ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

FLOOD RISK ANALYSIS (Case Study of Upper Awash River from Wonji to Awash Malkassa)

A Thesis in Hydraulic Engineering

By Dawit Mokonen

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A Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

The undersigned have examined the thesis entitled '**Flood Risk Analysis (Case study of Upper Awash River from wonji to Awash Malkessa'** presented by **Dawit Mokonen**, a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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DECLARATION

I confirm that research work titled "**Flood Risk Analysis (Case study of Upper Awash River from wonji to Awash Melkessa**" is my own work. The work has not been presented elsewhere. Where material has been used from other sources it has been properly acknowledged.

Dawit Mokonen

ABSTRACT

Flood is probably the greatest devastating, wide spread and frequently natural hazard of the world wide that producing several socioeconomic and environmental consequences within the affected floodplain. In Ethiopia, Awash River basin is one of the areas affecting by flood plain problem and among Awash River basin, wonji to awash melkessa is one the most frequently severed area by floodplain along Awash River, for those flood risk analysis is so important.

The main objective of this study was flood inundation mapping and quantifies the risk of flood on the area by using hydrological model HEC-HMS for peak flood forecasting for different return period and GIS extension HEC-GeoRAS integration with hydraulic model HEC-RAS for flood inundation mapping. For hydrological model (HEC-HMS) daily rainfall and stream flow data of 16 years from (1998-2013 G.C) was used. Among the data used eight years for calibration and five years for validation of HEC-HMS model at wonji Gauged station. HEC-RAS model was calibrated and validated using satellite imaginary Landsat-7 flood event and observed flood event of September, 06/2000 and September, 22/2007 G.C respectively. The missing values were filled by using normal ration method for daily precipitation data. Consistent data was checked by double mass curve method. The initial and constant loss method was selected for loss method and for transform method Clark unit hydrography was applied.

The estimated peak flood by hydrological model (HEC-HMS) was 147.2m^3/s, 161.9m^3/s, 329.4m^3/s, 409.5m^3/s and 506.8m^3/s for 5year, 10year, 25years, 50years and 100year return period correspondingly. The flood inundated area corresponding to peak flood were 1052.7 hectare, 1086.9 hectare, 1429.5 hectare, 1559.1 hectare and 1694.1 hectare respectively. The total crop losses were calculated for flood inundated area, for 5 years and 100 year return period of crop loss were 75501.6 quintal and 121503 quintal correspondingly.

Thus finding of the study may help in planning and management of flood plain area to mitigate probable disaster through technical approach.

***Key words:*-Arc GIS, HEC-HMS, HEC-RAS, Flood inundation map.**

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ABBREVIATIONS

USACE	United State Army Corps of Engineers
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-GeoRAS:	Hydrologic Engineering Center Geometry River Analysis system.
HEC-HMS	Hydrologic Engineering Center hydrologic modeling system
NMA:	National Metrological Agency
USGS:	United States Geological Survey
GIS	Geographical Information System
DEM	Digital Elevation Model
TIN	Triangular Irregular Network
MoWIE	Ministry of Water, Irrigation, and Energy
IDF	Intensity Duration Frequency
NSE	Nash-Sutcliffe Efficiency
DMC	Double Mass Curve
DTM	Digital Terrain Model
UH	Unit Hydrography
WSP	Water Surface Profile
LU LC:	Land Use Land Cover
MNDWI	Modified Normalized Difference Water Index
NDVI	Normalized Difference Vegetation Index
NDMI	Normalized Difference Moisture Index
XS	Cross Section
ha:	Hectare
m^3/s:	cubic meter per second
G.C:	Gregorian calendar
RF	Rainfall

CHAPTER 1 INTRODUCTION

1.1 Background

Flood is the most dangerous and damaging acts of nature. They cause widespread damage to agriculture residences and public utilities and amount to loss of billions of dollars each year in addition to loss of billions as well as animals lives. It is a common problem in all parts of the country. Generally flooding is caused by river over spilling its banks. This can be as a result of excessive rainfall combined with channels which have not sufficient capacity is a natural process and part of the hydrological cycle of rainfall, surface and ground water flow and storage. Floods occur whenever the capacity of the natural or manmade drainage system is unable to cope with the volume of water generated by rainfall. Floods are varying considerably in size and duration. Field-scale flooding is usually due to intense local storms where water and soil can flow straight off the land surface and may be over in a matter of hours. With prolonged rain falling over wide areas rivers are fed by a network of ditches, streams and tributaries and flows build up to the point where the normal channel is over whelmed and water floods onto surrounding areas. On large rivers flooding occur a considerable period after the Rainfall and last for many days or weeks as the large volumes of water drain out of the catchment(Daniel Alemayehu, 2007)

Flooding from a wide range of sources (river, pluvial coastal or maritime flood events) seemed to happen more frequently with snowballing effects for the landscape and society. In fact, in third of natural disasters and economic losses and more than half of all victims are flood related (Douben, 2006). Floods are overflow of rivers or burst their banks and inundate downstream plain lands (Kebede Bishaw, 2012) Flash flood is the type of flood common problem which is caused by high runoff from the surrounding mountains(Nigusse et al, 2019)

In Ethiopia, flood usually takes place at the peak of the rainy season (July and August) in most flood-prone areas. In East shoe oromia region flooding often happens during July and August. In study area Unseasonal and above-normal rainfall during September to October could also cause flooding in areas along Awash Rivers.

Flood risk Mapping is an important tool for engineers, planners, and government agencies used for municipal and urban growth planning, emergency action plans, flood insurance rates and ecological studies. A flood map displays the spatial extent of probable flooding for different scenarios. By understanding the extent of flooding and floodwater inundation, decision makers are able to make choices about how to best allocate resources to prepare for emergencies and to generally improve the quality of life. The Hydraulic Engineering Center's River Analysis System (HEC-RAS) is a software package that is well-suited for developing flood inundation maps for a variety of applications. An HEC-RAS model can be used for both steady and unsteady flow, and sub and supercritical flow regimes. With its companion utility, HEC-GeoRAS and ArcView©, seamless integration with GIS makes both the construction of the model geometry and the post-processing of the output very easy (Goodell, 2015)

HEC-GeoRAS is a geographic river analysis system developed using ArcGIS® Desktop and ArcGIS Spatial Analyst and 3D Analyst extensions. The geo data base design supports analysis of spatial data for hydraulic modeling and flood zone mapping. Besides floodplain mapping, we can use the results of a Geo-RAS analysis for flood damage computations, ecosystem restoration, and flood warning response and preparedness. Geo-RAS uses ArcGIS Desktop to develop spatial data input for HEC-RAS models from digital terrain models and other GIS datasets. After the model results are calculated in HEC-RAS, they can be post processed in Geo-RAS, and then the flood plain depths and extents can be mapped (Cameron T. Ackerman, 2011)

Flood modeling can easily be accomplished using the readily available tools such as HEC-HMS/RAS and GIS tools. When calibrated well, the results of the models offer a reliable tool to be used in decision making by the district and national policy makers in the country. The post-processing consists of analyzing the results from the HEC-RAS model with ArcMap(Kedric Curtis,et al., 2016). HEC-RAS tools have been tested and widely used globally in flood modeling for several years.

1.2 Statement of the problem

Flood is probably the greatest devastating, wide spread and frequently natural hazard of the world wide that producing several socioeconomic and environmental consequences within the affected floodplain. Flood is unusually high stage in a river, normally the level at which the river over flows its banks and inundates the adjoining area. The damage caused by floods in terms of loss of life , property and economic loss due to disruption of economic activity are all too well known. The country experiences two types of floods: flash flood and river floods. Flash floods are the ones formed from excess rains falling on upstream watershed and river floods are overflow of rivers or burst their banks and inundate downstream plain lands (Kebede Bishaw, 2012).

The main features of a flood, from the flood plain point of view; it is interference with human activities. The interference is measured in terms of actual and potential economic losses and danger to human life. The purpose of flood plain provides vital information for the planning and designs of many hydraulic and for risk assessment in flood plain use. In recent years, heavy rainfall frequently causes flood disasters, and quite a few of them cause tremendous damage to the areas. Nowadays, extraordinary floods are common to many parts of Ethiopia every year causing a lot of losses to human lives as well as damage to property. The majority of flood disasters‟ victims are poor people living in nearby stretch of floodplain.

The upstream of the Awash River basin has been flooded for short or week duration after intense or prolonged rainfall events, but the downstream area has been flooded for weeks or months every year during wet season. Timing and size of the flood cause influence the production of the crops cultivated in flood plain. Intense rainfall in the upper awash river basin occur at the end of rain season, the flood can damage the crops (Getahun SL and Gabre , 2015). Flooding is becoming a big concern in the Awash River basin due to crop losses.

The most severe flood occurs at some intervals in upper Awash River basin. Bacho is an agricultural potential experienced flooding problem of different level every year and their farming is constrained by the risk of crop losses by flood inundation that occurs every rainy season (Abeba Chibssa ,2007). Awash River cause flooding at Ilu, Sebeta Awas, and Ejerie floodplain. River conveys high runoff from upper catchment and have been damaged different crops and other property(Dawit, 2015)

Flood problem in the study area is also happen every year causing loss of different crops production. Hence, this study will identify peak flood, produce flood inundation mapping and risk of the flood that can be affected by flood inundation.

1.3 Research questions

The major questions that will be answered in this thesis are

- ✓ What is the magnitude of flood for different return period?
- ✓ Which area is highly vulnerable to the flood risk?
- ✓ What is the output of HEC-RAS software?

1.4 Objective of the study

1.4.1 General objective

The main purpose of this research is to identify flood inundation area in order to producing flood risk analysis for different magnitude of flood.

1.4.2 Specific objective

- ➢ To develop flood inundation mapping for the study area.
- ➢ To identify hazard level (high and medium)
- ➢ To quantify flood risk.

1.5 Significance of the study

Flood characteristics and its impacts are needs to identify to save the human life and economic loss of the local community. Flood inundation map and risk analysis are some of the main way to understanding the future risk of flood on the area. Early identification of flood-risk area helps community to save loss of properties during emergencies flood allows public safety organizations to establish warning and evacuation priorities. This study can provide information on the future worst area, and losses of property corresponding to peak flood magnitude. The output of this thesis work can also be as bench mark in knowing the impending flood from the upstream habitant to take measures for the downstream habitant in the next return period. This future information helps researchers who want to carry out further study on mitigation measure.

CHAPTER 2 LITERATURE REVIEW

2.1 Flood

Flood is an unusually high level in a river, normally the stage at which the river overflows its bank and inundates the plain area. The damage cause by flood in terms of loss of property and economic loss due to disruption of economic activity are all too well known. Wide range of cores of rupees is spent every year in flood control and flood forecasting(K.Subramanya, 2009).

Flooding is a natural process that happens at several times in a wide range of location. Flooding from the sea and from rivers is maybe best known but prolonged, intense and localized rainfall can also cause sewer flooding, overland flow and ground water flooding. Flooding has significant impacts on human activities; it can threaten people's lives, their property and environment. Asset at risk can include housing, transport and public service infrastructure and commercial, industrial and agricultural enterprises. The frequency pattern and severity of flooding are expected to increase as a result of climate change. Development can also intensify the problem of flooding by accelerating and increasing surface water runoff, altering water courses and removing flood plain storage. (Khan and Rahman, 2014). The country experiences two types of floods: flash flood and river floods. Flash floods are the ones formed from excess rains falling on upstream watershed and river floods are overflow of rivers or burst their banks and inundate downstream plain lands (Kebede Bishaw, 2012).

In Ethiopia flooding usually occurs within the three months of the rainy season and limited to areas of lower and flat topographic setting. It is usually the intense rainfall in the high lands that cause flooding at its downstream and disaster to settlements close to any stretch of river courses(Abeba Chibssa, 2007)

2.2 Flood plain

A flood plain is the normally dry land area adjoining river, stream, lake, or ocean that is inundating during flood events. The most common reasons of flooding are the overflow of streams and rivers and unusually high tides causing from severe storms. The flood plain can include the full width of narrow stream valleys, or broad areas along streams in wide, flat valleys. The channel and flood plain are both integral parts of the natural conveyance of a stream. The flood plain carries flow in excess of the channel capacity and the greater the discharge, the further the extent of flow over the flood plain. The first step in any flood risk analysis is to collect data, including topographic maps, flood flow data if a gaging station is nearby, rainfall data if flood flow data are not available and surveyed cross sections and channel roughness estimates at a number of points along the stream(Chow, 1964).

The general method for creating floodplain maps for a river has three major stages: pre-proceessing, processing and post-processing of the data. The floodplain mapping is done with ArcGIS, HEC-GeoRAS and HEC-RAS. The pre-processing stage consisted mostly of model input data preparation and in ArcGIS using the HEC-GeoRAS extension. The pre-processing stage is done completel within HEC-RAS using river geometry prepared in the previous stage. The post-processing consists of analyzing the results from the HEC-RAS model with ArcMap(Kedric Curtis,et al., 2016)

A determination of the flood flow for the desired return period is required. If gaged flow records are available, a flood flow frequency analysis can be performed. If gaged data are not available, then a rainfall-runoff analysis must be performed to determine the flood discharge. The rainfall hyetograph is determined for the desired return period, a synthetic unit hydrograph is developed for each subarea of the drainage basin, and the direct runoff hydrograph from each subarea is calculated. The subarea direct runoff hydrographs are routed downstream and added to determine the total direct runoff hydrograph at the most downstream part of the drainage basin. The peak discharge of the most downstream hydrograph is used as the design flood. Once the flood flow for the desired return period have determined; the next stage is to determine the profile of water surface elevation along the channel/river. This analysis can be carried out assuming steady, gradually-varied, non-uniform flow using a one-dimensional model such as HEC-1, two-dimensional model based upon either finite differences or finite elements.

After the water surface elevations have determined, the area covered by the flood plain is delineated. The lateral extent of the flood plain is determined by finding ground points on both sides of the stream that correspond to the flood profile. Ground elevation in the flood plain can be determined from topographic map, street maps, or stereo aerial photos.

Encroachment on flood plains, such as by artificial fill material, reduces the flood carrying capacity, increases the flood height of streams, and increase flood hazards in areas beyond the encroachment. One aspect of flood plain management involves balancing the economic gain from flood plain development against the resulting increase in flood hazard. The floodway is the channel of a stream plus any adjacent flood as shown as fig below. The floodway fringe is the area between the designated floodway limit and the limit of the selected flood. The floodway limit is defined so that encroachment limited to the floodway fringe will not significantly increase flood elevation(Chow, 1964).

Two types of flood plain inundation maps, flood-prone area and flood hazard maps have been used. Flood-prone area maps show areas likely to be flooded by virtue of their proximity to a river, stream, bay, ocean, or other water course as determined from readily available information. Flood hazard maps are commonly used in flood plain information reports and require updating when changes have occurred in the channels, on the flood plains, and in upstream areas. These changes include structural modifications and channel or flood plain modifications in upstream areas. Development of new buildings on the flood plain, obstructions, or other land use changes can affect the stream discharges, water surface elevation, and flow velocities, thereby changing the elevation profile defining the flood plain(Chow, 1964).

2.3 Hydrological modeling (HEC-HMS)

HEC-HMS conceptually represents watershed behavior as different components of runoff processes. It has an appropriate representation of the hydrological system, and its specification depends upon the information needs of the hydrological study. For flood hydraulic modeling and flood inundation mapping, the main objective is to accurately predict catchment outflows from upstream sub catchments and flood wave propagation along the drainage network.

HEC-HMS gives flexibility to the user by providing each component with suit of models. The model HEC-HMS is used for estimation of peak discharges and runoff hydrographs for different return periods at different location of the water shed out let (Feldman, 2000).

HEC-HMS computes runoff volume by computing the volume of water that is intercepted infiltrated, stored, evaporated, or transpired and subtracting it from the precipitation. Interception, infiltration, storage, evaporation, and transpiration collectively are referred to in the HEC-HMS program and documentation as losses. HEC-HMS considers that all land and water in a watershed can be categorized as either directly-connected impervious surface, or pervious surface. Directly connected impervious surface in a watershed is that portion of the watershed for which all contributing precipitation runs off, with no infiltration, evaporation, or other volume losses. Precipitation on the pervious surfaces is subject to losses.

HEC-HMS project requires four model data components:

Basin Model:-basin model represents the physical watershed. The user develops a basin model by adding and connecting hydrologic elements. Basin model comprises different hydrologic elements of the model that include: sub-basins that used to represent a physical watershed, junctions used to combine stream flow from elements located upstream of the junction, reach that helps in conveying stream flow basin model. The basin model contains different methods that are used in computing precipitation loss, excess precipitation transformation to direct runoff, base flow estimate, and flood routing (Abhaukajee et al, 2018).

Meteorological model: - The precipitation and evaporation data necessary to simulate watershed processes are stored in meteorological model manager**.** The meteorological model manager calculates the precipitation input of the all sub-basin. This model can make use of both points and gridded precipitation and has the capability to model frozen and liquid precipitation along with evapotranspiration(Abhaukajee et al, 2018).

Control specification: - The Control Specifications is defined as time related information in the simulation, including the starting dates, ending dates and the computational time interval(Abhaukajee et al, 2018).

Paired data:-In the paired data component of hydrological models require a hydrological recorded data. The paired data defines dependent variable items of an independent variable. For different cases the function must be monotonically increasing that means it only increased not decrease order. The paired data component contains different data type:-

- storage-discharge function
- elevation storage function
- elevation area function
- elevation discharge function
- inflow diversion function
- diameter percentage function
- cross section and
- unit hydrograph curves

Paired data model are separate different types of paired data with different data type. The paired data selected has to be entered one time. Paired data are part of the project and can be shared by multiple basin models(Abhaukajee et al, 2018).

2.3.1 Transform method

Transform method allows converting excess rainfall to direct runoff. The HEC- HMS model allows modeling direct runoff with six different methods: Clark unit hydrograph, Snyder unit hydrograph, SCS unit hydrograph, user-defined unit hydrograph, the Mod Clark quasi-distributed linear transform, and conceptual kinematic wave model. The mod Clark model take grid rainfall data subtracts the losses as specified through the loss rate and convert the excess precipitation to runoff hydrograph using variation of what is known as Clark unit hydrograph. If the specify base flow, the base flow will be add to the resulting direct runoff hydrograph to produce total stream flow hydrography (Venkatesh, 2012).

The Clark unit hydrograph method represents two key processes in the transformation of excess rainfall to runoff: translation and attenuation. Translation is based on a synthetic time– area histogram and the time of concentration, *Tc*. The time-area histogram specifies the basin area contributing to flow at the outlet as a function of time. Attenuation is modeled with a linear reservoir. The reservoir represents the aggregated impacts of all basin storage, *St*. The average outflow from the reservoir during a period *t.* The Clark unit hydrograph is commonly use in watershed rainfall runoff to transform direct runoff of storm. The method first developed a hydrograph based on the time area histogram. The Clark unit hydrograph is defined by two parameters., they are time of concentration tc and storage coefficient R. time concentration is defined as the time between the end of excess rainfall and point of inflection of the falling limb of runoff hydrograph (Wang et al, 2012).

2.3.2 Base flow method

Base flow is a flow of water that comes to the river from surface and groundwater aquifers. In the modeling of short rainfall-runoff events base flow does not usually play significant role in the formation of flood hydrographs. Nevertheless, the base flow component is important for modeling recession limbs of flood hydrographs as well as for more accurate estimation of flood volumes. Base flow is generally separate constant flow from total flow. It is a ground water contribution to stream flow, in the same case base flow considered as the result of natural processes such as delayed flow through wetlands and waste water discharge(Harouna et al, 2018)

The HEC-HMS model includes three methods for modeling base flow: constant monthly, linear reservoir, and recession. The constant monthly method is a simple approach that uses a constant base flow at all simulation time steps falling within a particular month. The linear reservoir method can only be used in conjunction with the SMA loss method. The recession method uses an exponentially declining base flow developed from standard base flow separation techniques. the base flow method is consist of two separate procedures; both procedures utilize daily stream flowrecords. The first procedure is digital recursive filter which is used to separate base flow from total flow and the second procedure is to modified hydrograph recession curve method(Allen et al, 2000)

In this project the recession method was adopted for modeling base flow. The method is suitable for basins where the volume and timing of base flow is strongly influenced by precipitation events. The recession method is also often used as a technique for base flow separation and groundwater recharge estimation(Allen et al, 2000). The parameters of the recession method are:

- Initial base flow
- Recession constant (0, 1) and
- Threshold *Td*, (m^3s^{-1} or ratio-to-peak).

The initial flow is equal to the base flow at the beginning of the simulation. The recession constant describes the rate of base flow decay. It is the ratio of base flow at time *t* to the base flow at time *t*-1. The threshold is the point on the hydrograph where base flow replaces overland flow as the source of flow from the basin.

2.3.3 Loss method

Runoff model in HEC-HMS computes runoff volume computing the volume of water that is intercepted, infiltrated, stored, evaporate and subtracted from the rainfall/precipitation. Interception and surface storage were intend to represent the surface loss of water by vegetation, depression the ground surface and surface area where water not free to move over land flow. Infiltrations represent the movement of water beneath land surface(Allen et al, 2000). The runoff model considers that all land and water in a watershed categorized as directly connected impervious surface and pervious surface. The loss model parameters are containing different loss method:-

- Initial and constant rate loss method
- Deficit and constant rate method
- SCS curve number loss method
- Green and ampt loss method

Each model rainfall loss are found for all computation time interval and reduce from the model depth for that interval and the remains depth are referred to as precipitation excess(Allen et al, 2000). Depth is considered uniformity distributed over water shed area, therefore it represents volume runoff.

Initial and constant rate loss model is the maximum potential rate of rainfall loss and constant throughout an event. Initial loss added to the model to represent interception and depression storage. Interception storages are a consequence of absorbed precipitation.

2.3.4 Flood routing method

Flood routing is a technique of determining the flow hydrograph at the downstream point catchment with sound information regarding of hydrograph at its upstream. It is an approach to estimate how the magnitude and celerity of the flood wave varies than at the inflow point at It moves along the catchment(Abhaukajee et al, 2018). There are six methods included in the HEC-HMS model to compute river routing: lag, kinematic wave, modified Puls, Muskingum, and Muskingum-Cunge. Two ways of flood routing method: storage routing and channel routing

- Uses storage rout to account for inflow and outflow rate and significant water storage characteristics associated with storage and detentions.
- Channel routing when known hydrographic data area located somewhere other than the point of interest or the channel profile is changed to other the natural velocity storage features.

Storage routing method:-A flood pass through a reservoir facility, it is necessary to make an account of inflow and outflow and out flow rates and water storage characteristics by routing a flood through the storage.

I and Q the inflow into and outflow from a reservoir and S the storage in the reservoir the continuity equation in the the differential form for the reservior ifs given by

$I - Q = \frac{\Delta sx}{\Delta t}$----------------------equation 2.1

Alternatively

$I\Delta t\text{-}Q\Delta t\text{=}\Delta S$-----------------------equation 2.2

Where ΔI is the average inflow rate in a time interval t, ΔQ is an average outflows rate the same time interval Δt and ΔS change in storage of the pond at the same time interval

Reservoir storage also apply when outflow depend only upon the volume of flood storage. Use storage routing method to do the point written below:

- To determine discharge from watershed containing reservoir flood water storage basin and other flow store structure.
- To specify overflow flood magnitude and
- To evaluate load interruption due to roadway overflow and associated economic losses.

In the elevation-storage-outflow method, outflow is computed from the storage-outflow data, and then, elevation is computed from the elevation-storage data. Required parameters for this method are: Inflow, elevation m, storage and outflow(Abhaukajee et al, 2018). The present version of the HEC-HMS reservoir component assumes that the outflow is a function of the upstream water-surface elevation. In some cases, the outflow from an uncontrolled reservoir component may significantly differ from actual water release reflecting specific water management practices or operation rules. The reservoir inflow produced in the sub basins upstream of the reservoir flows into the sink component. The source component then produces outflow that is identical with the actual controlled dam release for the specific time period.

Channel routing method: - The channel routing uses mathematical relation to calculate outflow from a stream once inflow, lateral contribution and channel characteristics are known. The terms channel routing and flood routing are interchangeably (Dark unit J.Sci; 2014). Most of the stream routing application are in flood flow, flood control and flood forecasting analysis. The length of upstream hydrograph is known and downstream channel section where determined is called channel reach.

The lag routing method is useful instance where known hydrograph data at a point other than interest and also where the channel profile is changed in such ways as a altering the natural channel storage characteristics. The Lag method is an especial case of other routing methods.

2.4 Flood forecasting

Flood forecasting is an expanding area application of hydrologic techniques. The goal is to obtain the real time rainfall and flow data through a microwave, radio or satellite communication network, insert the data into rainfall runoff and stream flow routing program and forecasting flood flow rates and water level for period of from few time to days ahead depending on the size of the watershed. Flood forecasting are used to provide warning for people to evacuate area threatened by flood and to help water management personnel operate flood control structure such as gate, spill way on reservoir(Chow, 1964). Flood forecasting has been help in the decisions making system for flood protection. The decisions making is develop in accordance with confidence level and lead time of flood fore casting(Brilly et al, 2005). Flood volume estimation is a central to a quantitative study. In fact, this is the most important variable for the design of water works for flood mitigation techniques. The model in combination with other methodologies is applied to investigate the variation of the hydrograph at different return period. In rainfall-runoff model, the hydrological processes are interpreted by using a conceptual model, which calculates the runoff and subsurface runoff that contribute to the stream flow(Mauro and Manfreda, 2008).

