ADDIS ABABA UNIVERSITY SCHOOL OF EARTH SCIENCES

Comparative study of nitrate levels in Groundwater's of Addis Ababa and Dire Dawa

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

By Tsnat Tsegay *Advisor Dr. Seifu Kebede*

May 31, 2017

Addis Ababa University School of Graduate Studies

This is to certify that the thesis prepared by Tsnat Tsegay, entitled: Comparative study of nitrate levels in Groundwater's of Addis Ababa and Dire Dawa submitted in partial fulfillment of the requirements for the Degree of Master of Science in Hydrogeology complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Nitrate is the most frequently introduced pollutant in the groundwater's of Addis Ababa and Dire Dawa city. This study was conducted to compare the level of nitrate pollution of the major cities Addis Ababa and Dire Dawa. The study tries to identify different source of nitrate pollution for both cities by revising of previous works and literatures on geological, hydrogeological and hydrochemistry of both areas. The possible sources of nitrates are city sewage, defective septic tank effluents, municipal waste, industrial waste, wastes from livestock and chemical fertilizers containing nitrogen. In Addis Ababa the mean concentration of nitrate is 7.9 and the standard deviation is ±14.96 and in Dire Dawa the mean concentration is 37.27 and the standard deviation is ±51.4. The spatial plot of nitrate of the study areas shows that the nitrate level of Dire Dawa is higher than Addis Ababa. The lowering of nitrate level in Addis Ababa is as a result of low nitrification process. The nitrate level in Dire Dawa becomes high because of shallow groundwater level depth which varies 9.3-93.5 meter whereas, in Addis Ababa it varies 0-260 meter, the main aquifer is sandstone, sandy soil and agriculture is dominant. Therefore, integrated waste management strategy and proper groundwater management should be practiced to provide safe drinking water with sufficient quality and quantity in both cities.

Key word: Addis Ababa, Comparison, Dire Dawa, Nitrate

ACKNOWLEDGMENTS

First of all, I would like to thank ' Almighty God ' who made it possible for me, to begin and finish this work successfully. I could never have achieved without Him and the people He put in my life.

I am grateful to express my feelings of gratitude to my Advisor Dr Seifu Kebede for his guidance and encouragement by supporting me to complete this research work successfully by providing constructive comments and relevant materials during my research study.

I also need to acknowledge my instructors Pr. Tenalem Ayenew, Dr. Dessie Nedaw, Dr. Tilahun Azagegn, Dr.Tarun K.Raghuvanshi and all Addis Ababa University, School of Earth Sciences instructors who supported me in gaining very important knowledge about the subject matter and related fields.

I would like to thank University of Mizan Tepi for giving me this chance.

My dear mom and my husband who were always been there for me, I extend my special thank you for your love, words of encouragement and for always believing in me no matter what.

I appreciate my friends Abel Abebe and Sintayew Mulu, whom I did not mention their name here, for their Support, encouragement and care. Also for all individuals who have contributions directly or indirectly that supported me in the completion of this research work.

Finally, I would like to thank Water, Mines and Energy Design and Supervision for providing me data.

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List of Acronyms

AAEPA- Addis Ababa Environmental Protection Authority

AAU- Addis Ababa University

AWSSA- Addis Ababa Water Supply and Sewerage Authority

BOD- Biological Oxygen Demand

COD- Chemical Oxygen Demand

CSA-Central Statistical Agency

DDAC -Dire Dawa Administrative Council

DO- Dissolved Oxygen

EC- Electrical Conductivity

EPA -Environmental Protection Agency

EIGS- Ethiopia Institute of Geological Survey

FAO- Food and Agriculture organization

M.a.s.l- meter above sea level

Mg/l or mgL^{-1}- milligram per liter

MoWR- Ministry of Water Resources

MCNC- Most Common Natural Concentrations

NUPI- National Urban planning Institute

RADWQ-Rapid Assessment of Drinking Water Quality

TDS- Total Dissolved Solids

WHO- World Health Organization

WWDSE- Water Works Design and Supervision Enterprise

CHAPTER ONE
INTRODUCTION

1.1 Background

Water pollution is a large set of undesirable effects upon water bodies such as lakes, rivers, oceans and ground water that caused by human activities. This matter requires urgent attention, since water is scarce and such an important resource needs detailed scientific research all over the world in order to sustain and protect the water resource from pollution and for its wise utilization. However, no water in nature is absolutely clean. Even as it rains, the precipitation is interact with solid dissolved salts and aerosols in the air prior to reaching the ground, running on the surface and finally percolating through the different geological formations. The major sources of water pollution can be classified as municipal, industrial, and agricultural and there are also other sources of water pollution like petroleum, radioactive substances and heat.

In our country, Ethiopia is also facing the problem of groundwater water quality degradation. There are indicators that the groundwater system has started being polluted in some big cities. According to Taye Alemayehu (1988) and Tamiru Alemayehu (2004) indicated the pollution of groundwater in Dire Dawa and Addis Ababa; on the other hand, the amount of pollution is commonly not large excluding the surface waters of Addis Ababa and groundwater of Dire Dawa city where the problem is at its climax at this time. Direct discharge of foreign materials from different sources to rivers and open lands and the leakage of industrial wastes from poorly designed septic tanks to the ground water, discharge of effluents without detoxifying the waste solid/liquid from domestic and municipal, organic matter of plant and animal origin, land and surface washing and sewage effluents are among few sources of pollution that changes the water quality in both cities. Surface washing and sewage effluents are among few sources of pollution that changes the water quality in both cities.

Nitrate is the most frequently introduced pollutant into the groundwater system. Nitrate in the environment comes from both rural and urban sources (Abdulrahman *et al.*, 2010; Syed and Saadat, 2005). Nitrate is the compound predominantly found in groundwater and surface waters.

High levels of nitrates in ground and surface water originate mostly from agriculture activities and disposal of human and animal waste (Fields, 2004; Ward *et al*., 1994). In agricultural areas, nitrogen-based fertilizers are a major source of contamination for shallow groundwater aquifers that provide drinking water (Babiker *et al*., 2004). Other sources of nitrate contamination are organic animal wastes and contamination from septic sewer systems, landfills, leaky sewage system and gasoline stations (Wakida and Lerner, 2005). Contamination of drinking water by nitrates is an evolving public health concern since nitrates can undergo endogenous reduction to highly toxic compounds such as; nitrites and nitrosamine (Ward *et al*., 1994; Chiu and Tsai, 2007). Methaemoglobinaemia is the primary adverse health effect associated with human exposure to nitrate or nitrite (Deana *et al*., 2010). Acquired Methaemoglobinaemia due to exposure to nitrates in drinking water is considered primarily an issue for infants less than six months old (Deana *et al*., 2010; Ayebo *et al*., 1997). Pregnant women are also considered vulnerable to the effects from exposure to high levels of nitrate in drinking water (Deana *et al*., 2010). The second adverse health effect of nitrates in drinking water is the possibility of increased cancer risk (via the bacterial production of N-nitroso compounds), hypertension, increased infant mortality, central nervous system birth defects, diabetes, spontaneous abortions respiratory tract infections and changes to the immune system (Gheisari *et al*., 2005; Babiker, 2004; Gupta *et al*., 2000; Ward *et al*., 1994; Chiu and Tsai, 2007). Groundwater with nitrate concentration exceeding the threshold of 20 mg/L is considered contaminated as result of human activities (Spalding and Exner, 1993). Recent studies revealed that water contamination with nitrate is globally growing problem due to the high rate of population growth and increasing consumption (Jalali, 2005). World Health Organization (WHO) guidelines on the quality of drinking water indicate a maximally admissible nitrate concentration of 50.0 mg/L (Stringer, 1988; Duijvenbooden, 1989).

Addis Ababa, the capital city of Ethiopia, enjoys a mid Afro-Alpine climate with an average temperature of 16^{0}C. The population of the city is 3,048,631 and living in 10 sub-cities and 99 kebeles divided for administrative purpose. It is center for modern economic and social activities because of the infrastructure services are found relatively in better situation than other cities of Ethiopia. In particular, the complete inadequacy of the solid waste management is major environmental problem in Addis Ababa. Waste is disposed off through informal means, except smaller percentage going to incineration, dumped on open sites, drainage channels, rivers and valleys as well as on the streets. The rivers that cross the city are widely used as disposal sites. The rapid population growth rate is also resulting in a rise urban waste generation. This implies that the current waste collection and disposal capacity of the city could not match with the growing population and generation of waste. Inadequate municipal and industrial solid waste collection and disposal creates a range of environmental problems in Addis Ababa.

In the case of Dire Dawa area, which is arid and semiarid, there are no perennial rivers and streams in the area making groundwater the primary water source. At present, almost 100% of the water supply for the urban and rural population of Dire Dawa administrative council gets its water supply for domestic, industrial, and irrigation purposes from boreholes, dug wells, and springs (WWDSE, 2002). The pollution of Dire Dawa groundwater system is a danger for the future sustainable domestic water supply of the city of Dire Dawa and Harar. The geomorphologic, geologic and hydro geologic characteristics of the basin facilitate the effect of pollution. The area is mostly covered by major geological complexes ranging from Precambrian rocks at higher elevations to the recent alluvial formation at the lower part of the basin (Seife, 1985) that can easily be penetrated by disposing wastewater.

Percolation of wastewater is also facilitated by gently dipping or almost flat nature of the topography of the city. Ground water table is encountered at shallow depth in the northern part of the city. High population intensity, industrial activities, lack of proper sewers, and waste disposal facilities, presence of open latrines, and the geological, morphological, and climatological conditions have facilitated groundwater pollution in Dire Dawa area (Taye,1988). The inputs of substances in the agriculture fields such a fertilizers, insecticides, and herbicides may pollute water sources and modified its quality. The water-rock interaction and its evolution play important role for the change of water chemistry in the groundwater system (Appelo, 2005). Several studies have been conducted related to geology and hydrogeology in the study area and its surroundings. Waste disposal sites are not selected according to hydro geological priorities.

The main solid waste disposal area is the sandy dry stream Channel of Dechatu River that divides the city into two almost equal parts. There are six major industries and more than 100 small scale manufacturing industries in the city of Dire Dawa. These are Dire Dawa textile, Dire Dawa food complex, ELFORA meat processing, East Africa bottling (soft drink), and Dire Dawa

Cement. The Dire Dawa textile factory is the main source of contaminant in the urban area. The chemicals used in this factory pollute the ground and surface water. There is no waste treatment and proper waste disposal system in Dire Dawa city. From the nature of its topography and soil, the ground water resource is very venerable to pollution. Water quality test from different sites of the city (bore holes) shows that nitrate concentration of water samples from Sabiyan and inner part of the town highly exceeds the WHO and Ethiopian Drinking Water Quality Guideline Values. There are numerous urban and rural agricultural activities such as Tony farm, chat farm, Amdael dairy farm, Hafecat dairy, and other small-scale cattle breeding and horticulture producers in the town. Generally, the agricultural inputs and by-products are the major constitutes of wastes and have a chance to contact the groundwater system. The groundwater quality is directly affected by microorganisms in organic fertilizers. The land disposal of municipal sewage is a potential nitrate source and landfills are sources of metals and variety of organic and inorganic compounds. The laboratory analyses conducted on the water samples taken from different localities at different times indicate that the level of groundwater pollution is increasing at an alarming rate. For instance, according to the hydro chemical analysis conducted by an Israeli geologist in 1959, the maximum concentration of NO3 at the center of the city was 45 mg/l. After twenty-two years (1982) Ketema Tadesse has reported a NO3 concentration of 320 mg/l within the city. Hence the level of pollution is exceeding the maximum allowable limits set by World Health Organization (WHO) and the National Standard (ENWQG). The water quality of alluvial aquifer is highly contaminated by human interferences, especially the alluvial water in the Dire Dawa city and dug wells near the community. This paper examines the source and compares the level of nitrate pollution in the ground water which were collected and analyzed from the cities of Addis Ababa and Dire Dawa. According to (Beeby *et al.,* 1979*)* in order to decrease and eventually overcome water pollution, one must understand the problems and become part of the solution.

An integrated approach to solid waste management seems to be the best option and could well hold the key to effective and sustainable waste management system in developing cities such as Addis Ababa and Dire Dawa.

1.2 Statement of the Problem

As cited in Exnner and Spadling, 1993, Groundwater pollution with nitrate is a global problem in many parts of the world; groundwater is the source of drinking, agricultural, industrial and domestic uses. In Ethiopia the degree of pollution is generally not large except the surface waters of Addis Ababa and groundwater of Dire Dawa city. Nitrate is one of the major contaminants in urban area in different parts of the world including agricultural areas where fertilizers are being extensively used. The possible sources for the enrichment of nitrate in both cities could likely be waste disposal in the urbanized areas and agricultural activities in rural areas and also the combined effects in some others. The nitrate enrichment of many localities in Addis Ababa could occur from different sources such as liquid and solid domestic wastes and industrial effluents and to some extent agricultural activities. In Addis Ababa, it was reported in some studies that urban and industrial centers play a role in polluting surface and groundwater. For example little Akaki river receives large part of the waste released from the west-central part of the city including the big market "Merkato" and a number of factories including a winery, a brewery, a soft drink factory, a liquor factory, several tanneries, a slaughter house, and others. These sources introduce significant organic and inorganic pollutants in to the river.

Chemical analysis of surface and shallow groundwater samples taken at various points along streams and different springs show that the level of unwanted chemical constituents such as nitrate and chromium, for example, are higher than the background level due to the in adequacy of controlled waste management strategies and waste treatment plants (Mohammed Ali, 2002; Tamiru Alemayehu *et al.*, 2005; AAEPA, 2005 and Macha Chamargachew, 2009). Additionally, almost all of the industries in Addis Ababa do not have any waste management place and drain their wastes to the adjoining river areas. The water supply distribution of Addis Ababa has enormous leakage problem. This may show the way to mixing of water that comes from reservoirs and wells with the sewerage system in the vicinity.

In Dire Dawa the geomorphologic, geologic and hydro geologic characteristics of the basin facilitate the effect of pollution. The city consists of mainly unconsolidated permeable alluvium deposit that can easily be penetrated by disposing waste water. Percolation of wastewater is also facilitated by gently dipping or almost flat nature of the topography of the city. Groundwater table is encountered at shallow depth in the northern segment of the town that is as low as ten meters below ground level. In the city and in its surrounding area, there are numerous urban and rural agricultural activities such as Tony farm, chat farm, Amdael dairy farm, Hafecat dairy, and other small-scale cattle breeding and horticulture producers in the city. Generally, the agricultural inputs and by-products are the major components of wastes and a probability to connect with the groundwater system. The additional possible source of water pollution, which can be inferred, is cemeteries which are away from the compounds. The Muslim and Christian cemetery sites are in the inner part of the city and near to Dechatu River. In addition the sources of pollutants are closely associated with land use pattern and to some extent to population density in the area.

Therefore, the need to compare the level of nitrate pollution of both cities is that even if Addis Ababa has high population, high urbanization, many septic tanks and unmanaged waste disposals, the nitrate level is low relative to Dire Dawa. Therefore this research helps to know the main reason that makes difference in nitrate level of both cities.

1.3 OBJECTIVES

1.3.1 General objectives:

The general objective of this study is

- To understand the mechanism of nitrate pollution of both cities.
- To compare the level of nitrate pollution of the major cities Addis Ababa and Dire Dawa.

1.3.2 Specific objectives:

- ✓ To know the source of nitrate level in groundwater's of both cities.
- ✓ To investigate the cause of variation in nitrate level in both cities.
- ✓ To investigate conversion factors affecting the level of nitrates.
- ✓ To locate spatial distribution of nitrates pollution on map.
- ✓ To propose the possible mitigation measure to reduce the level of nitrate.

1.4 Significance of the study

Scientifically the result of this research will provide the amount and mechanisms of nitrate pollution caused by human activities compared to the natural background. Detailed study of this nitrate level variation in both cities will help to understand the main source of nitrate and to devise suitable mitigation measures for future interventions.

1.5 Methodology

In order to attain the above objectives the following methods are used:-

- ✓ Review and analysis of available data or related studies:
- ✓ Study of previous works and literatures on geological, hydro geological and hydrochemistry of both areas.
- ✓ Evaluating water quality and chemical analysis.
- ✓ Interpreting hydro geochemical data and geological settings of the study area.
- ✓ Identification of different source of nitrate pollution for both cities.
- ✓ Analysis of nitrate concentration and its spatial variation.
- ✓ Discussion and comparison of hydro chemical parameters.

1.6 Overview of thesis

This thesis is set by chapters starting with the introduction, to make comparative study of nitrate levels in ground waters of Addis Ababa and Dire Dawa and general methodologies followed in chapter one. Chapter two discusses the previous works that have been done in both areas and the conceptual discussion of the nitrogen cycle. The general overview of the study areas are discussed in Chapter three which presents location, population, regional geology and hydrogeology, drainage and land use and land cover of the study area. Chapter four presents the results and discussions of the differences in nitrate level in both of the study areas. Chapter five presents about conclusion and recommendations for future research in these areas.

CHAPTER TWO

LITERATURE RIVIEW

2.1 Previous studies

Those are some of the works that have been conducted in both of the study areas by different researchers in the last few years.

2.1.1 In the case of Addis Ababa

The Effect of water hyacinth on the level of dissolved Oxygen in Aba Samuel Reservoir (Zeleke Teferi, 1992) and preliminary survey of pollutant load on great Akaki, Little Akaki, and Kebena rivers (EPA, 1997) and the degradation of Abo-Kebena River in Addis Ababa (Tesfaye Berhe, 1988). (Yesahak Worku *et al*.,1999) also studied the physical, chemical and microbiological characteristic of various sources of water in and around Addis Ababa City and produced an explicit data on few samples from little Akaki River and has showed the pollution of the river. Tamiru Alemayehu (2001) studied the impact of uncontrolled waste disposal on the surface water quality in Addis Ababa and found out higher than background values for pollutants such as Cr and Nitrates and related it with poor economy and lack of proper waste disposal systems.

Berhanu Gizaw (2002) had environmentally investigated the hydrogeology of the Addis Ababa city and produced a clear data on few samples from Little Akaki River and indicated the pollution of the river. In addition, EPA (2002) assessed the pollution status of the great and little Akaki Rivers with the purpose to investigate the pollution load of Akaki River and its effect on the neighboring environment and found that the BOD load is high and the DO level is low. Furthermore, confirmed on the pollution of both rivers and their potential to cause health effects on human and animals in addition to their impact on the aquatic life. In addition, it linked some industries and residential wastes with TDS values above the suggested limit and also found high chloride concentrations in little Akaki river.

Mohammed Ali (2002) studied industrial pollution and its impact on the little Akaki River and show that industrial effluents exceed the Ethiopian provisional industrial effluents discharge permit limits. Besides he identified Tanneries as the major polluter industrial sector. And using ANOVA (analysis of variance) he also indicated that the river is grossly polluted in all seasons and all over its course. Above all he concluded that river water cannot be used for irrigation, drinking, livestock watering and washing. (Tamiru Alemayehu *et al*., 2003) conducted a study on surface and ground water pollution status in Addis Ababa. Besides, (Samuel Melaku *et al*., 2004) had simultaneously determined the trace elements of Little Akaki River Water samples and found out that out of the eight elements analyzed except two (Cr and Mn) all fulfill the surface water quality standard of class 2 and 4. Thus he concluded that the water can be used for irrigation.

Tenalem Ayenew, Tamiru Alemayehu, Dagnachew Legesse, Yirga Tadesse, Solomon Waltenigus and Nuri Mohammed (2005) carried out a study on Hydrogeology, Water Quality and the degree of Ground water Vulnerability to Pollution in Addis Ababa, Ethiopia.

(Samuel Melaku *et al*., 2005) had carried out multi element analysis of Little Akaki River sediments and found out that the heavy metals pollution load in the sediments of TAR and its tributaries is alarming. Then he associated this pollution load with untreated domestic, municipal and industrial sources. Then Hussen Endre (2006) studied the hydrogeology of Berga River catchment, West Shewa Zone, Oromia Regional State with particular emphasis on water resources potential evaluation and cited in his work that the primary purpose of water quality analysis is to determine the suitability of water for the proposed use and identified the three main classes of uses of water as domestic, agricultural and industrial purposes.

Then (Molla Demlie *et al*., 2006) analyzed soils and ground water samples for trace metal pollution and witnessed Instances of ground water contamination with Cr and Cd in the industrial and highly urbanized centers of the city. Also he associated the case with fractures, joints and related preferential flow paths.

(Samuel Melaku *et al*., 2007) evaluated the pollution status of the Little Akaki River and Its tributaries using some physicochemical parameters, major ions and nutrients, and provided data on the physicochemical parameters: pH, temperature, EC, TDS, BOD, COD, DO, major ions and nutrients. They assessed the pollution status of the river by comparing values of the parameters with conventional standards and most common natural concentrations (MCNC) and found out that certain parameters disobey standards. Besides he also shows the increases in BOD, Nitrate, Ammonia, Phosphates and the decrease in DO downstream of TAR. And he also observed that the average concentrations of the major ions and nutrients surpassing the MCNCs and associated the situation with increasing domestic, industrial and agricultural activities,.

2.1.2 In the case of Dire Dawa

Previously geological, hydrogeological, water quality studies and other associated works have been performed for different purpose in the Dire Dawa region.

Most of studies have been conducted by the Federal sector organization of Addis Ababa and DDAC (Dire Dawa Administration council) in Dire Dawa i.e. Ministry of Water Resources (MoWR), Water Well Drilling Enterprise, Ethiopian Institute of Geological Survey (EIGS), Water Work Design and Supervision Enterprise (WWDSE), DDAC of Water Mines and Energy office and Harar water supply emergency project. These are the most important institutions working at the water sector in Ethiopia. Most of the previous works deal with specific issue but more comprehensive work was done by WWDSE (2004). The main hydrogeological work here was to plan and design water supply facilities for Dire Dawa and Harar towns as the ever increasing water demand far exceeded water supply.

According to Minalah Bushra (2007), Groundwater pumping from the study area is currently increasing and hence there is a concern that future water demands associated with expansion of urbanization, industrialization and increasing trend of local population in utilizing groundwater for their irrigation demand could cause water level declines.

According to Eyilachew Yitayew(2010) Anthropogenic Impacts on Groundwater Resources in the urban Environment of Dire Dawa, Ethiopia has also tried to conceptualize the groundwater evolution in the Dire Dawa area by considering the hydro geological settings and influence of anthropogenic activities. The geology and aquifer units are quite complex, therefore it is hard to develop modeling concepts and present the real situation of the area. The water chemistry results show a mixed type because the geological formation is complex with contributions both from natural processes and anthropogenic sources. The groundwater quality is modified by anthropogenic factors and natural groundwater evolution along the groundwater flow path. In general the water quality is hard and mostly carbonates water types at upstream and more modified in the downstream basin especially in the shallow wells with high chlorides and nitrates due to contamination of the aquifer by human activities.

Assessment of groundwater vulnerability to pollution in Dire Dawa, Ethiopia using DRASTIC approach by Ketema Tilahun and Broder J. Merkel identify and classify vulnerable and non-vulnerable areas to groundwater contamination so as to provide zoning of the groundwater safety and the implementation of effective groundwater management strategies.

According to Taye Alemayehu (1988) High population growth, industrial activities, shortage of proper sewers and waste disposal services, existence of open latrines, and the geological, morphological, and climatological conditions have facilitated groundwater pollution in Dire Dawa area. Even if the above indicated works addressed major issues on source of nitrate pollution, water quality parameters, water quality poverty and surface and groundwater vulnerability to pollution, the main cause of increasing in nitrate level pollution in ground water in the study areas has not been attempted.

