanya, 2008). Since the starting, Various Structural and non-Structural measures have been applied for flood control and the management. Different Non-Structural measures are utilized to Evaluate flood and by doing appropriate management, it's demonstrated to practical and productive approach to moderate flood. It incorporates measures like impact of precipitation on runoff produced from individual catchment, occurrence time of flood and immergence regions of certain or various sizes or recurrence and social and economic sides of floods.

Flooding is one of the genuine regular atmospheric hazards on the planet that causes serious consequences for all infrastructure and activities inside an influenced flood plain. Flood can possibly be the reason for loss of lives or to start any inability to the natural, altered or human framework.

The total flood disaster chain from the activating occasion to its results: "hydrological load – flood directing – potential collapsing of flood insurance structures – immersion/inundation – property harm" and the management of flood depends on the temporal component of disaster to arrange the crisis the management procedure into a cycle of four, regularly covering, stages: mitigation, preparedness, response, and recovery, Mitigation includes moves that are made to take out or lessen the level of long-term hazard to human life and property from risks. Preparedness comprise moves that are made ahead of time of a crisis to create operational capacities and encourage a powerful reaction to a crisis. The response stage includes moves that are made preceding, amid, or straightforwardly after a crisis happens, to spare lives, limit harm to property, and improve the viability of recuperation. The recovery stage is characterised by action to return life to typical or improved dimensions. Space innovation has made generous commitment in all the three stages, for example, preparedness, avoidance and relief phases of dry season and flood disaster management.

Coastal Floods are produced by winds from extreme seaward storms and Tsunamis; Urban Floods, as urbanization expands overflow two to multiple times what might happen on characteristic territory; Flash Floods can happen inside minutes or long stretches of unreasonable precipitation or a dam or levee disappointment, or an abrupt arrival of water.

A few clients, for example, top level policy makers at the national and global associations, scientists, center level policy creators at the state, region and local experts, mitigation offices and local producers including providers, merchants, farmers and water administrators are interested in dependable and precise drought and flood data for successful administration.

In any case, a major contribution to flood mapping and planning is gotten from the data made accessible by high resolution satellite innovation and field estimation.

Due to the huge spatial and transient inconstancy of Himalayan basin attributes, for example, snow pack, Land use/land cover, soil dampness, hydraulic conductivity, geology (relief), erratic precipitation in India, Nepal and Tibet, the effect of precipitation on runoff turns out to be increasingly serious and their appropriate gauge is fundamental for flood management.

Progressions in the remote detecting advancements and the Geographic Information Systems help in real time monitoring, early warning and fast harm evaluation of both drought and flood disaster. Flood calamity mitigation techniques ought to be founded on an exhaustive appraisal of the flood risk joined with a careful investigation of the vulnerabilities related with the hazard evaluation system. The most complete methodology is the hazard based structure approach which adjusts advantages and expenses of the plan in an explicit manner. With regards to risk- based structure, the flood risk comprises of the flood hazard (for example extreme events and related likelihood) and the results of flooding (for example property harms).

1.2. RESEARCH GAP

- Present flood resisting mechanisms are not good enough.
- Availability of fewer strategies that population can adopt in order to address the challenges they face.
- Low possibility to crosscheck information in all the cases, due to the high degree of local variation and scarcity of data and resources.

1.3. OBJECTIVE OF THE PROJECT

The fundamental target of this study is flood hazard evaluation of the Kosi basin dependent on geomorphic, topographic and hydrologic parameters in a GIS framework and thinking of suitable procedures for particular study area. Some of the important objectives of this project include:

- To Identify the causative factors for understanding the flood dynamics of the Kosi river basin by developing various feature Maps.
- To Prepare Flood Inundation Map using SWAT model & HEC-RAS and Remote Sensing & GIS software.
- To Develop efficient strategies for Flood mitigation along with prioritization of areas or zones using Flood Risk Map for study area.

1.4. STRUCTURE OF THESIS

This thesis presents Six chapters. Brief explanations for each chapter are as under: -

Chapter 1: Introduction

This chapter presents the general overview of the work. It briefly describes regarding the Flood, it's types, it's various stages of impact and about concerned authorities. It also briefs about study performed in the region and the works to be done. The objective of this dissertation is also defined in this chapter.

Chapter 2: Literature Review

This chapter describe the various analogies, observations, evaluation methods and various measures that can be taken to mitigate the flood given by various authors. It also present literature reviews related to Geomorphic Controls of Floods, Methods of Risk Assessment, Hydraulic and Hydrologic Approach, Remote Sensing and GIS approach, Flood Inundation Modelling

Chapter 3: Study Area and Data Availability

This Chapter Describe about the study area i.e. Kosi river sub-basin, it's rainfall- runoff, temperature, humidity, flooding and sedimentation characteristics and different data collected which are going to be used in ArcGIS, ERDAS, SWAT Model, SWAT-CUP and HEC-RAS Modelling set-up. And also about Flood Status in Bihar and its impact by showing History of

Flood in Bihar and Losses due to this in Kosi River Basin to show the importance of this project

Chapter 4: Material and Methodology

This chapter describes about the materials and Softwares used in accomplishing the respective result like Topographic Maps, RADARSAT SAR, ARCGIS, ERDAS, SWAT Model, SWAT-CUP, HEC-RAS, Flood Inundation Mapping, Flood Inundation Modelling and its detail Methodology followed and obtained respective result.

Chapter 5: Result and Conclusion

This chapter describe about the hotspots and Various results obtained from the Softwares used and lastly calculate the final scores for identification and prioritization of HOTSPOT by giving severity indices for various parameters and respective calculation.

Chapter 6: Summary and Conclusion

This chapter talk about various problems came during executing the whole methodology of the project and its probable solution. It also consists of various mitigation strategies for the respective situations/ problems of flooding in Kosi river Sub-basin.

Chapter 7: References

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL BACKGROUND

The most devastating flood in the different areas of Nepal and Bihar occurred due to Kosi stream calamitous nature. During last thirty years these spots have encountered the most elevated number of flood rates (Kale, 1997), the plain encounters broad death toll and property. This is attributed by transient changes in sedimentation burden and water volume and long-term changes in climate.

The geomorphology alongside the other persuasive parameters inspect the flood risk examination for the Kosi which will help in convenient accessibility of data for making choices and activities (Miranda et.al., 1988) for reducing the loss of lives, assets and properties. It has therefore turned out to be essential to make effectively comprehensible and rapidly accessible flood risk map, which will organize the mitigation impacts. A few methodologies were considered to think about the related danger of the waterway in the various pieces of the world with the utilization of various medium to characterize it. The present flood mapping approaches incorporate blend of the geomorphological, hydrology, hydraulic, the meteorological, the financial elements, with help of Remote Sensing and GIS condition and their combinations, some of which has been talked about with their contextual analyses below.

The birthplaces of precipitation-overflow modelling in the broad sense can be found in the middle the nineteenth century. In 1932, Sherman presented the "unit-graph" or unit hydrograph method. It was the principal endeavours to anticipate a whole hydrograph rather than simply the peak flow and time to peak. From the beginning of the twentieth century, hydrologists attempted to improve the appropriateness of the strategy to huge catchments with heterogeneity in precipitation and catchment qualities (Todini, 1988).

2.2. GEOMORPHIC CONTROLS OF FLOODS

Geomorphology can add to the decision and structure of flood control. It adds to the greater part of the cases identifying with the associations of flooding, channel behaviour and sedimentation. The difference in the stream geomorphology happens with the flood recurrence and the inclination inside a zone. The Flood 2010 was because of rare floods brought about by outrageous drying of embankments, splitting and rodent holes destroying the strength the structures. Subsequently, the methodologies for improving flood management incorporate;

foundation of new benchmarks including most occurred flood levels, Freeboard, and structure of banks to be made and the standard working techniques must be changed to guarantee their utility/sufficiency under the current conditions.

The flood controls bank encounters rupturing since their completion and are not exceptionally viable in decreasing the harm to the earth, economy and property as embankment and polders diminished floodplain storage limit during floods, prompting an expansion in water levels and releases in numerous streams (Chowdhury, 1998).

Rosen. 1997, exhibited Integrated Geomorphological ideas to rebuilding of curved stream. This idea depicts developmental propensities related with stream modifications prompting their most probable characteristic state.

2.3. METHODS OF RISK ASSESSMENT

The use of the computerized models, which join the hydrology, hydraulic models, advanced landscape models of flood plains related to Remote Sensing and GIS are progressively turning into the basic techniques for the outline of the floods and the related dangers and hazard. The hydraulic and hydrology give significant information identified with the flood danger however is costly and concentrated.

2.4. HYDRAULIC AND HYDROLOGIC APPROACH

Flood risk mapping and hazard appraisal of Kosi waterway in Nepal was done to recognize the need territories and high hazard zones utilizing Advanced Space borne Thermal Emission and Reflection (ASTER) picture joined with hydraulic model (HEC– RAS) which was utilized to recreate flood courses through the stream and its flood plain for releases relating to different return periods utilizing yearly greatest momentarily discharge for the period.

The 1960s brought the presentation of PCs into hydrological demonstrating. The primary extensive hydrologic processes model, the Stanford Watershed Model, was created at Stanford University (Crawford and Linsley, 1966). In the late 1960s, HEC-1 was created by the Hydrological Engineering Center, U.S. Armed force Corps of Engineers. Afterward, with expansion of User interface and spatial information and investigation highlights, HEC-1 was renamed as HEC-HMS. During 1960's and 1970's were the seasons of creating models with parameters having a physical understanding.

The model outcomes were confirmed through a field visit and information gathered on flood depths. Finally, long last flood chance factor was resolved utilizing the flood hazard and vulnerability factors dependent on matrix multiplication techniques on VDC level (Kafle et al. 2006).

Hydrological model forecasts are influenced by four causes of mistakes, prompting vulnerabilities in the aftereffects of the model. These are: 1-input errors (e.g., mistakes in calculating precipitation, Landuse map); 2-model structure/model speculation mistakes (e.g., blunders and disentanglements in the illustration of physical procedures); 3-Mistakes in the perceptions used to align/approve the model (e.g., mistakes in estimated release and residue); and 4-mistakes in the parameters, which emerge from an absence of information of the parameters at the scale of interest (e.g., hydraulic conductivity, Soil Conservation Service (SCS) and curve number). These origin of mistake are usually recognized in numerous studies (e.g., Montanari et al.2009).

Wu and Chen. (2015) thought about three adjustment techniques (SUFI-2, GLUE, and ParaSol) inside a similar displaying structure and demonstrated that SUFI-2 had the option to give more sensible and adjusted prescient outcomes than GLUE and ParaSol.

To evaluate the fit between reproduction result, communicated as 95PPU, and perception expressed as a single sign (with some mistake related with it) we thought of two insights: P-factor and R-factor (see Abbaspour et al., 2004, 2007 references gave in the reference rundown of SWAT-CUP). P-factor is the part of observed information wrapped by our displaying result, the 95PPU. R-factor is the thickness of the 95PPU wrap.

2.5. REMOTE SENSING AND GIS APPROACH

Venkata and Sinha (2008) recognized hazard territories and organize their relief/reaction endeavours in the flood-hazard zones in the Kosi river basin, North Bihar, India in a GIS situation with the guide of the information which incorporates region level maps, topographic maps and registration information of 1991 for the provincial divisions of Bihar, got from the Survey of India, National Atlas and Thematic Mapping Organization (NATMO), and District Statistical Office, Saharsa individually.

The essential choice components considered in this investigation are geomorphic highlights, separation to dynamic channels (seepage cradle), rise, vegetation, land spread, and population density which were utilized to arranged flood hazard map.

Forkuo (2011) has produced proficient and effective system for getting ready flood hazard maps in Ghana, especially those areas where floods represent an intermittent threat. The dimension 1b ASTER symbolism, topographic guide covering the study area at a size of 1:50000, the shapes produced DEM, land cover and statistic information has been utilized to make a district level guide demonstrating flood risk list for region scale utilizing an additive model which was adjusted for this study (Sanyal and Lu, 2003).

2.6. FLOOD INUNDATION MODELLING

As floods event and their genuine outcomes are common in numerous parts of the world, it has raised public, political and scientific awareness for appropriate flood control and management (Becker et al., 2003).

Iwasa and Inoue, 1982; Samules, 1985; Gee et al., 1990 showed that Utilizing non-structure systems, assessment and management of flood immersed territory for various sizes of floods is extremely fundamental. Different hydrologic models have been created in the past to simulate flood immersion in the bowl region.

These models consider overland and waterway streams. Additionally, these models are connected either just in test catchments or in some same level territories with theoretical conditions. Just a couple of models are accessible to simulate flood immersion in a river basin for genuine flood occasions considering all the spatial heterogeneity of physical attributes of geology, for example, HEC-GeoHMS, HEC-GeoRAS and different models.

By 1976, the strategies utilized for tackling the Saint-Venant conditions with scientific models observed to be satisfactory for enormous number of uses (Priessmann, 1976).

Bates et al. (1997) notice the further advancement of two-dimensional limited component models of waterway flood stream. They connected the two-dimensional finite element model to the Missouri waterway, Nebraskan with incorporation of Hydraulic modelling and remote detecting.

Han et al. (1998) and Chang et al. (2000) have likewise revealed 1-D, 2-D coupled displaying of stream flood plain stream. The models have utilized a full dynamic equation for the channel flow and for the two-dimensional flood plain stream; a diffusion wave approximation is used.

Anderson (2000), Robayo et al. (2004) and Knebl et al. (2005) talked about that flood inundation modelling includes hydrologic modelling to assess peak flow from storm occasions, hydraulic modelling to gauge water surface heights, and terrain analysis to assess the immersed regions.

Wright et al. (2008) introduced a procedure for utilizing remotely sensed information to both produce and assess a hydraulic model of floodplain immersion for a rural case analysis in the United Kingdom-Upton-upon-Severn.

Roy et al. (2011) talked about the non-structure measures to manage flood based on gauge to gauge co-relation among Basua, Baltara & Kursela with two base stations Barahkshetra and Birpur Barrage in the system.

2.7. FLOOD RISK MAPPING

Risk is defined as the probability of suffering loss, and risk analysis is evaluation of the probability of the adverse effects of a process (natural, technology, industrial etc.) or an agent (chemical, physical, etc.). In the context of natural disasters, risk can be described as the probability that natural events of a given magnitude will occur and cause certain amount of loss. Therefore, risk comprises of two major aspects i.e. hazard and vulnerability (Kaplan & Garrick, 1981, Mileti, 1999).

Inundation depth has been reported as the most important flood characteristic to have influence on flood damage (Penning-Rowsell et al., 1994, Wind et al., 1999). Flow velocity is another important indicator of flood intensity. Especially high velocity floods in mountainous areas (e.g. Kedarnath floods of 2013) can lead to severe damages to buildings, infrastructure etc. Risk assessment is a subjective or quantitative assessment of the ecological and health risk because of introduction to a compound or physical agent. Risk assessment is the recognizable proof of threat and estimation of the likelihood of an event (Enhealth, 2002). The most well-known strategy used to characterize flood risk comprises of computing the hazard, that is, the physical and measurable parts of the real flood (for instance: the degree and depth of the flood and stream rate) and the extent of vulnerability, the introduction of individuals and things to the flood and the weakness of the components in danger of damage because of flooding (Veleda et al., 2017).

CHAPTER 3

STUDY AREA AND DATA AVAILABILITY

3.1. THE KOSI RIVER SUB-BASIN

The Kosi River Sub-Basin produced by giving outlet point at Baltara, one of the primary checking station of Kosi waterway. Upper catchment of this basin lies in Nepal and Tibet at greater heights of the Himalayas. The total watershed area of the Kosi River is 74,030 km^2 out of which 9470 km^2 lies in Bihar region of India and the rest 63,667 km^2 lies in Tibet and Nepal and Total drainage area of indicated watershed is limited by the edge on the left side isolating it from the Brahmaputra River, while Ganga river frames its southern limit.

3.1.1. Location

The Kosi River is one of the significant left bank tributaries of the Ganga, ascending at a height of more than 7000 m above MSL in the Himalayas. The Kosi, known as Kaushiki in Sanskrit books, is a standout amongst the most ancient streams of India. Total length of principle stream in Bihar is 260 Km and up to Baltara it's 128 km. In Nepal, this waterway is known as "Sapt-Kosi", getting its name from the seven streams. The seven tributaries are; Arun Kosi, Tamur Kosi, Sun-Kosi, Indravati, Dudh Kosi, Tamba Kosi and Likhukhola. Tributaries of Kosi River are Kamla-Balan, Baghmati, Bhuthi Balan and Trijuga on the right side and Fariani dhar, Dhemama dhar on the left side. Location Map of the study area is given in Figure 3.1.

The Kosi River, with particular geomorphology and hydrological qualities incorporate a dynamic routine and extremely high residue load. It has for some time been considered as a tricky waterway because of repetitive and broad flooding and continuous changes in its courses. The elements of the Kosi River, for the most part portrayed as 'avulsive' shifts, has been all around documented by past specialists and an especially westbound movement of 150 km over the most recent 200 years. In opposition to a prevailing westbound move during the most recent 200 years, the Kosi stream shifted by 120 km eastbound in August 2008 activated by the break at the eastern afflux bund at Kusaha in Nepal at 12 km upstream of the Kosi barrage. The separated channel reoccupied the one of the paleo channel of the Kosi River and 80-85% of the flow of the river occupied into the new course. This has been named as one of the greatest separation in any large waterway framework over the world in past years that immersed a huge region in Nepal and north Bihar.

3.1.2. Rainfall-Runoff

The mean annual precipitation for the Kosi Basin is around 1456 mm (FMIS). The greater part of the precipitation (80 to 90%) is obtained in between mid-June to mid-October. The Kosi River has a normal release of 1560 cumec, which expands 18 to multiple times during high floods. The most astounding flood recorded in late history of this waterway is accounted for to be 24,100 cumec on 24thAug. 1954 (Reddy et al. 2008).

3.1.3. Temperature

The temperature in upper Kosi bowl underneath 00C and most extreme is roughly 100ºC. Kosi Basin has monsoon type tropical atmosphere with high temperature and medium to high precipitation. The temperatures in lower Kosi Basin are least during December-January with a normal least of 08-100ºC and limit of 24-250ºC. The temperatures in the hottest month of April to June are from least 23-25^{0}C and to greatest 35-38^{0}C (FMIS).

3.1.4. Humidity

The dampness in the catchment is the highest during the long periods of July to September and least during March to April.

3.1.5. Flood and sedimentation

The Kosi River basin is exceptionally erodible and its erosion modulus is 3420tkm^{-2} a^{-1} (the sediment density is determined by 1.8gcm^{-3} dependent on the field investigated information), the erosion modulus is more prominent than the standard of the Yellow River in China (Ran et al., 2004). An ongoing flood, on 18 August 2008, caused 1– 2m of sedimentation (Rashmi et al., 2010). The Kosi River transports 120millionm^{3} of silt every year into the downstream and its waterway mouth has moved westbound by 115km in the past 220yr (Yamada, 1991). The flood embankment is above 4m and the channel width is more than 1000m. In view of a basic estimation, such a channel ought to have capability to adapt to a flood release up to 12000 cumec.

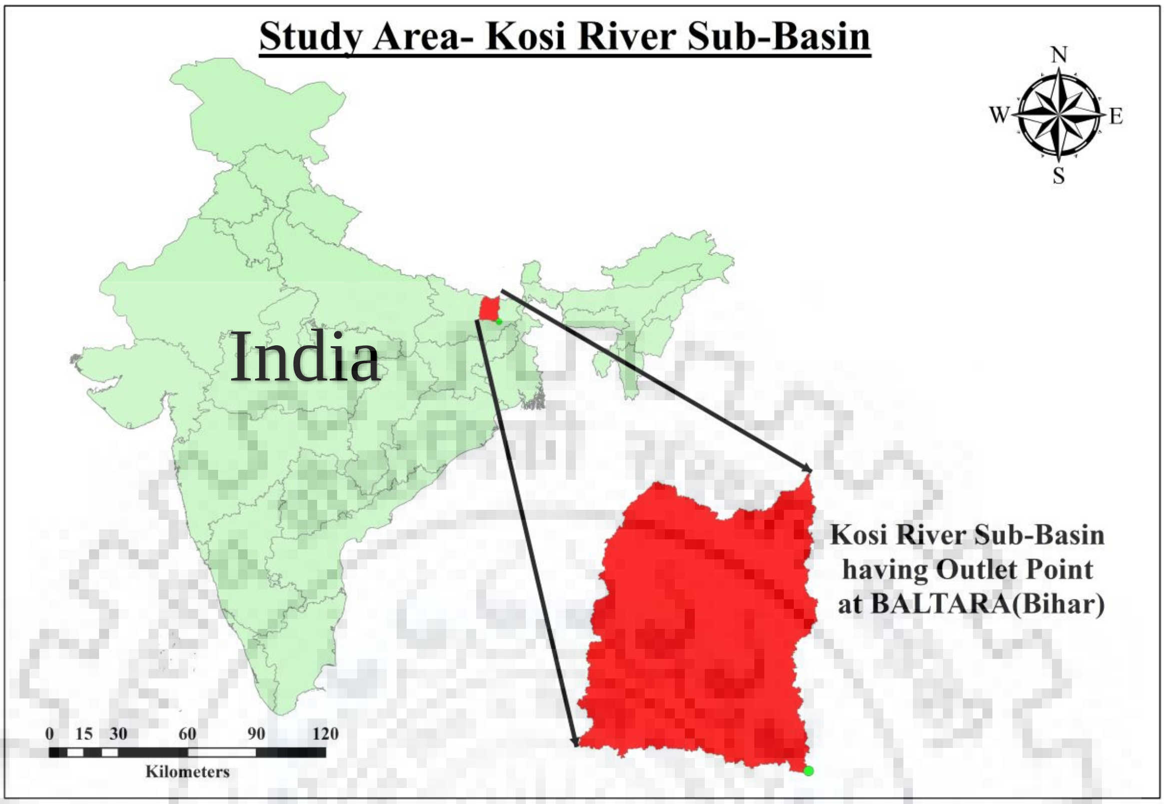

Figure 3. 1: Location of Study Area-Kosi River Sub-basin

3.2. DATA AVAILABILITY

The essential information required are precipitation data, daily discharge data or if available hourly discharge data, Digital Elevation Model (DEM), Land use/Land-cover and Soil types information of the investigation zone. For the setting up of HEC-RAS, the essential information required are the stream cross -section, water level, discharge, topographical map and Digital Terrain Model (DTM). These informational collections were gathered and obtained from various sources as appeared Table 3.1. They were examined and changed for legitimate use as input to the models.

Table 3. 1: Data Types and their Sources

Sl. No.	Source	Data Types
2	Central Water Commission (CWC), Patna, Govt. of India	Daily Water Level, Average Monthly Discharge Data, Peak Discharge Data
1	India Meteorological Department (IMD), Pune	Daily Rainfall Data
3	WRD/DMD-Bihar FMISC (http://fmis.bih.nic.in)	Flood Inundation Images
4	URS (an AECOM company), FMISC	Daily discharge data
5	https://eros.usgs.gov/	USGS' 30 arc-second Digital Elevation Model
6	https://zulu.ssc.nasa.gov (NASA)	Geo-Cover Data
7	NBSS & LUP	Soil Map
8	India Water Portal	Meteorological Datasets
9	NRSA/ISRO-AWiFS Data	Land-use/Land-cover-
10	TRMM	Daily TRMM Rainfall

For hydrological analysis, information got from Central Water Commission (CWC), Government of India has been utilized comparing to one of three gauge/discharge stations along the Kosi River to be specific, Baltara (see Figure 3.2). Information on month to month normal release and peak release of water are accessible for all the three stations for various periods. The month to month normal information was accessible for Baltara station just for a time of almost 20 years (1980– 2002), but data for daily discharge available only for 6 years (1997-2002). The inundation depth (water level over the threat level) information have additionally been utilized to think about the pattern and seriousness of floods (Table 3.1).

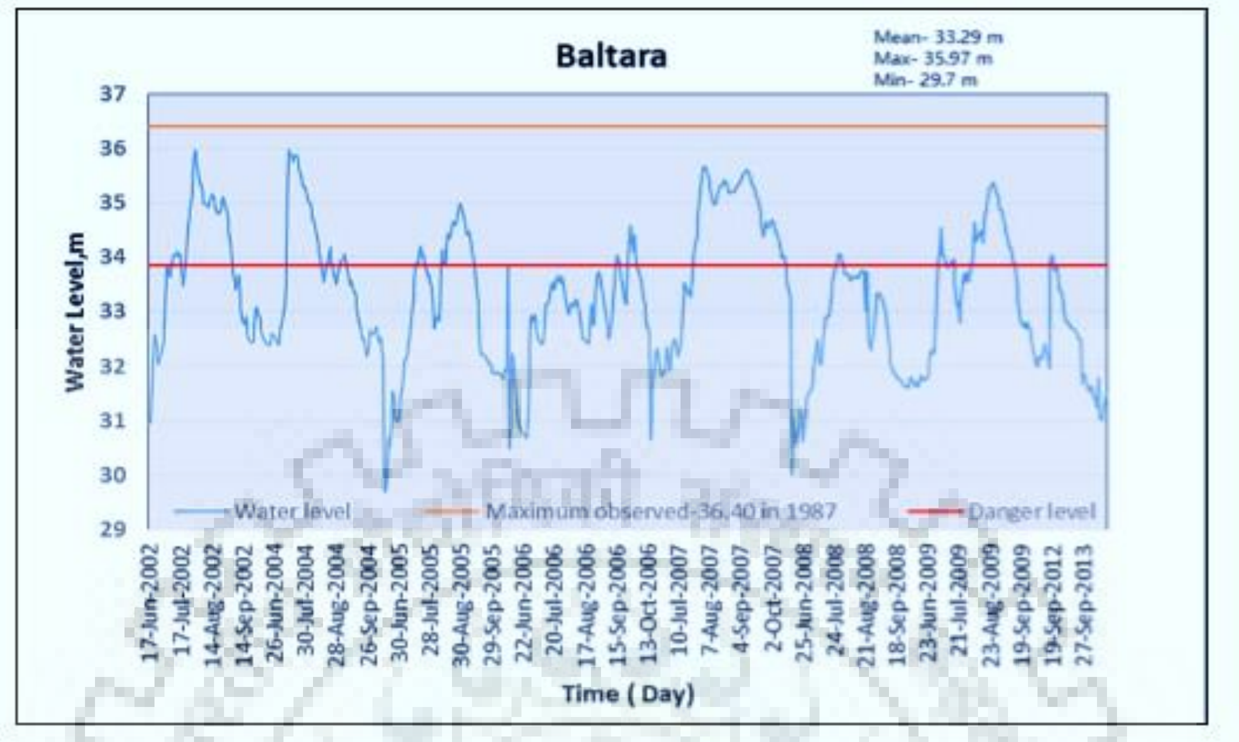

Figure 3. 2: Graph showing Water Level on various dates of different year

Table 3. 2: Warning Level, Danger level, HFL at various stations

Sl.No	Name of FF station/Type	Nearest Town/Vill/District/State	Warning Level (WL) (m)	Danger Level (DL) (m)	HFL	
					(m)	Year
1	Basua	Supaul/Bihar	46.75	47.75	49.17	2010
2	Baltara	Choutham/Khagaria/Bihar	32.85	33.85	36.40	1987
3	Kursela	Kursela/Katihar/Bihar	29.00	30.00	32.04	1998

Figure 3.3 demonstrates a typical monsoonal example of month to month release for the period 1985– 2002 which for the most part begins peak in the long stretch of June with the greatest in August/September. An increase in least month to month release lately (2000 onwards) is obvious. Such huge distinction among monsoonal and non-monsoonal release makes the stream vulnerable to flooding as the shallow waterway segments can't accommodate the abundance release. Figure 3.4 demonstrates variability of yearly peak release for the and Baltara (1957– 2001) stations. The records at Baltara begin from 1957 with the exception of 1968 information which is absent. The 1987 flood is well-recorded at both Barahkshetra and Birpur however isn't reflected at Baltara clearly because of attenuation of flood peak downstream. peak release at Baltara has anyway crossed the Qmaf value two or multiple times. Indeed, the Qmaf value at Baltara (7547 m^3/s) is a lot higher than the bank full release (6615 m^3/s) at this station and this shows the stream floods pretty much consistently at this area.

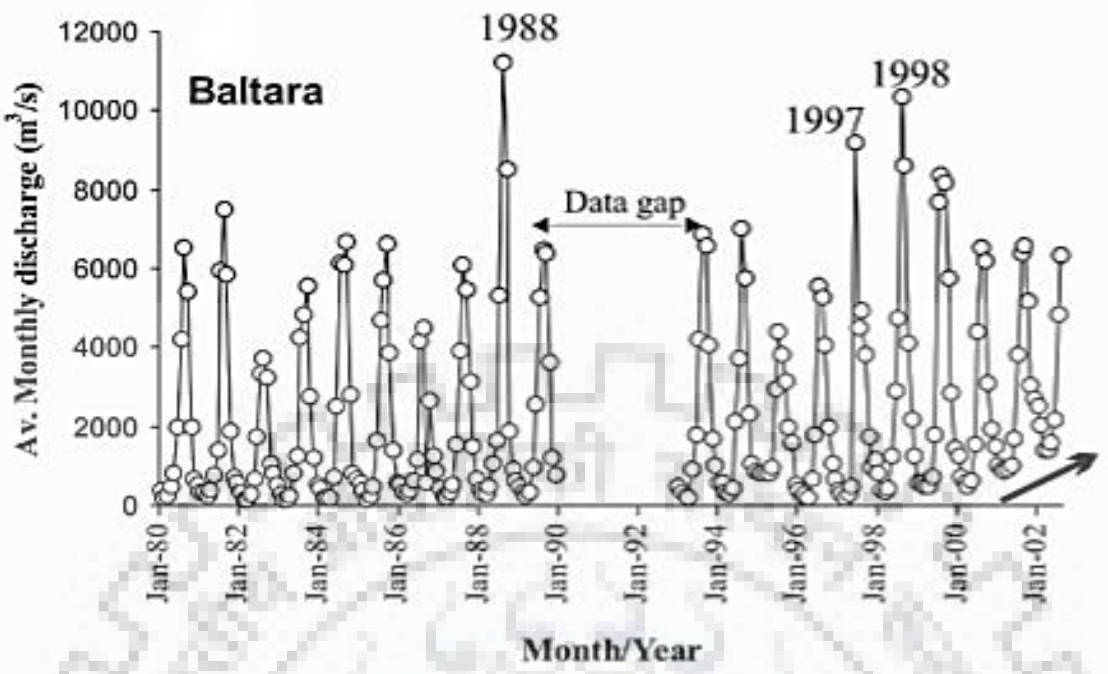

Figure 3. 3: Graph between Average monthly discharge and different years

Figure 3. 4: Graph between Peak discharge and years

To additionally evaluate the seriousness of floods, inundation depth (distinction of most extreme water level and risk level) at all the stations have been plotted in Figure 3.4. The threat level is typically taken as the 'bank full level' for various stations. The chart demonstrates that the risk level has been surpassed each year for every one of the stations with the exception of

Birpur for certain years. inundation depth is a lot higher at Barakshetra in contrast with different stations. Another graph is plotted showing Daily flow data at Baltara which we may use during SWAT and HEC-RAS analysis (Figure 3.5).

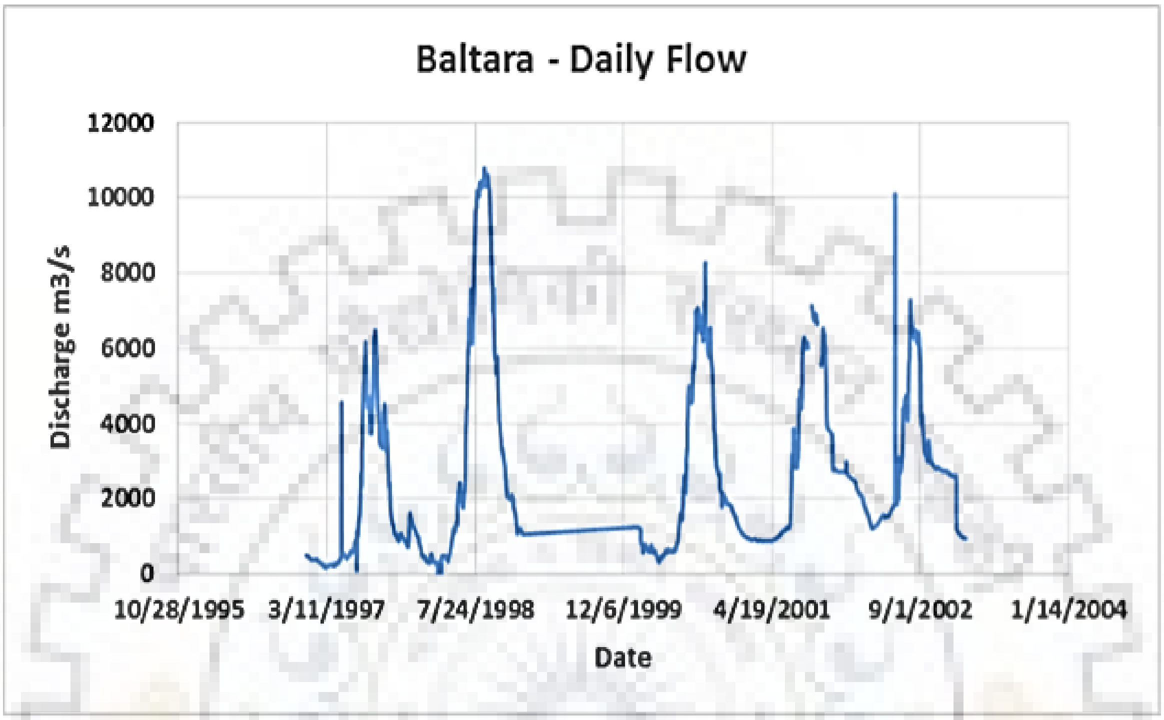

Figure 3. 5: Graph between Discharge and different dates of different years

3.3. FLOOD STATUS IN BIHAR

3.3.1. History of Flood in Bihar

In the year **1998** Maximum release in the first seven-day stretch of July in a large portion of the waterways in North Bihar caused excessive pressure on the embankment along the streams bringing about harms at a few spots. Banks of Burhi Gandak, Bagmati and Kosi were in part harmed.