2.5 Hydraulic modeling (HEC-RAS)

HEC-RAS is a hydraulic model developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers. The model is used to determination of water surface profiles for different flow situations .The peak discharge generated by the HEC-HMS model used to determine the flow profiles and flood plain profiles for the selected flood different return periods. HEC-RAS is planned for steady flow water surface profile computations and unsteady flow simulation. The system is capable of modeling subcritical, supercritical, and mixed-flow regimes for streams consisting of a full network of channels, a dendrite system, or a single river reach. HEC-RAS is designed to compute one-dimensional calculations for a full network of natural and constructed channels. The HEC-RAS system contains four one-dimensional river analysis components for: steady flow water surface profile computations, unsteady flow simulation, boundary sediment transport computations and water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design features that can be raised once the basic water surface profiles are calculated.

The floodplain visualization is carried out using one-dimensional numerical model HEC-RAS. HEC-GeoRAS is an Arc GIS extension that used as the interface between HEC-RAS and GIS for pre- processing and post-processing of the data in GIS(Keno Abu, 2020). The availability of floodplain survey records for the new and the old alignment of the river, the pre and post processing using the HEC-GeoRAS is not complicated.

The geometric data of the flood plain and River is obtained from the digital elevation model (DEM) for the points where the plain display less number of cross-sections. Water surface profiles along the river reach under study for floods of various return periods were computed with critical, sub critical and mixed flow simulation. These profiles were exported to GIS and water surface Triangular Irregular Network (TIN) generated. An intersection of the terrain TIN and water surface TIN results in flood map.

Hydrologic Engineering Center’s River Analysis System (HEC-RAS) is the software predominately used in the field of hydraulic analysis for floodplain delineation. HEC-RAS, combined with Hydrologic Engineering Center’s Geographical River Analysis

System (HEC-GeoRAS), offers engineers a powerful tool in the process of hydraulic modeling and analysis.

For each HEC-RAS project, there are three required components: the Geometry data, Flow data, and Plan data. The Geometry data for instance consists of a description of the size and shape. HEC-RAS uses a number of input parameters for hydraulic analysis of the stream channel geometry and water flow. These parameters are used to establish a series of cross-sections along the stream. In each cross-section, the locations of the stream banks are identified and used to divide into segments of left floodway (overbank), main channel and right floodway. HEC-RAS subdivides the cross sections in this manner, because of differences in hydraulic parameters. Thus, friction forces between the water and channel bed have a greater influence in flow resistance in the floodway leading to lower values of the Manning coefficient.

As a result, the flow velocity and conveyance are substantially higher in the main channel than in the floodway showing higher values of manning's resistance coefficient. At each cross-section, HEC-RAS uses several input parameters to describe shape, elevation, and relative location along the stream:-

- River station (cross-section) number
- Left and right bank

Reach lengths between the left floodway, stream centerline, and right floodway of adjacent cross-sections (The three reach lengths represent the average flow path through each segment of the cross-section pair. As such, the three reach lengths between adjacent cross-sections may differ in magnitude due to bends in the stream.)

- Manning's roughness coefficients (may vary horizontally or vertically)
- Channel contraction and expansion coefficients
- Geometric description of any hydraulic structures, such as bridges, culverts, and weirs Data requirements for the HEC-RAS model

2.6 HEC-RAS Parameter

The main parameters of HEC-RAS hydraulic model are geometric data and flow data. The geometric data has been developed by drafting the river schematically with the direction of flow.

For hydraulic analysis of the stream channel geometry and water flow, HEC-RAS uses several input parameters. These parameters are used to establish a series of cross-sections along the stream. In each cross-section, the locations of the stream banks are identified and used to divide into segments of the left floodway (overbank), main channel, and right floodway. HEC-RAS subdivides the cross-sections in this manner, because of differences in hydraulic parameters. To illustrate, the wetted perimeters in the floodway is much higher than in the main channel. Therefore, the frictional forces between the water and channel bed have a greater influence on flow resistances in the floodway, leading to a lower value of the Manning coefficients. As a result, the flow velocity and conveyance are substantially higher in the main channel than in the floodway showing higher values of manning's resistance coefficient(Zelalem, 2011). At each cross-section HEC-RAS uses many input parameter to describe a shape, elevation, and relative location along the stream:

- River stations (cross-sections) numbers
- Lateral and elevation coordinate for each terrain points
- Left and right bank stations locations
- Reach length between the left overbank, stream centerline, and right overbank of adjacent cross-sections.
- Manning's roughness coefficient.
- Channel contractions and expansions coefficients
- Geometric descriptions of any hydraulic structures, like a bridge, culvert, and weir.

The data needed for HEC-RAS models are:

Geometry Data**:** the development of river hydraulics model begins with terrain model and the development of geometric data element that represent how discharge move through the river. For one dimensional river model the geometric data parameters are river network lines, overbank flow paths, bank line, x-section, bridge and others. For two dimensional river model data element include the 2Dflow area with cell faces properly aligned to high ground such as banks and hydraulics structure pass water over through the ground(Gary W. Brunner, 2016). X-section data represent the geometric boundary of the river. X-sections are located at relatively short intervals along the stream to describe the flow carrying capacity of the stream and its adjacent floodplain. It is advisable to take a cross-section at a constant interval. Cross-sections are essential at sample location throughout the stream and at locations where alterations occur in discharges, slope, shape, roughness at the location where levee begins and end; and at hydraulic structures (bridge, culvert, and weirs).

***Flow Data*:** The flow data must be entered for each reach within the system. Also, flow can be changed at any location within the river system. Steady Flow Data analysis consists of the number of profiles to be computed the flow data and the river system boundary conditions. Flow values can be imported directly from the HEC-HMS model run for different design return period storms or entered manually from the model run result. The flow data for the Awash River at wonji gaging station was taken from the one that is computed by the HEC-HMS. Due different reason the peak discharge at upstream of the outlets is greater than at outlet gaging station because water reduced in koka reservoir and losses for irrigation purpose at the upstream of outlet gaging station.

Plan Data: - The first step in performing a simulation is to put together a plan. The Plan defines which geometry and flow data are to be used as well as provide a description and short identify for the run. If the geometry data and flow data do not exist, then this action is performed after their creation. Also included in the plan information are the selected flow regime and the simulation options(Zelalem, 2011).

***Boundary conditions*: -** boundary condition are a main part of hydraulic model as they allow hydraulic modeling like HEC-RAS to begin performing calculation.in HEC-RAS boundary condition in the steady flow data and unsteady flow data. For steady flow analysis, boundary conditions are required to establish a water surface elevation at the ends of all river reach. HEC-RAS can begin to perform hydraulic calculation. In subcritical regimes, the boundary condition is only needed at the downstream end of the river systems whereas for supercritical flow calculation boundary conditions are only needed at the upstream ends of the river and lastly for the mixed flow calculation boundary condition must be entered both at upstream and the downstream end of the river system. Four categories of boundary conditions are known water surface elevation, normal depth, critical depth, and rating curve.

Normal depth of boundary condition is the most widely used boundary condition for both steady and unsteady flow analysis. The users are required to enter slope. The energy slope is measured the slope of downstream model reach. Critical depth of boundary condition is not required to enter any data. However critical depth does not occur often in stream or channel. Using critical depth is only appropriate if there is a significant elevation change or drop structure. Known water surface elevation is typically based upon observed data and consistent with other existing model. The model is referenced to the corrected vertical datum

Rating curve boundary condition is a relation between discharge and stage for a given point of stream. Typically used where channel or stream flows into a lake.

2.7 Calibration and validation of model

Calibration and validation of model is important to analyses the difference between the values of model output with compare to the observed data under the same time. It is likely to find simulated value that deviate from observed data. So that it is essential to bring the difference to an acceptable reasonable. Model calibration is a procedure of adjusting simulated value with observed data for selected period and simulation entered to the model. Its accuracy is usually tested by Nash Sutcliffe model efficiency parameter and RMSE. The Nash criteria, varying within the interval [–1, +1] (Mathevet *et al.*, 2006). Sensitive analysis is the influence of each parameter by changing the value of one or more of them.

2.8 Flood inundation mapping

Flood inundation map is performing by using water surface elevation on the cross section cutline feature class and limit to bounded polygon feature. These two criteria should beaded or created first to perform the flood inundation map. The flood plain delineations are requiring the digital terrain model (Cameron T. Ackerman, 2011)

Flood inundation maps are commonly used in floodplain information reports and require updating when changes have occurred in the channels, on the floodplains, and in upstream areas. These changes include structural modifications and channel or floodplain modifications in upstream areas. Development of new buildings on the floodplain, obstructions, or other land-use changes can affect the stream discharges, water surface elevation, and flow velocities, thereby changing the elevation profile defining the floodplain. The vulnerability maps for the flooded areas were prepared by intersecting the land use map of the floodplains with the flooded area polygon for each of the flood event being modeled. Flood inundation time, flow depth and velocity map can be derived and overlaid to obtained flood risk (inundation) map(İcaga,et al, 2016)

This depicts the vulnerability aspect of the flood risk in the particular area in terms of the presence or the absence of flooding of a particular return period as a binary model.

2.9 Floodplain delineation

The flood delineations is performing using the water surface TIN and the terrain model to computes the floodplain boundary and the inundation depth. The plain delineation need to care during delineation because the inundated are may be present and must be remove in the GIS or prevented from occur by using levee in HEC-RAS.

Flood plain delineation method rasterize the water surface TIN use the rasterize cell size. In flood plain delineation the flood plain is computed/ calculated where water surface grid is higher than the terrain grid. The bound polygon also used to limit the flood plain only to the area modeled in HEC-RAS. The flood inundation depths are calculated by comparing the water surface and terrain. Flood risk analysis using HEC-RAS method has been used together with the HEC-GeoRAS extension in ArrcGISthe result are obtained(Iosub *et al.*, 2015)

2.10 Flood hazard level map

Flood hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, loss of property, injury or other health impacts, property damage loss of livelihoods and service, social and economic disruption or environmental damage(Chris Adebola et al, 2018). The main flood generating factors are used for flood vulnerability factors assessment are slope, average rainfall, drainage density, elevation, land use land cover and soil type. The digital elevation models are converted into slope and elevation raster layers using the Arc-GIS conversion tool. The lover slope values are the flatter terrain and in the same way higher slope values are the steeper the terrain. Based on their susceptibility to flood slope and elevation are classified into five classes. In the classification level, an area that lowest elevation and slopes are very highly affected by flood and then ranked to class five, high ranked class 4, moderate class ranked as 3, low ranked as class 2 and very low class is ranked as 1 which has very high elevation slope(Getahun and Gebre, 2015).

One dimensional steady flow model HEC-RAS was used for the flood hazard analysis of the floodplain. ArcGIS and HEC-GeoRAS are used to for the preparation of flood hazard map(Banstola, 2019)

2.11 Flood risk analysis

The flood risk analysis includes the combination of the result of both the vulnerability analysis and the hazard analysis. This is defined by the relation between the land use vulnerability classes and the flood depth hazard classes in a particular area. Flood risk analysis has a top priority for authority and stakeholder in many countries with aim of reducing flooding risk, considering the population needs and bench mark of improving risk awareness(Escuder *et al.*, 2014)

Integration of spatial devices of GIS for flood inundation map has made it possible to delineate water level, in particular, water spatial, and superimpose with land use and land cover data to generate areas that will be inundated. Flood risk is the combination of flood hazards and vulnerability at particular location that needs systematic assessment, collection and analysis of variables. GIS and its extension HEC-GeoRAS have emerged as an important devise in flood mapping and analysis because it enables the preparation of maps of inundated area(Nigusse et al, 2019).

The flood vulnerability depends on the land use characteristics of the area under influence of flood and their potential damage. The combined result of both the vulnerability analysis and the hazard analysis gives the flood risk analysis. It relates the land use land cover vulnerability classes and the flood depth hazard classes in a particular area (Manandhar, 2014).

2.12 Flood and previous study at upper Awash River

The flood history at the study area are known / experienced by the people living. The upstream of the Awash River basin has been flooded for short duration after intense or prolonged rainfall events, but the downstream area has been flooded for weeks or months every year during wet season. Timing and size of the flood cause influence the production of the crops cultivated in flood plain. Intense rainfall in the upper Awash River basin occurs at the end of rain season, the flood can damage the crops(Getahun and Gebre, 2015).

Flood flashing also affect the community below koka reservoir. The people identify flooding coming from Awash River, the surrounding areas and combination of both. Agriculture is the major source of the work for the study area communities and they depend on it for income and for food. The people mostly farm along the Awash River and use irrigation pump for with draw water from Awash River to the irrigation land. There are types crop growing at the study area. Some of those are; tomato, onion, maize, cabbage, teff, wheat, barley and etc. all peoples whose living in the study area is affected by flooding. During the rainy season they farming land and grow crop was loses by flood plain because the area is vulnerable to the flood. The highly ranges of flow of the main river and its tributary between the dry and rain season of rainfalls, overflows in the latter cannot used for irrigations and in large measures must be wasted and lost, while in contrast in the dry season there is a shortage of water. Therefore, water control during rainfall season has two main advantages are flood reduce during rainfall season and used during dry season but this method were not applied(FAO, 1965)

In flood frequency analysis the main objective is to determine the magnitude of flood corresponding to any specified recurrent interval of years. The estimation of flood magnitude using flood frequency analysis is complicated due to lack of a physical basis(Willems P et al., 2002)

Flood inundation mapping and mitigation measures (case study of upper Awash River Awash balo flood plain):-In his study developed hydrological modeling (HEC-HMS) for peak flood forecasting and hydraulic model for water surface profile. Hydrological model was calibrated and validated using daily and monthly time series at awash balo gauged station and hydraulic model calibrated by using satellite image (Yonata Belina, 2020). The flood inundation maps were developed for different return period but the total area inundated was not correctly estimated. Flood mitigation were proposed using three criteria like flood risk, environmental impact and balance of the two criteria (Yonata Belina, 2020)

Flood risk Analysis (case study of upper Awash River Awash balo flood plain);- the future peak flood forecasting were estimated by using flood frequency analysis(Dawit, 2015). The flood map done through HEC-GeoRAS and HEC-RAS software's and comparing the amount of crop loss yield produced previously from hectare of land and the expected crop yield from inundated area the flood damage could be estimated (Dawit, 2015). In his study calibration and validation of hydrological and hydraulic model were didn't worked in this case the output of model might be inaccuracy.

Flood damage analysis using HEC-FDA (case study at upper awash river Sebeta Awas):- flood frequencies were used in hydrology peak flood forecasting by selected appropriate probability distribution based on good fit. The major software used in his thesis work was GIS, HEC-RAS, and HEC-FDA. HEC-FDA software was proposed for damage estimation and flood evaluation and HEC-RAS for water surface profile. Without flood protection structure flood damage on cultivated land and resettlement is increase. Canal was selected for flood protection in terms of economical (Webeshet Hailu, 2019). The way of peak flood estimation was didn't consider physical characteristic of the basin (parameter) and calibration and validation didn't work that might lead inaccuracy of output.

Hydrological data processing and management system (case study of upper awash sub-basin flow data processing for koka reservoir management):- focused on determination of hydrological river flows using data processing technique. The flows were determined using both manual and HYDATA software. Rating curve was developed for all gauging station. The data were collected from using gauge books, flow measurement, automatic recorders, radar sensor and telemetry(Mikiyas Gurara, et al, 2020). The way of flow determination does not consider physical characteristics of the terrain.

Flood hazard assessment and mapping of flood inundation area of the Awash River basin in Ethiopia using GIS and HEC-GeoRAS/HEC-RAS Model: - in his study flood frequencies were used in hydrology peak flood forecasting by selected appropriate probability distribution based on good fit. Classify the hazard level into very high, high, moderate, low and very flood hazard. Inundated area in the upper middle awash river basin are low compared to lower part of the basin(Getahun and Gebre, 2015). The way of peak flood estimation was didn't consider physical characteristic of the basin (parameter) and calibration and validation of didn't work that might lead inaccuracy of result.

2.13 Reservoir at upstream of the study area

The net available capacity of koka reservoir is 1660hm^3, height of the dam 42m. The main purpose is the power generation. The maximum rate of flow through turbines 3.6hm^3/day (41m^3/s) and the normal annual outflows are around 1200hm3. The los by evaporations are around 315hm^3/year(FAO, 1965). The simply released water from the affect the communities living down of reservoir.

2.14 Flood Mitigation Measure

Mitigation is continued action taken to reduce the risk of flood on property or humans. It is refers a method or progress working for reduce/ avoid the impact of flooding on the communities living the area. The mitigation activities are working after flood, during a flooding, and before flooding. Flood mitigation measures can be classified into two(Subramanya, 2009). Those are:

1. Structural measure: is a method to control or reduce the flood impacts to the communities by constructing engineering structures. This used to control flood by using engineering structure likes:-

- Storage and detentions reservoir (store the income flood into the reservoir and reduce the flood peak by provide temporary storage by restricting the outlet flow rate)
- Levees, dykes or flood embankment (earthen bank constructing parallel to the river courses and the oldest and most common used)

- Flood ways(natural channels flood in which divert during peak flood)
- Channels improvements (increase flood way by widening deepening channel) and etc.
- Land management (developing vegetation and soil covers with land treatment like: check dams, contours bund, zing terrace and etc.)

2. Nonstructural measure: This is method of flood mitigation which is different from construction of engineering structures but its follow the method of communities living with the flood. Nonstructural mitigation measures are like:-

- Floodplain zoning(when river discharges high expected that the river overbanks and flow into the plain)
- Relocate (move the communities will affected with their assets to the nearest location /area)
- Flood forecast and early warning(warning to the communities that affected by flood for appropriate measure)
- flood insurances(the helping mechanism of communities) (subramanya, k)

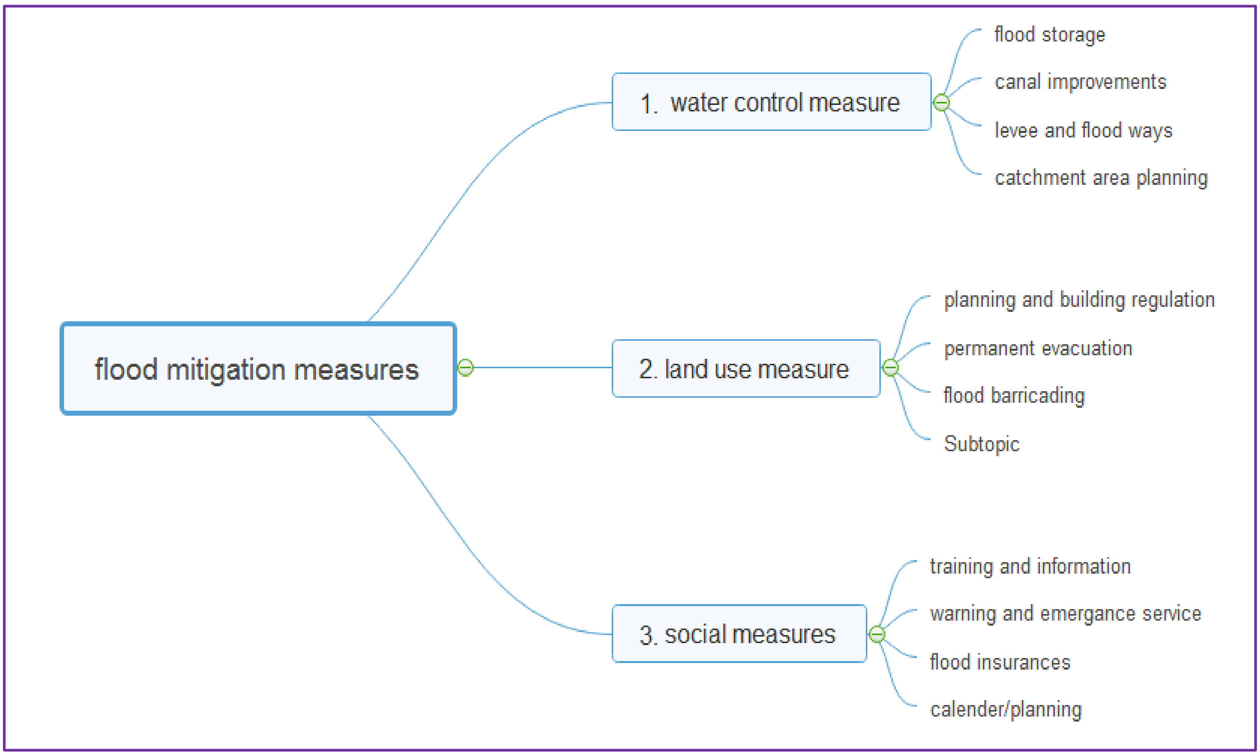


Figure 2-1: Flood mitigation measure method

Flood control measure:-flood protection in this case refers to the building levee, dam which is structural flood control measure. Structural measure build in the flood plain, can counteract flooding of the flood plains in several ways. For example new catchment dams can reduce flood peak, levee channels the flow into certain predetermined entry ways and flood ways help to channel excessive flow away. But, building and maintenance costs of this type of measure is high(Subramanya, 2009).

***Land use measure*:-**Land use planning in flood area has the aim of reducing expected flood hazard on the one hand and reducing the risk of the development in the flood area on the other hand. The different land use options within floodplains would be analyzed. Land use type is dividing into different zones according to river characteristics usually facilitates the analysis of land use option.

- Land use types are more susceptible to flood than other and the following options can be exercised; The most vulnerable land use land cover activities shall be discouraged in a flood area

- Land use land cover can be shifted to low vulnerable area, for instance where river has characteristically less flood risk.

2.15 Upper-Awash irrigation development and agricultural activities

The irrigation development activities are a rapid modern agricultural over past few year led to conversion remove forest for the purpose of irrigation development that may cause the problem of soil erosion easily by flooding. The basin is one of the river basins with active development by irrigation method in our country. The agricultural sector are given attention to the irrigation development and supply the inputs of agricultural activities, therefore the irrigation system increase the productivity and expand significantly the irrigation system. The future development trend in Awash sub basin will continue to be dominated by irrigation development. The basin is characteristic by large, medium and small agricultural activities, such activities are highly dependent on of agricultural inputs, fertilizer to be applied on the farmlands and pesticide that are applied to on crops are finally washed to the rivers and lake that is cause organic and inorganic material to the water system. The lands of upper awash basins large tracks good quality are cultivated with rain-grown and some are with irrigation pumps grown crops. At upper awash basin some areas are under irrigation, notably the plantation of 6000ha at wenji growing sugarcane (FAO, 1965).

Agronomical condition at the upper Awash basins are suitable for growing a high range of crops like;-vegetables(onions, tomatoes, potato, cabbages and etc.) , sugar cane, wheat, teff and etc. their selection was based on economic factors than agronomic conditions.

CHAPTER 3 MATERIALS AND METHOD

3.1 Description of study area

Awash River basin are the most important basin in Ethiopia and the fourth largest catchment in terms of area, following wabis-hebele, abay, and Ganale daw river basin. The basin is border by Dnakil, abbay, omo Gibe, Rift valley and wabi-shabeleand basin and republic of Djibouti. The total catchment of the basin is about114123 square kilometer and serves as home to 10.5 million habitants. The basin has significant water and land resource potential occupied wide range of development activities. The river basin contains rivers and large tributaries, natural lakes, swamps and spring, reservoir and dam expended for different uses: irrigation, hydropower, domestic, livestock, industry, tourism and recreation under wider level of exploitation. The river rises on the high plateau near ginchi town west of Addis Ababa Ethiopia and flow along a rift valley into afar and terminates in salty lake abbe on the border into Djibouti. The length of main course is some 1280km. depend on physical and socioeconomic factor divided into upland, middle and lower valley. The study area is upper Awash River basin below koka dam which is located in oromia region adama woreda, near to the Awash River.

The topography of study area is gentle and flat topography. The flood prone area around 120Km west of Addis Ababa, Which is located 8.45 Latitude and 39.23 Longitude. The elevation of the basin range is from 1540 masl and 1530 masl around below koka dam and melkasa respectively. The total length of river from wonji to melkessa is around 19km. The vulnerable flood plain of the study areas are Wakemawan, Awash malkessa and melka adama kebele.

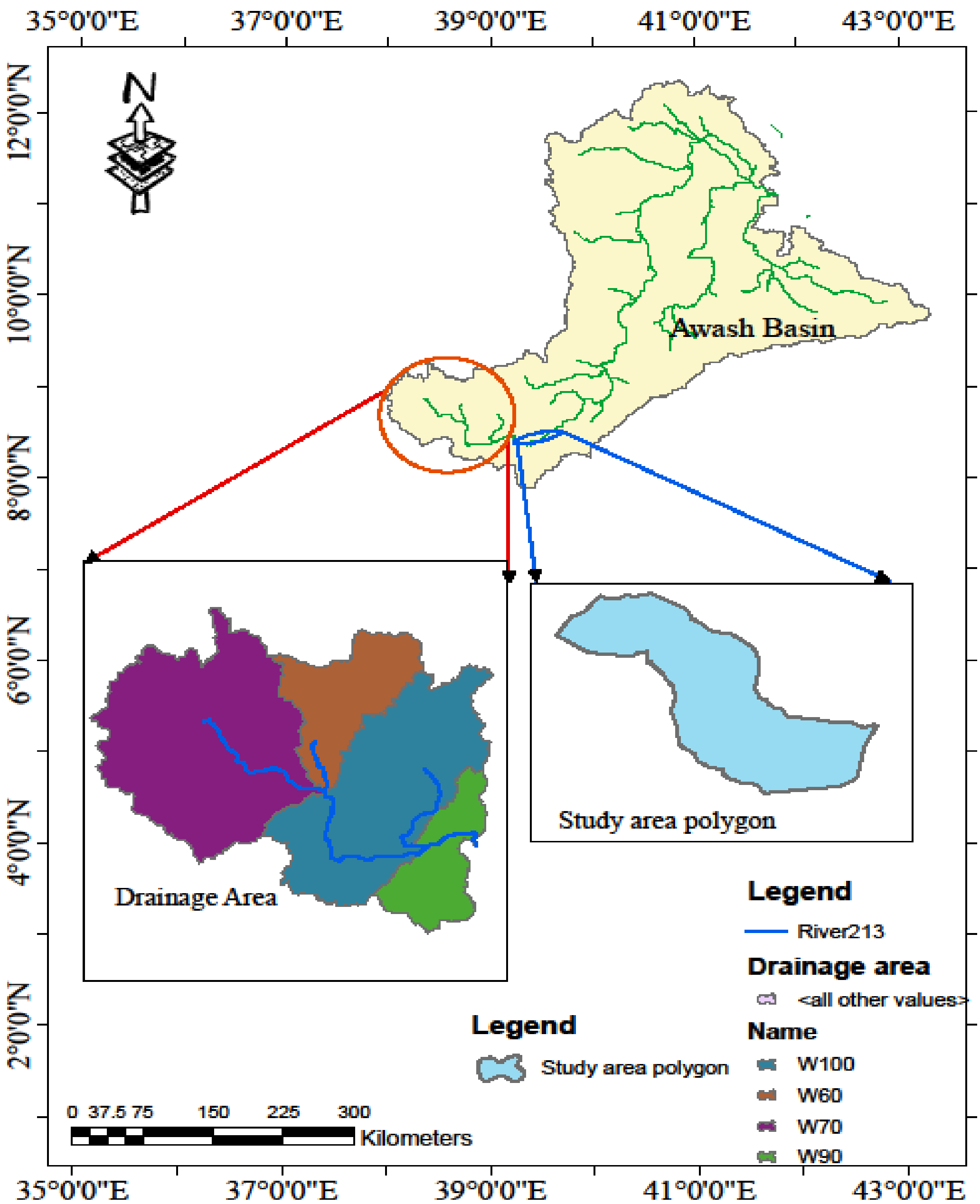


Figure 3-1: Location of study Area

3.2 Data collection and availability

Data collection is the first step in the thesis work ,those data are contain topographic map, stream flow , rainfall and site survey data and channel characteristics to roughness estimates at a points along the channel. Survey data directly gathered from the study site, however topographic, stream flow data and daily rainfall data are collected from different sources.

