ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

A thesis on:

Assessment of Surface Water Potential and Evaluation of Demands: In Case of Bilate River Sub-Basin: Rift Valley Lakes Basin: Ethiopia

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

(Major in Hydraulic Engineering)

By

Aklilu Megebo

Advisor: - **Dr. Daneal Fekersillassie**.

Addis Ababa, Ethiopia
June; 2020

Addis Ababa Institute Technology

School of Civil and Environmental Engineering

This is to certify that the thesis prepared by **Aklilu Megebo**, entitled "**Assessment of Surface Water Potential and Demands in Bilate River Sub-Basin: Rift Valley Lakes Basin: Ethiopia**" and submitted in partial fulfillment of the requirements for the Degree of Master of Science (MSc) in Civil and Environmental Engineering (Hydraulic Engineering Major) compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

Approval by Board of Examiners

Dr. Daneal F.Sillassie Advisor	____________ Signature	____________ Date
Dr. Yenesew Mengiste Internal Examiner	____________ Signature	____________ Date
Dr. Fiseha Behulu External Examiner	____________ Signature	____________ Date
Dr.-Ing. Mebruk Mohammed Chairperson	____________ Signature	____________ Date

DECLARATION

I, Aklilu Megebo, hereby present for consideration by Civil and Environmental Engineering School, my Thesis in partial fulfillment of the requirement for the Degree of Master in Civil Engineering (Hydraulic Engineering major), which entitled as **"Assessment of Surface Water Potential and Evaluation of Demands in Case Bilate River Sub-Basin: Rift Valley Lake Basin".** I sincerely declare that this thesis is the product of my own efforts. The work has not been presented elsewhere for assessment. The materials that have been used from other sources are acknowledged or referred properly.

Name: - Aklilu Megebo

Contact address:

Email: - Aklilumega2020@gmail.com

Wachemo University

Signature: - ……………

Date: - *June, 2020*

CERTIFICATION

The undersigned certify that he has read the thesis entitled "**Assessment of Surface Water Potential and Demands in Bilate River Sub-Basin: In Rift Valley Lake Basin**" and hereby recommend for acceptance by the Addis Ababa University in partial fulfillments of the requirements for the Degree of Masters of Science (MSc) in Civil and Environmental Engineering (Major in Hydraulic Engineering).

____

Daneal Fekersillassie (PhD)
(Advisor)

____

Date

ACKNOWLEDGMENT

First of all, I would like to thanks the "Almighty of God" for giving me the life, fortitude, courage, wisdom, and who made it possible, to begin and finish this work successfully. Thank you so much, my Lord!

I extend my deep appreciation to my advisor Dr. Daneal. F.Sillassie for his vital help and supervision during my thesis work. I am also thankful to the staff members of Civil and Environmental Engineering School; especially, Stream of Hydraulics engineering for their support and encouragement.

I hereby appreciate the support I have gotten from various Ministry and Departments of Government of Ethiopia throughout my study period. I note with great appreciation the help I received from Water, Irrigation, and Energy Ministry, National Meteorological Agency, and Central Statistical Agency of Ethiopia. I would like gratefully to acknowledge the Ministry of Education and Wachemo University for the sponsorship I have been taken for this program. I wish also to extend my gratitude to Wachemo University Academic and vice president offices and Engineering and Technology College for their timely support.

Finally, I would like to take this chance to thanks all of my family's members specially; Solomon M. and Mihret D.; for their moral and financial support and encouragement. And also, am grateful to my friends and classmates specially; Tagese Kalsido, for the encouragement and support received from you are beyond what words can express.

To all those who have supported me in varied and vital ways, I say Thank you and God Bless You!!!

ABSTRACTS

This study was carried out in Bilate River sub-basin to assess the surface water potential and demands. A DEM, LULC and soil data, slope, and climatic data were used to describe the hydrology of study area. The annual activity level, annual water use rate and the supply data used to estimate the current and the future water demands. ArcSWAT and WEAP models were used to evaluate the surface water potential and demands. The Bilate River Sub-Basin receives an estimated mean annual precipitation of 1106.2mm. The estimated mean annual runoff in the whole watershed is 851.5MCM which correspond to 162.3mm (14.7%) mean annual depth of surface runoff is equivalent to 14.7% of mean annual precipitation. The mean annual water balance shows that the significant number of the mean annual precipitation (69.4%) received by the watershed were lost via evapotranspiration. The remaining parts of annual precipitation (172.2mm which accounts about 15.9%) received by the watershed infiltrates to the soil to recharge GW aquifers as well as to contribute to baseflow (24.2mm as lateral flow and about 140.35mm as return flow). The model was calibrated and validated by using 14 years streamflow data. The performance was found good during calibration [correlation coefficient (R^2 = 0.75), Nash-Sutcliffe efficiency (NSE) = 0.62), PBIAS =18.8] and validation (R^2=0.78, NSE = 0.61, and PBIAS = 23). The water demand part of this study was considers environmental flow requirements, domestic, agricultural, and livestock by generating different scenarios based on a different set of assumptions in the sub-basin up to 2035. The study found that the watershed is highly sensitive to the Increasing water demand scenario and Irrigation command area projection, suggesting that the slight changes will change the current and future water demands. The estimated surface water potential was 851.5MCM in the sub-basin and the current utilization of these potential was about 322MCM for consumptive use and non-consumptive (EFR). The scenarios were developed to evaluate the future demands based on different sets of "what if" situations up to the 2035. Therefore, the estimated that total annual consumptive water demand may be expected to be 235.2MCM, 298.4MCM, 447.6MCM and 541.5MCM for the reference scenario, high population growth, projected irrigation area and increased water demand scenarios and 170.3MCM for environmental flow requirement. Hence, this study consider the environmental flow requirement of 20% of the mean annual flow volume to maintain the basic ecological functioning and water balance in Lake Abaya.

Keywords**: **Bilate River Sub-Basin, SWAT Model, WEAP Model, Surface Water Runoff, and Water Demands

TABLE OF CONTENT

CONTENTS PAGE

LIST OF FIGURE

LIST OF TABLE

ACRONYMS

AMC	Antecedent Moisture Condition
a.m.s.l	Above Mean Sea Level
BRSB	Bilate River Sub Basin
BCM	Billion Cubic Meters
CSA	Central Statistical Agency
CUP	Calibration Uncertainty Program
CWR	Crop Water Requirement
DSS	Decision Support System
DHI	Dutch Higher Institute
DWD	Domestic Water Demand
EFR	Environmental Flow Requirement
EIWR	Ethiopian Institute of Water Resources
ET	Actual Evapotranspiration
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GLUE	Generalized Likelihood Uncertainty Estimation
GTP	Growth and Transforming Plan
GWP	Global Water Partnership
Ha	Hectare
HRU	Hydrologic Response Unit
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
LAT Q	Lateral Flow
LULC	Land Use Land Cover
MoWIE	Ministry of Water, Irrigation, and Energy
MoFED	Ministry of Finance and Economic Development

MCM	Million Cubic Meter
MCMC	Markov Chain Monte Carlo
NMA	National Meteorological Agency
ParaSol	Parameter Solution
PET	Potential Evapotranspiration
PSO	Particle Swarm Optimization
SWAT	Soil and Water Assessment Tool
SUFI-2	Sequential Uncertainty Fitting-version 2
SURF Q	Surface Runoff
UN	United Nation
UTM	Universal Transverse Mercator
SC	Scenario
SNNP	Southern Nations, Nationalities and Peoples
SUB	Sub-Basin
WEAP	Water Evaluation and Planning
RVLB	Rift Valley Lake Basin
SCS-CN	Soil Conservation Service Curve Number
SEI	Stockholm Environment Institute
WDM	Water Demand Management
WMO	World Meteorological Organization

1 INTRODUCTION

1.1 General Background

Ethiopia is a country having a lot of surface water resources that can be used for many purposes. The country has 12 major basins, 12 large lakes, and differently sized water bodies. However, three of the major basins are dry basins, which do not have any stream flow in these basins. Although it needs update and further detailed investigation, the country's surface water potential was identified and estimated about 122 billion cubic meter as per different basins master plans. Since most of the rivers are transboundary, 97% of this estimated annual stream flow of the country flows out of Ethiopia into neighboring countries and only 3% of this amount remains within the country (Belete, 2014).

Water resources are the critical components for the development of countries and we can understand that "water-based development" is significant to the growth and transformation of the country. The Ethiopian growth and transforming plan also considers and aims to increase the uses of the country's water resources (MoFED, 2010). Ethiopia's surface water potential is large and it is the key for development of the country, but very little of it has been developed for irrigation development, hydropower plant development, municipality, and domestic water supply, and other purposes (MoWIE, 2012).

Water is one of the essential components of the environment and plays an important role in supporting productive human activities. So, it requires proper planning and management to achieve its sustainable utilization. With increasing population including urbanization, industrial production agricultural and livestock production, demands for water has increases rapidly over the years (GWP, 2010). Therefore, investigating surface water resource potential is beneficial as well as an ability to assess the availability of freshwater resources has been an issue of importance in most countries for many decades (WMO, 2012). Many researchers have done studies on water resource availability at different spatial and temporal scales ranging from watersheds to river basins scales worldwide (e.g. (Tadesse, 2006); (Daniel, 2011). These studies indicated that the assessment of water resources was undertaken at the watershed and basin scales in many countries for better water resources planning and management. Water systems should be designed to meet present and future water demands while maintaining a range of hydrologic variations necessary to preserve the ecological and environmental integrity of the basin (Loucks, 1997).

Due to high water demand from population growth, degradation of the rivers and pollution of surface and groundwater sources, and the loss of potential sources of fresh water supply due to use of an old and unsustainable water management practices (Wang, 2005).

In order to meet the demands, efforts should be intensified on the efficient use of all water resources such as surface water, and water allocation plans to maximize the resultant economic returns to limited water resources. Surface water is the primary source of water; Knowing the potential, availability, and use of surface water would help to increase the productivity of agriculture, improved ways and means of the traditional water management systems, increase drinking water supply and hydroelectric power generation in the coming future. The assessment of surface water resources and demands, or the efficient design of water resources projects, requires an adequate estimation of surface runoff and competing demand users from catchments of the basins.

The Bilate River is used as an important source for food, domestic water supply, agriculture, wildlife, grazing and water for livestock, and as a repository for human and agriculture. This makes the issue of water resources very crucial for effective water management and advances livelihoods. In Ethiopia, where agriculture serves as a backbone of the economy as well as ensures the wellbeing of the people, the availability of water resources is quite essential.

1.2 Statement of the Problem

The Rift Valley Lake Basin is hydrologically different from other river basins in that it contains a many lakes rather than rivers. Most basins are defined by their main river, but the RVLB is a series of lakes, some of which are connected and all of the connected systems are terminal. This means that the RVLB is hydrologically sensitive and fragile, so that water becomes a primary constraint to development as well as being a primary resource. The terminal lakes are also sensitive to pollution in that they are pollutant sinks, constantly receiving them in and never releasing them. This makes environmental and water quality management highly important, crucial to the lakes' existence as a resource, and as wildlife habitats. So it better to wisely use and manage the rivers in the basin and to conserve the lakes as resources.

Bilate River watershed is one of the main river watersheds in the Southern region in the rift valley lakes basin which is extending from Gurage zone up to Lake Abaya through Hadiya, Alaba, Wolaita and Sidama zones having more land suitable for agriculture purpose and it has to supply those different zones with different ethnic groups and many populations. So, it is one of the Ethiopian watersheds that needs an integrated water resource management system.

Most of the time, the river basin master plans studies do not consider the surface water resources of the country in open water systems; even if, these systems store a huge amount of water. This indicates us change our surface water accounting system to understand the surface water potential of the country (MoWIE, 2012), and it needs detailed investigation to come up with best estimate of available surface water potential of the basin at small scale or sub-basin level.

The assessment of surface water potential of a river sub-basin for the well-organized design of water resources development projects requires an adequate estimation of surface runoff from gauged and ungauged catchments of a basin. Since the demands and the water resources potential for Bilate watershed could not accurately be predicted, this study intended to predict the potentially available surface water and demands for different sectors.

Bilate river sub-basin provides resources for the livelihoods of the living population; Bilate River is used as a source of food, drinking, wildlife, transport, grazing and water for livestock, and as a repository for human and agricultural. This makes the issue of water resource availability very crucial for effective water resource management and improves livelihoods.

Because of geographic characteristics of the rift valley lakes basin, there is no inflow of water from the other basins. Under the natural circumstances, the surface water resources in a basin are created mostly by precipitation over the watershed area. Thus, the amount and distribution of the precipitation in the basin determine the number of surface water resources in the basin.

Therefore, this study covered the estimation of surface water potential, water requirements for various uses for different sectors, and analyze the impact of different scenarios on water demand variation in the current account year and in the near future in the Bilate river watershed for a better-integrated water management and decision making.

1.3 The Objective of the Research

1.3.1 General Objectives

- ❖ The main aim of this study is to conduct surface water potential assessment, evaluation of water demands and to analyze the impact of different scenarios on water demands variation in the current account year and in the near future in the Bilate River watershed for the better water management.

1.3.2 Specific Objectives

- ❖ To estimate the surface water potential of the Bilate River sub-basin;
- ❖ To evaluate the water demands of different water-using sectors within the sub-basin;
- ❖ To analyze the impact of different scenarios on water demand variation in the current account year and in the near future;

1.4 Research Questions

- ❖ What is the total surface water resource potential in the Bilate River watershed?
- ❖ What are the potential water users and their water demands within the watershed?
- ❖ Is there enough surface water resources potential in the sub-basin to satisfy future demand in different Scenarios?

1.5 Scope of the Study

The range of this research has been limited to assess surface water potential and water demands for various requirements (i.e. irrigation, domestic and livestock's), investigation on the potential factors that affect surface water quantity, demand and supply and the possible impacts of planned water projects on the availability of surface water potential and future water demands in the watershed due to time constraint and data availability.

In this study SWAT is used for surface water potential assessment while WEAP is for demand and scenario generation assessment part only.

1.6 Significance of the Study

Bilate River watershed is one of the main river watersheds in the Southern region in the rift valley lakes basin which is extending from Gurage zone up to Lake Abaya through Hadiya, Alaba, Wolaita and Sidama zones having more land suitable for agricultural purpose and it has to supply those so densely populated areas. So, it is one of the Ethiopian watersheds that needs an integrated water resource management system. As a contribution to the regional national and regional efforts, this study of the surface water potential and demands at sub-basin will have a paramount importance to understand the better picture of water resources and water demands for different competing sectors. It can be also used as decision support system for development of different water resource projects, and provide information for the government, planners, decision makers and concerned persons while designing and developing the new water schemes in the sub-basin.

1.7 Outline of the Thesis

This thesis contains six chapters and the main concepts of each chapter are summarized below.

Chapter One: an introduction part, which gives background information on the assessment of surface water potential, water demands, statement of the problem, objectives, research questions, and scope of the study.

Chapter Two: contains a detail description of the literature review of the assessment of surface water potential and demands in the sub-basin. It also contains a rationalization of the surface water potential and demands and a brief description of the review of the Rainfall-Runoff model. Hydrologic processes are covered in this chapter, which describes the scientific principle governing hydrologic phenomenon that is a system concept.

Chapter Three: This chapter includes details of the watershed, sources of hydro-meteorological data, meteorological data analysis, meteorological data gap filling, selection of representative meteorological stations, hydrological data analysis, methods used, description of SWAT and WEAP model, model selection criteria, descriptions of SWAT input data, watershed delineation, description of model on model performance and assessment of water demands.

Chapter Four: contains model results and discussion, and model performance, Sensitivity analysis, and sensitive flow parameters and summaries on different water requirements for various uses.

Chapter Five: This chapter contains the recommendations and conclusions parts of the study.

In the end, this paper contains lists of references that were used during the study and appendixes which contains some tables, computer outputs, and data used in this research.

2 LITERATURE REVIEWS

2.1 Overview of Surface Water Potential and Hydrological Models

Water is the single most important element of the environment. The availability of water highly governs the pattern of the Earth's terrestrial biomes (forest, grasslands, and deserts). Water is also a main controlling element of the Earth's climate and its water that's principally liable for sculpting the Earth's surface into the infinitely complex associations of erosional and depositional landforms. Water makes life on Earth easily, and, to an outsized extent, water makes the world itself.

Water resources are the central elements for the event of Ethiopia. We know that "water-centered development" is important to the growth and transformation of the country. The growth and transforming plan also considers and aims to improve the uses of the country's water resources (MoFED, 2010)

Therefore, water management is one of the critical challenges the world is fronting today. In order to meet the water needs of different users, efforts should be intensified on the efficient use of all water resources (surface water, groundwater, and rainfall) and also on water allocation plans that maximize the resultant economic returns to limited water resources and, similarly, protect the fragile ecosystem (Adeboye, 2008).

Surface water is water that is open to the atmosphere and fed by runoff from the surface, such as in a stream, river, lake, or reservoir. It also one of the crucial resource that can use for different anthropogenic activities like, the public, industrial, navigation, agricultural and demand-supply purposes. Therefore, awareness surface water potential and its use is a key aspect of water resource assessment, evaluation, and development.

The assessment of water potential at the watershed level is realized by quantifying runoff generated in the watershed (Daniel, 2011).

The assessment of surface water resources, or the efficient design of water resources projects, requires an adequate estimation of surface runoff from gauged and ungauged catchments of the basins (Getachew, 2015). Water resources assessment depends on the understanding of all the water flows and storages in the catchment under consideration is also very important for water resources investigation.

First we need to determine the quantity of available water in the catchments, In order to properly mention the surface water resource potential of a certain river watershed. Accordingly, that requires an understanding of the hydrological systems and its interaction with the environment and to be able to properly describe the water flow, 'in and out', of the basin. Information and data regarding the basin such as runoff, evaporation, and rainfall, for example, are some of the components that would be necessary for describing the water movement or circulation (Daniel, 2011).

Although there are different types of hydrologic and water resources models capable of simulating surface runoff and demands in a given catchments, the selection of suitable model for a specific study is really important to come up with adequate estimation results for the study area. Among these models, SWAT model selected to simulate surface runoff as well as others hydrological parameters and WEAP for demands in the sub-basin. Due to increasing number of availability, wide-ranging characteristics, and potential applications of the models, it's becoming a challenging job for the potential model users to settle on a specific model best suited for the given problem.

Hydrological Models to Assess Surface Water Potential

Although the hydrological processes are a system that is fairly easy to grasp and understand, is far from easy to quantify the process. Models are simplified systems that represent real systems (may be the whole river basin or parts of it). They can also respond to simulate natural process of the flow surface runoff and sediment yield within watersheds, also as quantify the impact of human activities on these processes.

The mathematical descriptions of the elements of the hydrologic process are called Hydrological models. They have been developed for many different reasons and therefore have many different forms. However, hydrological models are in general intended to satisfy one or two primary objectives. The primary objective of the watershed hydrologic modeling is to get a better understanding of the hydrologic processes in a watershed and how changes in the watershed may those phenomena (Tadele, 2007). Several hydrologic models are widely used for the assessment of the water resource. Rainfall-runoff models have broadly used in hydrology over the last century for a number of applications, and play an important role in optimal water resources planning and management in catchments reported that the main challenge associated with applying successfully rainfall-runoff model lies in the lack of monitoring data, mainly rainfall spatial distribution over the catchment area, since rainfall is the primary input in any hydrological model. Another potential problem is having no reliable flow data that can lead to reliable calibration and validation of catchment parameters.

Physically process-based models are described by mathematical formulated fundamental physical laws, where each basin is represented by a concept; a reservoir for instance. Empirical models are a synthesis and a summary of the field or experimental observations. Their fundamental parameters are not compulsory physically related. Empirical models are based on defining important factors through field observation; measured, experiments, and statistical methods. Empirical models are models that mainly developed as the result of many years of researches work. Statistically based models use many observations to estimate the behavior of watersheds and their interactions.

On the basis of the process description, the hydrological models can be classified into three main categories (Cunderlik, 2003).

Lumped model: - the Parameters of this do not differ spatially within the basin and thus, catchment responses are evaluated at the outlet of only, without explicitly considering the response of individual watersheds. The parameters often do not indicate physical attachment of hydrologic processes and usually involve a certain degree of empiricism. These models are not usually appropriate for events level processes. If the interest is primarily within the discharge prediction only, then these models can provide even as good simulations as complex physically-based models.

Distributed models: - These models can provide the highest accuracy in modeling rainfall-runoff. Parameters of these models are fully spatially varied at a given resolution and therefore require considerably more input data (Cunderlik, 2003).

Semi-distributed models: - Parameters of semi-distributed (simplified distributed) model is partly allowed to differ in space by dividing the basin into a number of small sub-basins. These models are more advantageous because more physically attached than the structure of lumped models, and less demanding on input data than fully distributed models. SWAT and HEC-HMS are the models developed and considered as semi-distributed models.

The HEC-HMS is developed by a group the United States Army Corps of Engineers HEC is designed for both continuous and event-based hydrologic modeling processes. It provides several different options to the users for modeling various elements of the water cycle. Originally, it was developed to model the rainfall-runoff processes for dendritic watershed but later it had been improved to unravel a variety range of problems including large river basin water supply, flood hydrographs, and natural watershed runoff. Limitations of this model, HEC-HMS does not simulate most of the components of the land phase of the water cycle like groundwater flow, it needs other HEC software to delineate the catchment and it needs smaller data than SWAT model.

The Soil and Water Assessment Tool (SWAT) model is a physically-based, continuous, theoretical, long-term, distributed watershed-scale hydrologic Model. SWAT was designed to calculate the land management practices' impact on the hydrological parameters, sediment yields and contaminant transport in large, Complex catchment. The only SWAT model that can simulate all the land phase elements of hydrologic cycle such as surface runoff, percolation and deep percolation, return flow, total water yield, and sediment transport, groundwater flow, channel transmission losses, total aquifer recharge, evaporation, plant water use and other supporting processes from small, medium and large watersheds.

For this reason, SWAT is increasingly being used to support decisions about alternative water management policies in the areas of land-use change, climate change, water rearrangement, and pollution control. There are numerous applications of the SWAT model all over the world (Dhami, 2019).

Out of the mentioned hydrologic models, only the SWAT model can simulate all of the components of the land phase of the water cycle. All the above descriptions of different scholarly models to quantify surface runoff potential in a given basin lead to the conclusion that the Soil and Water Assessment Tool (SWAT) model is the best fit to solve the problem in my study area. The SWAT model is basin level model where runoff is simulated based on the type of land uses and soil type of soils (Arnold, 1998), has a comprehensive structure that models basically all hydrologic processes in the watershed over long periods of time (Neitsch, 2005).

The Soils Conservations Services (SCS-CN) is used to predict runoff, which links rainfall response to soils, land use, and antecedents moistures conditions (AMC), and it is widely applicable in predicting event-based runoff volume (Teka, 2014). The SCS-CN is the best permanent methods for estimating the volume of direct surface runoff in the ungauged catchment (watershed) and is developed from an empirical study of runoff in small catchments (Kousari, 2010).

2.2 Overview of Water Demands and Water Resources Models

Water demand is defined as the volume of water requested by users to satisfy their needs. Water demands predicting is also a process achieved through several techniques and is typically used to predict future water needs for different uses including hydropower, domestic, and agricultural water demands. The type of technique used depends on the availability of the data needed, the general scope of the region for which the forecast is being conducted, and the resources available to the organization for which the forecast is being conducted. For all intents and purposes, future water demand is derived from basic functions. For all intents and purposes, future water demand is derived from basic functions. For instance, municipal demand is generally projected using population size and the number of households, industrial demand is often based on the number of employees, and agricultural demand commonly relies on crop type and irrigated land (Water Resources Planning (Dzurik, 1996). Water demand is an important technical design parameter. It can be measured (for an existing project scheme) or calculated using local data or more typically, established norms and Standards. Such calculations also take into account the number and type of users to be served, the anticipated population growth rate and the expected life span of the infrastructure being provided. It is also important to take into account the seasonal influence on water demand.

The key variables such as population growth rate, highly urbanization increment, increasing irrigation water consumption, changes in cropping patterns, increasing productivity of rain-fed agriculture, and the water demand for the environment and pollution controls were considered in forecasting future water requirements.

The accelerated growth of population, the rapid advances made in industry and agriculture have resulted in a rapidly increasing use of water by man, to the extent that the availability of water, as well as the control of excessive water, has become a critical factor in the development of the world. Over the decades, water supply management has proved to be insufficient to deal with strong competition for water with growing per capita water use, increasing population, urbanization pollution, and storages. Also, the need for domestic, industrial, and agricultural water supply is growing, but the absence of demand management strategies means that the increase in demand will likely outstrip the available supply, hence water scarcity is occurred (UNESCO, 2006). The issue of water scarcity in the world and its implication on the development of new political and economic relations among countries may result in a crisis in the future. The administration of water resources as a common resource would require trade-off among countries and water users ((Yang, 2007).

Over the years, population growth and urbanization, industrialization, and the expansion of irrigated agriculture are arresting rapidly increasing demands and pressure on the water resources, besides contributing to the rising of water pollution (GWP, 2010). The quantity of water that the population uses depends on minimum needs, amount of water available for use, level of economic development and extent of urbanizations. There are three categories of freshwater use globally: for agriculture, industry, and domestic (personal, household, and municipal) of which agriculture dominates.

Although Ethiopia's surface water resources are huge, very small volume of it has been developed for Irrigation, hydropower plants, domestic water supply, and other purposes. National coverage of potable water supply stood at 26% by 1992 while coverage of sanitation services is only 7%, which is low by even the Sub-Saharan standards. There is also a wide divergence in the water supply coverage between urban (76%) and rural (18.8%) areas. There is also a wide divergence in the water supply coverage between urban (76%) and rural (18.8%) areas (Seleshi, 2010). in order to satisfy the demands of water of different users, efforts should be intensified on the efficient use of all water resources (surface water, groundwater, and rainfall) and also on water allocation plans that increase the overall economic returns to limited water resources and, equally protect the fragile ecosystem.

Water consumption rate will be increased twice since 1950 (UNESCO, 2006). The direct consumption by the man and animals constitute about 50% of the freshwater use while agriculture (crop production, aquaculture, land, and water conservation), which is the predominant user, accounts for about 70% globally, and up to 95% in several developing countries. In order to cope with the ever-expanding demand for food, it has been estimated that in the next 30 years, about 14 % more freshwater will be withdrawn for agricultural purposes.

According to (Flint, 2004); the requirements for water of sufficient quantity and quality for human consumption, agriculture, and industrial uses will continue to intensify as the population increases and global urbanization, industrialization, and commercial development accelerate. Therefore, water management is one of the critical issues the world is facing today. Therefore, Water demand management (WDM) is essential to being part of the challenge to sustain the water resources. So Computer-based Decisions Supporting System is being used worldwide in order to manage more wisely our water resources (Arranz, 2006).

DSS allows decision-makers to combine personal judgment with computer output, in a user-machine interface, to produce meaningful information for support in a decision-making process. Such systems are capable of assisting in the solution of all problems using all information available on request. They use quantitative models and database elements for problem-solving. They are essential part of the decision maker's approach to problem identification and solution. A DSS must help decision-makers at the upper levels, must be flexible and respond to questions quickly, must provide for "what if" scenarios, and must consider the specific requirements of the decision-makers. Additional important characteristics are accessibility, flexibility, facilitation, learning, interaction, and ease of use (Simonovic, 1996).

Integrated management water needs consideration of current and future water resource availability. It involves a simulation of water demand and supply for agriculture, hydropower production, domestic sector, and the industrial sector. There are various models that can be used for appropriate water sharing based on resource availability. We have also two categories of water allocation models. These are simulations and optimizations models. Simulation-based water sharing models are used mass balance principles for the water allocation in a river watershed. Examples of these models are Mike Basin and WEAP.

WEAP calculates the operation of urban and rural water supply system during droughts periods, normal and high streamflow periods. The study inducts that fast economic and population growth has driven increased demand for water from the industrial and urban sectors then it set as a solution is to improve water supply by reducing shortfall application of irrigation.

The Mike Basin model is a river management model that addressed water allocation, conjunctive use, and reservoir operation. It can be characterized as a conceptual, distribute, and deterministic modeling system. The model is used by DHI Water and Environmental council to simulate river flow. Finally, the model provides a powerful means of simulating water availability under existing conditions.

Water Evaluation and Planning is a common simulation model developed at the SEI and incorporates some physical and hydrological system with the management of demands and infrastructure to allow for multiple scenario analysis. The model is used to evaluate water demand and it also allocates the water resource among various water-consuming activities and functions, under constraints (irrigation, domestic, environmental water demand, and industrial supply) set by the modeler. During allocation, it develops as a node-connected network, which represents the system. The nodes included in the network are source nodes (rivers, reservoirs, and groundwater aquifers), demand nodes (irrigation fields, domestic, environmental water demand, and industrial supply) for proper water allocation.

WEAP will attempt to supply all demand by considering demand Priority. A priority refers to the demand site's priority for supply relative to all other demands on the system. The graphical user interface of WEAP makes use of the model relatively simple and it requires relatively little data.

The relevant models which are commonly used in modeling water demand all over the world along with their suitability and limitations are presented here to reach the conclusion that the WEAP model was selected as the best suitable to model the water demand in my study area.

Water Evaluation and Planning System (WEAP)

The WEAP model tries to discourse the break between water managing and watershed hydrology and the requirements that an effective IWRM be useful, easy-to-use, affordable, and readily available to the broad water resource community (Yates, 2005). In addition, the data structure and level of detail may easily customize to meet the requirements of a particular analysis and to reflect the limits imposed when data are limited (Yates, 2010).

WEAP, in opposite to many other models, is not optimization focused in the sense that the optimal water sharing will be presented. The entire approach is based on assumptions to ensure that stakeholders, water managers, and policymakers are actively involved in the entire process of planning in order to guarantee the ownership feeling of the end decision making taken.

WEAP, in opposite to many other models, is not optimization focused in the sense that the optimal water sharing will be presented. The entire approach is based on assumptions to ensure that stakeholders, water managers, and policymakers are actively involved in the entire process of planning in order to guarantee the ownership feeling of the end decision making taken.

The WEAP has two main objectives based on the principle of constraints of water balance

1. Simulation of hydrological parameters like evapotranspiration, runoff, and infiltration to enable assessment of the potential of water within a watershed;

2. Simulation of anthropogenic movements on the natural system to affect consumptives and non-consumptives water requirement to enable evaluation of the impact of human water use.

2.3 Water Demands and Demanding Sectors

As we know there are two types of water uses such as consumptive and non-consumptive water uses and discussed below in detail as per my study area

2.3.1 Agricultural Water Demands

Ethiopia has a significant irrigation potential identified from both available land and water resources agriculture would supply irrigators with sustained livelihoods and improve general well-being.

Irrigation is the process by which water is applied to the soil artificially and which can increase agricultural production can be increased to meet the growing demands in Ethiopia (Awulachew, 2007). The expanding irrigation various scales, through river diversion, is one of the best solutions to consider for reliable and sustainable food security developments (Robel, 2005). Efforts are being made to involve farmers progressively in various aspects of management of small-scale irrigation systems, starting from planning, implementation, and management aspects, particularly, in water distribution and operation and maintenance to increase the irrigated agriculture productivity.

Water is supplied to agricultural fields in the form of irrigation to satisfy crop water requirements.

The depth of water required to encounter the water loss via evapotranspiration is considered Crop water requirements. ET_o is a climatic parameter stating the evaporation power of the atmosphere. The amount of water required to compensate for the evapotranspiration loss from the cropped field is defined as a crop water requirement. The demand of irrigation water fundamentally equivalent with effective rainfall minus the requirement crop water.

ET_O is articulated in mm per day and exemplifies the mean value over that period. For areas where measured data on temperatures, humidity, wind speed and sunshine radiation are available, an adaptation of the Penman-Monteith method is recommended by FAO to estimate reference ET_O according to FAO.

According to the RVLB master plan, there is around 8000 ha of land are identified for irrigation schemes but not yet fully implemented for the main crops such as maize, cotton, and vegetables. As a result, these crops were chosen to estimate the requirement of water by crop for proposed irrigation. Therefore, irrigation water demand was estimated by using the WEAP model by providing the total command area and crop water demand per hectare of land to be irrigated.

2.3.2 Domestic Water Demands

Public water companies provide water for different using categories such as:

- ❖ Domestic use by households
- ❖ Municipal use by government agencies for public functions, e. g. watering public lawns
- ❖ Commercial use by all kind of public and private offices, agencies and institutes
- ❖ Industrial use by factories.