In the year **1999** there was surprising heavy rains in the long stretch of October in the catchments in Nepal and flood level all of a sudden contacted the 1987 HFL at Jhanjharpur Railway Bridge in Kamla Balan stream and the spurs in Kosi river experienced risk all through the flood season.

In the year **2000** Kamla Balan and Bhutahi Balan catchments got substantial precipitation during first and a week ago of July bringing about unforeseen increase of water level. In first seven-day stretch of August 2000 Eastern Kosi Afflux Bund was punctured.

In the year **2001** north Bihar was seriously influenced by flood because of substantial rain in Nepal part of catchments of waterways. Western Kosi embankment, Bhutahi Balan right bank, Burhi Gandak left embankment and Bagmati left embankment were partially harmed.

During year **2002**, North Bihar experienced genuine flood and overtopping revealed in Kamla Balan left bank and Khiroi right embankment.

In the year **2003** High flood level at Bhagalpur outperformed the 1978 record of 34.18m and at Gandhi ghat, Patna the high flood level outperformed the 1994 record of 50.27m in Ganga river and the status of flood in different streams aside from Ganga and Gandak stay typical.

In the year **2004** catchment area of North Bihar streams got substantial precipitation in the main seven-day stretch of July itself which broke most recent three years flood record as well as outperformed the 1987 flood. Flood level at Dubbadhar site on stream Bagmati outperformed unsurpassed high flood level by about 1.18 m. So also, Burhi Gandak waterway and Kamla Balan stream all time high flood level. Numerous spots on the banks of north Bihar were ruptured, bringing about flood immersion in an immense areas of North Bihar. There were through and through 53 number of ruptures amid 2004 flood season.

Flood circumstance during **2005** and **2006** stay ordinary yet in the year **2007** the flood circumstance was serious in north Bihar because of overwhelming precipitation in catchments of practically all streams, flood circumstance during 2007 was intense in north Bihar. There were 28 breaks at various areas of the embankments during 2007 flood season. Substantial spell of precipitation (normal 82.70mm) was seen in the start of flood season.

2008: - An significant amount of precipitation was gotten on absolute first day of storm season i.e. fifteenth June (160mm at Chanpatia, 141 mm at Sikanderpur and 92.2 mm at Khagaria). There was an unexpected flood because of rupture close to 12.9km of Eastern Kosi Afflux Embankment in Kussha town in Nepal on eighteenth August 2008 that took a state of a disaster tragedies to lakhs of individuals in Sunsari and Saptari locale of Nepal and Supaul, Madhepura, Araria, Saharsa, Katihar and purnea areas of Bihar. Kosi river altogether changed its course from before one which was again restrained to its natural course by Water Resources Department after a huge exertion keeping in accordance with the advice of Kosi Breach Closure Advisory Committee (KBCAT).

2009: - The precipitation was insufficient in whole Bihar in the year 2009. The circumstance was aggravated to the point that Disaster Management Department GOB pronounced 26 locales as draught hit. Flood circumstance stayed ordinary this year with the exception of few ruptures, for example, Tilak Tajpur on right bank of waterway Bagmati under Runnisaidpur square of

Sitamarhi locale, Gobindpur site of Labha Choukia Paharpur dike of Mahananda stream and Sallehpur Tandespur site of Gandak stream

2010: - The flood circumstance this year remained very ordinary with typical normal precipitation. Just a couple of instances of breaks were accounted for viz. eastern Kosi Afflux Bundh and Saran 10 Embankment in a length of 200 m between 122.75 km and 122.95 km close Simaria town both because of sharp change in the stream course.

2011: - The flood circumstance stayed typical with a couple of special cases, for example, harm of nose of spur no-9 among Ismailpur and Bindtoli and that of covering in 30 m length close to Kazikoria of Raghopur town u/s of Vikramshila Setu and at spur no-9 and spur no-7 of length 138 m and 65 m individually in d/s of Vikramshila Setu under Gopalpur square of Bhagalpur area, both on left embankment of waterway Ganga due to non-finish of antierosion work on time. Harms were additionally detailed in Pataraha Chharki and P. D. ring bundh in Gopalganj area under Chief Engineer, Siwan ward.

2012-The issue was highlighted by dissolved length of spur at Dhuniawapatti at 26.75 km of PP right dike. Substantial rainfall in the catchment of Burhi Gandak brought about overbank flow in smaller waterways and rivulets causing some flash flood in West Champaran, where overtopping on railroad track was accounted for at Sikta rail route station.

3.3.2. Flood Losses in Kosi River Basin

Pretty much consistently floods seriously harmed property, both versatile and immovable decimates standing harvests and food grains and severely disables the foundation in Bihar. The death toll and appendage caused because of flood occasions can't be compensated as it costs a few crores consistently. Table 2.1. demonstrates the degree of flood misfortune in Bihar from 1968 to 2013.

Table 3. 3: Flood Damage Data of Kosi river Basin(1968-1992)

Sl. No.	Year	Area affected in Lakh (ha)	Damage to Crops: Area affected in Lakh (ha)	Damage to Crops: Value in Rs. Lakh: At then Current Price	Damage to Crops: Value in Rs. Lakh: At 1991 Constt. Price	Damage to Houses: Nos.	Damage to Houses: Value in Rs. Lakh: At then Current Price	Damage to Houses: Value in Rs. Lakh: At 1991 Constt. Price	Cattle Lives Lost (Nos)	Human Lives Lost (Nos)	Damage to Public Utilities in Rs. Lakh: At then Current Price	Damage to Public Utilities in Rs. Lakh: At 1991 Constt. Price	Total Damages In Rs. Lakh: At then Current Price	Total Damages In Rs. Lakh: At 1991 Constt. Price
1	1968	3.76	0.31	439.12	2728.02	55911	37.19	231.04	5969	7			476.31	2959.06
2	1969	1.32	0.13	104.70	625.11	9330	15.66	93.5	4	6	3.11	18.57	123.47	737.18
3	1970	1.45	0.66	420.68	2386.10	9426	16.99	96.37	1		0.55	3.12	438.22	2485.59
4	1971	6.75	2.44	1597.60	8628.60	199060	290.07	1566.67	1392	12	186.60	1008.20	2074.27	11203.47
5	1972													
6	1973	1.3	0.45	315.65	1360.45	14455	23.57	108.58		2	0.30	1.29	339.52	1470.32
7	1974	4.9	2.45	4744.91	15904.94	91789	171.18	573.8	33	11			4916.09	16478.74
8	1975	2.63	1.12	1316.10	4245.74	19951	57.42	185.24	1	3			1373.52	4430.98
9	1976	3.43	0.66	374.97	1233.65	17049	34.37	113.41	252	6			409.34	1347.06
10	1977	2.3	0.21	94.61	289.41	6050	15.34	46.93		4	1.38	4.22	111.33	340.56
11	1978	2.7	1.01	407.43	1249.14	17763	56.21	172.33	3	8			463.64	1421.47
12	1979	1.8	0.52	151.14	415.14	3611	14.52	39.88			0.14	0.38	165.80	455.40
13	1980	4.06	2.16	1083.61	2477.13	12826	93.76	214.34	19	14	15.49	35.41	1192.86	2726.88
14	1981	2.75	1.53	968.03	1971.88	11366	120.26	244.97	3	6	25.86	52.68	1114.15	2029.69
15	1982	1.24	0.31	934.20	1857.19	8548	86.13	171.23	0	0	0.64	1.27	1020.97	2269.69
16	1983	5.58	0.88	275.35	506.23	10664	60.07	110.44	3	3	52.26	96.08	387.68	712.75
17	1984	5.86	4.05	5071.18	8670.86	128036	1331.14	2260.27	43	20	1030.00	1748.94	7432.32	12680.07
18	1985	2.05	0.36	217.16	348.63	6292	25.95	41.66	0	8	9.24	14.83	252.35	405.12
19	1986	2.54	0.69	448.40	683.32	7540	50.57	77.06	0	17	3.99	6.08	502.96	766.46
20	1987	9.27	5.02	13044.00	18697.26	389090	4615.20	6615.42	1570	300	9466.00	13568.56	27125.20	38881.24
21	1988	3.67	0.95	1050.40	1390.10	2811	19.82	26.23	3	16	7.15	9.46	1077.37	1425.79
22	1989	1.88	0.41	317.38	393.30	2591	54.96	68.1	0	8	10.18	12.62	3825.52	474.02
23	1990	0.82	0.32	125.31	142.46	2995	29.83	33.69	1	8	0.14	0.16	155.28	176.31
24	1991	2.39	1.02	372.34	372.34	6928	88.92	88.92	10	15	62.68	62.62	523.94	523.88
25	1992	0.19	0.13	5.56		1012	7.14		0	4	0.75		13.45	0.00

(Reproduced from Annex 6 of Volume V (Part II) of Report of the Bihar State Second Irrigation Commission, 1994)

Table 3. 4: Flood Damage Data of Kosi River Basin(1991-2013)

Sl. No.	Year	Area affected in Lakh ha	Damage to Crops		Damage to Houses		Cattle Lives Lost (Nos)	Human Lives Lost (Nos)	Damage to Public Utilities in Rs. Lakh At then Current Price	Total Damages
			Area affected in Lakh (ha)	Value in Rs. Lakh At then Current Price	Nos.	Value in Rs. Lakh At then Current Price				In Rs. Lakh At then Current Price
1	1991	1.957	0.828	274.83	6585	85.02	5	10	45.02	404.87
2	1992	0.221	0.158	6.57	1015	7.14	0	4	0.75	14.46
3	1993	2.425	1.014	1308.14	7662	197.80	51	23	155.76	1661.69
4	1994	1.204	0.922	247.86	3616	200.64	0	5	3.26	451.76
5	1995	2.126	0.957	985.01	38638	995.14	133	28	95.09	2075.25
6	1996	3.387	1.930	959.43	39077	466.89	74	67	99.42	1525.74
7	1997	1.663	0.577	716.17	5348	146.71	2	32	17.99	880.87
8	1998	6.104	2.574	7590.22	3250	11.89	9	6	1.27	7603.38
9	1999	0.927	0.341	2365.92	8305	495.03	23	38	184.70	3045.66
10	2000	0.608	0.257	394.22	9650	409.75	76	23	40.34	844.31
11	2001	1.231	0.277	1047.95	18339	310.29	7	22	59.89	1418.14
12	2002	5.573	1.703	5996.13	69738	8599.58	125	70	4754.29	19350.00
13	2003	3.703	1.774	904.08	11493	173.60	14	26	171.53	1249.20
14	2004	8.806	4.433	8779.80	198207	7083.09	261	99	8171.60	24034.48
15	2005	0.336	0.133	89.16	1325	101.99	0	6	34.15	225.29
16	2006	0.077	0.025	63.61	1570	96.11	2	5	72.70	232.42
17	2007	1.550	0.897	7257.59	56859	8406.02	115	149	8833.95	24497.56
18	2008	4.096	1.588	11973.24	239415	30461.34	31999	550	46555.91	88990.50
19	2009	6.832	0.040	217.10	3512	308.16	0	20	70.43	595.69
20	2010	0.176	0.043	196.04	10577	463.93	0	20	21.61	681.59
21	2011	0.555	0.267	999.52	11786	1901.34	3	35	29.26	2930.12
22	2012	0.687	0.002	3.86	1739	103.87	0	5	3.86	111.59
23	2013	3.717	1.653		65593	1514.16	25	49	809.12	6286.72

(Source: Disaster Management Department, Government of Bihar)

CHAPTER 4

MATERIAL & METHODOLOGY

4.1. MATERIALS AND SOFTWARE USED

The Earth Observation satellites which incorporate both geostationary and polar circling satellites give exhaustive, multi worldly coverage of huge zones progressively and at frequent intervals and 'in this manner' - have turned out to be important for nonstop checking of environmental just as surface parameters identified with drought and floods. Geo-stationary satellites give nonstop and brief perceptions over enormous zones on climate including cyclone observing. Polar circling satellites have the benefit of giving a lot higher resolution imageries at low frequency, which could be utilized for point by point checking, damage assessment and long term relief management. Meteorological satellites (both GOES and POES) recognize different parts of the hydrological cycle — precipitation (rate and gatherings), dampness transport, and surface/soil wetness.

4.1.1. Topographic Maps had been utilized to extract various sorts of data layers: administrative boundaries, waterways, lakes, streets, railroad tracks, vegetated zones and other land use/land cover classifications.

4.1.2. RADARSAT SAR pictures are fundamental source to extract information to be utilized to study areas which are flooded, as these requirements to Pre-preparing to improve and align for adjustment of any undesirable mistake. Synthetic Aperture Radar (SAR) can accomplish customary perception of the world's surface, even within the sight of thick cloud cover.

4.1.3. ARCGIS joined with remotely detected imagery recognize the possible event of severe meteorological occasions. A fundamental component of the GIS was the capacity to give paper maps of spatial features including street systems, hurricane shelters, Red Cross offices and health centers. All things considered, GIS use will stretch out past mapping, towards a more effective utilization of its spatial scientific capacities and GIS-based hazard and disaster management will turn into a component of state and neighbourhood government's regular hazard management administration systems. Oversee land records, property estimations, arranging and zoning guidelines and other regulatory undertakings are being extended to suit characteristic hazard management administration needs.

4.1.4. ERDAS Topographical sheets are then Geo-referenced utilizing coordinates given in SOI. Earth pictures of the investigation region are utilized from Google-Earth and benefited picture pieces are joined with the assistance of ERDAS which is Geo-referenced by ArcGIS. Required topographical features are, for example, shapes, measure station and discharge level information are gathered from respective stations.

4.1.5. SWAT Model-SWAT (Soil and Water Assessment Tool) is a waterway basin scale model created to measure the effect of land management practices in large, complex watersheds. SWAT is a constant time model that works on an everyday time venture at basin scale. The target of such a model is to anticipate the long term impacts in large basins management and furthermore timing of vegetation practices inside a year.

4.1.6. SWAT-CUP: -The effective utilization of hydrological models depends on cautious calibration and vulnerability analysis. As, there are a wide range of adjustment/vulnerability analysis calculations, and each could be kept running with various target functions.

SWAT-CUP (SWAT Calibration and Uncertainty Procedures) is a program designed to integrate various calibration/uncertainty analysis programs for SWAT (Soil & Water Assessment Tool) using the same interface. Currently the program can run SUFI2 (Abbaspour et al., 2007), GLUE (Beven and Binley, 1992), and ParaSol (van Griensven and Meixner, 2006). To create a project, the program guides the user through the input files necessary for running a calibration program. Each SWAT-CUP project contains one calibration method and allows user to run the procedure many times until convergence is reached. User can save calibration iterations in the iteration history for later use. Also we have made it possible to create charts of observed and simulated data and the predicted uncertainty about them.

4.1.7. HEC-RAS- HEC-RAS is a PC program that models the hydrodynamics of water course through common streams and different channels. The essential computational technique of HEC-RAS for consistent stream depends on the arrangement of the one-dimensional energy equation. HEC-RAS discovers specific profit-making application in floodplain management and flood protection concentrates to judge floodway encroachments. The HEC-RAS model permits to performing unsteady flow, one-dimensional steady flow, silt transport/mobile bed calculations, etc. This model is utilized to acquire flood extent and depth because of high precipitation in the respective basin. HEC-RAS is a 1-D flow model in which the stream morphology is spoken to by a progression of cross areas listed by waterway station.

4.1.8. Flood Inundation Mapping

In ArcMap SDF document is changed over into a XML record utilizing Import RAS-SDF file button. RAS Mapping is finished utilizing Layers: project name, RAS GIS export file, landscape type, yield index and so on. Utilizing RAS Mapping (Read RAS GIS Export File) bounding polygon is made, which essentially characterizes the investigation degree for the inundation mapping, by associating the endpoints of cross-segment cut lines. After the analysis extent, characterized water surface profile is created utilizing profile with highest flow. This makes a surface with water surface rise for the chose profile. The TIN that is made in this progression will characterize a zone that will interface the external purposes of the bounding polygon, which implies the TIN will incorporate region outside the possible immersion.

4.1.9. Flood Inundation Modelling

The HEC-RAS model parameters (discharge and water level information utilizing Manning' n values) were adjusted and used to assess the flood inundation in the channel reach. Already downloaded digital Elevation Model(DEM) of the Kosi Basin changed over into Triangulated Irregular Network (TIN) position utilizing 3-D Analyst instrument in ArcGIS 10.4 as appeared for further investigation.

4.1.10. Flood Risk Analysis

Frequent flooding events with severe damages in middle Narmada Basin in recent past have shown the importance of flood risk analysis and management. One of the cornerstones of flood risk analysis is the information of people and property at risk. An adequate response to the threat can only be expected if the stakeholders i.e. people and decision makers are aware of the flood risk and are able to evaluate it. Risk analysis considering various aspects of the flood risk, e.g. economic, social, hydraulic, hydrological, and ecological aspects forms the basis of effective and efficient risk reduction measures. The spatial description of the flood risk plays an important role in communicating the results to decision makers and people at risk. The flood risk analysis may be done at different scales, ranging from the local to the global scale. Most of the flood risk mapping approaches work on the local scale. Such types of maps help in analysing the flood situation for smaller areas and objects like buildings and infrastructure and hence form the basis for local flood defence policies and measures.

Ideally, the flood maps should include the information about all type of consequences of floods i.e. social, economic and ecological. Mostly the scope of flood maps is limited only to the hazard aspects and vulnerability aspects are only considered as the land use information.

4.2. DETAIL METHODOLOGY

This section includes the detail procedure from generation the various required maps, generating daily discharge data, calibrating it with the available data and generating flood inundation modelling continuing to generating flood risk maps by prioritization of areas or zones for study area. One can get rough idea by seeing the flowchart shown below. (Figure 4.1)

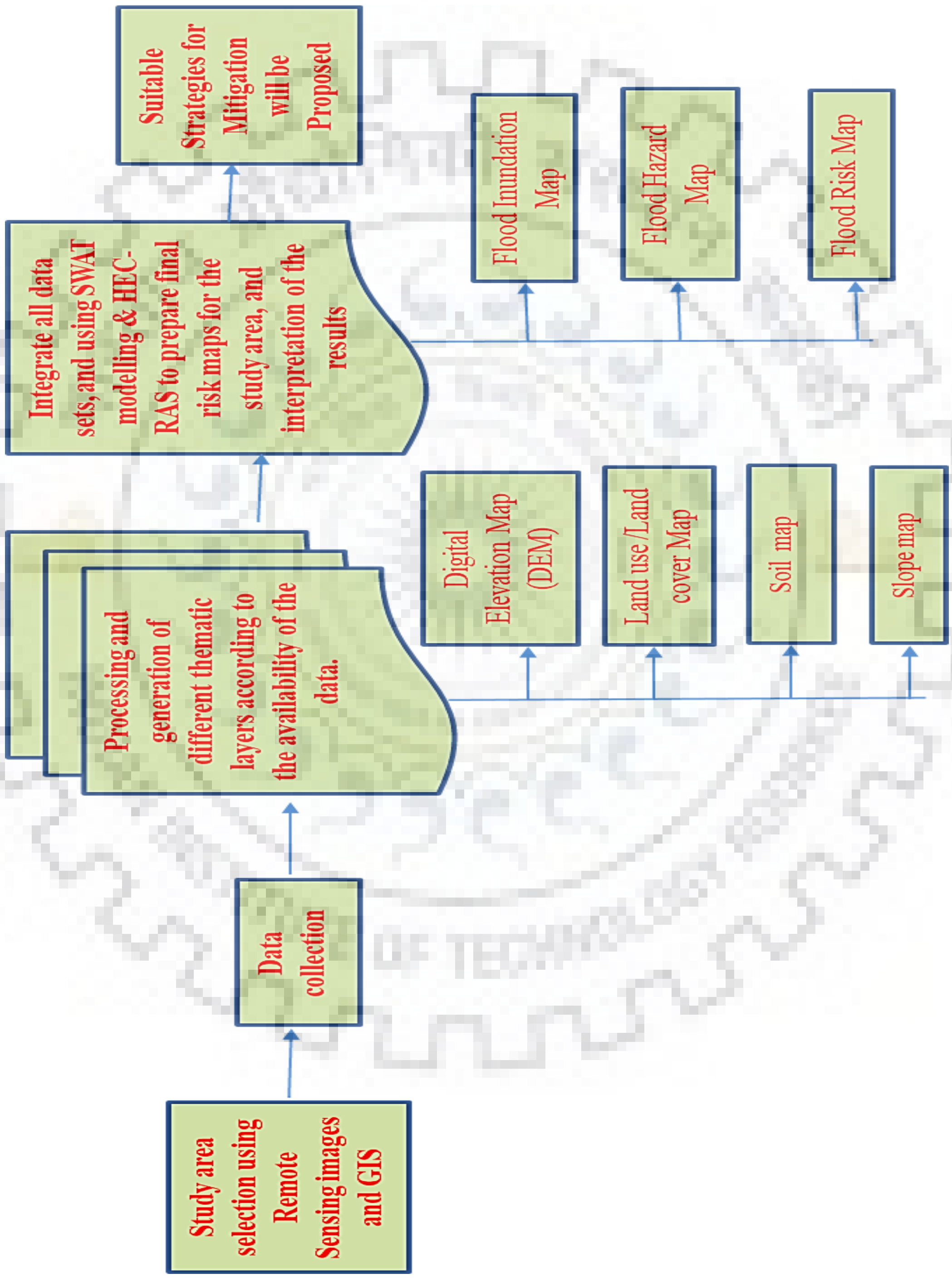

Figure 4. 1: Flow Chart showing methodology of dissertation

4.2.1 Creating various Thematic layers

Firstly, selection of appropriate study area took place on the basis of various factors like availability of data, prone to flooding etc. then data collection starts by various Bihar as well as India websites for rainfall, discharge, daily flow, water level of study area which will be used in further analysis.

After getting the available data, now it's time to get the information that was not available by using remote sensing and GIS. for which Dem was downloaded from USGS earth explorer covering the required area. then Processing of the downloaded DEM started with the help of ArcGIS 10.6 and ERDAS IMAGINE 2018 in which Layer stacking of band1 to 7 was the first step and then mosaic of all the Stacked DEM took place. For getting the required study area or watershed, drainage map was prepared by using respective procedure and making outlet at Baltara and using tool Watershed of Arc Tool Box respective watershed was generated. Once required study area got known all other necessary maps was prepared with the help of ArcGIS and ERDAS software then all the created thematic layers that have been created by the various arrangements of information types will be coordinated in the GIS software.

4.2.2 Daily Discharge data generation

As there is deficiency of daily discharge and water level data at the Baltara Outlet, there comes the need to do modelling for that area so that sufficient datas can be generated to accomplish the respective result. Later on calibration and validation of model generated data will be done with respect to observed/ true data at Baltara outlet. For Modelling one of best option is using ArcSWAT modelling. The Soil and Water Assessment Tool is a small watershed to river basin-scale model used to simulate the quality and amount of surface and ground water and forecast the natural effect of land use, land management practices, and environmental change.

BEFORE going for ArcSWAT modelling preparation or downloading of certain maps and datas which will be needed in the ArcSWAT modelling like LULC map (projected to UTM) Soil Map (projected in UTM) and also some of weather or climate data of the respective area which we will going to require as input in the swat model. Land use land cover map can be made using ERDAS and ArcGIS Softwares after processing Landsat 8 Dem, for Soil map there are various methods in which one is to download FAOsoil Map shape file from GeoNetwork website or form the of SWAT itself in the caption Soil waterbase. It consists of soil map / data for whole world we have clip it out from it for respective study area. Next thing we have to download is weather data specially for India region later on extract from it for our study area.

these data can be obtained from the website Global weather data for swat in which we can select data of required by drawing an approximate rectangle of polygon of that area. Different weather datas are Precipitation which contains daily measured precipitation for a measuring gauges, Temperature input file which contains daily measured maximum and minimum temperatures, solar radiation input file contains daily solar radiation, wind speed input file which contains daily average wind speed which is required when the penman-Monteith method is selected to calculate potential evapotranspiration, Relative humidity input file contains daily relative humidity values which requires when penman-monteith method is used to calculate potential evapotranspiration and for the calculation of vapour stress on plant growth, Weather generator input file which contains the statistical data needed to generate representative daily climatic data. As after downloading the data, before using it in ArcSWAT model, errors should be properly checked otherwise model can give faulty output data or can't run. this can be done using notepad++ because as there is a lots of data and notepad++ can open various files at the same time and also check the errors subsequently.

After getting all the above now we are ready to begin ArcSWAT model. Most importantly, Project set up is done in the appropriate folder, the names of SWAT Project Geodatabase and Raster Storage Geodatabase are initialized consequently. The SWAT Parameter Geodatabase stores the parameters that are required for SWAT model run. The index of this Geodatabase is given by the interface, user should not change this values. The sub basin general input files contain data identified with a diversity of features inside the sub-basin. Information contained in the sub basin input document can be gathered into the following classifications: sub basin size and area, specification of climatic information utilized inside the sub basin, the measure of topographic relief inside the sub basin and its effect on the atmosphere, properties of tributary channels inside the sub basin, factors identified with environmental change, the quantity of HRUs in the sub basin and the names of HRU input records.

with the help of the various option like flow accumulation and direction, create streams and outlet and defining the main outlet point of the study area watershed DEM setup, Stream Definition, Outlet and Inlet Definition, Watershed Outlet(s) Selection and Definition, Calculation of sub basin parameters, we can find the respective watershed and its delineation obtained and go for further processing as shown in flowchart Figure 4.5. We can also calculate various watershed parameters which we can see by clicking on watershed report which consists of minimum and maximum elevations with respective percentage of area above or below that.

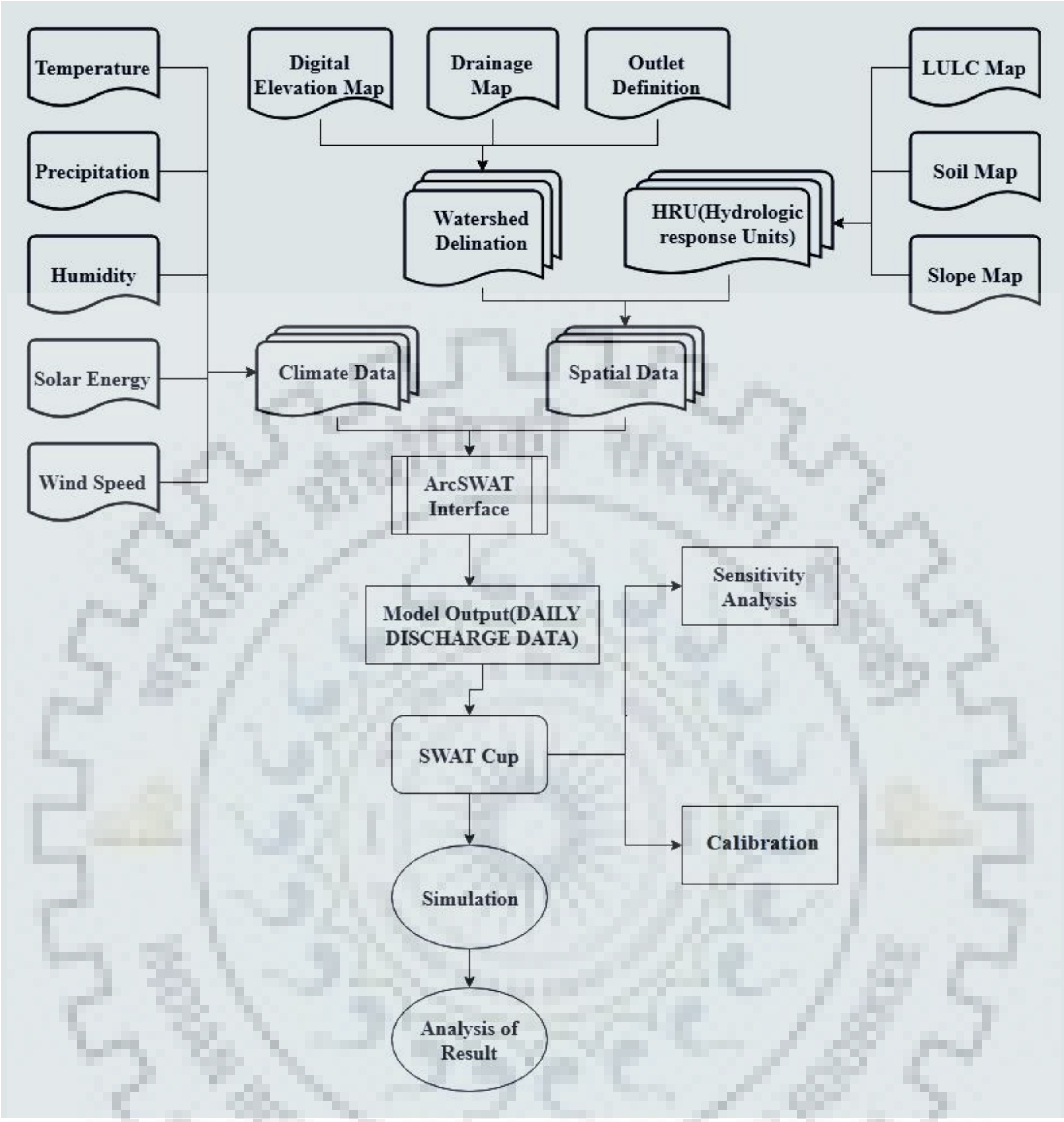

Figure 4. 2: Flowchart of SWAT modelling Process

For Simulation, a watershed is subdivided into various homogenous sub basin (hydrologic reaction units or HRUs) having one of a kind soil, slope and land use properties. The input data for each sub basin is assembled into classifications of climate; similar property regions of land cover, soil, and the management inside the sub basin; lakes/reservoirs; groundwater; and the principle channel or reach, depleting the sub basin. An HRU can be defined as the area having unique/similar Land use and soil which is expected to behave as same way with respect to precipitation but may or may not have different slope so steeper part behave differently with respect to flat part and given watershed will have various different HRUs. The Land area in sub basin is divided into various Hydrologic response units. These units are portion of sub basin that possess unique Landuse/management/soil Attributes. while individual fields with a specific Landuse, management and soil may be scattered throughout a sub basin, these areas are lumped together to form one HRU. So, first of all land use, soil map is defined or you can say, telling ArcSWAT the location and type of different land use land cover and soil as slope can be defined manually giving proper limits because ArcSWAT can extract it from the uploaded DEM. Focusing on Watershed Area the interface allows users to import or create a grid map that masks out a part of the DEM grid and/or a shape map that defines the stream network. and ArcSWAT automatically clip the land use, soil type and slope of the respective watershed. after giving the input we have check (tick mark) to create overlay report and to create HRU class and click on the overlay button to find out union areas of various HRUS. After that we will go for HRU definitions in which different appropriate percentage of Landuse, soil slope is considering which basically define that there should be this minimum percentage of the respective category to be counted as HRUs. Next Tab is Write Input Table in which various weather condition of the respective area will be defined like Precipitation, solar Radiation Data, relative humidity data, wind speed, Temperature variation datas which are important factors used in modelling.

Last step is go to SWAT simulation option and click on Run Swat. under which duration has to be give between which one want the output data, daily hourly option is selected as daily discharge for the for the given watershed has to be obtained. we have to give NYSKIP (No. of year to be skipped) minimum of 3 years as Model take certain years as a warm-up period. then Setup SWAT run and Run Swat.