3.2.1 Land use Land cover

The land use land cover map give the spatial extent and classification of various land use land cover of the study area. The land use land cover data combined with soil data generates the hydrologic characteristics of the study area. Land use map for the study area was obtained from ministry Agriculture as shown in figure 3.3. The land conditions in the upper awash are agricultural land, grass land, forest and rural and town settlement.

Land use land cover is essential influences on runoff. The basin has high cropland cover. Downstream of koka reservoir most of the portion of land is used for irrigation agriculture purpose. Land use in the study area has been classified into three categories; cropland with grassland, cropland with shrub land, and inland water. The study area is dominated by crop land.

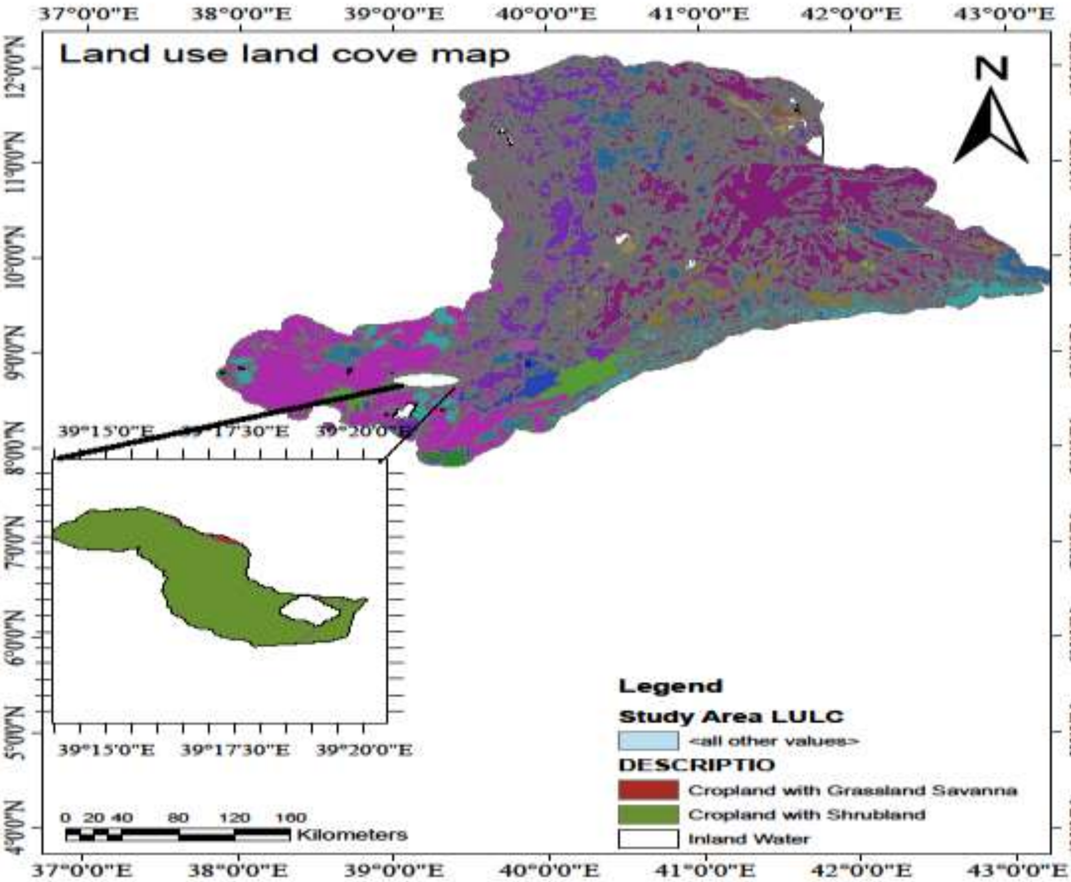


Figure 3-2: Land use Land cover map of the project area.

3.2.2 Soil characteristics

Different soil characteristics of the study area those soils are Eutric fluvisols, Eutric regosols, and molic. Soil types are plays a great role, especially in flood flow over soil characteristics. The soil data describes the surface and subsurface of the catchment area. In this case soil data collected from ministry of water, irrigation and energy. This type of soil affects the water characteristics.

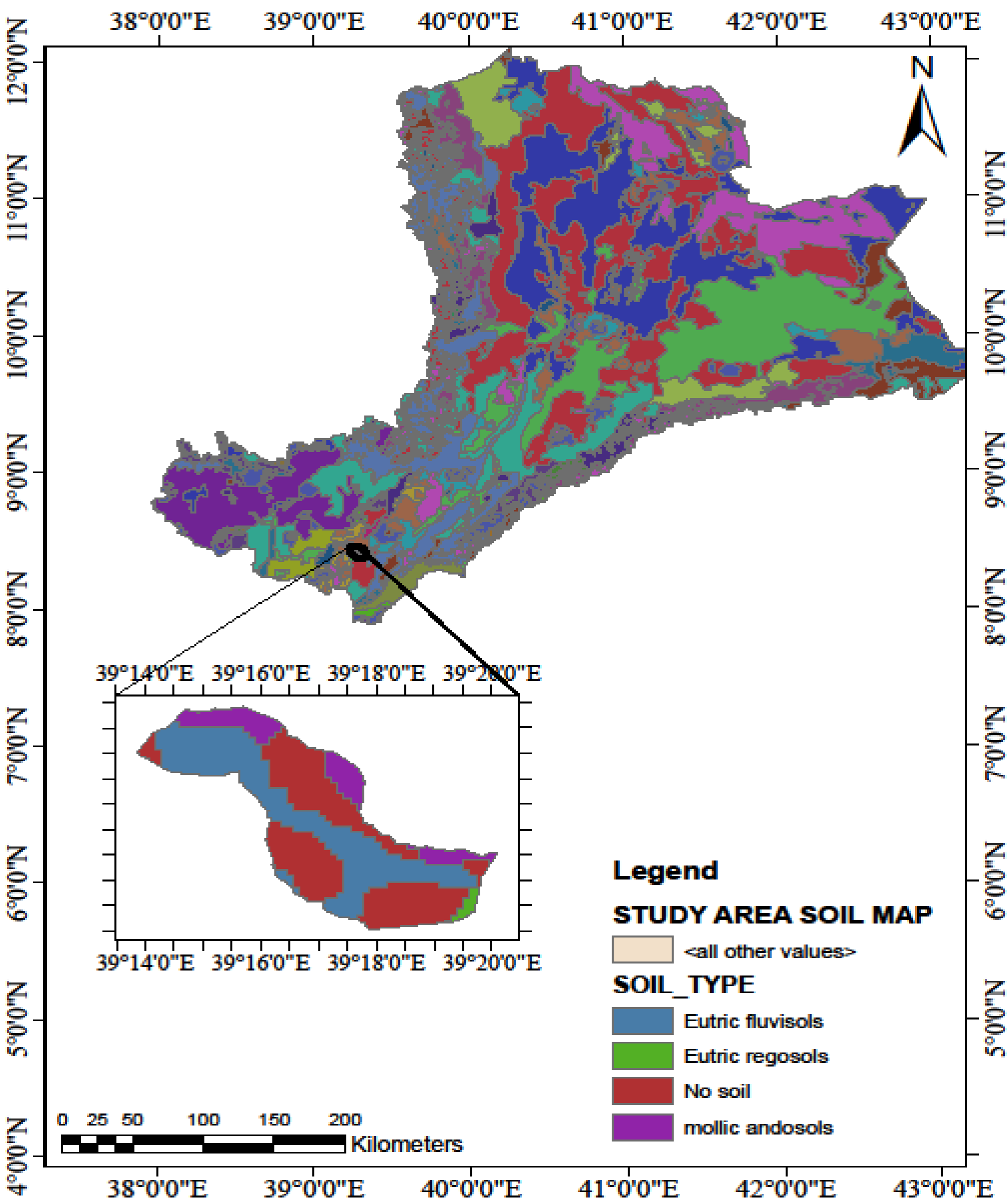


Figure 3-3: Soil type of study area

3.2.3 Metrological data

The most essential data for this thesis is meteorological data which is including daily continuous records of rainfall. Four rainfall gauging station situated within the basin were used. Those daily gauged rainfall stations were obtained from Ethiopia national meteorological agency (NMA). The rainfall data used in a basin was for the period of

1998 to 2013 G.C depended on the available stream flow records. Generally, the collected data have some missing that should be appropriately adjusted for inconsistency, corrected for errors, and filled for missing using different techniques.

Generally, the gauged rainfall stations used in the catchments were; Alem Tena, Tulubolo, Chafedonsa and Akaki Baseka. In figure 3.7 and graph 3.6 below are shows the location of the precipitation represent the pattern of rainfall of the study area respectively.

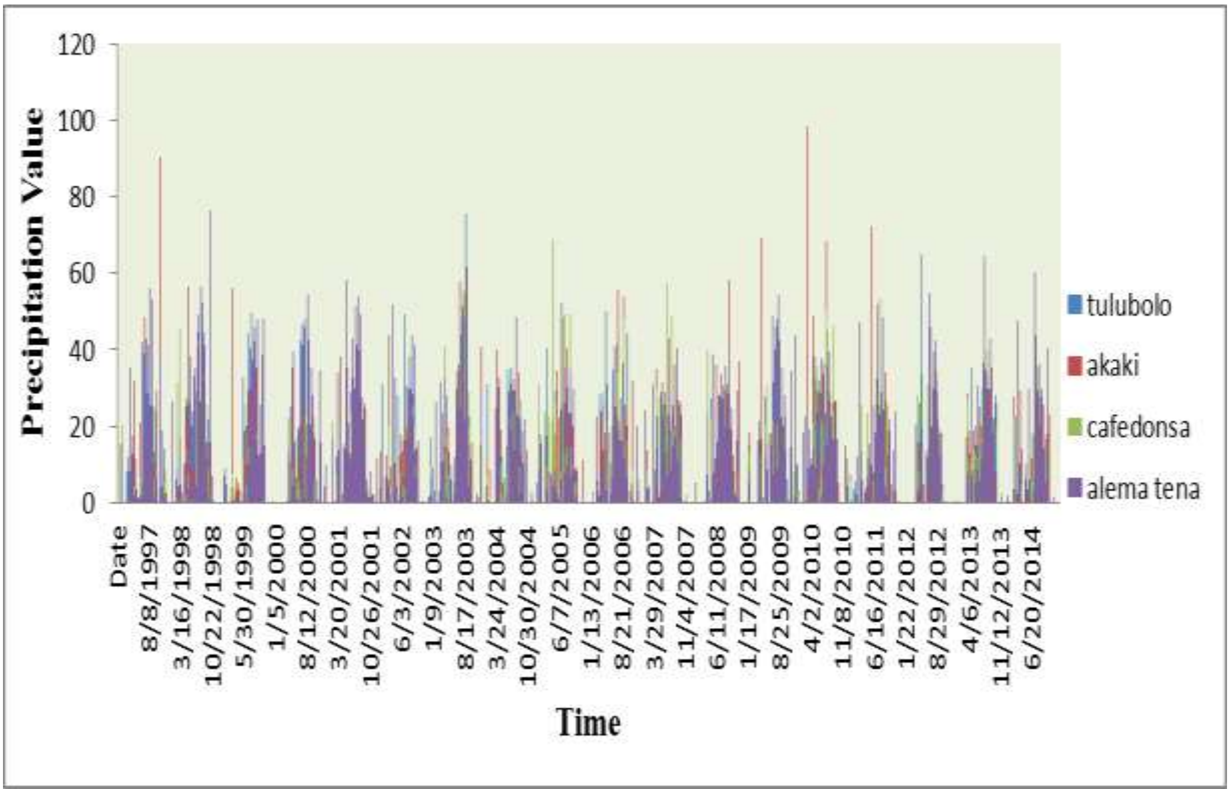


Figure 3-4: Daily rainfall pattern of all meteorological

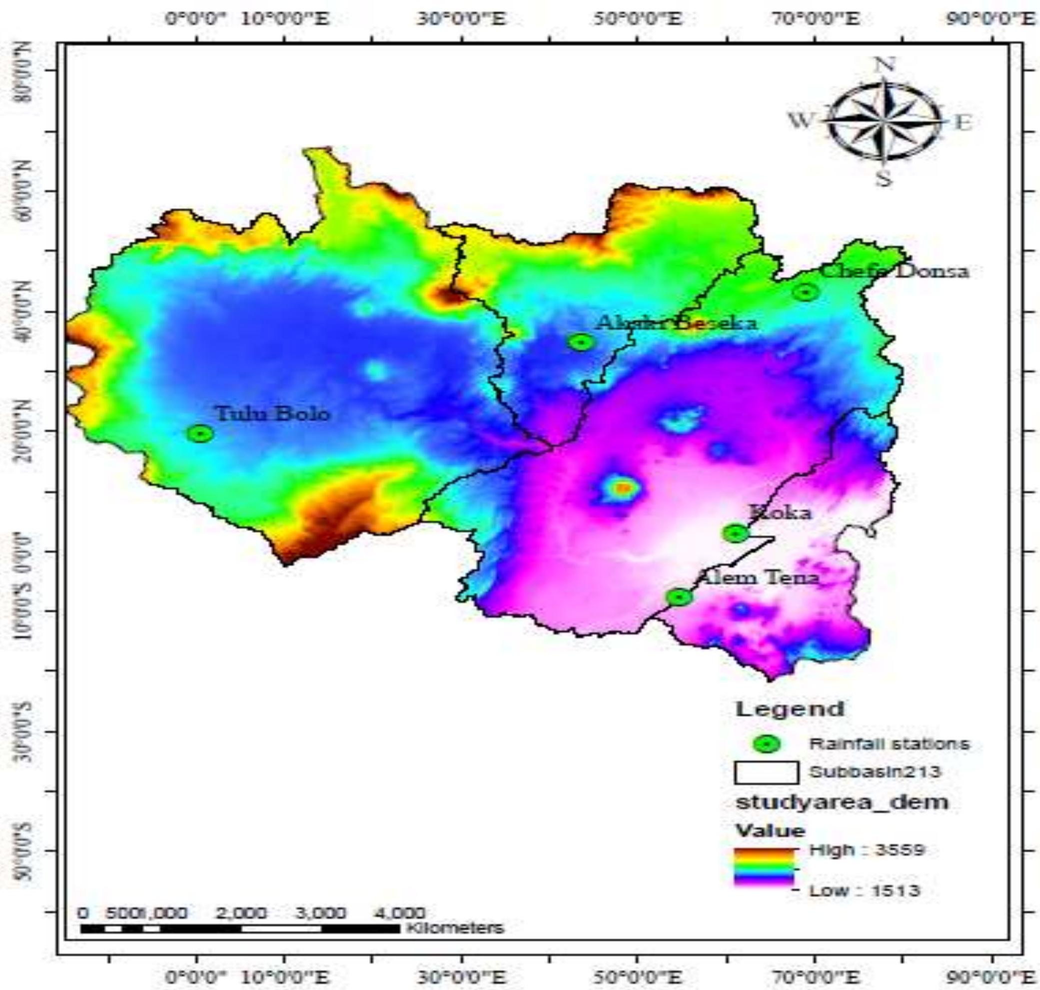


Figure 3-5: Rainfall Stations used for the study area

3.2.4 Flow data

The hydrological data for the Awash River basins are recorded for each gauging stations by ministry of water, irrigation, and energy hydrology department but some gauging stations are closed and some are not continuously recorded. The historical data from 1998-2013 G.C was collected. For this study daily discharge data of Awash River at wonji gauged station was used for calibration and validation of hydrological model. The gauged station is located at 933970 northing and 525685 easting.

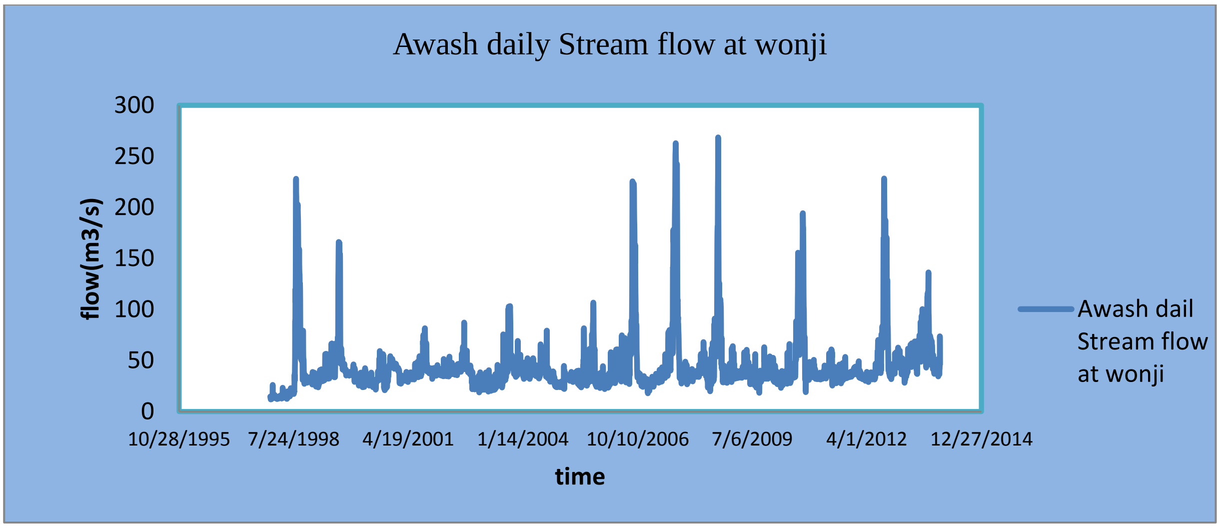


Figure 3-6: Daily stream flow pattern at wonji gauging station.

3.2.5 Digital elevation model

DEM (Digital elevation model) represented the topographic feature and required for hydrological model and hydraulic model of the study area. Topographic map for the study area was created from digital elevation data (DEM) 30x30m used in HEC-HMS model processing and 12.5X12.5m for river geometry. Digital elevation model data are collected from MoWIE and download from internet (Alaska University). The map is used to identify the land feature and characteristics of the catchment. The digitized contour map of the catchment is the most significant input to generate different basin out puts to regionalize the sub-basin and river geometry.

3.2.6 Elevation storage discharge data

Elevation storage discharge data of Koka reservoir level was identified and evaluated by halcow report. Surface water inflow into the Koka reservoirs are flow at malka hombolle station on Awash River and station on mojo stream. Outflow from koka reservoir was taken from flow recorded at below koka gauge station; it is down stream of koka dam which was gauged at upstream of wonji gauging station.

Table 3-1: Elevation **vs.** storage data

s. no	Elevation	Storage(1000m3)
1	1580.7	100000
2	1586.5	550000
3	1587	625000
4	1587.5	700000
5	1588	775000
6	1588.5	850000
7	1589.2	950000
8	1590.7	1170000
9	1591.7	1187000
10	1593.7	1615000

Data that are collected and to be analyze can be set under three categories according to their source and availability; Hydrological, Meteorological and Topographic data.

3.2.7 Summary of data

The data used in this thesis work for different software application were collected from different sources. Input data is an important part of rainfall runoff modeling which can be categorized into hydrological and physiographic data bases. The data used for HEC-HMS model are DEM (digital elevation model), stream flow data, precipitation data, and storage elevation data. Those databases were used to determine basin characteristic and hydrologic parameters. The basic information on physiographic characteristic are include digital elevation model, slope, soil data and land use land cover.

Table 3-2: Detail of data used and their sources

Data type	Data Name	Source	Purposes
Hydrological data	Gauged flow	MoWIE	For HEC-HMS calibration and validation
Meteorological data	Rainfall	NMA	Hydrological modeling

Topographic data	Digital Elevation Model (30x30m DEM)	MoWIE	Delineation(HEC-HMS)
	Digital Elevation Model (12.5x12.5m DEM)	Alaska University	Flood plain and River geometry(HE- RAS)
Elevation storage data	Elevation vs. storage	Hal cow report on Awash river	Reservoir routing
River Geometry	X-section data	field survey	For editing river cross section
River center line	Google Earth	online web	river line
Agricultural data	Crop data	Adama weroda ANR	To quantify flood risk
Satellite data	LandSat-7 Geotiff	USGS	for HEC-RAS Calibration and Validation

3.3 Software used

Table 3-3: Details of all software used

Name	Purpose
ArcGIS 10.3	✓ Prepare water surface TIN
HEC-RAS 5.0	✓ Steady Flow Simulation. ✓ To generate water Surface Profile ✓ To edit and generate cross section
HEC-Geo- HMS 9.2	✓ Watershed delineation. ✓ Prepare and export data for HEC-HMS model. ✓ Basin Development etc.
HEC-GeoRAS	✓ Prepare and export data for HEC-RAS. ✓ Water surface delineation ✓ Flood plain delineation
HEC-HMS 3.5	✓ For Hydrological Model. ✓ To Calibrate and validate simulated of model ✓ To peak flood determination

3.4 Thesis frame work

The research conceptual frame work step and method is identifying the required data and step to be analyses the objective of the study. The general flow chart shown below is including hydrologic model and hydraulic model as shown below chart.

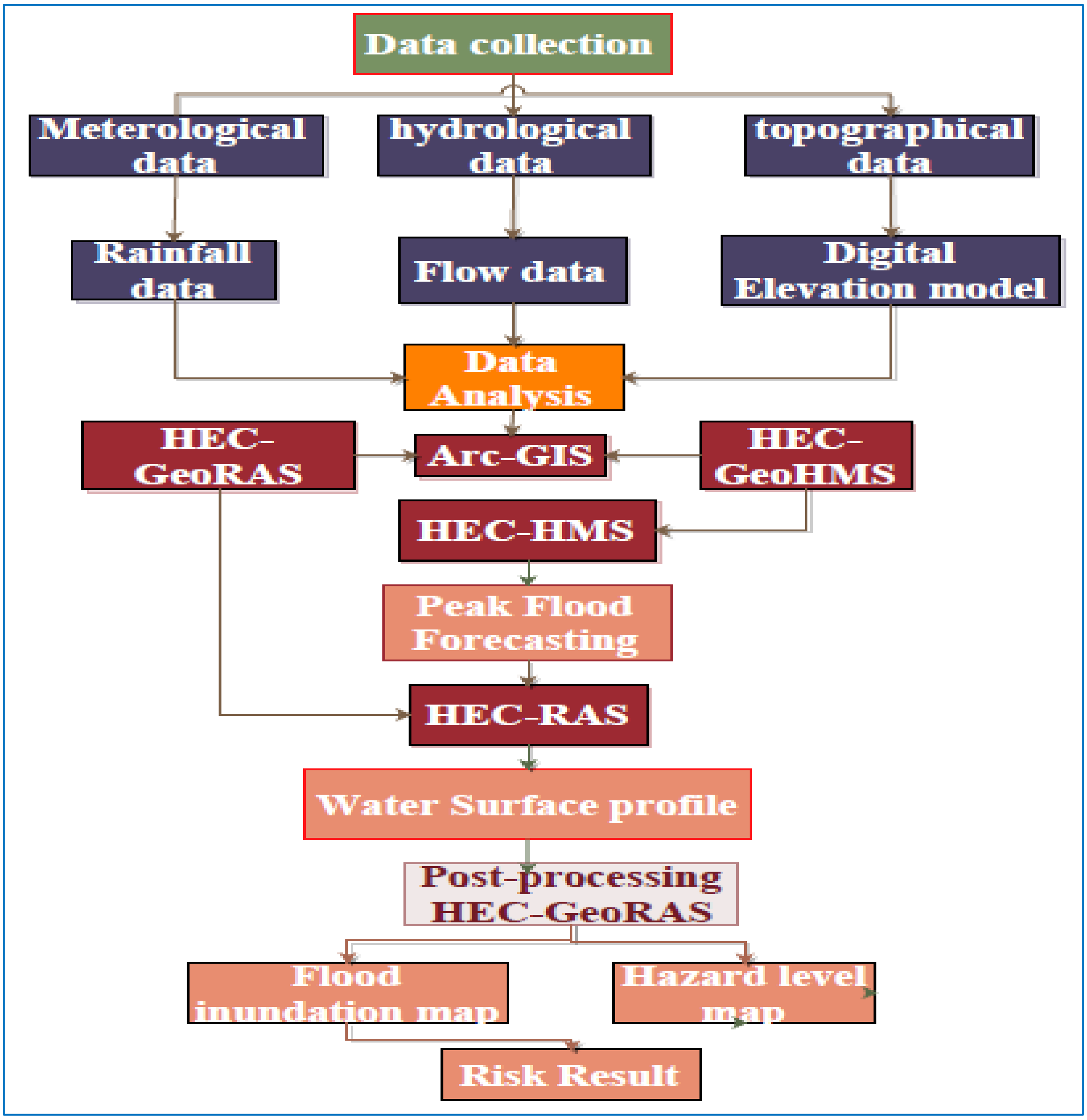


Figure 3-7: Overall thesis flow chart

3.5 Data analysis and Quality test

3.5.1 Estimation of Missing data

The data collected from different sources have some gap or which are not continuously recorded so the gap should be filled by using different filling techniques.