The following deals with the demand of the first three categories; domestic, municipal, and commercial water demand. These demands depend, among other things, on:

- ❖ Number of people within the considered area
- ❖ Connection rate for different types of supply
- ❖ Per capita consumption, which depends on such factors as level of development, type of supply, and price of water.

Estimating water demands for domestic supply and use at a catchment level for rural areas in Ethiopia is problematic owing to the lack of measured data available. Estimates of rural demand and use are mainly difficulties by the lack of definitions of the terms used. Hence in the context of assessing rural water demand and use it is important that various terms are clarified.

There are two main methods for assessing rural domestic demands:-

These are:

- ❖ Indirect methods, where the quantity of water consumed is calculated from population levels and estimated demand levels in terms of per capita consumption
- ❖ Direct methods where socio-economic surveys and participatory techniques involving the relevant stakeholders are used to estimate the current and future water demand.

In general estimation of rural water demand and use is difficult because:

- The majority of rural domestic water supply systems are unmetered;
- Data concerning domestic rural water demand and use is often expensive and time-consuming to collect;
- The level of service provided by the water supply system is often unknown.

For catchment management purposes indirect methods are the most appropriate for establishing rural domestic water demand and use.

Many projects of water supply in rural areas are fairly basic; however, the patterns of use and demand are more complicated and tend to be dependent on many factors. Such factors include Population, Household occupancy rate, Level of service of the water supply for each household, Tariff levels, Willingness and ability to pay, Local knowledge and indigenous practices, Cultural values, traditions, and religious beliefs, Climate and Water quality.

For this study, indirect methods for estimating rural demand were used which are relatively straight forward to use and are the most practical method for the demand estimation on a sub-catchment and catchment basis.

The Bilate River stretches Gurage zone to Lake Abaya through Silte, Hadiyya, Alaba, and Wolaita zones which are known by their higher population density. It is assumed that all the rural people adjacent to the river use the water for domestic purposes.

2.3.3 Livestock Water Demands

One of the first steps required for the livestock water use assessment is to gather proper knowledge of the animals, their populations, and the conditions in which they are managed. Water is critical for livestock health and production. Water requirements vary considerably depending on the species of the animal, breed, age, growth rate, pregnancy, production status, activity, feed type, and weather. Water requirement and intake are also highly affected by climatic factors particularly environmental temperature. Up-to-date steps to calculate water requirements of livestock species (as influenced by physiological status and environmental conditions) can be obtained from standard scientific guidelines detailing nutrient requirements of a livestock species. For example, the latest equations to determine the drinking water requirement of various classes of beef cattle are presented in a document released recently by (NAS, 2016).

Water use assessment on farm-scale requires the construction of a series of water balances to determine flows in each different component of the system. Ideally, data collected from water meters located on the farm may provide water use data but may provide little information on water consumption. In many cases, water consumptions and flows must be predicted by indirect means, based on livestock production, feed intake, crop production, climate and other data collected during a site assessment.

Often, greater than 90% of consumed water by livestock is associated with the production of feed (Legesse, 2017), to assess livestock water use, its productivity, and related impacts, it is necessary to define the population associated with the production of the products of interest (e.g. milk, meat, eggs, etc.).

There are no recent counts of livestock population density, but many pastoralists are moving with their large herds of cattle and other livestock in response to the annual regime of the Bilate River watershed area with their castles, sheep and goats and equines in searching for water and food for them.

2.3.4 Environmental Flow Demands

The environment is increasingly being considered a legitimate water user in many world countries. As a consequence, the water requirement of the environment needs to be estimated. The water amount that will be allocated to the environment is a decision made by society and is to some extent arbitrary. The quantity of water allocated to the environment will always be less than what the environment ideally would require, namely the natural, undisturbed, flow regime of a river. Society, therefore, has to weight the potential costs and benefits to the environment and to all other water users, of allocating (or not) a certain amount of water to the environment. In so doing, society accepts a certain modification of the natural ecology. This accepted level of modification may differ from river to river, and is sometimes defined in terms of "ecological management classes".

The environmental or Instream flow requirement is often defined as how much of the original flow regime of a river should continue to flow down in order to maintain the riverine ecosystem in a prescribed state. However, an environmental Instream flow often fulfills a number of different functions. Despite the simplicity of the concept, difficulties arise in the actual estimation of EFR.

This is mainly due to the lack of both the understanding of and quantitative data on relationships between river flows and multiple components of river ecology.

Since there is no hydropower generation existing at present in my study area and no data for the proposed projects in the sub-basin, the requirement water for non-consumptive uses were considered as environmental flow only requirement. Water resources planning, management, and allocation are the very important elements of EFR. The acceptable environmental flow benefits the health and maintenance of the aquatic ecosystem. The environmental flow in this study was assigned to be a suitable percentage of mean annual runoff, where streamflow is required at a point on a river to meet the different ecosystem related water demands such as maintaining river water quality, fish, and wildlife, etc.

The destination of Bilate River is Lake Abaya for the purpose of ecological conservation some reasonable percentage of river flow will be conserved to maintain the water level in Lake Abaya.

2.4 Description and Selection Criteria of Models

2.4.1 Selection Criteria of Models

So as to select the hydrological model, we consider different criteria. Most of the time these criteria were depends on research problems as well as objectives since every project has its own specific requirements and needs. But sometimes this criterion's depend on personal preference, computer operating system. These are required model outputs for the needed purpose, different hydrological processes that are required to be modeled for the desired purpose, input data availability and price. The hydrological practice would be improved if models were objectively chosen on the basis of making the best use of the information available and following some systematic procedure of selection and verification (James, 2009).

Based on the above criteria model selection were considering with wide-ranging availability of data, level of application, purpose, required accuracy, space and time scale, catchment area, simplicity, previous studies in the surrounding area as well as Ethiopia and to achieve the research objectives.

There are a lot of criteria that can be used for selecting the suitable model. These criteria’s are also projected dependent since every project has its own specific requirements and needs.

Depending on the following reason:

- ❖ Required model outputs important for the needed purpose and therefore to be estimated by the model - does the model predict the variables required by the project.
- ❖ Hydrologic processes that need to be modeled to estimate the desired outputs adequately
- ❖ Availability of input data - can all the inputs required by the model be provided within the time and cost constraints of the project
- ❖ Price - does the investment appear to be worthwhile for the objectives of the project?

In addition to the above criteria, adaptability of the hydrologic model, the type of problem is also considered. Items that should be considered in the selection process include:-

- ❖ The nature of the physical processes involved,
- ❖ The use to be made of the model,
- ❖ The quality of the data available and
- ❖ The decisions that rest on the outcome of the model's use

Based on the above criteria models were selected by considering wide-ranging availability of data, level of application, purpose, required accuracy, space and time scale, catchment area, simplicity, previous studies in the surrounding area as well as Ethiopia and to achieve the research objectives.

Therefore, SWAT and WEAP models were proposed for this specific research considering the above criteria.

2.4.2 Description of the SWAT Model

The SWAT model divides the watershed into HRUs based on the land use, the soil types and the slope classes. The model estimates relevant hydrologic components such as surface runoff and peak rate of runoff, Evapotranspiration, groundwater flow and sediment yield for each HRU unit (Demissie, 2013). The governing force behind everything that happened in the watershed is water balance. As simulated by the model, the water cycle must conform to what is happening in the watershed to accurately predicting the movement of sediments. The hydrology is simulated in two major ways: the Land Phase, which controls transport sediment, nutrient and pesticide loading to each channel from sub-basins and the Water or Routing Phase that controls the movement through the channel network to the watershed outlet.

The land phases of hydrologic cycle in SWAT

The land phase parameters of the hydrologic process is simulated depends upon the governing water balance equation (Neitsch et al., 2005) and computed by Equation (2.1) below:

$$SW_t = SW_o + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \quad \text{.......................................} \; 2.1$$

Where: - $SW_{t:}$ is final soil water content (mmH_2O),

$SW_{o:}$ is initial soil water content on day i (mmH_2O),

t: is time (days),

$R_{day:}$ is the amount of precipitation on day i (mm H_2O),

$Q_{surf:}$ is amount of surface runoff on day i (mm H_2O),

$W_{seep:}$ is amount of water entering vadose zone from the soil profile on day i (mmH_2O),

$E_{a:}$ amount of evapotranspiration on a day i (mm H_2O) and

$Q_{gw:}$ amount of return flow on a day i (mm H_2O).

Surface runoff Generation in SWAT

Surface runoff takes place when the rate of rainfall exceeds the infiltration rate. SWAT has the Soils Conservations Service Curve numbers equation and the Green and Ampt infiltration methods to estimate the surface runoff volume (Neitsch, 2005). For this study, the SCS curve no. approach was used over the Green & Ampt infiltration method. The Green and Ampt infiltration method assumes that there will be excess water at the surface at all times which was an invalid assumption in the study area, and also this method requires sub-daily precipitation data which was the other limitation to use this method.

$$Q_{surf} = \frac{\left(R_{day} - I_a\right)^2}{\left(R_{day} - I_a + S\right)} \quad \text{.......................................} \; 2.2$$

Where: -

Q_{surf} - is the accumulated rainfall excess (mm/day);

Rday - is the rainfall depth for the day (mm/day);

I_a - is the initial abstraction which includes surface storage, infiltration and infiltration prior to runoff (mm/day); and

S - is the retention parameter (mm/day).

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \qquad 2.3$$

Where: - CN is curve number for the day and this curve number is based on the areas, hydrologic soil group, land use, and hydrologic condition.

The initial abstractions, I_a, is commonly approximated as *0.2S* and then the above equation becomes:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \qquad 2.4$$

Evapotranspiration in SWAT

The PET in Bilate watershed was estimated by using SWAT model. SWAT estimates ET by the PET methods such as Penman-Monteith, Hargreaves and Priestley-Taylor methods using climate data, such as: - daily solar radiation, daily minimum and maximum air temperature, daily humidity, and daily wind speed data.

In this study, Hargreaves method was used to estimate potential evapotranspiration of the watershed which needs only maximum and minimum temperature.

2.4.3 Descriptions of WEAP Model

A computer based modeling method which considers different demand sites with their respective demand priorities for corporate water planning. WEAP model. Therefore, water distribution can easily be done by this model. WEAP is a does not substitute the skilled planner but it attempts to assist because it is comprehensive and easy for use. WEAP allows a chance for maintaining the demand of water and the supply information. WEAP has different capabilities and uses as data base tools, a policies analysis tool as well as forecasting tool. Hence, the WEAP model becomes a powerful tool to assess the water demand in the study area and well as the whole world.

The modeling of a watershed using the WEAP consists of the following four main steps

1. Define the study area and time frame. The setting up of the time frame includes the last year of scenario creation (last year of the analysis) and the initial year of application.
2. Create the current account, which is more or less considers the available water resources conditions of the study area. Under the current account, existing water and various existing demand nodes are specified.

3. Create alternative scenarios based on future policy assumptions and expected increases in the various indicators. This forms the heart of the WEAP model since this allows for possible water management processes to be approved from the outputs calculated from running the model. The scenarios are used to address a lot of “what if” situations.
4. Evaluate the alternative scenarios about the obtainability of water potential for the study area.

2.4.4 SWAT Calibration and Uncertainty Procedure

It is a program developed to do various calibrations and uncertainties analysis programs for SWAT using the same interface. Currently, the program can run SUFI2 (Abbaspour, 2007).

Each SWAT-CUP project contains one calibration method and allows running the procedure many times until convergence is reached. It allows saving calibration iterations in the iteration history for later use. SUFI-2 algorithm, in particular, is suitable for calibration and validation of the SWAT model because it represents uncertainties of all sources (Abbaspour, 2007) and this algorism was used for this study.

2.5 Overview of Water Resources Developments in the RVLB

The total surface water resource of the RVLB is estimated at about 5,300 MCM/year, calculated from total annual average river flow into the lake systems under ‘natural’ conditions without human abstractions. The Abayya-Chamo sub-system with catchment area 18,118km^2 contributes about 3018MCM/year to the basin; and it has three major tributary rivers which terminates into the system.

1. Water as a Constraint

Usually when considering water resources development, thought turns to large projects such as dams, irrigation, hydropower, etc. However, in the RVLB, this will not be the case. It is already known that water is the main constraint to the development of the RVLB.

2. Water for Irrigation development

With regard to irrigation, there is some scope for irrigation development in some areas of the basin. There are about 153,000 ha which may be developed in the RVLB with relatively small impacts on the lake environments and which may be considered sustainable. The Bilate sub-basin is one of this areas with more suitable land for irrigation development.

The development cost of irrigation schemes is high and may not be the best target for investment, in terms of maximizing benefits overall. There may be argument for building them anyway, for primarily social reasons, but this is also doubtful given the rate of failure of earlier schemes built in the RVLB and elsewhere in Ethiopia. Large schemes are major investments and, as there are other river basins of Ethiopia which have much greater irrigation potential, it is far more efficient from a national perspective to make such investments elsewhere.

3. Water for Hydropower

The opportunities for hydropower development are also limited. The RVLB is not considered an area of high potential for hydropower development because it lacks the physical attributes necessary for production. As a similar argument to irrigation, put into a national context, money is better spent in other river basins

4. Conservation and Watershed Management

The most important interventions in water resources development in the RVLB are conservation and watershed protection and management. As a hydrologically closed basin, the lakes of the RVLB are extremely vulnerable ecologically. The impact of uncontrolled water use is already well illustrated by the decline in Lake Abiyata and the loss of its fish habitat and that of most aquatic birds. Without good management and with unplanned abstractions, the remaining lakes will see a similar fate. The first concern is water management.

A significant proportion of the basin is in areas of high erosion potential and there are many areas which are already badly degraded. Reversing the land degradation trend and rehabilitating those areas already degraded must be a priority in the RVLB where good land for agriculture is scarce and increasing agricultural productivity is the key to economic growth.

5. Urban and Rural Domestic Water Supply

The major towns of the RVLB have urban water supply systems with varying levels of service. Service is either through standpipes or household connections depending on the town and the area within it. Most systems operate intermittently. With urban populations growing rapidly, this sector requires urgent attention.

Water supply is an area of high priority for national and regional governments alike. An analysis has been carried out to estimate the levels of investment required to ensure access to safe water. Because of the direct link between access for pure water and health, investment in water supply is of the utmost importance and should be one of the main priorities for government investment during the Master Plan period. Water supply has been given a lot of attention recently and is prioritized by government.

6. Water for Livestock Production

Livestock also places a significant demand on water resources. It is hoped that livestock numbers will actually reduce in the RVLB over the Master Plan period as they are already far too high and, as a result, actually retarding economic development.

7. Water for Industry development

Industry is made up of several components, especially in estimating water demand. Industrial water demands are linked to both urban and rural areas, because there will be significant small scale industry developing in rural areas based around agricultural production. Within urban water supply systems, water is used non-domestically in commercial services, public services and industrial establishments. Commercial services such as hotels, restaurants, private healthcare providers, private schools and colleges are major consumers of non-domestic water.

Policy decisions are necessary concerning the acceptable decline of lake levels and loss of lake area in the RVLB. In addition to the environmental consequences of lake level and area decline, there are economic and social considerations. Because of the constraint water resources impose on economic development in the basin, a choice will need to be made between irrigation and other approaches to economic development.

2.6 Related Studies on Surface Water Potential and Demands by SWAT and WEAP

According to (Subhash, 2016). Arc SWAT is a potent and powerful model once calibrated and validated effectively for a wide range of applications. The development of GIS-based interfaces, which provide a simple means of translating digital land use, topography, and soil data into model inputs, has greatly facilitated the process of configuring SWAT for a given catchment.

According to (Mulual, 2015), the analysis and simulation of surface water potential and allocation in the Bahr el-Jebel sub-basin was conducted under limited data availability, through the basic functions of WEAP, without using linkage to a groundwater analysis. Also, lack of flow data, particularly on crossing borders of South Sudan, Nimule, makes it very difficult to calibrate and validate the model for the current situation. However, all possible measures were taken to ensure the assumptions made herein are consistent with the realities observed in the sub-basin.

2.6.1 Related Studies in Ethiopia and in the Study Area

According to (Adgolign, 2015), the SWAT and WEAP models applied to Didessa Sub-Basin of Abay (Upper Blue Nile), West Ethiopia to assess surface water resources and Water allocation based on demands in the Sub-Basin, West Ethiopia. Due to the lack of sufficient hydrological data (shortage of streamflow monitoring stations) at important points in the sub-basin, it was not possible to use recorded flow data in this model. Hence, an output of the SWAT hydrological model of the sub-basin. Overall, the predicted monthly and annual stream flow and hydrologic components in Didessa; the obtained result showed very good values of model performance.

According to (Firisa, 2017), the SWAT model applied to assess the surface water potential of Sor watershed, located in Illubabor Zone of Oromia National Regional state near Metu town. The watershed is part of the Baro Akobo River Basin and has a total draining area of 1963.5km^2. The result was calibrated using stream flow data at the outlet of Sor River. The result showed a good performance of R^2 and NSE. From this it is clear that SWAT model can be applied for small as well as large area for the assessment of the surface water and sediment yield.

According to (Tadesse, 2006), the curve numbers and the coefficient runoff methods were used for surface water potential estimation for a Hantebet sub-basin of Tigray, Northern Ethiopia. The two methods were selected based on the absence of water level observations and flow measurements conducted in the basin due to lack of hydrometric station in any one of the rivers in the entire basin to analyze the runoff of the basin by computer models or scale models. According to him, other methods like the unit hydrograph and flood frequency analyses were also not used because of their requirements of historical records.

After the surface water potential was estimated using the two methods, Nata concluded that: since the curve method takes into account a number of hydrologic parameters than the runoff coefficient method, the calculated value of the curve method is taken as a representative of the basin

(Henock, 2017): applied the WEAP model for effective water resources management in Legedara River Catchment, SNNPR, and Ethiopia. He used the Hydro-meteorological, spatial and water demand data as the inputs to the model. He model the current demand for domestic and industrial water demand from (2013-2016) and then he do a reference scenario analysis and projected the water demand, supply requirement and unmet demands from 2017-2040.

(Wagesho, 2014) : Also used Distributed hydrologic modeling (SWAT) to characterize catchment dynamics. The author observed that the modeled surface water runoff component increases progressively since 1970s. The extreme daily river discharge near Alaba Kulito at Bilate river catchment is characterized by increasing trend during the analysis period but yearly streamflow does not show significant monotonic trend. In this research, the researcher only tries to characterize the catchment dynamics of the watershed without including development projects in the catchment and this may be taken as limitation of the study.

(Wagesho, 2013): Investigate the potential impact of climate change on runoff generation at two agricultural watersheds (Bilate and Hare Watershed). Simulated average annual water yield showed slight variations between the GCMs. It was within ±10% at Bilate catchment.

Thiemann et al., (2004) analyzed Water resource potential with respect to precipitation variability. It is concluded that precipitation depends altitude. Limitation of the study was Climate variable data's are limited in the study area which makes the result questionable.

Therefore, the above studies confirm that both SWAT and WEAP models are shows a good performance and applicable models at international as well as in the national levels to simulate surface water availability and demands but the availability and quality of data provide them with a best performances.

3 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Ethiopia is a country which is located in between $34^0$30'0" and $18^0$12'0" North latitude and $32^0$42'0" and $48^0$12'0" East longitude. The country has great geographical, topographical and climatological diversity: From high rugged mountains to deep gorges; from the lowest altitude between 120m below sea level to the highest altitude of 4600m a.m.s.l; from 2000mm high annual rainfall to 200mm of low annual rainfall. Moreover, the Great Rift Valley splits the country into two parts forming the eastern and western high lands (Belay, 2011).

The Bilate river watershed is situated in Southern Nation Nationalities and Peoples region in Rift Valley Lake Basin and located approximately 6º38′18"North-8º6′57"North latitude and 37º47′6"East - 38º20′14"East longitude. In this study, the Sub-basin has a total area equivalent to 5,248km² which is delineated by using 30m by 30m DEM in Arc SWAT software. The Bilate River is among the major watershed of the RVLB, which is the sub-basin of the Rift Valley Lake Basin. It drains to the northern part of the Lake Abaya-Chamo Drainage sub-Basin. The Bilate River is the main perennial river that flows in the basin. It originates from the Gurage Mountain and flows south into Lake Abaya.

The Bilate River flows from the Gurage Mountain in the north towards the south into the Lake Abaya. It is one of the three main perennial rivers such as Bilate, Gidado, and Gelana that flow into the Lake Abaya. The main source of water in the sub-basin is rainfall which comes from Gurage highland through Silte, Hadiya, and Kambata.

Bilate River sub-basin is one of the major river watershed in the RVLB having more land suitable for agriculture and it has to supply those most densely populated community. The sub-basin provides resources for the livelihoods of the population; used as a source of food, drinking, wildlife, transport, grazing and water for livestock, and as a repository for human and agricultural. This makes the issue of water resource availability very crucial for effective water resource management and improves livelihoods.

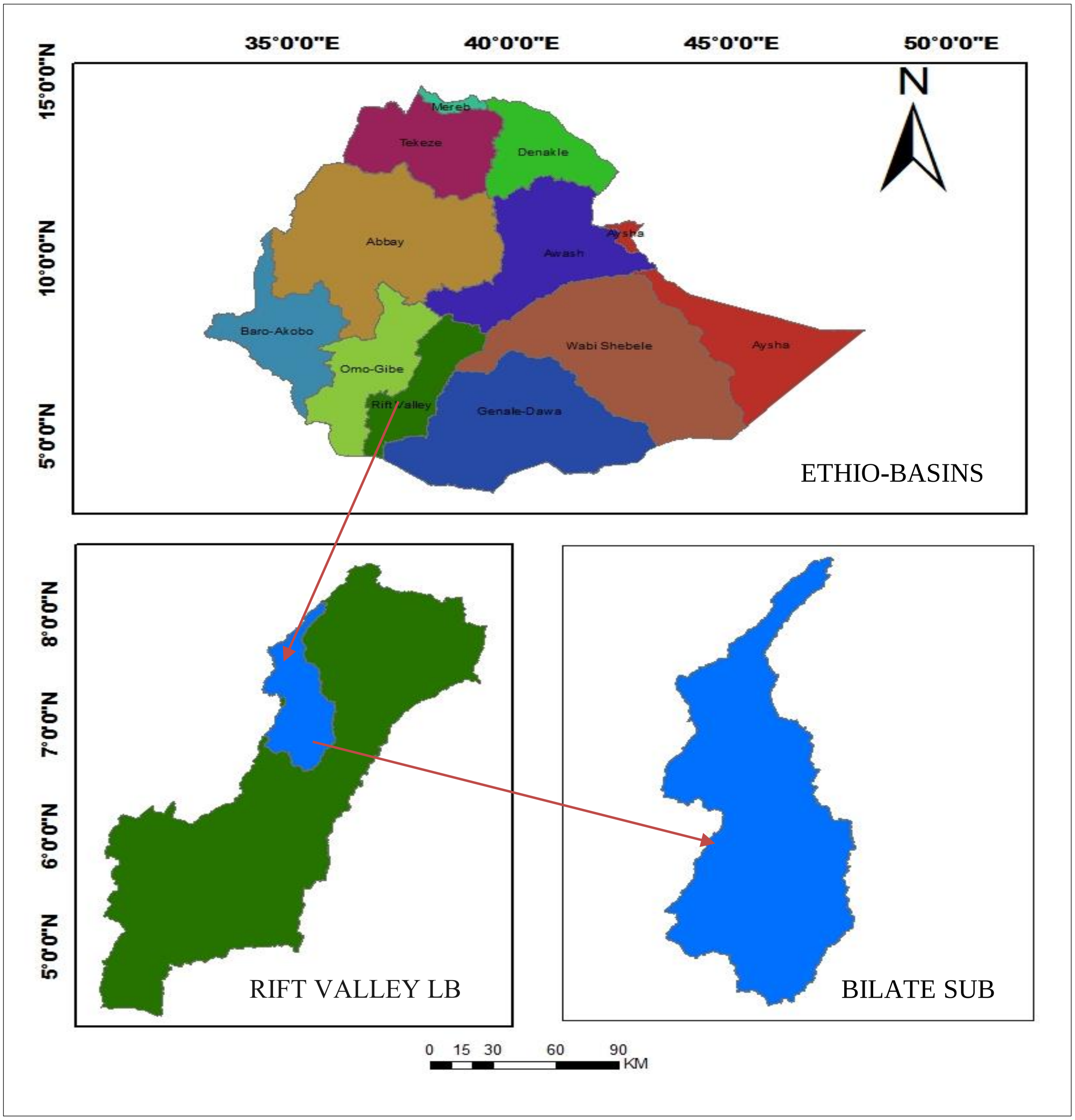


Figure: 3.1:- Location of the study area

3.1.2 Physiography and Drainage

The Bilate River basin is a tectonic valley along with its length much of the valley is bounded by fault scarps or steep slopes on either side. The floor of the valley is mostly flat plain and appears to be in part a remnant of the depositions floor of the ancient large water basin. The study area is part of the western rift margin which is characterized by chain ridge, hills, deep and wide valleys of small and large streams, and narrow flatlands between the valleys having gentle slopes.

The altitude of the catchment ranges from 1147m at Lake Abaya to 3361m at mountain Ambaricho and at Alicho Wiriro Woreda above sea level. This indicates that the topography of the area ranges from lowland plain areas to highly mountainous elevated terrains.

The small streams flows towards Abaya Lake along with the Bilate River. Most of its tributaries, as well as a large volume of water, come from Gurage, Silte, Hadiya, kambata and Wolaita zone high lands of the catchment. The increase downstream could be influenced by the corresponding low rainfall, high evapotranspiration, relatively slow drainage and thermal springs that join the river downstream (Gintamo, 2015).

3.1.3 The slope of the Watershed

The slope is derived from DEM input so that the model was used this slope for the development of Hydrological Response Unit (HRU) in addition to land use and soil input parameters. The slope is also an important characteristic of a catchment as it gives an indication of the kinetic energy available for water to move towards the basin outlet, and it has been found to be related to total runoff and base flows (Bullock, 1990).

ArcSWAT allows the integration of land slope classes up to five classes when defining hydrologic response units. There are possibilities to choose a single or multiple slope class. In this study, multiple slope classes were selected as given in fig 3.2.

The study area has been classified into multiple slope intervals: 0 -10% flatland, 10 -15% gentle, 15 - 20% intermediate, and 20 - 999% steep.

Most parts of the study area are characterized by flatland and gentle slope and to some extent, there is intermediate and steep as shown below in figure 3.2.

3.1.4 Digital Elevation Model Data

The DEM is a representation of any topographical surfaces by digital means and it is specifically made available in the form of regular grid spot height. It is the basic input data for SWAT hydrological model. The Bilate River Watershed was delineated and River networks were generated from DEM that has a resolution of 30m x 30 m.

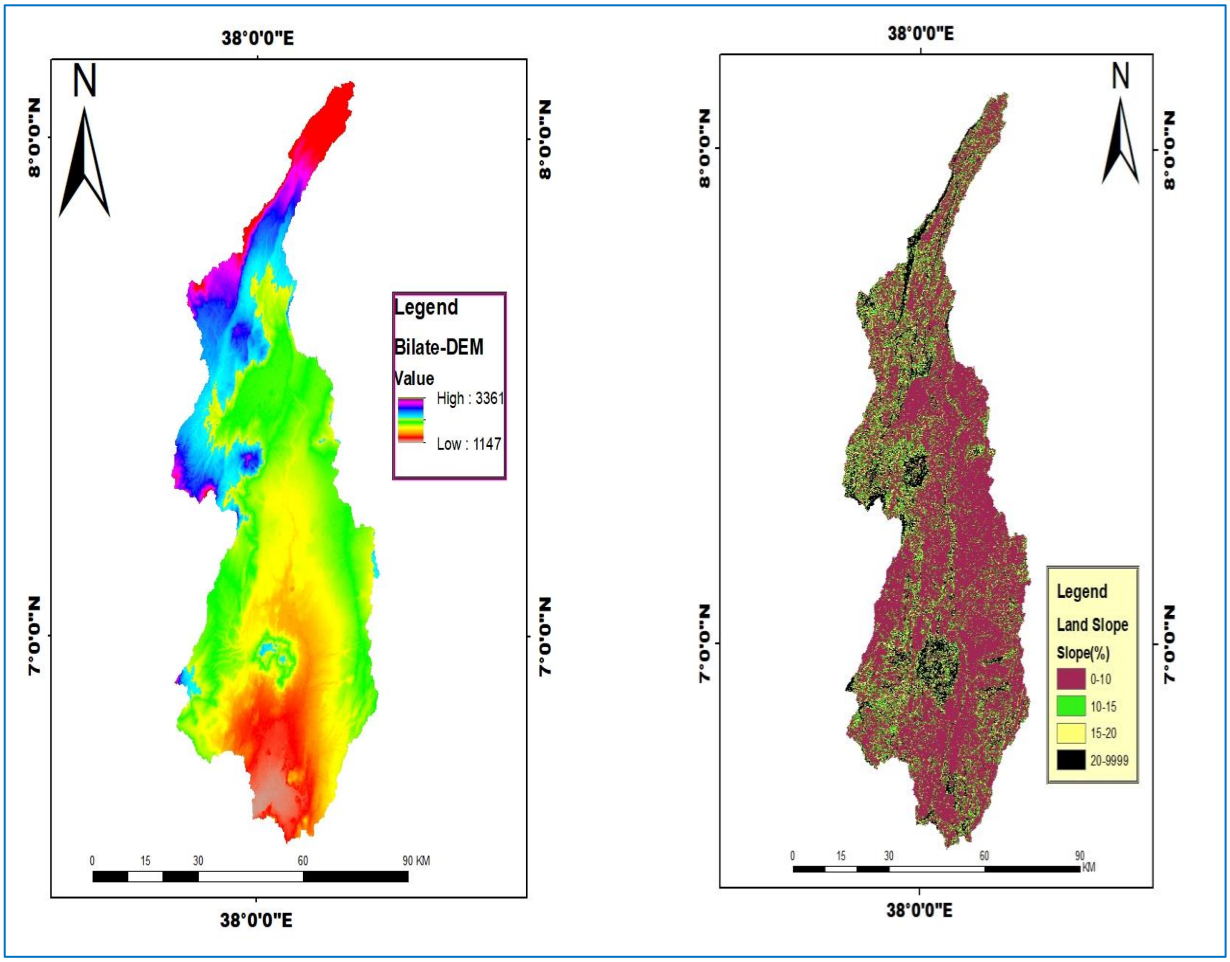


Figure: 3.2:-DEM and slope of the study area

3.1.5 Climate and Hydrology

The traditional way of classification of Ethiopia's climate is based on altitudes and temperatures. Based on such classification, there are five climate zones: Wurch with cold climate greater than 3000 altitudes, Dega having temperate like climate-highland with 2500-3000 altitude, Woyina Dega has also warm climate with 1500-2500 altitude, Kola having hot and arid type with less than

1500m altitude) and Bereha have hot and hyper-arid type climate . According to this classification, most portion of the study area fallen in Woyina Dega and Kola zones.

Annual average potential evapotranspiration varies from approximately 1200 mm in the northeast of the basin to approximately 1900 mm at Chew Bahir. Throughout the rift valley floor, from Lake Ziway to Lake Chamo, the average values are typically on the order of 1550 mm.

Annual average temperatures vary from approximately 27 degrees centigrade on the valley floor near Chew Bahir to a low of approximately 13 degrees centigrade at higher elevations, particularly in the northeast of the basin.

Analysis of 28 years of data from 1990 to 2017 of 10 meteorological stations in the study area shows that the watershed gets an average rainfall depth of 1106.2mm per annum. There is a high spatial and temporal variation of rainfall in the study area.

3.1.6 Land use and Land Cover

The land uses actual meaning is the technique in which land is used by people in an area to produce what is needed by the people for use through the involvement of labor, capital, and available technology.

According to (FAO, 2000), land use is considered by preparations, activities, and inputs people assume under a certain land cover type to produce, change, or maintain it.

The definition of land use in these ways indicates the direct connection between land covers and action of people in their habitats.

Land cover is observed physical cover on the earth's surface. In other words, land cover is what is physically appearing on the ground surface as a natural or manmade entity.

The watershed is mainly covered by the exposed surface, forest, grassland, intensively cultivated with population settlement, marshland, moderately cultivated, shrubland, and water body (Figure 3.3).

