Addis Ababa University

College of Natural and Computational Sciences

School of Earth Sciences

Structural Control on Ground Water Dynamics in Gur River Catchment of Jema River sub-basin at Middle Blue Nile Basin in Central Ethiopia.

Thesis Submitted to School of Graduate Studies of Addis Ababa University in Partial Fulfillment for the Degree of Master of Science in Hydrogeology

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Addis Ababa University School of Graduate Studies

This is to certify that the thesis prepared by Bekelech Ashenafi, entitled: Structural Control on Ground Water Dynamics in Gur River Catchment of Jema River sub-basin at Middle Blue Nile basin in Central Ethiopia**.** Submitted in partial fulfillment of the requirements for the Degree of Master of Science in Hydrogeology complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Date: June, 2018

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ABSTRACT

Structural Control on Ground Water Dynamics in Gur River Catchment of Jema River sub-basin at Middle Blue Nile basin in Central Ethiopia.

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In central Ethiopia, the structural control on ground water dynamics in Gur River Catchment of Jema River sub-basin at Middle Blue Nile basin have been investigated to characterize the ground water flow direction and lineaments orientation.

The development of ground water contour map, lineament orientation and flow direction is based on the interpretation of Water level data and from field measurement data of attitude (strike) were plotted on Rose diagram respectively. Lineaments were extracted from DEM using Geomatica software mapped using kriging interpolation tools in Arc GIS 10.3. The geological structure and regional fault system from NW-SE trending horst beneath volcanic rock unit and ridges control the aquifer distribution in the catchment. The lineament density is high on lithologic unit of sedimentary rock unit, but there are thin beds of mudstone and shale intercalation with upper sandstone domes are affected by fractures and faults, they form groundwater flow barriers. The volcanic rock unit is highly fractured and jointed with major lineament orientation N-S, E-W, and NE-SW direction. In sedimentary rock due to high deep gorge which is strongly disturbed by geological structure with varying attitude act as low permeability boundaries. Hence geological structure and attitude influenced on ground water storage and dynamics by hindering or deflected ground flow direction. Therefore the fractures and joints act as conduit though which ground water flow or barrier.

Key words: Geological structure**,** lineament orientation, Groundwater flow, controls Gur River Catchment

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Abbreviations (Acronyms)

DEM	Digital Elevation Model
EC	Electrical Conductivity
GSE	Geological Survey of Ethiopia
HDW	Hand Dug Well
SWL	Static Water Level
WWDSE	Water Works Design and Supervision Enterprise
GPS	Global Positioning System
M.a.s.l	Meter above sea level
FAO	Food and Agriculture Organization
NWP	North Western Plateau
NW	North West
SE	South east
Max.T	Maximum Temperature
Min. T	Minimum Temperature
WWDE	water well drilling Enterprise
OWWDSE	Oromia Water Works Design and Supervision Enterprise
RF	Rainfall

CHAPTER 1

1. INTRODUCTION

1.1. Background

The nature and distribution of aquifers and aquitards in a geologic system are controlled by the stratigraphy, lithology and structure of the geologic deposit and formation. Structural features, such as cleavages, fractures, folds, and faults are the geometrical properties of the geologic systems produced by deformation after deposition or crystallization. In unconsolidated deposits the lithology and stratigraphy constitute the most important controls. In most regions knowledge of the lithology, stratigraphy and structure leads directly to an understanding of the distribution of aquifers and aquitards (freez and cherry, 1979).

From regional geological setting of central Ethiopia is characterised by the area is underlain by geologic units that are strongly affected by tectonic activities (Tsegaye Abebe, 1995, Tsegaye Abebe et al., 1998, Assefa 1991,Russo et al. 1994).

Rocks ranging in age from the Precambrian basement to Tertiary and Quaternary volcanic with cover of alluvial sediments outcrop in the area. Precambrian basement rocks are covered in most parts by rare Paleozoic and dominantly Mesozoic sedimentary successions which in turn are overlain by thick Tertiary volcanic rocks.

The Mesozoic era in Ethiopia is marked by thick marine sedimentation and extensional tectonics. Several NW-SE striking structural basins have served as active depositional basins during the Mesozoic. Mesozoic sedimentation started with the permo-Triassic to Jurassic deltaic adigrat sandstone and was followed by a NE to SW marine transgressive sequence of middle to upper Jurassic Antalo limestone, argillites and gypsum. It ended with the deposition of upward coarsening Cretaceous sandstone indicating regression. These Mesozoic transgressive and regressive sequences mark successive subsidence and uplift episodes of tectonics in the horn of Africa between Permian and Cretaceous times (Merla et a1., 1973; Boselini, 1989, Russo et al., 1994).

1.2. Previous works

A number of studies have been conducted in to the geological structural, geomorphological and geological set up the NWP (e.g. kazmin, 1980; Merla et al.1973; Getaneh Assefa 1981;Tsegaye Abebe, 1995; Tsegaye Abebe et al., 1998; Mengesha et al. 1996; Gani et al., 2007, 2009; Ahmed Wolela, 2008, 2009 ;Russo et al., 1994). Some of the study shows that the geology of central Ethiopia is characterised by the Precambrian crystalline basement, Palaeozoic and Mesozoic sedimentary successions and the Tertiary continental flood basalts.

Some of the studies conducted on stratigraphic and structural evolution of the Blue Nile basin, northwestern plateau (Gani et al., 2007).

Tamiru Alemayehu (2006) Ground water occurrence in Ethiopia. Investigate that the Paleozoic and Mesozoic sedimentary rock both primary and secondary permeability that play role in the occurrence and movement of ground water.

Ground water dynamics in tributary stream of Muger and Holota river catchment in central Ethiopia. She investigated that by taking the catchments tributary streams of Muger river catchment from Abay river basin and Holota river catchment from Awash river basin using geochemical (major ions) and environmental approaches (Kidist Hailu ,2016).

Litho-structural control on inter basin groundwater transfer in central Ethiopia. In central Ethiopia litho-structural setup of the three sub-basins of the southern flank of the Middle Blue Nile basin (Guder, Muger and Jema) and the adjacent upper Awash river basin have been investigated to develop conceptual groundwater flow model and to characterize the groundwater hydrodynamic relationship between the aquifer systems of the two basins(Tilahun Azagegn et al. ,2014).

Characterization of aquifers and hydrochemistry in the volcanic terrain central Ethiopia which encompasses upper Awash, Jema, Muger and Guder river basins surrounding the city of Addis Ababa (Mekdes Nigatie, 2012).

Seifu Kebede et al. (2005) Groundwater recharge, circulation and geochemical evolution in the source region of the Blue Nile river, applied geochemistry.

The Geological Survey of Ethiopia et al. (2011) the alluvium along major rivers like the Abay, Jema, Muger and Guder is reworked and seems less compacted and more porous. The alluvial sediments are represented mainly by porous-sandy-gravels to silty sand which can be exploited by shallow dug wells. Elluvial sediments of the plateau consist of silty to clay soil.

Aquifers in alluvial and elluvial sediments are recharged directly by infiltration of rain. Alluvial sediments can also be recharged by rivers during high discharge and by groundwater from aquifers which are cut by the river. Groundwater of aquifers in alluvial and alluvial sediments is drained by small springs and rivers. Plateau Quaternary deposits also recharge the underlying aquifers

Tilahun Azagegn (2008) hydrogeochemical characterization of aquifer systems in upper Awash river basin and adjacent Abay plateau using geochemical modeling and isotope hydrology. As stated that the regional groundwater flow system of the area is therefore controlled by the structural and stratigraphic relationship of these rock formations which constitute confining beds, traps and aquifer systems in the study area.

Tilahun Azagegn (2014) groundwater dynamics in the left bank catchments of the middle blue Nile and the upper Awash river basins, central Ethiopia. The NW-SE trending horsts beneath thick volcanic layers and ridges control aquifer distribution in the middle Blue Nile basin into Guder, Muger and Jema groundwater sub-basins. The E-W trending impermeable mudstone capped horst underlying the volcanic aquifers controls aquifer distribution and constitutes a groundwater divide between the Blue Nile and the upper Awash basins, channeling recharged water in the former to the latter.

Andarge Yitbarek et al. (2012) hydrogeological and hydro chemical framework of upper Awash river basin, Ethiopia: with special emphasis on inter-basins groundwater transfer between Blue Nile and Awash rivers. In area where the weathered, fractured and scoraceous basalts is exposed to the surface in the adjacent blue Nile plateau north eastern and north western extremes of the study area. Recharge is possible directly from precipitation.

Behailu Berehanu et al. (2017) multiple approaches have been used to estimate groundwater recharge in the upper Awash river basin with aquifer system from the Blue Nile sub-basin.

Tenalem et al. (2008) from hydrogeological frame work and occurrence of ground water in the Ethiopia aquifer stated that the movement and occurrence of ground water is strongly controlled by large fault system.

Jiri Sima et al. (2009) water resource management and environmental protection of Jema river basin for improved food security conducted by a combined team from geological survey of Ethiopia (GSE).Quantitative classification of aquifers is made using water point inventory data, including various borehole pump test data. The plateau area is covered with various volcanic rocks intercalated by sediments in places. This area receives adequate precipitation and has moderate run-off resulting in good infiltration and formation of extensive and moderately productive or locally developed and highly productive fissured aquifers.

The aquifers are in parts classified as being mixed with porous sediments contributing to well yield.

The aquifers outcropping in the plateau area also feed deeper fissured aquifers developed in older volcanic and sedimentary rocks. They form extensive fissured aquifers of low productivity Muger mudstone forms the first base (aquitard) for groundwater that flows horizontally along this base and emerges in deep valleys as springs from the upper sandstone. The upper sandstone forms extensive and moderately productive fissured aquifers. The mudstone layer is not continuous within the whole basin and this fact allows water to infiltrate to greater depths and feed underlying aquifers developed in limestone. Limestone represents an extensive and highly productive fissured and karast aquifer and an underlying thick layer of gypsum forms the second base (aquitard) for groundwater that also flows along this base and emerges as large springs from the limestone.

WWDSE (2008) have been conducted some hydrogeological studies in the NWP in central Ethiopia.

1.3. Statement of the Problem

Several researchers (Tilahun Azagegn et al. ,2014, Behailu Berehanu et al. (2017, Seifu Kebede et al. 2005, Tilahun Azagegn (2014), Tsegaye Abebe, 1995, Tsegaye Abebe et al., 1998) have been carried out in central Ethiopia litho-structural set up of three sub basin of southern flank of middle Blue Nile basin (Guder, muger and jema) and adjacent upper Awash river basin. Some address ground water flow direction in the upper Awash river basin coincide with surface water flow path whereas, some researches point out that there is an inter basin groundwater flow from Abay river basin towards Awash river basin.

The main research problem therefore looks at what the nature of the controls on groundwater flow in the study area. The roles of regional and local geological structures on the dynamics of the groundwater in the Gur river catchment which flow towards Jema River in the middle Blue Nile basin are not well understood.

The geological structure, geology, topography, geological contacts and hydrogeology of the study area is fundamental to an understanding of the research problem. These structures can control flow by acting as barriers (low hydraulic conductivity) or as conduits (high hydraulic conductivity). This research work, hence, is intended to incorporate and contribute towards the effort to understand to how structural geology, regional geology and hydrogeology affect the ground water dynamics and ground water flow direction in the catchment.

The understanding of flow dynamics becomes crucial in the management of water resources. Recharge has to be translated into the flow regime within an aquifer, to understand where and how the water moves in the system. Flow can indicate discharge areas in a system.

The quantification of flow into and out of catchments for instance are the main source of data used by managers to strategize, plan and develop policy on utilization and development. Without flow information, resources can be over or under utilized.

1.4. Objectives of the study

1.4.1.General objective

The general objective of the study is to characterize geological structural that control ground water dynamics.

1.4.2. Specific objectives

The specific objectives of the study area are:-

- ✓ Characterize lineaments orientation
- ✓ Characterize the ground water flow pattern from water level measurement of borehole.
- ✓ Characterization of aquifer system from water chemistry measurement (insitu test) and pumping test data.

1.5.Approach and Methodology

The following approach and methodology were used in the research work.

- ✓ The desk study began with a literature search of reviewing of the available previous work and which includes, geological, hydrogeological and litho-structural control of the study area.
- ✓ Secondary data is collected from different organization, zone and wereda like information about deep well and shallow well ground water and related technical report from North shewa oromia water resource development office.
- ✓ Topographic maps of the study area purchased from Ethiopia map agency (EMA).
- ✓ Land use and land cover were also used from modified FAO land use /land cover map of Ethiopia.
- ✓ Pumping test data obtained from drilling companies and during field work, insitu measurement for EC, PH and water Temperature have been conducted.
- ✓ Strike orientation measured by using compass and their elevation using GPS record.

The following are methods employed in the research:

- ✓ Field measurement data of attitude (strike) of joint, fracture and fault taken with their elevation and plotted on Rose diagram (streoplot software) to identify major lineament patterns.
- ✓ Lineaments were extracted from DEM using Geomatica software mapped using kriging interpolation tools in Arc GIS 10.3.

- ✓ Water level, EC, and PH was used for each borehole and the data imported into Arc GIS 10.3 and calculating by ordinary kriging which was found to give satisfactory interpolation between data point.
- ✓ Geological and hydrogeological cross-section and has been produced ArcGIS10 and surfer 10(32 bit) respectively.

CHAPTER 2

2. DESCRIPTION OF THE STUDY AREA

2.1. Location

The study area is located in central Ethiopia surrounding the city of Addis Ababa which is situated in oromia regional state in central Ethiopia. It include at the middle Blue Nile basin of Jema sub- basin at Gur river catchment (fig.1).

The area is approximately its geographically bounded within 9°35'2.31" to 9°50'3.1"N latitude and 38°40'5.2" to 38°55'2.1"E longitude respectively, which covers a total area of about 750 km^2 and the elevation ranges from 1250-3250 m.a.s.l. The study area can be mainly accessed through Addis Ababa –Muka-turi **-**Debre-Tsige –fiche asphalts road. There are also several all weather gravel and dry weather soil roads which are inter connected each other and with the asphalts roads.