Normal ratio method was selected in filling of precipitation data for this thesis work. This method is used if any surrounding gauges have the normal annual precipitation exceeding 10% of the considered gauges(Muluken LE, 2020). The normal precipitations at the different rainfall station are considerable then PX was calculated by weighting rainfall by ration of normal daily precipitation. This method was selected for filled missing value of those station used in the catchment. The General formula for computing missing precipitation by this method is:

$$\text{PX} = \frac{Nx}{3}\left[\frac{P1}{N1} + \frac{\text{P2}}{N2} + \frac{\text{P3}}{N3}\right]$$ -------------------------------------equation 3.1

Where P_x= is the precipitation for the station with missing records

P1, P2 and P3 were the adjacent stations precipitation values

N1, N2, N3 were the long-term mean annual precipitation values at the respective stations and '**3**' is the number of stations surrounding the station X.

Generally, five gaging stations were used for the study area. Those stations were Chafe donsa, Tulu Bolo, Alema tena, Akaki baseka, and Koka dam

Flow data had been collected from ministry Water, Irrigation and Energy contain missed data. The missed data were filled with statistically acceptable values. The methodology used in filling missed river flow data was linear regression. For linear regression method, the selection of independent and dependent variables were based on the; the correlation coefficient between gauging station, data availability for independent variable and location of the gauging station within the catchment. Correlation coefficient indicates the strength between two variables(Mfwango et al, 2018). In this study, annual instantaneous daily flows were estimated by linear regression method. Linear regression was selected based on correlation coefficient.

3.5.2 Outliers test

Outliers test is one of the techniques to test quality of data which may have a problem during collection and recorded. The Outliers tests are data points that leave significantly from the trend of the remaining data. The retaining of these outliers can significantly affect the magnitude of statistical parameters computed from the data, especially for small samples. Procedures for considering outliers require judgment involving both mathematical and hydrologic considerations. According to the Water Resources Council (1981), the following equation can be used to detect high outliers

Yh=y+Kn*STD---------------------------------equation 3.2

Where: Yh is the higher outlier threshold and Kn is given from table size n.

The Kn values are used in one-sided tests that detect outliers at the 10-percent level of significance in normally distributed data. If the logarithms of the values in a sample are greater than Yh in the above equation, then they are considered high outliers. Flood peaks considered high outliers should be compared with historic flood data and flood information at nearby sites. Historic flood data comprise information on unusually extreme events outside of the systematic record. According to the Water Resources Council (1981) if information is available that indicates a high outlier is the maximum over an extended period of time, the outlier is treated as historic flood data and excluded from analysis. If useful historic information is not available to compare to high outliers, then the outliers should be retained as part of the systematic record.

A general equation can be used to test lower outlier:

Yl=y-Kn*STD-----------------------------------equation 3.3

Where: Yl is the lower outlier threshold.

Table 3-4: Outlier Test of Kn values

Sample size n	K_n	Sample size n	K_n	Sample size n	K_n	Sample size n	K_n
10	2.036	24	2.467	38	2.661	60	2.837
11	2.088	25	2.486	39	2.671	65	2.866
12	2.134	26	2.502	40	2.682	70	2.893
13	2.175	27	2.519	41	2.692	75	2.917
14	2.213	28	2.534	42	2.700	80	2.940
15	2.247	29	2.549	43	2.710	85	2.961
16	2.279	30	2.563	44	2.719	90	2.981
17	2.309	31	2.577	45	2.727	95	3.000
18	2.335	32	2.591	46	2.736	100	3.017
19	2.361	33	2.604	47	2.744	110	3.049
20	2.385	34	2.616	48	2.753	120	3.078
21	2.408	35	2.628	49	2.760	130	3.104
22	2.429	36	2.639	50	2.768	140	3.129
23	2.448	37	2.650	55	2.804		

Source: U.S. Water Resources Council, 1981. This table contains one-sided 10-percent significance level K_n values for the normal distribution.

Flood peaks considered low outliers are deleted from the record and a conditional probability adjustment described by the Water Resources Council (1981) can be applied. There is no outlier problem for precipitation for specific recorded period of data.

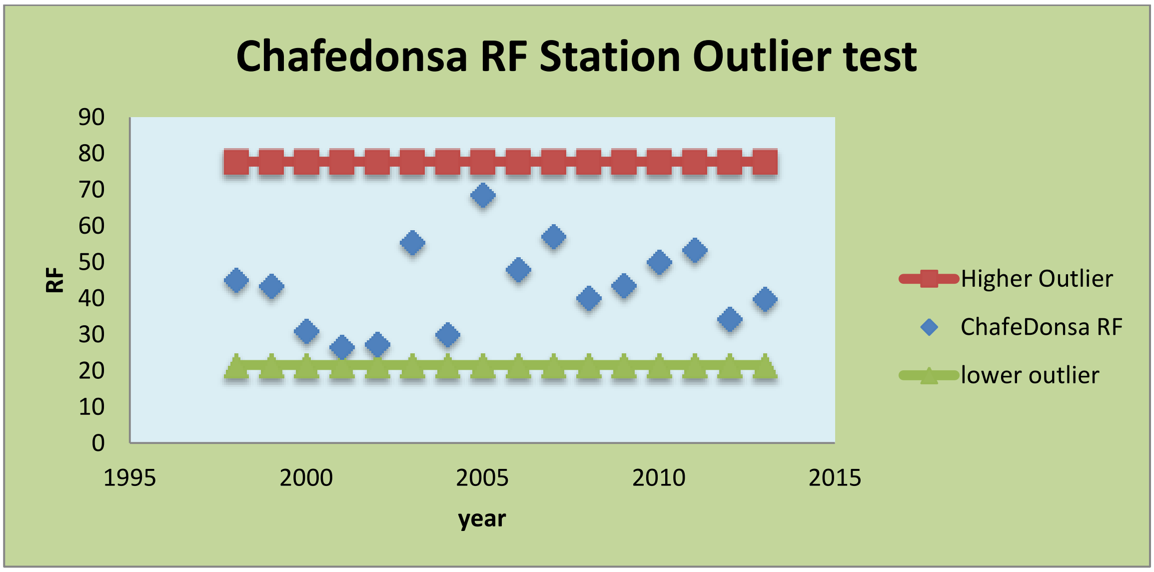


Figure 3-8: Outlier test for chafedonsa Rainfall station

There is no outlier problem for stream flow for this specified period awash at wonji gauging station. The higher outlier and lower outliers are 444.33 and 32.82 respectively.

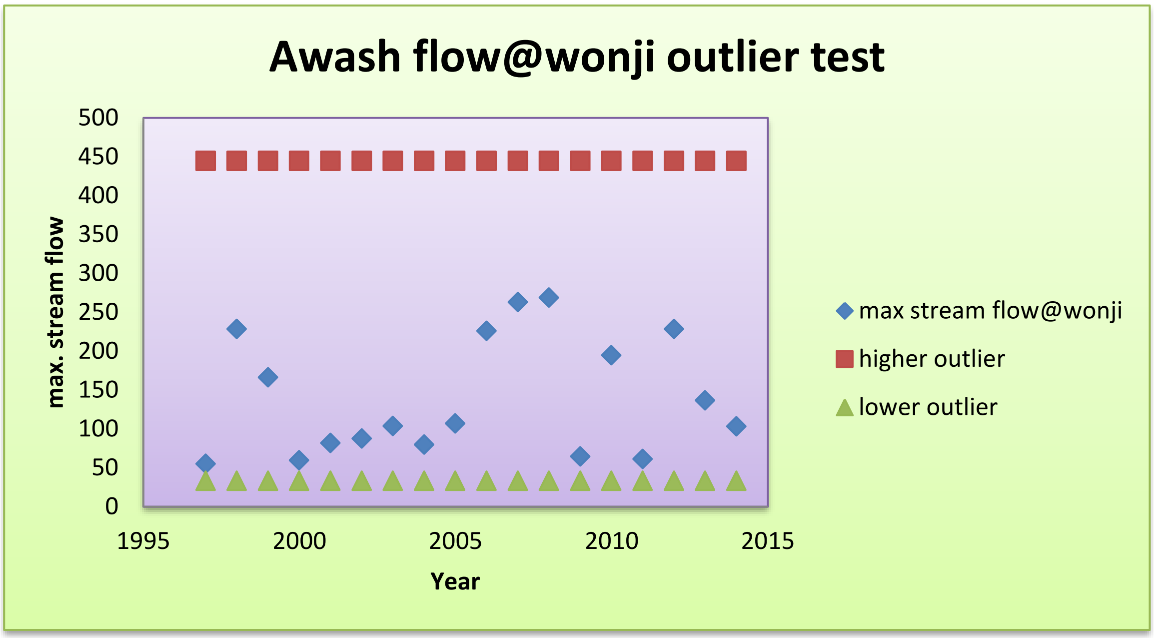


Figure 3-9: Outlier test for stream flow @wonji guaging station

3.5.3 Consistency test

Estimate missed precipitation is one problematic those researcher must be identify and the problem occur rain gages station was changed over a period of time and adjustment should be carry out provide a consistent data. Shifts of rain gage location may cause the inconsistency of data. The inconsistency problems are corrected by double mass curve method. To overcome the problem in consistency a technique most widely applied called double mass curve is used. Double-mass curve analysis is a graphical method for identifying and adjusting inconsistencies in a station record by comparing its time trend with those of other stations nearby.

The double- mass curve is used to check the consistency of many kinds of hydrologic data by comparing data for a single station with that of a pattern composed of the data from several other stations in the sub-basin(Searcy and Hardison, 1960). The double mass curve graph used to adjust inconsistence of stream flow data. The graph of the cumulative data of one variable versus the cumulative data of a related variable is a straight line so long as the relation between the variables is a fixed ratio. Breaks in the double mass curve of such variables are caused by change in the relation between the variables. These changes may be due to changes in the method of data collection or to physical changes that affects the relation. Poor correlation between the variables can prevent detection of inconsistencies in a record, but an increase in the length of record tends to offset the effect of poor correlation.

Here accumulated annual values at the station are plotted against those of nearby reliable station or group of stations. An rapid deviance in the slope of the Double-Mass Curve plot suggest some change not related to climatic variables, and adjustment should be made to the data on the basis of the ratio of the slopes of the two segments.

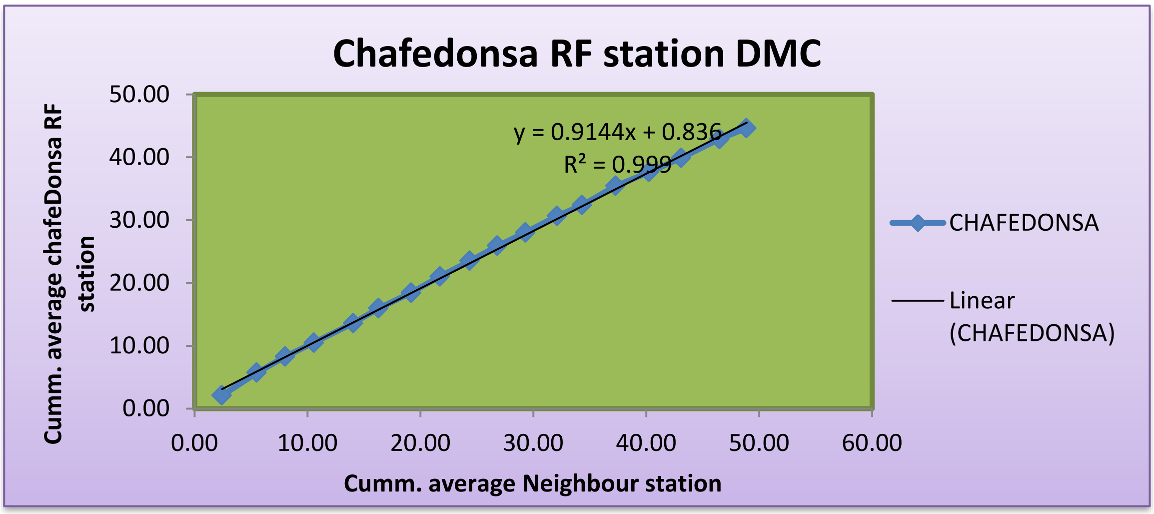


Figure 3-10**:** Double mass curve of the Chafedonsa Rainfall station

3.6 Basin model (HEC-HMS)

HEC-HMS modeling is used different time series data those are: daily, hourly and also annually. Hourly time series data are more accuracy output then annual time's series data used. In this thesis work daily time series was used.

3.6.1 Initial and constant loss method

This method was appropriate for watersheds that non-existence enough soil information and also suitable for certain flow frequency study. The initial losses define the quantity of precipitation that would infiltrate in the watershed before runoff started.

The constant rates define the infiltration rate after the initial loss started and impervious area no loss may calculated. Parameters were calculated during the calibration of model Initial and constant rate loss method is contain those components

- Initial loss *Li*, (mm)
- Constant loss rate *Lr*, (mm/hr)
- Impervious area of the sub basin *Ai*, (%)

The initial loss factor defines basin initial situation. If the basins are in a wet condition, *Li* approaches to zero. If the basins are dry, Li represents the concentrated rainfall depths that can reduction on the basin with no runoff. The constant loss rate is the ultimate infiltration capacity of the soils.

3.6.2 Clark unit hydrograph

Clark unit hydrograph is a commonly used technique for modeling direct runoff resulting from individual storm events. The technique is particularly valuable for remarkably shaped watersheds, and for application to watersheds containing several different physiographic areas. The Clark unit hydrograph is commonly use in watershed rainfall runoff to transform direct runoff of storm. The method first developed a hydrograph based on the time area histogram. The Clark unit hydrograph is defined by two parameters. they are time of concentration tc and storage coefficient R. time concentration is defined as the time between the end of excess rainfall and point of inflection of the falling limb of runoff hydrograph(Wang et al, 2012).

Application of the Clark model requires:

- Properties of the time-area histogram.
- The storage coefficient, R.
- Large catchment

Routing model properties are defined implicitly by a time-area. Studies at HEC have shown that, even though a watershed-specific relationship can be developed, a smooth function fitted to a typical time-area relationship represents the temporal distribution adequately for UH derivation for most watersheds. The required parameters of the Clark unit hydrography method are:

- Time of concentration *(hr)*,
- Storage coefficients *(hr*.

Both constraints can be estimated via calibration if observed rainfall and stream flow of awash at wonji gauged data are available.

3.6.3 Base flow

For this thesis work constant monthly base flow was applied because awash stream flow at my study area is flow through over the year. The constant monthly method is a simple approach that uses a constant base flow at all simulation time steps falling within a particular month. The other method that applied equal in base flow method to my work was recession method, which uses an exponentially declining base flow developed from standard base flow separation techniques. The recession method is also often used as a technique for base flow separation and groundwater recharge estimation(Allen et al, 2000)

3.6.4 Flood routing method

Lag channel routing for channel and modified puls method for koka reservoir routing were selected for study work. These include: backwater effects, floodplain storage, channel slope and hydrograph characteristics, flow network configuration and data availability.

Lag channel routing

The Lag routing method was selected for my study area catchment. There is less storage influence and there is no attenuation of discharge at on which lag routing method was selected. There is one river reach included in the event model structure

Modified puls reservoir routing

The elevation-storage-outflow method of level-pool routing model was used in the model from the koka reservoir. The HEC-HMS koka reservoir component represents controlled water body gate flow over the weir increasing storage-outflow function. The storage-outflow relationship can be specified from two available data: Storage-outflow, Elevation-storage, in the elevation-storage-outflow method, outflow is computed from the storage-outflow data, and then, elevation is computed from the elevation-storage data, which was I got from halcow report.

3.7 Calibration and validation of model

Model calibration

The calibration of the model was performed to estimate the peak flow and time of peak as closely as possible to the simulated and observed flow at wonji gauged station.

Calibration model is also a graphical agreement between observed flow and simulated flow. To compare a computed hydrograph to an observed hydrograph, the program computes an index of the goodness-of-fit. This function is an implicit measure of comparison of the magnitudes of the peaks, volumes, and times of peak of the two hydrographs. For optimization trial used Nelder mead method of search parameter that minimizes the value of the objective function was used for this study. These algorithms depend on a simple through examination. A total periods of 16 years of historical data from 1998 to 2013 was used, and out of this (1998- 2008) was used for calibration at the wonji gauged station. The model calibration procedure was undertaken combination of automated software and manual calibration. The optimization of the parameter was using the initial parameter from watershed characteristics. At the initial parameters, the calibration was then processed until the simulated value resembles the observed data.

Model validation

The model validation is the procedure of analysis the model's capability to simulate observed data without using other data use in calibration with satisfactory accuracy. In validation process the parameters values evaluated during calibration should kept constant without any change. The quantitative measure of the match is again the degree of variation between simulated and observed hydrography. The data used for validation was from 2009 up to 2013 G.C without change calibrated parameters.

Model efficiency/performance

For the Awash below koka at Adama weroda catchment, model simulation has been evaluated using efficiency criteria such as coefficient of determination R2 and Nash and Sutcliff ENS, 1970. Both coefficients above were used to measure the similarity of observed and simulated flow for specified time step.

a. Nash-Sutcliffe Efficiency (NSE)

The Nash-Sutcliffe Efficiency is used to evaluate the general agreement of profile of simulated and observed hydrograph during calibration and validation for study site. Recommended for monthly time step that NSE values between 0.75 and 1 are very good and NSE values between 0.65 and 0.75 are good.

$$\text{NSE} = 1 - \frac{\sum_{i=1}^{n}(qoi-qsi)^2}{\sum_{i=1}^{n}(qoi-\hat{q}oi)^2}$$ ------------------------------equation 3.4

Where NSE = Nash-Sutcliffe Efficiency

Q_{si}=simulated flow

q_{oi}=observed flow

b. Coefficient of Determination(R^2)

It expresses how good trends in measured data are reproduced by the simulated and observed result over specified period of calibration and validation. Suggested for monthly time values between 0.75 and 1 are very good and R2 values between 0.65 and 0.75 are good.

$$\mathbf{R^2} = \frac{\sum_{i=1}^{n}((\mathbf{Qsi}-\bar{Q}\mathbf{s})(\mathbf{Qoi}-\bar{Q}\mathbf{o}))^2}{\sum_{i=1}^{n}(\mathbf{Qsi}-\bar{Q}\mathbf{s})^2 \sum_{i=1}^{n}(\mathbf{Qoi}-\bar{Q}\mathbf{o})^2}$$ ----------------------------equation 3.5

Where:-

Qsi=simulated flow at the i^{th} time interval

Qoi=observed flow value at the i^{th} time interval

$\bar{Q}$o=average observed flow

$\bar{Q}$s=average simulated flow

3.8 Flood forecasting

Based on frequency storm method aanalysis peak discharge of each period is obtaioned.

Intensity duration frequency (IDF)

The rainfall intensity of 5, 10, 25, 50, and 100 year return periods was calculated. The Intensity duration e frequency equation of the study area was taken from the IDF equation which was taken from Ethiopia road authority drainage manual. The goodness of this equation is calculate the rainfall depth for any time with respect the rainfall region and its compared with graphs developed by Ethiopia road authority drainage manual for different rainfall regions of the countries.

ERA has developed 24-hour rainfall depth for different rainfall regions in ethiopia corresponding with return period. The table below was developed intensity rainfall of one hour upto one day using 24-hour and formula developed by ERA. Those intensity rainfall (mm/hr) value is used in HEC-HMS model inorder calculate the peak flood of different return period

$$Rt = \frac{R24*t(b+24)^n}{24(b+t)^n}$$ ---equation 3.6

Where: - R24=rainfall depth for 24hr

Rt=rainfall depth for a given duration t

b and n are coefficients b=0.3 and n=0.78-1.099

Table 3-5: Intensity rainfall of different return period

	TD	2	5	10	25	50	100
1	60	27.6322	33.80354	39.37212	48.16545	56.09992	65.341457
2	120	16.48317	20.1645	23.48627	28.73167	33.46475	38.977514
3	180	12.03545	14.72344	17.14888	20.97889	24.43482	28.460058
6	360	6.943999	8.494865	9.894254	12.10403	14.09797	16.420375
12	720	3.970355	4.857089	5.657215	6.920692	8.060762	9.3886404
24	1440	2.259614	2.764274	3.219643	3.938715	4.587554	5.3432777

3.9 Estimation of areal rainfall using thiessen polygon method

Gage weight was used for metrological modeling. The method contains the following inputs: basin, gage precipitation contribution weight.

Determination the amount of gage weight that falls during the given storm is required to determine frequency storm. A method for determine mean areal rainfall have developed. In this thesis work thiessen polygon method was used for the purpose of estimating the areal rainfall on each catchment. To determine gage weight, polygon were developed the area for which the point of precipitation was taken from the catchment. All polygon side was developed along the perpendicular bisector line joined all pair of adjacent gauge. The sum of all weights coefficient in each sub-catchment is equal to one.

Table 3-6: Gage Weight Metrological Model

s.no	Basin Name	Contribution s.no	contribution station	weight

		1	Tulu bolo	0.80
		2	akaki	0.20
1	W70		*total Area*	1.00
		1	Tulu bolo	0.01
		2	akaki	0.19
		3	Alema tena	0.53
		4	chafeDonsa	0.28
2	W100		*total Area*	1.00
		1	akaki	0.98
		2	chafeDonsa	0.02
3	W60		*total Area*	1
4	W90	1	alematena	1

3.10 HEC-GeoRAS

HEC-GeoRAS is an ArcGIS tools specifically design to process geospatial data for use with the HEC-RAS. The extension allows users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model and complementary data sets. The interface allows the preparation of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS. To import file is create from data extracted from ArcGIS and digital terrain model DTM, of the river system represent TIN format.

The user creates a series of line themes pertinent to developing geometric data for HEC-RAS. The themes created are the Stream Centerline, Flow Path Centerlines, Main Channel Banks, and Cross Section Cut Lines. Additional RAS Themes may be used to extract additional geometric data for imports in HEC-RAS these themes include Land Use, Levee Alignment, Ineffective Flow Areas, and Storage Areas. Water surface profile data and velocity data exported from HEC-RAS simulations may be processed by HEC-GeoRAS for GIS analysis for floodplain mapping, flood damage computations, ecosystem restoration, and flood warning response and preparedness. HEC-GeoRAS toolbar has four menus such as RAS Geometry, RAS Mapping, ApUtilities, and Help and seven tools (Assign River name, Reach name, Assign from Station to Station, Assign Line Type, Construct XS Cutline, Plot Cross Section, and Assign Levee Elevation).

3.11 HEC-RAS

The HEC-RAS software has found wide acceptance among hydraulic engineers and researchers due to its strong channel flow analysis capabilities and its ability to simulates unsteady flood wave propagation and identifies flood prone areas as the areas where the ground is lower than the computed water elevation and allows the user to visualize the flood propagation in real time, those making the software ideal for dam breach modeling

The model is used for determination of water surface profiles for different flow scenarios, is intended for steady flow water surface profile computations and unsteady flow simulation; perform sediment transport simulation and perform water quality simulation. The system is capable of modeling subcritical, supercritical, and mixed-flow regimes for streams consisting of a full network of channels, a dendrite system, or a single river reach.

For each HEC-RAS project, there are three essential components:-

3.11.1 Geometry data

The study area extracted from DEM 12.5*12.5 m and overlay to the Awash River. The geometric-processing contains digitization river characteristic which was used for HEC-RAS model input. The only performing activities of the geometric layer were creating and digitizing river, right and left bank, flow path, and cross-sections of the area

The Geometry data consists of a description of the size, shape, and connectivity of stream cross-sections. Also, the Flow data holds discharge rates. Finally, Plan data contains information pertinent to the run specifications of the model, including a description of the flow regime.

3.11.2 Survey data and editing geometric data

The first of the components were considered is the channel geometry. To analyze stream flow, HEC-RAS represents a stream channel and flood area as a series of cross-sections along the channel. 50-River cross section had been extracting using DEM 12.5X12.5m and edited using field collected river cross section data to give better output. The cross section extracting and collected are not uniform, the depth and width of the river vary from cross section to cross section. The survey data collected during field inspection are shown in appendix section.

3.11.3 Manning roughness coefficient

Manning's roughness coefficient were recommended according to the basin characteristic's and combine with chow book and the values were related and combines by Cowan method to set the value of manning's for channel as well as the floodplain for this study area. The manning's roughness of a plain affects the characteristics of runoff, whether the water is on the surface of the watershed or in the channel. Different factors that are affect the manning's values; those are Surface roughness, Vegetation's, Channel irregularities, and alignment, Scours and deposition, Obstructions, Size and shape of the channel, Stage, and discharge, Seasonal changes, Temperature, and Suspended material and bed load, etc.(Asnake Eshetu, 2018). The field data of channel and floodplain image used for estimation of initial manning value was as shown in figure below and at appendix section.

Figure 3-11 Field data for flood plain and channel for initial manning's determination

The manning values (n) were assigned based on the characteristics of the channel and flood area as shown in the table below.

