

***NO WATER, NO LIFE, NO BLUE, NO GREEN!!***



**WATER IS ALL OUR -----!**  
**-----!!**  
**-----!!!**



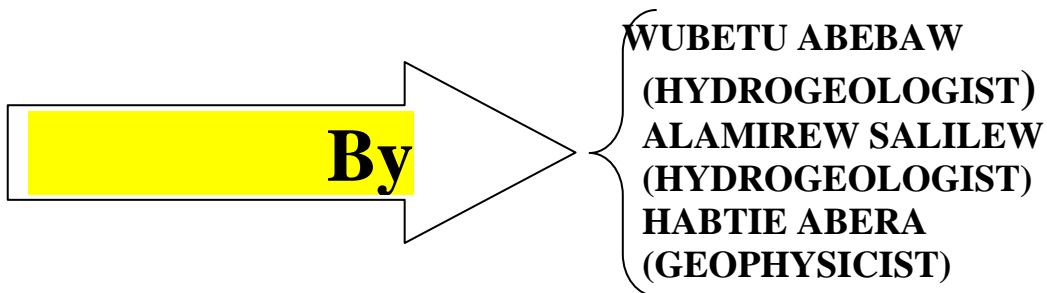
**THERE FOR, WE MUST DO -----?**  
**-----??**  
**-----???**

**AMHARA NATIONAL REGIONAL STATE  
WATER, IRRIGATION AND ENERGY  
RESOURCE DEVELOPMENT BUREAU**

**CENTRAL GONDAR ZONE WATER,  
IRRIGATION AND ENERGY RESOURCE  
DEVELOPMENT DEPARTMENT**

**HYDROGEOLOGICAL & GEOPHYSICAL  
FESIBILITY STUDY**

**FOR:  
DEEP WELL SITE LOCATING IN CENTRAL  
GONDAR -ZONE WEGERA DISTRICT**

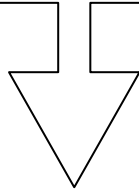
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**FEBRUARY – 2013 E/C  
GONDAR/ETHIOPIA**



**SUBMITTED TO:**



**YOTOR FARMERS CHARITABLE  
ASSOCIATION /YFCA/**

**Submitted-Date**  
**06/03/2021**

**FEBRUARY-2021 G/C**  
**- BAHIR-DAR /ETHIOPIA**  
**- STOCOLM / SWEEDEN**

## *Acknowledgement*

Prior to any thing, I would have thank and glorify the almighty **GOD** who is the ultimate means of my success.

I would like to express my great deal of gratitude to Central Gondar zone Water, Irrigation & Energy resource development department, especially water supply core process, for arranging the field work and giving me the chance to go to the study area as well as the guidance, encouragement and constructive comments during conducting this project.

I don't like to pass without mentioning that I am thank full to ato Alamirew Salilew (Hydrogeologist), ato Habtie (Geophysicist) and ato Mihret Teka (the driver, during the time of field study) for their measure less devotion, punctuality, honesty and patience.

I would also love to express my heartfelt thanks to Wegera woreda water resource development office for their kind support with input data, giving general information about the study area as well as minimization of the labor cost by coordinating and participating the local youths as a labor that reduces our labor cost.

Finally, I would love to extend my gratitude to the Ethiopian Yotor farmers charitable association coordinators (the client of the project), for their spectacular decision to flow their budget and sharing of financial power to solve the critical problems of water with the main objective of irrigation and supply quality & purified water for the user, the gratitude includes ato Wubie (field coordinator with in this study) for his genuine idea, constructive comments, sharing of his experiences about managmental issue's as well as he describe his feeling freely about the site and sharing of some field related photos. In addition to this, I need also to give many thanks to the community of the surrounding area (Direct beneficiaries of the project) for their responsibility and promise to manage and correct any road condition from the asphalt and gravel road to the site, their own active participation and for all their countless support during the field work.



## ***Abstract***

The present study is carried at Wegera wereda in Taga kebele, located in northern Ethiopia, 55km North-east of Gondar town, with the main objective of Identifying ground water potential site and to select the deep well sites, by using Geophysical methods, specifically of electrical resistivity method (ERM) and Hydro geologically by determining the aquifer properties of soils and rocks as well as by analyzing different geological structures for clean water supply & Irrigation purposes, which are to be used for the surrounding community and indirectly for the country as a whole.

To achieve the particular objective of the study, technical methods are deployed. Such methods are carried during field work, pre field and after field work.

The climatically conditions of the study area is grouped under Dega (Temperate) climatic zone of the country, with average temperature of 10°C - 20°C and mean annual rainfall of 950mm-1100mm.

In the study area different types of lithological units are existed. Among these, Dolerite, weathered and fractured basalt, Tuff unit, clay, quaternary and alluvial sediment, trachyte, Vesicular Basalt and the mineral quartz can be mentioned. But, clay, dolerite, weathered and fractured basalt as well as quaternary alluvio - colluvio sediments are the most common one relative to other lithological units. Each lithological unit has their own characteristics, hydro geological aspects and economic importance. These units are followed by different types of geological structures. From such structures: - fault, joint, mud cracks, subsidence structures and geological flute marks can be mentioned.

During conducting this study, we have tried to correlate the local geology to the regional geology & integrate geological, hydrogeological and geophysical methods for successful site location in terms of ground water potential. Therefore, special attention is given to locate potential groundwater sites for the safe water supply.

Finally, by following each procedure with detail observation and identification of each lithological unit and by using Geo physical methods with IPI2 wine software, two deep well sites are selected by comparing from different well fields for the purpose of Irrigation.

# TABLE OF CONTENTS

<b><i>Chapter</i></b>	<b><i>Page No</i></b>
Acknowledgement .....	i
Abstract .....	ii
TABLE OF CONTENTS .....	iii
List of Figures .....	vii
List of Tables .....	viii
ACRONYMS .....	ix
<b>CHAPTER ONE</b>	<b>1</b>
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Back ground .....	1
1.2 Problem statement.....	2
1.3 Objective of the project.....	3
<i>1.3.1 General Objective</i> .....	3
<i>1.3.2 Specific Objective</i> .....	3
1.4 Description of the study area .....	4
<i>1.4.1 Location</i> .....	4
<i>1.4.2 Accessibility</i> .....	5
<i>1.4.3 Physiography</i> .....	5
<i>1.4.4 Climate</i> .....	6
<i>1.4.5 Drainage pattern</i> .....	6
<i>1.4.6 Land use and Land cover</i> .....	7
1.5 Methodologies and Materials.....	8
<i>1.5.1 Methodology</i> .....	8
1.5.1.1. Pre-field Works .....	8
1.5.1.2. During Field Works.....	8
1.5.1.3 Post Field Works .....	10
<i>1.5.2 Materials</i> .....	10
1.6 Existing Water Supply System .....	11
<i>1.6.1 Existing water supply</i> .....	11
<i>1.6.2 Water Demand</i> .....	13
<i>1.6.3 Identification of well site</i> .....	13

<b>CHAPTER TWO</b>	<b>15</b>
<b>GEOLOGICAL SETTING</b>	<b>15</b>
2.1. Regional Geology .....	15
2.1.1 Basement rock.....	15
2.1.2 Paleozoic sedimentary rocks.....	16
2.1.2.1 Enticho sandstone formation (ESF) .....	16
2.1.2.2 Edaga Arbi Tillite Formation (EAF) .....	17
2.1.3 Mesozoic sedimentary rocks .....	17
2.1.3.1 Adigrat sandstone formation (ASF) .....	18
2.1.3.2 Transition bedes.....	18
2.1.3.3 Antalo Limestone formation (ALF).....	19
2.1.3.4 Agula shale / mudstone formation (ASF).....	19
2.1.3.5 Umbaradom sandstone formation (USF) .....	19
2.1.4 Cenozoic Rocks and Associated Sediment .....	20
2.1.4.1. Ashanghe Basalts .....	24
2.1.4.2. Aiba Basalt .....	25
2.1.4.3. Alaje Formation.....	25
2.1.4.4. Tarmaber Basalts .....	25
2.2 Local Geology.....	26
2.2.1 General description of the local geology of the study area. ....	26
2.2.2 Detailed description of the local geology of the study area:-.....	26
2.2.2.1 Amygdaloidal Basalte.....	27
2.2.2.2 Boulder unit .....	28
2.2.2.3 Clay unit .....	29
2.2.2.4 Dolerait rock unit .....	30
2.2.2.5 Quaternary sédiment.....	31
2.2.2.6 Quartz Mineral.....	32
2.2.2.7 Tuff unit.....	33
2.2.2.8 Vesicular Basalt .....	34
2.3 Geological structures of the study area.....	36
2.3.1 Faults .....	36
2.3.2 Joints .....	37
2.3.3 Mud cracks.....	37
2.4 Geological processes.....	38
2.4.1 Weathering.....	38
2.4.2 Erosion.....	39
<b>CHAPTER THREE</b>	<b>40</b>
<b>HYDROGEOLOGICAL SETTING</b>	<b>40</b>



3.1 Regional Hydrogeology .....	40
3.2 Local Hydrogeology .....	42
3.2.1 Dolerite rock unit.....	43
3.2.2 Quaternary sediment.....	43
3.2.3 Tuff unit.....	43
3.2.4. Vesicular basalt .....	44
<b>CHAPTER FOUR</b>	<b>45</b>
<b>METHODOLOGY</b>	<b>45</b>
4.1 Geophysical signature.....	45
4.1.1 Electrical Resistivity Method (ERM) .....	45
4.1.1.1 Vertical Electrical Sounding (VES) .....	48
4.1.1.2 Resistivity Profiling.....	49
4.1.2 Electrode configuration .....	50
4.1.2.1 Schlumberger electrode Array.....	51
4.1.2.2 Wenner electrode array.....	51
4.1.3 Relation between Geology and Resistivity.....	52
4.1.4 Limitation of the Electrical Resistivity Method .....	53
4.2 Data Acquisition and Processing .....	53
4.2.1 Field Procedure and Data Acquisition of ERM.....	54
4.2.2 Data Processing and Data Presentation ERM .....	56
4.3 Result and Discussion .....	57
4.3.1 VES 1 (Gezewuye).....	57
4.3.2 VES 2 (Gichit).....	58
<b>CHAPTER FIVE</b>	<b>60</b>
<b>ECONOMIC IMPORTANCE</b>	<b>60</b>
5.1 Amygdaloidal basalt .....	60
5.2 Dolerite .....	60
5.3 Clay .....	61
5.5 Quartz.....	61
5.6 Tuff unit .....	62
<b>CHAPTER SIX</b>	<b>63</b>
<b>CONCLUSIONS AND RECOMMENDATIONS</b>	<b>63</b>
6.1 Conclusions.....	63

6.2. Recommendations.....	65
References .....	66
Annex one .....	67

## ***List of Figures***

<i>Figure1.1 location map of the study area .....</i>	<i>4</i>
<i>Figure1.2 physiographic lay out of the study area .....</i>	<i>5</i>
<i>Figur1.3 meandering river types in the study area.....</i>	<i>6</i>
<i>Figure1.4 Very elongated crops of Chickpea &amp; Onion in and around the study area that taken at the time of the study and at the season .....</i>	<i>7</i>
<i>Figure1.5 The activities during the field work.....</i>	<i>9</i>
<i>Figure1.6 Nonfunctional water schemes in and around the study area .....</i>	<i>12</i>
<i>Figure2.1 Map of the Northern part of Ethiopian Plateau showing volcanic province (Source: Kiffer et, al 2004)    23</i>	
<i>Figure2.2 Amygdaloidal rock units .....</i>	<i>27</i>
<i>Figure2.3 Boulder units .....</i>	<i>28</i>
<i>Figure2.4 Brownish color Clay unit .....</i>	<i>29</i>
<i>Figure2.5 Dolerite rock units .....</i>	<i>30</i>
<i>Figure2.6 Quaternary sediments .....</i>	<i>31</i>
<i>Figure2.7 Quartz mineral .....</i>	<i>32</i>
<i>Figure2.8 Tuff units .....</i>	<i>33</i>
<i>Figure2.9 Vesicular basalts .....</i>	<i>34</i>
<i>Figure2.10 Geological Map of the study area.....</i>	<i>35</i>
<i>Figure2.11 Minor fault lines .....</i>	<i>36</i>
<i>Figure2.12 Joints .....</i>	<i>37</i>
<i>Figure2. 13 Mud crack .....</i>	<i>37</i>
<i>Figure2.14 weathering and its effects.....</i>	<i>38</i>
<i>Figure2.15 Gully erosion.....</i>	<i>39</i>
<i>Figure4.1ABEM Terra meter LS geo-electrical imaging system    48</i>	
<i>Figure4.2 Schematic Plans for Vertical Electrical Sounding (VES) (After Loke, 2001).....</i>	<i>48</i>
<i>Figure4.3 Schematic Plans for Electrical resistivity profiling (After Loke, 2001).....</i>	<i>49</i>
<i>Figure4.4 conventional electrode configurations .....</i>	<i>50</i>
<i>Figure4.5 Schematic diagram of a four point schlumberger array.....</i>	<i>51</i>
<i>Figure4.6 wenner electrode array configurations.....</i>	<i>51</i>
<i>Figure4.7 Field Procedures.....</i>	<i>54</i>
<i>Figure4.8 VES 1 model curve, resistivity and thickness of each layer .....</i>	<i>58</i>
<i>Figure4.9 VES 2 model curve, resistivity and thickness of each layer .....</i>	<i>59</i>

## ***List of Tables***

<i>Table1. 1 Some notes about each site .....</i>	<i>14</i>
<i>Table1.2 Bill of quantity for one deep well DTH/MUD drilling systems in Wegera wereda, Taga kebelle .....</i>	<i>67</i>

## ***ACRONYMS***

ALT:	Altitude
BW:	Bore well/shallow well
C1	Current electrode one
C2	Current electrode two
CGZ:	Central Gondar zone
DTH:	Drilling down the hole
EFBs:	Ethiopian flood Basalts
ERM	Electrical resistivity method
FIG:	Figure
GPS:	Global positioning system
GTP:	Growth and transformation plane
HDW:	Hand dug well
L:	Litter
M:	Meter
MM:	Millimeter
MUD	Drilling with mud system
P1	Potential electrode one
P2	Potential electrode two
SGZ	South Gondar Zone
UTM:	Universal transverse Mercator
VES	Vertical electrical sounding

# CHAPTER ONE

## 1. INTRODUCTION

### *1.1 Back ground*

Water is the vital tool for all living things, which plays a crucial role in the existence of life on earth, as being one of the key natural resources of the world. Without water humans can stay only for hours. Moreover food is the other basic need where the crops, fish and animals depend on water to grow and survive. The need for the quality and availability of water resources has always been the primary concern of our societies, especially in semi-arid and arid regions, and even the areas with abundant rainfall such as tropical region.