2.2 Occurrence and hydrochemistry of nitrate

Most of the earth's atmosphere is composed of nitrogen gas. According to (Hem, 1992) the amounts in the hydrosphere and biosphere are much lesser. Nitrogen is an organic material decomposes through bacterial action, the complex proteins alter through amino acids to ammonia, nitrites, and finally to nitrates (Devis and Dewiest, 1966). The molecular nitrogen from the atmosphere can be transformed into organic matter by nitrogen-fixing bacteria (Rhizobium Species), which subsist in symbiotic association with leguminous plants (clovers, peas, beans, etc) in nodules on the plant roots. The part of nitrogen fixed by these bacteria is taken up by the plants themselves. Further death and decay of the bacteria and plants, the nitrogen originally fixed from the atmosphere is mineralized by soil bacteria in to ammonium which under aerobic conditions are transformed in to nitrate by nitrifying bacteria. Several free-living microorganisms also have the capability of metabolizing atmospheric nitrogen including the soil bacteria Azotobacter and Clostridium, and the blue-green algae that normally live in water. Death and Decay of these organisms add ammonium and nitrate to the soil. According to (Bouwer, 1978) some of the ammonium and nitrate in the soil are absorbed once more by plants and microorganisms, and nitrate can be reduced to free nitrogen gas by denitrifying bacteria. The free nitrogen then returns to the atmosphere. Both processes are part of the nitrogen cycle. The nitrates thus formed are commonly in surplus of the plant's needs so a excess is available for leaching. Some of the nitrates produced may be reached by percolating water and eventually reach the groundwater. According to Tebbutt (1998) the oxidation and reduction of nitrogen in the nitrogen cycle in water are as follow:

Organic-N+O_2 →NH_3—N + O_2 →NO2—N + O_2 →NO_3—N Nitrification (Oxidation)

NO_3—N →NO_2—N →NH3 or N_2 Denitrification (Reduction)

In addition, nitrate originates by conversion of organic nitrogen or ammonium which occurs naturally or introduced to the soil by anthropogenic activities.

Ammonification, which produces NH4 from organic N, will proceed more rapidly under aerobic conditions.NH4 is relatively immobile due to its positive charge which causes it to bind tightly to negatively charged clay minerals and organic matter. Throughout, the process of nitrification ammonium is converted to nitrate. Ammonification and nitrification are processes that normally occur above the water table, generally in the soil zone, where organic matter and oxygen are abundant. In groundwater that is strongly oxidizing, nitrate is the stable form of dissolved nitrogen. It moves with the groundwater without transformation and little or no retardation (Cherry and Freeze, 1979) . Denitrification in the ground water zone, however is a process about which little is known. Lack of suitable types or amounts of organic matter in the groundwater commonly slow down the growth of denitrifying bacteria in the groundwater zone (Cherry and Freeze, 1979). The difference in chemical properties among these species is obviously substantial. Ammonium cat ions are strongly absorbed on mineral surfaces. An ionic species such as nitrate are readily transported in water and are stable over a considerable range of conditions. The nitrite and organic species are unstable in aerated water and are generally considered to be indicators of pollution through disposal of sewage or organic waste. The presence of nitrate or ammonium might be indicative of such pollution also. Ammonium and cyanide ions form rather strong soluble complexes with some metal ions, and certain types of industrial waste effluents may contain such species (Hem, 1992).

Nitrogen cycling is a most important ecological process, because of concerns about the impact of excess Nitrogen on ecosystems and the contribution of gases, such as N2O, to global warming. Nitrate (NO3-), nitrite (NO2-) and ammonium (NH4+) are reactive inorganic forms of nitrogen which pose most concern to water quality status (Hatch et al. 2002). NO3 is the most common form of nitrogen in the hydrological cycle and is highly mobile in water. NO3 is not matter to precipitation or adsorption processes as its negative charge prevents interaction with negatively charged soil or organic particles enhancing its leaching capacity (Appelo and Postma 2005). Therefore, reduction of NO3 concentrations in hydrogeological pathways must be achieved through plant uptake, leaching and biogeochemical processing (Hatch *et a*l., 2002).

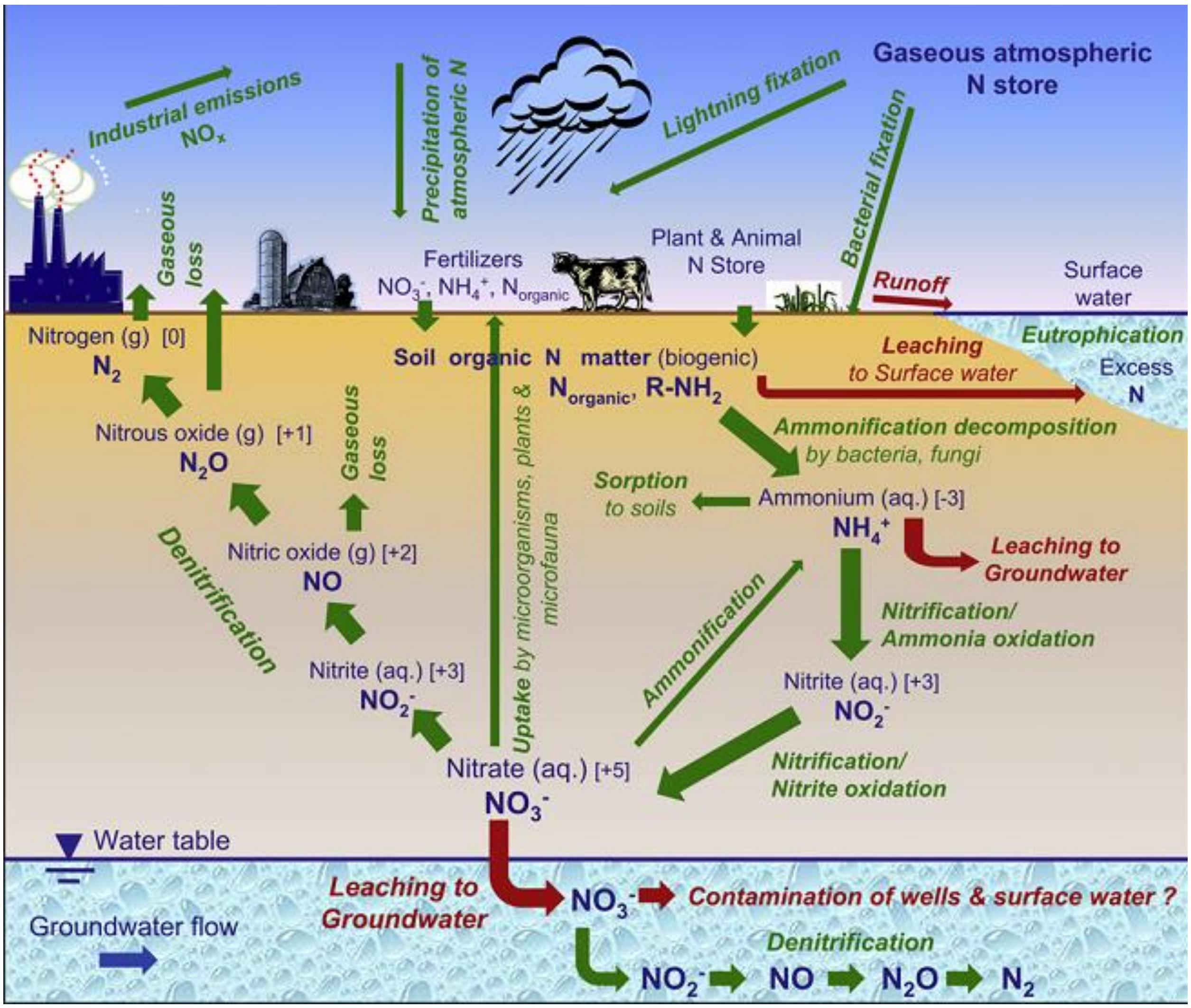

Fig 2.1 nitrogen cycle and its influence in water (source Michael, O et al., 2008)

The major biologically mediated reactions that direct nitrogen dynamics in the ecosystems are: - nitrogen fixation, ammonification, nitrification, and denitrification.

2.2.1 Nitrification

As cited in (Fetter, 1999). Nitrification is a microbial oxidation route by which NH4+ is converted NO_2^- and consequently NO_3^-.Therefore, nitrification take place under aerobic conditions and is mediated by autotrophic organisms (Kendall, 1998). The nitrification process has two different parts outlined (Willey *et al*., 2011).

$$NH_4+ + 1\ ½\ O_2 \rightarrow NO_2- + H_2O + 2H+ \quad \ldots\ldots\ldots (1)$$

$$NO_2- + ½\ O_2 \rightarrow NO_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

2.2.2 Nitrogen Fixation

Nitrogen gas (N_2) is about nearly 80% of the Earth's atmosphere. As a result nitrogen to be available to make proteins, DNA, and other biologically essential compounds and it must first be changed into a nitrogen fixation. Nitrogen gas is a very stable compound because of the strength of the triple bond in between the nitrogen atoms, and it needs a bulky quantity of energy to separate this bond. Consequently, only selected group of prokaryotes are able to carry out this energetically demanding process. Although, the majority nitrogen fixation is carried out by prokaryotes, a little nitrogen can be fixed abiotically by lightning or definite industrial processes, including the combustion of fossil fuels.

2.2.3 Denitrification

Denitrification is the process that changes nitrate to nitrogen gas, accordingly removing available nitrogen and returning it to the atmosphere. Unlike nitrification, denitrification is an anaerobic process, taking place regularly in soils and carried out by a various group of prokaryotes, and there is recent evidence that some eukaryotes are also capable of denitrification (Risgaard-Petersen *et al*., 2006). Denitrification is essential in that it get rid of fixed nitrogen (nitrate) from the ecosystem and returns it to the atmosphere in a biologically inert form (N_2). This is principally important in agriculture where the loss of nitrates in fertilizer is detrimental and costly.

$$NO_3—N \rightarrow NO_2—N \rightarrow NH_3 \text{ or } N \quad \text{Denitrification (Reduction)}$$

2.2.4 Ammonification

Ammonification is when an organism excretes waste or dies; the nitrogen in its tissues is in the form of organic nitrogen. Therefore, different fungi and prokaryotes then decompose the tissue and discharge inorganic nitrogen back into the ecosystem as ammonia in the process. Subsequently, the ammonia becomes available for uptake by plants and other microorganisms for growth.

CHAPTER THREE
DESCRIPTION OF THE STUDY AREAS

3.1 ADDIS ABABA

Addis Ababa is located in the central highlands of Ethiopia, with the altitude that ranges from 2100 m.a.s.l to 2700 m.a.s.l which covers an area of about 540 km2 with a population of more than 3 million inhabitants. Its geographic location is between 38.638^o and 38.906^o east and 8.832^o and 9.09^o north. The administration of the city is divided in to ten sub-cities: Bole, Arada, Cherkos, Kolfe Keraniyo, Addis ketema, Lidata, Akaki-Kaliti, Gullele, Nefas-Silk Lafto and Yeka.

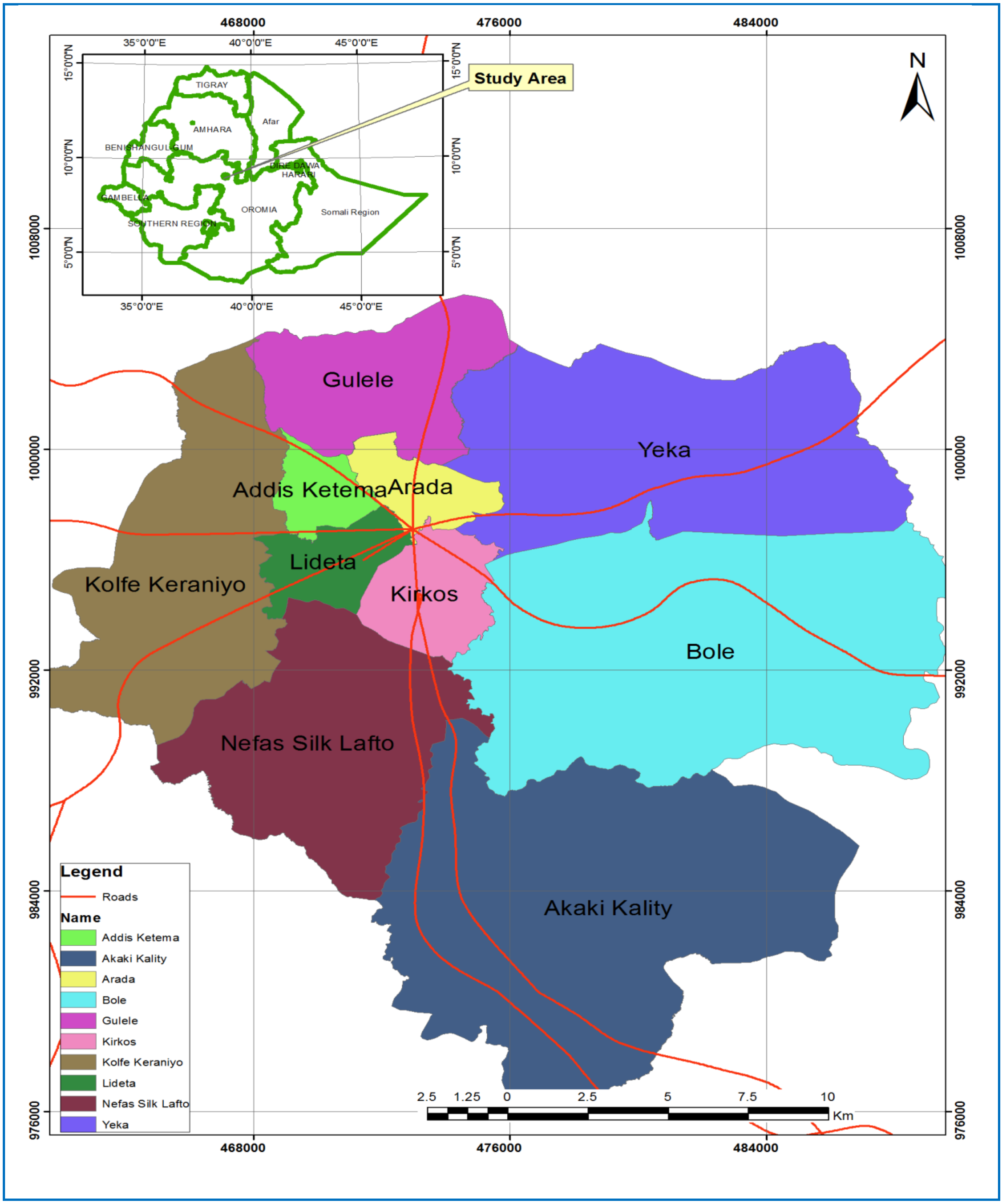

Fig 3.1 Location map of Addis Ababa area

3.1.1 Population of Addis Ababa

Addis Ababa is one of the fastest growing cities on the continent (UN-Habitat 2012). Its population has nearly doubled every decade the population of Addis Ababa has grown from 2 million to about 4 millions in the last fifteen years with the administrative area expansion from 220 to 540 square kilometers. This has been resulted in a heavy pressure on the Addis Ababa City Administration and the Addis Ababa Water and Sewerage Authority to extend safe drinking water supply and sanitation services (GWIACCES, 2012).

In 1984 the population was 1, 412, 575, in 1994 it was 2,112, 737, and this number will continue to rise, According to city government of Addis Ababa 2011/2012 report, the total population of Addis Ababa was estimated to 3,048,631 reaching 12 million in 2024. Deficiency o f water scheme maintenance and lack of new facilities combined with rapid population growth has brought water scarcity in Addis Ababa. High volume of water wastage due to faulty piping (as high as 35 percent), and needs priority given to industries, also contribute to the shortage. In terms of urban population it currently accounts for at least 22.9% of the country's total urban population (CSA, 2012). Addis Ababa is divided into 10 sub-cities with the population of each sub city as shown in the Table 1 below kolfe keraniyo, yeka and nifas silk lafto sub city are highly populated.

Table 1 population of sub cities of study area (Addis Ababa sub-cities population 2008(CSA, 2012)

Sub cities	population
Akaki-Kaliti sub-city	281,201
Nefas Silk Lafto sub-city	39,101
Kolfe Keranyo sub-city	532,653
Gulele sub-city	327,381
Lideta sub-city	201,613
Kirkos sub-city	260,991
Arada sub-city	282,009
Addis Ketema sub-city	321,192
Yeka sub-city	445,484
Bole sub-city	388,711
Total	**3,080,336**

3.1.2 Land use and land cover

Most of the upper part of the study area is occupied by settlement, mixed land use practices and planted trees in the up hills of the Intoto ridge whereas the southern part is dominated by non-irrigated agriculture. Most industries are concentrated along little and Big Akaki Rivers, which offer prospect for their effluents to get easily in to the rivers and end up in to the Aba Samuel reservoir (the confluence of Big and Little Akaki Rivers). Land use activities have direct impacts on water quality, while water quality greatly influences the sitting of land use activities. Presently industries areas are located in the southern sectors along the river channel. Inappropriate land use, particularly poor land management, causes continual groundwater quality problems. Acute groundwater quality problems are common and arise from unsuitable land use (Omran, 2012). Even though land is the largest economic resource of Addis Ababa, the land use pattern is characterized by random development which mainly geared towards horizontal expansion (Finance and economic development office report, 2010). Particularly, most of the riverside areas in the city are not well kept and utilized as per the acceptable standard. The city of Addis Ababa is classified in to five generalized land use land cover categories. The land use class is; residential, rain fed agriculture, market area, vegetation area, and slum area.

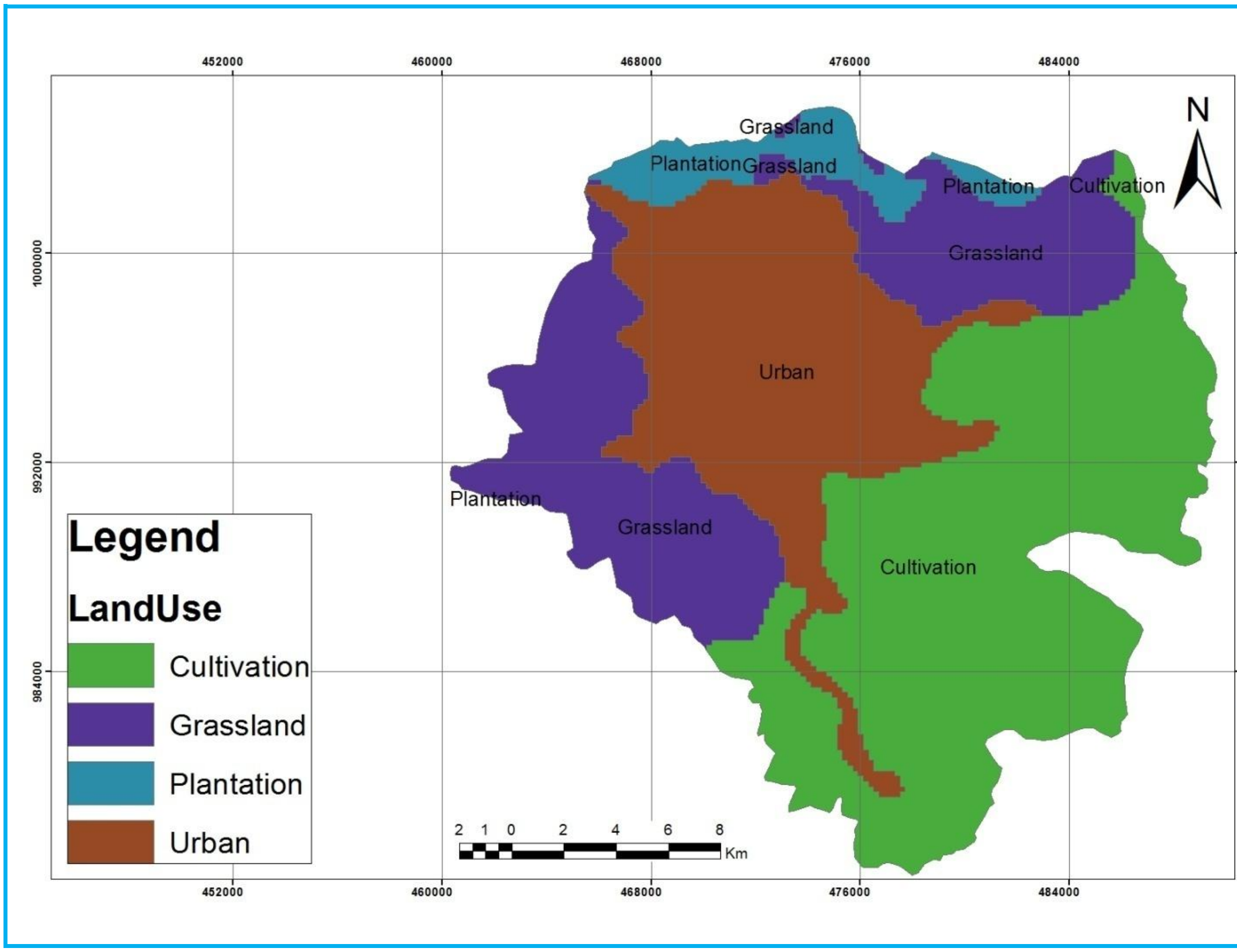

Fig 3.2 Land use and land cover map of Addis Ababa area

3.1.3 Soil Cover

The climatic condition and topography of the area favor the development of thick soil profiles mostly due to the physical breakdown and chemical decomposition of volcanic rocks on which it lies (Tamiru *et al.*, 2005). The weathering products either remain in place and form residual soils or are transported and deposited to form alluvial deposits in low-lying areas. In the localities where the topography is plain to gently sloping (central and southern parts) the area is covered by thick soils. According to (Birihanu, 2002) the types of soils which are found in the Addis Ababa are Black cotton soil, lacustrine and alluvial soil.

The Black cotton soil dominates the area. The thickness of lacustrine and alluvial silt and clay deposits in the area range between 5 to 50m. The soil map of Addis Ababa below is prepared based on FAO classification.

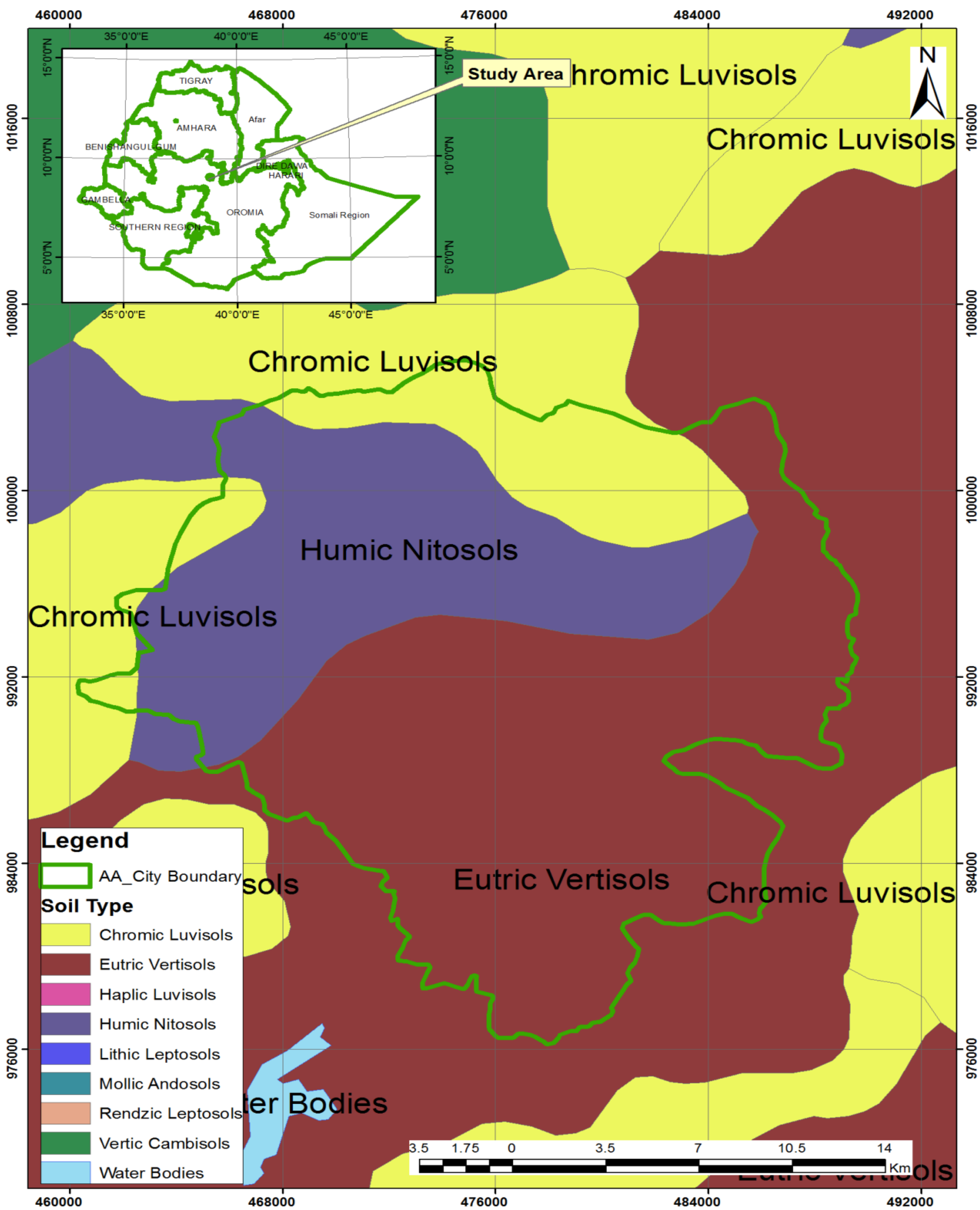

Fig 3.3 Soil map of Addis Ababa area

3.1.4 Drainage

Awash River basin covers a total area of 110000 km square and covers the regions of Oromia, Afar, Amhara, Addis Ababa City Administration and Dire Dawa Council. Awash Basin is an intensively used river basin in Ethiopia because of its strategic location, access roads, and accessibility of land and water resources. Akaki River is a tributary for upper Awash Basin.