3.1.7 Soil Type

According to (FAO, 1998) soil classification, the leading soil type in the study area is clay soil in the upper and middle part of the watershed and sandy loam in some middle part of the watershed.

The main soil types in the Bilate watershed was developed from soil map which is collected from MoWIE of Ethiopia and reclassified for the study area and shown below in the (figure 3.3). These soils in the Bilate watershed are Vitric Andosols, Chromic Luvisols, Humic Nitisols, Eutric Fluvisols, Eutric Vertisols, Mollic Andosols, Luvic Phaeozems, and Lithic Leptosols.

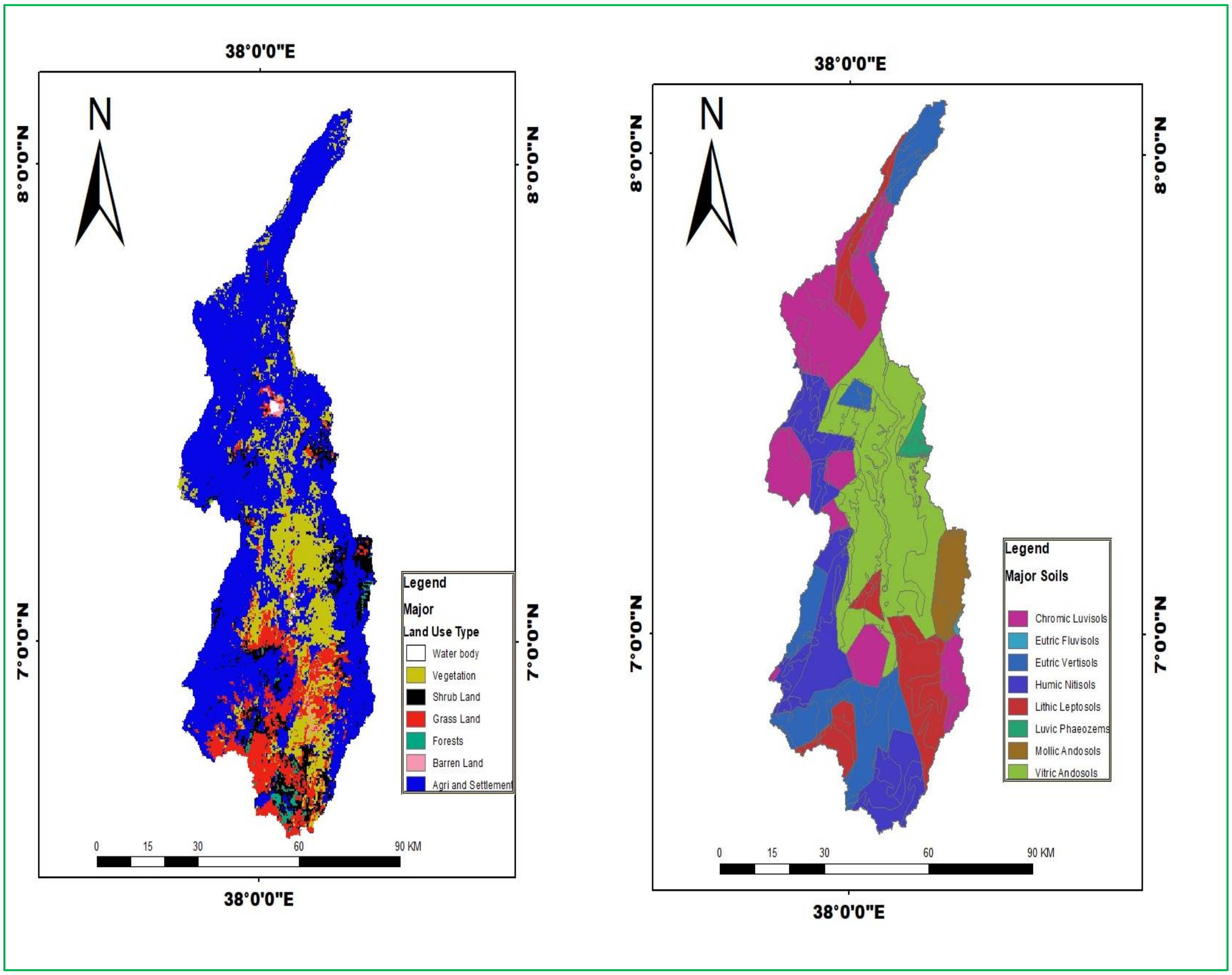


Figure: 3.3:- Land use and Soil Types of the study area

3.2 Materials Used, Data types and sources

General work was carried out by collecting secondary data and validated by comparing the data collected from different data sources.

3.2.1 Spatial Data

Land use land cover data, topographic data, soil data collected from the Ministry of Water, Irrigation, and Energy were required to characterize the sub-basin.

3.2.2 Hydrological and Meteorological Data

In order to determine the basic hydrologic parameters, meteorological and hydrological data were collected. The river flow data and climatic data (daily rainfall, temperature, solar radiation, wind speed, and humidity) data were collected from the Ministry of Water, Irrigation, and Energy, and National Meteorological Agency respectively. The data were processed into a daily time step.

3.2.3 Socio-Economic Data

Important socio-economic information such as Demographic survey data's (total number of population and population density) were collected from different governmental offices like from Ministry of Water, Irritation and Energy and demographic data from the Central Statistics Agency and Rift Valley Lake Basin Master plan).

3.3 Research Methods

Methodologies applied for this study include:-

- ❖ Collection of Secondary data from institutions such as MoWIE, National Meteorological Service Agency, Central statistical Agency, and Water, Irrigations, and Mines departments from different zones.
- ❖ Field observation and collection the necessary data and information in the watershed.
- ❖ Review of literature on related studies on assessment of surface water potential and demands.
- ❖ After, collecting all data, the filling of missed data and quality checking has been done.
- ❖ Preparation of necessary input data for the Arc SWAT model in a suitable format.
- ❖ Preparing DEM and delineating the watershed of the basin.
- ❖ Then, the ArcSWAT model is used to simulate surface runoff and WEAP was used for estimation of water demands for the watershed.

Materials used for the assessment of surface water potential and estimation of water demands for this research were:-

- Hydrological data (streamflow data),
- Meteorological data (daily Rainfall, Temperature, Relative Humidity, Sunshine hours, and wind speed).
- 30 by 30 m DEM data was used as an input data for Arc GIS and Arc SWAT software,
- ArcGIS:-was used to obtain hydrological and physical parameters and spatial information, to locate the geographical location of the Bilate watershed, to classify land use the land cover map, etc.,
- ArcSWAT software was used for the watershed delineation, Sub-basins, and HRUs of the sub-basin and to estimate surface runoff,
- SWAT CUP- was used for sensitivity analysis, calibration and validation of the Arc SWAT model,
- WEAP (Water Evaluation and Planning) system: - used to estimate water requirements or demands, unmet water demands, and scenarios generation based watershed characteristics for different uses in the sub-basin,

3.3.1 Meteorological Data Analysis

In Ethiopia, the source of raw meteorological data is the National Meteorological Agency (NMA). A request for daily rainfall and temperature data of 28 years from (1990-2017) periods of 20 stations and only 10 stations were extracted based on the availability and quality of the data.

First of all, the meteorological stations contributing the rainfall for the study area with their areal contribution were selected by using the Thiessen polygon method, and the following ten in and nearby stations were mainly contributes rainfall to Bilate watershed.

Table 3.1: Software used for the study and their purposes

Software	Purpose
ArcGIS	To prepare the study area map
	To select the contributing station for the watershed
	Used as extension with the SWAT model
	To prepare a GIS layer for WEAP background
Arc SWAT	To model rainfall-runoff
	To delineate the watershed & sub-basins
	To generate HRU
	To estimate the land phase of the hydrologic cycle
SWAT-CUP	For sensitivity analysis
	For calibration and validation of the model
WEAP	To estimate water demands and unmet water demands
	To develop scenarios (alternatives) based on watershed characteristics
Excel	To prepare meteorological and streamflow data in suitable formats
Weather Generator	Used to fill missing values in weather data.

Table 3.2: Meteorological Stations used in the study area

S.No	Stations	Area (km^2)	Longitude	Latitude	Record period	%age Missing	Area (%)
1	Alaba	985.5	38.0939	7.3105	1990-2017	2	18.9
2	Hossana	206	37.8399	8.0316	1990-2017	1.6	3.9
3	Fonko	749	37.9680	7.6423	1990-2017	6.3	14.3
4	Dimtu	1644	38.1166	6.9166	1990-2017	4.8	31.5
5	Angacha	159	37.8572	7.3405	1990-2017	9.2	3
6	Durame	326	37.8915	7.2406	1990-2017	6.2	6.2
7	Bodity	245	37.9550	6.9536	1990-2017	3.3	4.7
8	Shone	465	37.9526	7.1335	1990-2017	7.5	8.9
9	Wolaita	190	37.7305	6.8105	1990-2017	2.2	3.6
10	Arekit	253.5	37.5615	6.0616	1990-2017	6.8	4.9
Total		5,248					100

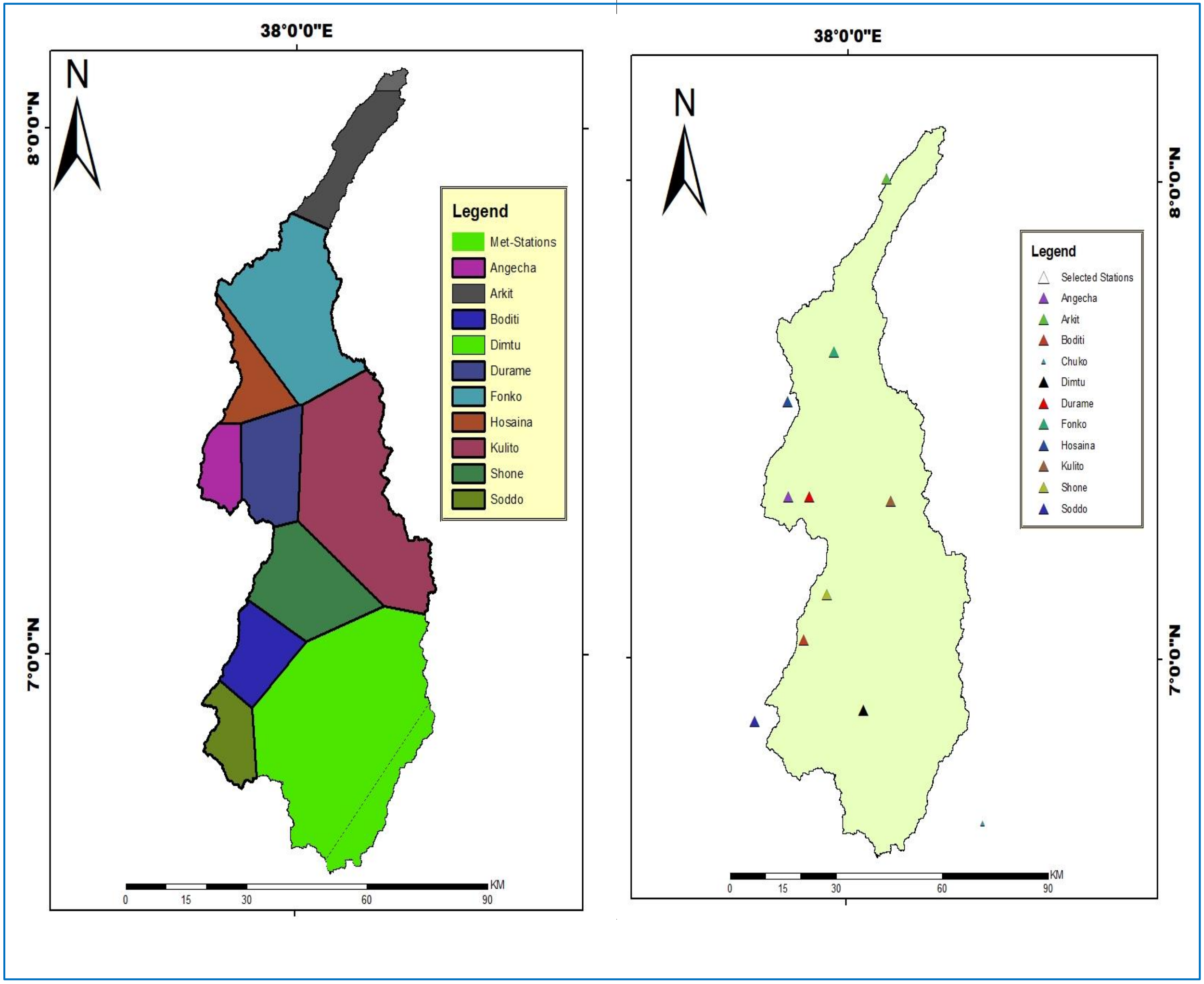


Figure 3.4:- Thiessen Polygon and Selected Met-Stations used in the study

The principal station which contains all five meteorological data with modest missing data in the study area was Hossana station. The collected meteorological data stations are shown above in Figure 3.4 and Table 3.2.

3.3.2 Filling Missing Data

Although complete hydro-meteorological data is a pre-requisite for successful water resource planning and management, significant data sets are usually missing due to interruption of measurements caused by natural and/or human-induced factors.

Missing data is a common problem in hydrology. To perform hydrological analysis and simulation using data of long time series, filling in missing data is very important.

The missing data can be filled using meteorological and/or hydrological stations located in the nearby, provided that the stations are located in the hydrological homogenous region. The rainfall, temperature, and other climatic data stations in the study area had missing data in their records and it is necessary to estimate the values to keep the continuous-time series of the data.

A number of methods have been proposed to estimate missing rainfall data for the stations. There are some techniques for filling missing rainfall data such as arithmetic mean method, simple linear regression, inverse distance, and normal ratio method.
The station average method for filling missing data is conceptually the same as the station average method for estimating mean precipitation. This method may not be accurate when the total annual rainfall at any of the n-region gauges differs from the annual rainfall at the point of interest by more than 10 %, with the former basing the weights on the mean.

The normal-ratio method is theoretically easy and it different from the station-average method that the average annual rainfall is used in deriving weights. If the total yearly rainfall at any of the n regions gauges different from the annual rainfall at the point of need by greater than 10%. The normal-ratio method is more preferable. Unlike the arithmetic mean, the normal ratio method takes account of the normal ratio between annual rainfall depths measured by the rain gauge which failed and all other rain gauges in the network. In this study, the missing values were estimated from other stations around the missed record station by using the normal ratio method; because the normal-ratio method is more advanced than the station average method and simple.

The general formula to estimate P_x is:-

$$Px = \frac{Nx}{N}\left(\frac{P1}{N1} + \frac{P2}{N2} + \cdots + \frac{Pn}{Nn}\right) \quad \text{3.1}$$

Where: - $\mathbf{P_x}$ is the missing value of precipitation to be computed,

Nx is the average value of rainfall for the station in question for recording period,

$\mathbf{N_1}$, $\mathbf{N_2}$**…Nn** is an average value of rainfall for the neighboring station,

$\mathbf{P_1}$, $\mathbf{P_2}$**...Pn** is the rainfall of neighboring stations during a missing period and
N is the number of stations used in the computation.

Graphical comparison of the rainfall data done by creating time-series plotting of monthly rainfall data showed that the ten stations show a similar periodic pattern of records.

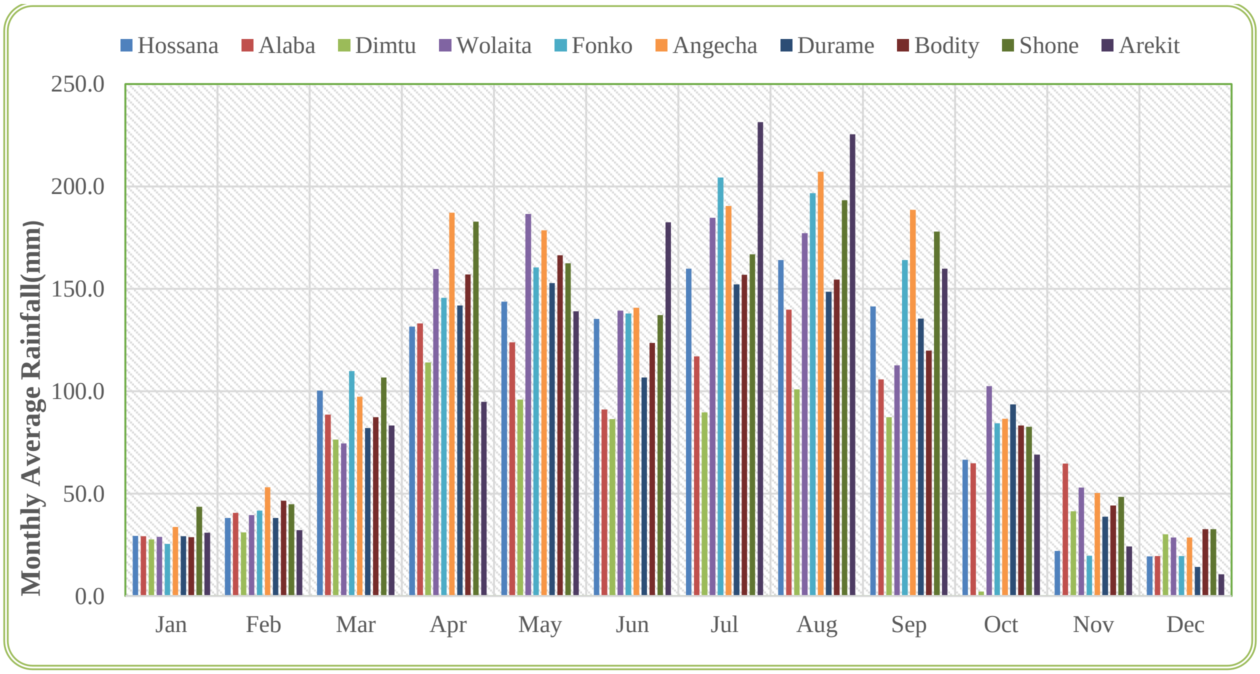


Figure: 3.5:- Average Monthly Rainfall Data series

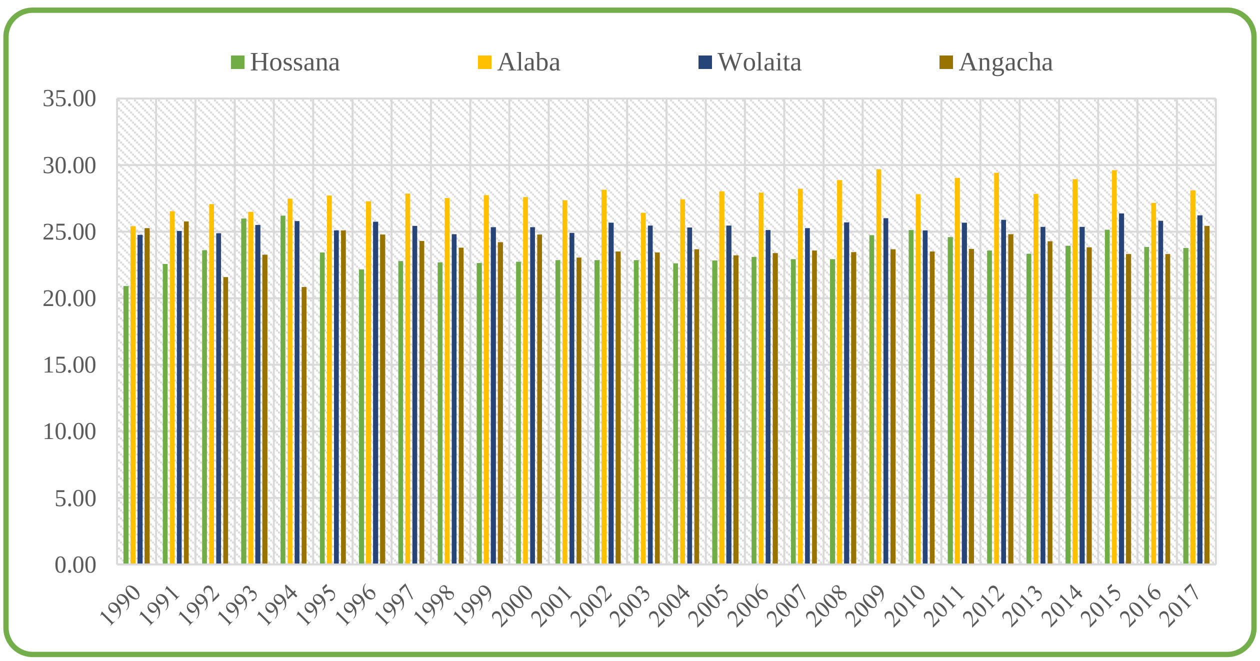


Figure: 3.6:- Average annual maximum temperature

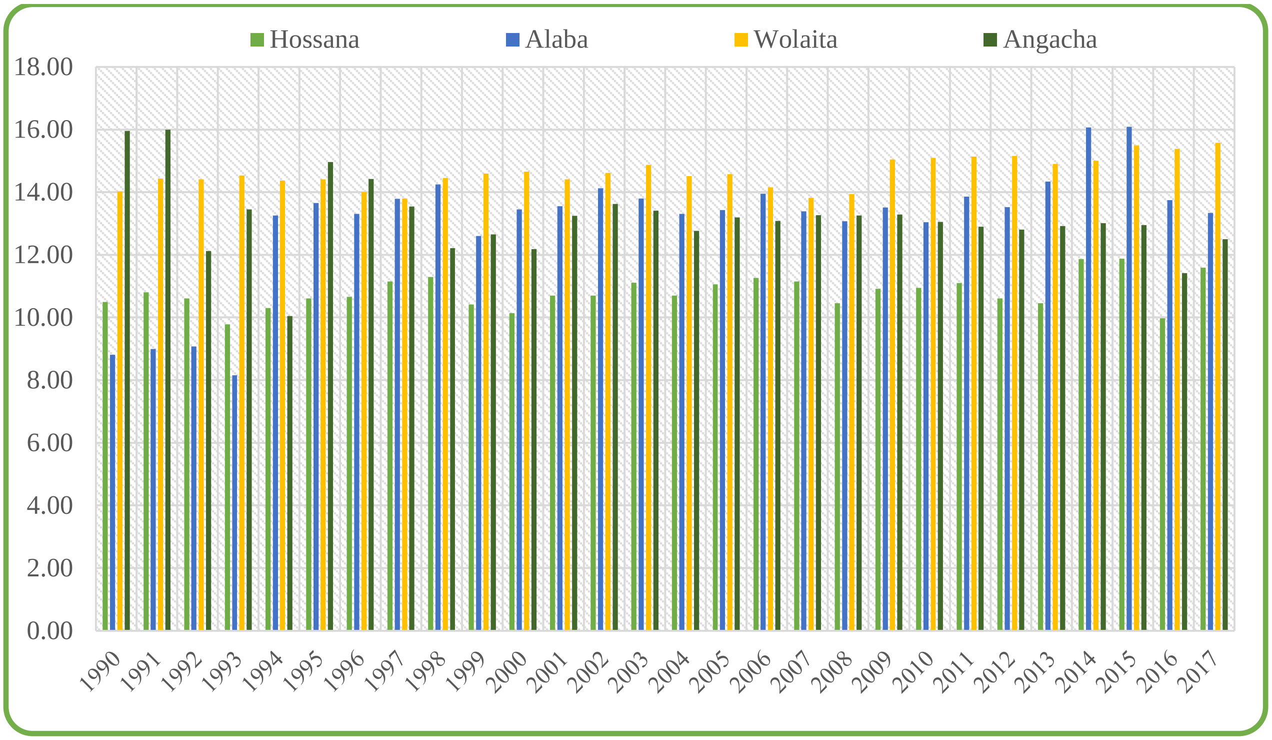


Figure: 3.7:- Average annual minimum temperature

The integrated Arc SWAT weather generator was used to generate the representative climatic data for the missing stations data in the selected stations. The ArcSWAT weather generator model WXGEN input file contains statistical data needed to generate representative daily climatic data for the subbasins. Weather generator model needs different weather parameters such as precipitation, maximum and minimum temperature, solar radiation, relative humidity, and wind speed to generate weather station statistics. The weather generator model included in SWAT-12 was used to fill the gaps in measured records. The available weather data of the station was prepared in order to generate SWAT weather parameters for other stations. Then once the weather generator parameters were prepared by WGEN model it was loaded into WGEN_ User of SWAT database.

The weather generator stations (Hossana) have been firstly prepared in the proper formats in which the ArcSWAT can read; all the necessary weather generator input parameters have been calculated and fed to the WXGEN file in the Arc SWAT database. The Arc SWAT model can call the meteorological data as input that is calculated and integrated through the weather generator model unless we can’t call it as input to Arc SWAT model.

3.3.3 Checking the Consistency of Data

Meteorological Data

Filled data still need to check for the trend that may suffer the data for unusual trends. The rainfall recording of the rain gauge stations has undergone a significant change during the period of record with various reasons; inconsistency would arise in the rainfall data of that station.

A consistent record is the one where the characteristic of the record has not changed with time. If the conditions relevant to the recording of a rain gauge station have undergone a significant change during the period of record, inconsistency would arise in the rainfall data of that station.

Adjusting for gage consistency involves the estimation of an effect rather than a missing value. The consistency of rainfall records on selected stations is commonly checked by double mass curve analysis.

The double mass curve is a graphical method for identifying and adjusting inconsistency in a station record by comparing its time trend with those of adjacent stations. If the conditions relevant to the recording of a rain gauge station have undergone a significant change during the period of record, inconsistency would arise in the rainfall data of that station.

If a significant change in the regime of the curve is observed, it should be corrected and the stations used in this study have undergone significant change during the baseline period (1990-2017) of the study. So, the adjustment required for the recorded rainfall data set. The sample DMC are shown below in Fig. 3.8 and others are indicated in the (appendix F). The accumulated total of the individual gauge is compared with the corresponding totals for a representative group of the nearby gauge. If a decided change in the regime of the curve is observed it should be corrected by the following equation.

$$Pcx = Px * \frac{(Mc)}{Ma} \qquad \text{3.2}$$

Where P_{cx}:-is corrected precipitation at station x

P_x: - is originally recorded precipitation at station x

Mc: - is Corrected slope of the double mass curve, and

Ma: - is original the slope of the double mass curve.

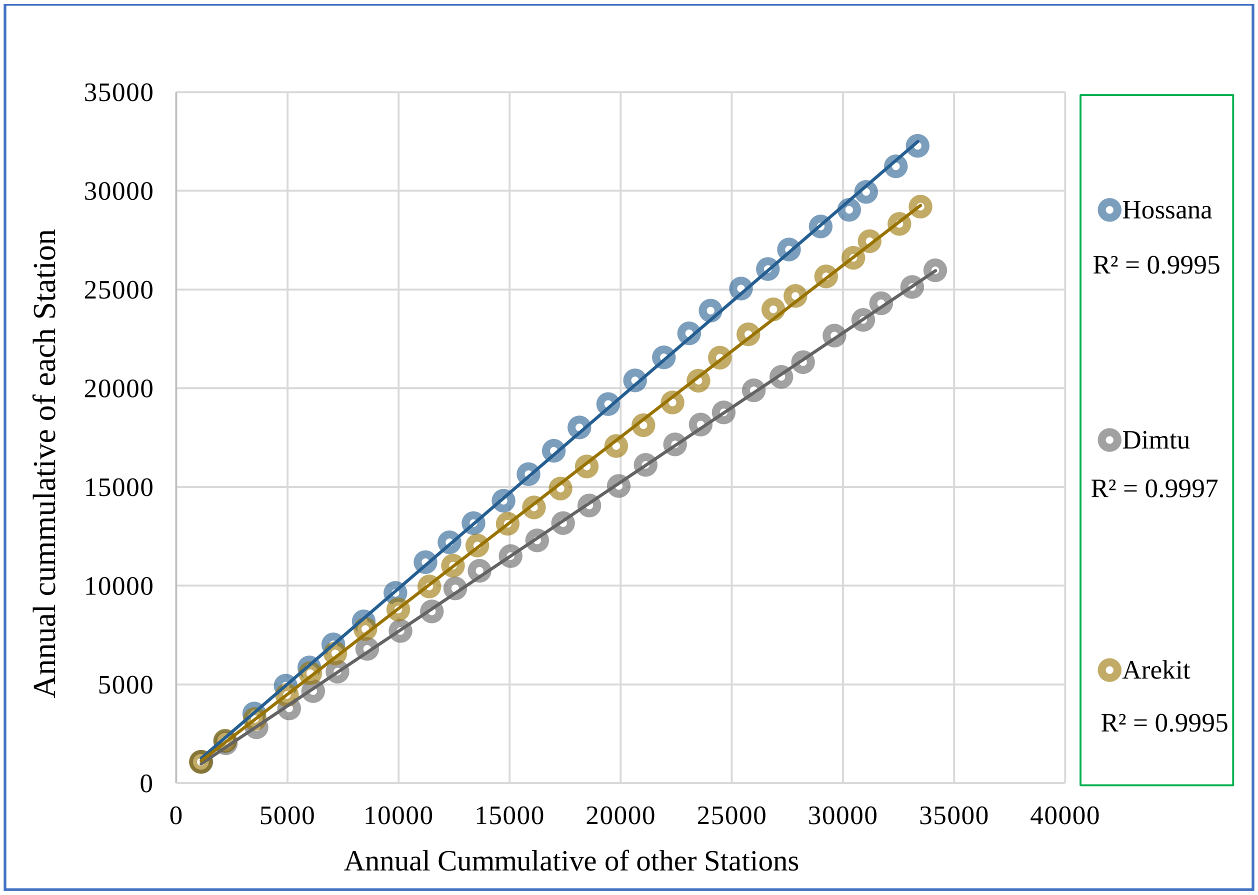


Figure: 3.8:- Double Mass Curve for checking data trends

3.3.4 Testing for Outliers

Outlier test for rainfall data

An outlier is the data points which are out of threshold limits significantly from the trend of the remaining data. The retention and deletion of these outliers significantly affect the magnitude of the statistical parameters computed from the data, especially the small sample size.

The station skew is greater than (+0.4), tests for high outliers are considered first; if the station skew is less than (-0.4), test for low outliers are considered first. Where the station skew is between (± 0.4), test for both high and low outliers should be applied before eliminating any outliers from the data set (Chow, 1998).

The following frequency equation can be used to detect high outliers:

$$X_H = Xav + KnS \text{……………………………………………………………} 3.3$$

Where

X_H: - Logarithmic high - outlier test threshold,

S: - standard deviation

K:-10- percent significance- level critical value for outlier test statistic for samples of size N from the normal distribution (Appendix E).

If the logarithms of values in a sample are greater than X_H in the above equations, then they are considered high outliers.

Accordingly, the information that indicates a high outlier is a maximum over an extended period, the outlier is treated as historic flood data and excluded from the analysis. If the record does not contain enough information to correct for high outliers, they shall be retained as part of the systematic record. A similar equation can be used to detect low outliers:

$$X_L = Xav – KnS \text{………………………………………..……………} 3.4$$

X_L: - logarithmic low- outlier test threshold.

The outlier test for basic stations has been done and tests for both high and low outliers were applied and the following results were obtained.

The outlier test result shows that the largest recorded value for all stations does not exceed high outlier test respective threshold value and the smallest recorded value is not below outlier test threshold value, so both high and low outliers were not detected and the rainfall data is safe for outliers and the indicated in the Appendix D.

Outlier test for hydrological data

Outlier tests for hydrological data Outliers are data points that depart significantly from the trend of the remaining data or outliers are peaks that depart substantially from the trend of the remaining peaks**.** The hydrological data were required for performing sensitivity analysis, calibration, validation, and uncertainty analysis of the model.

Table: 3.3:- Table outlier test for hydrological data

Year	$Q_{(arg)}$ (m/s)	Y=logQ
1994	291.032	2.46394
1995	280.748	2.44832
1996	186.606	2.27092
1997	170.32	2.23126
1998	279.919	2.44703
1999	267.865	2.42792
2000	227.692	2.35735
2001	295.615	2.47073
2002	324.463	2.51117
2003	159.283	2.20217
2004	187.415	2.2728
2005	317.68	2.50199
2006	440.851	2.64429
2007	403.089	2.6054

	Q_{arg}	Y
Xav	273.756	2.418
StDv	83.6757	0.134
KN		2.175
N		13
XH		**2.716**
QH(m/s)		**528.8**
XL		**2.119**
QL(m/s)		**131.8**

The outlier test result shows that the largest recorded value (Y = 2.644) does not exceed high outlier test thresh-hold value which is (XH = 2.716) and the smallest recorded value (Y = 2.202) is not low outlier test threshold value which is XL = 2.119. So both high and low outliers were not detected.