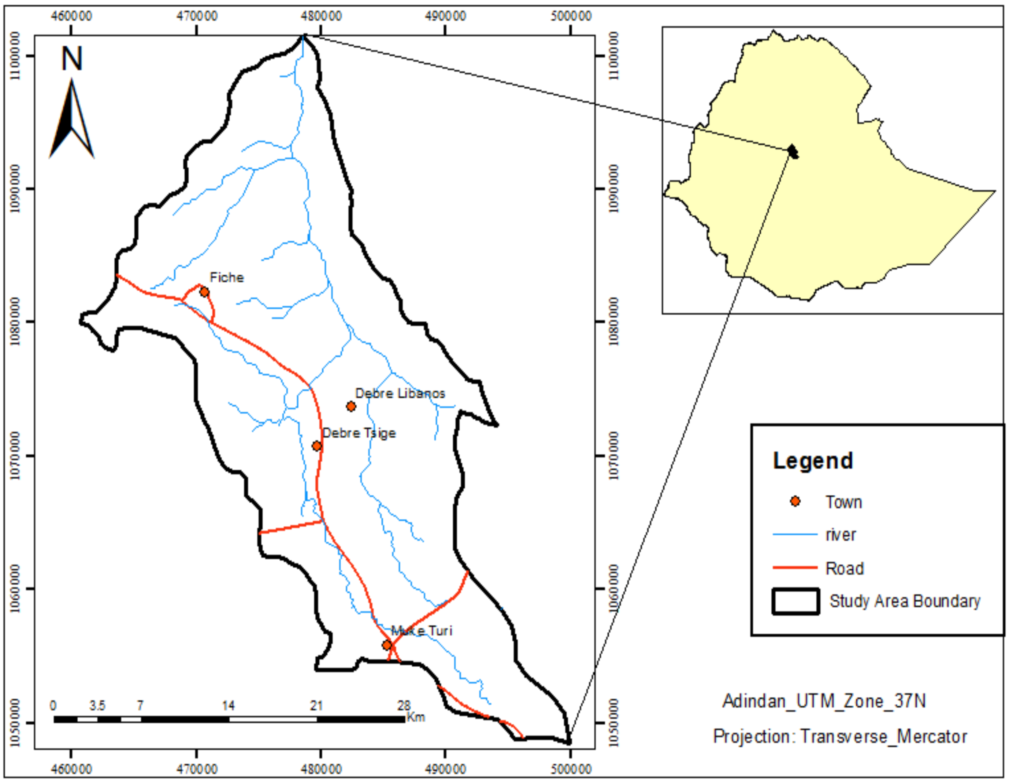

Figure 1. Location map of the study area.

2.2.Geomorphology and Drainage pattern

The geomorphology of the area is related to tectonic event followed by erosion. The study area is found on the south eastern margin of the Blue Nile (abay) basin and typically characterized by deep cut gorges with sharp escarpments, flat top hills, gently sloping. The DEM of the area is clipped from ASTER DEM of 30 meters resolution. From (fig.2) the digital elevation model without further enhancement shows the cliffs, mountains, plateau, canyons, gorges and other landforms. The paths of the major river and its tributaries can be easily traced. Elevated plateau of altitudes greater than 3,000 meters above sea level are visible in the northern part. The southern part is also elevated plateau. The river has made incisions below 2000 m.a.s.l. within the study area.

The major basin constitute of the study area abay basin the Gur river catchments drain to Jema river which is one of the biggest tributary of the abay river. The drainage pattern depends on the topography and geology. The river catchments dominantly dendritic pattern, its flow to W-E direction. The large majority of the river and stream are fault controlled and have eroded deep steep valley.

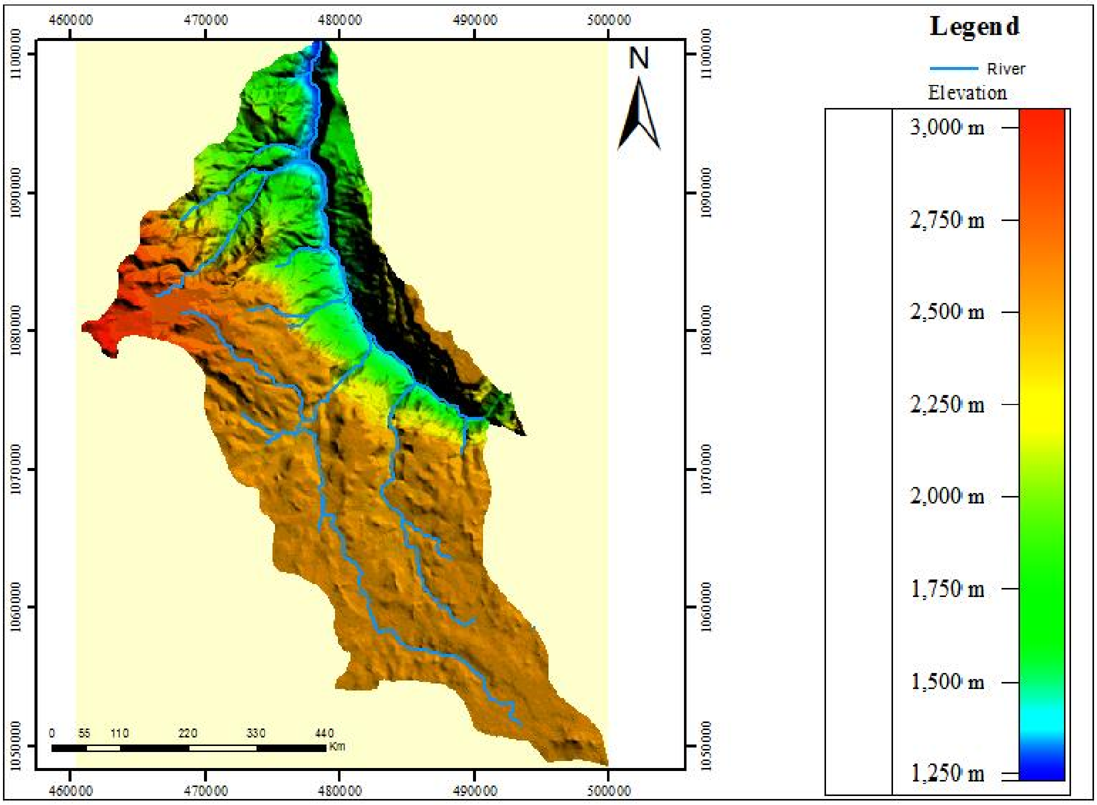

Figure 2. Geomorphology and drainage pattern set up of the study area from Digital Elevation Model (DEM).

2.3.Land use land cover, Vegetation and soil

The land cover of an area is controlled by its geographic, climatic, ecological and anthropogenic factors**.** The land use land cover classified into three units.

- ✓ Cultivated land cover with cereals
- ✓ Grass lands
- ✓ Forest and associated bush lands.

Mostly dominate flat topography and also there is gorge. The main vegetation types of the study area include eucalyptus trees juniper, acacia, olive trees and many undifferentiated ever green plants (fig.3).

The forest covering hills and mountains are dominated by eucalyptus trees and some juniper and acacia by lateritic. Black cotton soil and Sandy soils dominate the area this soil types residual types. The land use and soil were modified from FAO soil and Land use/land cover map of Ethiopia (FAO, 1984).

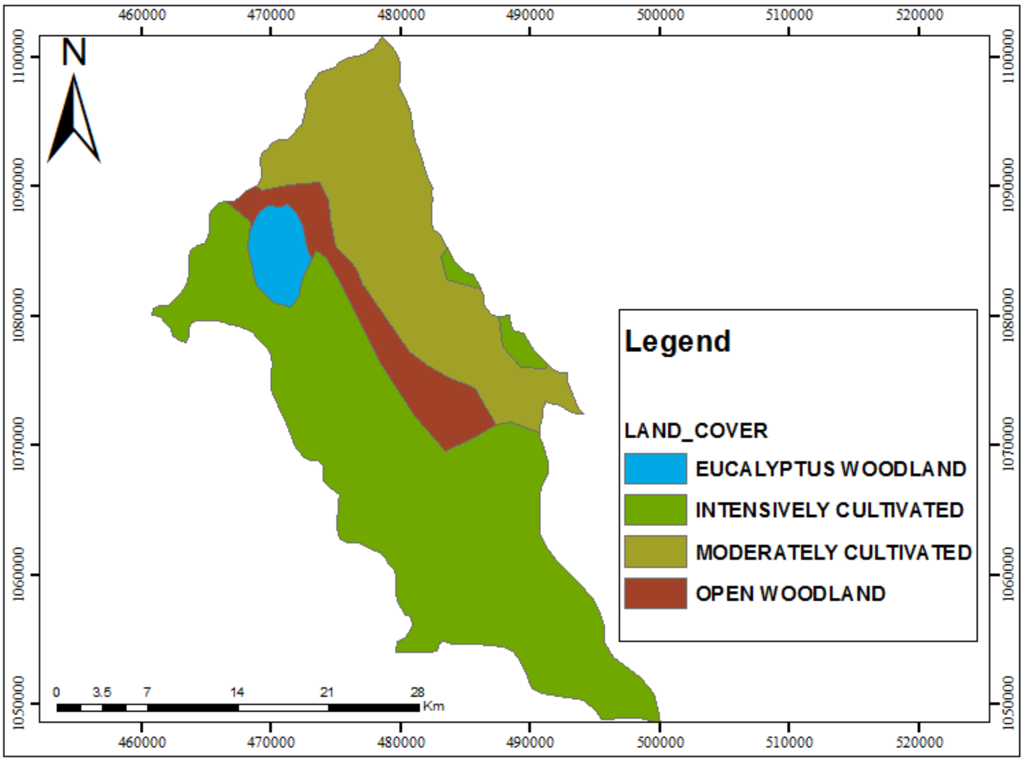

Figure.3.Land use land cover map (Modified from FAO, 1984).

2.4. Climate

In Ethiopia the climate condition is highly influenced by altitude. The climatic regions of the study area summarized in the following table. For this study the monthly mean average meteorological measurements were collected from National Meteorological Agency.

Table 1. Meteorological stations in the study area.

No	Station Name	UTM(E)	UTM(N)	Altitude	Observation Period	Mean monthly rainfall
1	Fiche	38.7333	9.7667	2784	1990-2017	RF,Temp
2	Debre-Tsige	38.82583	9.6375	2640	1990-2016	RF,Temp
3	Muka-Turi	38.87083	9.542	2649	1990-2016	RF,Temp

2.4.1. Rainfall

The main rainfall season in the study area is from June to September, but there is relatively small rainfall during the month of March and April. It is significant that the highest elevations have the most precipitation due to the orographic nature of the rainfall and these areas make up the main recharge zones. In summer, mainly June to September, the rain is very heavy with sporadic thunderstorm causing high runoff. The same rain pattern occurs in early spring and early autumn (March, April and may) with less intensity. During winter, October to February, it is sunny, dry with a very little or no rain fall.

Table 2. Mean monthly rainfall in mm from 1990-2017 for fiche, Debre- Tsige and muka-turi**.**

Month	Fiche (1990-2017)	Debre -Tsige (1990-2017)	Muka-Turi (1990-2017)
Jan	19	15	18.9
Feb	23.8	19.9	19
Mar	49.6	55.1	55.4
Apr	56.4	49.7	49.1
May	49.2	40.2	47.9
Jun	89.3	69.7	82.2
JUL	326.3	223.6	227.7
Aug	328.6	183	241.5
Sep	114.1	63.6	101.3
Oct	18.9	12.3	20
Nov	8.2	7.1	6.9
Dec	9.6	5.7	5.8

Almost in all stations the maximum peak rain is observed to be in August and July. The mean maximum monthly rainfall is recorded in the town of fiche, debre-tsige and muka-turi with value of 328.6mm, 223.6mm and 241.5mm respectively from (table 2.) above. September with mean monthly rainfall 114.1mm,279.1mm and 101.3 mm for fiche, debre-tsige and muka-turi respectively. In general this main rain season (summer) is crucial in replenishing fresh water reservoir, spring reinforcement and ground water occurrence. The other rain season from the end of February till April (autumn) is responsible for small scale agriculture, grazing grass and Flora and fauna in the area as shown (fig.4) below.

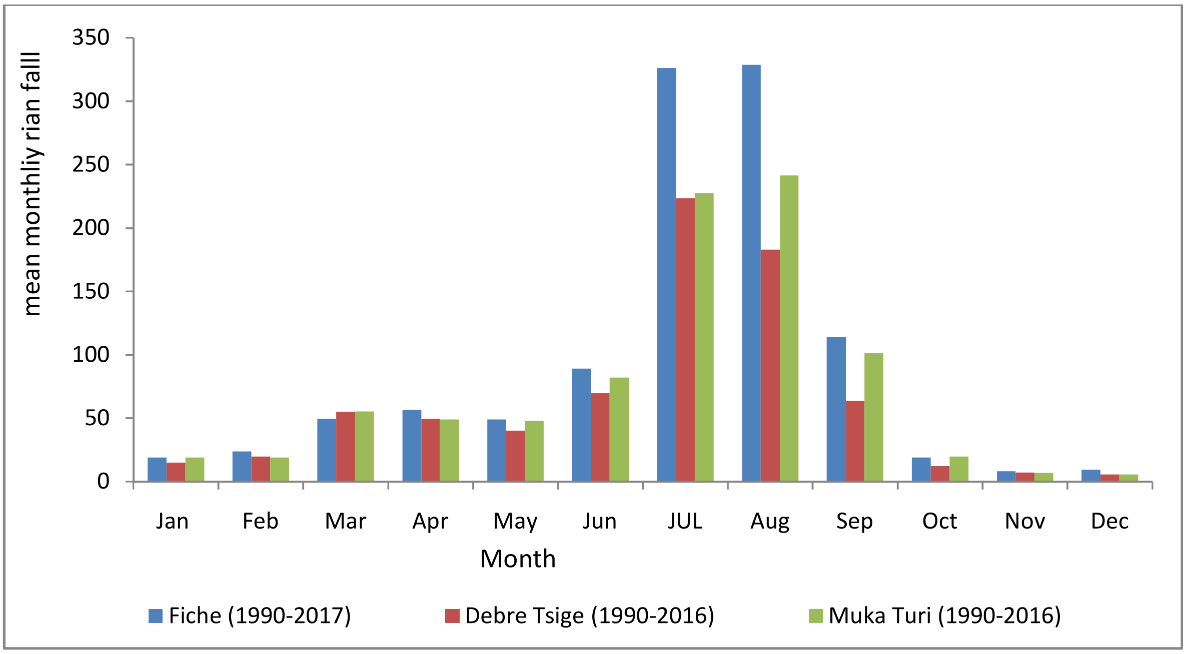

Figure 4. Mean monthly rainfall for study area.