Table 3-7: Computation sheet for manning's roughness coefficient.

Variables	Description Alternatives	Recommended value	Actual value of Channel	Actual value of Floodplain
Basic n1	Earth	0.02	0.02	0.02
	Rock	0.025		
	Fine gravel	0.024		
	Coarse gravel	0.028		
Irregularity n2	Smooth	0	0.005	0.005
	Minor	0.005		
	Moderate	0.01		
	Severe	0.02		
Cross-section n3	Gradual	0	0.005	0.005
	Occasional	0.005		
	Alternating	0.010 – 0.015		
Obstructions n4	Negligible	0	0.01	0.0125
	Minor	0.010 – 0.015		
	Appreciable	0.020 – 0.030		
	Severe	0.040 – 0.060		

Vegetation n5	Low	0.005 – 0.010	0.02	0.02
	Medium	0.010 – 0.020		
	High	0.025 – 0.050		
	Very high	0.050 – 0.100		
Meandering n6	Minor	0	0	0
	Appreciable	0.15 * ns		
	Severe	0.30 * ns		
Total Reach manning's roughness			0.06	0.0625

According to the above table analyzed the initial value of manning’s “n” were 0.06 and 0.0625 for main channel of Awash River and river banks respectively.

3.11.4 Boundary condition

Boundary conditions are necessary to establish the starting water surface at the ends of the river system upstream and downstream. A starting water surface is necessary in order for the program to begin the calculation. In a subcritical flow regime, Boundary conditions are only necessary at the downstream ends of the river system. If a supercritical flow regime is going to be calculated, Boundary conditions are only necessary at the upstream ends of the river system. If the mixed flow regime calculation is going to be made, then Boundary condition must be entering at all ends of the river system.

According to the model, there are four types of boundary conditions namely:

- Known water surface elevation
- Normal depth
- Critical depth and
- Rating curve

So that for this thesis normal depth had been selected. A normal depth should be calculated for upstream and downstream end profile of the study area. The slopes upstream and downstream of the channel bottom were 0.0013 and 0.0117 respectively.

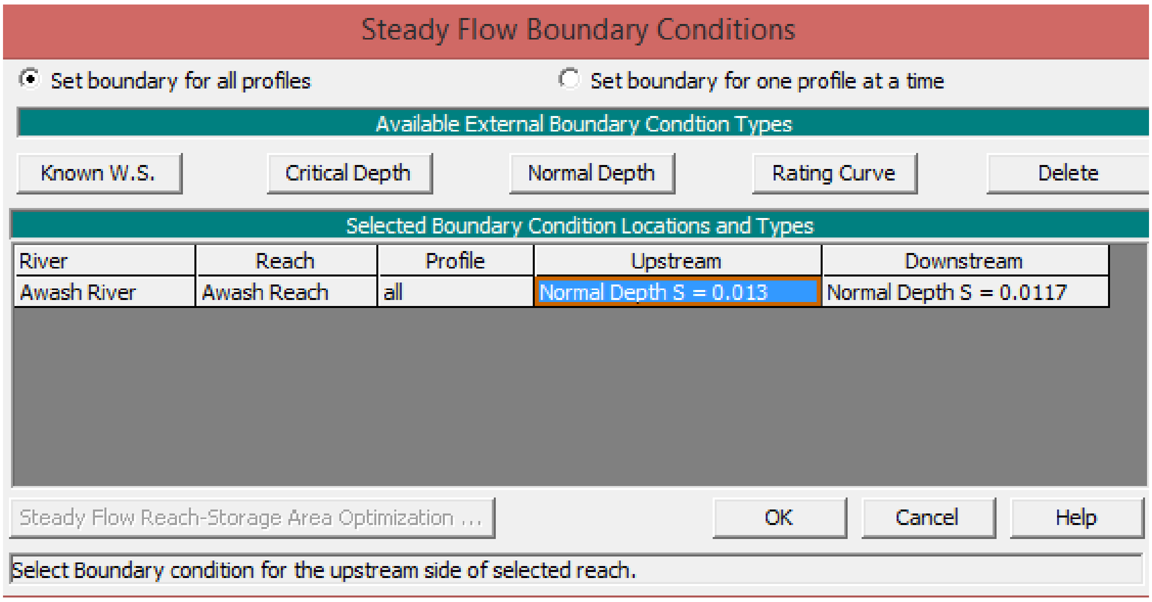


Figure 3-12: **Boundary Condition in Steady Flow.**

3.11.5 Steady flow simulation

The flood discharge for different return periods were entered in steady flow data. Boundary conditions and Manning Roughness were also entered in this table. Then, water surface profiles were calculated in steady flow analysis. Water surface profiles were computed from one cross section to the next by solving the energy equation. The flow data were entered in the steady flow data editor for five return periods as 5-yr, 10-yr, 25-yr 50-yr, and 100-year. Boundary condition was defined as normal depth for both upstream and downstream side.

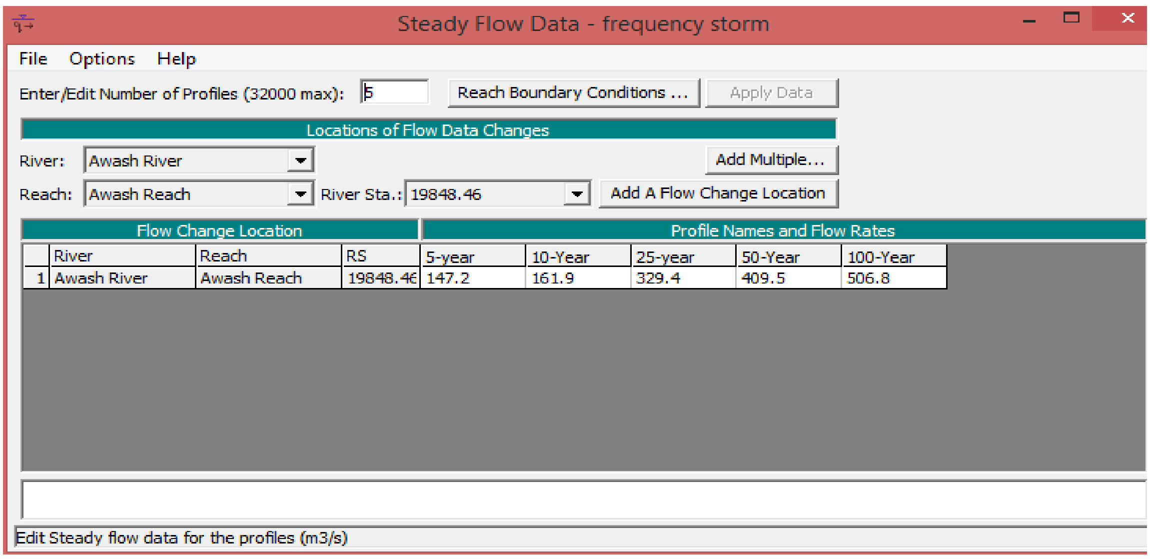


Figure 3-13: steady flow data

3.11.6 HEC-RAS Calibration and Validation

Hydraulic flood mapping is calibrated and validate by using satellite image remote sensing tools comparing simulated flood extent. Landsat 7-ETM+image processing method using the different water extraction index method. In the field of mapping and flood analysis, remote sensing has made a significant contribution by introducing Landsat satellite imagery. There are six indices for the identification of water bodies Modified Normalized Difference Water Index (MNDWI), Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), Automated Water Index (AWI), Water Ratio Index (WRI) and Normalized Difference Moisture Index (NDMI). The operation was required to get the most accurate model of the six calculated indices the accurate index was chosen (Elena *et al.*, 2019)

The general formula of water extraction index method(Enea *et al.*, 2018).

- MNDWI=(Green-MIR)/(Green+MIR)
- NDWI=(GreenNRIR)/(Green+NIR)
- NDVI=(NIR-Red)/(NIR+Red)
- AWI=4*(Green-MIR)-(0.25*NIR+2.75*SWIR)
- WRI=(Green+Red)/(NIR+MIR)
- NDMI=(NIR-MIR)/(NIR+MIR)

Where:-

NIR=near infrared; MIR=Middle infrared; SWIR=short wave infrared

Landsat Imagery specifications:-

Green=Band2; Red=Band 3; NIR =Band 4; MIR=Band 5; SWIR=Band 7

The satellite imagery Landsat-7 cloud free less 30% was downloaded during September for calibration and validation. Comparing the surface area extracted from each index to the area of the different return periods HEC-RAS flood band and selecting the best resembled water delineated area from indices with HEC-RAS simulated flood area was chosen for calibration and validation(Enea *et al.*, 2018). According to the above procedures NDVI and NDMI was the matching flood map with simulated flood by HEC-

RAS tools for calibration and validation respectively. Calibration done by changing manning coefficient until simulated map by HEC-RAS similar with satellite image flood map and validation was done without changing manning number(Yonata Belina, 2020).

3.12 Post RAS processing of geometric data

The simulated data directly exported to the ArcGIS is known as post processing of geometric, which is used to identify flood inundation map, depth of flood and etc.at the last risk of flood is calculated from an inundated area produced in ArcGIS.

3.13 Crop data

The production data from the study area was used to quantify the risk of flood on the agricultural production. The flood inundated agricultural area. Crops types and crop yields that have been produced from the inundated area were collected from Adama weroda agricultural and natural resource office for better estimation of the risk.

Table 3-8: Crop type and percentage of coverage at study area

S.no		Production (quintal/hectare)	percentage of coverage
1	Maize	35	35
2	Onion	100	30
3	tomato	150	23
5	teff	21	5
6	wheat	27	7

3.14 Flood risk analysis

First step is to identify the areas inundated by flooding. This require a digital elevation model DEM with a sufficiently fine grid resolution to resolve the river channel geometry, which predicts the inundation areas based on the transient hydrological variables. It requires data including stream channel geometry. Although inundated areas are expected to vary along the river course and reach, and localization of rainfall event.

The floodvulnerability maps were prepared by overlaying the flood extent grids with the land use land cover on the study area. Because almost all portion of the risk area is flat covered by different crop, then if the flood expands, it distributed to the two banks. The risk now estimated as the amount of crop production from the land in terms of quintal. Hazard level may be defined by the parameters like flood depth, magnitude of flood and accidence probability of the flood event. For the quantification of the flood hazard and potential of damage, magnitude of the flood is a determining parameter. According to Gillard (1996), the hazard aspect of the flood risk is related to the hydraulic and the hydrological parameters. For this weighted spatial coexistence model facilitates the analysis by ranking the hazard level in terms of magnitude of the flood. That is a flood having high magnitude, its hazard level becomes also high where as a flood having small magnitude have small hazard, and Also Cheng et al. (2003) proposed that flood hazard identification and assessment are based on information on the intensity and the frequency of flood events. Usually the spatial distribution of both flood flow depth and flow velocity has to be considered.

In this study, the flood flow depth was selected as indicator of flood identification and assessment. Dynamics of inundation flow on lowland area can be modeled as a shallow flow where the velocity distribution is integrated over the vertical direction. Therefore the definition of flood hazard is based on two-dimensional hydraulic model (flood inundation model) for the assumed flood events with the various return periods flood hazard map should be produced with GIS

CHAPTER 4 RESULT AND DISCUSSION

4.1 Model Evaluation

The model evaluation procedure included sensitivity analysis, calibration and validation of the model. The sensitive analysis of the model was performed to determine the important parameters precisely estimated to make perfect prediction of the study area. This method was follow by varying input parameter with prescribe range keeping the other constant and running the model. The result was analyzed to determine with respect to the initial value.

The systematic search for the optimum parameter was carried out using automatic HEC-HMS Model parameter optimization from the model compute toolbar regarding observed flow at Awash River at wonji gauged station.

4.1.1 Parameter optimization

The optimized trail parameters were containing initial values, optimized values and objective function sensitivity. The initial trial values were taken according to catchment characteristics. Finally the trial optimized values were used for flood frequency storm.

Table 4-1: Optimized parameter results for last trail

Project: MODELLING Optimization Trial: OptimizationTrial B

Start of Trial: 01Jan1998, 00:00 Basin Model: Catchment_Outlet
End of Trial: 31Dec2008, 00:00 Meteorologic Model: Met 1
Compute Time: 21Feb2021, 18:16:56 Control Specifications: Validation

Element	Parameter	Units	Initial Value	Optimized Value	Objective Function Sensitivity
W100	Clark Storage Coeffic...	HR	20.5	20.482	0.00
W60	Clark Storage Coeffic...	HR	22.84	22.946	-0.01
W70	Clark Storage Coeffic...	HR	22.2	22.167	0.00
W90	Clark Storage Coeffic...	HR	11.5	11.488	0.00
W100	Constant Loss Rate	MM/HR	1.7	1.9049	0.00
W60	Constant Loss Rate	MM/HR	0.049	0.0402935	-0.01
W70	Constant Loss Rate	MM/HR	2.6	2.9349	0.00
W90	Constant Loss Rate	MM/HR	5.97	6.0343	0.00
W100	Initial Loss	MM	13.2	13.342	0.00
W60	Initial Loss	MM	52.3	52.288	-0.00
W70	Initial Loss	MM	18.5	18.568	0.00
W90	Initial Loss	MM	12.1	12.443	0.00

4.1.2 Model calibration

Model calibration was done by using observed flow at wonji gauged station and simulated flow by HEC-HMS. The simulated flow was carried by setting initial value according to the characteristics of the basin and optimized the value again and again within the range and observed flow was from recorded data. The objective functions for optimization trial based on the output result peak weight RMS error was used depend on the calibrated agreement between the simulated flow and observed flow at wonji gauged station. The model was calibrated used daily data for eleven (11) year, from 1998 up to 2008 GC. The model goodness of fit and the model performance was evaluated after adjusting the parameters. The performance valuation Nash and Sutcliffe model efficiency (NSE) for monthly stream flow calibrated was 0.728. The other performance result Pearson's coefficient of determination (R^2) for calibration was 0.762

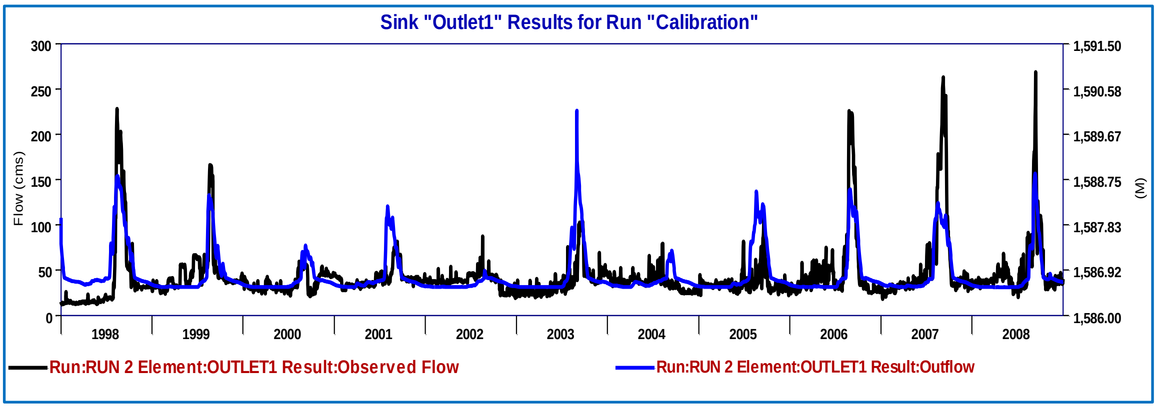


Figure 4-1: Observed and simulated flow graph Calibrated model

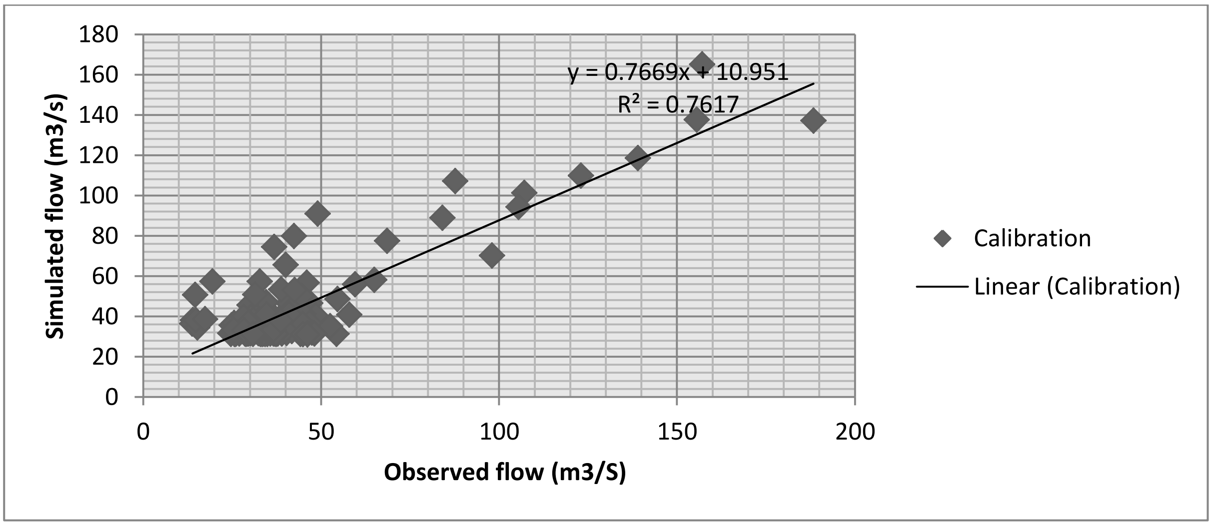


Figure 4-2**:** Average monthly Observed and simulated flow calibrated model

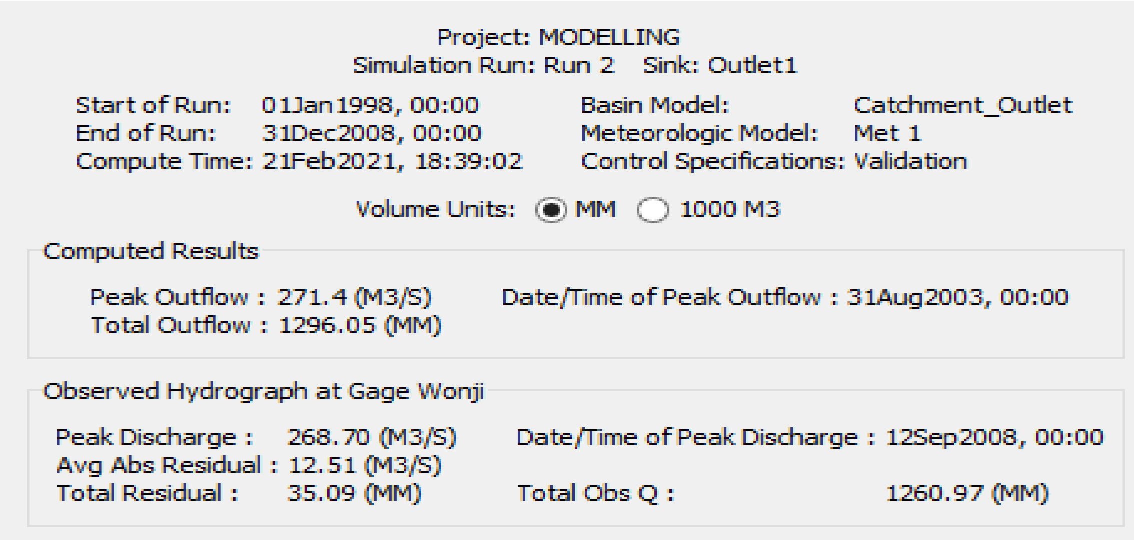


Figure 4-3: Summary result during Calibration

4.1.3 Model validation

The calibrated model was then used to estimate daily stream flow validation of the basins for the years 2009 and 2013 using without changing parameters. The performance valuation Nash and Sutcliffe model efficiency (NSE) for monthly stream flow validated was 0.65. The other performance result Pearson's coefficient of determination (R^2) for validation was 0.68.

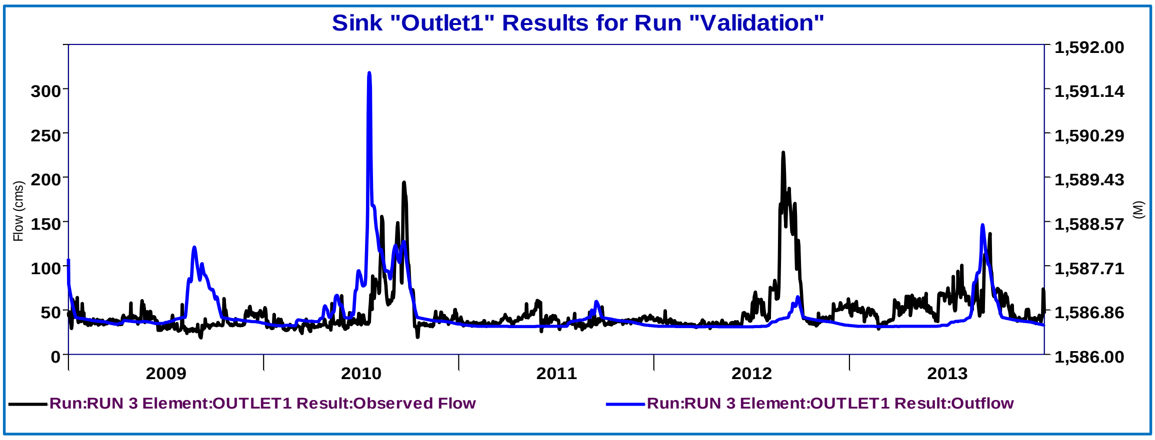


Figure 4-4: Observed and simulated graph during validation model

4.2 Flood frequency for different return period

The model result produced and generated flood for different return periods. According to the HEC-HMS output the minimum value of flood was calculated/ computed at 5-year return period for 24-hour storm duration was 147.2m^3/s and the maximum computed flood frequency storm at 100 year for the 24-hour duration was 506.8m^3/s. The peak flood increase with increasing return period.

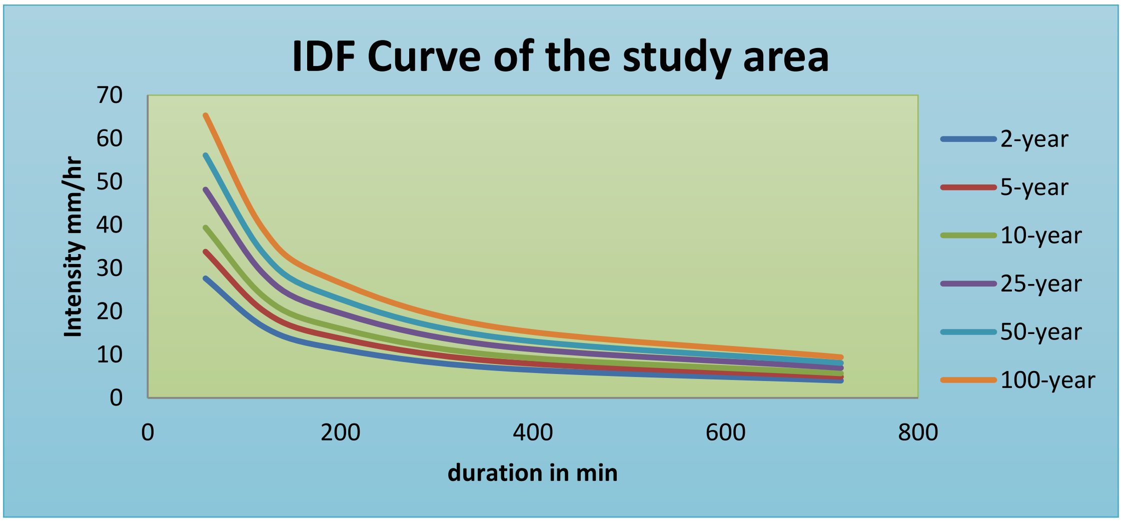


Figure 4-5: IDF curve of all return period

Table 4-2: Flood frequency for each return period

s.no	Return period	Peak discharge(m3/s)
1	5	147.2
2	10	161.9
3	25	329.4
4	50	409.5
5	100	506.8

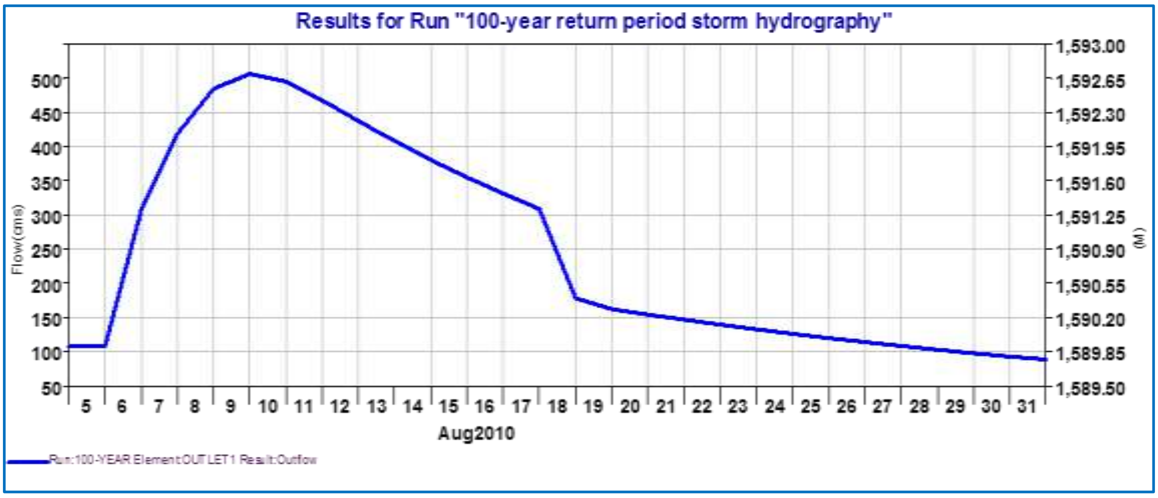


Figure 4-6: 100-Year frequency storm hydrography

4.3 Geometric RAS layer

4.3.1 Stream center line

The river and reach network is represented by the stream centerline layer. The stream center line was drawn from upstream of the study area to the downstream of the study along the Awash River channel. The producers were assign the river name and reach name.

