

Addis Ababa
University
(Since 1950)



SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF EARTH SCIENCES

**GROUND WATER POTENTIAL EVALUATION AND USE TRENDS IN
UPPER AWASH BASIN; WITH PARTICULAR EMPHASIS TO
BECHO –KOKA AREA**

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
IN PARTIAL FULFLIMENT FOR THE DEGREE OF MASTER OF SCIENCE
IN HYDROGEOLOGY

BY
REYS ASFAW ANGASU

May, 2016
Addis Ababa

DECLARATION

I the undersigned declare that this thesis is my original work and has not been presented for a degree in any other university. All sources of material used for the thesis have been duly acknowledged.

Name: Reys Asfaw

Signature: _____

Place: Addis Ababa University, School of Graduate Studies.

May, 2016

The Thesis has been submitted for examination with my approval as university advisor.

Tenalem Ayenew (prof) _____

ACKNOWLEDGEMENT

First and for most, I would like to gratefully Acknowledge Guraghe Zone Water ,Mines and Energy Department, for giving me the chance to attend this M.sc program and all the staffs for their care they gave for me during my study. I am grateful to GroFutures (Ground water futures in sub-Saharan Africa) project, for facilitating the field work with financial and logistics.

I am greatly indebted to my advisor Professor Tenalem Ayenew for his supervision encouragement and guidance he gave me all through my work.

I would like to express my appreciation for the data I received from the following Organization; Ministry of Water Resources, National Meteorological Service Agency, Ethiopian Water Works Design and Supervision Enterprise, Geological Survey of Ethiopia , Lume and Illu Woredas water resource development office and irrigation authorities.

I would like to stress my gratitude to professionals and friends who directly or indirectly involved for the successful completion of this research work, in particular a big thank to: Mr. Samuel Getachew and Mr. Abate Assen for their guidance in map preparations and others.

Finally, the biggest share of my deepest heart felt gratitude goes to all my family who were the source of my strength and inspiration, I love you.

ABSTRACT

The study area lies in the central part of Ethiopia within the upper Awash River basin with particular reference to the Koka and Becho areas. Koka is located in East Shewa Zone of Oromia regional state the center is located at North latitude of $8^{\circ}26'27.56''$ and longitude of $39^{\circ}1'54.45''$ East about 90 km south of the capital Addis Ababa. The Becho area is located between elevations of 2062 and 2109 m.a.s.l and the center is at 8.84° latitude and 38.36° longitude, with a total area of about 509 km².

The main objective of this research is to evaluate the groundwater potential and to study the changes in groundwater use trends with time. In addition to convectional hydrogeology study attempt was made to evaluate the recharge and discharge conditions. For the study of change in use trends of ground water different data on ground water like the number of shallow dug wells, amount of land irrigated with those wells, and others are collected for the past five years and analyzed for future management options of ground water.

On annual basis, the Koka area has 900.3 mm; 721 mm, and 27.31 mm of mean total rainfall, Actual Evapotranspiration (AET), and groundwater recharge respectively, and for the Becho area the results show that the mean annual rainfall of the area is 1026mm with actual evapotranspiration (AET) of 637mm, and recharge 227.34mm. The percentage of groundwater recharge to rainfall is about 22.2% in Becho while it is only about 3.03% of rainfall that recharges ground water.

Quaternary alluvial and lacustrine deposits are major hydrogeologic units in the study area in addition to this units, the Becho part is covered with massive ignimbrite which acts as regional aquiclude which separates the upper and lower volcanic basaltic aquifers. The major water bearing horizon of this aquifer is the fractured features resulted in secondary permeability.

The amount of land irrigated using shallow ground water in Koka area was only 330Ha in the year 2004 and in the year 2008, the area irrigated is about 1262Ha. The corresponding number of shallow ground water wells used to irrigate this amount of land is increased from 250 to 2305 within the past five years. In Becho area the amount of land irrigated using shallow ground water is increased from only 97 Ha to 496 Ha in the last five years with the increase in number of shallow wells from 202 to 935.

Different reasons are identified for change in ground water use trend in the study area among them: technology access, on-demand groundwater services, water shortage in Awash, Modjo and Teji Rivers and market demand for agricultural products are identified.

The shallow ground water table data around the Koka area shows that the ground water table becomes deeper and deeper as we go away from the lake and in turn the size of the lake is decreasing as a result of the shallow ground water pumping is increasing from year to year.

This study clearly identified problems in irrigation based agriculture. More innovative groundwater use in a sustainable manner demands proper water management practice. This has to be supported with better systematic control and research based groundwater use.

Key words: Ethiopia, Groundwater potential, Ground water use trends, Koka and Becho areas, Upper Awash River basin.

Table of contents

Contents	page
ACKNOWLEDGEMENT.....	i
ABSTRACT.....	ii
Table of contents.....	iv
List of Tables.....	vi
List of Figures.....	vi
Chapter One: - Introduction.....	1
1.1 Back ground.....	1
1.2 Objectives.....	3
1.2.1 General objectives.....	3
1.2.2 Specific objectives.....	3
1.1 Methodology and Approach.....	4
1.2 Previous Studies.....	5
Chapter Two: General Overview of the study area.....	8
2.1 Location and accessibility.....	8
2.2 Drainage and Physiography.....	10
2.2.1 Physiography.....	10
2.2.2 Drainage.....	11
2.3 Population.....	12
2.4 Climate.....	13
2.5 Socio economy.....	14
2.6 Land use land cover.....	15
2.7 Existing water supply and use.....	16
2.7.1 Rural water supply.....	16
Chapter Three: Geology.....	18
3.1 Regional Geology.....	18
3.1.2 Tertiary Volcanic Rocks.....	20
3.1.3 Quaternary Volcanic Rocks.....	22
3.1.4 Quaternary Lacustrine and Alluvial Deposit.....	23
3.2 Local geology of the study area.....	24
3.2.1 Rhyolites and trachyte.....	24
3.2.2 Ignimbrite.....	24
3.2.3 Quaternary Lacustrine and Alluvial Deposit.....	24
3.3 Geological Structures in the Upper Awash basin.....	25
Chapter Four: Hydrometrology.....	26

4.1 General Metrological Parameters.....	26
4.1.2 Determination of Aerial Depth of precipitation.....	29
4.1.3 Temperature.....	30
4.1.4 Wind Speed.....	31
4.1.5 Sunshine duration.....	32
4.1.6 Relative humidity.....	32
4.1.7 Climate Classification.....	33
4.2 Runoff.....	35
4.3 Hydrograph analysis.....	36
4.3.1 Base Flow Separation.....	37
4.5 Evapotranspiration.....	40
4.5.1. Estimation of potential evapotranspiration (PET).....	40
4.5.2. Actual evapotranspiration (AET).....	42
4.6 Groundwater recharge estimation.....	48
4.6.1 Base flow separation method.....	48
4.6.2Groundwater Balance Approach.....	48
Chapter Five: Hydrogeology.....	50
5.1 Alluvial Aquifers.....	52
5.2 Localized aquiclude (barriers).....	52
5.3 Upper basalt aquifer (UBA).....	53
5.4 Upper Regional confining (aquiclude) units.....	54
5.5 Lower Basalt aquifer (LBA).....	55
Chapter six: Ground water use trends.....	56
6.1 General use Trends.....	56
6.1 Ground water use trends of the study area.....	57
6.1.2 Water shortage in Awash and Modjo Rivers.....	60
6.1.3 On-demand groundwater services.....	61
6.1.4 Market demand for agricultural products.....	62
6.2 Ground water and irrigation.....	62
6.2.1 Temporal patterns.....	63
6.3 Ground water management and future challenges in the study area.....	67
6.3.1 General ground water management.....	67
Chapter Seven: - Conclusion and Recommendation.....	72
7.1 Conclusion.....	72
7.2 Recommendations.....	74
References.....	76

List of Tables

Table 4.1 Mean annual rainfall and temperature at selected stations.....	28
Tables 4.2 mean monthly RF of Koka and Becho area.....	29
Table 4.3 monthly maximum, minimum and average temperature of Koka area.....	32
Table 4.4 monthly maximum, minimum and average temperature of Becho area.....	32
Table 4.5 Average monthly wind speed of study area	33
Table 4.6- Average daily sunshine hour's duration for the study area.....	34
Table 4.7:-Average relative humidity of the study areas	34
Table: 4.8- Mean monthly moisture balance of Koka.....	35
Table: 4.9- Mean monthly moisture balance of Becho.....	36
Table 4.10 calculated potential evapotranspiration using Thornthwaite's method.....	43
Table 4.11a:- Estimation of, AET by using Thorenthwaite Mather Method for Koka area.....	46
Table 4.11b:- Estimation of AET by using Thorenthwaite Mather Method for Becho area.....	46
Table 5.1 Summary of Well Depth, Water Level, Discharge and Draw Down of Water wells in different formations.....	56
Table 6.1: Different manual well drilling techniques.....	60
Table 6.2 sustainability of pump techniques.....	61
Table 6.3 changes in number of shallow ground water wells in the Koka area.....	63
Table 6.4 number of shallow ground water wells in the Koka.....	63
Table 6.5: Area of land irrigated using ground water in Becho area.....	64
Table 6.6 number of shallow ground water wells in use for irrigation in Becho area.....	64

List of Figures

Figure 2.1 Location map of the study area.....	9
Figure: 2.2 Physiographic map of the study area.....	10
Figure 2.3 Drainage map of the study area.....	12
Figure 2.4 Rope pump in Becho area.....	17
Figure 3.1 geological map of the study area	18
Figure 3.2 lineament map of the study area	24
Figure 4.1 Mean Monthly rainfall of study area.....	26
Figure 4.2 mean monthly temperature of the study area.....	30
Figure 4.3 moisture balance of Becho area.....	33
Figure 4.4 Moisture balance of Koka area.....	34
Figure 4.5 Mean monthly rainfall and river discharge at selected stations.....	35
Figure 4.6 Mean monthly flow in the two gauging Awash River.....	36
Figure 4.7 Trends of annual runoff and base flow at Modjo and Teji Rivers.....	37
Figure 4.8 base flow separation of Teji River.....	38
Figure 4.9 base flow separation of Mojo River.....	38
Figure 5.1 hydrogeological map of study area.....	49

<i>Figure 6.1: Motor pumps in Koka area.....</i>	<i>58</i>
<i>Figure 6.2 Hand dug well in Koka area.....</i>	<i>59</i>
<i>Figure 6.3 Area of land irrigated using shallow ground water</i>	<i>62</i>
<i>Figure 6.4 Tube well in Becho area.....</i>	<i>63</i>
<i>Figure 6.5 number of shallow ground water wells in use for irrigation in Koka area.....</i>	<i>63</i>
<i>Figure 6.6: Area of land irrigated using ground water in Becho.....</i>	<i>64</i>
<i>Figure 6.7 number of shallow ground water wells in use for irrigation in Becho area.....</i>	<i>64</i>

List of Acronyms and Abbreviations

CSSP: Civil Society Support Program
EVDSA: Ethiopian Valleys Development Studies Authority
FHD: Focus on Human Development
GIS: Geographic Information System
Ha: Hectare
IDE: International Development Enterprise
ITCZ: Inter-Tropical Convergence Zone
IWMI International Water Management Institute
m.a.s.l.: Meters above sea level
MCM: Million Cubic Meters
MDG: Millennium Development Goal
MER: .Main Ethiopian Rift
mm: Millimeters
MoWR: Ministry of Water Resources
NMA: National Meteorological Agency
WWDSE: Water Works Design and Supervision Enterprise
WRMP: Water Resource Management Program
SGW: Shallow Ground Well

Chapter One: - Introduction

1.1 Back ground

Ground water is the safest and most reliable water source, use in domestic, irrigation, industries, and municipality purposes. Ground water development for water supply purpose is preferable to low discharge springs and dug wells, because they are found to be inadequate yield and no longer resistant drought while most of them might be completely dried out and never easily recovered after the prolonged drought time. The occurrence, origin, movement and chemical constituents of groundwater are dependent on geology/ lithology, Geomorphology /Landforms, drainage density, rain fall, Geological structures/lineaments, slope, Land use/Land cover and soil of groundwater regime Tesfaye Tessema(2015).

Ground water development can have undesirable qualitative and quantitative side effect as well environmental problems. A relatively safe sustainable level of exploitation is known as ground water potential.

Evaluation of ground water potential involves a quantitative understanding of aquifer system and ground water conditions. In view of increasing demand of water for various purposes like agricultural, domestic, industrial etc., a greater emphasis is being laid for a planned and optimal utilization of water resources. Due to uneven distribution of rainfall both in time and space, the surface water resources are unevenly distributed. Also, increasing intensities of irrigation from surface water alone may result in alarming rise of water table creating problems of waterlogging and salinization, affecting crop growth adversely and rendering large areas unproductive.

This has resulted in increased emphasis on development of groundwater resources. The simultaneous development of ground water especially through dug wells and shallow tube wells will lower water table, provide vertical drainage and thus can prevent waterlogging and salinization. Areas which are already waterlogged can also be reclaimed. On the other hand continuous increased withdrawals from a ground water reservoir in excess of replenish able recharge may result in regular lowering of water table. In such a situation, it creates serious problem is resulting in drying of shallow wells and increase in pumping head for deeper wells

and tube wells. This has led to emphasis on planned and optimal development of water resources.

Water balance techniques have been extensively used to make quantitative estimates of water resources and the impact of man's activities on the hydrologic cycle. On the basis of the water balance approach, it is possible to make a quantitative evaluation of water resources and its dynamic behavior under the influence of man's activities. In this paper, an attempt has been made to describe the methodologies to understand and evaluate the various recharge and discharge components of ground water balance equation and to establish the recharge coefficient with a view to work out the ground water potential of an area.

Groundwater use in irrigation is still extremely modest but several ambitious plans for groundwater based irrigation are ongoing in different parts of the country and especially in the awash basin, which this particular paper also focuses on. In the Koka and Becho areas with shallow groundwater farmer-driven groundwater development is taking off rapidly.

Along with the increasing groundwater development there is growing awareness that management is needed to ensure the sustainability of investments in groundwater development, to optimize the opportunities for groundwater recharge and re-use and to regulate the long term equitable use of the resource.

Until recently groundwater use beyond drinking water was limited in Ethiopia. With the drive towards more intense groundwater use developing regulation becomes more important to safeguard the source and guide the allocation of groundwater.

At present there is no encompassing institutional framework for groundwater management, but the principles of the Water Resource Management Policy (WRMP) of 1999 may be taken as a guideline.

The objectives of the WRMP that are particularly relevant for managed groundwater development are the integrated management of water; the recognition of water as a scarce and vital resource that needs to be managed on a strategic planning base; the integration of water resources development in the overall national economic development framework; adopting basins as fundamental planning units; participation of the private sector in water resources

management and conducive environment for linkages between the Federal and Regional States on the basis of the Constitution.

The general principles of allocation and apportionment of water in the WRMP may also hold true for managed groundwater development:

- Basic minimum requirement for essential human and livestock needs and environment
- Highest priority to water supply and sanitation, the remainder to use with higher socio-economic benefits
- Encourage efficient use of water resources
- Water allocations to be made not permanently but on the basis of agreed time horizons.

1.2 Objectives

1.2.1 General objectives

The main objective of this study is to assess the ground water potential of upper awash basin, particularly of Koka and Becho area and the change in use trends of ground water in order to increase its contribution in future managed use trend and the water resources policy of the government.

1.2.2 Specific objectives

- ✓ To perform water balance evaluation of the area based on available metrological and hydrological data.
- ✓ To describe and characterize the major aquifer systems and units in the area specially the shallow aquifers
- ✓ To modify geological and hydrogeological map of the study area.
- ✓ To identify driving factors for change in use trends of the ground water in the study area
- ✓ To show ground water management considerations of the area

1.1 Methodology and Approach

To satisfy the study objectives the following approaches and methodologies has been adopted:

- Collection of hydrometrological, hydrogeological and hydrological data from respective institutions to determine the different input parameters of the soil water balance method.
- The base flow separation method is used in addition to soil water balance method to estimate recharge indirectly by separating the total flow in to the direct run off and base flow components
- Interview based identification of how the shallow ground water irrigation is started in the area, its challenges and driving force for its rapid expansion, and what changes happen in the environment and the wells are analyzed to put forward ground water management related problems and solutions in the study area.
- Amount of land irrigated using shallow ground water and their respective number of shallow dug wells used to irrigate the land are collected for the last five years and the change is analyzed

1.2 Previous Studies

Several geological and hydrogeological studies have been conducted in the Upper Awash basin and its adjacent areas. Hydrogeological studies have been conducted in connection with the water supply of the towns of Debrezeit and Modjo under the Twelve Towns Water Supply Project (Ministry of Water Resources (MoWR), 1980). Based on these studies, wells were drilled in the vicinity of the two towns. The boreholes are shallow having a maximum depth of 90m. The lithologic logs of these wells show that lacustrine sediments form good aquifers. The lacustrine deposit has a thickness varying from 50 to 80 meters and is underlain by vesicular basalt. These wells represent the lacustrine aquifer of the south eastern part of the Upper Awash basin.

WWDSE (2007-2008) has been conducted a study on the title of evaluation of water resources of the Ada'a and Becho plains groundwater basin for irrigation. It was comprehensive study and Supported by geophysical investigation and deep well drilling. The work classified the main aquifers of the area in to upper and lower basalt aquifers and alluvial and lacustrine aquifers.

The Upper basalt aquifer include Weliso Ambo basalt, Akaki basalt and Addis Ababa basalt. Whereas the lower aquifers include Tarmaber basalt and Aiba basalt. The rhyolites and trachytes of Wechecha-Yere-Furi and Ziquala are mapped as regional groundwater barriers.

The study revealed that the annual groundwater recharge of the plains is about 965Mm³/year. The annual exploitable groundwater resources in Becho and Ada'a plains are estimated at detail reconnaissance to be about 642MCM/Year and 1046 MCM/Year respectively (WWDSE, 2008).

Tilahun, Azagegn conducted hydrochemical characterization of aquifer system in upper Awash and adjacent plateau using geochemical modeling and Isotope Hydrology. The research work addressed schematic conceptual model for special geochemical variations, evaluation and recharge area zonation for shallow and deep aquifer system along four groundwater flow path in geomorphic pattern (Plateau, transitional and rift).

The other hydrogeological investigation carried out in the Becho area is the ground water potential assessment of Teji river catchment (Andualem Eshetu, 2008).it investigates that the annual recharge of the catchment is 325.39mm.

Ketema Wogari (2006) evaluated the water resource potential of Holeta river catchment and identified that the basaltic lava flows (Alaji and Tarmaber Megeze formation); Trachytic and Rhyolitic volcanic rocks, pyroclastic deposits and Quaternary Alluvial sediments are major geologic units in the area.

Hussen Endre (2006) had conducted water resources potential evaluation of Berga river catchment on his MSC thesis work and he discussed that the main aquifer in the catchment is weathered and fractured basalt.

Yitbarek. , et al (2012) identified that the aquifer properties in the upper awash basin are controlled by the lithostratigraphy of the volcanic rocks and the structures that affect them. The volcanic rocks have highly variable primary porosity because of the nature and conditions of the lava flow. Later on through time, these volcanic rocks have been subjected to weathering and fracturing related to tectonic activities giving rise to secondary porosities. These volcanic aquifers can be considered as a double porosity medium due to the fact that both the matrix and the fracture porosity contribute to the circulation and storage of groundwater.

Relating to the flooding which is the problem of both Becho and Koka area there are also several studies were under taken in the past.Yinesulih,2014 discussed the productivity of shallow ground water wells and Hand-dug wells inside floodplain and investigated that they have drawn backs, which are, during inundation the wells either collapse or filled with sediment. Economically which means, farmers spent money every year for construction or maintenance of the wells. Whereas, those floodplain area which are within 100 meter distance from Mojo River, are not engaged with hand-dug wells due to frequent collapsing.

Nippon Koei (1996.) Feasibility study on the Becho plain agricultural development project Final report identified that all sites are covered with a thick clay layer of which thickness is 6m to 11m. The clay is sticky and plastic. The tuff layer lies under the thick clay layer.