Ground water is the main source for potable water supply, domestic, industrial and agricultural uses. The existence of ground water resource is basically renewable resource but the volume of water and quality actually in storage may vary greatly from place to place depending on its agricultural land activity, climate of regional hydrogeology and rate of different uses for different purposes. Due to this reason, the scarcity of ground water increases day to day, additionally with rapid population, urbanization, industrial and agricultural related activities, in such away surface water cannot be dependable throughout the year; hence other alternative is needed in order to supplement for surface water, i.e. drilling to the overburden depth, to add underground water source. These facts made humans from the beginning to study the occurrence, sources, characteristics, development and quality of water and even consider it as one of the basic natural resources.

Therefore, the central Gondar zone water resource development department, water supply core process is responsible to conduct water resource study, design and supervision within the zone to provide safe and adequate water throughout the zone. Hence, the core process has assigned a geologist from the region & zone (CGZ & SGZ) water resource development office, in order to accomplish the particular activity of deep well site selection. Then, the study is conducted at two similar well fields and the resulting well sites are selected.



## ***1.2 Problem statement***

The Ethiopian water resource is still not well studied and even the areas which are potentially known did not come in to practice. Those may due to economic problems since water resource development requires a large capital and well qualified professionals.

One of the fundamental conditions for growth and development of a nation like, Ethiopia is certainly the progressive fulfillment of its most urgent water needs.

In the case of our country, all most all of the rural areas are formed scaterilly without considering the existence of water near by the villages. However these areas have no enough supply of water, most societies get water from the cultural hand dug well, unprotected springs and rivers nearby. Especially in dry seasons when the other water source options become depleted, the communities (especially women and children) suffer a lot, also in the rainy season the springs and rivers become polluted from flooding and this also makes things more difficult. The problem also continues to the urban area (starting from small towns to capital cities), this is not seen only from scarcity point of view but also from purified clean water supply point of view, rather considering irrigation in such away and from such kind of place is headache and unbelievable.

Therefore, to improve the live hood of the societies and to solve the critical problem of water with in the country as a whole, investigation, extracting and construction of new water supply project is mandatory. Then, Yotor Farmrs Charitable Association (YFCA) assumes these issues and selects the potential deep well sites by using experts in the northern part of the country, specifically in Central Gonder zone – Wegera wereda in Taga kebele (Gichit & Gezewuye gote) to solve the critical problems of water and to use Irrigation in the area. Side by side the activity supports governmental millennium development goals /for secondary growth and transformation plane (GTP2)/.

## ***1.3 Objective of the project***

### **1.3.1 General Objective**

The general objective of the study is to identify ground water potential site and to select the specific deep well sites, by using Geophysical methods, specifically of electrical resistivity method (ERM) and Hydro geologically, by determining the aquifer properties of soils and rocks as well as by analyzing different geological structures for Irrigation purposes, which is carried by Yotor Farmrs Charitable Association (YFCA) (the client of the project) to solve the critical water shortage problem in the area and to use Irrigation with in the kebele as a whole.

### **1.3.2 Specific Objective**

- To conduct hydro geological investigation and identify the aquifer types in the study area,
- To map sub surface resistivity stratification of the study area,
- To know unsaturated zone moisture movement,
- To know the depth of existing water table
- To give general sub surface picture by correlating geophysical log with hydrogeological well data,
- To increase more productivity and improve the live hood of the user, better than the current activities and conditions within the kebele as a whole,
- To protect water born disease in the user.

## 1.4 Description of the study area

### 1.4.1 Location

The project area (deep well sites) is located in Amhara national regional state, Central Gondar zone, Wegera wereda in Gichit & Gezewuye kebele.

The average distance of the selected sites are, 18km, 48km, and 228Km from Amba-Giyorgis (Wereda center), Gondar (zone center) and Bahir Dar (region center) respectively.

Geographically, the area is located between latitude of N12°26'497'' and longitude of E037°30'277'' in UTM of north western flat plain part of the country.

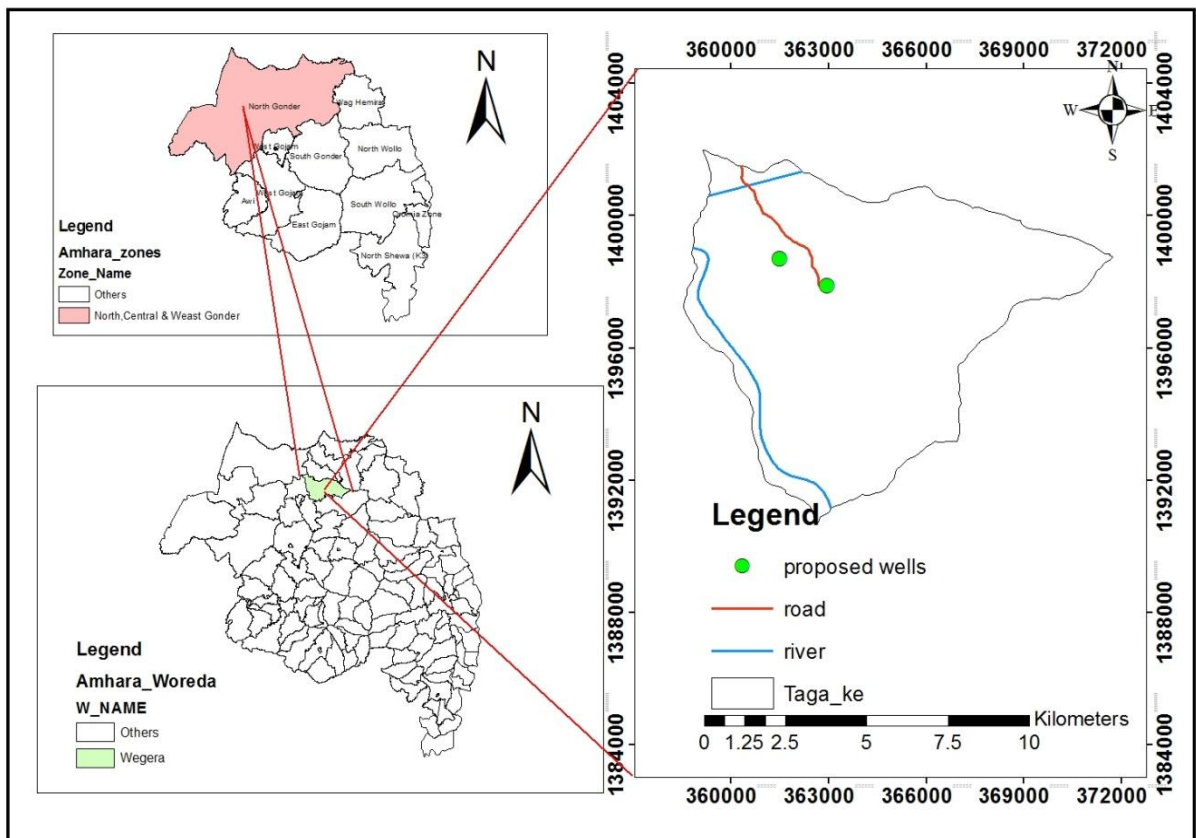


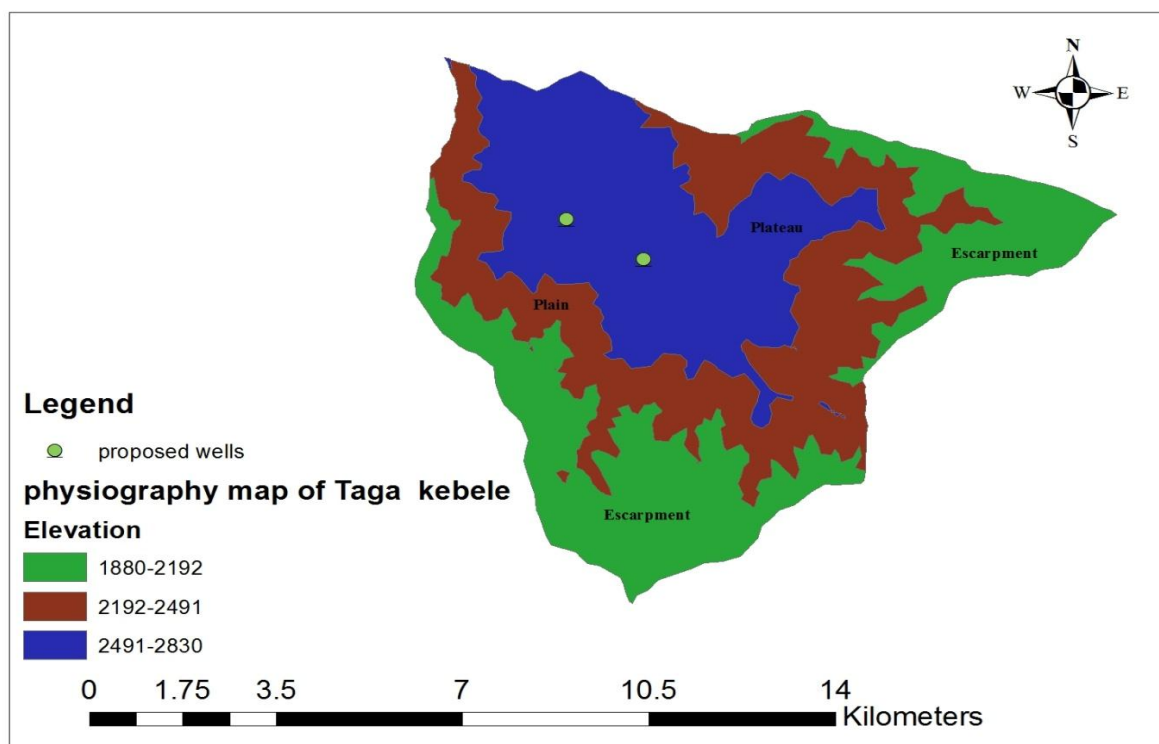
Figure 1.1 location map of the study area

### 1.4.2 Accessibility

The main high way connects Addis Ababa with the study area via Debre markos- Bihar Dar- Wereta- Azezo –Gonder – Ambagiorgis lines; the gravel road also connects south-east of Amba-Giyorgis to Taga kebele (study area) From woreda center Amba-Giyorgis, the average distance of the study area is 18-20km. But, in some parts of the study area the branched road needs from low to medium maintenance, otherwise it may usually reduce our activity during the actual work (drilling & related activities), especially if the season is rainy.

### 1.4.3 Physiography

According to the main Ethiopian physiographic classification system, the study area is grouped under the north western highland and lowland areas (Fig: 1.2).



*Figure1.2 physiographic lay out of the study area*

Generally, the most part of the study area (Wegera woreda) is steppe to undulating plain with general slop inclination from northwest to south east, interrupted by valleys, streams, scattered hills and seasonal wetland.

#### 1.4.4 Climate

The study area is classified under dega (Temperate) climatic zone of the country, according to the traditional climatically zone presented by Ethiopian mapping agency and has an average temperature of 10°C-20°C in the dry season, and 7°C-12°C in rainy season. The area has also a mean annual rainfall of 950mm-1100mm and the pattern shows high reading with in the months of June to September.

#### 1.4.5 Drainage pattern

The study area is dominated by the topography of mostly gentle and flat land areas, it has dendrite drainage pattern, flowing towards lowland and the gentlest slope of the study area and have denser green natural vegetation's along the tributary. The study area streams are majorly meandering river types and are nearly flowing along the geologically weak zones and joined to the main rivers and streams of the area.



*Figur1.3 meandering river types in the study area*



### 1.4.6 Land use and Land cover

The study area (Wegera woreda) has a total land coverage area of 1486.3 square kilometers. Most parts of the study area are covered by vegetations, largely grouped under woodland vegetation ecosystem with deciduous tree species. Some part of the study area is also covered with grasslands and thorny plant species which could be categorized in the Acacia-Commiphora ecosystem. As being flat land area, the study area is used as a farmland for agricultural purposes, there is also a forest in some parts of the study area (Amba-Giorgis zuria), which is used as a home of different small wild animals and for the balancing of natural ecosystems. From the agricultural products; wheat, lentil, teff, sorghum, barley, potato, onion, chickpea and so on are the most dominant crops and vegetable types in the study area.



*Figure1.4 Very elongated crops of Chickpea & Onion in and around the study area that taken at the time of the study and at the season*



## ***1.5 Methodologies and Materials***

### **1.5.1 Methodology**

As a common practice, review of published and unpublished sources is the most important tool to get an insight into the geological, hydro geological and geophysical conditions of the project area.

To achieve the general and specific objectives of the study, the methods listed below have been deployed. Which are performed at; pre field work, during field work and post field work.

#### **1.5.1.1. Pre-field Works**

- Preparation of working plan and scheduling the overall activities.
- Identification of the objective of the study and the problem within the area.
- Identification of important field equipment's.
- Existing water point data such as borehole (shallow wells and deep wells), Hand dug well, and developed springs have been collected and reviewed with respect to groundwater potential of the area.
- Meteorological data have been collected from different sources before the commencement of the fieldwork.