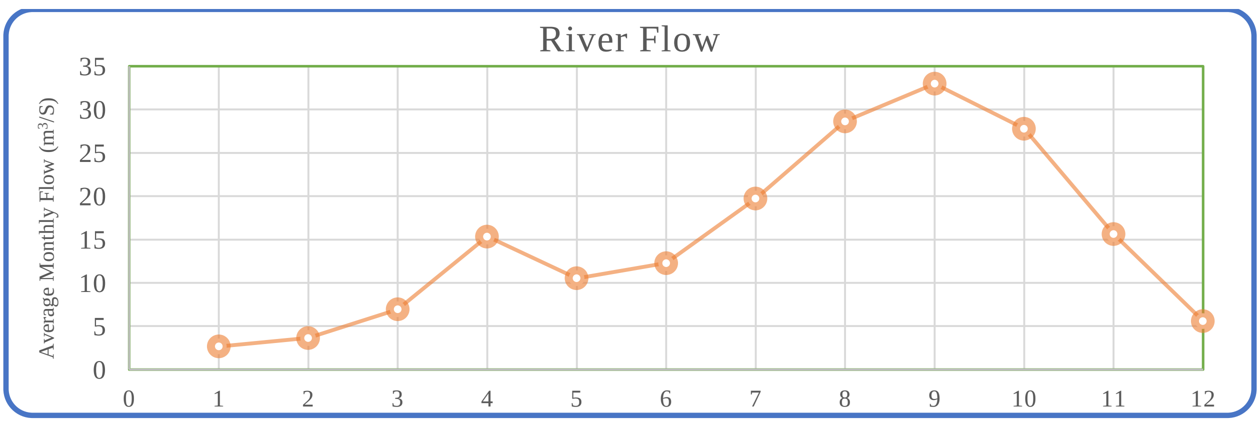


Figure: 3.9:- Average monthly river flow at the Bilate River nr. Alaba (1990-2007)

As presented above it shows that the Bilate gauging station has high mean monthly streamflow recorded in three months in a year (August, September, and October).

3.4 SWAT Model Setup and Application

3.4.1 Arc SWAT Model Setup

The SWAT model is an ArcGIS extension with its own user interface including SWAT project setup, watershed delineator, HRU analysis, Write Input Tables, Edit SWAT input and SWAT simulation. The initial step in initializing a watershed simulation is to partition the watershed into sub-basins.

The main steps in the ArcSWAT model:

- Project setup
- Watershed delineation
- HRU analysis
- Write input tables, and
- SWAT simulation.

The user has the option of allowing SWAT to automatically delineate the watershed and sub-watersheds using the DEM or the user can provide predefined sub-basins. HRUs are portions of a sub-basin and possess similar land uses, slope ranges, and soil attributes (Neitsch, 2005).The data required for the model are DEM, Soil data, Land use data, precipitation, and other weather data. For calibrating the model and also for validation purposes, river discharge (streamflow) data and are required on the outlet of the watershed.

The ArcSWAT2012 is an Arc View extension that provides a graphical user interface that allows for GIS data to be easily formatted for use in SWAT model simulations.

The initial stage in using SWAT is a projects Setup so that important folders and databases should have been created to save all the data. GIS data such as DEM, Soil, Land Use, and all the data was collected and prepared to define each step.

3.4.2 Watershed Delineation

The next step of the SWAT Model Setup is the delineation of the watershed from a DEM. Before going in hand with spatial input data i.e., DEM, LULC map, and soil map were projected into the same projection called UTM Zone 37N, which is a projection for Ethiopia.

The watershed delineation part includes five main steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub-basin parameters. For the stream definition, the threshold-based stream definition option was used to create the minimum size of the sub-basins. To delineate the whole Bilate watershed an outlet was taken at near Alaba kulito were just it starts releasing from. The last work in delineating watershed is generating parameters for all the sub-basins. Finally, the stream channels were defined as DEM cells having at least a 5,248sqkm contributing area and contributing area resulted in sub-basin of Bilate watershed being delineated. Based on this the Bilate watershed was divided into sub-basins and HRUs from the watershed area of 5,248 Km^2.

The topography is defined by a DEM that describes an elevation of any points in a given area at a specific spatial resolution. It is the basic input of the ArcGIS integrated SWAT hydrologic model to delineate the watershed, to extract information about the topography or elevation of the watershed and to analyze the drainage patterns of the land surface terrain. Hence, the definition of a watershed, sub-basin boundaries and streams was decided by selecting a threshold area or the minimum drainage area to define streams.

3.4.3 Hydrological Response Unit Analysis

HRU analysis becomes available after the water delineation is successfully completed where the basic SWAT inputs; land use land cover and soil data are clipped to the study area and finally land use land cover, soil data, and land slope are overlaid to the study area.

The HRU Analysis tool in Arc SWAT helped to load map of land use, map of soil, and slope map to the project for HRU definition. Then, prepared land uses maps and soils maps were loaded. For slope, the multiple slope option (an option that considers different slope classes for HRU definition) was selected. The LULC, soil and slope map was reclassified in order to correspond with the parameters in the SWAT database.

After reclassifying the land use, soil, and slope in the SWAT database, all these physical properties were made to be overlaid for HRU definition 20 sub-basins and 168 HRUs were obtained and sample results for HRU statistics are presented on appendix I.

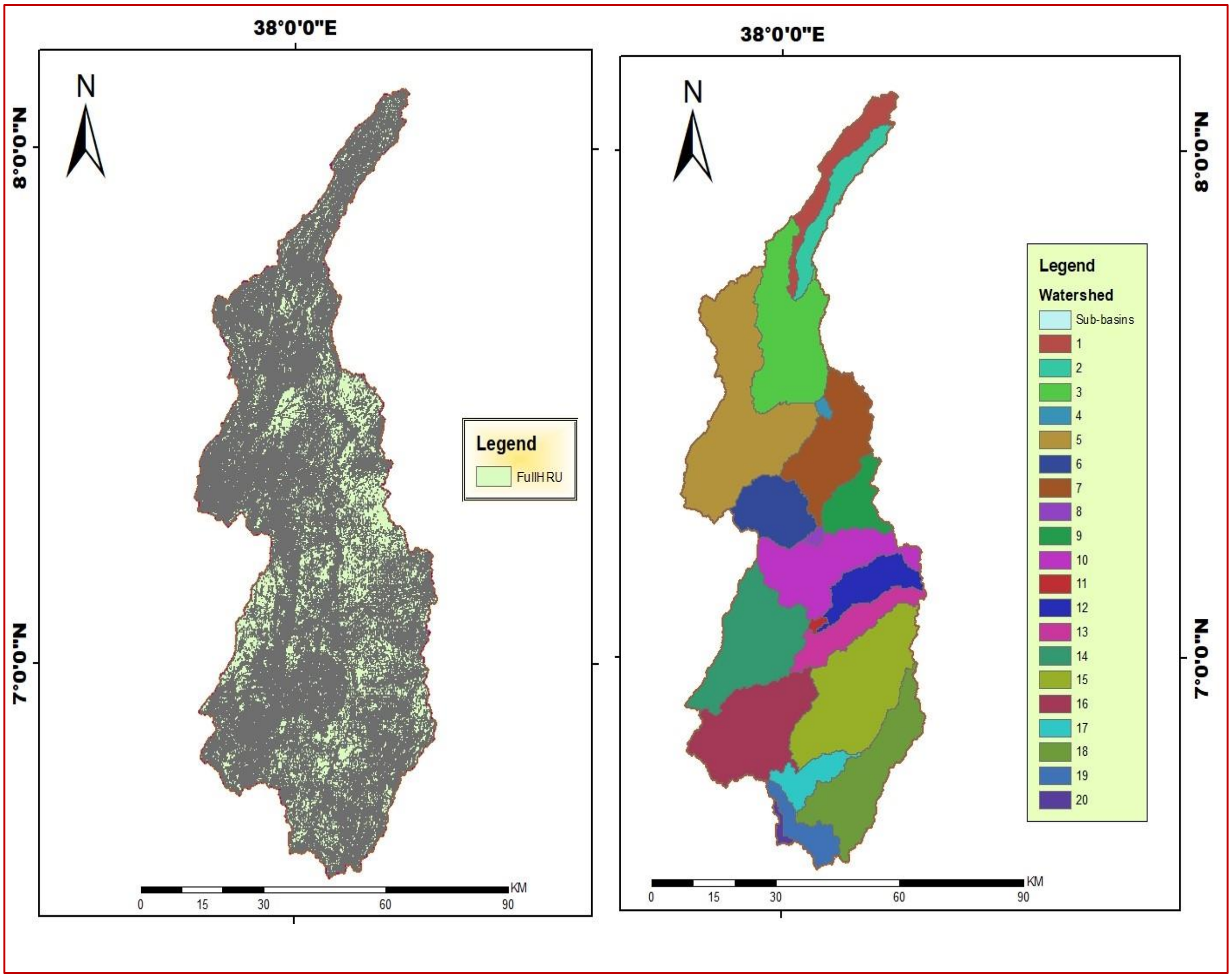


Figure: 3.10:- Full Hydrologic Response Unit and Sub-basins for the watershed

In this step the land use map and soil map of the study area use as the main inputs for SWAT model and they should be prepared in suitable SWAT format and inserted in SWAT2012 database.

The hydrologic response units approach lumps all the same LULC, soils types, and slopes classes within a sub-basin based upon user-defined thresholds. Fixing threshold level was used to eliminate the minor LULC in sub-basin, minor soil within a LULC area, and minor slopes class within a soil on the specific land use and land cover area. A watershed is subdivided into a number of homogenous sub-basins (hydrologic response units or HRUs) having unique soil, slope, and LU properties and use for simulation purposes. Then, after successful completion of HRU analysis:

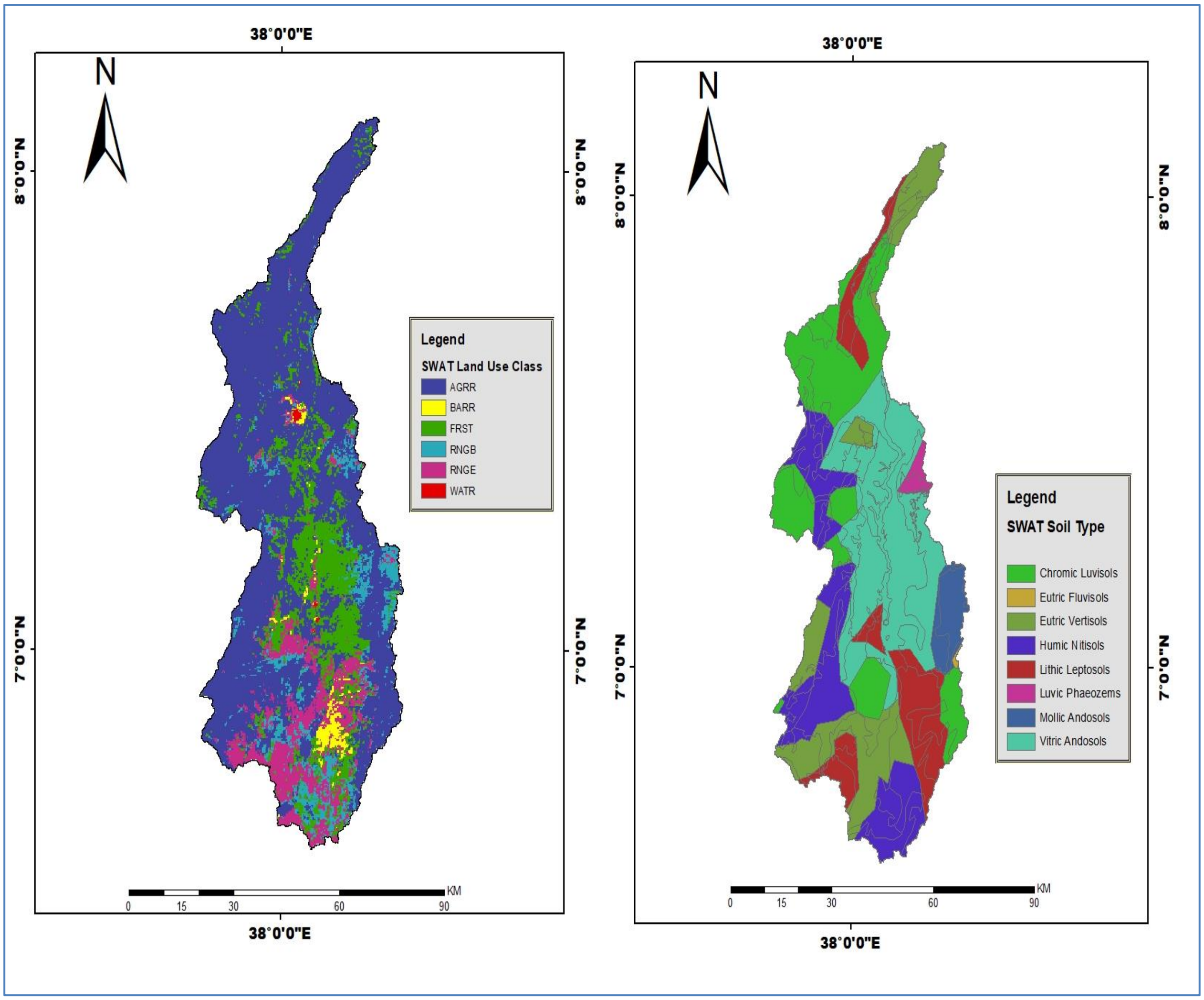


Figure: 3.11:- SWAT land-use and Soil classes

Write input tables become active after HRU analysis is successfully done where all the SWAT input data are written to the SWAT database for model processing.

Edit SWAT input is where the soil and LULC data properties are entered into the SWAT database in the form that the model understands the codes.

3.4.4 Weather Data Definition

SWAT requires daily climatic data that could either be taken from a measured data set in a suitable format or data generated by a weather generator model.

Weather data are one of the main inputs for SWAT simulation. The weather input data required for SWAT simulation includes daily data of rainfall, temperature (maximum and minimum), humidity, wind speed, and solar radiation. The weather generator model included in SWAT-12 was used to fill the gaps in measured records. This weather generator was developed for the Bilate watershed by providing all the necessary information from the meteorological records of the watershed. These statistics values were calculated from the meteorological data available in Hossana. Once the database setup is complete in Arc SWAT, the designated weather station locations are added to the Monitoring Point layer created during Watershed Delineation. The last step before a SWAT simulation can be run is to write all of the input files required by SWAT and produced from the preprocessed data from Arc SWAT. Once they are written, individual files can be edited through Arc SWAT, or externally.

SWAT simulation is the final stage that becomes active after all the previous stages have been successfully completed. Setting the default simulation the first task in this stage and then running the model. Sensitivity analysis, reading model outputs, auto, and manual calibration are also accessed here.

3.4.5 Sensitivity Analysis for the SWAT model

The way of estimating the rate of alteration in model output with respect to rate of change in model input parameter is known as sensitivity analysis. The SWAT model has several parameters that are used to identify the sensitivity of surface runoff. Sensitivity analysis was performed to limit the number of optimized parameters to obtain a good fit between the simulated and observed data.

In this study as indicated in Appendix F, many parameters were considered and from those parameters, only ten parameters were identified to have a significant influence in controlling surface water potential and water balance in the watershed.

3.4.6 Model Calibration

Calibration is a means whereby the model parameter is arranged to make the model output match with observed data. There are three calibration approaches widely used by the scientific community. The main objective of an interface is to provide a link between the input and output of a calibration program and the model. The simplest way of handling the file exchange is through text file formats. The manual calibration approach requires the user to compare measured and simulated values, and then to use expert judgment to determine which variables to adjust, how much to adjust them, and ultimately assess when reasonable results have been obtained (Gassman, 2014). First, the parameters were manually calibrated until the model simulation results were acceptable as per the R^2, NSE, and PBIAS values. Next, the final parameter values that were manually calibrated were used as the initial values for the auto-calibration procedure. Maximum and minimum parameter value limits were used to keep the output values within a reasonable value range. Finally, the auto-calibration tool was run with optimum values to give the best fit between the streamflow data and simulated data as determined by the R^2 reasonable values.

3.4.7 Model Validation

After calibration, the model with calibrated parameters was validated by using an independent set of measured flow data that was not used for model calibration. For my study, flow validation was carried out from January 1, 2001, to December 31, 2007, without further adjustment of the parameters of flows.

3.4.8 Model Performance Evaluation

The model performance was evaluated using three well-known statistical criteria, the determination coefficient (R^2), the Nash-Sutcliffe efficiency (ENS) and percent of bias (PBIAS) (Singh, 2014). The regression coefficient (R^2) is the percentage of variance in the measured data that is explained by the simulated data. If the (R^2) value is equal to zero, there is no incentive to use two regression parameters to summarize the data. The closer the value of R^2 to 1, the higher is the agreement between the simulated and the measured flow.

The R^2 value is calculated as:

$$R^2 = \frac{[\![\sum_{i=1}^{n}(YSi-YS)(Yos-Yo)]\!]^2}{\sum_{i=1}^{n}(Ysi-Ys)-\sum_{i=1}^{n}(Yoi-Yo)^2} \quad \text{..........} \quad 3.5$$

The Nash-Sutcliffe simulation efficiency (ENS) shows that how well the plot of observed values versus simulated value the 1:1 line fits.

It can be calculated as follows:

$$\mathrm{ENs} = 1 - \frac{\sum_{i=1}^{n}(Y_{oi}-Y_{si})^2}{\sum_{i=1}^{n}(Y_{oi}-Y_{o})^2} \quad \text{..........} \quad 3.6$$

Where: - Ysi is the simulated values of the quantity in each model time

Yoi is the measured value of the quantity in each model time

Ys is the average simulated value of the quantity in each model time

Yo is the average measured value of the quantity in each model time

Percent bias is the measure of the mean values of the simulated flow to be greater than or smaller than their streamflow data. Positive values that show model underestimation bias and negative values also show model overestimation bias. A value close to zero percent is best for P_{BIAS} and the recommended range for percent bias is between positive 25 and negative 25.

PBIAS is calculated as follows:

$$P_{BIAS} = \left(\frac{\sum Xi - \sum Yi}{\sum Xi}\right) * 100\% \qquad 3.7$$

SWAT-CUP is an extension that was developed for SWAT. Using this interface, any Calibration/uncertainty or sensitivity program can easily be linked to SWAT. The program can run SUFI2, GLUE, and Para Sol. The model leads the input data needed for running a calibration and validation program. Each SWAT-CUP project contains one calibration method and allows running the procedure many times until convergence is reached. It allows saving calibration iterations in the iteration history for later use. SUFI-2 algorithm, in particular, is suitable for calibration and validation of the SWAT model because it represents uncertainties of all sources (Abbaspour, 2007) and this algorism was used for this study.

There is an intimate relationship between calibration and uncertainty and reporting uncertainty is not a luxury in modeling, it is necessity. Without uncertainty calibration is meaningless and misleading (Abbaspour, 2007).

In SUFI2, uncertainty in parameters, expressed as ranges (uniform distributions), accounts for all sources of uncertainties such as uncertainty in driving variables (e.g., rainfall), conceptual model, parameters, and measured data. Propagation of the uncertainties in the parameters leads to uncertainties in the model output variables, which are expressed as the 95% probability distributions.

3.5 Modeling of Current and Future demands

3.5.1 Water Demands Guidelines

In general water demand projections and calculations are done by estimating the domestic water demand, commercial and institutional water demand, industrial water demand, and livestock water demand and water losses in systems. But the Ministry of Water and Irrigation has put guidelines for all these demand categories and additional climatic factors that affect consumption variation in the specific river basin under their master plan study based on the practical situation and lifestyle of the basin population. The following are the guidelines:

1. Domestic Water Demands

The domestic water demand is the demand for domestic household use; the water consumption per capita demand per day. The per capita demand of the basin is generally based on the newly revised water demand standard of the second Growth and Transformation Plan of Ethiopia (GTP-II, which goes from 2015 - 2020). Based on the newly revised water demand standard of GTP-II, it ranges from 40 to 100 lpcd depending on the population size for urban and 25 lpcd for rural up to the year 2020. But in my study, the water demand is forecasted up to the year 2035 which lies in the third Growth and Transformation Plan (GTP III), therefore, the per capita demand will increase for overall population as per Indicative Targets During RVLB Master Plan Period of for medium (2016 to 2024 and long term (2025 to 2035) periods.

As per the GTP-2 water supply service level standard, it is required to provide safe water in minimum 25 l/c/day within a distance of 1 km for rural areas while in urban areas it is required to provide safe water in minimum 100 l/c/day for category-1 towns/cities (towns/cities with a population more than 1million), 80 l/c/day for category-2 towns/cities (towns/cities with a population in the range of 100,000 - 1million), 60l/c/day for category-3 towns/cities (towns/cities with a population in the range of 50,000-100,000), 50l/c/day for category-4 towns/cities (towns/cities with a population in the range of 20,000-50,000) up to the premises, and 40 l/c/day for category-5 towns/cities (towns/cities with a population less than 20,000) within a distance of 250m.

2. Commercial and Institutional Water Demands:- In addition to domestic household use, water requirements in towns include the normal needs of the community for public schools, clinics,

hospitals, offices, shops, bars, restaurants, and hotels. The water demand for commercial and institutional needs is usually linked directly to the population and is taken as 5% of the domestic demand for this specific basin.

5. Industrial Water Demands

Industrial water demand which is consumed by industries is not usually linked directly to the population. But for the purpose of planning, it is assumed to use 10% of domestic water demand for all towns in the basin.

6. System Losses: - In estimating water losses in the water supply system a percentage of 20% of the total domestic, commercial, institutional, and industrial demands are assumed in the basin.
7. Average Daily Demands: - The average daily demand is taken to be the combined total of the domestic, commercial, institutional, industrial and livestock demands and the system losses.
8. Maximum Daily Demands:-The daily water consumption in a town varies depending on the time of day, season and climatic conditions. So that, the Maximum Daily Demand has been taken as 1.15 times the Average Daily Demand.

3.5.2 Current Water Requirements and Demands

The current water requirements were assessed for various water competing needs in the sub-basin. Since there is no hydropower schemes, the environmental requirements (non-consumptive) together with domestic water supply, livestock requirement, and agricultural or irrigation demands the three identified off-stream water users the sub-basin. Water demand analysis for these needs were performed. The water requirement was calculated at each demand node by using the disaggregated end-use based approach. The demands for domestic, livestock, and agriculture entities were estimated based on a disaggregated accounting approach for various measures of social and economic activities. The user can fix appropriate activity levels such as persons, heads, and ha of command area by standard water use technique for each disaggregated level and multiplies these by the appropriate annual water use rate for every activities.

3.5.3 Future Water Demands in the Bilate Watershed

Scenarios will be defined as an alternative or a set of assumptions based on increasing population and future development or policies. Changes in these assumptions could grow water demands. However, scenarios in the WEAP model encompass any factor that can change over time including those factors, which may change due to particular policy interventions, and reflect different socio-economic assumptions. Scenario projections for this study were established in the WEAP model based on the Rift Valley Lakes Basin master plan.

3.6 WEAP Model Setup and Application

Water demand sites and catchment were added and WEAP was run in its water-sharing model using the rainfall-runoff parameters determined from the SWAT model and demand site data. This was done in order to find water uses in the basin. The model used in this study works at the WEAP sub-watershed scale and at the monthly time base. WEAP software is composed of five different "setup views" onto the working Area: such as Schematic, Data, Results, Overview, and Notes. In WEAP, models are called “areas”. The background vector data of the study area, which was created by GIS software, was added to the model.

Once the area is open, the years, time steps and units are set. In this study, the current account is set to be year 2017 with the last year scenarios to 2035. The time steps per year was set to be 12 and the time step boundary “based on calendar month”, starting with the month of January was selected. The current account is the dataset from which the scenarios are built. A default scenario, the “reference scenario” carries forward the current accounts da ta into the entire project specified (2017- 2035). WEAP calculates a water quantity for every node and catchment and links in the system on a monthly time step. Water is required to meet in-stream and consumptive requirements, subject to demand priorities, supply preferences, mass balance, and other constraints.

Schematization is the first task in the WEAP model where rivers, demand sites, transmission links, reservoirs, and any necessary schematics are added to the study area in WEAP created from ArcGIS raster data done previously in the ArcGIS model. In the data view, all required data (annual activity levels, annual water use rates, consumption, and monthly variation) for all demand sites are entered. River path was drawn in WEAP by clicking on the “river” symbol in the element window and by drag and drop and enter data for the river head flow data.

Demand Sites and entering related data

Four demand nodes were created and the required data were imported to the model for each demand sites.

Connecting the Demand with Supply

In order to inform WEAP how the demand is satisfied, the water supply source (rivers) was connected to each demand sites. These were accomplished in the schematic view by adding the transmission link. The link was first positioned on the river, then pointing to each four demand nodes.

Creating the Return Flow Links

The return flow routing is the percent of total outflow from a demand node, and then the return flow routing for that link must be 100% due to only one return flow link is created for each demand nodes. The return flow links were connected back to the rivers and return flow routing was set to be 100% so as to use the return flow for other demands effectively.

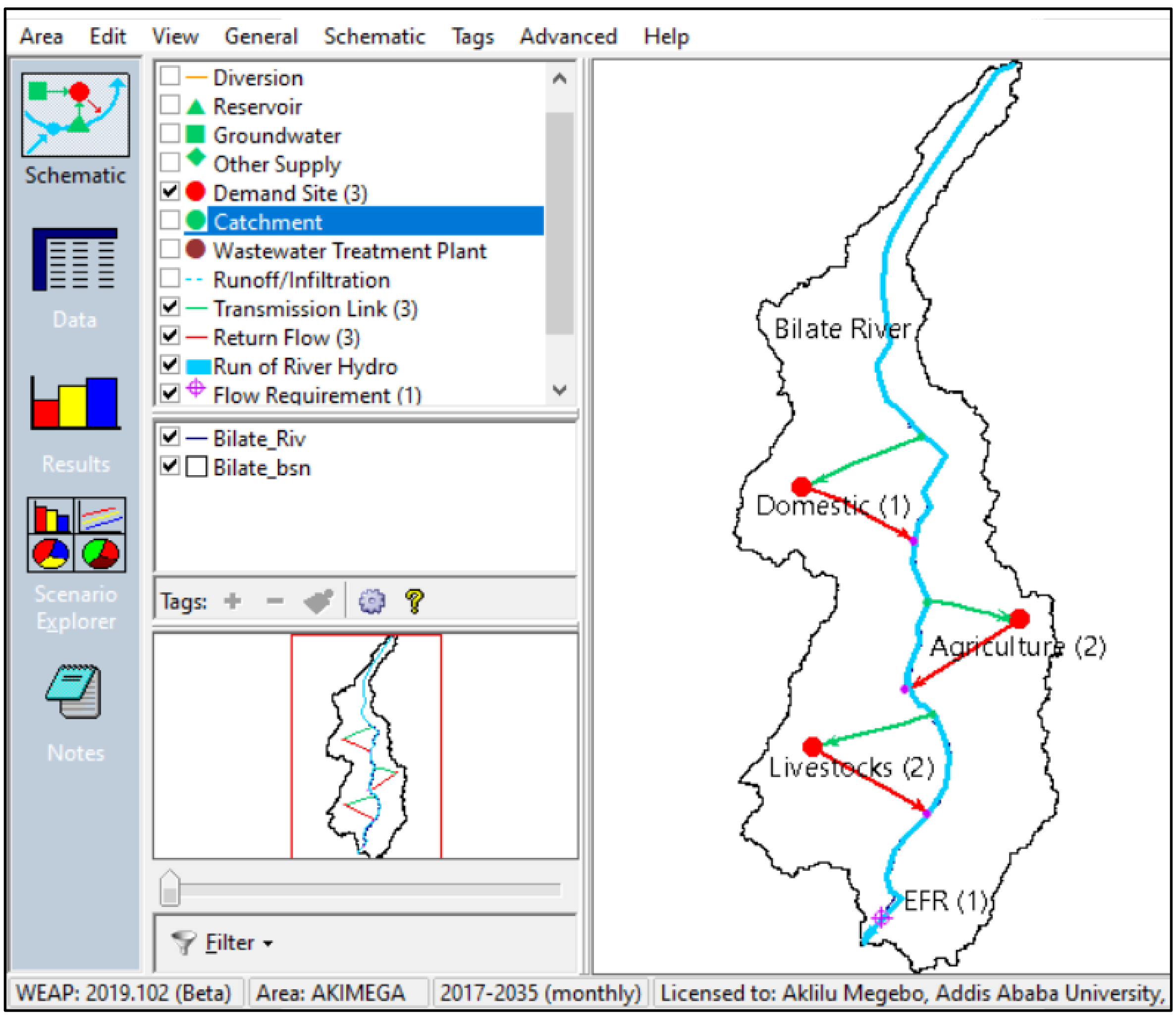


Figure: 3.12:- Schematic of WEAP model and Demand nodes

The Demand Priority represents the level of priority for allocation of constrained resources among multiple demand sites. WEAP will attempt to supply all demand sites with highest Demand Priority, then moving to lower priority sites until all of the demand is met or all of the resources are used, whichever happens first. The demand priority for domestic and environmental flow requirements were taken as one and agricultural and livestock demands as two in this study.

The Supply Preference parameter allows you to define which source should be used in priority to supply water to this Demand Site. WEAP will attempt to supply all of the demand with sources having the highest preference level, only using lower-level sources if the high level sources do not have sufficient supply.

3.7 WEAP Model Input Data

3.7.1 Population Data and Population Projection

One of the basic inputs in the WEAP model is the population data. The population data collected from the Central Statistical Agency is based on census 2007 when the number of the population was around 1,806,907, and the population growth rate of the basin is found to be 3.2%. Hence, the census of 2007 populations' density is projected to the current year of this study (2017); which is the current account year in my model. The populations of the study area with their projections are given in table 3.3 below. The current (2017 base year) population of the Bilate watershed is 2,522,105 people. Using the average population growth rate of 3.2%, the population is expected to double just after 2035. The total consumptive water requirement was based on the population census of the 2007 wereda (district) level.

Table: 3.4:- population data and projection in the study area

Year	2007	2017	2020	2025	2030	2035
Growth rate	3.2%					
Population	1,840,629	2,522,105	2,772,057	3,244,895	3,798,387	4,446,289

The annual water use rate per person which is calculated for the specific basin (29.2m³/year) and the projected population density is finally used for the WEAP model.

Annual Water Use Rate

The WEAP model needs annual water uses rate as basic input. Based on the specific guidelines given by Ministry of Water, Irrigation, and Energy, the annual water use rate per person in the basin is calculated below:

The Urban Water Demand per capita demand is 60 lpcd = 0.06 m^3/day =21.9 m^3/ year and the rural water demand case: the per capita demand is 20lpcd =0.02m^3/day= 7.3 m^3/year.

Therefore, annual activity level is 2,522,105 and the water use rate per person in the sub-basin is 29.2m^3 which is the input for WEAP model for domestic water demand assessment.

The industrial sector in the sub-basin is small-scale industries (mineral water) with a low water consumption rate, which considered under domestic demands.

3.7.2 Livestock's Demands Assessment

There are no recent counts of livestock population density, but many pastoralists are moving with their large herds of cattle and other livestock in response to the annual regime of the Bilate River.

The sub-basin was extensively utilized by the communities for livestock grazing. Livestock water requirement rate was given as the unit 25, 5, and 12litres/head/ day for cattle, goat/sheep and Equine respectively. The total number of livestock and their annual water requirement are given below as per estimated daily drinking water requirement of livestock under African conditions as well as in the basin (liters).

Therefore, the annual activity level and annual water use rate for livestock are 2,038,777 and 15.53m^3/year respectively.

Table: 3.5:- Average water demand for livestock

Livestock Type	Average Water requirement(l/hd/d)	Annual Water requirement(m^3/hd/y)	Total No. of animals (hd)	Annual Water Demand(Mm^3/y)
Cattle	25	9.2	1,121,327	10.23
Sheep and Goat	5	1.83	509,694	1
Equine	12	4.5	407,755	1.8
Total	42	15.53	2,038,777	13.03

3.7.3 Irrigation Water demand Assessment

The agriculture demand is estimated based on land use and water requirement for rainfed crops by using Area, Crop coefficients (Kc), and the Reference Crop Evapotranspiration (ET_O).