Andarghe Yitbarek (2009) identified that The aquifers in Upper Awash can be divided broadly into two categories; primary porosity aquifers and double porosity aquifers. The first category comprises aquifers related to Quaternary alluvial and lacustrine deposits and the second broad categories belongs to the basaltic volcanics.

Chapter Two: General Overview of the study area

2.1 Location and accessibility

Koka and Becho areas are the focus areas for this specific research, both the areas are located in the upper part of Awash River; which is one of the main rivers from the existing eleven main rivers in Ethiopia. Koka is located in East Shewa Zone of Oromia regional state within the North latitude of 8026'27.56" and altitude of 39001'54.45" East and with average elevation of 1,731m m.a.s.l. it is 93 Km far from the capital Addis Ababa to the Koka town and then it is accessed through walking, using motor bike or small car (Baggage) to the specific study area.

Being in the area, Koka Lake can be observed and also while Mojo River joins the lake in East side of town. Koka Lake is man-made lake, which is created through diverting Awash River. There is 458 m long dam constructed in the northern part of the lake for production of hydro power generation. Around Koka area, different companies are available which are; flower producing companies and leather factory. Other than these, farmers traditionally produce different crops using shallow ground water and pumping from Awash River.

The second focus area is found within Becho plain which is located in South Western Shewa Zone of Oromia regional state between Sebeta Hawasa woreda and Tulu bolo town which is located 80 km away from the capital Addis Ababa. The specific study area is located between elevation of 2062 and 2109 m.a.s.l and approximately between coordinates 8.84° latitude and 38.36° longitude, with a total area of about 509km².it is accessed by driving in the main road from Addis Ababa to jimma and access to the different parts of the study area is through all weathered road which are connecting Teji and Asgori towns to the different kebeles of illu woreda.

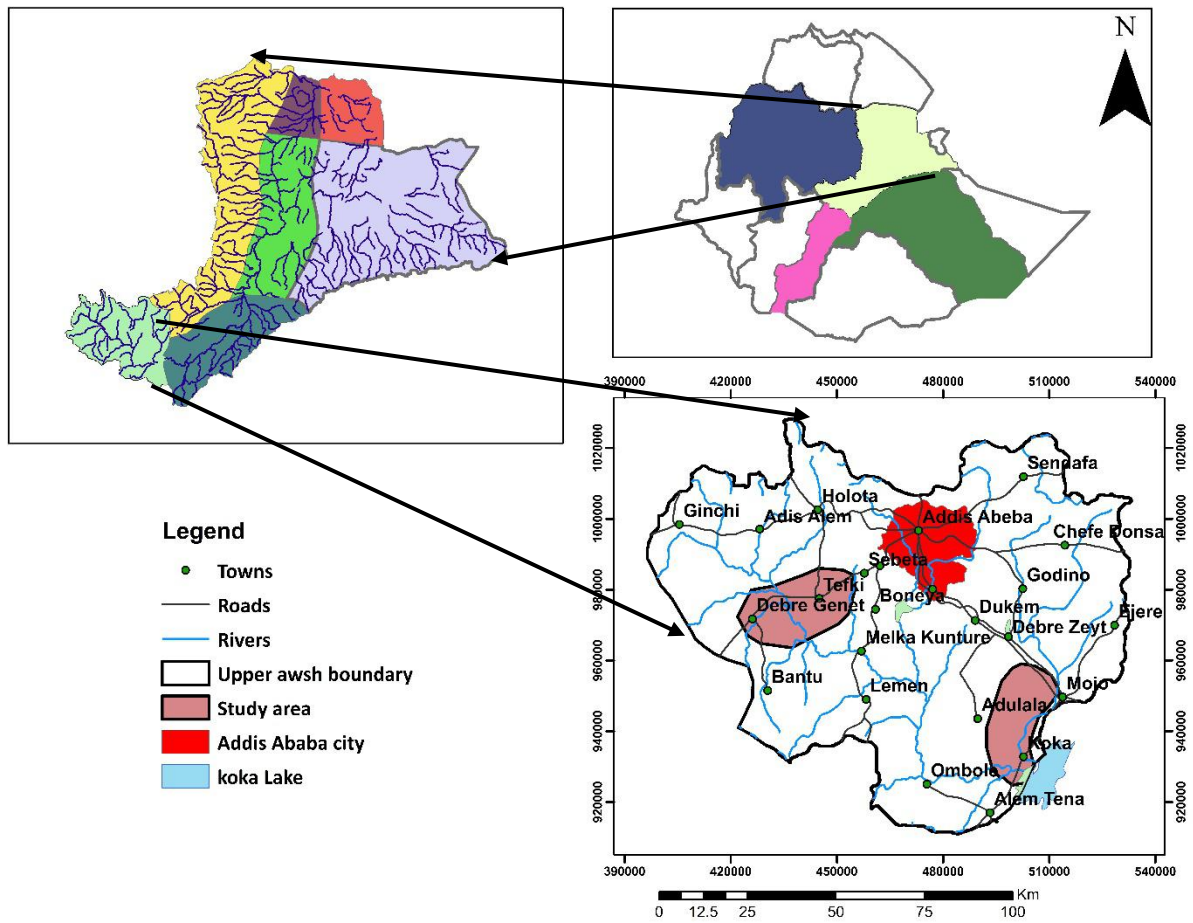


Fig 2.1 Location map of the study area

2.2 Drainage and Physiography

2.2.1 Physiography

Both the study areas are being situated in the plain area of Koka and Becho it is characterized by plain land features with gentle slopes, some valleys and stream channels. Becho plain is surrounded by wechacha mountain in the east direction which have elevation of about 3400m a.s.l and the rest of the plain is uniform flat land with small scrubs and trees. The study area in Koka area is also a flat land having its boundary in the Koka reservoir and the Awash River in the south direction with an average elevation of about 1590m a.s.l.

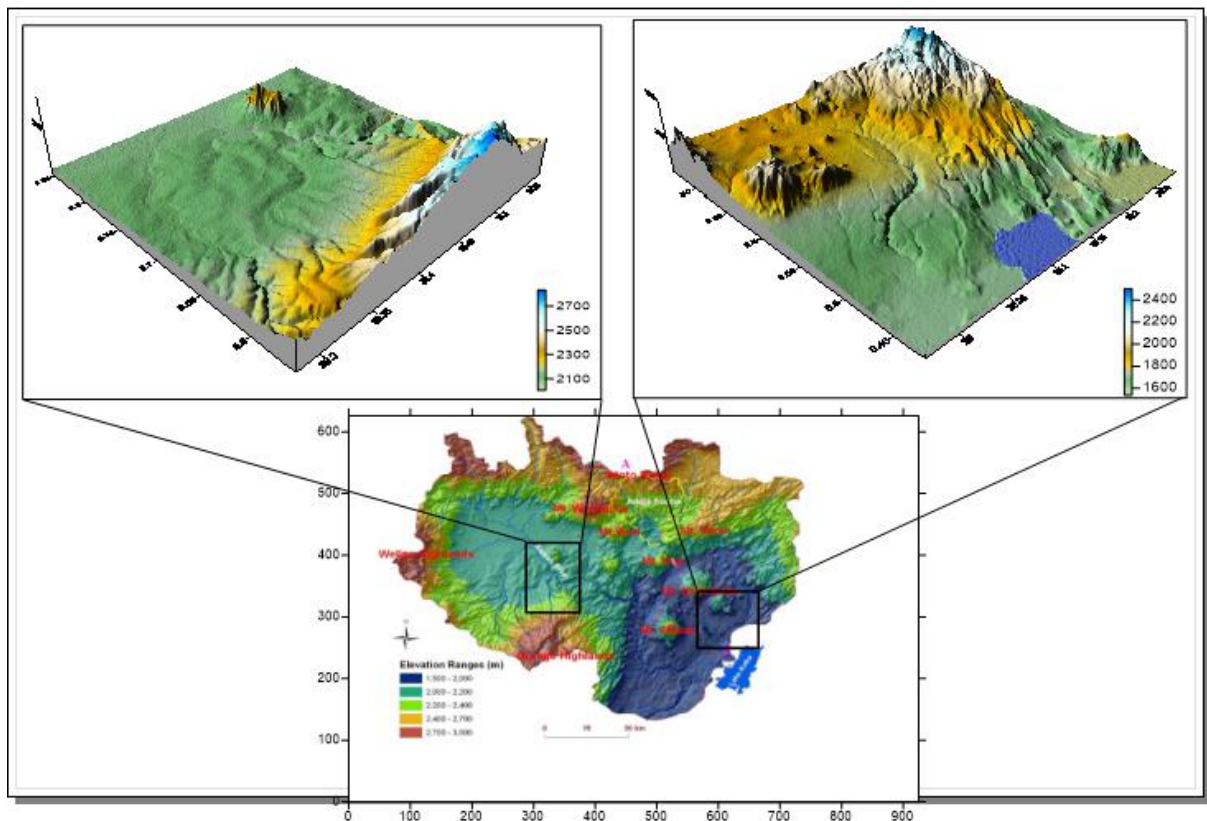


Fig: 2.2 Physiographic map of the study Area

2.2.2 Drainage

The Awash River originates from the mountain range at an altitude of 2,900m in the western most region of the basin near Ginchi and flows south-east ward. Afterward it debauches into the Becho plain which forms an alluvial plain with an average altitude of 2,060m. After the Becho plain, it runs through the hilly and mountainous areas of the Koka reservoir located some 135 km downstream of Teji Bridge (Nippon Koei, 1996).

The Upper Awash River sub catchment has an area of around 11 500 km² (EVDSA, 1989) and is located between 8°and 9°N latitude and 38°and 39°E longitude .The Becho plain has an average elevation of 2060 m and is surrounded by Wechacha Mountain in the east, the Guraghe highlands in the south and the Weliso highlands in the west (WWDSE, 2008).

The Awash River and several tributaries rise in these mountains that reach over 3300 m.a.s.l. The Berga, Holeta, Kelina, Dilolo Dilu, Teji and Watira tributaries join the Awash River in the Becho plain that flows towards Lake Koka in southeastern direction. The catchment of this upstream part of the upper Awash reach until the gauging station at Melka Kunture is 4541 km² (EVDSA, 1989).

Downstream of Melka Kunture the Akaki, Guracha and Dukem, Lemen and other smaller tributaries join the Awash River before it enters the plain surrounding Lake Koka. The Mojo River also flows into Lake Koka. This low-lying plain at the west shore of Lake Koka that is also surrounded by volcanic hills has a mean elevation of 1590 m (EVDSA, 1989).

The upper Awash River flowing down to Koka reservoir can be classified into three stretches:(i) 30 km river stretch in the upstream of Becho plain with a remarkably steep river bed slope ranging from 1/10 to 1/120, (ii) 60 km river stretches in Becho plain between Teji bridge and Kombolcha with a gentle river slope ranging from 1/1,200 to 1/6,000 and (iii) approximately 90 km long River stretch between Kombolcha and Koka reservoir with steep river bed slope ranging from 1/110 to 1/470.The tributaries of awash river also have a remarkably steep river bed slope in upper awash river basin. This is one cause of the sedimentation in Becho plain (Nippon Koei, 1996).

Most of the areas in the Becho plain have drainage and seasonal flooding problems. Water from upland accumulates on flat lowlands, flood plains and enclosed bottom areas where slowly permeable soils are found. Soils with imperfect, poor to very poorly drainage sites require removal of excess water and proper drainage management system.

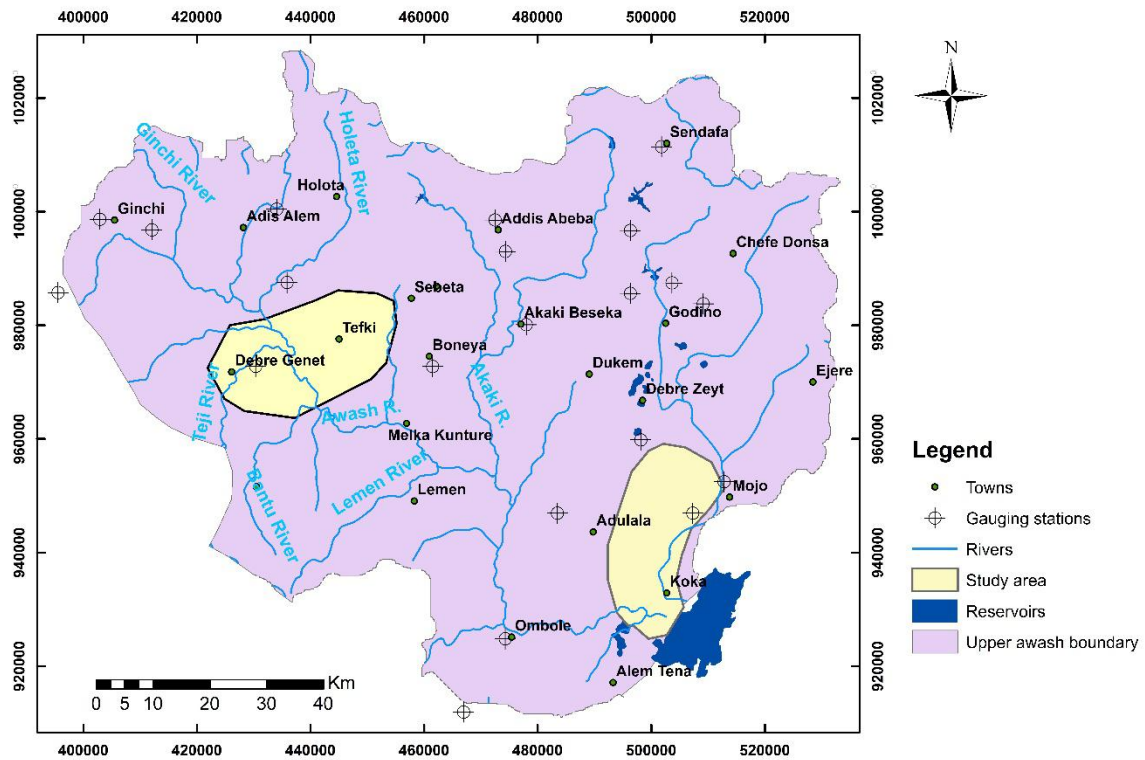


Fig 2.3 Drainage map of the study area

2.3 Population

The specific study area in Koka is located under Lume Woreda of East Shewa Zone of the Oromia regional state. The estimated 2007 total population of Lume Woreda is about 133,981. Of these, about 51.4% (68,866) male and 48.6% (65,115) are female. In terms of spatial distribution, 98.7% is rural and 1.3% urban populated.

The Becho part of the study area is found in illu woreda of south west Shewa Zone with a total population of **52,194**, of this total 25,157 is male and 27,037 is female.

2.4 Climate

The movement of the Inter Tropical Convergence Zone (ITCZ) that allows dry easterlies or moist westerlies dominates the climate of this part of Ethiopia. In March the ITCZ advances across the Awash Basin bringing spring rains in the 'Belg' season. The ITCZ reaches its most northern position when heavy summer rains come from the west. This season is the main rainy season called 'Kiremt' and lasts until September. Then the dry months of the dry season called 'Bega' extend from October to February (EVDSA, 1989).

Between February and the end of April, the weather becomes more unsettled and a convergence of moist southeasterly air stream causes small rains. The main rainfall is experienced between June to September when moist winds from the Atlantic and Indian Oceans converge over the Ethiopian highlands (Gemechu, 1977). Thus a year is characterized by a major rainy season for 4 months long, from June to September, during which about 70–75% of the annual rain falls in the study area, followed by a relatively dry season for 4 months long until the end of January and the short rains season from February to the end of April.

The climate of the study area is classified based on elevation above mean sea level in to cool temperate (2300-3300m.a.s.l) and temperate (2040-2300m.a.s.l).The mean annual precipitation is computed to be 900.3mm for Koka area and 1026 for the Becho. The temperature, wind speed and relative humidity are variable with altitude and latitude (Tenalem Ayenew & Tamiru Alemayehu, 2001). The average annual Temperature of the study area is about 17.1°C and 20.55°C for Koka and Becho respectively and is inversely correlated with the altitude.

The average relative humidity is calculated to be 56.85% and 57.05% respectively for the Koka and Becho areas, with average wind speed of 1.32m/sec and 0.7m/sec at 2m heights from the ground surface.

The annual Potential evapotranspiration rate value calculated from Thornthwaite method is 930.19mm and 763.13 for Koka and Becho areas respectively. Potential evapotranspiration of the study area decreases with increase in elevation, since it is related to temperature.

2.5 Socio economy

The livelihood of the population in the area is predominantly dependent on agriculture. It is subsistence agriculture in which crop production is predominant and livestock rearing is intimately integrated with crop production.

The main and serious constrains in the study area are the occurrence of recurrent inundation and floods. A considerable number of farmers in the study areas have lands located in inundation area both in Koka and Becho area. Their farming is considerable by the risk of crop losses by floods and inundation that occurs several times every wet season. The sociological damages caused by inundation are also serious. In Becho area some settlements are often isolated in the wet seasons due to flood and inundation (Nippon Koei, 1996).

Crop production is the main stay of the majority of the households. Of the total surface area of the Illu and Lume Woredas, 79% and 71% respectively is used for crop cultivation. The dominant crops cultivated in the project area are teff and wheat. Crop production is largely dependent on rainfall. In addition, there are some irrigation schemes that are dependent on Teji and Mojo rivers in addition to the hand dug wells irrigation schemes. Livestock plays a major role in the rural economy. Most rural farming, transport and source of income do directly or indirectly link with them. In terms of population cattle stands first comprising about 63% and followed by goats (15.3%) in Becho (WWDSE, 2008).

Small scale traditional irrigation schemes are common in the Koka area using Modjo River and hand dug wells. Even though it is not common like the Becho area there are some traditional irrigation schemes using Teji river and hand dug wells in the Becho area of this specific research. The major crops produced by irrigation include onion, tomato and chickpea. According to data obtained from woreda Agriculture and Rural Development Offices, the total area of irrigated land in Illu Woreda in the year 2007 is about 658 ha, and that of Lume woreda is about 1,245ha.

2.6 Land use land cover

In the Becho plain 78.4% of the land is agricultural land, 11.9% is used for grazing land and is seasonally inundated, the rest of the 9.7% of the land consists of villages, roads and woodlots (Nippon Koei, 1996). The main land use is agriculture; most farmers have normally 3-5 tropical livestock units, mostly oxen, primarily for draught power (EVDSA, 1989). The main crops and agricultural practices differ in the upland areas from the inundated areas. In the Becho plain all farmers have cropland in the inundated areas with an average plot size of 2.4 ha and 88% have land in the upland areas with an average plot size of 1.75 ha (Nippon Koei, 1996).

In the uplands most of the land is used for the production of teff (*Eragrostis tef*) (63.85 ha), chickpea (*Cicer arietinum*) (10.65 ha) and wheat (*Triticum aestivum*) (9.77 ha). These crops are planted in the beginning of the wet season and use rainwater for their growth. The low-lying inundated areas are used for the cultivation of lentil (*Lensculinaris*) (57.06 ha), chickpea (35.13 ha) and teff (31.63 ha). These crops are planted as water recedes at the end of the wet season and use residual soil moisture for their growth (Nippon Koei, 1996). Generally the higher areas are used for teff and other grains and the low-lying areas for pulses. This corresponds with agricultural patterns of other parts of the Upper Awash basin (EVDSA, 1989).

At a small scale some lands are irrigated in the dry season. Temporary bunds are constructed in two tributaries of the Awash, to divert water to the fields to grow barley (Nippon Koei, 1996). Since three years there is also pumped irrigation from the main Awash River to areas next to the river. These areas are cultivated with vegetables.

According to Yinesulih.T, in Koka area 44% of the land is cultivated under agriculture whereas the remaining 56% is occupied by urban and rural settlement, open bush lands etc. The inhabitants of the villages around Lake Koka, own around one ha of land and own five to ten units of livestock, mainly oxen. The people start plowing and sowing their fixed plots when the floods recede. Before the floods arrive there is also a plowing phase. Not all the land is used for agriculture; the areas that are not plowed and cultivated are used as grazing

land for animals. Also people from other kebeles let their cattle graze in the parts of the floodplain that are not cultivated.