#### **1.5.1.2. During Field Works**

After collecting necessary information about general over view of the study areas, the field started to the actual area of the works and accomplished the following activities;

- Collect information/data from woreda water resource development office and other persons who have some knowhow about the study area and Wegera woreda as a whole,
- Different traverses have been selected along the rivers in order to see the subsurface nature of the rock on the bank of the rivers. Across the rivers, traverses were taken to observe the lateral variation of rocks from **geological** and **hydro geological** point of view.

- Detail investigation and identification of different lithological units, i.e. geological, geomorphological and hydrogeological conditions of the identified areas of interest based on the prepared base map,
- Observation of certain type of vegetation was also studied, which are indicative of occurrence of groundwater. Since the structural features like dykes and faults play a significant role in the groundwater movement and accumulation, a thorough investigation were made in this fieldwork phase.
- Conducting geophysical investigations (VES) at the identified areas of interest, based on geological, Geomorphological and hydrogeological characteristics of the area by using the **ABEM 400** Geophysical terra-meter with two current and potential electrodes and record the resulting resistivity value,
- Take location (GPS) reading at the recommended deep well sites.



*Figure1.5 The activities during the field work*

### **1.5.1.3 Post Field Works**

Post field work activities include;

- Arranging the notes and all coordination's,
- Arrangement of the collected data,
- Putting the resistivity data's in the computer and analyze the resulting VES image using IPI2 win software,
- Interpretation of the result based on the data obtained from IPI2 win software, from potential and feasibility point of view,
- Draft report preparation,
- Submission of the final report to the client of the project (Yotor Farmrs Charitable Association (YFCA)).

### **1.5.2 Materials**

The materials that we used during conducting this project are;

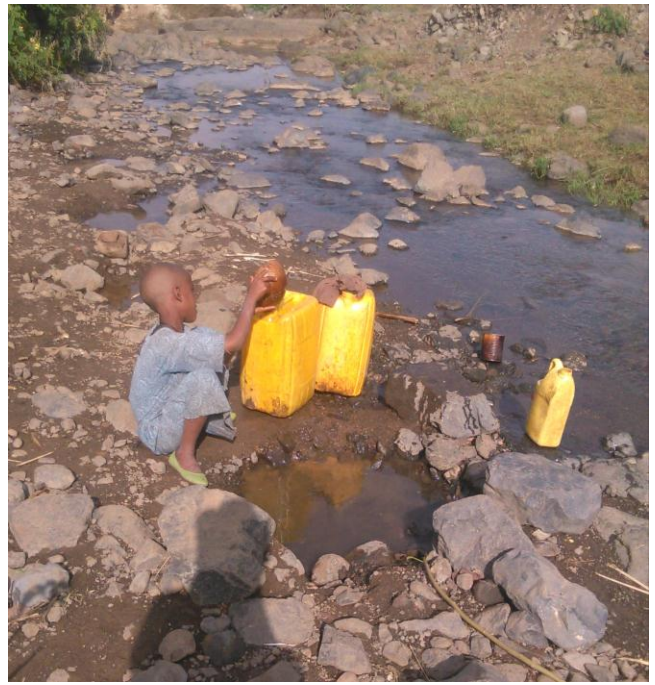
- ABEM Terra-meter LS Geo-electrical imaging system with all its components for looking and recording of the aquifer response in the study area.
- Car for transportation
- Man power as labor
- GPS and laptop computer
- Camera
- VES paper format/sheet/ and pens as well as drawing pencils
- Various computer soft ware's namely ARC GIS 10, Global mapper12, IPI2win.

## ***1.6 Existing Water Supply System***

### **1.6.1 Existing water supply**

The existing water supply sources for near the study area are; rivers & small streams, hand dug wells, undeveloped and little developed springs, shallow wells /which are drilled from nearby intermittent river bank/, and small streams. ANRS water, Irrigation and energy resource development bureau water supply project, and Wegera woreda water and energy resource development office in together drilled limited shallow wells and hand dug wells in some parts of the study area in 2008 E.C and before. The drilled hand dug wells solve some of series water shortage problem at this time and used as a data source for us. To use other options, there are no strong springs and streams existed within and around these areas. Because of these problems, the surrounding communities suffered by water shortage or forced to travel long distance outside their village to fetch/drink water. The problem is not only seen from degree of suffering point of view, but also it should be seen from poor water quality and time management point of view since it is consuming their precious productive time in the development activities and working time planned within the community members ,especially for students and women's. Some constructed water schemes have also their own problems; nonfunctional hand dug well water schemes in the study area are mentioned as an example. When we have tried to see the current conditions of this water schemes; due to pump and other installations, lack of water laboratory analysis reports and due to other security affairs & lack of fences those water schemes are not steel functional, simply they fishes water by using their own local and cultural methods from cultural and unprotected springs and hand dug wells.





*Figure1.6 Nonfunctional water schemes in and around the study area*

### **1.6.2 Water Demand**

The quantity of drinking water required for human survival will vary depending upon the climate, the amount and type of food intake, and human activity. The climatically condition of Gondar and its surrounding area (B/dar, Woreta, Metema, Quara, humera and other towns increased the requirement of drinking water. The minimum drinking water requirements lie in the range of 3-5l/person/day. Washing, cooking and other activity needs about 20-25l/person/day. The daily water demand is expected to be 25 L/person/day considering GTP-2 governmental water supply plane. The water demand analysis and population projection of the next 20years is made for only motorized schemes need.

In addition to this Irrigation activity by itself needs large & enough amount of water for a full production of the target area as we want as we like.

With this regard Geologist experts are sent by the water, irrigation and energy resource development bureau of region and zone (in together) to the target area and the study has conducted, where two potential deep well sites are selected, comparatively one is more promising from Irrigation activity point of view.

Therefore, taking this in to consideration immediate action has to be taken and the wells have to be drilled as fast as possible so as to conduct the construction of the remaining activities.

### **1.6.3 Identification of well site**

The water well site is selected on relatively weak zone (along the structure) of the area which follow the main river course and along the plain surface of the land and thick quaternary sediment. The potential aquifer is the fractured, jointed, and weathered basalt and quaternary deposit. The site is selected with Geophysical methods specifically of electrical resistivity methods (ERM) and with the participation of community members by expressing of their filling as the influence of water shortage and water borne diseases as well as the suitability of the area from irrigation point of view. The selected sites, GPS location, distance from town, type of scheme and site names are listed below in the table.



*Table1. 1 Some notes about each site*

Woreda	S/ N o	Kebele	Specific site name	GPS Location in UTM			Type of Scheme &depth	proposed Site ave. Dist.in km From road	Distance from wor eda town center in km	Road condition	Existin g water source	Contact person	Remark /Drilling system/
				North	East	Alt (m)							
Wegera	1	Taga	Gezewuye	1398717	361498	2746	BW_200	1	18	Accessible	Shallow well	Getahun (0918623 893)	<b>DTH/ MUD</b>
	2	Taga	Gichit	1397898	362950	2681	BW_200 /promising/	1	20	Accessible	Shallow well	>>	<b>DTH/ MUD</b>

Where, Ave = average

Alt = elevation

BW = borehole depth

DTH = drilling down the hole (air rotary drilling system)

HDW = hand dug well

HHs = house holds

Km = kilo meter

MUD = drilling with mud system,

SCH = school

\*\*\* The road conditions of the above mentioned water well sites are almost all of better (accessible) according to the current situation of the road that we have seen at the time of the study, but if there may need some maintenance during drilling, the surrounding societies are responsible to maintain and correct the road conditions of each water well sites, but it is possible during dry period only.

# CHAPTER TWO

## GEOLOGICAL SETTING

### *2.1. Regional Geology*

The regional geology of northern Ethiopia underlies by rock types range in age from Precambrian to recent. These rocks are categorized in to the following geological formations;

- Precambrian - Basement rocks
- Paleozoic sedimentary rocks
- Mesozoic sedimentary rocks
- Cenozoic volcanic rocks and associated sediments.

#### **2.1.1 Basement rock**

The Precambrian metamorphic and associated intrusive igneous rocks (volcanic plateau) make up 25% of the country's landmass. They are exposed in many parts of the country and have a fundamentally important tectonic position in that, they occupy the interface between the Mozambique belt in the south and the Arabian-Nubian shield to the north are consider by Kasmin (1971) and stern (1994). The Mozambique belt recognize throughout east Africa and the Arabian Nubian shield Achaean rock are oldest rock known so far on the earth, because rocks of the hadean age are not present due to various reasons . This age is generally known as fire age. Rocks of Achaean age in Ethiopia are recognized as the lower complex , comprising from the oldest crystalline rocks e.g. granites , gneiss and migmatites , with that of slate and phyllites , out cropping mainly in the south and south western part of Ethiopia , and can be traced in to typical Mozambique gneisses in Kenya having middle proterozoic age , which is composed of metamorphic rocks of pelitic composition , have typically sandstone, like quartzite's , amphibolites etc .Occurring in the southern

part of Ethiopia , specifically in Sidamo area . This unit is followed by the upper complex in ascending order which, is represented by a successions of terrigenous and carbonate sediments of upper proterozoic age only upper complex is exposed in northern Ethiopia , particularly in Tigray region . These units are separated from each other by unconformities representing huge time gaps during the formation .

The northern Ethiopia Precambrian rocks are characterized by the occurrence of low-grade volcanic, volcano-sedimentary, mafic and ultramafic rocks of ophiolitic character and plutonic rocks of typical Arabian-Nubian shield assemblage.

### **2.1.2 Paleozoic sedimentary rocks**

The Paleozoic sedimentary succession of northern Ethiopia exhibits a variable depositional environment . The Paleozoic sedimentary rock is sandwiched between basement rock ( the oldest outcrop litho logy ) and red sandstone outcrop litho logy. These sedimentary rock succession from the oldest to the youngest are as follows .

- ✓ Enticho sandstone formation
- ✓ Edaga Arbi Tillite formation

#### **2.1.2.1 Enticho sandstone formation (ESF)**

ESF is extensively exposed as remnants of conical hills un-conformably over lying the upper complex . There is huge time gap between the formation of upper complex and the depositions of ESF with angular unconformities . The Enticho sandstone formation is wide spread in northern Ethiopia and takes its name from town Enticho ( a town located on the Axum-Adigrat road ). It is well bedded ( with large scale cross beddings ) and is found as hills or irregular slopes below the cliffs of overlying Adigrat sandstone formation . EST was deposited by fluvial process during Paleozoic age ( 570 - 250 myr). However their exact age is not established so far due to absence of suitable tools . Paleozoic unit of northern Ethiopia are arranged by using measurable units in descending order.

### **2.1.2.2 Edaga Arbi Tillite Formation (EAF)**

A town on Axum – Adigrat main road, is type locality for this litho – unit.

This unit was studied for the first time in Edaga Arbi area from where it derives its name. This unit is also a thick succession of sedimentary rocks dominated by muddy lithologies and big boulders of granite, mapable on 1:50,000 scale and is dominated by tillite. This litho – unit of Ethiopia should be Gondwana and Corredovana super group, occurring in South Africa, South America, Madagascar, Antarctica, Australia and India.

The unit was deposited by glacier, so the unit was again given the name by its thin layer formation.

### **2.1.3 Mesozoic sedimentary rocks**

A thick succession of palaeo-mesozoic sediment covers 25% of country's landmass and is represented by three distinct sedimentary basins, particularly Mekelle, Ogade and Illu-Nile (Abay) basin. The Mesozoic sedimentary succession of Mekelle outlier, or generally of northern Ethiopia, exhibits a multi history depositional environment. The Mesozoic sedimentary rocks are sandwiched between basement rock and flood basalts. These sedimentary rock succession from the oldest to the youngest are.

- ✓ Adigrat sandstone formation
- ✓ Transition bed
- ✓ Antalo limestone formation
- ✓ Agula shale / mudstone formation
- ✓ Umbaradom sandstone formation

### **2.1.3.1 Adigrat sandstone formation (ASF)**

This is the name given by Bland Ford (1869) to the basal clastics on which the Adigrat locally overlies horizontal glacial rocks of Paleozoic age (Dowett al, 1971), Soxona asset, 1983).

The Adigrat sandstone (also known as lower sandstone) of mekelle basin has a maximum thickness of about 800m in vicinity of Abiadi, thinning westward over a short distance to about 80m above the Tekeze rivers and disappearing completely north of the Adigrat - Axum road and also 100-700m in abay river basin.

The sandstone have grey or red color, fine grained, well sorted and very mature (particularly, quartz arenite) type and is probably the result of the reworking of the underlying glacial sandstones cross bedding is quite common and bioturbation of the silt - shale occur frequently in the upper part of the section, where several red, ferruginous laterals beds occur.

The formation is clearly of fluvial to marine origin, as shown by the occurrence of point bar sequences, the abundant laterite beds and the presence of fossil wood. The Adigrat sandstone of mekelle basin consists of at least three major fluvial cycles, each capped by reddish mud units.

### **2.1.3.2 Transition bedes**

The boundary between the Adigrat sandstone and the overlying Antlo carbonates is transitional. There is around 20 - 25 m of shale with some calcarenite and sandstone intercalations. The sandstone vary in quartz of probable metamorphic provenance with rare feldspars and is scattered with small shale fragments, some oolite labeers and the common presence of brachiopods, cephalopods and echinoids document the shallow marine depositional environment of these transition beds on the other hand the occurrences of some laterite soils and ferruginous hard ground spotted with vertical borings points to repeated local withdrawal of the sea during the initial stage of Jurassic transgression.

### **2.1.3.3 Antalo Limestone formation (ALF)**

Antalo limestone is the next oldest Mesozoic sedimentary rock from Adigrat sandstone. Antalo limestone is a product of a major transgression caused by the flooding of the African continental margin and static sea level rise. The thickness of this litho- unit may reach from 100 to 4000m. This study area is continuous limestone – shale intercalated, the limestone variety is fossiliferous dominantly, because of marine depositional environment. This hard limestone unit was formed in shallow water, which is documented by the occurrence of oolitic bars coral offshore patches and more protected inshore facies. Boundaries on both sides of this unit are transitional.