2.4.2.Temperature

The temperature of the area is related with altitude. The monthly mean maximum and minimum temperature of those stations show slight difference. The mean monthly highest temperature is recorded from March to June with its average 18.6°C in fiche station. The monthly mean minimum temperature in November and December for Fiche station 7.7°c (fig.5) below.

Table 3. Temperature data

Fiche	Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(1990-2017)	Max	17.3	20.1	20.5	19.1	20.3	20.5	17.5	18	17.9	17.5	17.5	17.6
	Min	6.5	8.1	8.2	8.6	8.5	9	9	8.9	8.6	6.1	5.6	5.7

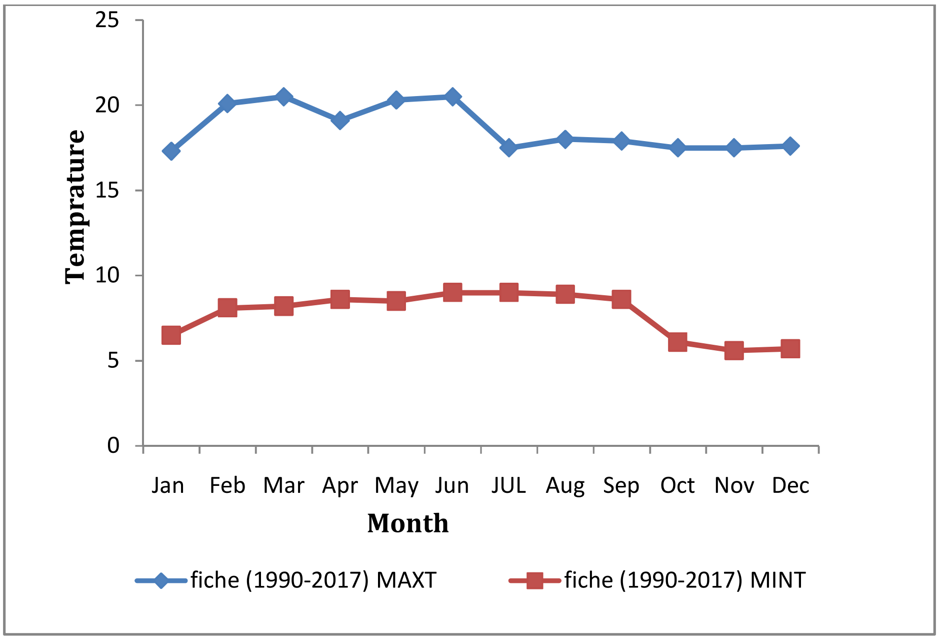

Figure 5. Mean Monthly Maximum and Minimum Temperature at Fiche station.

CHAPTER 3

3. GEOLOGY

The major geological formations and tectonic features of the research area were adopted from technical hydro geological report of Addis Ababa (2010) and Tilahun Azagegn et al. (2014).

3.1. Regional Geology

Ethiopia can be divided into four physiographic regions these are western plateau, south eastern plateau, main Ethiopia plateau and Afar depression.

The Precambrian basements of Ethiopia comprises a wide variety of sedimentary, volcanic and intrusive rock which have been metamorphosed to varying degrees (Getaneh, 1991).The extent of Mesozoic sediments in Ethiopia is revealed by the outcrops in the abay basin ,Mekele basin and denakil alps.

The Triasic –liassic adigrat sandstone formation rests unconformable on the Precambrian basements or with slight disconformity on sediments rock of the upper Paleozoic. Erosion surfaces (unconformity) developed before deposition of the adigrat sandstone formation and large scale down warping occurred in Triassic to Jurassic time resulting on the deposition of the alluvial fan, fluviatile ,lacustrine swampy and paludal facies of the adigrat sandstone formation in the blue Nile basin (wolela,2006).

A transition fancies developed between the adigrat sandstone formation and the hamanline limestone formation is also noted in the region.

The transitional interval is composed of mainly shale, sandstone, silt stone, limestone ,dolostone and evaporates the alteration of marine fancies and continental faceis reflects sources area variation and change of environments from continental environments to marine.

In the early Jurassic time a major transgression probably related to the drift phase and major sea level high stand occurred over the whole of eastern Africa, with the downward bedding of the craton as documented by the deposition of the antalo limestone formation.

In the late Jurassic to early cretaceous ,the sea began to withdraw from northern and central Ethiopia, resulting in the deposition of meandering river deposits and braided river dominated deposits of the debrelibanos sandstone formation; the youngest Mesozoic sedimentary rock of blue Nile basin (Getaneh ,1991,).

The Paleozoic and Mesozoic rock are exposed mostly in deep gorges. The general evolution of the tertiary volcanism in central Ethiopia is controlled by the process of uplifting and up warping.

The Mesozoic era transgression and regression event depositions of sediments, like Adigrat sandstone, which rests uncomfortably on the crystalline basement rock, Abet beds composed of gypsum and shale units, Antalo limestone which conformably overly the Abay beds, amba aradam sandstone; Tertiary and quaternary volcanic units includes: The Blue Nile basalts, amba aiba basalt, alaji rhyolites, Tamable basalt and Rift volcanic.

3.2. Local Geology

In the study area different litho-stratigraphy unit with distinctive stratigraphic set up in both sedimentary and volcanic rock unit (fig.6 and 8).

The brief description of the local geology of the area is as follows

- Sedimentary rock unit
- Volcanic Rock unit

3.2.1. Sedimentary rock unit

3.2.1.1. Paleozoic sediments (Pzst)

Lithologically they are represented by varying proportions of sandstone, siltstone, mud stone, shale and some Paleosoils. The sand stone dominates in the top part, while the shale is abundant in the lower most parts. Silt stone usually occupies the middle part and the mud stone occurs as intercalation within all the units. There is a development of Paleosoils with thickness 2- 3 meters between the lower part of Mesozoic sandstone and the upper part of Paleozoic sandstone. The thickness of Paleozoic sediment reaches up to 200 meters in some exposure.

They have variegated color ranging from light grey, reddish brown to yellowish grey. The sandstone is highly to moderately weathered with a characteristic of light grey when fresh but reddish brown when weathered and have medium to coarse grained texture with conglomeratic texture. They are highly compacted and at places shows jointing. There are also an intercalation of highly fractured shale and massive and compacted mudstone and siltstone.

3.2.1.2. Limestone (Antalo limestone) (Lst*)*

This unit is exposed in the northern, northeastern of the area. Most of the time limestone forms cliffs however at some places it shows gently sloping ridge.

The contact with the underlying mudstone formation is gradational which is marked by siltstone layer followed by calcareous siltstone, silty limestone and gradually to limestone.

However, the contact with the underlying gypsum unit is sharp (Assiged, G. 2006). This formation is characterized by alternating beds of marl and composed dominantly of slightly jointed and fractured limestone intercalated with thin beds of marl, shale and occasionally fine grained bands of sandstone. Most of the time the limestone appears as light gray & yellow; when weathered its color changed to dark, white and sometimes to deep yellow. At places, higher degree of weathering is observed, the precipitation of the secondary minerals such as calcite and silica are observed along fractures and weak zones. Structures such as karsts, chert nodules and stylelites are observed at the bottom of the limestone (Assiged, G. 2006) mentioned that the petrographic study indicated that this limestone has a range of texture from mudstone to wackstone and packstone.

3.2.1.3. Muger mudstone –siltstone Formation (Mmst)

It usually forms gentle slope at lower topography. It is overlain conformably by sandstone unit and underlain by antalo limestone having gradational contact in both cases.

The dominant types of rocks in this formation are mudstone, siltstone and shale. However, there are multiple beds of different intercalations. This formation has variegated color red colorful mudstone, light green to gray for shale and yellow to white for siltstone. It exhibits high degree of weathering. The main structures are laminations, cross laminations, ripple marks and bedding.

3.2.1.4. Debrelibanose Sandstone (Upper Sandstone) (Musst)

In most outcrops, this unit forms cliffs. The maximum thickness measured is about 328m. The thickness generally declines from East to west (Assiged, G. 2006). It has a sharp and unconformable contact with overlying basalt while with the underlying unit it has gradational contact.

The sandstone unit exhibits wide range of compositional variation ranging from top part yellow color, well sorted, medium grained to red color and conglomeratic cross bedded sandstone at the middle. The bottom part is dominated by jointed, fine grained white sandstone. This unit is slightly weathered at the top and highly weathered at the bottom. In general it exhibits coarsening upward sequence.

The upper coarse grained Sandstone unit is composed dominantly of sandstone with thick beds of conglomerates, thin beds of mudstone and shale, generally coarsening upward. The unit shows slight dip towards the south and southeast. In most parts of the basin, this unit outcrops below 2000 m.a.s.l. However, along the water divide between the Muger and Jema River sub-basins north of Fiche town, this unit outcrops at relatively higher altitude (over 2400 m.a.s.l.), attributed to its uplift before the eruption of Miocene shield volcanic centers located in the proximity. Regional faults also strongly disrupted the original stratigraphy position of this Unit (Tilahun et.al 2014) and there is mudstone rarely exceed a few meter in thickness intercalation of thin layer with sandstone and limestone.

Plate 1.Debrelibanose Sandstone (Upper Sandstone)

3.2.2. Volcanic Rock Unit

3.2.2.1. Trap series columnar basalt

This unit is exposed in northern and central parts of the map area in river valleys and canyons. It mainly forms steep slope cliffs and sometimes gentle slope. The contact with the underlying sandstone is characterized by abrupt nature.

This basalt has a dark grey color on fresh outcrops. Up on weathering, it has dark-brown, gray and reddish brown color. In this unit there is vertical compositional variation. The top part is composed of vesicular basalt. At the middle coarse grained basalt is noticed. The bottom of this unit is made up of columnarly jointed, cliff forming, relatively fresh aphanitic basalt. In general this basalt is characterized by well developed trap series columnar joints charatecterized with hexagonal faces, and cliff forming. The outcrops in the in the northeastern part of the study area overlying the sedimentary rock units.

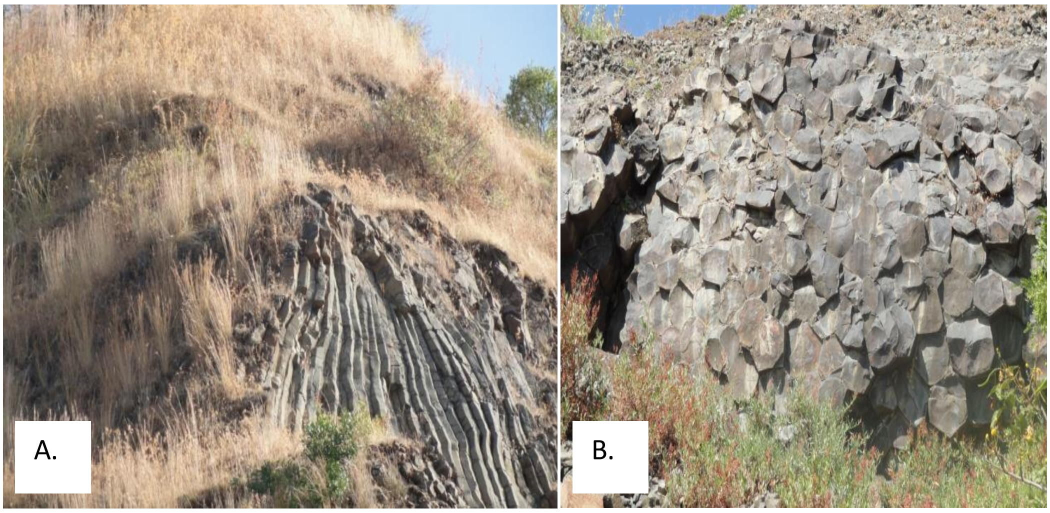

Plate2.Trap series columnar basalts A) Weathered jointed columnar basalt B) moderately jointed columnar basalt.

3.2.2.2. Trap series weathered vesicular basalt and Scoraceous Basalt unit.

This basalt is exposed in southern, central and southwestern parts of the study area. It mainly forms plateau and flat land resulted from fissural eruption. The trap series weathered vesicular basalt unit consists dominantly of highly weathered and altered basalts. Vesicular spaces in its lower domain are completely filled with amygdales of zeolites and silica. It exhibits stratified layers with varies compositions and structures.

The layers are fine to very coarse grained, aphanitic to porphyritic and sometimes very coarse grained phorphyritic basalt and vesicular basalt. Intense fracturing, columnar jointing and spheroidal weathering are very common features (Matebie, M., and et.al

2006) classify this unit in to phorphyritic aphanitic and very coarse grained porphyritic basalt based on compositional and structural variations. The rock shows high degree of weathering and fracturing. Scoraceous basalt unit consists dominantly of fresh to slightly weathered scoria and scoraceous basalts with thin intercalations of tuff.

