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Evaluation of Addis Ababa Water Supply System Using *Integrated Approach*

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This is to certify that the dissertation submitted by Getinet Assabu Ewunetu entitled ‘‘Evaluation of Addis Ababa Water Supply System Using Integrated Approaches’’ in Fulfillment of the requirements for the Degree of Doctor of Philosophy in Environmental Planning complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Abstract

Evaluation of Addis Ababa Water Supply System Using Integrated Approach

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The city of Addis Ababa gets water from Dire, Gefersa, and Legedadi reservoirs as well as miscellaneous boreholes concentrated around Akaki and scattered at both inside outside the city. Previous studies on Addis Ababa's urban water supply are fragmented focusing on specific issues without presenting the holistic view of the system. In the present study, we assess range of aspects of the city's water supply system in the past, present and future periods. Data were obtained through a literature review of relevant documents, personal communication, household interviews, and key informant interviews. The time series data were analyzed by stratifying the time periods, water source, and water supply branches. Descriptive statistics and various plots were used to present the most important characteristics of water consumption and production data. Addis Ababa was initially served by springs located at the foot of the Intoto mountain ridge together with a series of hand dug wells. Population growth, improved standard of life, economic diversification, and increased urban dynamics have increased the water demand over the past several decades. This has led to water source diversification (in terms of location and source type) and complex network system (due to hybrid sourcing, increased customer water line connections, pipeline aging, pressure variations related to topographic variations, service reservoirs, pumping and/or booster stations). In 2014/2015, surface and groundwater sources contributed somewhat equally (51% and 49 %, respectively) and supplied about 49 % of the demand with 45% Non-Revenue Water. Nearly half of the water demand of the city is not met. This supply deficit is causing frequent supply interruptions. The utility is supplying water via water trucks for low pressure areas where water does not reach easily. There are also efforts to develop additional groundwater sources at various well fields and develop the Sibilu and Gerbi dams. When all the proposed projects are completed, 971,483m^3/d additional water will be added to the existing water supply which will increase the supply by 273%. While efforts to increase water supply are encouraging, demand side management deserves more attention than it is receiving currently. WEAP model simulations have shown significant unmet future demand for the city even with complete implementation of the proposed projects. Households with greater number of supply failures tend to have the least access to drinking water. Similarly, both water quantity and water quality are deteriorating. A good example of water quality problem is the 2017/18 outbreak of cholera incidence. Customers are highly dissatisfied with the current service delivery characterized by long time persistent problems. Unless the water utility takes immediate action to solve these problems, the current situation which is affecting the health and economic status of water customers will exacerbate. In this study, it is identified that the major causes of the lack of adequate water supply in the city are depletion of groundwater sources, huge leakage volume, population growth, construction boom or enhanced economic activity and wasting of water by customer at lower parts of the city. Unless demand side and supply side management measures are enhanced, the gap between supply and unmet demand will resume as is.

Key words: Addis Ababa, Water supply, WEAP Model, Urban water management, Water loss

Dedication

This dissertation is dedicated to my father and my mother whom I lost during the progress of this study

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name: Getinet Assabu

Signature: _______________

Date: June 2019

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Lists of Abbreviations and Acronyms

AAEPA	Addis Ababa Environmental Protection Authority
AAiT	Addis Ababa institute of Technology
AAWSA	Addis Ababa Water and Sewerage Authority
CGAA	City Government of Addis Ababa
CSA	Central Statics Authority of Ethiopia
DSS	Decision Support System
ECA	Economic Commission for Africa
EPA	United States Environmental Protection Agency
GWP	Global Water Partnership
IUWM	Integrated Urban Water Management
IWRM	Integrated Water Resource Management
l/c/d	Liter per Capita per Day
MDG	Millennium Development Goal
MoWUD	Ministry of Works and Urban Development
NRW	Non-Revenue Water
UN	United Nations
UNCHS	The United Nations Center for Human Settlement
UNDP	United Nations Development Program
UN-ECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-HABITAT	United States Settlements Program
WEAP	Water Evaluation And Planning System

Chapter One

1. Introduction

1.1 Background

Water is a precious natural resource that is vital for human survival, health and dignity as well as for physiological processes of all organisms (WHO, 2005). It is a fundamental resource for human development. It has social and economic values for human beings (Alcamo *et al*., 2007; Kathpolia and Kapoor, 2002). Safe and readily available water is important for public health, whether it is used for drinking, domestic use, food production or recreational purposes. Today, major cities face many daunting challenges, but water management is one of the most serious. Potable water is scarce, many sources of water must be treated at high cost and volumes of waste water are growing.

The process of urbanization has several consequences that are either social, or economic or environmental. Similar to other developing regions, urban areas and populations which are growing in Ethiopia (Williams, 2000) are believed to continue as a major demographic trend (Engel *et al.*, 2011) since 70% of the world's population is projected to live in urban areas by 2050.

Cities emerge and grow accompanied with population growth as the result of human resources and labor force availability and their attraction to economic activities (Haughton and Hunter, 2004). Population growth and economic development put constant pressure on the ecosystems of water resources. There is a strong positive correlation between water demand and urbanization or population growth (Malmqvist and Rundle, 2002). There are authors like Halliday (2004) who have prophesied that the next world war will not be fought over by the lack of energy resources but rather on the lack of water. Similarly, Grigg (1997) has stated that comprehending the urban growth and clearly explaining options are two main requirements for effective decision-making about sustainable development of urban infrastructure.

Improved water supply and sanitation, and better management of water resources, can boost countries' economic growth and can contribute greatly to poverty reduction. In 2010, the UN General Assembly explicitly recognized the human right to water and sanitation. Everyone has the right to sufficient, continuous, safe, acceptable, physically accessible, and affordable water for personal and domestic use. However, population growth and economic development are putting constant pressure on water resources (WEF, 2014). However, the available amount of water is limited, scarce, and unevenly distributed. It is as such not surprising that many urban centers are facing increasing water demand. Hence, proper management of the available resource is needed to satisfy the current and future demands. This urges urban water systems to provide safe water for different uses without harming the environment (Hellström *et al.*, 2000). As noted by Biswas (2008), many of the water problems have already become far too complex, interconnected and large to be handled by any one single institution.

Water consumption is showing increment due to climatic conditions, improving living standards and industrialization. Competitions among different sectors, between urban and peri-urban areas are also challenges (Meinzen-Dick and Jackson, 1996). The problem induced by increased water demand is exacerbated in urban areas due to aging infrastructure and lack of appreciation for the value of water by the public (Kallis and Coccossis, 2003; Kallis and Coccossis, 2002; Swyngedouw *et al*. 2002).

Many authors, including Solo *et al.*, (1993) and Cronin *et al*. (2008) have summarized the major constraints that hinder the effor1ts of the various institutions to provide adequate water supply and sanitation as follows: institutional inadequacy and insufficiency of conventional approaches that did not recognize progressive improvement of infrastructure; supply-driven infrastructure provision sticking to rigid planning/ design standards and regulations; and high cost of conventional systems that did not recognize progressive improvement of infrastructure. Countries in which less than 50% of the population uses improved drinking water sources are all located in Sub Saharan Africa and Oceania (UNICEF and WHO, 2015).

Rapid urbanization over the last five decades is changing Africa's landscape as well as generating formidable challenges for supplies of water and sanitation (UN-HABITAT, 2011). Yet, drinking water coverage in Africa has increased from 56% in 1990 to 64% in 2006 (WHO and UNICEF, 2008). Yet, the increase in coverage has not kept pace with population growth. Who/UNICEF (2015) report has recorded that in 2015 only 3 countries namely Angola, Equatorial Guinea and Papua New Guinea – have coverage of less than 50%, compared to 23 countries in 1990.

The majority of citizens in Ethiopia are unable to get access to the quantity and quality of potable water (Bekele and Leta, 2016). As the result of Ethiopia's substantial progress in increasing water supply coverage, the country has developed a strong policy and planning framework. This includes the ambitious government led Universal Access Program that is backed by increased resource mobilization from both government and donor agencies (UNICEF and WSP, 2015). Many sources including Butterwoth *et al*., (2013) and Mason *et al*., (2013) that confirm water supply coverage in Ethiopia is on a strong upward trajectory. Hence, water supply coverage has risen from 19% in 1990 to 66% in 2009 62% in rural and 89% in urban (UNICEF and WSP, 2015). yet, the majority of the citizens in Ethiopia are unable to get access to the quantity and quality of potable water (Bekele and Leta, 2016).

Addis Ababa City is supplied with water from groundwater (wells bored at Akaki wellfields, Legedadi wellfield and other wellfields), various springs and wells scattered throughout the city and three main surface water sources (Legedadi, Dire and Geffersa reservoirs). The current accelerated urbanization of Addis Ababa has posed threats since the size and location of cities to some extent determine the types of threats posed and the types of possible solutions (WGP, 2011). AAWSA's Business Plan (AAWSA, 2011) has projected water shortage in Addis Ababa will continue up to 2020. The 2007 census baseline data have shown that only 66 percent of the customers receive water supply for 24 hours a day. The current fierce competition among water users on the available freshwater has aggravated resource depletion and compromised the water access to low income domestic users (Sharma and Bereket, 2008). The uncontrolled sprawl of urban areas can also affect water supply both in terms of quantity and quality.

1.2 Statement of the problem

Growing cities face increasing and new challenges that affect the provision of basic urban services. Such new challenges have made effectiveness of business as-usual approaches questionable. AAWSA has been supplying water over the past several years. The authority has conducted some technical studies in the past and also has been recording useful data on water use and production. However, studies that synthesize existing data and technical studies to show the challenges and opportunities of Addis Ababa's water supply is noticeably absent in the scientific literature. The data collected by AAWSA can be useful to understand the dynamics of water demand and supply in the city which can be a good addition to the limited empirical evidence of the water supply of big cities. Addis Ababa has spatially varying terrain characteristics and population density, which can lead to uneven distribution of water supply. However, spatial variation of water quantity and quality in the city is not well known. A quick and inexpensive approach to fill this knowledge gap was needed and was explored in this study through household surveys.

There are still severe shortages and frequent interruptions of water supply in many parts of the city. The frequently experienced interruptions in the water distribution system cause agonies to many city residents. AAWSA has short term and long-term plans to improve the service delivery. In the short term (GTP II), some additional water sources and other management interventions are targeted. However, the implication of partially achieving these targets has not been explored yet. For instance, the current trend of developing new sources such as Gabriel and Sibilu dams is time taking. It is always difficult to predict changes in customers' behavior to reduce water losses.

Understanding people's perception can help identify barriers to behavioral changes that are needed to achieve sustainable water management (Dessi and Floris, 2010) and effective formulation and implementation of policies (Patt and Schröter, 2008; Askew, 2012). Public perception of water quality is a key factor that governs the use (Alameddine *et al*., 2017), willingness to pay, water conservation, pollution abatement, and trust in water utilities (McDaniels *et al.* 1998; Means, 2002; Doria, 2010; Rodriguez-Sanchez and Sarabia-Sanchez 2016). Only few studies are conducted to explore the gap between customers' expectations and their perceptions of the actual water service delivery (Mukokoma and Van Dijk, 2011). Most of these studies address rural water supply and only few of them address metropolitan cities.

It is expected that water supply service providers face increasing challenges in big cities. The service quality may vary across cities, but all face complex and interrelated problems. As noted by the World Bank (2012), recognizing the importance of the interconnections and inter dependencies between urban planning, resource management, and service delivery enable cities develop in efficient, clean, resilient, and equitable manner. There is a knowledge gap in understanding the interconnections and interdependencies of the various factors which affect water supply systems of big cities. The main problems facing AAWSA are summarized as follows:

1. *Overexploitation of resources and resource depletion*: The current fierce competition among water users on the available freshwater has aggravated resource depletion and compromised the water access to low income domestic users. Changing lifestyles, the construction of water intensive houses, improving living standard, changing climate, mode of service and affordability and others are putting pressure on the available water sources;
2. *Aged, inadequate and inefficient water infrastructure*: Water infrastructure in the city is as old as the city itself with severely deteriorated quality and capacity due to long years of service. This aging of infrastructures is likely to pose significant challenge to sustain and advance their achievements in protecting public health and the environment;
3. *Problems related to water demand and supply, water tariffs and cost recovery*: The present water price is not free of government subsidy since AAWSA is enhancing its sources without considering such factors like quantity, quality, reliability and safety of sources, water rights, environmental impact and others that are used to select sustainable source type;
4. *Problems related to water quality*: Most groundwater sources that are scattered in the city and downstream of the city are highly impacted by city residents. Many wells are abandoned due to water pollution by metals, fluoride, and nitrate. Industrial development in areas of present and future potential water sources is inducing water pollution;
5. *Problems related to distribution system and water loss*: The current water supply system has non uniform distribution with some areas getting water once in a week/two weeks. Water is highly concentrated in a few areas with a recorded water loss of over 37% due to inefficient water systems which are the major sources of water loss. Inefficient use and water loss at different points in the supply network has contributed to observed clear water poverty/scarcity;
6. *Problems related to wastewater*: The volume of water used by industries and the associated wastewater production is not clearly quantified since nonresidential vital water users have their own groundwater sources. Wastewater generated from such users is not exactly known by both AAEPA and AAWSA due to the absence of complete inventory and proper regulation. Such unlicensed wells might cause faster groundwater depletion. The existing wastewater has multiple sources. The existing infrastructure can cover only less than 7 percent of the wastewater generated;

7. *Problems related to institutional, financial, and human resources issues*: Weak institutions which are underfunded, politicized, ill- organized, and under staffed resulting in deteriorated infrastructure and low efficiencies. The absence of information technology application has complicated data management. Hence data are inconsistent, incomplete, missing out dated, and fragmented. Lack of integration among the operator AAWSA and its project office, AAEPA and major stakeholders is worsening the situation; and
8. *Problems related to policy and regulation*: The traditional engineering –oriented responses to water demand is the development of additional water supply is demand side management. Weak regulatory frameworks preferred over incentive-based approaches, lack of or outdated legal frameworks and no enforcement, water resources management activities are diffused and fragmented particularly in private well licensing Such fragmented approaches are expensive, not long-lasting solutions and lead to irreversible environmental deadlocks responsible for the current situation (Koloytha *et al*., 2002). The present study was conducted to contribute in better understanding of the future challenges facing the city of Addis Ababa water supply and water resource management, solve this problem by suggesting alternative management strategies and provide policy makers a wider range of solutions, understand water's interaction with other sectors to secure resilience under a range of future conditions.

1.3 Research objectives

The main objective of this study was to describe historic and future water supply relation between water supply and demand, customers' perceptions of their water services, scenario-based analysis of water balance to identify the cause – effect relation of the water supply current and future water supply situation of Addis Ababa City using an integrated scientific approach.

The specific objectives of the study were:

- Describe the status and trends of urban water consumption and supply in Addis Ababa City
- Show customer's satisfaction with their provision services of a metropolitan city in terms of quantity, quality and overall satisfaction
- Show scenario based analyzed water balance of the city Addis Ababa for the base line, short term and midterm planning horizons using plausible scenarios and water allocation model

- Identify the relationship the various factors affecting the performance of the water supply service of Addis Ababa city through Problem Tree Analysis

1.4 Research Questions

The following research questions were addressed here:

- How is the current water production allocated between different water user categories?
- Is there a spatial difference in the performance of the water service delivery?
- What is the satisfaction level of AAWSA's customers in its service delivery?
- Can problem tree analysis enhance our understanding of the root causes for the customer's dissatisfaction with Addis Ababa's water supply?
- What unmet demands can be expected if current trends are projected into the future?
- What are the implications of plausible scenarios for the relationship between the water production and demand of Addis Ababa city?

1.5 Significance of the study

Studying the past trends and current actual situations and the dynamics of Addis Ababa urban water services is believed to help to identify the pressing problems in the management aspects that hamper service delivery. Thus, the findings of this study are believed to be significant not only for Addis Ababa as lessons can be drawn from the water supply system of other African cities.

The current study could serve as input to the concerned development actors of the city to evaluate past development actions of urbanization and identify further intervention areas. It may also help policy makers to draw lessons to sustainable urban, peri-urban development policy formulation. Researchers can make use of this study to strengthen the application of environmental and livelihoods integrated evaluation approaches. It can also be used as a complimentary reference to the hardly existing urbanization evaluation literature.

1.6 Structure of the thesis

This thesis document is organized and presented with six chapters as described below:

Chapter 1: The background information is presented in this section. It also describes the research gaps, objectives and research questions which were addressed in this study.

Chapter 2: Literature review was presented in this chapter. The reviews address issues in urban water supply and synthesize findings of past scientific studies. The importance of studying perception and application of problem tree analysis is reviewed. The application of the WEAP model in different countries, especially in urban regions, was also highlighted.

Chapter 3: In this chapter, the materials and methods which were applied in this study were presented. This study was conducted in Addis Ababa for most issues and limited to Legedadi subsystem in case of WEAP model simulation. The study has employed both secondary and primary data sources which were collected through the application of household surveys, key informant interviews and personal field observations as well as document analysis. Thus, both qualitative and quantitative research methods were used. It shows that a number of approaches from both natural and social sciences have been applied to address the stated research objectives.

Chapter 4: This is a chapter on

4.1 ‘’Evaluation of past, present and future situation of Addis Ababa City water supply system’’. The organizational structure and functioning of AAWSA was described followed by a description of the past and present water supply system of Addis Ababa city by analyzing data, reports and documents from relevant organizations. The monthly data which was collected by AAWSA was analyzed to understand the historical state of the water supply system.

- 4.2 The section on” Customers’ Perception of qquality of urban water Service in Addis Ababa, Ethiopia’’ has tried to describe the perception of customers about their water supply in terms of water quantity, physical water quality and the overall performance of the water supply services.

4.3. “Situation Analysis of the water supply service in Addis Ababa with WEAP”. Here, WEAP model was used to compare the future unmet demand, supply requirement and supply delivered and examining the reliability of the water supply system. This section has presented the model result of proposed strategies under a set of scenarios.

4.4 “Root Causes to the lack of Urban Water Supply in Addis Ababa City’. In this section, a problem tree analysis was undertaken to identify primary, secondary and tertiary causes for the current water supply shortage in the city.

Chapter 5 The “Discussion’’ section links the findings in relation to the global literature and the promising strategy that were considered as the option to cope with water supply problems in the study area.

Chapter 6: The chapter on “Conclusion and Recommendations” presents a brief account of the generalizations made based on the findings of this study. It also includes some recommendations for future research and for long-term planning of the water supply system of Addis Ababa city.

1.7. Research Frame

This study has employed the following schematic diagram (Figure 1-1)as its research framework:

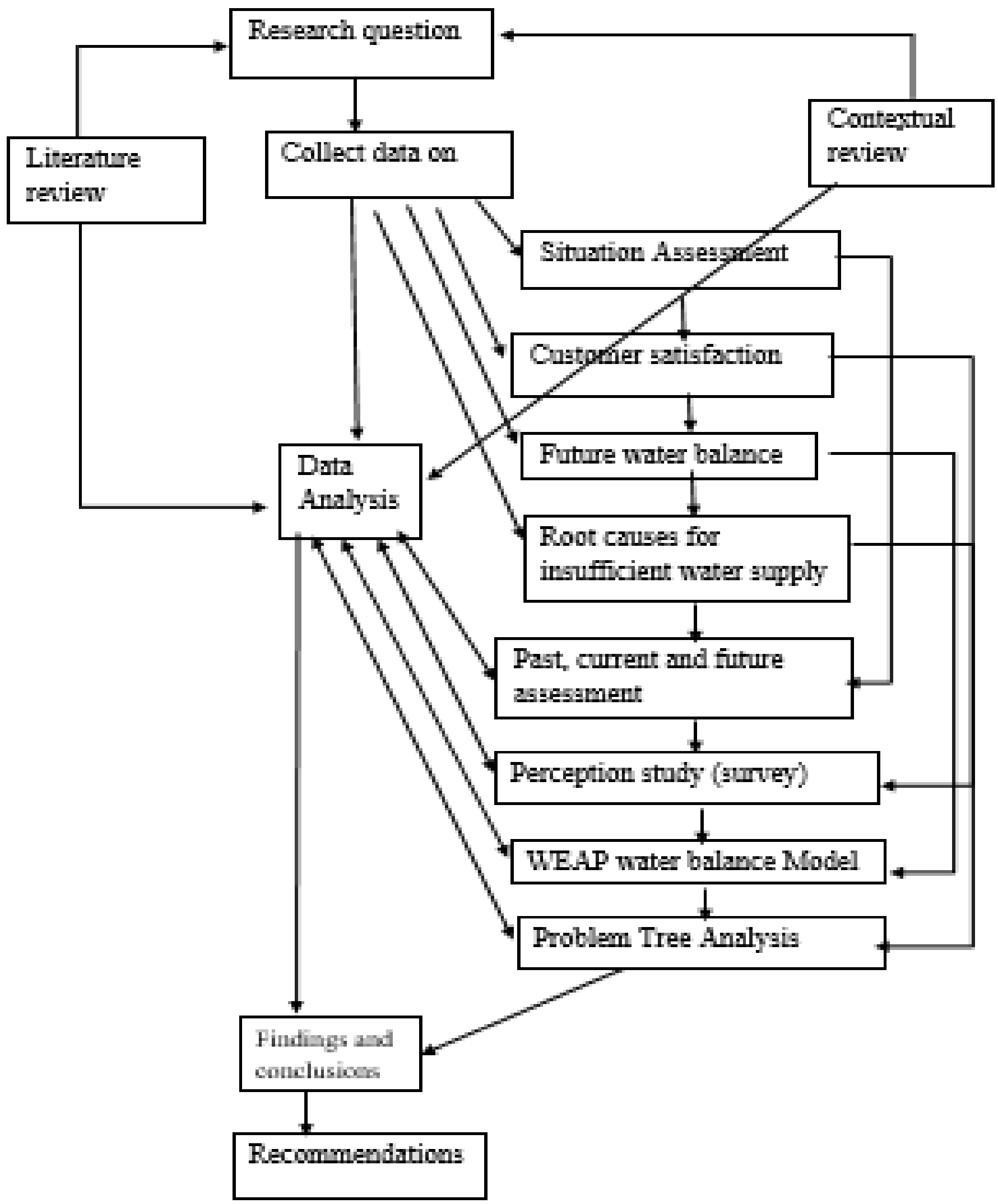

Figure 1-1:Schematic diagram of the Study framework

Chapter Two

2. Literature Review

2.1. Urban water supply

Water is the most vital public resource on earth for its indispensable role in sustaining life, ecosystems, economic and social values towards sustainable development of countries (Cutter *et al*., 2015). This precious and most important limited resource is unevenly distributed across space and time. The rising water scarcity is becoming a leading world problem (Chigwenya, 2010) particularly in urban areas of developing countries. Over 90 percent of the world's population now has access to improved sources of drinking water (WHO, 2015). According to the same source, in 2015 71% of the global population (5.2 billion people) used a safely managed drinking-water service – that is, one located on premises, available when needed, and free from contamination. 89% of the global population (6.5 billion people) used at least a basic service which is an improved drinking-water source within a round trip of 30 minutes to collect water. Yet, 884 million people lack even a basic drinking-water service, including 159 million people who are dependent on surface water with at least 2 billion people using a drinking water source contaminated with feces.

Providing sufficient, affordable and safe water and sanitation for all has become a critical challenge of increasing concern in the 21st century due to freshwater shortage, rapid population growth, water pollution, and unsustainable use of water resources, adverse climate change impacts, rapidly growing water demand and absence of cooperative water management frameworks. Water underpins many of the millennium Development Goals (MDGs) in that water is a vital role in food production, which constitutes one part of eradicating hunger, and water has a fundamental role in hygiene which is the main vehicle for reducing infections and child mortality (Jägerskog *et al*., (2015). But so far, less attention has been paid to it.

Water is explicitly included only in the targets of Goal 7of the millennium development goals though it is implied in others. The MDGs created momentum and constituted a vital instrument for focusing global attention on the lack of access to safe drinking water and sanitation. Consultative processes linked to the Post-2015 agenda highlighted the need to address the broader water agenda and the many institutional challenges such as lack of implementation capacity, weak stakeholder participation and unclear mandates within government structures (GWP, 2015; Jägerskog, *et al*., 2015). Among the 17 lists of proposed Sustainable Development Goals to be attained by 2030, list 6 (Goal 6) is secure water and sanitation for all for a sustainable world (Osborn *et al.*, 2015; ICSU and ISSC, 2015; UNDP, 2006). Goal 6 intends to ensure availability and sustainable management of water and sanitation for all.

Although there are few universal principles for sustainability, the ways of moving from those to policy implementation are many. Sustainable water system is part of sustainable development spurred by increasing urbanization, population increases, and climate change, the global issue of freshwater scarcity is likely to become more and more serious over the coming years (ICSU and ISSC, 2015; Hegerl *et al.*, 2015; Qiang *et al*., 2008; Wanger *et al*., 2002; UNDP, 2000). Sustainable urban development as a process which will necessarily vary between cities, and evolve in different ways in each city (Haughton and Hunter, 2004) and the very notion of what constitutes a sustainable city will change over time. If the problem is not addressed, there is a threat that several of the Sustainable Development Goals will not be reachable.

Urbanization, a major change taking place globally (Uttara *et al*., 2012) and a growing phenomenon around the world (Hunnes, 2012), is one of the most powerful and visible anthropogenic forces on earth (Cui and Shi, 2012). As a process, urbanization leads to the growth of cities due to industrialization and economic development (Uttara *et al*., 2012). The accelerated growth of urbanization is a relatively recent phenomenon. It is affecting global economic development (Zhao and Wang, 2015; Dociu and Dunarintu, 2012), energy consumption (Xiao-Ong *et al*., 2015; Zhao and Wang, 2015), natural resource use (Simms and de Loë, 2010), and human well-being (ICSU, 2011; WHO, 2005).

The global urban population that was 30 percent in 1950 reached 54 percent in 2014 and is projected to grow to 66 percent by 2050 (UN, 2014). The next few decades will be the most rapid period of urban growth in human history with 2.6 billion additional urban dwellers are expected by 2050 (UNEP, 2012; UN, 2014). Thus, all regions are expected to urbanize further over the coming decades. Africa and Asia are urbanizing more rapidly than other regions of the world with nearly 90 per cent of the increase expected to concentrate in Asia and Africa (UN, 2014). Nevertheless, these two regions, which are projected to reach 56 and 64 percent urban by mid-century, respectively, are still expected to be less urbanized than other regions of the world. The rate of urbanization is highest in Asia and Africa, where currently the proportion urban is increased by 1.5 and 1.1 per cent per annum, respectively (UN, 2014).
Addis Ababa increased its size from 37.4km^2 in 1970 to 230.35km^2 in1999 (UNEP/UNESCO, 2005) and now its size has reached 540km^2. Hence, the city expanded at a rate of 6.65 km^2/year. This rapid

urbanization will result in new water management challenges, particularly since an urban population in Sub Saharan Africa is expected to double over the next 20 years (Madlener *et al*., 2011). Ethiopia will be one of the countries in Africa having renewable water resources below the calculated threshold of 1500 m^3/ /capita/year by the year 2030 (Yang *et al*., 2003).

Surface water use and provision of quality services to a growing urban population underpins the success of future cities, enables them to act as poles of economic growth, at the core of social and economic development in an urbanizing world (Jacobsen *et al*., 2013). Urbanization is rising and driving water demand. Rapid urbanization can hinder the development of adequate infrastructure (Roudi-Fahimi *et al*., 2002) and has denied one billion people worldwide access to clean water supplies and half of the world's population lacks adequate water purification systems (Khatri and Vairavamoorthy, 2007).

2.2 Addis Ababa's water supply system

Addis Ababa is urbanizing and growing at a rapid pace. AAWSA is responsible for the supply of potable water as well as collection, treatment and disposal of wastewater and sludge for the city of Addis Ababa. This public institution is supervised by a board and directly responsible to the city manager. The city is already suffering from water scarcity that is expected to become even more significant due to rapid urbanization, increased individual water demand as incomes rises, and the impacts of climate change become real. The rapid growth of the city, the high rate of loss of water and the inadequacy of new source developing projects have an overall effect on the quality of water supply service of Addis Ababa city. The city is facing many infrastructural and environmental problems. High levels of water pollution (Gebre and Van Rooijen, 2010; Alemayehu, 2001), soil degradation and contamination (Melaku *et al*., 2007) are worsening the suffering.

Climate variability is affecting the water stored in reservoirs of Addis Ababa (Girma, 2012). According to AAWSA officials, Legedadi reservoir experienced a reduction of 1meter depth due to the 2015/2016 Ill Nino. Ayalew *et al.,* (2012) reported that future temperature of Addis Ababa will increase by 0.37°C per decade, accompanied with the projected increased precipitation amount. The increase in temperature and the change in rainfall will have adverse effects to the city due to its impact on flood occurrence requiring the city to have a more robust drainage system. The waste and storm water system of Addis Ababa City that drains towards River Akaki and finally to Lake Aba Samuel is compromising on the quality of the river making it very dreadful. This has in turn caused a critical, but the immeasurable extent of suffering on downstream users (Antonaropoulos and Associates, 2013). Both livestock and people use this polluted river water for domestic or irrigation purposes with grave sanitation hazards. The extent of the pollution is not only limited to the nearby downstream communities, but also far reaching to remote inhabitants using the Awash River.

2.2.1 Water supply sources

The metropolitan area of Addis Ababa is supplied with water from groundwater and three main surface water sources: Legedadi, Dire and Geffersa reservoirs. They are all situated in the upper northwestern awash sub basin. Intensive crop cultivation and free grazing by livestock, soil erosion, chemical pollution and siltation of Legedadi and Gefersa dams are becoming very serious problems. The situation has drastically reduced the water holding capacity of the dams worsening shortages in the water supply. AAWSA expends millions of Birrs annually for treatment of the dams. Water from Dire reservoir is transferred to Legedadi for treatment (Antonaropoulos and associates, 2012) and water from Gefersa dam are treated at the Gefersa treatment plant.

Akaki well field is situated south east of Akaki town at about 22 km south of Addis Ababa covering an area of about 16 km^2. Other groundwater sources include Akaki old city, Akaki New City, Akaki New City1, Akaki New City 2 well fields with different phases, Legedadi, Jemu, Asko, Mikililand, and other well fields with varying yields. There are scattered wells in the city, including Fanta, Asko Giorgis, Mikililand, Tsion Fuafate, Asama Erbata, and Abadir wells. The water wells located along the periphery of the city are capable of putting out 155,000 m^3d^{-1}.

2.2.2. Addis Ababa water supply system infrastructures

2.2.2.1 History and status of water supply in Addis Ababa City

Addis Ababa started getting piped water in 1901 (AAWSA, 2004). The first modern water supply system appeared when masonry channel was laid along Kebena River and the construction of earth dams around Sidist Kilo though 80milimter pipe in 1924. Increased demand and subsequent water supply shortages initiated the development of springs that originates from Intoto Mountain and other places. Several boreholes were also dug to augment the supply until the construction of the first dam, Gefersa I in 1942/43.

Water supply was gradually extended over the years when the main supply projects (Gefersa, Legedadi and Dire reservoirs; Akaki underground schemes together with a number of wells and springs scattered in and outside the city) came into operation (AAWSA, 2004). The distribution system was initially installed at the time the dams and treatment plants were constructed (1942-43 for Gefersa and 1970 for Legedadi). The existing treatment plants at Gefersa and Legedadi have design capacities of 30,000 and 165,000 (now improved to 195,000) m^3/d respectively. Raw water transferred from the two water treatment plants via ductile cast iron pipes is conveyed to the city through steel pipes. The water supplied for Addis Ababa return as a large volume of wastewater and contributes to the Akaki river flow. Today, most of the springs are abandoned due to water quality deteriorations. In 2016 the daily production capacity of AAWSA has reached 601,000 m^3.

2.2.2.2. Water supply sources of Addis Ababa city

The three surface water sources for the city of Addis Ababa are Legedadi, Gefersa and Dire reservoirs. They are all situated in the upper northwestern awash sub basin. Intensive crop cultivation and free grazing by livestock, soil erosion, chemical pollution and siltation of Legedadi and Gefersa dams are becoming very serious problems. The situation has drastically reduced the water holding capacity of the dams worsening shortages in the water supply. AAWSA expends millions of Birrs annually for treatment of the dams. Water from Dire reservoir is transferred to Legedadi for treatment (Antonaropoulos and associates, 2012) and water from Gefersa dam are treated at the Gefersa treatment plant.

Gefersa Dam: Gefersa dam, the first conventional surface water supply for Addis Ababa source is situated west of Addis Ababa along the road to Ambo town was originally constructed in 1942. It consisted of a masonry structure approximately 9 m in height. The dam was raised to 16 m crest height in 1955 which translated to an increased storage capacity of 6,200, 000 m^3. The operation of the treatment plant was commissioned in 1960. Gefersa III earth fill dam with an impoundment capacity of 1,200,000 m^3 and approximate height of 15 m and a crest length of 220 m was constructed in 1966 to augment the Gefarsa main reservoir. Gefersa subsystem comprises supplies from Gefersa water treatment plant to service reservoirs of Rufael, Saint Paul, and Ras Hailu. This first dam in the capital has the capacity to disperse 30,000 m^3/d.

Legedadi Dam.: Legedadi dam is situated to the east of Addis Ababa consisting of a rock fill section 22 m high and 600 m long, in combination with a concrete buttress 44 m high and 400 m long. It has a storage capacity of 44,000,000 m^3. Overflow is controlled by gates. The dam, together with its 50,000 m^3/d treatment plant, was commissioned in 1970. The treatment plant's capacity was increased to 150,000 m^3/d, by the completion of the expansion works in 1985. Legedadi subsystem includes supplies from Legedadi water treatment plant to service reservoirs of Kotebe terminal, Karalo, Ankorcha, Jan Meda, Gebrial Palace, Teferi Mekonnen, Entoto, Belay Zeleke, Police Hospital, Army Hospital and Kasa Gebre; and to pumping stations at Urale and Mexico Square. It churns out 195,000 m^3/d of water daily.

Dire dam: Dire dam is located about 10 km North of Legedadi dam. It was constructed in 1999 to complement Legedadi reservoir. Its impoundment capacity of 19,000,000 m^3 allowed the Legedadi treatment plant to operate to its design capacity. Height raising activities have started to increase by 1.25 m to enhance the volume capacity of the reservoir. The major characteristics of surface water supply source catchments are summarized in Table 2-1 below:

Table 2-1: Major characteristics of surface water sources

Name of reservoir	Legedadi	Dire	Gefersa I	Gefersa II	Gefersa III
Year of construction	1967-70	1999	1942-44	1955	1966
Capacity (10^6 m^3)	40	13	7	1	
Runoff (10^6 m^3)	70	40	27		
Surface Area (Km^2)	4.4	1.3	1.4	0.4	
Dam size (length, width) (m)	22, 600	46, 665 m	15, 150	18 m, 220	
Catchment Area (Km^2)	225	72	58		
Supply rate	127000	38000	30000		

Source: AAWSA (2002) Report

To augment surface water sources and alleviate water shortage in the city, AAWSA drilled deep boreholes in the southern part of the city that pump water to the system. Akaki well field is situated south east of Akaki town at about 22 km south of Addis Ababa covering an area of about 16 km^2. Other groundwater sources include Akaki old city, Akaki New City, Akaki New City1, Akaki New City 2 well fields with different phases, Legedadi, Jemu, Asko, Mikililand, and other well fields with varying yields. There are scattered wells in the city, including Fanta, Asko Giorgis, Mikililand, Tsion Fuafate, Asama

Erbata, and Abadir wells. The water wells located along the periphery of the city are capable of putting out 155,000 m^3d^{-1}.