4.2.3. Calibration of generated data

SWAT-CUP (SWAT Calibration and Uncertainty Procedures) is a program intended to incorporate different adjustment/vulnerability analysis programs for SWAT (Soil and Water Assessment Tool) utilizing the same interface. For creating a project, user need to pursue a method which contains giving the input files that is to be calibrated, in this task input data is every day discharge value at the Baltara outlet of Bihar. SWAT-CUP have certain advantages i.e. when somebody had worked or produced data from SWAT model, it takes direct input from the SWAT model calibrate the data as much as times until user is not getting the appropriate combination of result and can save the iteration for future application. The calibration data can be checked using different factors like R^2 and NS values which is to between 0 to 1, 0 as poor and 1 as best alignment. In SUFI2, we endeavour to get sensible estimations of these two elements i.e. R^2 and NS. While we might want to catch a large portion of our perceptions in the 95PPU envelop, we might in the meantime want to have a little wrap. The bigger they are, the better they are. For P-factor, we proposed an estimation of >70% for discharge, while having R-factor of around 1. As every iteration zooms into a superior region of the parameter space, acquired by the past cycle, it will locate a superior "best" arrangement. Along these lines, in the event that you have NS as your goal work, at that point you will show signs of improvement NS in subsequent iterations.

Parameters are then refreshed so that the new ranges are constantly smaller than the past extents, and are revolved around the best estimation (for more detail see Abbaspour et al., 2004, 2007). goodness of fit can be evaluated by the R^2 or potentially Nash-Sutcliff (NS) coefficient between the perceptions and the last "best" estimation. It ought to be noticed that we don't look for the "best simulation" as in such a stochastic methodology the "best solution" is really the last parameter ranges.

Above all else, Swat model output i.e. daily discharge information in this case is given as input for the task then after selecting available configuration or version of Swat-Cup It's time to choose various parameters which you know or discover from research is going to influence your watershed and its discharge and furthermore what number of iteration user need to run (which can go up to 300-1000) SWAT-Cup the under the tab- Par_inf.txt. Depending upon the quantity of parameters, model's execution time, and framework's abilities. SUFI-2 is an iterative strategy and does not require such a large number of keeps running in every cycle. Usually,3– 4 iterations should be enough to attain a reasonable result. The Parameters need their range of execution which one can know from - Absolute_SWAT_Values.txt. From that point one needs to put the observed information of that place concerning which information SWAT-Cup is going to calibrate the information under Observed_rch.txt tab. In this tab one has to mention number of observed variables, name of the variable and the observed Flow. At that point After user needs to adhere to the guidance and giving the correct input to that place like number of sub basins, number of HRUs, Number of sub basin or HRUs are engaged with getting the required Output. after giving every one of the sources of data, click on Save all and Run The SWAT-Cup.

After the effective run one should Save the Iteration and under their cycle user will discover the Plot showing Observed and most assessed plot of data, It likewise show Summary of Iteration demonstrating P-factor, r-factor, R^2, NS by which one can know that how precise was the calibration .If user has discovered that this outcome isn't satisfactory, at that point user can go for another set of iteration by giving new range to the individual parameters which can be found under New_Pars.txt tab of saved iteration fold.

4.2.4. Flood Inundation modelling

After getting the calibrated data this is time to generate flood inundation map along with others like velocity map required to generate Flood Hot Spots, for which One of the best option is utilizing HEC-RAS to process water surface elevation. This is the place Hydrology and Hydraulics meet up; hydrology enables us to ascertain data, for example, 100-year flood stream, likely most extreme flood stream (PMF), and so on., at that point utilizing this data in HEC-RAS we can make sense of what the possible hydraulic conditions will be for a given study area. In this manner, If User has Water surface elevation concerning different stream conditions then it will be helpful to realizing the possible water surface flooding; to decide the danger of construction; from natural resource agencies. HEC-RAS can likewise be utilized to create stream velocities to know sedimentation and scour. For getting above mentioned output one needs to pursue certain strategy as shown in Flowchart.

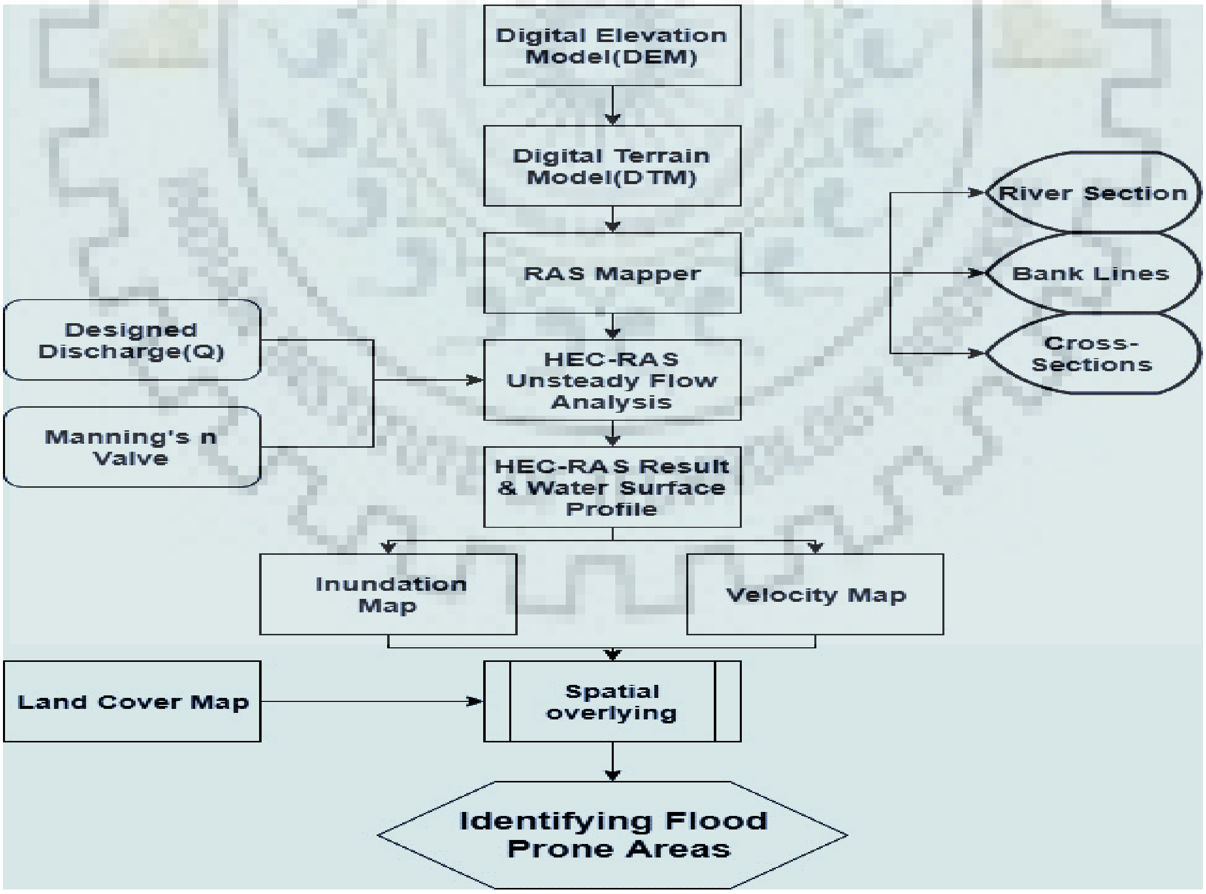

Figure 4. 3:Flow Chart Showing method of Identifying Flood prone area using HEC-RAS

First of all, user needs to give new project name at that point needs to set projection under which input data is going to prepared. As an input, user needs to give DEM of the spot of which discharge must be known. At that point Using the RAS Geometry Tab/function Geometrical information of Kosi waterway can be produced by making Center line of stream, banks, stream way lines, cross-areas at appropriate interval

Utilizing the RAS Geometry function stream centreline, waterway bank, stream way lines, cross-areas have been made as shapes files for pre-preparing of the information. The land-use/land-cover guide was utilized to produce the Manning's n esteems for waterway and basin. Discharge information was utilized as the upstream limit condition. Normal depth was utilized as the downstream limit condition. This limit condition requires the contribution of the Energy Grade Line (EGL)slope at the downstream limit. Daily Discharge and water level information were utilized for investigation. Stream cross section were utilized at respective separation each. Results acquired from the investigation of HEC-RAS were utilized to produce the water surface profile.

Input Data

HEC-RAS requires a Digital Terrain Model (DTM) of the waterway framework as a TIN or a GRID. Land-use/land-cover information is required to create Manning's n value.

creating RAS Layers

HEC-RAS layers consists of stream centerline, center line of stream flow, principle channel banks, and cross-segment. cut Lines are created utilizing Digital Terrain Model (DTM) of the waterway in HEC-GeoRAS. RAS layers are utilized to extricate extra geometric information for import in HEC-RAS. These topics incorporate Land Use, Levee Alignment, Ineffective Flow Areas, and Storage Areas.

Creating Stream Centerline:

The stream centerline is utilized to show the waterway network as shown in Figure. 4.4. The waterway network must be digitized toward stream. Remarkable stream and river name is allotted utilizing waterway ID tool. Network, length of every stream and reach is determined from beginning station to end station.

Bank Lines:

The bank lines layer is utilized to recognize the principle channel transport zone from that of the overbank floodplain regions as shown in Figure 4.4. Distinguishing proof of primary channel will likewise give greater understanding into the landscape, movement of water in the floodplain, and in recognizing non-conveyance regions.

Cross-Section Cut Lines:

Cross-segment cut lines are utilized to distinguish the areas where cross-sectional information is extracted from the Digital Terrain Model (DTM) as shown in Figure 4.5. The convergence of the cut lines with different RAS Layers will decide bank station areas, downstream reach lengths, Manning's n values, inadequate areas, blocked hindrances and levee positions. Cut lines should always be located perpendicular to the course of stream and arranged from the left to right bank. Cut lines must cover the whole extent zone of the flood plain to be displayed.

Later on to give software idea regarding roughness of the surface Value, Manning's n needs to give which can be produced utilizing land-use/land-cover map which is taken as 0.05 for right and left bank part and 0.035 for main channel.

Further user needs to give Discharge information to the upstream limit condition and Normal depth as the downstream limit condition. This Normal Depth Boundary limit condition requires the contribution of the Energy Grade Line (EGL) slope at the downstream limit which is given here as 0.001. These Daily discharge and water level information will be utilized for analysis. Finally, one needs to make a plan under which beginning date and time, finishing date and time, Computational interval, hydrograph output interval are given and after mentioning all the thing one should save the plan and run the software.

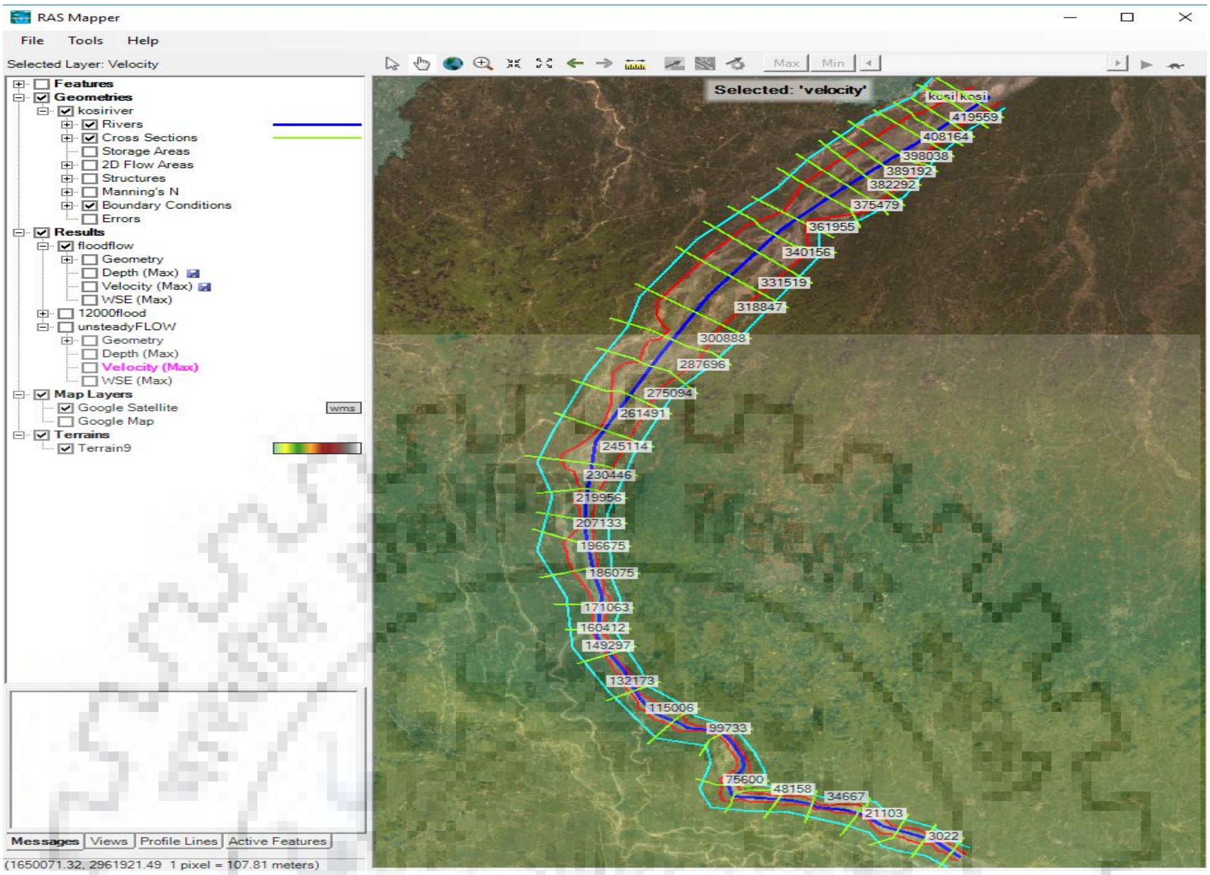

Figure 4. 4: various lines showing main river line(Blue), Bank line(Red), Flow path(sky colour), Cross-section Cut(Green)

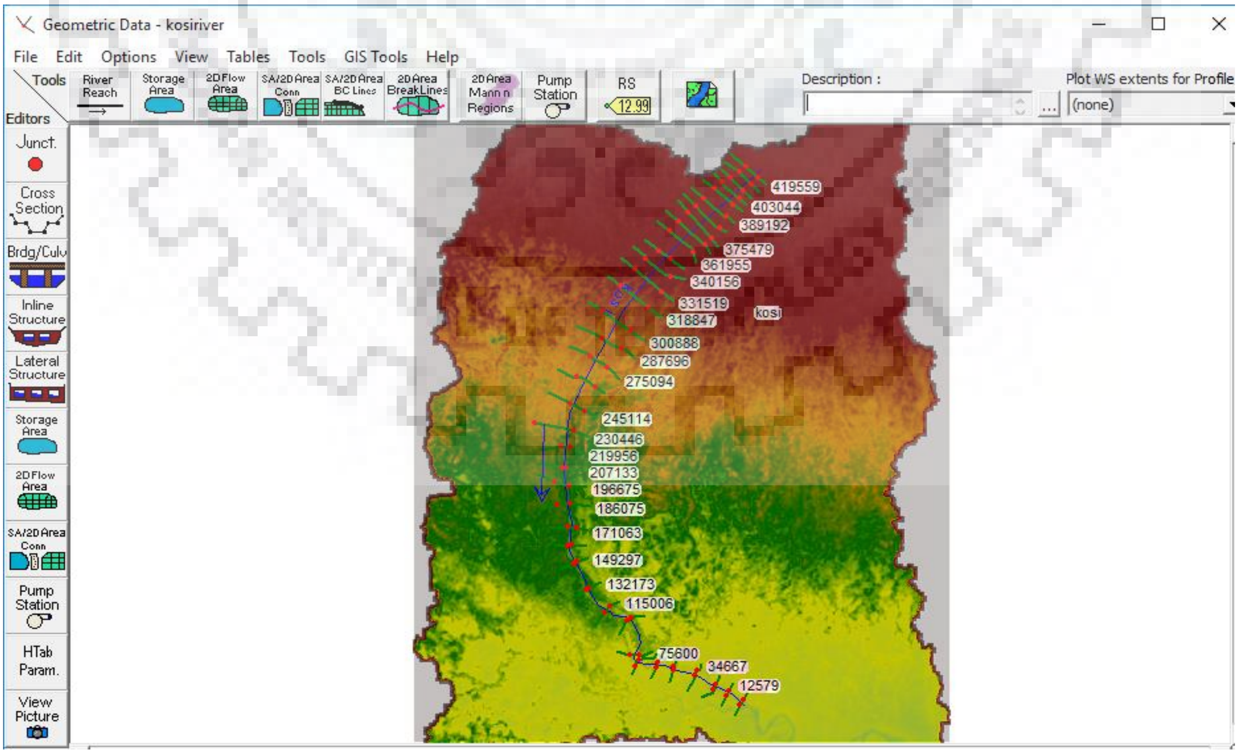

Figure 4. 5: Geometric data Kosi river

4.2.5. Flood Hotspot Identification and Prioritization

Flood risk isn't spread consistently over existence. Flood maps produced by geospatial analysis frequently demonstrate few limited locales of extensively high flood hazard. Various instruments are accessible that enable the clients to recognize and understand these locales of higher flood Risks. Among these devices "Hotspot" examination is generally acknowledged and progressively used to recognize regions where flood hazard is most prominent and where suitable assets and approaches ought to be sent to limit the harm. Recognizing flooding hazard hotspots is one of the initial phases in an integrated system for flood risk evaluation and mitigation. With respect to Natural disaster, Dilley et al. (2005) and Arnold et al. (2006) refer to the hotspots as geographic territories where the dangers of catastrophic events are especially high.

On the basis of various measurements, the map of the possibly flood-prone territories is overlaid with the map of respective study areas, so as to outline the hotspots. In Fact, outline of the hotspots can be viewed as a viable screening device for recognizing the zones for a thorough hazard assessment. Mapping of flooding hazard hotspots gives a screening instrument to the organizer so as to individuate efficiently the zones that need his/her necessity. After the potential sites for flood risk have been selected as hotspots, the decision makers may face the problem of resource quantity constraints against the requirement for these. Therefore, it is required to further prioritize these hotspots that are candidate for the allocation of resources. Prioritization of hotspots should be aimed at achieving the optimum allocation of resources considering various spatial, quantity, temporal, technical and financial constraints. Prioritization approach should also consider the mobility of resources and their simultaneous requirement. Decision outcomes are largely influenced by decision-making methods. According to Suhr (1999), outcomes are results of actions triggered by people's decisions and these decisions are influenced by decision-making methods. So the selection of decision making method is as important as the outcomes are. TOPSIS and CBA are two methodologies that are widely used in prioritization of hotspots in which CBA method is used for this dissertation.

4.2.5.1 Choosing by Advantages (CBA)

CBA is a decision-making system that compares advantages of alternatives for decision-making process. This method was developed by Suhr while working in the U.S. Forest Service.

This system makes use of well-defined vocabulary in the decision-making process to ensure clarity and transparency.

This system gives importance to identify the factors that will highlight significant differences among different alternatives instead of the factors that will be important in the decision. This method helps in making decisions based on relevant facts and hence minimizing the conflict. In contrast, the stakeholders may have problems in resolving conflicts when using value-based methods, as these methods need to weight the factors and therefore may not focus on the significance of the advantages between attributes of different alternatives to the same extent as that of CBA, Methods that weight factors are more likely to produce wrong decisions as the decisions taken are not based on the relevant facts. Addition of any factor on later stages of analysis in CBA can be done easily because it will be independent of previous factors whereas in methods that weight factors, weightage assigned to every factor need to be changed if a new factor is added to the analysis. CBA includes methods for almost all types of decisions rang from very simple to very complex decisions CBA method helps the decision makers to differentiate alternatives and understand the importance of those differences, The Decisions in this method are based only on the advantages of alterative (which are positive differences) instead of both advantages a disadvantages to avoid double counting.

CBA analysis should be possible utilizing straightforward steps as given below:

- Identifies choices prone to have critical points of interest over other choices
- Define factors that will calculate differences among selected choices.
- Decide the criteria to assess characteristics of different choices.
- Summarize the characteristics of every choice.
- Identify the least favoured characteristics for each factor, and then choose relative favoured characteristic over the characteristics of other option
- Decide on the significance of fundamentals. Initially, select the important fundamental, most significant among all.
- Finally, assess the choices to rank them in order of preference.

The decision as a whole can also be reconsidered, incorporating other factors, or new alternatives. In such case decision can easily be update using the CBA tabular method. Hence this method is used for prioritization of hotspots.

4.2.5.2 Identification and Prioritization

Five potential sites for the hotspot analysis have been identified on the banks with respect of 12000 cumec steady – flow and unsteady flow analysed flood as 12000 cumec is found to be the severe case so in hotspot identification this value generated velocity profile, depth profile, Flood map is taken into account. Hotspots have been selected based on the visual interpretation of geospatial data. floods have been overlaid on the LULC file of the area and visually inspected. Criteria for the selection of hotspots are as follow:

- Populated areas exposed to moderate, high and very high severity index for both of the parameters i.e. velocity or depth.
- Populated area exposed to very high severity index for any of the parameter as shown in
- Agricultural land exposed to very high severity index for any of the parameter.
- Land use areas other than residential and agricultural land exposed to severity index for any of the parameters.
- Any religious, historic or cultural monument exposed to moderate or higher

Severity of the flood corresponding to depth **(s1)** and velocity **(s2)** are assigned scores as per severity index. Vulnerability **(v1)** of different attributes for different locations is assigned as per Table 4.1 and maximum score of respective attributes Table 4.2.

Table 4. 1: Different degree of Severity for Depth, Velocity, Vulnerability

Severity/Vulnerability Index	Score for Depth Severity(S1)	Score for Velocity Severity(S2)	Score for Vulnerability(V)
Very Low	0.1	0.1	0.00
Low	0.2	0.2	0.25
Moderate	0.3	0.3	0.50
High	0.4	0.4	0.75
Very High	0.5	0.5	1.00

And using Equation 4.1 and 4.2, Scores for various identified Hotspots can be calculated and accordingly Prioritization of the same will be done.

$$\boldsymbol{Multiplying\ Factor(F) = (s1 + s2) * v} \text{..} \textbf{(4.1)}$$

$$\boldsymbol{Score\ (s) = Maximum\ score\ (MS) * Multiplying\ Factor(F)} \text{......................} \textbf{(4.2)}$$

Table 4. 2: Score to attributes for different locations are assigned as multiplication of multiplying factor (F) and maximum score

ATTRIBUTES		MAXIMUM SCORE
Social Impacts	Human Casualties and Injuries	2000
	Health Impacts due to water born disease	1600
	Public inconvenience	800
	Water logging and back ups	500
	Psychological effects	600
	Loss of shelter and livelihood	1000
	Effect on religious monuments	1000
	Effect on educational & administration working	800
Environmental Impacts	Water Pollution	600
	Erosion	500
	Ecosystem Degradation	800
	Habitat losses	800
	Impact on endangered species	800
	Sedimentation in lower areas	600
	Sewer outflows	400
Economic Impacts	Productivity Loss	800
	Agriculture Productivity	800
	Industrial & commercial impacts	1000
	Property Losses	1500
	Expenditure on evacuation & rehabilitation	1500

CHAPTER 5
RESULT AND DISCUSSION

With the use of ArcGIS and ERDAS various required thematic layer map were generated.

5.1. THEMATIC LAYERS AND THEIR DESCRIPTION

5.1.1 Landscape preparing- Utilizing the landscape information as info, Terrain pre-preparing is a series of steps to determine the drainage network. The means comprise of processing the fill sinks, flow direction, flow accumulation, stream definition, and ultimately getting watershed delineation.

5.1.2. Digital Elevation Model(DEM) is produced by gathering and assessing the shape guide of suitable interval (Figure 5.1). By considering the individual safe stream gauge level reference to lowest bank height and by applying this point of limit to DEM of the study area, Probable flood hazard map for probable coming flood occasions can be created.

5.1.3. Slope map - The length and the steepness of the topographic slope influence the stream and immersion of the specific region (Figure 5.1). For instance, low and flat geology diminishes the runoff, causing high infiltration inside the territory along these lines bringing about water logging condition. Additionally, the low-lying zone with low slope angle will be immersed first with respect to the high slope territory during flooding.

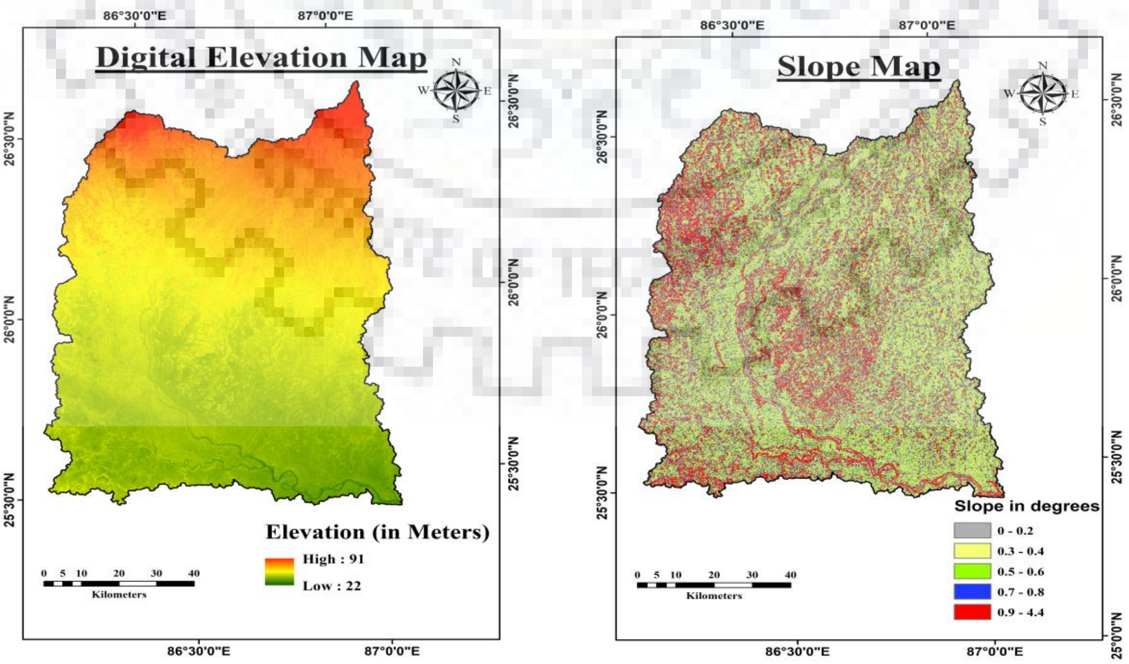

Figure 5. 1: Digital Elevation Map, Slope Map

5.1.4. Land use/Land cover (LULC) Map - The World Meteorological Organization (WMO, 2009), advanced the standard of Integrated Flood Management (IFM) as the joining of "the land and water assets improvement in the waterway basin and points in maximizing the net advantages from utilization of flood plains and limiting the death toll from the flooding" Areas with low forest cover, settlement are progressively helpless against harm as stream draining the plain, increases the runoff rate and its amount shortens the time of concentration and vice versa. The land cover classes represent on the land surface while land use represents the exercises inside which the land cover is being utilized. The layer "Land use Land cover" incorporate mainly four distinct classes to be specific: Agriculture, water, Forest and urban/settlements (Figure 5.2) and their respective area as shown in Figure 5.3.

5.1.5. Soil Characteristics

Soil Map or soil input files which contains information about the physical characteristics of the soil that governs the movement of water and air through the profile and have a major impact on the cycling of water within the HRUs. Soil type of the study area are generally of Clay-loamy type or complete loam as shown in Figure 5.2. Clay loam is a soil mixture that contains more clay than other types of rock or minerals which are good for agriculture purpose.

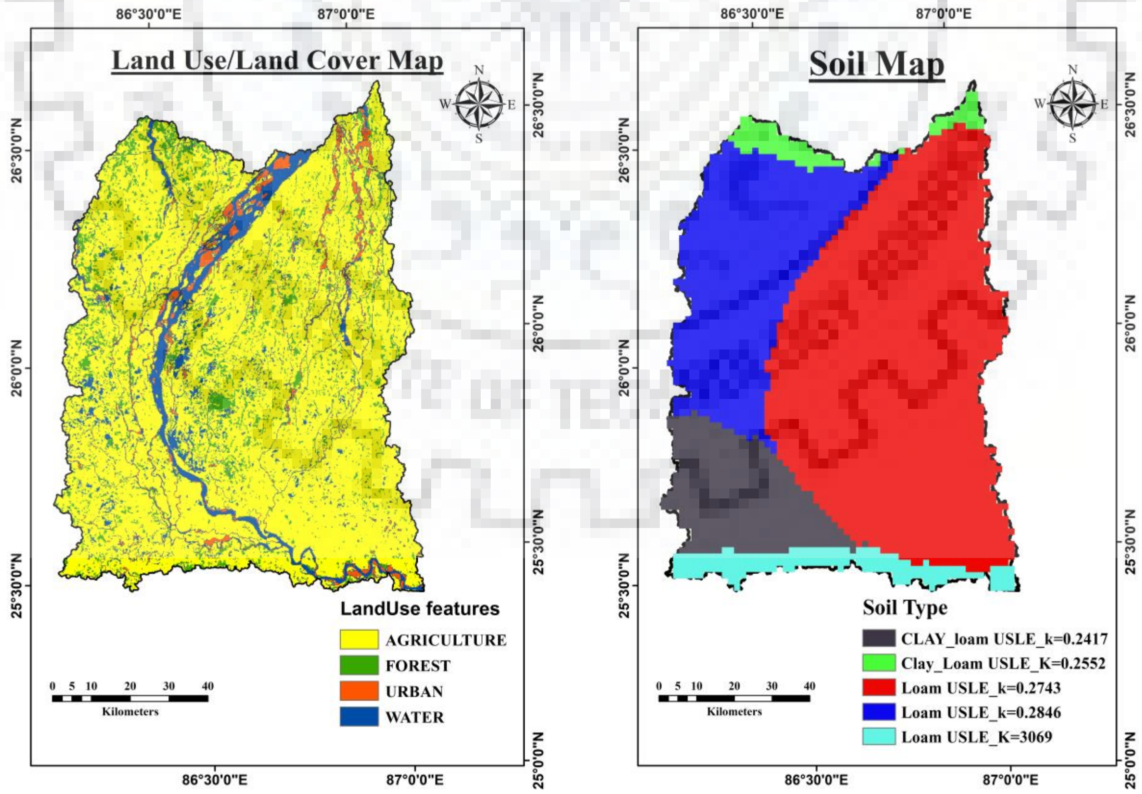

Figure 5. 2: Land Use/Land Cover Map and Soil map

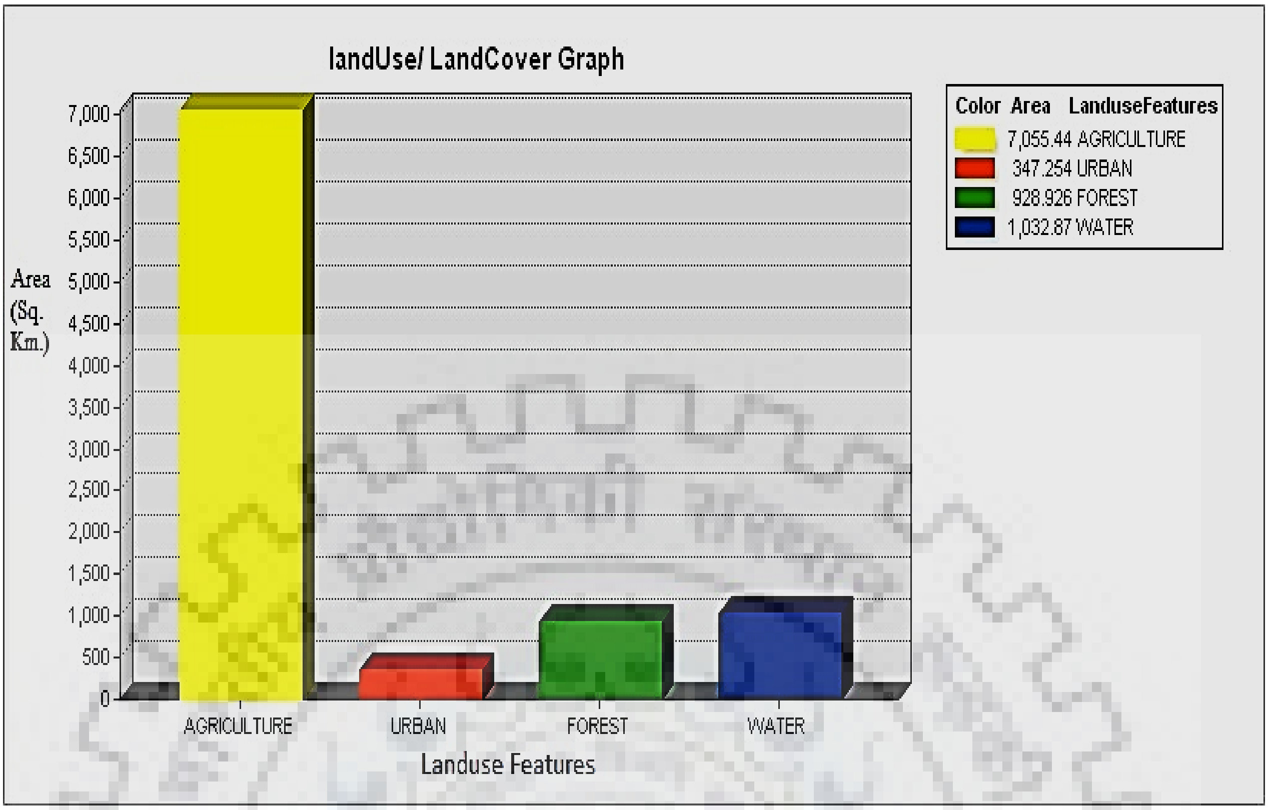

Figure 5. 3: Graph showing Areas of respective Landuse Features

5.2 SWAT MODEL GENERATED DATA

After SWAT run successfully one can read SWAT output and also an overview of hydrological cycle of respective watershed as shown in Figure 5.4. The result of this process can be seen in HRU analysis report as shown in Table 5.1. where one can find out amount of area(ha) covered by different land use classes, soil types and slopes and also the areas (ha) covered by different combination of land use, soil type and slopes under different HRUs column which give us the roughly idea of which combination covered most area and affect most our output like if Daily discharge has to find out then ArcSWAT model calculated discharge in different HRU having different combination and finally give more accurate daily discharge data.

