FLOOD INUNDATION MAPPING OF KANKAI RIVER BASIN, NEPAL

A Dissertation submitted to:

Central Department of Hydrology and Meteorology

Tribhuvan University

Kirtipur, Kathmandu

In Partial Fulfillment of the Requirements for the Award of Degree of

Master of Science in Hydrology and Meteorology

Submitted By:

BINOD BABU DHAKAL

T.U. Registration No.: 5-2-37-101-2012

T.U. Exam Roll No.: Hymet 51/073

February 2020

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Declaration

I hereby declare that the work presented in this dissertation is a genuine work done originally by me and has not been submitted elsewhere for the award of any degree. All the sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

…………………….

Binod Babu Dhakal

February 27, 2020

RECOMMENDATION

This is to certify that **Mr. Binod Babu Dhakal** has completed this dissertation work entitled **"*Flood Inundation Mapping of Kankai River Basin, Nepal*"** as a partial fulfillment of the requirements of M. Sc. in Hydrology and Meteorology was completed under my supervision and guidance. To my knowledge, this research has not been submitted for any degree, anywhere else.

We, therefore recommend the dissertation for acceptance and approval.

………………………..

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LETTER OF ACCEPTANCE

On the recommendation of **Dr. Tirtha Raj Adhikari,** this dissertation work of **Mr. Binod Babu Dhakal** is approved for the examination and is submitted to the board of examination for the partial fulfillment of the requirements of M.Sc. degree in Hydrology and Meteorology.

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CERTIFICATE OF ACCEPTANCE

This dissertation entitled "***Flood Inundation Mapping of Kankai River Basin, Nepal***" by **Mr. Binod Babu Dhakal** has been examined and accepted as a partial fulfillment of the requirements of M.Sc. in Hydrology and Meteorology.

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ABSTRACT

Flood is growing as major water related hazard in the world. The degree of impairment that it causes to each and every component goes on increasing with the time. The main objective of this research is to analyze the flood frequency, prepare inundation map of Kankai river basin corresponding to different return period, and to identify the hazardous region along the Kankai river basin. Kankai river basin of 1284 km² area is selected for the study. Frequency analysis is done with Gumbel calculation method and HEC-HMS. Flood hazard mapping is the one of the procedure to find the inundation level. Flood hazard map was prepared by using the HEC-RAS 5.0.7 with integration of ArcGIS 10.1 and its extension HEC-GeoRAS. ASTER DEM of 20*20 spatial resolution was used for the research. The discharge data we have used is validated with the discharge data we have measured in the study area. The discharge value was seen to be simultaneously increasing with the return period of 2, 10, 50, 100, 200, 500, 1000 years. The magnitude of flood depth increased with the increasing return period. The number of household inundated corresponding to the return period is also calculated. The maximum depth of inundation we obtained was 6.46m, which was of 1000 year return period and along the chure range where the cross-section is shorter and depth is greater and going downward the depth of inundation decreases. The depth is categorized as high risk, medium risk and low risk based on DHM reference for Kankai river. Inundation of area of settelements indicates that in future human lives are more prone to flood disaster. Thus, the study may help in future planning and management for future probable disaster.

Keywords: *Flood, hazard, inundation, HEC-RAS, HEC-GeoRAS*

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Abbreviations

ASTER : Advanced Spaceborne Thermal Emission and Reflection Radiometer
DEM : Digital Elevation Model
DEOC : District Emergency Operations Center
DHM : Department of Hydrology and Meteorology
DPTC : Disaster Prevention Technical Centre
FEWS : Flood Early Warning System
GCM : Global Climate Model
GIS : Geographic Information System
GPS : Global Positioning System
HEC-GeoRAS : Hydrologic Engineering Center for geological River Analysis System
HEC-HMS : Hydrologic Engineering Center’s – Hydrologic Modeling System
HEC-RAS : Hydrologic Engineering Center’s – River Analysis System
IEA : International Energy Agency
MoHA : Ministy of Home Affairs
NASEM : National System for Environmental Monitoring
NEOC : National Emergency Operations Center
OECD : Office of Environmental Compliance and Documentation
PMP : Probable Maximum Precipitation
SCS : Soil Conservation Service
UNISDR : United Nations International Strategy for Disaster Reduction
USLE : Universal Soil Loss Equation
WECS : Water and Energy Commission Secretariat

CHAPTER 1

INTRODUCTION

1.1 Background

Flood is one of the striking water induced disaster that hits most of the part of the world. In Nepal also it is one of the serious disaster which affect the human lives and huge amount of property. The increase of population and squatter settlements of landless people living at the bank of the river has tremendous pressure in encroachment of floodplain making them vulnerable to flood damage (Dangol and Bormudoi, 2015).

Floods can be explained as excess flows exceeding the transporting capacity of river channels, lakes, ponds, reservoirs, drainage system, dam and any other water bodies whereby water inundates outside water bodies areas. It causes damages to the crops and property, a lot of difficulties to the people and causes death of people also. It is one of the major natural hazards in terms of fatality and economic loss facing by the country every year. The historical data showed that the country witnessed major floods in Tinau ;1978, Koshi ;1980, Tadi ;1985, Sunkoshi ;1987, Kulekhani ;1993 and many more. The flood control is therefore required to reduce the flood damage.

Nepal is mountainous landlocked country having complex geographic feature. The country has total area of 147181 square kilometres and population of about 30 millions. Hills, Mountains and Terai are the three regions and climate varies from alpine, temperate monsoon to subtropical monsoon respectively. Nepal has enormous water resources. About 6000 river and rivulet drain Nepal. The large rivers in Nepal are snow-fed from the high Himalayas and are perennial. The medium rivers originate from the middle mountains and are rain-fed. The small rivers, originating in the southern slopes of the middle hills and the Siwalik, have little or no flow during the dry period. It is these small rivers that substantially contribute to total flood damage and sediment deposit. Among these rivers, about 1000 are more than 10 km long and approximately 100 are 160 km long. This dense river channels when face the high summer monsoon precipitation followed by low pressure system around the continent invent the devastating flood events inundates and damage the land and infrastructures on its territory. Along with the highly concentrated monsoon precipitation the other factors triggering flood hazards in Nepal are: high relief, steep mountain topography, and deep and narrow river valleys. Each year many people are killed and made homeless, and property and infrastructures are damaged by floods. As a result, the overall development of the country has been severely affected by repeating flooding. In the future the global warming and resulting climate change phenomenon is likely to increase the frequency of flooding by increasing the intensity of extreme precipitation events and enhancing the melting of Glacier Lake. The encroachment of areas susceptible to floods to establish human settlements and to carry out infrastructural development in the recent past has increased the exposure of these areas to flood hazards and also being a least developed, landlocked and mountainous country with limited access to socioeconomic infrastructure and service facilities, vulnerability to flood disasters is likely to increase in the future.

In South Asia, there is an increasing trend in the number of people affected by floods. India has the highest number of people affected by floods followed by Bangladesh. In the period from 1976 to 2005, 332 flood events killed about seven million and affected billion people in South Asia (Bajracharya et al., 2008). Developing countries are particularly vulnerable to extreme weather events especially given the current climatic instability which can cause substantial economic damage (Monirul and Mirza, 2003).

Very little research has been conducted in Kankai River Basin, although several reports related to disaster events have been prepared. River flooding in Nepal is a serious problem in Nepal during the main monsoon months of June to September. Continuous high rainfall during the monsoon period and intense rainfall in the pre-monsoon period during which about 80% annual of rainfall occurs, are the main causes of flooding. Three general types of flooding have been distinguished: riverine floods; which are common in the lower terai region, flash floods; which are common in mid-elevation mountain region and glacial lake outburst flood (GLOF); which occur in the upper Himalayan region.

According to the recent studies on disasters by National Emergency Operation Center (NEOC, 2074) under Ministry of Home Affairs (MoHA) has revealed that from 2068-2074 there were 664 dead, 443 disappeared and 221 injured in overall places of Nepal. Thus, ranking the flood as fourth most dangerous disaster by MoHA.

1.2 Rationale of the Study

The study has been carried out in the Kankai river which lies in Ilam and Jhapa districts located in the Eastern Development Region of Nepal. The present task of preparing dissertation in this topic for the Kankai river is research on how to protect the fertile valley, existing properties and inhabitants from the recurrent floods and their damaging effects in the study area. Flood in association deforestation, hill slope, cultivation and lack of soil conservation practices in the basin results in the prevalence of soil erosion and frequent landslides. Sediment carried by the Kankai river is deposited once it enters the plain region. Further its tributaries joining the river in the valley also contributes sediments. The combined effect of rising bed level and heavy rainfall in monsoon season result the flow which cannot be contained in the natural cross section of the river. Consequently very fertile land as well as settlements area gets inundated. It has resulted considerable loss of lives and properties in the past. Flood that occurred in the study area had swept away a couple of villages, killed number of people and livestock and damaged agricultural land and standing crops and other infrastructures in the past. Because of ever increasing concentration of the settlements, social and physical infrastructures in the flood prone areas higher degree of flood related damages are likely to occur in the future. So flood inundation analysis should be performed to overcome such problem.

1.3 Statement of the Problem

Nepal is hotspot for geophysical and climatic hazards. The country is relatively ranked high in terms of vulnerability to natural calamities. The risk is believed to be increasing very rapidly mainly due to the growth in population, especially in urban and urbanizing areas. Nepal is yearly facing problems of flooding since the past years. Flood is among such disaster which is ranked top in terms of loss of property, households etc. In case of Kankai which is originated in Churia range of Nepal, extreme precipitation in association with downstream area being plain causes flood to occur.

Nepal is the part of the Ganges/Brahmaputra river basin, which is one of the most disaster-prone regions in the world. The Terai region amounting to only 17% of the total area and river valleys in the mountainous region of the country regarded as the granary of Nepal is continuously suffering from flooding. The rivers in this area become wide and inundate and damages agricultural lands. The damages are further characterized by erosion of banks and deposition of infertile coarse material on the cultivated land. The channel capacity of the rivers in this regime is said to be decreasing due to increased sediment coming from increased erosion rate at upland, thus making these rivers unable to accommodate large floods; as a result the adjoining area suffers from inundation.

Besides, natural factors, anthropogenic factors also trigger floods and disasters. Encroachment of floodplains, obstruction of natural flow of rivers and sheet flow, faulty drainage system and river training works also contribute to the increased flooding and disaster. In Terai, devastation due to flood is also increasing due to rapid increase in population and human activities. The flood plains are being increasingly crowded to meet ever-increasing demands of food and fibre, and consequently the flood problem is exacerbated. Similarly, many hydraulic structures (dams/barrage, and bunds) constructed in some places just a few kilometres downstream of Indo-Nepal boarder on the Indian side have also exacerbated the flood situation in the Terai of Nepal (Bhusal, 2004).

The incessant rains devastating floods affect Terai and valley region and cause extensive damage to standing crops, physical and social infrastructure, environment, people's lives and livelihood and weaken the capacity of rural poor. Many people who live along the flood plains are poor, and are frequently overwhelmed by floods and other life-threatening extremes of weather. Because of economic reason, the poor and disadvantaged people of the rural communities are forced to settle in the areas adjoining riversides, marginal and vulnerable areas and therefore are the victim of flood disaster every year. Although various flood management measures are introduced in many places to prevent the negative consequences of flood disaster, the challenges are still at the forefront. It is generally found that the national government, local administration and the government have been mostly reliant on reactive approach to disaster management focusing mostly on the relief operation. Although relief operation is essential for proper flood disaster management, this is not adequate in itself and thus there is a need of measures for preventing hazards turning into disaster. Moreover, under proactive approach of reducing disaster risk, it is necessary to reduce the vulnerability of the people through improved livelihood opportunities and capacity build up and thus increased resilience. For designing an effective and efficient framework of disaster management there is a need to understand the grassroots problems, the institutional set up, and the livelihood assets of the community including local knowledge in flood management. While many studies have been conducted for reducing the disaster risk in many river basins of Nepal, most of these studies have been lopsided with major emphasis on the structural measures and have failed to address the root cause of disasters.

Seven VDCs were flooded by Kankai and Biring rivers in southern Jhapa. More than 500 houses were submerged and 10s of hectares of paddy field were inundated and Sarnamati fled their villages to safer places after the floods entered the villages. While the flood in Kankai caused much damage in Topgachhi 8 & 9, Rajgadh also suffered badly. Even if no loss of life were reported, the villagers incurred heavy loss of property as tens of hectares of land have been turned into riverbed. The worst affect were those people who had paddy fields near the river banks, i.e. on the flood plain.

1.4 Research Objectives

The main objective of this research is to detect the flood prone areas of Kankai river basin.

Specific objectives are:

1. To analyse the flood frequency of Kankai river.
2. To prepare inundation map of Kankai river for different return period.
3. To identify hazardous region around Kankai river.

1.5 Research Questions

The research questions of this study are as follows

1. How HEC-RAS performs flood hazard mapping?
2. Which are flood hazardous zone in Kankai river basin?
3. What will be maximum depth of flooding for different return period?

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CHAPTER 2

LITERATURE REVIEW

2.1 General

Although hydrological and hydraulic science started well before the 15th century, it advanced more rapidly only in the 19th century. It was during this period when most important theories that form the backbone of this science were developed. To mention a few, the theory of capillary flow by Hagen-Poiseuille equation; the law of porous media flow by Darcy; Fick's law of diffusion; and Manning's open channel flow formula (Chow et al., 1988).

While the 19th century saw many theoretical approaches, the 20th century saw the development of empirical physics based approaches. Darcy's law combined with the continuity equation was applied for unsaturated flows. Richards Equation developed in 1931 was the first of its kind to present one dimensional form for unsteady unsaturated flow in porous medium.

After the unit hydrograph method to transform effective rainfall to direct runoff and Hortonian overland flow was devised by Sherman in 1932, new doors opened in field of open channel flow and stream flow analyses. A lot of work then started in the area of rainfall-runoff relationship. One of the breakthroughs was development of Soil Conservation Service (SCS) method for computing abstractions from storm rainfall. The Universal Soil Loss Equation (USLE) for estimating gross erosion by water was developed and is by far the most widely used equation even today. Linsley and Crawford (1960) developed one of the earliest hydrologic simulation models widely known as Stanford watershed model.

The distribution of precipitation has high value of spatial variation in Nepal. Nepal experiences the seasonal summer monsoon rainfall from June to September. Most of the days during June to September are cloudy and rainy. About 80% of the annual precipitation in the country falls between June and September under the influence of the summer monsoon circulation system (Marahatta and Bhusal, 2009). The amount of precipitation varies considerably from place to place because of the non-uniform rugged terrain. However the amount of summer monsoon rains generally declines from southeast to northwest.

The winter months December to February are relatively dry with clear skies. However, few spells of rain do occur during these months. In winter, major weather effective elements are the western disturbances so rain decreases in amount from northwest to both southward and eastward direction. The direction of pre-dominating wind is Northwesterly during this season.

During March to May the country experiences pre-monsoon thundershower activities. The pre-monsoon rainfall activities are more frequent in the hilly regions than in the southern plains.

The period of October and November is considered as a post monsoon season and a transition from summer to winter. During October the country receives a few spells of post-monsoon thundershowers, similar in character to the pre-monsoon ones. The annual mean precipitation is around 1800 mm in Nepal. But owing to the great variation in the topography, it ranges from more than 5000mm along the southern slopes of the Annapurna range in the central Nepal to less than 250 mm in the north central portion near the Tibetan plateau (Karki, 2009).

There are many reports about the study on precipitation in Nepal. With regard to rainfall Nepal is highly dominated by summer monsoon and its circulation arising from Bay of Bengal. It is estimated that the summer monsoon accounts for 80% of the annual rainfall in Nepal. According to Pokharel (2003), summer precipitation is high over middle mountains i.e. Mahabharat range; and decreased slightly over and decreased rapidly over Himalayan range.

In recent study, Barros et al., (2000) and Lang and Barros (2002) have noted significant spatial variability in precipitation in central Nepal, factor of differences over 10km distance, but it did not show any specific dependence on elevation, particularly at the seasonal scale.

Studies by Barros et al., (2000); Shrestha (2000); and Lang and Barros (2002) have shown that large rainfall amounts, on the order of 300-400/year, can fall along the south facing slopes of the Himalayas. Practical Action (2009) has shown that the overall rainfall trend in monsoon season is increasing in eastern, central, western and far western development region reaching up to 30 mm/year.

Studies also have shown that the climatology of Himalayan rainfall variability differs markedly from the rest of the Indian subcontinent (Shrestha et al., 2000). Shrestha et al., 2000 have also analyzed the precipitation trend in Nepal and did not find any significant trend in annual and seasonal precipitation. But a study Shrestha (2004) conducted in Central Nepal clearly indicates the significant increase in extreme rainfall event in the recent decade (1991-2000) by three fold compared to 1971-1980 decade. Global Climate Model (GCM) estimate shows the total precipitation in June, July and August will increase with 9.1% by 2030AD (Agrawala et al., 2003). Similarly, other model based projections have also shown the rising trend in annual precipitation over Nepal.

Change in exposure and vulnerability is compounded by changes in frequency and magnitude of certain hazards due to climate change. Attribution of events to climate change is still an emerging field, particularly when considering individual events; however, there is strong evidence of the links between increasing trends of hydro-meteorological and climatological hazards and climate change (NASEM, 2016; The Royal Society, 2014).

In the cloudburst event of July 19–21,1993 monsoon trough (MT) laid directly over central and eastern regions of the country resulted in country’s highest 1-day precipitation record of 540 mm at Tistung of Kulekhani catchment on July 19, 1993 (Yogacharya and Gautam,2008; Shrestha, 2016).

This chapter includes some important topic related to Hydrologic, Meteorological and Hydraulic Sciences.

2.2 Rainfall

The term precipitation denotes all forms of water that reach the earth from the atmosphere. Precipitation may reach the surface of the earth in the form of drizzle, rain, snow, hail, sleets etc, The magnitude of precipitation varies with time and space. For precipitation to form :1) the atmosphere must have moisture, 2) there must be sufficient condensation nuclei present, 3) weather condition must be good for condensation of water vapour to take place, and 4) the product of condensation must reach the earth (Lal, 2003). The net precipitation a place and its form depend upon wind, temperature, humidity and pressure within the regions enclosing the cloud and the ground surface at the given place. During precipitation events, the water levels in most of the rivers rose above critical levels for a longer period of time (Talchabhadel and Sharma, 2014).

2.2.1 Extreme Rainfall

In Nepal, large amount of rainfall within a short period causes flash floods, massive landslides, soil erosion and sedimentation in hilly and mountainous regions and inundates the plain areas. The spatial distribution of highest 24 hours rainfall provides useful information of the flood and landslide prone zones. The extreme rainfall distribution is different from the annual or seasonal distribution. Siwalik and the Terai belt which generally receive less total seasonal rainfall received the highest 24 hour rainfall. The highest extreme rainfall was mainly in the foothills of Mahabharat and Siwalik in central development region and in foothills of Siwalik in western development region. Congruent with the regional and global pattern, and Nepal being located in fragile Himalayan mountainous terrain, the development of heavy precipitation events and subsequent floods have been more frequent in different regions in recent decades (Karki et al., 2017).

2.2.2 Probable Maximum Precipitation

The greatest depth of rainfall that can occur in a given duration at a given location is known as the possible maximum or the probable maximum precipitation, abbreviated as PMP (DoED, 2009). It is the upper limit of the physically possible precipitation depth. It has been defined as that depth of precipitation which for a given area and duration can be reached but not exceeded under known meteorological conditions. If PMP for a given catchment is estimated than it can be used to provide an estimate of the probable flood. The Probable Maximum Flood (PMF) has virtually no risk of being exceeded. PMP values are generally not considered for the design of the engineering structures due to the reason it cannot be economically feasible but it should be considered as an optimum reference.

2.3 Flood

The portion of precipitation which appears in the surface streams of either perennial or intermittent nature is called the runoff. This is the flow collected from a drainage basin and appearing in an outlet of the basin. In a general sense it is the precipitation excess after meeting the evapotranspiration and deep percolation demands. Such excess amount of precipitation may cause the flood in the river. A flood may be defined as an overflow coming out from river. Whenever the water overflows the banks of the river, the river is said to be flooded. It is the temporary covering by water on land.

Floods have always been natural disasters, which are associated with human and financial losses and have influenced human’s life (Abghari et al., 2007). While the number of deaths has not been increasing, there have been observed increases in the total number of people affected and monetary damages (Chang et al., 2012; UNISDR, 2013).

Floods are natural events and not only replenish alluvial soils, substantially increase the yield of the land, and sustain rich habitat for natural systems, but also inflict substantial damages on human activities in the floodplain (Pender and Faulkner, 2010).

Flooding is a global phenomenon that causes casualties and property loss on every inhabited continent. It occurs naturally when specific environmental factors or combinations of factors occur. Human intervention with natural processes, such as altering a river channel, can also cause flooding. It is probably the most devastating, widespread and frequent natural disaster for human societies. Flow regimes of Nepal's river are largely determined by the highly seasonal characteristics of precipitation, they are characterized by high fluctuations between the peak flows during the monsoon season from June to September and the low flows during the remaining months of the year from October to May (Chalise et al., 2003). Due to heavy monsoon rains, rivers regularly burst their banks and cause widespread flooding and have been the main cause for the loss of life and property in great number every year (Aryal, 2007). As the severity and frequency of flood events have considerably increased, there is a growing global concern about the need to decrease flood related fatalities and associated economic losses (Smith, 2001).

A hazard is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards may be natural, anthropogenic or socio natural in origin (UNISDR, 2013). The characteristics and circumstances of a community, system, or asset that makes it susceptible to the damaging effects of a hazard.

Despite considerable efforts to reduce the risk from natural disasters, floods remain the most devastation natural hazard in the world. Precipitation is a common cause of flood in the rainy season in Nepal, and has been most frequent, highly damaging and wide spread natural hazards. It is estimated that more than 6,000 rivers and rivulets are in Nepal flowing from north to south. Among these, snow fed rivers, such as the Koshi, Narayani, Karnali, and Mahakali, are perennial rivers. They originate from the Himalayas and snowcapped mountains and pass through the Hills to the Terai plains. During the monsoon (June-September), these rivers swell and cause damage to the villages, crops lands, and people and livestock remained within the river basins. Historical data has shown that Nepal witnessed major flood in Tinau basin ;1978, Koshi River ;1980, Tadi River Basin ;1985, Sunkoshi Basin ;1987 and devastating cloud burst in Kulekhani area ;1993 which alone claimed the lives of 1336 people. Between 1983 and 2012, the total number of loss of lives by landslide and flood is 8181 (DWIDP, 2013).

Every year floods claim thousands of lives in addition to leaving millions homeless and inflicting considerable loss to property and infrastructure. The flood problem is by no means limited to Nepal. South Asia has a long history of floods and for many of the countries in South Asia, combating floods is an annual feature. According to a study by the United Nations, floods claim an average of 22,800 lives annually and have caused an estimated damage of US$136 billion to the Asian economy (Kayastha et al., 2013). Floods can be of several types: riverine, estuarine, coastal, catastrophic, flash, hill torrential or, the recent trend: skewed urban practices. The floods lead to destruction of infrastructure, crops, vegetation cover and also erosion of landmasses besides land sliding.

The losses incurred by developing countries are five times higher per unit of gross domestic product than those of richer countries.

According to the MoHA dataset, during the period of two years under review (2015 and 2016), a total of 16 types of disasters have been noted and 13 types of disasters have been recorded. A total of 2,940 events of disaster have been recorded, of which incidents of fire are highest (N=1,856), followed by incidents of lightning (N=299), landslide (N=290), flood (N=244) and heavy rainfall (N=118). Other disasters also took place but less in frequency (by two digits or even less).

Flood events and impacts in recent times have arguably been unprecedented and affected the lives of hundreds of millions of people across the world. These impacts have been shared by both developed and developing countries (DCs) with rapid urban expansion taking place in many flood-prone areas. Concerns for flooding and the associated human impacts are clearly of global significance, especially when allied with the fears of climatic change and associated changes in rainfall events and sea level rise (Kundzewicz et al., 2014). The rapidly growing urban environments in many areas correspond with a lack of urban planning strategies, the deterioration and lack of capacity of urban drainage infrastructure and an increased rate of development on floodplains (Gill, 2004).

In July 1993, Nepal experienced the worst natural disaster in record. Two days of torrential rainfall in central Nepal triggered disastrous landslides, and caused many debris flows and major flooding in main streams and the Terai plains. About 28,000 people in the mountain areas and 42,000 people in the lowlands were affected. About 160 people in the highlands and over 1000 people in the lowlands were killed due to the devastating flood and landslides in Bagmati, Kulekhani and Narayani basins. Infrastructures like Kulekhani hydroelectricity power plant, Bagmati barrage in the plains, roads, bridges, irrigation canals and check dams were severely damaged .The rainfall on 19th July 1993 at Tistung was recorded 540 mm with maximum intensity of 70 mm per hour and recurrence interval of less than 100 years. Such high intensity precipitation occurred over 530 square km in the vicinity. On 20th July rainfall of 482.2 mm was recorded at Hariharpuri Garhi. About 500 to 800 square km of the central portion of the Bagmati watershed received such high intensity precipitation

2.3.1 Estimation of Flood in Nepal

There are several empirical formulas for the estimation of flood flows. Empirical formulae have limited regional application. Many of them do not provide information on the probable return period; hence they shall be used only when a more accurate method cannot be applied because of lack of data. Some of the empirical formulae suitable for the flood prediction in ungauged basins of Nepal are reviewed here but these shall be used with great caution and proper justification.

In the absence of maximum instantaneous flow data at the proposed site regional methods such as DHM, WECS/DHM and Prem Chandra Jha (PCJ) method can be used, which are derived for ungauged locations of Nepal. DHM method has been derived using the hydrometric data up to 1995 and hence can be considered an updated version of WECS Method. The following relationship has been used for computing the flood discharge by this method. WECS/DHM is extensively used for flood prediction in the ungauged locations of Nepal for small projects. The methodology of flood prediction by this method can be found in referenced literature (WECS & DHM, 1990). Using PCJ 1996, maximum storm-floods of different return periods could be derived based on maximum hourly intensity. This regional method was developed for the prediction of design floods in the absence of stream flow data at the ungauged locations of Nepal. The maximum hourly intensity of different frequency has been derived from daily maximum for 142 rainfall stations of Nepal that have more than 20 years of consistent data. Rainfall stations in the basin and/or nearby (outside) should be selected from 142 analyzed stations so that maximum hourly rainfall intensity on the entire basin could be carried out.