Akaki River consists of two main branches, the confluence of which is at the Aba-Samuel reservoir. The western branch of the river, the Little Akaki, raises north-west of Addis Ababa on the flanks of Wechacha Mountain and flows for 40 km before it reaches the reservoir. The eastern branch of the river, the big Akaki, rises north-east of Addis Ababa and flows into the Aba-Samuel reservoir after 53 km flow. In the Addis Ababa city, there are dissimilar perennial and intermittent streams which are tributaries of the little or Big Akaki rivers, and towards the south approximately all streams/or big tributaries crossing the city in different direction join either of the rivers. The two rivers flow on either side of Addis Ababa –Debrezeit road and end up at the artificial lake Aba Samuel. The perennial streams in the city are Bantyiktu, Kurtume, Kebena and Ginfile. The remaining streams are intermittent in nature. Streams are intense on the top of the mountain forming radial and dendritic drainage patterns. As cited in (Feven Solomon, 2007). All the major streams of the catchment originate in its northern part and maintain the name Akaki as they leave the lake passing via a gorge up to 100m deep which extends for about 8 km prior to joining the Awash River.

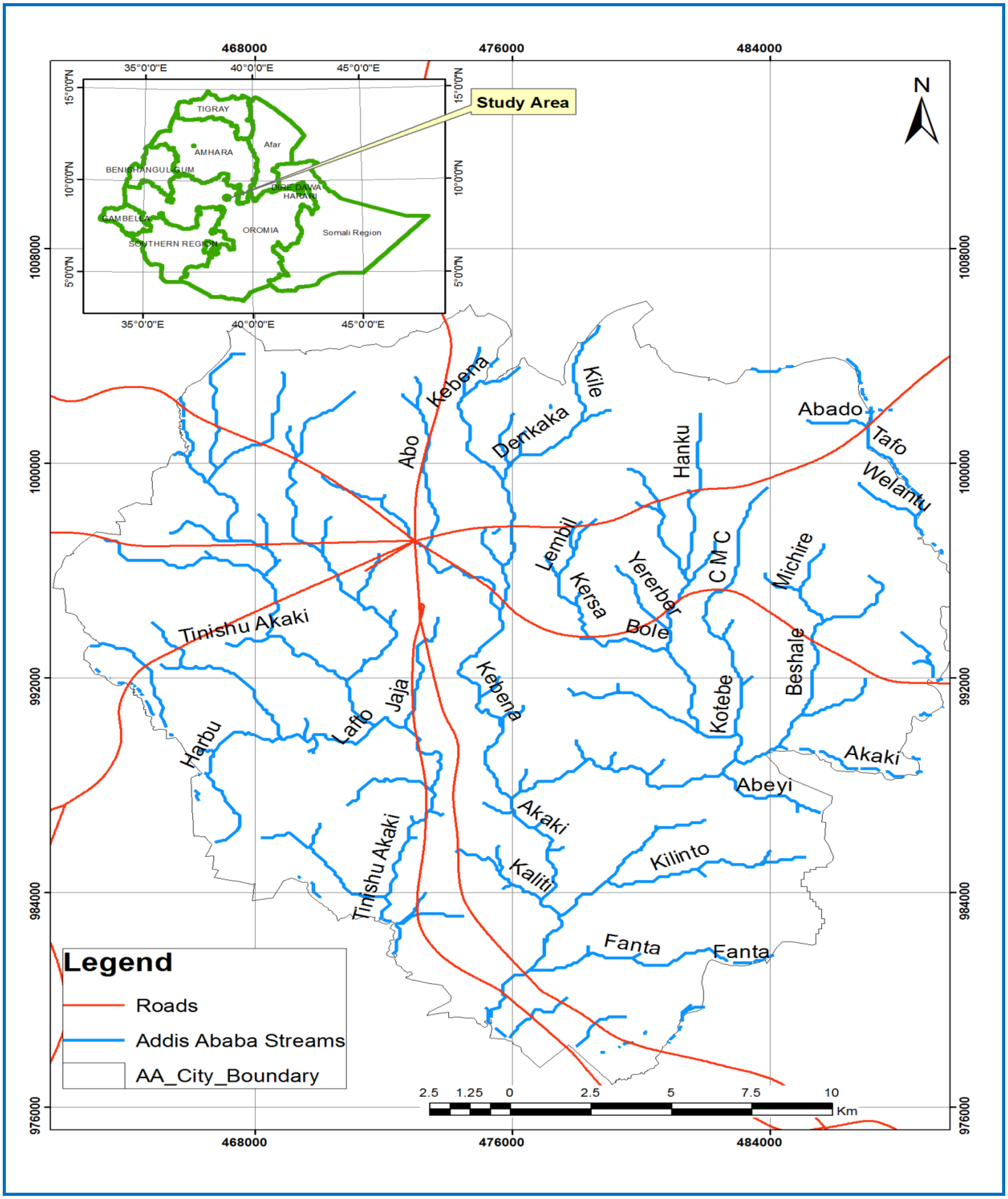

Fig 3.4 Drainage map of Addis Ababa

3.1.5 Regional Geology

According to AAWSA-Seureca (1991) the following lithostratigraphic units can be identified in the study area.

3.1.5.1 Younger Volcanics

This group includes the Nazareth Group and Bishoftu Formations. The Nazareth Group rocks outcrop dominantly south of the Filwuha Fault. They are composed of aphianitic basalts, welded tuffs, ignimbrites, trachytes, and rhyolites. It is overlain by aphianitic basalt and underlain by porphyritic basalt. The exposed thickness of the lava sequence is about 500 m (Girma, 1994).

3.1.5.2 Alaji Formation

It includes rhyolites, trachytes, tuff, agglomerate, and aphianitic basalt. This unit is dominant in the northern and central part. Earlier studies more subdivided this series into Alaji rhyolites and Intoto Silicics (Zanettin and JustinVisentin, 1974). It extends from Intoto to the northern adjacent Blue Nile (Abay) basin (Girmay and Assefa, 1979). The Intoto trachyte overlies the Alaji basalts. The Intoto Silicics represents massive Oligocene fissure-basalt, rhyolites, and trachytes with minor welded tuff and obsidian (Morton *et al*., 1979). It makes up a thick pile of flows, which accumulated along east-west fissures and downthrown southwards (Zanettin and Justin-Visentin, 1974).

3.1.5.3 The Bishoftu Formation

This formation consists of olivine porphyritic basalt, scoria, vesicular and scoriaceous basalt, and locally trachy-basalt lava flows. They are localized in the south and are 20 to 40 m thick in the Akaki well field. Locally it is overlain by scoria, tuff, sand, and gravel. This unit forms the major aquifer of the region.

3.1.5.4 The Intoto Silicics

These basalts overlay the Intoto Silicics and cover the central and southern part of Addis Ababa. Olivine porphyritic basalt outcrop in central Addis Ababa with a thickness varying from 1 m or less in the foothills of Intoto to more than 130 meters in central Addis Ababa (Vernier *et al*., 1985).

3.1.5.5 Recent Deposits

These formations include alluvial, residual, and lacustrine deposits. The thickness varies between 5 m and 50 m in the south (AAWSA2000). It is often overlain by dark younger black cotton clayey soils. Alluvial deposits are found in some places along the Little- and Big-Akaki rivers, predominantly south and southwest of Addis Ababa. The residual soils are located in the central, south-east, north-east, and western flat plains.

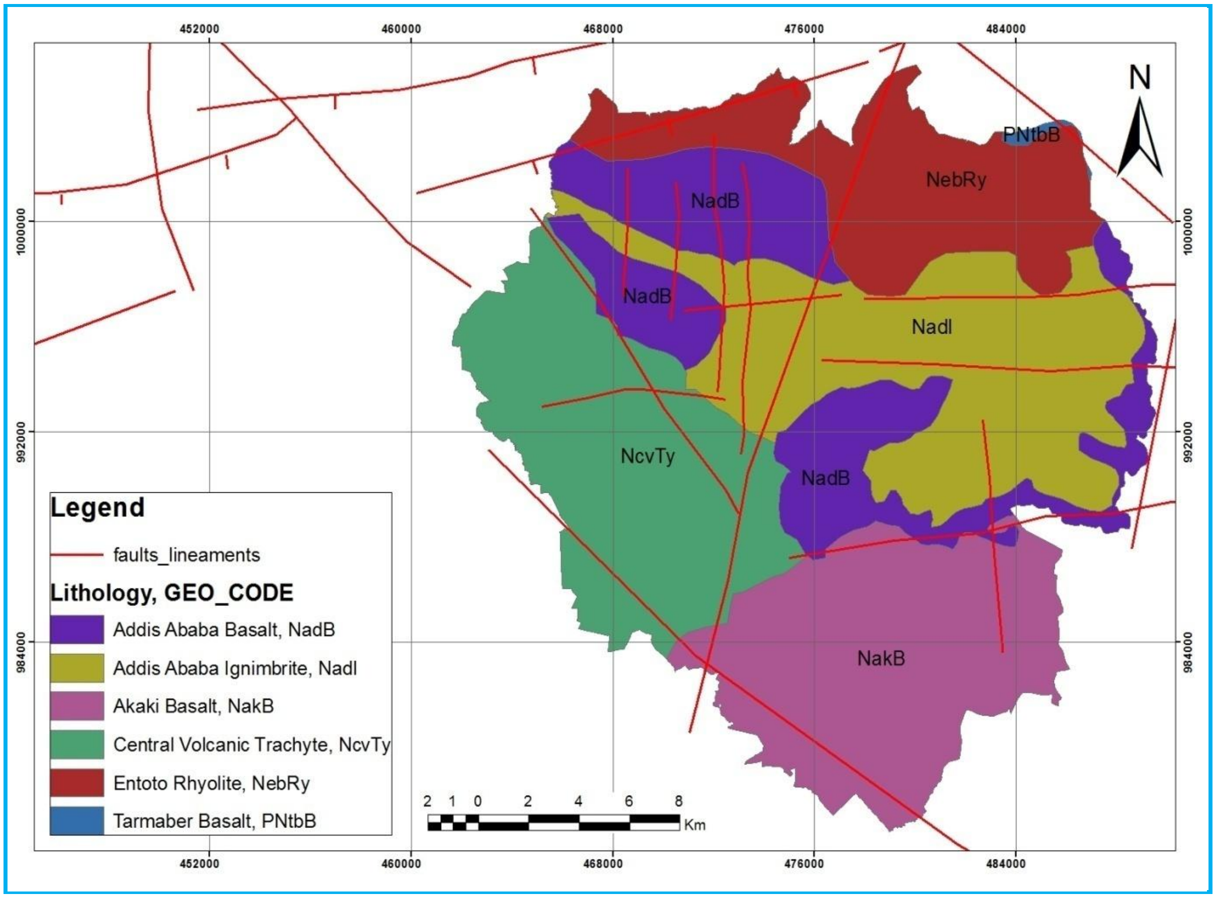

Fig 3.5 Geological map of Addis Ababa (Source Demlie et.al, 2007a)

3.1.6 Hydrogeology of Addis Ababa

The northern part of the city is made of rhyolites and trachytes of older age than the basaltic rocks of the southern part. The main volcanic centers are Intoto, Yerer, Furi and Wachacha.

The groundwater circulation and the dispersion of pollutants depend on the hydro geological characteristics of the material more specifically hydraulic properties such as porosity, permeability, transmissivity etc. furthermore, the stresses due to tectonism and weathering govern the hydro geochemical characteristics of earth materials. Volcanic rocks mainly basalts, rhyolites, trachytes; scoria; trachy-basalts, welded and unwelded tuffs are the dominant rock exposed in the area. These rocks are the major groundwater supply for large parts of Addis Ababa.

The area is characterized by alternate eruption of basic and acidic lava flows from different centers. In between successive lava flows physical disintegration and chemical decomposition of rocks exposed at the surface; subsequent erosion and deposition; and tectonic activity taken place that has modified significantly the geomorphologic set up of the area.

Generally, Scoria, scoriaceous, vesicular and fractured basalt of the Bishoftu Group located in the southern part of the catchment including the Akaki well- field are judged to be highly productive, Fractured and weathered Addis Ababa basalt aquifer with some inter-volcanic coarse sediment, located in central, western and northern Addis Ababa are considered to be moderately productive; the Young fractured ignimbrite of the Yerer volcano covering the eastern part of the catchment and young fractured trachyte of the Wechecha volcano covering the western part as low productive aquifers and the Weathered and fractured rhyolites and trachyte of the Intoto Silicics covering the Intoto Mountain Range could be considered as non-aquifer. The main porosity groups identified are fracture porosity and intergranular porosity. Fracture Porosity - high water storage and transmitting capacity of basaltic lava flows is due to joints caused by cooling, the presence of lava tubes, vesicles that are interconnected, tree moulds, fractures caused by buckling of partly congealed lava and voids left between successive flows. Old porphyritic basaltic lava flows dominantly cover the slopes of Intoto, and the central and western parts of Addis Ababa. The permeability becomes high in the area where welded tuffs are widely distributed in the northern, central and eastern part of area. The strongly welded tuff is mainly exposed in the central and western parts of the study area, while, the young welded tuff varieties cover an extensive area in the central and southern parts of Addis Ababa. Welded tuffs have medium to low primary porosity and very low permeability (Tamiru Alemayehu *et al*., 2005).

The most important characteristic features governing the groundwater movement and accumulation in the unconsolidated pyroclastic materials are related to fragment size, sorting and degree of cementation. The two major faults i.e. the East West running fault at Intoto and Northeast-Southwest oriented Filwoha fault changes the topography of Addis Ababa and its vicinity significantly. The occurrence of many springs at the foot of Intoto ridge and thermal water along the Filwoha area indicates the favorable nature of these faults. Moreover, during faulting associated fractures and fissures developed on different lithology adapt the hydrogeological characteristics of the rock units affected by the fault (Tamiru Alemayehu *et al*., 2005).

The aquifer types found in the Addis Ababa area are Shallow aquifer which is made up of weathered volcanic rocks and alluvial sediments along the river valleys, Deep aquifers which comprised of fractured volcanic rocks that tap fresh ground water and thermal aquifers which located at a depth greater than 300m.

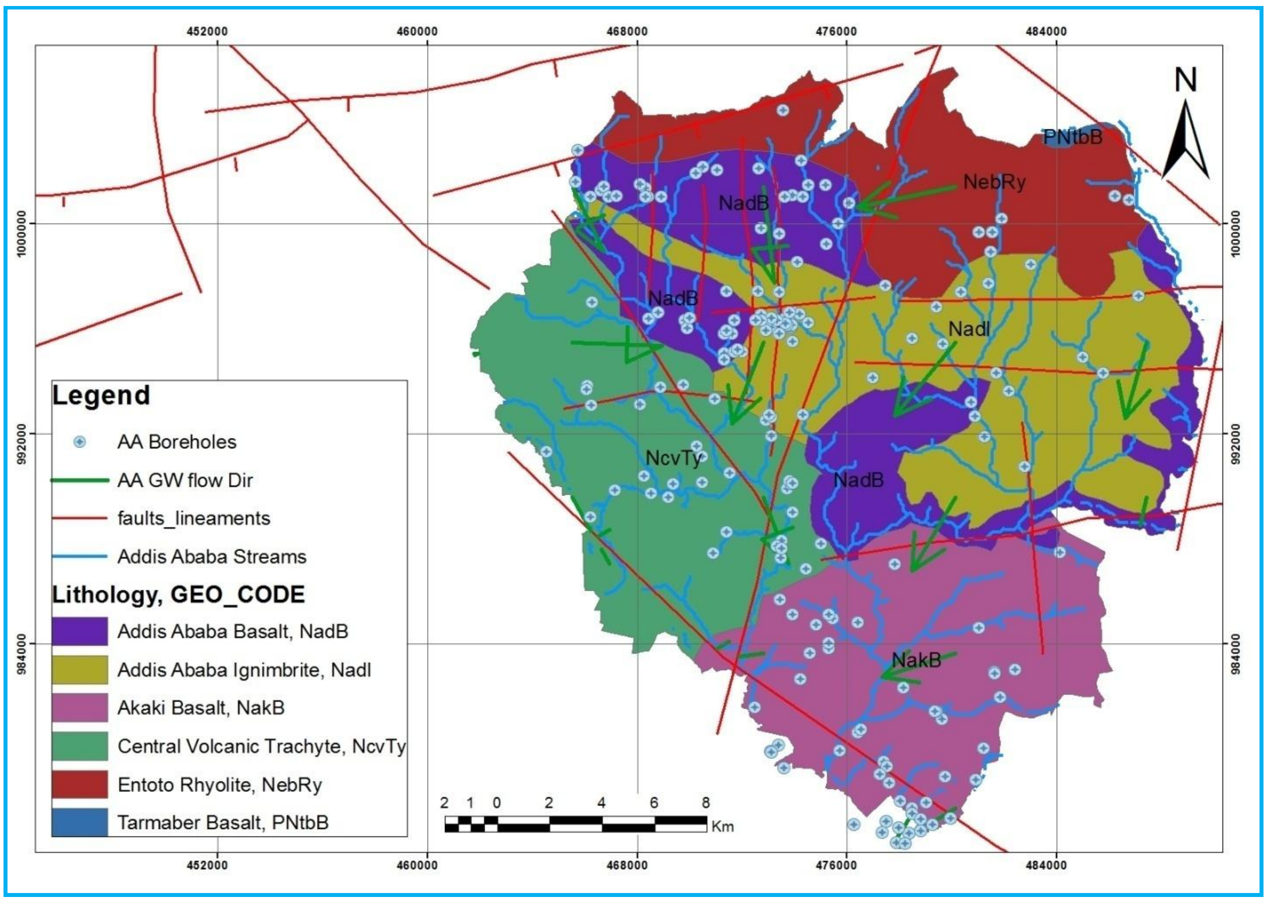

Fig 3.6 Hydrogeological map of Addis Ababa

3.2 DIRE DAWA

Dire Dawa Administrative Council (DDAC) is found at the margin of the eastern part of the Ethiopian Rift Valley and it covers 1500 Km^2. It lies between $09^0 28$`and $09^0 49$`N latitude and $41^0 38$`to $42^0 19$`E longitude. The total population of Dire Dawa by the year 2009 has estimated about 398,000. The city is situated at 1160 meter above sea level.

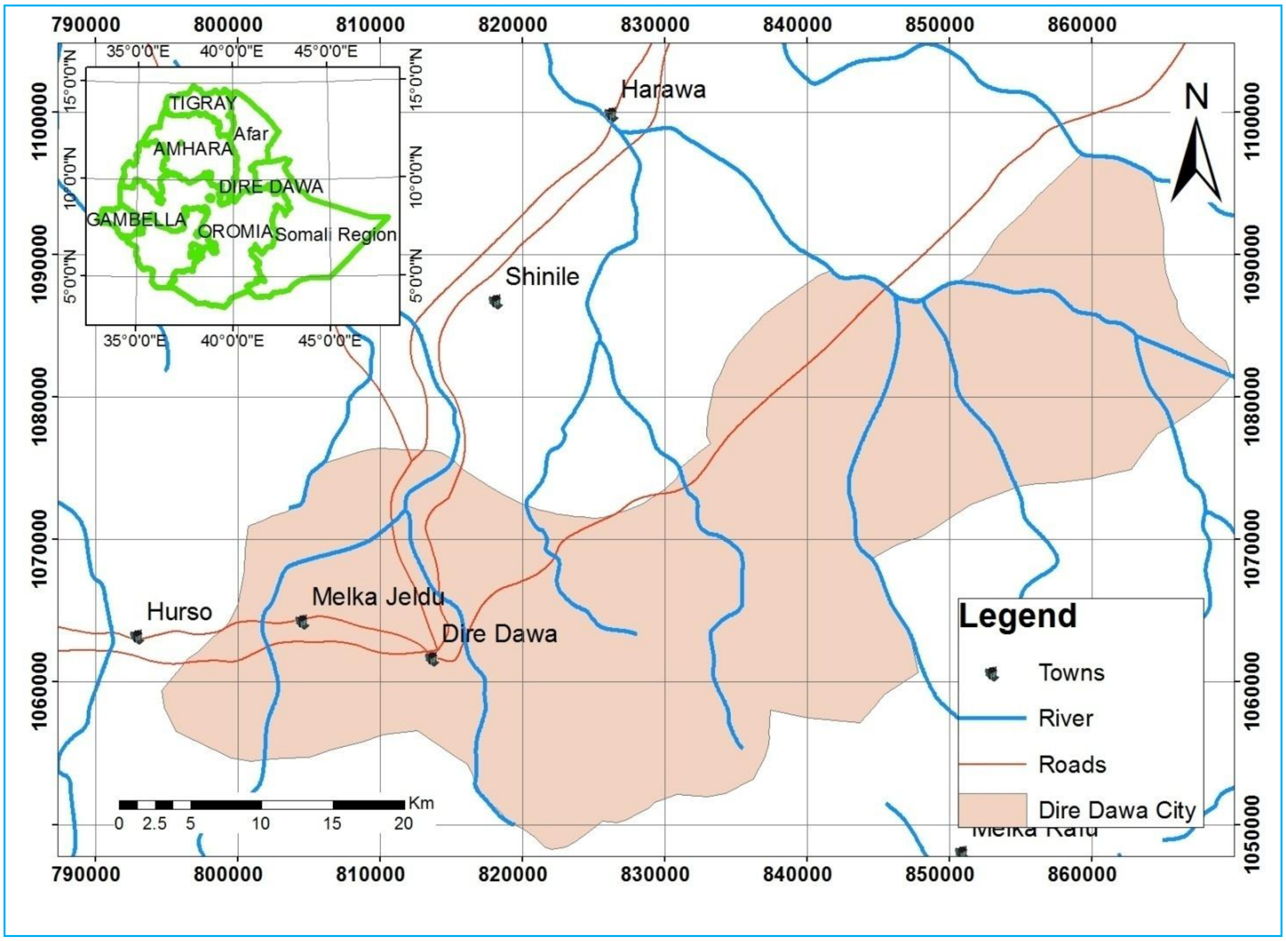

Fig 3.7 Location map of Dire Dawa

3.2.1 Population

The total population of Dire Dawa is estimated to be 384,000 out of which 74% (284,000) live in urban while the rest 26%(100,000) live in rural areas. According to the 1994 census result, Dire Dawa Administration had a total population of 252 thousands during the census period and in the year 2005; the population of the region has reached 384 thousands which exceeded the census period population by132 thousands. The incremental within a decade time accounts more than half of the size of the 1994 population, which is tremendous in magnitude. On the other hand, the average annual growth rate of the population was 4% for the region during the years 1995-2000. The growth rate declined to 3.8% for the years between 2000 and 2005 and expected to further go down to 3.5% for the years between 2005 and 2010 IDP (2006).

3.2.2 Land use and land cover of Dire Dawa

The land use system of the city is dominantly mixed as shown in Fig.3.7. This is true notably in the central part of the city where almost all buildings along the streets are used for commercial activities and their backyards or internal courtyards are used for residence purpose. Residential areas cover around 680 ha (10%); squatter settlement is estimated 980 ha (12%) and all about consists of 50% of the total built-up area.

Generally, the land use and land cover type of the area have been grouped by WWDSE in to four major classes. They are designated as urban build up, cultivated land, vegetation types, and bare land.