CROPWAT which is developed by the Foods and Agricultural Organization, FAO; is used to estimate the crop water requirements for existing and proposed irrigation schemes. According to the RVLB master plan, there are 8000ha previously identified irrigation schemes but not yet fully implemented for the main crops such as maize, cotton, wheat, potato, and vegetables. As a result, these crops were chosen to estimate the requirement of water for crops proposed irrigation. Since there are no existing large scale irrigation schemes in the basin.

This study have considered around seven planned irrigation sites under feasibility study to model the irrigation demand in WEAP with crop water requirement around 5,822m^3 per ha.

3.7.4 Water Requirement for Non-Consumptive Use

Since there is no hydropower generation plants existing at present and no data for the proposed dam in the sub-basin, the only water requirement for non-consumptive uses were considered as environmental flow requirement. In estimating the availability of water resources, consideration must be given to requirements for environmental flows to maintain the ecosystems of the river, to consider the obligations, and to maintain low levels of downstream users.

The environmental flow in this study was assigned to be 20% of mean annual runoff, where streamflow is required at a point on a river to meet the different ecosystem related water demands for downstream users such as maintaining river water quality, fish, and wildlife and to maintain the water level of Abaya Lake.

3.8 Structure of Scenarios in WEAP

Scenarios are defined as alternatives or a set of assumptions, increasing population and future development or policies. Changes in these assumptions could grow demand. However, Scenarios in WEAP encompass any factor that can change over time, including those factors that may change because of particular policy interventions, and those that reflect different socio-economic assumptions.

Water allocation models must precisely represent the substantial features of system water resources within any basin. Ideally, they should simulate water availability and demand (Etchells, 2005). The priority of demands in this case, represented the level of priority for sharing of the available water (SEI, 2008). This means, for example, the demand that all sites with the highest priority would be supplied first before moving to lower priority sites until all the demands are met or all the available resources are used, whichever comes first.

3.8.1 Current Accounts Year

When you are using WEAP, you are often asking questions about what will happen in water demand in the future (since we cannot go back and change the past). The current account years is meant to represent the system as it is in a point of time when you know the data that characterizes the system and is chosen to serve as a base year of the model where we feed basic data. In WEAP; first the Current Accounts system of water needs to be created under study. Current Account is chosen based on the data available data in that year. The year 2017 is chosen as the Current Accounts year in the study area because the data I have collected was until the year 2017; this is what the "current" system looks like, although the need for hydro-meteorological might mean your "current accounts" year is actually 2-3 years ago.

All data entered here are the basic raw data that actually exist in the base year without any projection. Hence, every data was fed to this Current Account year to serve as the base year for all processes of the WEAP model.

3.8.2 Reference Scenario

Depending on a variety of economic, demographic, hydrological, and technological trends, a “reference” scenario projection is established called a reference scenario. The reference scenario is developed from the current account to simulate the likely evolution of the system without intervention. This scenario serves as a reference to all other scenarios created to show different trends. Hence, every scenario developed to show its own trend on the model result is compared to the reference scenario as there are interventions in the reference scenario other than projecting the current account year to the future year.

Reference Scenario represents the changes that are likely to occur in the future without intervention new policy measures; it only increases in population growth. As we know, the reference scenario is the scenario in which the current situation was considered. Therefore, the total population within the basin was projected around 2,522,105 for the year 2017 based on Census 2007 data. The current account (the year 2017) was extended to the future (2018-2035). No major changes were imposed in this scenario. It was assumed a linear change in population increase.

3.8.3 Scenarios One: High Population Growth Scenario

This scenario was modeled to assess the impact of a high population growth rate than the current population growth rate in the sub-basin. The question of what will happen if the rate population growth density is set to a higher growth rate than the reference scenario population growths rates was answered.

3.8.4 Scenario Two: Projections in the Irrigation command Area

As the Bilate river watershed is known by its suitability for Agriculture, Irrigation in this basin is rapidly growing in terms of area and yield. Additional irrigation projects should be identified by different institutions yet the developed irrigation projects are quite small. The exploitation of all potential irrigation command areas as identified at the RVLB master plan, which can be expected to be around 40,000ha by the year 2035. Hence this scenario shows the impact of irrigation development by 10%. The basin is not fully developed in terms of irrigation; there are potential areas suitable for irrigation in the sub-basin. Hence, if these potential areas fully developed, what will be the effect in water demand will assess in projection in the irrigation area scenario. The rate of water consumption by domestic and livestock remained constant.

3.8.5 Scenario Three: Increased Water Demand Scenario

If the irrigation potential in the basin is developed and water consumption per capita per year is increased by half for domestic water demand. Moreover, the water consumption rate for livestock is increased similarly. If it is proposed that for well-living standards the per capita demand for all water demand sectors will be increased 50% from current water demand in the sub-basin. This scenario was modeled to assess the impact of consuming more water than the current water requirements.

The conceptual framework of this study is presented below and discussed in subsequent sections.

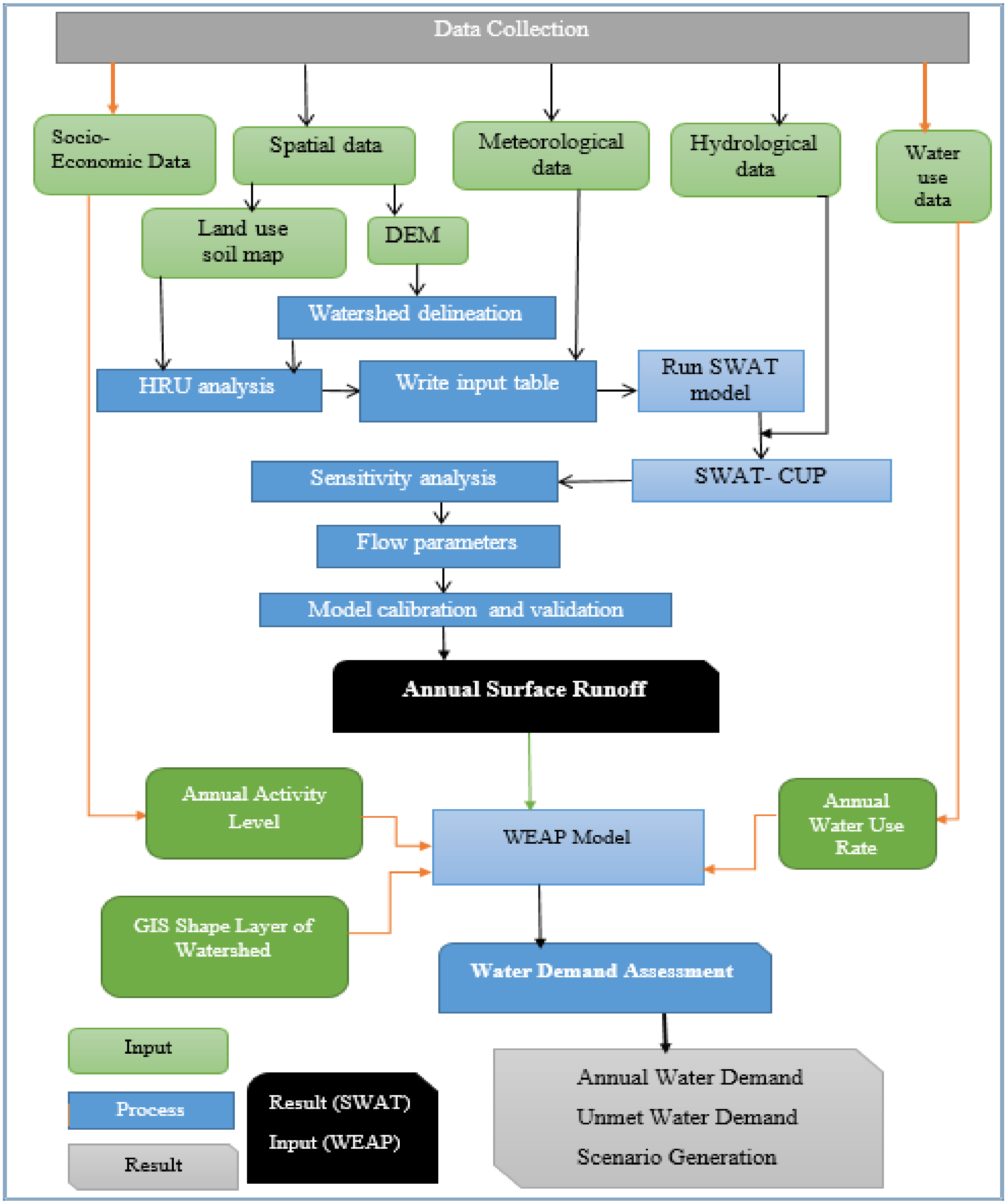


Figure: 3.13:- Conceptual framework of the study

4 RESULTS AND DISCUSSIONS

4.1 Results on Surface Water Potential

According to the result obtained from the SWAT model, the Bilate river watershed receives an estimated mean annual precipitation of 1106.2mm. The estimated mean annual surface runoff volume leaving the entire sub-basin area of 5,248km^2 is 851.5MCM which corresponds to 162.3mm mean annual runoff depth i.e. around 14.7% of annual precipitation falling in the watershed was changed into surface runoff. Therefore, the total quantity of surface water potential in sub-basin is 851.5MCM, as the only source of surface water in the study area is rainfall.

The portion of precipitation that infiltrates into the soil layer accounts about 172.2mm (i.e., 15.59%) of mean annual precipitation recharge groundwater aquifers and to contribute baseflow. Out of the mean annual rainfall of 1106.2 mm; the remaining 152.6 mm is lost due to percolation for the recharging of the aquifer and 24.2 mm as lateral flow and about 140.35mm as return flow. The estimated mean annual actual evapotranspiration is 767.5mm (i.e. about 69.4%) is lost due to Evapotranspiration. The mean annual water balance for both validation and calibration period was revealed that the largest portion of the average annual precipitation falling in the watershed was lost through the evaporation (Table 4.1). This indicates that the evapotranspiration parameter was most sensitive than any other hydrologic parameter, which governs the sub-watersheds hydrological water balance.

Table: 4.1:- Average Monthly Basin Value from the SWAT model

Month	RAIN (mm)	SURF Q (mm)	LAT Q(mm)	WATER YIELD(mm)	ET (mm)
1	28.81	1.62	0.57	16.26	29.87
2	35.46	2.42	0.64	14.82	31.57
3	86.66	8.16	1.31	21.44	57.56
4	149.69	23.07	2.48	36.28	92.28
5	133.21	19.8	2.84	33.54	105.87
6	110.07	10.73	2.22	23.44	86.22
7	138.42	18.79	2.71	32.41	79.01
8	147.8	28.82	3.47	43.79	75.83
9	122.12	26.81	3.2	36.81	70.2
10	84.22	21.31	2.6	33.53	62.32
11	46.8	8.71	1.43	24.53	43.35
12	22.61	2.02	0.68	17.42	33.24

The total annual river flow of Bilate River as simulated and calibrated by using SWAT model at Alaba Kulito. The high monthly average flows were occurred in months of August (157MCM), September (140.5MCM) and October (114.5MCM) and the lowest was found in month of January (8.5MCM) as indicated in (table 4.1).

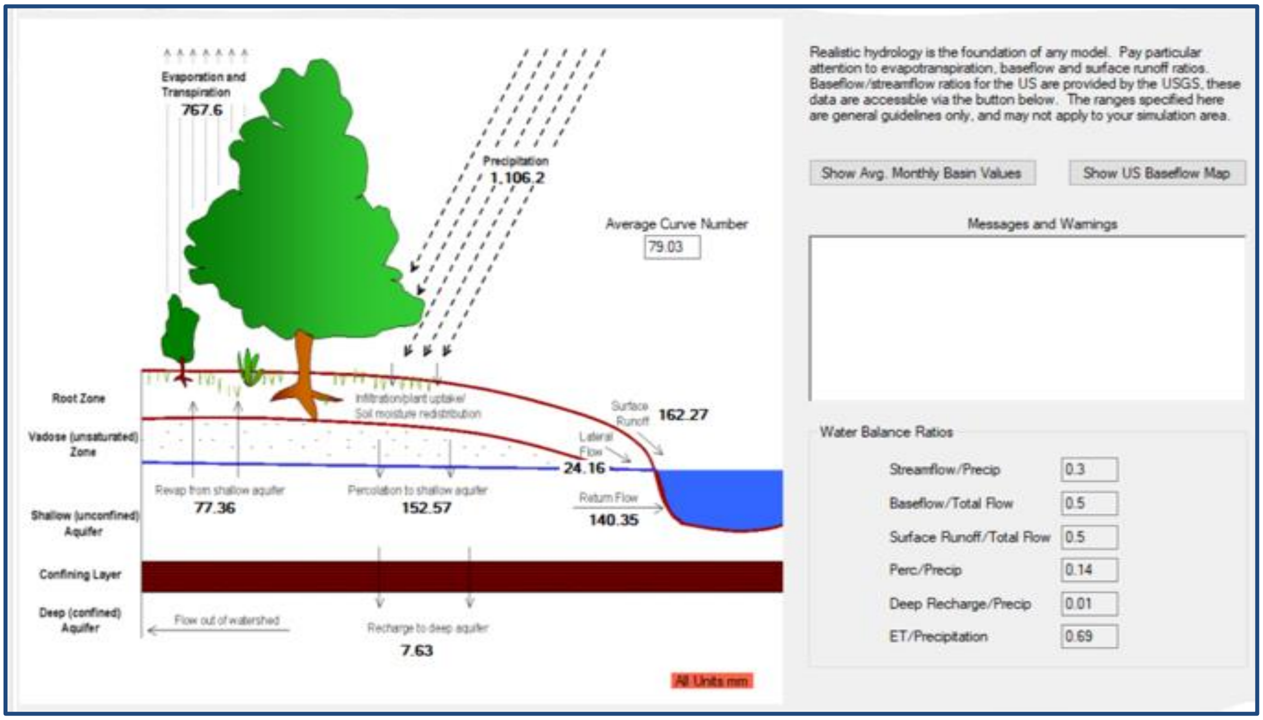


Figure: 4.1:- General results of annual water balance (hydrology) in the SWAT model

As realistic hydrology is the foundation of any model; this study should give particular attention to water balance ratios such as evapotranspiration, baseflow, and surface runoff ratios. The water balance ratios and guidelines are provided in hydrology part of the ArcSWAT results. These interval and general ranges are provided in the table.

Table 4.2:- Water balance ratios of the Bilate watershed ranges and result

Hydrologic Parameters	Ranges	Result
Stream to precipitation	0.2 - 0.4	0.3
Base flow to Total Flow	0.5 - 0.7	0.5
surface Runoff to Total Flow	0.4 - 0.8	0.5
Percolation to Precipitation	< 0.2	0.14
Deep recharge to precipitation	< 0.2	0.01
Evapotranspiration to precipitation	0.5 - 0.8	0.69

Table: 4.3:- Average Annual Basin Values from the SWAT model

Hydrological parameter	Simulated value(mm)	%annual precipitation
Surface Runoff Q	162.3	14.7
Lateral Soil Flow	24.2	2.2
Groundwater (Shallow Aquifer) Recharge	140.35	12.7
Groundwater Revap (Shallow Aquifer to Soil/Plants)	77.36	7.0
Groundwater (Deep Aquifer) Recharge	7.63	0.7
Total Aquifer Recharge	152.6	13.8
Total Water Yield	334.5	30.2
Percolation Out of Soil	153	13.8
ET	767.5	69.4
Precipitation	1106.2	

Table: 4.4:- Comparison of results of different studies in the sub-basin

Study	RVLB Master Plan	Tekle(Upper Bilate)	This Study
Area (km^2)	6,500	3,643	5,248
Surface Water (MCM)	875	255	851.5

The possible reasons for the variation in results may be due to the length of data period and number of stations taken into consideration for estimation of surface water potential and area of the sub-basin.

4.1.1 Sensitivity Analysis

The sensitivity analyses were carried out using 16 parameters to characterize the Bilate watershed using the Global sensitivity analysis method in SWAT-CUP SUFI2 (appendix G). Among these parameters used for the sensitivity analysis; only ten parameters were shown significant effects on the monthly flow simulation of the watershed. The first ten parameters were shown a relatively high sensitivity, being the evapotranspiration the most sensitive. The most significant parameter controlling the Streamflow in the watershed are shown below in Table 4.5.

Table: 4.5:- Fitted and best parameters giving the best value of objective functions

Parameter Name	SWAT Code	Range	Min value	Max value	Fitted value
Soil evaporation compensation Factor	ESCO.hru	0 - 1	0.25	0.95	0.53
Average slope length	SLSUBBSN.hru	10-150	10	100	26.1
Surface runoff lag time	SURLAG.bsn	0.05-24	5	20	10.8
Threshold depth of water in the shallow aquifer required for return flow to occur	GWQMN.gw	0-5000	100	2500	1445.1
Depth from the soil surface to bottom of the layer	SOL_Z (.).sol	0-3500	500	3000	2959.3
Saturated hydraulic conductivity.	SOL_K (.).sol	0-2000	100	1000	386.7
Threshold depth of water in the shallow aquifer for "revap" to occur	REVAPMN.gw	0-500	50	300	141.3
SCS runoff curve number	CN2.mgt	35 - 98	-0.15	-0.25	0.25
Groundwater delay	GW_DELAY.gw	0-500	221.9	150	450
Available water capacity of the soil layer	SOL_AWC (.).sol	0-1	0.45	0.25	0.75
Plant uptake compensation factor	EPCO.hru	0 - 1	0.84	0.25	0.95

4.1.2 Model Calibration and Validation

The calibration and the validation were done using SUFI2 with the objective function of R^2, NSE, and PBias for many numbers of iterations and simulations for 14 years observed flow data at Alaba kulito gauging station and the results are presented below. The calibration and the validation results were performed until a good agreement between the simulated and observed monthly flows at the outlet of the watershed.

The calibration was done using historical records of seven years. However, the simulation was run for nine years, where the two years were used to "warm-up" the model. In the validation process, data for a period of seven years was used to evaluate model accuracy. In the validation process, data for a period of seven years was used to evaluate model accuracy. The statistical criteria used during the calibration procedure were also checked here to make sure that the simulated volume is still within the accuracy limits.

ArcSWAT Model Calibration

Measured flow data of seven years from the period January 1, 1994, to December 31, 2000, were used for calibration.

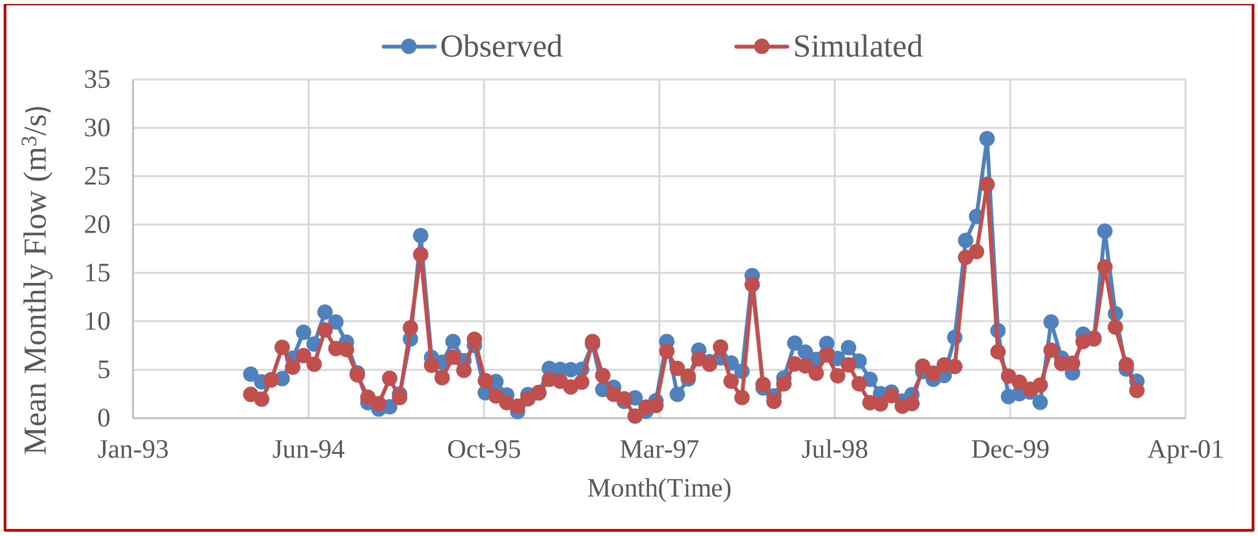


Figure: 4.2:- Simulated versus observed monthly flows in model calibration

The model was calibrated using monthly time step data of seven years in which the model showed the best performance on a daily basis. As the model, calibration result is shown in figure 4.2 above there are some under and overestimations in the model output in some points, but the overall result assures that the simulated flow is best correlated with the measured (observed data).

ArcSWAT Model Validation

Independently measured flow data set of Seven years from the period January 1, 2001, to December 31, 2007, were used to validate the model. Even though the model was calibrated, it is not enough to say the model output is representing the study area, it has to be validated using an independent dataset. Therefore, it was validated using a monthly time step isolated data to check its reliability as shown below.

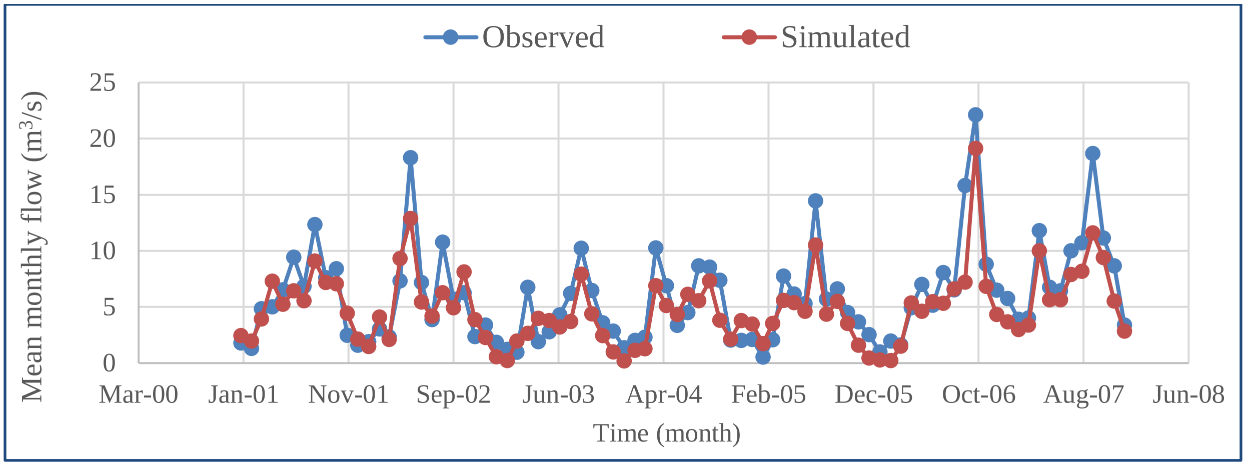


Figure: 4.3:- Simulated versus observed monthly flows in model validation

The model validation result shows that there are some under and overestimations in the model output is compared to the measured data but the overall validation result from the evidence there is the best correlation between the simulated model output and observed data.

Based on the model performance evaluation parameter numerical values of determination coefficient (R^2 = 0.78), (E_{NS} = 0.61) and (PBIAS = 23) assures that the model shows good performance during validation so as to able to simulate the runoff in the study area and estimated numerical values during model calibration and validation are summarized in the table below.

Table: 4.5:- Summary of statistical model efficiency criteria

Model runs	Model performance evaluation parameters			
	R^2	EN_S	P_{BIAS}	Remark
Calibration	0.75	0.62	18.8	ok
Validation	0.78	0.61	23	ok
Recommended	>0.6	>0.5	±25	

4.2 Results on Water Demands

4.2.1 Water Demands Results in the Current Account Year

The current accounts represent the basic definition of the water system as it currently exists. It is also assumed to be the starting or base year for all scenarios where we feed the currently available data. Hence, it is important to look at the nature of the demand in the current account year as it is the base for all scenarios and future demands.

The current account of the water consumption in the model was developed using the demand data of 2017 and simulated surface Water data as source of water supply from the Bilate River. The study has adopted a baseline scenario using the demand data of 2017, and simulated stream data (supply) 1990 -2017 assuming that similar trends of stream situation will exist in future without considering the climate change or by considering a constant supply and fluctuating demands. The basin has mainly three consumptive water demands, such as; domestic supply, agricultural, and livestock, and the environmental flow requirements.

The watershed has three consumptives water demands namely domestic (73.6MCM), livestock (31.7MCM), and agriculture (46.6MCM). The current total water consumption for this three users within the watershed was estimated to be 151.9MCM and the environmental flow requirement 170.3MCM, which is non-consumptive water user. Therefore, the water withdrawal in the Bilate River watershed is around 17.8% of the total available surface water in watershed, which is 851.5 million cubic meters per year.

The result shows that the total water demand for the current account year in the sub-basin is 151.9MCM. In the simulation, we further assume that 48.5% of the consumption of the demand sites is oriented towards Domestic water supply with 73.6MCM, being the largest user of water.

The water demand of agricultural sectors 46.6MCM which represents 30.7% of total demand, being the second-largest user of water, irrigation is the first sector to lose out as water scarcity increases. The Livestock water demand is 31.7MCM accounting for 20.8%. It is the least consumer water sector in the sub-basin.

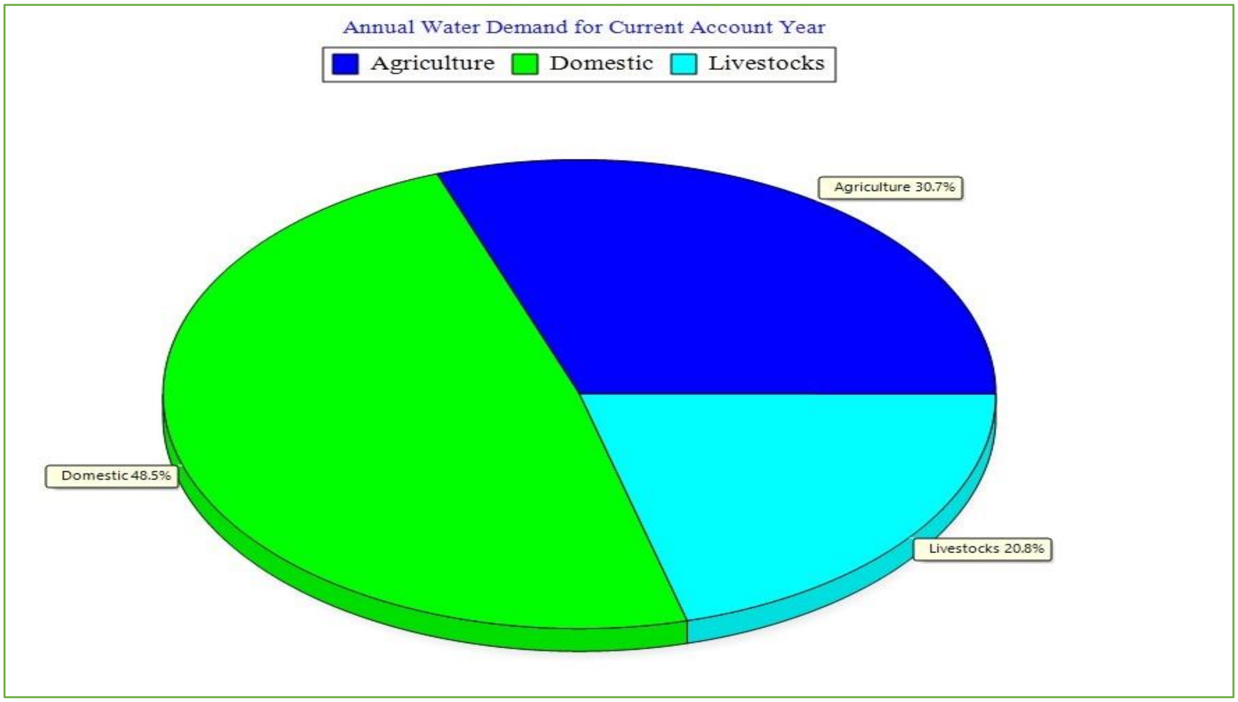


Figure: 4.4:-Percentage of total water consumption by sectors

4.2.2 Reference Scenario

In this scenario, the changes can be likely to occur in the future without intervention new policy measures were considered; it only increases in population and livestock growth intensity throughout the year. The annual population growth rate for domestic users and livestock was found to be 3.2% and 3.5% respectively. The “reference scenario” includes the current accounts data into the entire project specified (2018 - 2035).

Future overall water demand, Table 4.6, shows the net water demand for each sector was incorporated within the WEAP model, and the projected water demand for the year of 2018 - 2035. From the result, it was projected that in the year 2035, the total water demand will be increased to 235.2MCM**.** In the simulations, we further assume that 55.2% of the consumption of the demand sites will be oriented towards Domestic water supply with 129.8MCM, being the largest user of water. The water demand of agricultural sectors 46.6MCM which represents 19.8% of total demand, being the least user of water. The Livestock water demand is 58.8MCM accounting 25%. It is the second-largest consumer water sector in the sub-basin. As no change in policy measures, agriculture demand is still constant while others increase due to population growth intensity rate.

Table: 4.5:- Net total projected annual water demand for the reference scenario

Year	Demand Sites			
	Agriculture	Domestic	Livestock	Net Total
2017	46.6	73.6	31.7	151.9
2018	46.6	76	32.8	155.3
2019	46.6	78.4	33.9	158.9
2020	46.6	80.9	35.1	162.6
2021	46.6	83.5	36.3	166.4
2022	46.6	86.2	37.6	170.4
2023	46.6	89	38.9	174.5
2024	46.6	91.8	40.3	178.7
2025	46.6	94.8	41.7	183
2026	46.6	97.8	43.2	187.5
2027	46.6	100.9	44.7	192.2
2028	46.6	104.1	46.2	196.9
2029	46.6	107.5	47.8	201.9
2030	46.6	110.9	49.5	207
2031	46.6	114.5	51.3	212.3
2032	46.6	118.1	53	217.7
2033	46.6	121.9	54.9	223.4
2034	46.6	125.8	56.8	229.2
2035	46.6	129.8	58.8	235.2
Net Total	884.9	1,885.60	834.5	3,605

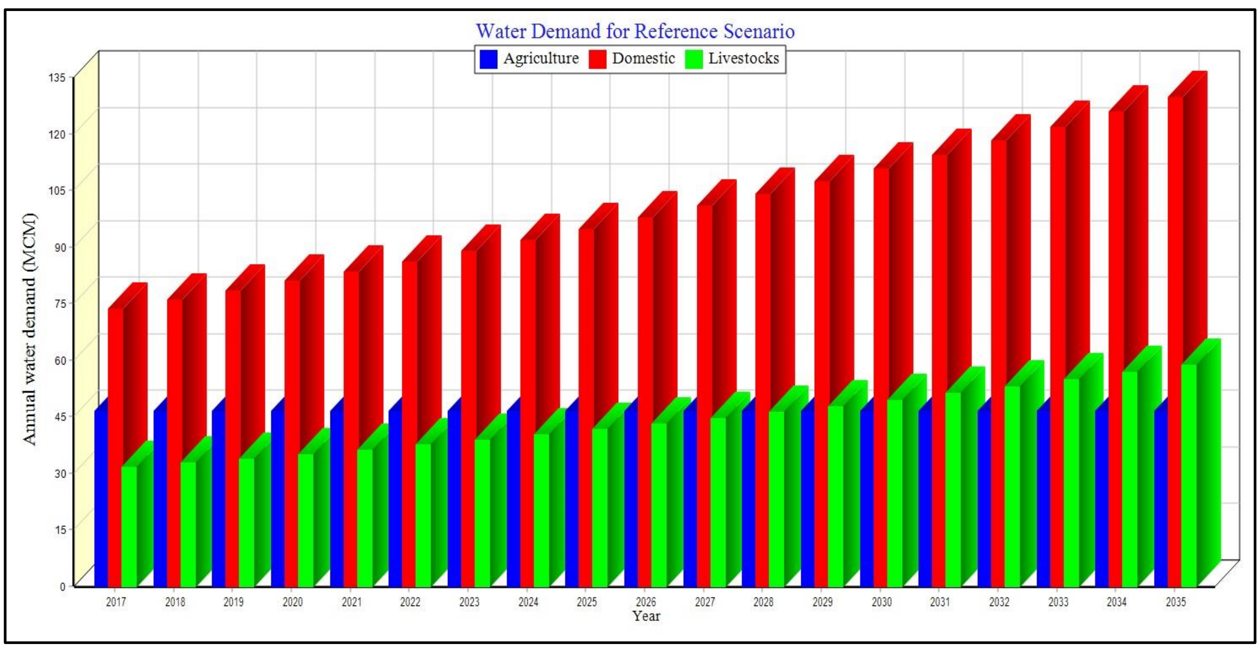


Figure: 4.5:- Annual water demand for reference scenario for all demand sites

4.2.3 Scenario 1: High Population Growth Scenario

But what will happen if the population growth rate is set to a higher growth rate than the reference scenario population growth rate? In this case, the population growth rate was raised to 5.5% from 3.2% to simulate the water demand in the future.