2.7 Existing water supply and use

There are two towns found in Koka area of this study, these are Koka and Mojo towns. And Teji, Tefki and Asgori towns are found within the Becho area of this specific study. Koka town is dependent on 2 deep wells for drinking water supply. Mojo town has around four deep wells for water supply with a depth varying from 90 up to 180.

The main water supply source of Teji town is also a deep well but also a number of shallow wells are found in the area including Tefki and Asgori towns.

2.7.1 Rural water supply

For the rural water supply almost all of the rural kebeles within the study areas are dependent on hand dug wells and some shallow and little deep well schemes for the drinking purpose. It is common to see hand dug wells in every farmer's compound both in Becho and Koka area with hand lifting technology.

The western part of the Becho area knows a considerable amount of tube wells, implemented by the non-governmental organisation iDE (International Development Enterprise). All wells have been drilled using simple sludging. The districts in the east of the plain were not part of the operative area of iDE and the number of tube wells is limited to a few trials. Hand-dug wells are not common in Becho due to the collapsing nature of the black clay soils.

Becho area is well known area in rope pump technology for pumping of shallow ground water for rural drinking water supply. There are about 7229 rope pumps in Illu Woreda only.

Rope pump is a very recent technology being implemented in Ethiopia as federal government and it was implemented to reach the MDG goals of safe drinking water especially in the rural parts of the country with appreciable potentials for shallow ground water.

Rope pump water delivery ranges in between 0.17 L/s at 35 meters depth and 0.67L/s at 10 meters depth (Olley, 2008). Rope pumps can extract up to 35 meters.



Fig 2.4 Rope pump in Becho area (source: spate irrigation network foundation)

Chapter Three: Geology

3.1 Regional Geology

The regional geologic setting of upper awash basin is situated to different rock units having different age of formation. Among this Mesozoic sedimentary succession, Tertiary and Quaternary age groups of acidic and basic volcanic rocks and Quaternary lacustrine and alluvial deposits composes the regional geologic formation of the study area. The regional geologic description of those units are adapted from the evaluation of water resources of the Ada'a and Becho plains ground water basin for irrigation development project which is done by water works design and supervision enterprise, and they are discussed as follows:

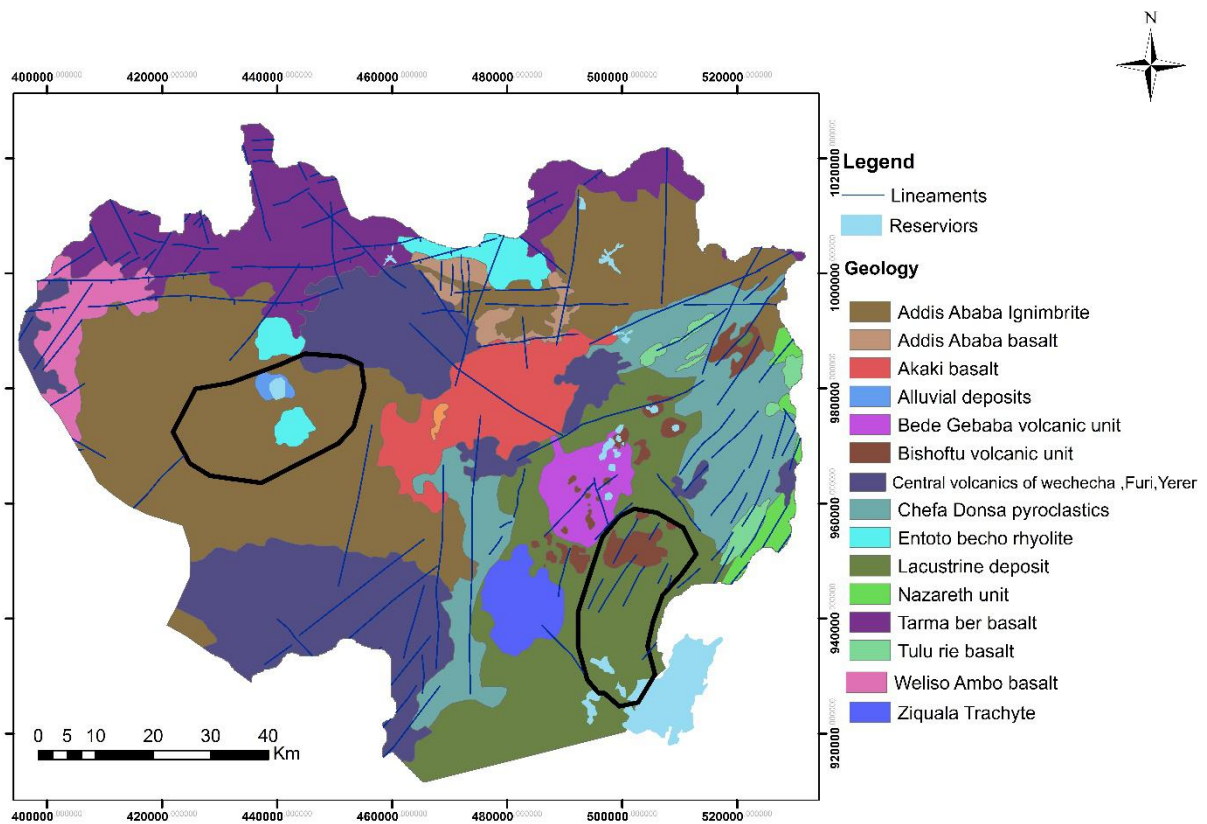


Fig3.1 geological map of upper awash basin referenced with study area (modified after
WWDSE)

3.1.2 Tertiary Volcanic Rocks

3.1.2.1 Addis Ababa Basalt

This unit is fine to coarse grained basalt composed of olivine and plagioclase phenocrysts. In most part of the outcropped area it is relatively thin (20m) lava flow overlying the ignimbrite. The age of the Addis Ababa basalt is 7.5-4.5 Ma (Chernet et al 1998 and Morton et al 1979).

3.1.2.2 Addis Ababa Ignimbrite

This Ignimbrite is outcropped in most part of the plane area around Addis Ababa and the Becho plane which one of the focus area in this study. It is composed of welded tuff (ignimbrite) and non-welded pyroclastic fall (Ash and tuff). It is grayish to white color and when welded it exhibits fiamme textures, elongated rock fragments of various color. Around the Lega dadi plane and melka kunture area the thickness of this unit reaches up to 200m (exploration drill data). In the Becho plane area it is covered by thin 5-7m thick residual soil developed from the same rock. The age of this unit is 5.11-3.26 Ma (Morton et al 1979).

3.1.2.3 Nazeret Unit

This unit is mainly exposed in the southeastern part of the area and forms rift floor. It consists of a sequence of welded peralkaline rhyolitic ignimbrite. The unit comprises numerous rhyolitic and trachytic domes. The ignimbrites generally show eutaxitic texture with oblate glassy fragments. Rock fragments and crystals, generally broken, are abundant; alkali feldspars, quartz, and amphiboles are the most common crystals. The age of this unit is 5.4 to 3.11 Ma (Morton et al 1979).

3.1.2.4 Akaki Basalt

This unit is outcropped at Daleti, Abasamuel Dam, Akaki, Dukem area. It is coarse grained porphyritic olivine basalt. It is highly vesicular basalt and at places the vesicles were filled by carbonate minerals. It is consisting of scoria and spatter cones with associated lava flows. Both the basalt and scoria is quarried for construction around Akaki and Dukem area. The thickness of this unit around Akaki is 202m (exploration drilling data). The age of the Akaki basalt is 2.9-2.0 Ma (Chernet et al 1998 and Morton et al 1979).

3.1.2.5 Central Volcanoes Unit

3.1.2.5.1 Wehecha, Furi and Yerer Trachyte

The Central Volcanoes units are mainly trachytic lavas exposed at Wehecha, Furi, Yerer, Western and Southwestern ridges of the study area forming an elevated ridges or mountain picks. The Yerer trachyte is elevated about 1000 m from the surrounding plane area.

The south and southern western ridges are a watershed divide between the Omo-Gibe and Awash River basins. It is grayish color fine to medium grained trachyte with subordinate ash falls and ignimbrite. The age of this unit is 10-3 Ma (Kazmin, 1979). It is porphyritic in texture with phenocrysts of feldspar up to 1cm across. In fresh hand specimen it is grayish in color. Petrographic studies conducted by Abebe et al (1999) indicates that Trachytes of Wehecha and Furi are composed of plagioclase and sanadine phenocrysts predominating the trachyte, alkaline pyroxene and rare olivine. The groundmass varies from glassy to microcrystalline and is constituted mainly by alkali feldspar, pyroxene and amphiboles and opaque. The ages of the trachytes are different with Wehecha 4.6-3.7 Ma, Furi 4.0-3.7 Ma (Chernet et al 1998), Yerer 3.9-3.3 Ma (Morton et al 1979).

3.1.2.5.2 Entoto ridge and Becho area Rhyolites

The Entoto ridge forms watershed divide of Abay and Awash River basins. The ridge forms steep slope towards the Abay basin steep to gentle slope towards the awash basin. In fresh hand specimen it is grayish pink and reddish brown to yellowish grey color when weathered. The rhyolites in the Becho plane forms isolated cones. Obsidian up to 10 cm across is common at the picks of the cones. Data on the ages of the rhyolites are not available; however from the cross-cutting relationship they can be younger than the adjacent ignimbrite.

3.1.2.3 Tulu Rie Basalt

This unit is outcropped in the southeastern part of the study area and forms NE trending escarpments. It is lava flow coarse grained basalt with olivine and plagioclase phenocrysts with rare clinopyroxene. The age of this rock is 2.7 to 1.44 Ma.

3.1.2.12 Chefa Donsa Unit

The Chefa Donsa volcanic rocks units are outcropped at the east, north east south and west extreme parts of Debrezeit. They are consisting of fall deposits (ash, tuff and pumice) and poorly welded ignimbrites of rhyolitic composition. At places in the Dukem and Mojo river valleys they are observed under the lacustrine deposit. The age of this unit ranges 2.24 to 1.71 Ma (Morton et al 1979).

3.1.3 Quaternary Volcanic Rocks

3.1.3.1 Weliso Ambo Basalts

This unit is outcropped at the western and northern extreme parts of the mapped area. It is a lava flow composed of porphyritic basalt with large crystals of plagioclase, olivine and pyroxene, basalt breccia's and minor tuff. In the area of Weliso it is scoraceous basalt. In the Abay Master Plan report this unit is mapped as basalt lava flows connected to volcanic centers (QVCB) and its age is Pliocene to present.

3.1.3.2 Ziquala Trachyte

Ziquala trachyte is isolated, well preserved cone standing about 1300m from the surrounding plane area, located in the southern part of the study area. It has a summit caldera 1.5 km wide and partially filled by water. The Ziquala trachyte is grayish pink in color, coarse grained and petrographically composed of anorthoclase, sanadine, minor clinopyroxene phenocrysts and glassy alkalifeldspar groundmass. The age of the Ziquala trachyte is 1.28-0.85 Ma (Morton et al 1979).

3.1.3.4. Bishoftu Volcanic Unit

This unit forms a NNE trending belt outcropping mainly in the central flat areas of Debrezeit. In the Bishoftu Volcanic spatter and cinder cones with associated tabular basaltic lavas flows and phreatomagmatic deposits are distinguished. The basalt is vesicular and coarse grained with olivine phenocrysts. The phreatomagmatic deposits are mainly consisting of surges and highly fragmented deposits associated with maars and tuff ring.

3.1.4 Quaternary Lacustrine and Alluvial Deposit

3.1.4.1 Lacustrine Deposits

The lacustrine deposit is particularly distinguished in the Adaa plain of the Lakes region. They are fine grained deposits generally brown-yellowish, thinly stratified and often contained volcanic matrix; whose thickness ranges from 5 to 8m. More thickness is reported in the groundwater well drilling reports. In these successions volcanic layers are frequent and become predominant and coarse grained near by the maars.

3.1.4.2 Alluvial Cover

The alluvial cover mainly outcropped above the Tertiary volcanics on the plateaus and Becho Plain and consisting of regolith, redish brown soils, talus and alluvium with maximum thickness of about 7 m (Becho area hand dug well data).

3.2 Local geology of the study area

3.2.1 Rhyolites and trachyte

In the study area are trachytic lavas mainly are exposed at Wechecha in the northern part of Becho area and rhyolites in the Becho plane.

The trachyte is porphyritic in texture with phenocrysts of feldspar up to 1cm across. In fresh hand specimen it is grayish in color. Petrographic studies conducted by Abebe et al (1999) indicates that Trachytes of Wechecha and Furi are composed of plagioclase and sanadine phenocrysts predominating the trachyte, alkaline pyroxene and rare olivine. The groundmass varies from glassy to microcrystalline and is constituted mainly by alkali feldspar, pyroxene and amphiboles and opaque. The ages of the trachytes are different with Wechecha 4.6-3.7 Ma.

Rhyolites in the Becho plane forms isolated cones. Obsidian up to 10 cm across is common at the picks of the cones. Data on the ages of the rhyolites are not available; however from the cross-cutting relationship they can be younger than the adjacent ignimbrite.

3.2.2 Ignimbrite

This unit composes of Ignimbrite which is outcropped in most part of the Becho area. It is composed of welded tuff (ignimbrite) and non-welded pyroclastic fall (Ash and tuff). It is grayish to white color and when welded it exhibits fiamme textures, elongated rock fragments of various color. In the study Becho area it is covered by thin 5-7m thick residual soil developed from the same rock. The age of this unit is 5.11-3.26 Ma (Morton et al 1979).

3.2.3 Quaternary Lacustrine and Alluvial Deposit

The lacustrine deposit is particularly distinguished in the plane area of Lake Koka. They are fine grained deposits generally brown-yellowish, thinly stratified and often contained volcanic matrix; whose thickness ranges from 5 to 8m.

The alluvial cover is mainly outcropped above the Tertiary volcanics on the Becho area and consists of regolith, redish brown soils, talus and alluvium with maximum thickness of about 7 m (Becho area hand dug well data).

3.3 Geological Structures in the Upper Awash basin

As Upper Awash is situated at the intersection of two major regional structures namely the NNE-SSW trending MER and the East-West trending Addis Ababa-Nekemit (Yerer-Tuluwelel) volcanic lineament. The Addis Ababa-Nekemit fault has a down-throw to the south in the Addis Ababa area and the Intoto silicic rocks are confined along this fault (Andarghe Yitbarek, 2009)

As cited in andarghe, prominent fault trending NE-SW is the Filwuha fault which is down-thrown to the south and is located at central Addis Ababa. Many hot springs and thermal wells exist along this fault.

The volcanic rocks of the region have undergone extensive faulting often having general trend Of NE – SW, E-W and at places NW-SE. Most of the lineaments follow the trend of the rift the density of faults and lineaments increases to the southeast towards the rift valley. Some of the basaltic lava and cinder cones seem to have erupted through these fractures as they are concentrated along the major NE - SW trending fault systems.

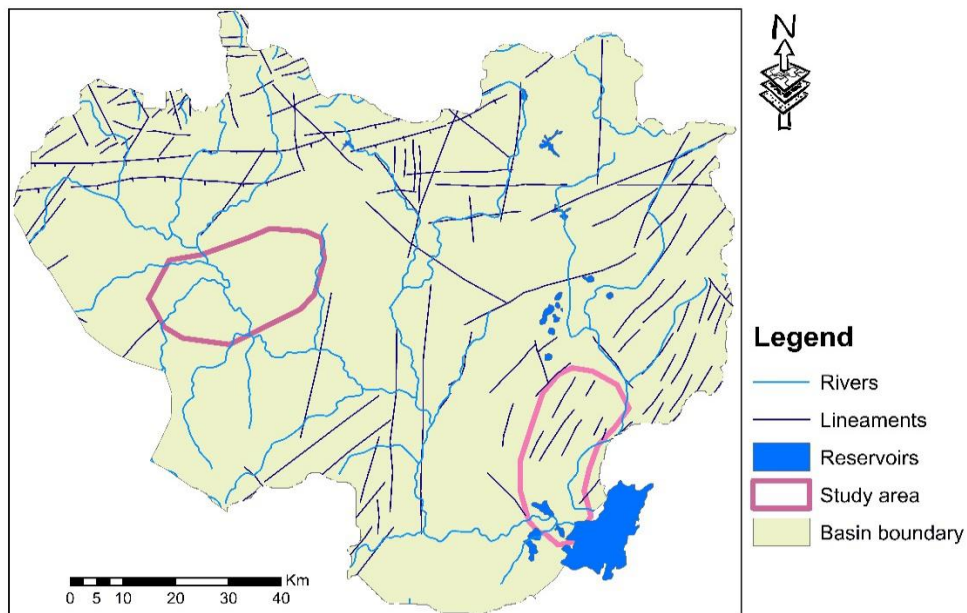


Fig 3.2 Lineament map of the study area (modified from WWDSE, 2008)

Chapter Four: Hydrometrology

4.1 General Metrological Parameters

Several metrological stations are found in upper awash basin and the majority of stations are 4th class, where there are only rainfall and temperature records and in some stations the records are incomplete. The 1st class metrological stations are found in Addis Ababa, Holetta and Debra Zeit stations within the upper awash basin. There are about seven metrological stations within and near the study areas in particular. Among this Koka, Modjo and Debre zeit stations are selected for the Koka area while Teji, Tefki, Bantu liben and Tulu Bollo stations are selected for the Becho area ground water study.

The monthly metrological data is collected from national metrological agency (NMA) selected on data availability and location with respect to the study area.

Stations	Record period	Class	UTM E	UTM N	Elevation(m)	Mean annual rainfall(mm)	Mean annual Temp.(°c)
Koka	1980-2014	4 th	502010	937436	1598	853.38	22.41
Modjo	1980-2014	3 rd	516504	952784	1870	1002.3	20.17
Debre zeit	1980-2014	1 st	494500	964941	1850	844.74	19.09
Addis Ababa	1980-2014	1 st	471983	997946	2405	1031.1	15.95
Tulu bolo	1980-2014	2 nd	414187	958396	2100	1120	17.1
Teji	1980-2014	4 th	430440	972917	2091	941.94	17.9
Bantu liben	1980-2014	4 th	426430	971756	2078	969.5	18.2
Tefki	2010-2014	4 th	444481	977983	2298	888.06	17.4

Table 4.1 Mean annual rainfall and temperature of some selected metrological stations (data from NMA)

4.1.1 Rainfall characteristics

The seasonal variability of precipitation is an important aspect of hydrology since it determines the river flow and groundwater recharge. The seasonal variation and distribution of rainfall in

Ethiopia is commonly explained with reference to the migration of the Inter-Tropical Convergence Zone (ITCZ) (Daniel Gemechu, 1977).

The monthly average rainfall shows a unimodal pattern with the heavy rains between June and September. Owing to high temperatures near the equator, the lower layers of air are heated. It thus expands and rises rapidly producing a lower pressure belt known as the

Inter Tropical Convergence Zone (ITCZ). ITCZ is the major rain causing mechanism and its movement in the north ward direction brings moisture from the South Atlantic Ocean. This results in the big kiremt rainfall in most parts of Ethiopia.

The mean amount of precipitation, in a River basin or any other area, is determined by precipitation gauges, installed within the area under study. In the case of an insufficient number of gauges, records of precipitation gauges installed in neighbouring regions may also be used to provide a more accurate computation of precipitation. For this specific study which is located in the upper awash basin with special attention to Koka and Becho area the same procedure is followed to overcome reasonable mean amount of precipitation.