### **2.1.3.4 Agula shale / mudstone formation (ASF)**

Agula shale is a rock which is sandwiched between Antalo limestone and Ambaradom sandstone. It is composed finely laminated shale, marl and limestone containing gypsum and dolomite. There is also shallow water and marine organisms are present, fine sediments are easily eroded / entruded to the ocean and mixed with carbonate. This unit has a thickness of about 100 - 300m

### **2.1.3.5 Umbaradom sandstone formation (USF)**

This unit is the youngest of Mesozoic sedimentary rock, which is also called upper sandstone. This rock unit is formed during regression of Indian Ocean and consists of coarse grained, mainly grey, brown and red sandstone commonly associated with conglomerate and clay stone lenses. It is also immature with respect to the underlying Adigrat sandstone. It has relatively 100 – 200m thickness, and is overlain by trap basalts. Main sedimentary structures seen in the sandstone are large and small scale planar-tabular and asymmetrical trough cross-beds, convolute beds, flat beds, scored and channel surface and massive beds. Quartz, k-feldspar and cherts are the major components.

The upper Jurassic sedimentary succession of Tigray is abruptly overlain with angular unconformity by silic clastic sediments the so called “ upper sand stone “ occurs in central Ethiopia, Eritrea and in south east Ethiopia. Pebble conglomerates occur throughout the formation.



## 2.1.4 Cenozoic Rocks and Associated Sediment

Cenozoic volcanic and sediments cover 50% of the country's land mass, and range in age from the late Eocene up to historical times. But the coverage of them in the present day is reduced time to time due to; erosion and dissolution (decomposition) effects, in which we are now living, began 66 million years ago. The Cenozoic is the final era of Geologic time, in which the continents and their landscapes acquired their present form. The era is separated into a tertiary and quaternary period.

The Cenozoic is a time of considerable tectonic plate motion and sea floor spreading, which is much more similar to basaltic flow, that is volcanic rocks. A major unconformity representing a marine regression does indeed serve nicely as a boundary between the paleogene and neogene systems. "A wedge of sediments that thickness sea ward" is particularly suitable description for the Cenozoic formation of the gulf coast, which is the best record of Cenozoic strata in north America.

At the close of the Paleozoic era and Mesozoic era the seas were withdrawn from the continental plate forms into the ocean basins, the continents were gathered into a super continental mass called Pangaea, the continental shelves were marine invertebrates thrived were highly restricted.

The fossil record of all vertebrate groups are much more complete in the Cenozoic than the other eras. The major reptilian groups that were present in the late Mesozoic have persisted into the Cenozoic (except for the dinosaurs and large marine reptiles). Geologists think of the Cenozoic as the age of mammals, for they are certainly the most conspicuous terrestrial vertebrates. Like the reptiles of the Mesozoic, mammals also radiated extensively in aquatic environments, and the bats achieved flight.

It is apparent from fossil evidence and oxygen isotope studies that the earth's climate was on somewhat fluctuating cooling trend during the Cenozoic (Levin – Cenozoic climate). The culmination of that trend was the beginning of extensive glaciations about 1 million years ago.

Cenozoic volcanic contains various semi-precious stones and industrial minerals including potash, bentonite, opal, diatomite and sulphure.

A wealth of gold, tin, copper, silver, and other metal is found in deposits or associated with intrusion of Cenozoic rock, the greatest resource of the era has been petroleum. This all are considered as a minerals resource of Cenozoic.

Generally, a compilation of the great historical events of the Cenozoic would certainly include the formation of the Alpine Himalayan mountain systems, the drift of continents to their present locations, the uplift of mountains around the perimeter of the Pacific, the development of an ice age, and the evolution of Homosapiens. Levin (The earth through time, 4<sup>th</sup> edition)

The Project/study area, Gondar specifically Wegera and those environs is part of the northwestern Ethiopian Highlands dominantly covered with Cenozoic volcanic covered with patchy Quaternary alluvio-colluvial deposits. The volcanic is dominantly Tertiary Trap Series basaltic lava flows with occasional acidic volcanic rocks. In the Lake Tana basin, Quaternary volcanic rocks exist along with thick alluvial and lacustrine deposits.

In terms of geodynamic, setting the region is located on relatively stable plateau. However, due to heterogeneity of the basement beneath the thick volcanic succession there are large faults affecting the region, particularly in the Lake Tana basin. These structures are very important from hydrogeological point of view. Major groundwater reserves are localized along these regional structures. These large faults are clearly observable on satellite images. These structures are younger than the Trap volcanism and possibly related to the local Quaternary extensional tectonic activity around Lake Tana (Chorowicz et al, 1998).

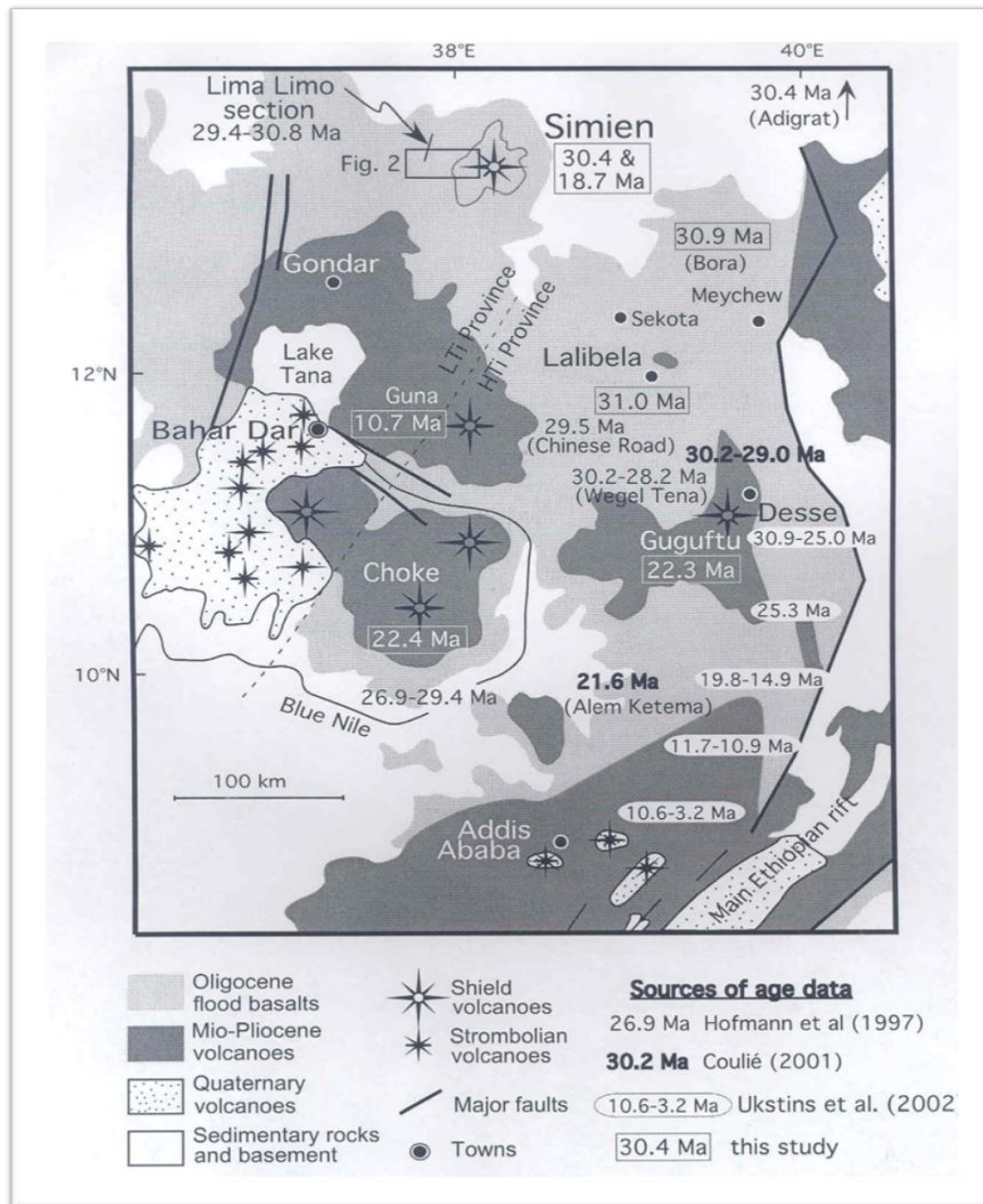
The Lake Tana basin is located at a triple junction of three aborted tectonic arms namely: the DebreTabor, Dengel Ber and Gondar arms. Most of the selected sites are confined in the Gondar tectonic belt, which is characterized by NNW-SSE and N-S striking faults. There are few NE-SW and NW-SE structures, which are interpreted as conjugates of the principal directions. The NNW- SSE faults are the most frequent structures, which have modified the morphology of the region enhancing differential erosion on the fractured

rocks. The most striking structural feature in the region is the Lake Tana Depression and the various faults associated to it.

The faults around the lake resemble a circular shaped tectonic subsidence (Chorowicz et al., 1998). South and east of the lake, the surface expression of this geological process are fresh lava flows, numerous scoria cones and plugs.

In the elevated plateau, the thick volcanic sequences are highly variable in terms of age and composition. The Trap Series rocks are made up of several distinct volcanic centers of different ages and magmatic affinities (Kieffer et al., 2004).

The following Figure shows the regional geological map established based on field observations and interpretation of satellite images and SRTM data.



*Figure2.1 Map of the Northern part of Ethiopian Plateau showing volcanic province (Source: Kiffer et, al 2004)*

From the oldest to youngest, Cenozoic volcanic rocks of northern Ethiopia (EFBs) can be classified in to the following four units as shown in the regional hydro geological map (Fig-3.1);

- ✓ Ashanghe Basalt Formations
- ✓ Aiba Basalt Formations
- ✓ Alaji Basalt Formations
- ✓ Tarmaber Basalt Formations

#### **2.1.4.1. Ashanghe Basalts**

The oldest fissure basalts on the Ethiopian plateau were described by Blanford (1869) as the Ashange group, which is dominantly basaltic in composition. This group consists predominately of alkaline basalts with interblended pyroclastics and rare rhyolites erupted from fissures. Dolerite sills, acidic, gabbro-diabase dykes, and other intrusions intrude them. The flows range in total thickness from 200 to 1,200m. The thickest exposed outcrop occurs close to the rift escarpment. However, the Trap Series attain their maximum inferred thickness in the plateau.

The upper part of the Ashange group is more tuffaceous containing lacustrine deposits including lignite seams and acid volcanic and locally over lays the older part of the group with angular unconformity. Out crops of the Ashenge basalts are restricted to the north central part of the Ethiopian plateau. The Ashangie Basalts have a Paleocene to Oligocene age.

#### **2.1.4.2. Aiba Basalt**

The Aiba basalts represent the second major volcanic cycle in the Ethiopian plateau. The basalts of these formations, which were produced by fissure eruptions, attain a thickness of 200 to 600 meters. They show a distinctive tholeiitic nature with transitions to alkaline varieties. The absolute age of the Aiba Basalts (P3a) ranges from 34 to 28 Ma. Placing them in Oligocene (Zanetti et al., 1980; Kazmin, 1979)

#### **2.1.4.3. Alaje Formation**

The top part of Ethiopian flood basalt is characterized by Alaje series intercalated with ignimbrites.

This formation is mainly represented by aphyritic stratoid basalts associated with rhyolites and to a lesser extent with trachytes as well as it includes the lithologies, ranges from mafic to felsic composition. The Alajae Formation contains basalts transitional to tholeiitic in nature and an increase in alkalinity is observed in the younger members of the formation.

According to Zonetime et al. (1974), northwest of the line joining Ambo and Richie, on the Addis Ababa-Dessie road, the Alaji basalts are of Oligocene age.

#### **2.1.4.4. Tarmaber Basalts**

On the Ethiopian highlands, the fissure eruptions of the Ashenge, Aiba, and Alaji basalts were followed by central type volcanism which created the large shield volcanoes of the Tarmaber group, Ras Dashin, Mengistu, Choke-Meghezez, Abune Joseph and other mountains. The Tarmaber group is represented by various basalts from femic pyroxen-olivine porphyritic basalts to leucocratic plagioclase porphyritic types and scoraceous horizons are in many places seen at the bottom of flows.



## ***2.2 Local Geology***

### **2.2.1 General description of the local geology of the study area.**

In Ethiopia there are three types of rocks; those are metamorphic, sedimentary and igneous (volcanic) rocks. But in the study area and in the region as a whole, igneous (volcanic) rocks are the most dominant. Those volcanic rocks are also classified based on their mode of occurrence, composition and texture. Based on their occurrence and composition many of them are similar, but texturally there are many lithological units exposed in the study area, each of these lithology's has its own characteristics in terms of degree of weathering, fracture, color and a little bit of composition. There are also some structures and Geological processes in our study area, among those structures:- Geological structure, sedimentary structure, subsidence structures and fractures are the common ones. And mainly different types of lithology's like clay lithology's and different types of basaltic rock lithology's are mostly observed in the study area. The color, grain size, texture and other characteristics are important to describe each lithological units.

### **2.2.2 Detailed description of the local geology of the study area:-**

Among the common lithological units that we have observed in and around the study area, the following units can be mentioned as an example;

- Amygdaloidal Basalt
- Boulder unit
- Clay unit
- Dolerite rock unit
- Quaternary & alluvial sediment deposits
- Quartz mineral
- Tuff unit and
- Vesicular Basalt (scoria)

### 2.2.2.1 Amygdaloidal Basalte

This is basalt; a dark colored volcanic rock formed from magma of basic composition erupted on the Earth's surface. ... Filled cavities in lavas are called amygdales, and a rock full of them can be called amygdaloidal. The amygdales are usually white in color. A related texture is amygdaloidal in which the volcanic rock, usually basalt or andesite, has cavities, or vesicles, that are filled with secondary minerals, such as zeolites, calcite, quartz, or chalcedony. Individual cavity fillings are termed amygdules (American usage) or amygdales (British usage).