The net water demand for each sector was incorporated within the WEAP model and shows the expected water quantity for the year 2018 - 2035. From the result, it was projected that in the year 2035, the total water demand will be increased to 298.4MCM**.** As expected in population growth, the domestic water demand is high water consumer than others (around 193.1MCM (64.7%), Irrigation (46.6 MCM (15.6%) and Livestock (58.8 MCM (19.7%). Table 4.6 describes and presents the projected net water demand for the year of 2018 - 2035 and each sector incorporated within the WEAP model simulation

Table: 4.6:- Net total projected annual water demand for scenario 1

Year	Demand Sites			
	Agriculture	Domestic	Livestock	Net Total
2017	46.6	73.6	31.7	151.9
2018	46.6	77.7	32.8	157
2019	46.6	82	33.9	162.5
2020	46.6	86.5	35.1	168.2
2021	46.6	91.2	36.3	174.1
2022	46.6	96.3	37.6	180.4
2023	46.6	101.5	38.9	187
2024	46.6	107.1	40.3	194
2025	46.6	113	41.7	201.3
2026	46.6	119.2	43.2	209
2027	46.6	125.8	44.7	217
2028	46.6	132.7	46.2	225.5
2029	46.6	140	47.8	234.4
2030	46.6	147.7	49.5	243.8
2031	46.6	155.8	51.3	253.7
2032	46.6	164.4	53	264
2033	46.6	173.5	54.9	274.9
2034	46.6	183	56.8	286.4
2035	46.6	193.1	58.8	298.4
Net Total	884.9	2,364.2	834.5	4,083

A sharp increment in the domestic water demand was witnessed due to the high population growth intensity than the reference scenario.

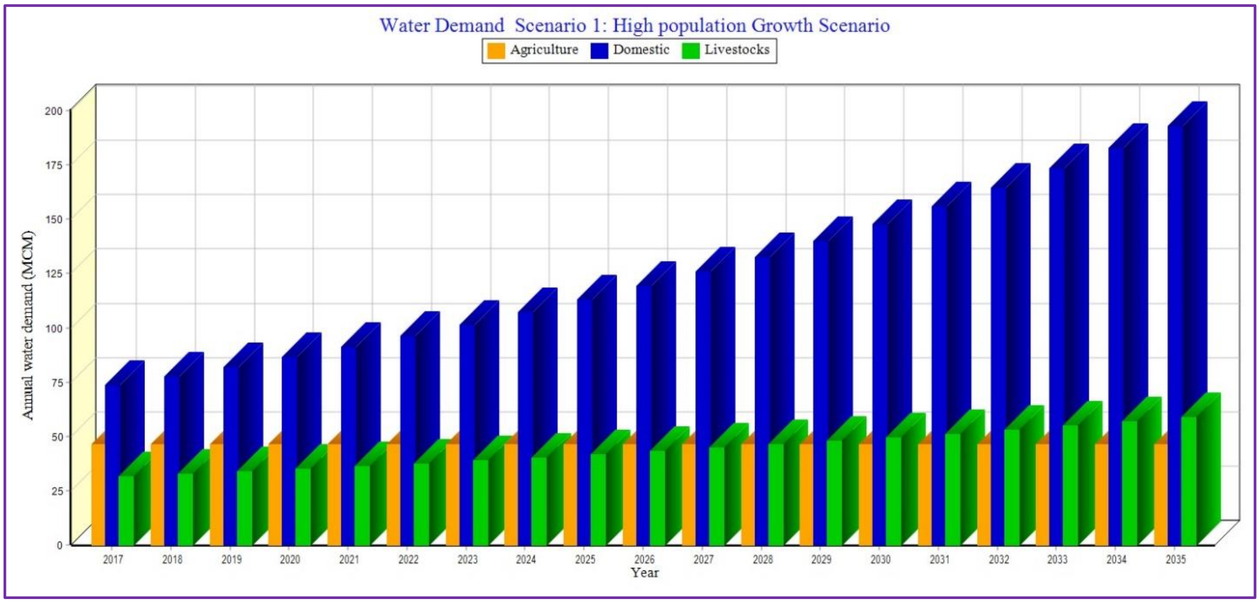


Figure: 4.6:- Annual water demand for high population growth scenario

The results show that the annual water demands when the population growth increases by 5.5% by keeping others as constant in the reference scenario. In this Scenario, the total water demand for all sites is 298.4 MCM per year.

4.2.4 Scenario 2: Projections in Irrigation Command Area

The exploitation of all potential irrigation areas was identified in the RVLB master plan, which brings developed the area to 40,000 ha by the year 2035 (anticipated growth of 10% per year from the current available command area of 8000 ha). Here, the population growth rate and livestock were considered as 3.2% and 3.5%, respectively. The water consumption rate for domestic and that of livestock remains constant. This scenario was modeled to show the impact of irrigation command area development by 10% on water demand.

Future overall water demand, Table 4.8 shows the projected water demand for the year 2018 - 2035. From the result, it was projected that in the year 2035, the total water demand is increased to 447.6MCM. From the net total, the agricultural water demand is was projected that in the year of 2035, the water demand is increased to 259MCM (58%), the projected domestic water demand is increased 129.8MCM (29%) and Livestock is 58.8MCM (13%). In this scenario, the results show that the water demand for irrigation dominates the domestic and livestock water demand due to increment in the command area by 2035.

Table: 4.7:- Net total projected annual water demand for scenario 2

Year	Demand Sites			
	Agriculture	Domestic	Livestock	Net Total
2017	46.6	73.6	31.7	151.9
2018	51.2	76	32.8	160
2019	56.4	78.4	33.9	168.7
2020	62	80.9	35.1	178
2021	68.2	83.5	36.3	188.1
2022	75	86.2	37.6	198.8
2023	82.5	89	38.9	210.4
2024	90.8	91.8	40.3	222.9
2025	99.8	94.8	41.7	236.3
2026	109.8	97.8	43.2	250.8
2027	120.8	100.9	44.7	266.4
2028	132.9	104.1	46.2	283.3
2029	146.2	107.5	47.8	301.5
2030	160.8	110.9	49.5	321.2
2031	176.9	114.5	51.3	342.6
2032	194.6	118.1	53	365.7
2033	214	121.9	54.9	390.8
2034	235.4	125.8	56.8	418
2035	259	129.8	58.8	447.6
Net Total	2,382	1,885	834	5,103

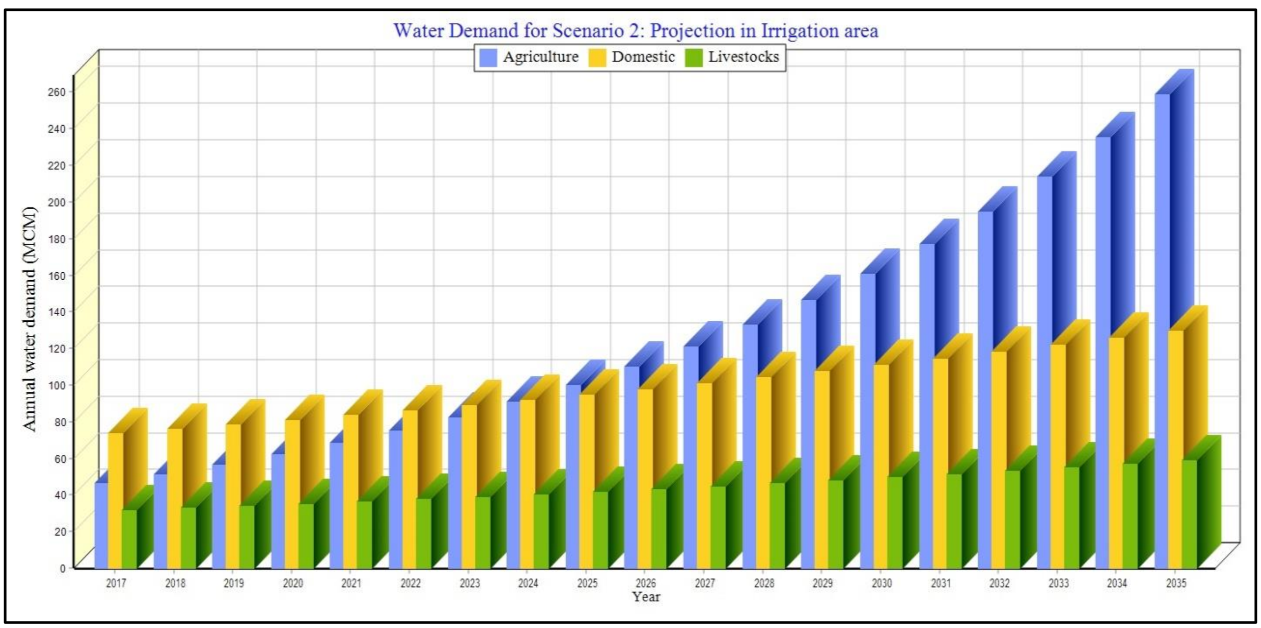


Figure: 4.7:- Annual water demand for projection in the irrigation area for all sites

4.2.5 Scenario 3: Increased Water Demands Scenario

If the irrigation potential in the watershed is developed constantly by anticipated growth rate of 10%, and water consumption per capita per year is increased by half for domestic water demand. Moreover, the water consumption rate for livestock is increased similarly.

If it is proposed that for well standard of living the per capita demand for all water demand sectors will be increased 50% from current water demand in the sub-basin.

In this scenario, the water demand grows higher than the other scenarios resulting in a large amount of water demand in the watershed.

Future overall water demand, Table 4.9 describes and presents the projected net water demand for the year 2018 - 2035. From the result, it was projected that in 2035, the total water demand is increased to 541.9MCM.

Table: 4.8:- Net total projected annual water demand for scenario 3

Year	Demand Sites			
	Agriculture	Domestic	Livestock	Net Total
2017	46.6	73.6	31.7	151.9
2018	51.2	114	49.2	214.4
2019	56.4	117.7	50.9	224.9
2020	62	121.4	52.7	236.1
2021	68.2	125.3	54.5	248
2022	75	129.3	56.4	260.7
2023	82.5	133.4	58.4	274.4
2024	90.8	137.7	60.4	288.9
2025	99.8	142.1	62.6	304.5
2026	109.8	146.7	64.7	321.2
2027	120.8	151.4	67	339.2
2028	132.9	156.2	69.4	358.5
2029	146.2	161.2	71.8	379.2
2030	160.8	166.4	74.3	401.5
2031	176.9	171.7	76.9	425.5
2032	194.6	177.2	79.6	451.3
2033	214	182.9	82.4	479.2
2034	235.4	188.7	85.3	509.4
2035	259	194.7	88.2	541.9
Net Total	2382.8	2791.7	1236.2	6,410.7

From the net total, the agricultural water demand will projected that in the year of 2035, the water demand will be increased to 259MCM (48%) which is the first largest consumer, the projected domestic water demand is increased 194.7MCM (36%) the second-largest consumer and Livestock is 88.2MCM (16%) the least consumer of water in the basin.

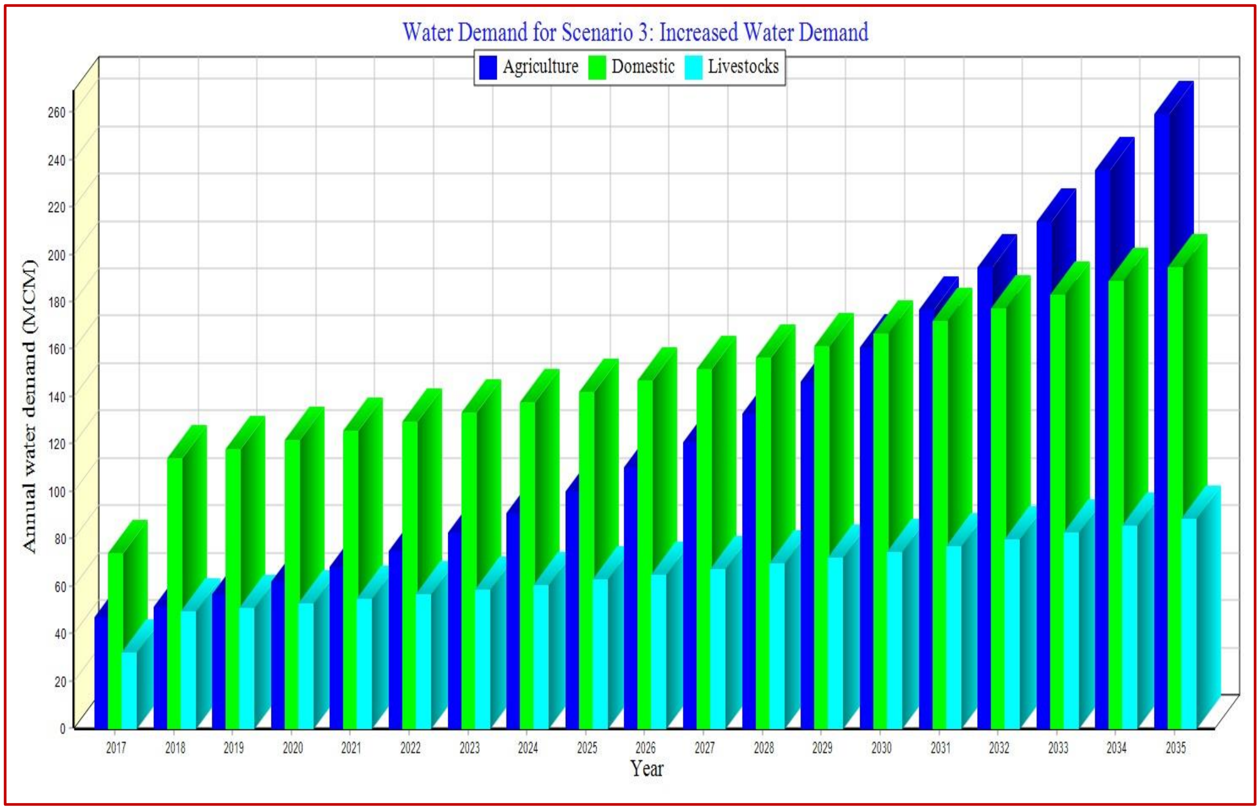


Figure: 4.8:- Annual water demand for increased water demand scenario for all sites

Generally, the net water requirement for each sectors was incorporated within the WEAP model and shows the projected water demand for the year 2018 - 2035. From the result, it was projected that in the 2035, the estimated that total annual consumptive water demand may be expected around 235.2MCM, 298.4MCM, 447.6MCM, and 541.5MCM for the reference scenario, scenario one, scenario two and scenario three, respectively.

The simulations in the above scenarios show that in the absence of intervention, the water deficit in 2035 will worsen in the future. Therefore, integrated water management should be necessary while developing projects in such scenarios.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Water is the single most important element of the environment and plays an important role in supporting productive human activities. The global water demand will primarily grow due to population and economic growth, rapid urbanization and the increasing demand for food and energy. Management and operation of water resources oriented to sustainability requires precise knowledge about water cycle parameters such as surface runoff, infiltration and groundwater recharge etc.

In order to meet the demands, efforts should be intensified on the efficient use of all water resources such as surface water, and water allocation plans to maximize the resultant economic returns to limited water resources. The assessment of surface water resources and demands, or the efficient design of water resources projects, requires an adequate estimation of surface runoff and competing demand users from catchments of the basins.

Therefore, this study was conducted to assess surface water potential leaving the entire basin as surface runoff, Water Demand and the impact of different scenarios on Water demand in the Bilate river watershed. The Bilate river watershed receives an estimated mean annual precipitation of 1106.2mm, while the estimated mean annual surface runoff leaving the whole basin is 851.5MCM which corresponds to 162.3mm mean annual runoff depth.

The estimated surface water potential was 851.5MCM in the sub-basin and the current utilization of these potential was about 322MCM for consumptive use and non-consumptive (EFR). The scenarios were developed evaluate future demands based on different sets of “what if” up to the year 2035. Therefore, the estimated that total annual consumptive water demand may be expected to be 235.2MCM, 298.4MCM, 447.6MCM and 541.5MCM for the reference scenario, high population growth, projected irrigation area and increased water demand scenarios and 170.3MCM for environmental flow requirement. Hence, this study consider the environmental flow requirement of 20% of the mean annual flow volume to maintain the basic ecological functioning and water balance in Lake Abaya.

5.2 Recommendation

The RVLB is hydrologically very different from other basins in that it does not contain a major river. The RVLB is hydrologically sensitive and fragile, so that water becomes a primary constraint to development as well as being a primary resource. So it better to wisely use and manage the rivers in the basin and to conserve the lakes as resources.

The hydrology of the watershed using improved climatic and hydrologic data monitoring should be conducted in the study area to enhance the estimation of current and future water resource availability and still open for other researchers by using the modified and updated socio-economic and biophysical data, to have current information on water resources potential and water demands in the watershed as they are continuously changing.

As the only source of water in watershed is precipitation because no other source, like lakes, oceans or ice lands, the rainwater harvesting should be promoted in order to improve water availability for productive use.

Groundwater potential needs to be investigated and explored to enable more understanding of water resources potential in this study area.

The environmental flow requirement is required more detailed studies before developing any other projects in the watershed and it needs wise water resource allocation patterns within the basin to keep the ecological balance and level of Lake Abaya whose main contributory river is Bilate.

Integrated and coordinated water resources development strategy is required to cope up with ever- increasing anthropogenic activities are leading to immense pressure on available surface water resources and growing water demands in the future.

This study was carried out at the watershed scale to come up with a better understanding and information of water potential and demands in the watershed. The scale of water resources assessment should be extended in the sub-basin level rather than basin as the accuracy of the information increases for small areas. An acceptable water resources assessment requires clear hydrological boundaries across which both surface water and groundwater flows can either be measured with reasonable confidence or effectively assumed to be zero. For a river basin, the broadest scale of assessment will be from the watershed with adjacent river basins to the outlet to the sea. However, for many purposes, assessments will be conducted in smaller sub-basin areas.

6. REFERENCES

Abbaspour. Yang, J., Maximov, I., Siber, R., Bogner, K., Mieleitner, J. & Srinivasan, R.(2007). Modeling hydrology and water quality in the pre-alpine/alpine Thur watershed using SWAT). Journal of hydrology, 413- 430.

Adeboye, Omotayo B. and Olarewaju M. Alatise. (2008), Surface Water Potential of the River Osun at Apoje Sub-Basin Nigeria, Soil & Water Resources Journal, vol.3, (2): 74–79.

Adgolign, T. G.S. Rao, and Y.E.R. Abbulu. (2015). Assessment of Spatio-Temporal Occurrence of Water Resources in Didessa Sub-Basin, West Ethiopia, Sustain. Water Resour. Manag. (2016) 2:55-70.

Arnold, J. G., Srinivasan, R., Muttiah, R. S., and Williams, J. R. (1998). Large area hydrologic modeling and assessment part I: model development. Journal of the American Water Resources Association, Vol. 34, No. 1.

Arranz. (2006). Evaluation of historic, current and future water demand in the Olifants River Catchment, South Africa. Colombo, Sri Lanka, . International Water Management Institute, (IWMI Research Report 118).

Awulachew. (2007). Water Resources and Irrigation Development in Ethiopia. International Water Management Institute, Working paper 123.

Belay. (2011). Evaluation of Climate change impacts on hydrology on selected catchments of Abbay Basin, Ethiopia. *Journal oF Hydrologic Engineering*, 1048-1065.

Belete. B., Yilma, S. and Assefa M. (2014), Surface Water and Groundwater Resources of Ethiopia: Potentials and Challenges of Water Resources Development. Ethiopian Institute of Water Resources (EIWR), Addis Ababa University, Ethiopia. Book chapter.

Bullock, A., Chirwa, A., Matondo, J. and Mazvimavi, D. (1990). Analysis of flow regimes in Malawi, Tanzania, and Zimbabwe: A feasibility study for Africa Friend. Overseas Development Report, Institute of Hydrology, Wallingford, UK. .

Chow, V.T. (1998). Applied Hydrology, International Edition, McGraw-Hill Inc.,Book Company. Singapore.

Cunderlik. (2003). Hydrological models selections for the CFCAS project: assessments of water resource risk and vulnerabilities to changing climatic conditions. The University of Western Ontario, Department of Civil and Environmental Engineering.

Daniel, E. C., Camp J.V, and Leboeuf E.J.(2011). Watershed modeling and its applications: a state-of the-art review. The Open Hydrology Journal 5, 26-49.

Demissie. (2013). Climate change impacts on the streamflow and simulated sediment flux to Gilgal Gibe 1 hydropower reservoir Ethiopia. European International Journal of Science and Technology.

Dhami and Pandey. (2019). a comparatives reviews of recently developed hydrologic models. Journal of Indian Water Resour. Soc., Vol. 33, No. 3.

Dzurik, A. (1996). Water Resources Development Planning, 2nd Edition. Usa: . Maryland, 20706.: Rowman And Littlefield Publishers.

Etchells, T. and Malano, H.(2005). Identifying uncertainty in water allocation modelling. International congress on modelling and simulation. The Modelling and Simulation Society of Australia and New Zealand Inc., Canberra, Australia, pp 2484–249.

FAO. (1998). The Soil and Terrain Database for northeastern Africa (CDROM), Major Soils of the World. Rome, Italy.: Land and Water Digital Media Series .

Firisa, C. (2017). Assessment of surface water potential based on watershed modeling, a case study of Sor watershed, Ethiopia, MSc Thesis. Jimma University Institute of Technology School of Civil and Environmental Engineering Hydraulics and Water Resoures.

Flint. (2004). The sustainable development of water resources, UCOWR. Journals of Contemporary Water Researches and Educations, 127:41-54.

Gassman, Sadeghi, A. M., and Srinivasan, R. (2014). Applications of the SWAT model . Journal of Environmental Quality, 43(1), 1-8.

Getachew, T. and Young, K. (2015). Surface Water Potential Assessment of Ungauged Catchments in Lake Tana Basin, Ethiopia. 10th Alexander von Humboldt International Conference, Avh10-11.

Gintamo, T. (2015). Ground water potential evaluation based on integrated GIS and remote sensing techniques, in Bilate river catchment: southern rift valley Ethiopia, MSc thesis, Addis Ababa, University, Addis Ababa, Ethiopia.

GWP. (2000). Global Water Partnership, Integrated Water Resources Management, Technical Advisory,Committee Background Paper No 4, Stockholm.

GWP. (2010). Integrated Water Resources Management, Technical Advisory Committee Background Paper No 4. Stockholm.

Henock, M. (2017). Modeling water resources using WEAP model for effective water management: A case study in Legedara river catchment, SNNPR, Ethiopia. M.Sc. Thesis. Hawassa University, School of Biosystems and Environmental Engineering,.

Kousari, M., Malekinezhad, H., Ahani, H., and Zarch, M. (2010). Sensitivity analysis and impact quantification of the main factors affecting peak discharge in the SCS curve number method: An analysis of Iranian watersheds. Quat. Int. 226, 66–74.

Legesse, G. (2017). Quantifying water use in ruminant production: a review. Journal of Animal Science, vol. 95.

Loucks, D. (1997). Quantifying Trends in System Sustainability. Hydrological Sciences Journal, 513-530.

MoFED. (2010). Draft Growth and Transformation Plan (GTP) 2010/11-2014/15. Addis Ababa (AWMISET). Addis Ababa.

MoWIE. (2009). Rift Valley Lakes Basin Integrated Resources Development Master Plan Study project report. Addis Ababa, Ethiopia: Halcrow Group Limited and Generation Integrated Rural Development (GIRD) Consultants, Ministry of Water Resources.

MoWIE. (2012). Coping up with scarcity of water- the importance of agriculture: developing a water audit for Awash Basin, part 4, water resources modeling. Ethiopia.

Mulual, D. (2015). Assessment of Surface Water Resources and its Allocation: Case Study of Bahr el-Jeber River Sub-basin, South Sudan. Msc. Thesis, Mekele Insitute of Technology.

NAS. (2016). Nutrient requirements of beef cattle. National Academies of Sciences, Division on Earth and Life Studies, Boards of Agricultures and Natural Resource,Committee on Nutrient Requirements of Beef Cattle, National Academies Press.

Neitsch. (2005). Soils and Water Assessments Tools, Theoretical Documentations: Version of 2005. Temple, TX. US Department of Agriculture, Agricultural Research Service and Texas A. & M. Black land Research Center.

SEI. (2008). Water Evaluation and Planning System Tutorial, Stockholm Environment Institute, Boston Center.

Seleshi, B. Teklu, E. and Regassa, N. (2010). Irrigation potential in Ethiopia, constraints and opportunities for enhancing the system. International water management Institute. Article of Water Resources Management.

Simonovic. (1996). “Decision Support Systems for Sustainable Management of Water Resources: Case studies”, Water International Vol 21 No 4. .

Singh, A., Imtiyaz, M., Isaac, R. K., & Denis, D. M. (2014). Assessing the performance and uncertainty analysis of the SWAT and RBNN models for simulation of sediment yield in the Nagwa watershed, India. Hydrological Sciences Journal, 59(2), 351-3.

Subhash, T., Deva, K., Hardaha, M.K., and S.K. Sharma.(2016). Land use /land cover change in a hydrologic regime using SWAT model-A Review International Journal of Science, Engineering and Technology Research (IJSETR), Vol. 5, Issue 1, p 1-6.

Tadele, K. (2007). Impact of Land uses change on streamflow: the case of Hare River Watershed, Ethiopia. Arba Minch Water Technology Institute, Arbaminch University.

Tadesse, N. (2006). Surface Waters Potential assessment of the Hantebet Basin, Tigray, Northern Ethiopia. Agricultural Engineering International; CIGR EJournal. Manuscript LW Vol 3

Tekle, A.(2014). Assessment of Climate Change Impact on Water Availability of Bilate Watershed, Ethiopian Rift Valley Basin, Journal of Environment and Earth Science, Vol.4, 148-156.

UNESCO. (2006). Executive summary on Water, a shared responsibility, The United Nations World Water Development Report 2.

Wagesho, N. (2014). Catchment dynamics and its impact on runoff generation: Coupling watershed modelling and statistical analysis to detect catchment responses. International Journal of Water Resources and Environmental Engineering, ISSN 2141-6613, Vol. 6.

Wagesho, N. and Goel, M. (2013). Effect of Climate Change on Runoff Generation: An Application to Rift Valley Lakes Basin of Ethiopia. American Society of Civil Engineering (ASCE), Hydrologic Engineering Journal, vol. 18, 1048-1063.

Wang, L. (2005). Cooperative water resource allocation among competing users, Ph.D. thesis, Department of Systems Design Engineering. University of Waterloo, Waterloo, Ontario.

WMO. (2012). Technical material for Water Resources Assessment Technical Report Series No.2-WMO - No. 1095. Geneva.

Yang, H. (2007). and Zehnder, A. "Virtual Water": An unfolding concept in integrated water resources management, water resources Research, vol.43, W12301.

Yates, D.; Purkey, D.; Sieber, J.; Huber-Lee, A.; Galbraith, H.(2000). WEAP21: A Demand, Priority and Preference, Driven Water Planning Model: Part 2, Aiding Freshwater Ecosystem Service Evaluation. Water International, Vol. 30,501-512.