A stream centerline feature class created in the Output Geo-database based on the centerline location in HEC-RAS. *River* and *Reach* attribute information were added.

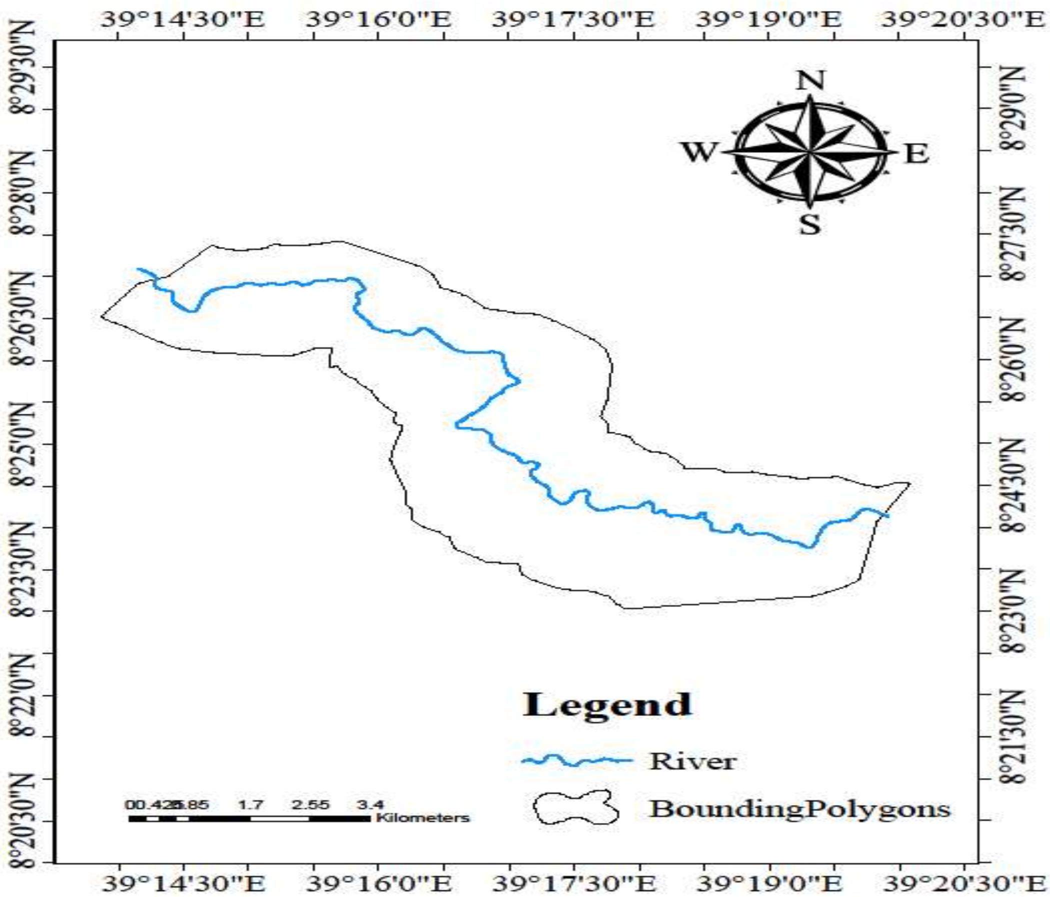


Figure 4-7**:** River centerline of Awash River at study area

4.3.2 Bank lines

The Bank lines layer defines the main channel flow from flow in the overbanks. Bank stations were assigned to each cross section based on the intersection of the bank lines with the cut lines. It is more efficient to skip this layer and complete the data in HEC-RAS using the graphical cross section editor tools.

In general, the bank lines are works for three purposes,

- Assign bank stations,
- Calculate overbank flow paths, and
- Serve as the distinction between channel and floodplain roughness.

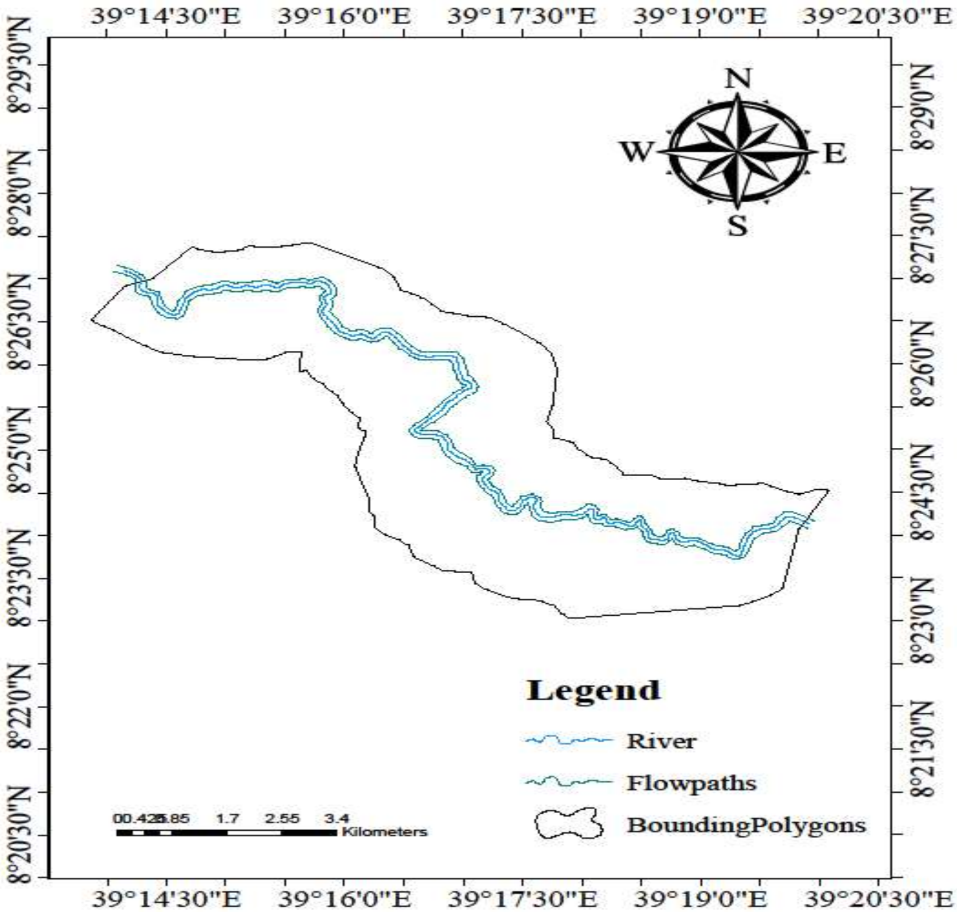


Figure 4-8: Bank lines of Awash at study area

4.3.3 Flow path center line

The flow path centerlines identify the hydraulics flow path in the left overbank, the main channel, and right overbank by identifying the center mass of flow in each region.

Further creating the flow path centerlines layer are assist properly laying out the cross-sections cut lines. If the stream centerline layer already exists you have the option to copy stream center line for the flow path in the main channel. Flow path were created in the direction of flow from upstream to downstream. The flow path lines are used to determine the downstream reach lengths between cross sections in the main channel and over bank areas.

4.3.4 Cross-sectional cutline

Cross section are shows the elevation of the basin area that is to defined the what ground surface profile and flow lines looked like across the river flow. The cross section lines were laid perpendicular to the river flow. The cross section cut lines, channel center and flow path lines are uses to compute HEC-RAS attributes, those are bank station, reach length and space between cross-sections. The number of cross section is used to define the good representation of the terrain. The feature class will have the name “XS Cut Lines” and will be added to the analysis Map. Cross-sections play great role in developing attribute table for HEC-GeoRAS model like right and left bank station at intersection with bank lines

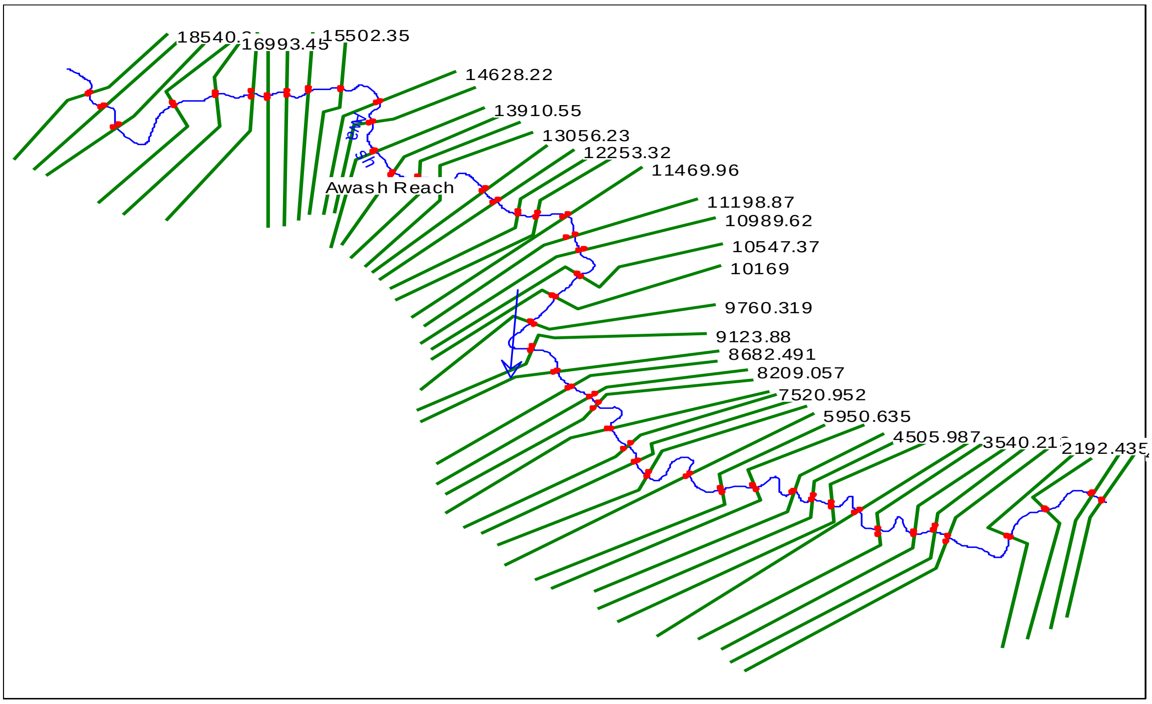
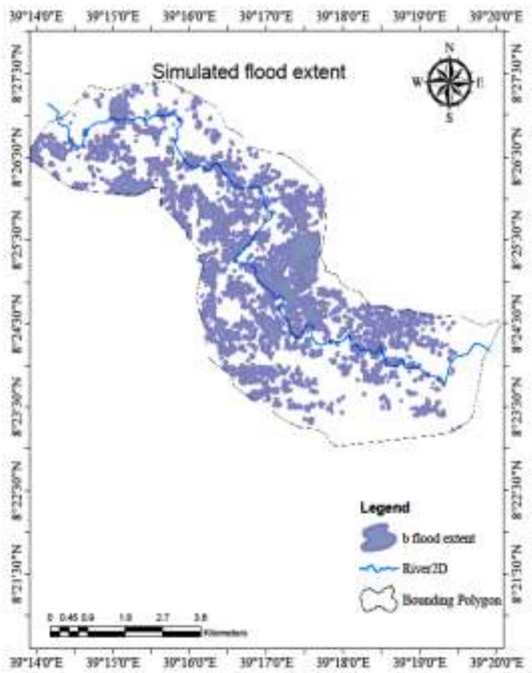


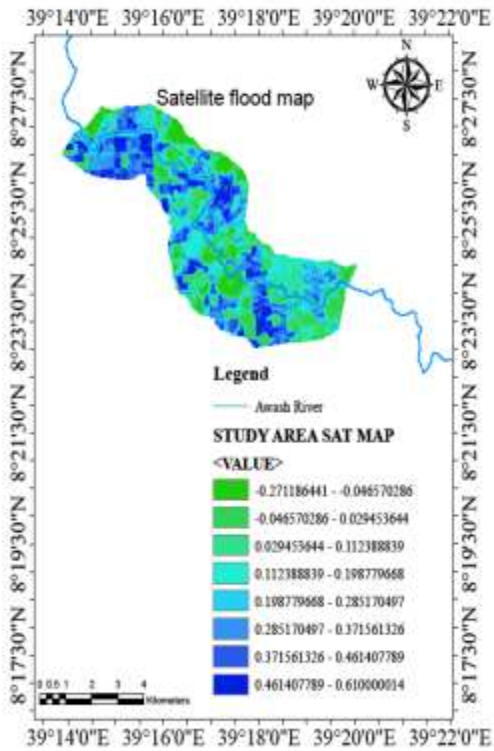
Figure 4-9: **Cross-sectional cut-line of Awash River at study area**

4.4 HEC-RAS Calibration and validation result

HEC-RAS Calibration

Calibration of flood extent was done by changing manning coefficient. The final most appropriate value manning coefficient after trial was 0.055 and 0.06 for channel and flood plain respectively. After several indices applied, the best matching flood extent with simulated flood extent NDV indices was chosen The calibrated accuracy of the HEC-RAS generated was more than 85% overlapped. The flood map comparison of simulated flood by HEC-RAS and Landsat-7 satellite image flood extent are as shown figure below.



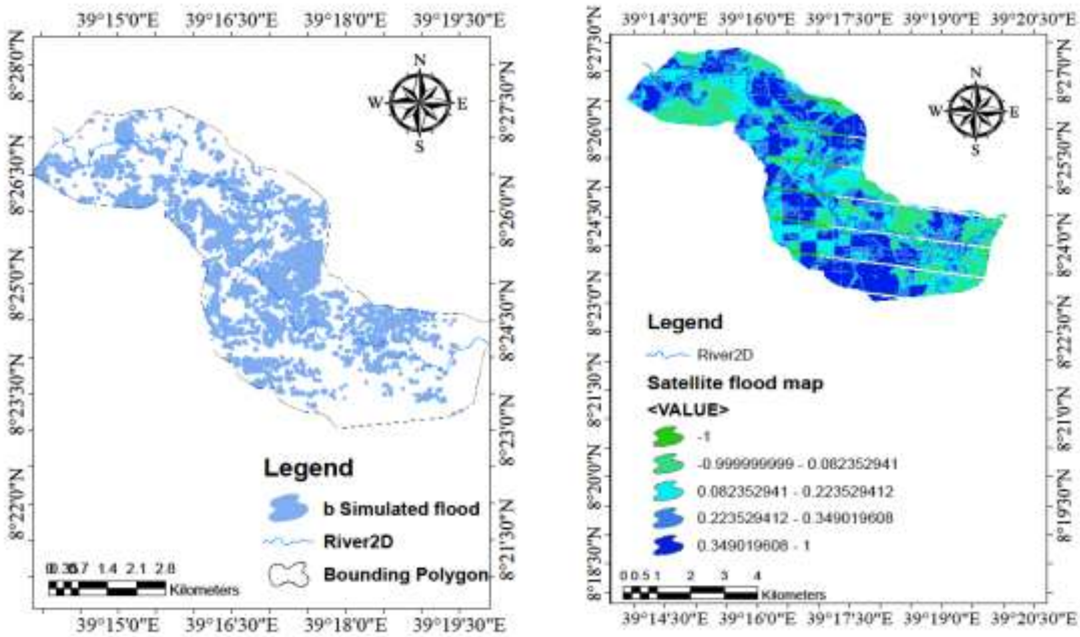


A. Simulated flood extent map B. Satellite flood extent map

Figure 4-10: HEC-RAS calibration according to NDVI and Simulated flood

HEC-RAS Validation

The satellite imaginary used was the highest resolution availability, which was the flood extent of September 2007 Landsat of geotiff image file. After applied several indices to satellite image, the best matching with observed flood extent was NDMI chosen during validation. The validated accuracy of the HEC-RAS generated was more than 75% overlay. The flood map comparison of simulated flood by HEC-RAS and Landsat-7 satellite image flood extent during validation is as shown figure below.



A. Simulated Flood extent map **B. Satellite Flood extent Map**

Figure 4-11: **HEC-RAS validation according to NDMI and Simulated flood**

4.5 HEC-RAS out puts

4.5.1 Cross-sectional view

The river cross section during 5-year return period and 10-year return period floods are 147.2 m^3/s and 161.9m^3/s respectively have not brought significant change because of the depth of flood corresponding to this discharge is less as compared with other 50-yearand 100 year water depth at the specified cross-section. But, the 50-year and 100-year return period floods have higher magnitudes of 409.5 and 506.8 m^3/s respectively; these discharges inundate the adjacent floodplains.

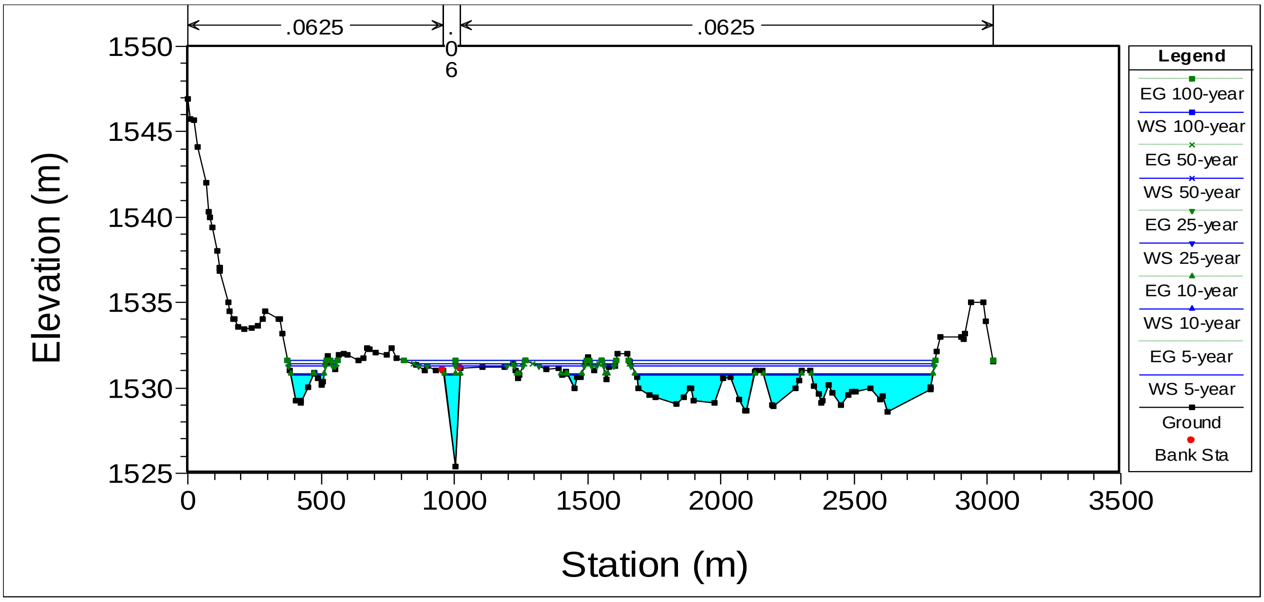


Figure 4-12: Cross-sections view Awash River at station 11470m

4.5.2 Water surface profile

The water surface profile calculation was done by using HEC-HAS for different flow through channel or river. Accordingly the Water surface profile for different return periods; such as 5, 10, 25, 50, and 100 years, were computed for the study area. It is basic for post-processing in the floodplain delineation of flooded area. The water surface profile for all return period is shown as figure below**.**

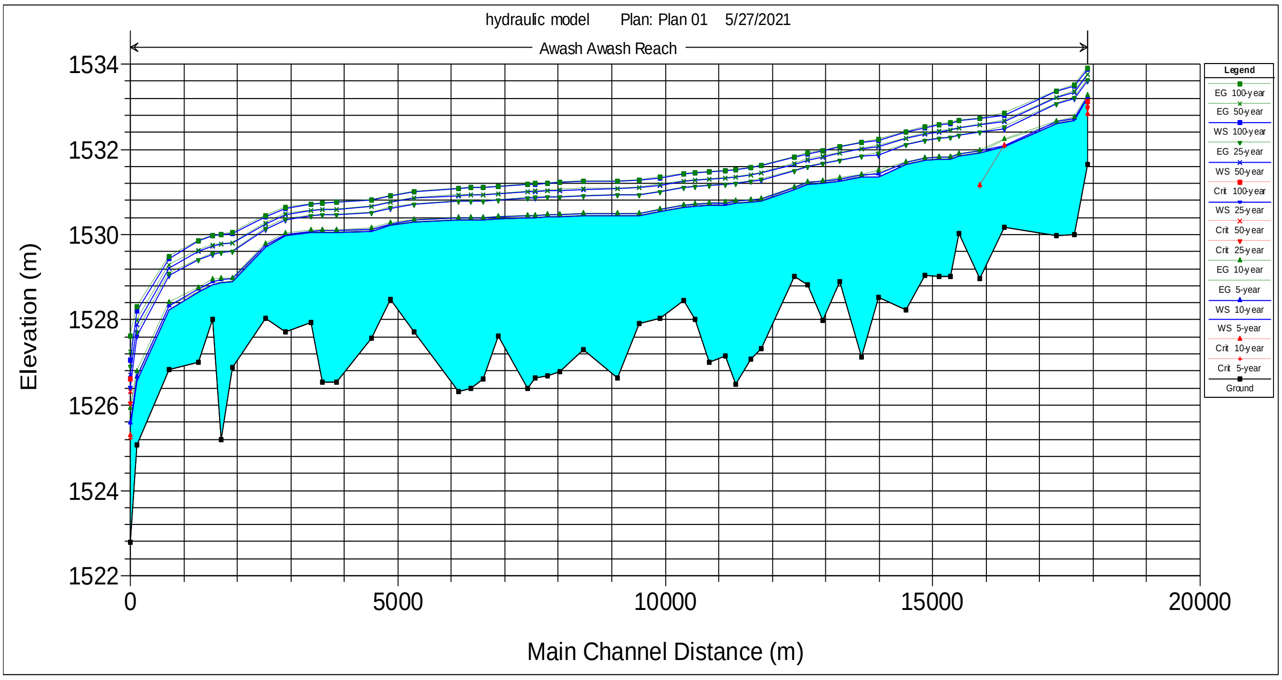


Figure 4-12**:** Water surface profile for each return period.

4.6 Flood inundation mapping

The inundation map was done by constructing water surface triangular irregular network from the x-sections.

4.6.1 Water surface TIN generation

The water surface TIN was created for 2, 5, 10, 25, 50 and 100 years of return period. The TIN was created based on the water surface elevation at each cross section and the bounding polygon data specified in the RAS GIS export file. The water surface TIN was generated without considering the terrain surface. After a water surface TIN has been created with water surface elevation for the selected profile, now it is added to the map.

The water surface TIN was created and added to the analysis map corresponding to the different return period as shown in figure below. Accordingly, water surface TIN was created for 5, 10, 25, 50 and 100 years of return period. It also covered the area out of the x-section but within the range of bounding polygon. The water surface elevation triangular irregular network for different return period was selected as below.

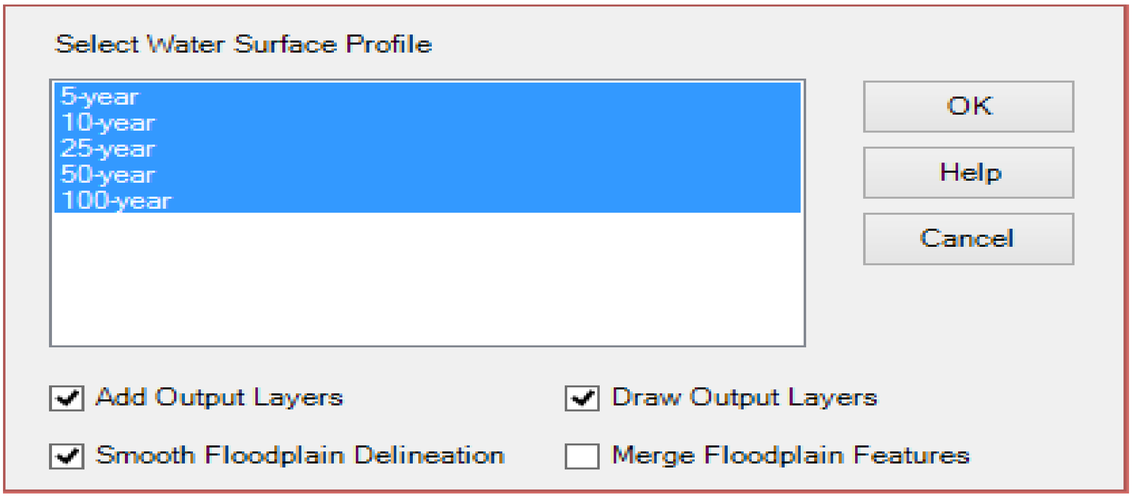


Figure 4-13: **Water surface profile selection**

The triangulation irregular network for the selected return periods creates the surface TIN using cross-sectional cut lines and connecting the outer points of the bounding polygon, therefore the TIN were included area outside the possible inundation.