Therefore for Koka area the data record from gauging station of Koka, Modjo and Debre zeit stations are used. Among this three stations Koka and Modjo stations are within the study area while Debre zeit station is the neighbouring station for the study area. For Becho area the data record of Teji, Tulu bolo, Bantu liben and Tefki are used to calculate the mean precipitation of the area. Accordingly the long term mean monthly precipitation of the areas are shown on the table 4.2 below with their respective graphs.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave for Koka	10.82	23.00	50.87	56.93	56.31	87.33	235.3	234.9	106.9	25.9	7.4	4.63	900.31
Ave for Becho	9.8	35.8	53.8	82.1	75.2	144.5	255.0	270.9	129.9	26.0	12.5	6.4	1026.0

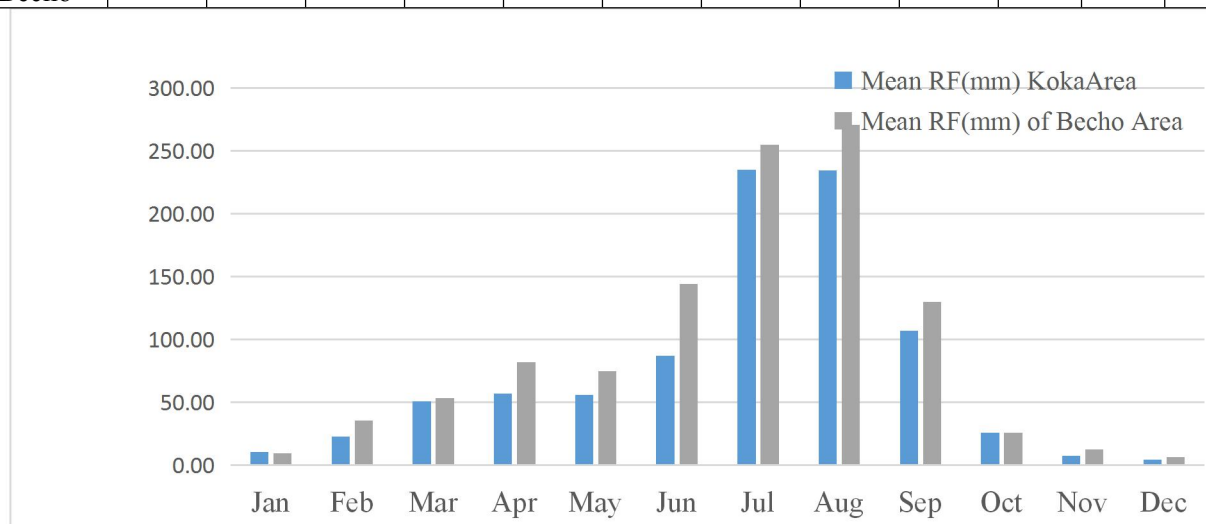


Fig 4.1 Mean Monthly rainfall of study area (1980-2014)

The temporal rainfall distribution indicates that the occurrence of two main seasons, the dry and wet seasons. As displayed in precipitation bar graph (Fig: 4.1), the maximum and

minimum rainfall is recorded in the month of August and December respectively. The majority of rainfall in the area is obtained in the months June to September covers about 70 % of the total annual rainfall.

Quantitative seasonal category based on the rainfall distribution can be explained by using the rainfall coefficient (R.C.), which is the ratio between mean monthly rainfall and one twelfth of the annual mean of the total rainfall (Gemechu, 1977).

$$\text{R.C.} = \frac{12 \text{ Pm}}{\text{Pa}}$$

Pa

Where, R.C. = rainfall coefficient (unit less),

Pa = annual total rainfall of the area (mm)

Pm = Mean monthly rainfall (mm)

Based on R.C. values the following precipitation category can be made for Koka area the study area.

- Dry months (R.C. < 0.6): October, November, December, January and February.
- Rainy months (R.C. > 0.6): This can be further grouped into the following:
 - small rain (0.6 - 0.9): March, April and May
 - big rain (> 1.0):
 - Moderate concentration (1.0 - 1.9): June and September.
 - High concentrations (2.0 - 2.9) : July and August at Becho area
 - Very high concentrations (> 3.0). July and August at Koka are

4.1.2 Determination of Aerial Depth of precipitation

In water budget studies, it is necessary to know the average depth of precipitation over a study catchment. This may be determined for time periods ranging from the duration of part of a single storm to a year. The data are generally measurements of precipitation and/ Or equivalent snow fall at a number of points throughout the catchment (Fetter, 1994).

Precipitation over certain durations for a given basin is rarely produces uniform rain fall depth with relative to others.

Depth of precipitation over the basin or catchment should consider altitude as one input variable. This means that using simple arithmetic mean of point rainfall data of the stations may not represent the actual aerial depth of precipitation over a basin or catchment with huge altitudinal difference. But in this case both the study areas are being situated in the plain areas of Koka and Becho which doesn't show considerable amount of altitudinal variation we can use arithmetic mean method.

4.1.2.1 Arithmetic mean method

This technique calculates areal precipitation using the arithmetic mean of all points or areal measurements considered in the analysis area. The simultaneous measurements for a selected duration of all gauges are summed and the total divided by the number of gauges. Sometimes neighboring rain gauges measurements could be considered if the area has similarity. Accordingly there are two gauging stations which are located within the Koka area (Koka and Modjo stations) and Teji and Tefki stations are enclosed with the Becho part of the study area.

Therefore the average rainfall of the area using arithmetic mean method is calculated as:

Where PA = average rain fall of the total area

Pi = Measured precipitation at a given station and time

n = Number of rain gauges.

The Annual aerial precipitation computed from Arithmetic method is **900.3mm** and **1026mm** for Koka and Becho area respectively.

4.1.3 Temperature

Temperature enhances evapotranspiration through making the environment hot and favors the passage of liquid state of water to vapor state. Air and water temperature are dependent on solar radiation and has direct influence on evaporation.

Temperature data are the major factor in computing potential evapotranspiration of an area.

Monthly average temperature in °c of the Koka area.

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Y.ave
Max	28.2	29.25	30.2	30.09	30.7	29.5	26.7	26.5	27.53	28.07	27.8	27.57	28.52
Min	10.6	11.91	13.45	14.11	14.16	13.87	13.79	13.81	13.31	11.57	10.51	9.92	12.58
Ave	19.41	20.58	21.82	22.1	22.43	21.69	20.28	20.16	20.42	19.82	19.16	18.75	20.55

Table 4.3 monthly maximum, minimum and average temperature of Koka area

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Y.ave
Max	24.5	24.6	24.7	24.8	24.5	25.0	25.0	25.2	25.0	25.7	24.7	24.1	24.8
Min	9.9	9.7	9.5	8.9	9.0	8.9	9.1	9.4	9.4	9.6	9.7	10.0	9.4
Ave	17.2	17.1	17.1	16.8	16.7	16.9	17.1	17.3	17.2	17.7	17.2	17.1	17.1

Table 4.4 monthly maximum, minimum and average temperature of Becho area

Table 4.3 and 4.4 above indicates that temperature decreases with increase of elevation. Becho area is found at a higher elevation than that of Koka area, and both its minimum and maximum temperature records are somewhat less than that of their respective records at Koka area. The average value of the mean monthly maximum and minimum of the stations were considered to characterize the temperature of the study area.

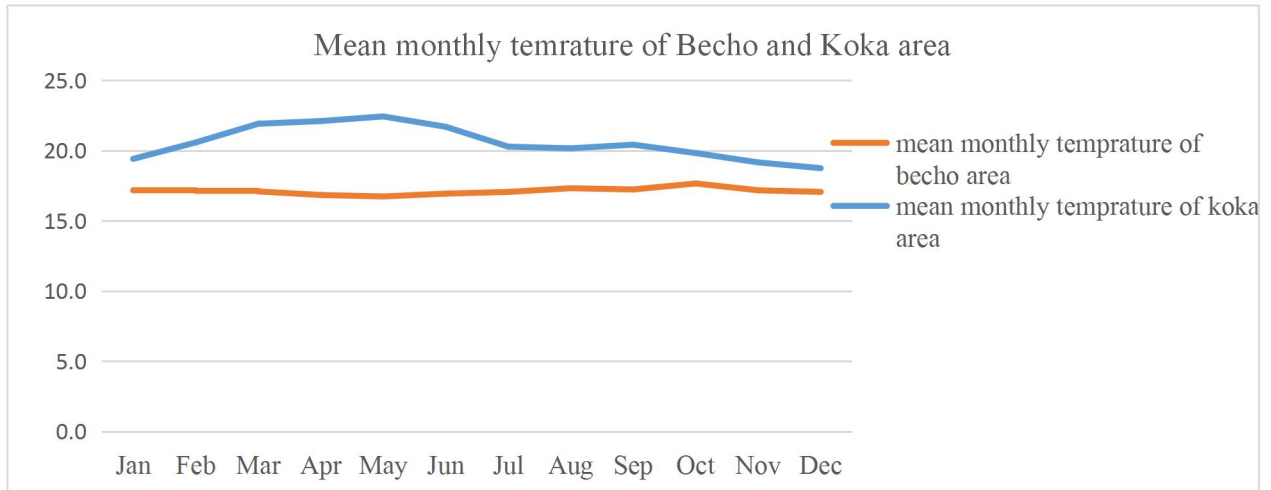


Fig 4.2 mean monthly temprature of the study area

4.1.4 Wind Speed

Wind speed, or wind flow velocity, is a fundamental atmospheric rate. Wind speed is caused by air moving from high pressure to low pressure, usually due to changes in temperature.

Wind speed affects the potential Evapo-transpiration of an area which is one important element in water balance study of specific area. High wind speed induces more evapotranspiration and vice versa.

The wind speed of Addis Ababa bole station is analyzed for the Becho area and the Debre zeit station wind speed data is used for the Koka area. The wind speed varies from **0.89-1.50m/sec** at Debre zeit station. And it varies from 0.4 to 1 at Addis Ababa bole station. Wind speed is relatively low during the rainy seasons (July- September).

Mon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave for Becho	0.9	0.8	1	0.8	0.9	0.5	0.5	0.4	0.5	1	0.9	0.8	0.7
Ave for Koka	1.13	1.45	1.45	1.50	1.63	1.33	1.17	1.0	0.89	1.33	1.55	1.47	1.32

Table 4.5 Average monthly wind speed (mille) of study area (1994-2005)

4.1.5 Sunshine duration

Sunshine duration or sunshine hours is a climatological indicator, measuring duration of sunshine in a given period (usually, a day or year) for a given location on earth, typically expressed as an averaged value over several years. It is a general indicator of cloudiness of a location, and thus differs from insolation which measures the total energy delivered by sunlight over a given period.

Mean daily sunshine hours of the study areas is given by table 4.6 below, and sun shine hours duration is minimum in August and maximum in November.

Mon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Y.ave
Ave for Becho	9.30	8.93	8.28	6.31	7.39	5.85	3.60	3.86	5.35	8.56	9.25	8.03	7.06
Ave for Koka	8.35	7.92	8.86	8.10	8.25	6.75	5.28	5.23	6.90	9.14	9.60	8.43	7.73

Table 4.6- Average daily sunshine hour's duration for the study area (2000-2012).

4.1.6 Relative humidity.

Relative humidity (abbreviated RH) is the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at the same temperature. Relative humidity depends on temperature and the pressure of the system of interest.

Relative humidity is normally expressed as a percentage; a higher percentage means that the air-water mixture is more humid. And evaporation is high in air with low humidity and it is low in atmospheric condition having high humidity. The monthly relative humidity of the study area is given below in table 4.7 shows that the average percentage relative humidity is maximum in August and minimum in February.

Mon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Y.ave
Ave for Becho	56	45.4	48	44.5	46.4	62.6	71.4	79	68	54	54	53	57.05
Ave for Koka	50.6	45.6	49.1	52.6	56.2	63.5	68.5	77.7	72.8	51.2	48	46.2	56.87

Table 4.7:-Average relative humidity (%) of the study areas (2001-2012)

4.1.7 Climate Classification

According to Thorenthwaite method of climate classification, where the precipitation analyzed month by month is just adequate to supply all the water that would be needed for maximum evapotranspiration in the course of year, the moisture index is considered to be Zero. The moisture index is calculated from rainfall and PET data as follows:

$$Im = 100 \times (s-d)/n (\%)$$

Where,

Im = moisture index

S = moisture surplus (rainfall – PET), yearly total

d = moisture deficiency (PET – rainfall), yearly total

n = PET, yearly total

According to Daniel Gemechu (1977), Aspects of Climate and Water Budget in Ethiopia the value of Im defines climatic type of the region. And he categorized the climatic region based on Im value as follows:

Im	Climatic (Moisture) Region
Over 100	Per humid
20-100	Humid
0 to 20	Moist Sub humid
-33 to 0	Dry Sub humid
-67 to -33	Semi-Arid
-100 to -67	Arid

Table: 4.8- Mean monthly moisture balance of Koka

Mo	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
R.F	10.8	23.0	50.8	56.9	56.31	87.33	235.3	234.9	106.9	25.9	7.4	4.63	900.31
PET of Koka	66.34	76.00	88.68	91.27	96.16	86.80	77.37	75.41	76.03	70.67	64.48	60.99	930.19
R-P	-55.5	-53	-37.8	-34.3	-39.8	0.53	157.93	159.49	30.87	-44.7	-57.0	-56.3	-30.03

Table: 4.9- Mean monthly moisture balance of Becho

Mo	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
R.F	9.8	35.8	53.8	82.1	75.2	144.5	255.0	270.9	129.9	26.0	12.5	6.4	1026
PET of Becho	62.47	62.68	63.51	62.55	63.08	62.56	65.41	66.27	64.39	66.62	62.41	61.23	763.17
R-P	-52.7	-26.8	-9.74	19.51	12.07	81.94	189.63	204.60	65.51	-40.5	-49.8	-54.8	338.72

Therefore, according to the above equation the calculated soil moisture index (Im) of Becho area is **88.7** which categorizes the area into humid region while that of Koka area is **- 6.4** which is categorized into Dry sub humid region.

Figure: (4.3 and 4.4) below Shows the moisture balance (rainfall-PET) relationship of the two focus areas, where rainfall is in excess of PET during the rainy season

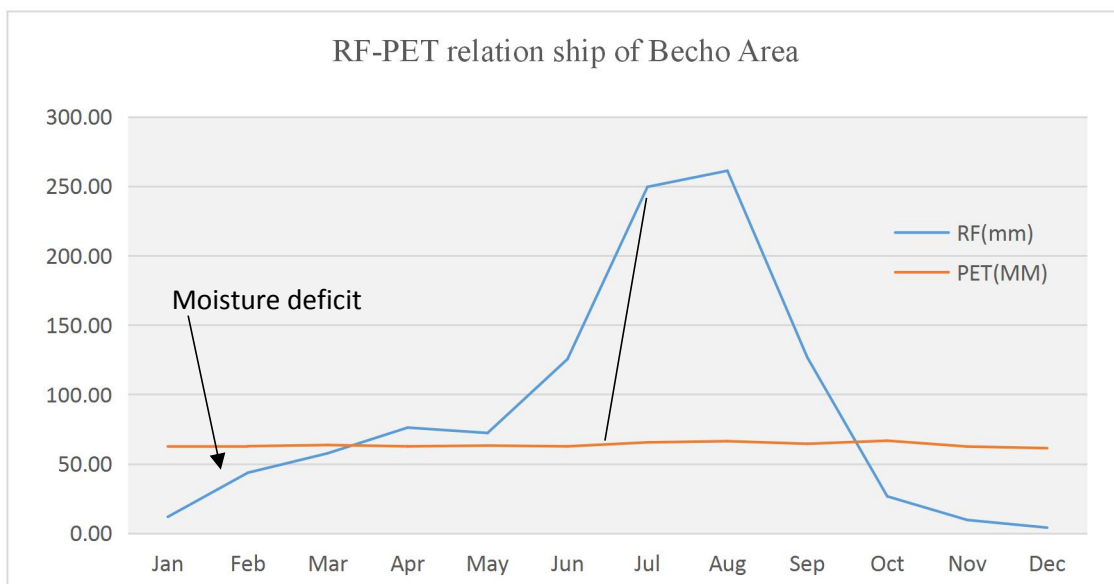


Fig 4.3 moisture balance of Becho area

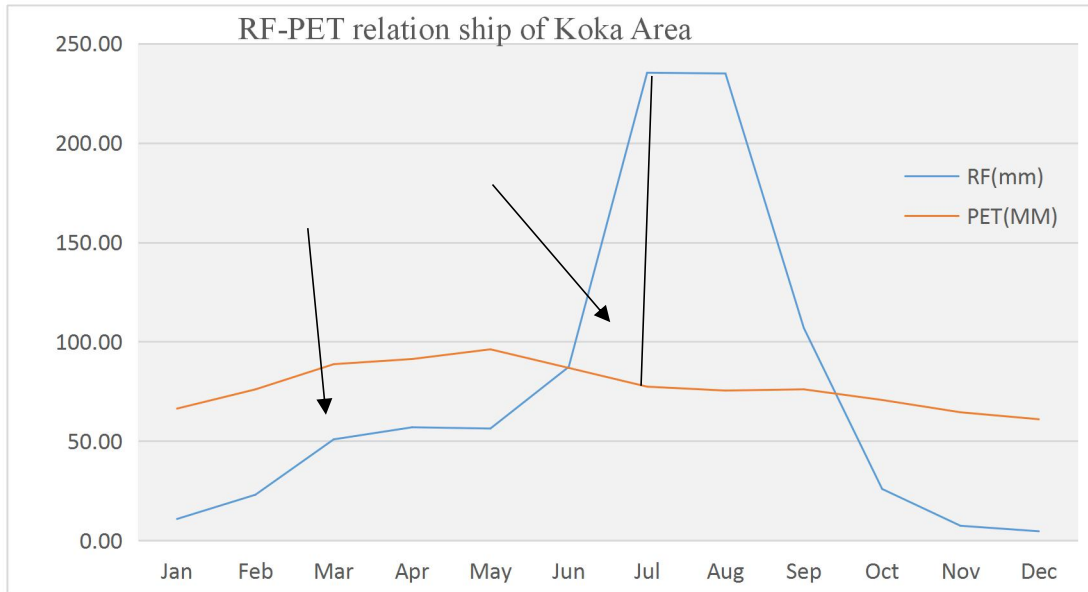


Fig 4.4 Moisture balance of Koka area

4.2 Runoff

Runoff is the water which moves in defined channels or all the water that moves over the land surface in undefined channel. Runoff process is strongly influenced by rainfall intensity and infiltration capacity of the soil. Infiltration capacity varies not only from soil to soil, but also different for dry verses moist conditions in the same soil. If the rainfall intensity is lower than the infiltration equilibrium capacity, but less than the initial infiltration capacity, at the beginning all the water will infiltrate, but when the infiltration capacity drops below the rainfall intensity, some of the water will remain on the land surface.

The water which does not infiltrate forms flow as a thin sheet across the land surface, which is called over land flow or surface runoff (Tenalem Ayenew and Tamiru Alemayehu, 2001).

4.3 Hydrograph analysis

The main Awash River and most of its major tributaries are gauged at different locations. Major tributaries: Akaki, Holeta, Ginchi, Modjo are gauged at their outlets before joining Awash. The main Awash River is gauged at Melkakunture, Hombole and near Koka reservoir.

For this study Teji river discharge data is used for Becho area which is gauged near Asgori town and Modjo river discharge data is used for the Koka area hydrograph analysis. As it is clearly seen from fig 4.5 below the highest flow corresponding with the wettest months of July, August and September. The modjo river flow is separated in to two time series for analysis (before diversion and after diversion) flow. Before the year 2000 there is diversion effect and from the year 1980-2000 there is no diversion effect. Therefore the fluctuation in the river flow is related with diversion effect.