There are many other empirical formulas which are used in Nepalese Catchments. Modified Dickens method is one of the methods widely used in Nepal and north India for the estimation of peak discharge. This formula includes area as only one parameter and constant CT depends on the return period and snow fed area (Subramanya, 1995). About monitoring of the data and stations DHM has organized training and quality managements. The task of operation, maintenance and upgrading of stations; maintenance of hydrological and meteorological equipment is done by district DHM offices. Operation of telecommunication systems and software management is outsourced with DHM supervision. Community is assisted in maintenance and operation of manual observation systems at monitoring sites by DHM. DHM also performs development of high resolution data and data validation.

For risk assessment hydrological and hydraulic modelling, floodplain mapping and risk identification with field verification is performed by flood forecasting center. DHM gets additional support from Common Alerting Protocol (CAP) such as Google Public Alerts and Global Flood Detection System (GFDS).

DHM, NEOC, DEOC is responsible for disseminating flash flood watches, warnings and severe flood warnings to communities and relevant agencies. Flood forecasting center performs Feedback through self-assessment and feedback from communities. For capacity building training awareness programs, piloting preparation of awareness materials, seminars, workshops and interactive programs, mock-drill exercises is held by all key stakeholders and NGOs. International collaboration and management of information - Decision Support System (DSS), Global Flood Detection System (GFDS), Quantitative Precipitation Forecast (QPF) from Regional Integrated Multi-Hazard Early Warning System-RIMES, National Oceanic and Atmospheric Administration -NOAA, Tropical Rainfall Measuring system is done by DHM (DHM, 2018).

For Flood Early Warning System (FEWS) DHM seeks to develop simplified sustainable instructions that define the roles and responsibilities of major stakeholders as well as community members. Since bottom-up approaches are limited due to Nepal’s existing infrastructural arrangements, it aims to ensure the involvement of local communities in all phases of FEWS development and implementation. Community members play a particularly important role during the delineation of vulnerable zones. Community-based disaster management units are particularly helpful in identifying vulnerable areas and evacuation routes, overseeing the operations of field stations and disseminating flood forecasts and warnings. Regular interactions among communities and major stakeholders are integral part of it.

2.3.2 Flood Frequency Analysis

Flood frequency analysis is the procedure for estimating the frequency of occurrence (return period) of a hydrological event such as flood. The technique involves using observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, and skewness and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedance probability. Though the nature of most hydrological events such as rainfall is erratic and varies with time and space, it is commonly possible to predict return periods using various probability distributions. In particular, analysis of annual maximum rainfall of different return periods (typically 2 to 100 years) is a basic tool for safe and economic planning and design of small dams, bridges and drainage work as well as for determining drainage coefficients (Bhakar et al., 2008). A return period is known as a recurrence interval which is an estimate of the interval of time between events like an earthquake, flood or river discharge flow of a certain intensity or size (Rakhecha and Singh, 2009). It is a statistical measurement denoting the average recurrence interval over an extended period of time and to dimension structures so that they are capable of withstanding an event of a certain return period (with its associated intensity). The terms "10 year", "50 year", "100 year" and "500 year" floods are used to describe the estimated probability of a flood event happening in any given year (Watson and Adams, 2010). Using historic weather, experts derive the estimated rate of flow or discharge of a river or creek. Flood frequency analysis are used to predict design floods for sites along a river. This method is useful to predict recurrence interval and helps to cause no damage to the public and government properties. There are different types of methods for the estimation of Flood Frequency Analysis (FFA). Before estimating the flood, analyzing is important to obtain probability distribution. The terms return period and recurrence interval are used to denote the reciprocal of the annual probability of exceedance. Calculation of recurrence interval using California method, Gumbel's method, and Hazens method. Reliable flood frequency estimates are vital for floodplain management; to protect the public, minimize flood related costs to government and private enterprises, for designing and locating hydraulic structures and assessing hazards related to the development of flood plains (Tumbare, 2000).

Flood frequency analysis is used for making probabilistic estimates of a future flood event based on the historical stream-flow record, with probability often expressed as the average length of time between floods and called the return period or average recurrence interval (T). The two main methods of flood frequency analysis are analytical and graphical, with the IEA recommending that both procedures are used in a complementary manner. The analytical method of flood frequency analysis usually involves fitting a probability distribution function to model the observed peak flow data from which the probability of exceedance of flow-discharge of a particular magnitude flood may then be calculated. Although this method is widely used, there is little theoretical basis in the choice of distribution, and despite extensive research, no particular distribution has emerged as the best fitted across and most uniform across different sites. The parameters of the probability distribution are generally estimated through analysis of the selected data sample, which is assumed to be representative of its parent population. Methods such as L-moment diagrams and associated goodness-of-fit procedures have been advocated for evaluating the suitability of various distributional alternatives for modeling flood flows in a region. However, the true distribution and its parameters may still differ significantly from the empirically fitted distribution, particularly when samples are small.

2.4 Flood Inundation Mapping

The traditional approach to simulating flow in river channels is through one-dimensional (1D) hydraulic modeling. However, 1D models are unable to accommodate the true physical and hydrodynamic conditions that are critical to understand different river processes.

Limitations of 1D hydraulic models include inability to (a) represent detailed river bathymetry that affect river processes, (b) simulate hydrodynamic conditions that are prevalent during large scale extreme events such as river flooding and glacial outburst floods, and (c) represent and simulate complex river systems such as anastomosing rivers. Consequently, to improve our understanding of river hydrodynamics and processes, the use of 1D hydraulic models in many applications is now being augmented or replaced by 2D and 3D hydrodynamic models (Leclerc et al., 1995; Bates and De Roo, 2000; Carrivick, 2006, 2007; Crowder and Diplas, 2006; Li et al., 2006; Dutta et al., 2007; Liu, 2007; Tayefi et al., 2007). Multiple approaches are used to create river terrain models for 2D/3D hydrodynamic modeling and flood inundation mapping.

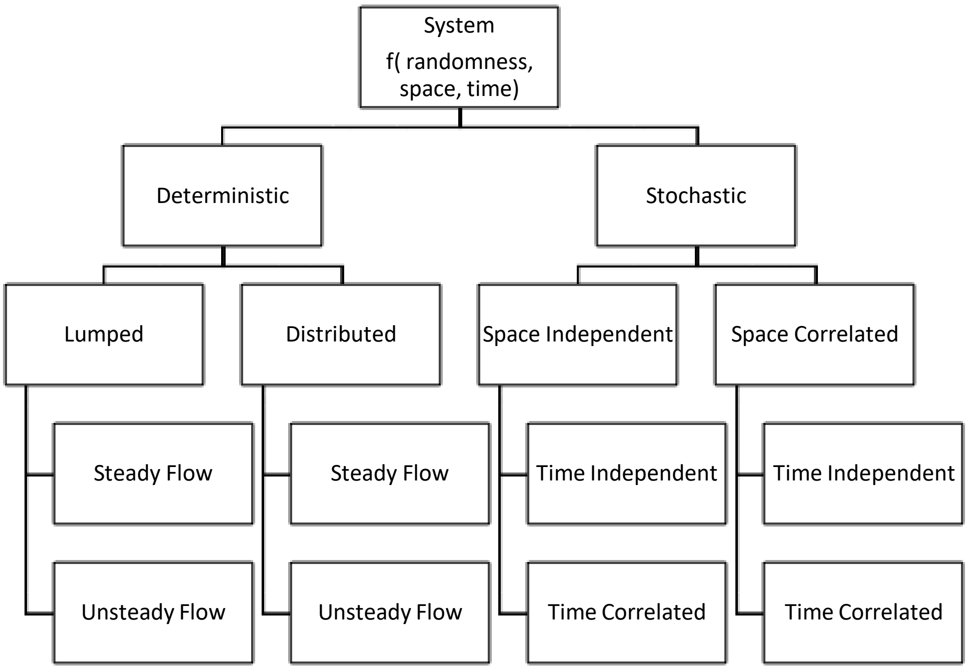
Flood inundation models are a major tool for mitigating the effects of flooding. They provide predictions of flood extent and depth that are used in the development of spatially accurate hazard maps. These allow the assessment of risk to life and property in the floodplain (Pender and Faulkner, 2010).Predicting susceptible floodplains and high potential flash flood prone areas can help authorities in planning management strategies for flood mitigation such as designing water control structures (reservoir levee projects), decision making for flood insurance and facilitating emergency preparedness to cope with flooding. Among various non-structural measures needed for disaster mitigation, hazard mapping is one of the important nonstructural measures (Mahato, et. al., 1996). Land flood hazard areas can be delineated based on hydrologic studies for selected flood peak magnitudes and topographic information (Joshi, 1987).

In hydraulic modeling, two critical factors: (i) stream flow data and (ii) topography of river channel influence flow hydraulics and the resultant areal extent of the simulated flood inundation. Flood magnitude prediction at ungauged reaches is an important task in designing river engineering and hydraulic structures and remains a fundamental challenge for hydrologists. Regionalization transfers hydrological information from one or more gauged catchments to geographically non-continuous regions and hydrological neighborhood ungauged catchments of interest.

Hydraulic model is a mathematical simulation of complex hydraulic equations. Different types of models are used today for the different purpose of simulation. The choice of the model primarily depends upon the expected output with the input from existing databases, input variables, and the type of analysis required. Researchers and scientists have tried to simplify the simulation process using a systems approach represented by set of governing equations that support laws of physics. As a result a lot of approaches have been developed which convert the physical laws to abstract mathematical forms. These mathematical forms are described by a set of equations linking various variables that could behave randomly or could be functions of space and time thereby giving rise to stochastic and deterministic models.

2.4.1 Types of Hydraulic Modeling

A model involving random variables having a probability distribution is termed as stochastic model whereas a model with no random variables is called a deterministic model. Both stochastic and deterministic models are further classified into either conceptual or empirical, depending on whether the model is based on physical laws or not. Another common method of classification of models is as distributed or lumped. These describe how the model treats spatial variability. A lumped model takes no account of the spatial distribution of the input, whereas distributed models include spatial variability (Narula et al., 2002). Most runoff models used today are deterministic distributed models. The availability of GIS tools and more powerful computing facilities have led to the development of more advanced distributed models based on available information in both analog and digital form. Advances in the various fields such as water quality modeling, hydrochemical modeling, and hydrogeological modeling have led to the development of different models at varying scales of application ranging from micro-watersheds to large river basins. The most important issues directly affecting the applicability of models include topography and terrain analysis and spatial distribution of inputs.



(Source: Narula et al., 2002)

Figure 2.1: Hydraulic modeling types

i. HEC-RAS

HEC-RAS is a product of the United States Army Corps of Engineers Hydrologic Engineering Center and is “an integrated system of software comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities”(U.S. Army Corps of Engineers, 1995). The HEC-RAS computes hydraulic analysis components for steady flow which involves solution of the one-dimensional energy equation, unsteady flow through the full solution of the 1-D St. Venant equations or dynamic wave, and sediment transport (Brunner, 2010).

HEC-RAS is well-tested and in use by the National Weather Service for hydraulic modeling as a part of the Community Hydrologic Prediction System (CHPS) (Roe et al., 2010).

However, this model makes many simplifications, including that flow can be represented by a mean velocity in a cross section, that the water surface is horizontal across the cross section, that vertical acceleration and complex floodplain flows can be neglected, and that Manning's equation can be used to approximate uniform flow (Pappenberger et al., 2005).

The HEC-RAS computer model has a large number of options, such as mixed flow regime analysis, allowing analysis of both sub- and supercritical flow regimes in a single computer run, culvert and bridge routines allowing for multiple openings of different types and sizes, quasi 2-D velocity distributions, and x-y-z graphics of the river channel system (U.S. Army Corps of Engineers, 1995).

The HEC-RAS model can handle a full network of channels, a branching system, or a single river reach. The steady flow component is capable of modeling subcritical, supercritical and mixed flow regime water surface profiles. The flow in natural and man-made channels is estimated by the use of the one dimensional Manning Equation (Chow, 1959). Where the water surface profile is rapidly varied, the momentum equation is utilized. By the use of these equations, the program can handle hydraulic jumps, hydraulics of bridges, and evaluate stream profiles.

ii. Components of HEC-RAS

The function of the HEC-RAS program is to determine water surface elevations at all locations of interest. The data needed to perform these computations are separated into geometric data and steady flow data (Brunner, 2010).

a) Geometric Data

The basic geometric data consists of establishing how the various river reaches are connected (River System Schematic); cross section data; reach lengths; and stream junction information. Hydraulic structure data will be covered in this module.

I. The River System Schematic

The schematic defines how the various river reaches are connected. The program can handle simple single reach modules or complex networks. The river system schematic is developed by drawing and connecting the various reaches of the system within the geometric data editor. This schematic data must be the first input into the HEC- RAS model (Brunner, 2010).

Each river reach on the schematic is given a unique identifier. Each cross section in a reach must use the unique "reach" identifier as well as a "river station" identifier. The user is required to draw each reach from upstream to downstream, in what is considered to be the positive flow direction. The connections of reaches are considered junctions and must be numbered. Junctions should be established at locations where two or more streams come together or split apart. Junctions should not be established with a single reach flowing into another single reach.

II. Cross Section Geometry

Boundary geometry for the analysis of flow in natural streams is specified in terms of ground surface profiles (cross sections) and the measured distances between them (reach lengths). Cross sections should be perpendicular to the anticipated flow lines and extend across the entire flood plain. Cross sections are requires at locations where changes occur in discharge, slope, shape or roughness; at locations where levees begin or end and at bridges or control structures such as weirs. Each cross section is identified by a Reach and River Station label. The cross section is described by entering the station and elevations (x-y data) from left to right, with respect to looking in the downstream direction (Brunner, 2010). Cross-section data are essential to describe the topography of rivers and floodplain areas and support flood propagation and inundation modelling. To date, there are only a few guidelines available to assist hydraulic modelers in determining the required quantity and location of cross-section. In terms of topographic data, 1D modeling requires a certain number of cross-sections to represent the river channel and its surrounding topography (Cook and Merwadee, 2009).

III. Reach Length

The reach length (distance between cross sections) should be measured along the anticipated path of the center of mass of the left and right over bank and the center of the channel (these distances may be curved).

IV. Manning's n Value

The value of n depends on: surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal change; temperature, and suspended material and bed load. Three values of n will be selected for each cross section in the following illustrative example; n for the left and right over bank and n for the center of the channel (Chow, 1959, French, 1985).

b) Boundary Conditions

Boundary conditions are necessary to establish the starting water surface elevations (WS) at the ends of the river system. The WS is only necessary at the downstream end for subcritical regime, the WS is only necessary at the upstream end for the supercritical regime, and the WS is necessary for both downstream and upstream for the mixed flow regime (Brunner, 2010). Boundary conditions are not necessary at junctions.

Discharge Data, discharge information is required at each cross section starting from upstream to downstream for each reach. The flow rate can be changed at any cross section within a reach (Brunner, 2010).

2.4.2 Calibration and Validation of the Model

Calibration and validation of model needs the observed long term data of gauge height and discharge. If the numerical calibration couldn’t be done because of the unavailability of the data due to the absence of hydrological station in the basin the data obtained from field survey can be matched with the model simulated data and the result of the model can be checked whether it will be justified or not.

CHAPTER 3

DATA AND METHODOLOGY

3.1 Study Area

3.1.1 General Features

The study is conducted in the Kankai watershed of Nepal. The Kankai river lies in south-eastern part of the country. It originates in Siwalik range in Ilam in Phakphokthum rural municipality. At the place of its origin it is called Deomai Khola. It flows through Jhapa until it crosses Nepal-India boarder and enters Bihar in India. The catchment area of this study basin is 1284 km². The altitude of its origin is about 1820m. The altitude in Sukedangi near the district boarder of Ilam and Jhapa is about 120m, and about 70m in Indo-Nepal boarder.

In Kankai river basin forest covers 837502 hectors of area while agricultural land, grassland, shrubland, barren land and water bodies covers 645881, 66086, 16216, 10801 and 25551 hectors of area respectively.

3.1.2 Climate

Kankai river basin lies in the south-eastern part of the country. It has tropical and subtropical climate regime. The period from March to June is predominantly hot and dry, July to August is hot and humid, September to October is pleasant, and November to February is cool and dry. The hot wave during the summer and cold wave during the winter reflects harshness of the climate in the study area. The temperature ranges up to 46°C in the summer to 2° during winter. The mean daily temperature at Gaida Meteorological station (25.58° N, 87.90° E, elevation 143m) has been estimated as 24.5°C. Similarly, the relative humidity (RH) is 75% and vapor pressure is 23.79. Kankai watershed falls in the class of 75-85% annual average RH. The estimated mean daily vapor pressure is 20. The average sunshine hour for almost 8 months of a year is about 80%, and falls below 50% during monsoon.

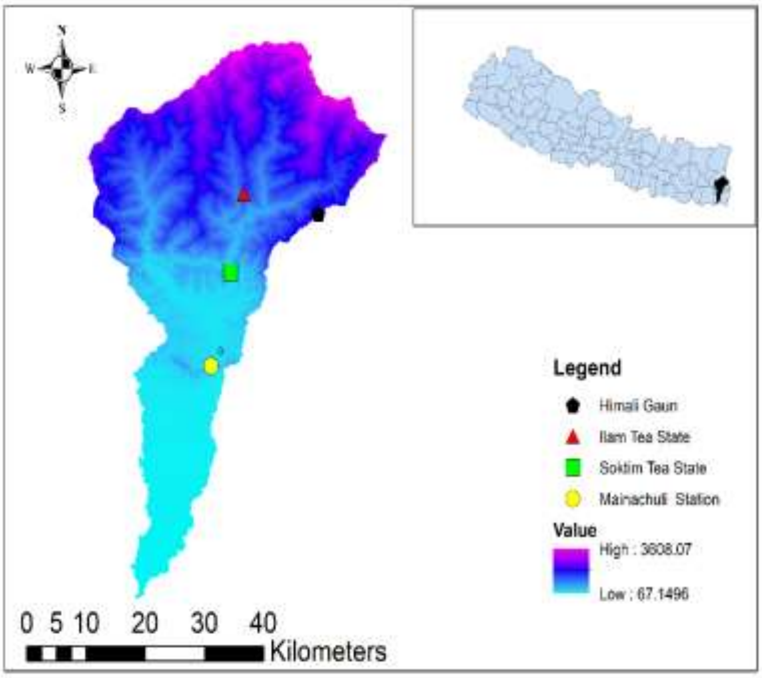


Figure 3.1: Study area of Kankai river basin

3.2 Research Process

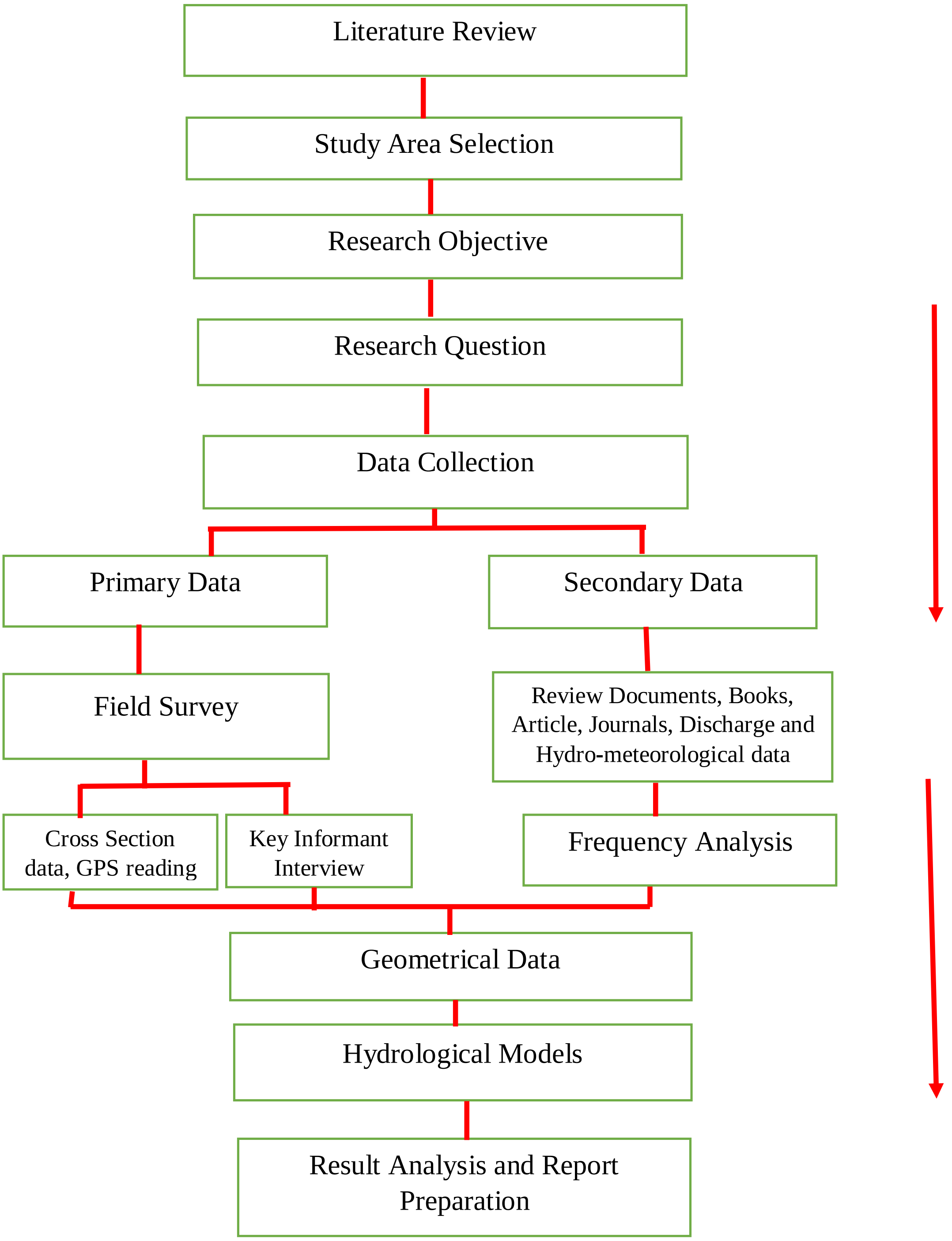


Figure 3.2: Research Design

3.3 Data Collection

The primary data collection was done from the field survey and the secondary data was collected from DHM, Kathmandu. DEM and other HEC-RAS model data required were taken.

3.3.1 Primary Data Collection

The collection of cross section data is the primary data. The data were collected from the 10 sites taking the width interval of 10m and length interval of 200 m in order to measure the depth of the river. The depth of the river was measured by dipping the stick. The elevation was noted down through GPS. Similarly, the questionnaire survey was conducted within the respective cross section data collection areas. The sampling was stratified sampling, which included sample of 10 households in each banks of the river. The discharge of the river was also measured. Also the discharge was measured in the Kankai river.

I. Discharge Measurement

Discharge measurement was carried out by current meter technique:

Current meter method: In this method if the depth is less than 1m, 0.6-depth method will be apply. An observation of velocity made in the vertical at 0.6 of the depth below the surface will be used as the mean velocity in the vertical.

If the depth is greater than 1 m two-point (0.2 and 0.8) methods will be apply. In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of those two observations is taken as the mean velocity in the vertical profile shown in following Figure. This method is based on many studies involving actual observation and mathematical theory.

Calculation procedure :- The discharge is calculated by following mid-section methods shown in Figure 5

Discharge can be computed by following formula:

$Q = \sum(A*V)$; Where, Q is discharge, A is area and V is average velocity.

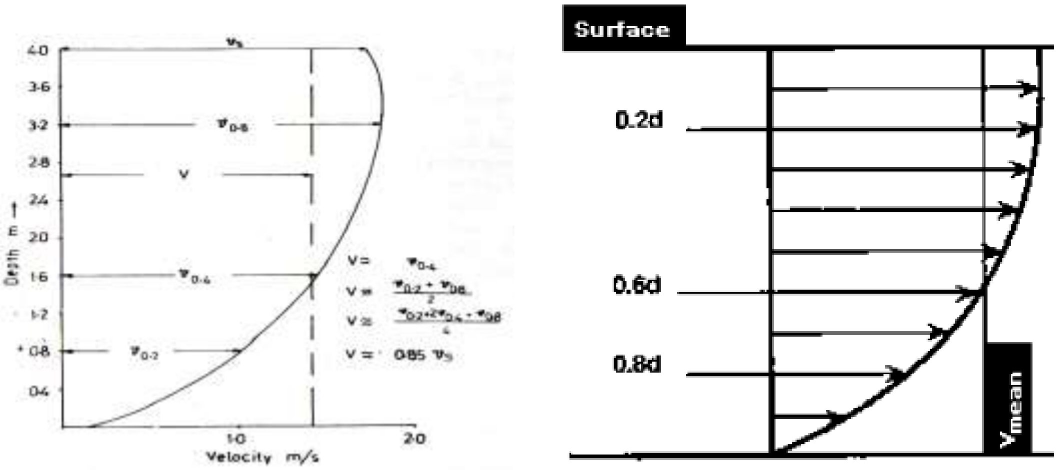


Figure 3.3: Vertical Profile

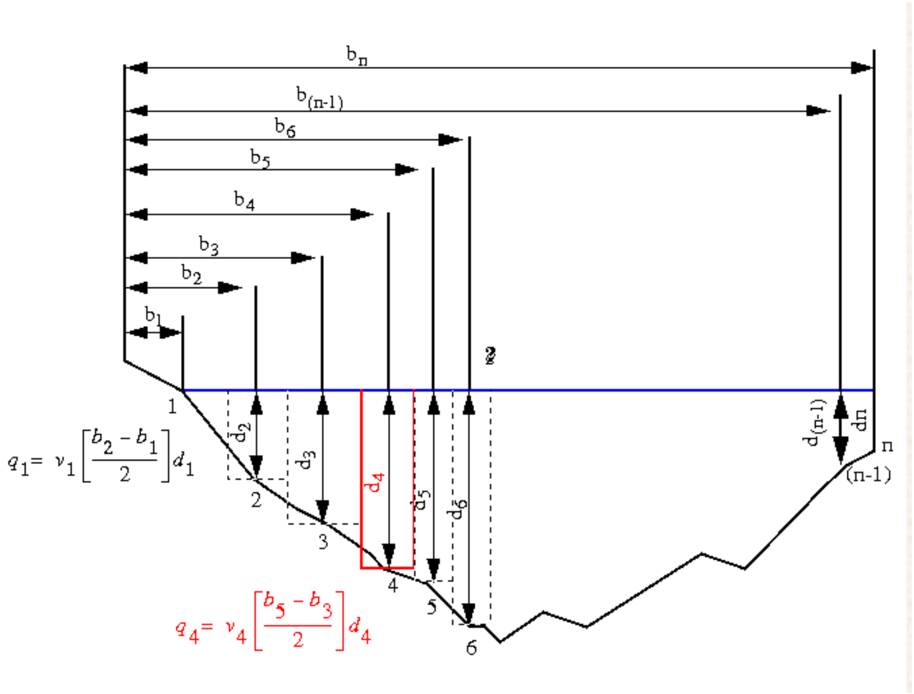


Figure 3.4 Discharge calculation at different cross-section

Letting people to gather at one place focal point discussion is done. Some questionnaire is prepared and asked them and discussed with them.