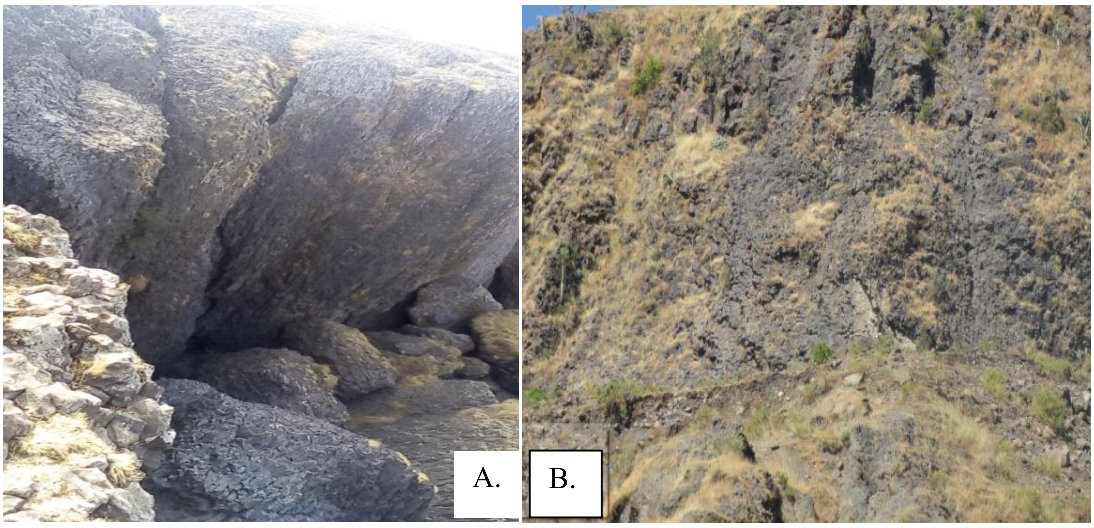

Plate 3. A) Weathered vesicular basalt B) highly weathered vesicular basalt

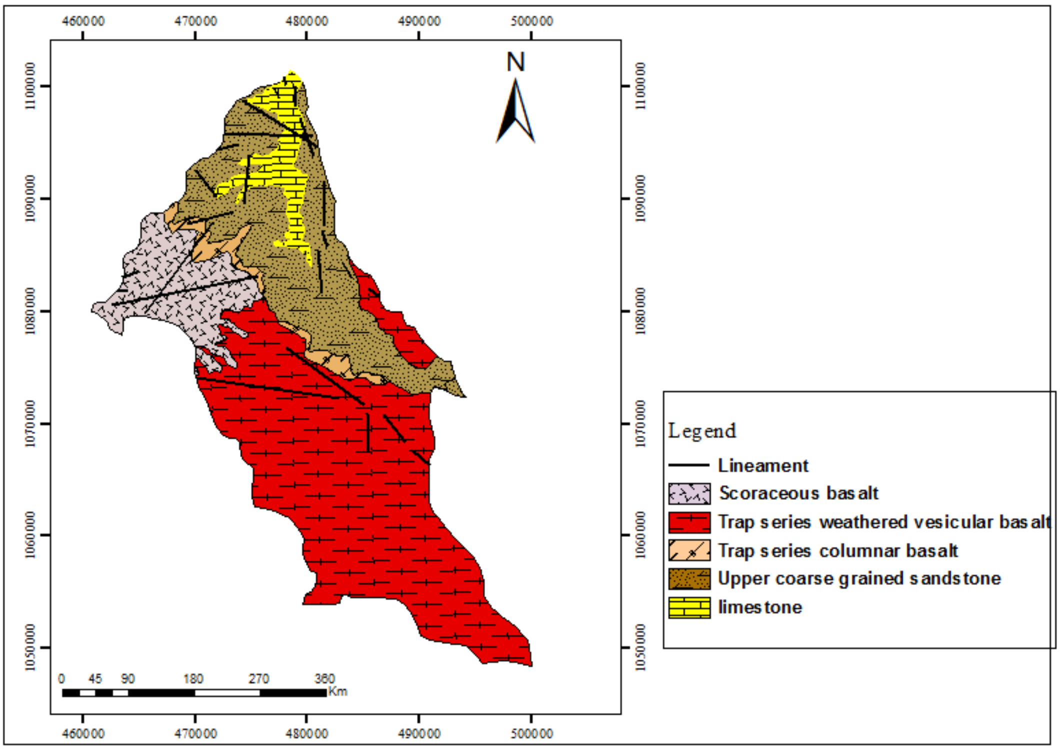

Figure 6.Geological map (modified from Tilahun Azagegn et al. 2014).

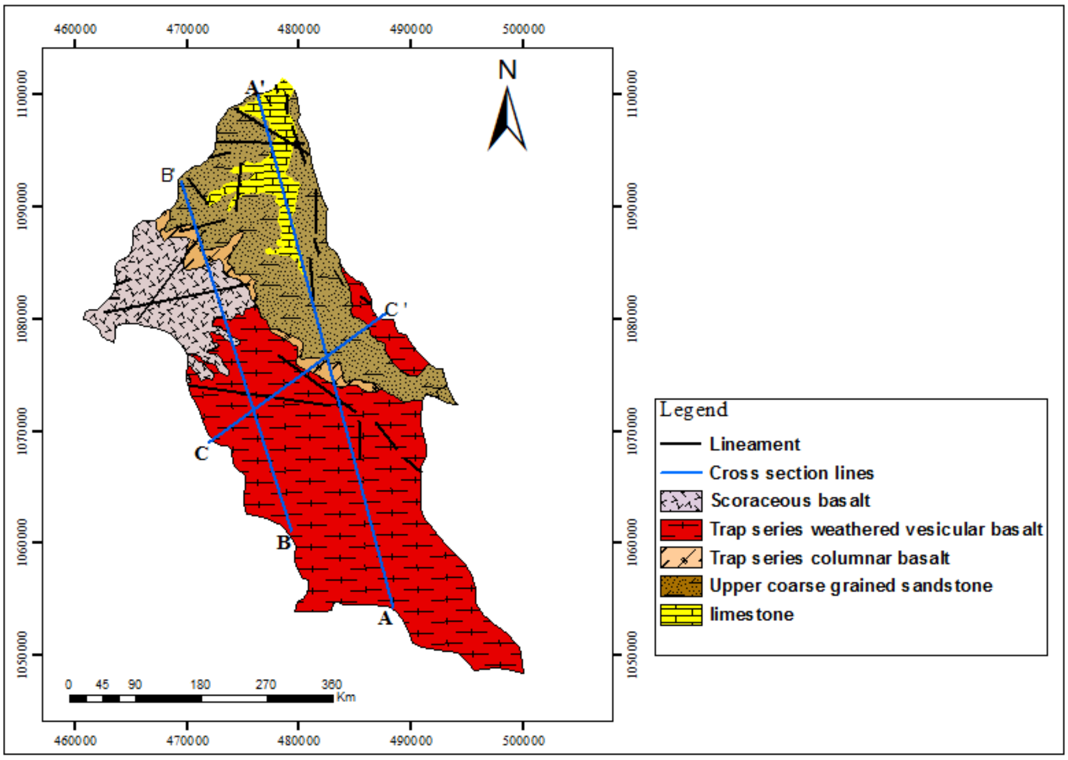

Figure 7. Geological map with cross-section selected.

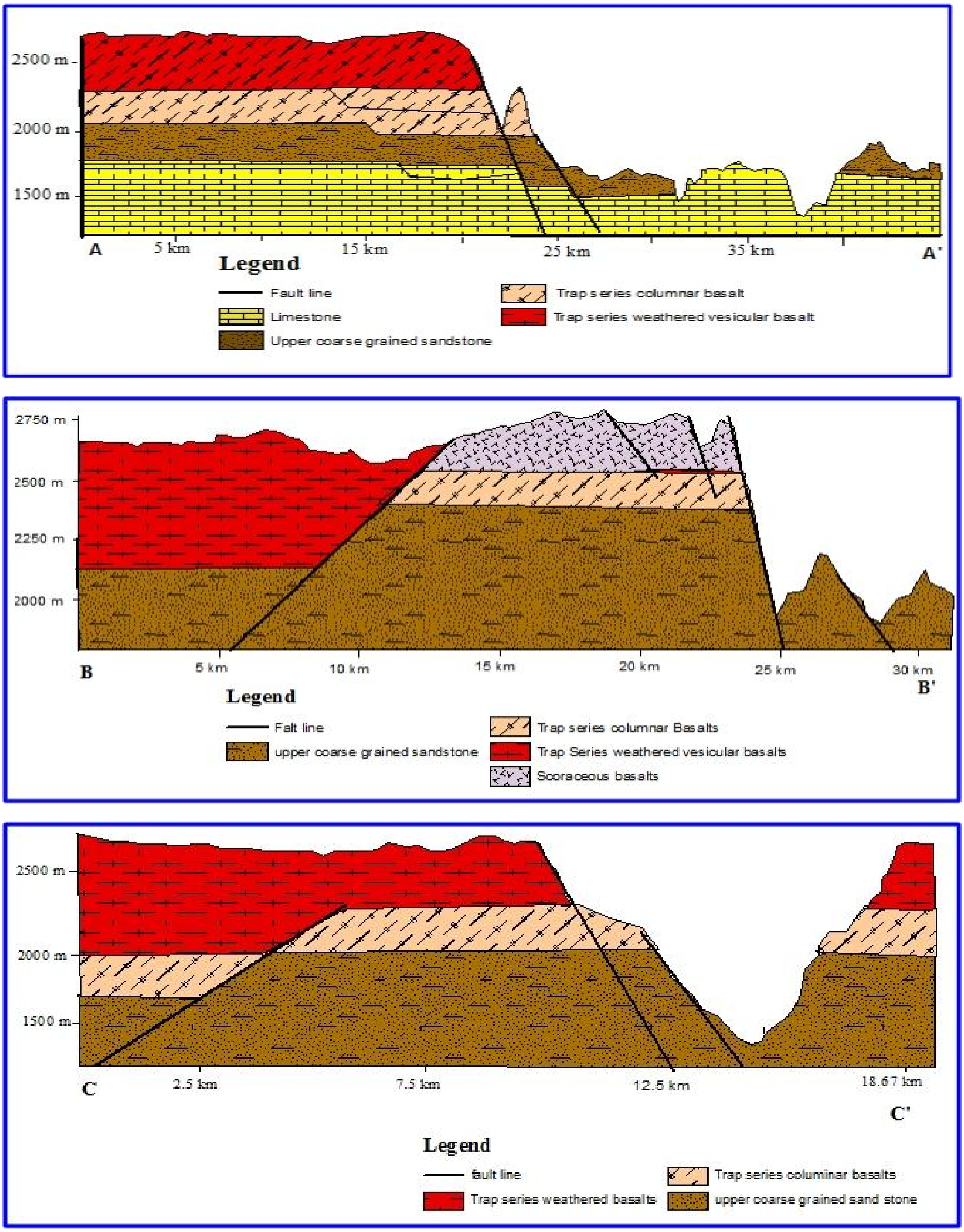

Figure 8. Geological cross-sections having hydro geological significance

3.3. Geological Structures

The main structures encountered in the area are lineaments, faults, joints and dykes.

- Lineament

The major lineaments in the study area trend NE-SW, NW-SE, N-S and E-W directions. The NE-SW lineaments being dominant in the area and they are parallel to the structures of the rift or rift margin. Most of the lineaments observed in all units. In addition there are some NWW and NEE trending lineaments which are more concentrated in sedimentary rocks. Most of the lineaments follow trends of liner of ridges, mountains and mainly river valleys and streams. The length of lineaments varies from few meters to about 12 km. (Assiged Getahun, 2006; Matebie, M., et al, 2006).

- Faults

Most of the faults are observed in the southeastern and northeastern part of the study area. These faults are trend NW and dip towards NE. They have a NE-SW trend.

- Joint

Joints are widely observed in the sedimentary and volcanic units. They are affected by NW-SE, NE-SW and N-S trending joint.

- Fracture

Local fracture are associated in lower basalts, limestone and sandstone unit. They have different orientation NNE-SSW, NW-SE, NE-SW, and N-S.

CHAPTER 4

4. HYDROGEOLOGY

4.1 General

The occurrence of ground water is mainly influenced by lithology, geological structures, and geomorphology and climate conditions. Lithology, geological structures and geomorphologic setting of the area strongly influence the quantity, quality and movement of groundwater. Since the climate condition throughout the area seems uniform, it has the same effect through the entire area. The geology of the area provides usable ground water and good transmission of rainfall to recharge aquifers, which produce springs and feed perennial rivers. Fractures, joints and weathering surfaces of different lithological units play a vital role in facilitating the infiltration amount and rate and also ground water flow. The majority of productive aquifers are characterized by their high degree of weathering and intense fracturing.

According to Tesfaye Chernet (1985) all rock units in the country were grouped into five major categories according to the type and nature of permeability of this rock.

- Sediment with dominant intergranular permeability
- Limestone and associated rock variable fracture fissure and karastic permeability.
- Volcanic rock and some sandstones, variable fracture and fissure permeability.
- Crystalline non-carbonate metamorphic and intrusive rock localized high permeability where fracture or deeply weathered.
- Other metamorphic and intrusive rock localized low or moderate weathered

4.2. Hydro geological classification

From Hydro geological reports of Addis Ababa map sheet NC-10 (2010), shows that classifications of different lithological units are made based on hydrogeological characterization of various rock types. This classification is also based on existing data. This study used the qualitative and quantitative parameter to classify the hydro geological unites in to aquifer/aquitards system. Since the quantitative parameters such as permeability, transmissivity, aquifer thickness and yield are not sufficient to make classifications, it is obligatory to assess the qualitative parameters in order to achieve on complete classification.

The qualitative classification is based on the ground water point data and pump test data, the major hydro geological units are characterization into pours permeability, fissured permeability and impermeability rock.

4.2.1 . Qualitative Parameters

4.2.1.1.Hydrogeological units with porous permeability

The ground water is available in the porous of unconsolidated sediments. The quaternary alluvium and Mesozoic sand stone represent dominantly the porous materials. The ground water availability and flow is mostly dependent on grain size, sorting, cementing material and thickness of deposition.

4.2.1.2.Hydrogeological units with fissured permeability

Most of the tertiary volcanic and Mesozoic limestone has fissured characteristics of permeability. The weathered and fractured surfaces play a significant role in ground water accumulation and flow. Majority of the tertiary volcanic are highly jointed and fractured but they are filled by secondary filling materials, which are a barrier for ground water flow.

4.2.1.3. Hydro geological units with impermeable nature

The fresh, massive and very surfaces limited fractures give the very low permeability and limited ground water occurrence characteristics.

4.3.The regional aquifer

The regional aquifer are constituted by the following lithologic units limestone intercalated with marl ,upper coarse sandstone ,columnar basalts ,weathered vesicular basalts and scoraceous basalts aquifer (fig.9) as shown below.

4.3.1.Limestone aquifer

The limestone aquifer is dominantly of jointed and fractured. The thick intercalated marl dominant in the lower level of the units limits hydraulic conductivity of this unit. Limestone receive ground water inflow from the overlain of upper coarse grained sandstone. This unit overlain by minor impermeable mudstone and associated paleosoles layer which hinder ground water transfer from volcanic rock.

However this unit is form of cliff and steep slopes in the gorges. In the northern part of the study area this unit form gentle slope. The impermeable mudstone and associated Paleosoils limits the hydraulic conductivity. Moreover due to regional fault zone the lineament density on this is low leading to its hydraulic conductivity.