Akaki well fields have yields of 43,000 m^3/d and 7300 m^3/d. While Akaki old city well field was put into operation in 2001, the new Akaki well field was commissioned in 2012. New Akaki City1 well field, which is situated about 15 km south of Addis Ababa (back of Gelan Condominium), started operation in 2012. Akaki subsystem includes the supply of water from Akaki well field to collection tanks namely Groundwater Collection Tanks GW1, GW2, and GW3 that are located at Kality, Saris Abo and Nefas Silk branch Office compound respectively), Bole Bulbula service reservoir and Lebu service reservoir.

2.2.2.3 Water supply system components

AAWSA's water distribution system comprises of service reservoirs, pumping stations, appurtenances and pipelines. Construction of the distribution system started in 1938 and continues until today. This system comprises water sources (dams and/or wells, springs), raw water collection structures or tanks, Akaki and Gefersa treatment plants, delivery system (distribution network/, transmission lines), service reservoirs, supply reservoirs, pipes, pumps and motors, Kality WWTP, Kality and Kotebe sludge drying beds, different appurtenances and other essential accessories as its main infrastructures as depicted in Figure 2-1 below

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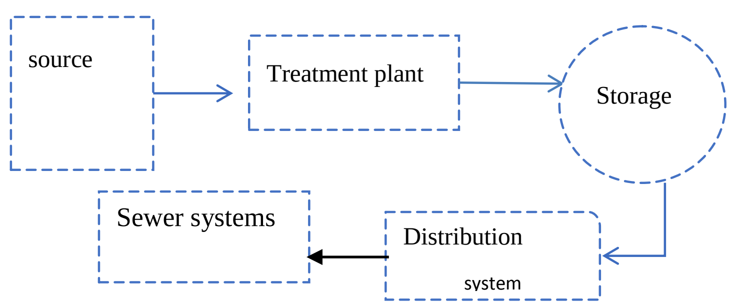

Figure 2-1 : Major infrastructure of the urban water system

Climate variability is affecting the water stored in reservoirs of Addis Ababa (Girma, 2012). For instance, Legedadi reservoir experienced a reduction of 1meter depth due to the 2015/2016 Ill Nino. Ayalew *et al.*, (2012) reported that future temperature of Addis Ababa will increase by 0.37°C per decade, accompanied with the projected increased precipitation amount. The increase in temperature and the change in rainfall will have adverse effects to the city due to its impact on flood occurrence requiring the city to have a more robust drainage system. The waste and storm water system of Addis Ababa City that drains towards Akaki River and finally to Aba Samuel Lake is compromising on the quality of the river making it very dreadful. This has in turn caused a critical, but the immeasurable extent of suffering on downstream users (Antonaropoulos and Associates, 2013). Both livestock and people use this polluted river water for domestic or irrigation purposes with grave sanitation hazards. The extent of the pollution is not only limited to the nearby downstream communities, but also far reaching to remote inhabitants using the Awash River.

2.2.3 Water quality

Water quality data analyzed from desk reviews of previous studies are summarized below: At present, most water sources are being contaminated with municipal sewage, industrial waste, industrial toxics, heavy metals, fertilizers, chemicals, radioactive substances, land sediment, and oil as noted by Abate (1994).

Although all streams in the upper part are free from pollution, the water quality at the lower part of the city has deteriorated gradually by organic pollution from domestic and municipal wastes. The problem is exacerbated during dry seasons when the flow of most streams is low (Berhe, 1988). Many industries are discharging industrial effluents into Little and Greater Akaki Rivers. There is an increasing concentration of heavy metal pollution, coliform and pathogen pollution in the surface water and groundwater sources (Alemayehu *et al*., 2003). Nitrate concentrations of higher than the accepted normal concentration of 10 mg/l were found in Surface water. Similarly, a study by UNEP/UNESCO (2005) has found high bacteriological concentrations in various groundwater bodies (springs, boreholes and dug wells). Downstream concentration of both *total coliforms* and *E. coli* was higher than upstream (**TABLE 2-2**).

Table 2-2: Concentrations of total Coliforms and E. Coli in major surface water of Addis Ababa City in January 2005 (based on Haile and Abiye, 2012)

Stream	*Total coliforms (per 100ml)*	*E.* coli*/100ml*
Little Akaki Upstream	2.4×10^{4}	2.4×10^{4}
Little Akaki down stream	3.5×10^{6}	3.5×10^{6}
Big Akaki upstream	*170*	*2*
Big Akaki downstream	5.4×10^{5}	2.4×10^{5}
Lideta River	5.4×10^{6}	5.4×10^{6}

The above finding suggests that the quality of groundwater in Addis Ababa is influenced by the quality of Surface water (rivers) and availability of pollution sources near by the water points. Many water professionals including Jafar *et al*. (2013) classify groundwater quality into excellent, good, poor, very poor and unsuitable for drinking based the water quality index that takes into account the nine parameters (pH, Total Dissolved Solids, Total hardness, Calcium, Magnesium, Sulphates, chlorides, fluorides and nitrates) where the index values are less than 50, 50-100, 101-200, 201 -300 and more than 300 in that order. Similarly, Tsegaye (2014) has reclassified the groundwater sources of Addis Ababa into four classes as flows based on his findings (Table 2-3).

Table 2-3: The four classes of groundwater sources

No.	Area (km^2)	Percent (%)	Water class
1.	422.17	78.18	Excellent
2.	112.62	20.86	Good
3.	4.87	0.9	Poor
4.	0.34	0.06	Very poor

Source: Adapted from Tsegaye (2014)

With regard to the quality and pollution status of Addis Ababa city water supply situation, Shitie (2011) has detected total coliforms in few water samples but within the permissible limits of WHO and Ethiopian Standard guidelines for drinking. The same study has also shown high electrical conductivity and toxic substances such as nitrates, phosphate and iron that displayed unexpectedly higher values and significant spatial variations. Secondary bacteriological analysis of time series data indicates occasional records in the piped waters. Microbiological analysis of raw water sampled from Legedadi and Gefersa showed *Total Coliforms* and Fecal Coliform >1MPN/100ml (most probable Number) (Shitie, 2011). Such observations can be associated with human activities.

The Total Coliform value of more than 1 MPN/100 ml observed at Akaki reservoirs and tap water might suggest inadequate treatment and possible regrowth or biofilm formation in the distribution system. The same researcher has recorded levels of iron exceeding the WHO guideline value of 0.3mg lit^{-1} in drinking water. This concentration was found to be higher in surface water than in groundwater. Contrary to the decreased value of iron concentration of surface water after treatment, the few enhanced cases could be related to corrosion of pipes and local breakage. Dependence only on single pump tests is not reliable in indicating both water quantity and quality. Some wells were abandoned at different location at different time such as the one around Lideta because of excess nitrate having a concentration value of greater than 50 ppm and three wells around CMC were abandoned due to excess fluoride. Excess Iron and Manganese wells are common in many parts of the city. These common water contaminants are not health hazards except they may cause offensive taste, appearance, and staining.

Industries don’t treat their effluents but release them into the nearby water bodies such as big Akaki River. Opposed to AAWSA’s claim of 99.3% quality water provision, the above findings and the abandoning of many wells and springs in different parts of the city due to high levels of nitrate, manganese, and Iron as reported by the utility’s anonymous professionals suggest that water quality is an issue of further investigation in Addis Ababa water supply system.

2.3. The importance of perception studies

Perception refers to a range of judgments, beliefs, and attitudes (Anderson *et al*., 2004). It can be viewed as an individual’s feeling of pleasure or disappointment resulting from comparing a product’s or service’s perceived performance (outcome) in relation to his or her expectations (Angelova and Zekiri, 2011). In the context of this study, perception can be defined as the valued judgments of the stakeholders relating to the infrastructural facilities of municipal towns (Alam *et al.*, 2011). It should be noted that the reception of stimuli and previous individual experiences comprises an individual interpretation of the surroundings (Schiffman and Kanuk, 2010). Perception is a personnel phenomenon in which the reception of stimuli and previous individual experiences comprises an individual interpretation of the surroundings (Schiffman and Kanuk, 2010). It can be viewed as an individual's feeling of pleasure or disappointment resulting from comparing a product's or service's perceived performance (outcome) in relation to his or her expectations (Angelova and Zekiri, 2011). Perceptions refer to a range of judgments, beliefs, and attitudes (Anderson *et al*., 2004). Parasuraman *et al., (*1985 and 1988) have provided a basis for this common understanding based on the gap between the customer's expectation and their perceived experience of performance.

Perception patterns are analyzed through the basic understanding of the behavior of the people in terms of their opinion, attitudes, and levels of satisfaction. These parameters are taken as proxy to evaluate how much customers are getting and what their expectations are. Perceptions are important to study about urban infrastructure since there is a wide gap between minimum entitlement of the service provisions and the supply constraints of authorities (IIR, 2006). Hence, perception studies are usually conducted in urban water facilities; sanitation and waste management facilities; road and transportation facilities; educational facilities; and health facilities (Haque, 2016).

Water demand management strategies are strongly underpinned by an understanding and knowledge of how consumers perceive and use their water (Jones *et al*. 2010; Jorgensen *et al*. 2009). Beal *et al*. (2011) have shown that householders' perceptions of their water use are often not well matched with their actual water use. Contrary to this, there has been less research investigating whether this bias is related to specific categories of end use and/or specific types of social-demographic and socio-psychological household profiles.

A perception can be deceiving, especially when one considers the role and involvement of various actors in the establishment process (Karar, 2017). It may also become complex when stakeholders bring with them their own issues, perceptions, expectations and interests. As noted by Guyot-Téphany *et al.* (2013), negative perceptions regarding the quality of available water reinforce such practices: Why should someone care about reducing consumption when their tap water is barely good enough to wash the dishes?

We can obtain perception data from survey of stakeholders' opinions through a structured questionnaire. As the end use of water is influenced by a number of subjective water use practices within a household, surveys or questionnaires provide important information about water users. Perception data in combination socio-demographic information can facilitate the identification of correlations between water behaviors and key demographic subsets within a population (e.g. Income, age, gender and family composition). High numeracy scores, older age, and male sex were associated with more accurate perceptions of water use (Attari, 2014). The same author reported that the overall perception of water use is more accurate than the perception of energy consumption and savings.

Customer satisfaction is an abstract concept with varying actual manifestations and thus conceptualized differently (Oliver, 1981; Parasuramann *et al. 1985*; Brady and Robertson, 2001; Kaplan, 2005; Benington, 2007). Customer perceptions of a service provides solid base for understanding what influences customer perceptions of service and the relationships among customer satisfaction, service quality, and individual service encounter. Customer perception demonstrates the meaning and importance of customer satisfaction, the factors that influence it and the significant outcomes resulting from it. Perceptions are strongly linked to behavior as they can predict or change behavior (Petrescu, 2013) and they sometimes become the reality replacing the objectively measured facts especially when it comes to the quality of drinking water (Sheat, 1992). Such public perceptions tend to be often worse than what is suggested by actual water quality assessment (Mc Daniels *et al.,* 1998), Lazo *et al.*, 2009 and Larson *et al*. 2009).

Combinations of different factors including changes in the social role of science, complexity and uncertainty contributes to the emergence of the general public as an important factor in water management (Doria, 2010). Thus, citizen feedback is considered an effective means for improving the performance of public utilities (Deichmann, and Lall, 2003), one reason to study them. Some limitations of perceptions are:

1) Households' perception of their water is often not well matched with their actual water use (Beal *et al.,* 2011);

2) Customers know that they need pressure, know if they don't have water out of their tap but beyond that they have only a small understanding of "the what is" required to run a safe and efficient water supply system;

3) Failing to quantify and/or dismissing public perception can be damaging towards the survival of modern water providers and has been linked to the worrying trend of consumers abandoning tap water in favor of bottled water, and the inability of utilities to fulfill their central mission of

providing adequate supplies of acceptable-quality at a reasonable cost (Means. 2002 and Baroque, 2003); and

4) Different factors including human sensory perceptions of taste, odor and color of water are related with mental factors.

Understanding people's perception can help identify barriers to behavioral changes that are needed to achieve sustainable water management (Dessi and Floris, 2010) and effective formulation and implementation of policies (Patt and Schröter, 2008 and Askew, 2012). Public perception of water quality is a key factor that governs the use (Alameddine *et al*., 2017), willingness to pay, water conservation, pollution abatement, and trust in water utilities (Mc Daniels *et al.* 1998; Means, 2002; Doria, 2010; Rodriguez-Sanchez and Sarabia-Sanchez 2016). The few studies conducted to explore the gap between customers' expectations and their perceptions of the actual water service delivery improvement (Mukokoma and Van Dijk, 2011) are to support prioritization in developing water service delivery improvement

2.4. Decision making in water management

The constantly shifting conditions of the urban water cycle are continually impacted by changes in population, urban development, wealth, politics, technology, climate, and others in a multitude of different ways (Philip *et al*., 2011). Estimating the current and future impact of these changes on water supply and demand is not an easy task. Still, urban water managers have to take decisions today that are the right ones for coping with future change. This involves proper planning and decision making for average lifetimes of infrastructures which may exceed 50 years. Planning is a continuous process, which involves decisions, or choices, about alternative ways of using available resources, with the aim of achieving particular goals at some time in the future (Conyers and Hill, 1989).

System dynamics is a problem evaluation approach which is based on the premise that the way essential system components are connected generates its behavior (Richard and Pugh, 1989; Sterman, 2000). It is not a new way of modeling future dynamics of complex systems (Stave, 2003). Sharifi and Rodriguez (2002) have stated that model-based planning support systems are useful to support logical, rational and transparent decision-making processes. They have developed and used the following framework for the planning and decision-making process for policy formulation in water resources rehabilitation:

- Define and describe the system in terms of content, environment, boundaries, space and time: ‘description and representation’.
- Understand how the system operates, which requires establishing the functional and structural relationships among its elements: ‘process/behavioral model of the system’.
- Assess the current state of system, and see if is desirable (the system is currently working well?) which requires the ability to appraise and judge the current state of the system: ‘evaluation of current situation/problem formulation’,
- Formulate objectives, clarify the goals and objectives of the decision and identify what should be achieved, and how the achievement should be measured.
- Study the ways that the current state of the system can be altered or improved, in terms of actions, time and space, which requires development of a simulation model to generate the required type of changes: ‘planning model’,
- Simulate different states of the system under desired changes: development of alternative options, plans, and scenarios,
- Assess the impacts of the different changes introduced, scenarios: ‘impact assessment /effects. and
- Decide on the type of changes: ‘decision’ which requires the comparative evaluation of impacts of alternatives changes, and decision on the change or conservation of the system as it exists: ‘evaluation and decision/choice’

Decision making must consider a range of different, and often conflicting, needs and opinions since the numerous stakeholders’ influence, or are influenced by, urban water management. A Decision support system does not make decisions but rather manages and presents information in a way that is easily understandable by decision makers. It is a tool to learn from past actions and explore potential interventions. Thus, it can be used for the following purposes within an integrated approach to decision making:

- Assessing the impact of different strategies through holistic evaluation of the system (Ong and Salle, 2014);
- Optimizing potential interventions based on defined criteria; analyzing the likely response of the system under different future scenarios (Montibeller and Franco, 2010); and
- Providing a data storage facility and source of knowledge. In order to perform these functions, a decision support system will usually consist of the following three integrated components: knowledge database, modeling programs, and user interface.

2.4.1 Issues in decision making in urban water supply

The consequences of decision making in urban water management should not be overestimated due to many unknowns in the future (Larson *et al*., 2015). Among the variety of reasons for bad decisions in the water sector, making decisions based on knowledge that is limited to a particular sector and/or narrowly defined assessment criteria; and deciding based on assumptions on how the future will pan out stand out most important. The authors have outlined the following as reasons:

Lack of data: accessing and interpreting data, making can be time consuming and costly;

Fragmentation of the water sector: The different sectors of often operate in isolation from one another, resulting in a lack of incentive and/or ability to consider impacts outside of the main area of responsibility;

Limited perception of future variability: The design of most standard water management interventions relies on assumed future conditions taking decisions based on a defined range of future variability which is difficult to predict;

Exclusion of data: while criteria such as construction costs and amount of water delivered are easy to quantify and make use of in a decision-making process, indirect criteria such as environmental and social costs and benefits are more difficult to put a figure to which disguises their true value and reduces their influence; and

Lack of stakeholder engagement: Stakeholder engagement in water management decision making process often extends no further than the public announcement of a decision that has already been taken.

2.4.2 Integrated urban water resources management

Growing pressures on water resources, increasing interdependencies between users, uncertain impacts of climate changes, the use of modern precision technology and an associated increase in demands for reliable water services are some of the factors underlying an ever-increasing complexity in water resources management. The management of water supply, sanitation and storm water has not occurred in concert, rather each has been planned and delivered as an isolated service missing the interconnections among problems and potential solutions. This has resulted in the main today's question of how-to best support stakeholders in managing their water demands in a context of increasing competition and interdependency (Hermans *et al*., 2006).

Urban water management sits within a highly demanding decisional environment where optimal planning, pre-supposes a synthesis of complex, heterogeneous information and data of varied spatial and temporal resolution but which must focus on site-specific implementation (Ellis *et al*., 2011). The way urban water is managed influences almost every aspect of our urban environment and quality of life. Conventional urban water management practice is the tradition of managing the elements of the urban water system as an isolated service and has resulted in an unbalanced urban metabolism (Novotny, 2010) as well as separated issues from broader urban planning process (Bahri, 2012). This model has failed to distinguish between different water qualities and to identify users for them (Steen, 2006). It has been found wanting in its ability to address key challenges for growing cities such as increasing competition for water, sanitation and storm water management and water resources protection (Loucks and Van Beek, 2017). It appears to be outdated given the challenges posed by urban growth and climate change (Bahri, 2012).

The characteristics of conventional approaches to urban water management are: storm water collection and disposal using concrete channels and pipes, centralized wastewater collection and treatment, increased water demand is met through new supplies, standard engineering solutions are applied, different sectors of the water cycle are managed separately, lack of integration, lack of flexibility, and energy intensive. This has resulted in the diversion of high –quality water for indiscriminate urban water needs, in the process contributing towards resource scarcity. Owed to the failure of the traditional urban water-management model to distinguish between different water qualities and identify uses for them, high-quality water has been diverted to indiscriminate urban water needs (Steen, 2006).

On the other hand, integrated Urban Water Management (IUWM) calls for the alignment of urban development and basin management to achieve sustainable economic, social, and environmental goals. It brings together water supply, sanitation, storm- and wastewater management and integrates these with land use planning and economic development (GWP, 2013) Cross-sector relationships are strengthened through a common working culture, collective goals and benefits are better articulated, and differences in power and resources can be negotiated. IUWM includes assessments to determine the quantity and quality of a water resource, estimate current and future demands, and anticipate the effects of climate change (Bahri, 2012). It is being considered in many cities around the world as a response to the water scarcity and increasing demand for water for both human consumption and meeting environmental needs. This emerging and alternative approach for urban water utilities to plan and manage urban water systems is seen by some urban water managers as a response to societal and statutory demands for multiple-bottom-line outcomes (Gabe *et al.*, 2009). IUWM is managing freshwater, waste water and storm water as components of a basin-wide plan in an urban area (Sunita, 2012). It is the practice of managing fresh water, wastewater, and storm water as links within the resource management structure using an urban area as the unit of management.

It seeks to develop efficient and flexible urban water systems by adopting a diversity of technologies to supply and secure water for urban areas. It can be applied to any urban area by any water utility that is wishing to make the most of its water resources while minimizing impacts on the environment. In addition to improved planning and management, the efficiency of securing and sustaining water resources for expanding cities can be increased through the implementation of alternative solutions like: innovative technologies planned around new urban clusters; decentralized infrastructure, and diversification of water sources. Best management practices can cope with (be easily adapted to cope with) a wider range of rainfall runoff rates than underground drainage pipes with fixed diameters (Table 2-4).

Table 2-4: Comparison of conventional and integrated approaches of decision making

Aspect of decision-making	Conventional approach	Integrated approach
Scope of the decision-making process	Single management sector	Urban development as a whole
Future uncertainty	The future is predicted as a fixed scenario	The future is acknowledged as being uncertain
Use of indicators	Performance indicators, limited set of sector goals	Sustainability indicators overall urban development

2.4.3. Water Resources management models

Accurate and informative integrated water models can help water managers better understand current and future issues within their catchment. Water resources planning and management, which was generally an exercise-based on engineering considerations in the past, is nowadays increasingly occurring as a part of complex, multi-disciplinary analysis that brings together a wide range of individuals and organizations with different interests, technical skills, and options (Yates *et al*., 2005; Hamlat *et al.*, 2013). Thus, successful planning and management of water resources requires application of effective integrated water resources management (IWRM) models that can solve the encountering complex problems in these multi-disciplinary investigations (Loucks and Van Beek, 2017; Laín, 2008).

As noted by Watkins and McKinney (1995), water resource planning and management processes aided IWRM models have become more common, however generic tools that can be applied to different basin settings are frequently difficult to use because of the complex operating rules that govern individual water resource systems. Water resource models can simultaneously incorporate and operate hydrology and management processes, are needed to help planners under different reality cases and management options (Yates *et al.*, 2005). The models must be effective, useful, easy-to-use, and adaptive to planners' priorities while dealing biophysical system, which create runoff generation and its movement, and the socioeconomic management system, which create water storage, allocation, and delivery.

2.5. WEAP

Water Evaluation and Analysis Planning (WEAP) is a computer tool for integrated water resources planning and provides a comprehensive, flexible and user-friendly framework for policy analysis. It incorporates water supply side and water demand side issues as well as water quality and ecosystem preservation issues (SEI, 2011). It simulates water supply system operation of a city on a user defined time step; computes the water mass balance for all water supply and demand sites, and evaluates and forecasts water development and management scenarios for the future (SEI, 2011; Hamlat *et al*., 2013). Its analysis results assist planners and water supply authorities in developing recommendation for future water supply and demand management.

WEAP model description:

WEAP is developed by the Stockholm Environment Institute's US Center (SEI-US). The current version is officially labeled as WEAP21 to distinguish from previous versions. WEAP21 combines water resources planning and management with a selection of conceptually simple models for watershed hydrology. It operates on the basic principle of a water balance and can be applied to a single watershed or the complex trans-boundary river basin (Yates *et al*., 2005; Psomas *et al*., 2016). Water allocation is performed by using linear programming on a daily or monthly basis.

It takes into account the schematization approach for the physical system (Riepl, 2013). The components of the natural system (catchments, aquifers, rivers and lakes) and the components of the technical system (reservoirs, boreholes, diversions, pipes, canals, cities, wastewater treatment plants, hydropower facilities and irrigated farms) are schematized using a network of interconnected model elements without geographical reference.

Model elements can fall into two main categories: nodes, where water is demanded or made available for supply, and links, which transfer water between the nodes. WEAP21 allows the user to specify demand priorities, supply preferences and environmental requirements for the various nodes. WEAP21 allows for the introduction of user-defined variables and scripts, dynamic links to spreadsheets, coupling with water quality, groundwater and energy models, flexible scenario building and analysis and visualization of model variables or output results (Sieber and Purkey, 2015).

Applications of WEAP model:

The WEAP model was first developed in 1988 with its first major application of studying water development strategies and water supply-demand analysis (Raskin *et al.,* 1992). It has the capability for a multiple-use river and reservoir (Johnson, 2010) although it has several limitations relating to allocation scheme, demand sites priorities, water allocations. Over the years, a modern Graphic User Interface and a robust solution algorithm to solve the water allocation problem were introduced. It also integrated hydrologic sub modules such as a conceptual rainfall-runoff model, an alluvial groundwater model, and a water quality model (Yates *et al*., 2005).

WEAP has been applied in many countries and river basins over two decades (Arranz and Mc Cartney, 2007; Mc Cornick *et al*., 2002). The application of the WEAP model can support integrated water resources management, sustainable water use, and to project the impacts of population growth and climate change on urban and environmental water demand and supply. Van Loon and Droogers (2006) have shown that WEAP is a powerful framework in the evaluating of current and future options of water resources, and evaluation can be performed within a few minutes by adding more accurate data to increase the accuracy of the analysis and validation of results. Assaf and Saadeh (2006) applied it to evaluate future scenarios for water quality control.

WEAP modeling allows discussions and dialogue among decision makers and local stakeholders, and promotion of public awareness and understanding of key issues and concerns (Lévite *et al*., 2003). It also provides a structure that allows a broad range of studies to be implemented using the built-in models.

The WEAP model was applied to major agricultural regions in Argentina, Brazil, China, Hungary, Romania, and the US to evaluate future scenarios about climate change, agricultural yield, population, technology, and economic growth (Rosenzweig *et al*., 2004). Purkey *et al*., (1998) used WEAP in the groundwater banking feasibility study in California by analyzing hydrology, legal and institutional, operation and economics aspect. Strzepek *et al.* (1999) introduced new methods of linking integrated water resources management models (WATBAL for water supply, CERES, SOYGRO, CROPWAT for crops and irrigation modeling, and WEAP for planning and water demand forecasting) with climate change scenarios for the study of future water availability in the U.S. Cornbelt's agriculture. WEAP's limitations can make it challenging to extend into areas that do not fit the situations for which WEAP is designed (Sieber *et al*., 2005; Yates *et al.*, 2005). The main limitation is an access to calculations. For instance, users cannot access the linear programming model to modify as per their needs. This can be significant limitation where short-term dynamics.

WEAP model is applied in Ethiopia for the following purposes:

- Assessing the impacts of existing and future demand on economic and environmental aspects (Shumet and Mengistu, 2016);
- Development of water allocation and utilization systems for Koka reservoir under climate change and irrigation development scenarios (Fufa, 2016);
- Simulating current and future water demand in the Blue Nile CP19 project (McCartney *et al*., 2009);
- Water and land management in the Ethiopian Highlands (Awulachew, *et al.*, 2009);
- Modeling of surface water resource allocation in a sub basin (Adgolign *et al.*, 2016);
- Analyzing water use and demand in Tana Basin (Hoff *et al.*, 2007),

WEAP application includes the following steps (SEI, 2011):

- Setting up the study definition, which includes the spatial boundary, the time frame, the system components, and the configuration of the problem;
- Entering data on the current accounts, which provides an overview of the actual situation of the system (water demand, supply resources, pollution loads), and can also be viewed as a calibration step in the development of an application;
- Creating key assumptions in the current accounts, if necessary, which represent policies, costs and factors that affect demand, pollution, supply, and hydrology;
- Building scenarios on the current accounts, which can be explored the impacts of alternatives on the future water supply and demand; and

- Evaluating scenarios, regarding with water demand coverage, costs, compatibility with environmental targets, and sensitivity to uncertainty.

2.2.1. Problem tree analysis methods for urban water supply planning

The problem tree method is a planning method used based on needs. The problem trees establish cause and effect to ensure that root problems are identified and then addressed. As a participatory planning technique, problem tree analysis was used to overview all the known causes and effects of the identified problems based on the above three sections of the situation analysis studies. Problem Tree Analysis is a participatory planning technique which provides an overview of the known causes and effects of the identified problem. It creates ownership and commitment among the involved parties: beneficiaries, implementing organization, and local government. It is of prime importance with regard to project planning since it strongly influences the design of the possible interventions (Cervante *et al*., 2008). Problem tree analysis also called situation analysis or just problem analysis helps to find solutions by mapping out the anatomy of cause and effect around an issue in a similar way to a mind map, but with more structure. This brings several advantages. It includes definition of the framework and the subject of analysis; identification of problems faced by target groups and beneficiaries; and visualization of the problem in the form of a diagram, called "problem tree" to help analyze and clarify cause-effect relationships (EC, 2004). The problem Tree shows the main problem by the trunk, the causes of the core problem by roots while the branches represent its effects.

The problem tree analysis is essential to many forms of project planning of water supply systems. Both demand and supply side management of a water supply project should be based upon a correct and complete analysis of the existing situation to address the real needs of the beneficiaries. Hence, applying the problem tree method supports the identification of the main problems along with their causes and effects. Thus, it helps experts and project planners to formulate clear and manageable objectives, how to improve and make sanitation and water system more sustainable. The process can be a useful method in building a community's awareness of the problem, how they and others contribute to the problem, and how these problems affect their lives.

ODI (2009) has summarized the advantages of the problem tree as follows:

- It can be broken down into manageable and definable chunks enabling a clearer prioritization of factors and helps focus objectives;

- It helps to a better understanding of the problem and its often interconnected and even contradictory causes which is often the first step in finding win-win solutions;
- It identifies the constituent issues and arguments, and can help establish who and what the political actors and processes are at each stage;
- It can help establish whether further information, evidence or resources are required to make a strong case, or build a convincing solution; and
- Present issues rather than apparent, future or past issues that are dealt with and identified. The process of analysis often helps build a shared sense of understanding, purpose and action The disadvantages of this method include: it may be difficult to understand all effects and causes of a problem right from the beginning, requires time to bring all relevant actors together and to discuss the problems of their water and sanitation system.

Chapter Three

3. Materials and Method

3.1 Study area description

This study was conducted in Addis Ababa city (Figure 3-1). It was founded by Emperor Menelik II in 1886 (Tegegne *et al*., 2015) although others have recorded in 1887 (UNCHS, 2000). Based on the 2003 revised city charter, the structure of the city government is categorized into three tiers of administration: city government, 10 sub-cities and 116 local districts (details are appended at Appendix A-1).

Addis Ababa was selected as the study area since it has vital role in every field such as an engine of growth and sources of environmental problems coupled with its projected rate of urbanization, and the concomitant pressures on resources which made this city increasingly important unit of integrated water management. The city is currently confronting with increased demand of provision of water supply and other associated socioeconomic development of domestic and other facilities owed to the city's rapid horizontal expansion and spontaneous growth as its spatial, physical and socio-economic conditions are by far behind the requirements fundamental to sustain its livelihood like the situations of other cities (GWP, 2011).

Location-Addis Ababa is located in the middle (heart) of the country between 8º55´-and 9º05´ North latitude and 38º40´-38º50´ East longitude (Mahiteme, 2007). The city is surrounded by mountains (Figure 3-1). Its altitude varies between 2300 m in the south of the city and 3.000 m in the north (CGAA, 2013). Its physical landscape is a mixture of undulating and rugged topography in the northern and central parts of the city, while relatively gentle morphology and flat areas characterize the city's southern reaches (Mahteme, 2008).

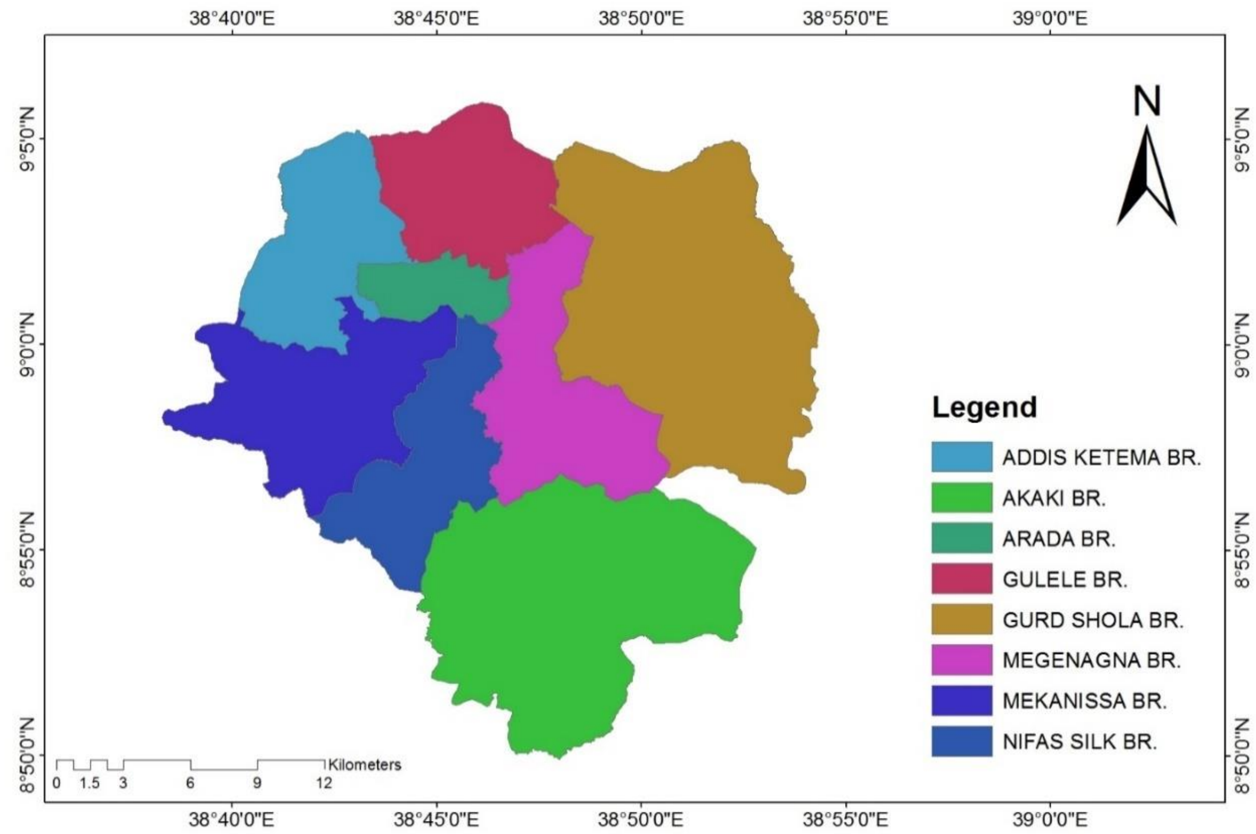

Figure 3-1: Location map of the study area with its water supplying branches

Spatial extent: There exists an inconsistency in the area coverage as reported in literature. It is estimated to enclose a total surface area of 540km^2 (Mahiteme, 2007) while Kifle (2002) has reported a value of around 530 km^2. Other sources also indicated smaller sizes of 526.99 km^2 (Kassa *et al*., 2011), and 519.76 km^2 (AAWSA, 2011). About 220 km^{2}of the city is allocated for green area (for forests, Parks, River Buffers, and urban agriculture) where vegetation cover of the city is 15 % (80 Km^2). The built-up area in Addis Ababa was expanded by about 53% of from mid-1970s to late 1990s. Current socio-economic activities in the city suggest that the city is expected to expand even more.

Drainage: As a fast-growing urban center Addis Ababa faces many infrastructural and environmental problems. Insufficient waste management is among the crucial problems. Tributaries of Big and Little Akaki Rivers with catchment areas of 900km^2 and 540km^2 drain the city from north to south and serve as natural sewerage lines for domestic and industrial wastes and thus they are known for their offensive odor (Alemayehu *et al*., 2005).

Population: The total population of the city is 3, 273,000 based on July 2015 CSA projection, although UN-HABITAT (2010) has reported a population size of 3.5 million although the 2014 AAWA report has estimated the population served at 3.64 million. With the current population growth rate of 2.1%, the city's population is estimated to reach 5 million after 10 years. The city is currently experiencing high social, economic, and structural changes.

Due in large part to the rapid urban population growth and migration, the number of urban Addis Ababa residents is increasing very fast. Both urban-urban and rural-urban migrations are important in Addis Ababa (UNCHS, 2000). The main reason for high migration to the city of Addis Ababa is an economic reason as the city enjoys a relatively higher concentration of facilities, infrastructure and industries compared with other parts of the country.