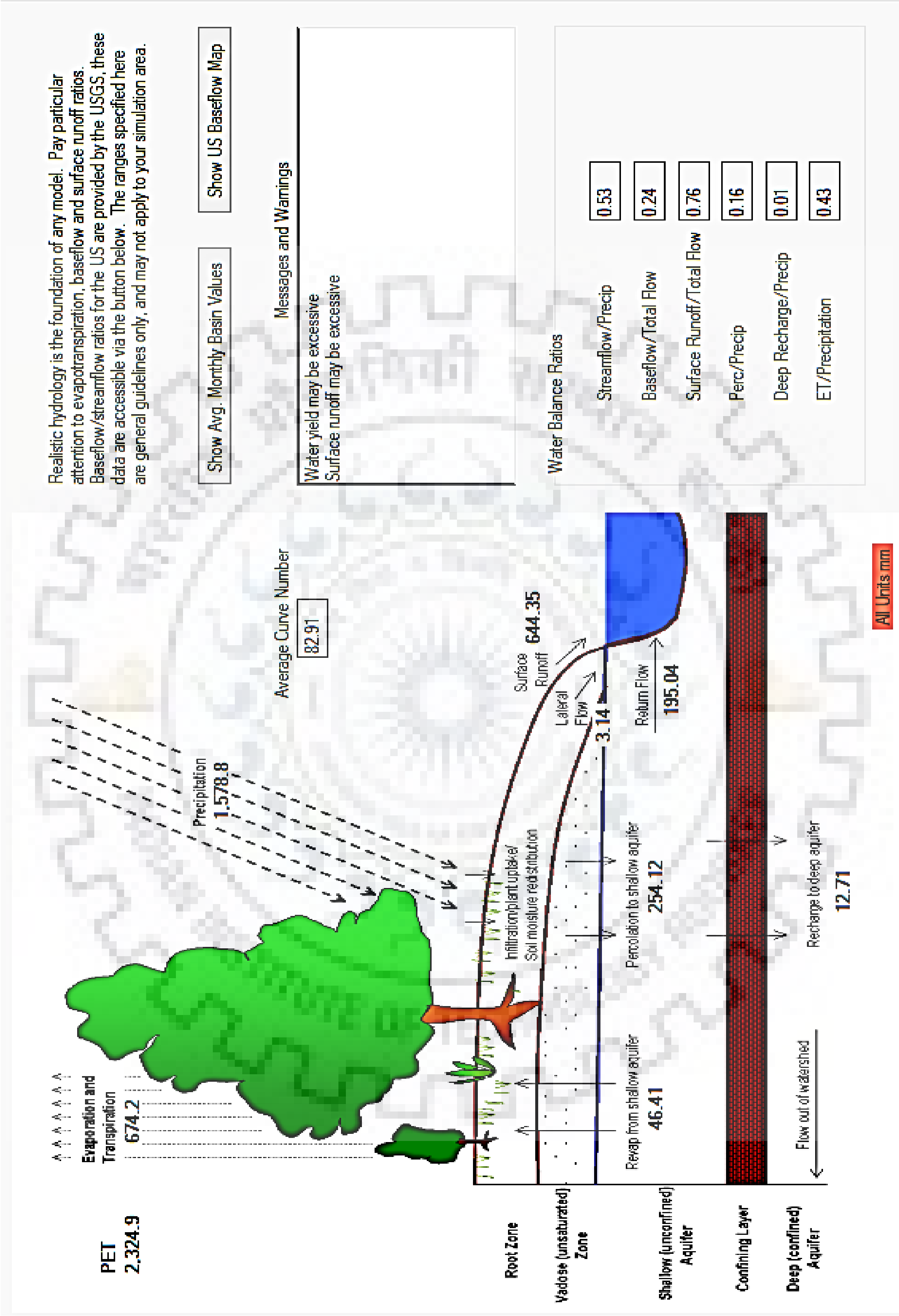

Figure 5. 4: SWAT hydrological overview for the Study Area

Table 5. 1: Final Hydrological Response Units Distribution Data

	MULTIPLE HRUs LandUse/Soil/Slope OPTION			
	Number of HRUs: 22			
	Number of Subbasins: 3			
			Area [ha]	Area[acres]
Watershed			947040.2068	2340183.703
LANDUSE:				
		Forest-Mixed --> FRST	80376.0645	198613.2742
		Residential-High Density --> URHD	150384.523	371607.6754
		Agricultural Land-Generic --> AGRL	714458.5613	1765462.828
		Barren --> BARR	1821.058	4499.9253
SOILS:				
	Be83-2a-3684	Loam	837408.6724	2069278.7
	Bc9-2b-8	Clay-Loam	109631.5344	270905.003
SLOPE:				
		0-3	212959.5056	526233.5864
		3-15	734080.7011	1813950.117
SUBBASIN #	1		521186.4662	1287877.817
LANDUSE:				
		Forest-Mixed --> FRST	80376.0645	198613.2742
		Residential-High Density --> URHD	72422.5203	178959.6688
		Agricultural Land-Generic --> AGRL	368512.7569	910613.4479
SOILS:				
	Be83-2a-3684		506970.6471	1252749.818
	Bc9-2b-8		14340.6946	35436.5734
SLOPE:				
		0-3	112242.6446	277357.1869
		3-15	409068.6971	1010829.204
HRUs				
	1	Forest-Mixed --> FRST/Be83-2a-3684/0-3	17914.4796	44267.5748
	2	Forest-Mixed --> FRST/Be83-2a-3684/3-15	62461.5849	154345.6995
	3	Residential-High Density --> URHD/Bc9-2b-8/0-3	3064.2676	7571.9584
	4	Residential-High Density --> URHD/Bc9-2b-8/3-15	11276.427	27864.6149
	5	Residential-High Density --> URHD/Be83-2a-3684/3-15	45590.3108	112655.9375
	6	Residential-High Density --> URHD/Be83-2a-3684/0-3	12491.5149	30867.1579
	7	Agricultural Land-Generic --> AGRL/Be83-2a-3684/3-15	289740.3743	715962.952
	8	Agricultural Land-Generic --> AGRL/Be83-2a-3684/0-3	78772.3825	194650.4959
SUBBASIN #	2		410069.3957	1013301.98
LANDUSE:				
		Residential-High Density --> URHD	74249.497	183474.2195
		Agricultural Land-Generic --> AGRL	335682.3998	829487.994
SOILS:				
	Bc9-2b-8	Clay-Loam	79493.8715	196433.3311
	Be83-2a-3684	Loam	330438.0253	816528.8824
SLOPE:				
		0-3	96219.525	237763.2572
		3--15	313712.3718	775198.9563
HRUs				
	9	Residential-High Density --> URHD/Bc9-2b-8/0-3	5050.7934	12480.7631
	10	Residential-High Density --> URHD/Bc9-2b-8/3-15	14607.3874	36095.5847
	11	Residential-High Density --> URHD/Be83-2a-3684/3-15	42121.8745	104085.258
	12	Residential-High Density --> URHD/Be83-2a-3684/0-3	12469.4416	30812.6137
	13	Agricultural Land-Generic --> AGRL/Bc9-2b-8/3-15	44793.7851	110687.6826
	14	Agricultural Land-Generic --> AGRL/Bc9-2b-8/0-3	15041.9055	37169.3007
	15	Agricultural Land-Generic --> AGRL/Be83-2a-3684/0-3	63657.3844	157300.5797
	16	Agricultural Land-Generic --> AGRL/Be83-2a-3684/3-15	212189.3248	524330.431

After getting the daily discharge, data needs to be calibrated based on some actual observed data.

5.3. CALIBRATED DATA ALONG WITH THE PARAMETERS USED

Generated data of daily discharge is calibrated using SWAT-CUP by following respective procedure by using 22 different parameters as detailed below.

-Best_Par.txt This record demonstrates the "best parameter" values with their range as shown in Figure 5.5 These are the parameters, which gave the best target function value in the present iteration. As the best parameter truly does not mean especially as the following target work esteem may not be measurably not very not the same as the best one. The parameter ranges are the solution for this iteration.

-Dotty Plots This plot demonstrates the dotty plots of 22 different parameters that are considered here. These are plots of parameter interval or relative changes versus target function i.e. R^2 in this Case. The principle reason for these charts are to demonstrate the circulation of the sample points just as give a thought of parameter sensitivity. In the Figure 5.6 you can see a pleasant pattern for CN2 as it increments. Plainly CN2 is a delicate parameter and its best fitting qualities are under -0.127859 in relative change (r__). Likely wise SOL_Z, SOL_BD, SOL_K showing effect of soil type by its best fitting values as shown in Figure 4.7. in relative change(r_) and ALPHA_BF, GW_DELAY, GWQMN, REVAPMN taking account of Ground Water present in that area, ESCO, EPCO, HRU_SLP, SLSUBBSN taking account of HRUs, SURLAG, SMFMX, SMFMN, SMTMP, SFTMP taking care of basin characteristics, CH_N1, CH_K2, CH_K2 taking account of characteristic of main channel in replace type(V__) In any case as shown in Figure 5.6- 5.9.

Sensitivity analysis This module of the program performs sensitivity analysis. Two kinds of sensitivity analysis are permitted. Global Sensitivity and One-at-a-time sensitivity analysis. The final global sensitivity can be observed in the Figure 5.10 and respective values in Table 5.2.

-95ppu plot This order demonstrates the 95ppu of all variables. Likewise indicated are observations and best simulation of the present iteration. The answer for the calibration at this stage is the 95PPU diagram as shown in Figure 5.11 and respective values of observed and simulated data in Table 5.3. and the parameter intervals that were utilized to produce it.

```
Goal_type= R2     No_sims= 300     Best_sim_no= 100     Best_goal = 3.596269e-001

 Parameter_Name          Fitted_Value     Min_value     Max_value
1:R__CN2.mgt            -0.127859        -0.168194     -0.127520
2:V__ALPHA_BF.gw        0.068404         0.068174      0.072362
3:V__GW_DELAY.gw        378.200714       377.313446    380.704254
4:R__SOL_Z(..).sol      -0.135330        -0.137229     -0.134561
5:V__ESCO.hru           0.004177         0.002829      0.007155
6:V__EPCO.hru           0.700229         0.697094      0.706182
7:V__HRU_SLP.hru        0.936865         0.934177      0.937125
8:R__SOL_BD(..).sol     -0.016662        -0.017215     -0.010707
9:V__SURLAG.bsn         -20.052155       -20.763552    -19.965723
10:V__SLSUBBSN.hru      107.565590       106.997604    108.072662
11:R__SOL_AWC(..).sol    -0.497805        -0.499622     -0.496618
12:V__CH_N1.sub         -0.415923        -0.546439     -0.395553
13:V__CH_K2.rte         329.607880       326.147217    332.536133
14:V__CH_N2.rte         0.111295         0.110031      0.114131
15:V__REVAPMN.gw        -21.283018       -22.009172    -18.220537
16:V__GW_REVAP.gw       0.035959         0.035525      0.036357
17:R__SOL_K(..).sol     0.042359         0.041532      0.042978
18:V__GWQMN.gw          3711.748047      3704.547607   3725.622314
19:V__SMFMX.bsn         7.035511         6.929009      7.087573
20:V__SMFMN.bsn         -6.205682        -6.346834     -6.185518
21:V__SMTMP.bsn         0.441469         0.294382      0.451694
22:V__SFTMP.bsn         5.289195         5.285166      5.315008


   -0.127859     0.068404   378.200714    -0.135330     0.004177     0.700229     0.936865    -0.016662   -20.052155
107.565590    -0.497805    -0.415923   329.607880    0.111295   -21.283018     0.035959     0.042359  3711.748047
7.035511    -6.205682     0.441469    5.289195

r__CN2.mgt                     -0.127859
v__ALPHA_BF.gw                 0.068404
v__GW_DELAY.gw                 378.200714
r__SOL_Z().sol                 -0.135330
v__ESCO.hru                    0.004177
v__EPCO.hru                    0.700229
v__HRU_SLP.hru                 0.936865
r__SOL_BD().sol                -0.016662
v__SURLAG.bsn                  -20.052155
v__SLSUBBSN.hru                107.565590
r__SOL_AWC().sol               -0.497805
v__CH_N1.sub                   -0.415923
v__CH_K2.rte                   329.607880
v__CH_N2.rte                   0.111295
v__REVAPMN.gw                  -21.283018
v__GW_REVAP.gw                 0.035959
r__SOL_K().sol                 0.042359
v__GWQMN.gw                    3711.748047
v__SMFMX.bsn                   7.035511
v__SMFMN.bsn                   -6.205682
v__SMTMP.bsn                   0.441469
v__SFTMP.bsn                   5.289195
```

Figure 5. 5: Various Parameters used for calibration with their respective values

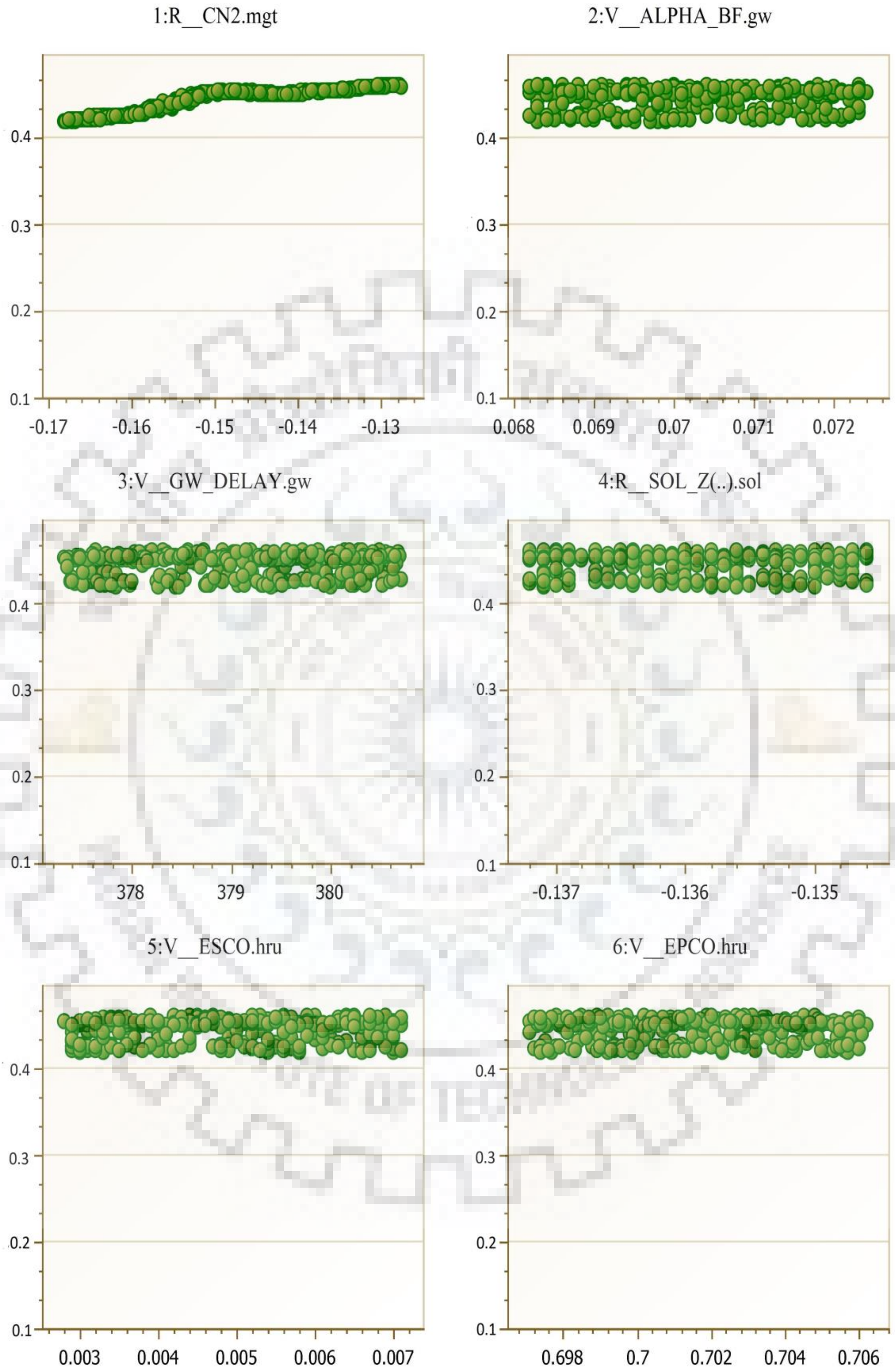

Figure 5. 6 : variation of different parameter values with respect to objective function

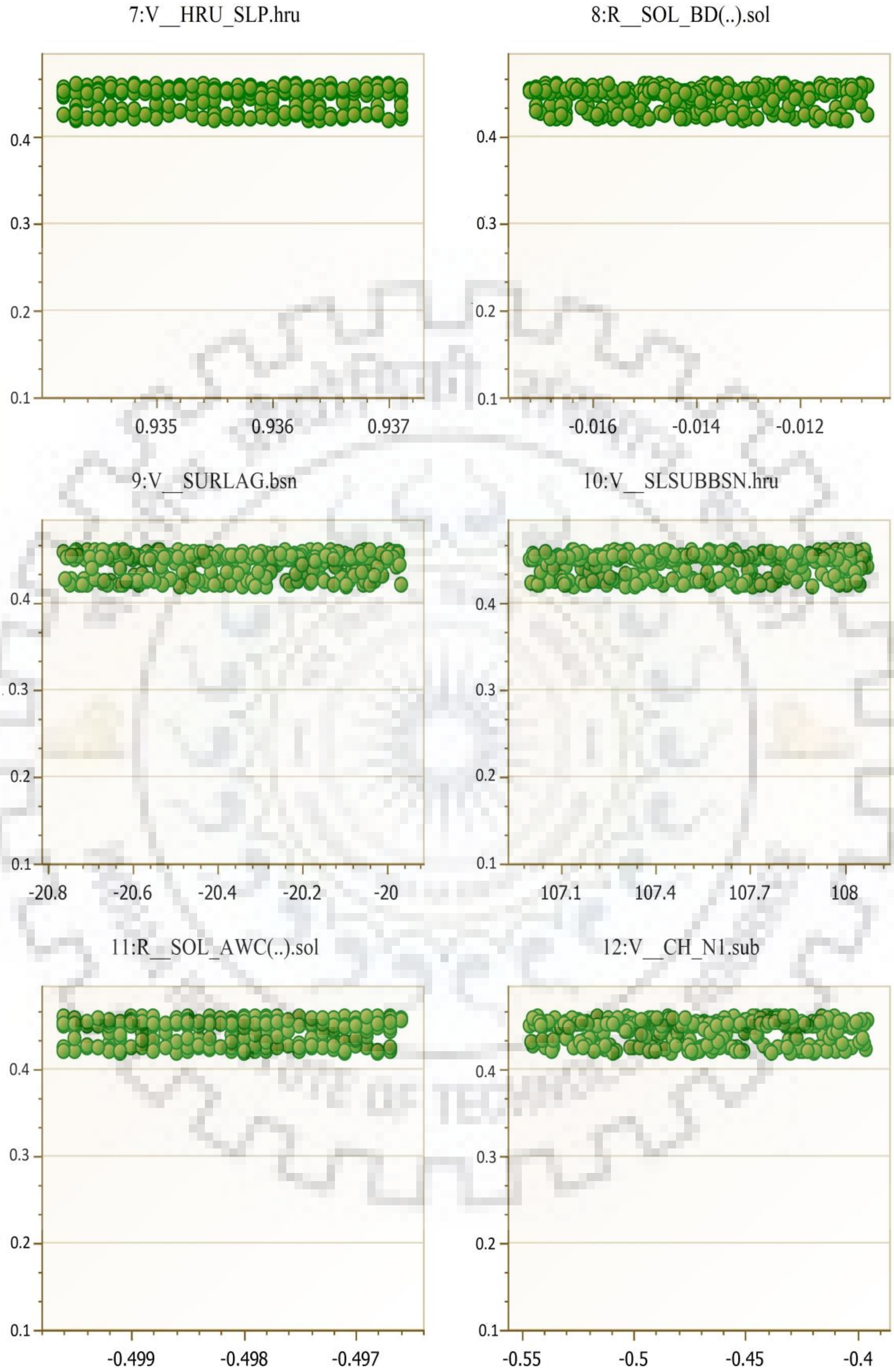

Figure 5. 7 : variation of different parameter values with respect to objective function

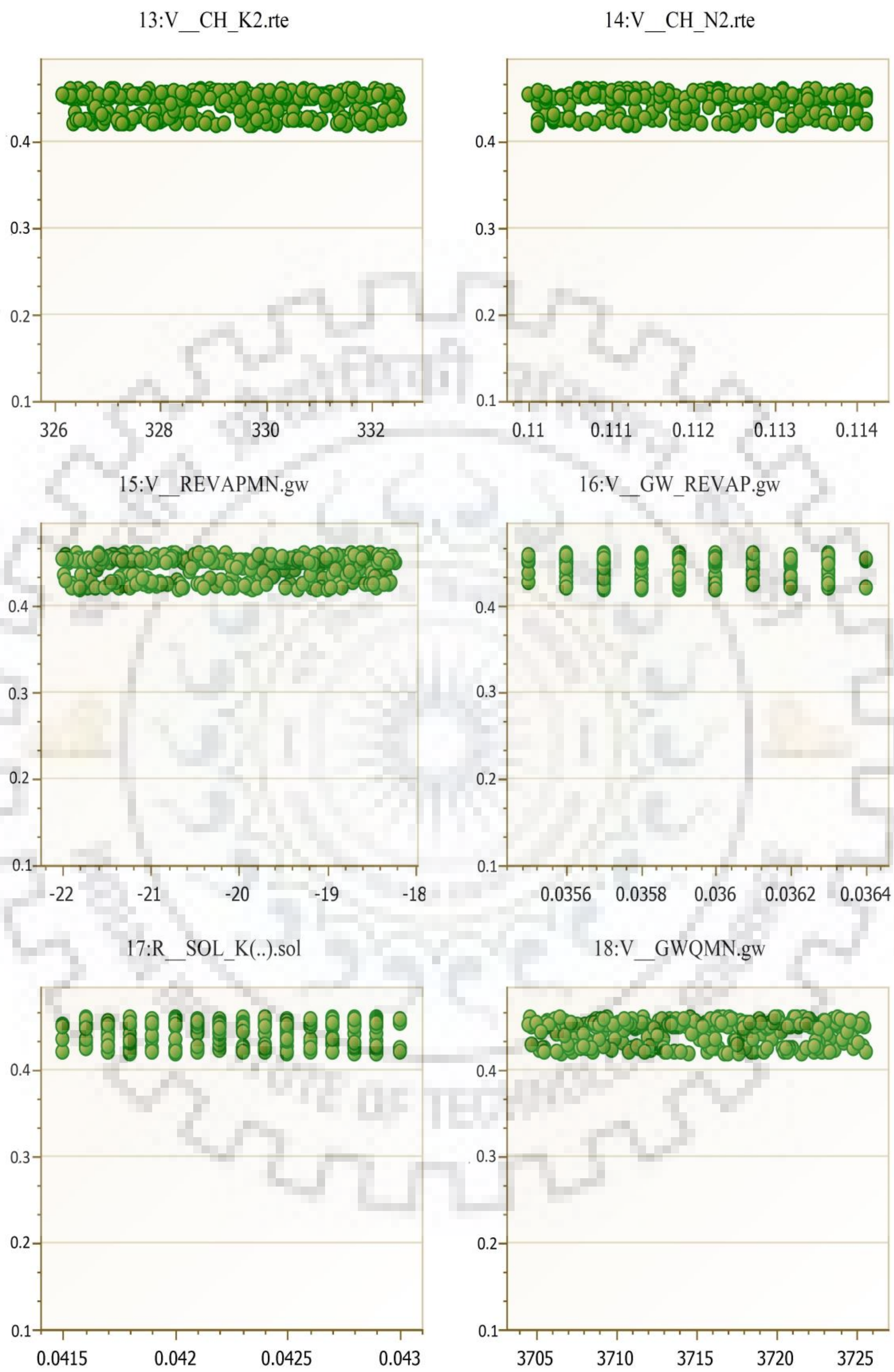

Figure 5. 8 : Variation of different parameter values with respect to objective function

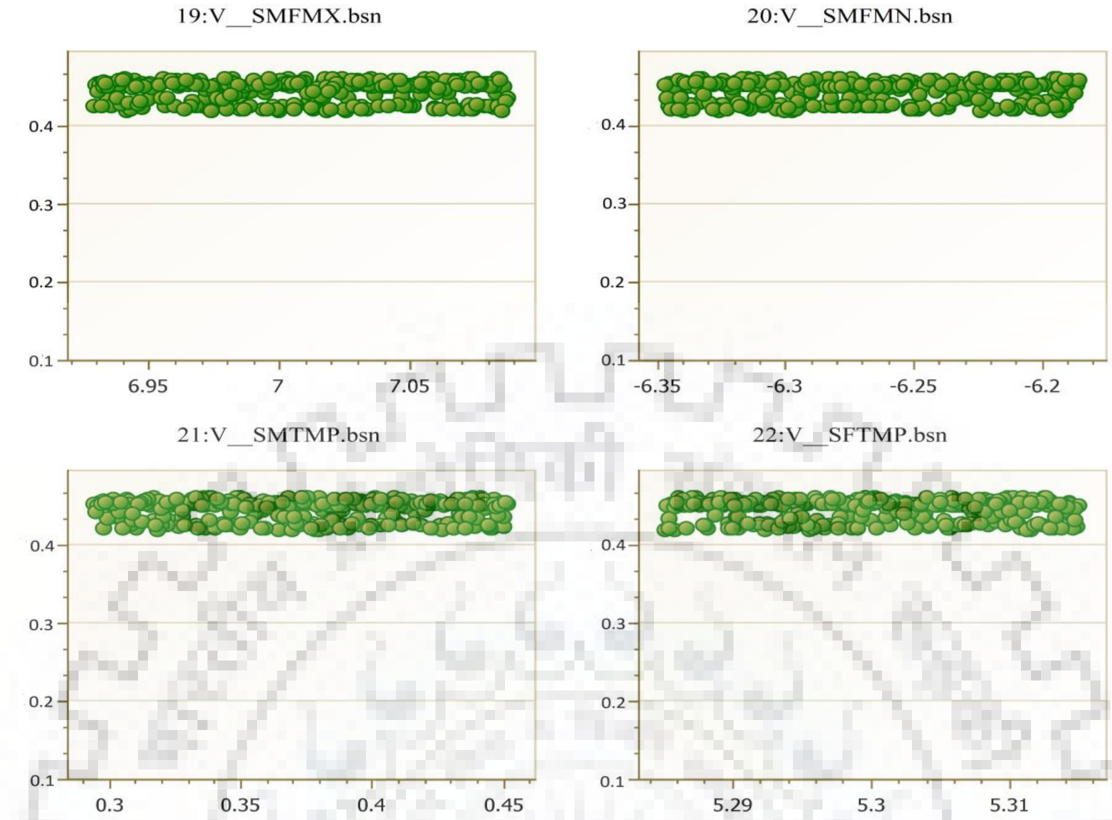

Figure 5. 9: Variation of different parameter values with respect to objective function

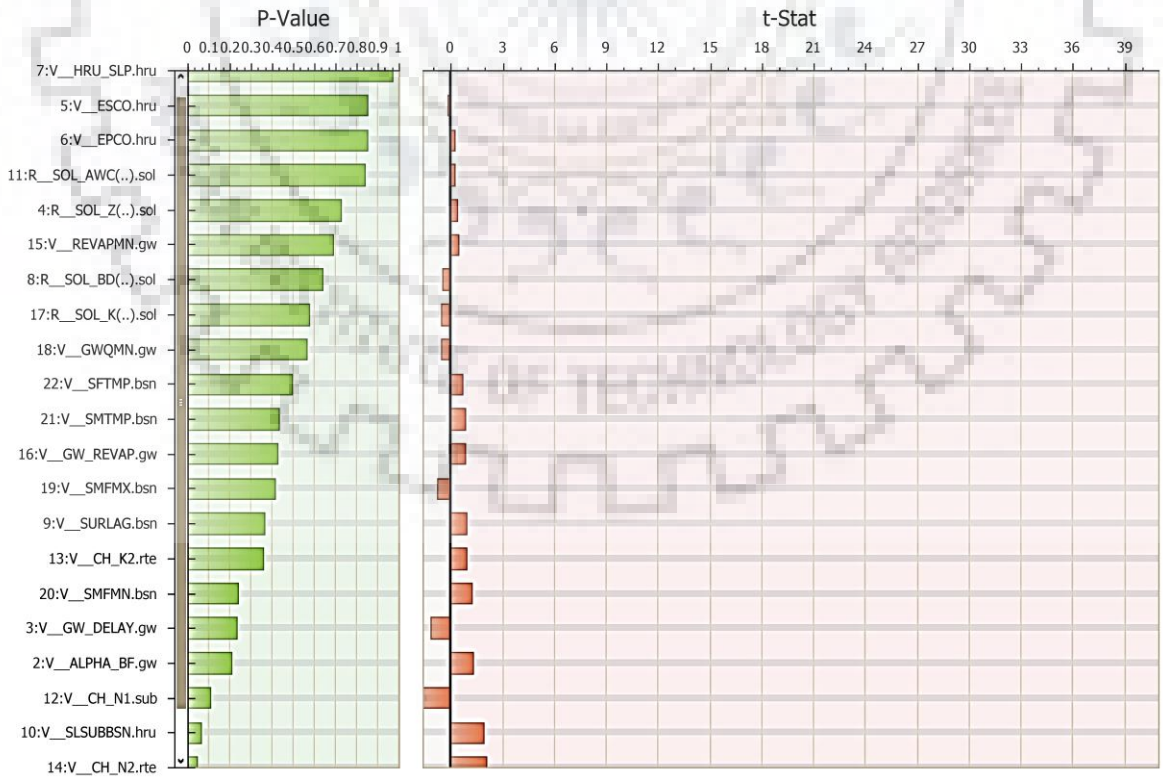

Figure 5. 10 : P-value and t-stat showing Global sensitivity of respective iteration

Table 5. 2: P-values and t-stat values of respective iteration

Parameter Name	t-Stat	P-Value
7:V__HRU_SLP.hru	-0.04	0.97
5:V__ESCO.hru	-0.19	0.85
6:V__EPCO.hru	0.19	0.85
11:R__SOL_AWC(..).sol	0.20	0.84
4:R__SOL_Z(..).sol	0.35	0.73
15:V__REVAPMN.gw	0.40	0.69
8:R__SOL_BD(..).sol	-0.47	0.64
17:R__SOL_K(..).sol	-0.56	0.58
18:V__GWQMN.gw	-0.58	0.56
22:V__SFTMP.bsn	0.69	0.49
21:V__SMTMP.bsn	0.79	0.43
16:V__GW_REVAP.gw	0.80	0.43
19:V__SMFMX.bsn	-0.82	0.41
9:V__SURLAG.bsn	0.91	0.36
13:V__CH_K2.rte	0.93	0.36
20:V__SMFMN.bsn	1.18	0.24
3:V__GW_DELAY.gw	-1.20	0.23
2:V__ALPHA_BF.gw	1.26	0.21
12:V__CH_N1.sub	-1.63	0.10
10:V__SLSUBBSN.hru	1.87	0.06
14:V__CH_N2.rte	2.05	0.04
1:R__CN2.mgt	40.94	0.00