4.3.2. Upper coarse grained sandstone aquifer

Upper coarse grained sandstone is dominantly composed of cemented coarse grained sandstone layer of conglomerate with mudstone and Paleosoils. The sandstone and conglomerate have high primary porosity. Where outcrops on gentle slope in the study area of Jema river sub-basin. This unit receives direct recharge from precipitation or from flood water from surrounding volcanic highlands. In the northern part of the study area the moderate lineament density allows the units to receive and store a good. Amount of ground water depth to ground water is shallow where unit is form gentle slopes. Because of pumping test data not available so its hydraulics properties could not be quantified. However its general uplift during sub-regional faults complicated the geometry of the strata and oriented NW and E-W direction.

4.3.3.The Trap series basalt aquifer

They have good water bearing characteristic with a variable mode of occurrence. Mostly their vesicular nature and boulder forming characteristics makes them a good aquifer with good groundwater occurrence and movement. However, the vesicles are filled by secondary materials; weathering process gives them a relatively good permeability. In northwestern part of map area this unit forms domes and hills and have poor groundwater availability instead they act as good recharge area to the underlying Aquifer. The trap series columnar basalt unit's outcrops on wide and direct recharge from precipitation is low. This unit from moderately hydraulic conductivity due to secondary porosity. Higher transmissivity value is associated with boreholes drilled close to stream course along higher lineaments density zone.

4.3.4. The scoraceous basalts aquifer

The scoraceous basalts aquifer is composed dominantly of scoria, scoraceous basalts and boulder of basalts with very thin of trachytes, rhyolites and palaeosols.This unit high hydraulic conductivity attributed to its high primary porosity The permeability is highly dependent on the degree and depth of fracturing and occurrence of joints development on scoraceous basalt gives to the good hydraulic property of the aquifer. Most fractures due to faulting are responsible for emerging of many springs.

In some places the development of thick soil act as good recharging media to his aquifer by hold the precipitating water which will percolate later through fractures to the aquifer.

Columnar joints developed on tarmaber basalt act as ground water discharge features at topographic breaks when enhanced by weathering.

4.4. Aquitard and/ or minor aquifers with limited groundwater resource.

The very poor hydraulic conductivity and permeability of the mudstone unit makes them an impermeable layer. They have a clay nature of high porosity but low permeability.

Their occurrence as intercalation of impermeable layer has a significant hydrogeological importance. There were no ground water points inventoried from this unit (fig.10). But there may be a probable of getting seepage through pore spaces of siltstone formation. Most of the time it acts as impermeable layer for appearance of springs at the contact with overlying sandstone.

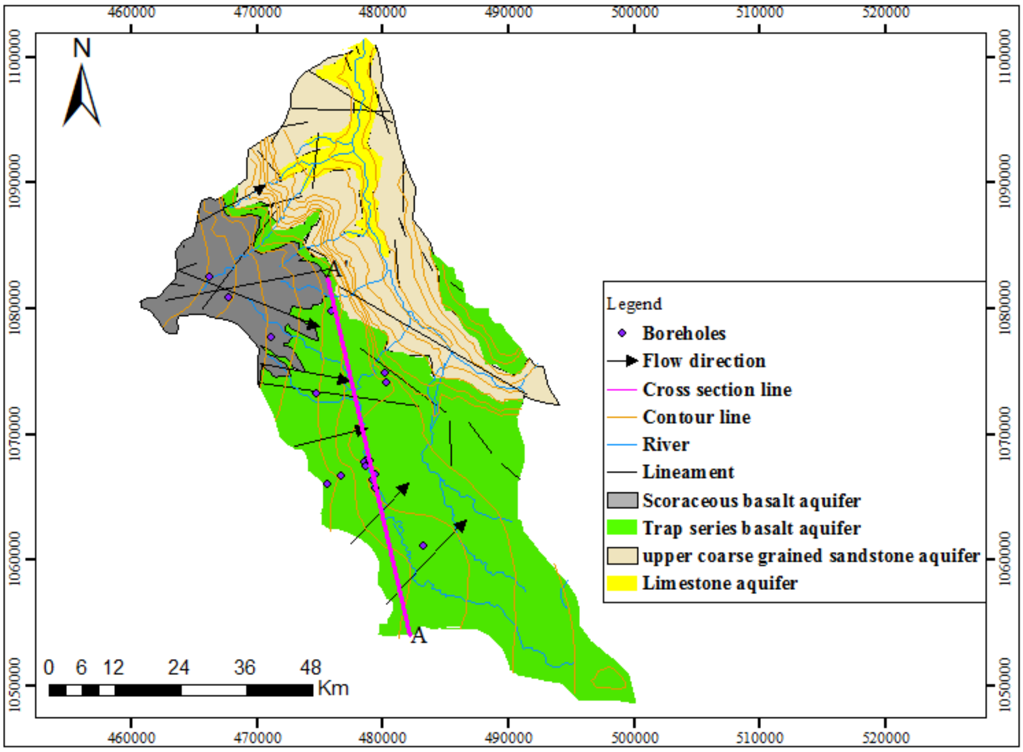

Figure 9. Simplified hydrogeological map of the study area (Modified from Tilahun Azagegn et al., 2014)

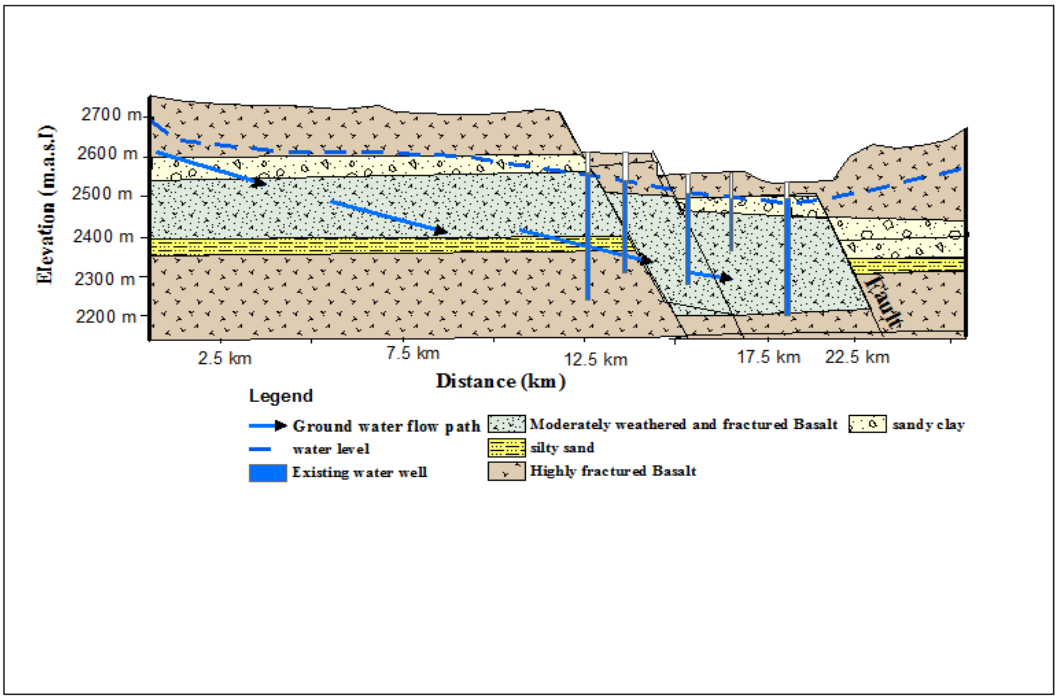

Figure 10. Hydrogeological model for local flow and geological cross-section

4.5. Hydrogeological Structures

Structural features, such as fractures, joints and faults, the geometrical properties of the geologic system produced by deformation or crystallization (Freeze &Cherry, 1979) may provide secondary hydrological properties to the various rock bodies, notably increased water transmissivity.

The hydrological structure describes the configuration of aquifers within the geological environment. It determines the ground water circulation from the recharge area, along percolation and circulation pathways (ground water reservoir) to the drainage area. The north part of the area is structurally simple and occasionally tectonized whereas the southern part of the study area is highly tectonized and is complex in structure since its vicinity to the main Ethiopia rift margin. The main structures encountered in the area are faults joints, lineaments and dikes.

There are few normal faults in the area. They are mainly found in north eastern, north western and southern part of the area. The dominant faults are those associated with the MER trending NE-SW faults. They are also N-S and S-W faults. They cut Mesozoic, sedimentary and tertiary Basalts. The NE-SW and N-S faults are act as good ground water conduits in the north western and southern part the study area.

The major lineaments in the study area trend NE-SW lineaments being dominant in the area and they are parallel to the structures of the rift or the rift margin. Most of the lineaments follow trend of linear of ridges, mountains and mainly river valleys and streams. The length of lineaments varies from few meters to about 12km. (Assiged, 2006; Matebie meten et al. 2007).

Joints are widely observed in tertiary basalts and upper sand stone. The E-W and NW trending joints are more common on the upper sand stone. Most of the joints are filled by secondary material such as calcite, iron oxide and silica and feldspar.

The occurrence of many springs at the foot of the former and thermal water along the latter may indicate the conductive nature of this fault.

These features are more observable in northern and central part of the area cutting the basalt Mesozoic unites. They are parallel and oriented in the NE direction with maximum width about 2 meters (Assiged, 2006). Its composition varies from pyroxene phyric to aphanitic and vesicular basalt. In general, dykes are barrier to ground water circulation but in relative term, the surface of basic dykes is fractured and slightly weathered. As aftermath, dykes may have some contribution for ground water circulation.

4.6. Ground Water Recharge

The major source of recharge to the ground water is highly sloping plains of the study area. In addition, different perennial rivers and streams of the area recharge the local ground water. Most of the hand dug wells and shallow wells placed along the rivers and streams are recharged by such condition in dry season. There are three types of recharge direct recharge: water added to the groundwater reservoir in excess of soil moisture deficit sand evapo-transpiration by direct vertical percolation of precipitation through the unsaturated zone (Mekdes, 2012). Indirect recharge: it is percolation to the water table following runoff and localization in Joints, as ponding in low lying areas or through the beds of surface water sources such as rivers, lakes and reservoirs. Localized recharge: resulting from horizontal surface concentrations of water in the absence of well-defined channels. However, estimating the different recharge processes is not simple. It requires understanding the various processes that affect recharge and quantifying the spatial and temporal variability. Unfortunately, there is no direct means of measuring groundwater recharge at regional and sub-regional level. Recharge estimation requires accounting the different factors. These include;

- Topography and geology
- Precipitation (intensity, duration, spatial distribution)
- Runoff and ponding of water
- Rivers (rivers flowing into and leaving out of the area under consideration, rivers Gaining water from or losing water to the aquifer, etc.).
- Soil zone (nature of the soil, depth, hydraulic parameters, variability of the spatially and with depth, rooting depth of the soil, and cracking of soil on drying out or swelling due to wetting).
- Unsaturated zones between soil and aquifer (flow mechanism through unsaturated zone, zones with different hydraulic conductivity, etc.)
- Ability of aquifer to accept water and variation of aquifer condition with time all the three types of recharge can be identified in the region. However, direct recharge and indirect recharge from rivers are the most important ones.

However in the study area due to impermeable rock and barrier fault form cliff, where direct recharge to the aquifer is low.

4.7. Ground Water Discharge

According to Jiri Sima et al. (2009) Ground water discharge areas are located on gently sloping and undulating plateau, inter mountain depression and at the middle and bottom of high cliffs of deep gorges. In most places, the ground water discharge areas are indicated by the appearance of springs. A lot of springs emerge at the weathered and fractured parts of topographic break, inter mountain depressions and high cliff of deep gorges. It is observed that the discharge of this groundwater is due to the presence of thin impermeable layers. Hydraulic conductivity resulting from lithological variation along cliff variation in the extent of weathering of the same rock along cliff and variation in degree and extent of fracturing. So it should be emphasized that the topographically of this ground water is due to the presence of thin impermeable layers in the middle or elevated ridges can also act as low discharge areas.

The variations of age and elevation affect the weathering and fracturing of volcanic rocks to give variable recharge and aquifer characteristics. Moreover, these structures are also affected the distribution of groundwater and its location in the area. All the above factors affect the groundwater distribution and aquifer characteristics of the area.

4.8. Water point inventory

Springs

Most of the springs are located at hill side of deep gorges and ridges and slop breaks of undulating plateau. However, they are also some springs located at the flat land. The springs of the area are dominantly depression and fracture type. There are also springs with contact and karast nature. In most places the occurrence of springs follows the NE-SW and N-S trending faults and lineaments.

They are found almost all types of lithologic unit with high variation in discharge. From Hydro geological Reports of Addis Ababa map sheet NC-10 (2010), field inventory and reported data shows that the discharge in dry season period shows wide variation ranging between 0.05-35 l/s on basaltic aquifers, 0.01 -1.5 l/s on ignimbrite, trachyte, rhyolite aquifers, 0.01 -2.5 l/s for alluvial and elluival sediments and 0.02-40 l/s for Mesozoic limestone and sand stone.

Most of the springs at gentle sloping plateau and flat lands covered by high productive basalt aquifers are developed for community use.

Borehole

Almost all boreholes drilled in the study area have water bearing units of basalt aquifers. Most of the bore holes have a total depth from 50 meters to 275 meters.

Unfortunately on the study area shallow wells are dominant, but there are some deep wells drilled by WWDSE, OWWDSE and WWDE with promising yield on those areas. Collected data and field inventory shows that, the yields of boreholes increase as the depth increase. In general all existing data reveals that the static water for basaltic aquifer ranges from artesian to 50- 60 meters below ground level.

Hand dug wells

The abstraction water using hand dug well is very common in the study area .Most of the hand dug wells are sunk on flat and gently sloping terrain on the recent deposits, alluvial fans and highly weathered basalt they are used for small community water supply. Most of them have a depth ranging from 10 to 25 meters below ground surface with average yield of 0.2 l/s.

4.9. Ground Water movement

The ground water flow of the area seems to follows the surface water flow and it is highly dependent on the geomorphology and structures. Small intermittent and perennial rivers that feed local aquifer follow those alignment lineaments, where the ground water flow also follows such pattern.