Rainfall: Addis Ababa has mild, Afro-Alpine temperate climate with dry winters from middle of November until January, a dry season from February until May and a rainy season from June until the middle of September. The nine climate data collection stations and LTM Rainfall depth of the ten sub-cities are appended in Appendix A-2 and Appendix A-3 respectively. The mean annual rainfall values of Addis Ababa were estimated by inverse distance squared weighting method for the period 1995-2015. The data were obtained from 8 rain gauges which are operated by National Meteorological Agency. The mean rainfall depth of Addis Ababa is estimated as 1086.4 mm. It decreases from Northeast towards the southwestern part of the city. The spatial distribution of the average rainfall of Addis Ababa in its sub sites is presented in (Figure 3-2).

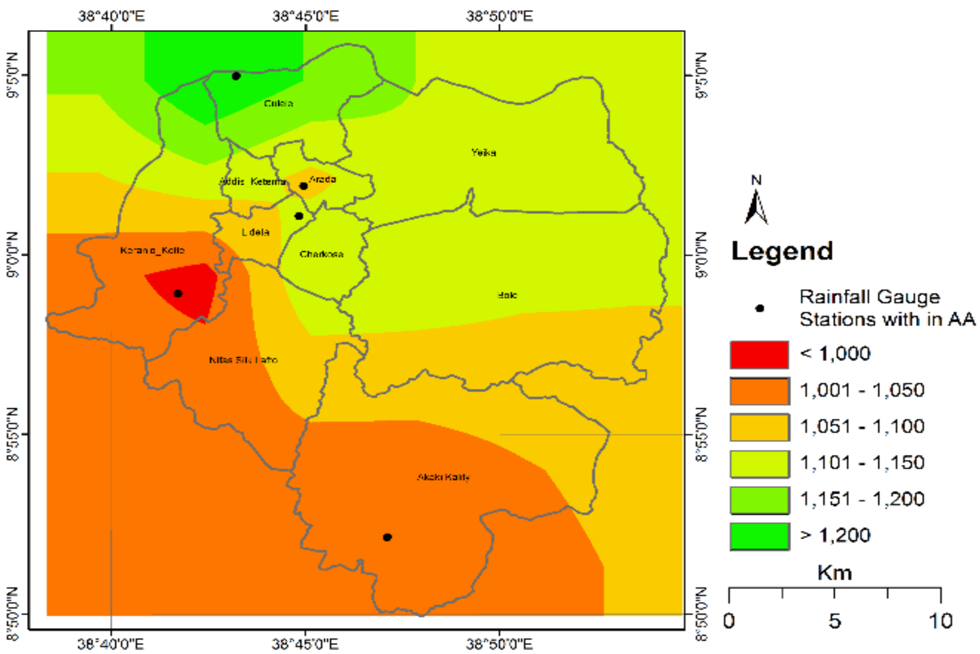

Figure 3-2: Amount of annual average rainfall (in mm) of the study area

Temperature: Addis Ababa enjoys a mild climate with daytime temperature that rarely goes beyond 26.33 ºC and rarely falls below 5°C depending on elevation and prevailing wind patterns. Its average temperature is 16.48 °C that varies from 5.0 up to 26.33 °C. Figure **3-3** shows the spatial distribution of the city's surface temperature. The temperature has an increasing trend that stretches from the north (cold) to south part (warm) of the city.

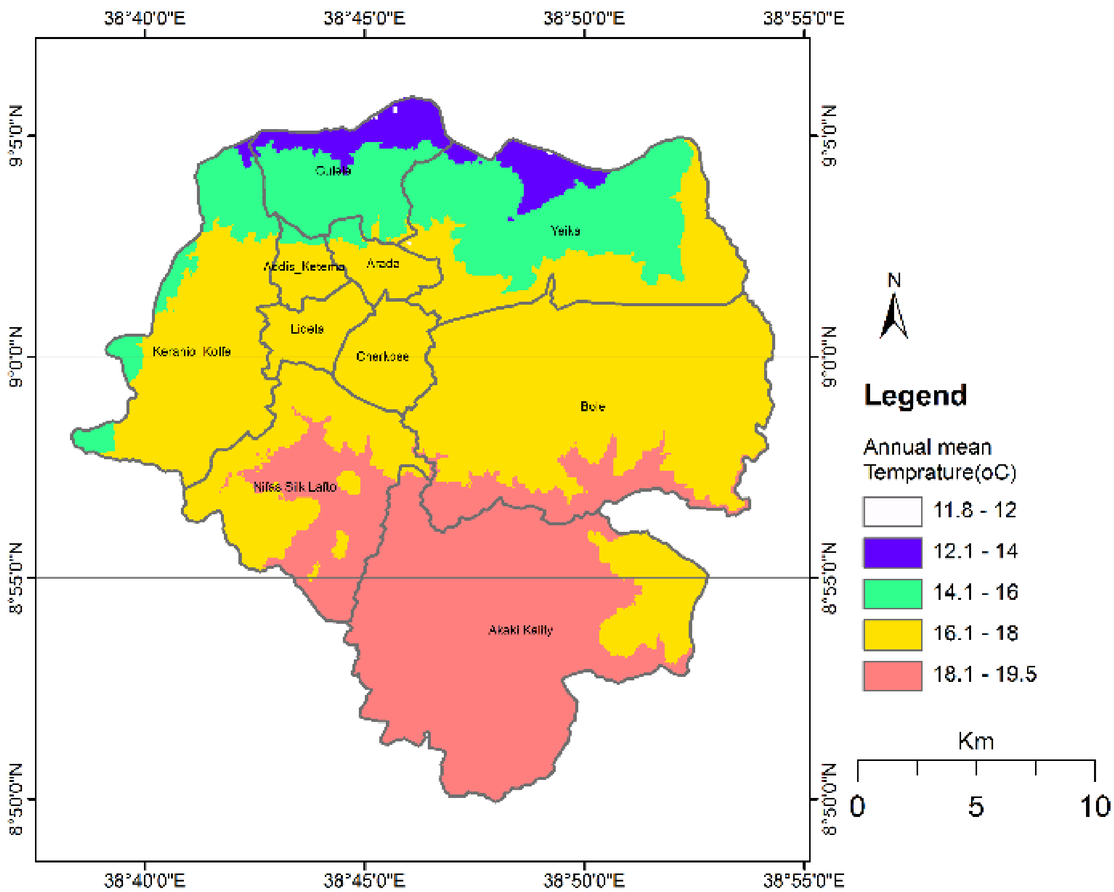

Figure 3-3: Mean surface temperature of the study area

Water Supply: Addis Ababa's surface water supply sources are located predominantly outside its political boundary. The sources are three dams (Legedadi, Dire and Gofersa), Akaki well field, Legedadi deep wells as well as wells and springs scattered in the city (Figure 3-4).

The public institution AAWSA is responsible for the supply of potable water. At present, it delivers 608, 000 m^3/day to the city. AAWSA's head office is located at Megenagna. It is divided into eight branch offices across Addis Ababa city to render efficient services. The eight branches are Gurd Shola, Megenagna, Arada, Gulele, Addis Ketema, Nifas Silk, Mekanisa, and Akaki branches. Their principal functions are the provision, connection and maintenance of minor water and sewer cannels (Kombe *et al*., 2015).

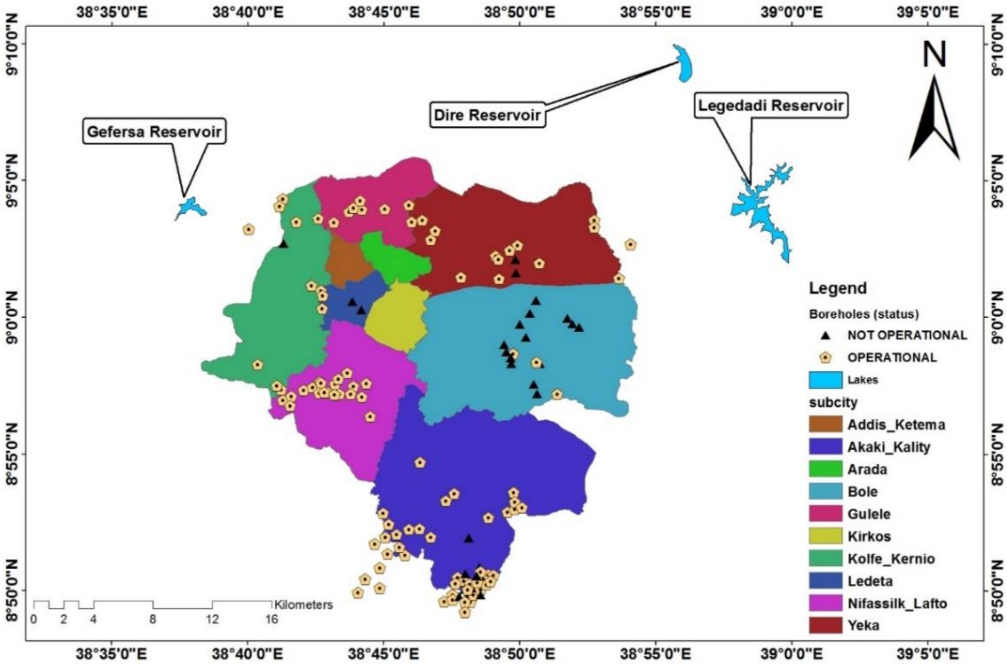

Figure 3-4: Surface and groundwater sources of Addis Ababa city

3.2. Materials and methods

3.2.1. Data set

Both qualitative and quantitative data were collected to counter balance the limitation of one tool upon the other. Both primary and secondary data were used in this study. Details of the collected data are presented below.

3.2.1.1 Secondary data

All the necessary data required for the study were obtained from both primary and secondary sources. The secondary data in this study include population, urban expansion, water production, water consumption, water quality and climate. AAWSA provided water production, water use (billed consumption), and water quality data. Historical billed water consumption data were also collected from consultant reports and AAWSA billing department even though data are either missing or inaccurate in some cases.

Historical records of groundwater and surface water production were also obtained from groundwater and surface water production case teams respectively. Historical record of surface water production data was obtained from Legedadi and Gefersa surface water production case teams based on data availability. Data which was collected from AAWSA also includes the number of customers and connections, well inventory and reservoir characteristics. For the analysis of water supply coverage, water supply hours and intermittency of supply, water distribution schedules and reports from the eight branches for the period June to October 2016 were taken. Data collected were organized and fed to Microsoft Excel for tabulation, graphing and descriptive statistics estimation. GIS maps of administrative boundaries and pipe network were obtained from AAWSA. GTP II plan of AAWSA was also consulted for the future planned water production, population projection and water demand estimation. Data and information relevant to this study were also extracted from academic and non-academic publications, annual and inventory reports, and previous studies. Progress reports of projects on the status and evolution of urban water supply in Addis Ababa were also reviewed.

The Central Statistical Authority provided historical, current, and forecasted population data at city and sub-city level. Rainfall and temperature data were received from the National Meteorological Agency (NMA). Data obtained from NMA incorporated 25-30 years of rainfall and temperature for 10 stations (6 and 4 located inside and surrounding Addis Ababa respectively). The ten stations have four classes: While Addis Ababa Observatory is a class I station; Addis Ababa Bole station is class II. Similarly, the rest are class III stations except Sendafa and Sebeta stations which are classified as class IV.

3.2.1.2. Primary data

3.2.1.2.1 Household survey

The main primary data for this study was collected through household surveys. A structured questionnaire was first prepared. The questionnaire was divided into sections which include general profile of the respondents (e.g. House ownership nature, house morphology, sex, water supplying branch, woreda of the respondent, water user category), and perceptions of adequacy, water quality, reliability and affordability. The questions were translated to Amharic (official language), pretested and refined. To test the questions, a pilot study was conducted with twenty people that included all water user categories. Respondents of the household survey were identified by random sampling technique.

The study covered 273households (different water user categories: domestic, commercial, industrial, institutional and public fountain). The respondents were 46.2% (126) male and 53.8%

(147) female. During the data collection, personal communications were made with selected AAWSA staff for additional details that was used for identifying for sampling and data analysis.

The survey covered all the ten sub cities and all of the 116 woredas of the city. This was found necessary since the sub-cities differ in many aspects including size, population, socio-economic status of households, altitude and water sources. The number of respondents under each water use category is shown in Table 3-1(Details of study participants, the English and Amharic versions of interview questions are appended as Appendix A-4, Appendix A-5 I and Appendix A-5-II respectively).

Table 3-1: Profile of study participants

User category	Commercial	Domestic	False domestic	Industrial	Institutional	Public fountain	Vendor	Total
No.	36	167	16	6	38	8	2	273
Percent	**13.2**	**61.2**	**5.9**	**2.2**	**13.9**	**2.9**	**0.7**	**100**

3.2.1.2.2. Key informant interviews and focus group discussion

Key informant interviews were made with various stakeholders, water service officers, and affected bodies. Personal observations and informal discussions were also served as data sources for this study. In case of key informants, three informants (branch manager, water customer service sub process owners and senior technician) were selected from all the eight branches. Branch managers Gulele and Mekanisa branches were not available. Water customer service sub process owners delegated as acting branch managers were interviewed. The total number of key informants were 22.

The key informants were of different responsibilities, knowledge and experience. Interview questions were framed on the city's water coverage, the balance between demand and supply of water in the city, major challenges facing the provision of the service, level of community awareness and participation in the provision of the service. The key informants were purposively selected assuming they have deep and relevant information from their official responsibilities and continued involvement about the issues (See Appendix A-6-I, Appendix A-6-II and Appendix A-7 for the details of Key informants, the English version of the questionnaire and the Amharic version of the questionnaire respectively).

3.2.1.2.3 Field observation

Field observation was mainly employed to gather data related to the type of water source, connection type of households to check water supply continuity and supply hours, areal coverage of water pipelines, standpipes or truck supply points and factors behind some variations like location and altitude. Physical water quality parameters including water taste, color, smell, turbidity and others were also noted through the help of checklists as crosscheck for survey responses. Operations, maintenance and rehabilitation or improvement activities were noted coupled with field observation of groundwater well fields and surface water dams. Data collected from miscellaneous sources are summarized in Table 3-2

Table 3-2: Summary of data sources

Organization	Role
AAWSA	Management and supply and wastewater
Bureau of urban agriculture	Provision of support for urban farmers
EPA	Environmental governance
The Addis Ababa and surrounding Oromia Integrated Development Plan Project Office	Master plan revision of Addis Ababa integrates the Oromia special zone is in the final stages,
Oromia Bureau of Environmental protection	Water and related resource governance

3.2.2. Data collected and sources of data

The data collected from different sources were summarized in Table 3-3 below.

Table 3-3: Summary of the collected data

Category	Data	Source	Remark
Water use and Water production	Water consumption	AAWSA	1994-2015 data on monthly basis but with inconsistent, missing and incomplete data for either source type or both
	Water distribution	AAWSA	
	Water loss	AAWSA	
	Water production	AAWSA	
New source development	Planned water source development activities	AAWSA (GTPII, Business Plan)	Both started and planned new source development activities are not realized as planned
Climate	Rainfall	NMA	Daily data covering the time period 1995-2015
	Min. and Max. Temperature	NMA	Daily data covering the time period 1995-2015
GIS map	Distribution map	AAWSA	The recent map was 2014 update
	Location of surface water source	AAWSA	
	Distribution of groundwater points	AAWSA	The map doesn't show the status of wells and boreholes

3.2.3 Data analysis and modeling

In this study, methods from both the natural and social science were applied. The following analyses were done in this study after data quality was assessed through visual inspection of the recorded data and time series plots.

3.2.3.1 Evaluation of past, present and future situation

To see the impact and extent of urbanization on Addis Ababa City's water supply situation, the physical expansion of the city between the years 1886 and 2015 was analyzed using descriptive statistics. Accordingly, in each expansion period (expansion phase), average area covered(ha), total built up area (ha), rate of expansion (%), annual growth rate (%), annual built up area expansion (%) and finally the built-up area expanded(ha) were calculated. For calculating population data, this study has included day time population estimations of about 30% of the CSA's projected population size to consider water demand by non-resident water consumers (Read, 2014).

Water production and water use data were analyzed using Microsoft Office Excel. Time series data of water production, water consumption, water demand, non-revenue water and the gap between demand-supply was analyzed. Descriptive statistics were used to summarize these data in tables, figures and maps. This helped to show both the spatial and temporal aspects of the water supply of Addis Ababa. Temporal trends of the city spatial extent, population density and water supply connections were analyzed graphically and tabular form. Most of the miscellaneous analyses were based on the population served by the entire water supply system in general and each supply branch in particular(Table 3-4)..Most calculations were done based on data presented in Appendix B-2.

Hence, the eight supplying branches, the sub cities served under each supplying branch, areas of the sub cities under each supplying branch and their population densities as well as the corresponding population served calculated based on (**Error! Reference source not found.**) were used to calculate the population size served by each supplying branch.

Table 3-4: Population Served by each branch based on AAWSA'S Network Map (2014)

Supply Branches	Sub cities Served	Area (Km^2)	Density (persons/km^2)	Population (persons)	Population served
Nefas Silk	Akaki-Kality	3.26	1790.14	5835.9	329,490
	Bole	0.06	2952.06	1771.2	
	Kirkos	7.57	17649.45	133606.3	
	NS Lafto	34.86	5400.92	188276.1	
Mekanisa	Kirkos	4.25	17649.45	75010.16	563,393
	Kolfe keraniyo	32.48	8165.93	265229.41	
	Lideta	3.77	25625.93	96609.76	
	NS Lafto	23.43	5400.92	126543.56	
Megenagna	Akaki-Kality	0.14	1790.14	250.62	182,468
	Arada	0.0004	24892.03	9.96	
	Bole	44.91	2952.06	132577.01	
	Kirkos	0.24	17649.45	4235.87	
	NS Lafto	0.02	5400.92	108.02	
	Yeka	9.63	4702.68	45286.81	
Gurd Shola	Bole	72.77	2952.06	214821.41	940,780
	Yeka	56.44	4702.68	265419.26	
Gulele	Addis Ketema	0.0015	40187.99	60.28	460,539
	Arada	5.78	24892.03	143875.93	
	Gulele	23.89	10341.15	247050.07	
	Yeka	14.79	4702.68	69552.64	
Arada	Arada	15.25	24892.03	379603.46	379,604
Akaki	Akaki kality	120.05	1790.14	214906.31	217, 817
	Bole	0.73	2952.06	2155	
	Nefas Silk Lafto	0.44	5400.92	756.13	
Addis ketema	Addis ketema	5.22	40187.99	209781.31	568,022
	Arada	0.0022	24892.03	54.76	
	Gulele	7.3	10341.15	75490.4	
	Kolfe keraniyo	31.01	8165.93	253225.49	
	Lideta	1.15	25625.93	29469.82	
Addis Ababa total		**519.46**	**6062.73**	**3149345.73**	**3,642, 112**

The difference between the total production without considering the water loss (system input volume) and total water distributed is known as volume of non-revenue water (unaccounted for water). It is the volume for which revenue is not collected by the water supply utility. Non-revenue water (NRW) can be aggregated value of the whole water supply system or disaggregated value of branches.

Water loss is a serious problem in Addis Ababa City Water Supply system, causing both severe water shortage and causing huge financial loss. In response to the inadequate investigation of this problem by AAWSA, the present paper has tried to compare AAWSA's report with own calculations based on time series data collected from AAWSA itself. Percentage by volume is used for calculating NRW as % of system input volume (Liemberger and Farley, 2004). Water loss was calculated from total water production and net supply as follows:

NRW (%) = (system input volume- billed volume)/system input volume **100%*

Where system input volume is assumed to be the total production without

considering water loss. Total billed consumption is the sum of the billed volumes of water used by all types of customers (domestic, non-domestic and public tap). Hence, the water loss in the city water supply distribution system was evaluated using top-down water balance method.

3.2.3.2 Perception of residents

Quantitative data generated from household survey were analyzed using simple descriptive statistical tools like frequency, mean, standard deviation and percentages and they were operated with SPSS and Microsoft Excel. Graphical presentations were managed by Origin pro version 7.0. Most of the spatial presentations and maps were done by the application of Arc GIS. Billed consumption and demand –supply gap was analyzed by simple descriptive statistical methods such as mean, average, percentage and others.

Customers' perception was evaluated for water quantity (interruptions, adequacy and reliability); water quality (taste, odor and smell), affordability and overall water customer satisfactions. Water supply interruptions during 2016 and any worst case were compared based on household survey data. The analysis was done also for each water user category.

3.2.3.3 Situation analysis with WEAP modeling

WEAP model was applied to investigate alternative scenarios taking into account multiple and competing uses of water systems and a wide range of drivers. The model received applications worldwide due to its capabilities and easy-to-use interface. WEAP has received an application in Ethiopia as well to evaluate water development options at basin level (example: McCartney and Girma, 2012). In this study, the model was used to evaluate water supply management scenarios for Addis Ababa taking the Legedadi subsystem as a case study. From the three AAWSA's sub systems, namely Legedadi, Gefersa and Akaki subsystems, the Legedadi sub system was selected for WEAP modeling since it is the largest sub-system in terms of number of customers served. Both groundwater and surface water sources are delivering water to this sub-system.

Legedadi subsystem includes supplies from Legedadi water treatment plant and to service reservoirs of Kotebe Terminal, Karalo, Ankorcha, Jan Meda, Gebrael Palace, Teferi-Mekonnen, Entoto, AAWSA Main Office, Belay Zeleke, Police Hospital, Army Hospital, and Kassa Gebre; and to pumping stations at Urael and Mexico square (TAHAL, 2005).

The baseline period covers the years from 2011 to 2015 while the medium term covers 2016 to 2020 which coincides with GTP II-time period. The long term stretches between 2026 and 2030. These scenarios were built to analyze the effect of population growth, management changes, and changes in water production capacities. In this study, the main inputs to the WEAP model are population, annual water use (consumption) per capita, and water loss. Average production (m^3/d) and production capacity (m^3/d) were also specified.

Population of the subsystem was calculated based on the proportion of the areas of sub-cites covered by this system multiplied by their respective population densities. Hence, the average annual growth rate of 2.54% was used for the period 2016-2020. During the period 2021-2025, this rate was assumed to be 2.67%, 1.95%, 2.64% and 2.64% for Arada, Gulele, Gurd Shola and Megenagna branches respectively but 2.78%, 2.01%, 0.86% and 2.74% in that order during 2026-2030. Population growth was estimated based on CSA projection (Hailemariam *et al*., 2009). This sub system has an estimated daily water supply of 179138 m^3/d. Megenagna, Arada, Gurdshola and Gulele branches constituting this sub system have supply areas of 54.94, 15.25, 129.21 and 44.45 km^2respectively.

The population of this subsystem for the period 2010-2015 and sample estimation procedure is shown in Table 3-5. It has increased slightly more than twice during 2010-2017. The population for the year 2017 was estimated based on population projection of the city and GTP II plan.

Table 3-5: Population of Legedadi subsystem during 2010-2015 and sample estimation

Branch	2010	2011	2012	2014	2015
Gulele (97%)	376883	401757	428273	456539	486671
Arada (74%)	26003	27719	29549	31499	33578
Megenagna (100%)	64675	68944	73494	78344	83515
Gurd Shola (100%)	217021	231344	246613	262890	280240
Total	**684582**	**729764**	**777929**	**829272**	**884004**

Source: own calculation based on AAWSA reports

Population growth rates of 6, 2.54 and 2 % were used for the baseline, medium and long terms respectively. Water consumption per capita is assumed to be 0.291 m^3/d in the baseline and 0.365 m^3/d in midterm and long-term. Industrial and institutional/commercial/administrative water demand was estimated from billed data. In this study, industrial and institutional or commercial growth rates were not used for the model since these organizations will not be supplied water from the city's water supply system as separate supply will be developed for them. There are some industries and commercial units which started abandoning AAWSA's supply upon developing their own sources. They have no the legal right to use the available urban water supply.

This subsystem includes supplies from water treatment plant to service reservoir of Kotebe terminal, Karalo, Ankorcha, Jan Meda, Gebriel Palace, Teferi Mekonnen, Intoto, AAWSA ex-main office, Belay Zeleke, Police Hospital, Army Hospital and Kassa Gebre; and pumping stations at Urael and Mexico square.

The water consumption and loss data has been used to estimate the input volume. The study has used AAWSA's water III projection of per capita water demand growth rate of 3.34% per annum during 2015-2020. The 2015 monthly average water consumptions of the four branches of

Legedadi subsystem were estimated from AAWSA's bill data. Supply was taken as the sum of consumption and average water loss of 40%.

Water demand (supply requirement) is assumed to grow at a constant rate of 3.52% /annum. The increase in consumption is assumed to be balanced by the decrease in leakage resulting in a constant rate of demand growth. For all user groups, total daily per capita water demand grew from 145 liters in 2015 to 176 liters in 2016 with an equivalent 2.13% annual growth rate. During 2026-2030, domestic, industrial and commercial consumption will be 74%, 5% and 20% respectively (GTP II). The sizes of industrial and commercial water customers were assumed to show an average annual growth rate of 2.76%, 0.0196% and 0.0251% during 2011-2015 (AAWSA Business Plan, 2011), 2016-2020 and 2026-2030 respectively.

Nondomestic customers (industry and commercial units) have shown an average of growth rate of 2.76% per annum during 2010-2015 (AAWSA, 2011). In the period 2026-2030 domestic, industrial, commercial, and other users were considered to be 74%, 5%, 6% and 15% respectively as the utility has planned to develop separate source for non-domestic users. According to GTP II projection, industrial and commercial as well as administrative demands are assumed to remain constant. Hence, change in demand is due to the growth of demand by domestic customers because of changed style of life, increased economic status, and increased awareness about sanitation, increased supply availability (connection type, supply hour, supply quantity or volume).

The system input volume at branch level or subsystem level is not known since bulk flow meters are not installed at branches or subsystem. One source supply as many as four or more branches due to the extremely complex water supply network of AAWSA. Therefore, the present study has used indirect method of calculating the system input volume to Legedadi subsystem.

Although GTP II has assumed increased consumption due to increased standard of living and increased population while projecting future water demand, this study has tried to revise demand variations since we have theoretical justifications and historical data evidence. In 2015, GTP II plan has put additional water production requirement of only 65, 952 m^3/d by reducing NRW to 37% and taking a resident population of 3,702,809 putting the net and gross demands 474,939 m^3/d and 664,952 m^3/d respectively. This study has calculated an estimated water loss value of 38.2 % based on for baseline period and 27.8% and 20 % based on GTP II target for short term and mid-term periods, respectively. After GTP II, this study has assumed NRW to continue at 20% believing that AAWSA will not be able to reduce NRW further than this value. The World Bank recommends that NRW should be less than 25% and NRW is 19% in England and Wales (Kingdom *et al.*, 2006).

The daily water demand of the Legedadi subsystem was calculated from the projected water demand of the city based on the GTP II plan and AAWSA Business plan of 2011. This study has introduced the concept of day time population labeled here as other demand for demand estimation. Thus, the city's demand was disaggregated into the eight branches based on their population density and area coverage. From this branch based disaggregated city wise demand, the components of the disaggregated demand comprising the Legedadi subsystem were re - aggregated. The basic assumptions employed fort the modeling are summarized in Table 3-6 below:

Table 3-6**:** Basic assumptions for the modeling

Basic assumptions	Baseline condition	Medium term scenario	Long term scenario	Remark
	2011-2015	2016-2020	2026-2030	
Water production				Based on GTP II
Water demand	-------	-----------	--------	Based on AAWSA's Business Plan Model, for baseline, GTP II for 2016-2020 and Water III Projections for 2026-2030
% NRW GTP II Plan	37,37,37,40,40	35,32,28,24,20	a constant 20%	
% NRW for business as usual	34,40,45,45,45	40% constant	a constant 20%	
Consumption				
a. Domestic	20%	20%	20%	
b. b. Industrial	10%	10%	10%	
c. c. Commercial	15%	15%	15%	
d. d. Other	20%	20%	20%	
Water consumption	-----	______	_____	Based on AAWSA's Business Plan Model, for baseline, GTP II for 2016-2020 and Water III Projections for 2026-2030 (30 % daytime population is also considered for all)
Annual water use rate				
a. Domestic	52%			
b. Commercial	11%			
c. Industrial	10%			
d. Other	27%			
Water demand growth rate	3.34% /annum	3.34% /annum		

The mode of service in Addis Ababa water supply system as studied by Urban Modeling consultants (Abo-El-Wafa et al.,2017) is believed to shift to house connections (Table 3-7). Possible increase in private connections and installation of new lines as well as public fountains might change to at least shared yard connection.

Table 3-7: Projected domestic water demand during 2016-2036

Mode of service	2016	2020	2025	2030	2036	Trend of change
House connection	10	16	25	32	40	Increasing
Yard connection	25	30	32	35	38	Increasing
Yard connection shared	15	14	13	10	8	Decreasing
Public fountain	50	40	30	23	14	Decreasing

In all the three planning horizons the volume of water was expressed in units of billion cubic meters. While unmet demand was taken as the difference between supply requirement and supply delivered, water loss equals the difference between supply requirement and water demand.

The water distribution system is designed to cope mainly with the domestic demand. Therefore, industrial, commercial, and institutional demands are included in the domestic consumption figure to form a total water demand per person per day. This study has used unit water consumers-based demand calculation ways to estimate water demand based on unit water consumers' number (using population number and extent of institutions, commercial and industrial exists). Water demands have the following categories:

- *Domestic or Residential water demands*: This includes water required for drinking, cooking, ablution/Bathing, washing utensils, washing clothes, flushing toilets and watering animals,
- *Commercial water demand*: This demand is affected by the number and types of commercial establishments and it is usually between 10-20% of the total water demand. According to MoWIE design criteria, it is assumed to be 10% of the total demand,

- *Industrial water demand:* This demand varies between 25 to 35% of the total municipal water demand worldwide and 5 to 10% in Ethiopia but this study has accepted GTP II 's estimation of 20%,
- *Institutional/public Water Demand*; This category includes water used for public buildings (city halls, jails, schools) and public services including street washing, park irrigation, health institutions, etc. This demand is normally estimated to be 5 to 10% of the total water demand,
- *Firefighting demand:* According to MoWIE (2006), about 10% of the total volume of the demand is required to balance demand fluctuations because of firefighting demand. This study has integrated 3% with commercial and public or institutional water demand. Which are estimated at 10% of the total demand are included in commercial water demand, making the aggregated commercial, institutional, public and firefighting demand is estimated at 23% of the total demand, and
- *Unaccounted for or system loss:* There is some unaccounted-for water in water supply system due to the following: Leak in the mains, overflow at various structures, water used for backwashing, faulty meters, and unauthorized water connections. According to MoWIE (2006), 25% to 40% is considered.

The present study has calculated NRW value of about 45% for Addis Ababa City water supply system. The results of reference scenario were verified using observed volume for supply sources and observed demand coverage of Addis Ababa city. These results have shown future unmet demands. Billed data was used to estimate the proportion of water consumed by nondomestic water customers.

3.2.3.4 Problem Tree Analysis

Problem tree analysis is central to many forms of project planning and is well developed among development agencies. Problem tree analysis (also called Situational analysis or just Problem analysis) helps to find solutions by mapping out the anatomy of cause and effect around an issue in a similar way to a Mind map, but with more structure. Its main output is a tree-shaped diagram, in which the trunk represents the focal problem, the roots represent its causes and the branches its effects. Such a problem tree diagram creates a logical hierarchy of causes and effects and visualizes the links between them. It is used to create a summary picture of the existing negative situation.

The problem hierarchy is formed following these six main steps:

1. *Identify existing problems* within the problem area/domain of interest (brain storming) A problem is not the absence of a solution, but an existing negative state or situation that distinguishes between existing, impossible, imaginary or future problems;

2. *Define the core problem* (focal problem or central point of the overall problem);

3. *Formulate the causes* of the core problem -consider that the problems identified in step 1 can also be causes of the core problem;

4. *Formulate the effects* (consequences) of the core problem-consider that the problems identified in step 1 can also be effects of the core problem;

5. *Draw a diagram* (problem tree) that represents cause-effect relationships (problem hierarchy) where; the focal problem is placed in the center of the diagram forming the trunk of the tree, causes are placed below and effects above, in sub-dividing the roots and branches (like a mind map), and if possible, all causes/effects of a problem should be on the same horizontal level; and

6. Review the logic and verify the diagram as a whole with regard to the validity and completeness. If necessary, make adjustments and questions to ask for each problem are these causes sufficient to explain why this occurs?

The problem tree method is a planning method based on needs, but not a mechanical translation of problems into objectives (Cervante *et al*, 2008). The problem analysis of major importance with regard to project planning since it strongly influences the design of a possible intervention(s). It is the basis and the justification for the project design. It includes;

- Verification of the subject of analysis;
- Identification of problems related to the subject;
- Make an inventory of all problems perceived by all participants;
- Establishment of a cause-effect hierarchy between the problems; and
- Visualization of the cause-effect relations in a diagram.

The qualitative data collected using Key informant interview and personal observations were also analyzed through description, narrating and interpreting the situation contextually so that the city's water supply situation has been properly revealed. Inferential statistics such as ANOVA (both one way and two) were employed to see daily water supply hours and weekly water supply days among branches, sub cities and weredas .

Chapter Four

4. Water Supply Situation Assessment Results of Addis Ababa Water Supply System

4.1. Evaluation of Past, Present and Future Situation of Addis Ababa Water Supply System

4.1.1. Urbanization, Population trends, and Population Served by Water Connection

This study has shown that Addis Ababa has been undergoing horizontal expansion as the result of rapid urban development over the past several decades. Table 4-1 shows that Addis Ababa city's surface area has increased from 37.4 km^2 in 1970 to 230.35 km^2 in 1999 (UNEP/ UNESCO, 2015). The lowest growth rate was 6.6 % (1.3% per annum) observed during the 5th phase (1996-2000). The highest annual rate of expansion (40.8%) was in the years 2001-2010. This also includes highest expansion of built-up area which is consistent with the findings of ORAAMP (2001) that estimated 60 percent of the city's core area is dilapidated with a quarter of all housing units built illegally and informally.

Table 4-1: Physical expansion between the years 1886 and 2015(Calculated based on ORAAMP, 2001, 2002) and Tadesse, 2009)

Expansion period	Duration (year)	Average area covered(ha)	Total built up area (ha)	Expansi on phase	Rate of expansion (%)	Annual growth rate (%)	Annual built up cover expansion (%)	Annual built up area expanded (ha)
1886-1936	51	1863.13	1863.13	1st		-	-	36.53
1937-1975	39	4186.87	6050	2nd	224.7	3.1	31.74	107.36
1976-1985	12	4788	10838	3rd	79.1	6	59.17	399
1986-1995	11	2925.3	13763.3	4th	27	2.4	80.61	265.94
1996-2000	5	904.4	14667.7	5th	6.6	1.3	95.04	180.88
2001-2010	10	25000	39667.7	6th	170.4	40.84	110.46	250
After 2010		No expansion						

Addis Ababa has experienced a highly accelerated population growth that grew from 443,728 in 1961 to 2,917, 295 in 2010 (Figure 1-1). The average annual population growth was 2.97% during 1996-1999 and between 2.92- 3.01% during 1999-2006. The increasingly haphazard expansion along the five regional outlets with no attention to sustainable expansion possibilities may add inefficiency in land utilization.