3.3.2 Secondary Data Collection

The secondary data were collected from the hydro-meteorological station. The hydrological data i.e. daily discharge data of 35 years from Mainachuli station, having station index 795, and meteorological data i.e. daily precipitation data of 3 stations of different durations were collected from DHM.

3.3.3 Hydrological Data collection

The rainfall and discharge data available for the study area was collected from the Department of Hydrology and Meteorology (DHM). Since the monitoring station of Kankai river basin are Himali Gaun, Soktim Tea State and Ilam Tea State Stations . Similarly, discharge data was also collected from the DHM stations of Mainachuli (Station Index: 795) collected for the analysis. The table below shows the data required.

Table 3 1: Hydrological Station in Kankai river basin

Station No.	Name of the River	Location
795	Kankai	Mainachuli

Table 3 2: Meteorological station in Kankai river basin

Index No.	Station Name	Type of Station	District
1407	Ilam Tea State	Agro-meteorology	Ilam
1410	Himali Gaun	Precipitation	Ilam
1411	Soktim Tea State	Precipitation	Ilam

3.3.4 GIS Data

Digital Elevation Model (DEM) generated from free Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) image in the Kankai river catchment. Spatial resolution 20 x20 m. River features such as bank lines, flood plain lines, river center line, were drawn from World imagery found in arcgis online.

Hydrodynamic model HEC-RAS are used to simulate flood in river. The HEC-RAS model is applied to route flood from two stations. HEC-RAS 5.0.7 is used to prepare inundation map to determine flooded area at floodplain by HEC-Geo RAS 10.1 which is an extension of Arc view-GIS 10.1.

3.3.5 Frequency Analysis

Flood frequency analysis often focuses on flood peak values and provides a limited assessment of flood events. Frequency analysis is further calculated using Gumbel method. Gumbel distribution is a statistical method often used for predicting extreme hydrological events such as floods . In this study it has been applied for flood frequency analysis because (a) the river is less regulated, hence is not significantly affected by reservoir operations, diversions or urbanization; (b) flow data are homogeneous and independent hence lack long-term trends; and (c) peak flow data cover a relatively long record (more than 10 years) and is of good quality (d) there is no major tributary of the river whose inflow can affect the flood peak.

The equation for Gumbel’s distribution as well as to the procedure with a return period T is given as,

$XT = Xav + K * SDV$

where;

XT = value of variate with a return period

Xav = mean of the variate

SDV = Standard deviation of the sample

K = Frequency factor expressed as $K = (yT – 0.577)/1.2825$; yT = reduced variate expressed by $yT (T – 1) = - (LN * LN)$; T = return period

3.3.6 Hydraulic Analysis

Application of HEC-RAS to obtain flood extent and depth. HEC-RAS software was used. HEC-RAS is a 1D flow model in which the stream morphology is represented by a series of cross sections indexed by river station. Each cross section is defined by a series of lateral and elevation coordinates that are typically obtained from DEM. DEM derived from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer).

Theoritical Background of HEC-RAS

Hydrologic Engineering Center's River Analysis System (HEC-RAS) was developed by the US Army Crops of Engineers to perform 1D analysis of steady flow water surface profile, unsteady flow simulation, movable boundary sediment transport computation and water quality analysis. HEC- RAS is applied in the current study as a part of hydrodynamic model. Steady flow case is only followed by this study as explained below.

Water surface profiles for steady flow are computed from one section to the next by using energy equation for 2 different sections.

$$\boldsymbol{Z}_2 + \boldsymbol{y}_2 + \frac{\boldsymbol{\alpha}_2 \boldsymbol{V}_2{}^2}{\boldsymbol{2g}} = \boldsymbol{Z}_1 + \boldsymbol{y}_1 + \frac{\boldsymbol{\alpha}_1 \boldsymbol{V}_1{}^2}{\boldsymbol{2g}} + \boldsymbol{h}_e$$

Where Z_1, Z_1: Datum head at 2 different sections

y_1, y_2: water depth at sections1 and 2

v_1, v_2: velocities at sections1 and 2

h_e = Energy Head loss

α_1, α_2 = Velocity weighting coefficients

g = gravitational acceleration

Energy head loss

The energy head loss between two sections is comprised of frictional loss and eddy loss (contraction or expansion loss). The energy head loss (h_e) is given by

$$\mathbf{h_e = h_f + h_c}$$

where

h_f = friction loss

h_c = eddy loss

$$\mathbf{h_c = LS_f + C}\left[\frac{\boldsymbol{\alpha}_2 \boldsymbol{V}_2{}^2}{\boldsymbol{2g}} - \frac{\boldsymbol{\alpha}_1 \boldsymbol{V}_1{}^2}{\boldsymbol{2g}}\right]$$

Where

L = Discharge weighted reach length

S_f = Representative friction slope between two sections

C = contraction or expansion loss coefficient

The discharge weighted reach length is given by

$$\mathbf{L- (L_{lob}Q_{lob} + L_{ch}Q_{ch} + L_{rob}Q_{rob})/(Q_{lob} + Q_{ch} + Q_{rob})}$$

Where

Q_{lob}, Q_{ch}, Q_{rob} = average flow in left, main channel and right overbank

L_{lob}, L_{ch}, L_{rob} = cross-section length in left, main channel and right overbank

Conveyance (K) is computed by

$$\mathbf{K} = \frac{AR^{2/3}}{n}$$

Where

n = Roughness coefficient

A = Cross-sectional area

R = Hydraulic radius = A/P where P = wetted perimeter

The cross-section is subdivided and K is computed for each sub-division, and total K is found.

Friction slope is computed using Manning's equation:

$$\mathbf{S_f = (Q/K)^{2/3}}$$

Representative friction slope between two sections is computed by different methods, such as taking arithmetic mean, geometric mean or harmonic mean.

$$\mathbf{S_f} = \left(\frac{Q1+Q2}{K1+K2}\right)^2 \qquad \text{(USACE, 2002)}$$

Friction slope is computed using Manning's equation. Alternatively, can also be computed by different methods such as taking arithmetic mean, geometric mean or harmonic mean.

Computation procedure

- Assume a water surface elevation at the upstream cross-section (or downstream cross- section is the supercritical flow profile is computed).
- Based on the assumed water surface elevation, determine the corresponding total conveyance and velocity heads.
- Compute L, S_f and h_e.
- Compute water surface profile by using energy equation (WS2).
- Compare the computed value (WS2) with assumed value and repeat above steps until the value agrees to 0.003m, or the user defined tolerance.

HEC-RAS simplifications of St. Venant equation

Assuming horizontal water surface at each cross-section normal to the direction of flow and neglecting exchange of momentum between channel and flood plain, the discharge is distributed according to conveyance, .i.e

$$Q_c = \phi Q$$

Where Q_c = flow in channel

Q = total flow

ϕ = total flow

$$\phi = \frac{Kc}{Kc+Kf}$$

Where

K_c= conveyance in channel

K_f = conveyance in flood plain

These equations are approximated using implicit finite difference schemes, and solved numerically using Newton-Raphson iteration procedure.

Boundary Conditions

For a reach of a river, there are N computational nodes which bound N-1 finite difference cells. From these cells 2N-2 finite difference equations can be developed. Because there are 2N unknowns, 2 additional equations are required. These equations are provided by boundary conditions for each reach.

- For subcritical flow, both upstream and downstream boundary conditions are required.
- For supercritical flow, only downstream boundary condition is required.

Interior Boundary Conditions

A network is composed of a set of M individual reaches. Interior boundary conditions are required to specify connection between reaches. Depending on type of reach junction, one of two equations, either continuity of flow or continuity of stage, is applied.

The major steps are as explained below:

HEC-GeoRAS is applied to create an import file of geometric attribute data for use in HEC-RAS and to view water surface profile data exported from RAS. The graphical user interface allows users with minimal GIS experience to create a HEC-RAS import file containing geometric attribute data from an existing digital terrain model. The pre-RAS application of HEC GeoRAS is used to prepare HEC-RAS input data file. The following data sets are prepared in the ArcView GeoRAS environment so as to export the geometric data file to the HEC-RAS model.

- TIN model as DEM input
- River Banks

- Flow path
- Centerline of river
- Cross-section cut lines

The pre-RAS operation is carried out in the order and sequence and then exported geometry file created to export to HEC-RAS model. Discharge is taken as upstream boundary, whereas rating curve is taken as downstream boundary. Set up of HEC-RAS model is than done and generation of several scenarios of flood inundation is carried out. With increasing magnitudes of discharge or stage at the upstream, the flood inundation scenarios are generated by running HEC-RAS model.

I. Model Inputs

Implementation of HEC-RAS requires inputs which come from three basic categories of data;

(i) Geometric Data (ii) Basin Characteristics and (iii) Flow Data

(i) Geometric Data

The requisite geometric data includes stream centerlines and cross section cut lines and these are prepared using the HEC-Geo RAS user interface. It is a set of procedures, tools, and utilities for processing geospatial data in Arc-GIS.

(ii) Basin Characteristics

Manning's friction coefficient 'n' falls under this category. The Manning's 'n' value is highly variable and depends on a number of factors including surface roughness, vegetation, channel irregularities, channel alignment, scour and deposition, obstructions, size and shape of the channel, stage and discharge, seasonal changes, suspended material and bed-load (Samarasinghea et al., 2010).

(iii) Flood Simulation

The initially used Manning's 'n' values were varied to give the downstream boundary condition. HEC-RAS model simulation results were exported to HEC-Geo RAS for further processing and visualization of flood extents. HEC-RAS simulations require each cross-sectional line to carry a manning 'n' value (land use type) in the geometric file. The land use categories are re-classified into open water, developed open land, urbanized land, barren land, vegetation, crops/grassland and wetlands and are represented by polygons. The corresponding manning values (as provided in HEC-RAS user manual) are assigned for each polygon and imported to the land use layer in HEC-Geo RAS.

CHAPTER 4

RESULTS

4.1 Discharge

The discharge of the Kankai river was measured by wading method as described in chapter data and methodology 3.3.1.1 on 29 Nov, 2018 which is found to be 14.89 m³/s. Near Mainachuli one cross-section was selected and discharge was measured one way on that cross-section. During the time of measurement the guage height was 1.49m. The discharge data are presented in Annexes 1.

4.2 Rainfall Analysis

Kankai River is one of the hazardous river of Eastern Nepal. Three meteorological stations of Kankai river basin were analyzed namely Ilam Tea Estate, Himali Gaun, and Soktim Tea Estate.The rainfall data of the period from 1956 to 2016 has been obtained from DHM. The average annual rainfall of these three stations has been presented in Figure 5-1 below. It shows that the annual rainfall in the basin varies from 881 mm (driest year) to 2936 mm (wettest year) with 1893 mm as the annual average value. The normal annual rainfall of Nepal is 1,861.3 mm (Practical Action, 2009); comparing the average annual rainfall of 1893 mm of the Kankai Basin with the national average, this basin falls under high rainfall receiving basin. Further, it also drops under high rainfall intensity area.

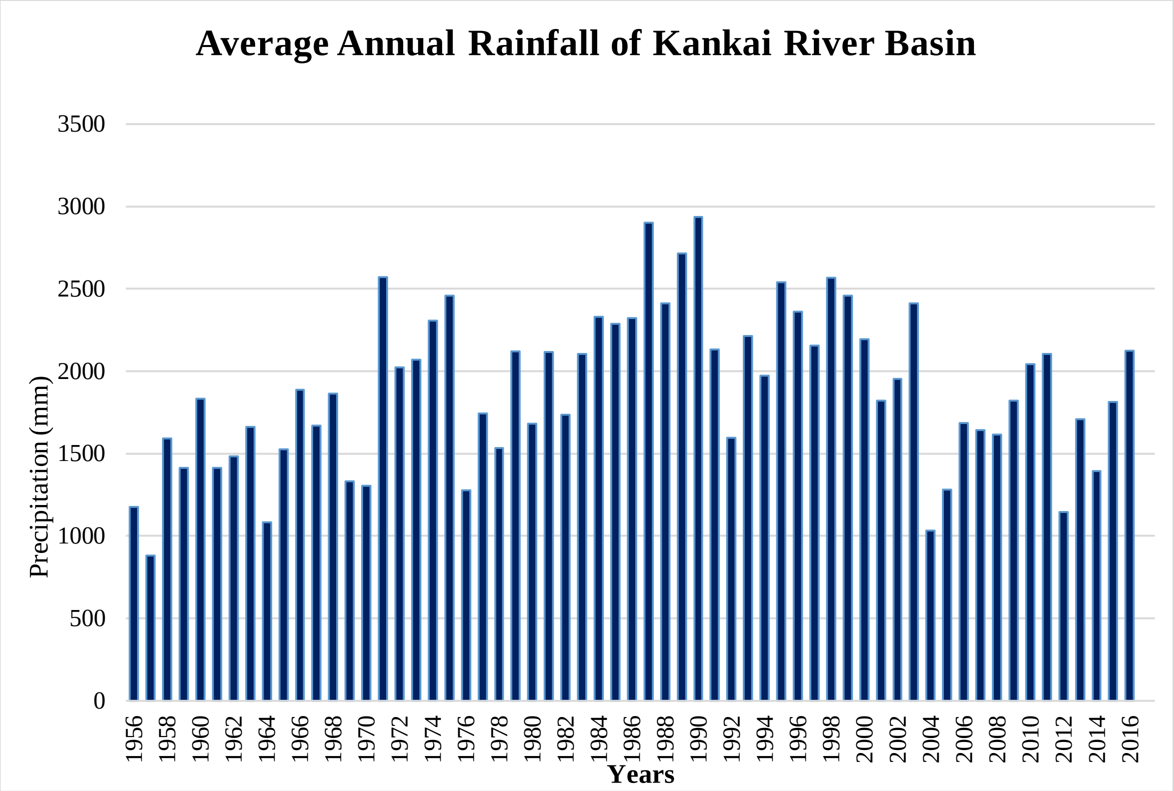


Figure 4.1: Average annual rainfall of the basin area

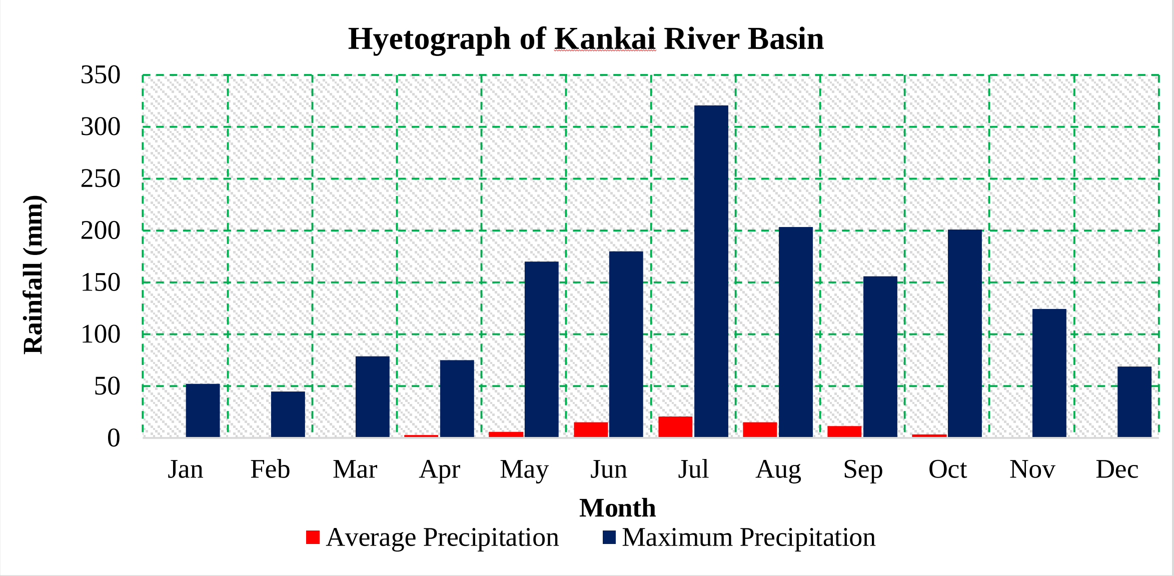


Figure 4.2: Rainfall hyetograph of Kankai river basin

Rainfall hyetograph of Kankai River Basin is prepared. Of the monthly extreme rainfall value, maximum rainfall occurs in July (15, July 1983) 320.6mm of which the flow is 1400 m³/s and extreme minimum rainfall occurs in February (15, Feb 2007) 45mm. From the average monthly rainfall value July has maximum value of about 20mm and December has minimum value of about 0.39mm. If we observe the October monthly extreme value which is 201mm (20, Oct 1987) it is higher than September monthly extreme value which is 156mm (16, Sept 1884) because it is one day extreme value not a monthly average value and one day extreme value may be greater because of long term monsoon retreat effect. The tabulated form of above figure is:

Table 4. 1: Average and extreme value of Kankai river basin

Month	Maximum Rainfall	Average Rainfall
Jan	52.3	0.45
Feb	45	0.74
Mar	78.5	0.98
Apr	75	2.63
May	170	5.88
Jun	180	15.11
Jul	181.5	20.56
Aug	203.3	15.21
Sep	156	11.36
Oct	201	3.13
Nov	124.2	0.54
Dec	68.8	0.40

Frequency analysis as described in 3.3.5, was carried out using 24 hour maximum rainfall based on the data recorded at Himali Gaun (1410) using Gumbel distribution. The 24 hour maximum rainfall for different return periods are presented in Table 4-1. The result shows that the 24 hour maximum rainfall for 10, 50, 100, 200, 500 and 1000 years return period are 228.5 mm, 310.5 mm, 345.2 mm, 379.75 mm, 425.33 mm and 459.78 mm respectively. It indicates the probability of having high flow in the Kankai River in monsoon because of rain shower.

Table 4. 2: 24 hour maximum rainfall for different return period

Return Period (Year)	24 Hour Maximum Rainfall (mm)
2	134.9
10	228.5
50	310.5
100	345.2
200	379.7
500	425.3
1000	459.8

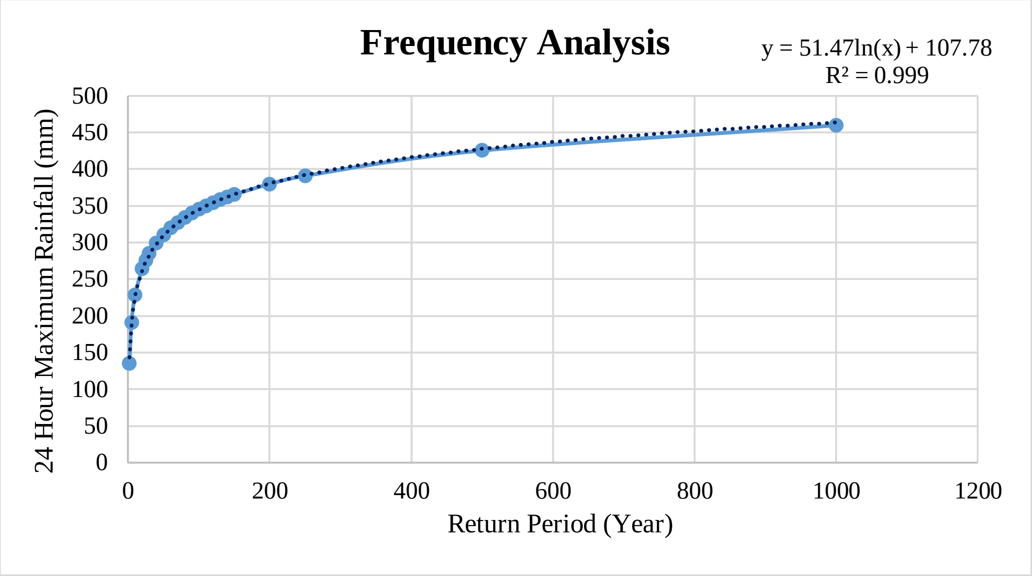


Figure 4.3: Frequency analysis of rainfall of Himali Gaun Station

4.3 Flow Analysis

The average monthly discharge at Mainachuli hydrological station is shown in the figure

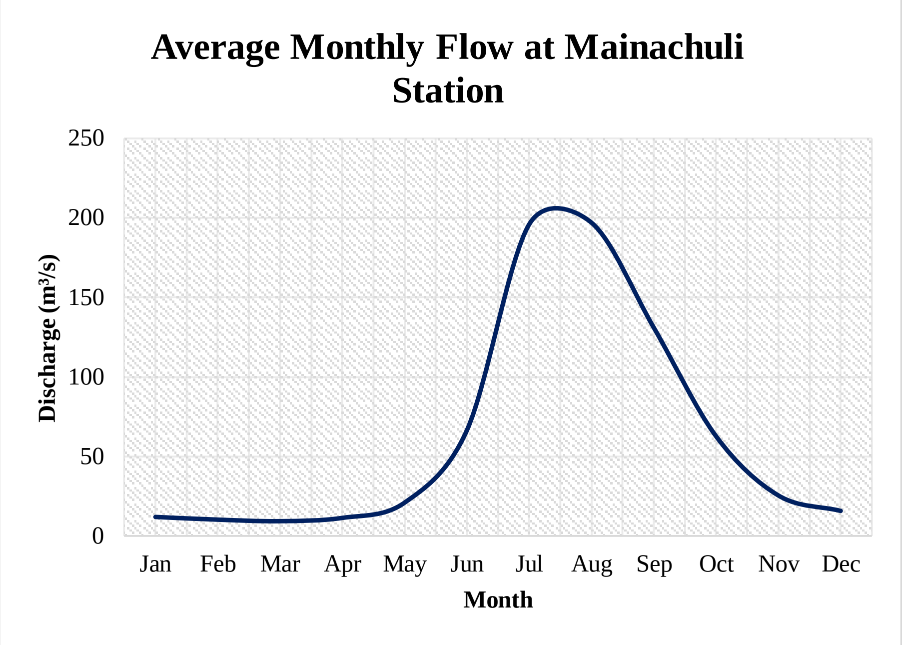


Figure 4.4: Average monthly discharge at Mainachuli (1972-2010)

(Source: DHM)

The relationship of the rainfall at Himali Gaun and discharge at Mainachuli is shown in figure below.

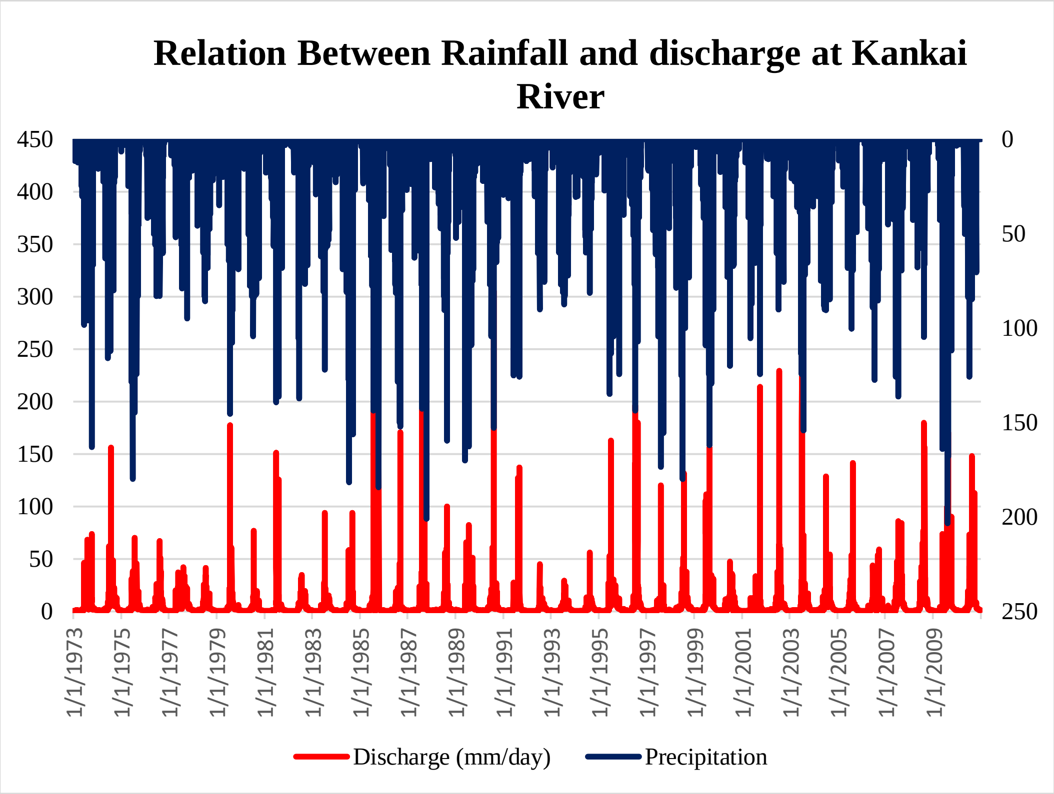


Figure 4.5: Relationship between rainfall and discharge at Kankai river

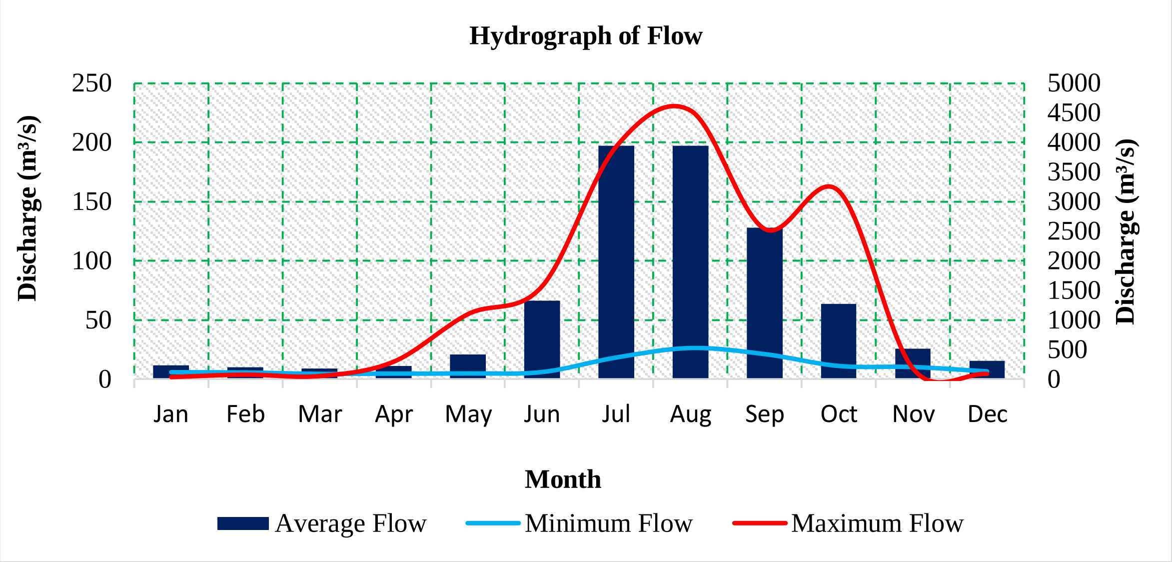


Figure 4.6:Hydrograph of Kankai river at Mainachuli

The hydrograph of Kankai River at Mainachuli is shown in the figure. The maximum flow is the extreme maximum flow observed at a time and mimimum flow is the extreme minimum flow observed at a time. Of the monthly extreme value August has maximum value of 4540 m³/s and January has minimum value of 37.80 m³/s. Of the minimum extreme value August has maximum flow of 26.4 m³/s and March has minimum value of 4.59 m³/s. The average flow at Mainachuli has maximum value August 197.02 m³/s and March has minimum flow of 9.31 m³/s. If we see the October maximum flow it is higher than September flow. Since it is one day extreme flow so it can be higher on October. Also on rainfall hyetograph the extreme maximum precipitation is higher on October than September so flow attained its higher value on October than September.