This rock unit is the common one in the study area, and is correlated with the regional Alaje series rock unit, based on its color, texture and grain size. This unit consists of mainly whitish and grey color in its weathered part.



*Figure 2.2 Amygdaloidal rock units*

### 2.2.2.2 Boulder unit

Boulders are unusually large and spherical boulders lying along a stretch of river Beach. They occur scattered either as isolated or clusters of boulders within a stretch of beach where they have been protected in a scientific reserve. The erosion by wave action of mudstone, comprising local bedrock and landslides, frequently exposes embedded isolated boulders. These boulders are grey-colored septarian concretions, which have been exhumed from the mudstone enclosing them and concentrated on the beach by coastal erosion. After the concretions formed, cracks are common as septaria formed in them. Brown calcite, yellow calcite, and small amounts of dolomite and quartz progressively filled these cracks when a drop in sea level allowed fresh groundwater to flow through the rock enclosing them.

In the study area, this unit is common especially near the site of Gichit and in some parts of Wegera woreda.



*Figure 2.3 Boulder units*



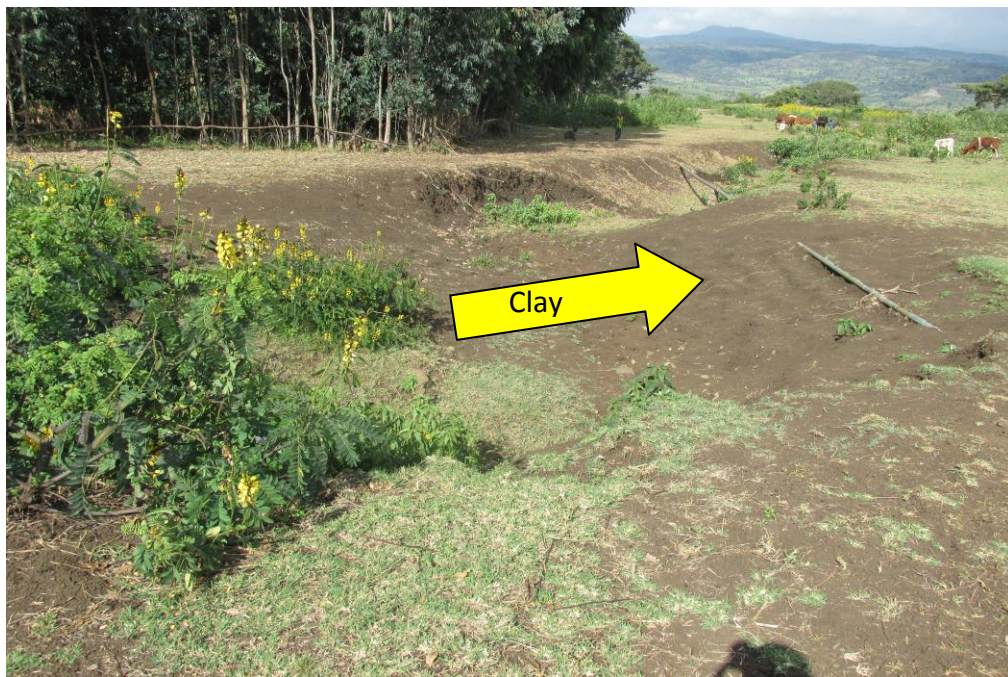
### 2.2.2.3 Clay unit

Clay unit is an earthy material that is plastic when moist but, hard when fired (heated), that is composed mainly of fine particles of hydrous aluminum silicates and other minerals or it is simply a fine-grained soil or water-soaked earth.

It is produced by the chemical decomposition of rocks or the deposit of fine rock particles in water.

Clay unit is found in & around some parts of the study area. Especially in the inter site gravel road of Amba-Giorgis to Taga line parts, and in the local name called “sub marine” has a composition of clay.

This rock unit has various types of color, among them black, greenish and brownish color is mentioned.



*Figure2.4 Brownish color Clay unit*

#### 2.2.2.4 Dolerait rock unit

Dolerite (diabase, microgabbro) is a dark-colored, medium-grained igneous rock which contains plagioclase feldspar of labradorite composition and pyroxene of augite or titanaugite composition as essential minerals, and magnetite, titano-magnetite, or ilmenite as accessory minerals. Where olivine also occurs as an additional mineral, the rock is termed an ‘olivine dolerite’. Where quartz occurs as an additional mineral in the groundmass, the rock is termed a ‘quartz dolerite’. Dolerites are the medium-grained equivalents of basalts and, like the basalts, can be divided into alkali and tholeiitic types (see also ALKALI BASALT; and THOLEIITE). Dolerites are commonly found in shallow level intrusions (dykes, sills, or plugs) of basaltic composition. This rock unit is also characterized by spherical weathering (onion like weathering) and number of joint with a few centimeter length openings which enhances the water infiltration until it reaches the massive part of it, that is; with increasing depth, the dolerite rock becomes massive. It is highly distributed in almost all of the study area, and which is also correlated with the regional geology of Alaje series.



*Figure2.5 Dolerite rock units*



### 2.2.2.5 Quaternary sédiment

The quaternary deposits are found in the gentle to flat topography of the study area and they are deposited from the above and the surrounding hilly areas due to erosion and gravitational force. However, erosion decreases currently due to different soil and water conservation methods conducted especially in some areas of the upper catchment.

The quaternary deposits contain fine, medium to coarse grained size soils with variable thickness. These quaternary deposits are either alluvial or colluvial. Alluvial deposits are limited to areas closer to stream routs while colluvial deposits are found in areas far from river courses around the study areas which are formed through weathering and transportations of its surrounding parent materials. The main agents of its formation could be water, gravity and little bit of wind. This unit is also correlated with the regional geology of Tarmaber formation.



*Figure2.6 Quaternary sediments*



### 2.2.2.6 Quartz Mineral

Quartz is the second most abundant mineral in Earth's crust after feldspar. It occurs in nearly all acid igneous, metamorphic, and sedimentary rocks. It is an essential mineral in such silica-rich felsic rocks as granites, granodiorites, and rhyolites. It is highly resistant to weathering and tends to concentrate in sandstones and other detrital rocks. Secondary quartz serves as cement in sedimentary rocks of this kind, forming overgrowths on detrital grains.

This litho unit is widely distributed mineral of many varieties that consist primarily of silica, or silicon dioxide ( $\text{SiO}_2$ ). Minor impurities such as lithium, sodium, potassium, and titanium may be present. Quartz has attracted attention from the earliest times; water-clear crystals were known to the ancient Greeks as *krystallos*—hence the name crystal, or more commonly rock crystal, applied to this variety. The name quartz is an old German word of uncertain origin first used by Georgius Agricola in 1530.

In the study area quartz is moderately abundant and distributed, especially in the south eastern, south western and in the central part of the study area.



*Figure 2.7 Quartz mineral*

### **2.2.2.7 Tuff unit**

A light, highly porous rock formed by consolidation of volcanic ash is known as tuff.

This unit exists in the form of unwelded (lapilli/ash) tuff, moderately welded or welded tuff/lithic fragments. In the study area, this unit is the moderately abundant formation and correlated with the regional geology of Aiba series.



*Figure 2.8 Tuff units*



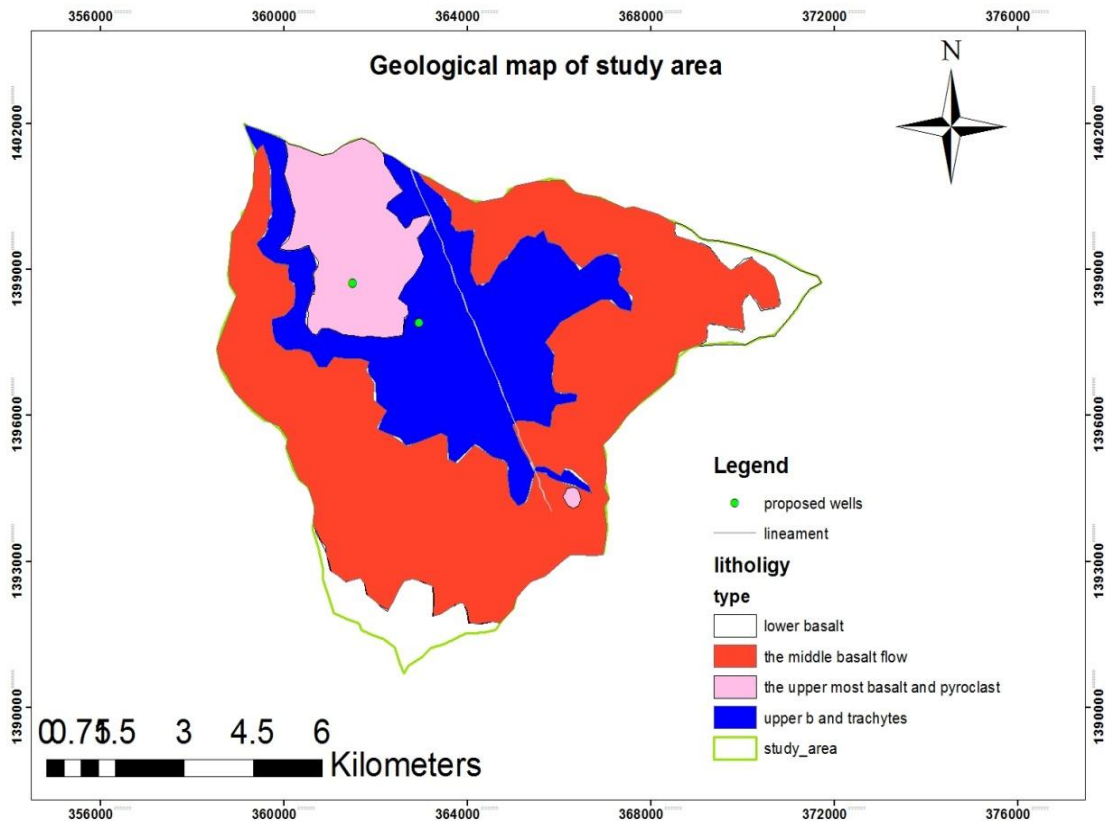
#### **2.2.2.8 Vesicular Basalt**

This type of basalt is formed during the lava solidifies before the gas escapes. Due to this, it includes numerous cavities or vesicles. Those gas bubbles gives a vesicular texture for this types rock that is why it takes its name “vesicular basalt” from this process. This rock unit is common in the study area especially in the site of Gezewuye. It is also correlated with the regional geology of Alaje series.



*Figure2.9 Vesicular basalts*

Lastly, the geology of the study area is generalized by the following figure (fig 2.10), i.e. The upper part of the area is basaltic unit and the underneath formation is pyroclastic rocks such as unwedded tuff (in the study area there are tuff units with in different ranges).



*Figure2.10 Geological Map of the study area*

## ***2.3 Geological structures of the study area***

The study area is characterized by different primary and secondary geological structures as well as with different geological intrusions. Primary geological structures are structures which are formed during the depositions of sediments, while secondary structures formed after depositions of the sediments. Among these structures, fracture (fault and joints), mud cracks and subsidence structures can be mentioned. Ground water direction and potential is determined by Geological structures.

### **2.3.1 Faults**

Faults are a type of fractures in which a measurable displacement between two blocks has occurred. In our study area a minor fault /weak zone) is present in between the borders of Gezewuye and Gichit, near the site / sheds of the borehole. From geological point of view major faults are ground water indicator structures.



*Figure2.11 Minor fault lines*

### 2.3.2 Joints

Joints are other division of fractures which has no measurable displacement. The study area joints are characterized by different set of joint orientations. Mostly in the area, those structures are observed in river cut rock units.



*Figure2.12 Joints*

### 2.3.3 Mud cracks

Mud cracks are multi directional (polygonal) pattern of cracks formed in very fine grained sediment as it dries (due to evaporation of water). Mud crack indicates that the sediments were initially deposited in the presence of water and it becomes subsequently dry by exposure to air before.



*Figure2. 13 Mud crack*



## ***2.4 Geological processes***

There are many Geological processes in the world, among them volcanic eruptions, earth quake, land slide, tsunami, weathering and erosion are the most common one.

But, in our study area weathering and erosion are the most dominant recent and current geological processes.

### **2.4.1 Weathering**

When we say weathering; it is the physical break down and chemical alteration of rocks and minerals at or the earth's surface in to products that are more in equilibrium with the conditions found in the environment.

The rock units which are highly affected by weathering are easily penetrated by plant roots, due to this they becomes important for percolation of rain and other water sources into the sub surface of the earth.



*Figure 2.14 weathering and its effects*

### 2.4.2 Erosion

This is one of the Geological processes, that the transportation of weathered materials from one place to another, through a transporting agent of water, wind or gravity.

However, erosion decreases currently due to different soil and water conservation methods conducted especially in some areas of the upper catchment.

This process is common in some sites of the study area. The following figure (Figure 2.10) Shows, part of the earth which is highly affected by gully erosions before, but at a time it is a little bit conserved with small plants.



*Figure2.15 Gully erosions*

## CHAPTER THREE

### HYDROGEOLOGICAL SETTING

#### *3.1 Regional Hydrogeology*

Four broad hydrogeological units can be recognized for the entire volcanic province of Ethiopian Plateau. The recognition of the four hydro stratigraphic units is based on geomorphic manifestations, aquifer properties and mode of groundwater occurrence, groundwater flow and discharge. The contrast in geomorphic appearance of the various stratigraphic sequences of the plateau flood basalt is the manifestation of differences in erosion resistance which in turn is partly related to permeability structure of the formations (S. Kebede, Groundwater in Ethiopia, Springer Hydrogeology).