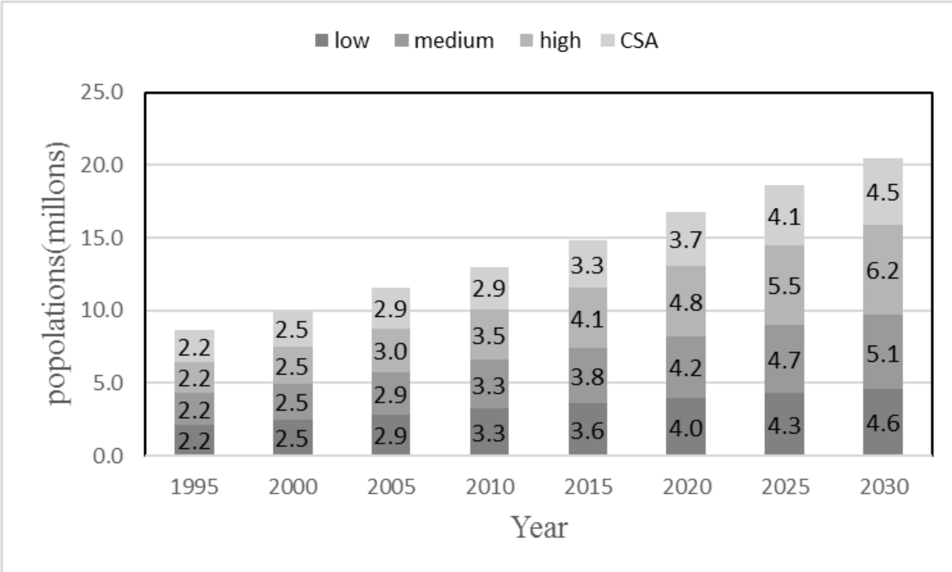

Figure 4-1: Historic and forecasted population of Addis Ababa for 1995-2030

Source: Adapted from CSA (2010, 2011, 2013, and 2016) reports

About 32.49% of city residents reside in the four central sub cities (Addis Ketema, Arada, Lideta and Kirkos) and make up 9.11 % of the surface area of the city. In 2017, the population density of Addis Ababa was 6516.3 persons per km^2. Figure 4-2 shows large variations in population density across the sub-cities. Addis Ketema and Akaki-kality sub cities have the highest and the lowest population densities respectively.

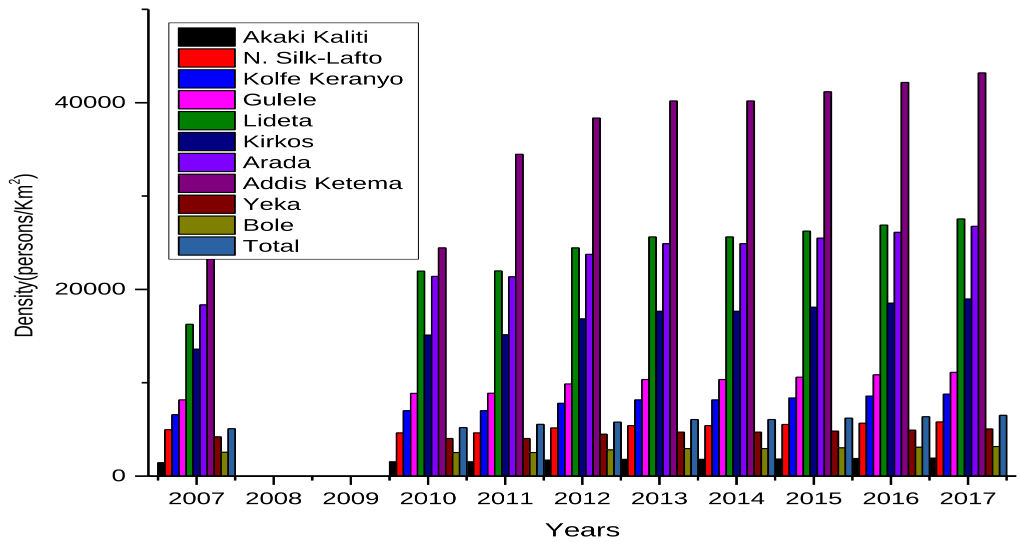

Figure 4-2: Population densities of sub cities during 2007-2015

Higher population sizes were used for the 2012-2020 Business plan preparation (AAWSA, 2011) and AACPPO, 2014). The high population size during 1996-2006 started lowering since 2007. The 2% constant annual average growth rate decreased to 1.5% in 2008 but grew again to 3% since 2009. This estimation has not considered the complex concept of daytime population owed to the shift in population during business hours. It is more difficult to capture at high precision or with certainty due to the lack of standardized day time population data.

4.1.2. Customer profile

AAWSA has either domestic or non-domestic customers based on its water tariff structures. The trend observed by the different connection types (Table 4-2)is discussed as follows:

Domestic connection numbers are highest in Mekanisa followed by Gurd Sholla and Nefas Silk branches; average in Gulele and Addis Ketema (since most households have ownership maps and are connected to AAWSA's supply); and lowest in Akaki, branch followed by Megenagna and Arada branches. This variation could be related to the performance of branches.

The growth rate in domestic connections of branches during 2007-2015 that ranges between 43 % (Akaki) and 79% (Gulele) translates to 2.9 to 14.5% increment per annum (data not shown here). The rate of increment in connection is 60.56% at the city level during this same time period. The highest non-domestic connections average rates of change were observed for Gurd Shola, Mekanisa and Addis Ketema. The number of public tap connections showed increment, except for Gulele. Gurd Sholla, Megenagna and Mekanisa have recorded average rates of changes of 527.5%, 102% and 74.69%. These values are higher than the average rate of 53.40% for the entire city. While Gulele showed a reduction in public connections at an average rate of -28.07%, Arada (9.83%), Addis Ketema (13.44%) and Nefas Silk (27.07%) branches demonstrated lowest increments. The same Table has shown that a smaller value of public tap connections suggests more of domestic private connections or inner-city area without new developments.

All types of connections and total connections showed a linear increment with time. The decreasing rate of change in the number of connections in 2010 that has resulted in declined rate of annual growth of total connections might be due to the installation of new connections for public tap users. The significant increase in domestic connections may be associated with AAWSA’s effort to respond to the growing demand for new connections owed to city expansion, population growth, and construction boom, intensive densification of the city and changed style of living that have increased and will keep with the demand for all types of connections even in the near and far future.

Table 4-2: Aggregated and disaggregated number of domestic, non-domestic, public tap

Connection type	Year	Addis Ketema	Akaki	Arada	Gulele	Gurd Shola	Megenagna	Mekanisa	Nefas Silk
Domestic Connection	2015	45,190	22,765	38,471	45,594	62,654	23,941	66,011	52,330
Grate growth 2007-2015		1514.6	1613.3	2224.4	1179.4	3626.8	717.6	4042.6	2679.4
Non domestic connections	2015	7,260	4,538	8,220	5,790	9,731	5,922	8,106	8,525
	Average	13119	6195	15268	13499	14355	9154	15788	14825
Rate growth		379.9	159.6	331	86.9	799.1	291.9	495.4	445.4
Public Fountains	2015	287	170	257	164	502	69	421	230
	average	269	142	297	208	203	49	331	198
Grate growth	2007-2015		6.5	2.875	-8	52.75	4.375	22.5	6.125
Total connections	2015	52,737	27,473	46,948	51,548	72,887	29,932	74,538	61,085
	average	46031	19540	43589	46577	52982	28021	57908	50278
Grate growth 2007-2015		1898.8	1779.4	2558.3	1258.3	4478.6	1013.9	4560.5	3130.9

Aggregated citywide or disaggregated branch wise number of connections are described based on service modes (types of connection) and water customer categories. Public tap/Public Fountain (PF) user are categorized as domestic yet they are charged differently. Hence, the volumetric charges are flat, progressive on seven band systems and fixed for non-domestic, domestic and public fountain customers respectively although public fountain users. In Addis Ababa City water supply system, the three connection types are private household connections, public fountain connections and yard connections (Table 4-3). Yard connection was introduced in 2008. During 1996-2015 periods, household connections, public fountain connections and total connections showed a 2.6, 2.2 and 2.5-fold increment, respectively, while the recently introduced yard connections showed a 15.1-fold increment during 2010-2015 period.

Table 4-3: Number of populations served via the three modes of connection against total served with their annual rate of change (%) for the period 1996-2015

Year	Household connections		PF connections		Yard connections		Total connections	
	No.	Growth Rate %)	No.	Growth Rate (%)	No.	Growth Rate (%)	No	Growth Rate (%)
1996	724960		552000		0		1,276,960	
1997	747615	3.13	569250	3.13	0		1316870	3.13
1998	770270	3.03	586500	3.03	0		1356770	3.03
1999	792925	2.94	603750	2.94	0		1396680	2.94
2000	811049	2.29	617550	2.29	0		1428600	2.29
2001	815580	0.56	621000	0.56	0		1436580	0.56
2002	860890	5.56	655500	5.56	0		1516390	5.56
2003	906200	5.26	690000	5.26	0		1596200	5.26
2004	951510	5	724500	5	0		1676010	5
2005	996820	4.76	759000	4.76	0		1755820	4.76
2006	1064785	6.82	810750	6.82	0		1875540	6.82
2007	1178490.4	10.68	897327.75	10.68	0		2075820	10.68
2008	1299286.9	10.25	989304.75	10.25	0		2288590	10.25
2009	1366141.8	5.15	1040209.5	5.15	0		2406350	5.15
2010	1458748.4	6.78	1076105	3.45	6716		2541570	5.62
2011	1554743.4	6.58	1114113.7	3.53	22080	228.77	2690940	5.88
2012	1641170.8	5.56	1149469.3	3.17	47840	116.67	2838480	5.48
2013	1699203.2	3.54	1172613.6	2.01	58880	23.08	2930700	3.25
2014	1782815.1	4.92	1206021.7	2.85	75440	28.13	3064280	4.56
2015	1862577.4	4.47	1238839.8	2.72	101200	34.15	3202620	4.51

The study found uneven customer distribution or unpredictable trend of connection densities (connections /km^2) (Table 4-4) has. High connection densities of 2749.87, 1106.03 and 1038.71 were registered by Arada, Nefas Silk and Addis Ketema branches respectively. While the two central branches Arada andAddis Ketema have high population, densities are characterized by infill type of development, new settlements such as condominium houses with connections characterize Nefas Silk, Akaki, Gurd Sholla and Megengna branches have registered low connection densities of 134, 361.14 and 505.89 respectively, lower than the city' average connection density of 631.05.

Table 4-4: Customer distributions by branch office (December 2010)

Branches	Area		Number of connections				Density (connections/km^2)	Percent area proportion when total area is	
	Case 1	Case 2	Domestic	PT*	Nondomestic	Total		519.76km^2	540 km2
Arada	15.6	16.21	34854	309	7735	42898	2749.87	3	3
Mekanisa	65.58	68.13	46717	293	5181	52191	795.84	12.62	12
Gulele	44.37	46.1	40267	195	5363	45825	1032.79	8.54	8
Addis Ketema	44.04	45.75	40075	263	5407	45745	1038.71	8.47	8
Megenagna	55.36	57.52	23474	41	4491	28006	505.89	10.65	10
Akaki	120.11	124.79	12692	133	3307	16132	134.31	23.11	22
Gurd Sholla	128.91	133.93	41597	98	4859	46554	361.14	24.8	24
Nefas Silk	45.79	47.57	44988	178	5479	50645	1106.03	8.81	8
Addis Ababa	**519.76**	**540**	**284664**	**1510**	**41822**	**327996**	**631.05**	**100**	**100**

PT* refers to public tap or public fountain

4.1.3. Past, Current and Future Water Supply Situation of Addis Ababa

Addis Ababa water supply is managed by the public institution, AAWSA which is responsible for the supply of water and collection, treatment and disposal of wastewater and sludge for the city. Water is delivered to households, public and business organizations through different sized pipes, reservoirs, and pumping stations. This utility serves its customers via eight branches by employing 100 pumps (32 pump stations and 91 storage reservoirs with a capacity of 20-20 000 m^3 constructed during 1959-2012. 32 of the 91 storage reservoirs are also pumping stations (AAWSA Business Plan, 2011). 57 temporary plastic reservoirs of in a city 15-25 m^3 temporary water shortage without being connected to the distribution system. They are used for tanker filling. There are also 36 small storage reservoirs that receive water from boreholes and springs serving approximately 9 localized areas and water is not treated at the central water treatment plant, but later mixed with water from the treatment plants. AAWSA's primary and secondary pipe lines and the three major surface water sources (reservoirs) are depicted in Figure 4-3 below.

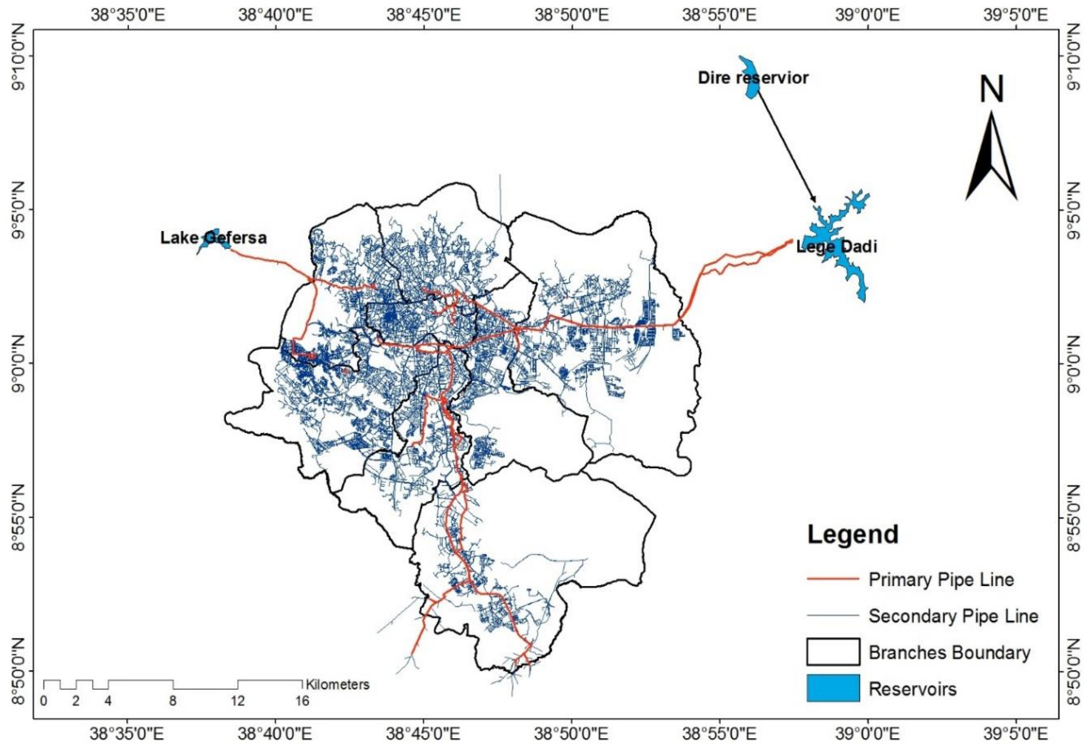

Figure 4-3: Major distribution pipes of the city's water supply system with major water sources

4.1.3.1.2 Annual water production (system input volume)

The total annual water produced from all dams, wells, springs and rivers introduced to the supply system is known as system input volume (SIV). SIV has increased from 10,425,137m^3 in 1996 to 58,443,725 m^3 in 1997 and reached 129,856,588 m^3 in 2015 with a rate of increase of 50.5% (5.1 per annum) during 2006 to 2015. The rate of increment decreased to 3.36% during 2006 to 2014. The reasons for this on uniform rate could be attributed to the more or less constant surface water production after 2006.The increase in SIV is accounted for by the corresponding increase in groundwater production. The capacity of Gefersa reservoir is constant over the years, though it was raised from 23,000 to 30,000 m^3/d upon rehabilitation (Figure 4-4). Legedadi-Dire treatment plant treatment's capacity that increased from 150,000m3/d to 165, 000 m^3/d and now has reached to 195, 000 m^3/d upon expansion. Its capacity is 6.5 times the capacity of Gefersa at present (see appendix B-1 for details of water infrastructure distribution among branches arranged in 2010).

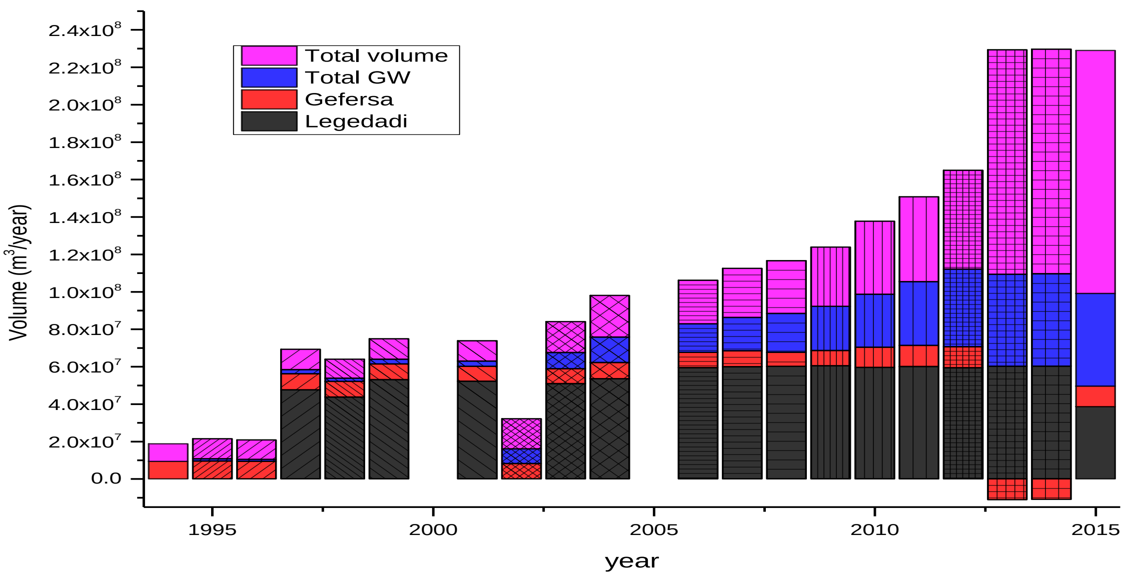

Figure 4-4: Surface water production of AAWSA during 1994-2015

Until 1994, surface water which was abstracted from Legedadi and Gefersa dams was the exclusive source for the city. The contribution of all sources of surface water decreased during 1995-2000 as all sources of groundwater water production increased (Figure 4-5). The rapid increase of the share of groundwater to system input volume after 2001-2002 could be associated with the strategic focus shift of the city's Government towards groundwater for firefighting reasons/getting breathing space to relive acute water shortages. The slow and small increase in surface water production associated with huge loss is also a factor for this observed trend change. Although groundwater sources are preferred over surface water sources for their rapid production and lower initial investment capital, they should not be taken long lasting solutions since their operational and maintenance costs are very high accompanied by high-energy demand.

Taking groundwater as a sustainable source is not welcomed by most senior /educated AAWSA technical staff consulted. The situation is compounded with a concentration of wells in few well fields at short distances only after single well test results that may not be trusted. The field observation in this study has revealed many instances of abandoned wells because of lesser production. This is often caused by increased numbers of wells and over abstraction beyond their sustainable yield or recharge potential. Even though surface water sources are initial capital intensive and time taking, they have longer service periods and require a relatively lesser operation cost.

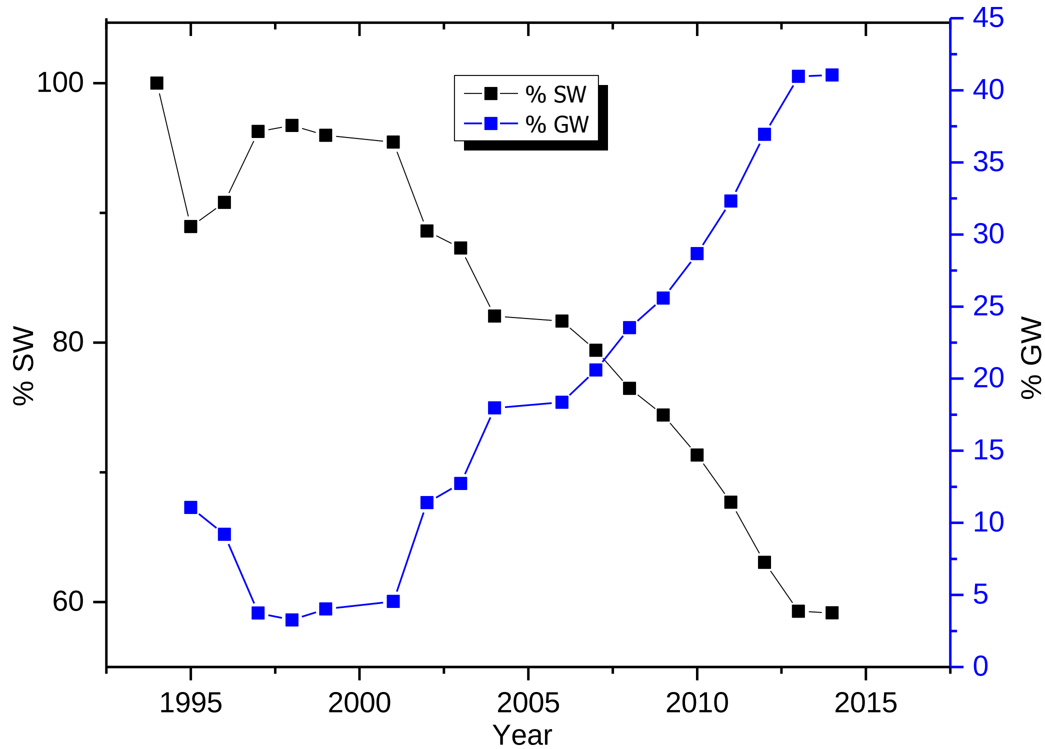

Figure 4-5: Proportion of the contributions of all groundwater and all surface water sources for system in put volume during 1994-2014

4.1.3.1.3 Total billed consumption and total water loss

In this study, total water loss was considered as the sum of apparent (administrative) losses and the real (physical) losses or leakage (McKenzie and Wegelin, 2009). The result of this study has found that the mean annual rate of total billed consumption increased by 89.6% between 1997 and 2015 with a mean annual consumption of 96,110,548 m^3. Water balance calculations were done based on approximation due to complete and accurate data unavailability particularly for apparent losses and unbilled consumptions. NRW is the measure of water distribution efficiency indicating either the percent or volume of water for which revenue is not collected. NRW can be aggregated value of the whole water supply system or disaggregated value of branches. Water loss is a serious problem in Addis Ababa causing both severe water shortage and huge financial losses. In response to

AAWSA's inadequate investigation of this problem, the present study has compared AAWSA's report with own calculations based on time series data collected from AAWSA itself. Water loss was calculated from total water production and net supply considering other factors using the following assumptions:

1. Gross supply (gross distribution) is assumed to be the total production without considering the water loss also known as system input volume,
2. System input volume is the sum of the annual readings of all the sources
3. Total billed consumption is the sum of the billed volumes of water used by all types of customers (domestic, non-domestic and public tap)
4. Annual total water loss (NRW) is calculated as the difference between system input volume (m^3) minus billed consumption
5. Physical loss (real loss) is considered to be 75% of total loss (AAWSA's case)
6. Net loss (apparent loss) is the difference between total loss and physical losses
7. NRW (%) is calculated as the percent of the difference between system input volume and billed consumption divided by total production and then multiplying by 100 percent

The lowest NRW values of 26.8% found by this investigation observed in 1998 (Table 4-5) could be associated with low water production recorded since 1997. The highest value of NRW recorded in 2003 could be because of inner city development and the average value of 39.7% is greater than AAWSA's reported value of 37%. The decrease in NRW since 2003 indicates NRW reduction measures and rehabilitation of old pipelines. At present, high volumes of apparent and real losses are causing serious water shortage and financial losses. During 1997-2015, the average annual water loss was 33,791,003.2 m^3 (100, 493.7 m^3/d).

Table 4-5: NRW based on AAWSA's different year's production and consumption data

Year	Legedadi reservoir	Gefersa reservoir	Total SW	Total GW	Annual SIV	Billed consumption	Total loss	A real loss	Apparent loss	NRW (%)
1997	47,591,408	8,668,216	56,259,624	2,184,101	58,443,725	32,017,622	26,426,103	19,819,577	6,606,526	45.2
1998	43,737,558	8,371,040	52,108,598	1,758,110	53,866,708	39,426,348	14,440,360	10,830,270	3,610,090	26.8
1999	53,134,069	8,297,900	61,431,969	2,574,394	64,006,363	37,400,209	26,606,154	19,954,616	6,651,539	41.6
2001	52,246,313	7,917,757	60,164,070	2,864,100	63,028,170	39,411,296	23,616,874	17,712,656	5,904,219	37.5
2002	52,716, 452	8, 244,938	60,961,390	7,843,600	68,804,990	37,376,052	31,428,938	23,571,704	7,857,235	45.7
2003	50,973,399	7,972,714	58,946,113	8,591,516	67,537,629	36,001,815	31,535,814	23,651,861	7,883,954	46.7
2004	53,595,590	8,607,688	62,203,278	13,620,911	75,824,189	41,691,787	34,128,371	25,596,278	8,532,093	45
2006	59,514,199	8,138,448	67,652,647	15,207,625	82,860,272	51,338,591	31,521,681	23,641,261	7,880,420	38
2007	60,038,338	8,467,053	68,505,391	17,773,198	86,278,589	53,285,445	32,993,144	24,744,858	8,248,286	38.2
2008	60,144,863	7,456,619	67,601,482	20,804,141	88,405,623	53,649,740	34,755,883	26,066,912	8,688,971	39.3
2009	60,475,493	8,132,038	68,607,531	23,593,746	92,201,277	60,753,774	31,447,503	23,585,627	7,861,876	34.1
2010	59,585,580	10,793,280	70,378,860	28,286,484	98,665,344	65,442,442	33,222,902	24,917,177	8,305,726	33.7
2011	60,112,071	11,262,008	71,374,079	34,066,919	105,440,998	69,262,863	36,178,135	27,133,601	9,044,534	34.3
2012	59,425,092	11,306,884	70,731,976	41,442,775	112,174,751	67,469,190	44,705,561	33,529,171	11,176,390	39.9
2013	60,225,000	10,902,154	71,127,154	49,152,898	119,972,725	66,283,391	53,689,334	40,267,001	13,422,334	44.8
2014	60,266,250	10,793,076	71,059,326	49,308,324	120,088,391	66,129,097	53,959,295	40,469,471	13,489,824	45
2015					129,856,588	71,421,123	58,435,465	43,836,595	14,608,866	45
Average					87,497,194	52,256,517	32,069,736	26,431,096	8,810,170	40

4. 1.3.1.4 Disaggregated NRW

Disaggregated NRW values among the eight water supplying branches were calculated from the aggregated NRW (%) value since their input volumes are neither known nor each branch owns separate source. This disaggregation It was done based on SIV and billed consumption data of branches. Five years' (2009- 2013) billed consumption data collected from AAWSA was employed to see the recent trends among the eight branches. The contribution of each branch to NRW was assumed uniform and the calculated values were 34.1, 33.7, 34.3, 39.9 and 44.8 % for the period 2009-2013 respectively. The corresponding NRW value of the eight branches is summarized in Table 4-6 below:

Table 4-6: Disaggregated NRW in the eight branches for the years 2009- 2013 (based on different years of AAWSA reports)

Year	Branch	AddisKetema	Akaki	Arada	Gulele	GurdShola	Megenagna	Mekanisa	Nefas Silk
2009	consumption	512,041	310,203	887,042	577,108	670,281	774,725	644,507	821,344
	NRW (%)	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1
	NRW (m^3)	174,606	105,779	302,481	196,794	228,566	264,181	219,777	280,078
2010	consumption	529,643	281,037	878,501	621,920	790,525	782,795	688,014	881,102
	NRW (%)	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7
	NRW(m^3)	178,490	94,710	296,055	209,587	266,407	263,802	231,861	296,931
2011	consumption	591,404	356,055	812,740	625,848	816,001	760,611	782,937	930,815
	NRW (%)	34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3
	NRW(m^3)	202,851	122,127	278,770	214,666	279,888	260,890	268,547	319,270
2012	consumption	541,003	381,329	787,087	536,115	880,404	725,297	791,903	891,893
	NRW (%)	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9
	NRW(m^3)	215,860	152,150	314,048	213,910	351,281	289,394	315,969	355,865
2013	consumption	513492	343528	833069	537664	883323	791030	818777	916116
	NRW (%)	44.8	44.8	44.8	44.8	44.8	44.8	44.8	44.8
	NRW(m^3)	230,044	153,901	373,215	240,873	395,729	354,381	366,812	410,420
Average	consumption	537,517	334,430	839,688	579,731	808,107	766,892	745,228	888,254
	NRW (%)	37.36	37.36	38.18	37.36	37.36	38.18	37.36	37.36
	NRW(m^3)	200,370	125,733	312,914	215,166	304,374	286,530	280,593	332,513

4.1.3.1.5 Net supply

Net water supply, water distributed including apparent loss, was calculated as the difference between SIV minus real loss. CSA's population data and AAWSA (2011) demand projection data were used for such calculations (Table 4-7). This study has found that net supply has not shown significant change over time but increased and decreased at different times. The decrease in the rate of growth of billed volume could be associated with AAWSA's very poor billing system, customers' unwillingness to settle their bills on time, illegal connections and unbilled authorized consumptions.

Table 4-7: Volume and percentage of billed volume compared to SIV for the period 1996- 2015

Year	production		Billed volume		Monthly billed volume (%)
	Annual (10^6m^3)	Monthly (10^6m^3)	Annual(10^6m^3)	Monthly (10^6m^3)	
1996	56.355157	4.696263	35.5	2.958333	62.99
1997	58.443725	4.87031	36.8	3.066667	62.97
1998	53.866708	4.488892	34	2.833333	63.12
1999	64.006363	5.333864	40.5	3.375	63.27
2000	65.793897	5.482825	41.5	3.458333	63.08
2001	63.02817	5.252348	39.7	3.308333	62.99
2002	68.796146	5.733012	43.3	3.608333	62.94
2003	67.537629	5.628136	42.6	3.55	63.08
2004	75.820158	6.318347	41.7	3.475	55.00
2005	80.07355	6.672796	51.2	4.266667	63.94
2006	82.860272	6.905023	49.9	4.158333	60.22
2007	86.278589	7.189882	52.5	4.375	60.85
2008	88.405623	7.367135	53.3	4.441667	60.29
2009	92.201275	7.68344	55.7	4.641667	60.41
2010	98	8.166667	63.1	5.258333	64.39
2011	105.574734	8.797895	68.8	5.733333	65.17
2012	112.215567	9.351297	67	5.583333	59.71
2013	120.93074	10.077562	72.5	6.041667	59.95
2014	119,759625	9.979968	75.4	6.283333	62.96
2015	129.86	10.821667	81.8	6.816667	62.99

4.1.3.1. 6 Daily Per capita consumptions (l/c/d)

The volume of time serious daily per capita billed consumption, calculated for the three population scenarios, was found to be less than 70 lit/c/d. This value is far below AAWSA's claim of 110 lit/c/d (Table 4-8).

Table 4-8: Aggregated per capita water consumption for the period 1996-2015

Year	AAWSA		CSA data		Day time (30% CSA)	
	Population	l/c/d	Population	l/c/d	Population	l/c/d
1997	2150000	46.9	2286000	44.1	2971800	33.9
1998	2190000	42.5	2354000	39.5	3060200	30.4
1999	2230000	49.7	2424000	45.7	3151200	35.2
2001	2320000	46.9	2570000	42.3	3341000	32.6
2002	2360000	50.2	2646000	44.8	3439800	34.4
2003	2400000	48.6	2725000	42.8	3542500	32.9
2004	2440000	46.8	2805000	40.7	3646500	31.3
2006	2520000	54.2	2973000	46	3864900	35.3
2007	2570000	55.9	2739551	52.5	3561416	40.3
2008	2967000	49.2	2792555	52.3	3630322	40.2
2009	3051000	50	2851862	53.5	3707421	41.1
2010	3136000	55.1	2914245	59.3	3788519	45.6
2011	3224000	58.4	2979481	63.2	3873325	48.6
2012	3314000	55.4	3049043	60.2	3963756	46.3
2013	3407000	58.3	3121654	63.6	4058150	48.9
2014	3503000	58.9	3197210	64.6	4156373	49.6
2015	3601000	62.2	3275348	68.4	4257952	52.6

4.1.3.1.7 Supply coverage and population served

Urban water use can be expressed in different units including cubic meters per year (m^3/y), m^3/ per month, m^3/d, lit d^{-1} and others. This volume is increasing linearly with time. It reached 81.8 $x10^6$ m^3 in 2015 from what it was 35.5 $x10^6$ m^3 in 1996 (Table 4-9).

Table 4-9 : Total Population served (resident population and a day time population equal to 30 % of the resident population (resident population estimated by CSA*)

Year	Population (No.)	Consumption (m^3/d)	Consumption (lit)	Total Demand (m^3/d)	Mean per capita demand (lit/c/d)	Demand growth rate
2010	2914245	179,172	179,171,641	231007.1	79.2	
2011	2979481	189,631	189,631,384	298354	100.1	0.26
2012	3049043	184,721	184,720,575	322106.6	105.9	0.08
2013	3121654	181,474	181,474,034	346214.8	111.4	0.07
2014	3197210	181,052	181,051,600	370696.4	116.8	0.07
2015	2914245	179,172	179,171,641	395569.7	122.1	0.06

The percentage of the population connected to the water supply system showed relatively smaller values in all the three population size scenarios (AAWSA projection, CSA projection and high scenario data used by other studies). But this percentage of the population served by AAWSA's water supply system is increasing linearly with time.

The implications of the evaluation of past, present and future water supply situation of Addis Ababa city can be generalized by the following major events presented in Table 4-10 below.

Table 4-10: Major events in Addis Ababa Water Supply system

Year	Major event	Remark
1886	Establishment /foundation of Addis Ababa city	
1901	Addis Ababa got the first piped water supply	
1942/3	Construction of GefersaI Dam	
1955	Construction of Gefers II dam	Rehabilitation
1970	Construction of Legedadi dam	The water treatment plant was also established
1985	Expansion of Legedadi dam	
1999	Construction of Dire dam	
2001	Commissioning of Akaki well field	
2012	Commissioning of new Akaki well field	

4.1.3.2. Current and future water demand in Addis Ababa City

The past and current imbalance between water supply and demand is expected to continue unresolved as past evidences and future projections show that demand is by far greater than supply. The exceeding rate of increase in demand over production of additional water is expected to widen this gap. The gap between supply and demand, called unmet demand, is summarized in Table 4-11. Water demand is expected to demonstrate a slow decreasing trend. There is a change in AAWSA's water service provision options (standpipes, yard and house connections) but with no remarkable supply increment which in agreement with the findings of UN-HABITAT (2006).