APPENDICES

Appendix A: - Average monthly Rainfall of stations used

	Average monthly rainfall									
	stations									
Months	Hossana	Alaba	Dimtu	Wolaita	Fonko	Angecha	Durame	Bodity	Shone	Arekit
Jan	29.4	29.3	27.8	29.0	25.6	33.8	29.2	28.7	43.7	31.0
Feb	38.2	40.7	31.2	39.6	41.9	53.2	38.1	46.6	44.9	32.3
Mar	100.4	88.7	76.4	74.7	109.9	97.3	82.0	87.4	106.9	83.3
Apr	131.7	133.1	114.2	159.8	145.8	187.2	142.0	157.1	182.9	94.9
May	143.8	124.0	96.0	186.6	160.5	178.7	152.8	166.5	162.6	139.1
Jun	135.3	91.2	86.5	139.5	138.1	140.8	106.8	123.7	137.3	182.5
Jul	159.9	117.2	89.8	184.7	204.5	190.5	152.3	157.0	167.0	231.5
Aug	164.1	140.0	101.0	177.2	196.7	207.3	148.7	154.7	193.3	225.5
Sep	141.5	105.9	87.5	112.7	164.1	188.6	135.6	119.9	178.1	159.9
Oct	66.6	64.9	2.2	102.6	84.4	86.7	93.6	83.4	82.8	69.1
Nov	22.1	64.8	41.5	53.1	19.8	50.4	38.8	44.3	48.5	24.2
Dec	19.4	19.7	30.2	28.7	19.6	28.7	14.2	32.8	32.7	10.8

Appendix B: - Average Annual rainfall of the Stations used in the study

	Average Yearly Rainfall of stations									
				Stations						
Years	**Hossana**	**Alaba**	**Dimtu**	**Wolaita**	**Fonko**	**Angecha**	**Durame**	**Bodity**	**Shone**	**Arekit**
1990	88.2	74.6	83.0	89.4	86.4	124.6	86.5	101.7	96.9	114.2
1991	87.8	79.7	59.7	92.7	86.2	93.1	106.4	101.1	101.1	117.0
1992	116.3	96.9	57.6	109.7	130.1	112.7	110.6	122.0	149.3	117.8
1993	117.8	106.2	63.4	120.3	125.9	128.9	93.1	108.7	197.1	133.9
1994	76.9	67.2	71.2	96.7	74.2	75.4	70.5	99.9	154.0	114.5
1995	96.7	81.3	79.2	90.0	78.8	132.2	74.2	89.9	118.3	83.8
1996	97.4	96.5	104.7	129.3	117.2	113.4	75.8	111.6	163.8	132.9
1997	120.2	99.5	59.4	121.5	141.6	130.4	99.5	120.8	202.9	110.4
1998	129.7	102.5	62.2	112.0	114.8	112.1	88.8	127.2	152.1	125.8
1999	84.3	63.8	84.5	78.2	96.1	111.7	88.8	83.5	99.3	117.9
2000	80.6	73.0	60.3	113.7	98.4	102.2	98.8	79.0	77.8	84.7
2001	95.5	78.7	53.9	125.5	118.4	200.6	110.0	117.7	127.6	116.4
2002	112.2	66.3	61.0	88.1	117.2	139.0	98.2	92.1	106.9	87.5
2003	97.3	78.6	69.5	104.5	124.4	160.2	87.8	96.9	77.6	73.8
2004	99.3	82.7	66.0	100.3	99.7	141.4	88.9	91.4	106.8	107.9
2005	98.3	72.2	71.4	134.9	103.2	164.7	121.7	111.2	107.1	100.6
2006	100.1	72.8	79.7	114.3	100.3	154.1	83.9	111.2	92.0	105.1
2007	97.9	90.1	82.7	135.1	105.9	157.7	86.1	127.3	95.7	118.1
2008	100.2	79.2	66.1	119.7	105.7	118.0	83.7	84.2	96.9	80.0
2009	96.2	70.5	42.1	90.9	84.1	104.7	71.2	81.7	77.8	100.0
2010	93.5	150.0	88.0	111.8	104.4	102.9	82.2	100.0	118.3	150.1
2011	82.2	79.7	52.6	99.8	178.9	108.9	100.1	100.6	127.6	134.3
2012	82.4	55.2	56.9	105.6	90.2	89.8	77.6	86.5	92.7	61.8
2013	97.9	168.1	86.2	122.9	97.5	116.6	118.0	117.6	93.6	118.5
2014	69.8	97.7	57.7	142.2	90.5	97.6	130.3	107.7	115.5	113.1
2015	75.5	42.9	35.0	73.9	147.3	60.8	61.3	62.5	72.4	102.8
2016	108.3	103.6	40.5	97.5	147.3	128.6	132.9	94.2	127.5	108.2
2017	86.6	48.8	35.6	85.1	93.7	84.8	119.5	76.1	73.1	106.1

Appendix C: - Annual average maximum and minimum temperature of selected stations

	Annual Average Temperature

stations	Hossana		Alaba		Wolaita		Angacha	
Year	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
1990	15.92	10.50	27.41	8.81	24.77	14.02	25.27	15.96
1991	22.57	10.81	26.54	8.99	25.04	14.43	25.78	15.99
1992	23.60	10.61	27.07	9.08	24.89	14.41	21.58	12.12
1993	25.99	9.78	26.49	8.15	25.51	14.54	23.27	13.45
1994	26.20	10.30	27.48	13.26	25.79	14.37	16.84	10.05
1995	23.43	10.61	27.72	13.65	25.10	14.42	25.10	14.96
1996	22.17	10.66	27.30	13.31	25.75	14.01	24.78	14.43
1997	22.80	11.15	27.87	13.79	25.43	13.80	24.30	13.54
1998	22.68	11.29	27.52	14.24	24.82	14.45	23.81	12.22
1999	22.65	10.41	27.75	12.60	25.34	14.60	24.20	12.65
2000	22.75	10.14	27.61	13.45	25.34	14.66	24.78	12.19
2001	22.85	10.70	27.36	13.55	24.91	14.41	23.06	13.24
2002	22.85	10.70	28.16	14.13	25.68	14.62	23.52	13.62
2003	22.87	11.11	26.41	13.80	25.47	14.87	23.44	13.41
2004	22.63	10.70	27.42	13.30	25.30	14.52	23.68	12.76
2005	22.84	11.05	28.04	13.43	25.46	14.57	23.21	13.19
2006	23.10	11.26	27.94	13.95	25.12	14.15	23.40	13.08
2007	22.94	11.15	28.22	13.39	25.27	13.82	23.58	13.26
2008	22.93	10.45	28.87	13.07	25.71	13.94	23.47	13.26
2009	24.73	10.92	29.69	13.51	26.01	15.05	23.68	13.29
2010	25.11	10.95	27.81	13.04	25.09	15.10	23.50	13.05
2011	24.60	11.10	29.04	13.86	25.68	15.13	23.71	12.90
2012	23.58	10.61	29.42	13.53	25.90	15.16	24.82	12.80
2013	23.34	10.46	27.84	14.34	25.37	14.91	24.28	12.92
2014	23.94	11.86	28.94	17.94	25.37	15.00	23.81	13.01
2015	25.15	11.88	29.62	18.08	26.36	15.50	23.32	12.95
2016	23.84	9.97	27.17	13.75	25.81	15.38	23.32	11.41
2017	23.77	11.59	28.10	13.34	26.23	15.58	25.43	12.50

Appendix D: - Outlier test for rainfall data

	Angecha		Durame		Bodity		Shone		Arekit	
Years	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-value**
1990	124.6	2.10	86.5	1.94	101.7	2.01	96.9	1.99	114.2	2.06
1991	93.1	1.97	106.4	2.03	101.1	2.00	101.1	2.00	117.0	2.07
1992	112.7	2.05	110.6	2.04	122.0	2.09	149.3	2.17	117.8	2.07
1993	128.9	2.11	93.1	1.97	108.7	2.04	197.1	2.29	133.9	2.13
1994	75.4	1.88	70.5	1.85	99.9	2.00	154.0	2.19	114.5	2.06
1995	132.2	2.12	74.2	1.87	89.9	1.95	118.3	2.07	83.8	1.92
1996	113.4	2.05	75.8	1.88	111.6	2.05	163.8	2.21	132.9	2.12
1997	130.4	2.12	99.5	2.00	120.8	2.08	202.9	2.31	110.4	2.04
1998	112.1	2.05	88.8	1.95	127.2	2.10	152.1	2.18	125.8	2.10
1999	111.7	2.05	88.8	1.95	83.5	1.92	99.3	2.00	117.9	2.07
2000	102.2	2.01	98.8	1.99	79.0	1.90	77.8	1.89	84.7	1.93
2001	200.6	2.30	110.0	2.04	117.7	2.07	127.6	2.11	116.4	2.07
2002	139.0	2.14	98.2	1.99	92.1	1.96	106.9	2.03	87.5	1.94
2003	160.2	2.20	87.8	1.94	96.9	1.99	77.6	1.89	73.8	1.87
2004	141.4	2.15	88.9	1.95	91.4	1.96	106.8	2.03	107.9	2.03
2005	164.7	2.22	121.7	2.09	111.2	2.05	107.1	2.03	100.6	2.00
2006	154.1	2.19	83.9	1.92	111.2	2.05	92.0	1.96	105.1	2.02
2007	157.7	2.20	86.1	1.93	127.3	2.10	95.7	1.98	118.1	2.07
2008	118.0	2.07	83.7	1.92	84.2	1.93	96.9	1.99	80.0	1.90
2009	104.7	2.02	71.2	1.85	81.7	1.91	77.8	1.89	100.0	2.00
2010	102.9	2.01	82.2	1.92	100.0	2.00	118.3	2.07	150.1	2.18
2011	108.9	2.04	100.1	2.00	100.6	2.00	127.6	2.11	134.3	2.13
2012	89.8	1.95	77.6	1.89	86.5	1.94	92.7	1.97	85.0	1.93
2013	116.6	2.07	118.0	2.07	117.6	2.07	93.6	1.97	118.5	2.07
2014	97.6	1.99	130.3	2.12	107.7	2.03	115.5	2.06	113.1	2.05
2015	60.8	1.78	61.3	1.79	62.5	1.80	72.4	1.86	102.8	2.01
2016	128.6	2.11	132.9	2.12	94.2	1.97	127.5	2.11	108.2	2.03
2017	84.8	1.93	119.5	2.08	76.1	1.88	73.1	1.86	106.1	2.03
Xav		2.07		1.97		1.99		2.04		2.03
skew		-0.33		0.05		-0.61		0.50		-0.47
StDv		0.11		0.08		0.07		0.12		0.07
KN										
XH		**2.34**		**2.18**		**2.18**		**2.35**		**2.22**
PCP(mm)		220.6		151.8		152.1		224.3		166.1
XL		**1.79**		**1.75**		**1.81**		**1.74**		**1.84**
PCP(mm)		61.7		56.7		64.2		54.5		69.9

	Hossana		Alaba		Dimtu		Wolaita		Fonko	
Years	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-valu**	**Avrg PC**	**Log-value**
1990	88.2	1.95	74.6	1.87	83.0	1.92	89.4	1.95	86.4	1.94
1991	87.8	1.94	79.7	1.90	59.7	1.78	92.7	1.97	86.2	1.94
1992	116.3	2.07	96.9	1.99	57.6	1.76	109.7	2.04	130.1	2.11
1993	117.8	2.07	106.2	2.03	63.4	1.80	120.3	2.08	125.9	2.10
1994	76.9	1.89	67.2	1.83	71.2	1.85	96.7	1.99	74.2	1.87
1995	96.7	1.99	81.3	1.91	79.2	1.90	90.0	1.95	78.8	1.90
1996	97.4	1.99	96.5	1.98	104.7	2.02	129.3	2.11	117.2	2.07
1997	120.2	2.08	99.5	2.00	59.4	1.77	121.5	2.08	141.6	2.15
1998	129.7	2.11	102.5	2.01	62.2	1.79	112.0	2.05	114.8	2.06
1999	84.3	1.93	63.8	1.80	84.5	1.93	78.2	1.89	96.1	1.98
2000	80.6	1.91	73.0	1.86	60.3	1.78	113.7	2.06	98.4	1.99
2001	95.5	1.98	78.7	1.90	53.9	1.73	125.5	2.10	118.4	2.07
2002	112.2	2.05	66.3	1.82	61.0	1.79	88.1	1.94	117.2	2.07
2003	97.3	1.99	78.6	1.90	69.5	1.84	104.5	2.02	124.4	2.09
2004	99.3	2.00	82.7	1.92	66.0	1.82	100.3	2.00	99.7	2.00
2005	98.3	1.99	72.2	1.86	71.4	1.85	134.9	2.13	103.2	2.01
2006	100.1	2.00	72.8	1.86	79.7	1.90	114.3	2.06	100.3	2.00
2007	97.9	1.99	90.1	1.95	82.7	1.92	135.1	2.13	105.9	2.02
2008	100.2	2.00	79.2	1.90	66.1	1.82	119.7	2.08	105.7	2.02
2009	96.2	1.98	70.5	1.85	42.1	1.62	90.9	1.96	84.1	1.92
2010	93.5	1.97	150.0	2.18	88.0	1.94	111.8	2.05	104.4	2.02
2011	82.2	1.92	79.7	1.90	52.6	1.72	99.8	2.00	178.9	2.25
2012	82.4	1.92	55.2	1.74	56.9	1.76	105.6	2.02	90.2	1.96
2013	97.9	1.99	168.1	2.23	86.2	1.94	122.9	2.09	97.5	1.99
2014	69.8	1.84	97.7	1.99	57.7	1.76	142.2	2.15	90.5	1.96
2015	75.5	1.88	42.9	1.63	35.0	1.54	73.9	1.87	147.3	2.17
2016	108.3	2.03	103.6	2.02	40.5	1.61	97.5	1.99	147.3	2.17
2017	86.6	1.94	48.8	1.69	35.6	1.55	85.1	1.93	93.7	1.97
Xav			1.98		1.91		1.80		2.02	2.03
skew			0.05		0.30		-0.56		-0.23	0.53
StDv			0.06		0.13		0.12		0.07	0.09
KN			2.519							
XH			**2.14**		**2.23**		**2.10**		**2.21**	**2.26**
PCP(mm)			138.0		168.8		124.9		162.7	180.1
XL			**1.82**		**1.59**		**1.50**		**1.84**	**1.80**
PCP(mm)			66.1		39.3		32.0		68.9	63.5

Appendix E: - OUTLET TEST K_N VALUE

OUTLIER TEST K VALUES

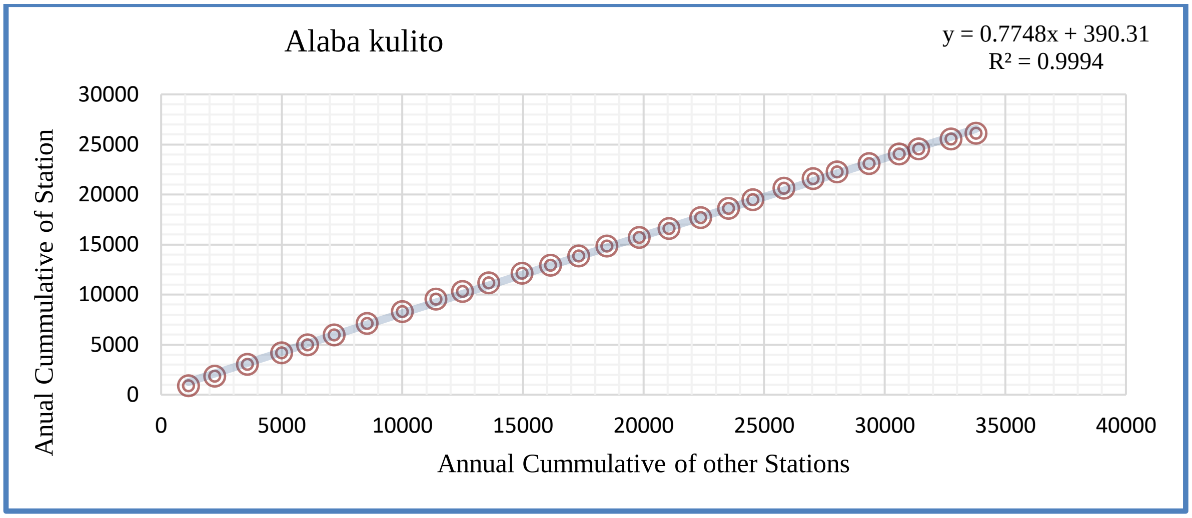
10 PERCENT SIGNIFICANCE LEVEL K VALUES

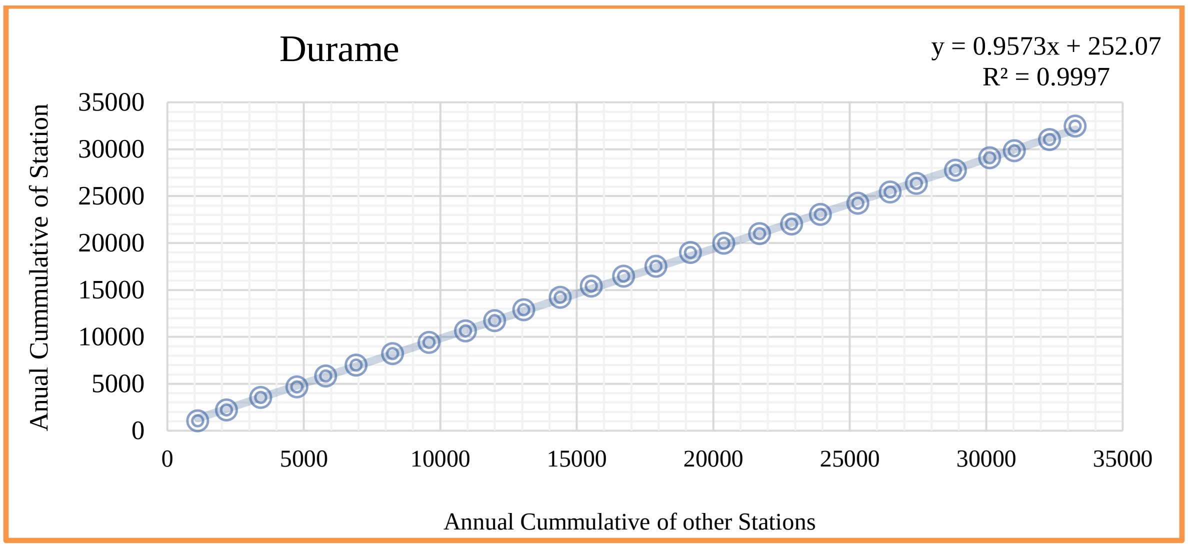
The table below contains one sided 10 percent significance level K_N alues for a normal distribution (38). Tests conducted to select the out-ier detection procedures used in this report indicate these K_N values are pplicable to log-Pearson Type III distributions over the tested range of kew values.

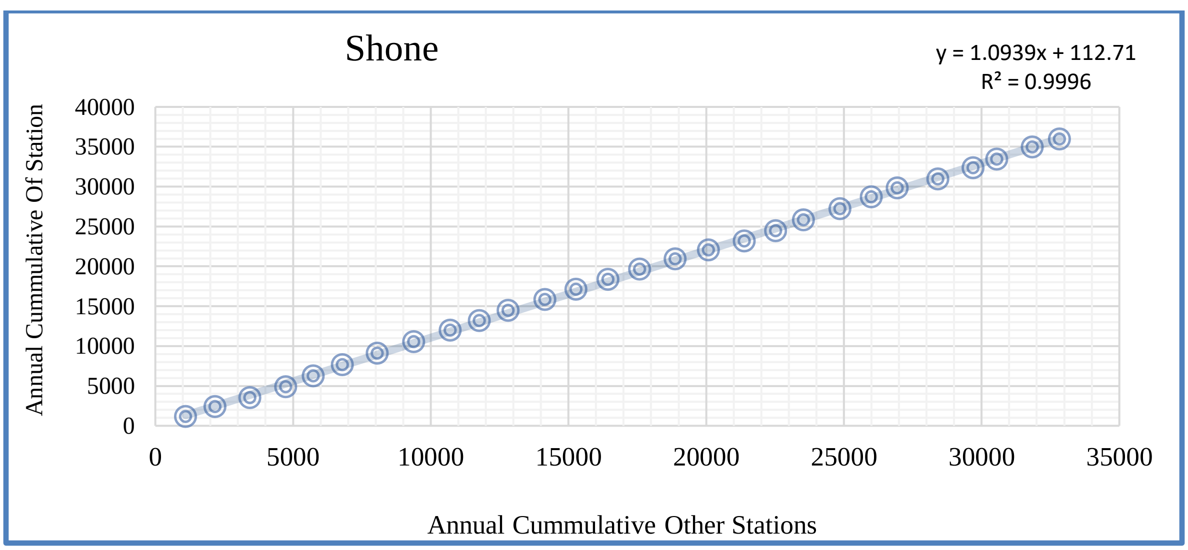
ample size	K_N value	Sample size	K_N value	Sample size	K_N value	Sample size	K_N value
10	2.036	45	2.727	80	2.940	115	3.064
11	2.088	46	2.736	81	2.945	116	3.067
12	2.134	47	2.744	82	2.949	117	3.070
13	2.175	48	2.753	83	2.953	118	3.073
14	2.213	49	2.760	84	2.957	119	3.075
15	2.247	50	2.768	85	2.961	120	3.078
16	2.279	51	2.775	86	2.966	121	3.081
17	2.309	52	2.783	87	2.970	122	3.083
18	2.335	53	2.790	88	2.973	123	3.086
19	2.361	54	2.798	89	2.977	124	3.089
20	2.385	55	2.804	90	2.981	125	3.092
21	2.408	56	2.811	91	2.984	126	3.095
22	2.429	57	2.818	92	2.989	127	3.097
23	2.448	58	2.824	93	2.993	128	3.100
24	2.467	59	2.831	94	2.996	129	3.102
25	2.486	60	2.837	95	3.000	130	3.104
26	2.502	61	2.842	96	3.003	131	3.107
27	2.519	62	2.849	97	3.006	132	3.109
28	2.534	63	2.854	98	3.011	133	3.112
29	2.549	64	2.860	99	3.014	134	3.114
30	2.563	65	2.866	100	3.017	135	3.116
31	2.577	66	2.871	101	3.021	136	3.119
32	2.591	67	2.877	102	3.024	137	3.122
33	2.604	68	2.883	103	3.027	138	3.124
34	2.616	69	2.888	104	3.030	139	3.126
35	2.628	70	2.893	105	3.033	140	3.129
36	2.639	71	2.897	106	3.037	141	3.131
37	2.650	72	2.903	107	3.040	142	3.133
38	2.661	73	2.908	108	3.043	143	3.135
39	2.671	74	2.912	109	3.046	144	3.138
40	2.682	75	2.917	110	3.049	145	3.140
41	2.692	76	2.922	111	3.052	146	3.142
42	2.700	77	2.927	112	3.055	147	3.144
43	2.710	78	2.931	113	3.058	148	3.146
44	2.719	79	2.935	114	3.061	149	3.148

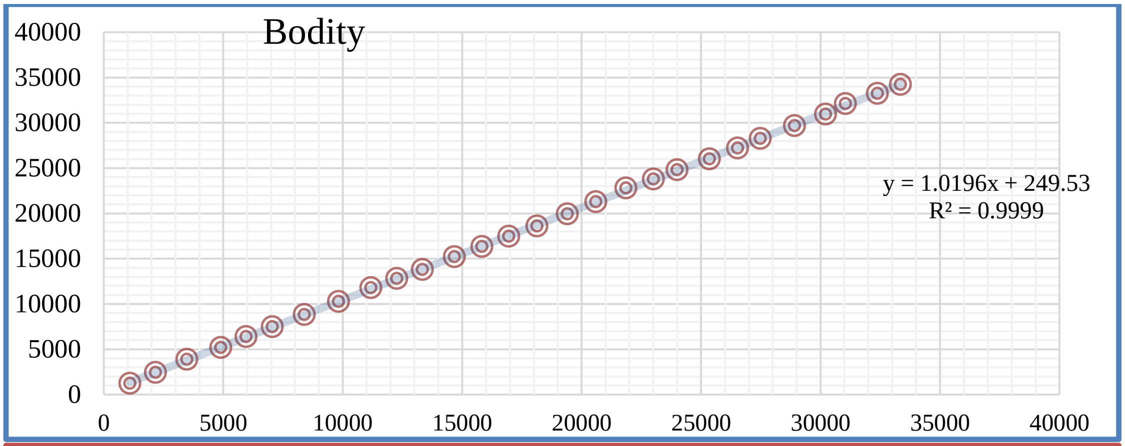
One-sided 10 percent significance outlier test KN values for a normal distribution (Interagency Advisory Committee on Water Data, 1982, after Grubbs and Beck, 1972).

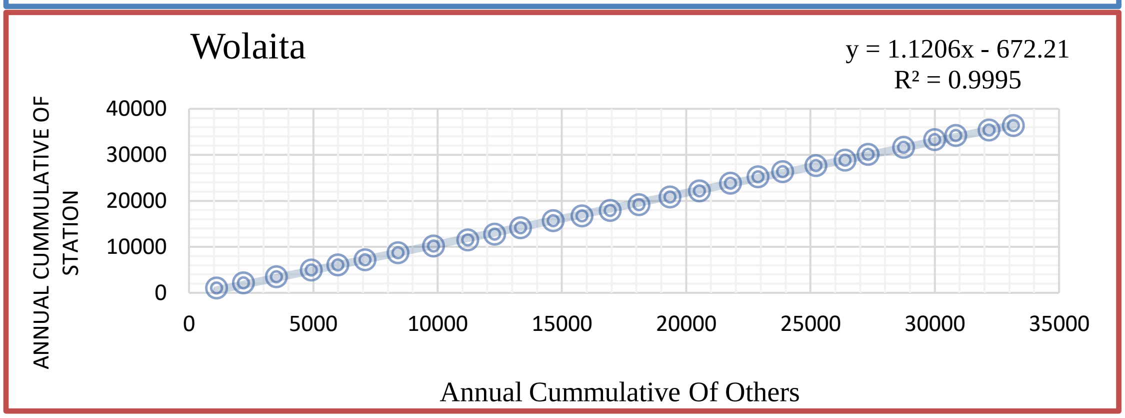
Appendix F:- Double mass curves of stations

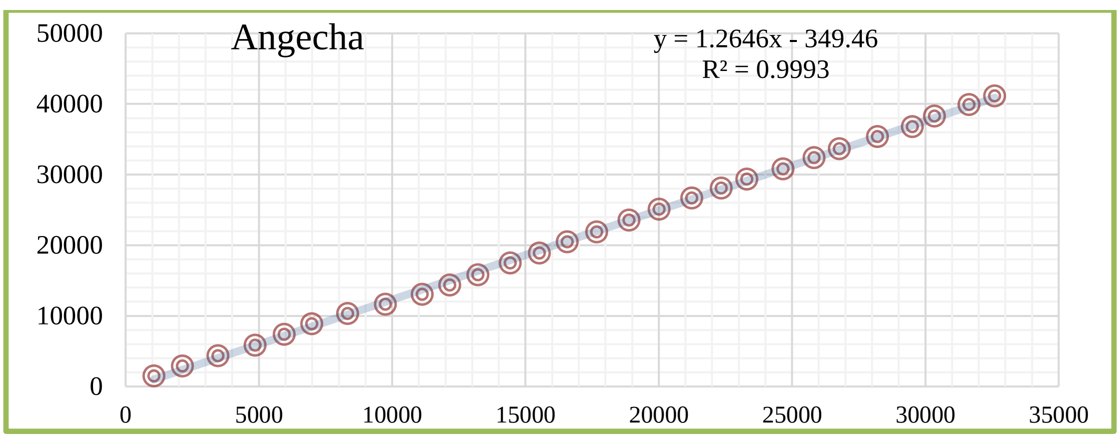


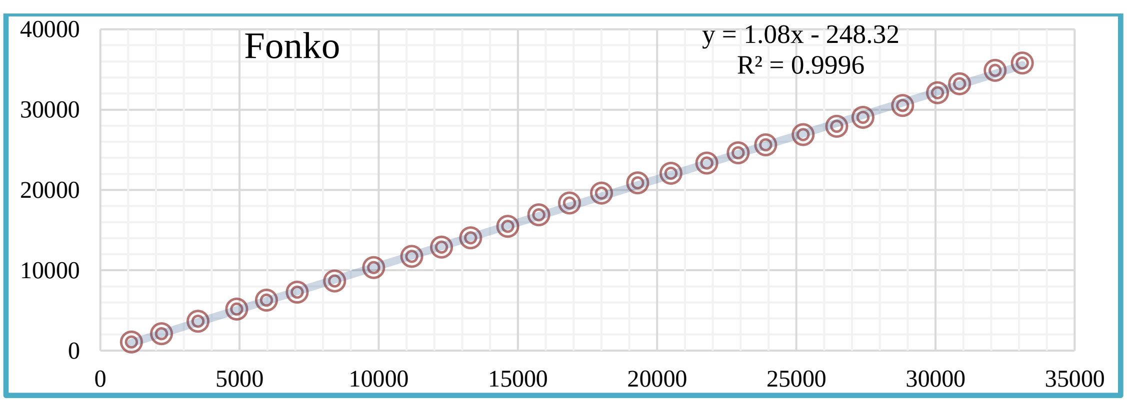





Bodity
y = 1.0196x + 249.53
R^2 = 0.9999


Wolaita
y = 1.1206x - 672.21
R^2 = 0.9995
ANNUAL CUMMULATIVE OF STATION
Annual Cummulative Of Others


Angecha
y = 1.2646x - 349.46
R^2 = 0.9993


Fonko
y = 1.08x - 248.32
R^2 = 0.9996

Appendix G: - Some SWAT Sensitive Parameters for Stream Flow of Watershed and their ranges

Parameters	Descriptions	Ranges
ALPHA_BF	Base flow alpha factor (days)	0 - 1
BIO MIX	Biological mixing efficiency	0 - 1
BLAI	Potential maximum leaf area index for the plant	0 - 1
CAN MIX	The maximum amount of water that can be trapped in the Canopy when the canopy is fully developed (mm)	0 - 0.25
CH_K2	Effective hydraulic conductivity (mm h^{-1})	-0 .01 - 24
CN2	Initial SCS runoff curve number for moisture condition II	35 - 98
EPCO	Plant evaporation compensation factor	0 - 1
ESCO	Soil evaporation compensation factor	0 - 1
GW_REVAP	Groundwater re-evaporation coefficient	0 - 1
GWQMN	Minimum shallow aquifer depth for “revamp” to occur (mm)	0 - 5000
REVAMP	Threshold depth of water in the shallow aquifer for “re-vamp” to occur (mm)	0 - 1
SLOPE	Average slope steepness (m m^{-1})	0 - 1000
SLSUBBSN	Average slope length (m)	10 - 150
SOL_ALB	Soil albedo	0 - 0.25
SOL_AWC	Available water capacity of the soil (mm H_2O mm soil-1)	0 - 1
SOL_K	Saturated hydraulic conductivity of the soil (mm h^{-1})	0 - 2000
SOL_Z	Soil depth (mm)	0 - 3500
SURLAG	Surface runoff lags coefficient	0.05- 24

Appendix H: - Sample Annual summary results for watershed in each year of simulation

SWAT Dec 23 2016 VER 2016/Rev 664

General Input/Output section (file.cio):
2019-09-09 12:00:00 AM ARCGIS-SWAT interface AV

Annual Summary for Watershed in year 3 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	27.25	0.38	0.49	8.28	0.06	0.00	66.25	27.77	126.96	9.55	0.00
2	93.93	9.84	1.36	7.10	2.63	0.00	92.21	53.79	121.03	18.50	0.08
3	86.35	6.59	1.57	7.11	5.58	0.00	95.48	69.07	146.80	15.77	0.05
4	117.64	13.43	2.18	6.54	9.60	0.00	93.28	94.23	139.31	22.57	0.12
5	106.51	12.92	2.39	6.61	6.71	0.00	71.76	106.51	137.00	22.35	0.09
6	104.36	8.25	1.97	6.37	4.66	0.00	83.59	77.57	109.19	16.91	0.06
7	128.52	17.16	2.33	6.54	16.60	0.00	97.64	78.02	105.11	25.96	0.14
8	190.72	34.57	4.02	7.30	47.82	0.00	109.40	91.93	122.57	46.41	0.23
9	110.17	15.73	3.59	9.16	26.30	0.00	98.08	76.63	134.94	29.20	0.08
10	127.45	32.05	3.31	11.56	26.35	0.00	91.08	73.15	138.29	47.44	0.20
11	77.04	5.74	1.57	12.48	1.77	0.00	101.02	58.01	129.43	20.35	0.03
12	24.75	1.13	0.80	12.96	0.10	0.00	83.78	40.36	130.11	15.51	0.01
1992	1194.67	157.78	25.59	102.01	148.20	0.00	83.78	847.04	1540.76	290.53	1.10

Annual Summary for Watershed in year 4 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	89.42	5.89	1.28	12.31	2.08	0.00	111.97	51.38	137.67	20.09	0.03
2	75.58	10.19	2.20	10.52	10.48	0.00	97.48	67.42	140.20	23.46	0.14
3	43.26	1.96	0.99	11.09	0.00	0.00	75.34	62.84	153.48	14.63	0.03
4	226.73	34.27	3.28	10.06	28.66	0.00	122.15	112.10	146.50	47.97	0.32
5	246.21	68.62	4.76	10.93	42.99	0.00	127.04	124.71	137.83	84.99	0.41
6	87.71	15.04	3.24	12.27	15.91	0.00	75.07	106.95	124.98	31.23	0.09
7	110.33	10.34	1.92	13.69	10.43	0.00	78.46	83.95	128.11	26.62	0.08
8	118.39	15.51	2.17	13.91	10.08	0.00	95.83	73.08	134.93	32.22	0.10
9	93.44	11.06	2.40	13.48	20.56	0.00	93.32	61.89	140.23	27.66	0.08
10	133.68	19.78	3.16	14.33	27.11	0.00	106.52	70.04	144.84	37.99	0.10
11	4.03	0.04	1.44	14.29	0.13	0.00	68.94	41.36	134.63	16.49	0.00
12	0.54	0.00	0.26	14.41	0.00	0.00	49.03	20.45	129.63	15.41	0.00
1993	1229.31	192.68	27.09	151.29	168.44	0.00	49.03	876.17	1653.01	378.76	1.38

SWAT Dec 23 2016 VER 2016/Rev 664

General Input/Output section (file.cio):
2019-09-09 12:00:00 AM ARCGIS-SWAT interface AV

Annual Summary for Watershed in year 5 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	0.34	0.00	0.04	13.46	0.00	0.00	34.73	14.63	134.47	14.23	0.00
2	11.33	0.00	0.10	11.15	0.00	0.00	32.97	12.86	130.33	11.87	0.00
3	85.11	1.33	1.08	11.19	0.01	0.00	73.65	41.38	144.81	14.23	0.01
4	145.63	15.84	2.01	9.71	6.32	0.00	109.07	85.31	138.00	28.13	0.09
5	129.57	17.29	3.17	9.40	14.28	0.00	89.79	114.67	133.92	30.38	0.11
6	119.43	9.17	2.07	8.93	10.58	0.00	91.69	95.54	120.25	20.53	0.04
7	160.68	19.95	3.32	9.36	32.71	0.00	109.02	86.86	120.23	33.27	0.11
8	124.78	20.40	3.54	10.54	27.09	0.00	105.85	77.48	124.98	35.10	0.10
9	93.69	11.20	2.38	11.45	16.01	0.00	101.62	68.35	128.32	25.61	0.08
10	14.44	0.02	1.01	12.48	0.00	0.00	68.07	47.71	138.44	14.13	0.00
11	17.99	0.02	0.48	11.84	0.00	0.00	54.61	31.09	126.11	12.94	0.00
12	7.74	0.00	0.27	11.47	0.00	0.00	42.99	19.19	126.15	12.36	0.00
1994	910.74	95.23	19.48	130.97	106.99	0.00	42.99	695.07	1566.01	252.78	0.54