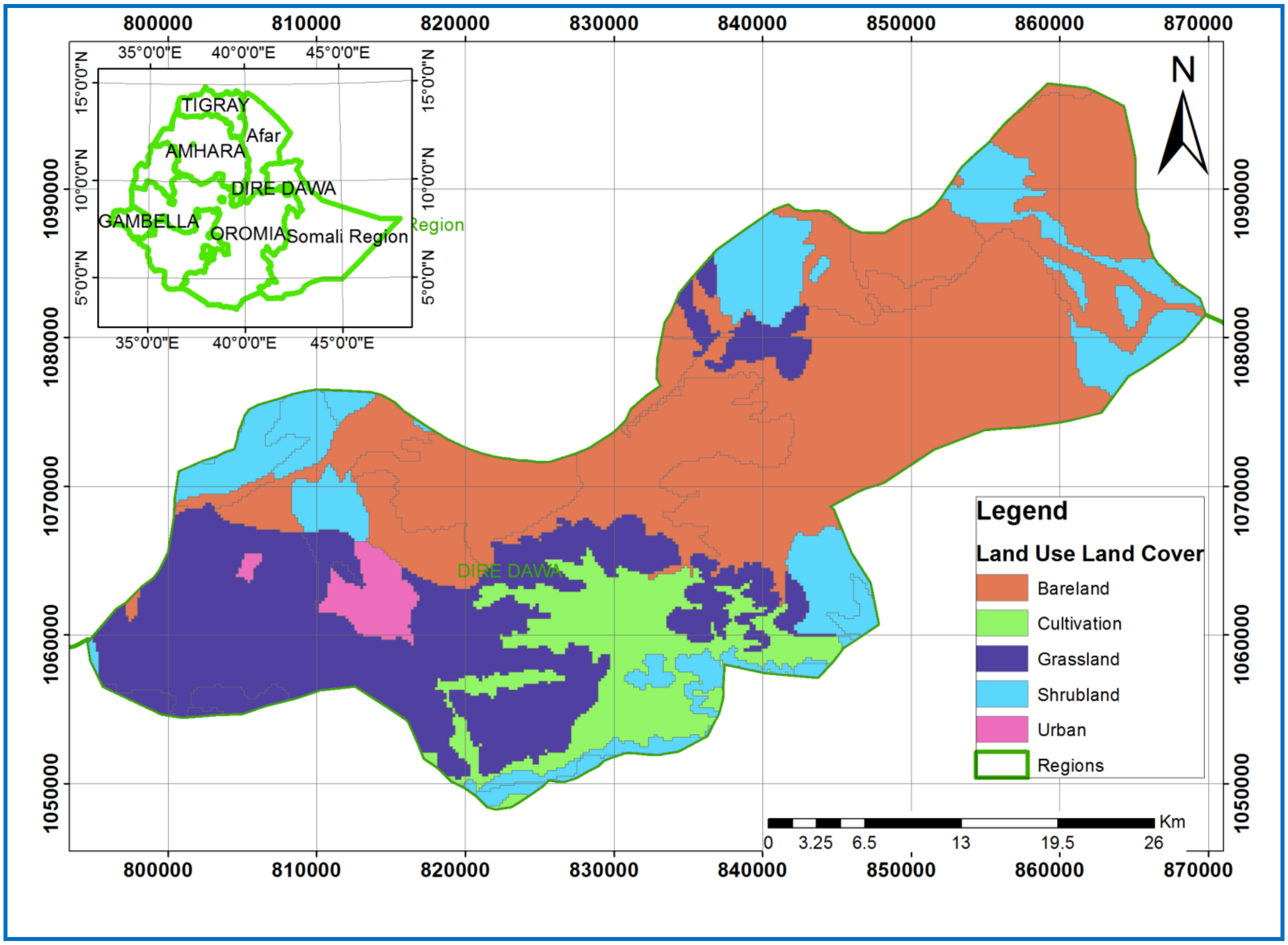

Fig 3.8 Land use land cover map of Dire Dawa

3.2.3 Drainage of Diredawa area

As we can observe from (Fig.3.8) most of the drainage patterns are South-North direction. Most of seasonal streams begin from the basin divider of Wabi Shebele-Awash River basin and flow towards the Dire Dawa plain areas. Springs originated from the escarpment zone of the catchment area, mostly within the Mesozoic sedimentary terrain. More than 100 deep bore holes and hand dug wells are located in the downstream (Fig.3.8) in the Dire Dawa town and its surrounding area.

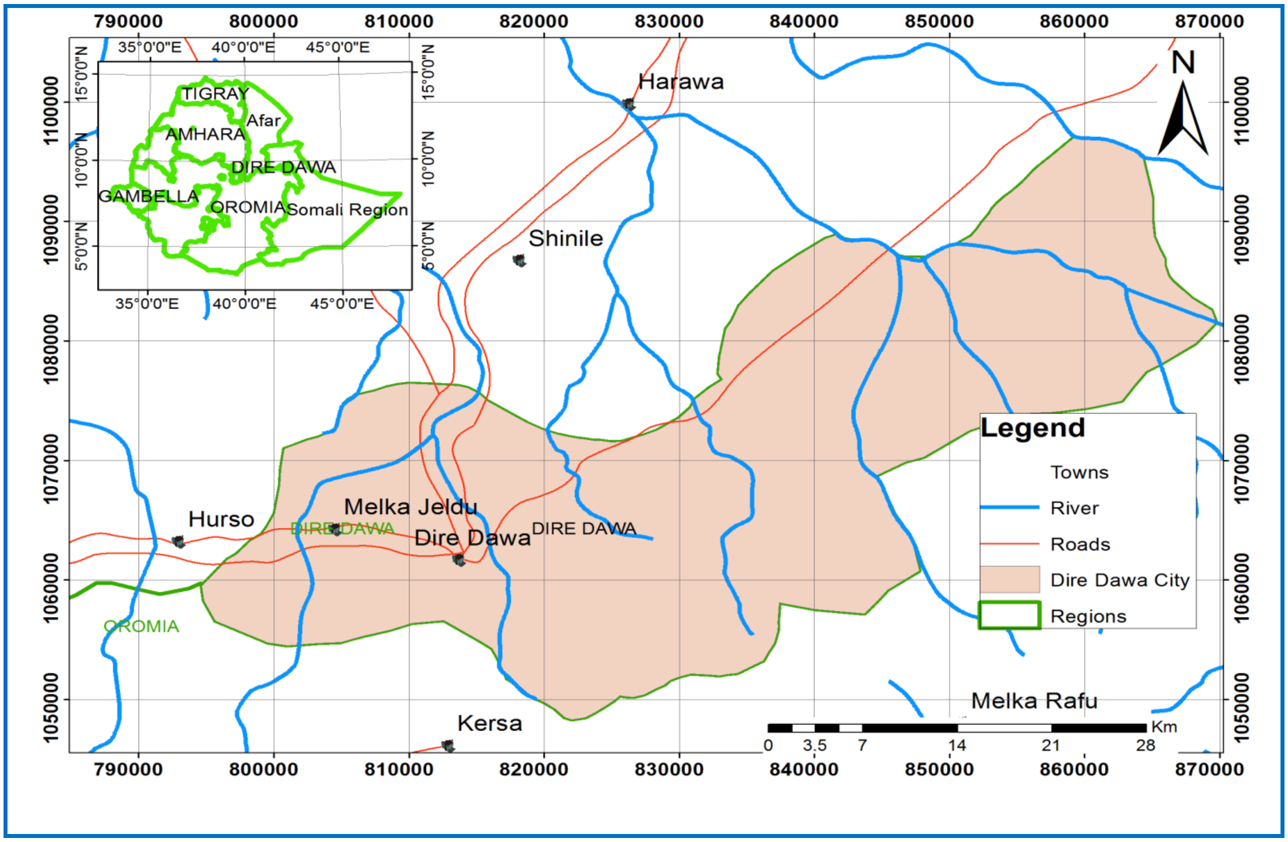

Fig 3.9 Drainage map of Dire Dawa area

3.2.4 Soil cover

The major soil types of Dire Dawa Administrative Council show a general relationship with altitude and slopes. Shallow and infertile soils being the characteristics of the mountains and hills where as the deep and fertile soils are the major properties of valley bottoms, river terraces and flat plains. Generally, the soils of the valley are developed on recent alluvial colluvial sediments resulting from the adjacent mountain ranges. Fluvisols and Vertisols are generally dominating the region and predominantly lowland flat plains, valley bottoms and river terraces. Texturally these soils are sandy loam and sandy clay respectively. Shallow Leptisols are the main type of soils found in the mountain and hills of the region WWDSE (2004). The soil map of Dire Dawa below is prepared based on FAO classification.

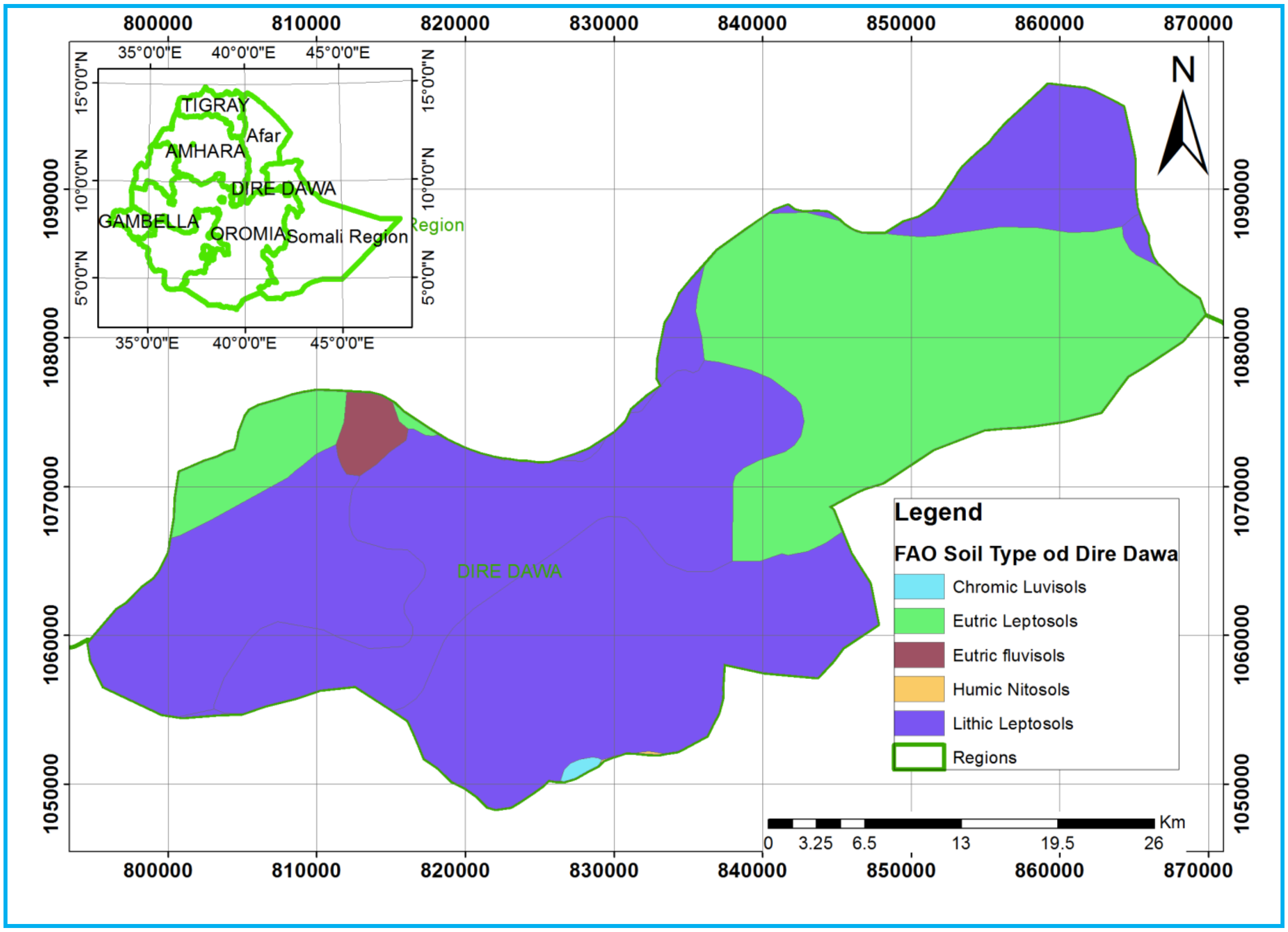

Fig 3.10 soil map of Dire Dawa area

Regional geology of Dire Dawa

According to (Tamiru Alemayehu, 2006) in terms of their surface exposure, the main lithologic units of the country have been grouped like, Precambrian metamorphic basement rocks, Mesozoic sedimentary rock, Tertiary volcanic rocks (largely basalts) and, Quaternary formations.

3.2.5.1 Precambrian basement rocks

Precambrian basement rocks are exposed in the northern, western, southern and Eastern parts of the country. In the Eastern part of the country, the basement rocks consist of crystalline acidic migmatites, gneisses and granites. The main components of this formation are migmatic quartz rich gneisses and the intrusive pegmatite-feldspathic granite (Tamiru Alemayehu, 2006). The Precambrian metamorphic rocks of the study area belongs to Archean complex of Alghe group and is mainly composed of high grade quartz-fieldspar-biotite, gneiss, biotie-hornblende gneiss and pegmatite.

3.2.5.2 Mesozoic sedimentary rock

Sandstone was deposited on the aged land surface, followed by the deposition of shale and limestone as the depth of water raise. In the west of the country sedimentation ended up with the deposition of clay, silt, sand and conglomerate as the sea reduced during the Jurassic. The sea invaded again in the lower cretaceous. Mesozoic sedimentary rock of the study area which is the effect of transgression and regression events are grouped in to three formations known as Adigrat sandstone, Hamaneli limestone and Amba Aradam sandstone.

3 .2.5.3 Adigrat sandstone/ lower sandstone

This formation is unconformable overlying the basement complex and is exposed mainly in the southern parts of the area under laying the Hamaneli limestone. Triassic to lower Jurassic in age, this sandstone is medium to coarse–grained and its color is red to brown. The thickness of the Adigrat sandstone in Dire Dawa area does not go beyond 50m. But kazmin (1975) indicates in his study report a maximum thickness of 800m for Ethiopia.

A. Hamaneli limestone

The Hamaneli limestone conformably, overlies the Adigrat sandstone and is the dominant formation in the study area. It is exposed in the southern part of the area forming different step ridges extended in the east-west direction and declining topographic elevation from south towards the north. In the absence of the Adigrat sandstone, it unconformably overlies the Precambrian basement rocks. Hamaneli limestone is composed of alternating layers of shale and chock at the lower part and brown to gray color limestone at the upper part. The overall thickness is not known although Gretzer (1970) cited in his study predicted to reach 175m for the upper limestone.

B. Amba Aradam sandstone/upper sandstone

This upper Jurassic to lower cretaceous formation is unconformably overlaying the Hamaneli limestone and is exposed mainly in the west, central, north and northeastern part of the area. This unit is estimated to have a thickness of about 200m (Tesfamichael Keleta, 1974).

3 .2.5.4 Tertiary volcanic rocks

The Tertiary volcanic rocks mapped in the study area are Alaji basalts and the stratoid basalt of the Afar series. (Seife Mikael Berhe, 1985).The Alaji basalt is exposed mainly in the northwest, central and northeastern part of area. This unit mainly consists of a phyric flood basalts associated with rhyolites and minor trachytes and ranges in age between 36-13 Ma (kazmin, 1979).The stratoid basalt exposed in the study area is the upper part of the Afar series and represented by the transitional type basalt (Seife Mikael Berhe, 1985). This rock unit is out cropped in the northwest and northeast of the study area forming an east-west trending continuous ridge, which is most likely fissural eruptions and serves as a barrier for the surface run off in the Dire Dawa area.

3.2.5.5 Quaternary formation

The quaternary sediments of the area consisting of alluvial sediments, lacustrine deposit (travertine) and river sand deposit.

A. Alluvial sediments:

The alluvial deposit, which is the weathering product of the existing rocks in the area, is mainly covering the lower most elevation of the study area. This deposits are consisting of boulders, gravel, sand, silt to clay sizes of the rock units of metamorphic rocks, sandstone, limestone and basalts. The alluvial sediment is mainly deposited over the tertiary basalts and has variable thickness.

B. Travertine:

Lacustrine deposit, travertine, is exposed in Dire Dawa and Melka Jebdu area. The rock is connected within the alluvial sediments. In both areas, the travertine is used for construction of houses and fences.

C. River sand deposits:

These are the most recent sediment in the study area; it is deposited in the flood plains of the main streams of the area. Important deposits are associated with Goro, Dechatu and Lega Hare intermittent streams crossing the Dire Dawa town. The sand deposit is the weathering product of the rocks within the watershed of the main streams and their tributaries. The deposit is composed of fragments of metamorphic, sedimentary and volcanic rocks of the area.

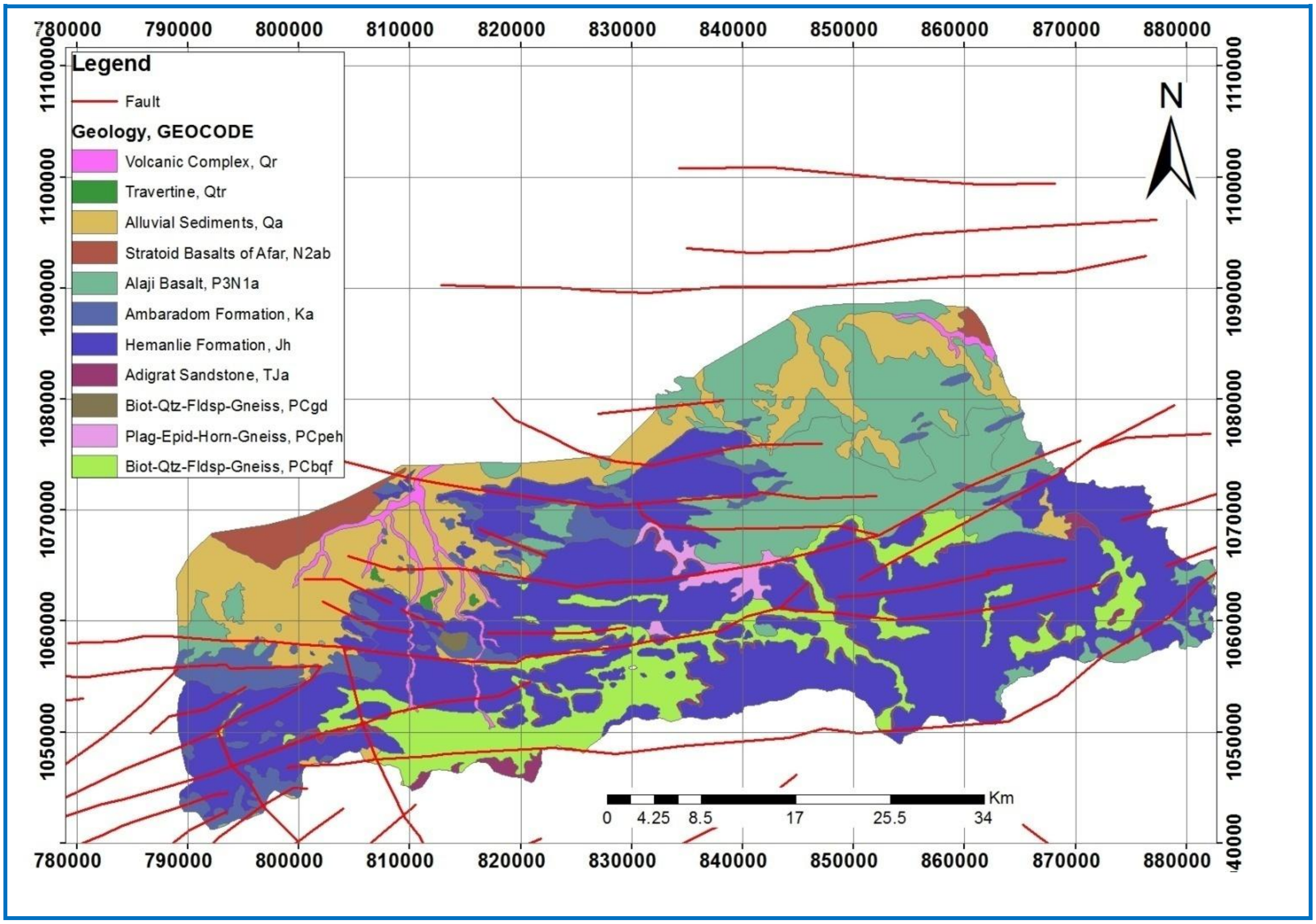

Fig 3.11 Geological map of Dire Dawa

3.2.6 Hydrogeology of Dire Dawa

In the previous studies of the hydrogeological condition of the surrounding areas according to EIGS (1986), WWDSE (2001) and Mesfin (1981) the major water bearing formation has been classified as: extensive alluvial sediments aquifer with intergranular permeability, localized volcanic rocks aquifer with fracture permeability and extensive sedimentary formation aquifer (sandstone and limestone) with fracture and permeability. The main hydstratigraphic aquifer units in the study area identified by WWDSE (2004) are:

3.2.6.1 Alluvial aquifers

The alluvial sediments are distributed in Dire Dawa groundwater basin, unconfined unit composed of clay, silt, sand, gravel and rock fragments. The groundwater depth on average varies in the alluvial sediments from 15 to 50 m with the mean values of saturated media is about 20m.

3.2.6.2 Tertiary volcanic rocks:

These rocks refer to the stratiod and Alaji basalt outcrops that reside in located in the elevated areas at the north and northeastern part of the area. This formation is generally a regional aquiclude and is the confining layer for the lower greatly productive confined aquifer .

3.2.6.3 Cretaceous upper sandstones:

This unit is found below the confining layer and alluvial deposits in most part of the lower part of the study area. The drilled wells in the aquifer show that the thickness of the aquifer is variable. The minimum thickness of the aquifer penetrated at the Dire Jara well field is 36m. On the other hand the estimated average thickness of the unit is 200m (Tesfamichael, 1974). The static water level varies from 10m (Sabiyian) to 70m (Dire-Jara).

3.2.6.4 Jurassic Hamanalei limestone:

The Hamanalei limestone is uncomfortably underlies the upper sandstone. The limestone and sand stone in the study area are characterized in the same way. The lower part of the limestone is a gray-white limestone inter-bedded with shale overlain with oolitic limestone as well as the upper part is well-bedded gray fossiliferous limestone (Seife B. 1982, Habteab Z. & Jiri S.1986). The Sabiyan well field has two types of aquifers (MoWR, 1999a) one is a shallow unconfined aquifer in the recent deposits about 15 to 25m depth at the same time the second aquifer is situated in the deeper quartz sandstone with water bearing fractures at depths greater than 35m.