Table 4-11: Population and population served based on different population sizes

Year	Total population based on			Population served per mode of service				Population served (%)		
	AAWSA	CSA	CSA*	HHC	PFC	YC	total	AWSA	CSA	CSA*
1996	2109000	2220000	2852700	724960	552000	0	1276960	60.55	57.52	44.76
1997	2150000	2286000	2931000	747615	569250	0	1316870	61.25	57.61	44.93
1998	2190000	2354000	2931000	770270	586500	0	1356770	61.95	57.64	46.29
1999	2230000	2424000	3093000	792925	603750	0	1396680	62.63	57.62	45.16
2000	2273800	2495000	3177140	811049	617550	0	1428600	62.83	57.26	44.96
2001	2320000	2570000	3266000	815580	621000	0	1436580	61.92	55.9	43.99
2002	2360000	2646000	3354000	860890	655500	0	1516390	64.25	57.31	45.21
2003	2400000	2725000	3445000	906200	690000	0	1596200	66.51	58.58	46.33
2004	2440000	2805000	3537000	951510	724500	0	1676010	68.69	59.75	47.39
2005	2480000	2887000	3631000	996820	759000	0	1755820	70.8	60.82	48.36
2006	2520000	2973000	3729000	1064785	810750	0	1875540	74.43	63.09	50.3
2007	2570000	2739551	3510551	1178490	897328	0	2075820	80.77	75.77	59.13
2008	2967000	2792555	3682655	1299287	989305	0	2288590	77.13	81.95	62.15
2009	3051000	2851862	3767162	1366142	1040210	0	2406350	78.87	84.38	63.88
2010	3136000	2914245	3855045	1458748	1076105	6716	2541570	81.04	87.21	65.93
2011	3224000	2979481	3946681	1554743	1114114	22080	2690940	83.47	90.32	68.18
2012	3314000	3049043	4043243	1641171	1149469	47840	2838480	85.65	93.09	70.2
2013	3407000	3121654	4143754	1699203	1172614	58880	2930700	86.02	93.88	70.73
2014	3503000	3197210	4248110	1782815	1206022	75440	3064280	87.48	95.84	72.13
2015	3601000	3275348	4355648	1862577	1238840	101200	3202620	88.94	97.78	73.53

Where, HHC = private in-house connection, PFC = public fountain connections and YC= yard connection

CSA* implies total population estimated by CSA plus 30% of this population

4.1.3.2.1 Demand-Supply Gap

Supply gap or unmet demand, the difference between the total water demand and the total water supply, was calculated from the values of SIV, billed consumption and projected projection. It is highly dependent on the magnitude of NRW. By calculating this gap both without and with considering NRW, the findings of this study have showed that demand was increasing faster than production. Demand coverage was 77.6%, lower than AAWSA's report of 81%. The decreasing trend of supply coverage contradicts with AAWSA's plan of increasing supply coverage to reach 100% in 2015. AAWSA's report of 79,100,106, 111 and 117 l/c/d consumption deviates from the calculated value of 61, 64, 58 and 58 for the same period (2010: 2014).

The decreasing per capita consumption from 2013 onwards might be associated with population growth and enhanced non-domestic consumption by the booming construction and other economic activities. Although there was additional water production from 18,932,903 m^3/y (2010) to 69, 267, 777m^3/y (2014), demand showed a higher average growth of rate of 11.8% over six years comparted to 2.64% average growth rate for water production over the same period. This calls for exploration of new water sources and practicing water management techniques (NRW reduction, demand management, rainwater harvesting, and wastewater treatment and at least re- use for non-potable uses (such as landscape watering, car washing and others) that are putting pressure over fresh water (Table 4-12**)**.

Table 4-12: Daily and annual demand -supply gap (m^3) during 2010:2015 (based on CSA, 2007)

Year	Total demand (m^3)		Supply gap without NRW(m^3)			Supply gap with NRW (m^3)		
	Daily	Annual	Daily	Annual	Coverage (%)	Daily	Annual	Coverage (%)
2010	231007.1	84,375,345	39123.9	14,289,999	116.9	-51835	-18,932,903	77.6
2011	298354	108,973,816	-9672.3	-3,532,818	96.8	-108723	-39,710,953	63.6
2012	322106.6	117,649,427	-14988.8	-5,474,676	95.3	-137386	-50,180,237	57.3
2013	346214.8	126,454,971	-17747.4	-6,482,246	94.9	-164741	-60,171,580	52.4
2014	370696.4	135,396,874	-41912.3	-15,308,483	88.7	-189645	-69,267,777	48.8
2015	395,569.7	144,481,832.9	-171,613.5	-62,681,833	56.6	-272, 394	-99, 491, 833	43.4

4.1.3.2.2. Disaggregated Water Demand

Water demand can be analyzed either aggregated for the entire city or disaggregated for a sub city (a given branch) for a more accurate planning purpose. The current investigation has disaggregated water demand based on the current eight water supplying branches. This disaggregation was done based on CSA (2008) and AAWSA (2010) branch data. Thus, the percentage contributions of each branch to the entire city population were estimated and the population of the eight branches was calculated taking constant proportion through 2007: 2015 (Table 4-13). The volume supplied by AAWSA is lower than 50-100 liters per person per day available water for all persons recommended by national and international guidelines but slightly higher than an absolute minimum of 20 l/c/d (UNDP, 2006).

Table 4-13: Summary of disaggregated demand of the three population growth scenarios

year	AAWSA's data				CSA projection			With day time population		
	Mean demand	population	Supply (l/c/d)	Unmet demand (l/c/d)	population	Supply (l/c/d	Unmet demand (l/c/d)	population	Supply (l/c/d	Unmet demand (l/c/d
2010	79	3136000	57.1	21.9	2914245	61.5	17.5	3788518.5	47.3	31.7
2011	100	3224000	58.8	41.2	2979481	61.5	38.5	3873325.3	49	51
2012	106	3314000	55.7	50.3	3049043	61.5	44.5	3963755.9	46.6	59.4
2013	111	3407000	53.3	57.7	3121654	61.5	49.5	4058150.2	44.7	66.3
2014	117	3503000	51.7	65.3	3197210	61.5	55.5	4156373	43.6	73.4
2015	122	3601000	49.8	72.2	3275348	61.5	60.5	4257952.4	42.1	79.9

Source: Adapted from AAWSA Business plan (2011)

4.1.3. 2.3 Population Distribution Among Branches

This investigation has shown unevenly divided population size among the eight branches supplied with AAWSA's water. Akaki branch serves only 4.9% of this population while Nefas Silk branch serves as big as 21.8% (Table 4-14). AAWSA's projection, CSA projection /census population data, and population size with day time population of about 30% of the CSA projected size were used for this analysis.

Table 4-14: Population distribution among the eight Branches

Branches	2010	2011	2012	2013	2014	% share
Addis Ketema	37816	48841	52729	56676	60684	16.1
Akaki	11528	14889	16074	17277	18499	4.9
Arada	42002	54247	58565	62949	67400	17.9
Gulele	12890	16648	17973	19318	20684	5.5
Gurd Shola	19168	24756	26726	28727	30758	8.2
Megenagna	30106	38883	41978	45120	48311	12.8
Mekanisa	30106	38883	41978	45120	48311	12.8
Nifas Silk	51212	66142	71407	76752	82179	21.8
Addis Total	234828	303289	327430	351939	376826	100
Annual growth rate (%)		22.6	7.4	7	6.6	

4.1.3.2.4. Disaggregated Daily Water Demand

The daily disaggregated water demand analyzed for the eight branches based on the total demand data of the entire city during 2010:2014 showed an average growth rate of 10.4 % assuming uniform demand growth for all branches. This categorized them into three categories:

High demand branches: the three branches Nifas Silk, Arada and Addis Ketema (in that order) have high water demand related with their high population density; vibrant economic activities demanding more water.; and characteristic developed lands. Customers may not have private water sources.

Moderate demand branches: Gulele, Mekianisa, and Megenagna have moderate water demands due to their moderate population densities with possibility of developing private sources as these areas are not completely developed.

Low demand branches: Akaki, and Gurd Shola branches showed the lowest demands related to their sparsely populated customers. Most vital water consumers concentrated here can have their own private water sources or may use river water at least for non-potable uses. The summary of total dis aggregated demand is presented in Table 4-15 below:

Table 4-15: Summarized daily water demand of branches (m^3)

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015
Addis Ketema	448255	457145	466854	477066	487745	499133	511019	523388	536179
Akaki	136646	139356	142315	145428	148684	152155	155778	159549	163448
Arada	497869	507743	518526	529868	541729	554377	567579	581317	595524
Gulele	152790	155820	159129	162610	166250	170131	174183	178399	182759
Gurd Shola	227204	231710	236631	241807	247220	252991	259016	265285	271769
Megenagna	356859	363936	371665	379795	388297	397363	406825	416672	426855
Mekanisa	356859	363936	371665	379795	388297	397363	406825	416672	426855
Nifas Silk	607038	619077	632225	646054	660516	675937	692034	708784	726107
Addis Ababa	**2738251**	**2792555**	**2851862**	**2914245**	**2979481**	**3049043**	**3121654**	**3197210**	**3275348**

4.2. Customers' satisfaction, perceptions, and experiences

4.2.1. The local reality of urban water supply

Goal 6 of the universal sustainable development goals is to ensure availability and sustainable management of water and sanitation for all. The number of people who use improved drinking water source increased from 82 % in 2000 to 91% in 2015. Yet an estimated 663 million people are still using unimproved sources or surface water (Hotton and Chase, 2016). Water stress affects more than 2 billion people around the globe and this number is projected to rise opposed to integrated water resources management plans under way in every region of the world .

4.2.2 Perception about the water supply service

This perception study took 2016 in order to link the previous situation (up to 2015) and the future from 2015 onwards since GTPII starts in 2016. The analysis and interpretation of customers' perceptions about the water supply service includes water supply interruption, and adequacy of water supply and pressure. About 1 out of 5 respondents said they did not experience water interruption in 2016. However, 4 out of 5 faced interruption which lasted for 1 day up to more than one month (Table 4-16). Nearly half of them said that water was interrupted for more than two weeks. However, the situation gets worst in some years as almost 95% of customers faced water supply failure. In such times, nearly seven out of ten customers failed to receive water supply for up to 1 week. The number of respondents who did no experience water interruptions increased from 5.9% in the worst-case year to 18.7% in 2016.

Table 4-16: Water Supply Interruptions During 2016 and Any Worst-case year(N=273)

Water supply interruptions	Percent	Cumulative percent	Percent	Cumulative Percent
Never	18.7	-	5.9	-
< 1 week	29.3	29.3	67	67
Two weeks	22.7	52	3.3	70.3
Three weeks	18.3	70.3	13.2	83.5
Four weeks	8.8	79.1	0.7	84.2
More than four weeks	2.2	81.3	9.9	94.1

As noted by areas Padowski and Jawitz (20120, ensuring that cities have an adequate supply of water is increasingly important as human populations continue to concentrate in urban since rapidly growing urban demands are straining local and regional water supplies and concerns over urban water scarcity are becoming more prominent (Levin *et al.*, 2002). Different societal strata experience urban water supply in different ways (Del Grande *et al.*, 2016). This survey has expressed and characterized reliability as the expected length of time between successive failures (i.e., time-to-failure), the number of outages or failures to meet supply commitments.

Duration of water supply: Nearly half of the respondents have reported that the average duration of piped water availability was generally less than 12 hours per day while a significant proportion of water customers (22.7%) have less than 1 hour (Table 4-17). The daily water supply of 2 customers out of 5 customers varies from less than 1 hour to and 6 hours. Only 4 out of 10 receive water between 18-24 hours a day. Domestic customers have the highest duration of water supply than other customer categories (data not shown).

Table 4-17: The length of water supply hours per day

Length of supply hour	Less than 1 hour	1-6 hours	6-12 hours	12-18 hours	18-24 hours	Total
Percent	22.7	11	10.3	15.4	40.7	100
Cumulative percent	22.7	33.7	44	59.3	100	

Adequacy of water supply: It is the volume of water supplied being able to meet customers' needs satisfactorily or being sufficient for the end in view. Nearly 69 % of respondents have rated their water supply as either acceptable or adequate or more than adequate (Table 4-18). The remaining 31% expressed dissatisfaction with the amount of water supplied to them. They perceived it either inadequate or highly inadequate. Vendors are most dissatisfied followed by public fountain and commercial categories. 27% of domestic comers are dissatisfied by the adequacy of their water supply.

Table 4-18: Survey results for the question: Do you have sufficient water in your home?

Respondents (%)	Slightly adequate	Adequate	more than adequate	Inadequate	Highly inadequate	% of this category
Commercial	8.3	55.6	0	22.2	13.9	13.2
Domestic	9	62.3	1.8	15	12	61.2
Pseudo domestic	12.5	62.5	0	6.3	18.8	5.9
Industrial	0	100	0	66.7	0	22
Institutional	10.5	55.3	0	13.2	21.1	13.9
PF	12.5	12.5	0	25	50	2.9
Vendor	0	0	0	0	100	0.7
All categories	**9.2**	**58.6**	**1.1**	**15.8**	**15.4**	**100**

Water pressure, a measure of the force that pushes the water through our pipe and into our property and as felt by water customers, was analyzed based on the perceptions of consumers. Dissatisfaction with low water pressure was reported by 30% of the respondents indicating that they had experienced either very low or low water pressure. Pressure is acceptable only for 3 customers out of 5 customers. Level of dissatisfaction is more (56%) for domestic customers than other categories of customers. Note also that level of dissatisfaction with the supplied pressure is high for commercial customers (Table 4-19).

Table 4-19: Customers' Perception of the adequacy of water supply pressure(N=273)

Perceived pressure	Low- Very Low	Optimum	High-Very High	Sample size (%)
Commercial	39	19	42	13.2
All Domestic	55	53	90	67
Industrial	33	17	50	2.2
Institutional	39	29	31	13.9
Public Fountain	25	25	50	2.9
Vendors	0	0	100	20.7
all categories (%)	**30**	**26**	**44**	**100**

Customers have witnessed that both low pressure and high-pressure values that have contributed to the dissatisfaction of consumers since they cause breakage of water pipes, tap and other facilities in areas located at lower part of the city with better and continuous supply. Low pressure lengthens water collection time disappointing the water collector, associated water wastage, and inflated water bills. This disable customer to collect adequate water in case of short supply hours for residents in high elevation places like Tsion Hotel, Silte Sefer, Biret Dildiy, Kara and other areas which were suffering from supply shortage as long as a month because of low pressure.

Low or no system pressure causes back siphonage and introduce bacteria into drinking water (Lee and Schwab, 2005). The reported low pressures in this study area might be either due to inadequate pressure in the water main or plumbing issues or low water flow. Plumbing issues include bursts, diameter of the pipe, corrosion in the pipes or on appliances, the length of the supply line, the presence of a leak on the supply, the number and type of fittings along the pipe: ferrules, stop taps, meter, bends, and any inconsistence in the pipe.

4.2.3. Water quality

Aesthetic parameters of water quality may not show water safety (Olukanni *et al*, 2014). Yet, they can provide important clues to water problem causes and treatment devices selection to improve water quality. Hence, reliance on senses may lead to avoidance of highly turbid or colored but otherwise safe waters in favor of more aesthetically acceptable but potentially unsafe water sources (WHO, 2017). Water provided by AAWSA could be classified into poor quality for drinking by nearly 31% of the customers compared to 69% of them who have perceived the quality of their water supply from regular to very good (Figure 4-6). Public fountain users and false domestic customers have not rated the overall quality of their supply. Only few customers from the commercial, domestic, industrial, institutional and vendor user categories have rated their supply as excellent (data not shown). In Addis Ababa 69% of the consumers perceived the quality of their overall water supply acceptable (regular to very good) (Figure 4-6).

The majority of the customers (58%) reported that the water delivered to them is not colorless. Two out of five customers reported that the water has rusty and black color.

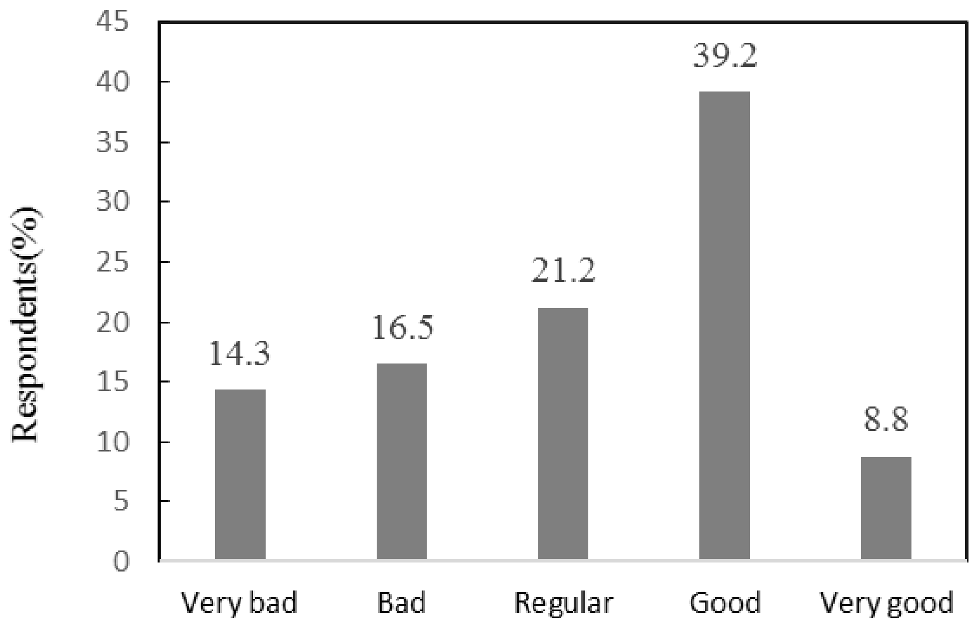

Figure 4-6: Color and appearance

The reddish hue seen when water is first drawn may indicate the presence of a significant amount of particulate iron in the water due to galvanized iron pipe in the building or rusted pressure tank, well casing or pump. Water color that varies from yellow to dark brown might suggest the presence of tannins (humic acid) in the water, consistent with the note by Leenheer (2004). Water color varying from blackish hue to almost black suggest a significant amount of dissolved manganese in the water (Adams, 1969; Olukanni *et al*., 2014). A milky appearance might be an indication of dissolved air in the water associated with the water supply system caused by problems such as the well pump sucking air or a malfunctioning pressure tanks (Wildrick *et al*., 1976; Russell *et al*., 1987). The appearance of suspended particles reported by respondents might have been caused by riled-up water in the water supply, sand pumping from a well or debris left in the piping after repairs. Similar observations were reported by Johnson and Scherer (2012).

The reported soap curds that are gel-like mixtures of soap, calcium and magnesium and lime scum (white deposits) and off-white scale might suggest that the water is hard due to elevated amounts of calcium and magnesium salts in the raw water supplies (MacAdam and Parsons, 2004; Sörme and Lagerkvist, 2002; Yang *et al*., 1998). Rust colored water and stained sinks are clue for iron contamination. Corrosive water may indicate heavy metal contamination (Chowdhury *et al*., 2016). Green residues or stains left on faucets, pots, and skins can be the results of corrosion of household plumbing and leaks in pipes are sure indicator of such corrosion (Oswald *et al*., 2014). As it is nearly impossible to taste, see or smell most heavy metals, they can reach toxic concentration before any symptoms. Black color water suggests elevated concentration of manganese (Figure 4-7).

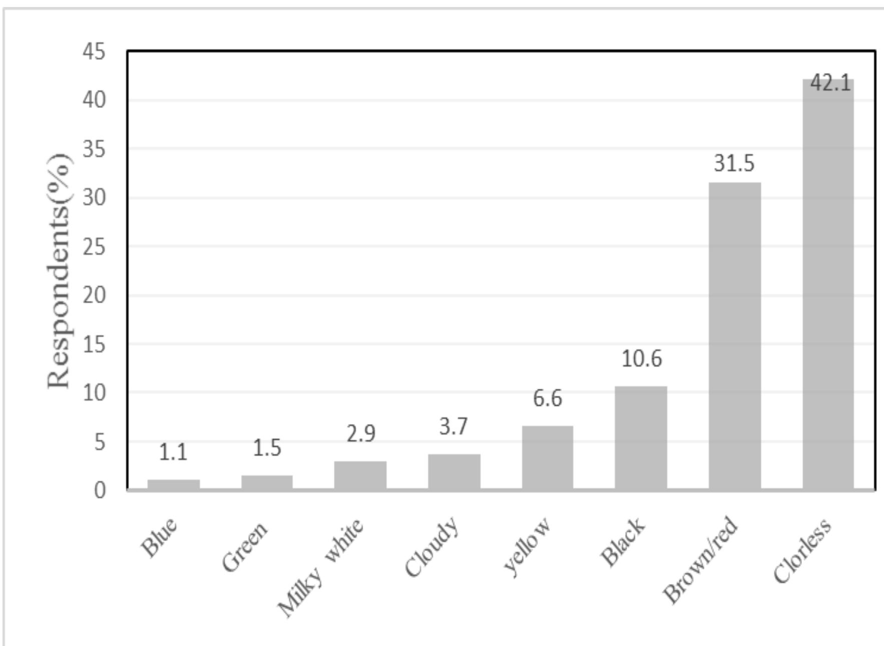

Figure 4-7: Water Customers' water color perception in 2016

4.2.3.1. Taste

Three out of five customers brand their water supply palatable (pleasant to drink). The perception of 43% of the customers is that the water has objectionable/bad taste. As high as 17 % of the respondents' suspect that their water taste is changed to sewer because the pipeline might be contaminated by sewer. This may lead to serious health risk. The Fishy/ /musty / earthy/

moldy taste of water might have resulted from harmless compounds from decomposing natural organic matter entering the water supply commonly associated with surface water supplies. Metallic or rusty taste might indicate possible contamination with elevated concentration of manganese or other metals (Williams and Suh, 1986). Sewer taste suggests sewer contamination of water (Figure 4-8) but it doesn't necessarily grantee either water quality or water safety. Minerals are certainly responsible for much of water's mouth feel since they can add a salty, sweet, bitter or sour flavor to water (Dietrich, 2006).

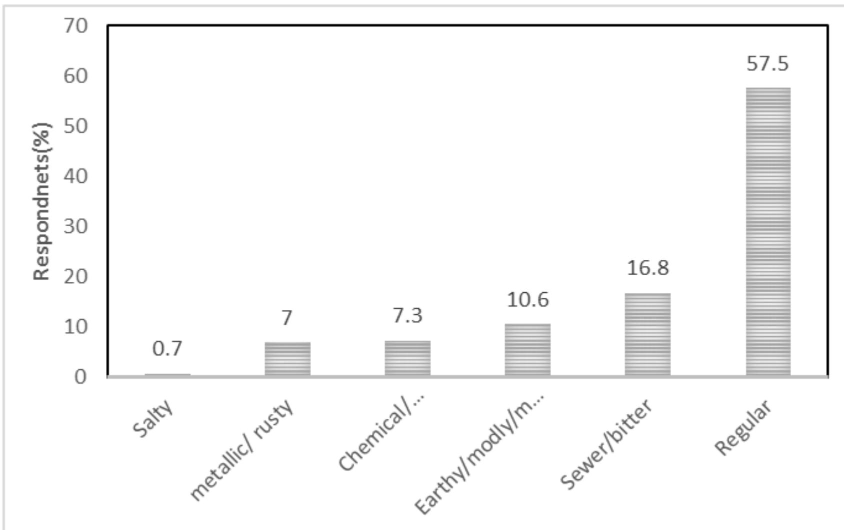

Figure 4-8: Taste perception of customers of their water supply

4.2.3.2. Odor or Smell

More than three quarter of respondents have perceived their water supply as odorless and the remainder quarter have classified it as having offensive or unpleasant smell. Some respondents have labeled their supply either earthy/ musty or rotten egg or sewer while smaller proportions of them have described it as chemical/ medicine or rust smell (Figure 4-9). This doesn't necessarily grantee water quality or water safety. The reported rotten egg odor can be due to hydrogen sulfide gas in the raw water.

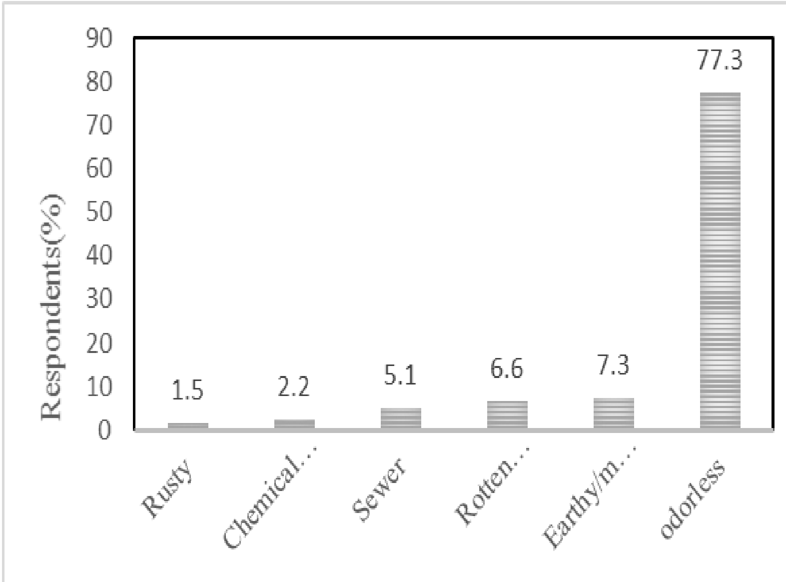

Figure 4-9 : Smell classification of the water supply

4.2.3.3. Affordability of services

Results of this section are analyzed based on customers' response to two main questions: The opinions of customers on the price of the water and whether they could afford to pay for the services i.e. customer were asked "how much do you pay for water per month?" and" how do you rate the water fee that you are paying are charged as expensive, reasonable or cheap?" Only 14% of the customers perceive that the water price they are charged is expensive. 63%, 9% and 28% of domestic customers perceive the amount they are paying for the water they use is cheap, expensive and average respectively. A larger proportion of 3 out of 5 customers rated this tariff as cheap. About 86% of water customers rated the water price as affordable that is either optimum or cheap. As shown in Table 4-20, the perception on affordability did not change significantly with water users' category. The current water tariff evaluation and water customer's residential sub city have very significant correlations, X^2 (18, N=273) =43.484, P<001. This demonstrates significant differences of water tariff evaluation values.

Table 4-20: Evaluation of water price by water customers in 2016

Respondents (%)	Water price			Sample size (No.)
	Cheap	Expensive	Optimum	
Commercial	44.4	30.6	25	36
Domestic	62.9	9	28.1	167
False domestic	75	18.8	6.3	16
Industrial	66.7	16.7	16.7	6
Institutional	57.9	13.2	28.9	38
PF	62.5	25	12.5	8
Vendor	50	50	0	2
All categories	**60.4**	**14**	**25.6**	**273**

The number of people who perceive the water price expensive is more in Lideta, Yeka and Bole sub cities than others (Table 4-21). Unconnected consumers were found to be paying much higher for water supply compared to those connected to the utility water supply

Table 4-21: customers' residential sub city and their current water tariff evaluation

Perceptio	Addis ketema	Akaki –kality	Arada	Bole	Gulele	Kirkos	Kolfe keraniyo	Lideta	Nefas Silk	Lafto
Cheap	58.3	76.9	61.1	42.2	86.4	50	78.3	70	75	
Optimum	33.3	11.5	22.2	37.8	13.6	42.9	10.9	0	16.7	
Expensive	8.3	11.5	16.7	20	0	7.1	10.9	30	8.3	
Sub total	8.8	9.5	6.6	16.5	8.1	10.3	16.8	3.7	4.4	

4.2.4. Overall water customer satisfactions

In this study, the aggregated overall satisfaction level of all types of customers with the water supply and water service were found to be less satisfied. About 43% of the customers have said that they are not fully satisfied with the service being offered to them. This indicates that roughly six out of ten customers are not yet satisfied. The level of dissatisfaction is highest with the users under industrial category. Three out of ten domestic customers have expressed some level of dissatisfaction. The analysis of overall satisfaction disaggregated by water use categories showed that institutional (18.4%) and domestic (12.6%) customers have witnessed very high satisfaction compared to the aggregated average of 11% (Figure 4-10).

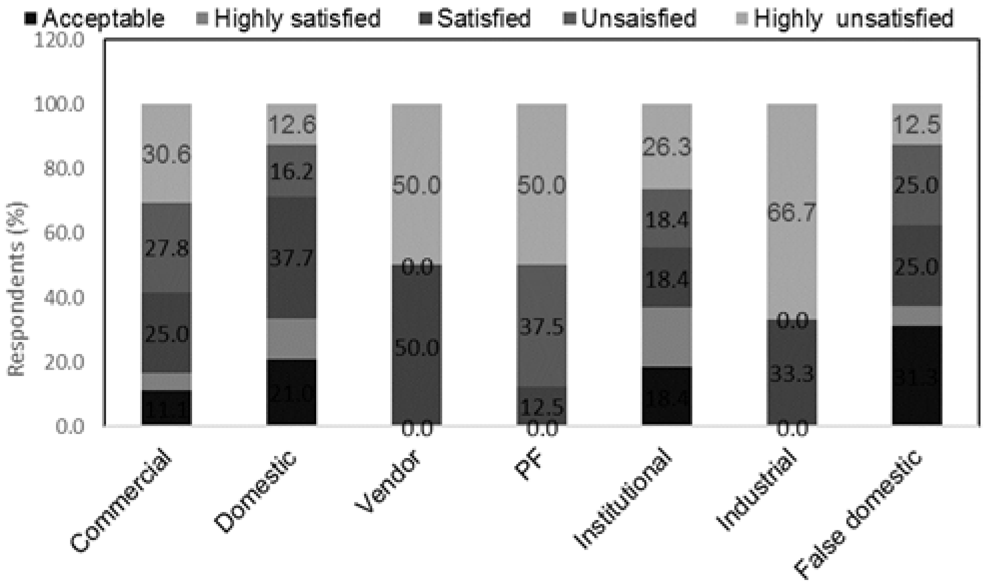

Figure 4-10: Water customers' s perceived satisfaction per user category

C*ustomer –operator relations:* Customer complain handling and dispute resolution: Based on the results of field observation and face to face customer interview nearly 3 out of 4 respondents reported that they did not get information from the utility (i.e. billing procedures, water demand management, etc.) while 25% said they get information about the activities of the water service provider. Thus, requests for service, complaints and suggestions are not welcomed but handled in an inconsistent manner as follows: no prompt response to the request/complaint; customers are not kept informed of the progress and outcome of the request/ complaint; no confidentiality of personal details; and no thorough and objective investigation of the complaints.

4.2.5. Persistency of water quality

As depicted in Figure 4-11 and Figure 4-12, most odor and taste problems of water directly taken from tap are persistent and have started since long time.

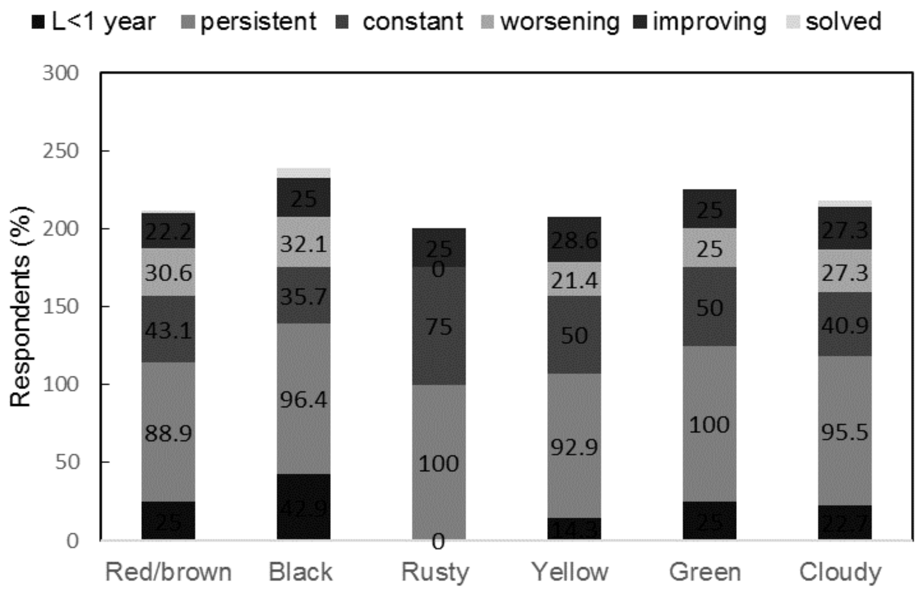

Figure 4-11: Persistence of color of tap water

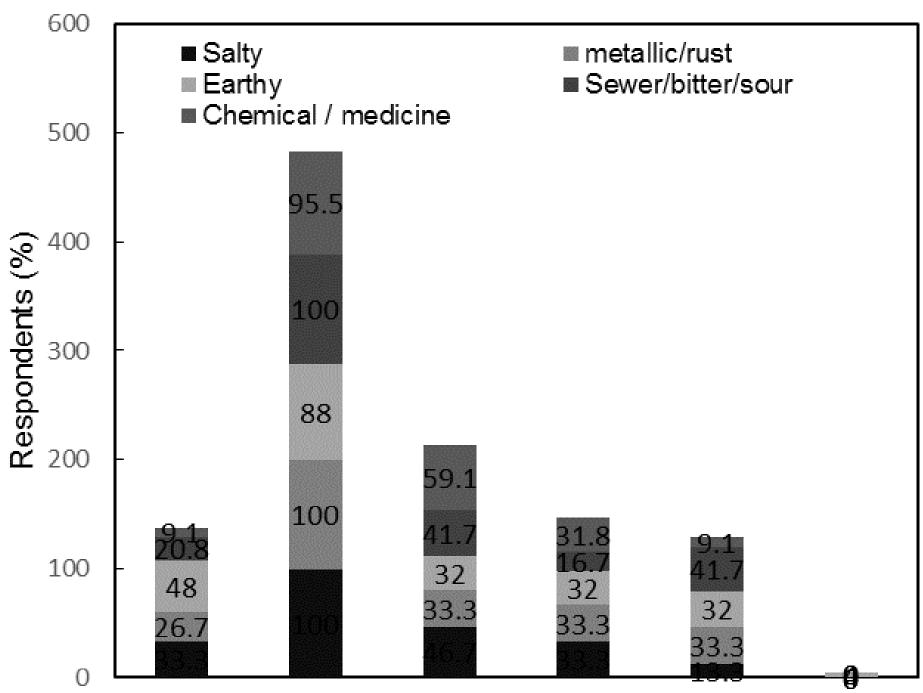

Figure 4-12: Taste of tap water

The quality of water stored in homes showed persistency (Figure 4-13).

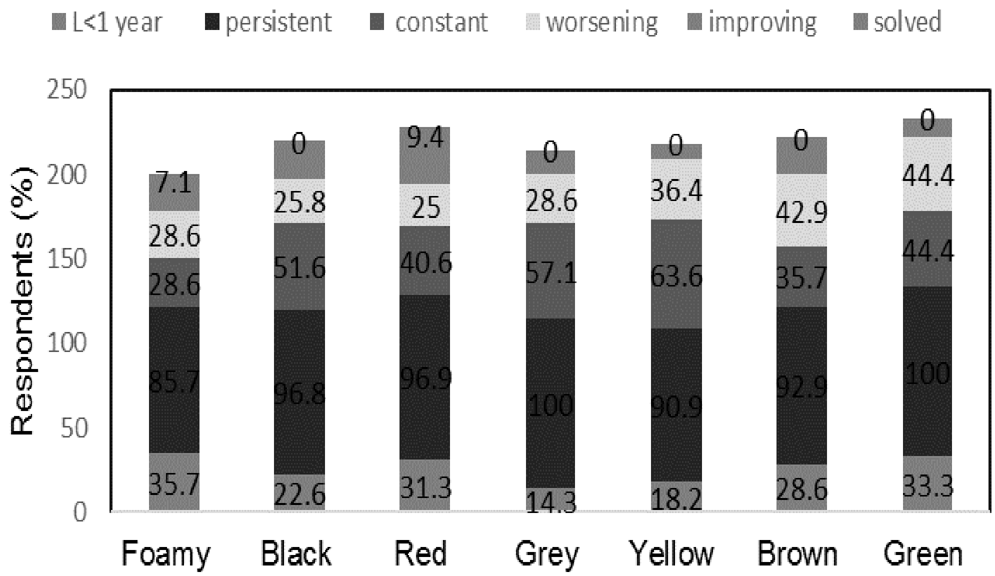

Figure 4-13: Persistence and color of water stored in home

Aesthetically unacceptable water supply undermines the confidence of customers leading to complaints and force them use water sources that are aesthetically more acceptable but potentially less safe. Customers have no means of judging the safety of their drinking water that appears dirty or discolored or that has unpleasant taste or smell even though these characteristics may not in themselves be of direct consequence to health. Thus, provision of safe and acceptable in appearance, taste and odor is of high priority. Customers have listed lack of water supply, exceeding of water demand over the capacity to supply, low piped water coverage, wasteful water usage practices by some customers due to lack of monitoring and evaluation as well coupled with the absence of strong laws, intermittency of supply, unacceptable physical water quality and uneven or unequal distribution of the available water due to the utility's inefficient and ineffective performance (low capacity) and low water tariffs as major characteristics .