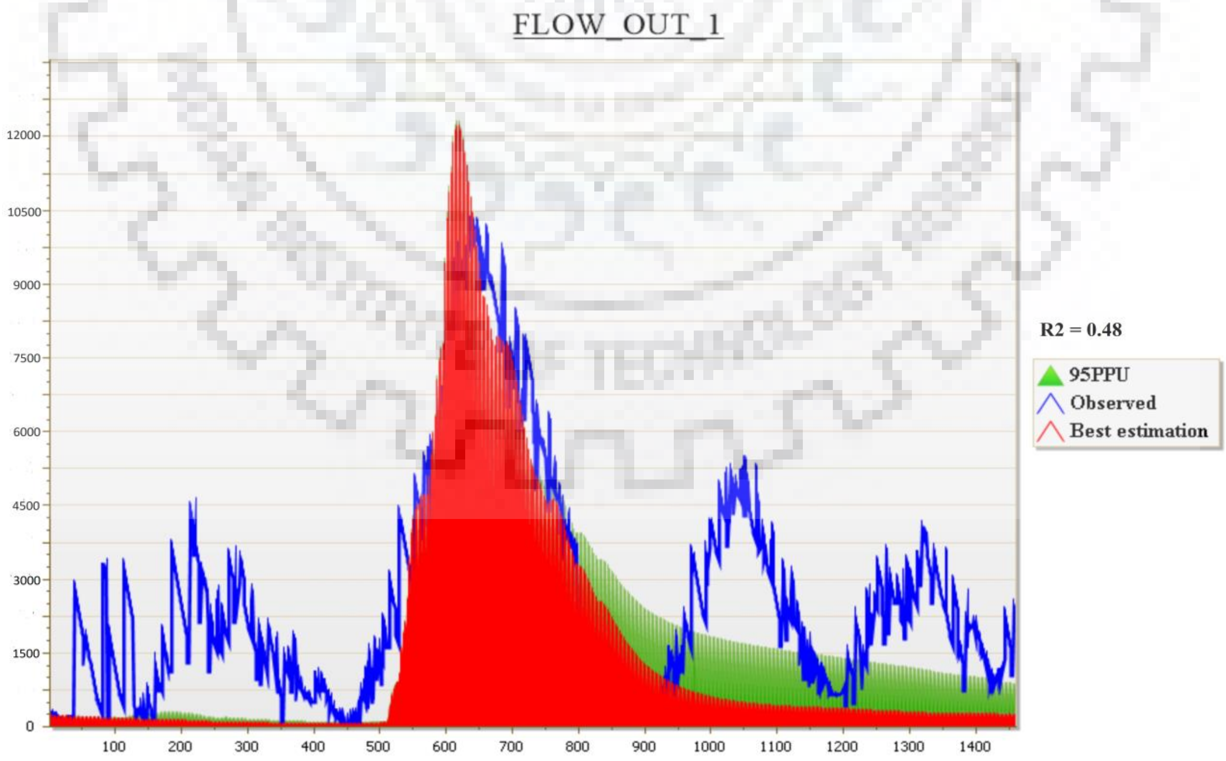

Figure 5. 11: 95ppu Plot showing compatibility of observed and best simulated value

Table 5. 3: Observed data and Best Simulated data obtained after calibration

Sl. no.	Observed Data	Simulated Data	30 31	158.0007913 137.2980469	23.955 219.45
1	375.8960257	249.15	32	240.1802269	103.695
2	362.3441815	140.595	33	240.1802269	23.655
3	290.4371753	26.7	34	158.0007913	216.6
4	290.4371753	245.7	35	281.4278303	100.83
5	375.8960257	136.425	36	209.5208241	23.34
6	362.3441815	26.34	37	3137.242162	214.05
7	290.4371753	242.4	38	3137.242162	98.145
8	290.4371753	132.27	39	3055.062726	23.055
9	321.4123492	26.175	40	2972.88329	211.8
10	259.7777725	239.4	41	2890.703855	95.58
11	321.5702348	128.175	42	2808.524419	22.815
12	249.6632286	25.89	43	2726.344983	209.7
13	249.6632286	236.55	44	2644.165548	93.15
14	260.0935436	124.215	45	2561.986112	22.59
15	188.1865374	25.575	46	2479.806677	208.5
16	219.1617114	233.85	47	2397.627241	91.185
17	219.1617114	120.375	48	2315.447805	22.425
18	136.9822757	25.26	49	2233.268369	207.15
19	198.774738	230.85	51	2068.909499	22.26
20	219.1617114	116.715	52	1986.730063	205.65
21	219.1617114	24.915	53	1904.550627	87.15
22	136.9822757	228	54	1822.371191	22.11
23	198.774738	113.205	55	2068.909499	204.15
24	126.8677318	24.6	56	1986.730063	85.215
25	126.8677318	225.15	57	1904.550627	21.945
26	198.9326236	109.875	58	1822.371191	202.95
27	137.2980469	24.255	59	1740.191756	83.37
28	240.1802269	222.3	60	1658.01232	21.795
29	240.1802269	106.71	61	1575.832884	201.6

62	1493.653449	81.6	94	1843.034464	184.65
63	1411.474013	21.645	95	1760.855028	66.675
64	1411.474013	200.4	96	1678.675593	19.98
65	1329.294578	79.905	97	1596.496158	183.3
66	1247.115142	21.51	98	1514.316722	65.655
67	1164.935706	199.35	99	1432.137286	19.89
68	1082.75627	78.3	100	1349.957851	182.25
69	1000.576835	21.375	101	1267.778415	64.665
70	918.3973997	197.55	102	1185.598979	19.755
71	836.217964	76.755	103	1103.419544	181.2
72	754.038528	21.165	104	1021.240108	63.72
73	671.8590924	195.9	105	939.0606725	19.62
74	589.6796568	75.285	106	856.8812368	179.7
75	589.6796568	20.985	107	774.7018011	62.805
76	507.5002211	194.4	108	692.5223655	19.5
77	507.5002211	73.89	109	692.5223655	178.05
78	425.3207855	20.82	110	610.3429299	61.935
79	343.1413499	193.05	111	528.1634942	19.35
80	3465.959904	72.555	112	3568.802613	176.7
81	3465.959904	20.7	113	3486.623177	61.095
82	3383.780468	191.4	114	3404.443742	19.23
83	3301.601032	71.265	115	3322.264306	175.5
84	3465.959904	20.58	116	3240.08487	60.285
85	3383.780468	189.45	117	3157.905435	19.14
86	3301.601032	70.035	118	3075.725999	173.55
87	3219.421598	20.4	119	2993.546563	59.505
88	3568.697356	187.65	120	2911.367127	19.05
89	281.5857159	68.865	121	2829.187692	171.75
90	2171.752207	20.235	122	2747.008257	58.725
91	2089.572771	186	123	2664.828821	18.81
92	2007.393336	67.74	124	2582.649385	170.85
93	1925.2139	20.1	125	2500.469949	58.335

126	2418.290514	18.945	158	200.0772939	51.795
127	2336.111078	169.65	159	1586.894742	17.475
128	2253.931643	57.78	160	1432.808299	156
129	446.02353	18.795	161	1350.628865	51.255
130	446.02353	168.6	162	1268.449429	17.25
131	363.8440943	57.165	163	1186.269993	154.65
132	312.5608899	18.645	164	1104.090557	50.76
133	405.1048548	167.7	165	1021.911122	17.055
134	322.9912049	56.55	166	785.6452441	153.15
135	394.9771538	18.51	167	785.6452441	50.25
136	394.9771538	166.8	168	939.7711572	16.905
137	487.4421761	55.92	169	857.5917222	155.4
138	610.7902723	18.405	170	2172.502163	53.1
139	384.8626099	166.05	171	2090.322727	16.89
140	302.6831743	55.275	172	2008.143292	155.7
141	220.5037387	18.33	173	1925.963857	55.26
142	734.1383685	164.85	174	1843.784421	16.815
143	487.6000616	54.66	175	1761.604985	155.25
144	487.6000616	18.255	176	1679.425549	55.92
145	117.8583869	163.5	177	1515.066678	16.755
146	56.22381016	54.06	178	1597.285585	154.05
147	939.6527431	18.21	179	1432.926714	55.92
148	857.4733073	162.3	180	1350.747279	16.62
149	857.4733073	53.475	181	1268.567843	152.85
150	610.9350007	18.075	182	1186.388407	55.575
151	693.1539077	160.8	183	1186.388407	16.53
152	528.7950365	52.905	184	3980.52869	151.8
153	446.6156009	17.88	185	3898.349254	55.05
154	446.6156009	159.3	186	3816.169819	16.425
155	364.4361652	52.35	187	3733.990384	150.6
156	282.2567295	17.7	188	3651.810948	54.42
157	200.0772939	157.65	189	3569.631512	16.23

190	3487.452076	149.685	222	3877.962281	14.7075
191	3405.272641	53.745	223	3795.782845	132.78
192	3323.093205	16.065	224	3713.60341	46.53
193	3240.91377	148.155	225	3631.423975	14.4975
194	3158.734334	53.025	226	3549.244539	129.99
195	3076.554898	15.915	227	3467.065103	45.945
196	2994.375463	146.595	228	2727.118133	14.193
197	2912.196027	52.305	229	3507.849086	127.14
198	2830.016591	15.75	230	3425.66965	45.3
199	2747.837155	145.215	231	3343.490215	13.815
200	2665.65772	51.6	232	3343.490215	123.9
201	2583.478285	15.615	233	3261.310779	44.835
202	2501.298849	143.445	234	3179.131343	13.371
203	2419.119413	50.895	235	3076.44652	121.275
204	2336.939977	15.42	236	3179.131343	44.31
205	2254.760542	141.945	237	2994.267084	13.0065
206	2172.620577	50.205	238	2994.267084	119.055
207	2090.441142	15.27	239	2912.087648	43.8
208	2008.261707	140.685	240	2829.908214	12.7125
209	1926.082271	49.545	241	2141.65544	117.27
210	1864.447694	15.15	242	1679.435586	43.335
211	4062.787069	139.635	243	2624.538566	12.483
212	4802.401989	48.915	244	2542.359132	115.845
213	4720.222554	15.06	245	2460.179696	42.885
214	4638.043118	138.555	246	2378.00026	12.3075
215	4555.863682	48.3	247	2295.820824	114.735
216	4473.684246	15	248	2213.641389	42.45
217	4391.504812	136.35	249	1967.103082	12.18
218	4309.325376	47.685	250	1884.923646	113.88
219	4227.14594	14.97	251	1802.744211	42
220	4144.966504	134.4	252	1720.564775	12.0345
221	4864.115509	47.085	253	2727.276019	113.19

254	2069.840534	41.595	286	3056.230589	103.995
255	2912.245534	11.868	287	3056.230589	41.34
256	2830.066099	113.1	288	3754.782106	11.6295
257	3014.982986	43.92	289	3672.602671	103.65
258	1823.407483	12.063	290	3590.423235	40.86
259	1741.228048	113.07	291	3590.423235	11.559
260	1679.593471	44.7	292	3487.738412	103.08
261	2645.241311	12.0105	293	3405.558977	40.38
262	2563.061876	113.055	294	3323.379541	11.5245
263	2480.88244	44.82	295	3241.200105	101.46
264	2398.703004	11.9595	296	3159.020669	39.9
265	2316.523568	113.13	297	2583.76462	11.247
266	2234.344133	44.655	298	2501.585184	99.81
267	2152.164698	11.937	299	2419.405749	39.42
268	2069.985262	112.035	300	2337.226313	10.977
269	1987.805826	44.295	301	2255.046878	98.535
270	1905.626391	11.943	302	2172.867442	38.985
271	3795.75341	109.89	303	2090.688006	10.77
272	3713.573975	43.845	304	2008.50857	97.605
273	3631.394539	11.973	305	2686.502072	38.565
274	3549.215103	108.015	306	3056.335846	10.62
275	3467.035667	43.35	307	2974.156411	96.975
276	3384.856232	11.94	308	2891.976975	38.16
277	3302.676797	106.56	309	2809.79754	10.518
278	3220.497361	42.855	310	1905.863219	96.585
279	3220.497361	11.8365	311	1823.683783	37.77
280	3138.317925	105.435	312	1741.504347	10.458
281	2727.420747	42.36	313	1659.324912	95.955
282	3857.466929	11.7705	314	1577.145477	37.395
283	2953.493138	104.595	315	1494.966041	10.4355
284	2871.313702	41.85	316	2316.799869	95.37
285	2789.134266	11.7405	317	2234.659904	37.02

318	2152.480469	10.446	350	796.8355517	33.705
319	2070.301033	94.26	351	714.656116	9.462
320	1988.121597	36.645	352	632.4766802	86.205
321	1412.865548	10.4655	353	550.2972445	33.51
322	1906.021104	93.3	354	1700.848815	9.465
323	1823.841668	36.285	355	1618.66938	86.31
324	1741.662233	10.3185	356	1536.489944	33.315
325	1659.482798	92.64	357	1454.310508	9.4965
326	1577.303362	35.955	358	1372.131073	86.58
327	1495.123926	10.221	359	1289.951637	33.09
328	1351.309914	92.07	360	1207.772201	9.5535
329	1413.023433	35.625	361	1721.778352	86.16
330	2316.997226	10.164	362	1639.598917	33.765
331	2234.81779	90.78	363	1557.419481	9.6195
332	2152.638354	35.295	364	1475.240045	85.665
333	2152.638354	10.0545	365	1393.060609	33.915
334	2070.458918	89.43	366	1310.881174	9.5715
335	1988.279483	34.965	367	1228.701738	84.6
336	1803.454695	9.846	368	2050.535566	33.825
337	1803.454695	88.47	369	1968.35613	9.4455
338	1721.27526	34.665	370	1968.35613	83.835
339	1639.095824	9.696	371	1886.176694	34.275
340	1556.916389	87.78	372	1886.176694	9.387
341	1474.736953	34.365	373	1803.997259	83.445
342	1228.198646	9.594	374	1146.601246	34.8
343	1906.192147	87.3	375	1064.42181	9.3495
344	1330.936097	34.08	376	1310.999588	82.635
345	2029.487615	9.5385	377	1228.820152	34.89
346	1125.553294	86.67	378	982.3213168	9.321
347	1043.373858	33.795	379	900.141881	81.855
348	961.1944232	9.462	380	828.2348751	34.755
349	879.0149875	86.325	381	1064.540224	9.276

382	879.7549078	80.535	414	942.0210266	8.1075
383	797.575472	34.515	415	1024.318876	70.8
384	715.3960364	9.1695	416	1024.318876	30.975
385	715.3960364	79.08	417	942.1789121	8.1795
386	859.3679345	34.2	418	859.9994764	70.245
387	777.1884987	8.9655	419	788.0924704	30.69
388	705.2814926	77.355	420	788.0924704	8.2725
389	705.2814926	33.855	421	726.5368365	69.69
390	756.8015254	8.649	422	819.028173	30.3
391	674.6220898	76.05	423	654.7087731	8.298
392	612.987513	33.51	424	654.7087731	69.42
393	777.5042698	8.445	425	572.5293375	30.165
394	695.3248342	75.135	426	736.9276801	8.322
395	613.1453986	33.18	427	490.4288446	69.42
396	613.1453986	8.2245	428	408.249409	29.91
397	613.1453986	74.565	429	408.249409	8.3355
398	551.5108219	32.85	430	572.6477517	69.645
399	551.5108219	8.1015	431	326.1489161	29.685
400	551.5108219	74.175	432	326.1489161	8.379
401	1188.401448	32.52	433	387.8624356	70.05
402	1188.401448	8.028	434	387.8624356	30.975
403	1106.222013	73.215	435	257.758153	8.415
404	1024.042577	32.19	436	326.3857445	69.255
405	941.8631412	79.98	437	244.2063088	31.395
406	859.6837054	72.6	438	182.6112035	8.277
407	1270.659826	31.875	439	408.6441229	68.19
408	859.8021195	8.007	440	326.54363	31.44
409	777.622684	72.285	441	326.54363	8.1705
410	777.622684	31.575	442	244.3641944	67.395
411	1188.559334	8.0475	443	408.7625371	31.32
412	1106.379898	71.55	444	265.0669389	8.043
413	1024.200462	31.275	445	265.0669389	66.705

446	17.6587231	55.23	478	1210.998819	78.285
447	18.56810334	7.92	479	1128.819383	32.715
448	18.56810334	65.73	480	1395.915706	7.8465
449	80.25530857	30.825	481	909.6873792	78.855
450	285.7696833	7.791	482	1765.788952	32.34
451	203.5902477	65.1	483	1683.609517	7.89
452	29.03788974	30.555	484	1601.430081	82.29
453	29.03788974	7.7115	485	1519.250646	33.87
454	368.0412188	64.635	486	1026.174032	7.9065
455	121.502912	30.255	487	1026.174032	85.17
456	121.502912	7.6725	488	1272.75181	35.835
457	255.1102805	66.36	489	1190.572374	8.0865
458	409.2756651	32.1	490	1108.392939	85.545
459	327.0962295	7.746	491	1930.226767	36.435
460	327.0962295	67.185	492	1930.226767	8.097
461	255.2681661	32.715	493	1848.047331	85.455
462	409.4335507	7.758	494	1437.150153	36.465
463	327.2541151	66.78	495	1365.243147	8.118
464	265.6590097	32.805	496	1663.222543	85.08
465	265.6590097	7.653	497	1581.043108	36.195
466	553.3265059	66.435	498	1498.863673	8.1615
467	471.1470702	32.67	499	1765.959995	85.95
468	656.0639576	7.5915	500	1889.308092	35.79
469	389.007106	72.75	501	1403.079764	8.2275
470	943.7577676	33.18	502	1601.706381	90.375
471	861.5783326	7.572	503	1519.526946	35.28
472	779.3988966	75.555	504	2423.540209	8.2275
473	697.2589324	33.21	505	2341.360773	92.07
474	635.6243556	7.614	506	2341.360773	36.075
475	1026.029303	77.355	507	2259.181338	8.262
476	841.1518872	33.03	508	2177.001902	92.325
477	1293.178255	7.7715	509	2094.822466	36.105

510	2012.643031	8.2305	542	3656.310686	2140.5
511	1766.104723	117.48	543	3574.13125	113.1
512	1683.925288	104.895	544	3491.951815	3433.5
513	1683.925288	9.2955	545	3409.77238	2290.5
514	3327.514001	190.65	546	3327.632415	134.925
515	3245.334565	441.15	547	3245.452979	3934.5
516	3163.15513	35.31	548	3163.273544	2464.5
517	3080.975694	261.45	549	3081.094108	160.65
518	2998.796258	640.8	550	3019.459532	4239
519	2916.616822	38.28	551	3019.459532	2544
520	2834.437387	507.3	552	5382.157777	159.45
521	2752.257952	778.2	553	5299.978342	4413
522	2670.078516	37.995	554	5217.798906	2562
523	2587.89908	736.5	555	5135.619471	152.85
524	2587.89908	856.95	556	5053.440035	4506
525	2505.719644	37.38	557	4971.260599	2548.5
526	1930.503066	889.8	558	4889.081163	145.365
527	1848.323631	901.2	559	4806.901728	4542
528	4724.643349	36.39	560	4806.901728	2527.5
529	4642.463914	1089.45	561	4724.761764	138.375
530	4560.284478	1004.4	562	4642.582328	4690.5
531	4478.105043	40.65	563	4560.402893	2830.5
532	4478.105043	1614	564	4498.768316	140.595
533	4395.925607	1434.3	565	5854.768475	4726.5
534	4313.746171	49.17	566	5772.58904	2962.5
535	4231.566735	1912.5	567	5772.58904	134.655
536	4149.3873	1762.5	568	5690.409604	4711.5
537	4067.207865	77.61	569	5608.230168	3012
538	3985.028429	2136	570	5526.050733	129.645
539	3902.848993	1962	571	5443.871297	4713
540	3820.669558	82.5	572	5957.505926	3138
541	3738.490122	2608.5	573	5957.505926	139.485

574	4786.475283	5104.5	606	8123.212425	205.2
575	6224.654878	3654	607	8123.212425	11262
576	6142.475442	153	608	8041.03299	5605.5
577	6060.296007	5551.5	609	7958.853554	212.7
578	5238.501651	4095	610	9951.718025	11875.5
579	5156.322215	163.35	611	9951.718025	5638.5
580	5074.142779	5970	612	8308.129313	207.3
581	4991.963343	4752	613	8677.963087	12136.5
582	4909.783908	192.45	614	8595.783652	5571
583	4837.876902	6324	615	8513.604216	197.1
584	5341.239102	5152.5	616	8431.42478	12207
585	6327.39233	208.95	617	10301.04641	5451
586	6327.39233	7068	618	10218.86698	186.9
587	5526.208618	5398.5	619	10136.68754	12241.5
588	5454.301612	206.55	620	10054.50811	5407.5
589	7498.515074	7446	621	10403.78387	181.35
590	7416.335638	5497.5	622	9951.823282	12132
591	7334.156202	203.55	623	9869.643847	5292
592	7251.976766	7671	624	9787.464411	172.65
593	7251.976766	5524.5	625	9705.284975	11938.5
594	7169.797331	194.1	626	9623.105539	5142
595	7087.617895	7773	627	9540.926104	163.8
596	7005.43846	5500.5	628	9458.746669	11689.5
597	6923.259024	190.5	629	9397.112092	4978.5
598	6841.079588	9426	630	10239.53025	158.1
599	6758.900153	5647.5	631	10177.89567	11407.5
600	6676.720717	217.35	632	10465.56317	4861.5
601	9027.186217	10347	633	10383.38374	152.85
602	8945.006781	5650.5	634	10301.20429	11085
603	8862.827345	213.45	635	10568.30062	4705.5
604	8780.647911	10881	636	10856.07337	145.14
605	8205.39186	5581.5	637	10773.89394	10767

638	10691.7145	4537.5	670	9459.338739	7851
639	10568.30062	137.955	671	9377.159303	3126
640	10856.07337	10474.5	672	9294.979868	117.27
641	10773.89394	4368	673	9212.800433	7758
642	10691.7145	131.715	674	9130.620997	3165
643	10609.53507	10141.5	675	9048.441561	122.475
644	10527.35563	4189.5	676	8966.262125	7950
645	10455.44863	125.355	677	8884.08269	3520.5
646	10815.10207	9804	678	8801.903254	165.75
647	10732.96211	4015.5	679	8719.723818	7944
648	10650.78267	119.145	680	8637.544383	3672
649	10568.60323	9450	681	8555.364947	168.75
650	10486.4238	3840	682	8483.457941	7884
651	10414.5168	113.745	683	10281.17257	3759
652	9767.393208	9096	684	10198.99313	179.55
653	10219.41957	3666	685	10116.8137	7830
654	10137.24014	108.42	686	10034.63426	3849
655	10055.0607	8767.5	687	9952.454824	200.4
656	9972.881269	3514.5	688	9870.275388	7770
657	9890.701834	104.475	689	9788.095953	3939
658	9808.522398	8748	690	7630.925239	208.8
659	10322.15703	3502.5	691	7548.745803	7825.5
660	10691.9908	115.665	692	7466.566367	4179
661	10609.81137	8587.5	693	7384.386932	225.75
662	10527.63193	3444	694	7302.207497	7761
663	10445.4525	126.195	695	8288.360724	4258.5
664	9705.877046	8362.5	696	8206.181288	220.8
665	9623.697611	3345	697	8124.001853	7618.5
666	9541.518175	123.615	698	8041.822417	4251
667	9459.338739	8106	699	7959.642982	211.35
668	9623.697611	3228	700	7877.463546	7450.5
669	9541.518175	119.01	701	7795.28411	4200

702	7713.104675	204.6	734	6624.385038	2916
703	8391.098176	7264.5	735	6542.205603	169.65
704	8925.290822	4111.5	736	6953.142252	5115
705	8843.111386	194.55	737	5556.131318	2848.5
706	8760.93195	7048.5	738	6871.002287	175.65
707	8678.752515	3999	739	6788.822852	5038.5
708	8596.573079	184.65	740	6460.10511	2847
709	8514.393643	6813	741	6377.925674	177.9
710	6953.023838	3870	742	6295.746238	4947
711	6870.844402	175.05	743	6213.566802	2832
712	6798.937396	6571.5	744	6131.387367	174.6
713	7199.562145	3733.5	745	6049.207932	4813.5
714	7117.382709	166.05	746	5967.028496	2776.5
715	7035.203273	6330	747	6131.387367	170.4
716	8350.113715	3594	748	6049.207932	4687.5
717	8267.93428	158.4	749	5967.028496	2700
718	7035.203273	6087	750	5884.84906	163.8
719	8350.113715	3451.5	751	5802.669624	4624.5
720	8267.93428	152.7	752	5720.490189	2671.5
721	8185.754844	5871	753	5638.310753	168.3
722	8103.575408	3310.5	754	5083.639034	4525.5
723	8021.395972	145.62	755	6706.682888	2613
724	7939.216537	5649	756	6624.503452	163.8
725	7857.037102	3171	757	6542.324017	4590
726	7774.857666	141.87	758	6542.324017	2538
727	7692.67823	5445	759	5371.30653	164.55
728	7610.498794	3045	760	5289.127095	4612.5
729	7528.319359	140.925	761	5206.947659	2499
730	7446.139923	5320.5	762	5124.768223	162.45
731	7363.960487	2962.5	763	5474.043982	4630.5
732	7281.781052	156.3	764	5761.698321	2448
733	6706.564474	5223	765	5679.518885	158.7

766	5597.339449	4587	798	3913.213618	122.895
767	5022.122871	2386.5	799	3666.714783	3304.5
768	4939.943436	155.4	800	1234.069847	1611
769	4857.764	4500	801	1162.162841	129.915
770	4857.764	2310	802	1398.46819	3282
771	5186.521214	148.77	803	967.0656244	1636.5
772	5104.341778	4389	804	884.8861886	130.995
773	4775.663508	2229	805	823.2516116	3250.5
774	4693.484072	142.665	806	823.2516116	1668
775	4611.304636	4275	807	823.2516116	134.265
776	4940.06185	2154	808	1069.803076	3187.5
777	4857.882414	137.58	809	1193.098543	1665
778	4056.632917	4144.5	810	967.2235098	135.81
779	4056.632917	2068.5	811	885.0440741	3115.5
780	4426.479849	131.49	812	885.0440741	1639.5
781	4344.300413	4008	813	823.4094971	133.005
782	4262.120977	1978.5	814	885.2019596	3028.5
783	4179.941541	125.625	815	813.2949536	1596
784	4097.762106	3870	816	864.8149863	131.145
785	4529.2173	1899	817	864.8149863	2935.5
786	4652.512768	125.655	818	864.8149863	1546.5
787	3995.116755	3730.5	819	803.1804093	129.285
788	3923.209748	1825.5	820	864.9728718	2839.5
789	4159.515097	123.345	821	803.3382955	1490.7
790	4056.830274	3592.5	822	865.1307572	126.015
791	4056.830274	1747.5	823	865.1307572	2740.5
792	3954.184922	119.205	824	803.496181	1433.85
793	3882.277916	3456	825	865.2886427	128.085
794	3728.230945	1666.8	826	865.2886427	2652
795	4015.898442	114.84	827	865.4465289	1424.25
796	3789.918151	3327	828	865.6044144	125.73
797	3789.918151	1605	829	865.6044144	2560.5

830	865.7622999	1391.7	862	930.0809306	1957.5
831	907.0099028	121.155	863	991.8733931	985.5
832	845.3753266	2551.5	864	930.2388169	89.22
833	907.1677883	1361.85	865	992.0312786	1891.5
834	845.5332121	118.485	866	930.3967024	941.85
835	845.5332121	2548.5	867	992.1891641	86.475
836	907.3256746	1365.6	868	930.5545878	1827
837	845.6910976	122.04	869	930.5545878	899.85
838	845.8095117	2509.5	870	992.3470503	83.895
839	845.8095117	1344.45	871	992.5049358	1764
840	907.48356	118.77	872	992.6628212	856.95
841	907.6414455	2451	873	992.8207067	81.495
842	907.799331	1308	874	910.7202137	1704
843	907.9572164	114.525	875	910.7202137	821.1
844	908.1151019	2385	876	828.540778	79.245
845	908.1151019	1264.5	877	828.540778	1647
846	949.3627056	110.265	878	746.3613425	784.35
847	887.7281286	2314.5	879	746.3613425	77.145
848	949.5205911	1219.95	880	992.9391208	1591.5
849	887.8860141	106.17	881	664.2608497	749.4
850	887.8860141	2242.5	882	582.0814141	75.18
851	949.6784766	1172.85	883	582.0814141	1539
852	888.0438996	102.315	884	510.1744078	715.95
853	949.836362	2169	885	510.1744078	73.35
854	949.836362	1124.85	886	910.8386278	1487.85
855	888.201785	98.7	887	828.6591921	684.3
856	949.9942475	2097	888	746.4797567	71.64
857	949.9942475	1077.45	889	438.3463444	1439.4
858	950.152133	95.325	890	643.8738763	654.3
859	950.3100184	2026.5	891	561.6944407	70.035
860	950.4679047	1030.8	892	561.6944407	1393.2
861	991.7155077	92.175	893	489.7874345	625.65

894	582.3971852	68.535	926	809.6537174	417.3
895	500.2177496	1349.1	927	727.4742821	57.975
896	438.5831728	598.5	928	1076.750041	992.4
897	438.5831728	67.125	929	645.3343178	405.9
898	603.0999296	1307.1	930	1179.540121	57.015
899	520.920494	572.85	931	1282.277572	967.2
900	603.0999296	65.805	932	1076.855298	395.4
901	520.920494	1268.1	933	994.6758618	55.98
902	438.7410583	548.55	934	933.0412855	943.35
903	438.7410583	64.575	935	1734.330254	385.8
904	521.0783796	1236.3	936	1734.330254	55.005
905	438.8989439	526.95	937	1652.150818	920.4
906	356.7195083	63.51	938	1569.971383	376.95
907	267.7838863	1203.15	939	1487.791948	54.075
908	267.7838863	508.35	940	1652.150818	898.8
909	377.4222527	63.495	941	1569.971383	368.7
910	315.8666188	1169.7	942	1487.791948	53.205
911	418.6698562	490.5	943	1405.612512	878.1
912	377.6590811	62.565	944	1241.293112	361.2
913	500.9413917	1137	945	1159.113676	52.425
914	500.9413917	473.55	946	2063.12694	858.45
915	542.1758379	61.56	947	1980.947504	354.3
916	459.9964023	1105.65	948	1898.768068	51.675
917	449.8818584	457.8	949	1816.588633	839.7
918	542.3468807	60.585	950	1323.512019	348
919	542.3468807	1075.35	951	1323.512019	50.955
920	665.7607626	443.25	952	1570.089797	821.85
921	583.5813269	59.655	953	1487.910362	342.15
922	583.5813269	1046.4	954	1405.730926	50.295
923	511.6743207	429.75	955	1734.48814	804.9
924	974.0125889	58.8	956	1734.48814	336.75
925	891.8331532	1018.8	957	1662.581134	49.68

958	2556.282496	788.7	990	2392.042039	44.835
959	2474.10306	331.8	991	2309.862603	653.85
960	2391.923625	49.125	992	3953.503945	296.55
961	2309.744189	773.25	993	3522.088222	44.52
962	2227.564753	327.3	994	3727.576282	644.7
963	2227.564753	48.615	995	3645.396846	294.45
964	2145.385318	758.7	996	3573.48984	44.235
965	2063.245354	323.1	997	3830.313734	635.25
966	1981.065918	48.09	998	4446.725287	292.5
967	1898.886482	744.75	999	4364.545851	44.895
968	1816.707047	319.2	1000	4282.366416	624.75
969	3871.232409	47.61	1001	4446.725287	290.7
970	3789.052974	731.4	1002	4364.545851	43.665
971	3706.873538	315.6	1003	4282.366416	614.7
972	3624.694102	47.175	1004	4200.18698	289.05
973	3542.514666	718.65	1005	4118.007544	43.38
974	3706.873538	312.3	1006	4035.828109	605.1
975	3624.694102	46.755	1007	3953.648673	287.25
976	3542.514666	706.65	1008	3871.508709	43.095
977	3460.335231	309.15	1009	3789.329273	596.1
978	3378.155795	46.32	1010	3707.149837	285.75
979	3295.97636	695.1	1011	3645.515261	42.84
980	3213.796924	306.3	1012	5248.053727	587.25
981	3131.617488	45.945	1013	5165.874291	284.25
982	3049.438053	684	1014	5083.694856	42.585
983	2967.258617	303.6	1015	5001.51542	579
984	2885.079181	45.57	1016	4919.335985	282.75
985	2802.899745	673.5	1017	4837.156549	42.345
986	2720.72031	301.05	1018	4754.977113	571.35
987	2638.540875	45.18	1019	4672.797677	281.4
988	2556.40091	663.45	1020	4590.618242	42.12
989	2474.221475	298.8	1021	4508.438807	563.4

1022	5412.412598	280.05	1054	5430.647253	499.2
1023	5330.233163	41.835	1055	5348.467817	267.45
1024	5515.15005	555.9	1056	5266.288381	39.735
1025	4405.753984	278.85	1057	5184.108946	494.55
1026	4323.574548	41.55	1058	5101.92951	266.4
1027	4939.999258	548.7	1059	4691.032332	39.57
1028	4857.819822	277.5	1060	4608.852896	490.05
1029	5597.474214	41.28	1061	4526.67346	265.5
1030	5515.294778	542.1	1062	4444.494025	39.405
1031	5433.115343	276.3	1063	4362.31459	486
1032	5350.935907	41.04	1064	4280.135154	264.45
1033	5268.756472	535.8	1065	4197.955718	39.285
1034	5186.577036	275.1	1066	4115.776282	481.95
1035	5104.3976	40.845	1067	4043.869276	263.4
1036	5032.490594	529.95	1068	5595.045595	39.18
1037	5371.638652	274.05	1069	5512.86616	477.75
1038	5289.459216	40.665	1070	5019.789545	262.35
1039	5207.27978	524.4	1071	4937.61011	39.03
1040	5125.100345	272.85	1072	4855.430675	473.85
1041	5042.920909	40.515	1073	4773.251239	261.45
1042	4960.741474	519.3	1074	3807.64287	38.865
1043	4888.834467	271.8	1075	3848.772059	470.25
1044	5474.376104	40.395	1076	3951.509511	260.4
1045	5492.163415	514.2	1077	4403.562193	38.73
1046	4875.857119	270.6	1078	4321.382757	466.65
1047	4793.677684	40.275	1079	4239.203321	259.5
1048	5553.85062	508.95	1080	4157.023886	38.58
1049	4978.594571	269.55	1081	4074.84445	463.35
1050	5759.364995	40.08	1082	3746.126707	258.45
1051	4978.594571	504	1083	3890.019663	38.46
1052	5759.364995	268.5	1084	3807.840227	459.9
1053	5677.185559	39.915	1085	3561.30192	257.55

1086	3479.122485	38.31	1107	3129.951983	37.425
1087	3396.943049	456.6	1108	3581.965194	436.2
1088	3314.763613	256.5	1109	3499.785758	249.75
1089	3232.584178	38.175	1110	3417.606322	433.8
1090	3992.757114	453.6	1111	3335.426886	433.8
1091	3664.039372	255.6	1112	3253.247451	248.85
1092	4362.590889	38.055	1113	2331.512661	37.215
1093	4280.411453	450.75	1114	2783.539028	431.55
1094	4198.232018	254.55	1115	2701.359593	247.95
1095	4116.052582	37.965	1116	2619.180157	37.14
1096	3027.214531	447.75	1117	2537.000722	429.3
1097	2945.035096	253.65	1118	2454.821286	247.05
1098	2862.85566	37.86	1119	2372.641851	37.065
1099	2780.676224	444.6	1120	2886.27648	426.9
1100	2698.496788	252.75	1121	3420.469126	246
1101	2616.317353	37.71	1122	3338.289691	37.02
1102	2534.137918	441.6	1123	3256.110255	424.2
1103	2451.958482	251.7	1124	3173.930819	245.1
1104	2369.779046	37.56	1125	3091.751383	36.9
1105	2287.59961	438.75	1126	3009.571948	421.5
1106	2205.420175	250.8	1127	2269.996499	244.2

After required calibration as it did not come satisfactory i.e. R^2=0.48, there will be many reasons like presence of Kosi Barrage just before entering Kosi river in Bihar region, other reason can be taking daily flow data for calibration because in cases like flood changes takes place within 2-4 hours and daily discharge considers only 24-hour data that can be said average data for that day. But, one can utilize this information as a contribution to HEC-RAS and produce Flood inundation map and successively Flood hazard map of given study area.