Table 4. 3: Flow at different return period

Return period (Year)	Flow Obtained from Gumbel calculation (m³/s)	Flow from HEC-HMS (m³/s)
2	3460.11	3243
10	6321.11	5081
50	8829.34	6693
100	9889.71	7374
200	10946.2	8053
500	12340.05	8948
1000	13393.49	9625

4.4 Hydraulic Simulation

Execution of the HEC-RAS model for the three different cases showed varying values of the different hydraulic parameters such as water surface elevation, velocity of channel, flow area etc. The result of the case for 2yr, 10yr, 50yr, 100yr, 200yr, 500yr, and 1000yr return period has been presented in ANNEX II.

4.5 Inundation Analysis

The model was run at steady state condition as explained in 3.3.6.1, on how HEC-RAS is run, and the flood prone area was delineated and the output was imported in HEC-GeoRAS for further processing. Initially, the model was run to calculate the water surface profiles for the discharges of different return periods. The digitized river on HEC-RAS is given in figure below.

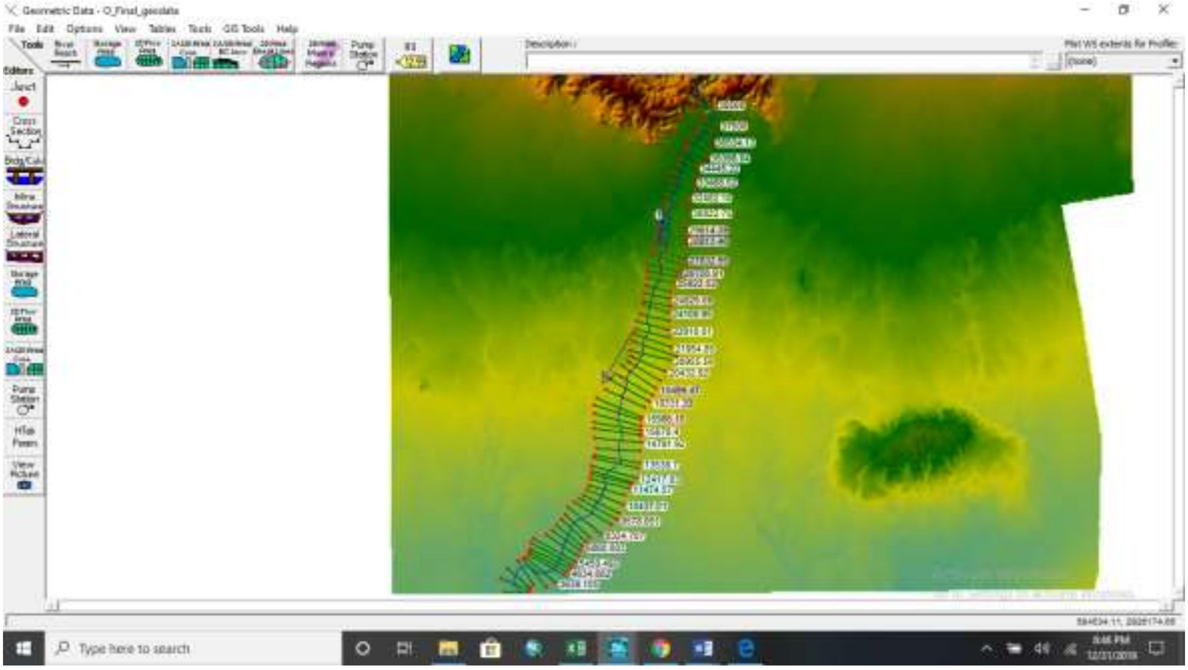


Figure 4.7: Cross section river profile with integration of HEC-RAS and Arc-GIS

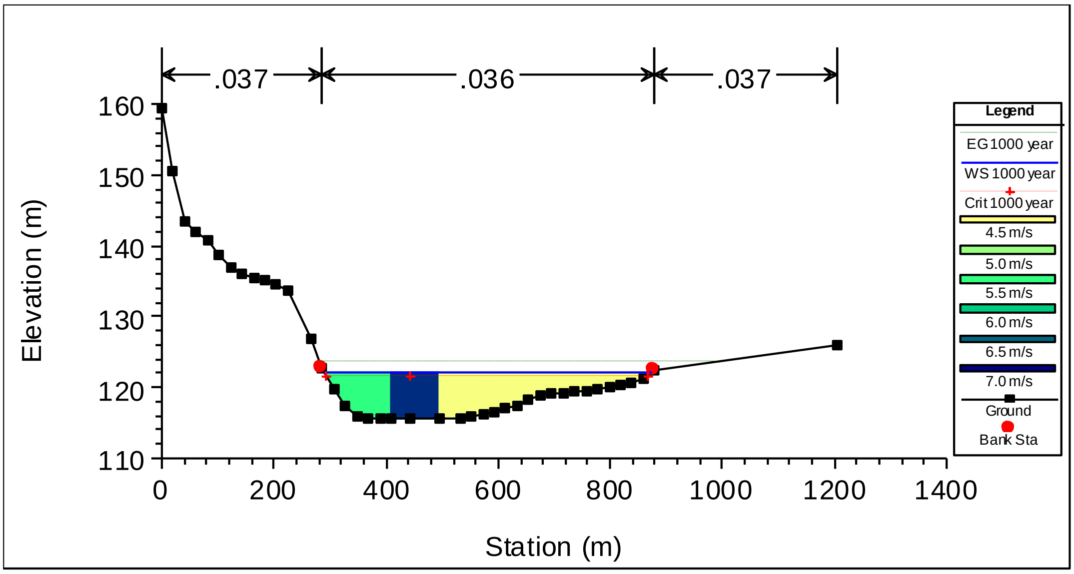


Figure 4.8: Typical cross sections of the flow at chainage 38500

This chainage connects Kankai ward no. 2 and Shivasataxi ward no.10. The inundation depth with different return period, which is on the Annexes 2 under hydraulic simulation, for this chainage is shown in table below

Table 4. 4: Return period and its flood depths at cross-section 38500

Return Period (Year)	Inundation Depth (m)
2	3.89
10	4.8
50	5.45
100	5.71
200	5.95
500	6.25
1000	6.46

The detail result obtained about the cross-section, its return period and its corresponding depths and zone connected by the cross-sections are given in table. The more and detail information on this is presented in the Annexes 4 under major cross-sections and their information.

Table 4. 5: Cross-sections and its depth at different return period

S. No.	2-Year Return Period Flood Depth	10-Year Return Period Flood Depth	50-Year Return Period Flood Depth	100-Year Return Period Flood Depth	200-Year Return Period Flood Depth	500-Year Return Period Flood Depth	1000-Year Return Period Flood Depth	Hazardous Region
1	3.89	4.8	5.45	5.71	5.95	6.25	6.46	Kankai-2, Shivasataxi-10
2	2.64	3.45	4.04	4.26	4.47	4.73	4.92	Kankai-4, Shivasataxi-10
3	2.11	2.83	3.34	3.54	3.73	3.96	4.13	Kankai-4, Shivasataxi-9
4	1.81	2.53	3.02	3.21	3.39	3.61	3.77	Kankai-4, Shivasataxi-7
5	2.37	3.02	3.48	3.65	3.82	4.03	4.18	Kankai-5, Shivasataxi-7
6	2.03	2.56	2.95	3.09	3.24	3.42	3.55	Shivasataxi-7
7	2.15	2.71	3.11	3.27	3.42	3.62	3.75	Shivasataxi-6
8	2.39	3.06	3.52	3.70	3.87	4.07	4.22	Jhapa-7, Shivasataxi-5

9	1.9	2.47	2.87	3.02	3.17	3.36	3.49	Jhapa-4, Shivasataxi-5
10	2.02	2.64	3.06	3.22	3.37	3.57	3.70	Jhapa-4, Shivasataxi-4
11	2.58	3.13	3.52	3.67	3.82	4.0	4.12	Jhapa-4
12	2.47	3.02	3.38	3.51	3.64	3.79	3.91	Jhapa-2, Shivasataxi-4
13	2.03	2.59	2.98	3.12	3.26	3.43	3.55	Jhapa-2, Gaurigunj-1
14	3.00	3.67	4.08	4.23	4.38	4.57	4.70	Jhapa-1, Gaurigunj-1
15	1.94	2.63	3.12	3.31	3.49	3.71	3.88	Gaurigunj-2

Use of HEC-GeoRAS for inundation analysis with the results obtained from HEC-RAS simulation was applied for flood zonation. The Figure 4.9 and 4.10 below show the inundation maps for 1000 year and 500 year return periods respectively. The more such images are presented in the annexes 3.

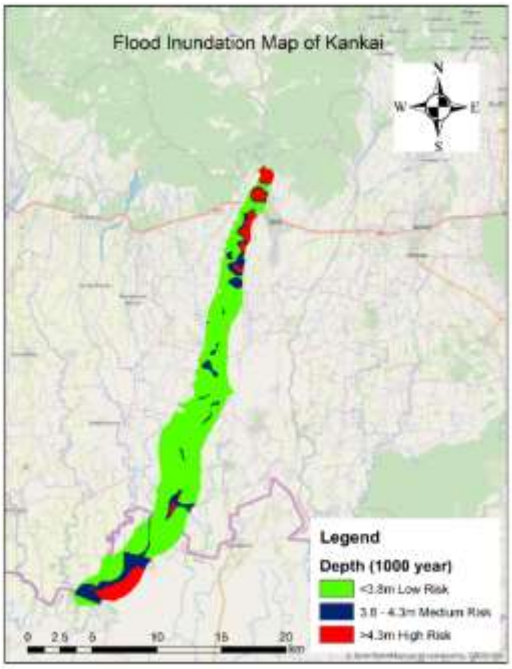


Figure 4.9: Inundation map of Kankai river with 1000 year return period

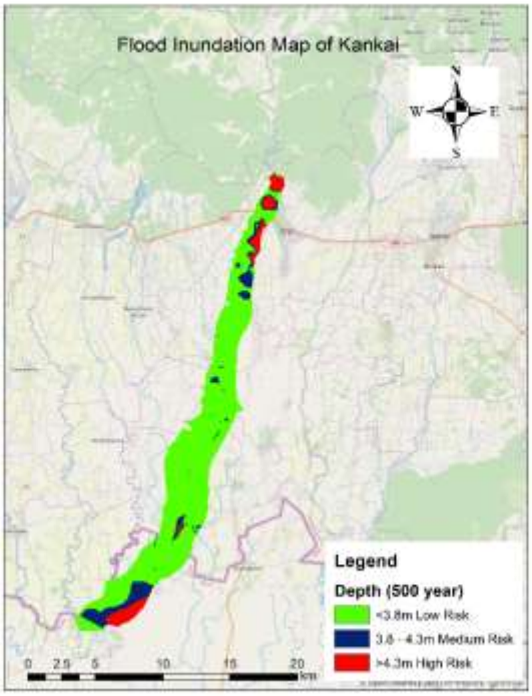


Figure 4.10: Inundation map of Kankai river with 500 year return period

The risk level here like low risk, medium risk and high risk are taken from DHM's warning level and danger level standard.

Figure 4.11: Reference of defined risk level

The pictorial representation of the output of HEC-GeoRAS as drawn above (Figure 4.9 and Figure 4.10) shows that the total area inundated for the different return period of 1000 and 500 years are 78.51 km² and 72.03 km² respectively. Table below shows the flood inundated area with flow of different return period calculated from Gumbel calculation and HEC-HMS. The below table is supported by Annexe 3.

Table 4. 6: Return period with its corresponding inundated area

Return Period (Year)	Inundated Area with flow calculated from Gumbel Calculation (km²)	Inundated Area with flow calculated from HEC-HMS (km²)
2	66.21	65.71
10	69.33	68.4
50	70.13	69.04
100	71.39	69.91
200	73.02	70.13
500	74.03	71.91
1000	75.21	74.13

Table 4. 7: Relation between return period, inundated area and households

Return Period (Year)	Inundated Area (km²)	Inundated Households
2	66.21	396
10	69.33	445
50	70.13	478
100	71.39	493
200	73.02	509
500	74.03	521
1000	75.21	543

The graph is plotted between return period, inundated area and households and shown in figure below.

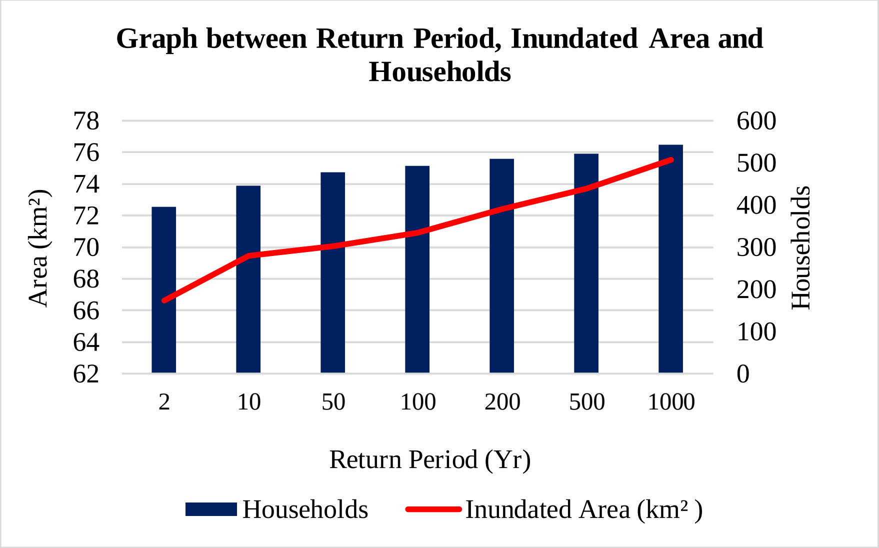


Figure 4.12: Graph between return period, inundated area and households

Graph is plotted between return period and depth, taken from Annexes 2, which shows on increasing return period, inundation depth also increases.

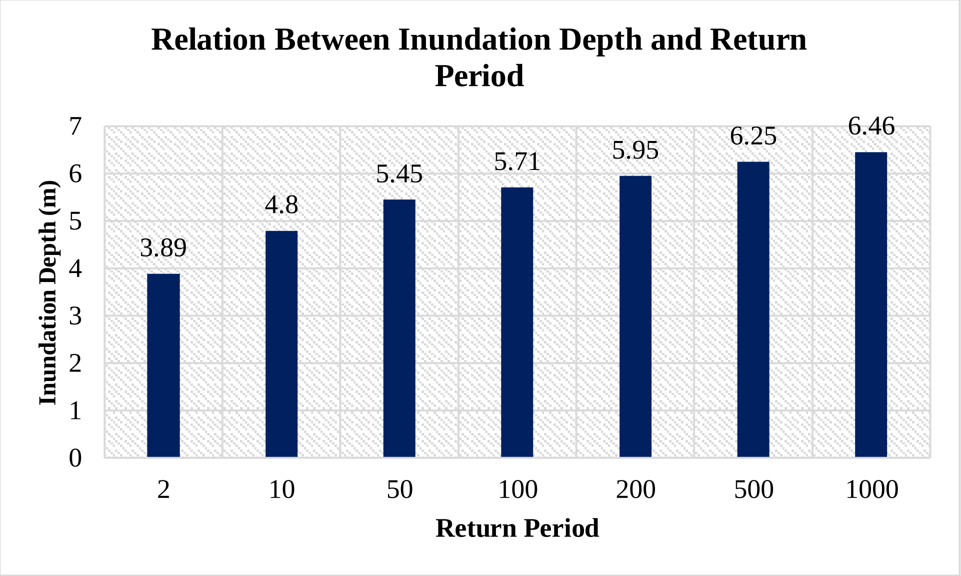


Figure 4.13:Graph of inundation depth v/s return period

Floods and frequency curves developed from precipitation estimates can be used for comparison and to potentially adjust flood frequency curves, including extrapolation beyond experienced values (England et al 2017). From extreme precipitation and their corresponding discharges frequency analysis of those rainfall and flows is done which is shown in the table below.

Table 4. 8: Frequency analysis from extreme rainfall and its corresponding flows

Return Period (Year)	Rainfall (mm)	Discharge (m³/s)
2	162	1091
5	224	2451
10	265	3351
20	304	4215
25	317	4489
30	327	4711
40	343	5062
50	355	5332
60	365	5553
70	374	5739
80	381	5901
90	388	6043
100	394	6170

If we are concerned with the individual extreme event of 1983 July 15, 16, 17 the rainfall are 320.6mm, 66.8mm, 51.5mm respectively and flows of those days are 1400 m³/s, 958 m³/s, 125 m³/s respectively. This clearly suggest that when there is high rainfall, flood is probable to occur.

CHAPTER 5

DISCUSSIONS

5.1 Analysis of flood frequency

The maximum discharge was calculated from Gumbel method and HEC-HMS. The hypothetical plotting by Gumbel is in light of the presumption that the watched esteem is the most likely, or modular, estimation of this rank of flood. Its arrival period is along these lines skewed towards the method of the hypothetical circulation. The overbanks and the main channel will have the same water surface elevation. From the obtained results as well, as the return period increases, so does the discharge become maximum. Thus the magnitude of occurrence decreases. The near yearly flood should be mostly focused. A lean flow occurs in December, January and February, whereas high flows occur in July, August and September. The record of extreme max. Discharge exhibits that the least discharge occurs in February and the greatest discharge occurs in August. Since the rainfall is maximum in July and August, the flood level tends to be higher in that period of month that is around 4540 m^3/s. In addition to these, the data shows the average annual rainfall of 1894 mm. Thus, heavy rainfall could also be the cause for increase in discharge. The average monthly and annual rainfall of Kankai River is shown in figure 4.1 and 4.6. The urban dwellers becoming the second causative factors responsible for flooding, in addition to natural events occurrence time might be very risky.

The precipitation when high, there is high flow observed which shows contribution of rainfall to runoff. But when flood is seen with high value, the precipitation has not attained its highest value which shows there may be other factors which have affected it.

Although studies have employed several statistical distributions to quantify the likelihood and intensity of floods, none had gained worldwide acceptance and is specific to any country.

The flow calculated for different return period from HEC-HMS model is low compared to that obtained from Gumbel Calculation. The lump model gives best result for watershed less than 500 km^2, so for this watershed the distributed model gives best output.

5.2 Flood hazard mapping

HEC-RAS model was run to compute the depths corresponding to maximum discharge obtained through Gumbel's distribution and HEC-HMS. HEC-RAS and its companion GIS extension HEC-GeoRAS can aid in the development of flood inundation maps. After processing and editing the two models we have found that the HEC-RAS models are valuable tools for inundation mapping. The return period of 2, 10, 50, 100, 200, 500 and 1000 years have been seemingly increasing. The depth ranges from 0.000053406m to 6.46m. Higher the depth , higher the chances of flooding in relation with the intensity of flood (Dangol et al., 2015). HEC-RAS and HEC geo-RAS integration with GIS helped to determine the hazardous area with respect to the corresponding depth. The hazardous region has been divided into three classes. They were high risk, medium, low risk region. The high hazard region was found to be randomly distributed at any places based on the topography of river. These regions had the consequent increase in the depth from 2 to 1000 years in the same particular regions which depicts the higher risk areas with higher depth.

We have done the frequency analysis and corresponding flood hazard mapping for 2 to 1000 year return period. In doing so one ask, for 1000 year return period flood occurring chances is very low of about 0.1% so it may be less reliable. Since the disaster is random and uncertain it can reoccur in 1000 year return period too. And also there is practice of estimating flow on the order of thousand year return period.

A small scale leads to identification of the higher risk zone upon which a large scale and a detailed mapping eventually identifies the high hazard areas (Sanyal and Lu, 2005). The condition of river cross section and floodplain is an important factor. Means, in parts of the study reach where the floodplain is relatively lowland the hazard of the river flood is higher than the other locations. During flood event, flood flow exceeds the river banks and overflows to the floodplain, in this case, the characteristics of the floodplain topography affects on the river flood hazard distribution (Alaghmand et al., 2010).

Since the flow calculated from Gumbel method is comparatively higher than the flow calculated from HEC-HMS so the depths of inundation is higher in case of flow of Gumbel calculation. The depths of inundation of flow calculated from HEC-HMS has lower value. According to the flood mark on the river bank and local people the flow calculated from Gumbel method seemed to produce better result.

5.3 Calibration and Validation

The data is calibrated with observed data and validated through the percentage of difference. The data which we have used in this research was compared with the flow we obtained by measuring by wadding method and the following table is produced.

Table 5 1: Data validation table

S No.	**Month**	**Measured flow (m^3/s)**	**Recorded monthly average flow (m^3/s)**	**Percent of Difference (%)**
1	Early December	14.89	15.76	-6

Since the percentage of difference between the measured and recorded monthly average value is 6% we can say that the data we have used is reliable one.

The flow calculated from Gumbel method is the flow obtained by using the formula only on the observed value. There is not any boundary conditions applied but in case of flow calculated from the HEC-HMS there is several other factor incorporated in the model that might affect the result to be more reliable. So the Gumbel flow can be called as observed flow but HEC-HMS flow can be called as modelled flow. There is some variation between the two flows. By seeing the flood mark on the riverbank and interaction with few local people the depth of inundation from Gumbel method gave good result.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The major portion of Kankai River lies in the Siwalik range that is having relatively soft rocks and the river flows through the old river terrace and occasionally encounters the Siwalik rocks. Kankai River generally exhibit braded nature with constantly shifting its channel and is meandered at some location. In the past, the river has severely affected the fertile agricultural land situated on either banks of the river. Thus the integrated impact is a complex, resulting the planning and implementing preventive and protective works a challenging task. Based on the past Hydrological events of Kankai River and present condition, the following conclusions can be drawn through the present study:

- The flood frequency analysis and rainfall frequency analysis is performed.
- The flood hazard map is prepared and it shows that with increasing return period the extent of hazard also increases.
- The hazardous regions of Kankai river basin are the Kankai 2, Kankai 4, Kankai 5, Shivasataxi 4, Shivasataxi 5, Shivasataxi 6, Shivasataxi 7, Shivasataxi 9, Shivasataxi 10, Jhapa 1, Jhapa 2, Jhapa 4, Gaurigunj 1, Gaurigunj 2.

6.2 Recommendations

The following recommendations can be drawn from the results and discussion made in the previous chapters.

- Well managed planning for the household settlement should be done. The remaining squatter settlements should be shifted as soon as possible.
- The watershed management should be implemented to control runoff and erosion by enforcing land use regulation, conservation of open land and conservation of forest.
- Urban drainage systems, made up of channels, culverts, sewers etc, are meant to prevent local floods by conveying storm water away from vulnerable sites. This is generally done with the aim of drainage storm water as fast as possible out of the area. If cities or urban districts upstream of other riverside settlements drain storm water too quickly, this may cause urban floods downstream. Thus the government aims for sustainable urban drainage systems should be adequate for mitigation of local floods, without creating new hazards downstream.
- It is recommended to study the other meteorological, geological and Socio-economic parameter of the basin to get more reliable information that can be the important gear for the further study.

6.3 Limitations of the Study

The limitations of the study occurs when we can't get what we aim for. Since the model is used for the study, the limitation of the study matches the limitations of the model parameters and data used as generalised below.

- Manning's n are taken from the table fixed on the observed river morphology.
- The DEM of the eastern region being used for this research is of 30m resolution. Higher resolution DEM could give better results.