Annual Summary for Watershed in year 6 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	0.00	0.00	0.05	10.49	0.00	0.00	29.11	13.88	136.52	11.11	0.00
2	51.66	0.26	0.64	8.58	0.00	0.00	57.07	22.40	132.25	9.96	0.00
3	117.34	10.16	1.78	8.57	2.72	0.00	89.09	70.18	150.12	21.00	0.07
4	291.80	80.76	4.56	7.83	50.84	0.00	124.08	119.17	139.39	93.58	0.56
5	96.90	8.21	3.00	9.33	3.62	0.00	92.22	115.27	131.90	21.05	0.04
6	71.11	3.20	1.54	9.66	0.31	0.00	74.85	83.72	121.42	14.87	0.01
7	133.93	14.68	2.34	9.85	11.49	0.00	108.03	71.80	107.61	27.36	0.11
8	119.09	23.96	2.74	9.98	29.50	0.00	102.85	67.75	112.65	36.86	0.16
9	113.66	16.19	3.15	10.51	17.84	0.00	109.33	70.42	122.84	30.77	0.13
10	28.78	1.69	1.25	11.52	1.09	0.00	85.23	49.54	133.13	15.04	0.01
11	0.70	0.00	0.32	10.97	0.00	0.00	57.71	28.21	132.08	11.85	0.00
12	60.44	4.91	0.56	10.66	0.00	0.00	85.21	26.92	125.65	15.82	0.03
1995	1085.39	164.01	21.94	117.93	117.41	0.00	85.21	739.26	1545.57	309.28	1.11

Annual Summary for Watershed in year 7 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	73.80	4.60	1.73	9.83	3.49	0.00	95.97	53.32	123.05	17.58	0.03
2	29.11	0.32	0.77	8.46	0.00	0.00	80.99	43.08	142.60	10.02	0.00
3	176.03	32.18	2.62	8.26	22.84	0.00	117.46	80.48	145.02	43.41	0.20
4	158.93	25.90	3.43	8.17	20.99	0.00	119.06	107.16	129.54	38.09	0.21
5	157.96	22.19	3.23	9.20	16.41	0.00	122.35	113.06	125.38	35.10	0.10
6	162.67	40.32	3.84	10.01	40.94	0.00	104.51	95.85	107.52	54.69	0.14
7	114.20	15.73	2.24	12.01	18.28	0.00	112.02	70.17	105.73	30.46	0.08
8	190.30	48.18	3.59	13.27	39.76	0.00	132.26	77.82	118.94	65.64	0.21
9	128.29	28.46	3.55	14.52	29.21	0.00	124.52	75.43	123.57	46.17	0.18
10	35.84	2.55	1.72	16.44	3.26	0.00	98.08	55.69	132.73	22.62	0.01
11	30.14	2.08	0.80	16.04	1.09	0.00	84.70	39.78	126.17	19.70	0.01
12	6.89	0.09	0.33	15.82	0.00	0.00	62.77	28.60	127.89	17.02	0.00
1996	1264.17	222.60	27.84	142.03	196.27	0.00	62.77	840.44	1508.15	400.49	1.16

Annual Summary for Watershed in year 26 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	4.09	0.00	0.19	13.02	0.00	0.00	49.36	21.87	136.49	14.05	0.00
2	2.67	0.00	0.08	10.36	0.00	0.00	35.57	16.42	135.27	11.15	0.00
3	19.61	0.00	0.25	10.05	0.00	0.00	31.69	23.07	155.21	11.03	0.00
4	56.23	1.49	0.81	8.51	0.00	0.00	34.30	51.01	150.84	11.46	0.01
5	93.27	4.00	1.43	7.99	0.16	0.00	51.07	70.52	141.45	14.00	0.03
6	80.33	3.03	1.74	6.99	0.52	0.00	60.30	65.89	127.22	12.34	0.01
7	74.79	3.53	1.44	6.27	0.56	0.00	78.81	50.71	126.16	11.72	0.02
8	69.76	6.45	1.46	5.48	5.38	0.00	87.28	48.07	114.70	13.85	0.05
9	86.28	6.45	1.67	4.84	7.31	0.00	95.57	62.40	123.40	13.38	0.05
10	33.73	1.02	1.31	4.82	0.43	0.00	74.48	52.59	149.47	7.54	0.01
11	76.72	5.06	1.50	4.49	3.83	0.00	93.69	46.93	104.78	11.42	0.04
12	13.60	0.00	0.66	4.44	0.00	0.00	72.87	34.18	113.58	5.45	0.00
2015	611.07	31.04	12.54	87.26	18.20	0.00	72.87	543.66	1578.58	137.39	0.23

Annual Summary for Watershed in year 27 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	37.15	0.51	0.54	4.11	0.00	0.00	75.94	32.87	124.79	5.47	0.01
2	37.13	0.98	0.61	3.50	0.00	0.00	71.43	40.07	144.01	5.33	0.01
3	56.49	1.53	0.82	3.37	0.00	0.00	65.39	59.99	144.52	6.00	0.02
4	238.15	54.00	3.54	3.06	44.92	0.00	101.06	98.48	130.20	59.97	0.51
5	169.51	43.30	4.59	4.28	38.56	0.00	70.70	114.19	143.93	53.33	0.33
6	110.26	7.24	2.10	5.93	3.68	0.00	84.74	83.37	124.45	15.56	0.04
7	161.54	25.49	3.49	8.01	31.10	0.00	90.16	95.46	141.96	37.35	0.14
8	135.34	24.01	3.83	9.35	32.13	0.00	95.25	70.41	126.74	37.80	0.18
9	126.58	21.88	3.38	9.56	30.35	0.00	97.20	69.25	134.56	35.39	0.16
10	56.24	1.60	1.75	11.50	1.54	0.00	93.61	55.70	108.55	15.49	0.01
11	44.49	2.87	0.91	11.18	1.57	0.00	88.23	44.58	107.36	15.60	0.02
12	16.24	0.05	0.64	10.50	0.00	0.00	66.26	37.87	128.10	11.86	0.00
2016	1189.11	183.45	26.20	84.34	183.84	0.00	66.26	802.24	1559.19	299.15	1.43

Annual Summary for Watershed in year 28 of simulation

UNIT TIME	PREC (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	PET (mm)	WATER YIELD (mm)	SED YIELD (t/ha)
1	3.88	0.08	0.19	9.18	0.09	0.00	47.40	22.48	141.09	10.11	0.00
2	32.77	0.13	0.32	7.51	0.00	0.00	57.76	21.65	130.85	8.52	0.00
3	28.51	0.31	0.53	7.36	0.00	0.00	44.19	41.31	155.87	8.78	0.00
4	47.90	0.16	0.64	5.62	0.00	0.00	44.69	46.36	142.74	6.93	0.00
5	126.17	5.82	1.85	4.63	0.27	0.00	63.59	99.03	136.02	12.84	0.04
6	89.87	3.94	1.51	3.93	0.11	0.00	71.94	76.04	124.97	9.81	0.02
7	125.99	9.40	2.33	3.79	13.75	0.00	94.59	77.49	113.29	15.87	0.07
8	116.27	14.21	2.66	4.10	23.02	0.00	97.20	73.47	127.78	21.37	0.11
9	134.29	23.60	3.66	5.06	38.19	0.00	101.82	63.97	123.05	32.64	0.14
10	56.09	6.28	2.39	6.94	8.49	0.00	85.01	56.68	137.55	16.23	0.05
11	25.65	2.42	0.89	7.76	0.67	0.00	68.33	38.82	128.71	11.55	0.02
12	0.00	0.00	0.24	7.79	0.00	0.00	47.10	21.23	120.95	8.53	0.00
2017	787.41	66.34	17.22	73.69	84.59	0.00	47.10	638.54	1582.86	163.19	0.45

Appendix I: - Sample HRUs statistics for year 1

LULC	HRU	SUB	YEAR	MON	AREAkm2	PETmm	ETmm	SW_INmn	SWENDmm	GW_RGm	DA_RCHr	REVAPm	LATQ_m	GW_Qmr	WYLD_Qr	DAILYCN
AGRR	1	1	1992	1	10.40	116.71	51.23	97.33	81.27	9.71	0.49	5.84	1.70	10.20	19.08	84.94
AGRR	2	1	1992	1	5.43	116.71	51.06	97.14	81.17	9.17	0.46	5.84	2.35	9.66	19.01	84.88
AGRR	3	1	1992	1	31.64	116.71	51.47	97.59	81.41	10.46	0.52	5.84	0.80	10.97	19.19	85.01
AGRR	4	1	1992	1	63.34	116.71	53.39	107.99	91.25	8.27	0.41	5.84	0.91	8.81	16.79	85.46
AGRR	5	1	1992	1	21.22	116.71	52.91	107.44	90.89	7.66	0.38	5.84	1.84	8.18	16.83	85.31
AGRR	6	1	1992	1	11.42	116.71	48.20	224.46	208.41	0.65	0.03	5.84	14.08	0.67	15.16	72.19
AGRR	7	1	1992	1	5.99	116.71	53.38	236.12	218.67	5.41	0.27	5.84	5.24	5.78	12.45	76.02
AGRR	8	1	1992	1	4.12	116.71	52.27	233.71	216.57	4.24	0.21	5.84	7.14	4.49	12.79	75.19
AGRR	9	1	1992	1	14.80	116.71	55.02	239.54	221.63	7.12	0.36	5.84	2.50	7.65	12.03	77.22
AGRR	10	2	1992	1	7.98	116.89	28.61	68.89	95.80	8.45	0.42	5.85	0.72	9.29	11.52	75.88
AGRR	11	2	1992	1	14.86	116.89	28.80	69.20	96.45	8.90	0.45	5.85	0.52	9.80	11.89	75.98
AGRR	12	2	1992	1	34.93	116.89	29.06	69.66	97.35	9.54	0.48	5.85	0.25	10.51	12.39	76.13
AGRR	13	2	1992	1	10.25	116.89	28.17	68.16	94.28	7.42	0.37	5.85	1.19	8.15	10.70	75.64
AGRR	14	2	1992	1	24.60	116.89	29.66	76.83	103.56	6.78	0.34	5.85	0.59	7.36	9.35	76.13
AGRR	15	2	1992	1	63.89	116.89	29.95	77.35	104.57	7.33	0.37	5.85	0.29	7.97	9.72	76.29
AGRR	16	3	1992	1	43.83	117.30	28.04	67.77	93.64	7.12	0.36	5.87	1.34	7.82	10.46	75.51
AGRR	17	3	1992	1	31.24	117.30	28.62	68.74	95.67	8.47	0.42	5.87	0.72	9.31	11.52	75.83
AGRR	18	3	1992	1	58.73	117.30	28.81	69.06	96.33	8.93	0.45	5.87	0.52	9.83	11.86	75.94
AGRR	19	3	1992	1	126.77	117.30	29.07	69.50	97.19	9.54	0.48	5.87	0.26	10.51	12.16	76.08
AGRR	20	3	1992	1	68.80	117.30	37.73	196.39	219.84	5.71	0.29	5.87	0.72	6.15	7.18	65.77
AGRR	21	3	1992	1	18.10	117.30	35.28	188.61	205.90	0.41	0.02	5.87	3.80	0.43	4.26	64.74
AGRR	22	3	1992	1	22.57	117.30	37.06	194.32	216.12	4.12	0.21	5.87	1.55	4.40	6.17	65.47
AGRR	23	3	1992	1	12.16	117.30	36.61	192.91	213.59	3.10	0.16	5.87	2.11	3.30	5.57	65.28
AGRR	24	3	1992	1	98.14	117.30	26.31	47.75	74.04	11.19	0.56	5.87	0.13	12.41	16.44	84.58
AGRR	25	3	1992	1	16.29	117.30	26.21	47.61	73.74	10.23	0.51	5.87	0.32	11.34	16.39	84.55
AGRR	26	4	1992	1	7.20	151.78	25.52	34.76	30.37	5.94	0.30	7.59	0.04	6.16	6.48	81.21
AGRR	27	4	1992	1	0.95	151.78	25.44	34.64	30.25	5.40	0.27	7.59	0.11	5.60	5.96	81.17
FRST	28	4	1992	1	0.52	151.78	20.72	25.01	22.78	1.57	0.08	7.59	0.15	1.63	1.86	77.78
FRST	29	4	1992	1	0.45	151.78	20.58	24.70	22.48	1.32	0.07	7.59	0.25	1.37	1.68	77.66
FRST	30	4	1992	1	1.09	151.78	20.77	25.13	22.90	1.69	0.09	7.59	0.11	1.76	1.95	77.84
FRST	31	4	1992	1	2.28	151.78	20.85	25.31	23.08	1.89	0.09	7.59	0.05	1.96	2.10	77.91
AGRR	32	5	1992	1	130.76	116.04	34.42	70.94	88.85	16.87	0.84	5.80	0.96	18.33	20.23	76.55
AGRR	33	5	1992	1	83.74	116.04	34.14	70.54	88.22	16.19	0.81	5.80	1.33	17.59	19.83	76.42
AGRR	34	5	1992	1	93.18	116.04	33.59	69.73	86.93	14.96	0.75	5.80	2.08	16.25	19.16	76.15
AGRR	35	5	1992	1	239.72	116.04	34.78	71.46	89.68	17.79	0.89	5.80	0.48	19.33	20.80	76.72
AGRR	36	5	1992	1	24.01	116.04	34.11	70.55	87.55	11.51	0.58	5.80	1.97	12.46	15.12	78.69
AGRR	37	5	1992	1	56.82	116.04	34.89	71.67	89.29	12.66	0.63	5.80	0.96	13.72	15.45	79.02
AGRR	38	5	1992	1	125.28	116.04	35.27	72.20	90.12	13.25	0.66	5.80	0.47	14.36	15.65	79.18
AGRR	39	5	1992	1	30.23	116.04	34.60	71.26	88.65	12.24	0.61	5.80	1.33	13.25	15.33	78.90
AGRR	40	6	1992	1	23.71	116.35	31.62	66.67	81.73	14.70	0.74	5.82	2.77	16.12	19.71	75.20
AGRR	41	6	1992	1	14.65	116.35	33.16	68.99	85.04	18.60	0.93	5.82	0.56	20.43	22.03	75.95
AGRR	42	6	1992	1	9.46	116.35	32.49	67.99	83.62	16.87	0.84	5.82	1.52	18.52	20.97	75.63
AGRR	43	6	1992	1	11.21	116.35	32.78	68.43	84.25	17.62	0.88	5.82	1.09	19.36	21.43	75.77
AGRR	44	6	1992	1	6.73	116.35	32.31	67.67	82.68	12.02	0.60	5.82	2.38	13.08	16.10	77.80
AGRR	45	6	1992	1	7.59	116.35	32.94	68.60	83.99	13.13	0.66	5.82	1.51	14.30	16.52	78.08
AGRR	46	6	1992	1	24.23	116.35	33.65	69.62	85.43	14.40	0.72	5.82	0.54	15.71	17.03	78.38
AGRR	47	6	1992	1	12.74	116.35	33.24	69.03	84.61	13.67	0.68	5.82	1.10	14.90	16.74	78.20
AGRR	48	6	1992	1	65.15	116.35	33.16	50.45	65.58	19.54	0.98	5.82	0.24	21.51	23.96	84.99
AGRR	49	6	1992	1	13.76	116.35	32.98	50.26	65.32	17.96	0.90	5.82	0.54	19.77	22.43	84.95
FRST	50	6	1992	1	25.57	116.35	33.23	51.08	66.13	13.28	0.66	5.82	0.25	14.45	16.59	85.13
FRST	51	6	1992	1	8.05	116.35	33.05	50.90	65.88	12.19	0.61	5.82	0.55	13.25	15.62	85.10
AGRR	52	7	1992	1	263.53	151.93	25.52	34.73	30.34	5.95	0.30	7.60	0.04	6.18	6.50	81.20
FRST	53	7	1992	1	16.51	151.93	20.78	25.12	22.88	1.70	0.09	7.60	0.11	1.77	1.96	77.83

FRST	54	7	1992	1	81.68	151.93	20.86	25.29	23.06	1.90	0.10	7.60	0.05	1.97	2.11	77.90
FRST	55	8	1992	1	2.50	152.30	20.79	25.04	22.81	1.70	0.09	7.62	0.11	1.76	1.95	77.80
FRST	56	8	1992	1	11.05	152.30	20.87	25.23	22.99	1.90	0.10	7.62	0.05	1.98	2.11	77.87
AGRR	57	9	1992	1	120.78	152.16	25.53	34.70	30.31	5.98	0.30	7.61	0.04	6.21	6.53	81.19
FRST	58	9	1992	1	31.33	152.16	20.88	25.27	23.03	1.92	0.10	7.61	0.04	2.00	2.13	77.89
AGRR	59	10	1992	1	7.92	152.42	29.73	54.86	48.28	2.77	0.14	7.62	0.41	2.82	3.35	73.97
AGRR	60	10	1992	1	38.66	152.42	29.95	55.29	48.70	3.01	0.15	7.62	0.19	3.08	3.40	74.10
AGRR	61	10	1992	1	130.94	152.42	25.53	34.64	30.25	5.95	0.30	7.62	0.04	6.17	6.49	81.17
FRST	62	10	1992	1	22.38	152.42	20.79	25.02	22.79	1.70	0.09	7.62	0.11	1.77	1.95	77.79
FRST	63	10	1992	1	177.70	152.42	20.88	25.22	22.98	1.91	0.10	7.62	0.04	1.99	2.12	77.87
AGRR	64	11	1992	1	4.15	130.45	38.60	177.30	171.61	11.93	0.60	6.52	0.69	13.54	14.97	63.63
AGRR	65	11	1992	1	0.52	130.45	37.77	174.39	168.51	9.82	0.49	6.52	1.59	11.13	13.32	63.42
FRST	66	11	1992	1	1.05	130.45	33.46	160.35	157.07	5.45	0.27	6.52	0.83	6.24	7.41	62.68
FRST	67	11	1992	1	0.18	130.45	32.21	155.72	152.13	2.66	0.13	6.52	2.21	3.06	5.44	62.51
FRST	68	11	1992	1	0.43	130.45	32.78	157.87	154.42	3.92	0.20	6.52	1.58	4.49	6.32	62.58
FRST	69	11	1992	1	2.47	130.45	23.13	35.98	38.05	7.95	0.40	6.52	0.10	9.15	9.91	81.55
FRST	70	11	1992	1	0.71	130.45	23.00	35.76	37.83	7.27	0.36	6.52	0.22	8.38	9.20	81.48
AGRR	71	12	1992	1	4.42	152.49	30.94	66.63	59.49	3.72	0.19	7.63	0.22	3.82	4.21	75.64
AGRR	72	12	1992	1	24.20	152.49	31.06	66.89	59.75	3.96	0.20	7.63	0.10	4.06	4.34	75.71
AGRR	73	12	1992	1	35.89	152.49	25.53	34.62	30.22	5.92	0.30	7.63	0.04	6.14	6.46	81.16
AGRR	74	12	1992	1	5.13	152.49	25.46	34.49	30.10	5.41	0.27	7.63	0.10	5.62	5.97	81.13
FRST	75	12	1992	1	50.59	152.49	20.88	25.20	22.96	1.91	0.10	7.63	0.04	1.99	2.12	77.86
RNGB	76	12	1992	1	3.44	152.49	22.10	51.20	48.17	1.71	0.09	7.63	0.23	1.76	2.07	71.77
RNGB	77	12	1992	1	17.27	152.49	22.22	51.58	48.54	1.88	0.09	7.63	0.10	1.94	2.12	71.87
RNGB	78	12	1992	1	24.99	152.49	21.21	30.48	28.01	3.56	0.18	7.63	0.05	3.71	3.93	79.83
RNGB	79	12	1992	1	3.97	152.49	21.13	30.30	27.84	3.24	0.16	7.63	0.10	3.38	3.64	79.77
AGRR	80	13	1992	1	28.71	118.23	23.39	71.93	62.76	2.84	0.14	5.91	0.08	3.31	3.60	76.98
AGRR	81	13	1992	1	5.13	118.23	23.28	71.65	62.52	2.68	0.13	5.91	0.18	3.12	3.50	76.91
AGRR	82	13	1992	1	41.21	118.23	19.22	38.22	31.15	4.12	0.21	5.91	0.05	4.74	5.06	82.21
AGRR	83	13	1992	1	7.59	118.23	19.14	38.05	31.02	3.77	0.19	5.91	0.11	4.35	4.71	82.17
FRST	84	13	1992	1	62.18	118.23	9.98	11.08	8.31	3.89	0.19	5.91	0.05	4.47	4.78	70.66
FRST	85	13	1992	1	10.96	118.23	9.96	11.00	8.23	3.57	0.18	5.91	0.10	4.11	4.45	70.61
RNGE	86	13	1992	1	3.10	118.23	11.22	20.57	17.16	3.89	0.20	5.91	0.36	4.47	5.09	63.84
RNGE	87	13	1992	1	3.21	118.23	11.15	20.26	16.87	3.70	0.19	5.91	0.49	4.25	4.99	63.80
RNGE	88	13	1992	1	9.03	118.23	10.95	19.33	15.99	3.16	0.16	5.91	0.88	3.64	4.74	63.67
RNGE	89	13	1992	1	3.77	118.23	11.30	20.97	17.54	4.17	0.21	5.91	0.18	4.78	5.24	63.90
RNGE	90	13	1992	1	0.91	118.23	9.69	12.09	9.43	3.35	0.17	5.91	0.25	3.85	4.33	71.30
RNGE	91	13	1992	1	4.14	118.23	9.77	12.45	9.78	4.47	0.22	5.91	0.04	5.13	5.47	71.52
RNGE	92	13	1992	1	0.84	118.23	9.74	12.34	9.67	4.08	0.20	5.91	0.11	4.68	5.06	71.45
AGRR	93	14	1992	1	115.13	130.51	36.94	76.13	64.91	10.73	0.54	6.53	0.26	11.95	12.83	75.91
AGRR	94	14	1992	1	176.60	130.51	35.91	68.51	57.81	10.16	0.51	6.53	0.26	11.31	12.16	78.08
AGRR	95	14	1992	1	49.86	130.51	35.61	68.08	57.45	9.52	0.48	6.53	0.59	10.60	11.75	77.95
FRST	96	14	1992	1	11.12	130.51	31.02	45.64	37.31	5.81	0.29	6.53	0.10	6.66	7.12	84.11
FRST	97	14	1992	1	43.45	130.51	31.13	45.78	37.43	6.47	0.32	6.53	0.04	7.41	7.85	84.15
RNGE	98	14	1992	1	5.06	130.51	32.18	46.71	37.89	9.12	0.46	6.53	0.14	10.21	10.89	84.36
RNGE	99	14	1992	1	9.66	130.51	32.20	46.74	37.92	9.75	0.49	6.53	0.10	10.90	11.58	84.36
RNGE	100	14	1992	1	29.09	130.51	32.23	46.78	37.97	10.68	0.53	6.53	0.04	11.92	12.60	84.37
RNGE	101	14	1992	1	6.19	130.51	32.12	46.65	37.81	8.00	0.40	6.53	0.22	8.97	9.67	84.34
AGRR	102	15	1992	1	100.50	118.42	29.27	171.12	158.83	1.69	0.09	5.92	0.44	2.00	2.58	63.23
AGRR	103	15	1992	1	119.47	118.42	23.39	71.86	62.68	2.84	0.14	5.92	0.08	3.31	3.60	76.96
AGRR	104	15	1992	1	26.31	118.42	23.29	71.58	62.44	2.68	0.13	5.92	0.19	3.12	3.51	76.89
FRST	105	15	1992	1	76.72	118.42	10.15	39.95	37.00	1.57	0.08	5.92	0.43	1.86	2.42	61.73
FRST	106	15	1992	1	10.81	118.42	10.05	38.14	35.17	1.35	0.07	5.92	0.98	1.60	2.69	61.73
FRST	107	15	1992	1	40.83	118.42	9.99	11.06	8.29	3.90	0.20	5.92	0.04	4.49	4.80	70.65
FRST	108	15	1992	1	5.18	118.42	9.97	10.98	8.21	3.57	0.18	5.92	0.10	4.11	4.46	70.60
RNGE	109	15	1992	1	9.66	118.42	10.95	22.20	18.91	2.59	0.13	5.92	0.39	2.98	3.55	63.65
RNGE	110	15	1992	1	77.48	118.42	11.04	22.73	19.41	2.82	0.14	5.92	0.16	3.23	3.58	63.71

RNGE	111	15	1992	1	97.04	118.42	15.54	93.65	88.02	1.65	0.08	5.92	0.49	1.96	2.58	61.78
RNGE	112	15	1992	1	21.89	118.42	13.71	78.88	74.09	1.44	0.07	5.92	1.03	1.71	2.85	61.75
AGRR	113	16	1992	1	125.76	130.81	36.89	75.95	64.73	10.63	0.53	6.54	0.32	11.83	12.77	75.85
AGRR	114	16	1992	1	42.05	130.81	36.56	75.42	64.29	9.94	0.50	6.54	0.67	11.07	12.32	75.69
AGRR	115	16	1992	1	25.89	130.81	34.92	66.93	56.46	8.15	0.41	6.54	1.36	9.07	10.90	77.61
AGRR	116	16	1992	1	94.14	130.81	35.88	68.37	57.68	10.11	0.51	6.54	0.30	11.25	12.14	78.04
AGRR	117	16	1992	1	25.56	130.81	35.41	67.67	57.09	9.11	0.46	6.54	0.83	10.13	11.49	77.83
AGRR	118	16	1992	1	48.51	130.81	35.61	67.98	57.34	9.53	0.48	6.54	0.60	10.60	11.76	77.92
RNGE	119	16	1992	1	15.96	130.81	36.53	74.76	63.65	7.08	0.35	6.54	0.67	7.97	9.06	75.49
RNGE	120	16	1992	1	48.90	130.81	36.87	75.30	64.11	7.70	0.39	6.54	0.31	8.66	9.43	75.65
RNGE	121	16	1992	1	35.00	130.81	45.25	188.73	172.93	8.90	0.45	6.54	0.81	9.97	11.30	64.79
RNGE	122	16	1992	1	8.50	130.81	44.38	186.36	170.78	6.90	0.35	6.54	1.78	7.73	9.92	64.53
AGRR	123	17	1992	1	12.09	118.69	22.74	64.99	56.15	2.38	0.12	5.94	0.15	2.76	3.07	72.55
FRST	124	17	1992	1	17.85	118.69	9.88	15.96	13.21	2.20	0.11	5.94	0.15	2.55	2.86	62.95
FRST	125	17	1992	1	4.74	118.69	9.89	14.65	11.90	2.23	0.11	5.94	0.14	2.57	2.86	63.95
FRST	126	17	1992	1	0.75	118.69	9.86	14.42	11.66	2.05	0.10	5.94	0.33	2.37	2.84	63.91
RNGE	127	17	1992	1	4.39	118.69	10.96	22.14	18.85	2.59	0.13	5.94	0.39	2.98	3.55	63.64
RNGE	128	17	1992	1	28.39	118.69	11.05	22.66	19.34	2.82	0.14	5.94	0.16	3.24	3.59	63.70
RNGE	129	17	1992	1	17.66	118.69	15.61	93.95	88.29	1.66	0.08	5.94	0.47	1.96	2.57	61.78
RNGE	130	17	1992	1	3.18	118.69	13.73	78.77	73.98	1.44	0.07	5.94	1.03	1.70	2.85	61.75
RNGB	131	17	1992	1	1.00	118.69	11.41	24.55	21.03	2.89	0.14	5.94	0.39	3.31	3.89	63.94
RNGB	132	17	1992	1	6.98	118.69	11.53	25.11	21.56	3.16	0.16	5.94	0.16	3.61	3.98	64.02
RNGB	133	17	1992	1	0.88	118.69	11.43	22.20	18.68	2.91	0.15	5.94	0.35	3.33	3.87	65.42
RNGB	134	17	1992	1	3.07	118.69	11.52	22.60	19.06	3.09	0.16	5.94	0.17	3.54	3.91	65.51
BARR	135	17	1992	1	14.12	118.69	19.89	51.05	43.59	5.43	0.27	5.94	0.15	6.17	6.67	68.85
AGRR	136	18	1992	1	13.99	118.69	21.67	57.41	49.08	3.29	0.17	5.93	0.35	3.80	4.38	72.22
AGRR	137	18	1992	1	79.79	118.69	21.87	57.91	49.51	3.55	0.18	5.93	0.15	4.10	4.49	72.37
AGRR	138	18	1992	1	21.39	118.69	27.04	161.52	150.22	1.45	0.07	5.93	1.04	1.72	2.88	62.74
AGRR	139	18	1992	1	66.61	118.69	29.07	170.08	157.87	1.66	0.08	5.93	0.51	1.97	2.61	63.17
FRST	140	18	1992	1	12.66	118.69	9.86	14.42	11.66	2.05	0.10	5.93	0.33	2.37	2.84	63.91
FRST	141	18	1992	1	57.46	118.69	9.89	14.63	11.88	2.21	0.11	5.93	0.16	2.55	2.86	63.95
RNGE	142	18	1992	1	10.37	118.69	10.27	17.92	14.90	2.08	0.10	5.93	0.85	2.40	3.40	64.56
RNGE	143	18	1992	1	14.89	118.69	11.03	20.22	16.90	2.66	0.13	5.93	0.35	3.05	3.58	65.02
RNGE	144	18	1992	1	43.59	118.69	11.11	20.62	17.28	2.83	0.14	5.93	0.17	3.25	3.61	65.10
RNGB	145	18	1992	1	18.26	118.69	11.43	22.20	18.69	2.91	0.15	5.93	0.35	3.33	3.87	65.42
RNGB	146	18	1992	1	62.09	118.69	11.52	22.62	19.08	3.10	0.16	5.93	0.16	3.55	3.91	65.51
AGRR	147	19	1992	1	6.89	118.86	22.74	64.92	56.08	2.38	0.12	5.94	0.15	2.75	3.08	72.53
AGRR	148	19	1992	1	4.46	118.86	21.96	58.08	49.64	2.41	0.12	5.94	0.13	2.78	3.07	74.94
FRST	149	19	1992	1	15.64	118.86	9.90	14.63	11.88	2.23	0.11	5.94	0.14	2.57	2.87	63.95
FRST	150	19	1992	1	2.36	118.86	9.87	14.40	11.64	2.05	0.10	5.94	0.33	2.37	2.85	63.91
RNGE	151	19	1992	1	10.87	118.86	11.06	22.63	19.31	2.83	0.14	5.94	0.16	3.24	3.60	63.70
RNGE	152	19	1992	1	1.43	118.86	10.96	22.12	18.82	2.60	0.13	5.94	0.39	2.99	3.56	63.64
RNGE	153	19	1992	1	19.85	118.86	11.12	20.59	17.25	2.84	0.14	5.94	0.17	3.25	3.61	65.09
RNGE	154	19	1992	1	5.56	118.86	10.29	17.92	14.90	2.10	0.11	5.94	0.83	2.42	3.40	64.56
RNGE	155	19	1992	1	7.35	118.86	11.03	20.16	16.84	2.66	0.13	5.94	0.35	3.05	3.58	65.00
RNGE	156	19	1992	1	10.81	118.86	15.59	93.65	88.00	1.65	0.08	5.94	0.48	1.96	2.57	61.78
RNGE	157	19	1992	1	2.27	118.86	13.73	78.71	73.91	1.44	0.07	5.94	1.03	1.70	2.85	61.75
RNGB	158	19	1992	1	17.80	118.86	11.54	22.61	19.07	3.12	0.16	5.94	0.15	3.57	3.92	65.51
RNGB	159	19	1992	1	3.37	118.86	11.44	22.17	18.65	2.92	0.15	5.94	0.35	3.34	3.87	65.42
AGRR	160	20	1992	1	0.53	118.85	22.49	64.31	55.55	2.15	0.11	5.94	0.40	2.49	3.04	72.36
AGRR	161	20	1992	1	3.64	118.85	22.73	64.90	56.06	2.37	0.12	5.94	0.16	2.74	3.07	72.53
RNGE	162	20	1992	1	1.38	118.85	10.96	22.10	18.80	2.59	0.13	5.94	0.40	2.98	3.56	63.63
RNGE	163	20	1992	1	5.68	118.85	11.06	22.62	19.30	2.82	0.14	5.94	0.17	3.24	3.59	63.70
RNGE	164	20	1992	1	1.05	118.85	10.76	21.02	17.77	2.14	0.11	5.94	0.87	2.47	3.48	63.50
RNGE	165	20	1992	1	0.51	118.85	10.84	19.53	16.28	2.49	0.13	5.94	0.49	2.86	3.52	64.88
RNGE	166	20	1992	1	0.60	118.85	10.29	17.96	14.93	2.12	0.11	5.94	0.82	2.44	3.40	64.57
RNGE	167	20	1992	1	0.98	118.85	11.11	20.54	17.20	2.81	0.14	5.94	0.20	3.22	3.61	65.08
RNGE	168	20	1992	1	0.80	118.85	11.03	20.15	16.83	2.65	0.13	5.94	0.36	3.04	3.58	65.00