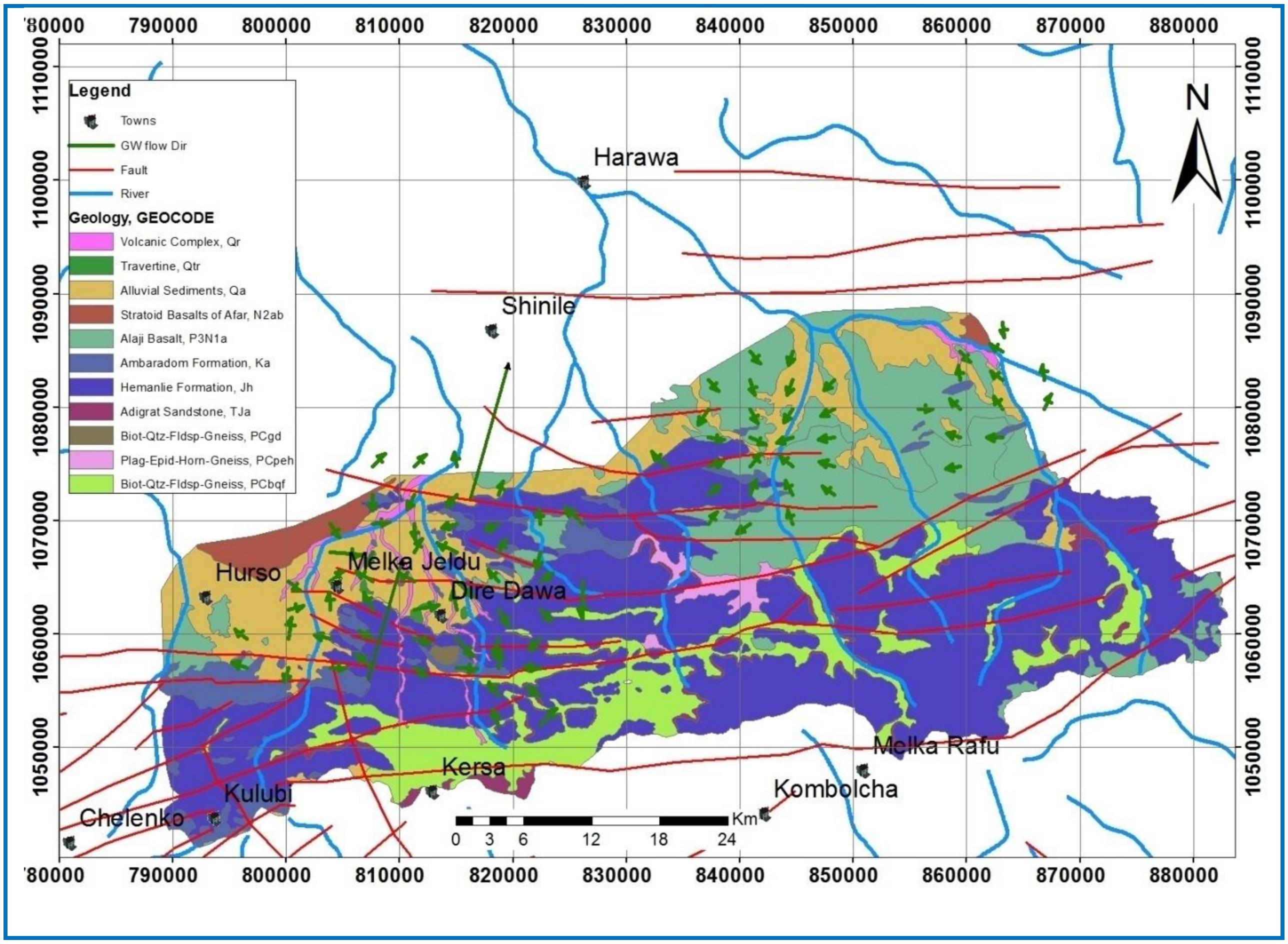

Figure 3.12 Hydrogeological map of Dire Dawa area

Aquifer system and Vulnerability

The aquifer systems are characterized by the upper relatively low productive unconfined aquifer (which composed of alternation of silt, sand, and gravels, outcropped and weathered basement, sandstone and limestone) and the lower relatively high productive confined aquifer composed of fractured sandstone and highly jointed and cavernous limestone which are found below confining unit at the lower part of the Dire Dawa. This confined aquifer is overlain by tertiary basalts, which are the confining unit in the area and underline by lower part of the limestone that composed of the massive limestone intercalated with shale. The lower part of the limestone is considered as aquicludes. The main aquifer that is exploited for the Dire Dawa city water supply is the upper sandstone. The main aquifer (upper sandstone) is semi confined overlaid by the alluvial aquifer. The groundwater level depth and groundwater level elevation maps (fig.4.2) show that the groundwater level is deep along Dechatu river and at the same time is the overlying alluvial and the upper sandstones are highly permeable and the groundwater flow concentrates along the river. Along Dechatu river fan the upper sandstones aquifer is highly susceptible to pollution due to the high permeability. Away from the Dechatu river to the west the alluvial becomes finer and the permeability decreases. The upper sandstone aquifer is also vulnerable to pollution. Generally the upper sandstone aquifer at Dire Dawa town area is vulnerable to pollution due to the high to moderate permeability of the alluvial sediments overlying the aquifer.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 SOURCE OF NITRATE

4.1.1 Source of nitrate in Addis Ababa

The possible sources of nitrate in Addis Ababa are:-

Pit Latrines

A significant population of Addis Abba uses pit latrines. Observations have also shown that the many pit latrines are merely a pit in the ground. This does not provide any liquid retention and the waste percolates into the ground. The large number of pit latrines and their location, irrespective of soil and geologic structures, is likely to be a significant element in increasing groundwater contamination. The major threats from the extensive spread of pit latrines include chemical as well as pathogens sourced from human waste

Domestic Waste

Some studies have suggested that the upper Awash basin is becoming increasingly polluted by sewage generated in the city of Addis Ababa (DHV, 2003). Tamiru (2005) indicates that, of the total water supplied to the city of Addis Ababa (163,000 m^3/d from surface and groundwater), about 70% returns as sewage, 60% of the returned flow has an outlet through Big Akaki river and the remaining 40% joins the Little Akaki river.

The recharge zone of the main borehole site located to the south west of the city consists predominantly of expansive soils (commonly called black cotton soil). These soils are considered to be impervious and will not readily absorb water. This, it is argued, inhibits water from penetrating to deeper aquifers (BCEOM, 1970). Based on this, Tamiru (2004) (2005) suggests that the areas to the south west of Addis Ababa fall within a low vulnerability category.

Solid Waste

Solid waste collection and disposal coverage is considered to be low in many urban areas in Ethiopia. In Addis Ababa, coverage is cited to have increased from 38% in 1993, to 40% in 1994, 53% in 1995 and 53.9% in 1996. This is a significant increase compared to 21.6% collection in 1986 (Yami, 1999).

A study by Tamiru and Vernier (2000) indicated that the daily volume of solid waste generated in Addis Ababa was about 15 kg per person. It was estimated that this would amount to 450 tones if the population of the city was considered to be about 3 million. Of this generated waste, only 55% was collected with the remaining 45% uncollected.

In 2003, it was estimated that the city of Addis Ababa generates about 520 tones or 1440 $m^3$of solid waste daily. Of this amount 1152 m^3or 80% of that generated is accessed out of which only 65% is normally collected and disposed of in a land fill located 12 kms to the southwest of the city centre. Nearly 90% of the generated waste is organic in nature with the rest recyclable matter such as plastics, glass rubber and other materials (BCEOM, SEURECA, & Tropics, 2003).

Solid waste collection/disposal in the city of Addis Ababa is managed by municipal dirt trucks which dump the collected waste at the refuse site south west of the city. Over the last few years the number of solid waste collection trucks has shown a steady increase. In 1999 the number of trucks stood at 60, half of which were inoperative due to old age (Yami, 1999). Tadesse (2004) reports that in 2004 the number of trucks had risen to 72, out of which only 35-40 work daily, the rest inoperative due to old age. In 2008 the collection capacity increased to a total of 800 m^3/day through the purchase of additional 20 trucks out of which 17 are operational (The Reporter, September 21 2008).

At present solid waste collection has taken a new direction. The introduction of private solid waste collection services has significantly enhanced service coverage. As cited in Tadesse (2004) estimates that 74 Micro and Small enterprises were engaged in the collection of household waste. This is encouraging as an alternative means of widening service coverage in the city. While service coverage is likely to improve with the introduction of private collection services, lack of alternative waste tip sites may restrain development. The city has only one dump site which has been in use for the last 40 years. Although there has been some suggestion of moving it further out of the city, it is still functional, albeit in an environmentally unsuitable manner.

Although standard procedures in the management of sanitary fills recommend covering the refuse with fresh soil before laying the second layer, the practice in the city has been to merely pile the waste. The decomposition of the waste and the ensuing generation of gases appear to be fuelling the continuous fire and smoke. Besides generating an almost perpetual smoke, it has also made access difficult to a point where the sanitary trucks have difficulty discharging waste at the site. In addition to this, during periods of heavy rain, the fill site has been observed to flood the surrounding areas.

Industrial Waste

As a major economic centre, the city of Addis Ababa is now home to 65% of all the industries in the country (Tamiru et al., 2005). A 2003 inventory records 85 main industries located in Addis Ababa (BCEOM, SEURECA, & Tropics, 2003). It is also reported in this study that 96% of the industries discharge waste without treatment into these rivers, (WWD&SE, 2007), (BCEOM, SEURECA, & Tropics, 2003), (Zewde, 1990) (EVDSA,1990).

In a 2002 study the Addis Ababa city government Environmental Protection Bureau has recorded that 31 industries discharge untreated waste into the Little Akaki River. The chemicals discharged included, heavy metals, which has surpassed the natural assimilation capacity of the river within the city limits making the river highly polluted (Tesfaye, 2002). Another study cites at least 53 industries located in Addis Ababa discharge effluents including sulphides, chromium, organic compounds, ammonia, phenol, carbon monoxide and even cyanide. These chemicals are believed to find their way into the groundwater resource nearby. It is also recorded that the Akaki spare parts factory discharges its effluents directly into the soil overlaying the Akaki well field (BCEOM, SEURECA, & Tropics, 2003). Industries located on the edges of the Akaki rivers including the Mekanissa Liquor Factory the Akaki Textile mills and the steel mills around Kaliti routinely discharge untreated effluents into the water courses. Although anecdotal evidence suggests that some industries may have treatment facilities, it is doubtful whether the treatments are effective enough to reduce pollutant concentration. A study by Mohammed (2002) records that nitrate levels as high as 375 mg/L has been discharged into the river from individual tannery industries alone.

Although the city administration cites the inappropriate location of tanneries and textile factories as causing ground and surface water pollution, posing serious health problems to the population (AACG, 2002), no action appears to have been taken to mitigate this. New industrial plot allocation for instance appears to have not taken this into consideration. New tanneries and other industries are allowed to be erected near streams, where untreated waste is discharged into streams.

Agricultural Fertilizers and Pesticides

Fertilizer use increases the level of nitrates in the groundwater (McMahon et al., 2008). Nitrate from nitrogen fertilizers use has been indicated as one of the anthropogenic sources of contamination and decrease in groundwater quality.

The areas around the Akaki well field a comparatively sparsely populated area and used as farming land, extensive fertilizer utilization has been reported. It is therefore possible that chemicals from the fertilizers used may have found their way into the groundwater.

4.1.2 in Dire Dawa

The major activities which contribute for the nitrate pollution are:-

1. Industrial activities: Industry is the second important economic activity in urban area. There are six major industries and more than 100 small scale manufacturing industries in the town of Dire Dawa. These are Dire Dawa textile, Dire Dawa food complex, ELFORA meat processing, East Africa bottling (soft drink), and Dire Dawa Cement.

Dire Dawa Cement Factory: Major wastes and byproduct of the factory are carbon dioxide, carbon monoxide, dust and sometimes sulfur dioxide. Carbon monoxide is produced when there is incomplete combustion of raw material. The main raw material is lime ($CaCO_3$). This lime when it partially combusted gives cement, CO_2 and CO. Both CO_2 and CO release to the air, which ultimately contribute to the green house effect in the atmosphere. Sulfur dioxide that liberates from the factory has been causing bad smell for the nearby residents.

Dire Dawa Textile Factory: The Dire Dawa textile factory is the main source of contaminant in the urban area. The chemicals used in this factory pollute the ground and surface water. The factory has no waste treatment plant and it directly releases all sort of wastes into the stream channel.

In the city, there are about 100 medium and small-scale factories. All medium and large-scale industries do not treat their effluent or liquid waste. They simply discharge in the open field, near by the dry river channel or sandy stream channel. The centre of the city is highly populated around 350-500 per hectare which directly or indirectly contribute to the groundwater pollution. ELFORA-Dire Dawa meat processing plant: Solid waste has been dumped at the public waste disposal site while the liquid waste has been discharged into the stream channel. When the plant functions with its full capacity, the load would be significant to cause environmental pollution and contamination of surface and ground water around it.

2. Municipal Wastes: Domestic wastes have been discharged directly into the open ditches and sandy streams. Degradation of ground water quality is intensifying by point sources such as septic tanks, pit latrines and industrial effluents. There are also other pollution sources in Dire Dawa like markets, cemeteries, fuel stations, garages and etc. The waste generated from the market centers are various types and are not systematically collected. As a result, it may contribute for the worsening of groundwater in the study area. In Dire Dawa town, there is no central municipal sewerage system at present. Each household is in charge of disposing of its" own waste at any open place in their surroundings. One of the problems facing urban settlements is the skill to cope with increasing quantity of wastes both solid and liquid wastes, in spite of the growing demand of the population. As a result urban settlements are facing with serious health and environmental complications, as the existing sanitation conditions turn out to be worst by unrestrained population increase and urbanization. For example the distributions of housing units or households are made by types of toilet facilities used shown in the table.4 below. As to the information obtained from CSA (1998) the sanitation facility coverage is more than 75% in the town of DDAC. The solid waste disposal system is generally weak. The solid waste collection mechanisms and location sites of containers are not systematically in place. The dumping site also has conducted at open fields.

3. Agricultural Wastes: In the city and its vicinity, there are numerous urban agricultural activities such as Tony farm, „chat" farm, Amdael dairy farm, Hafecat diary, and other small-scale cattle breeding and horticulture producers in the town. Generally, the agricultural inputs and by-products are the major constitutes of wastes and have a chance to contribute for the groundwater pollution. Animal wastes are classified as solid and liquid. Such animal waste may become the source of groundwater pollution.

4.2 Main causes of nitrate level variations in Addis Ababa and Dire Dawa

4.2.1 Population

The estimated population of Addis Ababa is above 4,000,000. On the other hand the estimated population of Dire Dawa is 384,000. This shows the population amount has not direct effect on their nitrate pollution level difference.

4.2.2 Land use land cover

The land use land cover have great role in nitrification process. As shown in fig 3.2 the high nitrate level zone of Addis Ababa is exposed to urbanization. On the contrary as figure 3.7 shows the high nitrate level zone in Dire Dawa and its surrounding is covered by grass land and cultivation.

- Since nitrification is highly affected by agriculture and cultivation as a result the nitrate level in Dire Dawa is higher than that of Addis Ababa.

4.2.3 Soil

Soil has a considerable impact on the amount of recharge which can percolate to the water table. The presence of fine textured materials, such as silts and clays, can reduce relative soil permeability and control contaminant migration. In Dire Dawa Loamy sand, Sandy Loam, Sandy clay loam and Sandy clay textured soils are dominant. Whereas in Addis Ababa the central and southern parts the area is covered by thick soils. The types of soils found are Black cotton soil, lacustrine and alluvial soil. Of which the Black cotton soil dominates the area. The thickness of lacustrine and alluvial silt and clay deposits in the area range between 5 to 50m (Birehanu, 2002).

- Therefore higher nitrate level in Dire Dawa is as a result of sandy soil.

4.2.4 Aquifer type

The aquifer types of Addis Ababa are Scoria, scoriaceous, vesicular and fractured basalt, Fractured and weathered Addis Ababa basalt and fractured rhyolites, Young fractured ignimbrite of the Yerer volcano, and Weathered and fractured rhyolites and trachyte of the Intoto Silicics. On the other hand the aquifer types of Dire Dawa are Extensive alluvial sediments aquifer with intergranular permeability, Localized volcanic rocks aquifer with fracture permeability and Extensive sedimentary formation aquifer (sandstone & limestone) with fracture permeability.

- From this we can observe the Dire Dawa aquifers are more vulnerable to nitrate pollution since its aquifer is more permeable which enhances movement of pollutants to groundwater.

4.2.5 Groundwater level depth

The static water level of Addis Ababa varies from 0 to 260 meter and the static water level of Dire Dawa varies from 9.3 to 93.5 meter. Therefore the groundwater of Dire Dawa is found at shallower depth than Addis Ababa. Shallow groundwater depth is easily contaminated by anthropogenic activities than deep groundwater depth.

- The shallow groundwater depth of Dire Dawa makes the nitrate level to be high. From the figures below the high nitrate level zone are found in shallow groundwater level depth.

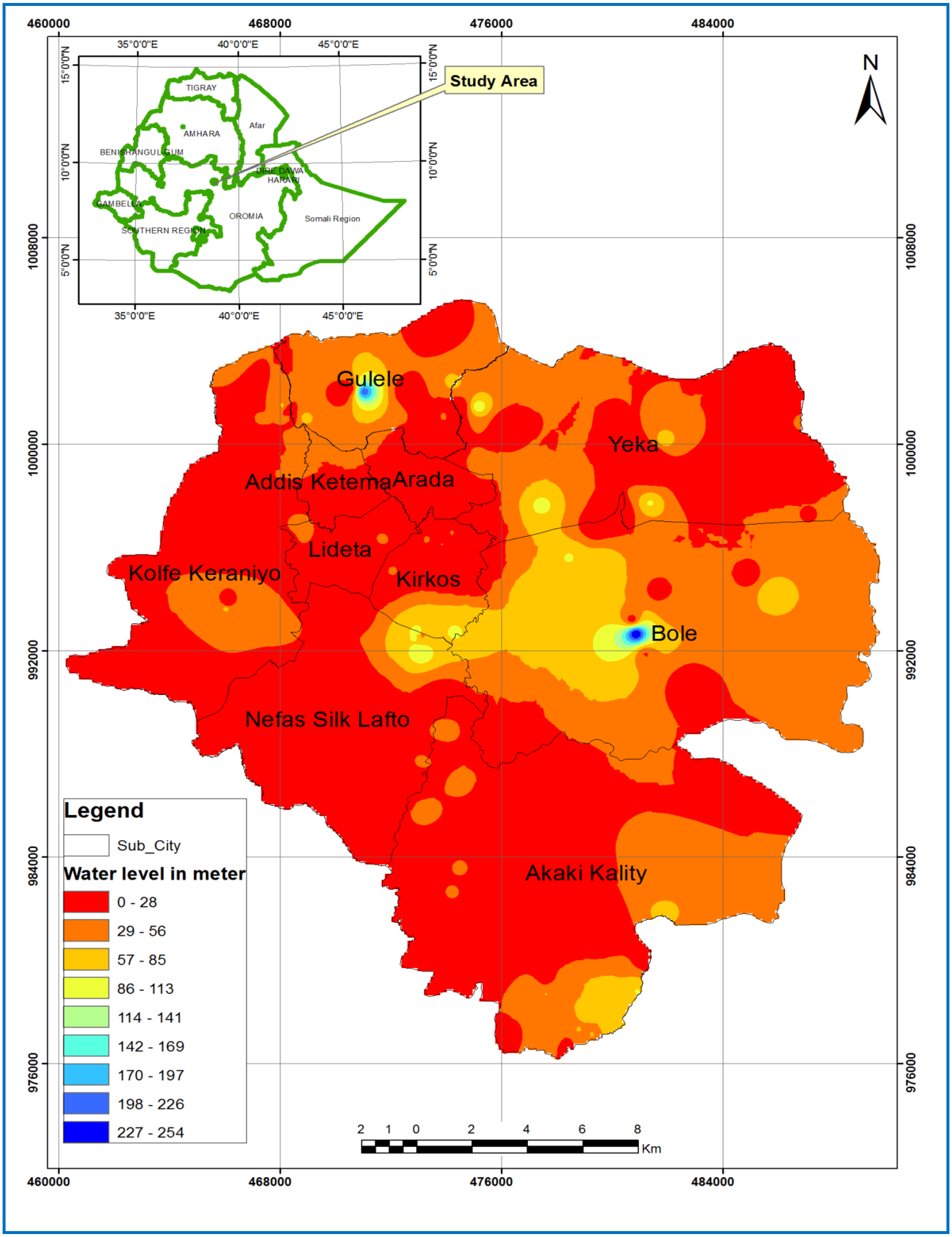

Fig 4.1 water level depth of Addis Ababa

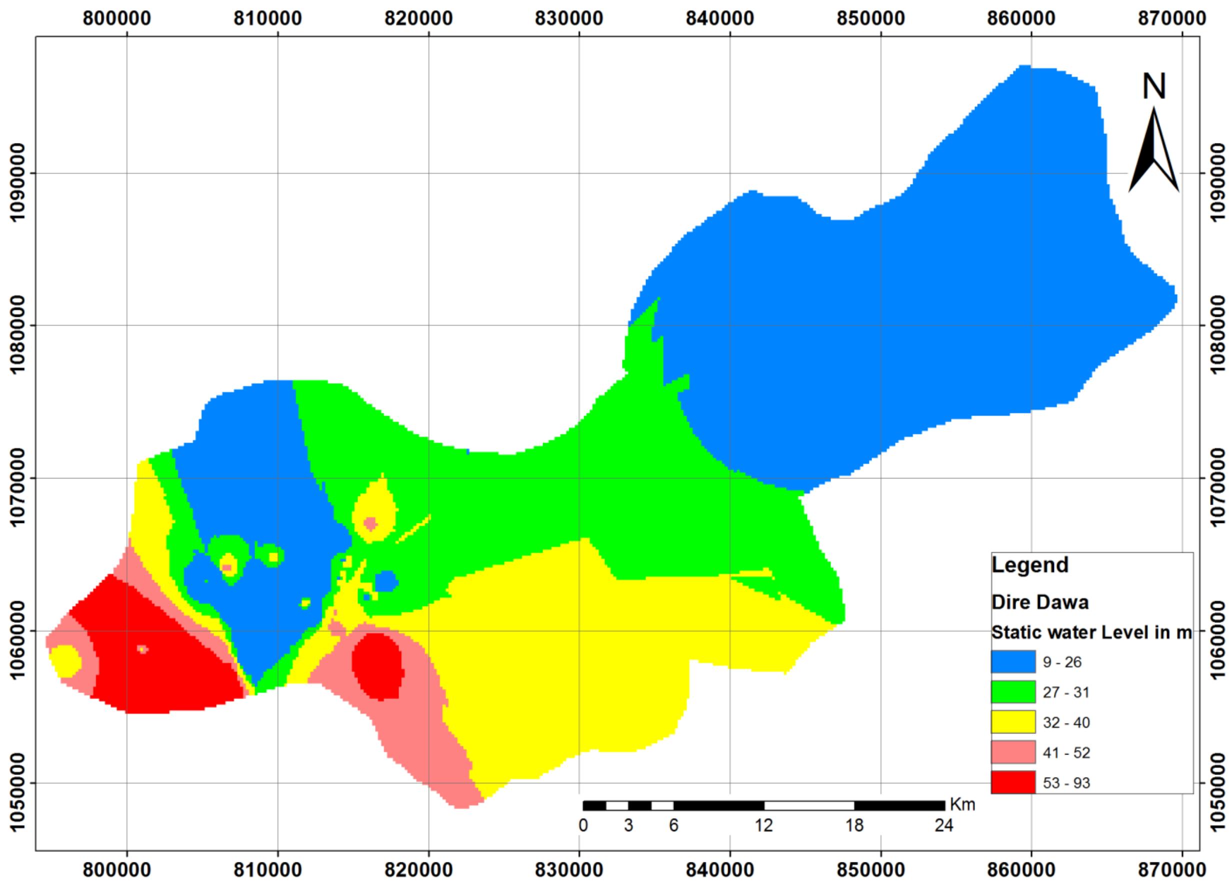

Fig 4.2 water level depth map of Dire Dawa

4.2.6 Spatial plot of Nitrate

The spatial plot of nitrate concentration in both study areas is prepared by using IWM (Inverse Weighted Distance Method) helps to distinguish the spatial distributions of nitrate level and source of these variations. Nitrate level in Addis Ababa ranges (0.0 mgL^{-1}-176 mgL^{-1}) and the mean concentration is 7.9 and the standard deviation is ±14.96. Nitrate concentration from Coca Cola Factory#2, Addis Ababa Brewery1, Africa Hotel, Addis Ababa Brewery8, Addis Beer9 and Meskerem soft drinks (Abay Mesk soft drinks factory) are above the drinking water guideline or limit > 50 mg $L^{-1}NO3^{-}$(WHO, 2008 and AAWSA, 2002). Figure 4.7 shows low nitrate level (0-10) which is found at eastern part of Addis Ababa, medium nitrate level (11-45) in the central and south of Addis Ababa that have average industries and average population, and high nitrate

(46-175) is found at the central part of Addis Ababa where there is higher population and many industries like coca cola factory, Addis Ababa Brewery, Addis beer, awash winery and Africa Hotel are found.

The high concentration of NO3 in the **central Addis Ababa** particularly in Addis ketema sub city could probably be due to infiltration of pit latrines from the big market center "Merkato", infiltration of surface runoffs polluted by commercial wastes, domestic wastes from overcrowded dwelling houses and service delivery institutions and also seepage from open field sanitation.

Ras Hotel well - is found in Kirkos Sub city and is a hand dug well located in the SW corner of the Hotel compound behind the Hotel building and used in cooking, gardening and washing purposes. The sources of nitrate Pollution could be infiltration of pit latrines and septic tanks and to some extent fertilizers from the upstream of the study area.

Africa Hotel well - is found in Lideta Sub city and located north of the Mexico Square in the compound of Africa Hotel. The water receives no chlorine treatment and used normally for washing clothes, as a cold water component in bathing and drinking purposes. The possible source of nitrate Pollution could be infiltration of pit latrines and septic tanks from residential houses.

Coca Cola well- is located in Lideta Sub city in the compound of East Africa Bottling Company very near to the highly polluted TAR and to the West of Building College in a highly overcrowded area above the factory. The water is used for drinking and raw input to the production process of the soft drink. The sources of nitrate pollution could be seeping of septic tanks, infiltration of pit latrines and leakages from the nearby river polluted by upstream industrial effluents.

On the other hand nitrate level in Dire Dawa ranges (0.44 mgL^{-1} – 244 mgL^{-1}) and the mean concentration is 37.27 and the standard deviation is ±51.4. Figure 4.8 shows the nitrate level in Dire Dawa.

- Very high nitrate (77-242) in the eastern and south eastern part of Dire Dawa which includes palace, Dire Dawa food complex, Hafcat number 1and sabian PW7.