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ANNEXE 1: Discharge Computation

S. No.	Dist. to initial point M	Width m	Meas. depth M	Rev	Time sec	Area m2	Discharge m3/s
1	2	3	5	8	9	18	19
1	0.0	1.00	0.00	0	0	0.00	
2	2.0	2.00	0.38	30	47	0.76	0.326
3	4.0	2.00	0.81	40	44	1.62	0.981
4	6.0	2.00	0.57	50	44	1.14	0.861
5	8.0	2.00	0.41	45	45	0.82	0.545
6	10.0	2.00	0.52	45	43	1.04	0.724
7	12.0	2.00	0.47	40	41	0.94	0.610
8	14.0	2.00	0.62	30	41	1.24	0.607
9	16.0	2.00	0.65	45	40	1.30	0.972
10	18.0	2.00	0.72	45	42	1.44	1.026
11	20.0	2.00	0.57	45	40	1.14	0.853
12	22.0	2.00	0.60	45	41	1.20	0.876
13	24.0	2.00	0.63	35	41	1.26	0.718
14	26.0	2.00	0.65	;;30	41	1.30	0.637
15	28.0	2.00	0.64	30	46	1.28	0.560
16	30.0	2.00	0.72	35	41	1.44	0.820
17	32.0	2.00	0.74	45	43	1.48	1.030
18	34.0	2.00	0.62	40	41	1.24	0.805
19	36.0	2.00	0.55	40	41	1.10	0.714
20	38.0	2.00	0.47	40	51	0.94	0.493
21	40.0	2.00	0.32	30	40	0.64	0.321
22	42.0	2.00	0.29	25	48	0.58	0.204
23	44.0	2.00	0.12	20	50	0.24	0.056
24	46.0	2.00	0.08	20	57	0.16	0.066
25	48.0	2.00	0.05	0	0	0.10	
26	50.0	2.00	0.12	15	43	0.24	0.049
27	52.0	2.00	0.07	20	46	0.14	0.035
28	54.0	1.00	0.00	0	0	0.00	
						24.78	14.890

ANNEXE 2: Hydraulic Simulation

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m/s)	(m2)	(m)	
1	38500	2 year	3460.11	115.48	119.58	3.71	1196.79	455.8	0.59
1	38500	10 year	6321.11	115.48	120.47	5.07	1631.7	523.25	0.73
1	38500	50 year	8829.34	115.48	121.12	5.85	1986.16	562.22	0.8
1	38500	100 year	9889.71	115.48	121.37	6.09	2126.43	567.94	0.81
1	38500	200 year	10946.2	115.48	121.6	6.31	2260.54	573.35	0.82
1	38500	500 year	12340.05	115.48	121.9	6.59	2430.04	580.12	0.84
1	38500	1000 year	13393.49	115.48	122.11	6.79	2553.31	584.99	0.85
1	38250	2 year	3460.11	115.56	118.4	4.54	1048.02	597.78	0.86

1	38250	10 year	6321.11	115.56	119.4	4.98	1652.89	610.28	0.81
1	38250	50 year	8829.34	115.56	120.06	5.45	2056.18	617.08	0.82
1	38250	100 year	9889.71	115.56	120.3	5.64	2208.51	619.63	0.83
1	38250	200 year	10946.2	115.56	120.53	5.83	2351	622	0.83
1	38250	500 year	12340.05	115.56	120.81	6.07	2526.71	624.92	0.85
1	38250	1000 year	13393.49	115.56	121.01	6.25	2652.74	627.01	0.85
1	38000	2 year	3460.11	115.38	118.47	1.45	2556.85	845.22	0.26
1	38000	10 year	6321.11	115.38	119.47	1.99	3411.15	854.96	0.31
1	38000	50 year	8829.34	115.38	120.18	2.36	4015.57	862.42	0.34
1	38000	100 year	9889.71	115.38	120.45	2.51	4248.56	865.65	0.36
1	38000	200 year	10946.2	115.38	120.7	2.64	4469.08	868.69	0.37
1	38000	500 year	12340.05	115.38	121.02	2.81	4744.63	872.48	0.38
1	38000	1000 year	13393.49	115.38	121.25	2.93	4944.44	875.21	0.39
1	37500	2 year	3460.11	115.38	118.27	1.45	2597.49	900	0.27
1	37500	10 year	6321.11	115.38	119.22	1.99	3449.77	900	0.32
1	37500	50 year	8829.34	115.38	119.89	2.37	4050.56	900	0.36
1	37500	100 year	9889.71	115.38	120.15	2.51	4281.96	900	0.37
1	37500	200 year	10946.2	115.38	120.39	2.65	4500.31	900	0.38
1	37500	500 year	12340.05	115.38	120.69	2.82	4772.07	900	0.39
1	37500	1000 year	13393.49	115.38	120.91	2.94	4968.87	900	0.4
1	37000	2 year	3460.11	115.32	117.03	3.78	1073.91	900	1
1	37000	10 year	6321.11	115.32	117.6	4.65	1587	900	1.04
1	37000	50 year	8829.34	115.32	118.03	5.19	1974.69	900	1.05
1	37000	100 year	9889.71	115.32	118.19	5.4	2121.2	900	1.06
1	37000	200 year	10946.2	115.32	118.35	5.58	2265.49	900	1.07
1	37000	500 year	12340.05	115.32	118.56	5.79	2455.61	900	1.07
1	37000	1000 year	13393.49	115.32	118.72	5.94	2592.84	900	1.07
1	36534.13	2 year	3460.11	113.41	116.4	1.68	2937.05	1201.26	0.31
1	36534.13	10 year	6321.11	113.41	117.25	2.24	3955.46	1201.26	0.37
1	36534.13	50 year	8829.34	113.41	117.79	2.66	4609.08	1201.26	0.41
1	36534.13	100 year	9889.71	113.41	118	2.81	4862.14	1201.26	0.42
1	36534.13	200 year	10946.2	113.41	118.2	2.96	5098.05	1201.26	0.43
1	36534.13	500 year	12340.05	113.41	118.45	3.15	5394.96	1201.26	0.45
1	36534.13	1000 year	13393.49	113.41	118.62	3.28	5608.37	1201.26	0.46
1	36021.73	2 year	3460.11	113.41	116.13	1.48	2899.02	1507.62	0.29
1	36021.73	10 year	6321.11	113.41	116.94	1.83	4123.13	1507.62	0.31
1	36021.73	50 year	8829.34	113.41	117.44	2.13	4883.68	1507.62	0.34
1	36021.73	100 year	9889.71	113.41	117.64	2.23	5184.57	1507.62	0.35
1	36021.73	200 year	10946.2	113.41	117.83	2.33	5464.44	1507.62	0.36
1	36021.73	500 year	12340.05	113.41	118.06	2.46	5819.96	1507.62	0.36

1	36021.73	1000 year	13393.49	113.41	118.23	2.55	6076.65	1507.62	0.37
1	35398.04	2 year	3460.11	113.03	114.75	3.62	1093.14	962.91	0.93
1	35398.04	10 year	6321.11	113.03	115.35	4.34	1732.61	1180.14	0.94
1	35398.04	50 year	8829.34	113.03	115.86	4.48	2410.5	1365.01	0.88
1	35398.04	100 year	9889.71	113.03	115.98	4.68	2577.41	1365.01	0.89
1	35398.04	200 year	10946.2	113.03	116.11	4.82	2755.6	1365.01	0.9
1	35398.04	500 year	12340.05	113.03	116.27	5.02	2966.36	1365.01	0.91
1	35398.04	1000 year	13393.49	113.03	116.38	5.16	3119.03	1365.01	0.92
1	35117.38	2 year	3460.11	110.13	112.7	1.81	1473.14	861.02	0.53
1	35117.38	10 year	6321.11	110.13	113.51	2.44	2230.76	1003.84	0.56
1	35117.38	50 year	8829.34	110.13	114.09	2.84	2835.08	1091.5	0.57
1	35117.38	100 year	9889.71	110.13	114.31	2.99	3078.83	1116.41	0.58
1	35117.38	200 year	10946.2	110.13	114.52	3.12	3314.39	1145.39	0.58
1	35117.38	500 year	12340.05	110.13	114.78	3.28	3615.43	1183.78	0.59
1	35117.38	1000 year	13393.49	110.13	114.96	3.39	3833.73	1210.36	0.59
1	34445.22	2 year	3460.11	109.6	111.52	2.02	1691.37	948.18	0.49
1	34445.22	10 year	6321.11	109.6	112.33	2.62	2502.06	1033.95	0.52
1	34445.22	50 year	8829.34	109.6	112.92	3.01	3122.79	1098.52	0.54
1	34445.22	100 year	9889.71	109.6	113.14	3.15	3368.93	1123.8	0.55
1	34445.22	200 year	10946.2	109.6	113.35	3.28	3607.56	1147.02	0.55
1	34445.22	500 year	12340.05	109.6	113.61	3.43	3911.59	1168.13	0.56
1	34445.22	1000 year	13393.49	109.6	113.8	3.53	4131.7	1168.13	0.56
1	33986.86	2 year	3460.11	109.5	110.47	0.98	1697.65	949.46	0.4
1	33986.86	10 year	6321.11	109.5	111.34	1.64	2546.84	1008.54	0.44
1	33986.86	50 year	8829.34	109.5	111.92	2.08	3151.87	1050.89	0.47
1	33986.86	100 year	9889.71	109.5	112.14	2.23	3386.8	1068.8	0.48
1	33986.86	200 year	10946.2	109.5	112.35	2.38	3611.76	1086.27	0.49
1	33986.86	500 year	12340.05	109.5	112.61	2.56	3896.95	1101.84	0.5
1	33986.86	1000 year	13393.49	109.5	112.8	2.68	4103.9	1113.88	0.51
1	33468.52	2 year	3460.11	108.67	110.19	1.12	2326.85	1088.86	0.33
1	33468.52	10 year	6321.11	108.67	111.05	1.72	3278.97	1136.63	0.38
1	33468.52	50 year	8829.34	108.67	111.62	2.13	3938.97	1169.06	0.42
1	33468.52	100 year	9889.71	108.67	111.83	2.28	4193.36	1183.58	0.43
1	33468.52	200 year	10946.2	108.67	112.04	2.42	4435.94	1198.83	0.44
1	33468.52	500 year	12340.05	108.67	112.29	2.6	4743.5	1220.35	0.46
1	33468.52	1000 year	13393.49	108.67	112.48	2.72	4967.83	1237.26	0.47
1	33009.28	2 year	3460.11	108.63	109.81	1.18	2516.09	1382.2	0.35
1	33009.28	10 year	6321.11	108.63	110.65	1.71	3729.52	1498.41	0.39
1	33009.28	50 year	8829.34	108.63	111.21	2.04	4579.24	1512.82	0.41

1	33009.28	100 year	9889.71	108.63	111.43	2.16	4902.86	1512.82	0.41
1	33009.28	200 year	10946.2	108.63	111.63	2.28	5208.13	1512.82	0.42
1	33009.28	500 year	12340.05	108.63	111.88	2.42	5590.69	1512.82	0.43
1	33009.28	1000 year	13393.49	108.63	112.06	2.52	5865.75	1512.82	0.44
1	32482.18	2 year	3460.11	108.09	109.13	0.98	2200.74	1253.46	0.33
1	32482.18	10 year	6321.11	108.09	109.93	1.55	3245.74	1349.52	0.38
1	32482.18	50 year	8829.34	108.09	110.43	1.92	3929.68	1349.52	0.41
1	32482.18	100 year	9889.71	108.09	110.63	2.06	4189.42	1349.52	0.43
1	32482.18	200 year	10946.2	108.09	110.81	2.19	4435.2	1349.52	0.44
1	32482.18	500 year	12340.05	108.09	111.04	2.35	4743.64	1349.52	0.45
1	32482.18	1000 year	13393.49	108.09	111.2	2.46	4964.15	1349.52	0.46
1	31982.98	2 year	3460.11	107.95	107.84		1119.35	708.53	0
1	31982.98	10 year	6321.11	107.95	108.56	2.01	1937.59	1249.33	0.9
1	31982.98	50 year	8829.34	107.95	109.03	2.85	2527.78	1310	0.92
1	31982.98	100 year	9889.71	107.95	109.21	3.1	2768.28	1331.34	0.93
1	31982.98	200 year	10946.2	107.95	109.38	3.33	3003.13	1353.67	0.92
1	31982.98	500 year	12340.05	107.95	109.6	3.58	3307.28	1382.26	0.92
1	31982.98	1000 year	13393.49	107.95	109.77	3.75	3532.89	1398.98	0.92
1	31349.96	2 year	3460.11	104.98	107.08	1.93	2282.62	1391.3	0.45
1	31349.96	10 year	6321.11	104.98	107.8	2.41	3273.28	1391.3	0.48
1	31349.96	50 year	8829.34	104.98	108.31	2.74	3989.96	1391.3	0.5
1	31349.96	100 year	9889.71	104.98	108.51	2.87	4265.25	1391.3	0.51
1	31349.96	200 year	10946.2	104.98	108.7	2.99	4526.67	1391.3	0.51
1	31349.96	500 year	12340.05	104.98	108.93	3.13	4855.27	1391.3	0.52
1	31349.96	1000 year	13393.49	104.98	109.1	3.24	5091.75	1391.3	0.53
1	30822.75	2 year	3460.11	104.95	106.57	1.6	2549.07	1669.3	0.4
1	30822.75	10 year	6321.11	104.95	107.33	1.97	3814.42	1669.3	0.41
1	30822.75	50 year	8829.34	104.95	107.86	2.23	4703.1	1669.3	0.42
1	30822.75	100 year	9889.71	104.95	108.06	2.33	5042.28	1669.3	0.42
1	30822.75	200 year	10946.2	104.95	108.26	2.43	5363.76	1669.3	0.43
1	30822.75	500 year	12340.05	104.95	108.5	2.55	5767.3	1669.3	0.43
1	30822.75	1000 year	13393.49	104.95	108.67	2.63	6057.62	1669.3	0.44
1	30167.6	2 year	3460.11	104.4	106.14	1.17	2920.17	1556.12	0.29
1	30167.6	10 year	6321.11	104.4	106.88	1.58	4080.17	1556.12	0.33
1	30167.6	50 year	8829.34	104.4	107.39	1.88	4878.16	1556.12	0.35
1	30167.6	100 year	9889.71	104.4	107.59	1.99	5182.07	1556.12	0.36
1	30167.6	200 year	10946.2	104.4	107.77	2.09	5469.98	1556.12	0.37
1	30167.6	500 year	12340.05	104.4	108.01	2.22	5830.89	1556.12	0.38
1	30167.6	1000 year	13393.49	104.4	108.17	2.31	6090.86	1556.12	0.38

1	29614.39	2 year	3460.11	104.1	105.5	1.57	1796.27	1306.1	0.5
1	29614.39	10 year	6321.11	104.1	106.22	2.07	2923.27	1602.84	0.5
1	29614.39	50 year	8829.34	104.1	106.71	2.37	3709.42	1602.84	0.51
1	29614.39	100 year	9889.71	104.1	106.9	2.48	4007.79	1602.84	0.51
1	29614.39	200 year	10946.2	104.1	107.08	2.59	4290.39	1602.84	0.52
1	29614.39	500 year	12340.05	104.1	107.3	2.72	4644.81	1602.84	0.52
1	29614.39	1000 year	13393.49	104.1	107.46	2.81	4899.55	1602.84	0.52
1	29157.12	2 year	3460.11	102.97	104.94	1.37	2531.24	1509.76	0.35
1	29157.12	10 year	6321.11	102.97	105.67	1.86	3721.15	1664.89	0.39
1	29157.12	50 year	8829.34	102.97	106.16	2.19	4533.78	1664.89	0.42
1	29157.12	100 year	9889.71	102.97	106.34	2.31	4840.72	1664.89	0.43
1	29157.12	200 year	10946.2	102.97	106.51	2.42	5131.55	1664.89	0.44
1	29157.12	500 year	12340.05	102.97	106.73	2.56	5496.93	1664.89	0.45
1	29157.12	1000 year	13393.49	102.97	106.89	2.66	5758.55	1664.89	0.45
1	28813.46	2 year	3460.11	103.64	104.62	0.94	2149.32	1320.16	0.35
1	28813.46	10 year	6321.11	103.64	105.27	1.54	3119.21	1682.08	0.42
1	28813.46	50 year	8829.34	103.64	105.73	1.89	3890.08	1682.08	0.44
1	28813.46	100 year	9889.71	103.64	105.9	2.02	4184.28	1682.08	0.45
1	28813.46	200 year	10946.2	103.64	106.07	2.14	4464.96	1682.08	0.46
1	28813.46	500 year	12340.05	103.64	106.28	2.28	4820.4	1682.08	0.47
1	28813.46	1000 year	13393.49	103.64	106.43	2.38	5074.01	1682.08	0.47
1	28475.36	2 year	3460.11	103.48	103.79	1.05	1421.56	1350.02	0.66
1	28475.36	10 year	6321.11	103.48	104.35	2.11	2197.39	1430.53	0.75
1	28475.36	50 year	8829.34	103.48	104.71	2.7	2726.54	1460.4	0.79
1	28475.36	100 year	9889.71	103.48	104.86	2.9	2934.34	1471.34	0.81
1	28475.36	200 year	10946.2	103.48	104.99	3.09	3133.45	1488.41	0.82
1	28475.36	500 year	12340.05	103.48	105.16	3.33	3395.3	1558.65	0.83
1	28475.36	1000 year	13393.49	103.48	105.29	3.49	3592.81	1626.79	0.84
1	27832.95	2 year	3460.11	99.7	101.86	1.98	2535.37	1843.93	0.44
1	27832.95	10 year	6321.11	99.7	102.44	2.41	3661.21	1976.74	0.47
1	27832.95	50 year	8829.34	99.7	102.86	2.68	4478	1976.74	0.49
1	27832.95	100 year	9889.71	99.7	103.01	2.78	4788.95	1976.74	0.49
1	27832.95	200 year	10946.2	99.7	103.16	2.87	5086.03	1976.74	0.5
1	27832.95	500 year	12340.05	99.7	103.35	3	5451.42	1976.74	0.51
1	27832.95	1000 year	13393.49	99.7	103.48	3.08	5715.88	1976.74	0.51
1	27459.52	2 year	3460.11	99.95	101	1.68	1998.23	1730.71	0.56
1	27459.52	10 year	6321.11	99.95	101.59	2.18	3041.38	1856.4	0.57
1	27459.52	50 year	8829.34	99.95	101.99	2.51	3817.26	1947.89	0.58
1	27459.52	100 year	9889.71	99.95	102.15	2.63	4123.12	1978.91	0.58
1	27459.52	200 year	10946.2	99.95	102.3	2.74	4417.45	2005.56	0.59

1	27459.52	500 year	12340.05	99.95	102.48	2.87	4787.61	2005.56	0.59
1	27459.52	1000 year	13393.49	99.95	102.62	2.96	5055.03	2005.56	0.59
1	26726.91	2 year	3460.11	98.22	99.79	1.59	2231.61	1680.94	0.48
1	26726.91	10 year	6321.11	98.22	100.41	2.13	3356.98	2019.73	0.51
1	26726.91	50 year	8829.34	98.22	100.81	2.48	4163.1	2019.73	0.54
1	26726.91	100 year	9889.71	98.22	100.96	2.6	4467.52	2019.73	0.55
1	26726.91	200 year	10946.2	98.22	101.11	2.72	4755.79	2019.73	0.55
1	26726.91	500 year	12340.05	98.22	101.29	2.87	5119.43	2019.73	0.56
1	26726.91	1000 year	13393.49	98.22	101.42	2.97	5381.38	2019.73	0.57
1	26350.29	2 year	3460.11	97.51	98.65	1.75	1614.22	1351.22	0.67
1	26350.29	10 year	6321.11	97.51	99.18	2.6	2462.6	1817.59	0.75
1	26350.29	50 year	8829.34	97.51	99.57	3.04	3178.48	1863.66	0.76
1	26350.29	100 year	9889.71	97.51	99.71	3.18	3456.71	1863.66	0.77
1	26350.29	200 year	10946.2	97.51	99.86	3.32	3725.18	1863.66	0.77
1	26350.29	500 year	12340.05	97.51	100.04	3.48	4063.69	1863.66	0.77
1	26350.29	1000 year	13393.49	97.51	100.17	3.59	4310.42	1863.66	0.77
1	25922.52	2 year	3460.11	96.54	97.61	1.22	2077.49	1664.95	0.46
1	25922.52	10 year	6321.11	96.54	98.18	1.79	3020.88	1664.95	0.51
1	25922.52	50 year	8829.34	96.54	98.59	2.15	3703.58	1664.95	0.53
1	25922.52	100 year	9889.71	96.54	98.75	2.28	3967.97	1664.95	0.54
1	25922.52	200 year	10946.2	96.54	98.9	2.4	4218.5	1664.95	0.54
1	25922.52	500 year	12340.05	96.54	99.09	2.55	4536.56	1664.95	0.55
1	25922.52	1000 year	13393.49	96.54	99.23	2.66	4767.25	1664.95	0.56
1	25319.04	2 year	3460.11	94.99	96.37	2.04	1988.34	1604.48	0.59
1	25319.04	10 year	6321.11	94.99	96.89	2.67	2825.36	1604.48	0.65
1	25319.04	50 year	8829.34	94.99	97.28	3.08	3439.45	1604.48	0.68
1	25319.04	100 year	9889.71	94.99	97.43	3.23	3677.45	1604.48	0.69
1	25319.04	200 year	10946.2	94.99	97.57	3.37	3904.72	1604.48	0.69
1	25319.04	500 year	12340.05	94.99	97.75	3.54	4193.04	1604.48	0.7
1	25319.04	1000 year	13393.49	94.99	97.88	3.67	4400.39	1604.48	0.71
1	24825.09	2 year	3460.11	94.2	94.93	1.36	1743.02	1593.59	0.55
1	24825.09	10 year	6321.11	94.2	95.49	1.98	2631.74	1593.59	0.58
1	24825.09	50 year	8829.34	94.2	95.89	2.36	3276.21	1593.59	0.6
1	24825.09	100 year	9889.71	94.2	96.05	2.49	3526.2	1593.59	0.6
1	24825.09	200 year	10946.2	94.2	96.2	2.62	3765.2	1593.59	0.61
1	24825.09	500 year	12340.05	94.2	96.39	2.77	4067.16	1593.59	0.61
1	24825.09	1000 year	13393.49	94.2	96.52	2.88	4286.56	1593.59	0.62
1	24324.24	2 year	3460.11	91.99	93.86	2.19	2032.47	1533.86	0.55
1	24324.24	10 year	6321.11	91.99	94.48	2.68	3015.34	1648.09	0.57

1	24324.24	50 year	8829.34	91.99	94.92	2.98	3741.29	1658.14	0.58
1	24324.24	100 year	9889.71	91.99	95.08	3.1	4020.35	1658.14	0.59
1	24324.24	200 year	10946.2	91.99	95.24	3.21	4284.64	1658.14	0.59
1	24324.24	500 year	12340.05	91.99	95.44	3.34	4616.43	1658.14	0.59
1	24324.24	1000 year	13393.49	91.99	95.59	3.44	4856.3	1658.14	0.6
1	24100.95	2 year	3460.11	91.12	93.05	2.01	2101.11	1444.6	0.49
1	24100.95	10 year	6321.11	91.12	93.61	2.61	2927.75	1510.15	0.55
1	24100.95	50 year	8829.34	91.12	94.01	3	3555.88	1566.02	0.59
1	24100.95	100 year	9889.71	91.12	94.17	3.14	3806.17	1589.53	0.6
1	24100.95	200 year	10946.2	91.12	94.32	3.27	4048.28	1612.3	0.61
1	24100.95	500 year	12340.05	91.12	94.52	3.43	4358.86	1642.97	0.62
1	24100.95	1000 year	13393.49	91.12	94.65	3.54	4588.02	1667.7	0.62
1	23447.88	2 year	3460.11	89.94	91.67	2.1	2161.74	1865.43	0.56
1	23447.88	10 year	6321.11	89.94	92.28	2.45	3307.95	1865.43	0.55
1	23447.88	50 year	8829.34	89.94	92.73	2.7	4134.53	1865.43	0.55
1	23447.88	100 year	9889.71	89.94	92.9	2.8	4452.69	1865.43	0.55
1	23447.88	200 year	10946.2	89.94	93.06	2.89	4755.45	1865.43	0.55
1	23447.88	500 year	12340.05	89.94	93.26	3.01	5134.39	1865.43	0.55
1	23447.88	1000 year	13393.49	89.94	93.41	3.09	5408.07	1865.43	0.55
1	22910.01	2 year	3460.11	88.59	90.98	1.58	2944.43	2031.27	0.33
1	22910.01	10 year	6321.11	88.59	91.65	1.87	4339.37	2078.68	0.34
1	22910.01	50 year	8829.34	88.59	92.11	2.06	5309.89	2078.68	0.35
1	22910.01	100 year	9889.71	88.59	92.29	2.14	5674.79	2078.68	0.36
1	22910.01	200 year	10946.2	88.59	92.46	2.22	6018.65	2078.68	0.36
1	22910.01	500 year	12340.05	88.59	92.66	2.31	6447.78	2078.68	0.37
1	22910.01	1000 year	13393.49	88.59	92.81	2.38	6756.1	2078.68	0.37
1	22385.85	2 year	3460.11	88.72	90.56	1.24	3404.79	2097.94	0.3
1	22385.85	10 year	6321.11	88.72	91.21	1.61	4770.62	2097.94	0.33
1	22385.85	50 year	8829.34	88.72	91.66	1.87	5710.49	2097.94	0.35
1	22385.85	100 year	9889.71	88.72	91.83	1.98	6059.24	2097.94	0.36
1	22385.85	200 year	10946.2	88.72	91.98	2.07	6386.95	2097.94	0.37
1	22385.85	500 year	12340.05	88.72	92.18	2.19	6795.52	2097.94	0.38
1	22385.85	1000 year	13393.49	88.72	92.32	2.28	7088.73	2097.94	0.39
1	21954.85	2 year	3460.11	89.49	89.9	0.39	2627.08	1864.45	0.27
1	21954.85	10 year	6321.11	89.49	90.47	0.97	3803.82	2220.72	0.35
1	21954.85	50 year	8829.34	89.49	90.87	1.31	4732.72	2428.26	0.38
1	21954.85	100 year	9889.71	89.49	91.02	1.42	5109.24	2449.4	0.39
1	21954.85	200 year	10946.2	89.49	91.17	1.53	5469.54	2449.4	0.4
1	21954.85	500 year	12340.05	89.49	91.36	1.65	5922.33	2449.4	0.41
1	21954.85	1000 year	13393.49	89.49	91.49	1.73	6247.93	2449.4	0.41