The poor water service levels have forced city residents to adopt expensive coping strategies such as installing ground storage tanks or purchasing storage materials and household filters and/or chemicals. Those without connections (mostly in expansion areas known as illegal settlers) have the additional burden of purchasing water of unknown quality at expensive costs from far distances as well as often not knowing to the nearest day when water may come.

4.3. Situation analysis of the water supply service of Legedadi with WEAP

4.3.1 The situation of water supply hours and volume in Addis Ababa

4.3.1.1 Weekly water supply days among branches

Water distribution in the city is haphazard and inefficient and follows neither the city's administrative divisions nor have defined pattern (Table 4-1).

Table 4-1 : The eight Branch Offices of AAWSA and their Areas of Water Supply service (based on AAWSA's June- December 2016 Supply Schedules)

Branch	Sub cities served	Weredas served	Total weredas served	Remark
Addis Ketema	Addis ketema	4,6,7,9,10	19	Has the 2nd highest number of services weredas
	Gulele	5,6,9,10		
	Kolfe Keranyo	6-10, 12-15		
Akaki	Akaki Kaliti	1-5,7-11	10	Most of the weredas have 24-hour supply
Arada	Arada	1,8-10	19	Has the 2nd highest number of services weredas
	Kirkos	1-12		
	Lideta	3-9		
	Addis ketema	1-4,8		
	Yeka	6		
Gulele	Gulele	1,2,5-8	14	The worst water shortage branch
	Arada	4-7,9		
	Yeka	1-3		
Gurd Shola	Bole	6-11,13,14	12	Has the highest number of customers
	Yeka	9-13		
Megenagna	Bole	1-5	9	Serves the lowest number of weredas
	Yeka	5,7,8		
	Kirkos	1		
Mekanisa	Nefas Silk Lafto	1-4	19	Has the 2nd highest number of services weredas
	Kolfe keranyo	1-6,9		
	Lideta	1,10		
	Kirkos	4-7,10,11		
Nefas Silk	Nefas Silk Lafto	Lebu 01,5-12	22	Serves the highest number of with 24-hour supply except three weredas
	Kirkos	1-12		
	Akaki	6		

According to this investigation, weekly water supply days and daily water supply hours have significant differences among branches. Thus, weekly water supply days were the highest weekly water supply days (6.55± 1.41) and the lowest weekly water supply days of 2.23 ± 2.15 in Akaki and Gulele branches respectively with city wise average value of 4.96 ±2.43. accordingly, the weekly water supply days were less than 3; between 3-5 days and more than 5 days for Gulele; Addis ketema, Megengna and Nefas Silk; and Akaki, Arada, Gurd Shola, and Mekanisa branches in that order. Akaki branch provides 3 times more days in a week compared to Gulele branch (Table 4-2). The standard deviation comparable to mean of Gulele branch suggests absence of precision in water provision.

4.3.1.2 Daily water supply hours among branches

Mekanisa branch supplies water for longest average hours per day (22.92±7.73) compared to Gulele branch that supplies water the shortest (7.67±7.4) hours per day (Table 4-2). Gulele branch has very high distribution variability as shown by its very high standard deviation with supplying water 2 times shorter hours daily compared to the aggregated city wise mean daily supply hours of 15.17±8.48. Thus, the current branch wise water supply distribution is characterized by supply inequity both in terms of weekly water supplying days and daily water supply hours. There are very strong variations in weekly water supply days among branches with $F (7, 2474.5) = 27.36$, $P = .000$ and highly significant variations in daily water supply hours among branches, $F (7, 29913.2) = 31.4$, $p = .000$.

Table 4-2: Mean weekly water supply day and mean daily water supply hours of the eight branches of Addis Ababa City in 2016

Branch	Weekly water supply days				Daily water supplying hours			
	mean	N	Std	CV(%)	mean	N	Std	CV(%)
Addis Ketema	4.884	43	2.4805	50.8	10.9298	43	7.59391	69.48
Akaki	6.548	63	1.4060	21.5	21.3333	63	5.61105	26.30
Arada	5.615	78	1.6997	30.3	17.4718	78	6.05198	34.64
Gulele	2.229	70	2.1479	96.4	7.6743	70	7.40238	96.46
Gud shola	5.350	60	2.3349	43.6	18.2600	60	8.11638	44.45
Megenagna	4.420	30	1.9493	44.1	8.7633	30	6.19095	70.65
Mekanisa	6.684	19	1.3765	20.6	22.9158	19	4.72596	20.62
Nefas Silk	4.993	54	2.3695	47.5	15.1278	54	7.62450	50.40
Total	**4.956**	**417**	**2.4389**	**49.2**	**15.1673**	**417**	**8.47979**	**55.91**

Sources : own Analysis of AAWSA Supply schedule reports

4.3.1.3 Weekly supply days and daily supply hours among sub cities

Based on the findings of this study, Arada and Gulele sub cities showed the highest (6.67± 1.41) and the lowest (1.58 ±12.61) weekly water supply days respectively. The city wise average weekly water supply days is 4.95 ±2.44. Hence, Gulele sub city was critically water scarce and supplied less than 3 days per week compared to either water scarce sub cities namely Lideta, Nefas Silkn_Lafto, and Yeka that got water between 3-5 days weekly or water sufficient sub cities (Akaki-Klity , Arada, Addis ketema , Bole, and Kirkos, Kolfe Keraniyo) which were supplied more than 5 days a week.

Arada sub city residents get water 3 times more days in a week than Gulele sub city residnets. The sstandard deviation greater than the mean in case of Gulele sub city suggests that distribution is seriously unreliable and inconsistent (Table 4-3). Akaki-Kality sub city residents are supplied water for longest average 21.15±5.82 hours daily. Gulele sub city residents have the lowest weekly water supply days with high distribution variability (very high standard deviation). The daily range in water supply hours between Akaki-Kality and Gulele sub cities is 16.57.

Table 4-3: Mean weekly water supply days and mean daily water supply days among the ten Sub cities of Addis Ababa during 2016

water supply by sub city level	water supplying days per week				water Supplying hours per day			
	Mean	N	Std. Deviation	CV (%)	Mean	N	Std. Deviation	CV (%)
Addis Ketema	5.947	38	1.4510	24.4	16.6500	38	6.28683	37.8
Akaki Kality	6.485	65	1.4957	23.1	21.1523	65	5.81660	27.5
Arada	6.667	18	1.4142	21.2	18.8556	18	6.91114	36.7
Bole	5.293	46	2.0275	38.3	14.2783	46	8.76150	61.4
Gulele	1.580	50	1.6174	102.4	4.5880	50	3.41017	74.3
Kirkos	6.333	30	1.6678	26.3	19.7133	30	6.62580	33.6
Kolfe Keraniyo	5.476	21	2.2499	41.1	13.8086	21	9.82674	71.2
Lideta	4.548	31	1.6500	36.3	14.6258	31	4.99946	34.2
Nefas Silk Lafto	4.650	44	2.3976	51.6	14.8636	44	7.84516	52.8
Yeka	4.407	74	2.5757	58.4	14.9027	74	8.97662	60.2
Total	**4.956**	**417**	**2.4389**	**49.2**	**15.1673**	**417**	**8.47979**	**55.9**

Source: Own analysis of AAWSA water supply schedule data

The mean daily supply hours in Addis Ababa was 15.17$\pm$8.48. Each week, Arada sub city got water more than 3 times of Gulele sub city which is more than twice the city average weekly water provision days. The daily water supply in Gulele sub city was less than one fifth hours of Akaki-Kality sub city or less than a quarter hour compared to the aggregate city average. The overall water supply situation seen from sub city perspective was characterized by unequal weekly water supply days and daily supply hours. The variation was very strong among sub cities in terms of both mean weekly supply days and mean daily supply hours with $F(9,2474.5) = 26.34$, $p = .000$ and $F(9,29913.2) = 19.36$, $p = .000$ respectively.

Branch based provision narrows supply inequality in weekly number of supply days with better citywide average. Wereda based weekly supply days and daily supply hours have similar result compared to sub city-based modality. There is no significant difference in the number weekly supply days in the three sub cities Kolfe keraniyo, Kirkos and Arada. weredas in Yeka. Nefas Silk –Lafto, Gulele, Akaki-Kality and Addis ketema sub cities, showed very strong differences in weekly water provision days. Weredas of Bole and Lideta sub cities have strong differences (Table 4-4). A customer's residence wereda has strongly affected both weekly supply days and daily supply hours. There was strong difference among sub cities in both weekly supply days and daily supply hours which was also true in case of water supplying branches. Customers who are better off and live in the inner parts of the city enjoy 24 hours daily per week water supply at subsidized prices while the poor who live at higher elevations buy water from vendors up to 7-fold the price paid by these privileged due to altitudinal advantages.

Table 4-4: ANOVA Table of weekly supply days and daily water supplying hours and wereda of residence

Weekly supply days at wereda level	Weekly water supply days				Daily water supply hours			
	mean	N	Std. deviation	CV(%)	mean	N	Std. deviation	CV(%)
Yeka	4.407	74	2.5757	58.4	14.9027	74	8.97662	60.2
Nefas Silk Lafto	4.650	44	2.3976	51.6	14.8636	44	7.84516	52.8
Lideta	4.548	31	1.6500	4.000	14.6258	31	4.99946	13.7000
Kolfe keraniyo	5.476	21	2.2499	7.000	13.8086	21	9.82674	10.0000
Kirkos	6.333	30	1.6678	7.000	19.7133	30	6.62580	24.0000
Gulele	1.580	50	1.6174	1.000	4.5880	50	3.41017	3.4000
Bole	5.293	46	2.0275	7.000	14.2783	46	8.76150	17.1000
Arada	6.667	18	1.4142	7.000	18.8556	18	6.91114	24.0000
Akaki-kality	6.485	65	1.4957	7.000	21.1523	65	5.81660	24.0000
Addis Ketema	5.947	38	1.4510	7.000	16.6500	38	6.28683	13.8500

This disparity in water provision in Addis Ababa agrees with Keivani (2010) observation that has described that cities are prone to huge intra-urban social inequalities.

4.3.2 Characteristics of the Legedadi sub system

The Legedadi sub system is selected as a case study site as it covers large and heterogeneous area of the city. This sub system covers 469302 and 489606 eastings and 987441 and 1005636 northing (UTM) with a total area of 243.85km^2 accounting for 46% of Addis Ababa. This sub system supports about 35.3% of the city's population that receives water supply service. The location map of the Legedadi Subsystem is shown in Figure 4-1.

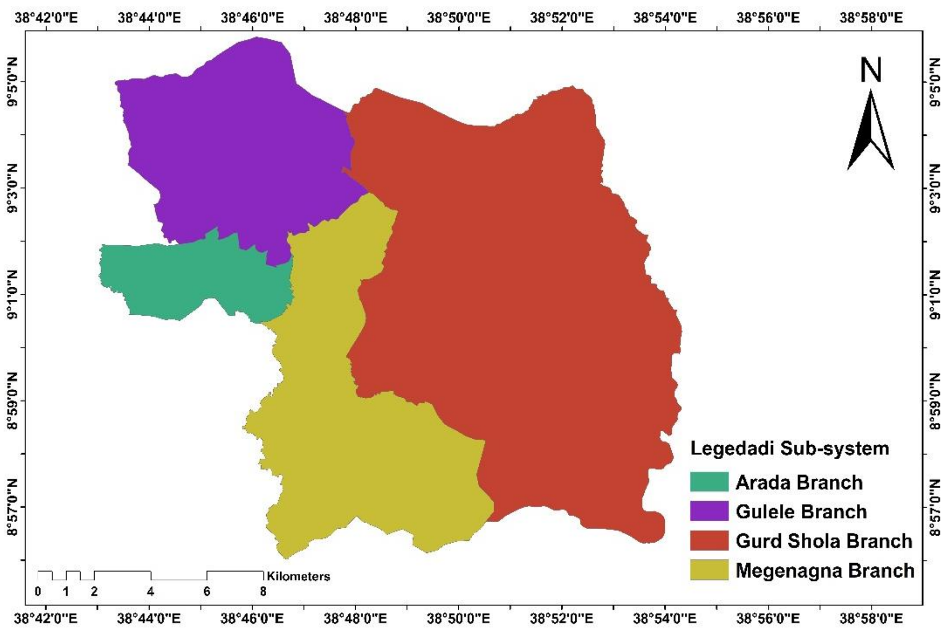

Figure 4-1: Map of Legedadi sub system and its four water supply branches

Legedadi sub system consists of supplies from the water treatment plant to service reservoir of Kotebe terminal, Karalo, Ankorcha, Jan Meda, Gebriel Palace, Teferi Mekonnen, Intoto, AAWSA's ex-main office, Belay Zeleke, Police Hospital, Army Hospital and Kassa Gebre; and pumping stations at Urael and Mexico square. AAWSA's daily water supply for this sub-subsytem for the year 2011 was estimated at 179,138 m^3/d (47.93% of the total supply by the authority) (373725.86 m^3/d). Megenagna, Arada, Gurdshola and Gulele branches constitute this subsystem and supply areas of 54.94, 15.25, 129.21 and 44.45km^2 respectively).

Population size served by the Legedadi sub system was estimated by multiplying the proportions of the areas of sub-cites served by this system by their respective population densities (TABLE **4-5**). The population served increased slightly more than 1.35 times during 2010-2017. This increase could be due to the increase in water supply as a result of increased production. The details of population projection for analyzing population of the subsystem are appended in Appendix B-3.

Table 4-5: Population of Legedadi sub system during 2010-2015

Branch	2010	2011	2012	2013	2014	2015
Gulele	376883	376855	419372	439506	439506	450236
Megenagna	156368	156490	174146	182519	182519	186977
Gurd Shola	411455	411748	458202	480240	480240	491970
Arada	222507	247693	275638	288867	288867	295919
Total	1167214	1192786	1327358	1391133	1391133	1425102

Domestic, industrial, institutional, commercial, landscape/greenery, firefighting and other water users are classified into either domestic or nondomestic for water tariff setting purposes. The number of domestic customers for the period 2011-2017 is summarized in Table 4-6 which also shows that this subsystem covers an average 35.5% of the total water supply users supplied by AAWSA although this proportion has levelled off at 35.3% after 2012.There is drastic increment over time and it is expected to affect water demand significantly.

Gulele Branch area of the Legedadi subsystem has shown the lowest average annual rate of population growth rate of 3.6% per annum which is 4.7 times less than the Legedadi Subsystem's average annual growth rate of 16.9%. This is could be associated with the geographic location of the branch which is neither expansion nor densification area. Arada, Megngna and Gurdshola branches of the Legedadi subsystem demonstrated greater annual average rates of changes of 156.3%, 29.0% and 19.7% respectively. The exceptional high growth rate of population registered by Arada branch is because of the high population density of this area as a result of very high in fill development and the associated densification compared to the other branches.

Table 4-6: Summary of the number of domestic customers in the Legedadi subsystem

Population	2010	2011	2012	2013	2014	2015	2016	2017	Average annual rate of increase (%)
Gulele	376883	376855	419372	439507	439507	450236	461104	472385	3.6
Arada	26003	247693	275638	288867	288867	295919	303060	310473	1563
Megenagna	64675	156490	174146	182519	182519	186977	191493	196178	29
Gurd Shola	217021	411748	458202	480240	480240	491970	503851	516181	19.7
Total	**684582**	**1192786**	**1327358**	**1391133**	**1391133**	**1425102**	**1459508**	**1495217**	**16.9**
% of total supply area	35.1	35.2	37.2	35.3	35.2	35.3	35.3	35.3	35.5

The spatial distribution of organizations in the ten sub cities of Addis Ababa city depicted in Figure 4-2 has relatively larger total number at inner parts of the city compared to peripheral areas. There is industrial concentration in the newly developed and expansion areas, particularly at Akaki-Kality sub city while other organizations such as Garages, Health Centers and Enterprises show higher concentrations in sub cities located at the inner and older parts of the city. The distribution of organizations or institutions in the Legedadi Subsystem (Figure 3-1) has followed a similar pattern to their distribution among the ten sub cities. Their concentrations are higher in Arada and Gulele branches located in the inner and older parts compared to in Gurd Shola and Megengna branches located at the periphery of the city.

Garages and Health centers are denser in the inner parts of the city where population density is high because of infill development and very high population number compared to their distribution in the peripheral areas characterized by a relatively lower population number or population density. The opposite trend followed by the distribution of industries and enterprises has to do either with their earlier establishment before these areas were occupied by city residents or the availability of large vacant places for their construction (Figure 4-6).

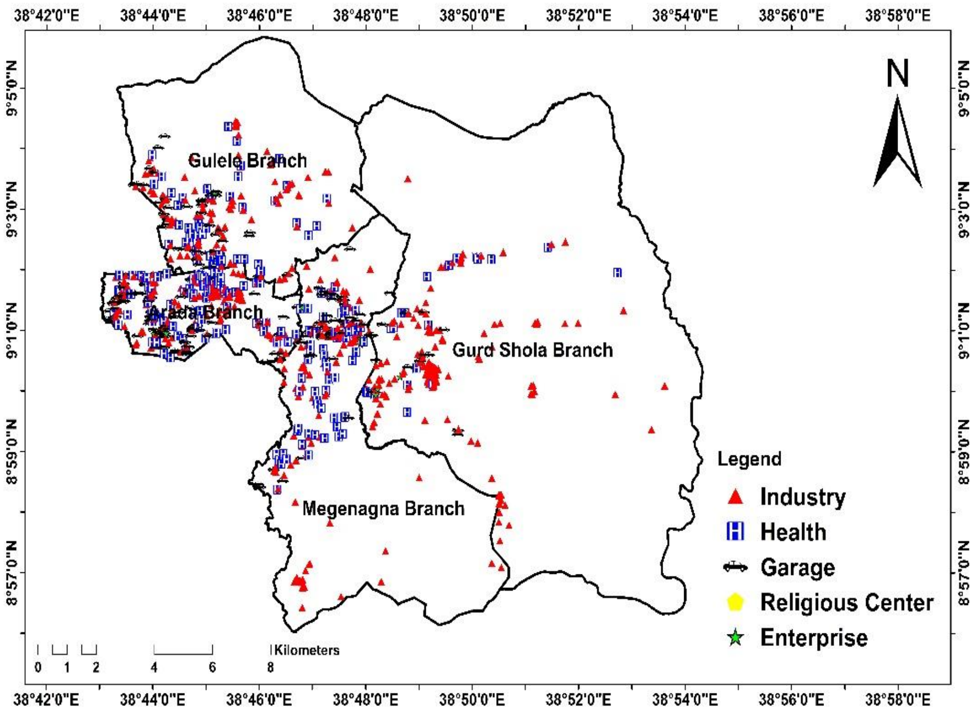

Figure 4-2 : Spatial distribution of organizations in the Legedadi subsystem

4.3.4. The Drastic Scenario

The drastic scenario assumes 100% successful leakage reduction of GTP II plan and 30% non-domestic water demand reduction due to a potential private source development of these non-domestic customers. The outputs of this scenario, presented in Table 4-7 below, has shown that a 30% reduction in non-domestic water demand can balance demand and supply. The unused excess yield water can be stored for future uses during lower water production because of drought or other intensive water demands. Based on the results of this scenario, AAWSA should force by law industrial and commercial units to develop their own water sources, particularly for non-domestic demands that don’t need high quality treated fresh water.

Table 4-7: Water balance during 2026-2030 under 30% groundwater yield reduction

(Billion cubic meters per annum)

Component	2026	2027	2028	2029	2030	average	% Growth Rate
water demand	0.129	0.139	0.15	0.162	0.175	0.151	8.7
supply requirement	1.973	2.043	2.114	2.189	2.265	2.117	3.7
supply delivered	0.163	0.175	0.19	0.205	0.22	0.191	8.8
unmet demand	1.81	1.867	1.925	1.984	2.045	1.926	3.2
Water loss	1.844	1.904	1.964	2.026	2.091	1.966	3.3
Loss rate	93	93	93	93	92	93	(-) 0.3

The causes, patterns, consequences and policy implications of the ongoing urbanization in Ethiopia though not clearly studied have impact on water demand. Therefore, the scale and nature of the urban population and the demographic causes that contribute to this change; the level, pattern, and trends of urbanization; policy suggestions that highlight the consequences of rapid urbanization, reviewing of Government policy and considering causes for the low level of urbanization seek immediate study for the successful and sustainable future infrastructure installation, upgrading and renewal of services. The study and implementation of study results should be integrated with all service giving institutions/ organizations on obligatory basis and not on voluntarism.

The sustainability of the current water system in Addis Ababa is under pressure from a range of challenges which include: rapid population growth and resulting urbanization, climate change impacts, ageing infrastructure, increased water demand and consumption due to modern style of living, over abstraction and source depletion due to land use change and land development, increased demand from non-domestic consumers as well as the development of water intensive condominium houses. Hence, new approaches with new mentalities are required with a sense of urgency to successfully face the current urban water challenges in Addis Ababa.

4.4. Root Causes to the Lack of Urban Water Supply in Addis Ababa City

4.4.1 Overview

Rapid urbanization, inadequate public services, and out-of-date urban planning models have marginalized vast numbers of new arrivals crowded into informal settlements or slums, exacerbating inequality and urban poverty and compromising efforts to increase water security. In many parts of the world, city dwellers lack safe drinking water and fall ill with waterborne diseases. As cities seek new sources of water upstream and discharge their effluent downstream, surrounding communities suffer and the hydrological cycle and aquatic systems, including vital ecosystem services, are disrupted. Urbanization in Africa is characterized by insufficient basic infrastructure, particularly in low-income areas (Bahri, *et al*., 2016). Urbanization and population growth, climate change, drinking water and sanitation, ageing and deterioration of existing infrastructure and water governance are the major urban challenges of Africa (Bahri *et al.*, 2016). Countries in which less than 50% of the population uses improved drinking water sources are all located in Sub-Saharan Africa and Oceania (UNICEF and WHO, 2015). African cities are expected to experience difficulties in efficiently managing water resources due to increasing pressures from global changes such as urbanization, climate change and others (Bahri *et al*., 2016).

This study has found that the lack of water supply in Addis Ababa has manifested itself by the exceeding of water demand over supply, low piped water coverage, and intermittency supply. Its root causes include poor governance, low water tariffs, insufficient water production, lack of funding(reduced amount of money release of World Bank below what was required) or poor fund management, weak inter and intra-sector coordination, outdated system/old database, slow construction permit, limited capacity and efficiencies of contractors and consultants usually accompanied with corruption, low quality and incomplete bid documents, low skills and attitudes of leaders and employees, frequent damage of infrastructure by construction boom, purchase policy that doesn’t allow urgent /immediate purchase for inputs shortage requests, and others.

Current realties show that developing new ground and surface water sources will not be enough to meet these challenges. To this end, informants’ responses, study reports and government media broad casts have witnessed groundwater depletion with possible further draw down due to land use changes and unsustainable water abstraction beyond the recharge potentials of well fields. The size of the city, climate conditions, cost of water, the pressure of the distribution system, conditions of the supply system, water quality, and habit and/or living style were also listed as factors affecting water demand. Some branches, such as Mekanisa and Gurd Shola have wider areas and large number of customers but few resources and input supply, power cuts and water supply interruptions, absence of integration, busy staff on firefighting activities forgetting planned activities, rent seeking, centralized old bill printing software and others.

4.4.2. Causes of lack of urban water supply

4.4.2.1 Incorrect Population Estimation

Accurate population data is always needed to estimate water demand as the size of population puts pressure on existing water sources. Many people come from other parts of the country to Addis Ababa for business and stay in the city between few hours and days but consume the water supply of the city. But their exact number is not well known. This exclusion of daytime time population in water supply planning has serious impacts on the accuracy of water demand estimates. This study has used the concept of day time population for demand estimations. The available data have uncertainties with varying vintages, sometimes decades old (Table 4-8).

Table 4-8: Projected water demand for projected population in selected years

	Year	2005/2013		2006/2014		2007/2015		2008/2016	
	Category	Resident	Day time	Resident	Day time	Resident	Day time	Resident	Day time
Projected demand	Unit	3121654	4058150	3197210	4156373	3275348	4257952	3355791	4362528
Domestic	m^3d^{-1}	194,425	194,425	232,910	232,910	271,394	271,394	309,879	309,879
Commercial/administrative	m^3d^{-1}	77,770	77,770	93,164	93,164	108,558	108,558	123,952	123,952
Industrial	m^3d^{-1}	68,048	68,048	81,518	81,518	94,987	94,987	108,457	108,457
net demand	m^3d^{-1}	340,243	340,243	407,591	407,591	474,939	474,939	542,287	542,287
	%	37	45	37	45	37	45	34	45
NRW	m^3d^{-1}	136,097	157,500	171,680	208,800	193,140	234,900	184,377.7	269,550.0
Real loss*	m^3d^{-1}	102,073	118,125	128,760	156,600	144,855	176,175	138,283.3	202,162.5
gross demand	m^3d^{-1}	476,377	476,377	570,665	570,665	664,952	664,952	726,699	726,699
Existing gross supply	m^3d^{-1}	350,000	350,000	464,000	464,000	522,000	522,000	599,000	599,000
Net Supply **	m^3d^{-1}	247927	231875	335240	307400	377145	345825	460716.7	396837.5
Corrected demand***	m^3d^{-1}	442,316	458,368	536,351	564,191	619,794	651,114	680,570.30	744,449.5
Deficit	m^3d^{-1}	194,389	108,368	201,111	100,191	242,649	129,114	219,853.60	347,612.0
	%	44.5	69	56.7	78.4	53.5	75.3	63.3	42
Unmet demand (% of corrected demand)	%	43.9	49.4	37.5	45.5	39.1	46.9	32.3	46.7
Domestic supply	m^3/d	141318.5	132168.8	191,087	175218	214972.7	197120.3	262608.5	226197.4
	$m^3/c/d$	0.045	0.033	0.06	0.042	0.066	0.046	0.078	0.052
Daily domestic consumption	l/c/d	45.3	32.6	59.8	42.2	65.6	46.3	78.3	51.9

Where ;

- *=real loss is 0.75 x NRW, **= Net supply which is production – real loss
- Corrected demand is net demand + real loss
- Deficit is additional water production requirement i.e., the difference between corrected demand and existing net supply
- Domestic supply is 57% of net supply

4.4.2.2. Unprecedented increase in water demand and water loss

Addis Ababa city has undergone rapid population growth, urbanization and industrialization with remarkable economic growth. Consequently, water demand trends have increased dramatically and resulted in water demand exceeding water supply. Hence, the water demand is about 736,816 m^3d^{-1} and water supply is 376186 m/d^{-1} indicating 50% unmet demand. The exceeding water demand over supply might be associated with rapid population growth, inefficient management, inefficient water uses of users, ageing and deteriorating existing infrastructure, bureaucratic inefficiency of AAWSA whose unskilled workers causing poor maintenance, delayed responses and unmannered interactions. The root causes, primary causes, secondary causes of inadequate water supply with their corresponding effects are summarized in figure 4-21 below.

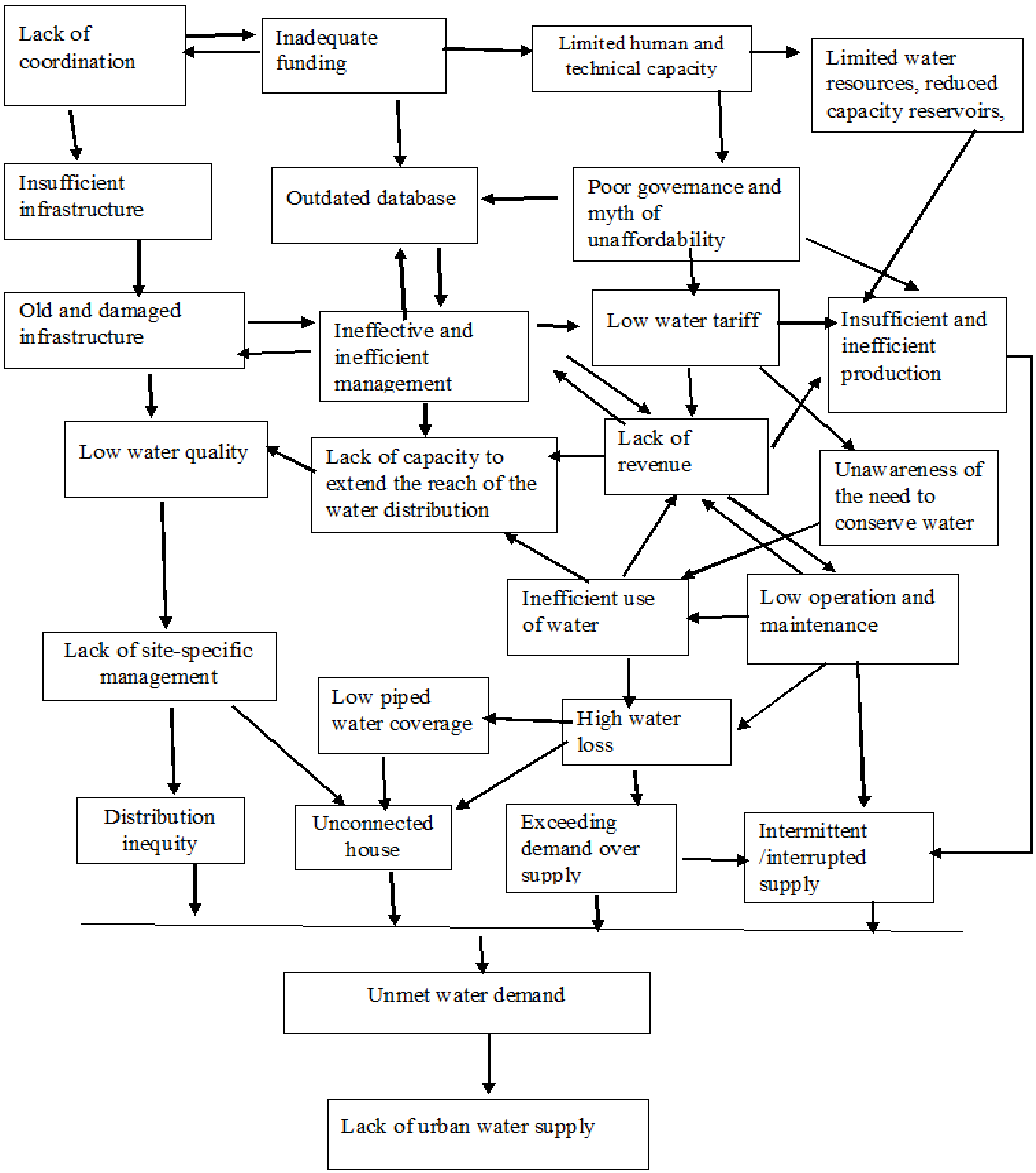

Figure 4-21: Problem Tree for the lack of adequate water supply

The results of household survey have shown that inefficient water use is caused by the unawareness of consumers that water is scarce and regard it as everybody's property and as a free item that belongs to all. About four out of ten respondents of the households surveyed expect their future water demand to increase. They expect improved livelihood will allow them to use more water (e.g. bath rooms, flushing toilets, washing machine). Only 4.4% customers have plans to decrease their future water consumption by practicing conservation and increasing usage efficiency.

4.4.2.3. Decline in production and ageing infrastructure

All key informants do not approve the use of groundwater for strategic plans except as firefighting sources due to the land use changes that have converted the recharge catchment areas into impervious lands discouraging water infiltration into the ground. Their overall assessment of the current water production by AAWSA has rated it inadequate for its customers as this production is associated with very high-water loss. Key informant interviews, household survey and field observation in this study has identified the major impacts of water shortage in the city as follows:

- Domestic and commercial activities are seriously affected;
- Customers are incurring high water charges from water vendors and wasting too much time in search of water;
- The long queues for fetching water have led to social pressures such as conflicts in some cases and are becoming reasons for school lateness and absenteeism;
- Children are risking their lives searching for water;
- The problem is leading to hike in prices of food items; and
- Health risks in using untreated water from streams and wells.

The reported sources of water losses were leaking house service connections, old conservancy lane, old lead joints, non-working meters, illegal connections, poor quality of meters, absence of water accounting and others. Water wastes through poor plumbing in homes, leaks in distribution system, and overflow of storage, send no water-conserving-alarm to users and to those who are in charge of urban water management. In most of Addis Ababa, there is no attempt at all to conserve water through retrofitting water-using-device and little awareness to conserve it by reuse. Old infrastructure is also contributing for low water quality and customer dissatisfaction.

4.4.2.4. Inadequate inputs and capacity

The water governance in almost all of AAWSA's branches is characterized by the absence of transparency, responsiveness and accountability. Poor water governance is reflected by many effects such as low water tariff and absence of pressure efficiency regulation for people at higher floors. This shows that AAWSA is not performing to its expectation to extend the reach of water distributions to hilly areas in the city and at reducing the number of unconnected houses. The effect of poor governance is also exacerbated by unplanned settlements. Severe inputs shortages including pumps, pipes, fixtures, connectors, water meters, and vehicles owed to centralized but slow purchase and distribution by the head office were reported by all key informants. This study has found very serious shortage of work space and office materials in most branches. The technical staffs are overcrowded in small cars when they go for maintenance and installing new connections as the few available cars are often used for political meetings. There is no clear job description. In very sensitive situations, many technical staffs are forced to buy some spare parts (e.g. small fittings and connectors) from their own pockets. Overall, there is staff dissatisfaction accompanied with the common phenomena of frequent staff turnover.

In addition to salary deduction, written warning, terminating work agreement of outsourced meter readers, the utility is employing miscellaneous solutions including Rotto supply, water storage construction, purchase of water filling trucks, employing meter readers and controllers, installation of wireless phones for information exchange, organizing change forum, undergoing political and economic transformation, bringing change in attitude, formulating clear in ethics, training to develop employees 'skills, meter testing and reinstalling, meter investigation without replacement and setting standard for readers based on daily capacity.