5.4. FLOOD INUNDATION MAPPING

The HEC-RAS model parameters (Discharge and water level information utilizing Manning' n values) were aligned and used to evaluate the flood inundation in the channel reach as Rating curve will be appeared as shown in Figure 5.16 for unsteady flow. Results acquired from the investigation of HEC-RAS were utilized to create the water surface profile at different cross-section as shown in Figure 5.17 for unsteady flow analysis and Figure 5.19 for steady flow analysis and in Figure 5.22 in RAS mapper. Along these lines the outcomes are showing the flood inundation as shown in Figure 5.23 at low lying regions inside the waterway reach. The outcomes acquired were compared and the flood inundation areas of Kosi river sub-basin (for different periods) as appeared in Table 5.4 to 5.8 showing total discharge, water surface elevation, critical water surface elevation, energy gradient elevation, slope, velocity of channel, Froude no of channel. The inundation is more on inside the reach because of different reasons including overabundance precipitation, drainage, waterlogging, soil dampness, geology, land use etc. this may be because of high speed, tremendous measure of sediments and high slope on the upstream of Baltara. so one need to utilise available data as much as possible and to get more idea about the characteristics of given stream by seeing from X-Y-Z perspective plot (Figure 5.12), Stage and flow hydrology (Figure 5.14), cross-sectional view (Figure 5.13) and general profile plot showing velocities at right bank, left bank and main channel (Figure 5.18 and 5.20)

Evaluation of flood inundation area (Figure 5.25) and velocity variation map (Figure 5.23) using HEC-RAS is successful for the Kosi channel reach.

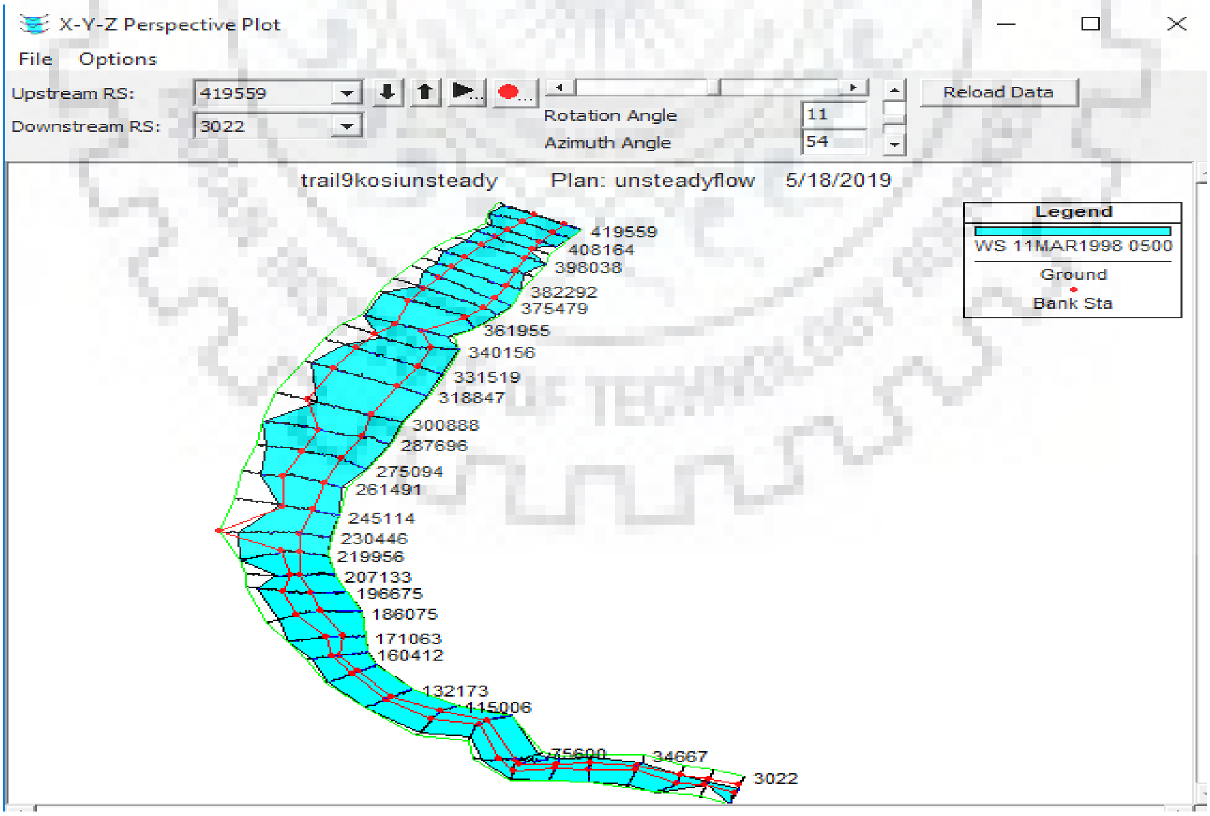

Figure 5. 12: X-Y-Z perspective plot along the Kosi river

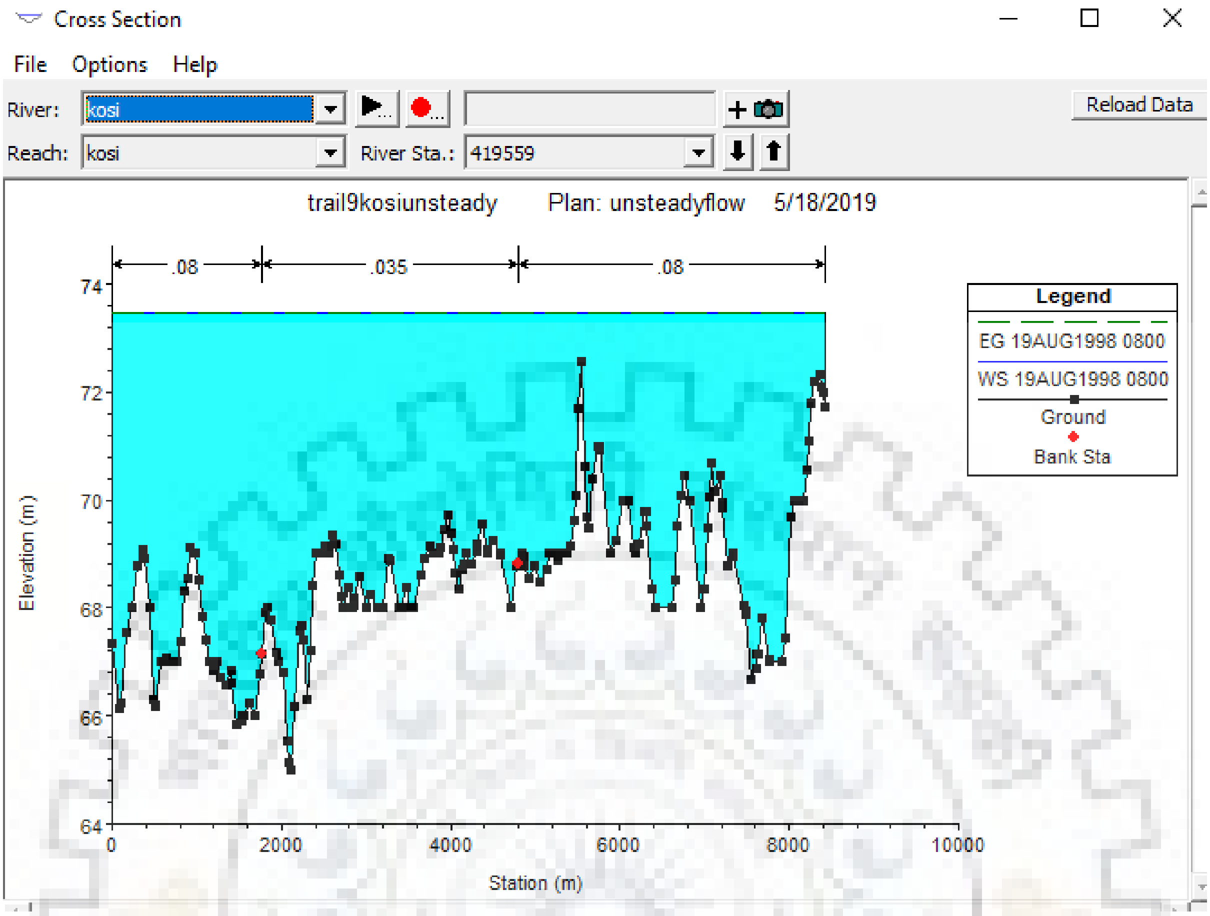

Figure 5. 13: Cross-section view of Kosi river in unsteady Flow analysis

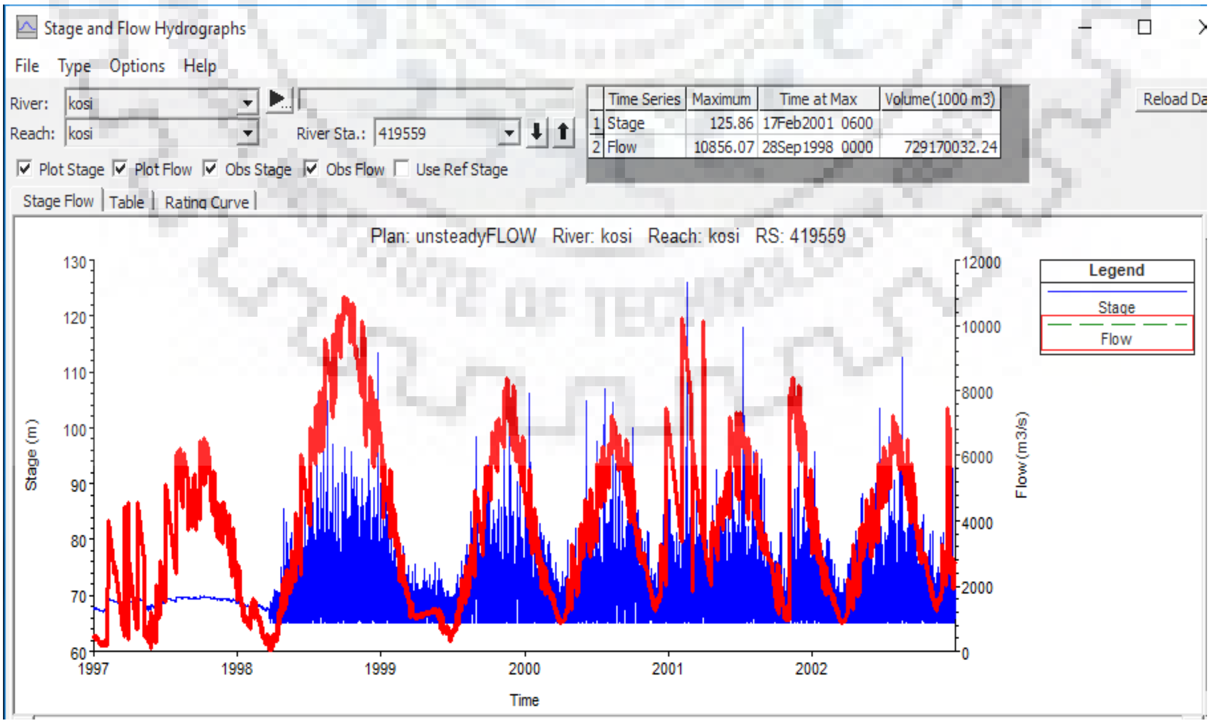

Figure 5. 14: Stage and Flow hydrograph at different cross-section

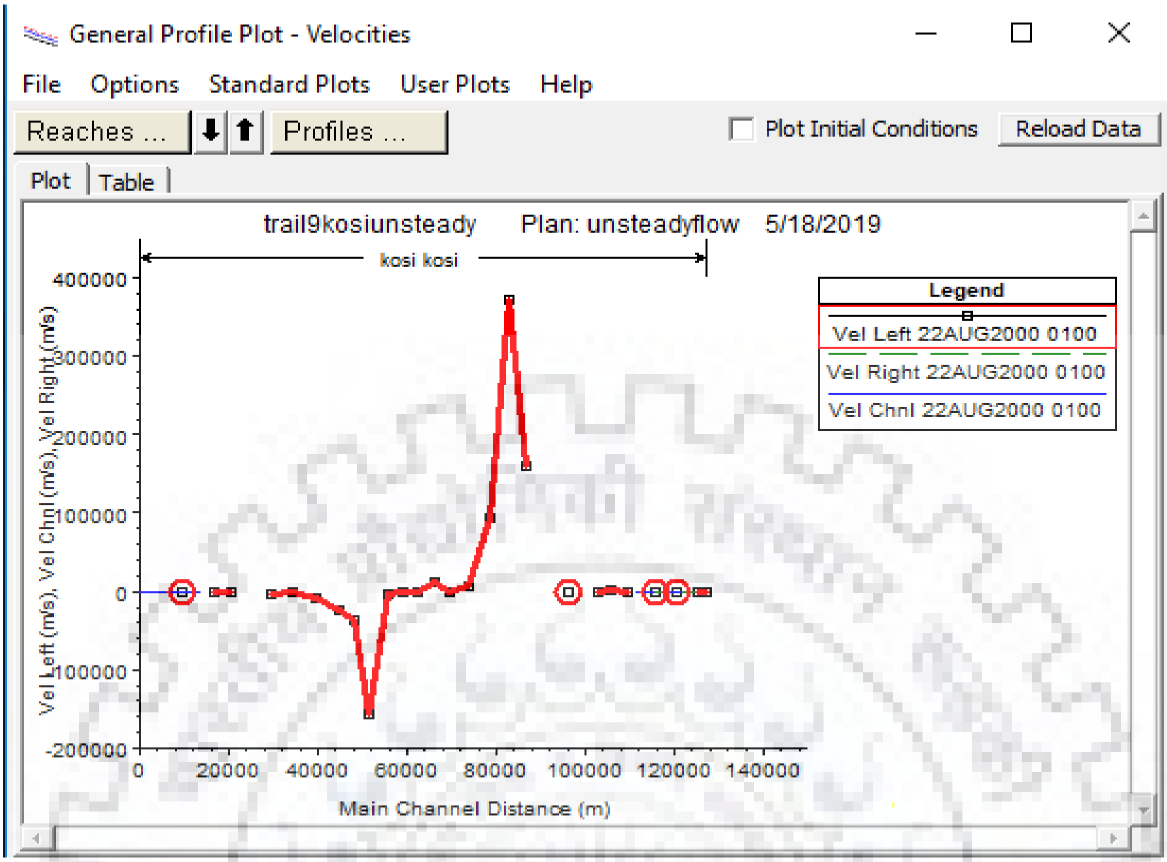

Figure 5. 15: General profile plot showing Velocities at right bank, left bank and center along the Kosi river under unsteady Flow analysis

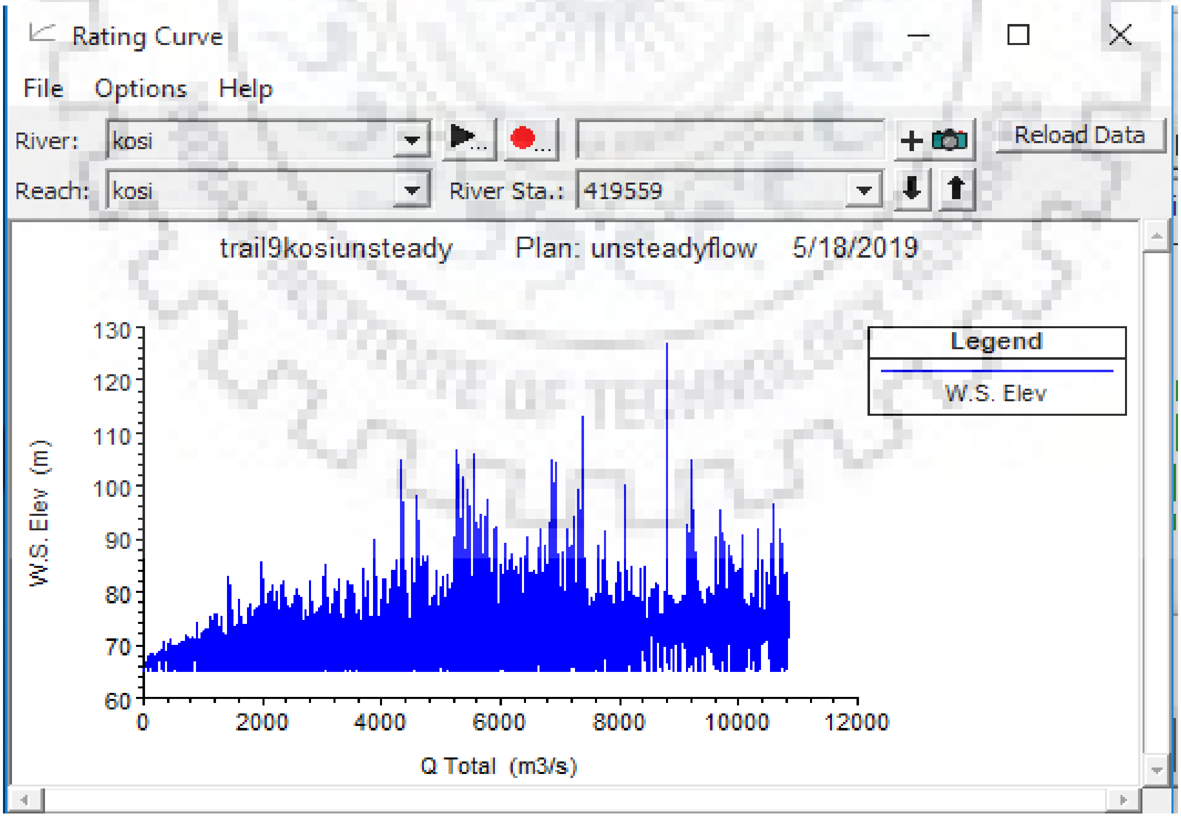

Figure 5. 16: Rating curve of Kosi river for Unsteady Flow analysis

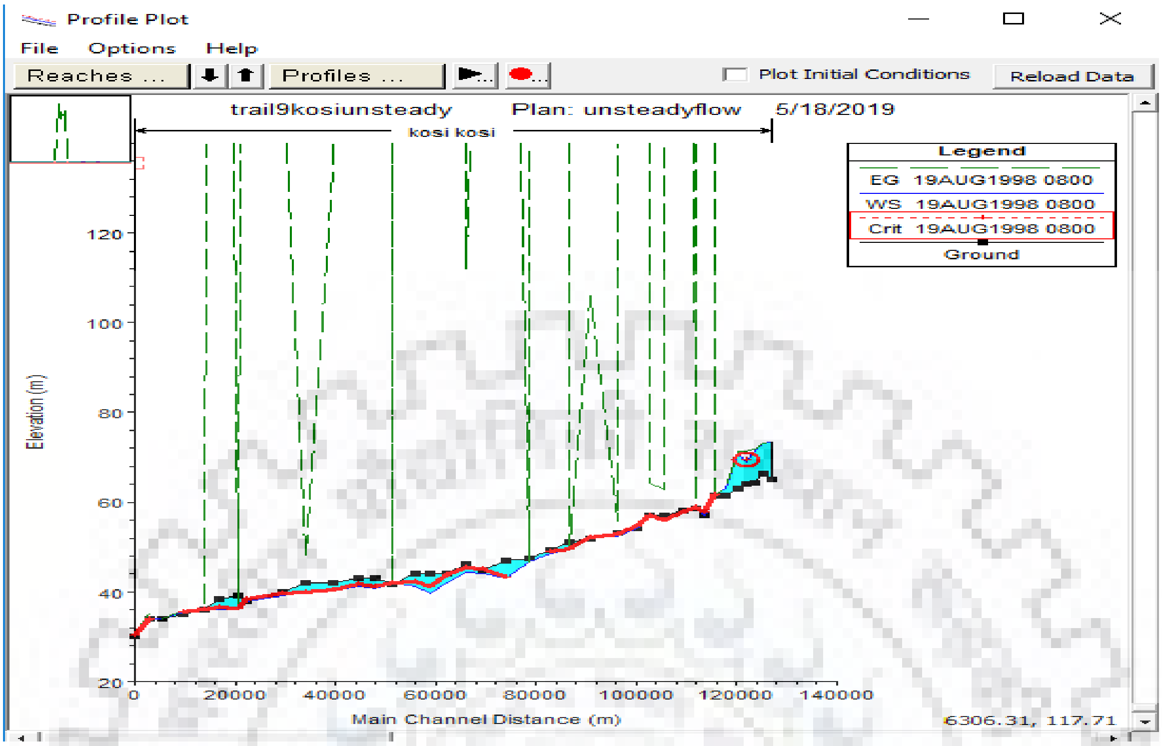

Figure 5. 17: Profile plot of Water level, Energy gradient, Critical water level along the Kosi river

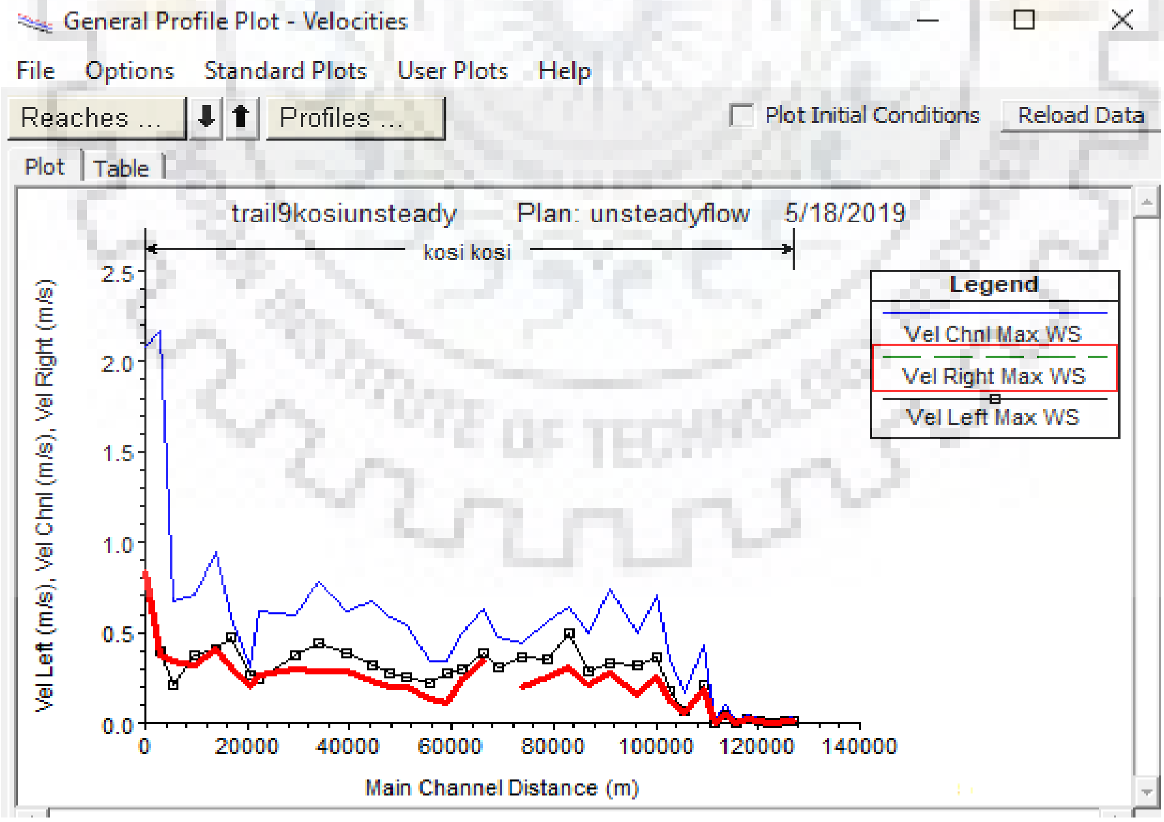

Figure 5. 18: General profile plot showing Velocities at right bank, left bank and center along the Kosi river

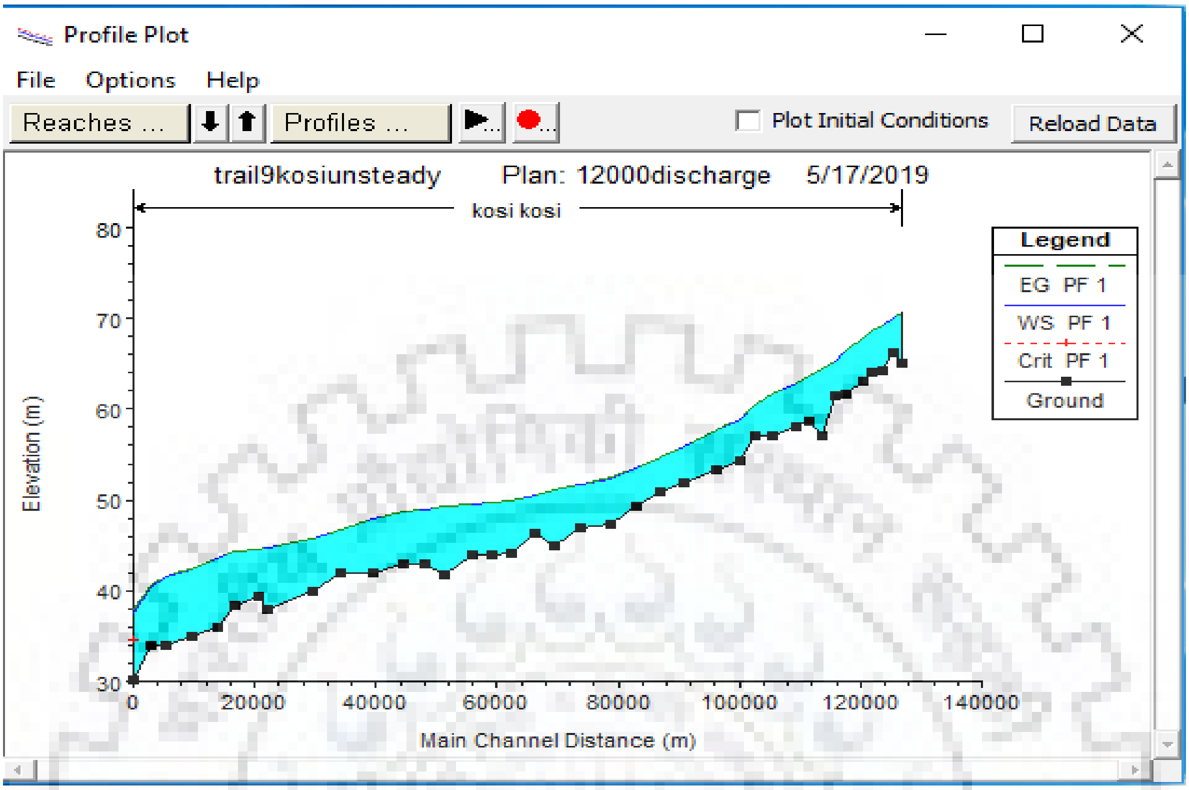

Figure 5. 19: Profile Plot of Kosi river along the channel for 12000 cumec discharge

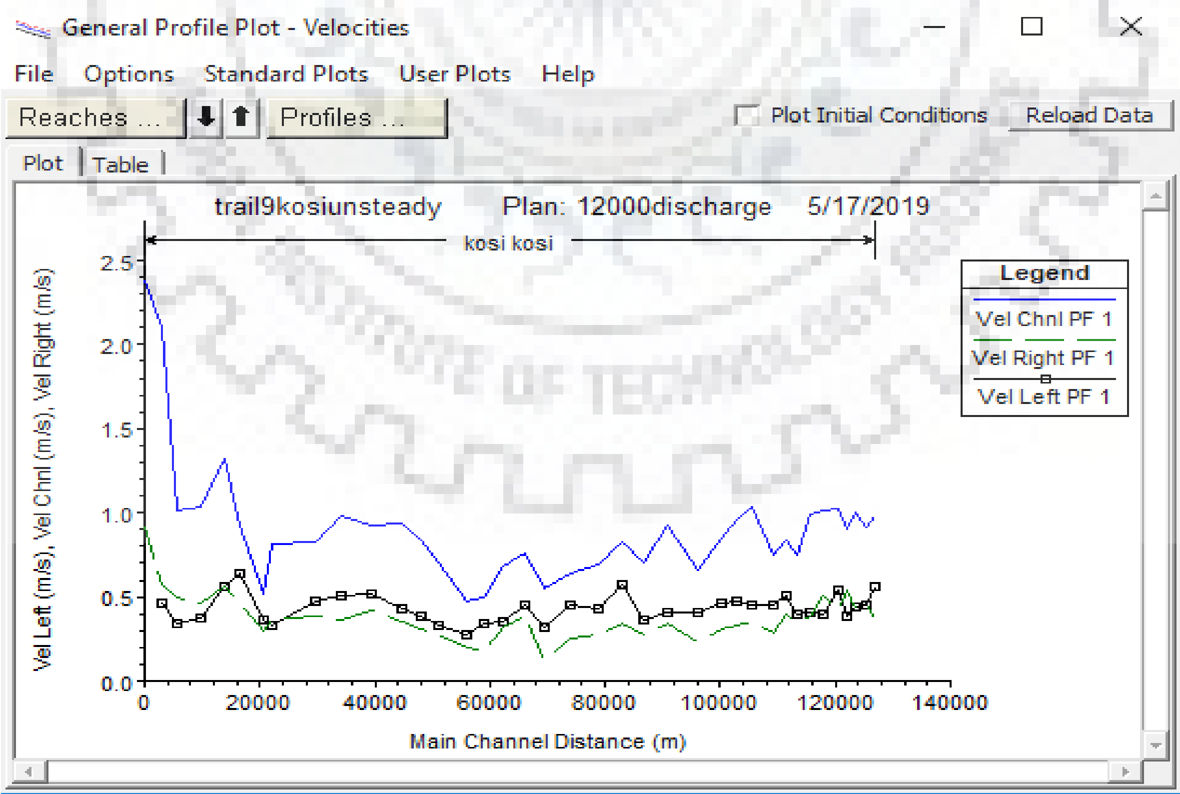

Figure 5. 20: General Profile Plot of Velocities for Steady flow analysis (12000 cumec)