The direction of emergency of spring points on the tertiary volcanic and Mesozoic sediments are some show structurally controlled, indicating the structural tendency of ground water flow. It is also highly dependent on the surface water flow from (fig.11) shows that the ground water flow direction identified from the pattern of the water level contour map of the aquifer. The contour spacing becomes wider in the flat lying topography of the upper part of the area.

Ground water flow following the general surface of topography because the fault convey ground water barrier or hinder to low elevated areas. Therefore the flow direction converges into the respective river flow direction. Therefore local geomorphic setup and subsurface configuration of permeable and impermeable rock unit also control depth and pattern of ground water circulation in the area.

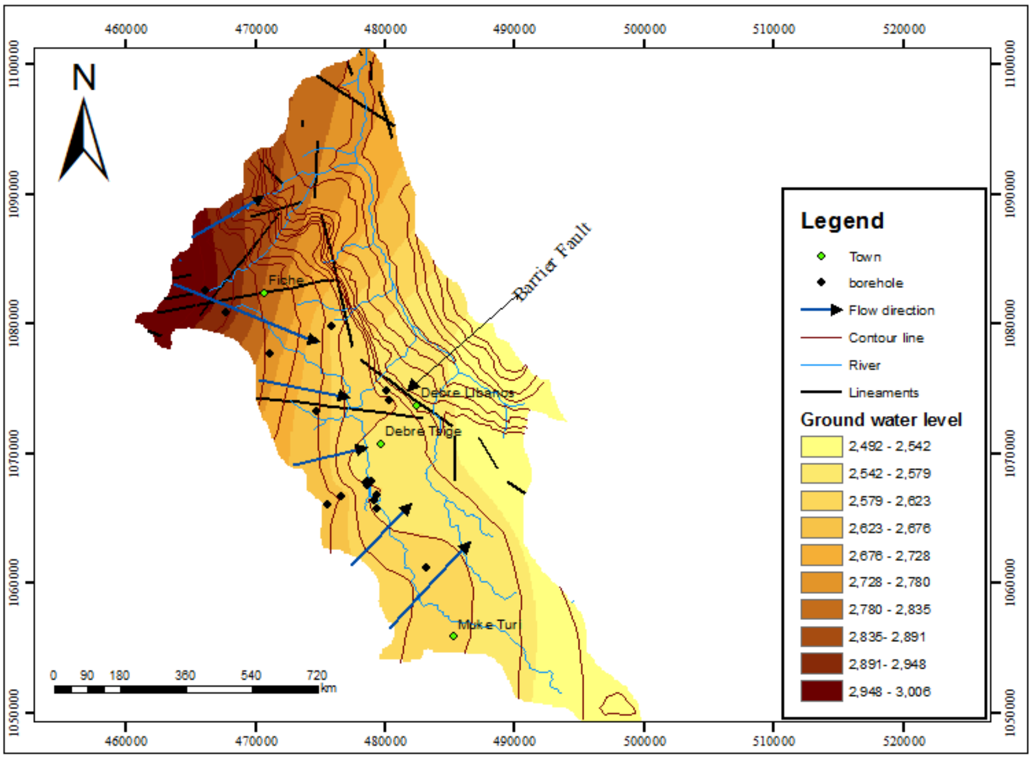

Figure 11. Groundwater level contour map and the general groundwater flow direction.

CHAPTER 5

5. RESULTS AND DISCUTION

5.1.Introduction

The aquifer properties of the study area controlled by the litho-stratigraphy of the volcanic and sedimentary rock units. The sedimentary rock aquifer in the study area are controlled by rugged erosional terrain, the dislocation of sedimentary beds due to tectonic activities, and intercalations of fine grained clastic terrigeneous rocks in sandstone and limestone units. These factors that affect the sedimentary rock aquifer to be less productive compared to aquifer in similar geological terrains.

5.2.Structural Evidence

Mainly based on field evidence the indications of what the characteristics of geological structures and the assumptions are presented. The different structures are discussed separately. The study area has a complex structural setting marked by extensional tectonics (fractures, joints and normal faults) related to the evolution of the active MER (Tsegaye Abebe, 1995; Tsegaye Abebe et al., 1998).Sedimentary rock of the study area found in rugged terrain.bed are also dislocated and highly affect by normal fault of big magnitude of displacement.

Plate 4.Fault plane of the study area.

5.2.1. Fractures and joints

Lineament (fracture and joint) density is high on lithologic units outcropping close to along older tectonic zone (Fig.12). In the study area the older units, notably the mudstone intercalation, limestone and the upper coarse grained sandstone units was affected by lineaments dominantly oriented NW–SE.

The volcanic rock unit the trap series columnar basalts unit, weathered vesicular basalts units was affected by lineaments dominantly oriented NW–SE and NE-SW.

Scoraceuos basalt units are younger volcanic rock highly fractured and jointed with major lineaments orientation along N-S, E-W and NE-SW direction.

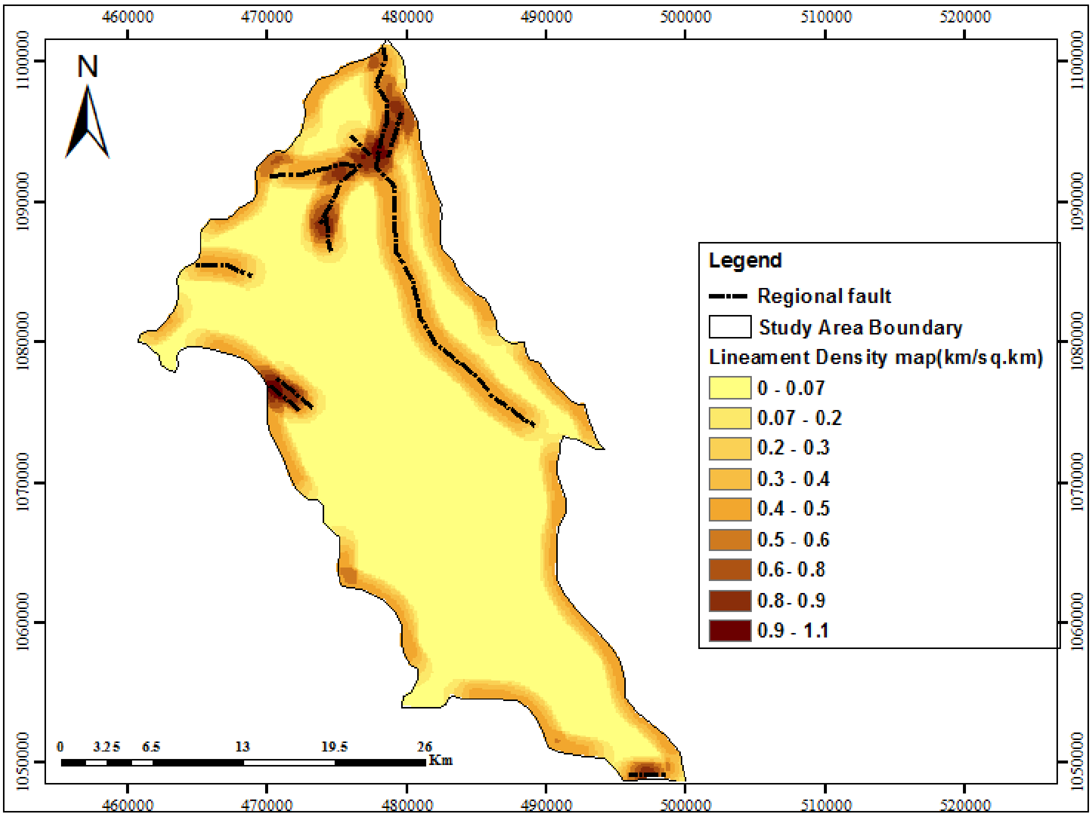

Figure 12. Lineament density Distribution map

The younger volcanic rock units are highly fractured and jointed. With major lineaments orientations along NE-SW, E-Wand N-S directions.

The strike orientation of joint, fracture and lineament of sedimentary and volcanic rock unit plotted on rose diagram (Fig.13) shown below.

The lineament density of the mudstone intercalated is very low (Fig. a).The unit is affected by slight penetrative to non penetrative, non extensive joints. The dominant joint set orientation is nearly NW-SE strike 140^0 and 150^0 and from NE-SW (strike of 50^0 and 60^0).

The limestone and unit is affected dominantly of slightly jointed and fractured and the orientation of joint set and fracture of different sizes. The dominant orientation of the joint set is nearly NW-SE strike of 140^0 (Fig.b).The major fault system that cause significant disruption of the limestone block are NW-SE, N-S and NE-SW ruining.(Fig.8)

The upper coarse grained sand stone of the study area the dominant joint set orientation is nearly NW-SE (strike of 118^0-120^0) and to lesser extent joint oriented from NE-SW direction exist (Fig.c).The unit slightly dip towards SE and the outcrop in the study area relatively at higher altitude and strongly disturbed by regional fault.

The trap series columnar basalts unit is slightly jointed with dominate joint set orientation of NW-SE (strike of 160^0) and from NE-SW orientation (strike of 55^0) as shown (Fig.d) below.From geological cross-section map of9 fig.8) above the major fault block system NW-SE and NE-SW running.

It outcrops in the northeastern part the study area overlying the sedimentary rock units, representing the earliest flood basalt volcanism in the area.

The fractured and weathered trap series weathered vesicular and where observed densely distributed in the study area and highly weathered and altered basalts. The dominant joint set orientation is nearly NW-SE (strike 155^0) and to lesser extent NE-SW (strike 70^0) orientation is exist (Fig.e).

The scoraceous basalts unit moderately to highly jointed and fractured in same locality. With dominant orientation of the joint nearly NE-SW strikes of 30^0-35^0 (Fig.f).

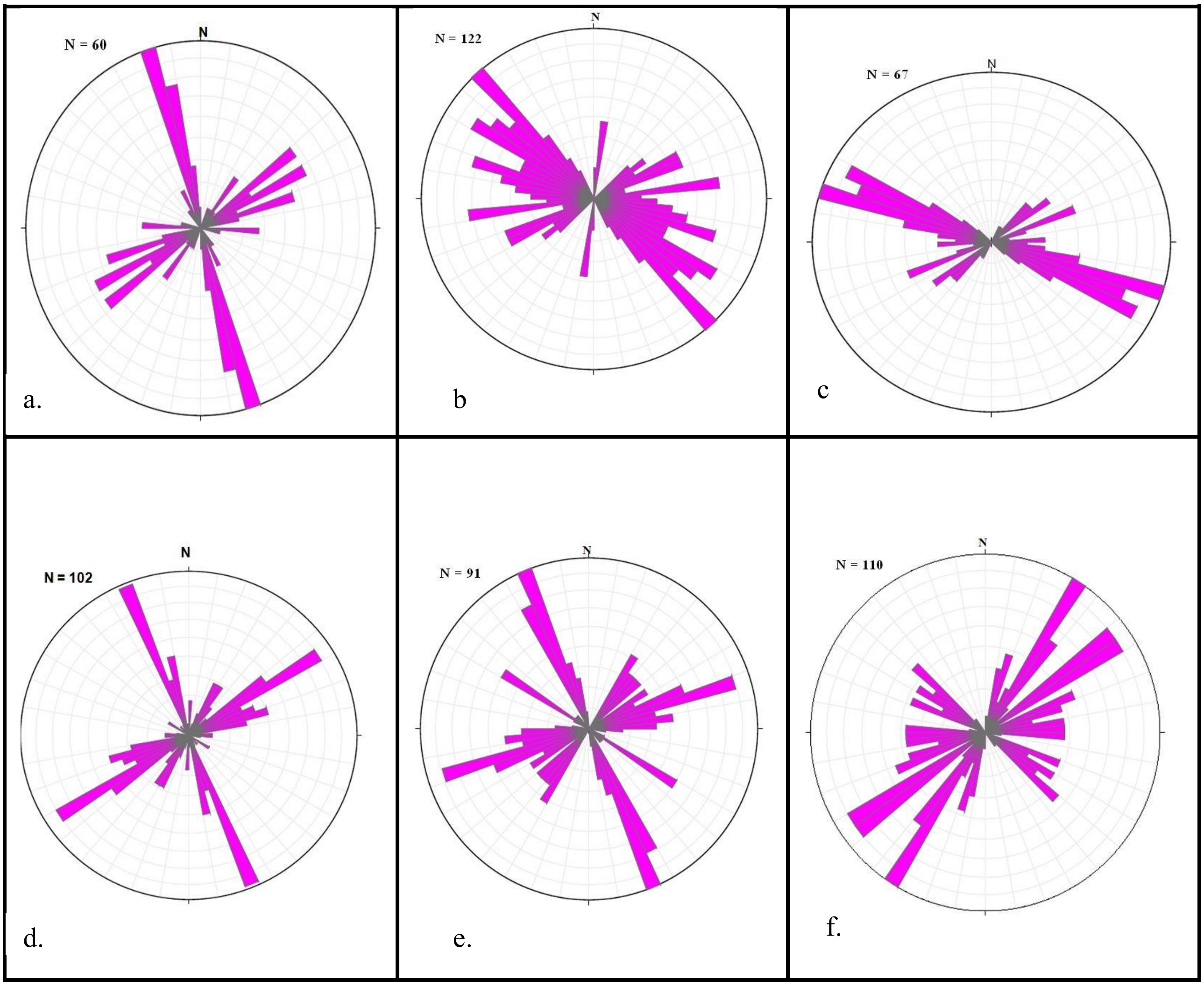

Figure 13. Rose diagrams of joint orientations on the (a) Mudstone intercalated (b) Limestone (c) Upper coarse grained sand stone (d) Columnar basalts (e) Weathered vesicular basalts (f) Scoraceous basalts.

5.2.2. Lithological contact

As indicated that the unconformity in the study area along deep gorges in the basement showing horizontal, bedded sandstone and basalt layer of the formation. There is sharp and unconformable contact with overlying basalt while with the underlying unit it has gradational contact. With no visible hydraulic connectivity with the overlying aquifer. The dip of these sediments is downward sloping barrier. The aquifer flow would appear follow these joint and then be deflected with the lithogical contact between aquifers and aquitard elsewhere in the study area. At this interface there is very low hydraulic conductivity.