The four hydro-stratigraphic units are:

1. Basal sequence: The gently undulating, rugged thinly bedded, brecciated, deeply weathered and low permeability base of the flood basalts (traditionally called Ashangie basalts)
2. Upper sequence: The flat topped, cliff forming, thickly bedded scoriaceous, slightly weathered, permeable and relatively higher productivity aquifers with some intercalations of acid rocks, capping the entire Ethiopian volcanic plateau. Traditionally this hydrostratigraphic unit is made of the Aiba, Termaber and Alaji formations.
3. Shields: The morphologically prominent, shield volcanics made up of composite stratigraphy of volcanic materials (ashes, rhyolites, trachytes, basalts) occupying broad area. Typical hydrogeologic features are emergence of springs at various locations of shield volcanoes.

From hydrogeological point of view, volcanic rocks are not treated as hard rocks (rocks without primary porosity and conductivity for feasible groundwater extraction). Structures such as shrinkage cracks (cooling joints), vesicles, lava tubes, rubble beds, tree molds, voids left between successive flow, buried soils, buried river channel, give primary porosity and permeability for these rocks(Tamiru,2006). The presence and

abundance of these structures play a great role in the distribution and circulation of groundwater. Other conditions being favorable weathered, fractured basalt with primary volcanic structures is found to be a promising aquifer as confirmed by the productive wells that tap this formation in different parts of the region. In the study area recharge to groundwater is mostly from rainfall, and rivers.

Alluvial deposit in the study area is generally located primarily along water courses with the coarser material confined to areas in the immediate surrounding streams. From the hydrogeological point of view the alluvial deposits have shallow depths (10m on average) except Fogera plain which thickness reaches about 100m that have significant hydrogeological importance. Lineaments are large scale linear features which express itself in terms of topography which is in it an expression of the underlying structural features. From hydrogeological point of view, such features includes

- ✓ valleys controlled by faulting and jointing and ridge lines
- ✓ abrupt truncation of rocks
- ✓ straight segments of streams
- ✓ and right angled offsetting of streams

As these linear features are commonly associated with dislocation and deformation, they provide the path ways for groundwater movements. Different lineaments predominates the study area and efforts were made to locate the proposed wells at the proximity of these lineaments.



### ***3.2 Local Hydrogeology***

The recharge to the aquifer systems of the study area is from surrounding highland, rainfall and from some surface waters. Source of recharge in the area mainly includes stream and precipitation. Cracks, fractures bedrock depression and weathered basalt are the geologic subsurface structure in volcanic terrain that can favor groundwater accumulation. Porosity, permeability and transmissivity are the parameters of an aquifer. A good aquifer must have high porosity, high permeability and transmissivity.

Locally, the intensity of fracturing and faulting as well as the degree of weathering determine the aquifer potential and direct infiltration of the rock (Tesfaye and Gebretsadik, 1982).

The ground water potential of the study area depends on number of factors. These factors include climate, geology, vegetation, physiography, etc. Among these physiography, geology and climate play a great roll, (Children's home society, 2009)

The existing bed rocks, observed in the study area such as vesicular basalt, dolerite and other rocks in the study locally, due to their intensive fracturing they contribute a good amount of recharge to the aquifer systems of the area.

The study area is situated on the lowland and highland plateau of northern Ethiopia, with dominant rock units of Dolerite, clay, quaternary sediment and pyroclastic materials like tuff. These rock units are highly weathered and fractured with high permeability at places, especially at the margin of river channel.

Rather than this the pre-existing shallow well and deep well data's of Wegera wereda shows the ground water is not deeper than 150-200m. The following lithological units have their own properties to be a potential aquifer in the study area.

### **3.2.1 Dolerite rock unit**

This rock unit is characterized by spherical weathering /Exfoliation process/ and number of joint with a few centimeter length openings which enhances the water infiltration until it reaches the massive part of it. The exposed part of this rock unit is highly weathered and fractured. But with increasing depth the dolerite becomes massive. There for, from hydro geological point of view, highly weathered and fractured dolerite is act as groundwater bearing formation (potential aquifer) but massive dolerite does not serve as media for groundwater movement.

### **3.2.2 Quaternary sediment**

These sediments are formed due to erosion and depositional process. However, erosion decrease currently due to different soil and water conservation methods conducted especially in some areas of the upper catchment. Since these sediments consist, proportions of different grain size that are transported from various parent materials. They become very important for infiltration and storage of ground water. Their transmissive capacity and productivity vary from place to place depending on their grain size, sorting and thickness. As I have seen in the study area, this unit is suitable and very important for transmissivity and storage of groundwater.

### **3.2.3 Tuff unit**

Naturally this unit is very soft and it acts as pores media for transmissivity of ground water. That, it is a potential aquifer in the site of it exists. Next to dolerite, this unit is common and the best permeable formation in the study area.

Not only tuff unit but also all other pyroclastic materials are very important to be an aquifer, due to their properties of high porosity and permeability nature.

Generally tuff and other related pyroclastic materials are important for transferring and storing ground water and the water raised from those is fresh due to the presence of plagioclase feldspar mineral.



### **3.2.4. Vesicular basalt**

As we have recognized from its name, it has numerous cavities and vesicles, and those vesicles are very important for transferring and storage of ground water. That is it has good transmissivity and storage capacity and act as a potential aquifer.

# CHAPTER FOUR

## METHODOLOGY

### *4.1 Geophysical signature*

Searching for groundwater has become quite intense in human history. This is due to the fact that supply is unable to meet the ever-increasing water demand with surface water only; inhabitants have/ had to look for alternative sources such as surface streams, shallow wells and boreholes. I.e. directly indicates searching different types of Geophysical methods to meet the overburden depth, for extracting the buried fresh underground water.

Geophysical evaluation with different Geophysical methods like seismic, magnetic, resistivity and gravity methods are used for ground water exploration to identify different types of strata, subsurface lithological units and geological structures within it.

Seismic method provides fairly accurate estimates to the depth of different layers and bed rock units, while gravity methods used in determining broad and deep valleys and caves. However, the current investigation is directed by direct current resistivity methods to identify different lateral and vertical ground water bearing formations and structures.

#### **4.1.1 Electrical Resistivity Method (ERM)**

Surface electrical resistivity surveying is based on the principle of distribution of electrical potential in the ground and measure the potential difference between two potential electrodes, when the current is injected through the current electrode.

I.e. direct or low frequency alternating current is introduced in to the ground by means of two electrodes connected to the terminals of portable sources. The resulting potential distribution on the ground is the ability of gathering information about the distribution of electrical resistivity below the surface. Frischknecht (1966).

The electrical resistivity method measures apparent resistivity of soils and rocks as a function of depth to study the sub surface hydrogeological set up of the area.

The potential electrodes are in line between current electrodes, the current electrodes but in principle they can be located anywhere. All analysis and interpretation are done in the basis of direct current (DC) of low frequency. The distribution of potential can be related theoretically to ground resistivity and their distribution for some sample cases, the case of horizontally stratified and the case of homogeneous masses separated by vertical structures. (AL-Garni, M.A. 1996.)

The resistivity of soil and rock is governed primarily by the amount of pore water, to the extent that differences of lithology are accompanied by differences of resistivity. The aims of this method are to map the sub surface change in earth resistivity and correlate with the hidden lithology of the area or geological formation of the area.

Resistivity method is measuring variation of electrical resistance by causing an electrical current to flow through the ground using wires connected to it. For most material, the current through of the material, increasing in proportion to the potential difference, doubling the potential double the current and the voltmeter measures the potential difference at two potential electrode and the ammeter measures the current flowing through it.

The electric current  $I(A)$  in a short thin, linear conductor of uniform cross section is given by ohm's law as

$$I = -dV/R$$

Where  $-dV$  is potential difference (volt, v) between the ends of the conductor.

- $R$ (in Ohm) is the resistance of the conductor
- The minus sign expresses the fact that the current flow is from high to low potential.
- $R$ - length of the  $dl(m)$  of the conductor
- $R$ -inversely proportional to the cross sections  $A(m^2)$

$$R = \rho L / A$$

$\rho$  is the resistivity of the material for the conductor.

The resistance is a characteristic of a particular path of an electric current whereas resistivity is a physical property of the material. This expresses its ability to oppose a flow of charged particles. The unit of resistivity is ohm-meter.

If  $R$  is substituted by  $V/L$ , then the equation become,  $V/L = \rho I/A$

$V/L$  is the ratio of the electric field (assuming the potential gradient to be constant along the length of the conductor)

$I/A$  is the ratio of current per unit cross sectional area of the conductor. It is called as current density and denoted by  $J$ .

Ohm's law gives

$$E = \rho J$$

This formula is useful to calculating the formulas used in resistivity methods of electrical surveying, the quantities that are measured as  $V$  and  $I$ .

In ERM there are two types of resistivity surveying methods; the first one is vertical electrical sounding (VES), provides information about resistivity variation with depth. The 2<sup>nd</sup> method is electrical profiling, which provides information about the lateral variation of resistivity.

#### 4.1.1.1 Vertical Electrical Sounding (VES)

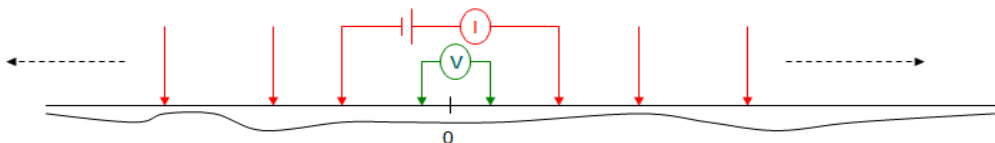
This method is also called depth sounding/ point sounding/, which is used to identify horizontally stratified sub surface layers based on the resistivity variation. Within the uniform layer the current path are smooth curves but they bend as they cross an interface separating different resistivity. Apparent resistivity of the VES Survey is the ratio of current to potential difference and is measured with increasing electrode separations. The ratio changes for two reasons because of change of resistivity but also simply because the electrodes are being moved apart. Van Nostrand and cook (1966)

The instrument used during the investigation was a portable integrated terrameter resistivity meter of mark ABEM Terrameter LS1, powered by 12v battery.



*Figure 4.1 ABEM Terra meter LS geo-electrical imaging system*

The measurements are taken with gradually increasing distances of the current electrodes (the potential electrodes remain constant at some station) and the procedure is called “electrical drilling” (Fig 4.2). As the distance between current probe is increased, there is also an increased in the depth at which the current penetrates below the surface of the distribution, below the center of the array is determined (Loke, 2001).

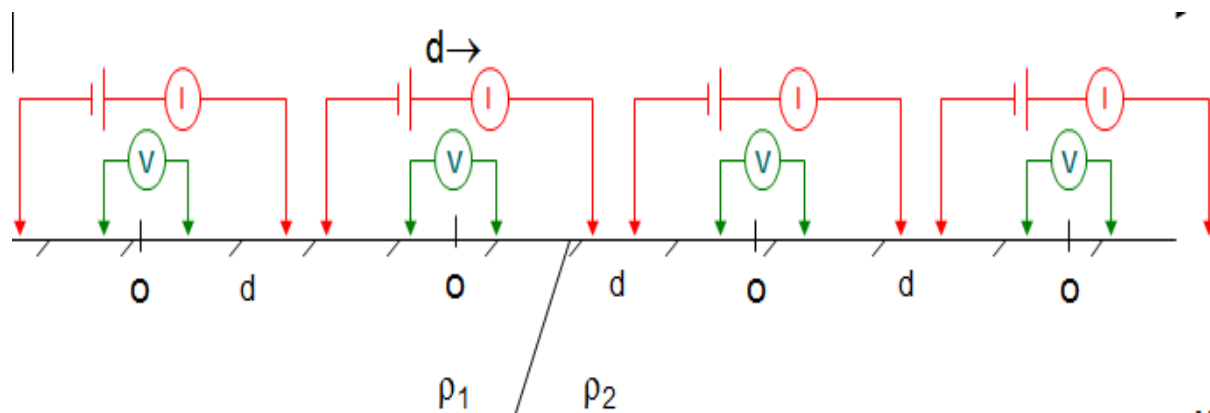


*Figure 4.2 Schematic Plans for Vertical Electrical Sounding (VES) (After Loke, 2001)*

#### 4.1.1.2 Resistivity Profiling

Electrical resistivity profiling investigates lateral changes such as mineral vein, geologic contacts, igneous intrusion, etc. The entire electrode moved laterally along the profile, the procedure is also called lateral inhomogeneity hunting, and it is shown in Fig 4.3. The procedures are especially useful to locate and map vertical contacts like dykes, faults, fissures segregated mineralization zones (Loke, 2001).

In resistivity profiling the whole array is moved along the profile with constant geometry, i.e. with constant depth of investigation. Lateral/horizontal resistivity changes are the target.



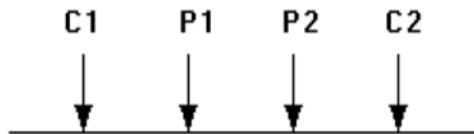
*Figure 4.3 Schematic Plans for Electrical resistivity profiling (After Loke, 2001)*



### 4.1.2 Electrode configuration

The two potential and two current electrodes can be placed over the ground in various ways. This disposition of the four electrodes gives rise to what are known as the **Electrode Arrays, Configurations, Layouts or Arrangements**.

In practice, the conventional array to measure subsurface resistivity is as shown below.



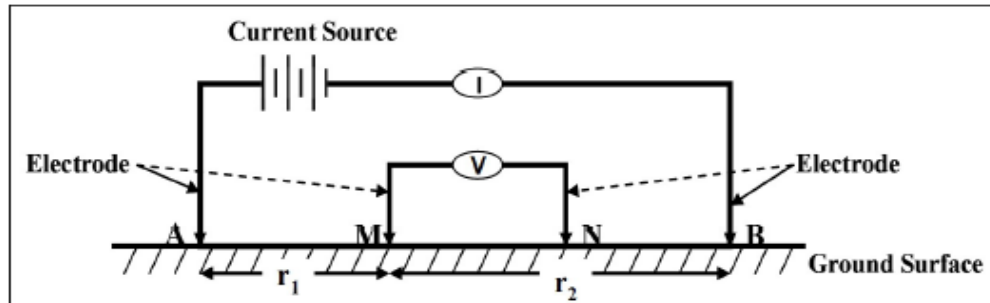
*Figure 4.4 conventional electrode configurations*

Current is injected into the ground through the current electrodes, C1 and C2, and the resulting potential difference (V) is measured between the two potential electrodes, P1 and P2.