Table 5. 4: Hydraulic modelling results of unsteady flow condition of 18th August 1997

Reach	River Station	Profile	Total Discharge (m^3/s)	Minimum channel elevation (m)	Water surface Elevation (m)	Critical water surface slevation (m)	Energy gradient elevation (m)	Energy gradient slope (m/m)	Velocity of channel (m/s)	Flow Area (m^2)	Top Width (m)	Froude no. of channel
kosi	419559	18AUG1997 1600	5902.4	65	69.71	58.11	69.73	0.000401	0.71	11528.31	7221.16	0.19
kosi	414223	18AUG1997 1600	5904.99	66.28	69.08	57.58	69.09	0.000351	0.66	12655.02	7703.13	0.18
kosi	408164	18AUG1997 1600	5907.65	64.23	68.44	57.05	68.46	0.000365	0.73	11413.18	7033.53	0.19
kosi	403044	18AUG1997 1600	5909.98	64	67.84	56.55	67.86	0.000443	0.66	11201.93	7493.64	0.2
kosi	398038	18AUG1997 1600	5912.44	63.15	67.1	55.94	67.13	0.000454	0.77	10199.73	6877.61	0.21
kosi	389192	18AUG1997 1600	5916.32	61.59	65.73	54.80	65.76	0.000612	0.78	10014.57	8067.6	0.23
kosi	382292	18AUG1997 1600	5919.63	61.55	64.5	53.77	64.52	0.000544	0.79	9259.36	7712.42	0.22
kosi	375479	18AUG1997 1600	5923.25	57.09	63.65	53.06	63.67	0.000268	0.58	13379.92	8881.48	0.16
kosi	369238	18AUG1997 1600	5926.9	58.61	62.89	52.43	62.91	0.000495	0.68	10922.33	8471.51	0.21
kosi	361955	18AUG1997 1600	5931.54	58.07	61.97	51.66	61.99	0.000281	0.6	12992.72	8820.9	0.16
kosi	349216	18AUG1997 1600	5938.68	57	60.86	50.73	60.88	0.000303	0.76	12842.58	8161.25	0.18
kosi	340156	18AUG1997 1600	5942.87	57	59.69	49.77	59.72	0.000611	0.83	9826.36	8557.13	0.23
kosi	331519	18AUG1997 1600	5948.16	54.26	58.21	48.52	58.22	0.000404	0.68	11440.85	8617.58	0.19
kosi	318847	18AUG1997 1600	5956.17	53.22	57.08	47.58	57.09	0.000195	0.48	16181.93	11038.33	0.13
kosi	300888	18AUG1997 1600	5967.82	52	55.2	46.02	55.22	0.000498	0.73	10819.26	9338.27	0.21
kosi	287696	18AUG1997 1600	5976.98	51	53.91	44.93	53.92	0.000152	0.48	18399.64	10718.41	0.12
kosi	275094	18AUG1997 1600	5986.1	49.35	52.67	43.91	52.69	0.000451	0.63	12622.63	8523.2	0.2
kosi	261491	18AUG1997 1600	5993.41	47.35	51.34	42.79	51.35	0.000178	0.55	15527.04	7988.23	0.13
kosi	245114	18AUG1997 1600	5999.25	47	50.67	42.23	50.67	0.000112	0.41	18587.63	8455.29	0.1
kosi	230446	18AUG1997 1600	6000.67	45	49.95	41.63	49.96	0.000197	0.54	15511.95	8996.52	0.14
kosi	219956	18AUG1997 1600	5992.26	46.27	49.1	40.93	49.11	0.000268	0.62	15106.34	7108.09	0.16
kosi	207133	18AUG1997 1600	5969.81	44.19	48.48	40.41	48.49	0.000122	0.49	20402.69	8038.36	0.11
kosi	196675	18AUG1997 1600	5938.79	44	48.23	40.19	48.23	0.000059	0.34	22512.96	8261.51	0.08
kosi	186075	18AUG1997 1600	5881.25	44	48.01	40.02	48.02	0.000042	0.34	26507.41	8612.34	0.07
kosi	171063	18AUG1997 1600	5819.73	41.69	47.76	39.80	47.76	0.000074	0.54	19808.19	6878.82	0.1
kosi	160412	18AUG1997 1600	5780.91	43	47.52	39.61	47.53	0.000066	0.57	20005.95	5629	0.09
kosi	149297	18AUG1997 1600	5741.69	43	47.21	39.35	47.22	0.000097	0.65	17629.33	5542.9	0.11
kosi	132173	18AUG1997 1600	5689.49	42	46.53	38.78	46.54	0.00014	0.59	16056.86	5242.5	0.12
kosi	115006	18AUG1997 1600	5631.96	42	45.29	37.76	45.31	0.000301	0.77	11993.13	6185.54	0.18
kosi	99733	18AUG1997 1600	5568.72	40	44.22	36.86	44.23	0.000183	0.59	15391.99	6028.91	0.14
kosi	75600	18AUG1997 1600	5449.71	38	43.24	36.04	43.25	0.000119	0.63	15901.87	6404.6	0.12
kosi	70369	18AUG1997 1600	5390.83	39.27	43	35.84	43.01	0.00005	0.29	22044.96	6169.71	0.07
kosi	57656	18AUG1997 1600	5345.13	38.44	42.73	35.62	42.74	0.000164	0.54	12919.79	4229.83	0.13
kosi	48158	18AUG1997 1600	5302.81	36	41.99	35.01	42.01	0.000324	0.95	10761.93	4459.3	0.19
kosi	34667	18AUG1997 1600	5233.02	35.01	40.95	34.14	40.97	0.000167	0.66	13173.3	5296.77	0.14
kosi	21103	18AUG1997 1600	5162.45	34	40.34	33.63	40.35	0.000141	0.64	14151.1	5614.5	0.13
kosi	12579	18AUG1997 1600	5125.78	34	38.29	32.08	38.5	0.001182	2.09	2947.5	1821.29	0.38
kosi	3022	18AUG1997 1600	5111.07	30.18	35.17	33.48	35.33	0.001001	1.94	3357.74	1124.37	0.35

Table 5. 5: Hydraulic modelling results of unsteady flow condition of 18th August 1998

Reach	River Station	Profile	Total Discharge (m³/s)	Minimum channel elevation (m)	Water surface Elevation (m)	Critical water surface slevation (m)	Energy gradient elevation (m)	Energy gradient slope (m/m)	Velocity of channel (m/s)	Flow Area (m²)	Top Width (m)	Froude no. of channel
kosi	419559	18AUG1998 2300	8945.71	65	73.17	69.69	73.17	0.000019	0.23	39564.69	8429.1	0.05
kosi	414223	18AUG1998 2300	4483.35	66.28	67.65	64.50	67.73	0.006517	1.24	3618.66	3964.59	0.66
kosi	408164	18AUG1998 2300	7.31	64.23	64.04	64.07	64.12	0.63176	1.21	6.03	141.54	0.24
kosi	403044	18AUG1998 2300	10.23	64	64.02	64.03	64.06	1.115953	0.93	10.97	595.5	0.19
kosi	398038	18AUG1998 2300	12.41	63.15	63.13	63.37	67.68	729723.4	0.31	40	6.22	0.06
kosi	389192	18AUG1998 2300	2.07	61.59	62.31	61.68	62.31	0.000039	0.07	28.63	110.06	0.01
kosi	382292	18AUG1998 2300	0.14	61.55	61.57	61.59	62.14	8.685791	1.56	0.09	5.4	0.31
kosi	375479	18AUG1998 2300	0.19	57.09	57.1	57.2	68.05	1584.383	0.10	2	0.64	0.02
kosi	369238	18AUG1998 2300	0.06	58.61	58.63	58.64	58.67	0.378002	0.86	0.07	6.17	0.17
kosi	361955	18AUG1998 2300	1.86	58.07	57.62	57.63	57.67	0.206778	0.93	2	30.16	0.19
kosi	349216	18AUG1998 2300	0.33	57	55.93	55.99	61.07	337.381	1.10	0.3	3.63	0.22
kosi	340156	18AUG1998 2300	5.12	57	56.93	57.01	57.87	16.43424	3.32	1.54	48.22	0.66
kosi	331519	18AUG1998 2300	0.14	54.26	54.29	54.33	54.52	1.247843	2.00	0.07	4.06	0.40
kosi	318847	18AUG1998 2300	6.88	53.22	52.35	52.54	61.35	91.48657	1.32	5.2	13.99	0.26
kosi	300888	18AUG1998 2300	20.72	52	52.08	43.42	52.1	0.008894	0.50	41.37	516.12	0.10
kosi	287696	18AUG1998 2300	0.37	51	49.31	49.37	62.53	1201.257	0.19	2	3.18	0.04
kosi	275094	18AUG1998 2300	0.01	49.35	48.62	48.63	48.83	31.54972	1.00	0.01	1.36	0.20
kosi	261491	18AUG1998 2300	11.89	47.35	46.48	46.73	59.52	86.40048	1.61	7.4	14.56	0.32
kosi	245114	18AUG1998 2300	4.23	47	43.02	43.1	45.12	64.76031	0.64	6.6	40.82	0.13
kosi	230446	18AUG1998 2300	39.62	45	44.04	44.67	56.56	392567.9	1.65	24	4.28	0.33
kosi	219956	18AUG1998 2300	6.19	46.27	43.71	43.99	53.79	1484047	0.04	156	1.7	0.01
kosi	207133	18AUG1998 2300	7.91	44.19	42.05	42.17	46.6	80.84296	1.41	5.6	34.34	0.28
kosi	196675	18AUG1998 2300	8.16	44	39.58	39.76	46.14	59798	1.17	7	9.68	0.23
kosi	186075	18AUG1998 2300	0.5	44	41.27	41.3	41.48	4.019313	2.50	0.2	10.47	0.50
kosi	171063	18AUG1998 2300	2.08	41.69	42.63	42.01	42.63	0.000003	0.02	115.14	288.72	0.00
kosi	160412	18AUG1998 2300	52.23	43	40.77	41.14	44.9	7.705901	2.17	24.1	43.94	0.43
kosi	149297	18AUG1998 2300	10.87	43	41.46	41.62	43.45	9.659464	0.43	25.21	26.88	0.09
kosi	132173	18AUG1998 2300	40.64	42	40.21	40.48	43.95	11.00672	3.21	12.65	50.53	0.64
kosi	115006	18AUG1998 2300	5.82	42	40.07	40.25	51.73	132.1761	0.43	13.54	11.28	0.09
kosi	99733	18AUG1998 2300	3.14	40	39.15	39.33	49.5	896012.3	0.06	54.95	1.89	0.01
kosi	75600	18AUG1998 2300	11.8	38	38.15	36.35	38.16	0.003524	0.40	29.66	257.54	0.08
kosi	70369	18AUG1998 2300	7.8	39.27	36.01	36.02	36.04	1.893946	0.78	9.94	1020.69	0.16
kosi	57656	18AUG1998 2300	32.21	38.44	36.07	36.07	36.11	0.162611	0.84	38.19	558.04	0.17
kosi	48158	18AUG1998 2300	5.56	36	36.09	35.38	36.09	0.002202	0.22	25.71	290.19	0.29
kosi	34667	18AUG1998 2300	3.44	35.01	35.05	34.36	35.05	0.01033	0.21	16.7	409.03	0.54
kosi	21103	18AUG1998 2300	7.38	34	34.17	33.50	34.17	0.001372	0.20	37.67	229.73	0.25
kosi	12579	18AUG1998 2300	8.26	34	34.07	33.40	34.07	0.003363	0.28	29.81	436.08	0.34
kosi	3022	18AUG1998 2300	9.99	30.18	30.86	30.56	30.87	0.001146	0.51	19.76	52.32	0.26

Table 5. 6: Hydraulic modelling results of unsteady flow condition of 18th August 1999

Reach	River Station	Profile	Total Discharge	Minimum channel elevation	Water surface Elevation	Critical water surface slevation	Energy gradient elevation	Energy gradient slope	Velocity of channel	Flow Area	Top Width	Froude no. of channel
			(m^3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m^2)	(m)	
kosi	419559	18AUG1999 0900	3013.58	65	70.56	69.86	70.56	0.000026	0.25	18042.35	7981.53	0.05
kosi	414223	18AUG1999 0900	589.98	66.28	66.54	65.92	66.58	0.0049	0.52	733.93	1299.18	0.46
kosi	408164	18AUG1999 0900	9.32	64.23	64.04	64.08	64.2	1.569694	1.76	5.3	140.79	0.35
kosi	403044	18AUG1999 0900	11.59	64	63.97	64.04	9227.48	1390989	2.07	5.6	5.61	0.41
kosi	398038	18AUG1999 0900	49.74	63.15	63.13	63.61	193176.9	29314030	2.11	23.54	5.24	0.42
kosi	389192	18AUG1999 0900	163.46	61.59	61.85	62.64	135.15	23.93098	1.86	87.65	30.51	0.37
kosi	382292	18AUG1999 0900	245.28	61.55	61.56	62.23	11681960	339424500	1.56	156.98	3.32	0.31
kosi	375479	18AUG1999 0900	209.65	57.09	57.33	58.87	1450.06	569.4662	1.65	127	10.62	0.33
kosi	369238	18AUG1999 0900	255.85	58.61	58.62	59.82	18133640	526554800	0.72	354.57	2.78	0.14
kosi	361955	18AUG1999 0900	223.4	58.07	57.5	58.3	21743850	3300791000	0.70	321.25	2.22	0.14
kosi	349216	18AUG1999 0900	81.96	57	55.92	56.64	1427900	155743800	0.35	235.54	2.48	0.07
kosi	340156	18AUG1999 0900	54.51	57	56.95	57.09	78.01	214.6003	2.03	26.8	74.07	0.41
kosi	331519	18AUG1999 0900	225.01	54.26	55.13	54.97	55.52	0.075826	2.16	104.05	384.32	0.43
kosi	318847	18AUG1999 0900	85.32	53.22	52.29	52.95	1286663	127764500	0.67	126.58	2.53	0.13
kosi	300888	18AUG1999 0900	381.04	52	52.12	52.38	54.23	0.944318	3.06	124.65	531.86	0.61
kosi	287696	18AUG1999 0900	622.11	51	49.42	50.52	6759.04	34191.47	2.54	245.21	27.58	0.51
kosi	275094	18AUG1999 0900	1576.86	49.35	48.65	50.2	11678160	282129400	2.91	542.32	5.38	0.58
kosi	261491	18AUG1999 0900	2448.6	47.35	46.79	48.17	2314.46	2274.352	2.11	1161	55.17	0.42
kosi	245114	18AUG1999 0900	2379.18	47	43.03	45.86	240539.7	4098620	2.11	1125	43.57	0.42
kosi	230446	18AUG1999 0900	2882.51	45	44.55	46.74	2103.15	1439.61	2.01	1435	52.01	0.40
kosi	219956	18AUG1999 0900	3352.74	46.27	43.74	46.02	90794280	2475250000	1.03	3245.51	4.49	0.21
kosi	207133	18AUG1999 0900	1546.28	44.19	42.02	44.13	18229930	1525994000	2.05	753.24	10.73	0.41
kosi	196675	18AUG1999 0900	1318.49	44	39.64	41.57	44029.68	416947.8	1.92	687.54	36.36	0.38
kosi	186075	18AUG1999 0900	158.02	44	41.23	41.83	11301440	1714513000	0.24	658.75	2.18	0.05
kosi	171063	18AUG1999 0900	2854.63	41.69	41.53	43.66	1040591	6870368	3.33	856.24	12.34	0.67
kosi	160412	18AUG1999 0900	3360.39	43	40.59	42.86	1.28E+09	1.94401E+11	0.62	5423.65	4.35	0.12
kosi	149297	18AUG1999 0900	3840.81	43	41.34	43.57	7.68E+09	1.1666E+12	0.62	6241.3	2.03	0.12
kosi	132173	18AUG1999 0900	4143.13	42	40.06	42.45	52987700	2202817000	0.76	5421.32	9.98	0.15
kosi	115006	18AUG1999 0900	3814.65	42	40.03	42.43	2.41E+08	9961678000	1.12	3412.68	4.28	0.22
kosi	99733	18AUG1999 0900	722.81	40	39.71	40.29	53.72	11.05038	1.66	436	202.69	0.33
kosi	75600	18AUG1999 0900	637.08	38	38.01	38.85	14538.97	175124.4	3.21	198.23	126.82	0.64
kosi	70369	18AUG1999 0900	1750.09	39.27	36.01	36.65	1616.03	95289.14	1.76	994	1020.69	0.35
kosi	57656	18AUG1999 0900	276.7	38.44	36.13	36.29	36.83	1.311829	3.09	89.65	569.33	0.62
kosi	48158	18AUG1999 0900	1595.24	36	36.01	37.51	14632.62	142942.3	2.81	568.24	272.92	0.56
kosi	34667	18AUG1999 0900	957.39	35.01	35.32	35.94	39.7	0.855455	2.72	352.14	432.75	0.54
kosi	21103	18AUG1999 0900	3023.38	34	34.07	36.49	3583.89	5298.65	2.10	1443	218.78	0.42
kosi	12579	18AUG1999 0900	1444.62	34	34.24	35.02	43.51	1.480019	1.35	1071.4	443.47	0.27
kosi	3022	18AUG1999 0900	3.65	30.18	30.19	30.42	16709.36	484680.8	2.92	1.25	1.31	0.58

Table 5. 7: Hydraulic modelling results of unsteady flow condition of 18th August 2000

Reach	River Station	Profile	Total Discharge (m^3/s)	Minimum channel elevation (m)	Water surface Elevation (m)	Critical water surface slevation (m)	Energy gradient elevation (m)	Energy gradient slope (m/m)	Velocity of channel (m/s)	Flow Area (m^2)	Top Width (m)	Froude no. of channel
kosi	419559	18AUG2000 1500	6819.82	65	73.53	72.10	73.54	0.000008	0.16	42650.29	8429.1	0.03
kosi	414223	18AUG2000 1500	4045.09	66.28	73.52	72.08	73.52	0.000002	0.08	49400.67	8361	0.02
kosi	408164	18AUG2000 1500	1196.53	64.23	73.52	72.08	73.52	0	0.02	49734.64	7606.4	0.03
kosi	403044	18AUG2000 1500	3.81	64	63.98	64.01	74.85	2143.59	1.47	2.6	12.44	0.29
kosi	398038	18AUG2000 1500	1	63.15	63.13	63.2	71.7	11926.07	0.33	3	5.24	0.07
kosi	389192	18AUG2000 1500	2.3	61.59	61.61	61.78	76.62	9244.059	0.79	2.9	2.22	0.16
kosi	382292	18AUG2000 1500	1.9	61.55	61.56	61.67	76.2	20357.55	0.90	2.1	3.32	0.18
kosi	375479	18AUG2000 1500	0.57	57.09	57.1	57.26	74.27	17669.9	0.29	2	0.61	0.06
kosi	369238	18AUG2000 1500	0.19	58.61	58.62	58.66	68.39	283.5708	0.13	1.5	2.78	0.03
kosi	361955	18AUG2000 1500	28.87	58.07	57.64	57.91	63.73	23.66278	1.09	26.5	34.67	0.22
kosi	349216	18AUG2000 1500	69.23	57	55.94	56.59	62.55	2276823	2.83	24.5	5.14	0.57
kosi	340156	18AUG2000 1500	40.65	57	56.89	57.07	79.82	5927769	0.72	56.57	9.52	0.14
kosi	331519	18AUG2000 1500	8.09	54.26	54.27	54.51	77.5	2983566	0.34	23.65	1.17	0.07
kosi	318847	18AUG2000 1500	7.54	53.22	52.29	52.55	79.23	5455777	0.60	12.54	1.84	0.12
kosi	300888	18AUG2000 1500	62.83	52	52.01	52.12	56.96	37.63964	1.16	54.32	478.39	0.23
kosi	287696	18AUG2000 1500	2.97	51	49.31	49.47	68.87	612156.6	0.50	6	2.16	0.10
kosi	275094	18AUG2000 1500	219.95	49.35	49.22	49.44	50.05	0.690453	3.22	68.3	235.66	0.64
kosi	261491	18AUG2000 1500	311.09	47.35	46.4	47.37	53	1221875000	1.33	234.21	2.26	0.27
kosi	245114	18AUG2000 1500	313.58	47	43.01	43.99	57.39	2350322	0.89	354.21	38.89	0.18
kosi	230446	18AUG2000 1500	31.71	45	45.19	40.23	45.19	0.001347	0.33	96.82	279.43	0.07
kosi	219956	18AUG2000 1500	371.87	46.27	43.9	45.19	65.07	3206.86	1.51	246	25.03	0.30
kosi	207133	18AUG2000 1500	345.67	44.19	42.18	43.04	68	187.9559	3.86	89.6	83.97	0.77
kosi	196675	18AUG2000 1500	143.56	44	39.59	40.28	74.4	2129088	3.11	46.23	14.52	0.62
kosi	186075	18AUG2000 1500	38.5	44	41.23	41.57	74.4	101770800	3.12	12.35	2.18	0.62
kosi	171063	18AUG2000 1500	8.45	41.69	41.44	41.76	72.37	6734146	0.36	23.54	1.4	0.07
kosi	160412	18AUG2000 1500	4.48	43	40.59	40.74	78.72	345823.3	0.21	21.01	4.35	0.04
kosi	149297	18AUG2000 1500	66.44	43	41.53	42.04	53.42	31.21277	2.82	23.54	42.54	0.56
kosi	132173	18AUG2000 1500	90.53	42	40.16	40.61	65.92	241.9625	2.00	45.21	39.03	0.40
kosi	115006	18AUG2000 1500	3.18	42	40.02	40.2	66.59	44406.99	1.06	3	3.02	0.21
kosi	99733	18AUG2000 1500	2.3	40	39.15	39.3	45.98	478921.9	1.15	2	1.89	0.23
kosi	75600	18AUG2000 1500	10.04	38	38.07	38.08	38.12	0.064352	1.03	9.79	188.36	0.21
kosi	70369	18AUG2000 1500	82.64	39.27	36.06	36.09	36.16	0.654252	1.46	56.58	1033.2	0.29
kosi	57656	18AUG2000 1500	143.14	38.44	36.02	36.19	41.59	96.09624	1.04	137	550.35	0.21
kosi	48158	18AUG2000 1500	138.2	36	36.05	36.31	42.26	9.435235	0.97	142.1	281.42	0.19
kosi	34667	18AUG2000 1500	126.99	35.01	35.02	35.25	64.72	895.7109	2.58	49.21	406.18	0.52
kosi	21103	18AUG2000 1500	68.79	34	34.44	33.25	34.48	0.004682	0.66	103.92	257.75	0.53
kosi	12579	18AUG2000 1500	1.12	34	34.01	32.41	34.01	0.041493	0.26	4.23	433.7	0.86
kosi	3022	18AUG2000 1500	73.64	30.18	31.78	31.08	31.81	0.001033	0.78	93.99	119.19	0.28

Table 5. 8: Hydraulic modelling results of steady flow of discharge 12000 cumec.

Reach	River Station	Profile	Total Discharge (m^3/s)	Minimum channel elevation (m)	Water surface Elevation (m)	Critical water surface slevation (m)	Energy gradient elevation (m)	Energy gradient slope (m/m)	Velocity of channel (m/s)	Flow Area (m^2)	Top Width (m)	Froude no. of channel
kosi	419559	PF 1	12000	65	70.57	66.60	70.6	0.000407	0.99	18118.79	7985.18	0.21
kosi	414223	PF 1	12000	66.28	69.94	66.01	69.97	0.000353	0.91	19532.17	8144.68	0.2
kosi	408164	PF 1	12000	64.23	69.27	65.39	69.31	0.000391	1	17493.19	7469.62	0.21
kosi	403044	PF 1	12000	64	68.66	64.80	68.69	0.000421	0.91	17573.45	7885.49	0.21
kosi	398038	PF 1	12000	63.15	67.9	64.09	67.94	0.000501	1.03	16071.84	7813.08	0.23
kosi	389192	PF 1	12000	61.59	66.43	62.71	66.47	0.000634	1.01	16141.84	9180.91	0.25
kosi	382292	PF 1	12000	61.55	65.21	61.56	65.25	0.00054	0.99	15431.31	9465.36	0.23
kosi	375479	PF 1	12000	57.09	64.39	60.76	64.41	0.000309	0.75	20878.76	10880.24	0.18
kosi	369238	PF 1	12000	58.61	63.66	60.08	63.69	0.000451	0.84	18511.06	10757.52	0.21
kosi	361955	PF 1	12000	58.07	62.86	59.32	62.88	0.00027	0.75	21466.7	10086.66	0.17
kosi	349216	PF 1	12000	57	61.64	58.19	61.68	0.000377	1.03	19606.13	8719.56	0.21
kosi	340156	PF 1	12000	57	60.42	57.04	60.46	0.000587	0.96	17151.54	11005.73	0.24
kosi	331519	PF 1	12000	54.26	58.96	55.65	58.99	0.000433	0.85	18686.96	10736.22	0.21
kosi	318847	PF 1	12000	53.22	57.73	54.48	57.75	0.000247	0.66	23717.22	11881.81	0.16
kosi	300888	PF 1	12000	52	55.84	52.72	55.88	0.000517	0.93	17350.58	10840.13	0.23
kosi	287696	PF 1	12000	51	54.65	51.58	54.67	0.000195	0.7	26775.67	11573.94	0.15
kosi	275094	PF 1	12000	49.35	53.52	50.51	53.54	0.00043	0.83	20884.32	10487.21	0.21
kosi	261491	PF 1	12000	47.35	52.4	49.45	52.42	0.000183	0.69	25223.46	9620.73	0.14
kosi	245114	PF 1	12000	47	51.63	48.72	51.64	0.000148	0.64	27232.73	9426.41	0.13
kosi	230446	PF 1	12000	45	51.03	48.16	51.05	0.000125	0.55	25941.12	9984	0.12
kosi	219956	PF 1	12000	46.27	50.48	47.64	50.5	0.000213	0.76	25595.76	7909.18	0.15
kosi	207133	PF 1	12000	44.19	49.99	47.17	50	0.000111	0.68	32851.41	8348.2	0.12
kosi	196675	PF 1	12000	44	49.75	46.94	49.76	0.000063	0.5	35581.53	8687.18	0.09
kosi	186075	PF 1	12000	44	49.56	46.75	49.56	0.000046	0.48	39960.82	8759.7	0.08
kosi	171063	PF 1	12000	41.69	49.28	46.50	49.29	0.000081	0.71	30403.85	6972.6	0.11
kosi	160412	PF 1	12000	43	49.01	46.25	49.02	0.000092	0.83	28365.04	5629	0.12
kosi	149297	PF 1	12000	43	48.64	45.91	48.66	0.000127	0.93	25580.67	5542.9	0.13
kosi	132173	PF 1	12000	42	47.84	45.15	47.86	0.00019	0.92	22902.56	5242.5	0.16
kosi	115006	PF 1	12000	42	46.7	44.08	46.72	0.000237	0.98	21012.56	6456.6	0.17
kosi	99733	PF 1	12000	40	45.79	43.22	45.81	0.000175	0.83	25144.24	6273.6	0.15
kosi	75600	PF 1	12000	38	44.81	42.29	44.83	0.000126	0.82	26167.77	6643.87	0.13
kosi	70369	PF 1	12000	39.27	44.6	42.08	44.6	0.000074	0.52	32226.37	6500.36	0.09
kosi	57656	PF 1	12000	38.44	44.3	41.82	44.33	0.000216	0.93	19780.39	4394.31	0.16
kosi	48158	PF 1	12000	36	43.49	41.07	43.53	0.000333	1.32	17465.3	4459.3	0.21
kosi	34667	PF 1	12000	35.01	42.42	40.04	42.44	0.000217	1.03	21385.14	5775.8	0.17
kosi	21103	PF 1	12000	34	41.63	39.29	41.65	0.000205	1.01	21384.48	5614.5	0.16
kosi	12579	PF 1	12000	34	40.39	38.26	40.56	0.00086	2.1	9873.43	4356.33	0.34
kosi	3022	PF 1	12000	30.18	37.63	34.65	37.87	0.001002	2.38	6583.27	1751.67	0.37