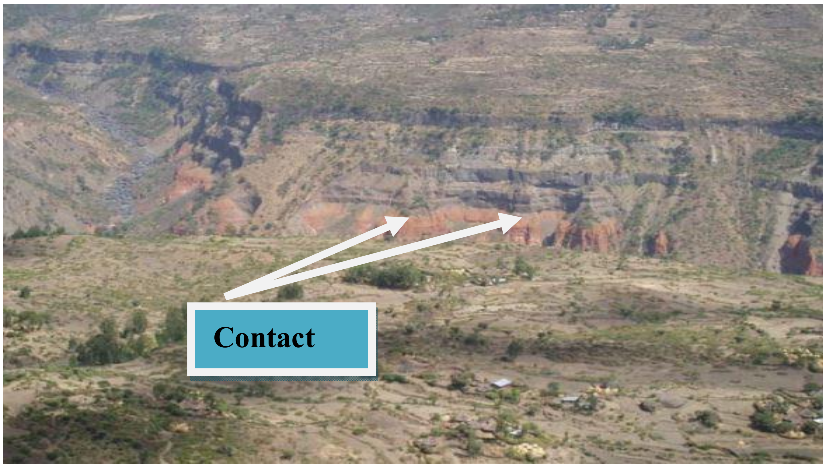

Plate 5.Contact between Tertiary volcanic and upper grained sandstone

5.3. Hydrogeolgical Evidence

The evidence from water Level and field Water chemistry presented below to explain the link with flow and structure.

5.3.1. Water Level measurements

The water level data obtained from different field measurement and different database were mentioned above (fig.11).In the northern western of the study area water level high .There is ground water watershed which has high on the northern and north western part of the area. Water levels are required to help launch hydraulic gradients and as outcome of that, directions of groundwater flow, rates of groundwater flow and locations of groundwater recharge and discharge the amount of water in storage in aquifer the change in storage over time and aquifer hydraulic characteristics. In the study area from the general flow direction due to fault barrier and impermeable rock between volcanic and sedimentary rock divert the direction of ground water flow to Gur river catchment.

5.4. Physico –chemical water characteristics

A physico-chemical parameter is considered for domestic water use.

Borehole chemistry data of EC and pH for selected hole in dataset were compiled. The parameters considered for the quality test are conductivity, PH, and temperature.

Temperature: groundwater temperature, as a function of surface elevation, shows that temperature increases when surface elevation decreases. Water temperatures in the in the trap series basalt aquifers have relatively higher mean temperatures. This is mainly governed by their location in the area i.e. in the study area the temperature of water from borehole measurement is at from the minimum temperature 13.8 and maximum temperature is 21.8^{0}c.

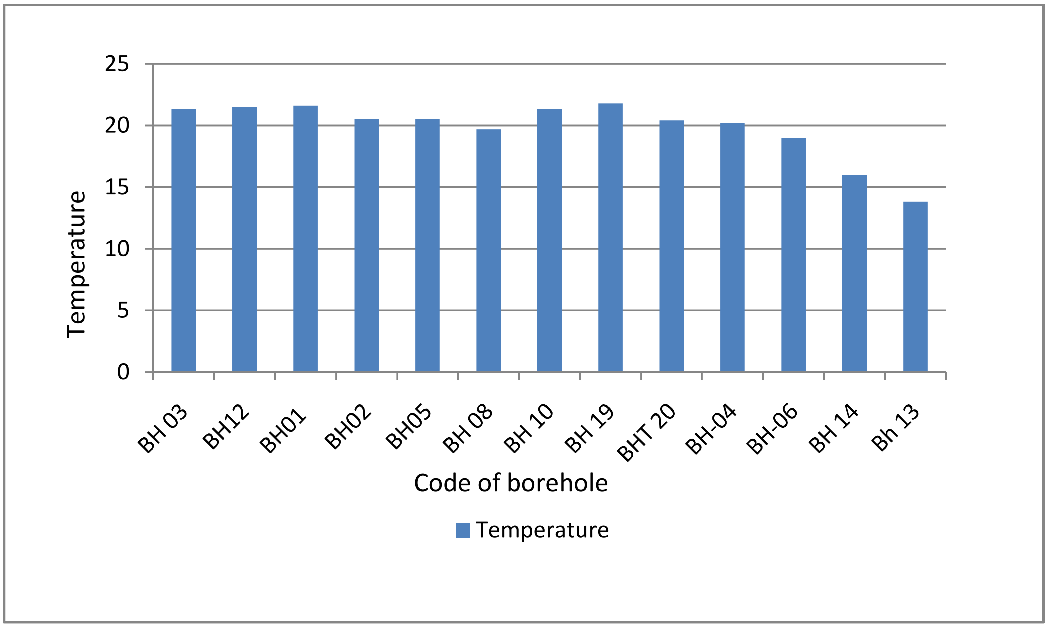

Figure 14 .Temperature of various boreholes

Electrical Conductivity The electrical conductivity is a measure of the ionic strength of water. Conductivity relates to the nature and extent of various dissolved substances, as well as their actual and relative concentration. The measured conductivity value may indicate the extent of salinity in the water. The data was analysis using ordinary kriging to compiled there was a noticeable relation with the major faults.

The EC data plotted for the study area shows fig (14) there is a very wide spread of data point and interpolated based on this seem not to show up any pattern that may be inferred as faults control. However there was a generalized increases in EC values at the middle part of the study area with peak in the eastern and decreases along a high elevation from the northwestern.

The expected lower values in the northern and eastern mountain due to high recharge show a slight indication of bounding between faults.

At the catchment where ground water flow direction follows and at high ground water storage EC can be high. Therefore due to fault barrier there is low transmitting water and EC to the deep gorge area of the study area.

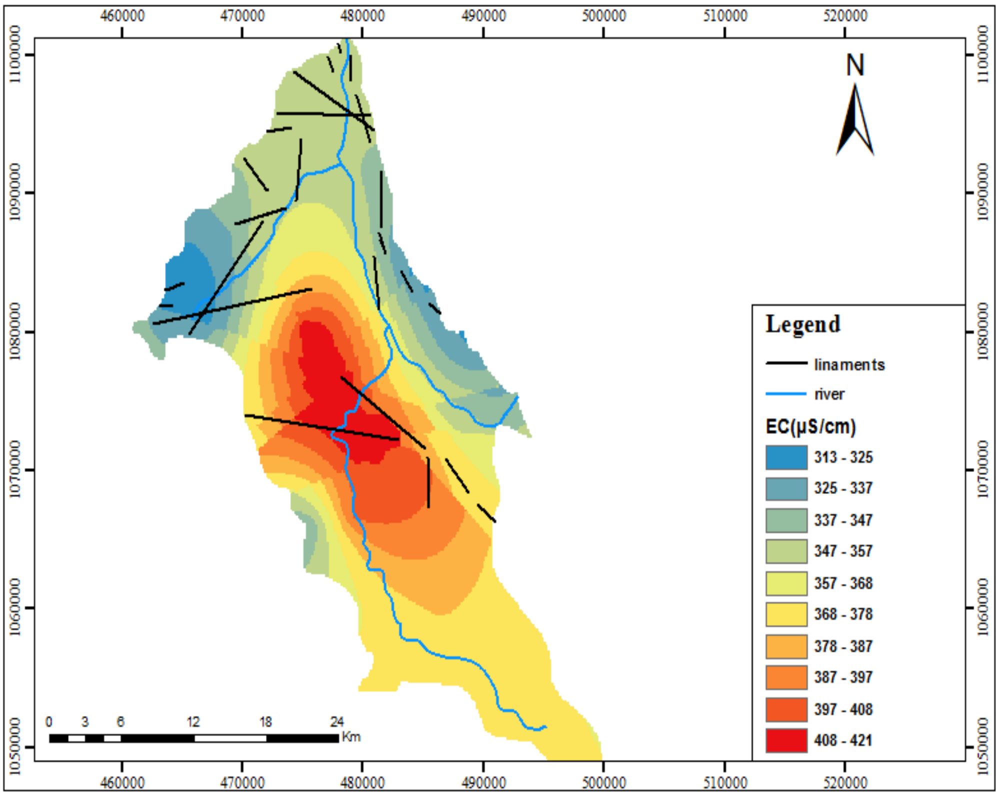

Figure 15.EC value contours (using ordinary kriging)

PH is a measure of water quality of acidity and alkalinity. The data speared was very wide with fewer data point in the NE and eastern part of the study area and higher value from the southern part of the area this may suggest that deep flow discharge, possible from the northern mountains.Altenatively it could be a response to the volcanic underlying area.

The very low PH values in the extreme NW and northern appear where the recharge is taking place. Water with PH in range of 6.5 and 8.5 is suitable for drinking.

In the study area the pH value measured 7.3-8.7 this indicates that water from the study area is suitable for drinking in regard to PH.

The data speared was very wide with fewer data point in the NE and eastern part of the study area and higher value from the southern part of the area this may suggest that deep flow discharge, possible from the northern mountains. Alternatively it could be a response to the volcanic underlying area. The very low PH values in the extreme NW and northern appear where the recharge is taking place.

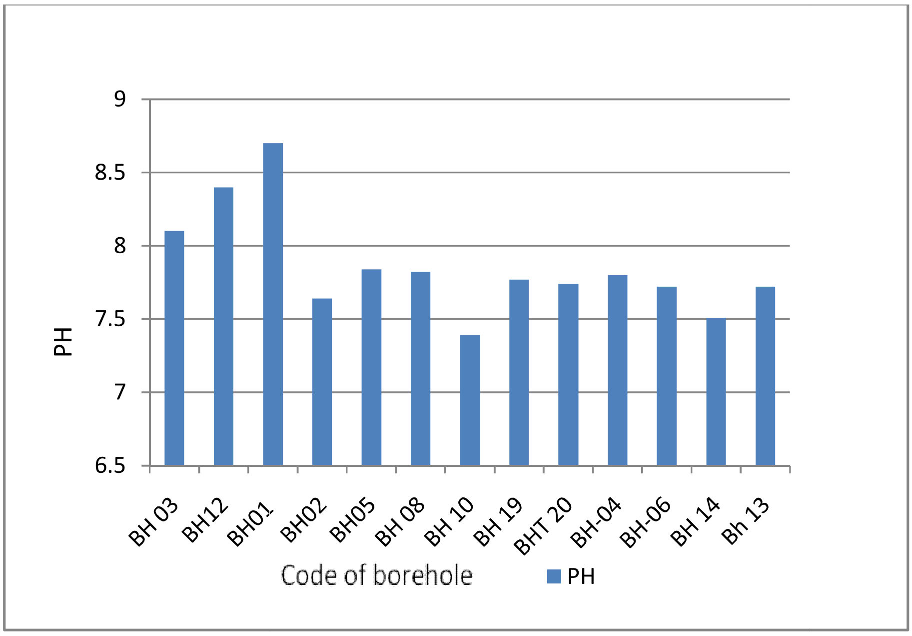

Figure 16. PH in various boreholes

Water quality analysis results taken from pumping test data of WWDE and OWWDSE the water type of the study area is predominantly bicarbonate type (Ca-HCO3, Na-HCO3).It means it has relatively high sodium & calcium cation and bicarbonate anions.

Ground water storage and flow varies widely due to difference in texture and structure of the geological units. This factor Influenced as to hindering ground water flow or deflected ground water flow direction.

The fault system form structural depression which is filled by sedimentary rock unit and covered by the tertiary volcanic. These volcanic unit covered have high productive. Limestone and upper course grained sandstone show high depression which is strongly disturbed by structure along the deep gorge with varying attitude of geological structure act as low permeability boundaries.

The productivity of volcanic aquifer is determined by the primary and secondary porosity of the rock unit and topographic setup. The volcanic aquifer unit the fractured basalt and scoraceous as well as trap series columnar basalts have moderate to high moderate hydraulic conductivity. The recharge from high elevated areas contributes to higher groundwater storage for lower elevation volcanic rock unit.

The fault and associated fracture that affected transmit ground water from the overlaying volcanic rock to those of sedimentary rock unit. The deep gorge of the study area form cliff where direct recharge to aquifer system is low. Generally the fracture and fault between volcanic and sedimentary rock unit influence groundwater barrier.

The outcrop of the valley sides deep gorge there is the process of landslide/rockslide occur due to high erosion structure exist. The ground water flow probably follow the same weak zone and divert the lateral flow direction. Therefore the fracture and joint act as conduit through which ground water flow or barrier.

Hence the impact of topography is significant for low aquifer yield on the high erosion and irregular geomorphic terrain of the lower study area.

In the study area of the ground water is productive in relatively on flat topography at volcanic rock units. This volcanic rock aquifer can be considered as high porosity medium. Due to the fact that both the matrix and fracture porosity contributes to the circulation and storage of groundwater.

CHAPTER 6

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The objective this studies to provide the structural factor on ground water dynamics with, characterize lineaments orientation and ground water flow direction from the water level and lineaments orientation measurements.

The integrated approach and methodology has indicated that attitude (strike) of joint, fracture and fault were plotted on streoplot (rose diagram) software to identify major lineament patterns. Lineaments were extracted from DEM Musing Geomatica software different lineament density were mapped using kriging interpolation tools in Arc GIS 10.3.

Water level contour was obtained from measure of well by using deep meter,EC,and PH was used for each borehole and the data imported into Arc GIS 10.3.The method used of calculating the data was ordinary kriging which was found to give satisfactory interpolation between data point.

The lineament density is high on lithologic units outcropping close to the older tectonic zone in the study area limestone and upper coarse sandstone units was affected by lineament dominantly oriented NW-SE.As well as highly jointed and fractured trap series columnar basalts and Trap weathered vesicular basalts also oriented NW-SE and to lesser extent NE-SW orientations. The scoraceous basalts dominantly oriented to NE-SW. Due to barrier fault between sedimentary and volcanic rock aquifer influenced on ground water movement.

From hydrogeological the general flow direction follow to the respective river flow. Because the geological structural and subsurface configuration of permeable and impermeable rock unit hinder on ground water ground water flow.

The volcanic rock unit have high productive. Sedimentary rock aquifer show high depression which is strongly disturbed by geological structure with varying attitude act as low permeability boundary and have low productive to the deep area of the study area. Therefore ground water follows the same weak zone and also diverts the lateral flow direction to the Gur river catchment. Hence fracture and joint act as conduit through which ground water flow or barrier.