There are many electrode configurations, such as wenner, schlumberger, dipole dipole, pole dipole, pole pole, gradient, square electrode configurations (array). Among these arrays wenner and schlumberger arrays are widely used.

#### 4.1.2.1 Schlumberger electrode Array

In this system, the electrodes are symmetrically placed about a point at the center of the array. The two current electrodes C1C2 moves outward symmetrically but the potential electrodes are kept fixed to a certain distance.

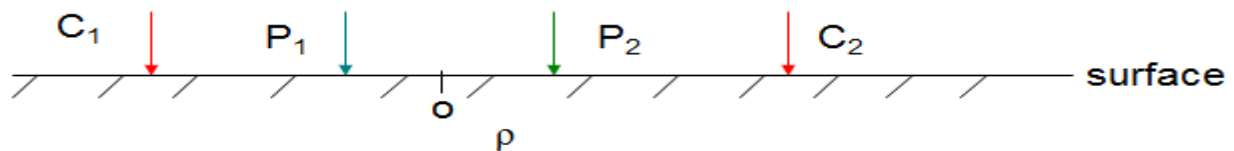


*Figure4.5 Schematic diagram of a four point schlumberger array*

Where, A & B are current electrodes, M and N are potential electrodes (modified after van nostrand and cook, 1966 [22], in stummer, 2003[23]).

#### 4.1.2.2 Wenner electrode array

In this system, all the four electrodes are equally spaced.



*Figure4.6 wenner electrode array configurations*

But here, the schlumberger configuration is used since we are investigating the depth at a point for potential water well. The maximum electrode separation  $AB/2$  used was between 750m.

### **4.1.3 Relation between Geology and Resistivity**

Geophysical investigation involves the measurement of the apparent resistivity of soil and rocks as a function of depth to study subsurface hydrogeological set up of the area.

The objective of electrical resistivity survey is to map the subsurface change in earth resistivity and correlate them with hidden geological formation and degree of fracturing filled with ground water. Rocks which usually are more porous and have a higher water content normally have lower resistivity values. Wet soils and fresh ground water have lower resistivity values. Clay soil normally has lower resistivity value than sandy soil of the same composition. The resistivity of any formations mainly dependent on two factors, the porosity of the formation and the salinity of the solution held in the pore. Electrical resistivity survey can be used profitably for solving various ground water problems such as:-

- To determine qualitatively the type of water bearing formation,
- To determine between saline and fresh water aquifers, provided the lithology of the aquifer is uniform

Generally the resistivity method is used to determine depth of water table, extent of salt water intrusion, type and thickness of lithological unit, type of geologic structures and over burden depth.

#### **4.1.4 Limitation of the Electrical Resistivity Method**

The electric resistivity method has some limitations that affect the resolution and accuracy that may be expected from it. Like other Geophysical methods using measurements of potential field value of measurement obtained at any location represents a weighted average of the effects produced over a large volume of material. With the near portions contributing most heavily tends to produce smooth curves. Which do not lend themselves to high resolution for interpretations. Another common to all potential field geophysical method is that a particular distribution of potential at the ground surface does not generally have a unique interpretation.

In addition, this method uses long cable to investigate greater depth, it consumes much field time and its interpretation for complex geologic structures is difficult and ambiguous. The presence of metal pipes, cables, fences and electrical grounds can also complicate interpretation, therefore accuracy of depth determination is lower than with seismic techniques. For these reasons it is always advisable to use several complementary geophysical methods in an integrated exploration program rather than relying on a single exploration method. (Flathe, H. 1970.)

#### ***4.2 Data Acquisition and Processing***

Electrical resistivity method is a major Geophysical tool in ground water exploration efforts. Principle of electrical resistivity method is by applying direct current into the ground by means of two metal electrodes and measures the resultant potential difference between two potential electrodes. Because of resistance of earth materials to current passage, some voltage loss will be occurring as the current flows between the current electrodes. This voltage loss is measured at the other two electrodes placed between the current electrodes. Generally, electrical resistivity surveys measure variation in the electrical resistivity of the ground by applying small electric currents through two metal electrodes into the ground.

The survey data is processed to produce graphic depth sections of the thickness and resistivity of the surface electrical layers. The resistivity sections are correlated with ground interface such as soil, bed rock interface to reveal detailed information on subsurface ground conditions.

### 4.2.1 Field Procedure and Data Acquisition of ERM

Geophysical methods are important to save cost expenses and time of drilling. Before conducting drilling operation, Geophysical methods are investigated to select appropriate sites. Therefore, the first actual step after planning to carry out Geophysical survey is data acquisition. A set of measurements made with a Geophysical instrument (Fig. 4.7)



*Figure 4.7 Field Procedures*

Resistivity surveys are made to satisfy the needs of two different kinds of interpretation problems.

- The variation of resistivity with depth reflecting more or less vertical stratification of the earth material.
- The lateral variations in resistivity that may be indicate soil lenses and isolated faults or cavities.

The 1<sup>st</sup>, kinds of problem measurement of apparent resistivity are made at a single location (or around a single center point) with systematically varying electrode spaces. This procedure is called vertical electrical sounding (VES). Surveys of lateral variation may be made at spot or grid location or along definite lines of traverse, this procedure sometimes called horizontal profiling.



The arrays of data acquisition from vertical electrical sounding (VES), point of are either the schlumberger or less effectively the wenner array is used for sounding. Since all commonly available interpretation methods and interpretation aids for sounding are based on these two arrays. The resistivity raw data of the current research work were collected by using the schlumberger array method. VES surveys with the schlumberger arrays are made with fixed center point. An initial spacing (the distance from the center of the array to either of the current electrodes) is chosen and the current electrodes are moved outward with the potential electrodes fixed at a point.

Schlumberger array is a linear array with potential electrodes placed close together. AB (spacing of current electrode from the center) is set equal to or five times greater than the values of the MN (spacing of potential electrode from the center). The simplest target of VES is a vertical boundary between two resistivity values such as; two lithologies offset by a vertical fault or the contact of a large intrusion.

For either type of electrode array minimum and maximum spacing are governed by the need to define the asymptotic phase of the apparent resistivity curve and the needed depth of investigation. Apparent resistivity curve should be plotted as the survey progresses in order to judge whether sufficient data have been obtained. Also the progressive plot can be used to detect errors in reading or spurious resistivity values due to local effects.

### **4.2.2 Data Processing and Data Presentation ERM**

At the end of a survey, the result should be presented in tabular and graphic forms. This offers an opportunity to emphasize features, particularly for two dimensional grid systems.

The interpretation needs to take account of all valuable information from Geological context with in which the survey was carried out to interpret the current boreholes and any other Geophysical survey. The interpretation is likely to use the curve of apparent resistivity versus electrode spacing (with thickness of layers) by using measurements to obtain the parameters of the geologic structures and the tendency of each layer.

Layer thickness can be determined from log – log VES curve. There is interplay between thickness and resistivity. There may be anisotropy of resistivity in the same strata, large difference Geo-electrical section. Particularly at depth produce small differences in apparent resistivity and accuracy of field measurement is limited by the natural variability of surface and subsurface rock and by instrument capabilities to deal with the problem of ambiguity, the interpreter should check all interpretation by computing the theoretical VES curve for the interpreted section and comparing it with the field curve. The test of Geological reasonability should be applied.

Because of the accuracy limitation caused by instrumental and Geological factors, adjustments to the interpreted values may be made on the basis of the computed VES curves and checked by computing the new curves.

There are different types of data presentation methods, among these methods the common one is computer software advanced data processing, specialist inversion software removes distortions caused by the effect of electrode geometer. It is important to produce a high resolution image variation in ground resistivity with depth.

The model is contoured using a color scale to produce a two dimensional cross section model of ground resistivity.

### ***4.3 Result and Discussion***

This part includes the interpretation and discussion of different electrical resistivity data.

Before interpretation, two VES data were processed and gives model curves from which layer resistivity and thickness revealed. Using the IPI2win software the subsurface resistivity stratification was determined. Using this software the number of layers, their thickness and resistivity values of the multiple layer earth are approximated.

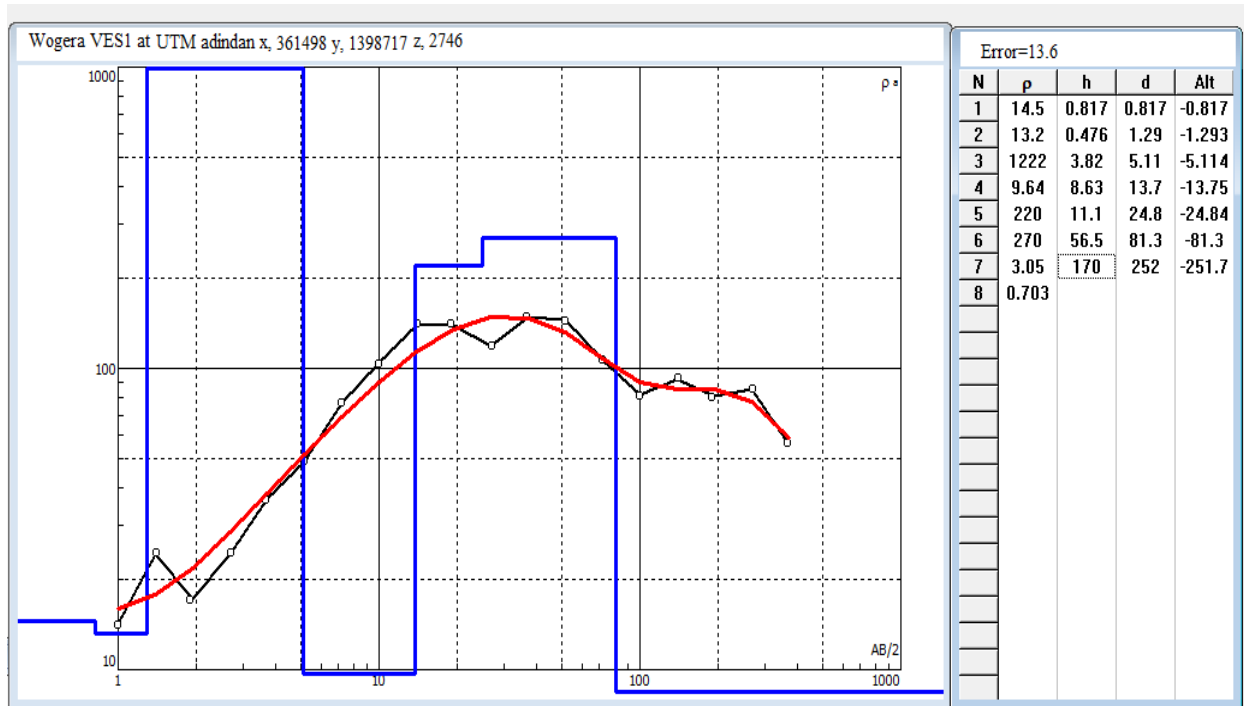
The processed data gives VES model curves with minimum error, then the resistivity value and thickness of each layers resulted from model VES curves.

The response of the aquifer is interpreted and generalized in the following way.

#### **4.3.1 VES 1 (Gezewuye)**

This is the first VES station. This VES point has been conducted NW-SE azimuth. The electrical resistivity survey result shows Eight (8) geo electric layers. The first and second layers having resistivity value of 14.5  $\Omega$ -m & 13.2  $\Omega$ -m respectively, and response of clay soil accordingly. The third layer characterized by higher resistivity value of 1222 $\Omega$ m is the response of moderately weathered and fractured basalt. The forth layer, having resistivity value of 9.64 $\Omega$ m is attributed welded tuff and is water strike depth. The fifth and sixth layer, having a resistivity value of 220  $\Omega$ -m and 270  $\Omega$ -m is possibly associated with basaltic unite with different degree of weathering and fracturing conditions. The seventh layer having resistivity value of 3.05 $\Omega$ m and a thickness of 170m could be a response of medium size gravel & it may the next water strike layer of depth. The 8<sup>th</sup> layer with resistivity value of 0.703 $\Omega$ m is correlated tuff.

The interpretation result of the sounding curve is presented in the figure below.