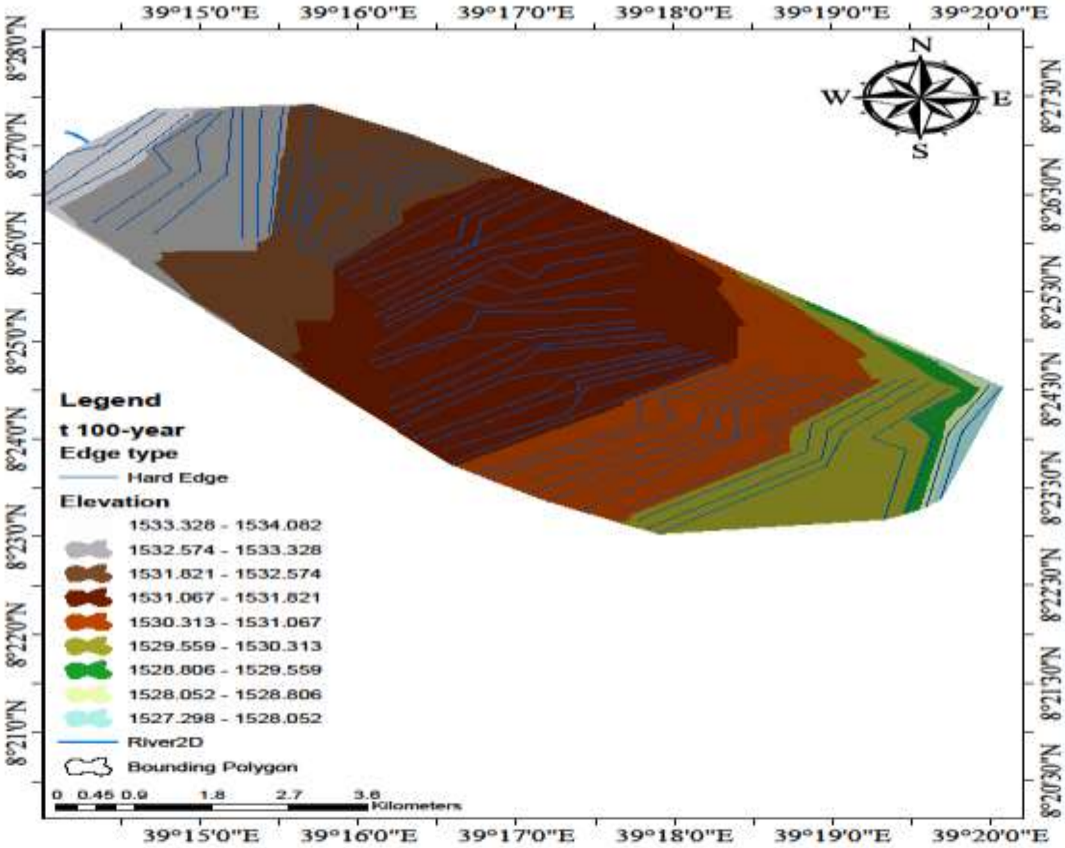
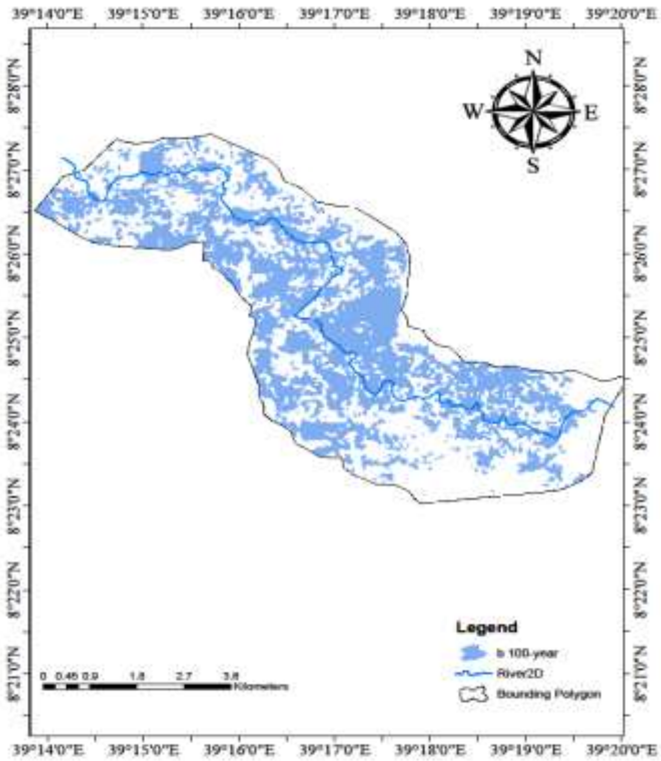


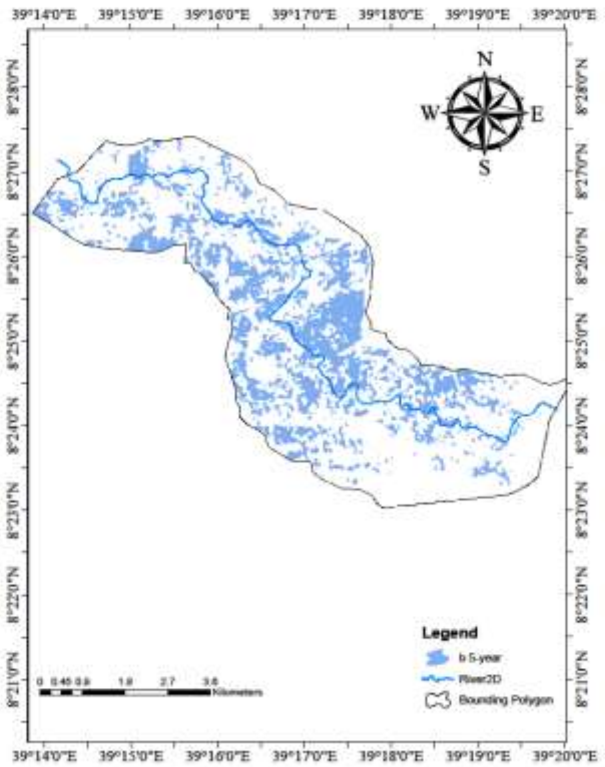
Figure 4-14: **Water surface TIN generated using cross-sectional cut line**

4.6.2 Flood plain delineation using raster

The Floodplain delineations were use the Water surface triangular irregular network and terrain to compute the plain boundaries and flood inundations depth. The flood inundation was extracted by relating water surface TIN and DTM of the basin. Flood plain depth was also formed depend on the grid depth. At this stage the water surface TIN was first converted to a grid, and then digital terrain model was subtracted from the water surface grid. The area water surface is higher than the terrain is flood area, and the area with lower (negative) results is dry. After the inundation map was created, check on quality of the inundation polygon was made. The ability to judge the quality of terrain and flood inundation polygon comes with the knowledge of the study area and experience.

The flood inundation map for 5 year and 100-years return period discharge is shown as figure below.





I. Flood inundation map during 100-year return period

II. Flood Inundation map for 5-year return period

Figure 4-15: **Flood inundation Map for 100 year and 5-Year return period**

The statically flood polygon of the flood inundation area were summarized and analyzed corresponding to the return period. Flood for higher return periods have high flows which can immerse and loss a large amount of agricultural land. Also this flood can bring in water logging in the area which consequently can result in yield reduction. The inundation areas corresponding to different return periods floods are indicated in below table.

Table 4-3:- **Flood magnitude and corresponding inundated area**

s.no	Return period(Year)	peak flow(m^3/s)	Flood Inundation area(Hectare)
1	5	147.2	1052.7
2	10	161.9	1086.9
3	25	329.4	1429.5

4	50	409.5	1559.1
5	100	506.8	1694.1

4.6.3 Flood hazard level map

Flood hazard assessment level was produced by flood generating factors; those were slope, elevation, drainage condition, and water depth of the study area. The flood hazard area or maps were classified as very high hazard level, high hazard level, moderate hazard level, low hazard level and very low hazard threats level respectively based on water depth. The hazard level or vulnerability levels of very high and high flood level terrorizations the basin area. Most of the areas of flood plains are agricultural land.

The 100 year return period hazard level was indicated the large inundated flood plain of the catchment area and 5-years return period was the low floodplain covers of catchment area and hazard level increase with increasing peak flood.

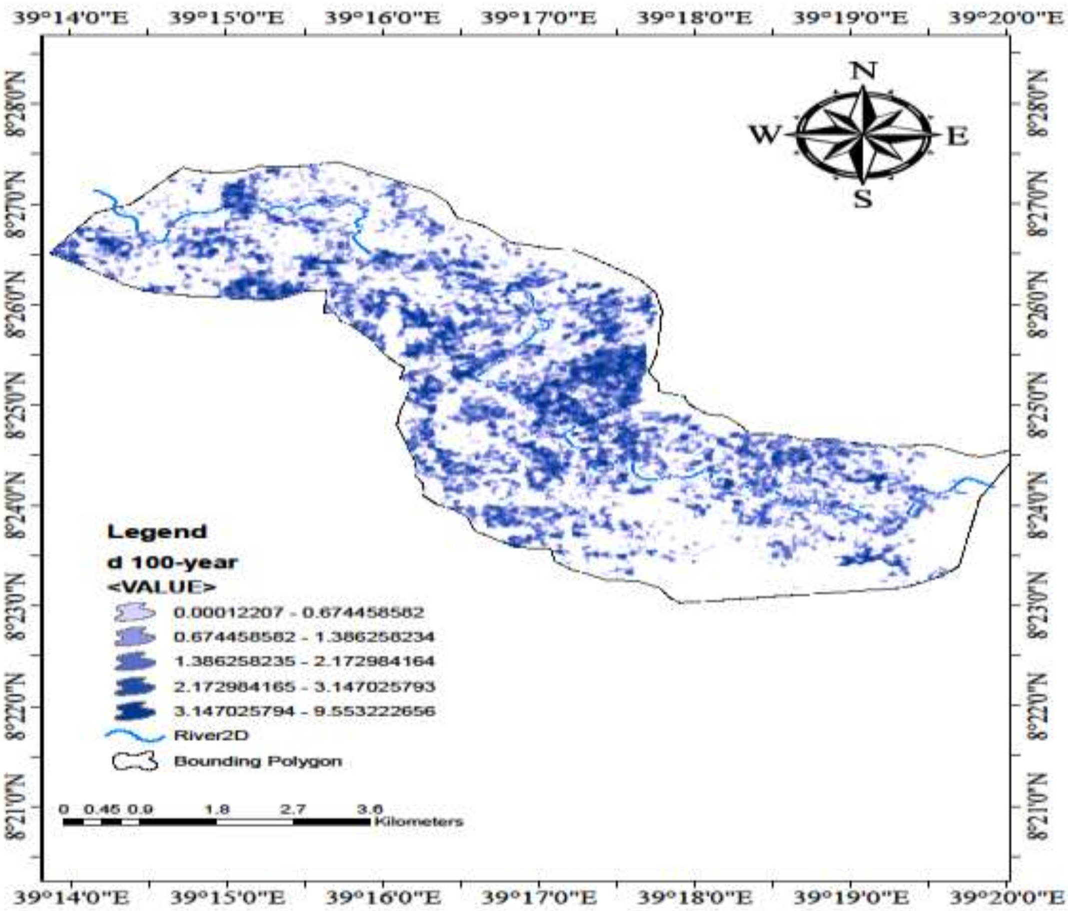


Figure 4-16: 100 years return period flood hazard level of study area

4.7 Flood vulnerability map

Vulnerability map for the floodplain were prepared by intersecting of land use land cover area with the flood area polygon for each flood plain modeled. Vulnerability identifying the land use area under potential influence of a flood of particular return period. Flood risk includes the combination of result of both vulnerability and hazard. According to the figure 4:18 of the flood areas indicated that a very high percentage of vulnerable area lied on agricultural area.

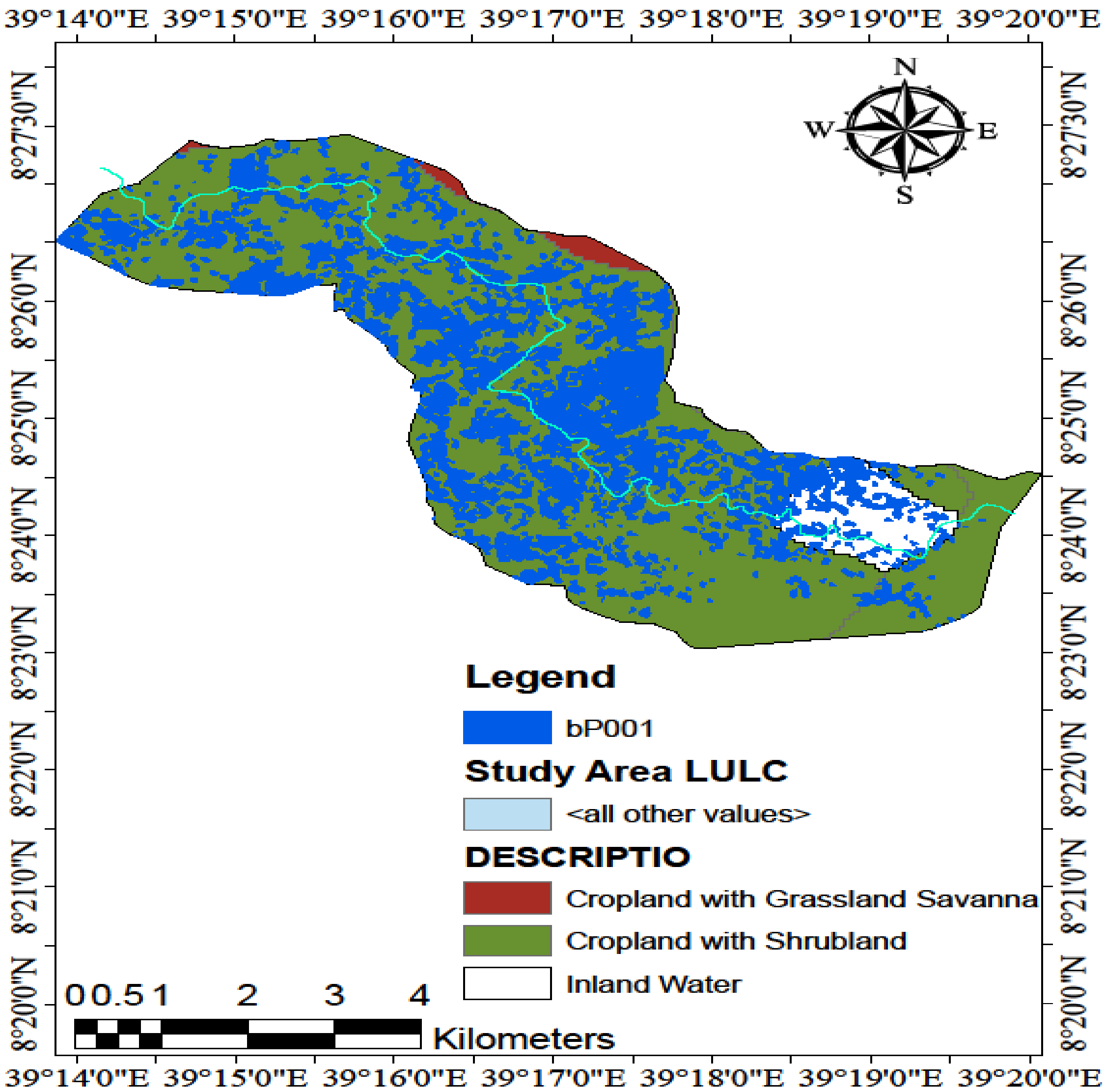


Figure 4-17: flood Vulnerability map for 5- year return period

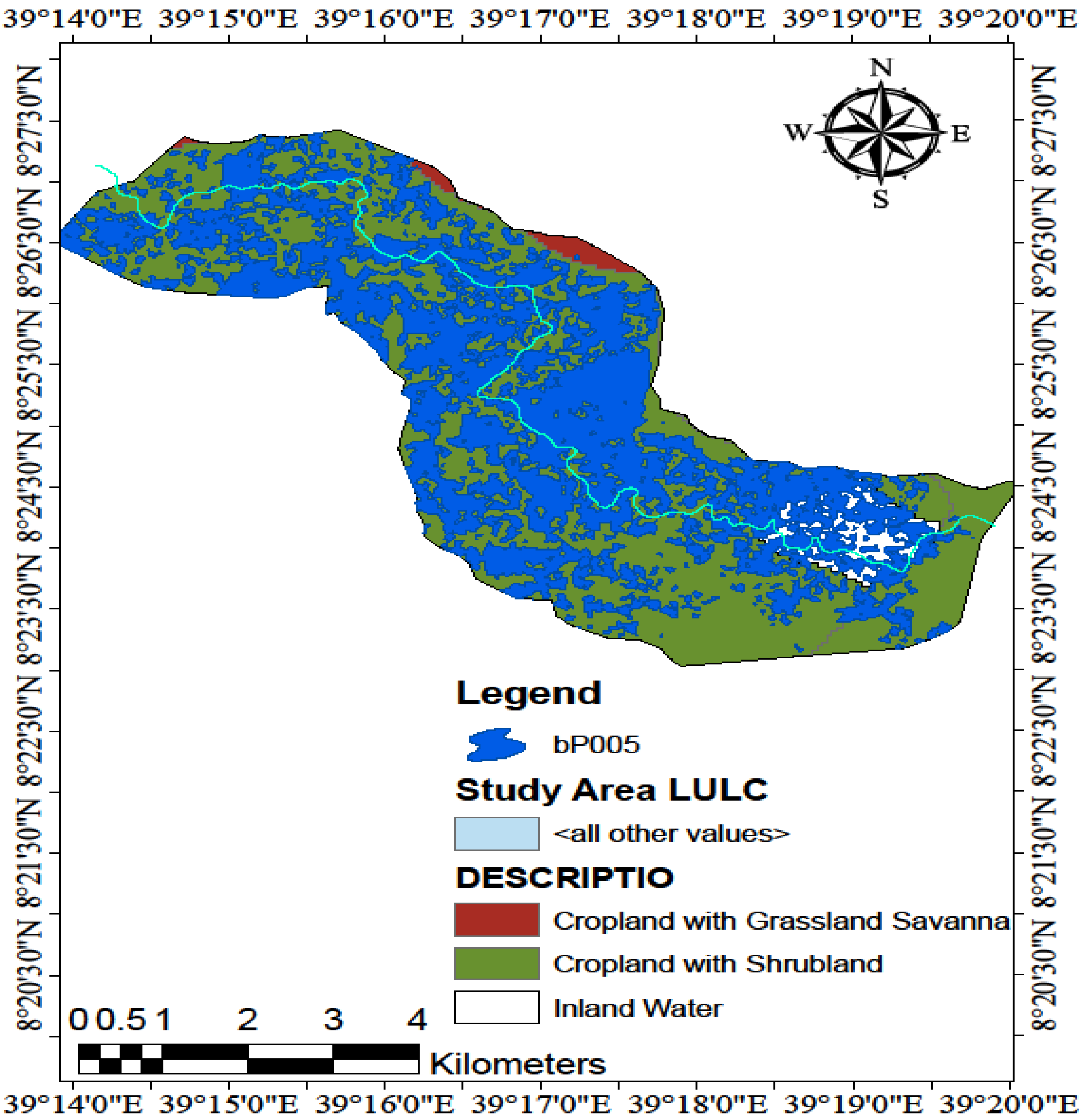


Figure 4-18: flood Vulnerability map for 100 year return period

4.8 Flood risk result

The estimated crop loss due to flooding for different return periods is indicated in table below. The location and topography of these areas make them highly vulnerable to flooding. About ninety percent of the total inundation areas were flooded over agricultural area and ten percent were water body. This study mostly focused on the risky areas especially near Awash River that include Melka Adama, Awash Melkasa, and Wakemawan kebele of west shewa zone adama weroda.

Table 4-4 Flood inundated area for different return period per crop planted

S.no	crop type	Average crop yield per hectare	percentage of covarage(%)	Flood inudated area (Hect) for differnet return period				
				5	10	25	50	100
				947.441	978.245	1286.600	1403.204	1524.696
1	Maize	35	35	331.604	342.386	450.310	491.121	533.643
2	Onion	100	30	284.232	293.473	385.980	420.961	457.409
3	tomato	150	23	217.911	224.996	295.918	322.737	350.680
5	teff	21	5	47.372	48.912	64.330	70.160	76.235
6	wheat	27	7	66.321	68.477	90.062	98.224	106.729

Flood inundated area per crop type= total inundated area*% area cop inundated*%crop planted

Table 4-5:- Crop loss for different return period

S.no	rop typ	Average crop Yield per hectare	percentage of covarage(%)	Crop loss (kuntal) for differnet return period				
				5	10	25	50	100
				947.441	978.245	1286.6	1403.2	1524.7
1	Maize	35	35	11606.2	11983.5	15760.9	17189	18678
2	Onion	100	30	28423.2	29347.3	38598	42096	45741
3	tomatc	150	23	32686.7	33749.4	44387.7	48411	52602
5	teff	21	5	994.813	1027.16	1350.93	1473.4	1600.9
6	wheat	27	7	1790.66	1848.88	2431.67	2652.1	2881.7
	Total crop loss(kuntal)			75501.6	77956.3	102529	111821	121503

Crop Loss= flood inundated area per crop type*% crop inundated* average crop production per hectare

Finally total crop losses were calculated by sum up of each crop loss. The total crop loss for 5-year and 100-year return period is 75,501.6 quintal and 121,503 quintal respectively.

CHAPTER 5 CONCLUSIONS AND RECCOMENDATIONS

5.1 CONCLUSIONS

Awash River basin has significant water resource and floods are happened frequently in the study area. The flood inundation map and flood risk analysis are an important non-structural flood risk management techniques and help preparedness to cope with such peak flood happened frequently.

The flood inundation areas have been mapped based on different return period by using hydraulic model (HEC-RAS) and HEC-GoeRAS for interference between HEC-RAS and GIS software. The flood inundates agricultural lands along the study area. The peak flood estimated by Hydrological model (HEC-HMS) using wonji gauged station were inundated area 1052.7, 1086.9, 1429.5, 1559.1, and 1694.1 hectares for 5, 10, 25, 50, and 100 year return period respectively. Due to the increased peak flood in the 100 year return period, the inundated area was very high and 5 year return period was inundated low area relative to the other return period.

The study also made flood hazard level map using water depth on the floodplain. The map was prepared with relation to different return period of peak floods. Flood hazard level were done by classified flood hazard depth into five level those are; very high hazard level, high hazard level, moderate hazard level, low hazard level and very low hazard threats level. The flood water depth increase with increased peak flood and most of the areas under flooding hazard level were moderate hazard level.

The analysis of the flood risk indicated a considerable increase in flood inundated area with peak discharge found in successive return period. The flood inundated the agricultural lands in the study area and loses the crop planting. The total annual crop losses were 75501.6, 12619.4, 102529, 111821 and 121503 quintal for successive return period. Due to the increased flood inundation area in the 100 year return period, the expected loss was very high relative to other peak flood.

Flood is natural disasters which cannot be stopped unless reduce by better planning and management techniques.

5.2 RECCOMMENDATIONS

The study area is an agricultural area, it highly exposed to flood risk especially during summery season (July and august) every year. Therefore the effective non-structural flood mitigation management such as Agricultural Crop calendar plan, Soil and water conservation activities has to be developed for the study area. The flood management measures have to be planned across administrative and sector boundaries. It is recommended to achieve sustainable management all stake holder shall contribution.

The existing control mechanism and releasing rule of koka reservoir is too simply, it cause downstream communities suffered to the flood risk. It is recommended that reservoir release rule should be developed considering flood manage situation and notifies the community via information exchange mechanism. These mechanism should include communities awareness and dissemination information (strengthen communication linkage between awash river basin authorities, woreda and communities level).