1	21486.81	2 year	3460.11	88.87	89.37	0.59	2717.55	2322.88	0.33
1	21486.81	10 year	6321.11	88.87	89.95	1.12	4129.41	2555.67	0.38
1	21486.81	50 year	8829.34	88.87	90.37	1.41	5249.21	2727.99	0.39
1	21486.81	100 year	9889.71	88.87	90.53	1.5	5696.96	2751.61	0.39
1	21486.81	200 year	10946.2	88.87	90.69	1.59	6130.14	2774.82	0.4
1	21486.81	500 year	12340.05	88.87	90.88	1.69	6674.63	2812.43	0.4
1	21486.81	1000 year	13393.49	88.87	91.02	1.77	7067.88	2835.65	0.4
1	20955.59	2 year	3460.11	87.88	88.82	1.07	2298.89	1923.86	0.43
1	20955.59	10 year	6321.11	87.88	89.44	1.56	3535.93	2088.08	0.45
1	20955.59	50 year	8829.34	87.88	89.86	1.86	4434.14	2184.23	0.46
1	20955.59	100 year	9889.71	87.88	90.02	1.97	4792.09	2247.62	0.46
1	20955.59	200 year	10946.2	87.88	90.17	2.07	5145.93	2367.86	0.47
1	20955.59	500 year	12340.05	87.88	90.37	2.19	5613.69	2504.84	0.47
1	20955.59	1000 year	13393.49	87.88	90.5	2.27	5962.39	2575.24	0.48
1	20432.92	2 year	3460.11	85.77	87.57	1.28	2845.03	1889.91	0.34
1	20432.92	10 year	6321.11	85.77	88.2	1.75	4111.76	2082.02	0.39
1	20432.92	50 year	8829.34	85.77	88.62	2.02	5004.58	2130.11	0.41
1	20432.92	100 year	9889.71	85.77	88.78	2.12	5350.87	2148.86	0.42
1	20432.92	200 year	10946.2	85.77	88.94	2.21	5681.04	2165.84	0.42
1	20432.92	500 year	12340.05	85.77	89.13	2.33	6098.38	2186.93	0.43
1	20432.92	1000 year	13393.49	85.77	89.27	2.41	6401.65	2202.13	0.43
1	19983.63	2 year	3460.11	85	86.76	1.73	2749.33	2131.45	0.44
1	19983.63	10 year	6321.11	85	87.3	2.18	3915.87	2180.24	0.48
1	19983.63	50 year	8829.34	85	87.7	2.48	4777.76	2212.51	0.5
1	19983.63	100 year	9889.71	85	87.85	2.59	5112.37	2224.52	0.51
1	19983.63	200 year	10946.2	85	87.99	2.69	5431.38	2235.52	0.52
1	19983.63	500 year	12340.05	85	88.17	2.82	5833.89	2249.34	0.52
1	19983.63	1000 year	13393.49	85	88.3	2.91	6125.88	2259.3	0.53
1	19499.47	2 year	3460.11	85	85.99	1.21	2732.85	2333.53	0.4
1	19499.47	10 year	6321.11	85	86.54	1.61	4020.61	2379.66	0.43
1	19499.47	50 year	8829.34	85	86.93	1.87	4966.3	2410.66	0.44
1	19499.47	100 year	9889.71	85	87.08	1.97	5331.98	2422.79	0.44
1	19499.47	200 year	10946.2	85	87.23	2.06	5678.2	2434.21	0.45
1	19499.47	500 year	12340.05	85	87.41	2.17	6113.85	2448.52	0.45
1	19499.47	1000 year	13393.49	85	87.53	2.25	6428.89	2458.81	0.46
1	18890.93	2 year	3460.11	85.23	85.17		2343.63	1882.14	0
1	18890.93	10 year	6321.11	85.23	85.72	0.6	3406.09	1996.14	0.39
1	18890.93	50 year	8829.34	85.23	86.08	0.96	4142.63	2093.06	0.45
1	18890.93	100 year	9889.71	85.23	86.21	1.15	4427.4	2132.82	0.47

1	18890.93	200 year	10946.2	85.23	86.34	1.32	4698.79	2158.79	0.49
1	18890.93	500 year	12340.05	85.23	86.49	1.51	5042.17	2212.25	0.51
1	18890.93	1000 year	13393.49	85.23	86.61	1.65	5293.98	2255.07	0.53
1	18331.33	2 year	3460.11	83.82	84.39	0.6	2454.86	1956.35	0.35
1	18331.33	10 year	6321.11	83.82	84.9	1.1	3641.82	2765.38	0.43
1	18331.33	50 year	8829.34	83.82	85.22	1.47	4530.5	2765.38	0.47
1	18331.33	100 year	9889.71	83.82	85.34	1.6	4869.89	2765.38	0.49
1	18331.33	200 year	10946.2	83.82	85.46	1.72	5194.48	2765.38	0.5
1	18331.33	500 year	12340.05	83.82	85.61	1.87	5603.19	2765.38	0.51
1	18331.33	1000 year	13393.49	83.82	85.71	1.97	5899.75	2765.38	0.52
1	17697.75	2 year	3460.11	82.45	83.2	1.32	1941.61	2226.02	0.54
1	17697.75	10 year	6321.11	82.45	83.67	1.82	3100.34	2733.95	0.56
1	17697.75	50 year	8829.34	82.45	84.01	2.06	4037.78	2733.95	0.55
1	17697.75	100 year	9889.71	82.45	84.14	2.14	4402.15	2733.95	0.55
1	17697.75	200 year	10946.2	82.45	84.27	2.22	4743.28	2733.95	0.55
1	17697.75	500 year	12340.05	82.45	84.42	2.31	5174.12	2733.95	0.55
1	17697.75	1000 year	13393.49	82.45	84.54	2.38	5487.35	2733.95	0.54
1	16986.18	2 year	3460.11	80.21	82.17	1.68	3238.86	2790.68	0.39
1	16986.18	10 year	6321.11	80.21	82.73	1.95	4850.31	2945.02	0.39
1	16986.18	50 year	8829.34	80.21	83.13	2.14	6029.82	3032.79	0.4
1	16986.18	100 year	9889.71	80.21	83.28	2.21	6489.67	3064.6	0.4
1	16986.18	200 year	10946.2	80.21	83.43	2.25	6964.41	3064.6	0.4
1	16986.18	500 year	12340.05	80.21	83.6	2.34	7481	3064.6	0.41
1	16986.18	1000 year	13393.49	80.21	83.72	2.4	7855.91	3064.6	0.41
1	16601.4	2 year	3460.11	79.79	81.79	2.01	2853.48	2393.84	0.47
1	16601.4	10 year	6321.11	79.79	82.35	2.38	4259.24	2568.37	0.48
1	16601.4	50 year	8829.34	79.79	82.74	2.66	5268.95	2708.46	0.5
1	16601.4	100 year	9889.71	79.79	82.88	2.77	5664.19	2828.16	0.51
1	16601.4	200 year	10946.2	79.79	83.02	2.96	6074.39	3060.65	0.53
1	16601.4	500 year	12340.05	79.79	83.19	3.03	6591.82	3060.65	0.53
1	16601.4	1000 year	13393.49	79.79	83.31	3.08	6967.02	3060.65	0.53
1	16160.76	2 year	3460.11	79.02	81.44	1.54	3404.33	2589.64	0.32
1	16160.76	10 year	6321.11	79.02	81.98	1.91	4874.09	2973.63	0.36
1	16160.76	50 year	8829.34	79.02	82.35	2.12	6005.7	3028.29	0.37
1	16160.76	100 year	9889.71	79.02	82.49	2.18	6434.93	3028.29	0.38
1	16160.76	200 year	10946.2	79.02	82.63	2.25	6843.29	3028.29	0.38
1	16160.76	500 year	12340.05	79.02	82.8	2.32	7357.36	3028.29	0.38
1	16160.76	1000 year	13393.49	79.02	82.92	2.38	7730.14	3028.29	0.39
1	15678.4	2 year	3460.11	78.54	81.06	1.62	3235.1	2981.46	0.35

1	15678.4	10 year	6321.11	78.54	81.57	1.85	4758.04	2981.46	0.36
1	15678.4	50 year	8829.34	78.54	81.93	2.03	5834.55	2981.46	0.37
1	15678.4	100 year	9889.71	78.54	82.07	2.09	6247.96	2981.46	0.38
1	15678.4	200 year	10946.2	78.54	82.2	2.15	6641.63	2981.46	0.38
1	15678.4	500 year	12340.05	78.54	82.37	2.23	7137.96	2981.46	0.38
1	15678.4	1000 year	13393.49	78.54	82.49	2.28	7498.46	2981.46	0.38
1	15348.85	2 year	3460.11	78.18	80.58	2.1	3021.42	2875.51	0.45
1	15348.85	10 year	6321.11	78.18	81.09	2.36	4497.79	2875.51	0.45
1	15348.85	50 year	8829.34	78.18	81.43	2.59	5479.21	2875.51	0.47
1	15348.85	100 year	9889.71	78.18	81.56	2.67	5858.78	2875.51	0.47
1	15348.85	200 year	10946.2	78.18	81.69	2.75	6222.11	2875.51	0.48
1	15348.85	500 year	12340.05	78.18	81.85	2.85	6683.21	2875.51	0.48
1	15348.85	1000 year	13393.49	78.18	81.97	2.92	7020.25	2875.51	0.49
1	14791.92	2 year	3460.11	79.13	79.62	0.52	2713.15	2526.56	0.34
1	14791.92	10 year	6321.11	79.13	80.09	0.87	3985.05	2925.8	0.4
1	14791.92	50 year	8829.34	79.13	80.44	1.21	4986.18	2925.8	0.43
1	14791.92	100 year	9889.71	79.13	80.57	1.32	5391.74	2925.8	0.43
1	14791.92	200 year	10946.2	79.13	80.71	1.42	5785.62	2925.8	0.44
1	14791.92	500 year	12340.05	79.13	80.88	1.54	6291.61	2925.8	0.44
1	14791.92	1000 year	13393.49	79.13	81.01	1.62	6666.06	2925.8	0.44
1	14168.56	2 year	3460.11	77.04	78.45	1.56	2922.49	2686.2	0.42
1	14168.56	10 year	6321.11	77.04	79.03	1.76	4486.31	2686.2	0.4
1	14168.56	50 year	8829.34	77.04	79.46	1.92	5645.36	2686.2	0.39
1	14168.56	100 year	9889.71	77.04	79.63	1.98	6095.54	2686.2	0.39
1	14168.56	200 year	10946.2	77.04	79.79	2.03	6524.9	2686.2	0.39
1	14168.56	500 year	12340.05	77.04	79.99	2.1	7066.31	2686.2	0.39
1	14168.56	1000 year	13393.49	77.04	80.13	2.16	7458.32	2686.2	0.39
1	13538.7	2 year	3460.11	76.23	77.95	1.17	4064.64	2856.34	0.29
1	13538.7	10 year	6321.11	76.23	78.58	1.46	5863.51	2856.34	0.31
1	13538.7	50 year	8829.34	76.23	79.03	1.65	7149.18	2856.34	0.32
1	13538.7	100 year	9889.71	76.23	79.2	1.73	7643.45	2856.34	0.32
1	13538.7	200 year	10946.2	76.23	79.37	1.8	8112.76	2856.34	0.33
1	13538.7	500 year	12340.05	76.23	79.58	1.88	8702.06	2856.34	0.33
1	13538.7	1000 year	13393.49	76.23	79.72	1.95	9127.03	2856.34	0.33
1	13170.08	2 year	3460.11	75.78	77.78	1.37	3893.83	2931.88	0.31
1	13170.08	10 year	6321.11	75.78	78.42	1.61	5763.4	2931.88	0.32
1	13170.08	50 year	8829.34	75.78	78.87	1.79	7086.4	2931.88	0.33
1	13170.08	100 year	9889.71	75.78	79.05	1.85	7594.17	2931.88	0.33
1	13170.08	200 year	10946.2	75.78	79.21	1.92	8075.92	2931.88	0.33
1	13170.08	500 year	12340.05	75.78	79.42	2	8680.45	2931.88	0.34

1	13170.08	1000 year	13393.49	75.78	79.56	2.05	9116.03	2931.88	0.34
1	12417.03	2 year	3460.11	75.36	77.4	1.32	3640.5	2907.49	0.31
1	12417.03	10 year	6321.11	75.36	78.09	1.46	5653.23	2907.49	0.29
1	12417.03	50 year	8829.34	75.36	78.55	1.62	6985.18	2907.49	0.3
1	12417.03	100 year	9889.71	75.36	78.73	1.67	7491.81	2907.49	0.3
1	12417.03	200 year	10946.2	75.36	78.89	1.73	7970.75	2907.49	0.3
1	12417.03	500 year	12340.05	75.36	79.1	1.8	8570.12	2907.49	0.31
1	12417.03	1000 year	13393.49	75.36	79.24	1.85	9000.56	2907.49	0.31
1	12030.88	2 year	3460.11	75.07	77.19	0.81	4396.79	2603.09	0.2
1	12030.88	10 year	6321.11	75.07	77.89	1.08	6214.55	2603.09	0.23
1	12030.88	50 year	8829.34	75.07	78.33	1.29	7375.97	2603.09	0.25
1	12030.88	100 year	9889.71	75.07	78.5	1.37	7817.43	2603.09	0.25
1	12030.88	200 year	10946.2	75.07	78.66	1.44	8234.53	2603.09	0.26
1	12030.88	500 year	12340.05	75.07	78.86	1.54	8756.5	2603.09	0.27
1	12030.88	1000 year	13393.49	75.07	79.01	1.6	9130.98	2603.09	0.28
1	11851.09	2 year	3460.11	75.31	77.14	0.75	4517.11	2544.9	0.19
1	11851.09	10 year	6321.11	75.31	77.82	1.04	6265.99	2544.9	0.22
1	11851.09	50 year	8829.34	75.31	78.26	1.26	7374.72	2544.9	0.24
1	11851.09	100 year	9889.71	75.31	78.43	1.34	7796.25	2544.9	0.25
1	11851.09	200 year	10946.2	75.31	78.58	1.42	8194.65	2544.9	0.26
1	11851.09	500 year	12340.05	75.31	78.78	1.52	8693.48	2544.9	0.27
1	11851.09	1000 year	13393.49	75.31	78.92	1.58	9051.38	2544.9	0.27
1	11474.57	2 year	3460.11	74.54	77	1.11	4036	2486.75	0.24
1	11474.57	10 year	6321.11	74.54	77.67	1.39	5691.05	2486.75	0.27
1	11474.57	50 year	8829.34	74.54	78.08	1.62	6710.58	2486.75	0.29
1	11474.57	100 year	9889.71	74.54	78.23	1.71	7099.06	2486.75	0.3
1	11474.57	200 year	10946.2	74.54	78.38	1.79	7466.53	2486.75	0.31
1	11474.57	500 year	12340.05	74.54	78.57	1.89	7927.32	2486.75	0.32
1	11474.57	1000 year	13393.49	74.54	78.7	1.97	8257.84	2486.75	0.32
1	10924.38	2 year	3460.11	73.89	76.56	2.18	2517.55	1959.35	0.47
1	10924.38	10 year	6321.11	73.89	77.16	2.82	3859.68	2359.85	0.54
1	10924.38	50 year	8829.34	73.89	77.51	3.11	4692.21	2359.85	0.56
1	10924.38	100 year	9889.71	73.89	77.64	3.22	5010.5	2359.85	0.57
1	10924.38	200 year	10946.2	73.89	77.77	3.32	5311.34	2359.85	0.58
1	10924.38	500 year	12340.05	73.89	77.93	3.46	5690.44	2359.85	0.59
1	10924.38	1000 year	13393.49	73.89	78.05	3.55	5960.16	2359.85	0.59
1	10437.01	2 year	3460.11	73.29	75.72	2.31	2350.18	2295.11	0.52
1	10437.01	10 year	6321.11	73.29	76.16	2.84	3440.12	2448.97	0.58
1	10437.01	50 year	8829.34	73.29	76.46	3.14	4172.57	2448.97	0.61

1	10437.01	100 year	9889.71	73.29	76.58	3.25	4454.23	2448.97	0.62
1	10437.01	200 year	10946.2	73.29	76.69	3.35	4729.18	2448.97	0.62
1	10437.01	500 year	12340.05	73.29	76.83	3.47	5076.3	2448.97	0.63
1	10437.01	1000 year	13393.49	73.29	76.94	3.56	5330.4	2448.97	0.64
1	9941.13	2 year	3460.11	72.67	74.42	2.78	2143.28	2505.68	0.7
1	9941.13	10 year	6321.11	72.67	74.86	3.06	3253.6	2507.36	0.68
1	9941.13	50 year	8829.34	72.67	75.2	3.24	4099.3	2507.36	0.67
1	9941.13	100 year	9889.71	72.67	75.34	3.3	4440.15	2507.36	0.66
1	9941.13	200 year	10946.2	72.67	75.47	3.36	4773.66	2507.36	0.66
1	9941.13	500 year	12340.05	72.67	75.64	3.42	5205.39	2507.36	0.65
1	9941.13	1000 year	13393.49	72.67	75.77	3.46	5527.15	2507.36	0.64
1	9578.051	2 year	3460.11	72.28	73.76	1.45	2831.33	2662.4	0.4
1	9578.051	10 year	6321.11	72.28	74.29	1.72	4245.48	2688.58	0.4
1	9578.051	50 year	8829.34	72.28	74.69	1.88	5310.56	2688.58	0.4
1	9578.051	100 year	9889.71	72.28	74.85	1.94	5735.48	2688.58	0.4
1	9578.051	200 year	10946.2	72.28	75	1.99	6149.73	2688.58	0.39
1	9578.051	500 year	12340.05	72.28	75.2	2.05	6681.6	2688.58	0.39
1	9578.051	1000 year	13393.49	72.28	75.34	2.1	7074.77	2688.58	0.39
1	9105.728	2 year	3460.11	71.73	73.25	1.27	3292.2	2727.07	0.34
1	9105.728	10 year	6321.11	71.73	73.81	1.56	4822.76	2727.07	0.35
1	9105.728	50 year	8829.34	71.73	74.24	1.74	5990.42	2727.07	0.36
1	9105.728	100 year	9889.71	71.73	74.41	1.8	6454.91	2727.07	0.36
1	9105.728	200 year	10946.2	71.73	74.57	1.86	6908.97	2727.07	0.36
1	9105.728	500 year	12340.05	71.73	74.79	1.93	7489.84	2727.07	0.36
1	9105.728	1000 year	13393.49	71.73	74.94	1.97	7918.2	2727.07	0.36
1	8324.707	2 year	3460.11	71.31	72.48	0.96	3396.32	2625.88	0.3
1	8324.707	10 year	6321.11	71.31	73.09	1.28	5004.89	2625.88	0.31
1	8324.707	50 year	8829.34	71.31	73.57	1.46	6250.27	2625.88	0.32
1	8324.707	100 year	9889.71	71.31	73.76	1.53	6746.5	2625.88	0.32
1	8324.707	200 year	10946.2	71.31	73.94	1.59	7226.69	2625.88	0.32
1	8324.707	500 year	12340.05	71.31	74.17	1.66	7840.58	2625.88	0.32
1	8324.707	1000 year	13393.49	71.31	74.35	1.71	8290.92	2625.88	0.32
1	7741.295	2 year	3460.11	70.57	71.77	1.33	2721.78	2067.65	0.39
1	7741.295	10 year	6321.11	70.57	72.45	1.69	4111.23	2067.65	0.4
1	7741.295	50 year	8829.34	70.57	72.96	1.9	5173.67	2067.65	0.4
1	7741.295	100 year	9889.71	70.57	73.16	1.98	5590.35	2067.65	0.4
1	7741.295	200 year	10946.2	70.57	73.35	2.05	5990.72	2067.65	0.4
1	7741.295	500 year	12340.05	70.57	73.6	2.14	6498.47	2067.65	0.4
1	7741.295	1000 year	13393.49	70.57	73.78	2.2	6868.19	2067.65	0.4

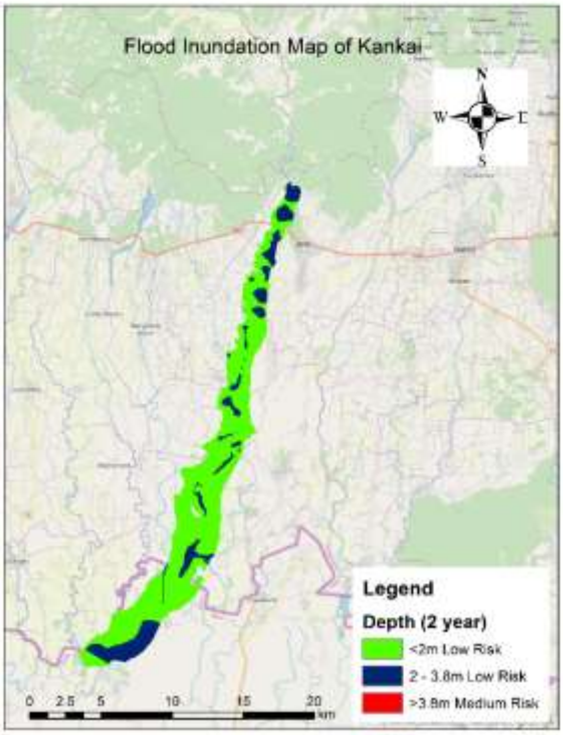
1	7352.397	2 year	3460.11	70.05	71.39	1.22	2954.36	2100.7	0.34
1	7352.397	10 year	6321.11	70.05	72.12	1.51	4494.81	2100.7	0.34
1	7352.397	50 year	8829.34	70.05	72.66	1.69	5634.63	2100.7	0.34
1	7352.397	100 year	9889.71	70.05	72.87	1.76	6077.09	2100.7	0.34
1	7352.397	200 year	10946.2	70.05	73.07	1.83	6499.46	2100.7	0.34
1	7352.397	500 year	12340.05	70.05	73.33	1.91	7032.06	2100.7	0.34
1	7352.397	1000 year	13393.49	70.05	73.51	1.97	7418.72	2100.7	0.34
1	6860.003	2 year	3460.11	69.46	71.08	1.23	3301.7	2012.14	0.31
1	6860.003	10 year	6321.11	69.46	71.85	1.54	4839.93	2012.14	0.32
1	6860.003	50 year	8829.34	69.46	72.4	1.75	5954.81	2012.14	0.33
1	6860.003	100 year	9889.71	69.46	72.61	1.83	6384.76	2012.14	0.33
1	6860.003	200 year	10946.2	69.46	72.82	1.9	6794.15	2012.14	0.33
1	6860.003	500 year	12340.05	69.46	73.07	2	7309.09	2012.14	0.34
1	6860.003	1000 year	13393.49	69.46	73.26	2.06	7682.31	2012.14	0.34
1	6468.22	2 year	3460.11	69.06	70.92	0.96	3909.35	2104.73	0.22
1	6468.22	10 year	6321.11	69.06	71.69	1.24	5521.71	2104.73	0.25
1	6468.22	50 year	8829.34	69.06	72.24	1.43	6689.34	2104.73	0.26
1	6468.22	100 year	9889.71	69.06	72.46	1.51	7139.58	2104.73	0.26
1	6468.22	200 year	10946.2	69.06	72.66	1.57	7568.27	2104.73	0.27
1	6468.22	500 year	12340.05	69.06	72.92	1.66	8107.44	2104.73	0.27
1	6468.22	1000 year	13393.49	69.06	73.1	1.72	8498.27	2104.73	0.27
1	6066.293	2 year	3460.11	68.76	70.77	0.93	4342.35	2335.83	0.21
1	6066.293	10 year	6321.11	68.76	71.53	1.2	6108.86	2335.83	0.23
1	6066.293	50 year	8829.34	68.76	72.08	1.38	7396.01	2335.83	0.24
1	6066.293	100 year	9889.71	68.76	72.29	1.44	7893.4	2335.83	0.25
1	6066.293	200 year	10946.2	68.76	72.49	1.5	8367.43	2335.83	0.25
1	6066.293	500 year	12340.05	68.76	72.75	1.58	8964.06	2335.83	0.25
1	6066.293	1000 year	13393.49	68.76	72.93	1.64	9396.92	2335.83	0.26
1	5450.492	2 year	3460.11	68.36	70.5	1.02	4307.69	2985.77	0.22
1	5450.492	10 year	6321.11	68.36	71.25	1.19	6550.84	2985.77	0.22
1	5450.492	50 year	8829.34	68.36	71.8	1.31	8198.7	2985.77	0.23
1	5450.492	100 year	9889.71	68.36	72.02	1.35	8837.12	2985.77	0.23
1	5450.492	200 year	10946.2	68.36	72.22	1.39	9446.05	2985.77	0.23
1	5450.492	500 year	12340.05	68.36	72.48	1.44	10212.84	2985.77	0.23
1	5450.492	1000 year	13393.49	68.36	72.67	1.48	10769.62	2985.77	0.23
1	5173.428	2 year	3460.11	68.24	70.35	1.3	3957.07	2992.79	0.29
1	5173.428	10 year	6321.11	68.24	71.12	1.48	6264.89	2992.79	0.28
1	5173.428	50 year	8829.34	68.24	71.68	1.61	7943.23	2992.79	0.28
1	5173.428	100 year	9889.71	68.24	71.89	1.66	8590.79	2992.79	0.28
1	5173.428	200 year	10946.2	68.24	72.1	1.7	9207.44	2992.79	0.28