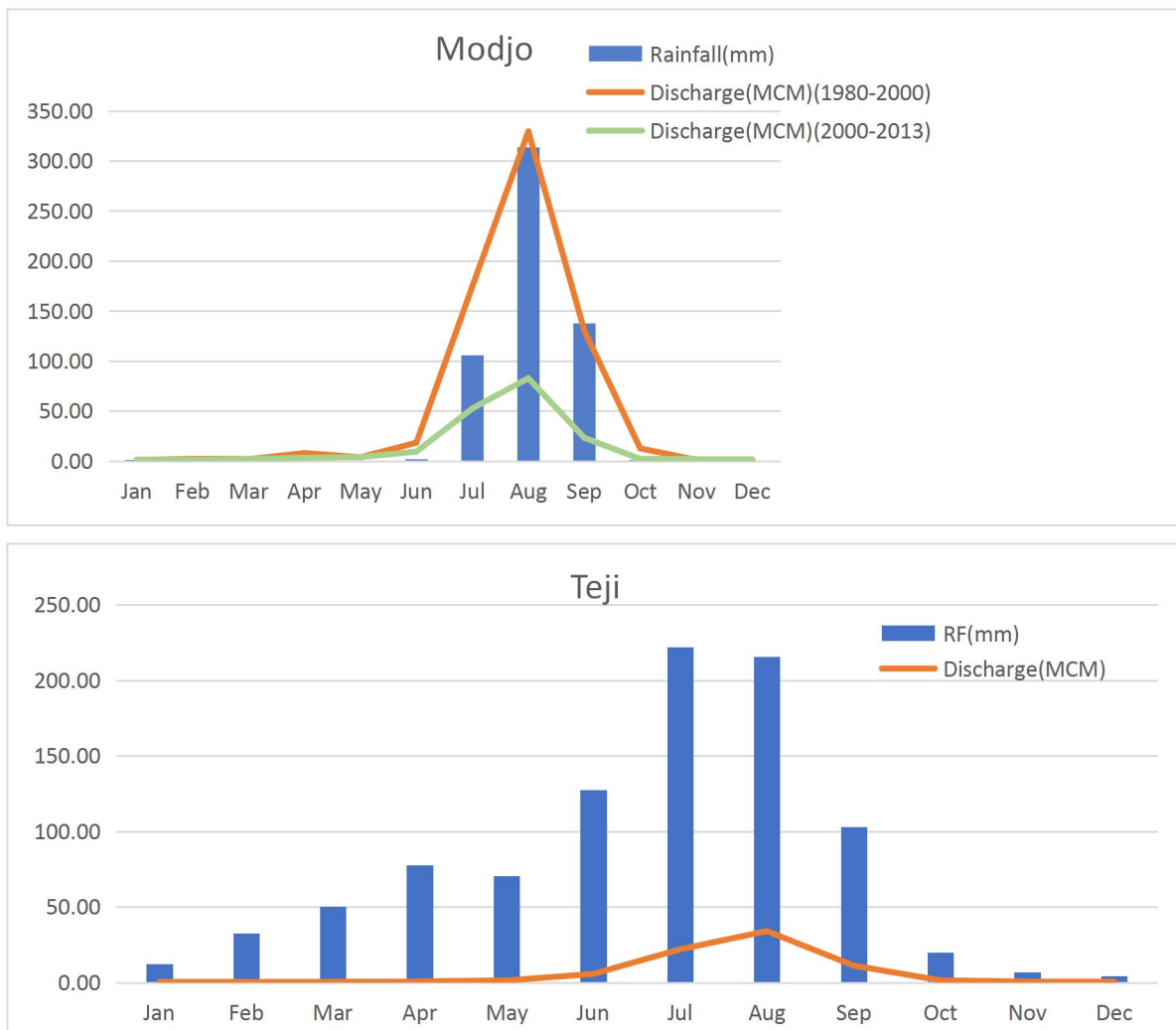


Figure 4.5 Mean monthly rainfall (mm) and river discharge (mcm) at selected stations

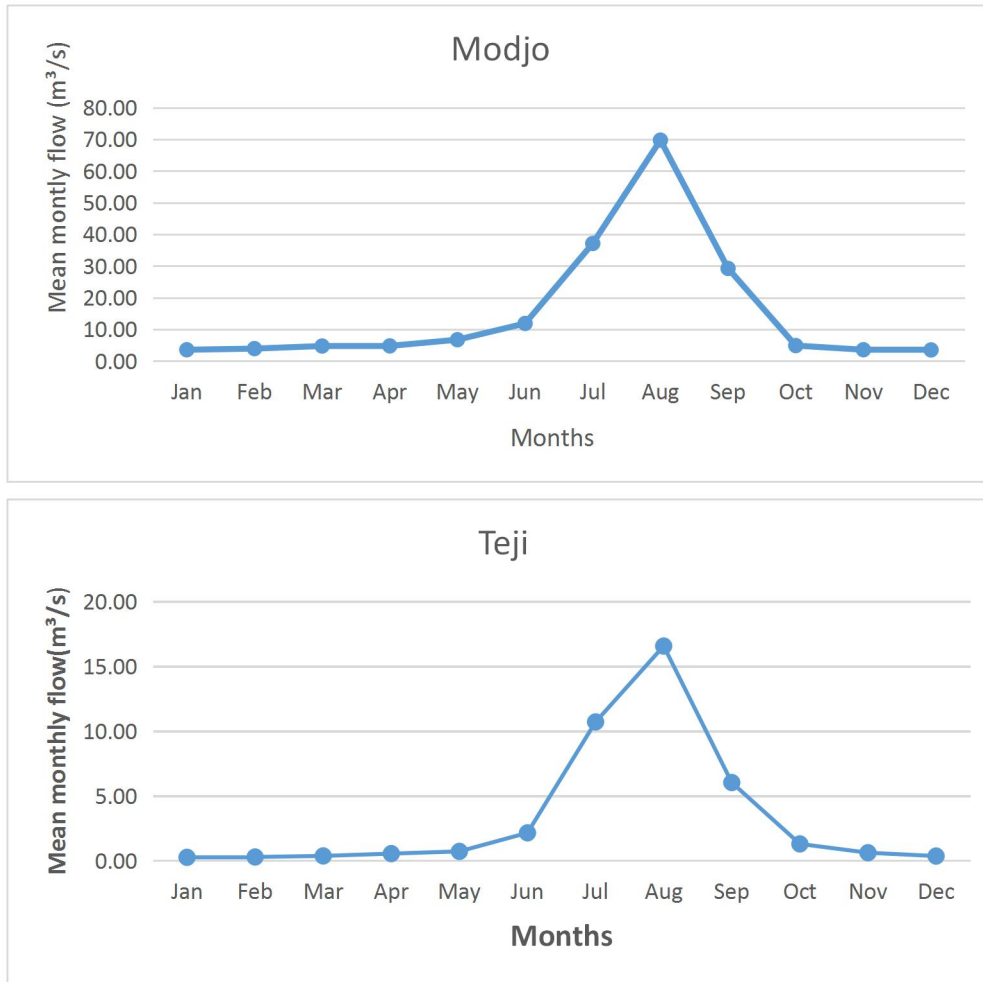


Figure 4.6 Mean monthly flow volumes in meter cubes per second (m^3/s) in the two gauging stations of the main Awash River.

4.3.1 Base Flow Separation

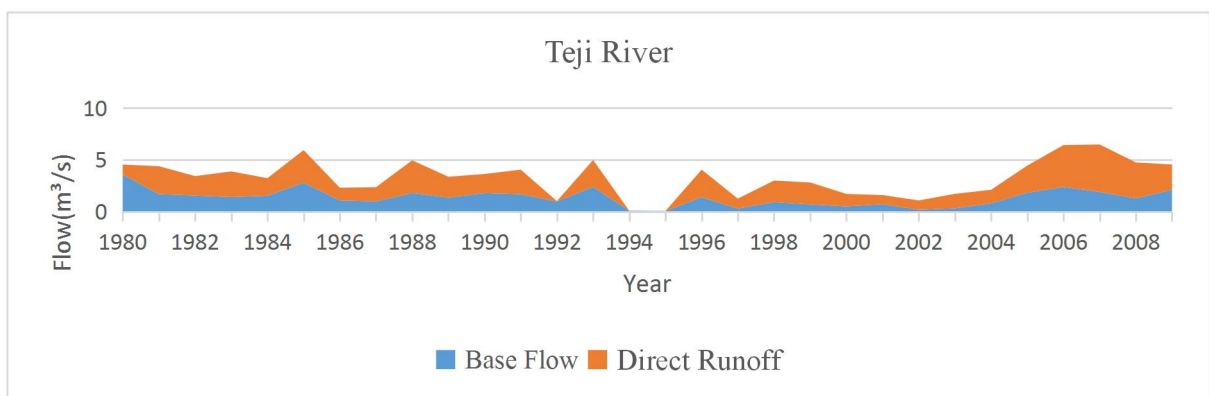
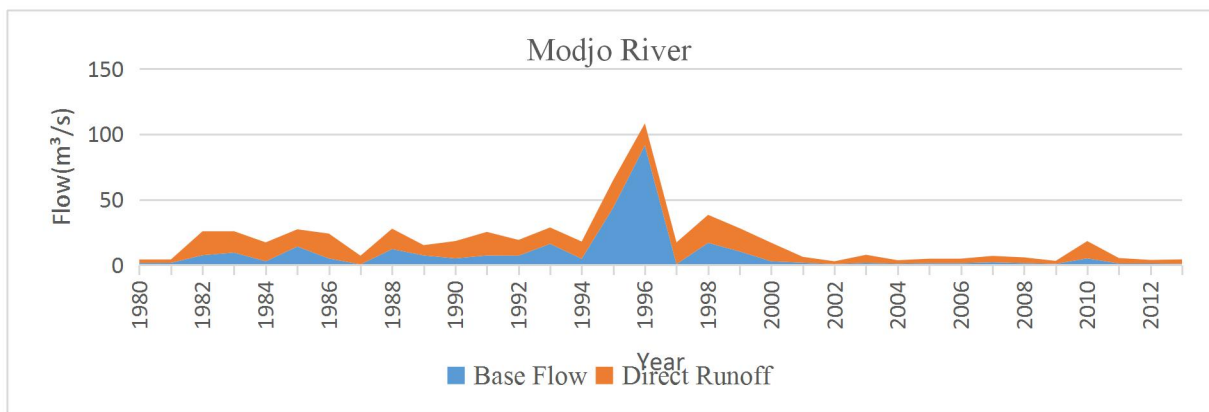
Base flow is defined as water which enters a stream or river from persistent, slowly varying sources, maintaining stream flow between water input (precipitation, snowmelt) events, which contrasts with water that enters a stream or river promptly, called storm flow or event flow (Dingman, 1994).

The process of base flow separation, also termed hydrograph analysis, is concerned with partitioning stream flow records into runoff and base flow components, i.e. differentiate total flows into the high-frequency, low amplitude 'base flow' component and the low-frequency, high-amplitude 'flood' flows (Andarghe Yitbarek, 2009).

In figure 4.6 above it only shows the mean monthly flow on the hydrograph and doesn't give indication to their origin (overland flow, inter flow, direct precipitation and base flow). therefore it is important to separate in to its components (base flow and direct run off) so that the origin and contribution of base flow and direct runoff to the river discharge is estimated.

For this specific study excel spread sheet program is used to separate the base flow from direct runoff.

In the graph below the base flow and direct run off results of the year 1995 and 1996 shows huge deviation from the other year's result which cannot be a logical result. Therefore it needs some consistency check, while for this specific study to estimate the base flow and direct runoff amount in the Modjo River the data of those years is ignored to overcome with reasonable result.



Figures 4.7 Trends of annual direct runoff and base flow at Modjo and Teji Rivers

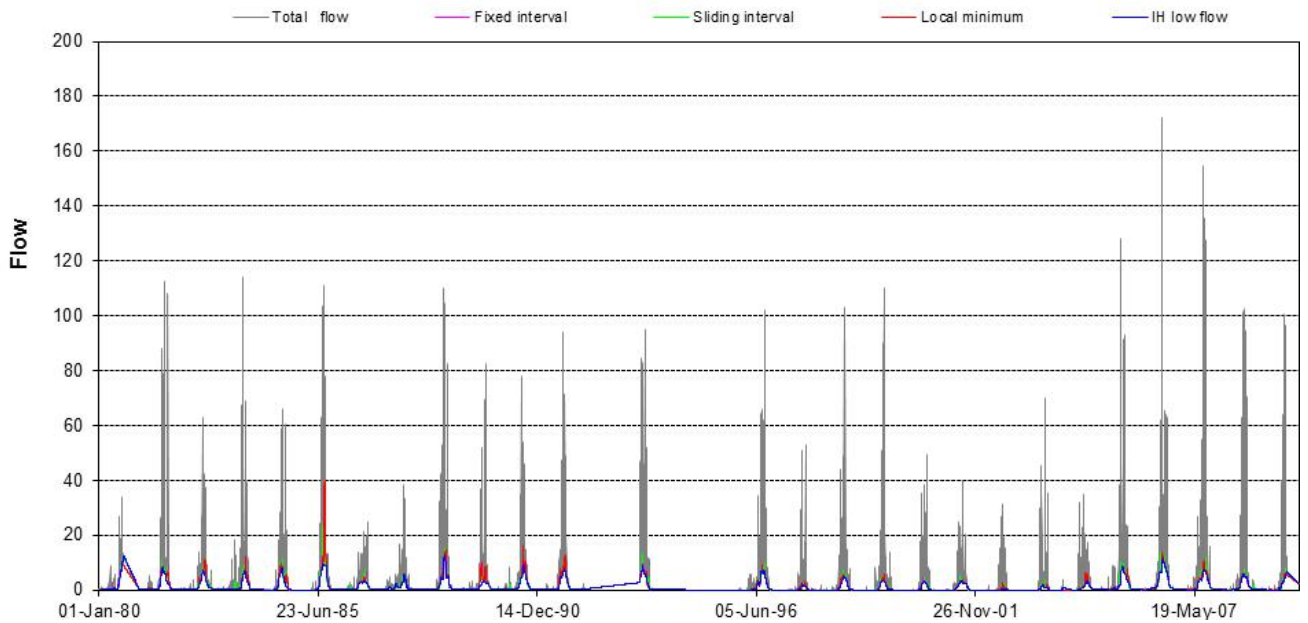


Fig 4.8 Separation of total flow of Awash River at Teji River into direct runoff and base flow.

The base flow separation of Teji river shows that about 35.1 % (54.9mm/year) of total 156.3 mm/year annual flow is contributed from base flow and the rest 64.9 % (101.4mm/year) is surface run off.

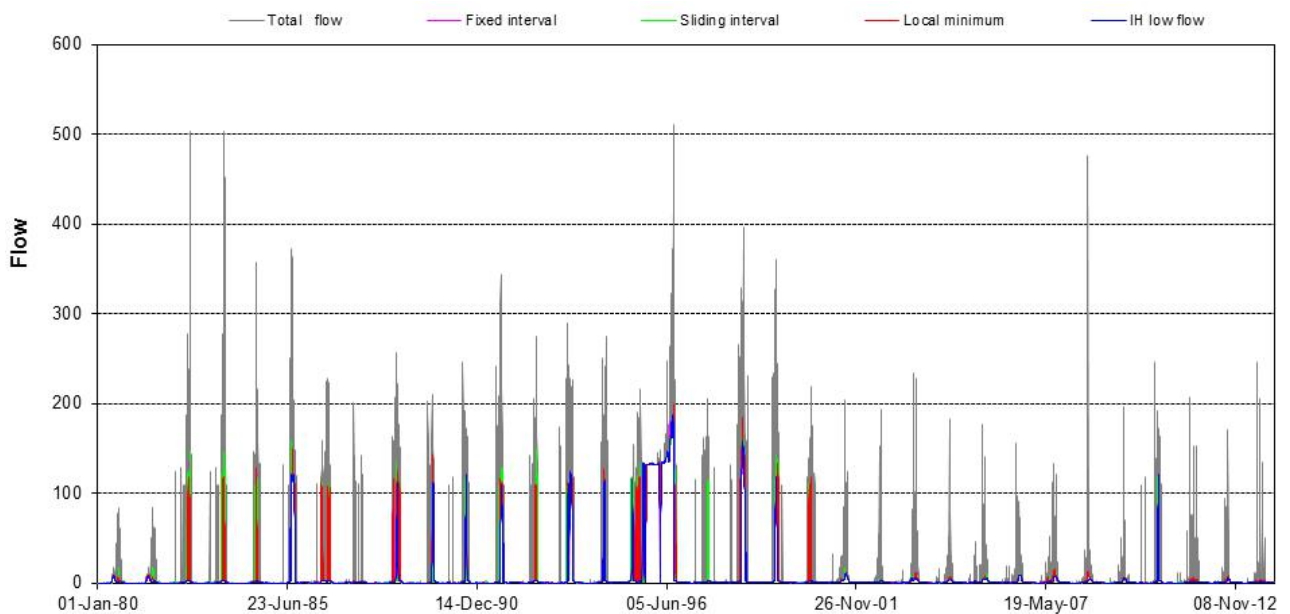


Fig 4.9 Separation of total flow of Awash River at Modjo River into direct runoff and base flow.

From the total of 10.1 m³/s mean annual flow 39.6 % (4 m³/s) is contributed from base flow and about 60.39% (6.1 m³/s) is surface runoff at Modjo river.

4.5 Evapotranspiration

Under field condition it is not possible to separate evaporation from transpiration totally. Indeed, we are generally concerned with the total water loss, or evapotranspiration, from a basin or catchment. Either the loss is from free water evaporation, plant transpiration or soil moisture evaporation is of little importance. Therefore evapotranspiration is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for the movement of water to the air from the sources such as the soil and water bodies. Transpiration accounts for the movement of water within a plant and subsequent loss of water as vapor through stomata in its leaves. Evapotranspiration is an important part of water cycle.

In the study area, there is no direct measurement value of evaporation from open water body or pan evaporation. There for evapotranspiration has been computed using the recorded data of meteorological stations of the areas employing the pen man, Thornthwaite's and Turc empirical formulae.

4.5.1. Estimation of potential evapotranspiration (PET)

Potential Evapotranspiration (PET) is defined as the amount of evaporation that would occur if a sufficient water source were available. This term implies an ideal water supply to the plants. In case water supply to the plant is less than PET, the deficient would be drawn from the soil moisture storage until about 50 per cent of the available supply is utilized. With further moisture deficiency, the actual evapotranspiration (AET) will become less than PET until the wilting point is reached, and when the evapotranspiration stops Or it is the maximum possible evaporation under given meteorological conditions (Tenalem Ayenew and Tamiru Alemayehu,2001).surface and air temperature, insolation, and wind all affect potential evapotranspiration positively while relative humidity affects it negatively.

4.5.1.1 Thornthwaite's formula

This formula is based mainly on temperature with an adjustment being made for the number of daylight hours. An estimate of the potential evapotranspiration, calculated on a monthly basis, is given by:

$$PE_m = 16N_m \left(\frac{10T_m}{I} \right)^a \text{ mm}$$

Where m is the months 1, 2, 3...12, N_m is the monthly adjustment factor related to hours of daylight, T_m is the monthly mean temperature (C), and I is the heat index for the year, given by:

$$I = \sum i_m = \left(\sum \frac{T_m}{5} \right) \quad \text{for } m = 1 \dots 12$$

And: $a = 6.7 \cdot 10^{-7} I^3 - 7.7 \cdot 10^{-5} I^2 + 1.8 \cdot 10^{-2} I + 0.49$

Given the monthly mean temperatures from the measurements at a climatological station, an estimate of the potential evaporation for each month of the year can be calculated. This method has been used widely throughout the world.

Accordingly, the calculated potential evapotranspiration using this method is given below for both focus areas.

Table 4.10 Calculated potential evapotranspiration using Thornthwaite's method.

Mo	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
PET of Becho	62.47	62.68	63.51	62.55	63.08	62.56	65.41	66.27	64.39	66.62	62.41	61.23	763.17
PET of Koka	66.34	76	88.68	91.27	96.16	86.80	77.37	75.41	76.03	70.67	64.48	60.99	930.19

4.5.2. Actual evapotranspiration (AET)

Actual evapotranspiration is the quantity of water that is actually removed from a surface due to the process of evaporation and transpiration.

4.5.2.1 TURC METHOD

The method determines the annual actual evapotranspiration (AET), directly from two meteorological parameters, precipitation and temperature.

It is an empirical formula developed based on data from various catchments of different climates, and hence could be applied in humid or arid climates, either hot or cold, Shaw (1988). It is given by the formula:

$$AEP = (P) / (\sqrt{[0.9 + (P/L)^2]})$$

Where AET= Actual evapotranspiration of a year in mm.

P=Annual mean precipitation in mm.

T= Annual mean temperature in °C

L= $300 + 25T + 0.05 T^3$ in mm.

For the Koka area P and T are **900.31mm** and **20.55 °C** respectively

Computing for L gives us **1247.6**

Therefore, substituting this results in the above equation the actual evapotranspiration for the Koka area is **756.5mm/year**. And For the Becho area the calculated actual evapotranspiration using Turc method is **727.6 mm/year**.

4.5.2.2 Thorenthwaite and Mather soil water balance method

The Thorenthwaite and Mather soil water balance method merely requires inputs of mean monthly temperature, precipitation, latitude, and an estimate of soil storage capacity. The PET values are calculated based on observed temperature (and day-length) data and, when applied to typical, calibrated paired experimental watersheds where one is treated and the other is a control may be correlated with and evaluated for any observed change in runoff quantity and timing, thereby illuminating the impact of incidental or managed vegetation change.