- High nitrate (49-76) which includes Hafcat number 2, Gende kurto and Sabian PW6 which are central part of the city.
- Medium (22-48) and low (0-21) nitrate level is found at the western part of Dire Dawa.

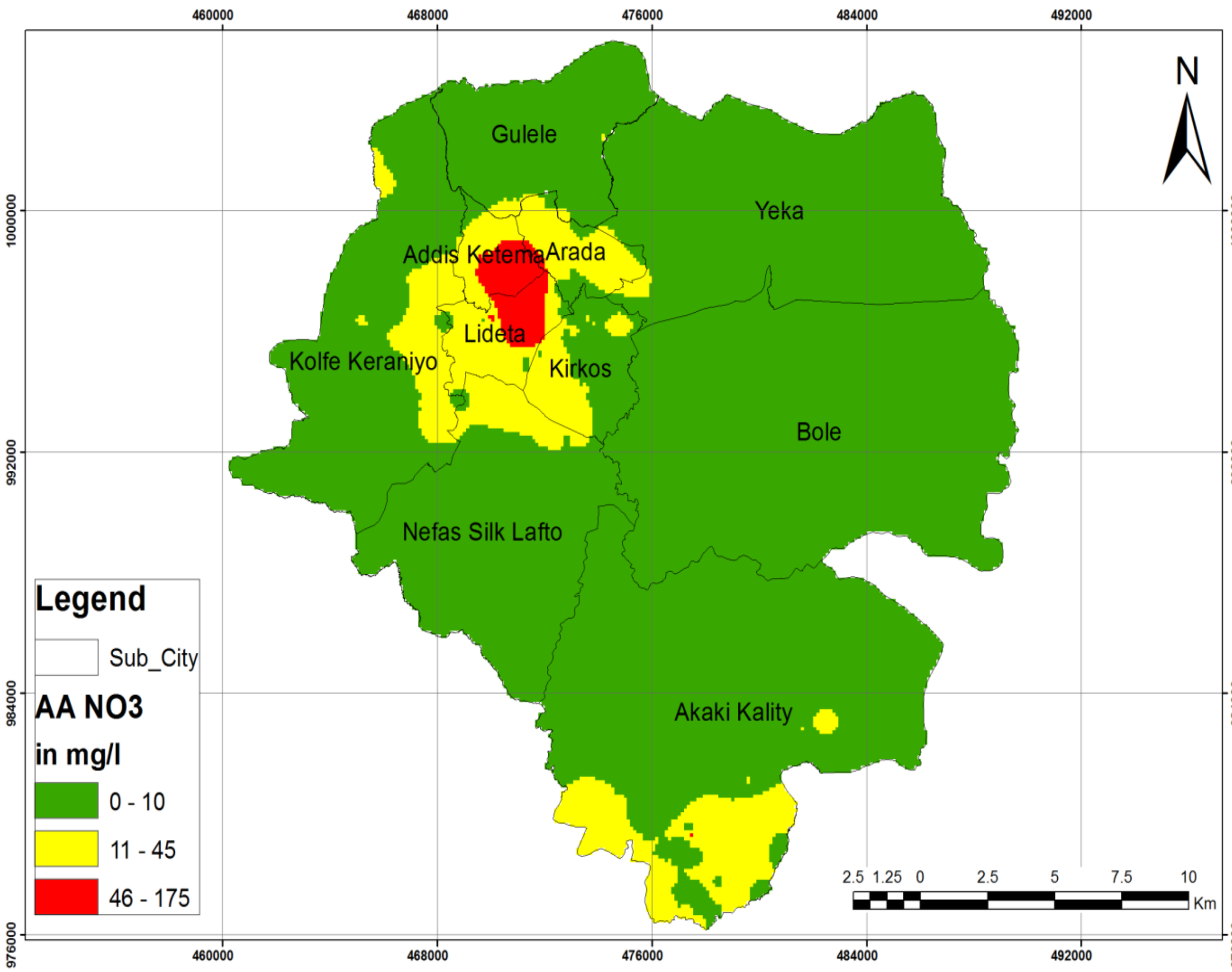

Fig 4.3 spatial plot of nitrate level in Addis Ababa

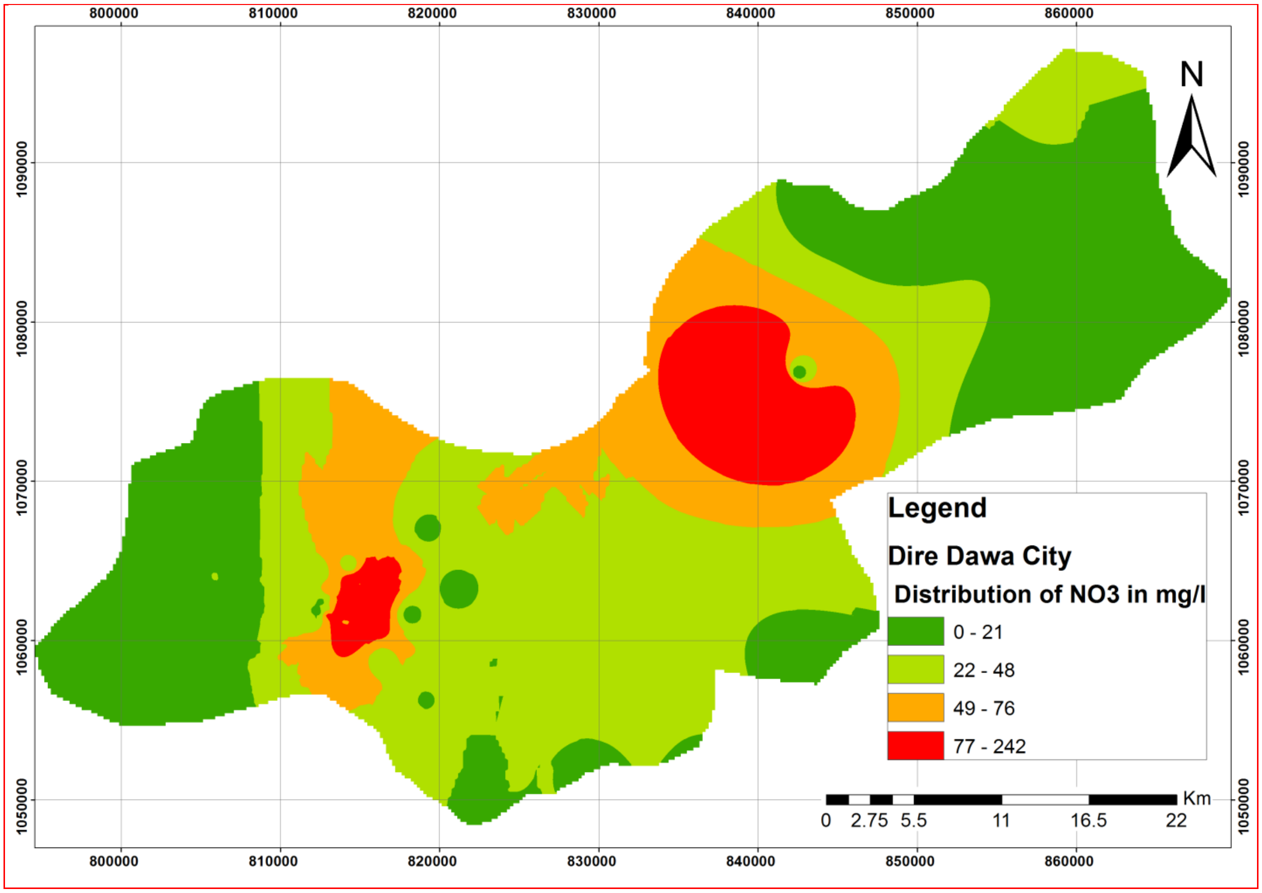

Fig 4.4 spatial plot of nitrate level in Dire Dawa

- Spatial plot of Nitrate of both cities indicates that there is high difference in the concentration of Nitrate.

CHAPTRE FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Groundwater resources are in rising risk from growing demands, unwise use, urbanization and contamination. The purpose of this study is to identify the possible source of nitrate and to investigate the cause of nitrate variation in Addis Ababa and Dire Dawa. The possible sources of nitrates are city sewage, defective septic tank effluents, municipal waste, industrial waste, wastes from livestock and chemical fertilizers containing nitrogen.

Compared to Addis Ababa, Dire Dawa has higher nitrate level. Even though Addis Ababa has high population, many industries, high urbanization and high and unmanaged wastes it has low nitrate relative to Dire Dawa. This is as a result of low nitrification process and might be due to denitrification process by denitrifying bacteria as the water circulates through the low oxygen soil media that reduce the nitrate in the water wells in Addis Ababa. In addition to this the variation in nitrate level of both cities is as result of

- **Shallower groundwater level depth in Dire Dawa.**
  In Dire Dawa the groundwater level is shallow that ranges from 9.3 to 93.5m however; in Addis Ababa the wells are deep ranges from 0 to 260 meter. Shallow groundwater depth is highly vulnerable to pollutants because shallow groundwater depths are easily affected by the human activities and natural hydrogeological activities. Therefore, shallow groundwater level depth in Dire Dawa made the nitrate level higher.
- **The aquifer type of Dire Dawa is mainly sand stone and alluvial formation**. Whereas, in Addis Ababa the aquifer type is fractured basalt formation. Since, sand stone have high permeability which enhances the migration of pollutants to the groundwater. Therefore, the sandy aquifer type made the Dire Dawa´s nitrate level higher.
- **The soil in Dire Dawa is sandy soil**. Soil has a significant impact on the amount of pollutants which can infiltrate to the groundwater. The presence of fine textured materials, such as silts and clays, can reduce relative soil permeability and control contaminant migration. Therefore, sandy soil of Dire Dawa facilitates flow of pollutants however the soil of Addis Ababa is clay dominant which controls flow of pollutants

- **The land use and land cover of Dire Dawa is mainly agriculture and urbanization** whereas; in the case of Addis Ababa urbanization is major one. In several situations nitrate that enters the groundwater system originates as nitrates in wastes or fertilizers applied to the land surface and nitrate originated by conversion of organic nitrogen or which occurs naturally are introduced to the soil zone by human's activities. Since, ammonification and nitrification processes are normally occur above the water table, commonly in the soil zone, where organic matter and oxygen are abundant. Therefore, agriculture in Dire Dawa made the nitrate level higher.

5.2 Recommendations

- Since there is high population migration to the cities, there must be enough urban facility, therefore integrated waste management strategy and proper groundwater management should be adept for sustainable development of the city.
- Bacteriological and organic matter load in both cities needs further studies
- improving sewerage systems to avoid possible leakage of sewage in to groundwater from sewer lines ,treatment of industrial effluents before disposal , avoiding indiscriminate liquid and solid waste disposal to the environment.
- Reducing waste water discharge nearby streams or rivers.
- There should be monitoring well to landfill for continuous monitoring of leachate contamination to the ground water.

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Annex-1 Ground water sample result of Addis Ababa from AAWSA

ID	East	North	EC	TDS	ToC	PH	Na	K	Ca	Mg	Cl	NO3	HCO3	CO3	SO4	Depth	SWL
Militatry Food Kichin	466050	993650	459	280	20.0	7.1	36	4.9	45.7	20	14	0.03	317.2	0	6	200	71
AA-Mekanisa-99	467135	989840	344	226	20.0	7.05	17	6.8	46.64	9.18	5.96	4.56	234.97	0	0.11	213	3
Mekanisa BH 16	469360	990078	344	226	20	7.05	17	6.8	46.64	9.18	5.96	4.56	234.97	0	0.11	181	0
MIKILILAND-3	466601	1001250	147	98	20	6.87	12.7	4.1	13.2	2.7	1.8	0.52	87.84	0	4.65	196	7.26
AA-Shegole Mesgid-	468295	1001339	311	174	20	7.04	8.4	1.8	42	12.75	7.94	1.00	197	0	0	200	0
Lebu mekanisa	469191	989547	309	200	20	7.28	22	8.3	36.96	11.22	5.96	5.00	221.8	0	1.24	230	4.15
Salayish	480999	999648	464	308	20	7.38	62	5	33.6	8.16	21.9	5.00	274.5	0	23.5	250	
Mekanisa-19	468261	990357	295	194	20	7.71	14.5	5.7	42.24	9.18	1.99	3.08	197.64	0	0.74	196	0
Ankorcha-2	481462	998906	414	272	20	7.24	30.5	3.2	53.76	10.71	7.94	0.16	258.6	0	6.38	200	0
Luke Stream	482994	998429	213	142	20	6.87	9.8	3.4	27.7	4.59	8.94	1.00	109.8	0	10.8	203	0
Ketchene Meketeya	472608	1002066	194	128	20	6.88	9	4.3	25.2	5.1	6.95	1.49	129.3	0	2.28	170	0
Sheromeda	474238	1002370	234	154	20	7.74	19	7.4	22.68	4.08	7.94	10.00	134.2	0	4.95	184	67.94
Selam Technique	481519	999648	422	282	20	7.39	55	4.6	35.28	8.16	10.9	8.50	263.5	0	11.3	200	5
Egzeabher Ab	471026	1002023	189	126	20	7.42	22.5	10.5	10.4	2.04	4.97	0.40	112.24	0	3.86	222	222
East bole,EBV 03	480717	993193	1742	1132	20	7.44	380	35.5	17.64	8.94	23.8	0.24	1176.08	0	40.84	260	12.6
Summit,SMV-15	485733	994302	490	318	20	7.19	102	8.2	5.4	2.04	23.83	0.36	256.2	0	3.5	210	74
Addis Alem-	430267	987498	630	380	20	7.36	42	3.6	82.7	14.3	19.2	7.00	350	0	21.7	200	
Legetafo	486723	1000881	625	410	20	7.89	132	2.4	21	7.14	12.36	0.18	389.42	0	2.28	250	32
Abo Church	476078	1000763	267	182	20	8.17	41.5	7	19.32	2.55	8.94	7.48	169.99	0	5.99	252	
Akaki	478130	982300	532	344	20	7.66	66	9.3	45.36	8.16	20.8	3.80	285.48	0	15.61	260	5.75
East Bole,EBV 24	480863	992647	735	477	20	7.32	128	12.1	31.08	7.65	11.92	1.00	492.88	0	14.09	260	260
Summit SMV- 13	484971	994879	1904	1394	20	6.5	495	24.5	25.2	5.61	47.66	0.30	1434.72	0	48.6	290	15.64
Ferensay,Ras Kasa	475165	1001449	319	210	20	7.72	35	9.1	24.36	3.06	17.87	4.80	148.8	0	18.1	260	106.36
Bole Lemi,SMV 19	482757	990710	478	314	20	7.11	58	6.6	47.04	6.63	9.93	1.02	309.88	0	3.43	270	0
Summit SMV 10	482163	993603	750	492	20	6.89	123	12.9	38.64	6.63	11.9	0.40	490.44	0	5.62	250	36.35
Hana Mariam	465729	1002755	192	128	20	7.44	30.5	7.1	8.4	3.57	8.24	0.21	120.41	0	2.86	270	52.4
New Kara Road	481368	997713	445	292	20	7.5	42	5.9	50.4	7.14	14.89	0.30	239.12	0	23.1	260	88.37
Hana	468094	1001478	220	140	20	7.25	30	4.6	17.64	4.08	7.21	0.50	128.1	0	5.05	250	66.25
East Bole EBV 22	481213	991853	498	332	20	7.1	80	7.4	33.6	5.61	8.94	1.70	314.76	0	0.76	250	25.52
Summit,Michael	481681	994296	1908	1246	20	6.96	465	22	15.12	6.12	23.82	4.10	1307.84	0	30.1	250	12.15
Akaki BH20	477945	976985	398	259	20	7.5	23.8	4.6	43.3	13.6	14.2	4.90	244	0	0	93	51.45
WF01-PW17	472460	981553	590	340	48.1	8.42	112	8.6	3.04	0.91	26.39	0.87	243.39	18.2	18.12	477.4	0
Akaki BH5b	476574	975607	385	250	20	8.1	25.5	4.3	44.9	11.6	14.2	3.20	244	0	0	90	51.4
AkakiBH06	479714	978929	485	315	20	7.5	24.5	4.2	45.7	27.2	9	18.60	307.4	0	6.6	105.9	67.93
AkakiBH06	479714	978929	485	315	20	7.5	24.5	4.2	45.7	27.2	9	18.60	307.4	0	6.6	105.9	67.93
Akaki BH12	478808	976897	508	330	20	8	27.2	3.96	59.3	24.32	11.96	9.80	341.6	0	6.5	95	20.85
Total Belay Zeleke-	470504	1002135	181	128	20	7.34	24	5.5	12.6	2.04	1.99	5.40	117.12	0	0.8		
Belay Zeleke-2	470218	1001886	209	138	20	7.61	38	4.3	9.24	2.04	5.96	1.20	129.32	0	6		
Mekanisa-19	468515	989719	295	194	20	7.71	14.5	5.7	42.24	9.18	1.99	3.08	197.64	0	0.74		

Ayat old	489669	996423	524	344	40	7.42	77	22	16.63	3.24	32.77	5.00	225.46	0	29.73	280	39
Chebe	493247	1001478	366	240	21	7.89	32	1.4	46.2	6.63	9.27	6.90	210.1	0	4	432	7.3
Akaki city	475697	979915	595	390	21	6.89	46	8.6	64.68	15.3	14.42	7.20	348.4	0	5	448	9.45
Akaki	473583	979260	488	320	28.5	7.86	79	11.9	30.4	1.84	9.5	28.60	281.8	0	6.6	484	16
Akaki	471909	979461	582	360	30.1	8.2	69	6.9	29.6	14.4	29.12	0.42	284.38	5.04	21.87	500.8	8.8
Akaki	473944	978722	539	314	24	7.6	59	6.5	43.3	5	21.8	28.60	266.6	0	7	492	30.3
Akaki	473386	980122	479	302	29	8	50	10.1	35.72	10.49	14.56	10.77	266.57	0	16.94	549	11.4
Akaki	471677	971640	540	350	20	7.09	54	8.8	60.8	9.12	6.37	14.90	353.56	0	14.76	498.6	80.1
Akaki	469738	971752	573	344	30	7.07	37	15	53.2	12.31	14.56	3.99	310	0	24.85	341	83.4
SANFTW1	477819	987018	484	308	38.9	7.34	82	9.1	24.32	3.65	15.47	0.40	281.82	0	8.57	411	8.91
SANFTW 2	484094	987465	1571	1026	44.5	7.52	360	9.8	29	12.53	40.7	0.27	1049.2	0	29.58	442	0.35
SANFTW3	481012	984597	711	460	36.3	7.55	154	17	13.68	1.82	35.49	0.55	405.04	0	14.63	440	29.8
Sebeta	438871	977181	651	376	35.9	7.86	136	4.8	3.8	4.1	70.99	0.38	230	0	35.41	443	12.65
sebeta	447224	978514	590	383	29.2	7.1	91	8.7	36.8	8.83	42.77	0.78	229.48	0	72.49	440	13.44
sebeta	449082	980399	480	312	30.3	7.3	78	8.1	29.64	6.84	23.66	3.18	259.62	0	18.24	440	10.67
legedadi	501033	1006222	425	260	26.4	7.64	43	7.9	34.2	8.21	16.38	0.95	239.12	0	10.36	180	27.06
legedadi	497455	1006373	458	298	28.5	7.62	62	8.9	34.2	7.75	19.11	7.07	270	0	7.32	440	32.2
Holeta,Illala	446260	1004149	211	137	20	8.58	24	0.3	18	3	7	6.65	107	6	2		
AA-French	474300	1001005	310	189	20	7.9	26.6	5.53	27.81	6.89	11.42	2.13	158	0	6.79		
Hamele 19, 20 /	474510	1001445	273	177	20	7.85	33	5.3	20	2	5	0.44	151	2.4	8		
New Kara Road-	480321	997370	440	286	20	7.05	41	3.2	54.6	9.18	10.92	0.40	278.16	0	11.42		
legedadi	498961	1005177	438	278	23	7.34	54	7.7	30.4	11.86	17.29	0.17	241.07	0	8.36		
Sombo/Gedeberet	361058	1073321	65	42	20	6.48	1	0.8	8	2	1	0.40	37	0	1		
Alem Gena-Debel	445643	973409	333	219	20	7.06	17	4.2	50	8.3	2.9	7.50	235.7	0	0.53		
AkakiBH-9	476246	977104	512	333	20	7.3	27.2	3.6	48.5	27.7	8.7	16.70	327	0	7		
Akaki BH 25-2	477162	976038	494	321	20	7.3	27.2	4.3	49.7	23.4	14.2	9.40	292.8	0	8.85		
Akaki BH16	478347	976752	542	353	20	7.5	27.2	5.3	56.1	24.4	14.2	3.90	329.4	0	5.35		
AA-Water lll	479246	977104	512	312	20	7.3	27.2	3.63	44.9	29.2	17	25.70	305	0	6		
AA-Water lll	478199	976361	486	300	20	7.99	27.7	5.3	56.1	24.4	14.2	3.90	329.4	0	5.35		
Akaki BH08	479061	976370	464	302	20	7.3	27.2	3.63	44.9	29.2	17	25.70	305	0	0		
AA-Water lll	478780	977307	516	315	20	7.4	30.6	3.96	40	28.2	14.2	3.90	329.4	0	6.58		
TW2 Test well No.2	473576	972821	498	305	20	7.8	45	7.7	60	7.3	7.2	8.80	302.6	0	4.5		
TW3 test well No.3	484475	975622	672	408	20	7.5	40	3.5	96.8	18	7	9.70	444	0	0.5		
Gelan	484266	976150	545	362	20	7.65	36	5.9	55.44	23.97	11.92	4.88	346.5	0	5.43		
Akaki Beverly	480895	977403	489	298	20	7.52	23	3.4	39	26	9	0.33	315	9	2.5		
Mikililand, 15/16 /	466727	1001399	183	119	20	7.67	15.4	3.8	18	3	4	0.44	101	0	7		
Ministry of defence	472700	996500	174	106	20	7.2	23.8	1.3	11.2	3	28.4	0.20	73.2	0	0		
Alem Gena-Dika	466662	970715	427	276	20	7.28	24	6.1	67.3	6.1	5.8	7.00	284.4	0	1.32		
Akaki BH26	477086	975624	476	310	20	7.8	27.2	3.96	49.7	23.35	12	12.30	292.8	0	7.4		
Ayer tena	466082	993808	308	200	20	7.74	12	3.4	40	8	3	6.65	193	0	3		