6.2. RECOMMENDATIONS

Based on the methodologies employed, information gathered, analysis made and findings of the research the following could be recommended:

- ✓ Further investigation is required with all possible method detailed litho-structural with hydro geological investigation needed.
- ✓ Using all available borehole data for selected area within blocks or fault bounded zone detail investigation of water level should be done to establish impact of structure.

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Appendix 1 .Field measurement data of different geological structure in different geology units

Lithology	X	Y	Z	strike from N
Mudstone intercalation	480240	1074280	2604	230
	480241	1074281	2614	215
	480242	1074282	2605	210
	480244	1074283	2618	200
	480243	1074283	2624	205
	480245	1074284	2634	255
	480246	1074285	2664	250
	480247	1074286	2628	256
	480248	1074287	2629	240
	480249	1074288	2654	231
	480250	1074289	2653	235
	480251	1074290	2652	254
	479211	1074986	2502	60
	479212	1074985	2503	61
	479213	1074987	2504	62
	479214	1074988	2505	64
	479215	1074989	2506	65
	479216	1074990	2507	70
	479217	1074991	2508	71
	479218	1074996	2509	75
	489016	1074211	2603	242
	489017	1074210	2613	245
	489018	1074212	2612	232
	489019	1074213	2618	233
	489020	1074214	2605	234
	489021	1074215	2606	239
	489022	1074216	2609	238
	489023	1074217	2621	244
	489024	1074218	2602	218
	489025	1074219	2607	219
	489026	1074220	2611	221
	480240	1074280	2604	55
	480241	1074286	2604	54
	480242	1074285	2604	58
	480243	1074287	2604	60
	480244	1074287	2605	355
	480209	1074278	2655	344
	480219	1074258	2656	343
	480229	1074238	2674	341
	480239	1074298	2644	342
	480249	1074218	2634	344
	480259	1074208	2658	345
	480269	1074248	2659	346
	480279	1074258	2657	347
	480289	1074238	2644	348

	480249	1074228	2624	349
	480249	1074218	2614	352
	480249	1074228	2656	340
	480249	1074348	2694	352
	480249	1074828	2650	271
	480249	1074728	2624	333
	480249	1074618	2674	327
	480249	1074818	2634	280
	480249	1074038	2673	243
	480249	1074148	2742	348
	479231	1074956	2502	349
	479221	10749866	2502	303
	479241	1074976	2502	345
	479281	1074986	2502	340
Limestone	479222	1047954	2501	45
	479221	1047955	2511	48
	479223	1047957	2504	47
	479224	1047958	2506	49
	479225	1047953	2509	50
	479226	1047956	2508	55
	479227	1047954	2509	58
	479232	1047951	2502	60
	479413	1075044	2513	250
	479414	1075046	2512	285
	479415	1075056	2514	287
	479418	1075057	2511	286
	479416	1075058	2512	245
	479427	1075059	2513	246
	479426	1075055	2514	247
	479425	1075052	2515	248
	479424	1075053	2516	249
	479423	1075054	2517	300
	479422	1075060	2518	311
	479421	1075061	2519	315
	479420	1075062	2520	313
	479428	1075063	2522	308
	479429	1075064	2523	86
	479430	1075065	2532	88
	479431	1075067	2533	85
	479418	1075069	2535	280
	479420	1075019	2537	122
	479417	1075068	2534	83
	479421	1075015	2538	125
	479422	1075016	2539	241
	479423	1075017	2540	242
	479424	1075018	2545	230
	479425	1075019	2546	231
	479426	1075020	2541	233

	479427	1075021	2542	235
	479428	1075022	2553	244
	479429	1075023	2575	128
	479430	1075024	2543	130
	479431	1075025	2542	135
	479432	1075026	2550	134
	479433	1075029	2551	136
	479434	1075030	2550	60
	479435	1075031	2552	65
	479436	1075032	2553	64
	479437	1075033	2554	70
	479438	1075039	2555	80
	479439	1075040	2556	75
	480240	1074228	2624	300
	480241	1074218	2614	301
	480243	1074218	2624	310
	480246	1074219	2614	304
	480245	1074229	2615	307
	479448	1075059	2575	305
	479458	1075039	2555	311
Upper Coarse grained sandstone	479210	1075432	2476	70
	479212	1075435	2478	74
	479214	1075436	2479	69
	479215	1075437	2480	45
	479216	1075438	2477	40
	479217	1075439	2476	44
	479218	1075440	2478	50
	479219	1075441	2479	85
	479223	107542	2480	86
	479226	1075443	2481	88
	479221	1075444	2482	84
	479215	1075445	2483	50
	479213	1075446	2484	44
	479212	1075447	2485	30
	479264	1075449	2467	125
	479261	1075440	2460	126
	479262	1075441	2461	122
	479263	1075443	2462	123
	479264	1075442	2464	119
	479265	1075446	2467	118
	479268	1075448	2470	117
	479268	1075449	2472	110
	479269	1075445	2468	120
	479302	1075487	2472	130
	479301	1075487	2471	124
	479303	1075488	2473	116
	479303	1075489	2474	109
	479311	1075490	2475	108
	479312	1075491	2476	107

	479322	1075492	2476	105
	479321	1075493	2477	99
	479324	1075497	2475	96
	479325	1075496	2478	92
	479328	107549	2479	98
	479329	1075499	2471	91
Columnar basalt	485332	1074091	2640	120
	485356	1074094	2643	210
	485361	1074096	2646	214
	485372	1074097	2640	215
	479312	1075480	2472	75
	479399	1075492	2471	77
	479311	1075470	2472	76
	479389	1075422	2467	275
	479313	1075480	2472	273
	479319	1075492	2471	274
	479314	1075470	2472	265
	479315	1075412	2467	250
	479316	1075413	2468	251
	479317	1075414	2469	253
	479320	1075415	2472	252
	479321	1075416	2473	254
	479323	1075418	2474	256
	479324	1075419	2475	266
	479326	1075417	2467	264
	480568	107350	2650	300
	480570	1073753	2660	345
	480578	1073754	2670	350
	480589	1073834	2670	245
	480580	1073824	2671	315
	480543	1074091	2640	160
	480544	1074092	2642	159
	480545	1074094	2643	155
	480546	1074096	2646	156
	480547	1074097	2640	157
	480548	1074097	2641	165
	480549	1074098	2644	158
Weathered Vesicular Basalt	480272	1074024	2649	65
	480271	1074023	2648	68
	480273	1074025	2650	66
	480274	1074026	2645	67
	480275	1074027	2644	70
	480276	1074028	2643	62
	480277	1074029	2646	65
	480278	1074033	2647	55
	480279	1074030	2649	60
	480280	1074032	2650	40
	480281	1074034	2651	30
	480282	1074035	2652	42

	480283	1074036	2653	45
	480281	1074037	2654	46
	480284	1074038	2654	47
	480285	1074039	2655	33
	480286	1074040	2656	34
	480287	1074043	2657	35
	480288	1074042	2658	36
	480289	1074043	2659	38
	480290	1074044	2660	39
	480291	1074046	2668	70
	480292	1074047	2666	75
	480293	1074048	2667	72
	480294	1074049	2669	73
	480317	1074341	2611	115
	480316	1074342	2621	125
	480318	1074343	2621	120
	480319	1074344	2614	124
	480315	1074345	2615	123
	480268	1074308	2607	80
	480240	1074318	2617	59
	480241	1074319	2610	55
	480242	1074309	2608	63
	480243	1074317	2619	58
	480244	1074306	2611	85
	480246	1074305	2613	81
	480247	1074304	2617	83
	480248	1074303	2618	82
	480243	1074313	2628	310
	480240	1074309	2658	332
	480245	1074323	2648	334
	480248	1074383	2608	335
	480249	1074353	2678	336
	480247	1074363	2668	163
	480242	1074373	2638	158
	480249	1074393	2688	345
	480241	1074323	2610	350
	480234	1074403	2611	300
	480208	1074803	2612	120
	480228	1074903	2615	123
Scoraceous Basalt	479238	1075445	2474	30
	479230	1075447	2476	27
	479233	1075448	2477	10
	479235	1075450	2478	15
	479236	1075455	2479	16
	479248	1075457	2484	18
	479258	1075459	2480	19
	479268	1075453	2481	20
	479266	1075452	2482	22

	479267	1075458	2486	25
	479270	1075460	2487	24
	479271	1075462	2489	65
	479273	1075465	2490	66
	479275	1075467	2495	85
	479442	1075475	2476	86
	479443	1075468	2475	88
	479432	1075665	2477	84
	479443	1075645	2486	50
	479452	1075545	2472	45
	479456	1075461	2663	44
	479457	1075481	2665	45
	479466	1075462	2666	40
	479422	1075463	2664	44
	479459	1075464	2668	50
	479496	1075465	2670	70
	479497	1075466	2671	65
	479490	1075467	2675	74
	479494	1075468	2678	69
	479197	1075443	2480	320
	479183	1075423	2470	318
	479184	1075425	2475	325
	479182	1075429	2476	340
	479204	1075447	2481	335
	479205	1075449	2483	330
	479206	1075448	2411	145
	479247	1075450	2414	148
	479271	1075493	2476	80
	479274	1075494	2478	75
	479276	1075494	2479	82
	479291	1075494	2476	70

Appendix 2.static water level measurements.

Code	X	y	z	SWL(m)	GWE
FDT 03	478624	1067822	2627	56.9	2570.9
FDT 12	479406	1065700	2632	59.3	2572.7
FDT 01	478531	1067748	2622	56	2566
FDT 02	478945	1067822	2613	60.4	2552.6
FDT 05	478676	1067490	2640	57.4	2612.4
FDT 08	479368	1066747	2645	57.5	2587.5
FDT 10	480318	1074084	2643	58	2585
FDT 19	466178	1082495	2973	6.7	2966.2
FDT 20	479193	1066345	2615	50.4	2564.6
DW10	478411	1068253	2610	55	2555
DW11	478847	1068289	2618	45	2573
HD1	479695	1073212	2589	4	2583
HD2	475621	1065990	2647	5	2642
DW12	483172	1061127	2631	28.15	2602.5
HD3	425376	1100923	2511	3	2508
HD4	467782	1080827	2939	4	2922
HD5	475954	1079777	2627	5	2622
HD6	480142	1074817	2575	5.1	2569.9
HD7	476651	1066670	2642	4.25	2637.75
HD8	471128	1077659	2759	5.5	2753.5

Appendix 3.physical-chemistry measurement

code	x	y	z	EC(µS/cm	PH	T
FDT 03	478624	1067822	2627	452	8.1	21.3
FDT 12	479406	1065700	2632	376	8.4	21.5
FDT 01	478531	1067748	2622	368	8.7	21.6
FDT 02	478945	1067822	2613	332	7.64	20.5
FDT 05	478676	1067490	2640	426	7.84	20.5
FDT 08	479368	1066747	2645	468	7.82	19.7
FDT 10	480318	1074084	2643	386	7.39	21.3
FDT 19	466178	1082495	2973	282	7.77	21.8
FDT 20	479193	1066345	2615	390	7.74	20.4
SUW-1	478411	1068253	2610	380	7.8	
SUW-2	478847	1068289	2618	455	7.72	
HD1	479695	1073212	2589	494	6.993	17.4
HD2	475621	1065990	2647	263	7.411	14
DW12	483172	1061127	2631	377	7.51	16
HD3	425376	1100923	2511	412	7.721	13.8
HD4	467782	1080827	2939	318	7.76	17.3
HD5	475954	1079777	2627	480	7.84	15
HD6	480142	1074817	2575	354	7.45	17.5
HD7	476651	1066670	2642	498	7.42	18
HD8	471128	1077659	2759	644	7.4	19.1

Appendix 4. Selected Lithologic logs.

Drilled Depth(m)		Lithological Description	Formation type	Thickness	Remark
From	To				
0	3	Top soil	soft	3	
3	6	Sandy silt clay layer	soft	3	
6	10	Highly to moderately weathered& fractured basalt	medium	4	
10	27	Highly weathered Basalt	medium	17	
27	31	Scoraceous basalt	medium	4	
29	31	Highly fractured Basalt	medium	2	
31	40	Moderately fractured Basalt	medium	9	
40	46	Slightly fractured Basalt	hard	6	
46	55	Moderately fractured Basalt	medium	9	
55	70	Pyroclastic unit	medium	15	
70	85	Slightly fractured Basalt with secondary material	hard	15	
85	94	Highly weathered basalt	medium	9	
94	103	Slightly fractured Basalt	hard	9	
103	109	Moderately & highly fractured basalt	medium	6	Minor aquifer
109	115	Highly fractured intercalated with scoraceous basalt	medium	6	Major aquifer
115	118	Moderately weathered &slightly fractured basalt	medium	3	
118	121	Moderately weathered basalt	medium	3	
121	133	Weathered ignimbrite with organic material	medium	12	
133	139	Moderately weathered & fractured Basalt Intercalated with ignimbrite	medium	6	
139	149	Moderately fractured Basalt intercalated with ignimbrite	medium	10	

Appendix 5. Two deep Wells Groundwater for Selale University, which is located at Debre-Tsige well field area. Lithological description for well #1for Selale University

No.	Depth range	Geological description
1	0-1	Black cotton clay soil
2	1-28	Slightly fractured basalt
3	28-32	Massive basalt
4	32-38	Moderately fractured basalt
5	38-54	Pumice(white color)
6	54-86	Pumice(grey color)
7	86-106	Pyroclastic rock
8	106-114	Moderately weathered & fractured basalt
9	114-122	Pumice
10	122-126	Slightly fractured basalt
11	126-130	Pumice
12	130-134	Highly fractured basalt
13	134-140	Moderately weathered & fractured basalt
14	140-164	Pyroclastic rock
15	164-174	Vesicular basalt
16	174-186	Moderately to Slightly fractured basalt
17	186-242	Highly weathered basalt with quartz
18	242-266	Pumice
19	266-271	Highly weathered basalt with quartz

Lithological description for Well#2 for Selale University

No.	Depth range	Geological description
1	0-2	Black cotton clay soil
2	2-8	Highly weathered and fractured basalt
3	8-36	Slightly fractured basalt
4	36-40	Highly fractured basalt
5	40-56	Intercalation of basalt and pyroclastic materials
6	56-104	Highly weathered basalt
7	104-112	Massive basalt
8	112-116	Moderately fractured basalt
9	116-140	Highly fractured basalt
10	140-184	Slightly fractured basalt
11	184-275	Welded tuff