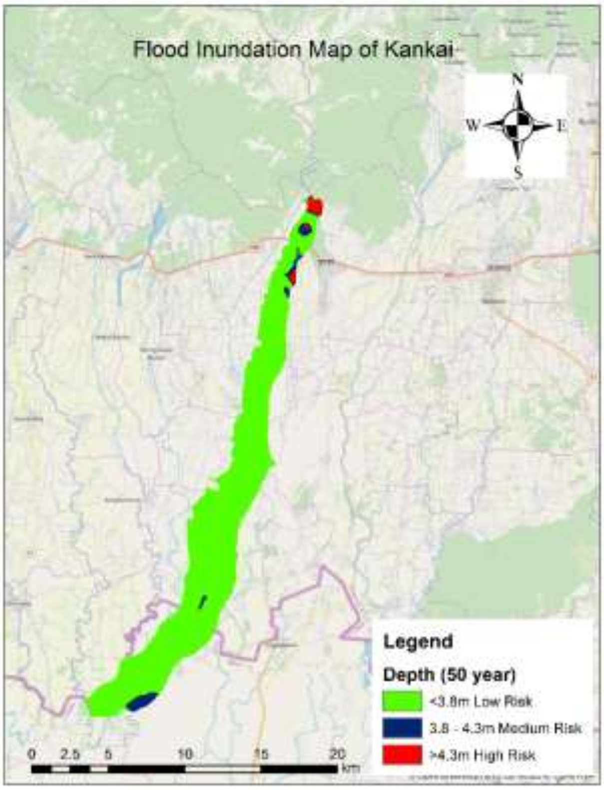
1	5173.428	500 year	12340.05	68.24	72.36	1.76	9982.67	2992.79	0.28
1	5173.428	1000 year	13393.49	68.24	72.55	1.8	10544.97	2992.79	0.28
1	4890.576	2 year	3460.11	68.01	70.2	1.18	3876.26	2797.3	0.26
1	4890.576	10 year	6321.11	68.01	70.98	1.35	6066.28	2797.3	0.25
1	4890.576	50 year	8829.34	68.01	71.54	1.47	7648.92	2797.3	0.25
1	4890.576	100 year	9889.71	68.01	71.76	1.52	8257.64	2797.3	0.25
1	4890.576	200 year	10946.2	68.01	71.97	1.56	8836.54	2797.3	0.25
1	4890.576	500 year	12340.05	68.01	72.23	1.61	9563.26	2797.3	0.25
1	4890.576	1000 year	13393.49	68.01	72.42	1.65	10089.97	2797.3	0.25
1	4634.682	2 year	3460.11	67.83	70.08	1.11	3886.53	2695.97	0.24
1	4634.682	10 year	6321.11	67.83	70.88	1.26	6047.6	2695.97	0.23
1	4634.682	50 year	8829.34	67.83	71.45	1.37	7589.8	2695.97	0.23
1	4634.682	100 year	9889.71	67.83	71.67	1.42	8180.6	2695.97	0.23
1	4634.682	200 year	10946.2	67.83	71.88	1.46	8741.34	2695.97	0.23
1	4634.682	500 year	12340.05	67.83	72.14	1.51	9444.28	2695.97	0.23
1	4634.682	1000 year	13393.49	67.83	72.33	1.55	9953.33	2695.97	0.23
1	4369.542	2 year	3460.11	67.65	69.99	1.02	4423.25	2587.54	0.21
1	4369.542	10 year	6321.11	67.65	70.8	1.22	6516.88	2587.54	0.22
1	4369.542	50 year	8829.34	67.65	71.37	1.37	8002.03	2587.54	0.23
1	4369.542	100 year	9889.71	67.65	71.59	1.42	8569.92	2587.54	0.23
1	4369.542	200 year	10946.2	67.65	71.8	1.48	9108.56	2587.54	0.23
1	4369.542	500 year	12340.05	67.65	72.06	1.54	9783.33	2587.54	0.24
1	4369.542	1000 year	13393.49	67.65	72.25	1.59	10271.83	2587.54	0.24
1	3639.105	2 year	3460.11	67.48	69.85	0.77	4832.57	2452.02	0.17
1	3639.105	10 year	6321.11	67.48	70.66	1	6821.22	2452.02	0.18
1	3639.105	50 year	8829.34	67.48	71.23	1.15	8224.38	2452.02	0.19
1	3639.105	100 year	9889.71	67.48	71.45	1.21	8760.17	2452.02	0.2
1	3639.105	200 year	10946.2	67.48	71.65	1.26	9268.11	2452.02	0.2
1	3639.105	500 year	12340.05	67.48	71.91	1.33	9904.07	2452.02	0.2
1	3639.105	1000 year	13393.49	67.48	72.1	1.38	10364.51	2452.02	0.21
1	2549.081	2 year	3460.11	68.05	69.72	0.75	4531.31	2284.99	0.19
1	2549.081	10 year	6321.11	68.05	70.51	1.04	6354.67	2284.99	0.22
1	2549.081	50 year	8829.34	68.05	71.08	1.24	7640.14	2284.99	0.23
1	2549.081	100 year	9889.71	68.05	71.29	1.32	8130.98	2284.99	0.24
1	2549.081	200 year	10946.2	68.05	71.49	1.39	8596.34	2284.99	0.24
1	2549.081	500 year	12340.05	68.05	71.75	1.47	9178.9	2284.99	0.25
1	2549.081	1000 year	13393.49	68.05	71.93	1.53	9600.94	2284.99	0.25
1	2112.102	2 year	3460.11	67.93	69.47	0.88	3296.83	1825.1	0.24
1	2112.102	10 year	6321.11	67.93	70.24	1.22	4692.62	1825.1	0.26

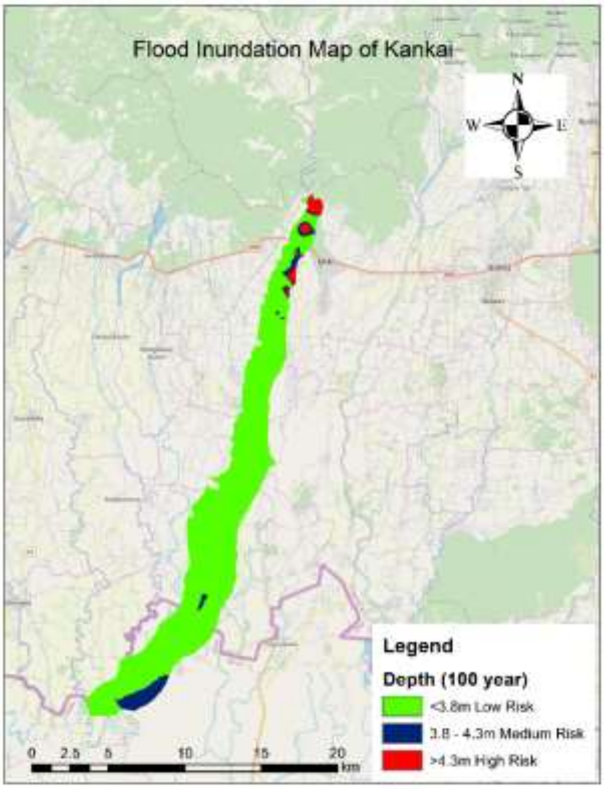
1	2112.102	50 year	8829.34	67.93	70.77	1.45	5672.16	1825.1	0.28
1	2112.102	100 year	9889.71	67.93	70.98	1.54	6045.63	1825.1	0.29
1	2112.102	200 year	10946.2	67.93	71.17	1.62	6399.47	1825.1	0.29
1	2112.102	500 year	12340.05	67.93	71.41	1.72	6841.85	1825.1	0.3
1	2112.102	1000 year	13393.49	67.93	71.59	1.79	7162.59	1825.1	0.3
1	1391.544	2 year	3460.11	67.15	69.27	1.03	3790.6	1822.42	0.23
1	1391.544	10 year	6321.11	67.15	70	1.39	5118.68	1822.42	0.26
1	1391.544	50 year	8829.34	67.15	70.51	1.64	6055.26	1822.42	0.29
1	1391.544	100 year	9889.71	67.15	70.71	1.74	6413.51	1822.42	0.29
1	1391.544	200 year	10946.2	67.15	70.9	1.82	6753.44	1822.42	0.3
1	1391.544	500 year	12340.05	67.15	71.13	1.93	7178.83	1822.42	0.31
1	1391.544	1000 year	13393.49	67.15	71.3	2.01	7488.22	1822.42	0.32
1	797.3861	2 year	3460.11	67.15	69.09	0.97	3869.64	2003.14	0.22
1	797.3861	10 year	6321.11	67.15	69.78	1.31	5251.58	2003.14	0.26
1	797.3861	50 year	8829.34	67.15	70.27	1.54	6235.21	2003.14	0.28
1	797.3861	100 year	9889.71	67.15	70.46	1.63	6613.57	2003.14	0.29
1	797.3861	200 year	10946.2	67.15	70.64	1.71	6973.6	2003.14	0.29
1	797.3861	500 year	12340.05	67.15	70.86	1.81	7425.02	2003.14	0.3
1	797.3861	1000 year	13393.49	67.15	71.03	1.88	7754.88	2003.14	0.3
1	127.994	2 year	3460.11	67.15	67.95	3.01	1231.16	1543.29	1.08
1	127.994	10 year	6321.11	67.15	68.34	3.68	1840.02	1543.29	1.08
1	127.994	50 year	8829.34	67.15	68.65	4.1	2307.52	1543.29	1.07
1	127.994	100 year	9889.71	67.15	68.76	4.26	2488.68	1543.29	1.07
1	127.994	200 year	10946.2	67.15	68.87	4.42	2656.59	1543.29	1.08
1	127.994	500 year	12340.05	67.15	69.02	4.59	2882.38	1543.29	1.07
1	127.994	1000 year	13393.49	67.15	69.12	4.73	3036.9	1543.29	1.08

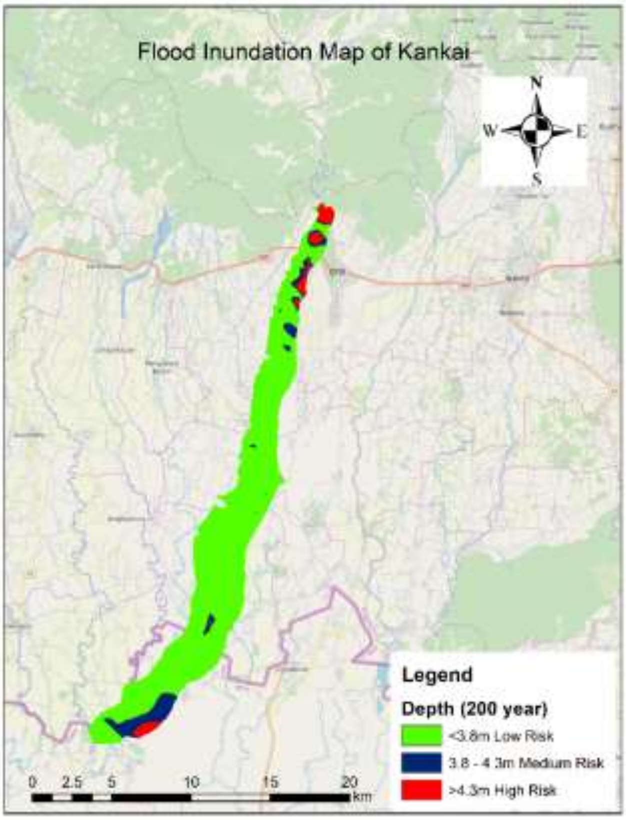
ANNEXE 3: Inundation Map

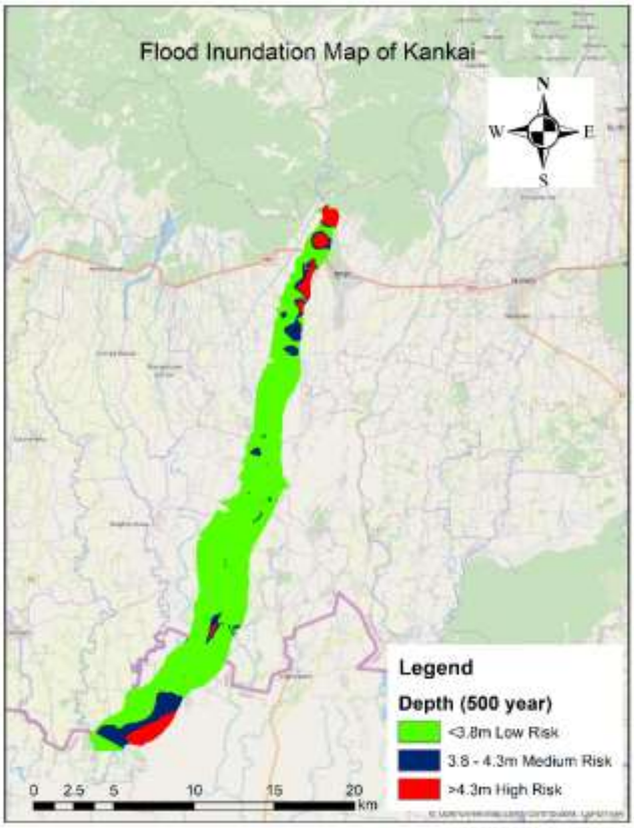
Map of flow obtained with Gumbel Calculations

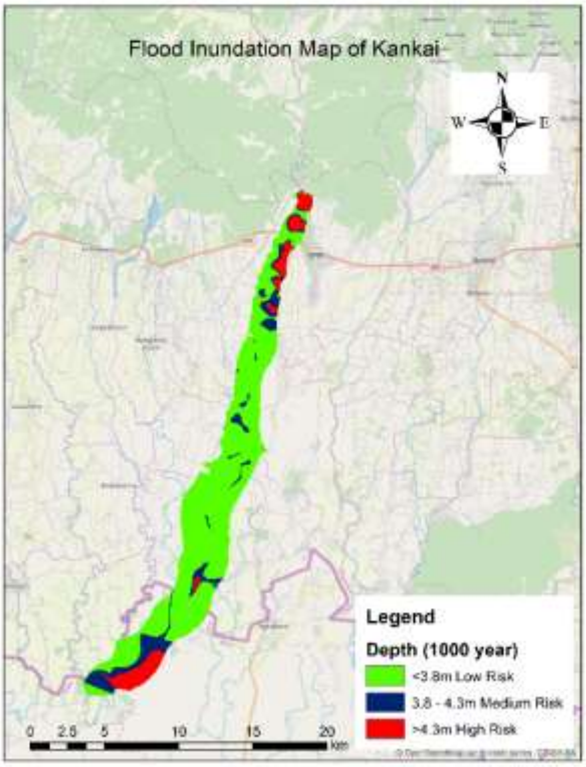



Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (50 year)
<3.8m Low Risk
3.8 - 4.3m Medium Risk
>4.3m High Risk
0
2.5
5
10
15
20
km

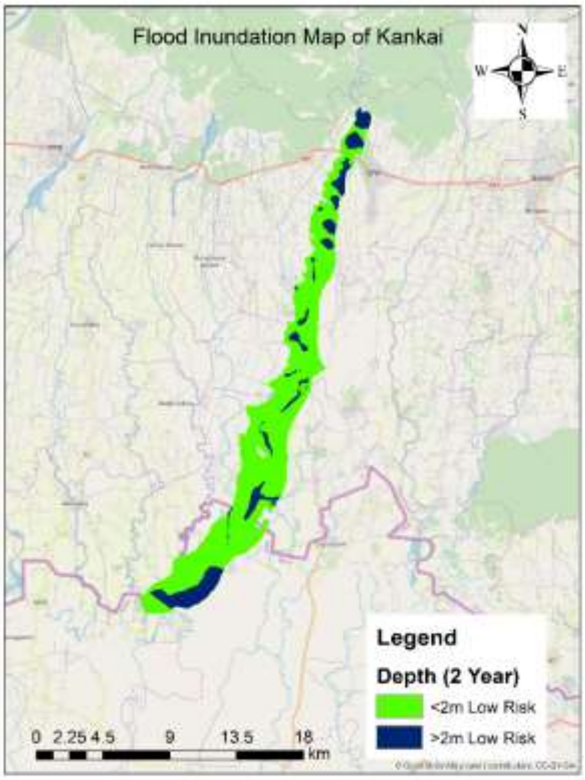

Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (100 year)
<3.8m Low Risk
3.8 - 4.3m Medium Risk
>4.3m High Risk
0
2.5
5
10
15
20
km


Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (200 year)
<3.8m Low Risk
3.8 - 4.3m Medium Risk
>4.3m High Risk
0 2.5 5 10 15 20 km


Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (500 year)
<3.8m Low Risk
3.8 - 4.3m Medium Risk
>4.3m High Risk
0 2.5 5 10 15 20 km



Inundation Map of Flow Obtained from HEC-HMS

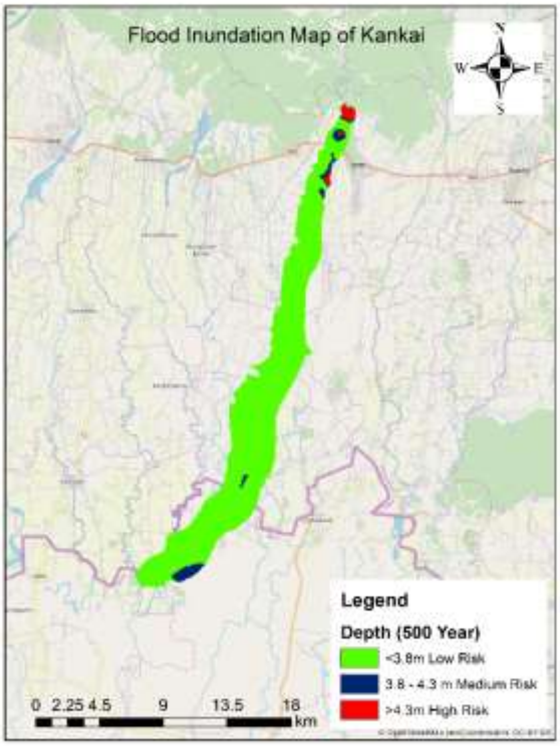


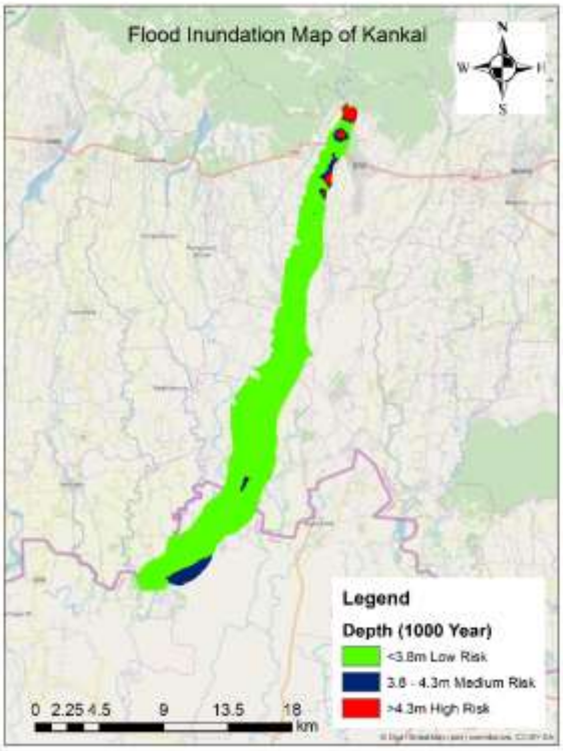

Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (10 Year)
🟩 <3.8m Low Risk
■ 3.8 - 4.3m Medium Risk
🟥 >4.3m High Risk
0 2.25 4.5 9 13.5 18
km

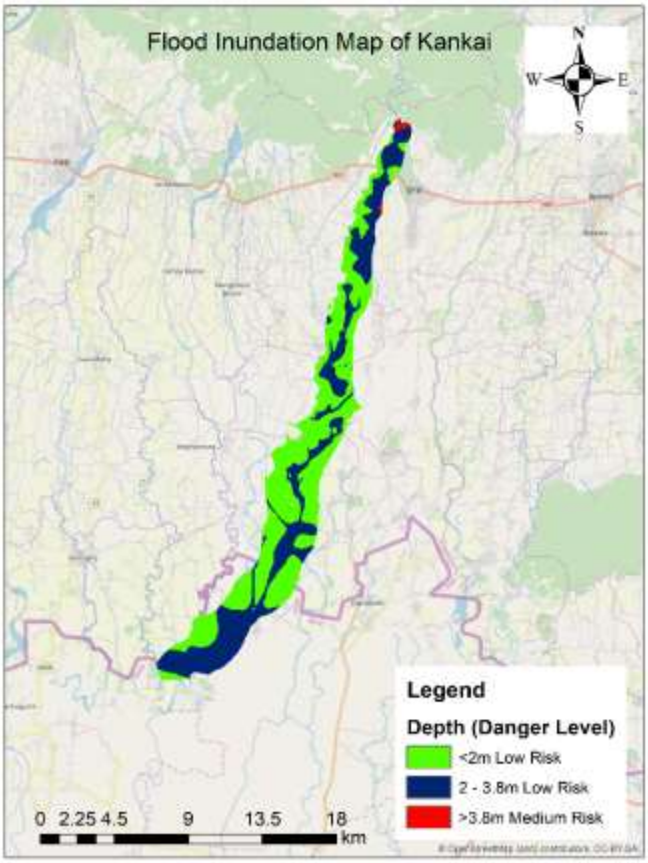

Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (50 Year)
🟩 <3.8m Low Risk
■ 3.8 - 4.3m Medium Risk
🟥 >4.3m High Risk
0 2.25 4.5 9 13.5 18
km

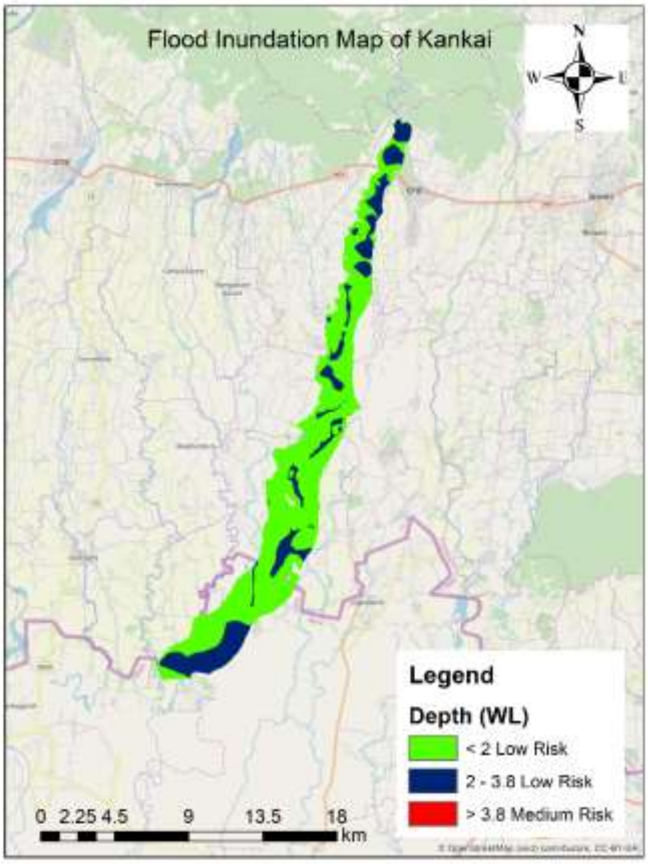

Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (100 Year)
<3.8m Low Risk
3.8 - 4.3m Medium Risk
>4.3m High Risk
0 2.25 4.5 9 13.5 18
km


Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (200 Year)
<3.8m Low Risk
3.8 - 4.3m Medium Risk
>4.3m High Risk
0 2.25 4.5 9 13.5 18
km


Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (500 Year)
<3.8m Low Risk
3.8 - 4.3 m Medium Risk
>4.3m High Risk
0 2.25 4.5 9 13.5 18
km


Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (1000 Year)
<3.8m Low Risk
3.8 - 4.3m Medium Risk
>4.3m High Risk
0 2.25 4.5 9 13.5 18
km

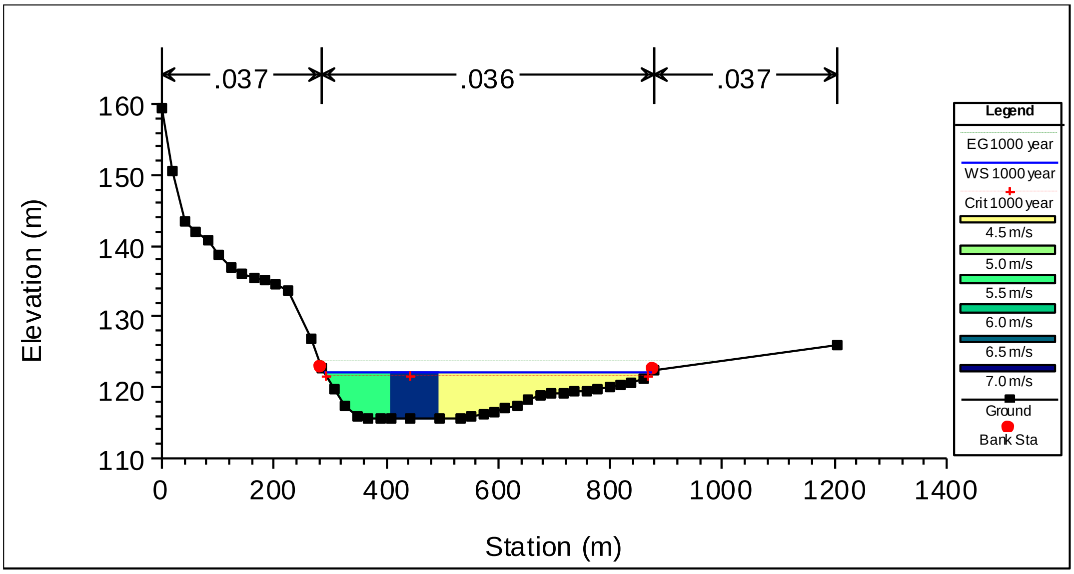

Flood Inundation Map of Kankai
N
W
E
S
Legend
Depth (Danger Level)
🟩 <2m Low Risk
🟦 2 - 3.8m Low Risk
🟥 >3.8m Medium Risk
0 2.25 4.5 9 13.5 18
km


Flood Inundation Map of Kankai
N
W
U
S
Legend
Depth (WL)
🟩 < 2 Low Risk
🟦 2 - 3.8 Low Risk
🟥 > 3.8 Medium Risk
0 2.25 4.5 9 13.5 18
km

ANNEXE 4:Major Cross-Sections and Their Information

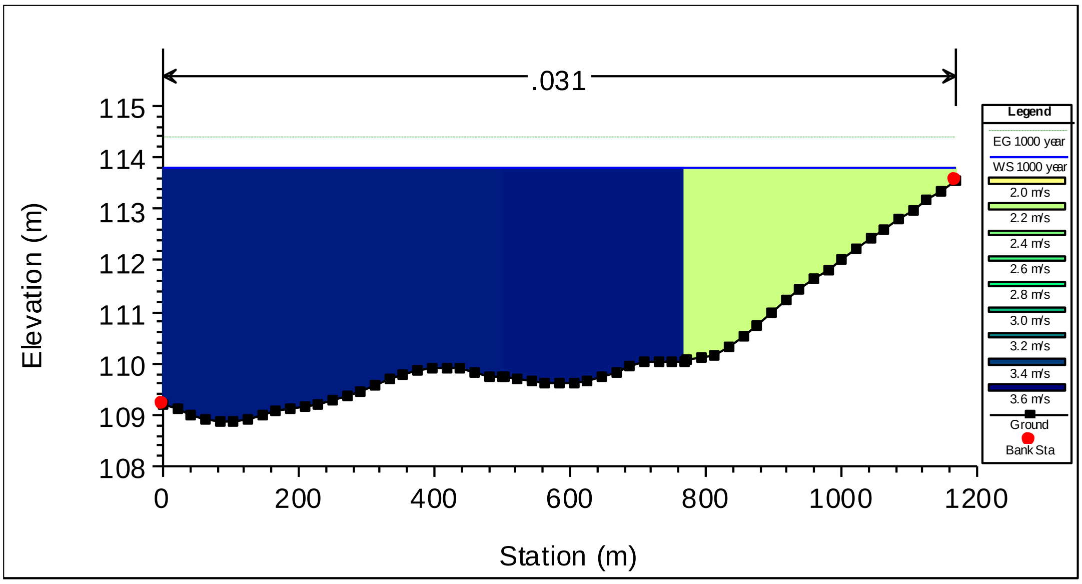
Cross-section connecting Kankai-2 and Shivasataxi-10 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	3.98	4.8	5.45	5.71	5.95	6.25	6.46