Addis mender real	487089	997218	401	261	20	7.71	35	4	40	7	4	0.44	261	0	4	150	28
Country	487920	1003552	474	308	20	7.87	33	3.4	58	10	4	0.44	316	0	4		
FW-BH2	473713	996131	4400	3080	78	7.1	800	19.5	4.8	0.97	34.74	0.00	2171.6	0	39	300	
FW-BH1	473678	996200	3890	2723	76	7.05	800	18	6.4	0.97	43.7	0.88	2208.2	0	53.48	249	0
GHION-DW	473799	996041	4300	3010	84.4	7.23	800	20.5	4	0.97	29.78	1.32	2220.4	0	80.87	77.7	0
GHION-SW1	473846	996042	3450	2415	42.4	7.06	900	28.5	4.8	1.46	29.78	0.44	2110.6	0	65.22	56.4	7.6
GHION-SW2	473849	996100	3030	2121	39.7	7.04	750	28.5	8.8	1.96	29.78	0.00	1903.2	0	60.2	60	59
Z-HOSPITAL	473605	996364	790	553	18	7.17	80	7.5	84	9.73	62.7	14.91	329.4	0	65.22	8	2
HILTON-NBH	473955	996585	3150	2205	43.3	7.11	750	15	5.6	1.46	37.4	10.00	1903.2	0	27		
HILTON-OBH	473950	996583	3140	2198	47.6	7.14	750	16	5.6	1.46	39.4	8.00	1939.8	0	39	400	9.8
RAS-HOTEL	473069	996040	596	417	19.7	7.08	20	3.5	92	9.73	18.7	33.00	244	0	37	41	30
National Palace Old	473818	996216	4600	3220	74.7	7.24	900	22	6.4	0.97	48.4	15.00	2257	0	61	200	0
National Palace	473822	996091	4590	3213	68.7	7.15	900	20	6.4	0.97	46.2	5.00	2269.2	0	51	109	0
GHANDI-HOSPITAL	473413	997389	1092	764	23	7.39	250	7	4	1.46	17.6	8.80	610	0	26	80	
ST.JOSEPH	473890	996131	3197	2238	33.4	8.27	700	8.9	6.4	2.92	39.6	11.00	1878.8	60	40	50	6
Jacros shola bh1	479631	995410	1724	1120	25	7.35	470	22.5	11.2	3.36	30.03	0.37	1083.36	0	55.84	220	77.05
Tefki STTW-2	448502	978502	1074	520	20	7.37	53	7	118.8	59.8	99	0.01	258.2	0.25	306	440	12.56
Legadadi	493518	1004421	382	244	24	7.43	33	6.7	37.4	8.64	5.73	0.14	225.86	0	16.2	354	27.75
AA-American	473900	1001050	227	139	23.3	8.6	28.9	5.3	24.1	10.7	14.2	2.10	170.8	12	0	201	34.5
AA-Glass and Bottle	467200	1001017	188	115	20	7.4	43.4	3	16	3.9	7.1	0.10	146.4	0	18	150	35.3
AA-Anbessa	468400	1001016	176	107	17.3	8.6	38	5	8	2	14.2	0.30	98	0	14.3	192	3
Lafto BH 1	471500	990500	438	280	20	7	13.8	5.2	65.63	10.26	9.93	6.20	245.95	0	2.75	34	17
French Embassy	475638	999991	333	216	20	7.89	48.5	9.8	18.48	3.06	24.83	0.20	173.24	0	8.85	51.8	27.4
Akaki	470888	987426	492	296	20	7.82	43	3.3	57.12	9.69	21.8	5.00	280.6	0	8.85	121.5	
AA-Kality Metal	474225	982650	470	356	18.3	8	54.4	11.6	35.3	15.6	28.4	0.70	317	0	0	177.8	30.78
AA-Kality Metal	474225	982650	470	356	18.3	8	54.4	11.6	35.3	15.6	28.4	0.70	317	0	0	177.8	30.78
AA-Water lll	486200	1001042	240	369	20	7.5	65.5	2.7	36.9	14.6	25.5	0.50	292.8	0	15		
AA-Water lll	486200	1001042	240	369	20	7.5	65.5	2.7	36.9	14.6	25.5	0.50	292.8	0	15		
AA-Water lll	473566	978610	652	424	20	7.65	33.6	5.1	60.1	19.95	26.8	0.50	317.2	0	4.7	122	23.5
AA-Water lll	473566	978610	652	424	20	7.65	33.6	5.1	60.1	19.95	26.8	0.50	317.2	0	4.7	122	23.5
AA-Water lll	461500	1001023	171	111	20	7.3	4.1	1.3	14	4	7.1	3.00	61	0	4.7	110	82
AA-Water lll	466200	988800	429	279	20	7.5	16.1	6.9	26.4	6.3	7.1	0.02	152.5	0	4.7	100	
AA-Water lll	466400	987600	540	351	20	7.9	20.4	4	56.1	9.7	7.1	0.50	268.4	0	4.7	125	18.3
AA-Water lll	481200	980000	530	385	20	7.6	40.8	5.3	67.3	15.6	14.2	11.70	366	0	4.7	173	8.9
AA-Water lll	481600	982900	540	380	20	7.4	44.2	4	56.1	20.4	14.2	9.60	341.6	0	15	120	37.33
AA-Water lll	480900	978800	500	330	20	8.4	78.9	3.4	9.6	8	28.4	2.70	158.6	9	42.4	160	86
AA-Water lll	479400	981400	430	362	20	7.4	44.2	4	91.4	2.9	20	0.10	366	0	5	74	2.8
AA-Watet lll	473108	979851	397	258	20	7.6	37.4	5.3	54.5	22.4	14.2	18.90	317.2	0	24.7	103	7.07
Akaki BH23	477477	977216	463	301	20	7.5	18.7	4.64	59.3	19.5	14.2	1.33	305	0	0	145	44
Akaki BH23	477477	977216	463	301	20	7.5	18.7	4.64	59.3	19.5	14.2	1.33	305	0	0	145	44

Akaki Water Supply	479942	977322	480	310	26	7.78	24.5	3.96	49.7	23.35	12	12.30	292.8	0	7.4		64.44
Akaki Water Supply	479942	977322	480	310	26	7.78	24.5	3.96	49.7	23.35	12	12.30	292.8	0	7.4		64.44
AA-Water lll	479405	976735	493	301	20	7.3	26	4.2	45.7	27.2	9	18.60	307.4	0	6.6	129	71.7
Akaki Water Supply	478998	977937	496	303	20	7.8	36.6	3.3	39.7	23.6	9.2	16.40	302.6	0	7.9	130	73.48
Ginch china2	401801	996640	552	352	20	7.57	37	6.7	72	14.4	2.84	0.45	356.24	0	4.18		
Sebeta Agro No.1,	460850	985850	244	159	20	6.65	16	3.1	28.8	4.84	3.88	14.00	141.5	0	1.8	106	43
Alem Gena-Bonoya	460464	974637	376	236	20	7.1	15.5	1.8	46.98	13.8	5.8	11.50	226.5	0	0.55	100	27.12
Netherlands	468800	996600	375	253	20	7.9	23.8	2.8	40.1	6.8	11.3	15.10	195.2	0	0	124	50.35
Korea Embassy,	468425	996350	395	246	19.2	7.34	19	5	42	14	5	2.83	242	0	3	68	19.6
AA-Hagbes PLC.,	468875	993750	251	163	21	7.2	29	3	16	5	6	7.40	134	0	0	130	11.16
Hillton Hotel	474175	996550	3359	2049	25.4	7.48	840	15	6	2	43	0.04	2198	0	55	120	40.25
AA-Ato Tahas	465410	1002944	135	89	20	6.83	11.5	4.6	9.6	3.4	1.99	1.50	76.86	0	1.6	124	11.22
AA-Burayu	465161	1003103	201	130	20	7.8	18	4.9	21.6	4	8	0.50	136.6	0	3.2	66.7	18.24
AA-Repi Enyi	464538	991302	248	168	20	7.36	14	4.3	30.4	6.32	4.4	5.00	153.7	0	1	94	5.33
Yeka-Ankorcha 1	477446	997611	367	240	20	7.52	27.5	6.3	34.4	10.21	6.95	0.52	215.2	0	17.56	170	91.86
Fanta valley III	481828	981943	558	364	20	8.01	53	3.9	58.08	18.36	11.92	0.41	358.68	0	18.49	140	75.95
Sebeta-Dragados	457030	984617	979	597	20	6.85	16	3.4	36	9	5	8.69	178	0	2.6	140	88.52
AA-Batu Tannery	473466	987247	337	206	20	7	34	4.6	56.1	14.6	11.4	1.80	317	0	2.5	65	9.25
Gebrechefie,	473540	1004307	59	38	17.8	6.65	3	2.1	7	0.8	1	3.10	29	0	3		
Abasamuel spring	469142	966835	571	371	20	7	46	6	40	22	9	6.00	304	0	6		
Gefersa Ethio-Cup	454124	1002590	240	148	20	7.01	5.3	1.1	40.9	4.9	4.8	8.50	148.6	0	0.53		
Billbile, wata bicha	457146	1004953	84	55	17	7	3	0.8	10	2.3	1	3.50	44	0	2		
Tulu Bolo TWS	412197	957215	324	216	20	7.07	21.5	9.5	32.2	7.4	5.8	8.00	189.1	0	0.83		
Entotomariam,	474208	1005540	196	127	16	7.57	4	1.4	28	5	4	8.40	107	0	4		
yeshy debele,	466260	996974	362	235	16	7.59	13	3	44	12	3	7.53	227	0	4		
FW-SP1	473710	996129	4400	3080	79.6	7.25	800	18.5	4.8	0.97	34.7	1.30	2196	0	46.96		
FW-SP2	473633	996163	4280	2782	50	7.19	800	18	5.6	0.49	29.7	0.44	2196	0	43.04		
Gulele Glass-Factory	466900	1001005				7.10	14.6	1.3	20.8	6.8	7.1	0	122	0	0	150.0	20.4
Burayu, Ethio-Libya J	464600	1003075	402	340		7.80					1.5	0			9.2	96.0	14.45
Meta Abo Brewery B	455550	983750				8.20	2.7	1.8	35.3	2.9	7.1	0	73.2	0	37	181.0	46.8
Repi Enyi General Bu	464538	991302	248	168		7.36	14	4.3	30.4	6.32	4.4	0	153.7	0	1	94.0	5.33
NAS Food Factory BH	488150	1002300	1035	595		8.80	220	2.9	10.4	3.4	130.9	0	309.88	16.8	50.12	175.0	26
Water III Testwell-B1	466200	988800		279		7.50	16.1	6.9	26.4	6.3	7.1	0.02	152.5			100.0	Flowing
Military Food Service	473900	985100	459			7.10	36	4.9	45.7	20	14	0.03	317.2	0	0	72.0	8
Genesis Farm N.1, D	495447	968068	469			7.57	23	6.2		24	8	0.03	306			70.0	49.68
Kotebe Selam vocati	481878	1000148	320				17.2	3.8	36	8	7	0.03	165		7	140.0	75.95
Hilton Hotel	474175	996550	3359			7.48	840	15	6	2	43	0.04	2198		55	420.0	40.25
Glass and bottle fact	467200	1001017	188			7.40	43	3	16	3.9	7.1	0.1	146.4	0	18	150.0	35.3
Prefabrication Facto	474429	986828			-	7.50	30.6	4.6	67.3	16.5	10.4	0.1	329.4	Nil	13.2	187.0	40.5
Artificial Inseminatio	475300	983800		391	-	7.60	48.3	8.1	40.1	12.6	21.3	0.1	292.8	Nil	Nil	140.0	0

Water III Testwell-B1	479400	981400	500	390		7.80	37.4	4	91.4	2.9	20	0.1	366	NIL	NIL	100.0	2.7
Meta Abo Brewery E	455300	985250				7.30	14	6.6	20	46	7.1	0.1	122	0	0	101.0	37.5
Ministry of Defence	472700	996500	174.3			7.20	23.8	1.3	11.2	3	28.4	0.2	73.2	0	0	186.0	2.6
Burayu Spring water	462743	1002521	332			7.24	59	4.8	22	4	13	0.23	215		15	250.0	35
Anbessa Transport	468400	1001016	176			8.60	38		8	2	14.2	0.3	98	0	14.3	192.0	3
Tadele Gelecha Plast	465243	1003393	179	85		8.17					9.5	0.3			0	115.0	26.17
Ethio- Plastic Factory	478450	995600	1182			8.70	346		12.8	5.8	34	0.4	805.2	48.8	0	171.0	86.65
Adey Abebe Cotton I	473848	990072		99		7.15			9.6	2.4	62	0.44	26		Nil	100.0	40.7
Debre-Zeit Veternary	500078	968505	1041			7.87	138	12	36	36	50	0.44	625		6	56.0	14.5
Burayu Simachew M	465161	1003103	201	130		7.80	18	4.9	21.6	4	0	0.5	136.6	Trace	3.2	66.7	18.24
National Road Trans	475000	987800	355			8.60	91.8	3.3	16	1.6	14.2	0.7	219	24	16.5	172.0	27.8
Kality Metal Product	474225	982650	470		-	8.00	54.4	11.6	35.3	15.6	28.4	0.7	317	Nil	Nil	177.8	30.78
MA Thermoplastic a	474556	983625	597	288		8.35					32.5	0.8			155	219.0	38.75
Addis Ababa Univers	473400	999600		249		7.30			62	11.31	6	0.88	188		20	57.9	21
Defence Inustry-2	471300	995050	560.6			6.70	15.3		64.1	29.2	70.9	0.9	311.7	0	0	114.0	0
Sebeta Agro Industry	460500	986500	211			6.00					3.5	1.1				100.0	27.12
Kality Airforce-1	476400	984800				7.90	69	8.3	35.3	9.2	17.7	1.2	311.1	0	0	90.0	12
Debrezeit Water Sup	500615	974742				8.00	28.6	8.9	57.3	18.7	10.6	1.2	341.6	0	0	80.0	22.6
Gandi Memorial Hos	473000	996300		932		7.70			18.4	5.22	1	1.32	764		28	80.0	1.83
Dukem Industrial Pa	490000	968000	671	454		8.44	120	9	29.6	6.81	6.09	1.32	387.96	24	2	115.0	94.85
Army Camp Constru	474300	992700	293.4			7.60	26	3.6	40	14	14.2	1.5	244	0	0	129.0	89.2
Ato Tahas Burayo	465410	1002944	135	89		6.83	11.5	4.6	9.6	3.4	1.99	1.5	76.86		1.6	124.0	11.22
Akaki Ethio-fiber-1	477400	979500	347		-	7.70	37.5	7.8	62.5	20.5	Nil	1.6	390	Nil	8	96.0	27.4
East Africa Industrial	473433	985658	522	344		7.74	40	7.5	57	13	7.76	1.8	322	Trace	1.3	98.0	44.18
Batu Tannery, Kality	473466	987247	337			7.00	34	4.6	56.1	14.6	11.4	1.8	317	0	0	65.0	9.25
Abay Mesk Soft Drin	473000	992700				7.20	12	3	43	8	13	2	171	0	0	90.0	23.67
American Embassy-1	473600	1001013	227.2			8.60	29	5	24.1	10.7	14.2	2.1	170.8	12	0	154.2	14.55
French Embassy	474300	1001005	310			7.90	27	6	27.81	6.89	11.42	2.13	158		6.79	83.0	22
Shola Dairy	479400	996800		74		6.75			14.4	3.4	160	2.2	50		Nil	126.0	
St. Joseph's School	473400	995800		1868		8.04			0.8	6.4	0.5	2.2	1680		3	50.0	6
Water III Testwell-B6	470800	982900	500	332		8.40	23.6	5.5	53.7	16.4	10.6	2.45	259.25	16.5		114.0	Flowin
AAWSA, Lafto Hana	471400	988250	527	254		7.43	22	3.6	68.07	17	3	2.5	280.42		0.2	84.0	12.5
Ghion Hotel-3	473300	996300		1848		7.22			8.8	1.16	1	2.6	1610		55	60.0	59
Debrezeit Water Sup	501081	974632				8.00	33.2	9.9	54.5	16.8	10.6	2.6	335.5	0	0	80.0	24.1
Addis Tyre Factory-1	473900	989000		451		7.65			70.4	9.86	78.5	2.64	226		26.2	201.5	45.4
Minilik Hospital	475200	999200		73		7.80			15.2	2.4	12.5	2.64	50		Nil	51.0	39
Debrezeit Water Sup	501003	974094				7.80	31	5.6	52.1	17.5	15.9	2.65	311.1	0	0	80.0	25
Ethio-Metal Meal-1	476400	980600		395		8.00			71.2	25	25	2.7	320		20	120.0	16.9
Water III Testwell-B1	480900	978800	500	330		8.40	78.9	3.4	9.6	8	28.4	2.7	158.6	9	42.4	160.0	86
Armay Hospital	469800	996300		104		7.60			12.8	3.48	28.5	2.8	40		Nil	51.9	1.5

Debrezeit Water Sup	500903	973662	418.1			8.10	30.5	8	51	16	14.2	2.8	305	0	0	79.0	28.6
Korea Embassy, Keta	468425	996350	395			7.34	19	5	42	14	5	2.83	242	0	3	68.0	19.6
Ethiopian Iron And S	476521	980711	500		-	8.00	79.9	7.4	71	23.3	28.4	3	439.2	Nil	Nil	120.0	
Water III Testwell-B1	461500	1001023		111		7.30	4.1	1.3	14	4	7.1	3	61			110.0	82
General Winget Scho	468300	1001003		164		7.80			25.6	12.18	0.1	3.08	126		Nil	63.0	41
Stadium Total	472900	995900		50		7.25			8.4	2.61	6.5	3.08	28		Nil	32.0	1.5
ETHARSO-1	470250	991500		94		7.20			18.4	4.8	4	3.1	70		Nil	40.0	8
Kality Military Camp	475300	983800		237		7.10			46.4	12.5	30	3.1	190		Nil	93.0	Artesia
Mekane Iyesus	470465	991100		247		6.95			58.4	8.6	16.5	3.3	182		13.5	123.5	16
Water III Testwell-B1	488600	1001027		158		7.00	14.6	4	22.4	6.8	14.2	3.4	122			125.0	16
Woreda 17 Kebele 2	476963	994106	330	159		7.57					1	3.44			3.8	132.0	72.5
Hilton Hotel	473800	996600		2253		8.40			4.8	2	49.6	3.5	1720		54.7	400.0	9.8
Filwooha Hotel-1	473100	996400		2292		8.25			2.4	1.45	0.5	3.5	1870		40	249.0	
Water III Borehole B	478347	976752	542.4				27.2	5.3	56.1	24.4	14.2	3.9	329.4	NIL	5.35	148.0	47.5
Ethio-Marble Industr	468900	1001007		132		7.90			10.4	2.9	2.5	3.96	110		Nil	116.0	72
Cement Factory-2	473100	991900		246		7.16			54.4	12.76	5	4.4	186		20	153.9	112.7
Akaki Water Supply	479942	977322	572	275		8.16						4.4				0.0	64.44
Awash Tannery-1	473500	987900		285		6.80			60.8	10.4	70	4.8	212		15	90.5	9.1
AAWSA, Mekanissa	470450	990125	362	173		7.99			42	8.74	20	4.92	221.89		Nil	0.0	15
Blue Nile Plastics De	495765	966397	614			7.69	34	9	44	36	7	5		0	7	94.0	46.6
NMWC Pump Factor	477609	978690	-			8.20	4	-	32.1	11.7	14.2	5.3	170.8	Nil	21.7	116.0	57.7
Dimtu Peasant's Villa	481694	965913	546	308		7.20					16	5.5			15.7	0.0	95.4
Ethio-Spice Extractio	473300	987700	-			7.20	24	5	58	20	13	5.6	322	Nil	Nil	103.0	44.7
Ras Biru Sefer	473900	995500		529		7.10			50.4	7.2	4	5.7	162		12	130.0	
Cigarette Factory	471300	994800		114		6.80			12.8	1.74	35	5.7	46		Nil	62.0	4.1
Misrak Flour and oil	472900	992500		264		7.30			60.8	8.6	4.5	5.72	208		Nil	156.2	89.6
NMWC Spare Parts 8	478463	977722			-	7.50	34	4.6	49.07	22.4	19.9	6	292.8	Nil	13.7	150.0	50
Ethiopia Thread Fact	473800	990200		315		7.10			72	9.5	8.5	6.2	258		4	100.0	
Ethio-Meat Concent	473500	987600	403.5		-	7.40	38	5.6	72	9.8	17.02	6.4	292.8	24	Nil	86.7	25.2
Water III Testwell-B3	463700	988500		336		8.50	19.7	4.9	60.1	15.8	10.6	6.5	256.2	18	0	130.0	19
Water III Borehole B	477945	976985	532	294	23.9	7.46	24	3.5	77.6	11.2	3.6	6.6	317.3	7.2	Trace	148.0	49.9
Elfora Agro-Industry	494145	966864	480	196		7.38	2.21	3.7	50	22.8	2	6.7			Nil	102.0	
Hora Tannery Debre	498633	970028					57.8	5.6	43.3	26.3	12.8	6.7	380.6	0	9	74.0	34.1
Hagbes PLC., Bisrate	468875	993750	251	163		7.20	29	3	16	5	6	7.4	134			130.0	11.16
TW4 Test well No.4	489950	976019	537	315	24.2	8.00	40	11.4	56	16.5	7	7.5	317		0.5	217.0	91
Total Nifas Silk	473900	990100		412		7.06			93.6	7.54	55	7.7	246		2	60.0	
Repi Soap Factory	466250	993050		180		7.20			35.2	10.1	2	7.9	140		Nil	142.0	50
Chelaba Silasie Bore	481162	958481	510			7.62	44	11	30	19	13	8	330		10	140.0	58.32
Sebeta Dragados	457030	984617	979			6.85	16	3.4	36	9	5	8.69	178		2.6	140.0	88.52
Water III Borehole B	480517	977974	544	314	25.4	7.98	26	2	70.4	20.4	4.5	8.8	324.5	13.2	1	170.0	65

TW2 Test well No.2	473576	972821	498	305	26.7	7.80	45	7.7	60	7.3	7.2	8.8	302.6		4.5	150.0	74
Debrezeit Airforce N	499500	964500				7.80	64.6	11.9	44.9	29.2	28.4	8.9	402.6	0	0	72.0	30.5
Water III Borehole B	479058	976020	478.7				30.6	3.96	40	28.2	14.2	9.2	305	NIL	7.4	130.0	72.2
Water III Testwell-B9	481600	982900	520	423.5		7.45	39.6	4	40.9	31.15	19.9	9.25	176.9		129.5	120.0	35.1
Meta Abo Brewery	455500	985200	191.3			7.70	23.8		24.1	3.9	14.2	9.3	122	0	0	126.0	50.86
Water III Borehole B	477162	976038	494.2				27.2	4.3	49.7	23.4	14.2	9.4	292.8	NIL	8.85	135.0	42
Oda Nabe Peasants	484325	969692	516	291		7.60					8	9.5			1.5	0.0	118.4
Water III Testwell-T5	481600	982900	540	380		7.40	44.2	4	56.1	20.4	14.2	9.6	341.6	NIL	15	120.0	37.33
Water III Testwell-T2	479400	981400	430	362		7.40	37.4	4	52.9	26.3	14.2	9.6	317.2	NIL	36.2	74.0	2.8
Akaki Water Supply	481600	982850	1180			7.52					5	9.68			27.55	136.0	33.48
TW3 Test well No.3	484475	975622	672	408		7.50	40	3.5	96.8	18	7	9.7	444		0.5	220.0	100
Water III Borehole B	478808	976867	508.2		22.5	8.00	27.2	3.96	59.3	24.32	11.6	9.8	341.6	NIL	6.5	152.0	47.5
TW5 Test well No.5	485798	968308	627	344	29	7.40	35	6.6	62.4	25.3	6.1	11	38.5.5		1.3	220.0	69.4
Akaki Koye Air defen	482400	983000	-	400	-	7.70	49	6.3	51.7	28	21.3	11.3	384.3	Nil	Nil	83.3	56.15
AAWSA, Ayer Tena,	466050	993650	336	160		7.61			36.84	11.66	1.5	11.52	170.69		Nil	136.0	71.28
Nigeria Embassy, Afi	472700	999800				7.20	34	2.6	56.1	16.5	48.2	11.6	219.6	0	23.3	120.0	11.7
Arena Dukem	487900	972421	632			7.31	32	7	62	31	12	11.67	383		8	135.0	75.75
Water III Testwell-T1	481200	980000	530	385		7.60	40.8	5.3	67.3	15.6	14.2	11.7	366	NIL	NIL	173.0	8.9
Akaki Water Supply	479340	981400	1227			7.81			142	92	10.07	11.73			20.48	108.7	0.73
Indonesian Embassy	470950	993300					25	4	53	9	23	12	220	0	0	120.0	18.93
Akaki Beverly Intern	480895	977403	489			7.52	23	3.4	39	26	9	12	315		9	104.0	84.8
Water III Borehole B	477330	976793	477.6		22	8.10	40.8	4.6	40.1	19.5	14.2	12.3	292.8	NIL	NIL	130.0	42.9
Water III Borehole B	477181	975680	476.4		23	7.80	27.2	3.96	49.7	23.35	12	12.3	292.8	NIL	7.4	116.0	51
Water III Borehole B	478019	977985	432			8.37	27	2.9	31	23	11	12.85	249	4	9	150.0	51.5
Total Ras Hotel	472700	996300		348		7.20			84	11	12.5	13.2	224		31	20.0	6.8
Abay Mesk Soft Drin	473100	992600		279		7.15			57.6	15.08	18.5	13.2	182		16.5	84.0	36
Water III Borehole B	479405	976735	493		23	7.30	26	4.2	44.1	27.7	8.5	13.7	312.5	NIL	7.6	151.0	67.2
Water III Borehole B	477651	975923	494.2				27.2	4.3	49.7	23.35	14.2	13.7	292.8	NIL	7	142.0	47.9
Water III Borehole B	477856	976402	512				27.2	3.96	52.9	24.3	14.2	13.8	292.8	NIL	26.75	151.0	44.7
Sebeta Agro Industry	460850	985850	244	159		6.65	16	3.1	28.8	4.84	3.88	14	141.5	0	1.8	106.0	43
NMWC Spare Parts &	478463	977506	371.9		-	7.50	28.9	3.3	41.7	23.3	14.2	14.2	292.8	Nil	Nil	123.0	50
Water III Borehole B	478199	976361	452		23	7.70	27.2	3.96	49.7	25.3	17	14.6	317.2	NIL	NIL	144.0	45.9
Satcon, Bisrate Gabr	469750	993850	482	350		7.10	33.9	1.6	53.71	16	35.5	14.96			20	150.0	14
Netherlands Embass	468800	996600	375			7.90	23.8	2.8	40.1	6.8	11.3	15.1	195.2	0	0	124.0	50.35
ALERT-2 West Well	468100	993100		279		7.20			56.8	12.1	15	16.2	186		Nil	80.0	50
Akaki Water Supply	478998	977937	496			7.80	36.6	3.3	39.7	23.6	9.2	16.4	302.6	Nil	7.9	130.0	73.48
Water III Borehole B	479246	977104	512		24	7.30	27.2	3.6	48.5	27.7	8.7	16.7	327	NIL	7	146.0	58.7
Water III Borehole B	479696	976936	485		23	7.50	24.5	4.2	45.7	27.2	9	18.6	307.4	NIL	6.6	145.0	67.8
Water III Testwell-B1	473069	979881		346		7.50	40.8	5.3	54.5	22.4	14.2	18.9	317.2	NIL	24.7	116.0	5.8
Water III Testwell-B5	481200	980000	44	393.5		8.00	40.8	13.2	46.6	31.15	14.2	19	378.2			150.0	11