4.4.2.5. Limited human and technical capacity

AAWSA is characterized by vivid limited human and technical capacity both at the head office and branch level. Some instances that demonstrate these limitations include:

- Lack of manpower to handle policy and regulatory issues; and to plan, operate and maintain the services. Some branches such as Akaki and Megenagna are serving only few customers

(34,000) but others such as Nefas Silk and Gurd Sholla serve huge number of customers (100,000). This has made workload differences among branches;

- There is lack of site-specific management strategies /policies particularly for areas distant from existing water sources and localities with complex topographies. This lack of site-specific management strategies has caused water distribution inequality among city residents;
- Water distribution in the city is haphazard and inefficient following neither the city's administrative divisions nor a defined pattern (Table 4-9);
- Ill-defined service areas of branches. Some branches including Nefas silk supply water to as high as 22 weredas in different sub cities but Megengna and Akaki serve only 9 and 10 weredas, respectively. Such distribution of customers has resulted in very highly different customer service delivery practices and consequent customer satisfaction differences. The poor operation and maintenance works have resulted in the observed leakages;
- Many customers who are using the water supply for commercial and institutional purposes are still charged as domestic customer due to the failure of AAWSA to update its customer profiles; and
- Corruption has resulted in shifting supply, reporting fable reading results, purchase of low-quality materials and others. Such corrupted activities imply lenient leadership and absence of monitoring and evaluation creating a big challenge during operation and maintenance. Illegal connections are existent in all the eight branches.

Respondents associate the lack of capacity to extend the reach of the water distribution system particularly in expansion areas with AAWSA's ineffective management that lacks capacity to reduce its costs by improving efficiency and generate capital fund for major investments. This has resulted in low piped water coverage in high elevation areas. Many houses are not connected to the piped water supply network ending up in unmet demand of the residents.

Table 4-9: The eight branch offices of AAWSA and their areas of water supply service

Branch	Sub cities served	Weredas served	Total weredas served	Remark
Addis Ketema	Addis ketema	4,6,7,9,10	19	Has the 2nd highest number of weredas being served
	Gulele	5,6,9,10		
	Kolfe Keranyo	6-10, 12-15		
Akaki	Akaki Kaliti	1-5,7-11	10	Most of the weredas have 24-hour supply
Arada	Arada	1,8-10	19	Has the 2nd highest number of weredas being served
	Kirkos	1-12		
	Lideta	3-9		
	Addis ketema	1-4,8		
	Yeka	6		
Gulele	Gulele	1,2,5-8	14	The worst water shortage branch
	Arada	4-7,9		
	Yeka	1-3		
Gurd Shola	Bole	6-11,13,14	12	Has the highest number of customers
	Yeka	9-13		
Megenagna	Bole	1-5	9	Serves the lowest number of weredas
	Yeka	5,7,8		
	Kirkos	1		
Mekanisa	Nefas Silk Lafto	1-4	19	Has the 2nd highest number of services weredas
	Kolfe keranyo	1-6,9		
	Lideta	1,10		
	Kirkos	4-7,10,11		
Nefas Silk	Nefas Silk Lafto	Lebu 01,5-12	22	Serves the highest number of with 24-hour supply except three weredas
	Kirkos	1-12		
	Akaki	6		

Source: Adapted from AAWSA's eight branches June- December 2016 Supply Schedules

4.4.2.6. Low Technical Skills and Poor Operation and Maintenance

Water wastes through poor plumbing in homes, leaks in distribution system, and overflow of storage, sending no water-conserving –alarm to users and to the concerned urban water managers. This study has found that many AAWSA officials and staffs are inadequately trained, poorly qualified, inexperienced and have irrelevant or outdated background knowledge about their field of management and hence AAWSA lacks skilled workers. The general manager and 50% of branch managers don't have the required back ground knowledge for their positions. Both managers and workers are busy on firefighting activities rather than strategic issues. The utility's central purchase policy is sluggish and handicapping. AAWSA is very slow in responding to customers' requests for repairing pipe bursts and leakages contributing for the frequent water infrastructure damage and the resulting high leakage. Fluctuating and high price of tap water from vendors was one reason for the low per-capita water consumption. This entails AAWSA to install additional public standpipes to provide adequate water to a large number of people at minimum cost.

AAWSA staffs associate the present outdated database that is neither up-to-date nor reliable but causing inefficient management to inadequate funding. Inefficient management is highly related to the lack of capacity of AAWSA to extend the reach of the water distribution as demonstrated by the lack of piped water coverage particularly in expansion and high-altitude areas of the city characterized by unconnected houses and truck supply and hence associated unmet demand.

4.4.2.7. Inadequate Funding and Poor Fund Management

The finance sources for AAWSA are the revenue collected from sale of water, sewerage services, connection fee and other miscellaneous incomes; foreign grant and loans; and capital subsidy from Addis Ababa city administration. The very low water tariff is one reason for AAWSA's highly dependence on the city administration to cover major expenditures particularly capital expenditures. Varying estimates depending on assumptions related to status, service standards and existing financial flows, rigorous estimates and scenarios lacking for urban water supply are financial challenges identified by this study. AAWSA staffs have witnessed finance challenges for investing on more infrastructures and financing improved water supply services for increased coverage at increased/ affordable access for the poor and leveraging additional local resources.

The reported underinvestment in infrastructure couldn't provide more water supply infrastructure and ensure good service as it demands huge amount of finance to make the services reliable, well targeted, actually used, and sustainable institutionally, financially and environmentally. Low water tariff (underpriced water), subsidy reduction of the city government, and slow but small foreign donor finance release are reported as causes of the lack of funding for the utility. Its outdated and unreliable database (information management policies and procedures are not introduced) due to capacity problems is associated with lack of funding and poor fund management. This is backed up with low water meter reading quality because of the centralized but un-modern billing software.

Although AAWSA has huge operational expenses for power, chemicals and personnel; its poor data management has led to undefined data owners of uncontrolled and owners of individual data processes since the utility has no functioning asset inventory or GIS (fixed asset register). Such lack of data is causing inadequate information or knowledge which is the prime cause of inadequacy to respond promptly to customers' requirements to new connections, upgrading, transfer and maintenance services making them a day to- day episode.

4.4.2.8. Low Water Tariff and Lack of Awareness

The current water tariff structure consists of service connection fee, deposits, water meter rent, volumetric charges and reconnection fee. Based on the views of many respondents, the current low water tariff has caused the absence of awareness about the need to conserve water by most water consumers. Water is regarded as everybody's property and as a free item that belongs to all by most Addis Ababa residents. This perception by water consumers has created the impression that water is plentiful and nothing is lost when water is wasted. Nearly all respondents have witnessed that the current unawareness to conserve water is caused by low water price imposed on urban water consumers. Meaning, it has caused unawareness for conserving it.

Inefficient water use is evident in the lower parts of the city where residents play with water contributing most to the rise of demand over of supply capacity of urban water supply system where water supply is continuous. Inefficient use contributes to high water loss noted throughout the city. This ultimately contributes to the exceeding of water demand over the supply capacity by reducing supply volume and making the supply intermittent. There is lack of revenue to support the extension of water distributions caused by the low water tariff. It is very common to see water wasting at standpipes and through pipe breaks.

Most consumers and some AAWSA professionals have the opinion that low water pricing is caused by corrupted and unethical utility staffs, and government officials elected with vested interests in maintaining the current status quo that allows considerable amount of informal revenue (the price paid by vendors for water at source) to enter their pockets. This manifests the hidden role of poor governance as a prime cause for the exceeding of water demand over that of supply. The supply areas of some branches (Gurd Shola and Mekanisa) are expanding at high rates resulting in workload on their employees. Future demand for water by new house construction sites and industrial parks developments are expected to worsen the situation. Direct showering of all the compound and floor washing should be prohibited by law and customers should be told the cost of not getting water by showing monthly water wastage cost.

The inconsistency between the responses of respondents and information on the water profile imply absence of shared common information on water issues in place. In high altitude areas, there is intermittency of water supply and water is not running 24 hours. In almost all of Gulele sub city, half of Kolfe Keraniyo sub city, higher elevation parts of Yeka and Nefas Silk Lafto sub cities, there is no water during the day and water run only at night and morning – during which pressure by customers at other parts of the city is low. Low water tariff is the reason for the lack of revenue to extend the service system and the low piped-water coverage.

4.4.2.9. Poor institutional organization and lack of coordination with stakeholders

4.4.2.9.1 Poor Institutional Organization

AAWSA has limited human resource and capacity in the management, operation and maintenance of its system coupled with the heavy pressure on water supply put by development activities. The utility's poor institutional organization has created institutional multiplicity including the problem of integration and coordination of various institutions and disciplines that characterize urban service delivery. Such organizations have caused the absence or low-level involvement of the private sector or civil society in the design, construction, operation and maintenance of water supply systems. Urban utilities demand responsive approach with decentralized implementation through benches including increased participation in planning at lower levels of water provision. Hence, more cost-effective technologies such as protected springs being selected, increased levels of disbursements are required.

4.4.2.9.2. Lack of Coordination

In Addis Ababa service givers have no realistic integration. Fragmented roles and responsibilities, poor organizational commitment, lack of or limited available information that has resulted in the poor development of guidelines and standards, lack of documentation regarding design, construction, maintenance, monitoring and evaluation. There is no strong coordination between the developer, Addis Ababa water and sewerage Development and Rehabilitation Office and the operator, AAWSA. This weak coordination has resulted in the drilling of deep wells near shallow and medium wells without getting AAWSA's inventory data on which ones are abandoned, malfunctioning and are reducing yield. This trend is leading to unsustainable groundwater abstraction in some well fields beyond their weakening recharge capacity.

The evident weak coordination between and among the different teams of AAWSA including surface water, ground water, non-revenue water control, water quality management, planning, and others are hampering the proper functioning of the utility. Poor customer –operator relations is causing the purchase of unclean water with oily yellow jerry cans. Customers are forced to go to other branches to find someone who lobbies an employee in their branch for solving their complaints

There is no single institution that coordinates storm water management at city level. Addis Ababa City Roads Authority (AACRA) is responsible for managing roadside drainage structure. AACRA which is responsible for managing storm water has neither the appropriate drainage infrastructure. AAWSA has almost no integration with the regulator Addis Ababa Environmental Protection Authority (AAEPA). This has resulted in depleted groundwater sources from overexploitation of dense licensed and unlicensed private wells.

Although it is improving, Ethiopian Electric Utility (EEU) / Ethiopian Electric Power's (EEP) frequent power cut is a big challenge thereby causing intermittent /interrupted supply since water productions /treatment and distribution are dependent on electric power. AAWSA's pumps and other structures are burnt due to such interruptions. Groundwater sources cannot operate without electric and hence AAWSA is purchasing huge generators and transformers dedicated for groundwater sourced lines. This entails the need for dedicated teams from all service providing institutes to work in obligatory coordination but not based on voluntary cooperation.

For its proper management, AAWSA should coordinate with different sectors providing infrastructural services including: AACRA, AAEPA, and the Ethiopian Telecommunication Authority, EEU/EEP and others. Indeed, weak institutional arrangement for urban storm water drainage exacerbates the management problem (Parkison and Mark, 2005).

4.4.9.3 Unmanaged stormwater and water pollution

In some parts of Addis Ababa with no sewerage system, there are many residents and business premises that have illegally connected their flush toilets to the storm water network. Storm water runoff from steep slopes can cause flooding particularly in high sloping areas including the Jemo mountain chain, Repi hills and Little Akaki River banks. Floods may increase soil erosion affecting or damaging the water infrastructure and quality. The findings of Birhanu *et al*. (2016) indicate a possible increase of flood risk and vulnerability of Addis Ababa due to climate change and urbanization. Storm water is polluting AAWSA supply through mixing to the distribution system at manholes and other broken points.

4.4.2.10. Geographic gradient

The locality of a water user can be an advantage or a disadvantage concerning water supply provision. In cities like Addis Ababa where supply is less than demand, the available water is used by customers at low elevations since such distributions could not go up to high elevations without first satisfying users at lower elevations. This is confirmed by the low piped water coverage in the high-altitude parts of the city and expansion areas caused by both low water production volume and by the lack of capacity on the part of AAWSA to extend the water distribution system to reach urban parts that are not yet served. All respondents have suggested the construction of wells, pumps, canals, boreholes, tanks, cisterns, reservoirs, water yards, dams and water harvesting systems as some ways of increasing water availability. They have also suggested computerizing the distribution system and modernize it, developing modern call center, catchment management and environmental protection works, and construction of check dams as solutions.

4.5 solutions to the lack of urban water supply

For the causes for the lack of adequate water supply in Addis Ababa City mentioned and discussed above, the following solution tree is proposed (Figure 4-3)

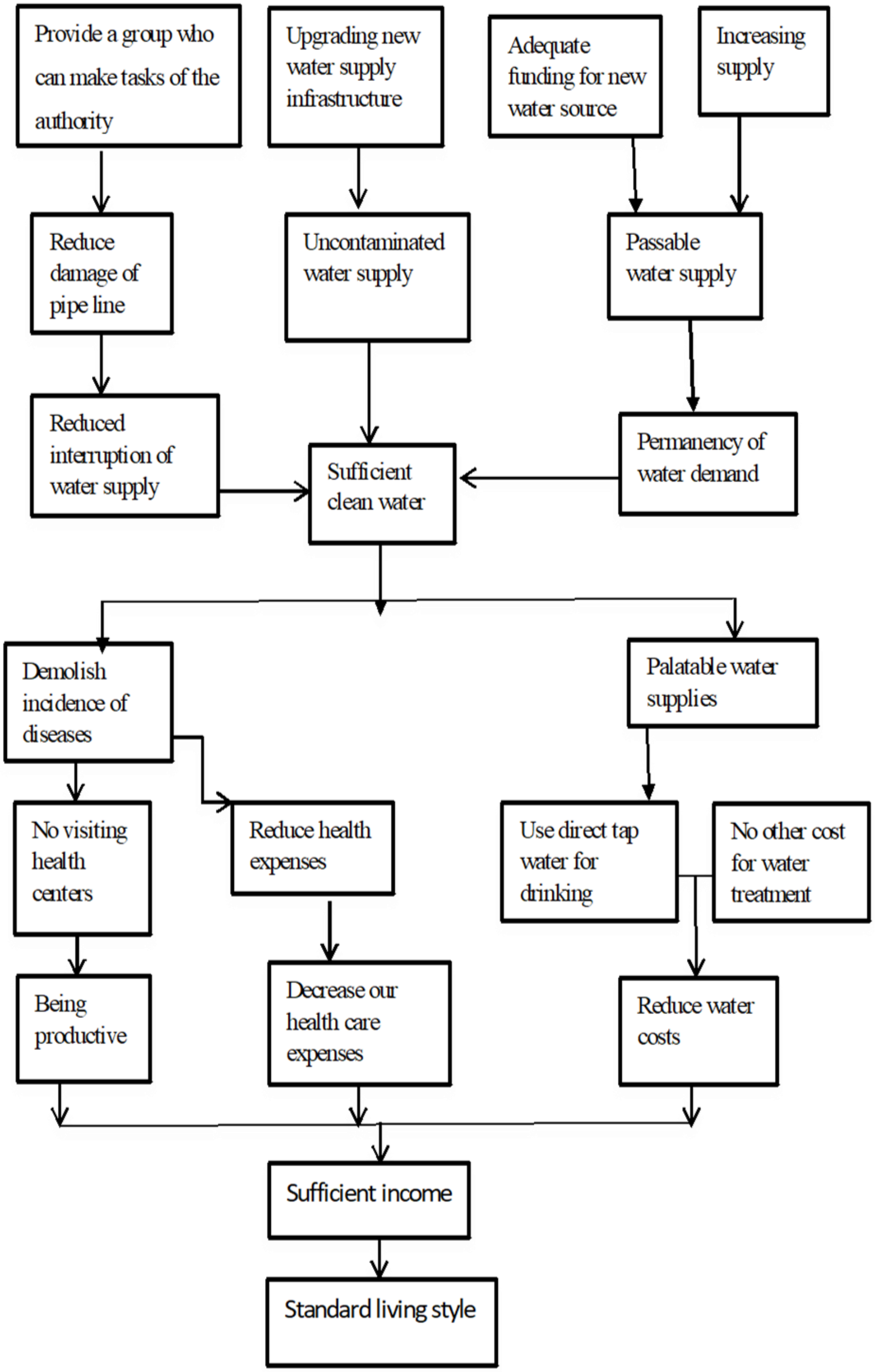

Figure 4-3: proposed solution tree for the lack of urban water supply in Addis Ababa City

Chapter Five

5. Discussions

This study has assessed the water supply situation of Addis Ababa water supply system. The major findings of the study are discussed under four major categories comparing with the current global literature and describing the implications of the issues/problems identified:

The problem caused by the current water production and its allocation among different user categories; the reasons for the spatial difference in the performance of the water service delivery; the reasons for the reported dissatisfaction level of AAWSA's customers by its service delivery and outline of possible solutions to improve this situation; the implications of the WEAP model simulation results about the water supply situation of Addis Ababa city water system and the relationship between the water production and demand of Addis Ababa city; future expected unmet demands if current trends are projected into the future and possible improvement measures; the application of problem tree analysis to enhance our understanding of the root causes for the customer's dissatisfaction with Addis Ababa's water supply; and the root causes and their consequences of inadequate water supply situation of Addis Ababa water supply system and outline tangible and practical recommendations.

5.1 Evaluation of Past, Present and Future Situations

Urbanization, a process of population concentration, increases water demand by multiplying points of concentration and the increase in the size of points of concentration (Oluwaso, 2007). Development inevitably entails an increase in urbanization since by and large impetus for economic growth lies in the cities (Hoselitz, 1953). When population becomes more urbanized, the social, economic and environmental activity of growing cities are highly wholly dependent upon the planning and management of water (Whitler and warner, 2014) since without adequate water resources and infrastructure urban life is impossible.

Today, Ethiopia's urban population growth is among the highest in the world (UNDEP, 2003) but it has the lowest level of urbanization even by African standard (Kassahun and Tiwari, 2012; Tegenu, 2010) with unbalanced distribution of urban population and urbanization.

Addis Ababa has been experiencing rapid urbanization (Givnetal, 2017) expanding by 129.95 km^2 in three decades at 6.65 km^2/year rate of increase associated with population growth that is estimated to increase by about 38 percent (GTPII). This has attracted migrants to Addis Ababa making it a single primate city home to 25 percent of the country's urban population (WBG, 2015) increasing pressure on the city's capacity for affordable and adequate housing, employment, and access to basic services, particularly for the poorest and vulnerable (UN-HABITAT, 2017.This out stretching rate of urban growth more than its ability to cope is an inevitable process of development, is presenting both challenges and opportunities in developing countries (Puttaswamaiah ,2005). It has experienced rapid but uncontrolled physical expansion towards peri-urban areas to accommodate the ever-increasing population, industry concentration, and commercial expansion. The rapid spatial extension of the city not fully supported by infrastructural development is contributing for low piped water coverage.

The supply of adequate amount of water to this rapidly urbanizing city (Gebrehiwot *et al*., 2017) is one of the main challenges facing this city accompanied with water quality problems. Population growth and improved standard of living are increasing the demand for water from time to time (Tesfazghi *et al*., 2010). Day time population, the number of people who are present in an area during normal business hours including workers (Clarke, 1984), has significant impact on the existing urban water supply of Addis Ababa City. The major current and future environmental challenges of the city are strongly linked to rapid population growth, inappropriate land-use management and uncontrolled physical expansion outpacing infrastructure development and agree with what was found by Gebremichale *et al*, (2014).hence , it is facing a serious deficit in water supply from increased population and extended economic activities in and around its subsystems.

The challenges of serving the unserved is related with the lack of mature infrastructure and governance structures, a situation set to worsen as cities grow. The challenge for providing water supply for this growing urban population due to the absence of urban planning practice that gives a real opportunity to the city to implement innovative solutions (Brikké and Vairavamoorthy, 2016; Jacobsen *et al*., 2013; Tsegaye *et al*., 2012) is expected to continue unless the planned water development projects will be operational soon. This agrees with the observation of WGPIA (2017).

AAWSA doesn't have full control over the resources or the catchment areas since the Ethiopian water resources management regulations (Regulation No., 115/2005) denies it to have no influence or power on water resources by policy but puts it a user It couldn't protect the resource from possible pollution, catchment degradation or similar potential impacts by others. AAWSA's dedicated NRW reduction and catchment management and water quality unit has limited authority.

Like in most Sub Saharan African cities, the quality and coverage of services ((Njiru and Sanson, 2003), AAWSA expected to remain poor with possibility of worsening situation with high urban population growth rates. The challenge prevails in the form of administrative issues; policy issues; operational issues; involvement of non-governmental service providers; large size of population; and financial challenges.

5.2 Customers' perceptions about their water supply

Customers' satisfaction level with a city's water delivery reflects the individual's aggregated impression about the water supply service. The disaggregated overall customer satisfaction level of this study result has shown variations with water use category. The increased rate of failure of home infrastructure in certain areas is raising customer's concerns about the reliability and quality of their water provision.

In places with insufficient water distribution system or unacceptable water quality, some customers report improvement while others report deterioration. This contradiction could be associated with their perceptions of values that are influenced by differences in monetary costs, non-monetary costs, customers' tastes, and customers' characteristics which is comparable to the findings of Ferrier (2001) and Doria (2006). The paradox of rating the current water supply by some customers as either acceptable or adequate amidst the observed severe water shortage could be related to low income or low standard of living or poor prior experience or fear of losing it at all or low level of knowledge of their right to get water. This shows the need to safeguard the global supply of healthy water and to ensure that everyone has access to it(Annan, 2001).

Existing customer satisfaction drivers (attributes) have hierarchical approach of relationships in that operational performances like service hour, service driver attributes such as service frequency and service drivers (timeliness) are supposed to affect overall satisfaction in such hierarchy (Keiningham *et al.,* 2007). Day to day continuity of supply, adequacy and quality of the water supply system, and long-term continuity of water supply services are major factors for the overall customers' dissatisfaction.

The urban poor in Addis Ababa who are not-being served by piped-water get their daily water from street water vendors, springs and rivers as well as private wells. They are willing to pay for it at price level 10 to 100 times higher than what is paid by most urban rich and others connected to piped water network. had they been given improved and reliable water service. Thus, rising water price is something which is quite possible provided that the service is improved and reliable.

5.2.1 Water supply shortage and inadequate supply

As water lies at the core of human welfare, environmental sustainability and economic development (Chen, 2015), the human right to water emanates from other fundamental human rights – first and foremost, the inherent right to life of every human being (McCaffrey, 1992). It is also closely related to the right to an adequate standard of living and the continuous improvement of living conditions, codified in Article 11 of the International Covenant on Economic, Social and Cultural Rights (ICESCR). Yet, this study has revealed that the status of water supply in Addis Ababa is characterized by an overall water shortage owed to limited water sources, high proportion of water loss or leakage, high level of consumption by non-domestic customers, and faster development of urbanization in the city administration. Hence, in all the ten sub cities, people are seen carrying yellow water Jerry cans. This suggests flawed methodology and definition err in AAWSA reports.

The urban landscape of Addis Ababa is characterized by a mix of areas without water supply and those with erratic and unrealizable supply (high geographic elevation areas and old –age dilapidated infrastructure infill development areas). Opposed to the common African position which states that every citizen should have affordable and sustainable access to quality basic services including access to adequate and clean water and sanitation, water availability in Addis Ababa is far below the recommended value of 24 hours for urban areas attributed to short supply hours evidenced by water rationing to sections of the city due to water inadequacy. Some areas, especially at the periphery, are hit by hard water interruption with frequent reports of staying without water as long as a month due to water supply shortage, huge water loss or both.

Severe water shortage areas including Hayahulet, Megengna, Gerji, Wofichobet, Yerer, Gofa and others. This very low overall access level to water supply has critical implication to sustainable economic, social and for environmental protection (Iyo, 2015) calls the immediate attentions of all stakeholders since water is a finite and fundamental resource to human well-being (UNF-DPAC, 2015) but renewable only if well managed.

Daily water availability or the lengths of water service to a customer indicates the reliability of the water supply system. Reliability has a significant bearing on customer attitudes since service reliability apart from easy access strongly influences water customers' satisfaction (Gulyani *et al.*, 2005). An increased and increasing number of urban dwellers who lack access to water are forced to rely on unsafe sources for their water supply. The situation is raising a question of adequacy and equity. Short supply schedule for house renters by house owners, absence of coordination among service providers, power interrupts, cuts in supply and reductions in pressure are factors responsible for many customers seen in very corner of the city carrying yellow Jerry cans to purchase water from vendors at expensive rates and bear boiling costs (charcoal and electricity). The current water insecurity in Addis Ababa might continue in the future as rapid change in population, economy, geopolitics and climate will make achieving water security more difficult.

Addis Ababa faces a serious deficit in water supply due to increased population and extended economic activities in and around its subsystems (UN-HABITAT, 2017). These problems are often compounded by the fact that they are being addressed in a disconnected way, by different actors across neighboring jurisdictions. Outdoor facilities such as swimming pools, car wash, balconies, machines that need water to operate should use non-potable water. Empirical literatures on water demand have not dedicated much attention to determinants other than economic ones (price and income). Characterization of habits to reduce consumption such as flow reducing mechanisms and strategies to reduce bathroom discharges, leaks, and washing machines without full load are helpful. Elements to typify the consumer perceptions and the consumer effective behavior could also help to compare perceived consumption and actual consumption.

Water availability enables pumping water to the consumers at 24 hours with a constant flow rate while insufficient water availability forces pumping it for shorter time periods at higher flow rate to meet the demand of consumers. In Addis Ababa, a storage tank is usually provided in order to provide storage where the pumping rate is higher than the demand at night times. This storage can be used in the case the pumping rate is below the needed demand, and to equalize the pressure in the network in the cases of pressure increasing. This scarcity of water resources is the result of reduced water availability, over abstraction of and/or contamination of existing supplies because of the change in hydrological pattern related with land development

5.2.2. Supply interruption and intermittent supply

Access to drinking water as considered by this study constitutes the quantity of water, the safeness or quality of water and the distance for collecting water similar to Grady *et al. (*2014). High demand in one place induces low pressures and sometimes service interruptions into adjacent areas. Most customers have reported the presence of supply interruption and intermittency of supply. They have mentioned the extended and frequent water interruption with water loss and quality reductions as the most important problems in the water supply system. Periodic water interruptions have come an integral part of the everyday life of its residents similar to other urban centers (Genius and Tsagarakis, 2006). Water interruptions may give rise to several deficiencies including serious risks to health from ingress of contaminated groundwater into the distribution system, inability to practice efficient supply management; inability to practice effective demand management; operational inadequacies that unduly weaken physical infrastructure as well as customer inconveniences. This supply inadequacy and intermittency contradicts water's importance to human wellbeing (WWC, 2015).

Such dissatisfactions have extended to other aspects of service delivery such as water quality, mistrust of the utility, and loss of security of the customers as evidenced by the physical damage of mothers when fetching water from distant springs around Kechenie area, customers are forced to store water in all kinds of materials including dishes due to the lack of reliability when to get water agrees with the results of Vasquez (2012). This shows the severity and urgency of the problem.

Uninformed service interruptions, delayed maintenance of broken infrastructure, and public fountains not being open for customers at the time they like it were reasons for customers' dissatisfaction similar to the findings of Keiningham *et al. (*2007) that asserts satisfaction, the most commonly used perceptual metric, is strongly influenced by customer expectations. Their causes could be on –site and off-site construction, damage of water infrastructure by vehicle, failure related to the utility provider and failure related to the facility infrastructure (Kiparsky *et al*., 2012). This has caused the loss of household income or productive time for many people in Addis Ababa (WSP, 2003) and ultimately diversion, evacuation and cancellation of services.

5.2.3 Water Quality and Safety

Primary aesthetic water quality indicators that can cause water to be perceived as unacceptable include true color, Turbidity (the cloudiness caused by particulate matter present in source water, suspension of sediment in the distribution system), the presence of inorganic particulate matter in some groundwater or sloughing of bio-film within the distribution system, particulate matter and visible organisms (WHO, 2004). They can contribute to the unacceptability of water sources. Taste and odor can originate from various natural chemical contaminants, biological sources, and microbial activity, from corrosion or chlorination due to water treatment (WHO, 2004).

AAWSA customers have reported that they have experienced water related health problems and unacceptable experience with the previous water source status based on its taste, color and odor change perceive water safety risks. These parameters may not show water safety (Johnson and Scherer, 2012) but they can provide important clues to the causes of the problem and selection of treatment devices to improve the quality of the water. This author takes WHO (2004) position that reliance on senses may lead to avoidance of highly turbid or colored, but otherwise safe waters in favor of more aesthetically acceptable, but potentially unsafe water sources. Customers' satisfaction with water quality is mostly influenced by organoleptic-characteristics of water perceived by the senses and agrees with the findings of many authors including (Doria, 2010; Fie-Schaw *et al*., 2007).

Water color is more important as it may detect water contamination related to chemicals. Change from yellowish to bluish suggest that the water is perceived not good water (Doria, 2010). Although the salty flavor felt by few customers might suggest high salt in the water. Although unreasonable proportion, this is true since as groundwater sources that contribute to nearly half of the supply do have salt contents with probable laxative effect in some situations (Johnson and Scherer, 2012). Meaning, taste perceptions should be considered with great care since some respondents might have given socially desirable responses to the survey.

Customer reported water related ailments principally in low water supply areas include: dysentery, diarrhea, skin allergies, jaundice, acute fever, pneumonia, cold and cough, headache, eye infections, tuberculosis, polio, hysteria, diabetes, hypertension, stone in gallbladder and kidney, asthma, leprosy and digestive disorders. According to the opinions of customers, leaks in water mains and household water systems are increasing public health risks such as water-borne disease in addition to degraded water taste, odor, and/or appearance. There were alike findings of increasing public perception of the human health risks associated with water quality deteriorations (Trvett *et al., 2005*) as the ingestion, contact or breathing of inappropriate water may result in disease and could cause death.

During water failure, the distribution system sucks in contaminants that will be dissolved and supplied to consumers when the water reflows. Customers associate childhood diarrhea with the quality and the use of water which is identical to Water Aid (2011) and Rousdy *et al.*, (2012) statements. This explains why the large proportions of customers render their water for drinking and for domestic purposes to some form of treatment before use particularly after 2016 cholera incidence. Hence, urban water system should provide safe water for different uses without harming the environment but increasing demand for sustainable development will deeply affect all urban infrastructures (Hellström *et al.,* 2000).

Sources downstream of the city lack proper water treatment and filtering facilities. Public health is seriously threatened by polluted drinking water. Lead poisoning as a serious health risk due to corroding water pipes was reported by (Alemayehu *et al*., (2003) and Itanna (2002) and has alarming growth in toxics, radioactive, heavy metals and chemicals in the water supply amidst the long –lasting damage caused by this life threatening contaminates (pollutants), wastewater is still used as a source of irrigation water as well as for drinking (Biru, 2002).

In Addis Ababa, customers' satisfaction with water quality is mostly influenced by organoleptics-characteristics of water perceived by senses consistent with the findings of Dietrich *et al*., (2015) and Doria (2010). Consumer perception about acceptability of their drinking water quality depends on their sense of taste, odor and appearance (Dietrich *et al*., 2015: Doria, 2010; Sheat, 1992). The persistency of water quality problems may be due to the intermittent nature of the supply associated long residence time during distribution and possible storage before use. This agrees with studies conducted by Kerneis *et al*., (1995) and Tokajian and

Hashwa (2003). The persistent water quality of the water directly taken from taps can be correlated with the travel of water through the distribution system and in some cases is stored before use which is consistent with the findings of (Evison and Sunna, 2001; Tokajian and Hashwa, 2003).

5.2.4 Unreliable, long and complex distribution system (or network)

The unreliable water supply in Addis Ababa is resulting in the agonizing hardships to the residents particularly at higher geographic locations characterized by low pressure (especially in North and inner-city areas with aged, low and insufficient water infrastructure systems). This problem is highly affecting domestic and commercial customers owed to their demand and usage pattern. Most domestic users share a tap, are unable to store water or cannot afford to purchase water from vendor. Commercial users demand uninterrupted supply since most of their activities are impossible without water. They do not want to bear the extra bill for purchasing water from kiosks and private sources. Vulnerable groups including women and the poor are bearing a disproportionate amount of the economic costs associated with low levels of access and poor-quality basic water supply services. This result complements with ADB (2014) claim of growing pressure on basic infrastructure services, including water supply when urban centers expand.

Among the top five global risks of most impactful and highest concern, water crisis ranks 3rd (Gosling *et al*., 2016). Water shortage and topographic conditions in most parts of Addis Ababa have forced the division of the water distribution networks into several pressure zones that pump water alternatively through them. This lack of sufficient available water resources to meet the water needs might be due to four factors: increase in population growth and rapid urbanization, non-revenue water, industries and industrial waste and drought.

Many sectors of water distribution systems in most parts of Addis Ababa suffer from the deficiency of water supply quantities and sharp deficiency in pressure to achieve the consumer demand at satisfactory levels. The deficit in the performance of the water network in most parts of the city is negatively influencing most of the socio-economic sectors and it is serious in the old parts of the city where water infrastructures are old, increased water demand by higher population growth rates, increased per capita water consumption, and frequent damage of water pipes during laying down telephone and internet lines, road construction and other activities. This has important implications on the city’s water supply even though the dynamics of what is happening in Addis Ababa is not understood to get a full picture of the development challenges the city faces. Eextensions beyond the haydrulic capaicty of the distribution system are undoubtedly done without consideration of the hydraulic capacity of the system, indicate that poor-governance is the root cause to the intermittency of water supply and agreees witht he findings of McIntosh (2003).

5.2.5 Mandatory water storage

Unreliable water distribution that caused mandatory water storage by residents at home by customers' may end up with crisis, rehabilitation costs and unsafe for long term economic development, peace and security, poverty reduction and control of preventable diseases unless AAWSA ensures continuous supply particularly for the poor and the needy who cannot afford to buy water from vendors or don't have water storing materials but need a minimum volume of water on a daily basis. The change of aesthetic water qualities to unacceptable level after interruptions is a common problem in other places (Liu *et al*., 2017). This AAWSA's limited capacity is responsible for the additional costs of purchasing water storing facilities, in house water treatment of chemicals such as aqua tab, and storage space problems. The low volume supply and its frequent interruptions have forced customers in water shortage areas to use all sorts of buffet materials including dishes as evidenced around Abebe Bikela stadium (Free Doro area) even though stored water should not be used for potable uses.

5.3 Situation analysis of Legedadi sub system water supply service with WEAP

For Addis Ababa, the target for drinking water SDG of achieving universal and equitable access to safe and affordable drinking water for all by 2030 (Thompson and Koehler, 2015) seems ambitious. Ensuring access to drinking water is increasingly challenging as the population is growing; increasing urbanization, agriculture and industry, and other sectors all competing for water (Pangare and Idris, 2012) and historically significant structural social inequalities (Castro and Heller, 2009).

5.4 The Root Causes for the Lack of Adequate Water Supply in Addis Ababa

This study has found the following as the root causes for the observed inadequate water supply in Addis Ababa water supply system:

Limitations in access to services in Ethiopian urban areas including Addis Ababa advocate faster pace of urbanization than the rate of increase in service delivery (MUDHc, 2014). This is the very reason for the low water, sanitation and hygiene coverage in Ethiopia compared to other African countries. Like many world urban centers (Jayawardena, 2014), the main water problem in Addis Ababa today is the lack of potable water, the most vital ingredient for sustaining life next to oxygen as a direct result of the increase in urbanization (Hamaideh *et al*., 2015). Addis Ababa needs to scale up its urban water services to meet the needs of its low-income population thereby meeting this pressing challenge. Service should be reliable; targeted and actually used; sustainable (institutionally, financially and environmentally) (WSUP, 2013). The prominent urban water issues (rapid urbanization, leadership and governance, investment, water availability and quality are consistent with the observations made by Gemma *et al*. (2014).