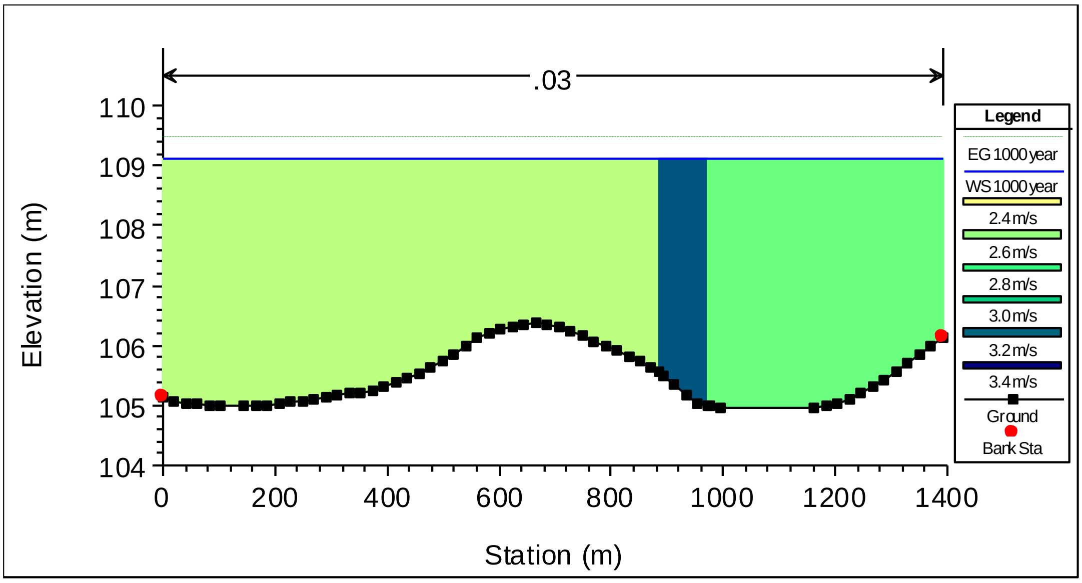
Cross-section connecting Kankai-4 and Shivasataxi-10 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.64	3.45	4.04	4.26	4.47	4.73	4.92



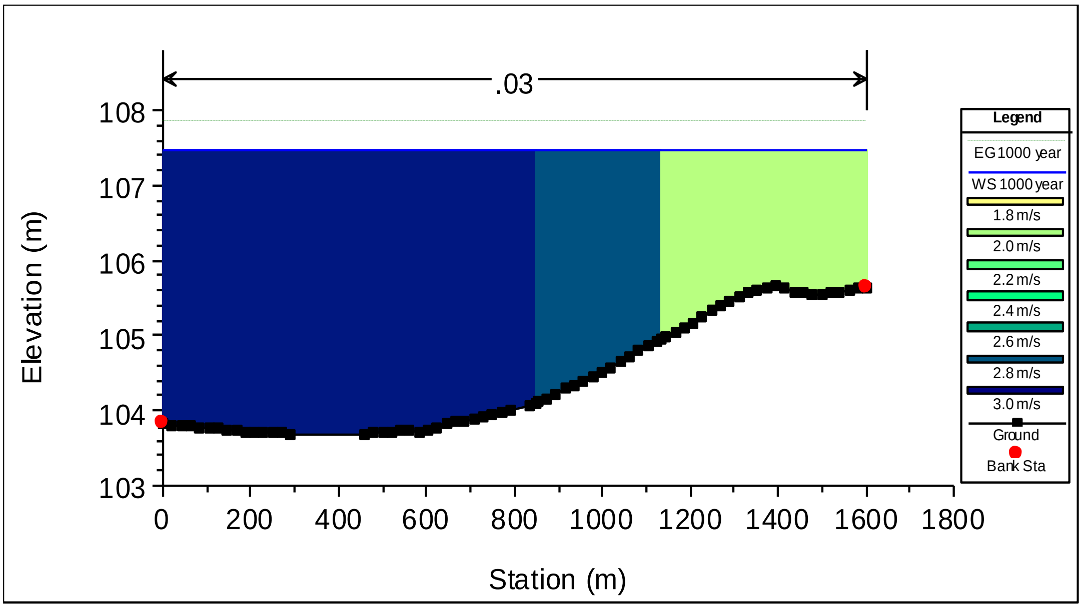
Cross-section connecting Kankai-4 and Shivasataxi-9 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.11	2.83	3.34	3.54	3.73	3.96	4.13



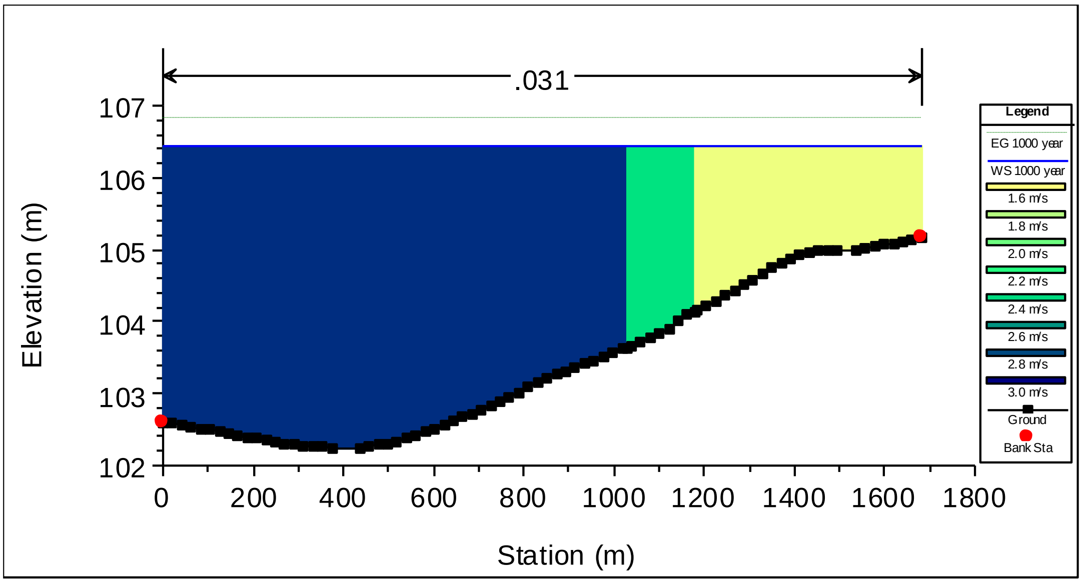
Cross-section connecting Kankai-4 and Shivasataxi-7 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	1.81	2.53	3.02	3.21	3.39	3.61	3.77



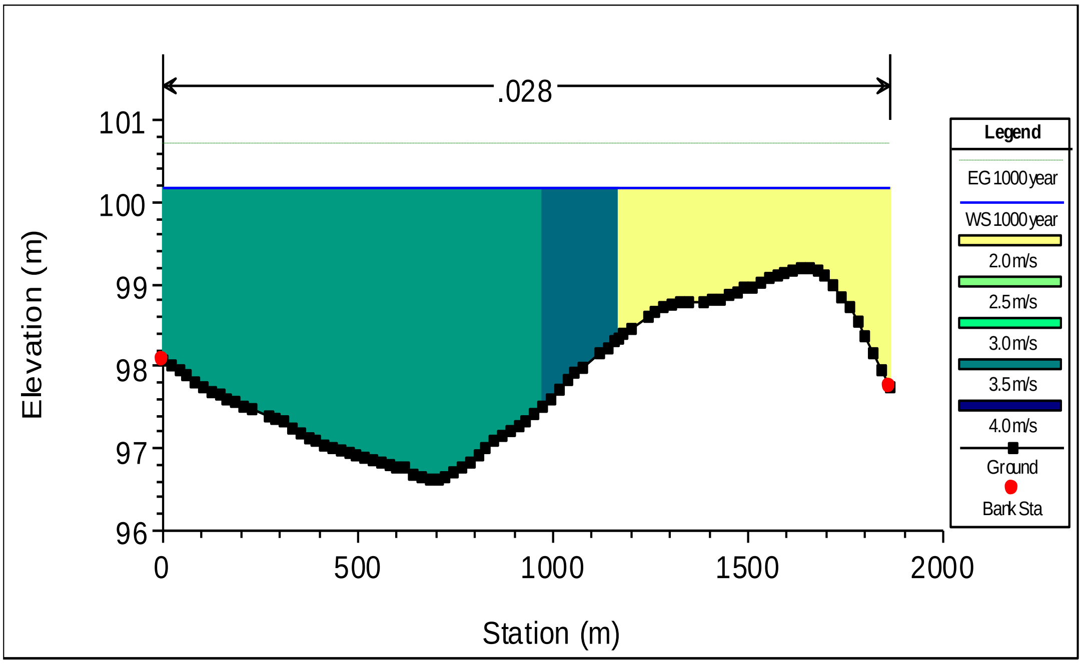
Cross-section connecting Kankai-5 and Shivasataxi-7 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.37	3.02	3.48	3.65	3.82	4.03	4.18



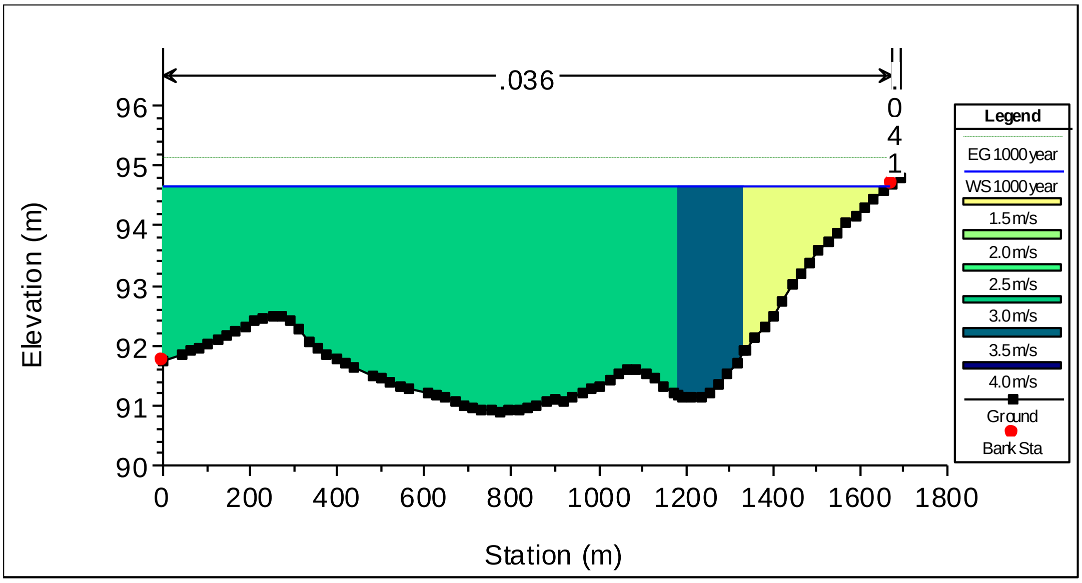
Cross-section of Shivasataxi-7 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.03	2.56	2.95	3.09	3.24	3.42	3.55



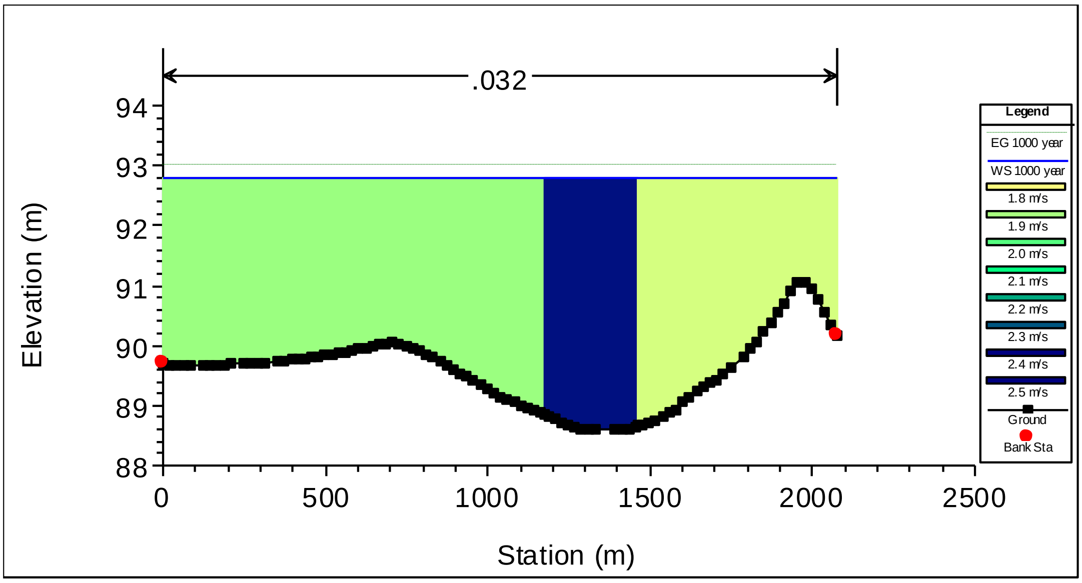
Cross-section of Shivasataxi-6 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.15	2.71	3.11	3.27	3.42	3.62	3.75



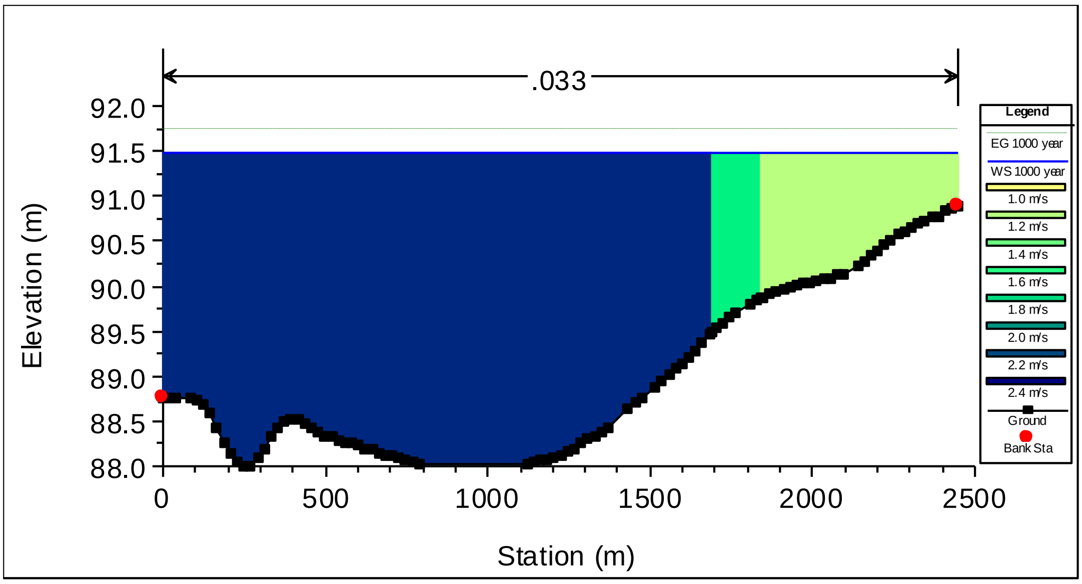
Cross-section connecting Jhapa-7 and Shivasataxi-5 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.39	3.06	3.52	3.70	3.87	4.07	4.22



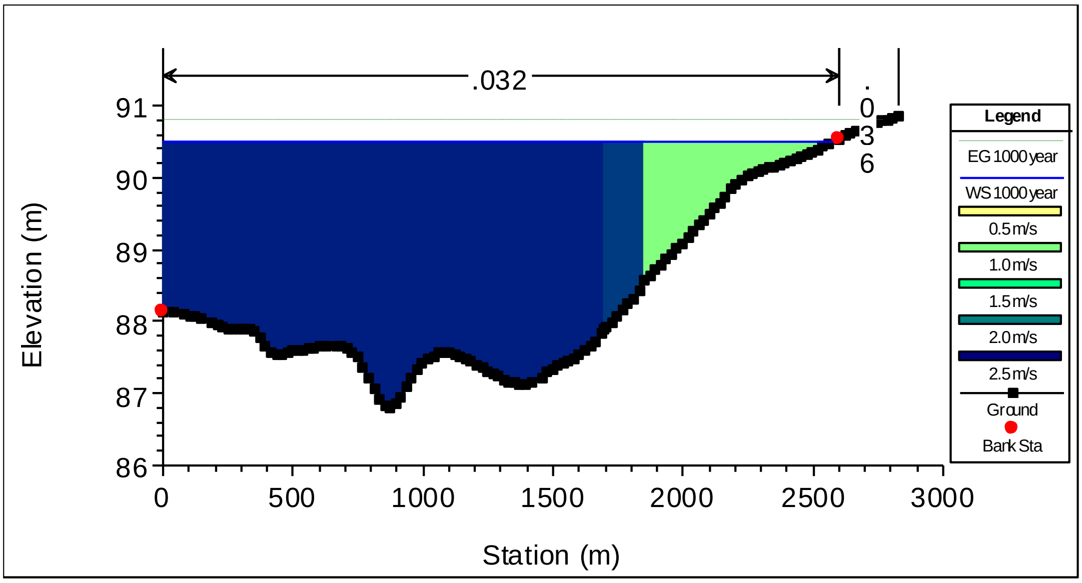
Cross-section connecting Jhapa-4 and Shivasataxi-5 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	1.90	2.47	2.87	3.02	3.17	3.36	3.49



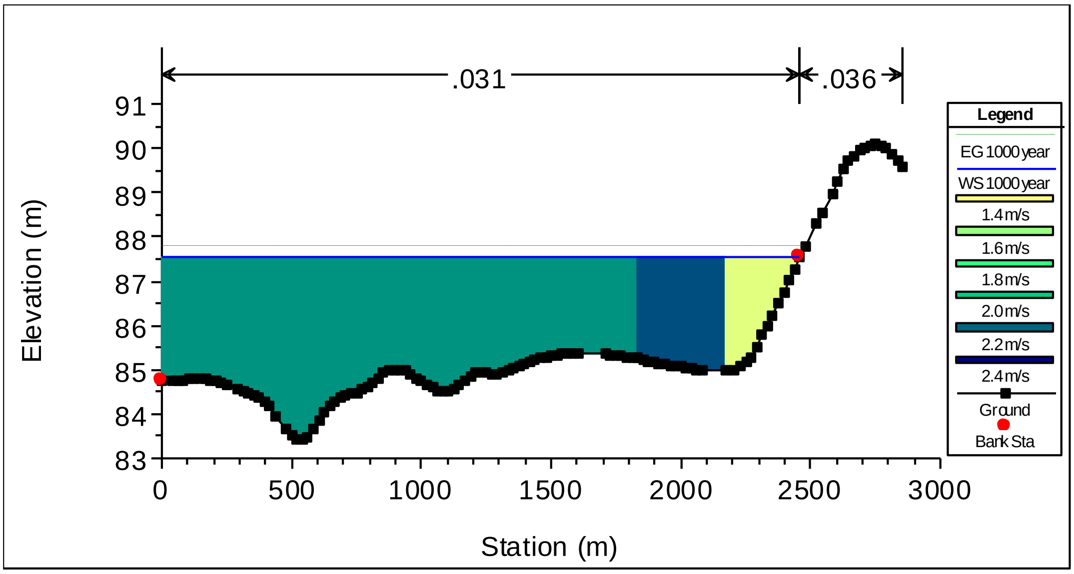
Cross-section connecting Jhapa-4 and Shivasataxi-4 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.02	2.64	3.06	3.22	3.37	3.57	3.79



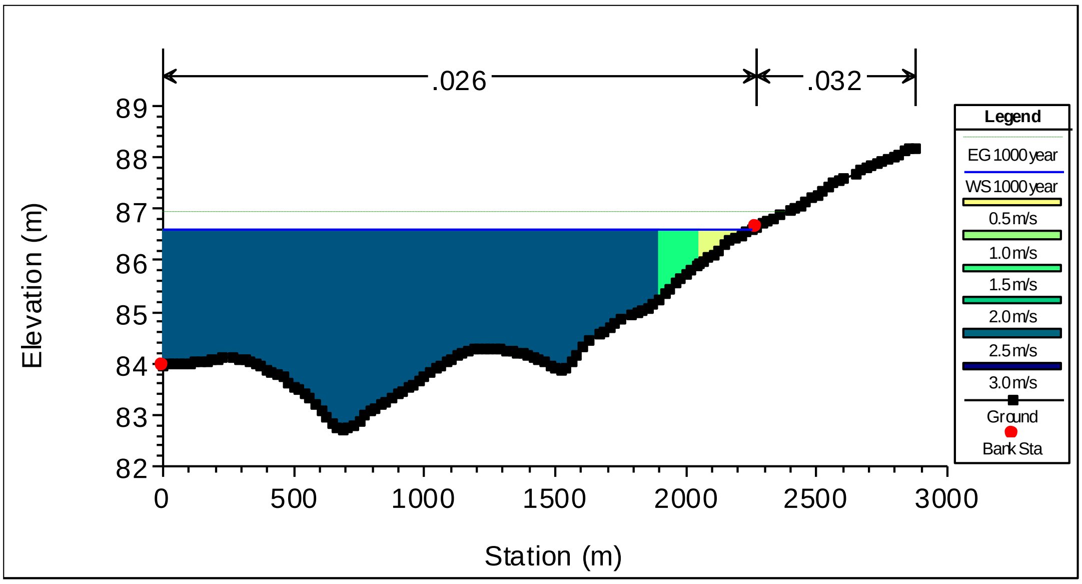
Cross-section of Jhapa-4 depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.58	3.13	3.52	3.67	3.82	4.00	4.12



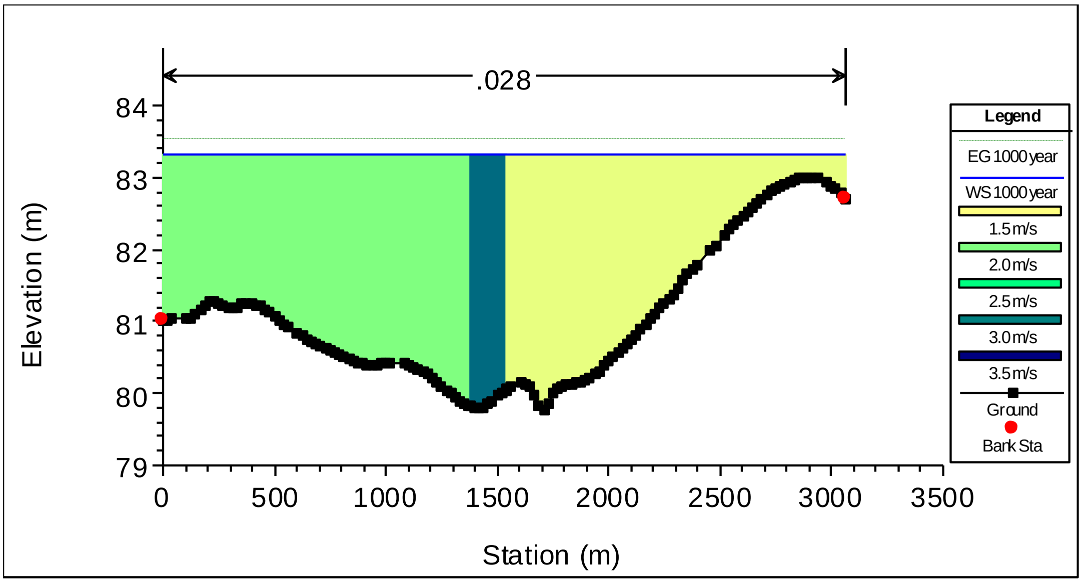
Cross-section connecting Jhapa-2 and Shivasataxi-4 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.47	3.02	3.38	3.51	3.64	3.79	3.91



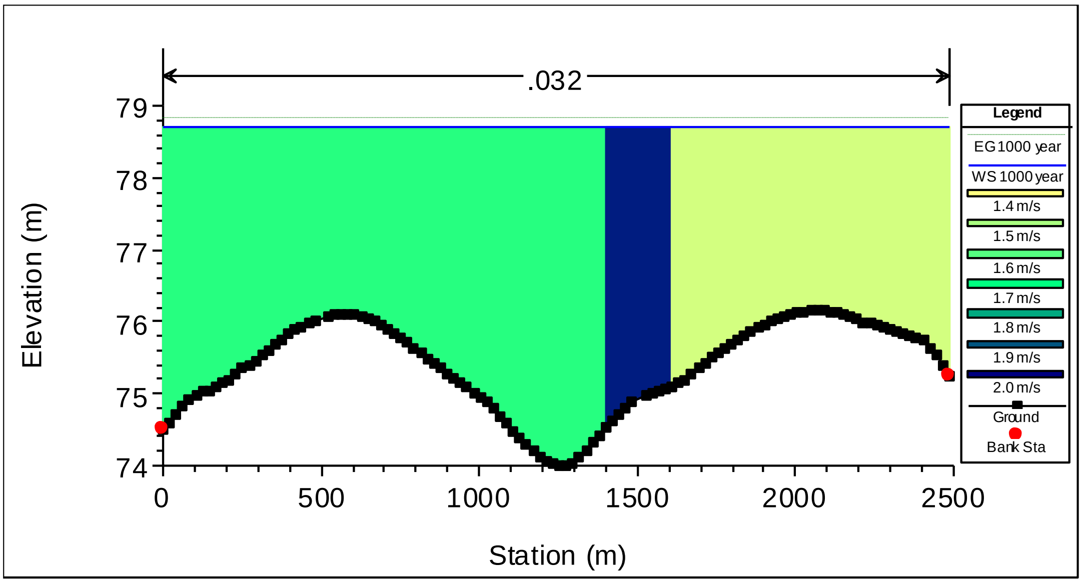
Cross-section connecting Jhapa-2 and Gaurigunj-4 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	2.03	2.59	2.98	3.12	3.26	3.43	3.55



Cross-section connecting Jhapa-1 and Gaurigunj-1 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	3.00	3.67	4.08	4.23	4.38	4.57	4.70



Cross-section connecting of Gaurigunj-2 and depth for different return period are:

Return Period (year)	2	10	50	100	200	500	1000
Flood Depth (m)	1.94	2.63	3.12	3.31	3.49	3.71	3.88