Genet Hotel	472000	995100		278		7.60			38.8	27.6	22	19.8	182		1	56.4	44
Water III Borehole B	478780	977307	516				30.6	2.97	46.5	26.3	11.3	21.2	292.8	NIL	17.5	138.0	61.1
Tikur Abay Shoe Fact	466200	1001008		517		7.00			43.2	13.4	70	22	130		5	53.0	22.6
Ministry of Public W	474500	996200		249		7.90			36.8	14.2	10.5	23.8	146		Nil	29.0	
Ras Hotel	472500	996300		516		8.10			106	10.15	33	25.1	300		45	41.0	8.7
SEDE(plant-A) - 1	471700	995100		393		6.85			97.6	Nil	80	25.1	210		42	62.0	7.4
Water III Borehole B	479061	976370	464				27.2	3.63	44.9	29.2	17	25.7	305	NIL	NIL	144.0	67.2
Abay Mesk Soft Drin	473000	992700		564		7.40			88.8	44.06	100	26.4	210		4	121.2	110.6
Water III Testwell-T4	473108	979851		397		7.60	37.4	9.9	64.1	21.4	21.3	27.5	256.2	NIL	28	103.0	7.07
Awash Winery	469900	996000		388		7.25			80	24	103	40.5	200		19	67.1	13.7
Menilik School	474100	998500		614		7.20			140	32.6	82.5	41.8	310		37	41.0	
Coca Cola Factory-2	470000	996400				7.70	18.7	2.3	68.9	48.9	35.4	50.68	616	0	0	44.0	13.3
Addis Abeba Brewer	471600	995800		509		7.70			92.8	34.6	60	74.4	230		16.5	36.4	19
Africa Hotel	471700	996300		522		7.60			96	36	67.5	75	242		16	96.0	40.95
Addis Abeba Brewer	471300	995800	592			7.90	27.2	2.6	86.8	23.4	62.4	75.3	244	0	5	85.0	7.6
Addis Beer-9	471400	995900				7.90	17.9	2.4	81.8	40.9	78	97.5	268.4	0	0	88.0	16.8
Meskerem Soft Drin	471400	997400		1059		7.20			228	71.1	253	176	320		45	40.0	5
Gulele Misionery of	465600	1001855	267	127		8.10					7.5	10			0.7	104.0	13.2
Gulele Misionery of	465651	1001575	380	250		7.40	7.41	3.2	40.8	15.5	10	15	185.4	9.6	0.9	76.0	7.3
Kality Food Factory B	475430	984955	-			8.50	24.8	4.2	72.1	18.5	10.6	0	317.2	24	Nil	0.0	
Gebremariam Schoo	472600	997400		71		7.22			16.8	1.16	7	0	44		Nil	51.0	
Campo Asmara Gara	471800	995200		194		7.40			15.2	18	14	0	150		14.5	0.0	5
Galetti Project	474800	984700	-	354	-	7.80	36.1	9.4	33.3	11.7	10.5	0	298.9	Nil	Nil	71.3	0.5
Akaki Metal Product	477233	979000	510	351	-	8.35	-	-	-	-	5		-	-	20	82.3	51
Kality Military Camp	475300	984000	350	-	-	7.60	54.4	9.1	43.3	6.8	14.2	0	292.8	Nil	3	128.5	Artesia
Water III Testwell-B4	486200	1001042		369		7.50	65.5	2.7	36.9	14.6	25.5	0	292.8		15	100.0	10
Water III Testwell-B1	466400	987600		351		7.90	20.4	4	56.1	9.7	7.1	0	268.4			125.0	18.3
Water III Borehole B	478580	976051	476.4		23	7.70	27.2	5.94	48.1	26.3	9.2	0	329.4	NIL	6.58	130.0	59.2

Annex- 2 Ground water sample result of Dire Dawa from water works design supervision enterprise.

Index	LOCAL NAME	East	North	EC	TDS	ToC	PH	Na, mg/l	K, mg/l	Ca, mg/l	Mg, mg/l	Cl, mg/l	NO3 mg/l	HCO3,mg/l	CO3,mg/l	SO4,mg/l
BH-01	Armakule	8E+05	1E+06	1093	653	35	8	120	1.1	84	15.08	78.1	9.24	400.16		145.1
BH-02	Hurso	8E+05	1E+06	1829	1296	23	7.5	100	1	208	65.66	188.1	25.52	466.04		448.4
BH-04	Cheremiti-#2	9E+05	1E+06	758	466	22.7	7.9	55	2.8	88	14.11	39.6	9.68	363.56		73.8
BH-09	Melka Jebdu-3	8E+05	1E+06						1.3	104	37.9	67.1		392.84		31.6
BH-52	Rail way statio	8E+05	1E+06	1582	1092		8.1	60	2.2	214	29.5	165.9	129.4	322	16.8	56.7
BH-07	D/Dawa food co	8E+05	1E+06	1996	1060	28.6	7.6	40	1.3	188.8	36.5	144.1	155.32	319.64		92.3
BH-15	Hafcat #2	8E+05	1E+06	2250	1583	26	7.3	125	1.8	264	68.1	331.1	58.96	412.36		448.5
BH-16	East Afri Bot#1	8E+05	1E+06													
BH-08	Melka Jebdu #2	8E+05	1E+06	957	598	24.2	7.3	30	2.5	128	34.1	67.1	9.68	441.64		47.5
BH-12	Palace	8E+05	1E+06	2140	1570	18.7	7.5	125	3.2	240	41.34	314.6	220	414.8		23.7
BH-14	Hafcat #1	8E+05	1E+06	1810	1245	26.3	7.7	80	1.1	240	44.75	215.6	184.8	353.8		221.5
BH-29	Dire Jara W-4	8E+05	1E+06	967	469		7.6					18	0.2			114
BH-05	Cement Factory	8E+05	1E+06	994	532	24.6	7.4	30	1.7	116	28.7	83.6		373.32		18.46
BH-06	Ras Hotel # 2	8E+05	1E+06	1393	946	19	7.6	60	1.5	200	20.92	149.6	115.28	378.2		50
BH-34	Dire Jara W-9	8E+05	1E+06	986	477		8.5					35	0.2			131
BH-35	Dire Jara w-10	8E+05	1E+06	955	461		7.9					15				145
BH-36	Dire Jara W-11	8E+05	1E+06	928	449		7.7					13	0.6			119
BH-39	Dire Jara W-14	8E+05	1E+06	893	433		8.2					13	0.3			77
BH-25	Jeldesa	8E+05	1E+06	1436	703		7.7						0.03			284
BH-10	East Afri Bot#2	8E+05	1E+06	1137	834	24.8	7.3	40	1.2	152	30.16	80.6	92.84	373.32		39.56
BH-11	East Afri Bot#3	8E+05	1E+06			25.3	7.2	20	2.7	160	19.46	72.6	98.56	334.28		26.37
SP-7	Belewa	8E+05	1E+06	786	458	22.3	7.5	13		144	17.02	28.6	14.52	446.52		15.82
SP-8	Medekedjima	8E+05	1E+06	1081	644	19.4	7.6	50	1.3	148	31.62	94.6	12.76	461.16		47.5
SP-9	Gende Boru	8E+05	1E+06	746	426	18	7.6	20	1.3	128	19.46	34.1	12.32	419.68		2.64
DW-14	D/DEdible oil f	8E+05	1E+06	1084	650	29.5	7.7	60	1.1	140	24.32	100	34.76	397.72		31.65
DW-20	Jelobelina	8E+05	1E+06	1844	560	22	7.6	200	4	188	21.89	298.1	24.64	610		15.8
DW-30	Tony farm #1	8E+05	1E+06				7.1	5	1.1	183	18	91.2	25.5	475.8		65.9
SP-10	HARAWATU	8E+05	1E+06	774	462	18.9	7.7	20	1.3	120	24.32	39.6	12.76	419.68		10.6
SP11	Borte	8E+05	1E+06	749	432	19.7	7.3	9	1.3	140	17.02	17.6	14.08	427		7.9
SP-13	Fechase	8E+05	1E+06	1056	686	20.9	7.4	6	0.9	160	9.73	94.6	25.96	402.6		7.9
SP-14	Cement Factory	8E+05	1E+06	908	526	24.8	7.6	4	1.9	132	17.02	94.6	18.92	356.24		7.9
SP-15	Eftua	8E+05	1E+06	719	408	17.3	7.4	8	1.4	144	9.73	23.1	12.32	405.04		10.6
SP-30	Legahrtu(hotsp)	8E+05	1E+06	3330	2414	60	8	600	31.5	82.3	8.5	412.3	0.44	161	7.2	1000.5
SP-1	Legemeda	8E+05	1E+06	1890	1268	21.5	7.4	14	2.9	184	60.8	281.6	18.92	427		290.2

SP-2	Halobusa(Legeg	810084	1E+06	1797	1270	20	7.6	140	7.3	172	82.67	226.6	44	524.6		168.8
SP-3	Keche	820449	1E+06	546	408	20.3	7.1	35	3.1	200	4.86	34.1	17.6	231.8		5.27
SP-4	Adada	819112	1E+06	810	480	16.7	7.4	40	3.5	128	7.29	83.6	7.92	324.52		15.8
SP-16	Serkama	845129	1E+06	800	468	18.1	7.7	30	3.9	140	12.16	34.1	11.88	392.84		13.2
SP-18	Awale Roresa	836775	1E+06	730	408	18	7.4	12	1.7	128	19.46	28.6	10.56	412.36		15.8
SP-19	Bishambaye	830595	1E+06	1062	680	20.7	7.4	60	1.2	152	9.73	105.6	35.64	390.4		5.27
SP-5	Biyoawale	829794	1E+06	466	270	17.3	7.3	35	1.2	64	4.86	34.1	15.4	187.88		18.2
SP-6	Gende kurto	837595	1E+06	1108	752	21	7.6	50	4.5	176	24.32	78.1	46.2	429.44		31.6
SP-21	Legehare	818219	1E+06	966	570	24.8	7.4	50	6.1	140	24.32	56.1	4.84	507.52		15.8
SP-22	Mudi Anano	820995	1E+06	890	559	20.6	7.7	20	0.9	200	109.44	39.6	2.64	480.68		2.6
SP-24	Jarso-Gendelege	852823	1E+06	314	190	14.3	7.9	9	3.7	52	4.86	12.1	8.8	165.92		2.4
SP-25	Legedomirga	813438	1E+06	966	570	21.5	7.4	50	6.1	140	24.32	56.1	4.84	507.52		15.8
BH-40	Dire Jara W-15	801425	1E+06	978	472		7.6					18				122
BH-41	Dire Jara W-16	800276	1E+06	859	418		8					8	0.2			125
BH-42	Dire Jara W-17	801738	1E+06	965	467		8					18	0.2			142
BH-43	Sabian Pw-1	812491	1E+06	1057	622		7.2	50	1.3	136	30.16	105.6	34.32	424.56		44.8
BH-46	Sabian Pw-4	812527	1E+06	1060	670	20	7	50	1.4	160	15.57	105.6	35.2	407.48		29
BH-47	Sabian Pw-5	812362	1E+06	1017	618		7	40	1.3	159	3	75.7	23.76	407.5		47.5
BH-48	Sabian Pw-6	812767	1E+06	1232			7	60	1.4	176	22.87	138.6	69.52	383.08		63.3
BH-49	Sabian Pw-7	813081	1E+06				7.2	34	16.5	176	64.2	130.5	99.7	320		
BH-50	Sabian Pw-8	812573	1E+06				7.4	56.1	2	156	20.4	81	9	360		
BH-51	Sabian Pw-9	813111	1E+06				7.2						13			
SP-26	Jelobelina	817946	1E+06	882	544	20.3	7.6	20	1.4	128	26.75	94.6	22	295.24		50.1
SP-27	Jarso Sebelo	858960	1E+06	230	146	12.6	7	11	7.7	32	4.86	17.6	7.92	107.36		3.96
SP-28	Koriso	799366	1E+06	835	554	20.5	7.2	12	1.8	152	21.89	23.1	12.32	400.16		81.6
BH-53	Elfora	810907	1E+06	1080	650		7.2	50	1.6	151.2	21.5	83.4	23.8	446		56.7
BH-77	Bore TW4(2002	796050	1E+06	704	415		7.5	15	1.5	134	11.5	14.6		392.8		43.5
BH-13	Amdael well #1	814356	1E+06	1302	790	24	7.1	100	2	112	31.13	160.6	21.12	383.08		14.5
BH-2	Dechatu	816294	1E+06	784	470	25.7	7.3	10	3	140	8.27	28.6	27.72	400.16		12.1
DW-01	Jeldesa	841574	1E+06	890	526	23.4	7.6	40	3	120	27.86	61.6	244	297.68		147.7
DW-02	Garba Anano	857203	1E+06	3780	3110	24	7.5	300	1.5	472	109.44	694.1	2.64	363.56		1213
DW-03	Kalicha	833527	1E+06	1250	882	21.5	7.7	80	1	180	24.32	533.1	45.76	441.6		55.4
DW-04	Tsehay Hotel	813009	1E+06	1380	878	22.2	7	80	4.3	180	19.46	133.1	92.4	700.28		15.8
DW-05	Mudi Anano	819238	1E+06	704	446	27.7	8.1	130	2.1	32	4.86	23.1	11	378		5.3
DW-06	Kenchera #1	810272	1E+06	964	610	23.1	7.7	50	2.2	150	17.02	78.1	14.08	439.2		42.2

DW-07	Ejaneni	819113	1E+06	1245	884	23.1	6.7	80	1.9	184	19.46	160.6	30.8	431.88		55.4
DW-08	Belewa#1	840894	1E+06	890	508	21.2	7.4	9	1	160	24.32	23.1	2.64	531.92		5.3
DW-09	Gende Sur	799308	1E+06	872	532		7.9	100	1.1	68	17.02	23.1		524.6		21.1
DW-10	Bore	798554	1E+06	1218	804	25.2	7.9	140	1.4	88	29.18	34.1	3.08	563.64		200.4
DW-12	Grba Anano	857182	1E+06	2260	1710	25	7.6	150	4.7	288	55.94	325.6	0.44	327		685
DW-11	Koran Goga	800714	1E+06	1373	872	25.3	7.8	220	0.9	60	19.46	72.6	8.8	549		208.4
DW-13	Melka Jebdu	805579	1E+06	1457	974	27.3	7.2	240	1	136	31.62	127.6	10.12	549		184.6
DW-15	Goladeg	802030	1E+06	1257	862	25.5	7.4	100	0.8	128	41.34	23.1	6.16	470.92		329.7
DW-16	Arsho Adele	806000	1E+06	2090	1416	26.5	7.4	200	0.9	144	75.39	248.6	13.2	463.6		448.4
SP-29	Melka(Fuad Ha	805106	1E+06	720	412	22.5	6.7	40	2.5	80	24.32	78.1	3.08	275.72		39.56
DW-18	Gende Alo	805943	1E+06	1223	808	26.7	7.3	60	1.9	188	31.62	138.6	26.84	446.52		81.8
DW-19	Gende Rige	806316	1E+06	1068	670	26.4	7.3	40	1.7	168	24.32	83.6	11	461.16		42.24

Annex -3 Groundwater points and water level in Dire Dawa

Well index	Local Name	X	Y	GWL(m)	Well Dep	SWL(m)
BH-04	Cheremiti-#2	864535	1079607	1130.6	101	21.42
BH-09	Melka Jebdu-3	805167	1063299	1108	106	23
BH-52	Rail way station	813936	1061662	1150.2	62	29.77
BH-54	Textile-1(old)	816702	1062643	1166.9	45.7	25.1
BH-07	D/Dawa food co	814520	1063426	1147	115	30
BH-08	Melka Jebdu #2	805241	1063341	1111.5	95.6	29.5
BH-12	Palace	814172	1061499	1167.9	48.8	34.1
BH-26	Dire Jara W-1	801010	1058803	1180.4	163.5	49.6
BH-27	Dire Jara W-2	801394	1059555	1121.8	161.5	88.22
BH-29	Dire Jara W-4	800965	1058414	1181.4	123.4	56.6
BH-30	Dire Jara W-5	801225	1058126	1180.5	156.5	64.5
BH-31	Dire Jara W-6	800965	1058414	1180.4	105.5	59.6
BH-05	Cement Factory	812378	1061804	1199		16
BH-06	Ras Hotel # 2	813870	1061350	1152		45
BH-32	Dire Jara W-7	801409	1057966	1179.6	172	67.45
BH-33	Dire Jara W-8	801047	1057939	1181.2	187.6	69.8
BH-34	Dire Jara W-9	801238	1058620	1262.9	176	52.08
BH-35	Dire Jara w-10	801606	1058257	1180.6	150.45	58.45
BH-36	Dire Jara W-11	800722	1058418	1181.3	126	57.71
BH-39	Dire Jara W-14	801484	1058356	1274.9	154	50.12
BH-56	Textile Old W-3	816481	1062864	1165.1	61	25.9
BH-57	Textile No. 4	816792	1062510	1161.6	62.5	27.4
BH-17	Amdael #2	814239	1064632	1112	124	24
BH-18	Cheremiti-1	865002	1079210	1163	70	
BH-19	Haseliso	801010	1058803	1235.8	119.4	28.21
BH-24	WMERO	814262	1063811	1133.4		35.57
BH-25	Jeldesa	842515	1076753	1049.3	90	23.7

BH-10	East Afri Bot#2	814020	1061049	1168.5	120	36.5
BH-11	East Afri Bot#3	814520	1061049	1168.5	125	36.5
BH-74	Sabian TW-9(89)	812461	1064371	1113	129.2	17
BH-75	Sabian TW-10(89	813117	1063444	1139	76	21
BH-76	Sabian TW-11(89	811921	1063785	1139	78	11
BH-80	Genderige BH-3	805170	1063115	1138.5	80	11.55
BH-91	Hurso mil.camp	788387	1057037	1269.6	115	23.84
BH-92	Bisrate Gebriel	814120	1063340	1136.5		38.5
BH-93	MIN.of Mines	814200	1063530	1161.8		30.2
BH-94	Min.of Mines	813010	1061970	1146.6		25.42
BH-20	Ras Hotel #1	813883	1061280	1154		45
BH-21	High school	813851	1060388	1164	79.2	48
BH-22	Dil Chora Hospi	813892	1061139	1170.9	47	39.1
BH-23	Dire dawa food c	814400	1063426	1137	112	33
BH-40	Dire Jara W-15	801425	1058252	1180.4	175	60.56
BH-41	Dire Jara W-16	800276	1058325	1181.4	198.5	54.64
BH-43	Sabian Pw-1	812491	1063930	1133.5	72.4	13.5
BH-44	Sabian Pw-2	812097	1063961	1134.7	98.8	9.3
BH-46	Sabian Pw-4	812527	1063543	1143.3	104.6	19.7
BH-47	Sabian Pw-5	812362	1063793	1141.1	101.8	15.9
BH-48	Sabian Pw-6	812767	1063462	1151.2	86.2	22.8
BH-49	Sabian Pw-7	813081	1063268	1145.3	82.7	23.7
BH-50	Sabian Pw-8	812573	1062411	1175	87.7	15
BH-51	Sabian Pw-9	813111	1063263	1147.8	71	21.25
BH-55	Textile-2(old)	816573	1062781	1176.2	61	18.8
BH-53	Elfora	810907	1062360	1187.7	82	22.32
BH-77	Bore TW4(2002)	796050	1058100	1133.9	160	31.06
BH-95	Prison	814010	1063530	1138.3	47.8	21.7
BH-96	Cement factory	815900	1062330	1176		19.05

BH-99	Municipality#1	812440	1061310	1166.7	33.5	25.3
BH-100	Municipality#2	812460	1060990	1175.1	35	21.9
BH-101	Municipality#3	812460	1060990	1184.7	32.5	10.3
BH-13	Amdael well #1	814356	1064666	1112	135	24
BH-82	Commnd post	811190	1062310	1174		26
BH-107	Former Railway	814025	1061390	1174	54.9	38
BH-108	Gebremedihn	813700	1060750	1177		41
BH-109	Coca Cola(old)	813910	1060990	1187		30
BH-83	Genderige BH-5	808532	1063462	1126.32	80	18.68
BH-84	Genderige BH-6	805945	1063792	1082	50	18
BH-102	Shinile milit.	814072	1065654	1101	119	11
BH-103	Russian camp	813531	1061868	1164.2		25.8
BH-104	Ejaneni	816386	1058772	1046.5		93.5
BH-105	Police training	812730	1061950	1167	65.6	22
BH-106	Well drilling c	811900	1061880	1158.9		41.1
BH-112	D/D CFE	814091	1061785	1161	54.9	39
BH-61	Textile Old W-8	816460	1062460	1150	52.6	45
Bh-62	Textile Old W-9	816080	1062886	1135	50	39
BH-63	Textile Old W10	816025	1062825	1144	50	41
BH-64	Textil Old W-11	816677	1062984	1158	59	17
BH-65	Textile O.W-14	816103	1067017	1134.8	78	42.2
BH-66	Textile A.W-1	814343	1064427	1095.7	116	37.3
BH-67	Textile A.W-2	814652	1064390	1102.87	82.3	32.13
BH-68	Textile A.W 3	814531	1064064	1107.58	91	26.42
BH-69	Textile A.W. 4	814522	1064772	1156.29		35.71
BH-70	Textile N.W 3	816584	1062892	1175.14		14.86
BH-85	Cement old BH-2	811170	1062350	1179.2	25	12.8
BH-86	High way author	813073	1062031	1159.5	47.2	30.5
BH-87	D/D R.R.C.	814072	1064275	1159.5	63	27.5
BH-88	Locust control	811806	1062708	1139	48.7	21
BH-111	TW5(2002)	809796	1064843	1095.6	124	33.4
BH-113	Melkajebdu(old)	806549	1064183	1056.6	125.9	43.4
BH-89	Pig farm	810987	1062681	1166.26		20.74

Source EIGS, 1986, Taye A. 1988, DDAC, 2000, WWDSE 2003/2004, E.Abate and MoWR, 2004,

Annex-4 Drinking Water Quality Guidelines/Standards

S.N	Water Quality parameters	Guidelines/Standards			
Inorganic parameters(mg/l)		WHO	EU	MoWR	AAWSA
1	PH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
2	Colour(TC)	15	20	21.75	15
3	Turbidity(NTU)	5	-	7	-
4	TDS(mg/L)	1000	500	2175.99	1000
5	Total alkalinity as $CaCO_3$	500	-	-	500
6	Total Hardness as CaCO3	300	-	392	500
7	Ca Hardness as CaCO3	300	-	-	500
8	Sodium (Na)	200	150	3570.53	200
9	Potassium (K)	11	-	-	-
10	Calcium(Ca)	100	-	-	-
11	Magnesium(Mg)	30	-	-	-
12	Chloride(Cl)	250	25	532.67	250
13	Sulphate(SO_4^{2}-)	250	250	482.69	250
14	Fluoride(F^-)	1.6	1.5	3.02	1.6
15	Nitrate (NO_3^-)	50	50	130.57	50
16	Ammonia (NH_3)	1.5	-	2.08	1.5
17	Sulphides (H_2S)	0.05	-	0.07	-
18	Aluminium(Al)	0.2	0.2	0.43	0.2
19	Arsenic (As)	0.05	0.05	-	0.1
20	Barium (Ba)	0.7	1	1.8	-
21	Nitrite (NO_2-)	3	0.1	7.52	-