Ultimately, the Thornthwaite and Mather soil water balance method is useful for description, classification, management, and research. The method's biggest shortcoming is the minimum time division, the month. That may produce a situation where end-of-the-month precipitation should not in fact appear as runoff until the following month, a delay that may be confusing in the computed water balance. However, the mean annual computations do wrap around the start of the calendar year: for example, January runoff is calculated from appropriate water balance components and mean annual December runoff.

If there is no rain to replenish the water supply, the soil moisture gradually becomes depleted by the demand of vegetation to produce a soil moisture deficit (D). As soil moisture deficits increases, actual evapotranspiration becomes increasingly less than potential evapotranspiration. The values of soil moisture deficit and actual evapotranspiration vary with soil type and vegetation. When the moisture supply becomes limiting, the computed potential rate is modulated by a factor that depends up on the amount of water in the soil.

The relationship can be expressed as (Dunne and Leopold, 1978);

$$AET = PET \times f(AW/AWC)$$

Where AET and PET are actual and potential rates of evapotranspiration respectively, $f()$ is some function of the term inside the parentheses, AW is the available soil moisture which is equal to soil moisture content minus permanent wilting point times the rooting depth of vegetation (cm), AWC is the available water capacity of soil which is equal to field capacity minus permanent wilting point times rooting depth of vegetation (cm).

A soil moisture budget can be made on a monthly basis for various types of vegetation classified according to their root constants (Dunne and Leopold, 1978). Therefore, to evaluate actual evapotranspiration over a basin area, the proportions of different types of vegetation covering the basin must be known.

Accordingly, the study area has been classified in to two major groups of soil type (Clay loam and silty loam) with average field capacity of 200 mm, and the types of rooting depth of vegetation cover are taken 1m on average, Based on these and available meteorological data,

the actual evapotranspiration is calculated using Thornthwaite and mother standard soil water balance model.

Using this method and the potential evapotranspiration from Thorenthwaite method, the actual evapotranspiration (AET) of the study area is **721.39 mm/ year** (Table 4.11a) for Koka area. And the calculated actual evapotranspiration (AET) is **666.72mm/ year** for Becho area (Table 4.11b).

Table 4.11a:- Estimation of Actual evapotranspiration, AET by using Thorenthwaite Mather method for Koka area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
P	10.82	23.00	50.87	56.93	56.31	87.33	235.28	234.90	106.91	25.91	7.40	4.63	900.31
PET	66.34	76.00	88.68	91.27	96.16	86.80	77.37	75.41	76.03	70.67	64.48	60.99	930.19
P-PET	-55.52	-53.00	-37.81	-34.34	-39.84	0.53	157.91	159.49	30.88	-44.76	-57.08	-56.35	
APWL	-213.71	-266.71	-304.52	-338.86	-378.7	0	0	0	0	-44.76	-101.84	-158.19	
Sm	68.70	52.71	43.63	36.75	30.11	30.64	188.55	200	200	159.90	120.20	90.68	
ΔSm	-21.98	-15.99	-9.08	-6.88	-6.64	0.53	157.91	11.45	0	-40.10	-39.70	-29.51	
AET	32.80	39.00	59.95	63.82	62.95	86.8	77.37	75.41	76.03	66.02	47.10	34.14	721.39
D	33.54	37.01	28.73	27.45	33.21	0.00	0.00	0.00	0.00	4.65	17.38	26.84	208.81
S	0	0	0	0	0	0	0	148.04	178.92	0	0	0	326.96

Table 4.11b:- Estimation of Actual evapotranspiration, AET by using Thorenthwaite Mather method for Becho area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
P	9.77	35.82	53.77	82.07	75.15	144.50	255.04	270.87	129.90	26.04	12.54	6.42	1026.0
PET	62.47	62.68	63.51	62.55	63.08	62.56	65.41	66.27	64.39	66.62	62.41	61.23	763.17
P-PET	-52.70	-26.86	-9.74	19.51	12.07	81.94	189.63	204.60	65.51	-40.57	-49.87	-54.81	
APWL	-197.95	-224.81	-234.55	0.00	0.00	0.00	0.00	0.00	0.00	-40.57	-90.44	-145.25	
Sm	74.34	64.99	61.90	81.42	93.49	175.43	200.00	200.00	200.00	163.28	127.25	96.75	
ΔSm	-22.41	-9.34	-3.09	19.51	12.07	81.94	24.57	0.00	0.00	-36.72	-36.03	-30.50	
AET	32.18	45.16	56.86	62.55	63.08	62.56	65.41	66.27	64.39	62.77	48.58	36.92	666.72
D	30.29	17.52	6.65	0.00	0.00	0.00	0.00	0.00	0.00	3.85	13.84	24.31	96.45
S	0.00	0.00	0.00	0.00	0.00	0.00	165.06	369.66	435.17	0.00	0.00	0.00	969.89

- ❖ **P**= precipitation, **PET** =Potential Evapotranspiration, **AC.P.WL.** = accumulated potential water loss, **SM**= Soil moisture, Δ **SM**= change in soil moisture, **AET**= Actual evapotranspiration, **D**=soil moisture deficit, and **S**=annual moisture surplus

Δ soil moisture: - soil moisture is tabulated by means of the soil water balance methods published in Thornthwaite (1955) and Thornthwaite and Mather (1955, 1957). In order to track changes in soil moisture ,several intermediary values are calculated, including precipitation minus potential evapotranspiration (P-PET) ,accumulated potential water loss(APWL),actual evapotranspiration, soil moisture surplus and soil moisture deficit. These terms are described below.

P minus PET(P-PET): The first step in calculating a new soil moisture value for any given grid cell is to subtract potential evapotranspiration from the monthly precipitation (P-PET).negative value of P-PET represents potential deficiency of water, whereas a positive **P-PET** value represents a potential surplus of water

Accumulated potential water loss (APWL):- The accumulated potential water loss is calculated as running some of the monthly **P-PET** values during periods when P-PET is negative. This running some represents the total amount of unsatisfied potential evapotranspiration to which the soil has been subjected. Soils typically yield water more easily during the first month in which P-PET is negative. On subsequent months as the APWL grows, soil moisture is less readily given up.

Soil moisture, Δ soil moisture: - The soil moisture term represents the amount of water held in soil storage for a given grid table. Soil moisture has an upper bound that corresponds to the soils maximum water holding capacity (roughly equivalent to the field capacity; soil moisture has a lower bound that corresponds to the soils wilting capacity.

When **P-PET** is positive , the new soil- moisture value found by adding this P-PET term directly to the preceding soil moisture value. If the new soil moisture value is still below the maximum water holding capacity the thornthwaite –mather moisture tables are consulted to back calculate a new ,reduced accumulated potential water loss value.

If the new soil moisture value exceeds the maximum water holding capacity the soil moisture value is capped at the value of maximum water holding capacity, the excess moisture is converted to recharge, and the accumulated potential water loss term is reset to zero.

When **P-PET** is negative the new soil moisture term is found by looking up the soil moisture value associated with the current accumulated potential water loss value in the Thornthwaite –Mater tables.

Actual ET:-When P-PET is positive actual evapotranspiration equals potential evapotranspiration. When P-PET is negative, the actual evapotranspiration is equal only to the amount of water that can be extracted from the soil (Δ soil moisture)

Soil moisture SURPLUS :- the soil moisture reaches the maximum soil moisture capacity, any excess precipitation is added to the monthly soil moisture surplus value. Under most conditions, the soil moisture surplus value is equivalent to the monthly ground water recharge value.

Soil moisture DEFECIT :- the monthly soil moisture deficit is the amount by which the actual evapotranspiration differs from the potential evapotranspiration.

Therefore, in order to have a reasonable value for actual evapotranspiration it is better to take the average results that is calculated from the two methods (Turc and Thornthwaite). So taking the average result the actual evapotranspiration (AET) of Becho area becomes **697.16 mm/year** and for the Koka area the actual evapotranspiration calculated is **738.95mm/year**.

4.6 Groundwater recharge estimation

Estimating groundwater recharge is an important issue in hydrogeologic studies. In most cases, recharge is estimated by multiplying the magnitude of water-level fluctuations in wells by the specific yield of the aquifer material or by applying the water budget model or using the water-balance method. While other parts of the water-balance equation, such as precipitation and runoff, are relatively easy to measure, recharge remains an elusive process to quantify. This is especially so because it depends not only on precipitation but also on meteorological conditions, as well as on soil type, soil-moisture status, vegetation cover and condition, slope, cultivation practices, and most of all, on evapotranspiration, which is a function of the previously noted factors. In this research groundwater recharge estimation is made using the base flow separation method in addition to the water balance approach.

4.6.1 Base flow separation method

Although several methods have been used to estimate the groundwater discharge and recharge from streamflow records, the most commonly used are the techniques of base flow separation. These methods aim at estimating a continuous or daily record of base flow under the streamflow hydrograph. In other words, it requires an extended period of recording efforts in estimating the long-term groundwater discharge, as well as the exercise of a variety of manual methods.

Base flow separation is done by using excel spread sheet program and from annual flow of **156.3** mm/year at Teji River, **54.9**mm/year is base flow and **101.4**mm/year is surface run off. And base flow separation of Modjo River shows that **99** mm/year is base flow and **152** mm/year is surface runoff from a total of **251** mm/year.

4.6.2 Groundwater Balance Approach

In this method, all components of the groundwater balance equation, except the rainfall recharge, are estimated individually. The algebraic sum of all input and output components is equated to the change in groundwater storage, as reflected by the water table fluctuation, which in turn yields the single unknown in the equation, namely, the rainfall recharge. A prerequisite for successful application of this technique is the availability of very extensive and accurate hydrological and meteorological data.

The estimation of groundwater balance of a region requires quantification of all individual inflows to or outflows from a groundwater system and change in groundwater storage over a given time period. The basic concept of water balance is:

Inflow=out flow + change in storage.

Here, the inflow includes precipitation and ground water inflow whereas the out flow includes surface run off, ground water out flow, Evapotranspiration and change in storage.

This can be expressed as:

$$P+G_i= AET+SRO+R+G_o\pm\Delta SG$$

Where; **P**=precipitation,

G_i=groundwater inflow,

AET=actual evapotranspiration,

R= Recharge,

SRO=surface runoff,

G_o= groundwater outflow,

ΔSG=change in groundwater storage,

On annual basis change in storage is assumed to be zero for an aquifer under steady state condition because the assumption is made that the inflow and outflow amount are in balance.

The water balance equation of the catchment becomes:

$$R=P-AET-SRO$$

Therefore, putting the figures in to the above the equation the calculated recharge for Becho and Koka area is **227.34mm** and **27.31mm** respectively.

Therefore, the amount of recharge in Becho area is calculated as 227.34mm. And the above result shows that recharge, AET and SRO are **22.2%**, **67.9%** and **9.9%** for Becho area and **80%**, **3.03%**, **16.8%**, for Koka area respectively of the total rainfall.

Chapter Five: Hydrogeology

The aquifer properties in the basin are controlled by the litho-stratigraphy of the volcanic rocks and the structures that affect them. Because of the complex nature of the lava flow, the volcanic rocks have highly variable primary porosity. Later on through time, these volcanic rocks have been subjected to weathering and fracturing related to tectonics giving rise to secondary porosities. These volcanic aquifers can be considered as a double porosity medium due to the fact that both the matrix and the fracture porosity contribute to the circulation and storage of groundwater.

The aquifers in Upper Awash can be divided broadly into two categories; primary porosity aquifers and double porosity aquifers. The first category comprises aquifers related to Quaternary alluvial and lacustrine deposits and the second broad categories belongs to the basaltic volcanics and again subdivided in to upper and lower basaltic aquifers separated by less permeable, along fractured and weathered zones and/or impermeable otherwise, of acidic Volcanics (Andarghe Yitbarek,2009).

The alluvial and lacustrine aquifers are found dominantly in the southeast around Debrezeit and Modjo towns, and locally in the north-western part of the Becho plain and along the main perennial river courses. The alluvial and lacustrine deposits around Debrezeit and Modjo have thickness up to 80 meters and composed of coarse sediments (WWDSE, 2008). Depth to static water level varies from 7 to 39 meters. The alluvial aquifers in the southern part are with direct hydraulic connection with the underlying basaltic main aquifer.

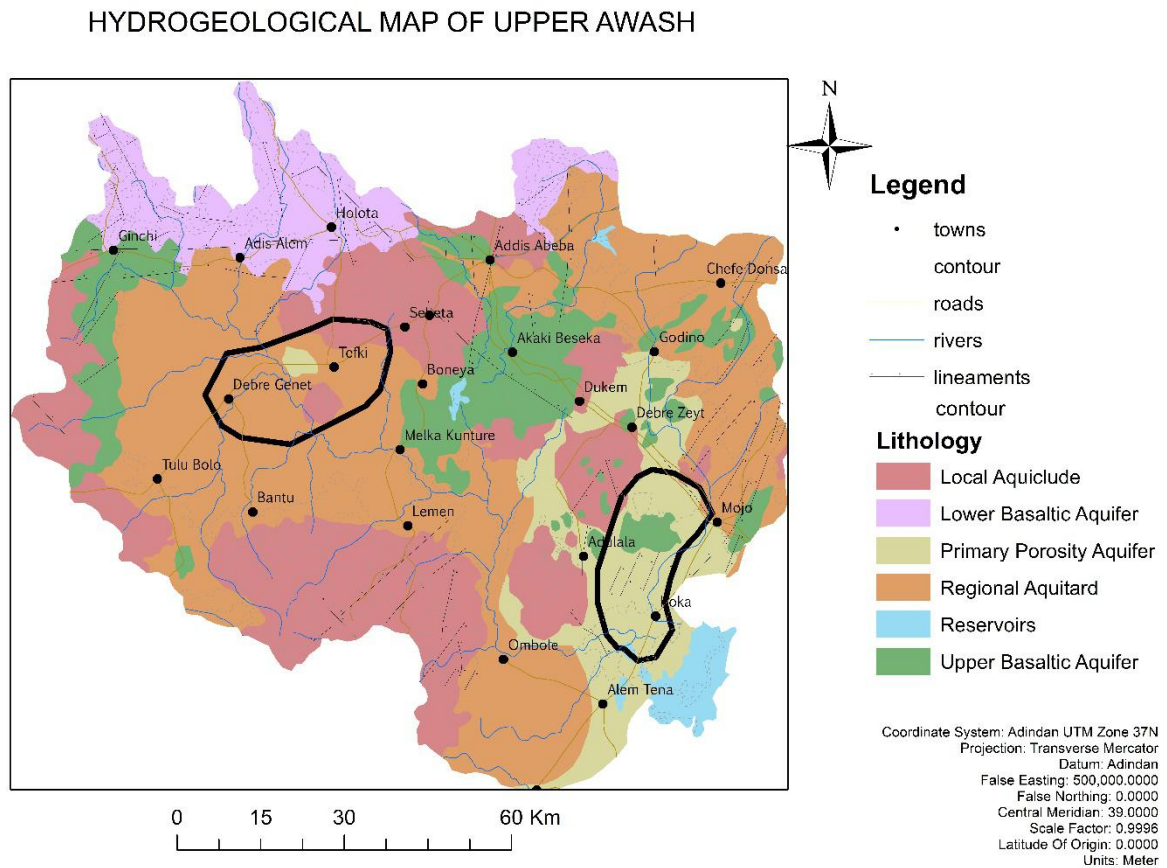


Fig. 5.1 hydrogeological map of upper awash basin and highlighted with study area. (Modified after WWDSE, 2008).

The aquifers and confining (aquiclude) identified are can be referred to as hydrogeologic units because the differentiation takes into account both the geologic and hydraulic characteristics of the units. Water works design and supervision enterprise identified the following hydrogeologic units in the study area.

- Alluvial aquifers
- Localized aquiclude (barriers) – Trachyte and Rhyolites mountains and ridges
- Upper basalt aquifer (UBA)
- Upper Regional confining (aquiclude) units
- Lower Basalt aquifer (LBA)

5.1 Alluvial Aquifers

The Quaternary alluvium includes soil, slope scree and debris deposits, caldera, crater and graben fillings. The thickness of this unit is more than 5 meters. The grain size shows great variation ranging from clay and silt to sand and gravel sometimes boulder size. This unit is one of the most important source of shallow groundwater. The Quaternary alluvium has a relatively good permeability and productivity with sand to gravel size as well as with some fine undifferentiated grains. In some places the grains of the sediment show poor sorting ranging from clay to boulder resulting in a very low permeability and water bearing capacity. This aquifer gets mostly its recharge from perennial and intermittent streams and rivers coming from the neighbouring highlands and ridges and also from direct precipitation (Bereket Fenatw and Mihret Manaye, 2011).

Unconfined aquifer consisting of coarse sediments. The static water level varies from 7 to 39 meters deep. The static water level is shallower at the Debre Zeit lake areas and becomes deeper to Mojo area. The specific capacity of bore holes varies from 950 to 90000m³/day/m. The water quality is generally fresh and the electrical conductivity varies from 444 - 841 μ S/cm and total dissolved solids from 220 to 750 mg/l. The unit occurs geological units of alluvial and lacustrine sediments of Debre Zeit area. Highly permeable and forms one aquifer system with the upper basalt aquifer in the area. (WWDSE, 2008).

5.2 Localized aquiclude (barriers)

Quaternary Bede Gebaba volcanic unit: Rhyolitic to minor trachytic lavas and pumice and Ziqwala trachytes and Tertiary Entoto-Becho Rhyolites and Central Volcanic of Wechecha, Furi, Yerer: prophyritic trachytic lavas.

This unit is have varying structures and weathering conditions, their water condition and storing capacity also vary accordingly. They dominantly form volcanic domes of Ziqwala, Wechecha, Yerer and Furi and the surrounding area. The water that precipitates on this dome lost as a runoff instead of vertical infiltration. This is due to that the trachytic lava domes have steeper slopes, massive and slightly weathered surfaces. In addition the absence of thick soil development facilitates runoff to be higher. As a result there is little groundwater stored except the appearance of springs with variable discharge.

On the Wechecha trachytic dome there are very often occurrences of major tectonic displacement and deep weathering zones, which have a strong effect on the hydraulic property of the rock. Moreover the development of minor fractures have local permeability effect and also water holding properties. This is highly dependent on the favorable climatic condition of the study area especially the precipitation.

5.3 Upper basalt aquifer (UBA)

In most part of groundwater system it is unconfined except at some part of Becho plain, where it is slightly confined. The geological formation is highly variable from place to place i.e. massive basalts, scoriaceous basalt and scoria. The basalts when it is faulted and fractured the yield of bore holes increases. The static water level varies from place to place from 5 to 20 meters. The transmissivity of this aquifer is less than 50m²/day. Transmissivity reaches more than 10,000 m²/day.

The Akaki basalt which is exposed in the north eastern part of the study area south of Addis Ababa varies from massive to fracture and fresh to highly weathered type. It forms flat terrain to small weathered scoria cones at places.

The water bearing characteristics of this aquifer is highly dependent on the secondary permeability which is the result of fracturing and weathering activities. The interconnections of the vesicles which are abundant in Akaki basalt are poor or may be filled by secondary infilling materials. Thus the vesicles have little importance in the permeability of the rock. However in some places the vesicles are affected by fractures resulted in interconnection between them and hence increased the permeability. But the high permeability of scoria fallouts of the Akaki group is highly dependent on the vesicles and pour spaces. The recharge of this aquifer is mainly from the northern part of Addis Ababa city (Entoto and the surrounding area) and from local streams. The aquifer is also recharged from direct precipitation of the area. It is the main groundwater source for the Addis Ababa city municipality water supply.

The Scoria fallout deposit together with Akaki basalts are considered as one principal hydrogeological unit which is upper basaltic aquifer. And the basalts are more scoraceous than the plateau trap series basalts of Tarmaber and Addis Ababa basalts. In the study area these aquifers are found around Bishoftu. The fractured surfaces and vesicles with good interconnection in scoria and basalts are responsible for high permeability of this unit.