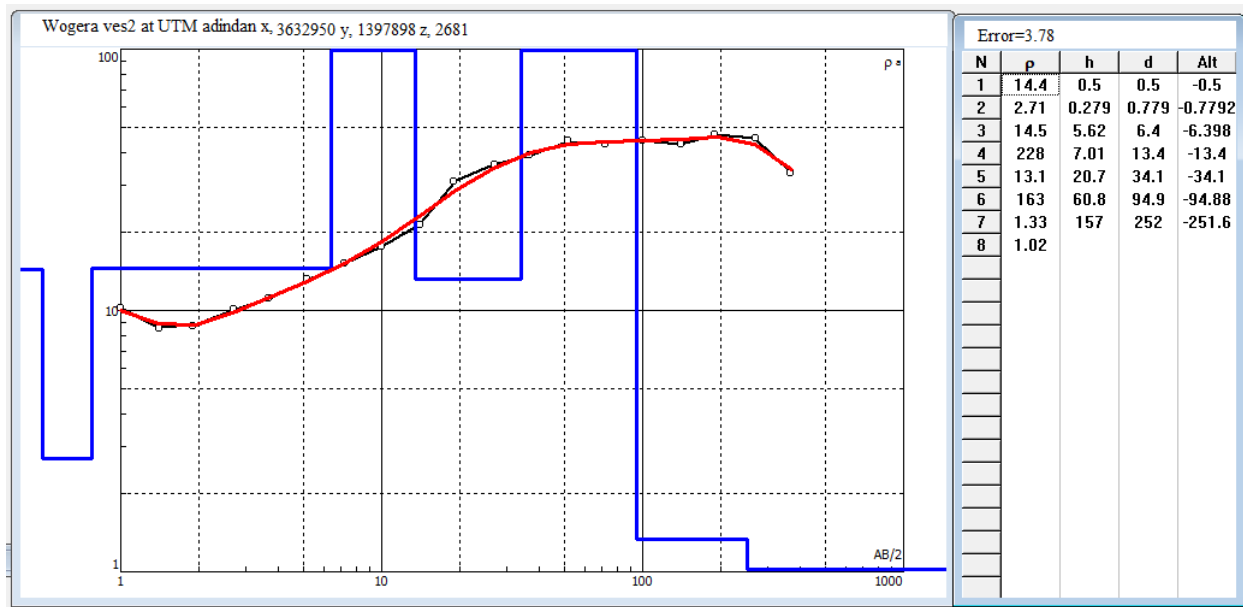


*Figure 4.8 VES 1 model curve, resistivity and thickness of each layer*

#### 4.3.2 VES 2 (Gichit)

This station also shows Eight (8) geo electric layers and conducted N-S azimuth. The first and second layers having resistivity value of  $14.4\Omega\text{m}$  and  $2.71\Omega\text{m}$  responses clay soil. The third layer characterized by resistivity value of  $14.5\Omega\text{m}$  responses moderately weathered and fractured basalt. The fourth layer, having higher resistivity value of  $228\Omega\text{m}$  is relatively massive rock unit. The fifth and sixth layer, having a resistivity value of  $13.1\Omega\text{m}$  and  $163\Omega\text{m}$  respectively is possibly associated with basaltic unit with different degree of weathering and fracturing conditions. The seventh layer having resistivity value of  $1.33\Omega\text{m}$  and could be a response of unwelded tuff and is the layer of water strike depth. The 8<sup>th</sup> layer with resistivity value of  $1.02\Omega\text{m}$  is correlated tuff. The potential aquifer at this location is expected to lie at the depth below 95m (7<sup>th</sup> layer) with the resistivity of  $1.33\Omega\text{m}$ . The interpreted result of the sounding curve is presented in the figure below.

The maximum depth of the investigation generally shows up to 252m.



*Figure 4.9 VES 2 model curve, resistivity and thickness of each layer*

Generally, based on the electrical resistivity survey conducted in the study area, groundwater potential producing zone has been delineated. The study reveals that the 2<sup>nd</sup> VES station of the study area has good groundwater potential. Weathered and fractured horizons have been identified in the study area underlying VES stations and all of these constitute the aquifer zones. A good prospect therefore exists for groundwater development in the study area where the depth to basement is relatively thick and has favorable low resistivity values.

As we have seen from the graph, the probable station and more suitable for making borehole is VES station TWO (2) of the study area. Then VES station TWO (2) is identified as productive groundwater potential zone of the study area.



# CHAPTER FIVE

## ECONOMIC IMPORTANCE

We all use products consisting of rocks in our day to day life. Specifically Rocks and minerals are used in almost in our everything activities, starting from food, medicines, jewelry to pencil, makeup, roads, tools, floors, monuments, statues etc. Many types of rocks are the building blocks of structures from ancient times and are still being used for the same.

In the world, money scientists and geologists study volcanic rocks by considering their;

- Economic aspects
- Hydrological aspects and
- Engineering aspects

In the study area, there are different Types of rock units that I describe before in local geology. These rock units have their own economic importance as described below.

### ***5.1 Amygdaloidal basalt***

It is mainly used for building material. Due to its high porosity, it acts as an aquifer for ground water. It is also highly important for construction as being the best raw material.

It is also serving as a decorative stone: paving, building facades, capstone etc. It is also serving as a structural element before steel in bridges, multi-story buildings and also as blocks for walls, grindstone in flour mills and for sharpening metal tools.

### ***5.2 Dolerite***

The main application of this rock unit is for road construction as a raw material and based on its degree of weathering (high degree of weathering) it act as groundwater bearing formation (potential aquifer) but massive dolerite does not serve as media for groundwater movement from hydro geological point of view.

### ***5.3 Clay***

From prehistoric times, clay has been indispensable in architecture, in industry, and in agriculture. As a building material, it is used in the form of brick, either sun-dried (adobe) or fired. Clays are also of great industrial importance, e.g., in the manufacture of tile for wall and floor coverings, of porcelain, china, and earthenware, and of pipe for drainage and sewage. Highly absorbent, bentonite is much used in foundry work for facing the molds and preparing the molding sands for casting metals. The less absorbent bentonites are used chiefly in the oil industry, e.g., as filtering and deodorizing agents in the refining of petroleum and, mixed with other materials, as drilling muds to protect the cutting bit while drilling. Other uses are in the making of fillers, sizing's, and dressings in construction, in clarifying water and wine, in purifying sewage, and in the paper, ceramics, plastics, and rubber industries.

### ***5.5 Quartz***

Quartz crystal is valued for its piezoelectric and pyro electric properties, by which it can transform mechanical pressure or heat into electromagnetic energy, and vice versa. Its ability to focus, amplify, store and transform energy is used throughout the technology world in ultrasound devices, watches, microphones, radio transmitters and receivers, memory chips in computers and other electronic circuitry. [Raphaell, 10-11][Simmons, 317][Melody, 503]

The same properties of energy amplification, programmability and memory also make Clear Quartz the most versatile and multidimensional stone in the mineral kingdom for healing, meditation, expansion of consciousness, communication with guides, past-life recall, attracting love or prosperity, or virtually any purpose. However, with this power comes responsibility. To benefit from Rock Crystal's blessings, one must feel in harmony With it and deserve its gifts. Intent other than for good inevitably brings harm back on oneself. [Simmons, 318][Megemont]

## ***5.6 Tuff unit***

This rock unit has its own applications. However the major one is its interior and exterior applications.

Interior Uses;

Decorative aggregates, entryways, flooring, homes and interior decoration.

Exterior Uses; As Building Stone, As Facing Stone, Garden Decoration, Office Buildings and Paving Stone.

## CHAPTER SIX

### CONCLUSIONS AND RECOMMENDATIONS

#### *6.1 Conclusions*

Hydrogeological and Geophysical survey involving vertical electrical sounding technique has been carried out to delineate the subsurface formation at Wegera woreda - Taga kebele within Gezewuye and Gichit gote. After detail observation of all sites and their surroundings, from geological, and sanitation investigation result, it is possible to generalize the study area within the conclusions below **hydro geologically**;

- According to the main Ethiopian physiographic classification system, the study area is grouped under the North Western highland and lowland areas(Figure 1.2).The areas are classified under dega climatic zone of the country, according to the traditional climatically zone presented by Ethiopian mapping agency
- The area has variety of thicknesses including the whole succession of volcanic rocks resting unconformable on the sedimentary successions (Geological Map of Ethiopia, 1996).
- The study area is found on the western margin of the rift valley forming the north western water dived towards the Tana basin drained to the Abay River. Although the rift faults are tensional faults and can contribute to an increase in the fracturing of the volcanic rocks in the vicinity of the escarpment the influence of inter volcanic and post volcanic fracture activities are also the most important.
- In the study area, presence of fractured, weathered, jointed, and also various big natural trees and grasses are present around the selected site which allows water to be easily percolate into the ground are good indicators for ground water potential
- From the field observation view of exposed structural area, it can be concluded that the main geological unit of the area is highly fractured, jointed, foliated, weathered volcanic rock, mainly Dolerite, tuff and quaternary deposit that serves as an aquifer.

- The well site is selected on relatively weak zone (along the structure) of the area which follow the main river course and along the plain surface of the land.
- Because of the absence of any spring that can be developed, it is possible to conclude that bore well/shallow well/ is the only water source for the surrounding communities and governmental organizations.

### **Geophysically;**

- The result of the survey has revealed that the subsurface geologic material in the study area is mainly fractured and weathered rock units. The top lithologies are relatively dry with a downward increase in wetness cumulating in a semi-infinite basalt unit of relatively low resistivity which is considered to correspond to the aquiferous unit. The study reveals the absence of thick clay layers overlying the aquifer units hence the aquifer systems is not protected from any likely contaminants percolating from the surface. This study also reveals a better understanding of the soil properties that control the geophysical responses in this region and will thus aid in groundwater development within the study area. Based on the electrical resistivity survey conducted in the study area, groundwater potential producing zones have been delineated. The study reveals that more than 50% of the study area has good groundwater potential. Weathered and fractured horizons have been identified in the study area underlying VES stations and all of these constitute the aquifer zones. Good prospects therefore exist for groundwater development in the study area where the depth to basement is relatively thick and has favorable low resistivity values. The productive groundwater potential zones are identified. Based on the results of the survey, the exploration and exploitation of groundwater in Wegera woreda – Taga kebele, VES station #2 is encouraging and promising.



## **6.2. Recommendations**

The Geological, Hydro geological and Geophysical investigation results reveal that, the area is promising in ground water potential. Accordingly, the following recommendations are forwarded.

- Based on the results of the survey, the exploration and exploitation of groundwater in Taga kebele – Gichit gote i.e. VES station #2 is more recommended. It is therefore recommended that boreholes for sustainable water supply within the study area be drilled in excess of 250m.
- Using the surface geological and hydro geological observation results deep well sites is selected. The drilling and construction time should be during dry period because; there are few roads accessible only in dry season, especially around the selected site. Surface casing needs during well drilling time because well collapse may happen in some loose/clay soil deposits. The drilling systems of this well are DTH as well as MUD rotary, according to the tendency of the well.
- The drilling time should be in dry season and the well depth may be increase or decrease during in actual drilling time.
- Drilling should be carried out under the supervision of the client's Hydro geologist.
- The actual well drilling depth decided on site by the client's Hydro geologist based on the hydrogeological conditions and the cutting samples during drilling.
- Cutting should be labeled and sampled as per the order of the client's Hydro geologist.
- The casing arrangement should be as per the order of the client's Hydro geologist
- The casing installation, gravel packing and well development should be carried out under the supervision of the Hydro geologist.
- Drilling should be conducted with 14'' or 16'' drilling bit diameter with installation of 12'' internal diameter Steel/PVC productive casing.

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## *Annex one*

*Table1.2 Bill of quantity for one deep well DTH/MUD drilling systems in Wegera wereda, Taga kebele*

Item. No.	Description	Unit	Qty	Rate	Amount
<b>1</b>	<b>General Item</b>				
1.1	Mobilization of man power, drilling rig, tools & construction materials.	L.S	1		
1.2	Inter site mobilization	L.S	Unit rate		
1.3	Demobilization	L.S	1		
1.4	Site clearing and rigging up	L.S	1		
1.5	Excavation of mud pit	M3	8		
<b>2</b>	<b>Bore Hole Drilling</b>				
<b>2.1</b>	<b>Drilling in soft formation</b>				
2.1.1	DTH and Mud Rotary drilling with 18/20 inch for surface casing	m	15		
2.1.3	DTH and Mud Rotary drilling with 14 inch bit diameter		55		
<b>2.2</b>	<b>Drilling in medium formation</b>				
2.2.2	DTH and Mud Rotary drilling with 14 inch bit diameter	m	80		
<b>2.3</b>	<b>Drilling in hard formation</b>				
2.3.2	DTH and Mud Rotary drilling with 14 inch bit diameter	m	50		
<b>3</b>	<b>Well Logging</b>				
3.1	Drilling rate & Lithological logging	well	1		
3.2	Geophysical well logging	well	Unit rate		
<b>4</b>	<b>Supply and installation of Materials</b>				
4.5	Supply and Install steel Blind casing 12 inch ID	m	135		
4.6	Supply and Install Steel Screen Casing 12 inch ID	m	65		
4.10	Supply and Install Steel Surface Casing 16 inch ID	m	15		
4.11	Installation of 3"/4 GIS observation pipe	m	170		
<b>5</b>	<b>Gravel packing and Well Development</b>				
5.1	Supply and Pack Selected well rounded river gravel (5 to 8 mm diameter grain size)	m3	10		
5.2	Well Cleaning and development	Hr.	10		

<b>6</b>	<b>Pumping Test</b>				
6.1	Mobilization of Crew, materials and pump testing equipment	L.S	1		
6.2	Inter site mobilization	L.S	Unit rate		
6.3	Site clearing and rigging up	L.S	1		
6.4	Provisional or preliminary test	Hr.	3		
6.5	Step draw down test (Four step, 1:30 hour for each test)	Hr.	6		
6.6	Constant yield pumping	Hr.	24		
6.7	Recovery test	Hr	12		
6.8	Demobilization	L.S	1		
<b>7</b>	<b>Sanitary &amp; Protection works</b>				
7.1	Grout with mass concrete to a depth not exceeding 5m (1:3:6 mix)	L.S	1		
7.2	Construction of well head with mass concrete (0.60m x0.60m base and 0.70 m height Trapezoidal shape)	L.S	1		
7.3	Supply and weld iron cover on the top of the borehole	L.S	1		
7.4	Collection of water samples during test pumping in sealable plastic bottles and conduct water quality analysis( complete physico chemical &bacteriological)	L.S	1		
8	Prepare end report of the wells that is well drilling and pumping test which includes geological column, well profile, drilling diameter, casing installation, well yield, pumping test data, curve analysis etc, with hard copies and soft copy	L.S	1		
9	Prepare end report of abandoned wells that is well drilling which includes geological column, well profile, drilling diameter, etc including reason for the abandonment of each well with hard copies and soft copy	L.S	Unit rate		
<b>Total</b>					
<b>VAT (15%)</b>					
<b>Grand Total</b>					

\*\*\* **Note:** The proposed average anticipated depth of the well is 200m, considering the mandatory of the contractor i.e.  $\pm 20\%$  of the initial agreement.