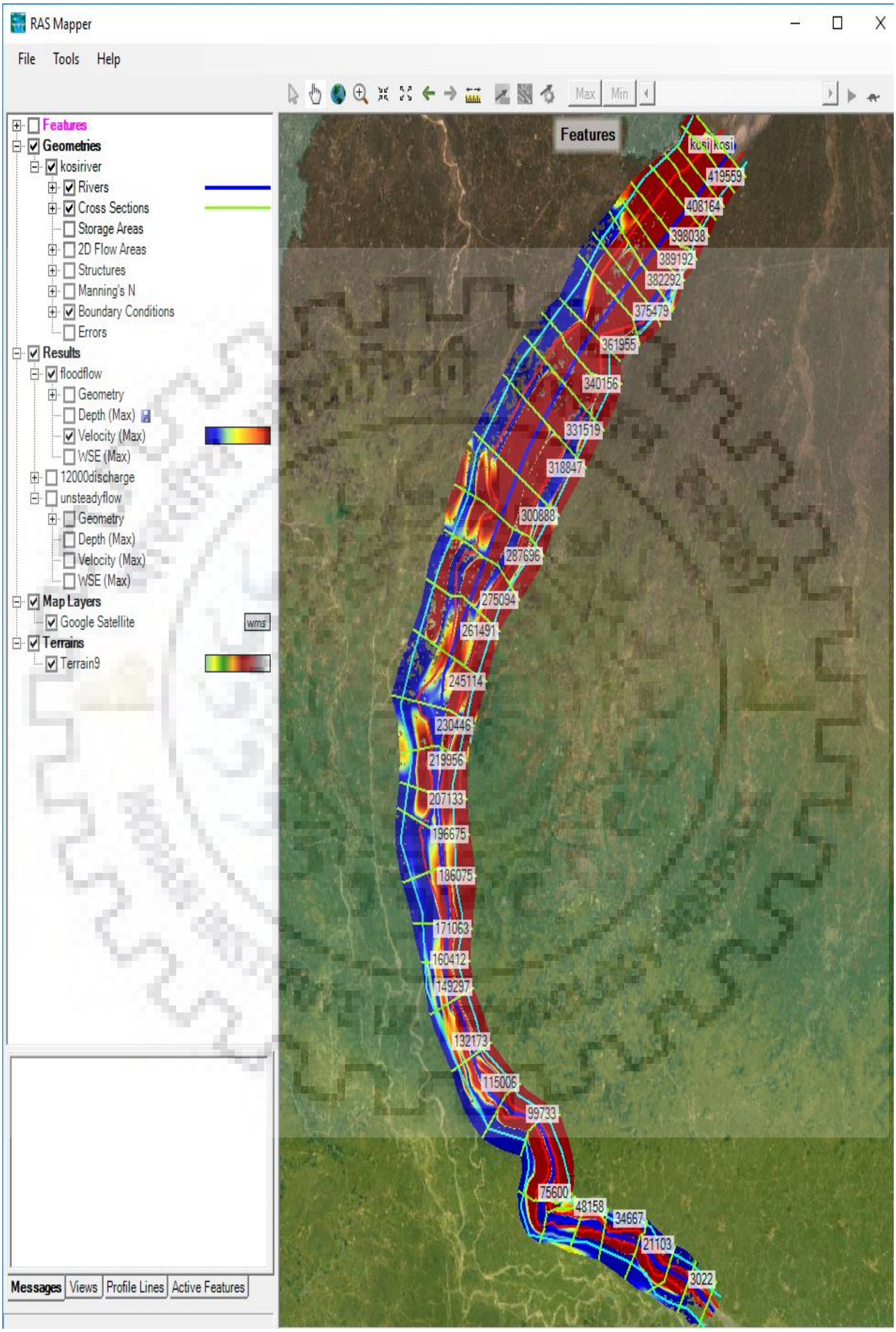

Figure 5. 21: RAS Mapper showing the velocity variation along the Kosi river

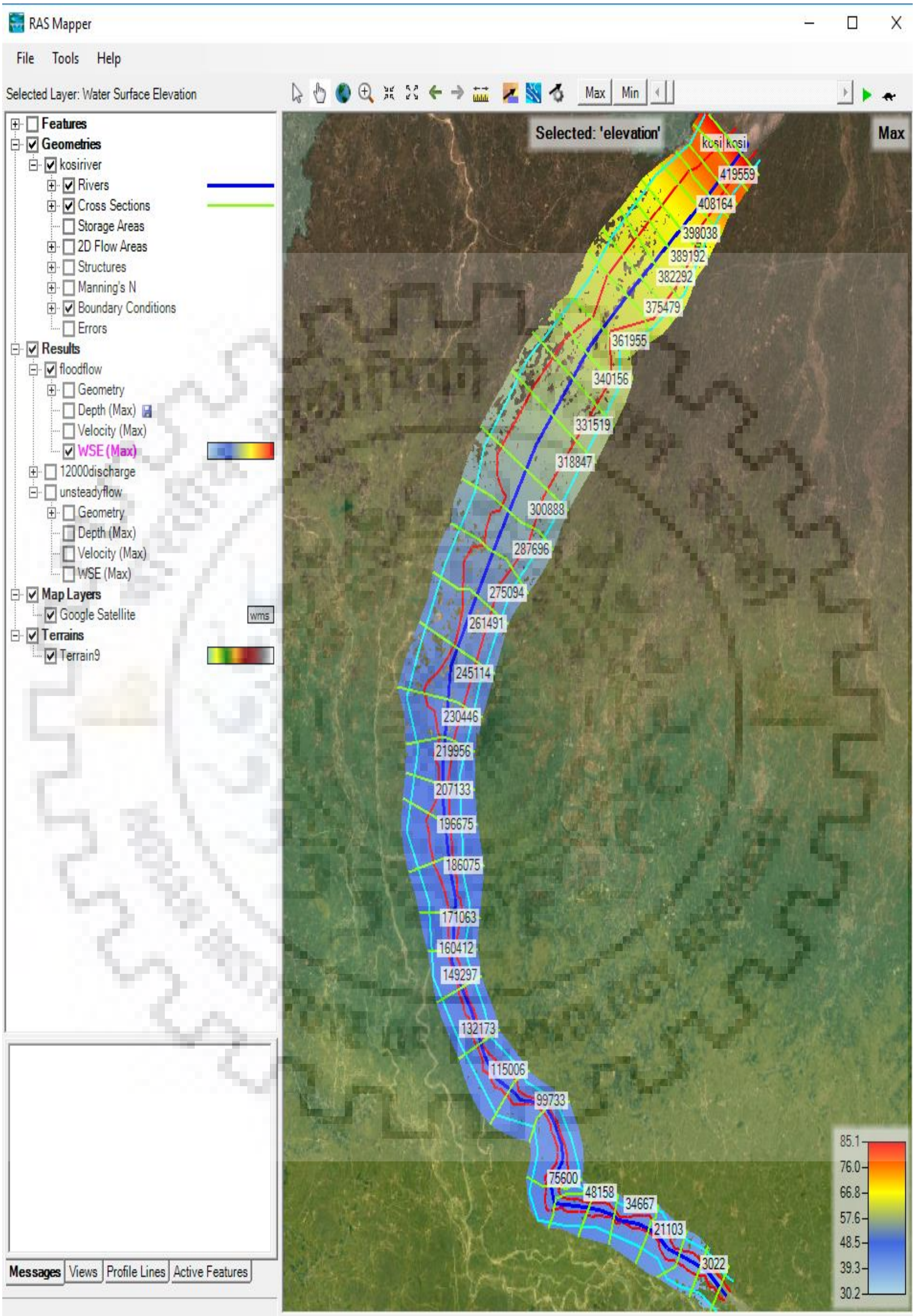

Figure 5. 22: RAS Mapper showing Water surface elevation along the Kosi river

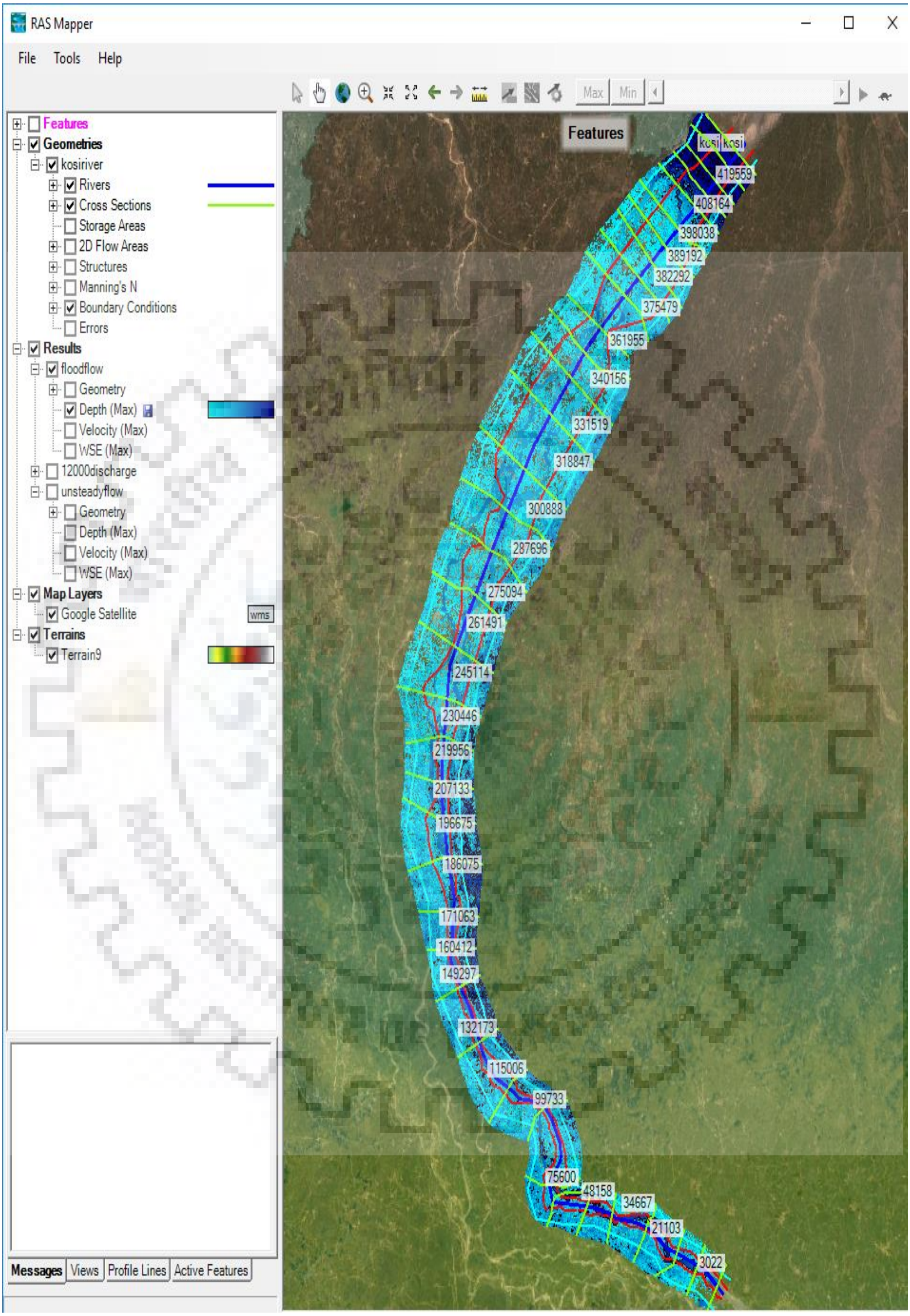

Figure 5. 23: RAS Mapper showing Flood inundated area along the Kosi river

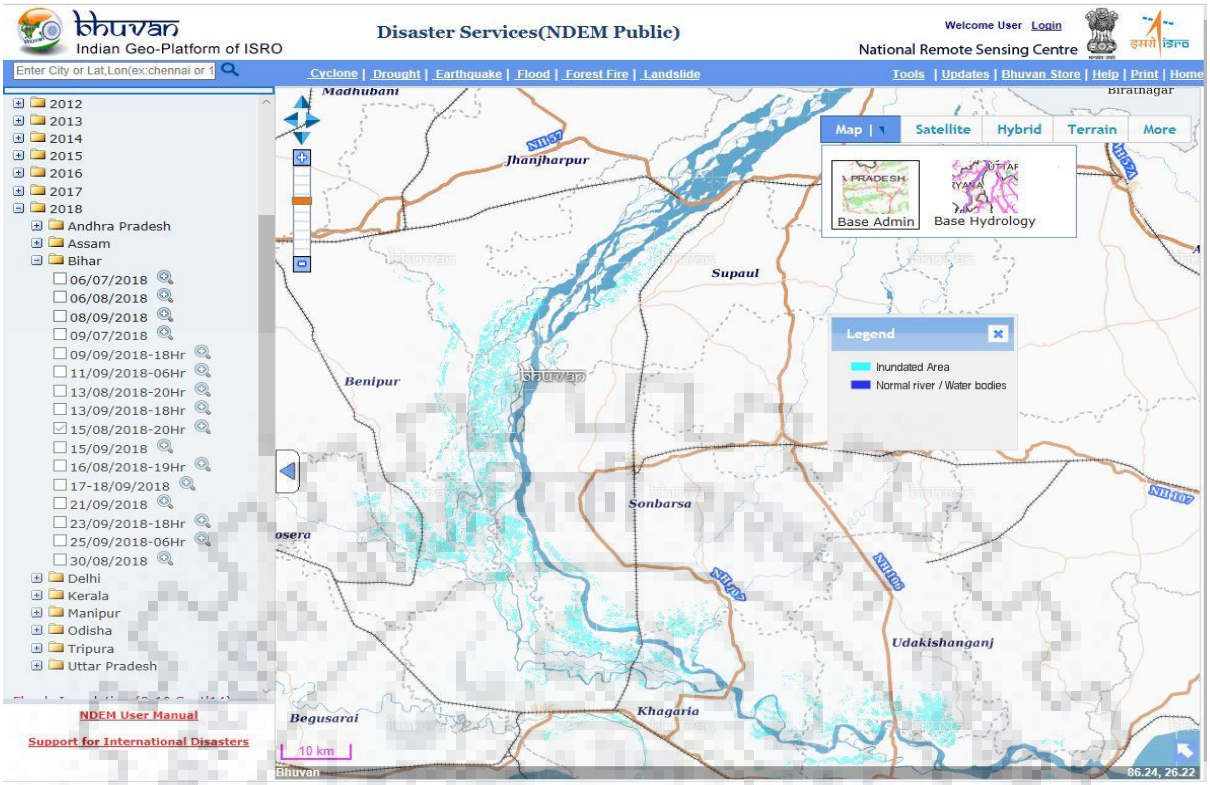

Figure 5. 24: Observed Flood Inundation Area along the Kosi River on 15/08/2018 from Bhuvan: Indian geo-Platform of ISRO

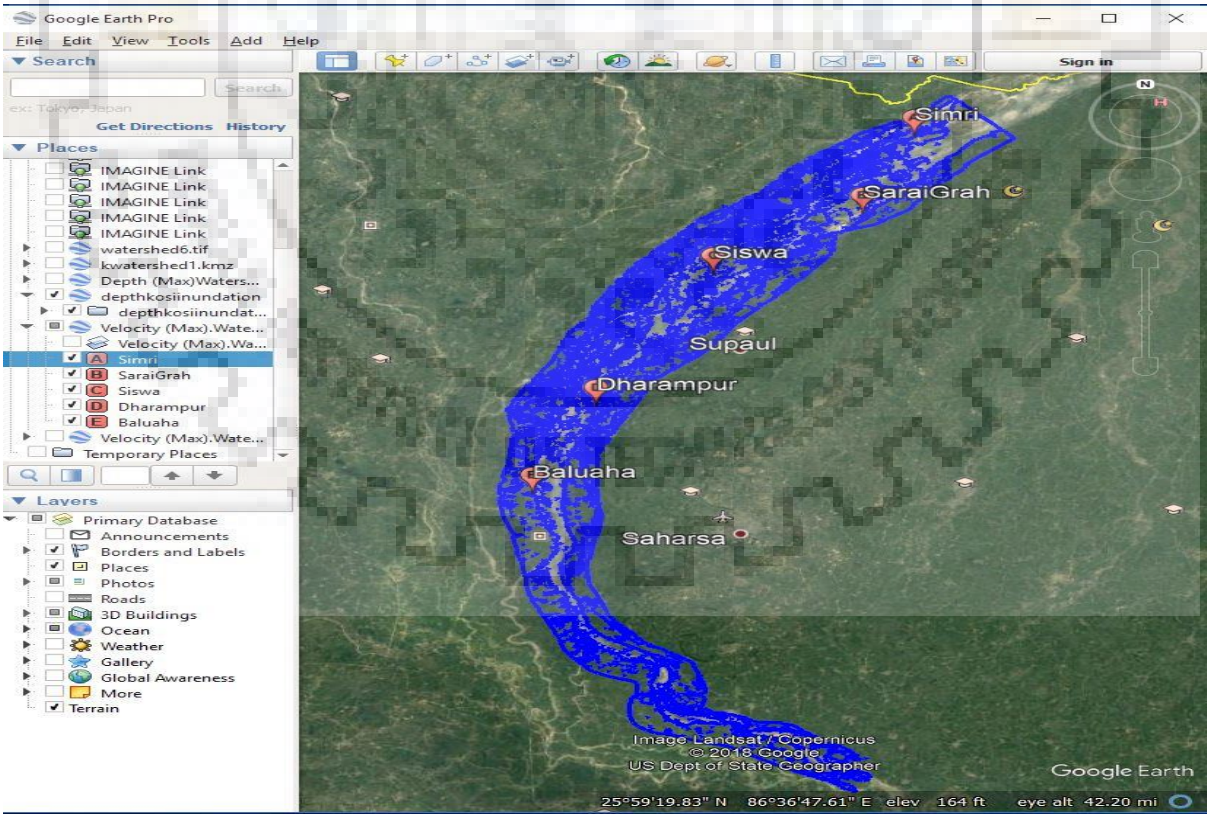

Figure 5. 25: Simulated Flood Inundation Area along the Kosi River on 15/08/2018 from HEC-RAS analysis

By Comparing both the map one that is obtained from the Bhuvan, Indian Geo-Platform of ISRO and other I.e. obtained from the analysis of flood using HEC-RAS, it can be seen that originally the flood affected more areas than HEC-RAS generated Flood Inundation Map. One of the reason for this will be there is absence of hourly Duration data for respective station as here Simulation is performed on the basis of Daily duration data because as catchment area is around 9470 km^2 water will drain out in 10-12 hours (approximately) thus affect the result.

5.5. FLOOD HOTSPOT IDENTIFICATION

Based on the above results five Hotspots have been selected and evaluated for Prioritization. Evaluation of different locations has then been done and hotspots have been prioritized based on the total scores using following steps:

- Identifies choices prone to have critical characteristics over different choices based on inundation and velocity map as shown in Figure 5.26 and 5.27 and also shown on google earth (Figure 5.28).
- Define factors as discussed above in methodology section that will show significant characteristics among choices.
- Decide the severity value of the different factors like for depth ranges from less than 1 to more than 4, assign 0.1 to 0.5 to respective ranges as shown in Figure 5.26, for velocity range from less than 0.5 m/s to greater than 2.5 m/s (Figure 5.27), assign 0.1 to 0.5 from very low effect to very high severity effect and score for vulnerability from 0 to 1.
- Then using the maximum Score for each factor, decide on the scores for advantage of the different attributes and Calculate the Final score for each Hotspots as Shown in Table 5.9.
- Finally, assess the choices to rank them in increasing order.

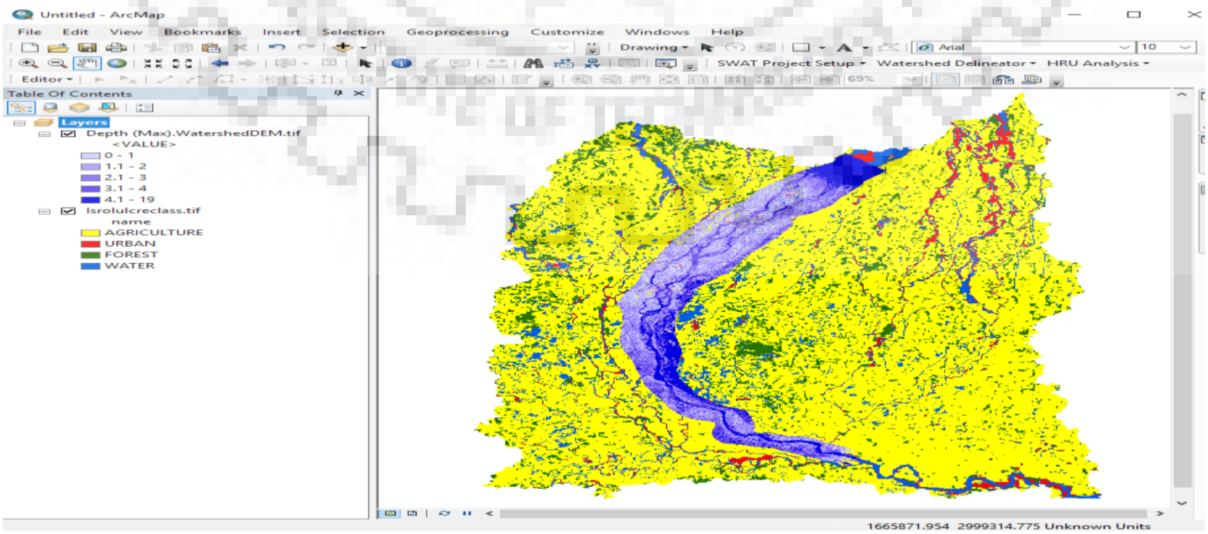

Figure 5. 26: Inundated area Overlaid on LULC Map

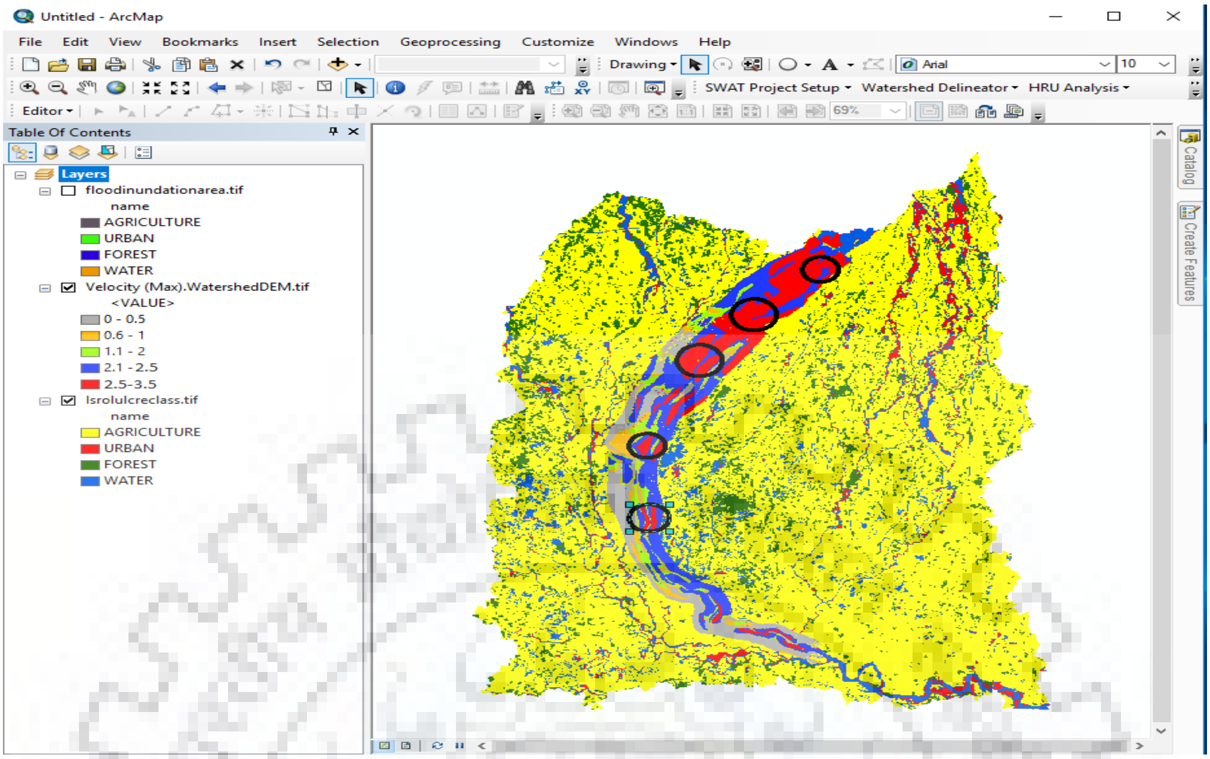

Figure 5. 27: Velocity distribution Map with potential hotspots Overlaid LULC Map

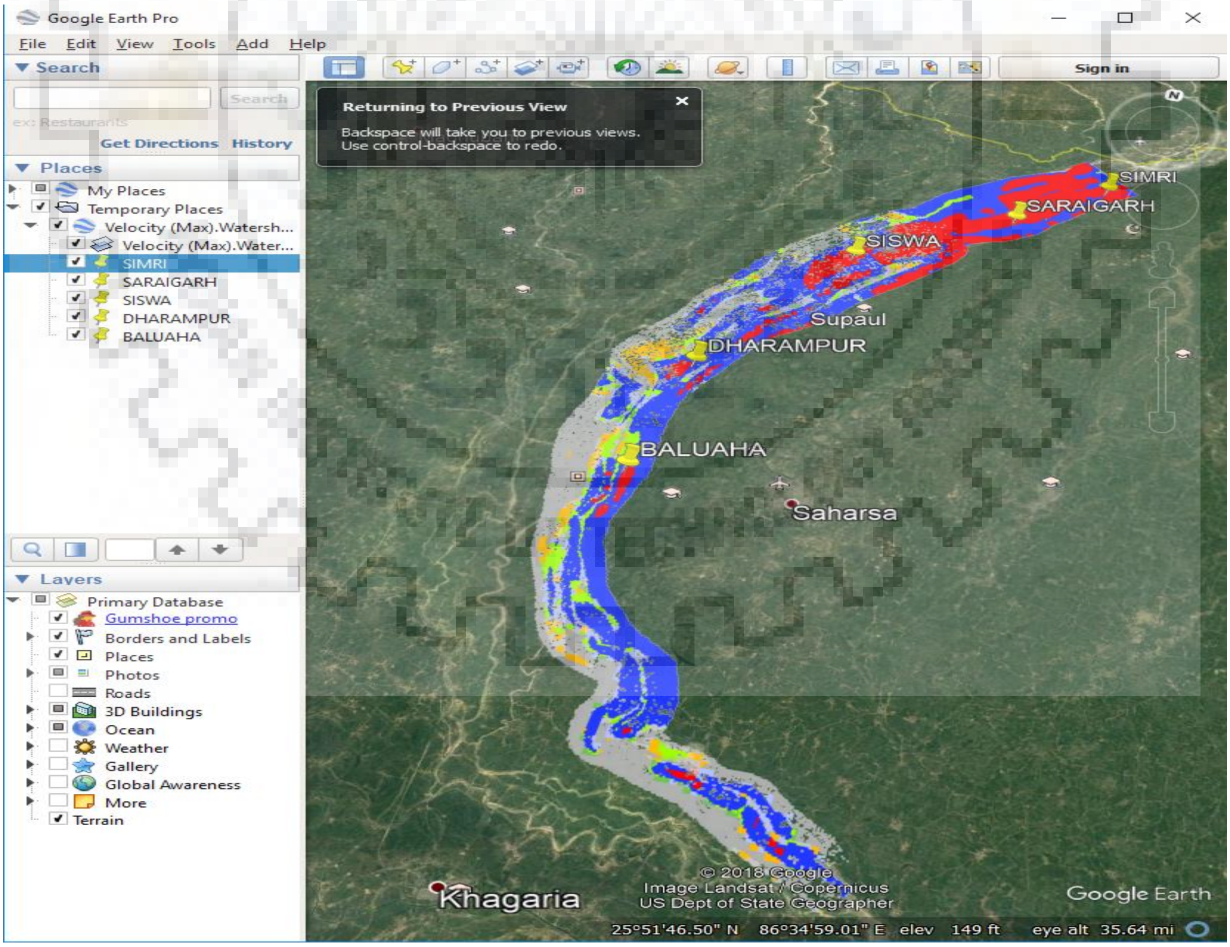

Figure 5. 28: Potential Hotspots places imposed on Google Earth

Table 5. 9: Prioritization of selected hotspot areas

ATTRIBUTES		Max - Score	SARAIGARH		SIMRI		SISWA		DHARAMPUR		BALUAHA	
			S1=0.5	S2=0.5	S1= 0.4	S2= 0.4	S1= 0.3	S2= 0.4	S1=0.4	S2=0.3	S1=0.5	S2=0.4
			V	S	V	S	V	S	V	S	V	S
Environmental Impacts	Water Pollution	600	0.5	300	0.25	120	0.25	105	0.75	315	0.25	135
	Erosion	500	0.75	375	0.5	200	0.5	175	0.5	175	1.0	450
	Ecosystem Degradation	800	0.25	200	0.25	160	0.5	280	0.5	280	0.5	360
	Habitat losses	800	0.25	200	0.25	160	0.5	280	0.5	280	0.5	360
	Impact on endangered species	800	0.25	200	0.25	160	0.25	140	0.25	140	0.5	360
	Sedimentation in lower areas	600	0.5	300	0.25	120	0.5	210	0.5	210	0.5	270
	Sewer outflows	400	0	0	0.25	80	0.25	70	0.25	70	0	0
ATTRIBUTES		Max - Score	SARAIGARH		SIMRI		SISWA		DHARAMPUR		BALUAHA	
			S1=0.5	S2=0.5	S1= 0.4	S2= 0.4	S1= 0.3	S2= 0.4	S1=0.4	S2=0.3	S1=0.5	S2=0.4
			V	S	V	S	V	S	V	S	V	S
Social Impacts	Human Casualties and Injuries	2000	1	2000	0.5	800	0.5	700	0.75	1050	0	0
	Public inconvenience	800	0.75	600	0.75	480	0.75	420	0.75	420	0.5	360
	Health Impacts due to water born disease	1600	0.5	800	0.5	640	0.5	560	0.5	560	0	0
	Psychological effects	600	0.5	300	0.5	240	0.5	210	0.5	210	0.25	135
	Loss of shelter and livelihood	1000	0.75	750	0.5	400	0.5	350	0.5	350	0	0
	Effect on religious monuments	1000	1.0	1000	0.5	400	0.75	525	0.5	350	0	0

	Effect on educational & administration	800	0.25	200	0.5	320	0.5	280	0.5	280	0.25	180
ATTRIBUTES		Max - Score	SARAIGARH		SIMRI		SISWA		DHARAMPUR		BALUAHA	
			S1=0.5	S2=0.5	S1= 0.4	S2= 0.4	S1= 0.3	S2= 0.4	S1=0.4	S2=0.3	S1=0.5	S2=0.4
			V	S	V	S	V	S	V	S	V	S
Economic Impacts	Productivity Loss	800	0.25	200	0.5	320	0.5	280	0.75	420	0.5	360
	Agriculture Productivity	800	0.25	200	0.25	160	0.25	140	0.25	140	0.25	180
	Industrial & commercial impacts	800	0	0	0.25	160	0.25	140	0.5	280	0	0
	Property Losses	1500	0.5	750	0.75	900	0.75	787.5	0.75	787.5	0.5	675
	Expenditure on evacuation & rehabilitation	1500	0.5	750	0.75	900	0.75	787.5	0.75	787.5	0.25	337.5
	Total importance			9125		6720		7880		5105		4162.5
	Rank			**1**		**3**		**2**		**4**		**5**

Five Hot spots have been identified along the course of the rive based on inundated areas (in respect of depths) and velocity map. That are Saraigarh, Simri, Siswa, dharampur, baluaha. After CBA analysis, it is found that Saraigarh has been ranked one for the Flood risk and it is followed by Simri, Siswa, Dharampur and Baluaha in order. Saraigarh has the highest flood-risk because of its distance of the river channel is less, high population and it has one railway station that will be going to inundated if flood happen other the all the factors taken into consideration.

CHAPTER 6
SUMMARY AND CONLUSIONS

6.1. SUMMARY

This study broadly covers collection of the data and identifying various causative factors for understanding the flood dynamics of the Kosi river basin, developing various feature maps and processing it through various requestic Softwares to prepare Flood Inundation Map using SWAT model & HEC-RAS and Remote Sensing & GIS software. Finally generating most flood prone areas along with prioritizing the corresponding areas for given study area shows many drawbacks as well as important characteristics as follows.

6.2 LIMITATION OF THE STUDY

After Calibrating the SWAT model output data in SWAT-CUP, it is found out that the calibration results are not satisfactory as R^2 value comes out to be only 0.48 and also it is observed by comparing the flood inundation map generated using HEC-RAS simulation and originally occurred inundation due to flood (Bhuvan website) that it's coming relatively less. These may be happened due to various region like as Kosi Barrage and various other mid-way storage also is coming in between Nepal and Bihar that might have affected the natural/virgin flow, and also because in the cases of flood, hourly variations are taken into account as it gives accurate result but here daily variation is taken into account (hourly data was not available for this site) which gives the approximately average result. This can be improved if the barrage functioning and discharge regulation are considered and other parameters which may have affected the respective watershed and not considered here as well as adequate hourly data.

Flood maps mainly represent imaginary situation are which are outside everyday life experiences and have not been observed before. Therefore, it is usually very difficult to validate such maps which are expected to be uncertain as they are based on the modelling of complex natural processes. Potential sources for uncertainties are data quality, data processing algorithms and methodologies, assumptions associated with modelling and extrapolation of results to rare events without enough data for validation of model results. Assumption on stationary and homogeneity associated with flood frequency analysis is increasingly questionable due to both climate change and land use change in catchment.

6.3. CONCLUSIONS

Based on the Present study, the following conclusions can be drawn: -

I. With the use of ArcGIS and ERDAS, various required thematic layer maps like Digital Elevation model(DEM) and Slope map were generated which gives the idea that low-lying zone with low slope angle will be immersed first with respect to the high slope territory during flooding. Land use Land cover map shows four distinct classes to be specific: Agriculture covering 75.34%, water covering 11.02% of area, Forest covering 9.9% and urban/settlements 3.7% of total area. Soil map shows type of soils the study i.e. Clay-loamy or complete loamy soil.

II. As the daily discharge data available at the Baltara Outlet is of shorter period, those are used for the calibration of the ArcSWAT model using the SWAT-CUP. It is found out that calibration results are not satisfactory as R^2 value come out to be 0.48 which is quite low. This may be attributed to the data availability and its quality. The long-term data are generated using calibrated model. These data are used for further processing

III. By giving the daily discharge data as input to HEC-RAS (river Analysis system), Flood inundation map along with other maps like velocity map are prepared and Flood Hot Spots are generated.

IV. Flood inundation maps are prepared utilising Bhuvan satellite data as well as the data generated from HEC-RAS. Both the inundation maps are compared. The flood affected areas obtained from the Bhuvan satellite data are more than that obtained from the HEC-RAS generated Flood Inundation Map.

V. Flood inundation maps were generated to assess the flood risk for Kosi river Sub-basin hotspot for prioritization of resources and policies have been identified using choosing by Advantage(CBA) method. After CBA analysis, it is found that Saraigarh has been ranked one for the Flood risk and it is followed by Simri, Siswa, Dharampur and Baluaha in order. Saraigarh has the highest flood-risk weightage because of its distance from the river channel is less, greater population density and has a railway station that will be going to inundated if flood happen other than all the factors taken into consideration. Therefore, it has been shown that this method has the potential to provide information for decision making in disaster studies.

VI. Proper Flood protection works should be done as making of embankments of suitable height as there are embankments of height 4m already made on the side of the river but the problem is it's made everywhere of same height and it is observed from the flood inundation map that level of water are not same at all places like somewhere it will cross 4 m whenever flood event will occur due to various reasons like formation of shoals, deposition of sediments, elevation of that place etc.

Therefore, it can be concluded that based on the above results, proper evacuation plan can be prepared and the damages resulting from the catastrophic floods can be reduced significantly.

6.4. FUTURE SCOPE

I. This study also points towards the lack of availability of reliable data that ultimately leads to inaccurate results. A strong need is felt for record or inventory of historic disaster events and other meteorological and socioeconomic data along with an easy access to it.

II. The results from the above used Models did not come out to be satisfactory. Therefore, there is a strong need of the Models developed specially for the estimation of flood like catastrophes for accurate results.

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