The primary permeability of this scoria and scoraceous basalt different from those of unconsolidated alluvial and lacustrine sediments by which it is not only constituted by interstitial space but also dominantly by primary structures such as flow contact or inter flow space, vesicles, degassing cavities, lava tubes or tunnels, shrinkage cracks or joints and tree moulds. As a result the most important characteristics feature governing the groundwater movement and accumulation in this aquifer system are the interconnected primary structures and pours and the associated fractures.

5.4 Upper Regional confining (aquiclude) units

Chefe Donsa Pyroclastic, Nazaret unit (Welded ignimbrites) and Addis Ababa ignimbrites of low productive along the weathered and fractured zone makes this unity in the study area. In Becho area this unit is massive and acts as a regional aquiclude which separates the upper and lower volcanic aquifer in Becho plain. This rock unit covers majority of the Becho area. At places where there is well developed fractures and joints, it exhibits good permeability. The major water bearing horizon of this aquifer is the fractured features resulted in secondary permeability. The primary structures of volcanic flows are also significant if they are affected by secondary weathering and tectonic activities.

5.5 Lower Basalt aquifer (LBA)

Lower Basalt aquifer (LBA) is composed of tertiary Tarmaber basalt composed of dominantly scoriaceous basalt. Static water level varies from artesian condition to a depth of 67.5 meters. Regional aquifer transmissivity 100 -1700 m²/day. Highly permeable. This has been proved by the drilling of mapping wells at Asgori (Becho plain) ,Legadadi ,Melka Kunture ,and Sebeta by water works design and supervision enterprise, during Ada'a Becho ground water potential study. This formation is leaticular basalt with large proportion of scoriaceous lava flows. The formation is highly pervious, which highly favors groundwater storage and movement.

According to the WWDSE, 2008 the geological formations of the study area have been categorized into three aquifer system and the summarized major aquifer parameters are given in table 5.1 the summary table show that the specific capacity of Basalt and scoriaceous basalt, scoria is very high compared to the others. The high specific capacity of alluvial is mainly due to interconnection of the alluvial with basalt and scoria.

Table 5.1 Summary of Well Depth, Water Level, Discharge and Draw Down of water wells in

Geological formation	Static water level, m			Discharge, l/s			Specific capacity in l/s/m		
	max	Min	Avg	max	min	Avg	max	min	Avg
Alluvial	113.3	3.0	40.4	25.0	2.0	7.8	56.0	0.1	8.2
Basalt and scoriaceous basalt, scoria	200.0	0.0	44.0	74.9	0.4	10.7	354.5	0.0	14.7
Ignimbrites, Rhyolites, trachytes and pyroclastic	207.6	0.0	34.5	38.0	0.1	6.1	41.3	0.0	2.1

different formations (source WWDSE)

Alluvial and Lacustrine deposits occupy large part of the study area. The alluvial deposit is sandy clay and silty clay with gravel at the lower bed. The lacustrine sediments are

distributed around Debre Zeit lakes. This formation moderately favors groundwater storage and movement.

Chapter six: Ground water use trends

6.1 General use Trends

Several studies and ground water potential assessments indicate the rechargeable or replenish able ground water potential of the country is in the order of 2.6 billion cubic meters (BCM). More recent emerging studies and implementations like that of Addis Ababa, Kobo and Raya well field indicate the potential is far greater. Estimations of the ground water require a good understanding of the regional geology, hydrology, hydrogeology, hydraulics of ground water flow.(Semu Moges,2012).

This emphasizes the importance of understanding the regional groundwater aquifers and Movement when considering ground water assessment and development for highly water consuming agricultural use.

The use of groundwater for agriculture in the country is low. Assessment of data from 8,000 boreholes from federal sources and the regional water bureaus indicate over 80% of the groundwater use is for domestic water supply. The depth range of assessed wells indicates most wells are shallow (most 83%) and have low yield in the order of less than 10 lps (>60%)(Semu Moges,2012)

Apart from surface water sources, ground water can provide year round water availability. This requires of technologies and techniques adequate to field characteristics and local conditions.

For this reason this research paper will try to address the change in use trends of ground water especially the shallow ground water in Becho and Koka plains.

6.1 Ground water use trends of the study area

The use of ground water was very limited up to recent times in the area, but now a days due to many reasons it is common to see that ground water is playing an important role especially in Koka and Becho area for irrigation purpose. Among the factors that were changed the trend of using ground water the following are common:

Technology access

On-demand groundwater services

Water shortage in awash and Modjo Rivers

Market demand for agricultural products

Government extension program and increased private investments are common

6.1.1 Technology access

The extensive use of groundwater in agriculture has been limited by the labor intensity and high cost of lifting groundwater with human labor and animal traction. Advances in and easy access to pumping and drilling technologies and spread of rural electrification have meant that groundwater development has offered opportunities to tap this beneficial resource for improving agriculture and livelihoods.

Unlike surface water ground water extraction needs some drilling techniques and water lifting technologies from the well. Hand dug wells are common throughout the study area and are constructed in many different ways.

However manually drilled shallow tube wells are still uncommon. This type of low cost and simple technology includes several methods using only human labour. Drilling techniques include hand auguring, percussion, sludging and wash boring (or jetting).

Organizations such as IDE and the Oromia Water Bureau, have introduced shallow tube well in a number of locations, using simple and rotary sludging in particular, although this type of technology has not been fully implemented in the country.

Methods	Techniques	Average Depth(m)	Geology	Advantage	Drawbacks	Execution Time(days)
Manual Auger	Manual Auger	10-15	Sand,silt clay(soft soil) Gravel<4mm	Easy to use	Temporary casing difficult to remove when there is thick layer of clay	
Sludging	Madrill, rotary,emas, rota-sludge	20-35	Sand, silt, clay (soft soils),soft consolidated formation (alterities)	Easy to use	Significant water consumption in permeable soils	2-4
Washbore	Jetting,wash bore	6-15	Sand and silt	past	Needs a significant volume of water over a short period of time	<1
Percussion	Percussion, stone hammer	15-25	Consolidated formation (laterite, rock	Adapted to hard formation	High cost of equipment and not always available in time	7-10
Motorized auger	Motorized rotary,PAT Drill 201	35-45	Any type of rock free consolidated formation	Fast in hard soil	Significant consumption of water, equipment, and implementation cost very high	1-5

Table 6.1: Different manual well drilling techniques (Source: Abric et al. 2011)

6.1.1.2 Pump alternatives

The extraction of shallow groundwater potential is determined by the soil type, static water level, and user requirements (e.g. cost, capacity, availability). Suction pumps cannot extract water beyond 6 to 7 meters depth. If the static water level is situated deeper, the pump must still be installed within this range, e.g. by means of an excavation next to the well. This is not desirable for flood plains, as excavations collapse easily during the rainy season. The alternatives, i.e. rope or deep-well pumps could be used to extract water beyond 7 m, but the required installation impedes its mobility.

Table 6.2 provides an overview of the available Pump alternatives for shallow ground water use. The suitability of each alternative is determined by the flow requirements, water table depth, labour requirements and irrigated surface. Treadle pumps and rope pumps are low cost technologies being implemented in Ethiopia (developed by organizations like iDE and JICA).

Treadle pumps require little maintenance. They can carry water over 100 metres on flat land or lift 7 meters above the level of the pump. Water delivery is 1.4 L/s at 4 meters depth (Olley, 2008). Rope pump water delivery ranges between 0.17 L/s at 35 meters depth and 0.67L/s at 10 meters depth (Olley, 2008). Rope pumps can extract up to 35 meters.

Motorized pumps are another alternative for water extraction. The average water delivery is 10 L/s with 6 meters total head with fuel consumption of 1 liter per hour (Olley, 2008), (2002). Extraction depth is no more than 7 meters. On the other hand small petrol pump sets is an innovative option with significant less cost for both purchasing and fuel consumption. Another added value is mobility due to its reduced weight (10–12kg) endeavoring pump sharing among farmers.

Pump technique	Water demand(flow requirement)	Water table depth(m)	Financial requirement
Bucket and rope	Low	Up to 15(or more sometimes)	Low
Rope pump	Low	Up to 35	Medium
Treadle pump	Medium	Up to 7	Medium
Diesel pump	High	Up to 7	High
Micro pump set	Medium-high	Up to 7	Medium

Table 6.2 sustainability of pump techniques (from spate irrigation network foundation)

Motorised suction pumps are the most popular pumping technology for small scale irrigation in Koka area, since they are physically less demanding, widely available and easy to install.



Fig 6.1: Motor pumps in Koka area

6.1.2 Water shortage in Awash and Modjo Rivers

The common practice in Koka area for irrigation was to pump the river discharges from Awash and Mojo rivers while, in the Becho area the farmer's was using Teji and awash bello rivers for irrigation. But, in the past decade the discharge of those rivers were decreasing due to many reasons like pumping the Rivers in upper stream, change in precipitation and decrease in base flow to the rivers can be found. Therefore as the river discharge decreases from time to time the farmers started to look for water alternatives to farm their land, and this gives the rise for shallow ground water use in the area which is extracted mostly from hand dug wells and tube wells.



Fig 6.2 Hand dug well in Koka area

However the extraction of ground water from shallow aquifers has its own advantages and disadvantages. The advantages include:

- **Year-round water availability:** Accessing shallow groundwater resources alleviates water scarcity in dry seasons. Moreover water can be used informally and thus enhancing irrigation practices.
- **Aptitude for low cost technologies:** The unconsolidated soils and shallow water levels allow for to the use of manual well drilling and low-cost pumping technologies.
- **Local capacity building:** Water extraction and manual drilling technologies require human labour and supply chains developed locally which strengths local economies.

And among the constraints:

- **Clay layers decrease water yields:** especially lacustrine flood plains are characterized by thick clay layers. Water extraction from such impermeable soils is only feasible by means of seepage in large diameter wells. Tube wells cannot generate sufficient yield in these soils.
- **Pollution hazards:** shallow groundwater is more sensitive to pollutant sources from superficial and subsoil sources (sewage, runoff, etc.).

6.1.3 On-demand groundwater services

Another argument explaining the groundwater revolution emphasizes groundwater's many favorable characteristics. First, it is ubiquitous, available in lesser or greater degree, almost everywhere. Second, unlike large surface irrigation structures that may necessitate government initiative or cooperative effort on a large scale, groundwater irrigation can be developed quickly by individual farmers or small groups. Third, while operating costs of groundwater may be higher, the capital costs of groundwater structures are much lower per

hectare of irrigation than those of surface structures. Fourth, groundwater irrigation also demonstrates greater drought-resilience; groundwater aquifers keep yielding during a dry year even when all surface water bodies dry up. Fifth, and most important, groundwater provides irrigation on demand, offering a high-class captive irrigation source that provides farmers freedom to apply water when their crops need it the most. Sixth, due to its reliability in time and space, transmission and storage losses (for example, leakage and evaporation) from groundwater irrigation are lower than with surface irrigation. As a result, farmers tend to economize on its use, optimize other inputs (such as seeds, fertilizers, and pesticides).

These unique advantages of groundwater are important in explaining why farmers throughout the study area have taken to groundwater irrigation. However, these are not enough to stimulate intensive groundwater use in the vast high-recharge regions that are well endowed with groundwater. This suggests that other drivers of the groundwater revolution are at play.

6.1.4 Market demand for agricultural products

As towns and cities grow, their demand for food grows too. Urban consumers need quantity and demand quality. Irrigation has been the principal strategy to maintain national food security in Ethiopia. Increasing year-round national consumption of fruit and vegetables has prompted the mobilization of groundwater near urban center.

6.2 Ground water and irrigation

Groundwater has contributed significantly to growth in global irrigated areas since the 1970s. The irrigated areas supplied wholly or partly by groundwater are officially reported at 69 million hectares (ha), but independent studies suggest a higher figure, closer to 100 million ha, up from approximately 30 million ha during the 1950s (Jacob Burke and Karen Villholth).

Aquifer depletion and groundwater pollution are a direct result of the intensive use of groundwater, implying that existing trends cannot be sustained unless accompanied by far more intensive regimes of resource management than are currently deployed. The

groundwater boom has been driven by supply-push factors, such as government subsidies and easy availability of inexpensive pumps and drilling technologies.

This intensive-but essentially unplanned-groundwater use faces several challenges. Pumping costs are rising, and irrigation-supporting subsidies are compromising the viability of rural energy providers. Moreover, the impacts of groundwater depletion on water quality, stream flows, wetlands, and down gradient users in certain pockets are rapidly nullifying the widely dispersed beneficial impacts on livelihoods and food security at the society level. In addition, with anticipated shifts in precipitation patterns induced by climate change, groundwater's value as a strategic reserve is set to increase all over the country. The challenges bring the central issue of the sustainability of groundwater use systems into sharp focus.

6.2.1 Temporal patterns

Data on groundwater use are scarce. Data on the impact of agricultural groundwater use on food security, rural livelihoods, and ecological systems are even more so. But there is little doubt that groundwater has increasingly come to dominate agriculture in many parts of the irrigating world. Moreover, groundwater irrigation around the country over the past decades has emerged and proceeded in waves. Shallow ground water irrigation is in the beginning stage in the Becho area and it is not that much expanded, while in the Koka area it is highly expanded around the lake Koka.

Table below shows how the ground water irrigation is rapidly increasing from year to year, when we see the amount of land irrigated using ground water it was only 330Ha in the year 2004 according to Ethiopian calendar, and when this data was collected from Lume woreda irrigation authority on March 2008 the area irrigated up to date was about 1262Ha and it is increased by 932Ha land within the past five years.

Before the year 2004 Koka area was not that much familiar with ground water irrigation and it was a common practice to use Modjo River for irrigation. And shallow ground water irrigation were introduced in some few farmers which have enough initial investment budget.

The first three years show sharp increase on the graph in using shallow ground water for irrigation purpose in Koka area, and that was the ground water revolution period in the area where the new pulling technologies emerged and most of the farmers began to irrigate using

ground water. Later on as these technologies are expanded and introduced in the area, all the land owner farmers around the area becomes ground water users for irrigation and that's why amount of land irrigated is not growing like before as the revolution period.

Year	Amount of land Irrigated using Shallow Ground Water(Ha)
2004	330
2005	974
2006	1230
2007	1245
2008	1262

Table 6.3 Amount of land Irrigated using Shallow Ground Water (Ha)

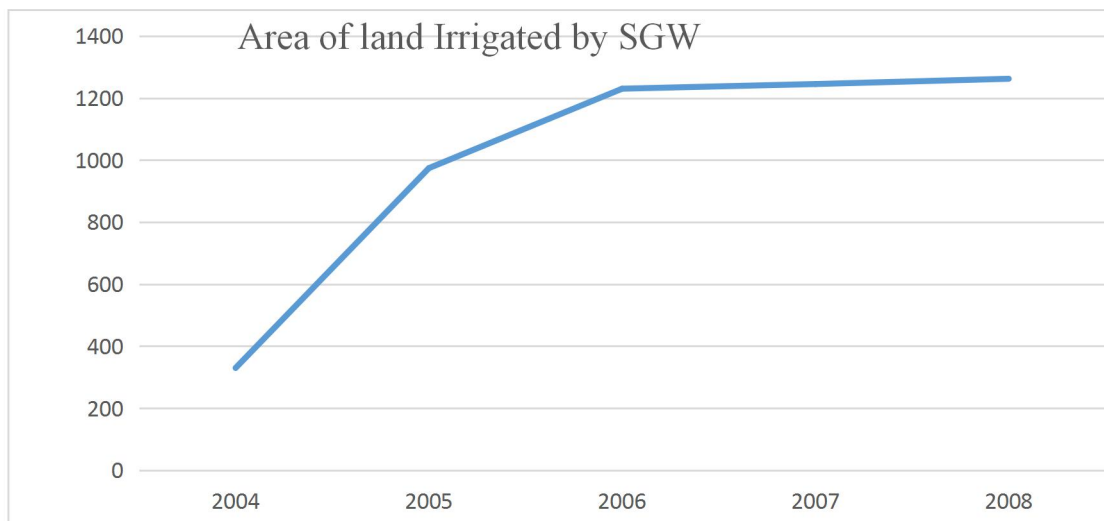


Fig 6.3 Area of land irrigated using shallow ground water (data from Lume woreda irrigation Authority)

In other regions of the country, however, groundwater use in agriculture has been slight but shows signs of rapid growth in the near future.

Groundwater use in agriculture in much of the country is still very slight and concentrated on commercial farms. But groundwater is increasingly important in supporting extensive pastoralism.

The study areas are located above abundant aquifers, but lifting water manually or with animal labor has restricted the use of these aquifers in the past. The rise of groundwater irrigation with tube wells and mechanical pumps transformed many of these into highly

productive agricultural areas. The key driver of the groundwater revolution here was the demand pull for water control through irrigation-the only missing input that kept agriculture in these areas from performing at full potential. In Becho area tube wells are also being used for irrigation purpose in addition to hand dug wells with motor pumps. This new technologies are introduced in the area by different non-governmental organizations like international development enterprise (IDE), focus on human development (FHD) and civil society support program (CSSP).



Fig 6.4 Tube well in Becho area

The introduction of this recent water pulling technologies from shallow ground wells gives the opportunity to use shallow ground water intensively.

Table 6.4 below shows the changes in number of shallow ground water wells in the Koka area for the last five years.

Year	Number of Shallow Ground Water well being used for Irrigation
2004	250
2005	325
2006	426
2007	1115
2008	2305

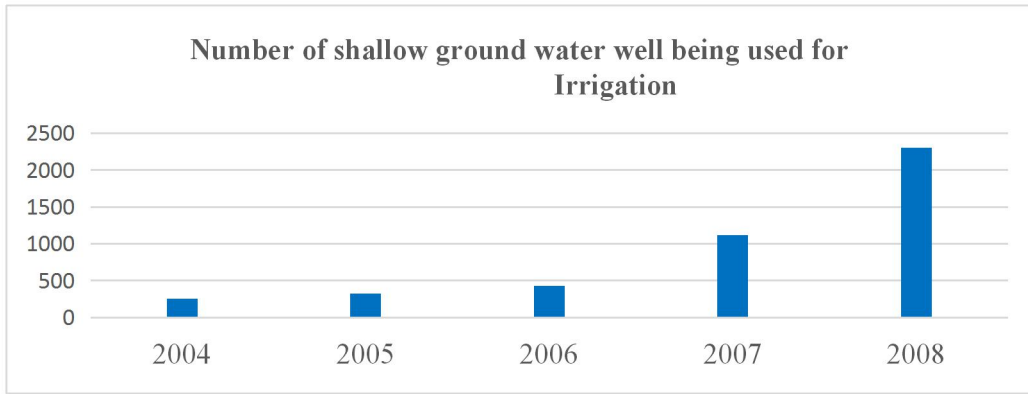


Fig 6.5 number of shallow ground water wells in use for irrigation in Koka area.

In Becho area the amount of land irrigated using shallow ground water is increased from only 97 Ha to 496 Ha in the last five years. When compared to the Koka area and the potential of the ground water potential of the area this number is may be small but, the awareness of the farmers in the area is changing from year to year and becoming familiar with different technology access for lifting ground water which may change the use of ground water for irrigation rapidly in the near future.

Year	Amount of land Irrigated using Shallow Ground Water(Ha)
2004	97
2005	156
2006	265
2007	376
2008	496

Table 6.5: Area of land irrigated using ground water in Becho area

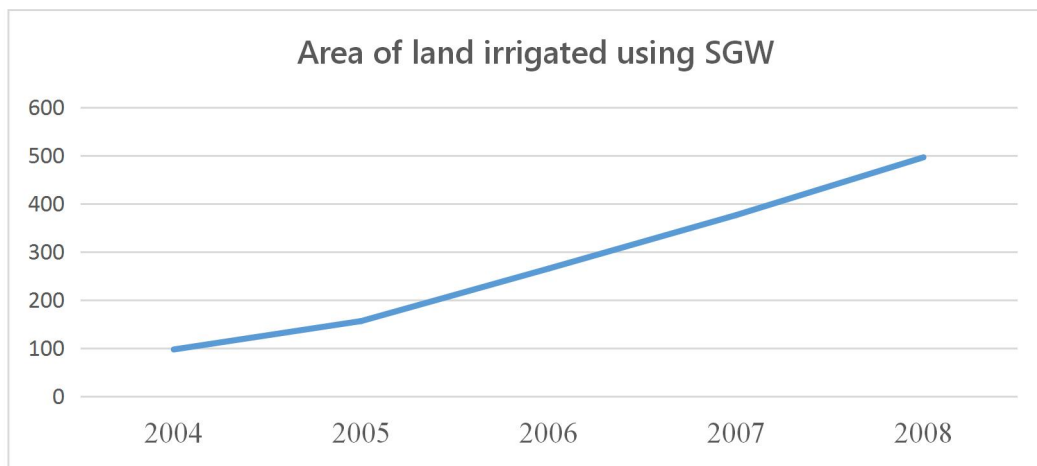


Fig 6.6 Area of land irrigated using shallow ground water in Becho

This graph shows linear increase in the amount of land being irrigated from shallow ground water source. This pattern shows a similarity with the Koka part of the first three years. Therefore, it can be concluded that the ground water irrigation is in initial stage and not that much expanded as compared to the Koka area in Becho.