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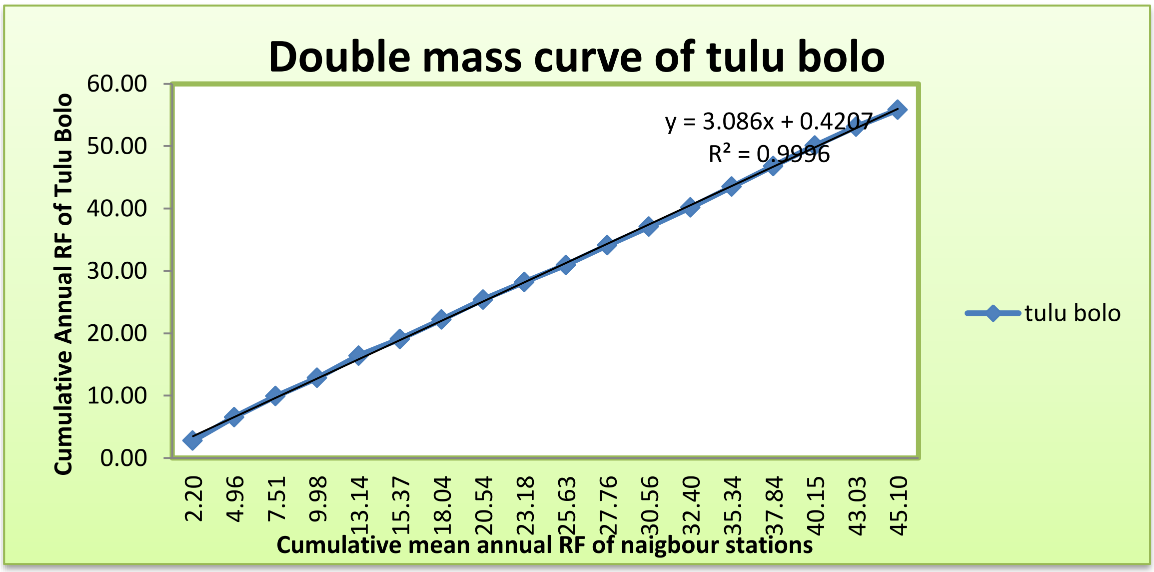
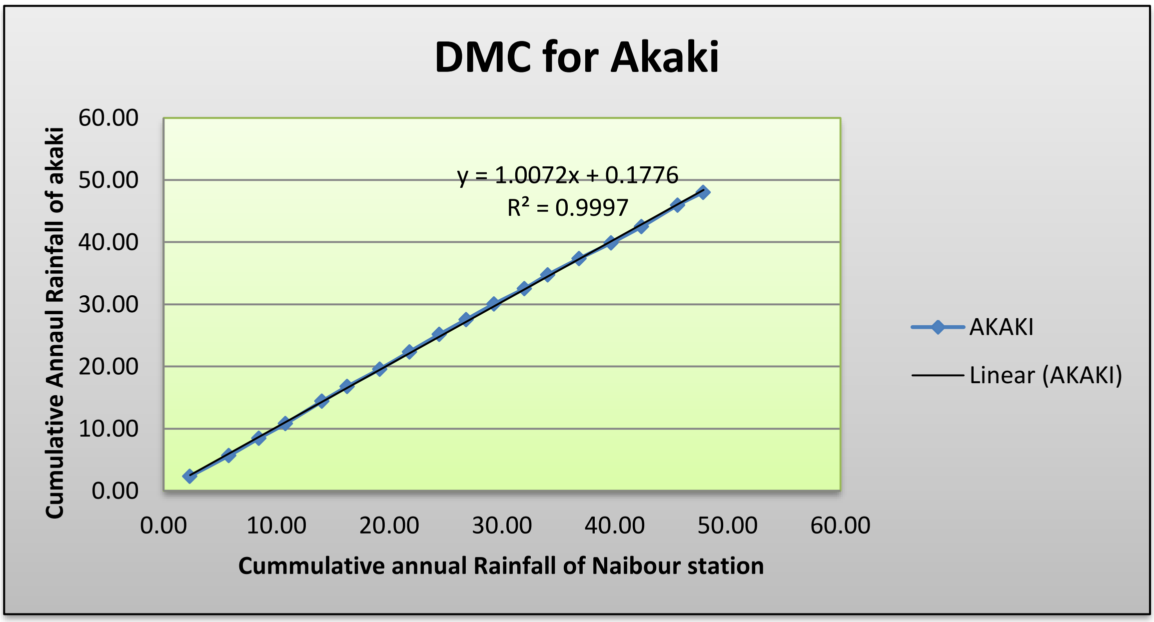
APPENDIX

APPENDIX A: Consistence test

Appendix A1: Double mass curve of Tulubolo RF station

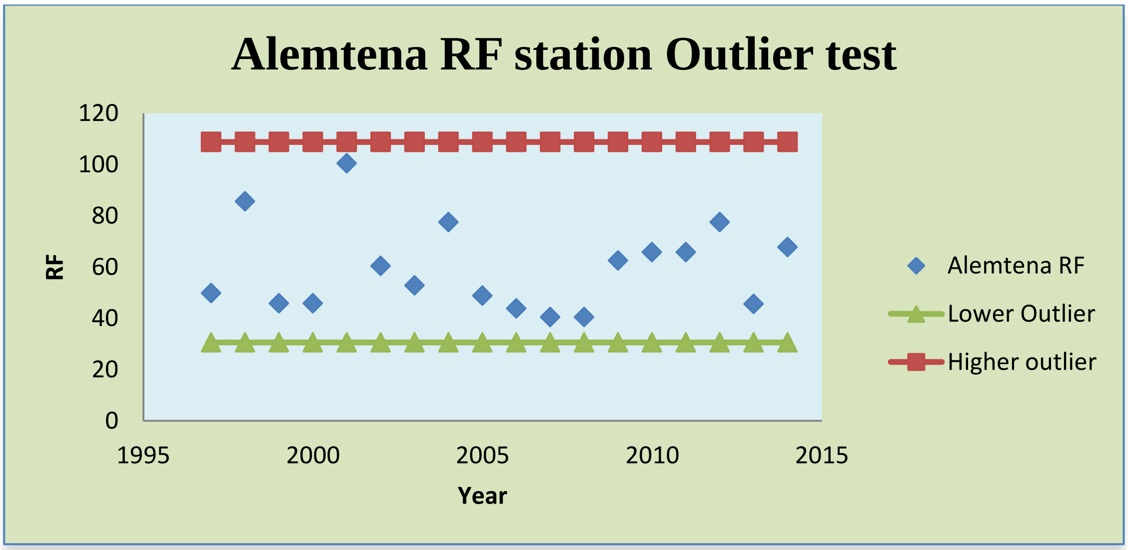


Appendix A2: Double mass curve of Akaki RF station

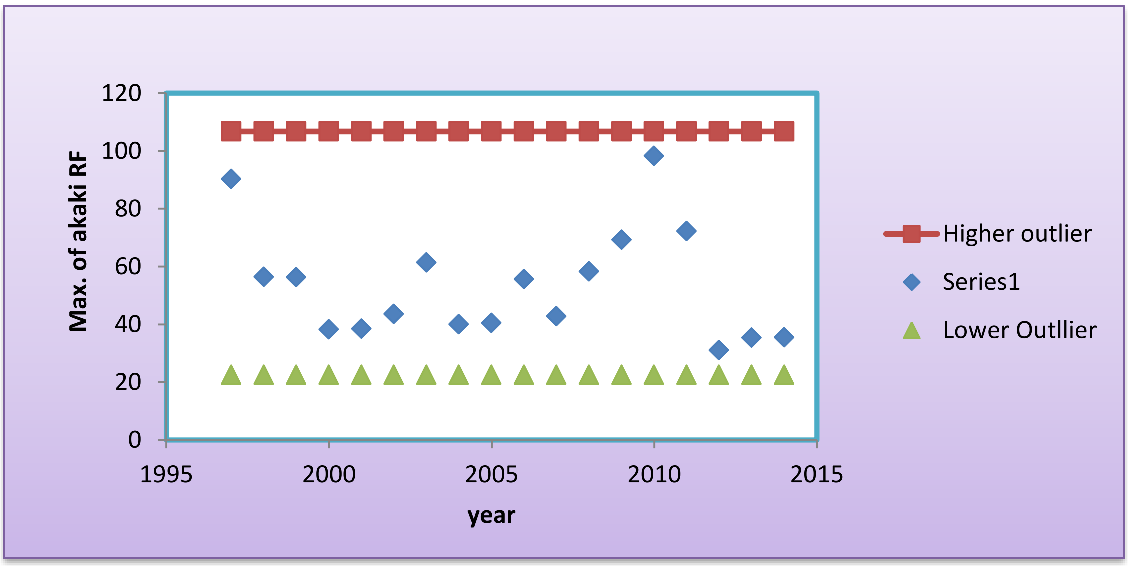


APPENDIX B: Outlier test

Appendix B1: Outlier Test of Alemtena RF station

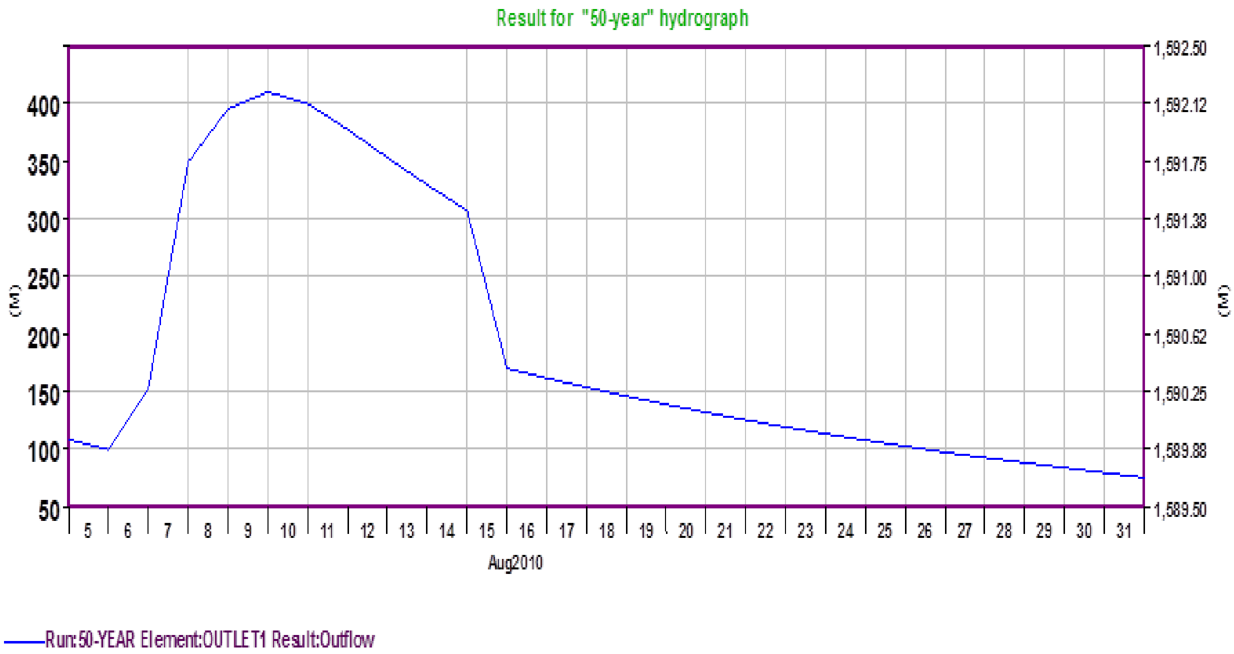


Appendix B2: Outlier Test of Akaki RF station

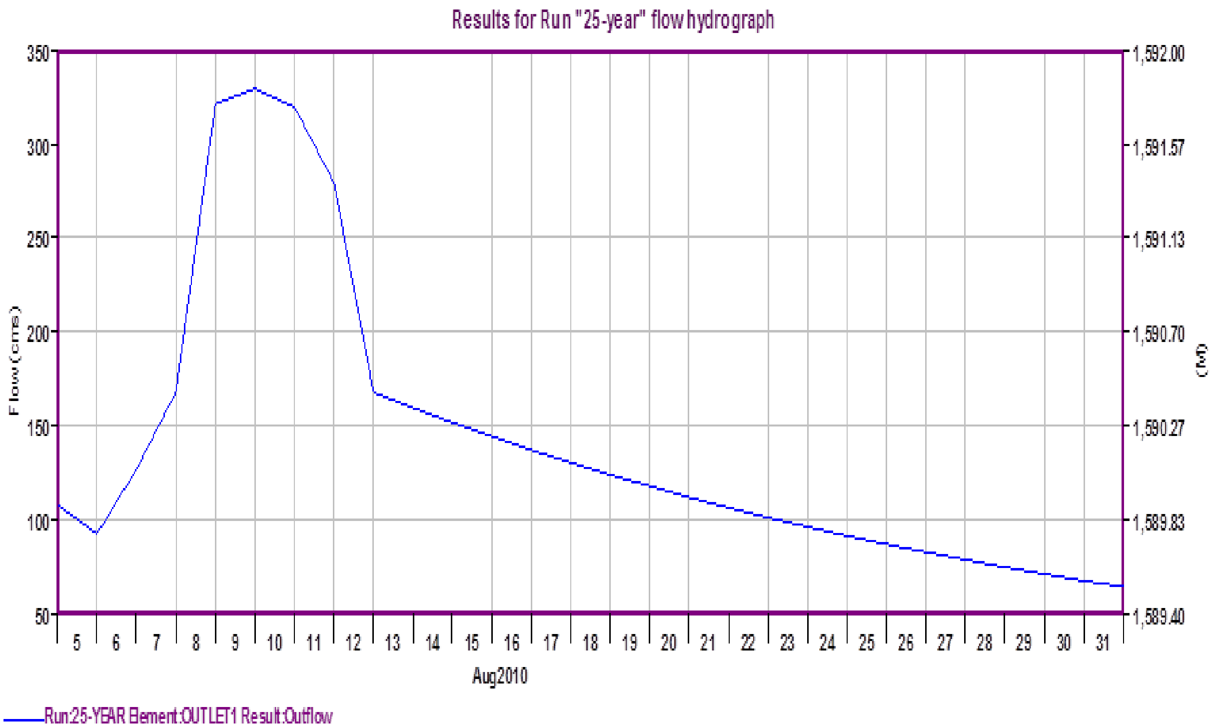


APPENDIX C: Frequency Storm hydrography

Appendix C1: 50-Year frequency storm hydrography



Appendix C2: 25-Year frequency storm hydrography



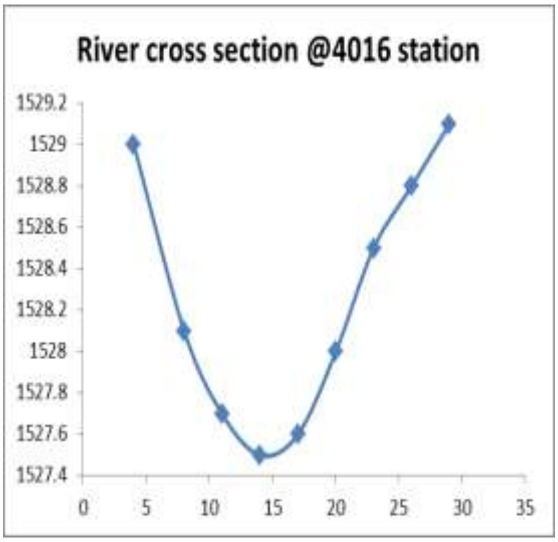
Appendix D: Field data

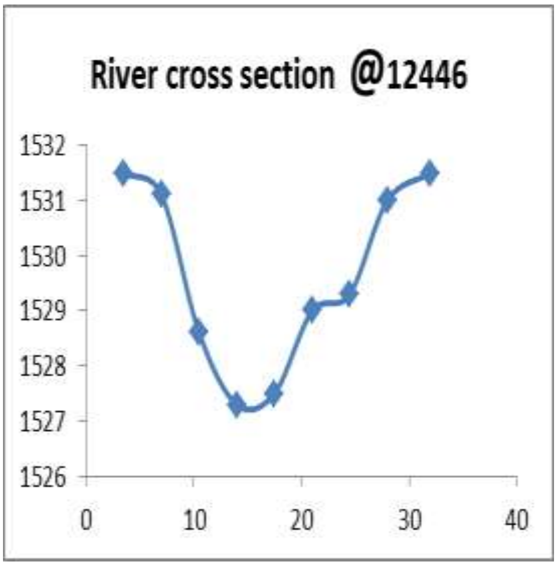
Appendix D1: Study area agricultural activities

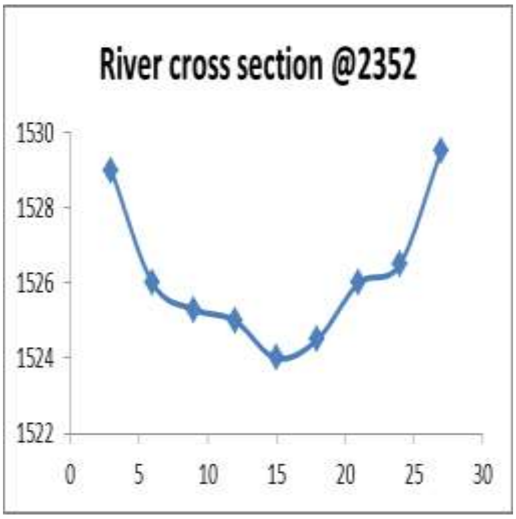
Appendix D2: Picture during field data collection

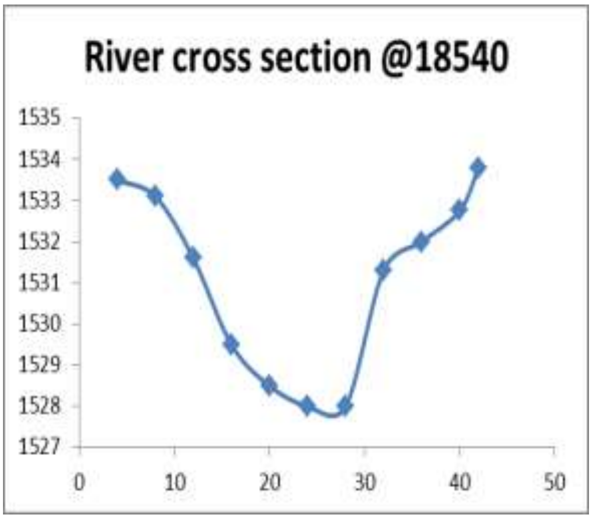
Appendix D3: Field river cross section data

Station(m)	Depth(m)	Top width(m)	Station(m	Depth(m)	Top width	Station(m	Depth(m)	Top width
18540	6	42	12253	4.5	29	6787	5.2	39
18291	5	40	11972	3	39	5950	5	31
17961	4	35	11774	4	32	5503	3.7	31
16993	4	36	11470	4.1	26	5159	3.3	33
16525	5.2	25	11199	3	29	4506	3	31
16137	3.4	27	10990	4.5	26	4233	3.7	34
15974	3.5	38	10547	4.8	32	4016	2.5	29
15760	4	28	10169	4.7	27	3540	2.5	38
15502	4.2	25	9760	6.1	29	3171	3.8	45
15154	4	28	9123	4	33	2563	4.8	49
14628	5	33	8682	5.4	32	2352	6	27
16317	6	33	8438	4.9	25	2192	3	41
13910	5	33	8209	5	34	1319	2	46
13592	4	31	8077	4.3	32	765	3.5	35
13300	4.1	38	7521	5.2	31	173	9	25
13056	3.5	27	7237	4.25	32	44	8	32
12446	4.7	33	7006	3.5	28			

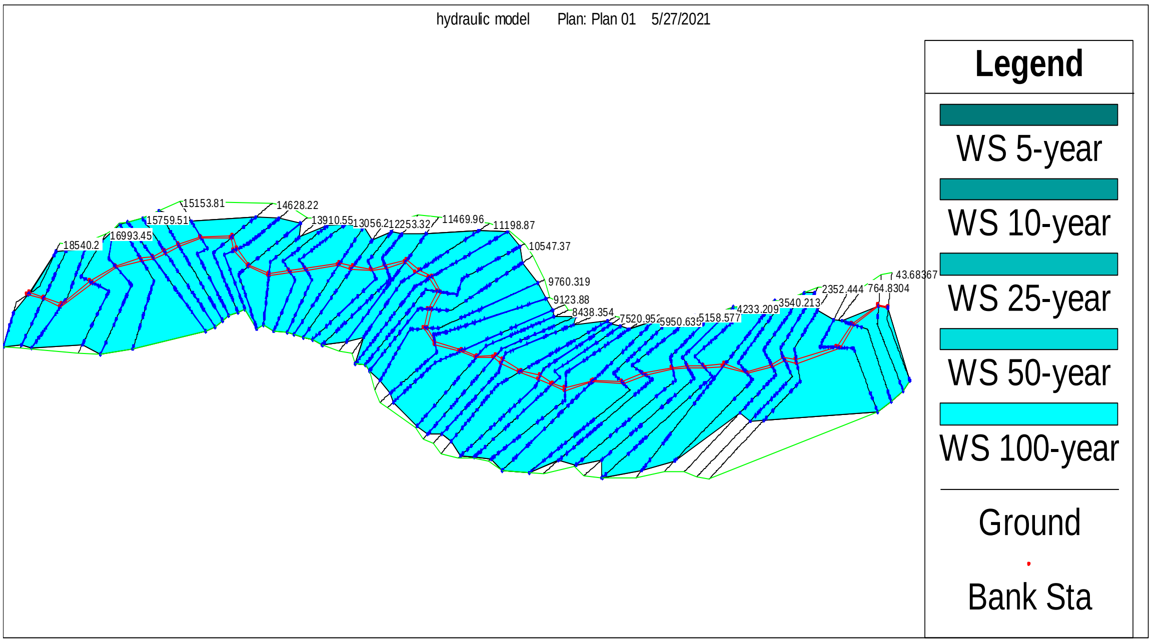




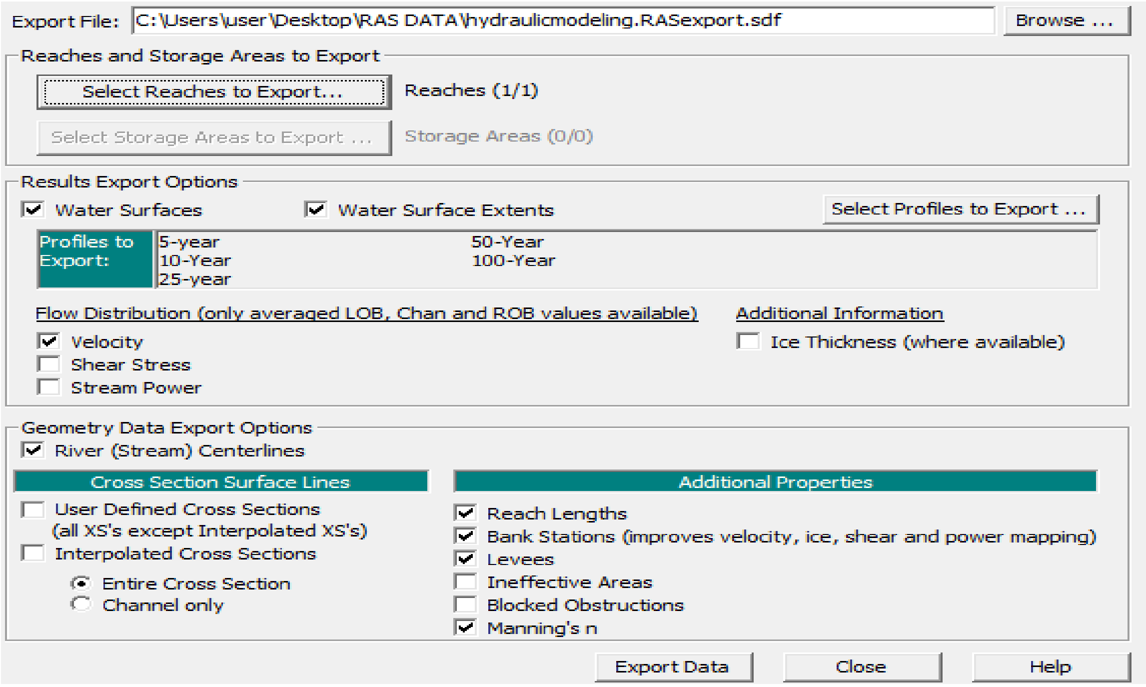




Appendix E: 3D Water surface profile

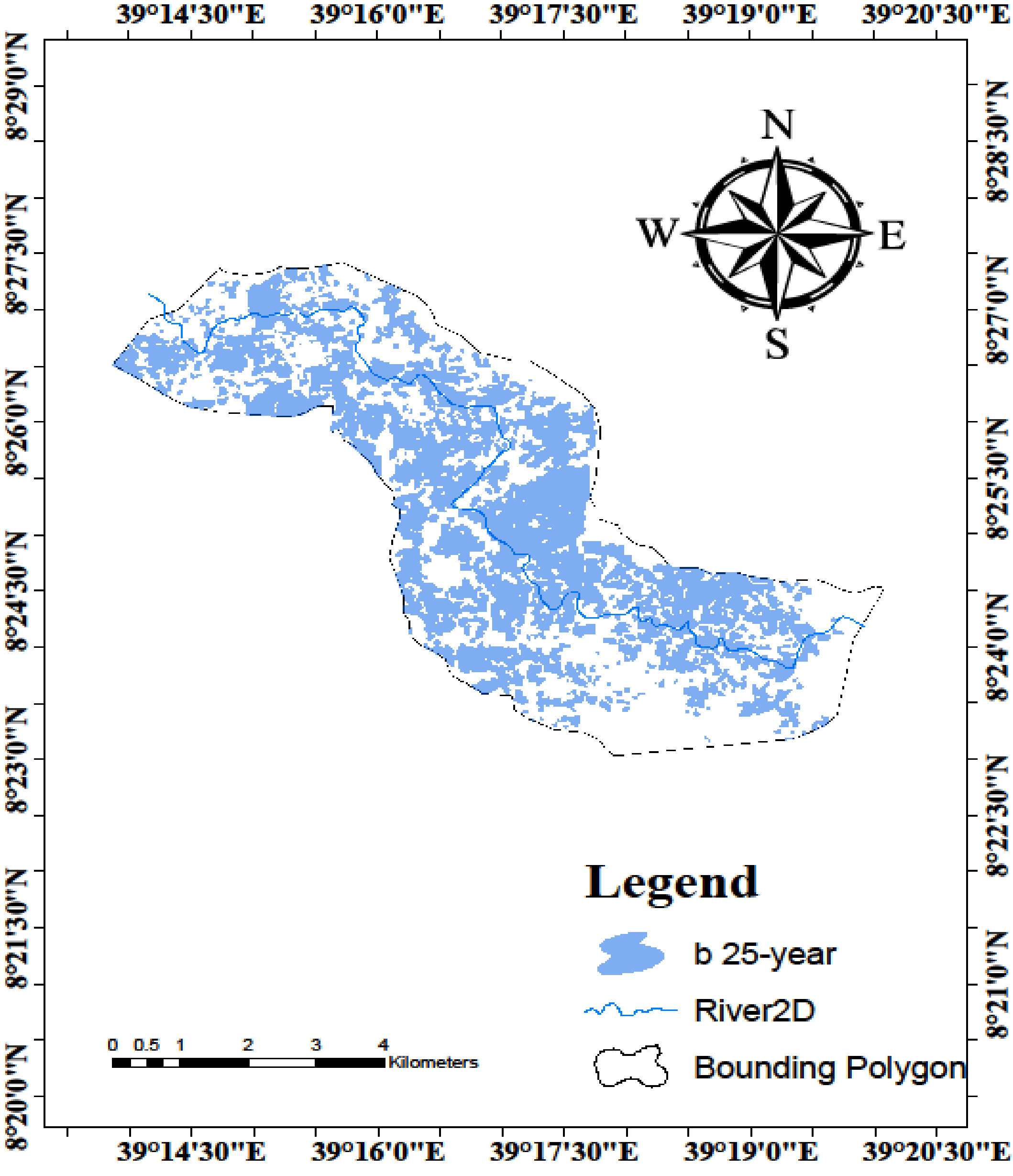


Appendix C6: HEC-RAS Geometry selected to GIS export



Appendix F: Inundation map

Appendix F1: Inundation map of 25-year return period



Appendix E: Hazard level

Appendix E1: Hazard level of 25-year return period