The number of shallow ground water in use for irrigation was 202 in the year 2004 in Becho and this number reaches 935 in the year 2008. table below shows the number of shallow ground water in use for irrigation in the past five years with its corresponding graph.

Year	Number of Shallow Ground Water well being used for Irrigation
2004	202
2005	432
2006	678
2007	874
2008	935

Table 6.6 number of shallow ground water wells in use for irrigation in Becho area

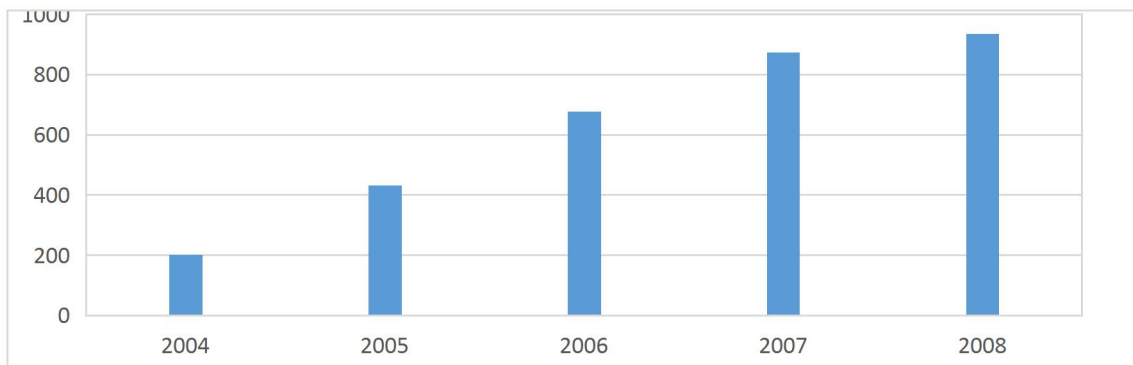


Fig 6.7 number of shallow ground water wells in use for irrigation in Becho area

6.3 Ground water management and future challenges in the study area

6.3.1 General ground water management

Accelerated development over the past few decades has resulted in great social and economic benefits, by providing low-cost, drought reliable and (mainly) high-quality water supplies for both the urban and rural population and for irrigation of both staple and high value

crops. But investment in management and protection of the resource base has been seriously neglected.

The sustainability of groundwater is closely linked with a range of micro- and macro-policy issues influencing water and land use, and represents one of the major challenges in natural resource management. Practical advances are urgently needed, but there is no simple blueprint for action due to the inherent variability of groundwater systems and related socioeconomic situations. It is, however always feasible to make incremental improvements, and many developing nations need to appreciate their socio-economic dependence on groundwater, and invest in strengthening institutional provisions and building institutional capacity for its improved management before it is too late.

Sustainable groundwater utilization requires action to be taken at three different administrative levels:

- macro-economic policy interventions-because groundwater demand is strongly influenced by national subsidies (on water well drilling, electrical energy, diesel fuel, food crops etc.) and they affect the size of existing groundwater-based agriculture and the rate of transition to less water dependent livelihoods
- local-level management measures-to create effective organizational arrangements (empowered government agency within the existing legal and institutional framework, user awareness and participation, groundwater abstraction charging, land-use constraints etc.) to regulate, protect and monitor groundwater resources
- major state or national adjustments to the legal and institutional framework - but after identifying how to implement preferred management and protection measures, defining the most feasible local organizational arrangements and only then attempting to introduce legal reforms where they can be realistically implemented.

The approach taken to groundwater management at any moment in time will depend, to a considerable degree, upon information about, and interaction between, the following factors:

- The size and complexity of groundwater resource
- The degree of climatic aridity and rate of aquifer recharge and resource renewal

- Water well inventory, scale of groundwater abstraction, and number and profile of groundwater users
- Groundwater resource accounting, with detailed understanding and breakdown of the components of the 'groundwater balance', which is the basis for making management decisions
- The ecological role of environmental services dependent upon groundwater
- The susceptibility and vulnerability of the aquifer system to degradation

6.3.1.2 Ground water management in the study area

The study area is experiencing shallow ground water irrigation, and this use of ground water is increasing rapidly with no management consideration for the future.

The underlying aquifer in Koka area is identified as high potential water bearing alluvial and lacustrine deposit .Access to this groundwater for SGI is mainly through the digging of shallow wells. Farmers dig shallow wells along the Modjo River for dry season farming (irrigation).

The location suitable to dig a shallow well is purely based on the farmer's local knowledge of the area. Farmers use trial and error methods to find suitable areas where one can get good water yield. Wells are closed at the end of the dry season to prevent animals falling into them or rains eroding the area close to the well, resulting in well instability.

Typically, there are 2 to 3 wells on smaller farms whereas larger ones have between 3 and 5 wells. The intensity of use of these wells during the dry season causes a lowering of the water levels each day, but fortunately they collect (regain) enough water overnight for the next day's irrigation.

Irrigated plots in the study area range from 1 to 10 ha along the Modjo river stretch and the Koka flood plain. Farmers identify suitable areas for irrigation based on their local experience of the availability of water in the area for dry season farming. Data collected from Lume woreda irrigation authority indicates that areas under SGI increased dramatically between 2004 and 2008.in the year 2004 according to Ethiopian calendar the total area irrigated under shallow ground water was 330Ha and it is increased to 1262 in the year 2008. And number of SGW wells that are used for irrigation are increased from 250 to 2305 in the past five years.

Therefore, the increasing number of SGW well clearly indicates that the exploitation of ground water is also increasing from year to year which needs serious management procedure in the future .but present and future scarcities matter more than ever before.

Population growth, industrialization, and urbanization are depleting and polluting lakes, rivers, and aquifers irreversibly. New technologies empower us to extract water supplies faster than the rate of replenishment. Catastrophic human-made environmental damage is done on a global scale never before possible. And with the integrating forces of globalization, we are all now implicated in the troubles of others, no matter how distant.

Managing these disparities effectively and fairly constitutes one of the great imperatives of governance that now confront us. But it is an imperative complicated by still other hard facts. Water is a renewable resource, in the sense that the global hydrological cycle turns endlessly through the dynamics of evaporation, condensation, and runoff. In every practical way, however, the global supply of fresh water available for human use is fixed while human demand is ever-growing. In some places the supply is severely insufficient, and declining by the day.

Facts like these generate their own consequences - and raise urgent issues of water management. The scarcity of water, like any resource scarcity, imposes the inevitable questions: Who gets how much? At what cost? , But there are deeper questions that also need to be addressed: Who decides? By what procedures? What features of governance will most likely produce management decisions that are fair, effective, and environmentally sustainable?

Around the world, irrigation accounts for two-thirds of all the fresh water used by humans. Around the world, irrigated land produces some 40 percent of all the food we eat. So irrigation is vital to our very survival.

These facts alone would argue for careful management of irrigation water, whether gathered from the surface or pumped from the subsurface. But there are still other and demanding reasons why irrigation -and watershed management more generally -require new and more knowledgeable local management. First of all, the per-capita sum of land under irrigation has been contracting. Not only is population growth outracing expansion of irrigation, but considerable areas of farmland are being removed from irrigation because of salinity and contamination, or because of urban encroachment.

Second, appalling volumes of costly irrigation water is wasted. In the developing countries, as much as 75 percent of water diverted or pumped for irrigation is lost to evaporation, leakage, seepage, or simply bad management. And third, most of the water that flows through irrigation systems serves multiple purposes. An irrigation canal, for example, might also be used to raise fish, to water animals, to wash clothes, to flush away wastes, and sometimes (if inadvisably) for drinking water. Conserving irrigation water for these other uses contributes to productivity and to public health.

Improving the management of watersheds and irrigation raises difficult issues of equity and efficiency, along with the technical problems of hydrology and agronomy. Large irrigation schemes, and expensive pumping from aquifers and groundwater, usually call for large investments of money - which tends to favour those with money to invest.

Poor farmers, remote communities, and indigenous minorities may face special obstacles securing a say in such management decisions - and in sharing the benefits. Some of these issues arise in the research reported here, exploring local management of subsurface water. Other issues of course require research at broader levels. Notably, substantial gains can be made in crop water-use efficiency in rain-fed agriculture, and far higher water-use efficiency can be achieved in irrigated agriculture. Actions in these areas would not merely reduce the need for additional water to grow food, but would also increase the scope for local management.

In the Koka area the over pumping of shallow ground water for irrigation purpose has showing its negative impact on the environment like the lake size shrinking and salinity of the water which intern affects the soil fertility and decreases the productivity.

The shallow ground water table data around the Koka area shows that the ground water table becomes deeper and deeper as we go away from the lake and in turn the size of the lake is changing from year to year as the shallow ground water pumping is increasing from year to year.

Local water management permits a democratizing decentralization of decision and accountability. Well done, it empowers people (particularly the poor and otherwise disadvantaged) to take part in the decisions that define their own futures. And it encourages the integration of traditional knowledge with innovative science to promote fair and efficient

supply management. In these ways, water degradation and shortage can be transformed into sustainable sufficiency.

Skilled management of subsurface water therefore turns on a detailed understanding of hydrogeology, geochemistry, and the other hard sciences of rock, soil, and water. More than that, it requires institutionalizing ways to prevent over-pumping and competitive drilling - and to promote the fair sharing of the resource and the costs of its conservation. Ultimately, subsurface water management demands as much knowledge about communities and their needs as about the engineering of deep wells.

Chapter Seven: - Conclusion and Recommendation

7.1 Conclusion

The Awash River basin has been divided in to three main sub-basins: Upper (upstream of Koka Dam station), Middle (between Koka and Awash station), and Lower (comprising the deltaic alluvial plains in Tendaho, and the terminal lakes Abhe area). The Upper Awash basin is located in central Ethiopia at the western margin of the Main Ethiopian Rift (MER). The area is confined within the limits of 8°15'-9°15'N latitude and 38°-39° 15' E longitudes.

Koka and Becho areas are the focus areas for this specific research, both the areas are found in the upper part of Awash River basin; Koka is located at North latitude of $8^{\circ}26'27.56''$ and longitude of $39^{\circ}1'54.45''$ East about 90 km south of the capital Addis Ababa. The Becho area is located between elevations of 2062 and 2109 m.a.s.l and the center is at 8.84° latitude and 38.36° longitude.

The main objective of this work was to evaluate the ground water potential of the area and to study the changes in use trends of ground water in the area on the basis of water balance techniques and other convectional hydrogeology. Different data on ground water use are collected and analyzed to study the change in use trends of ground water, and some future ground water management options in the study area is forwarded.

In this paper, the long term mean annual groundwater recharge of Koka and Becho area is estimated with the help of a water-balance approach coupled with the base-flow separation method. The water balance uses meteorological and discharge measurements.

With water balance approach, it is possible to evaluate quantitatively individual contribution of sources of water in the system, over different time periods, and to establish the degree of variation in water regime due to changes in components of the system. to study the ground water use trends short term data on ground water use is collected and analyzed.

Results from water balance technique shows that the annual recharge for Becho and Koka area is 227.34mm and 27.31mm respectively.

The amount of recharge from rainfall to ground water was estimated from a hydrograph base flow separation software program mentioned in the previous chapter (under hydro meteorology) so that the total annual groundwater reserves replenished in the area is known. It is estimated that the annual recharge to groundwater from rainfall is about 22.2% of the mean annual rainfall of the in Becho area and for Koka part about 3.03% of the rainfall recharges the ground water annually.

The study areas are located above abundant aquifers, but lifting water manually or with animal labor has restricted the use of these aquifers in the past. The rise of groundwater irrigation with tube wells and mechanical pumps transformed many of these into highly

productive agricultural areas. The key driver of the groundwater revolution here was the demand pull for water control through irrigation-the only missing input that kept agriculture in these areas from performing at full potential.

The ground water irrigation is rapidly increasing from year to year in the study area, when we see the amount of land irrigated using ground water it was only 330Ha in the year 2004 according to Ethiopian calendar, and when this data was collected from Lume woreda irrigation authority on March 2008 the area irrigated up to date was about 1262Ha and it is increased by 932Ha land and the number of shallow wells irrigating this land is increased from 250 to 2305 within the past five years. In Becho area the amount of land irrigated using shallow ground water is increased from only 97 Ha to 496 Ha in the last five years with the increase in number of wells from 202 to 935.

Computations of water balance elements often involve errors, due to shortcomings in the techniques used. The water balance equation therefore usually does not balance, even if all its components are computed by independent methods and this work is also limited in accurate estimation of ground water recharge. This work is also limited to ground water use data records on the basis of the amount of daily or annual abstraction.

The hydrogeological units recognized in the study area can be classified as alluvial aquifers, localized aquiclude (barriers) – Trachyte and Rhyolites mountains and ridges, upper basalt aquifer (UBA), Upper Regional confining (aquiclude) units, and lower Basalt aquifer (LBA)

7.2 Recommendations

The following points, if addressed, will help in resolving the problem in future groundwater studies.

- Proper campaign has be done to collect all the hydrogeological information and water uses. This will help in sustainable utilization and timely interventions under the changing climatic and hydrological conditions.
- It is highly recommended to develop systematic database of shallow wells being extensively used in the basin including crop water requirement studies.

- Records on groundwater use (abstraction rate) has been given a very little and/or no attention in the country. But it is a very essential step towards evaluating and managing ground water resources. Simple database system on ground water abstraction rate can be done with simple database management system.
- Hydrological and hydrometrological data are not recorded continuously and have lot of missing data. Even which are fully recorded data shows some unreliable result due to recording error or data management. There should be consistency checks on the data quality.
- Data on the impact of agricultural groundwater use on food security, rural livelihoods, and ecological systems are scarce. This will lead to improper utilization of ground water and salinity of agricultural land which in turn decreases productivity.

References

- Abric, S., Sonou, M., Augeard, B., Onimus, F., Durlin, D., Soumaila, A., Gabelle, F., 2011.** Lessons learned in the development of smallholder private irrigation for high-value crops in West Africa. Joint discussion paper Issue4: The World Bank, FAO, IFAD, PRACTICA, ARID, IWMI.
- Andarghe Yitbarek. (2009).** Hydrogeological and hydrochemical framework of complex volcanic system in the Upper Awash River basin, Central Ethiopia: with special emphasis on inter-basins groundwater transfer between Blue Nile and Awash rivers. Unpublished PhD Thesis, University of Poitiers, France, pp233.
- Andualem Eshetu. 2006.** Evaluation of Ground Water Resources Potential of the Teji River Catchment South West Shewa Zone, Oromia Region. Unpublished M.Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 114 pp.
- Bereket Fenatw and Mihret Manaye. (2011).** Hydrogeology and hydrochemistry of The Akaki-Beseka Sheet (NC 37-14).ministry of mines, Geological survey of Ethiopia, Addis Ababa, 142pp.
- Daniel Gemechu, 1977.** Aspect of climate and water balance in Ethiopia. Addis Ababa University press, Addis Ababa, 79pp.
- David B. Brooks, 2002.**Water local level management. International Development Research Centre, Ottawa, ON, Canada, 47pp.
- Dingman S.L. 1994.** Physical hydrology. Prentice-hall, New Jersey, 557pp.
- Dunne T. and Leopold B.L.1978.** Water in Environmental Planning. Freeman, San Francisco, 815pp.
- EVDSA – Halcrow, 1989.** Master Plan for the Development of Surface Water Resources in the Awash Basin, Final Report Vol.2, Main Report.
- Fetter, C.W. (1994).** Applied hydrogeology. Prentice Hall, New Jersey, 695pp.
- Halcrow. (1989).** Master plan for the development of surface water resources in A wash basin. Final report, Ethiopian valley development Authority, Addis Ababa, Ethiopia.

Halcrow. 2006. Awash River Basin Flood Control and Watershed Management Study Project. Halcrow and MoWE, Addis Ababa, Ethiopia.

Hussen Endre. (2006). Water Resource Potential Evaluation of Berga River Catchment, West Shewa Zone, Oromia Regional State. Unpublished M.Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 102 pp.

Jacob Burke and Karen Villholth. (2007). Groundwater: a global assessment of scale and significance, Joint discussion paper, IWMI Part 4 Ch8-16.

Kazmin V, 1975. Explanation of the geological map of Ethiopia. Bulletin number one. Geological survey of Ethiopia, Addis Ababa, 14pp.

Kazmin V. (1979). Stratigraphy and Correlation of Volcanic Rocks in Ethiopia, Note No. 106, Ethiopian Geological survey, Addis Ababa.

Ketema Wogari. (2006). water resources potential evaluation of Holeta river catchment central Oromia, west Shewa. Unpublished M.Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 141 pp.

Ministry of Water Resources (1980): Twelve town's water supply Project, Debrezeit/Modjo, well report (unpublished). Addis Ababa.

MoWR (Ministry of Water Resources). 1999. Ethiopian water resources management policy. MoWR, Addis Ababa, Ethiopia.

Nippon Koei. 1996. Feasibility study on the Becho plain agricultural development project. Final report. Volume II, Annex I and II.

Olley, J. (2008): Human-Powered Hand pumps for Water Lifting. Technical Brief, Practical Action, and Rugby, United Kingdom

Semu Moges. (2012). Agricultural Use of Ground Water in Ethiopia: Assessment of Potential and Analysis of Economics, Policies, Constraints and Opportunities. Ag water solutions project Case Study paper, Addis Ababa University, Ethiopia, pp49.

Shaw E.M. (1988). Hydrology in Practice. Chapman and Hall London, New York, 539pp.

Tenalem Ayenew and Tamiru Alemayehu, 2001. Principle of hydrogeology. Department of geology and geophysics, Addis Ababa University, 125pp.

Tesfaye Tessema, 2015. Ground Water Potential Evaluation Based on Integrated GIS and Remote Sensing Techniques, in Bilate River Catchment: South Rift Valley of Ethiopia .American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) Volume 10, No 1, pp 85-120.

Tilahun Azegegn. (2008). Hydrogeochemical characterization of aquifer systems in Upper Awash River Basin and adjacent Abay plateau using geochemical modeling and isotope hydrology. Unpublished M.Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 100 pp.

Thornthwaite, C. W., and J. R. Mather 1955. The Water Balance, Publications in Climatology VIII (1): 1-104, Drexel Institute of Climatology, Centerton, New Jersey.

Thornthwaite, C. W., and J. R. Mather 1957. Instructions and Tables for the Computing Potential Evapotranspiration and the Water Balance, Publications in Climatology. Center ton, NJ. pp311.

Thornthwaite, C.W. And Mather, J.R. (1975). Instructions and tables for computing potential evapotranspiration and the water balance; Laboratory of climatology, publication No.10, Center ton, NJ.

Tsion Yinesulih. (2014). Towards Productive Shallow-Well Supported Floodplain Area Challenges and Solutions, Case of Koka Flood Plain, Ethiopia. Unpublished M.Sc. Thesis, UNESCO-IHE Institute for Water Education, Delft, the Netherlands.

Water Works Design and Supervision Enterprise. 2008. Evaluation of water resources of Ada'a and Becho plains ground water basin for irrigation development project. Annex I. Vol I and II.

Water Works Design and supervision Enterprise, WWDSE (2008): Evaluation of water resources of the Ada'a and Becho plains ground water basin for irrigation Development project, Phase II Report, Addis Ababa, pp189

ANN