5.4.1 Inefficient and ineffective water use; and poor management

The way in which water is managed in cities has consequences both for city dwellers and for the wider community. AAWSA is experiencing gridlock in water management attributable to institutional barriers. At present, the utility seems to concentrate on supply side management approaches neglecting effective demand side management approaches. The low performance of AAWSA is related to the shortage of financial resource and huge investment requirements of water resource projects (Girma, 2013); uneven and distant spatial distribution of water resources potential; low level of infrastructure development; and limited implementation capacity at the head office and branch levels. AAWSA has to recognize that efficient water management plays a vital role in strengthening the resilience of social, economic and environmental systems in the face of rapid and unpredictable changes.

As wasting water is regarded as nothing lost by quite many residents, particularly those living at lower altitudes getting continuous supply, water is being wasted at standpipes and through pipe breaks in most Addis Ababa urban. This major problem of inefficient water usage unquestionably has contributed to the current and observed rising of water demand, a situation expected to resume since these problems are often overlooked and lack the attention of those who are in charge of managing urban water supply. The problem is evident when one compares domestic consumption with average daily water production.

Expanding the distribution system beyond its hydraulic capacity is very common by the insistence of urban water officials to extend water distribution system to serve the section of the urban area from which s/he will get the political support (vote) of the poor for promotion to higher position or elections to legislative positions etc. The very high-water shortages have made the utility busy in system control and shift supply activities. There is still acute water shortage in the city, a critical problem that needs immediate attention. The defect in the performance of the water network has led to the negative influence in most of the socio-economic sectors especially in the old parts of the city coupled with increased water demand due to high population growth rate and increased per capita water consumption.

Poor management is hindering the available quantity of water from being conveyed in acceptable and proper manner to water consumers. It has caused the social burden of the frequent leave of house maids in the 3^{rd} and 4^{th} floors of condominium houses not to fetch water from long distances or raising to high floors. The use of potable water for non-potable purposes such as irrigation of urban green areas, car washing, compound washing and compound cleaning are worsening the problem. Residents pay five birr per 20-25 liters Jerry can for purchasing water and ten birr for transporting it since water management is often affected by city's geographical location noted by Bahri (2012). This contradicts with the necessity of daily access to clean water to satisfy basic needs of drinking, washing and bathing collectively known as domestic uses of water (Hall *et al*., 2014).

This inadequate and inefficient water resource management hosts a number of problems evidenced by water scarcity, uneven distribution and quality problems as a result of uncontrolled domestic and industrial pollution. This contradicts with the Ethiopian water sector policy that aims the efficient, equitable and optimum utilization of the available water resources of Ethiopia (MoWIE, 2013). This poor management of existing infrastructural assets is likely to increase the level of water losses associated with complex and fragmented water governance system (Naik and Glickfeld, 2015) unless leakage reduction measures are in place. This calls for cultural change based on effective leadership to identify and implement needed reforms in water management issues.

5.4.2. Ineffective coordination/harmonization with other sectors

This study has found weak or non-existent sectoral coordination among and between service givers was a significant challenge facing AAWSA which opposes UNESCO (2015)'s assertion of the crucial importance of well-functioning coordination among urban service providers at different levels and joint planning involving different interests that are important for sustainable management of water. The lack of coordination has triggered inefficient infrastructures causing low water quality is consistent with the findings of Gebremichael *et al*. (2014) that have shown a wide gap in institutional and professional gap in the areas of water management and governance. This problem has caused frequent damage of water pipes during activities such as laying down telephone and internet lines and road construction, inadequate funding and inefficient infrastructure, the uncommon integrated infrastructure and housing development approaches have reduced provision of infrastructure and environmental services in high altitude areas, frequent failures of water supplying motors and pumps caused by power interruptions; and storm water drainage systems become open sewers leading untreated water to streams and rivers. There were similar findings by Damhaug *et al. (*,2000). The major challenges of integrated urban water management are related to barriers to integration and sustainability (De la Harpe, 2008).

5.4.3. Low water tariff, and inadequate political and financial support

AAWSA's low water tariff is associated with poor-governance and the misconception that the poor cannot afford water at full-cost. This misconception has led AAWSA's officials to be reluctant to raise water tariff to its cost-recovery level and to the level that will induce awareness to conserve water. They think that the urban poor are unwilling and cannot afford to pay the full cost of piped-water and agrees with the findings of McIntosh (2003). Stability and predictability in financing are important and can be achieved by improving effectiveness in the use of public resources through improved water sector governance and leveraging additional local resources.

The urban poor who are not being served by piped water but fetch water daily from street water vendors at seven to ten-fold time the price of pipe water are willing to pay up to 500% of its current tariff to be connected to AAWSA's supply and to improved and reliable water services. This is consistent with the findings of Shofiani (2003). This misconception coupled with the political interests of city managers, have hindered regular tariff adjustment though rising water price is acceptable. This in turn has resulted in the lack of revenue for reconstructing impaired component of the system and motivating staff to carry out good operation and maintenance similar to other places (McIntosh, 2003). Cognizant to UN (2008), AAWSA should recognize that adequate investments in water management, infrastructure and services can yield a high economic return by avoiding costs related to water pollution, contamination and disasters.

The lack of inputs has steered delayed services and service inefficiency of branches deteriorating their performance and/or worsening of leakages. Low level water pricing undoubtedly creates the impression that water is plentiful and its wastage is nothing lost (McIntosh (2003). Low pricing is caused by utility staff, government officials, and elected officials, with vested interests in maintaining status quo, that allows a considerable political support during elections. Low water tariff is contributing to high water losses worsening low piped water coverage, and intermittent supply. Hence, stability and predictability in financing are essential and can be achieved by improving the effectiveness in the use of public resources through improved water sector governance as well as leveraging additional local resources for urban utilities

5.4.4 weak and fragmented institution and instability

Leakage, illegal connections and billing inefficiency caused by low operation and maintenance have caused high water loss in the water distributions owed to low human and technical capacity. This insufficient institutional capacity and instability coupled with historically entrenched authoritarian political culture might put the city at most risk of being severely affected by climate change (Ndaruzaniye (2011) like other African cities. Such lack capacity of the utility to extend water distribution to unserved parts of the city is one of the causes for the observed intermittent or non-existent water supply provision and agrees with what was noted by McIntosh (2003).

Damage costs from weak institutional structure associated with poor coordination are very high (for repairing, rebuilding and improving the network) and can be as high 20% of the total income of the water utility (Saghi and Aval 2015). This in turn has initiated defect in the performance of the water network which has already started negatively influencing most of the socio-economic sectors. Its prime cause is aged pipe system (especially in the old parts of the city) showing AAWSA's delirious calculations contributing for inconsistent and incorrect reports notifying it to ensure good governance in urban water supply to enhance sustainability, effeteness and efficiency of the service. Inadequate monitoring and evaluation have underestimated growth in water demand.

The fragmented management of the different water cycles (water supply, wastewater and storm water) in Addis Ababa has led to missed opportunities such as failure to exploit rainwater and recycled wastewater as a source of water supply for non-potable uses; and unexpected impacts including the over abstraction of groundwater reducing sustainable yield. In response to rapid and unplanned urban growth, and relatively poor water management practices, AAWSA is struggling to address the gap between the demand of rising population and the limited availability of a completed resource to deal with significant extended bureaucracy, turnover of personnel, limited human resource capacity and expertise. Amidst significant progress in improving economic and social conditions, still challenges remain for AAWSA to become a more inclusive, safe, resilient and sustainable city as population growth, construction boom and other economic activities have resulted in a deficit of water supply for the city population. unplanned urban growth, and poor water management practices have forced Addis Ababa to struggle with problems of water scarcity, water pollution, inadequate service provision, and increased flooding, directly affecting its population's quality of life and economic prospects.

5.4.5 Poor technical and human resource capacity

With respect to institutional challenges, the findings of this study agree with most researches into integrated urban water management that tend to prioritize /emphasize technical studies instead of examining institutional barriers. The paucity of the water supply services sector and development in Ethiopia is due to the lack of capacity on management, policy and regulatory matters and to handle planning, operation and maintenance activities that are also common in other places (Macro, 2006). This author has taken the stand that the current water production insufficiency is consistent with the under development of water supply sector. This could be associated with institutional instability, management problems, and lack of coordination and weakness in operation and maintenance of the projects (MoWR, 2002). Unskilled professionals, low staff awareness, negative attitudes and low interest are expected to worsen the absence of data backup owed to the very laggard nature of AAWSA towards using technology.

5.4.6 Absence of proper database and poor information exchange system

AAWSA has limited available good quality data and lacks data base for most issues or the available ones are outdated. This in turn has caused high dependence on global average statistics which mostly leads to inappropriate interventions at a local level. The scope of national and international data collection and analysis systems and the reporting mechanisms are mostly limited to country or city level. Information is hardly disaggregated to a local level in small geographic areas. This study has suffered from inaccessible, missing or incomplete or inconsistent data.

AAWSA's very poor data recording system is complicating the water provision services. Lacking or inconsistent data on water availability, distribution, water consumption by each user category, water quality and water management methods have resulted in water shortages. The absence of internet service in all the eight branches is instigating the loss of huge important data by virus attack of the few computers shared among various staffs. This has impaired sharing relevant data, available information, experience sharing and horizontal relations among branches or between the head office and branches.

In 2015, percentage coverage was 88.94, 97.78 and 77.30 based on AAWSA, CSA and high scenario population sizes respectively. The first two reports don't agree with the fact on the ground. AAWSA has no accurate total water consumption data owed to unknown volumes of water abstracted from the 125 private wells by non-domestic customers mostly for non-potable uses because of the lack of smart meters. The number of private wells is not known with certainty. This has made water demand analysis difficult. AAEPA estimates 1000 private wells but it has licensed only about 500 wells manifesting the unreliability of its performance information. The lack of up-to-date data base has resulted in the lack of adequate and timely available data.

5.4. 7. Defective water policies, strategies and plans

The preconditions for successful environmental policy implementation which are weak at best (UNEP, 2013) show that many policy and planning decisions made by AAWSA are taken without access to adequate data. As this conceivably increases the risk of inappropriate measures being adopted (Šliužas, 2004), city residents without land ownership certificates are not entitled to AAWSA connections, a challenge that is expected to escalate like in most developing country cities (World Bank, 2005).Meaning, the water supply sector in Ethiopia has crippled development due to legislation, investment, policy and participation gaps (Dessalegn, 1999) coupled with projected rapid population growth of the city and intensity of urbanization (WBG, 2015). Fully recognizing the challenge of adequate water supply, this author takes the stand that the problem is expected to become even more significant because of rapid urbanization, increased individual water demand as incomes rise, and the impacts of climate change. The present estimated per capita distribution of 40 liters per day is well below the utility's goal of 110li/c/d augments the authors' assertion. Poor-governance is behind the screen and stands as the prime cause to the exceeding of water demand over that of supply

5.4.8. Mismatch between demand and supply (enhanced consumption)

Water scarcity is broadly defined as the lack of access to adequate quantities of water for human and environmental uses. Both physical and social or economic water scarcities complement each other (Kummu *et al*., 2010) and highlight important aspects of the problem. Physical water scarcity may develop over time into the future, with a time span of a few decades ahead. Meaning, a rapid increase in the number of people under water stress or water shortage is expected as a result of the increasing population and/or water use. In some cases, this could be due to climatic change (V¨or¨osmarty *et al., 2000*, Oki and Kanae 2006).

Addis Ababa is affected by economic (social) water scarcity as a result of the lack of adequate finance, skill, technology and human capacity to bring water from distant sources. even though physical and economic water scarcities complement each other (Kummu *et al*., 2012). The driving factors are increased population growth and rapid urbanization, high volume of NRW, industries and industrial water pollution, and reduced infiltration. The combined effects of population growth and increased per capita consumption have increased water supply deficit by increasing water demand.

The scarcity of the quantity of water supply (service level; accessibility of the supply; affordability of water tariff and continuity of the supply) are disproportionally felt inadequacies. The reality of leaving considerable part of the urban population without access to sufficient and potable water certainly deteriorates public health, growth and economy by forming part of a systematic urban problem (Barata *et al*., 2012; Rousdy *et al*., 2012; Path ,2007).

Low level of water supply services adequacy is threatening the health and the environments of people in water scarce areas of the city thereby bringing about a declined standard of living and threatening their dignity. This reality is analogous to the observations of Barata *et al*. (2012) and Pah (2007) who have stated that leaving considerable part of the urban population without access to sufficient and potable water certainly deteriorates public health, growth, and economy of the urban area.

The critical observed and reported mismatch between water supply and water demand in Addis Ababa like many parts of Sub Saharan Africa might continue to be a significant problem (Marobhe, 2008).

AAWSA is attempting to address the problem through new source development, expansion and rehabilitation of existing water treatment plants and dam rising, wells construction in pocket areas, truck water supply for low pressure areas via shift supply, water line installation for the poor and elderly with the support of charity organization. It is important that today's water challenges be addressed in a way that reflects an integrated approach, keeping in mind the long-term vision towards which the city and region should move (Chen, 2010).

5.4.9. Increasing water demand

Ethiopia, has the lowest level of water and sanitation service provision in the world (Dowa *et al.*, 2007), and faces a range of challenges in water management. It is the second lowest among Sub Saharan African countries in access to safe/improved drinking water (WHO/UNICEF, 2015) attributed to limited capacity to develop water resources including groundwater, limited absorption capacity of public sector, limited drilling capacity and involvement of the private sector, lack of contract management capacity and weak sector coordination. Although access to safe water is a human need and a basic right (Mason, 2009), its shortage and quality deterioration in Addis Ababa from increasing demand (McDonald.*et al*., 2014) is attributed to urban growth. The 350,000 condominium houses planned to be constructed during the second GTP (2015/16-2020/21) will worsen the current situation. Advances in technology and rapid urbanization are also transforming residents, their economies and their ways of doing business evidenced by their increased water consumption and demand.

5.4.10. Deteriorating and malfunctioning infrastructure system

Like in many cities, the water infrastructure in Addis Ababa is as old as the city itself with little replacement of water pipes or equipment making AAWSA's performance one of the most critical issues in the water supply sector requiring immediate action to revert the current discontinuous water supply. Deteriorating and malfunctioning infrastructure system have forced AAWSA supply water to certain parts of the city on a rotating basis, with some areas receiving water only two days a week through distribution lines or water trucks. Hence, comprehending the urban growth and clearly explaining options are two main requirements for effective decision-making about sustainable development of urban infrastructure (Grigg,1997).

AAWSA's operation and maintenance services are not delivered similar to other traditional centralized systems that are the responsibilities of municipalities and utilities (Sohail *et al*., 2005).There are many cases of poor operation and maintenance works done by its employees All respondents have associated the current old, insufficient and malfunctioning infrastructure with the rapid and steady population growth, urbanization and industrialization /enhanced economic activities, budget shortage, lack of manpower.

5.4.12. Huge volume of water leakage and water loss

Most customers believe that half of the water produced by AAWSA is lost because of the slow response or negligence of AAWSA employees to reports of concerned customers. Huge water loss due to poor operation and maintenance is contributing to the low piped water coverage, exceeding of demand over supply and intermittency of supply. Both the opinions of most customers who estimated water loss at 50% and the findings this study showed the presence of huge water loss. This considerable difference between the amount put into the distribution system and the amount of water billed to consumers is one of the major issues affecting the water utility like in most developing world (Kingdom *et al*., 2006). Such huge losses from the distribution is one of the major issues affecting AAWSA which is also a problem of most developing world (Kingdom *et al*., 2006).

The reported rising up of water inside a house like spring near Abebe Bikela stadium shows the gravity of invisible leakage. AAWSA has estimated real loss (physical loss) caused by leaks, pipe break downs, and other incidents to amount 25% of the total water delivered. Water not accounted for because of wrong estimations, errors in measurement (faulty meters), fraud and other causes added to up to 20% of the total water delivered. Development activities are causing frequent breakages and increased leakage and finally supply interruption making AAWSA's performance in the low service/ low –revenue trap. Huge leakage and many invisible leakage points throughout the city are obliging AAWSA long time to replace or update its infrastructure

The current increasing number of leaks in water pipes due to corrosion and breaks in the water main or ageing and deteriorating public infrastructure is affecting water quality and water service seriously but geographically uneven with certain areas facing significantly higher incidence of problems like the observation made by Saghi, and Aval (2015). The recent special attention of AAWSA to reduce NRW via district area metering to investigate invisible leakage in the water distribution service hoping to reduce NRW in urban water distribution networks to 20% by 2020 is also true in many countries (Saghi and Aval, 2015) even though the utility has not conducted prioritization of effective factors in causing leakage study. This study has identified pipe materials, pipe age , pipe diameter , pressure, the movement of soil around the pipe, unsuitable pipe basis and coverage materials and pipe coverage , incorrect installation, water hammer hit, clogging the components joints and pipes, the pressure of the cars on the surface roads and ground, corrosive waters, the damages to the pipes by other service organizations, poor quality connections and nonstandard plumbing, the summit of the ground and climate conditions as factors that cause leakage. Material, age, pressure, diameter, the depth of the placement of the pipe, and length were emphasized.

Serious water loss manifests inefficient resource utilization and ineffective water utility management Lai *et al.*, (2017). Reducing water loss is a key sustainable water management response to the absence of integrated water management plans responsible for the gradual increase in the problems of drinking water scarcity (Van den Berg, 2014). But reducing water loss is a challenge particularly in developing countries cities including Addis Ababa, a situation discouraging citizens from participating in water management enhancing water shortage in addition to money lost from wastage of treated potable water.

The major sources of water loss include leaking house service connections, old conservancy lane, non-working meters, illegal connections, poor quality of meters, and absence of water accounting.

Customers located at the lower parts of Addis with better and continuous water supply have experienced breakage of their water pipes, tap and other facilities because of high and very high pressures values. This calls for pressure management measures to reduce the water losses occurring within the pipe system supply (Mutikanga *et al*., 2012; Nicolini and Zovatto, 2009; Girard and Stewart, 2007) since a one percent increase in pressure results in a 1.15% increase in the leakage rate. The very high volume of NRW and intermittency of supply are caused by most of the existing water infrastructure that date back to several decades or even more than half a century, are very old and dilapidated in most part of the city. The very high value of NRW in

Addis Ababa is nearly twice higher than World Bank's recommended value (less than25%) or the recorded value of 19% by England and Wales (Kingdom *et al.*, 2006).

5.4.13. Over abstraction and depleted sources

Changes in industrial structure and economic developments have commanded unsustainable abstraction of the available water resources beyond their sustainable yield. Production of groundwater is increasing at steady pace since 1994 together with the linear increment of production of water. The reduced capacity of existing water sources that is severely affecting the water supply of Addis Ababa City, is happening in the form of depletion of groundwater sources and reduced capacity of reservoirs is consistent with the findings of Siraj *et al. (*2016). The current fierce competition among water users on the available freshwater is aggravating resource depletion compromising on water access to low income domestic users.

Enhanced demand from increased water consumption by the growing population, construction boom and changed style of living has resulted in the over abstraction of the available sources in Sebeta, Ayat, Legedadi, Mekakuntire, Yeshi Debele, Meriluke, Ayat Summit, and Lebu wellfields. It is caused by sedimentation due to low level catchment management; deplted groundwater sources from over abstraction, competition of neighboring unlicensed private wells, and pollution by domestic, industrial and commercial wastes.The present actual and potential depleting recharge zones and quality deterioration could be associated with absence of catchment management, land use change into developed land, population growth, rapid urbanization, climate change and water mismanagement.

Several production boreholes abandoned because of yield reduction and three of the 129 bore wells have ceased functioning because of filling up due to upland flooding. These malfunctioning wells are located in the middle of the lower slopes of the city near Mekanissa and on Little Akaki River (Kombe *et al.,* 2015). The absence of catchment management and enhanced economic activities in Gefersa, Dire and Legedadi surface water catchments are reducing the capacities of the reservoirs through sedimentation (DAR AL-ORMAN and Associates, 2012).

The concentration of shallow, medium and deeps wells in well fields has started fierce competition among production wells causing frustration among water users since the increasing number of wells in small radius can significantly increase the existing unmet demand and decrease groundwater recharge by ultimately decreasing their yields very soon. The problem is compounded with the conversion of recharge zones into impervious developed land at a faster rate. Possible land use change in catchments might reduce the volume of water entering these reservoirs.

The low level of awareness from all parties (decision makers, households and public connection beneficiaries) identified by this study calls for an integrated approach to achieve social equity, sustainable environment, and the economic efficiency. This makes identification and implementation of effective solutions much easier and improves the efficiency in water use (GWP, 2004). The fragmented management of the different elements of the water cycle has led to missed opportunities such as failure to exploit rainwater and recycled wastewater as a source of water supply for non-potable uses and unexpected impacts including the over abstraction of groundwater thereby reducing its sustainable yield. New approaches with a new mentality are required with a sense of urgency to successfully face the current urban water challenges in Addis Ababa. Planning, developing, and managing water resources to ensure adequate, inexpensive and sustainable and quality water supply for all types of demands can only be successful by addressing the causal socio-economic factors of inadequate education, population pressures and poverty (LoucksandBeek,2005).

CHAPTER SIX

6. Conclusion and Recommendations

6.1. Conclusion

Based on the findings of this study, the major conclusions were:

AAWSA's design of water distribution systems is implemented by using universal design factors without taking into account the effects of local conditions, so that the design parameters should be modified to achieve water requirements. The current branch-based water supply distribution is characterized by supply inequity both in terms of weekly water supplying days and daily water supply hours. Although intermittent supply could be taken as the last measure in conditions of water shortage, it is mandatory for AAWSA to avoid it through proactive planning and timely response to critical conditions. Thus, investments in mere infrastructure and financing improved water supply systems, increased coverage and affordable access to the poor, leveraging additional local sources, estimations based on status assumptions, service standards and existing financial flows, and rigorous estimates are not adequate.

Amidst AAWSA's miscellaneous efforts including new sources development, expansion and rehabilitation of existing water treatment plants and dam raising, wells extraction in pocket areas, truck water supply for low pressure areas via shift supply, water line installation for the poor and elderly with the support of charity organization demonstrates higher rates of water demand growth than the growth of water supply. Fluctuation in access to drinking water supply are due to inadequate institutional arrangement, lack of proper management of water resources, poor data collection, collation and archiving, poor community and private sector participation, epileptic power supply and inadequate awareness on issues of water conversation and management, weak management and executive capacity and low investment level in operation and maintenance.

The majority of customers reported perceived improvement of water service compared to a reasonable proportion who reported worsening of the service. This overall expected increased water demand found by this study (due to the gradual deteriorations in the performance of the water system; inadequate and unreliable power with frequent and long-lasting power interruptions; old distribution network; inadequate pipes with many bursts along the main line; damages to service pipes during road construction and other land use activities; severe and frequent technical failure; insufficient infrastructure, rapid and steady population growth, urbanization, better and modern style of life due increased income, and water intensive modern houses are also contributing factors is putting high pressure on the utility.

The existing Legedadi subsystem layout which has aged pipelines requires immediate replacement or extensive rehabilitation works to ensure satisfactory static pressure conditions. additional water sources, both surface and groundwater, will be needed to meet the needs of Addis Ababa metropolitan area. To avert this water customers' suffering from the deficiency of water supply quantities and sharp pressure drops and meet consumer demand at satisfactory levels, the utility must improve and increase the efficiencies of the water distribution and management systems.

The WEAP model results signify the growth of demand at a faster rate than the growth of supply or production and can be the result of population growth, increased household income, economic growth, induced increased water consumption due to increased awareness and hence demand, increased connections to AAWSA water distribution network and/or change into better connection type, modern style of life with increased water use for sanitation and other activities as well as water intensive modern house types that are water intensive including condominiums lead to increased demand. GTP II's leakage reduction plan to 20% may not be achieved due to AAWSA's very long water distribution network having very old pipes and other infrastructure. If achieved, it can produce water volume equal to eight times Gefersa dams' current capacity or 1.23 times the current production volume of Legedadi water treatment plant.

AAWSA's lack of a common strategy, multiplicity of institutions, institutional weakness and absence of integration among the various service providing institutions to integrate their action plans and programs at the city level have resulted in massive pollution of surface water resources. Lack of coordination has made the city suffer from fragmented institutional arrangement and overlapping mandates with confusing duties and responsibilities hampering the ability of city leaders to address critical socio-economic and environmental challenges. Sectors' accountability differences since few are accountable to the city administration and others to the Federal State is contributing to the observed glitches. AACRA frequently breaks AAWSA's water distributions while constructing and rehabilitating roads due to absence of prior communication or common plan.

The defect in the performance of AAWSA's network which has started negatively influencing most of the socioeconomic sectors. Customers disappointing by outages; and frequent interruptions have developed stress among customers could be improved if better information management systems that could give early warnings of requirements are in place. The absence of appropriate database about customers' profile and inaccurate meter reading are enforcing the poor customers to pay more. Low quality inputs, slow and inefficient workmanship of technicians, budget shortage and wasting valuable working time with political meetings are believed to lag the renewal of these old infrastructures and hence slow down the achievement of leakage reduction target period. Eventually outdated database has brought both less effective and inefficient management. These inefficiencies originating from limited infrastructure and absence of effective management systems are still most relevant to resolve.

6.2. Recommendations

Based on the findings of this study, the following recommendations are forwarded to the respective stakeholders:

There are few scientifically documented literatures on the urban water supply problem of Addis Ababa city. Therefore, more empirical evidence is needed. This calls for research to assess the feasibility of shifting from predominantly imported water supply sources to more local resources through conservation, recycled water usage, storm water capture, and groundwater management. This perception study could be more comprehensive by including socio-economic input data and increasing sample size. It should also be backed up by monitoring. Loss reduction and demand reduction measures are expected to narrow the gap between supply and demand better than the development of new water sources or additional water production. As most new source development projects are either expensive or slow or usually fail, AAWSA better look for other alternatives. Conducting research on the extent of water demand increment or reduction due changed style of living, increased living standard or income, awareness, increasing water tariff, water conservation, and climate change is worth doing and timely. Water scarcity trend projection is very crucial and worth a study in order to prevent possible environmental degradation and prepare for possible remedies for the near future.

There remains much for AAWSA and its branch offices to do to narrow the wide gap between water supply and water demand, thereby changing its complex and fragmented water governance system. The utility has to shift from engineering-based supply side management to technology-based demand side management approaches. It should shift from predominantly imported sources to more local sources through conservation, recycled water usage, storm water capture, and groundwater management. AAWSA can enhance efficient use via awareness campaigns and /or tariff increments. AAWSA need to organize research and study unit in order not to depend on the recommendations of consultant reports which are expensive but might lack reliability. It should conduct full inventory of all boreholes in the city and keep accurate and up-to-date data of production capacity/status, GPS locations, and others for proper planning.

AAWSA may consider establishing updated geo-referenced data base for the boreholes and other basic water infrastructures and commence the use of up-to-date technology like digital water meters and leakage detectors. Branches should know their system input volume for proper leakage reduction and need to have full autonomy and strive for quality during the purchase and installation of infrastructure. Huge water consuming industries and commercial units should be advised to recycle their wastewater to minimize their pressure on treated freshwater for non-domestic demands which don’t need high quality water. This should be backed up with strong policy and government intervention. Water demand of day time population should be included in the planning of future water supply planning.

Efficiency improvements in water use require setting up of mechanisms for changing people’s attitudes and behaviors towards water use. This requires very strong and workable integration equivalent to positive attitudes and affections of the staff towards their institution and their customers; and developing professionalism to serve the poor and the needy. Inter-sectoral integration among the different service giving organizations with different accountabilities needs consolidation and requires their full autonomy. Training and short-term courses are mandatory to develop the skill and efficiencies of the technical staff. Developing positive and strong relationship with stakeholders such as water customers shouldn’t be overlooked. Commencing monitoring of corrupted and illegal activities is mandatory. Water lines should be connected to illegal settlers since water is both a necessity good without substitution and a basic human right that should be supplied to anyone without any precondition.

Emphasizing exclusively on either source is an issue of further investigation for reasons of budget, source sustainability, long years of design period, and water quality. Hence, groundwater sources should be used as alternative sources to augment surface sources for ensuring water security during reservoir maintenance and during drought periods is recommended.

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Appendices

Appendix A: Details of the materials and methods section

Appendix A-1: Number of weredas and kebeles of the ten sub cities

Sub city	Kebele (#)	Wereda (#)	Area (Ha)	% (area)
Addis Ababa city	190	116	51949.89	100
Addis Ketema	21	10	663.86	1.66
Akaki Kality	19	11	12400.71	23.87
Arada	16	10	949.85	1.83
Bole	22	14	11849.49	22.81
Gulele	21	10	3119.1	6
Kirkos	19	11	1464.76	2.82
Kolfe	16	15	6348.09	12.22
Lideta	17	10	918.28	1.77
Nifas Silk Lafto	18	12	8213.11	15.81
Yeka	21	13	8213.11	15.81

Source: CGAA (2013)

Appendix A -2: Climate data collection weather stations in and around Addis Ababa

Station Name	Addis Ababa Bole	Observatory	Addis Alem	Akaki	Ayer Tena	Intoto	Kality	Sebeta	Sendafa	Sululta
Longitude (Deg)	38.75	38.748	38.383	38.786	38.696	38.721	38.767	38.63	39.022	38.733
Latitude (Deg)	9.033	9.019	9.042	8.87	8.983	9.084	8.933	8.93	9.152	9.183
Elevation(m)	2354	2386	2372	2057	2325	2903	2186	2240	2569	2610

Source: NMA (2015)

Appendix A-3: LTM rainfall depths of the ten sub cities

Sub City	Area (km^2)	Minimum Rainfall (mm)	Max rainfall (mm)	Mean Rainfall (mm)
Addis_Ketema	7.36	1087.5	1087.5	1087.5
Akaki- Kality	124.15	1001.5	1045.5	1023.8
Arada	9.46	1087.5	1087.5	1087.5
Bole	118.91	1079.9	1125.9	1102.1
Kirkos	14.65	1146.9	1146.9	1146.9
Gulele	30.98	1195.6	1195.6	1195.6
Kolfe-keranyo	62.55	980.6	1255.1	1096.1
Lideta	10.85	1087.5	1087.5	1087.5
Nefas Silk Lafto	57.89	1019.1	1071	1045
Yeka	81.85	1118.6	1137.5	1127.7

Source: Own Interpolation from the nine stations climate record of NMA

Appendix A-4: Summary of water user interview participants

No.	Sub city	Branch	Wereda	GPS location			User category	Name of participant	Sex	House morphology	Household size
			Woreda	Latitude	Longitude	Elevation					
1	Yeka	Gurd Shola	11	481724.49	998729.49		Commercial	Debebe Ejeta Clinic	F	Villa	variable
2	yeka	Megenagna	5	477761	997887		Domestic	HaileGiorgis Damitew	M	Villa	7
3	Yeka	Megenagna	5	477490	997813	2458	Domestic*	Asbegiorgis Jembere	M	G+1	Variable
4	Bole	Megenagna	4				Commercial	Eyerusalem Simegn	F	G+5	Variable
5	Bole	Gurd Shola	6				Domestic	Tewabech Tesfa	F	Villa	6
6	Bole	Gurd Shola	6	478868.03	996759.94		Commercial	Hizkiyas Dawit	M	Villa	Variable
8	Yeka	Gurd Shola	13	485032.35	999165.02		Commercial	Yonas Lemma	M	Villa	8
9	Yeka	Gurd Shola	12	482819.9	997251.66		Domestic	Mulatu Damite	M	Villa	8
10	Yeka	Gurd Shola	12	484642	999210	2555	Institutional	Haileleul Dagne	M	Villa	Variable
11	Yeka	Gurd Shola	12	483711	998895	2505	Domestic	Meaza	F	Villa	8
12	Yeka	Gurd Shola	12	484358	999281		Domestic	Menerwork Lijalem	F	Villa	3
13	Yeka	Gurd Shola	9	480912.57	998903.87		Domestic	Getachew W/Gebriel	M	Villa	10
14	Yeka	Gurd Shola	10	479821.91	999569.87		Domestic	G/Mariam Tewolde	M	G+2+b	6
15	Yeka	Gurd Shola	11	481871.93	999142.94		Domestic	yeshi kassa	F	Villa	5
16	Yeka	Gurd Shola	10	480058.17	999553.2		Domestic	Tsige Belda	F	Villa	16
17	Yeka	Gurd Shola	9	480890.18	999448.38		Domestic	Mekasha Digafe	M	Villa	4
18	Yeka	Gurd Shola	11	481508.41	999079.16		Domestic	Addis Zewdu	M	Villa	7

19	Yeka	Gurd Shola	9	480265.7	996477.28		Institutional	Tsigereda Tesfaye	F	Villa	Variable
20	Bole	Gurd Shola	6	38°45"54'	9°00"54'	2293	Institutional	Gizachew Yadeta	M	G+1	Variable
21	Bole	Gurd Shola	6	37°04".73374	993784		Commercial	Dawit Tolesa	M	G+4+b	Variable
22	Bole	Gurd Shola	7				Institutional	Getachew Mengistu	M	G+4+b	Variable
23	Bole	Gurd Shola	7	480262.89	996384.58		Domestic	Mulunesh Molla	F	Villa	6
24	Bole	Gurd Shola	10				Domestic	Peruz Murad	F	Condo	5
25	Bole	Gurd Shola	10				Domestic	Kanchiwodiya Seyoum	F	Condo	5
26	Bole	Gurd Shola	10				Domestic	Addis Assefa	F	Condo	5
27	Bole	Gurd Shola	10				Domestic	Zenebech Mergia	F	Condo	5
28	Bole	Gurd Shola	6				Commercial	Ababaye Ayana	M	Condo	Variable
29	Bole	Megenagna	3				Institutional	Abera Alemayehu	M	G+2+b	Variable
30	Bole	Megenagna	4				Commercial	Belay Negash	M	G+6	Variable
31	Bole	Megenagna	4	476415	996281		Institutional	Mulunesh Darmie	F	G+4	Variable
32	Bole	Megenagna	4				Institutional	Kebede Deresse	M	G+7	Variable
33	Bole	Megenagna	4				Domestic	Asegedech Gemechu	F	Villa	10
34	Bole	Megenagna	3				Commercial	Mathias Desta	M	G+8	Variable
35	Bole	Megenagna	3				Commercial	Muhaba Sherif	M	Villa	Variable
36	Akaki Kality	Nefas Silk	6				Domestic	Nahom W/Mariam	M	Villa	7
37	Akaki Kality	Nefas Silk	1	477113	980481		Domestic	Abdulahi Edris	M	Villa	10
38	Aka. Kal	Nefas Silk	6	474121	988712	2215	Industrial	Nebil Abdurahman	M	Villa	Variable

39	Aka. Kal	Akaki	3	476638	980770	2068	industrial	Colonel Tsehay Feleke	M	G+1	Variable
40	Aka. Kal	Akaki	1	476755	980384	2076	institutional	Birhanu Tolera	M	Villa	Variable
41	Aka. Kal	Akaki	3	476353.09	979923.5		Domestic	Yasin Hassen	M	Villa	16
42	Aka. Kal	Akaki	9	478622	983625	2157	Institutional	Getawork Belay	M	G+4	Variable
43	Aka. Kal	Akaki	2				Domestic	Etagegnehu Belay	F	Villa	5
44	Aka. Kal	Akaki	1	476892	980081	2105	Domestic	Alemie Bobassa	F	Villa	6
45	Aka. Kal	Akaki	1	476687	981095	2063	Institutional	Legesse Ketema	M	G+1	Variable
46	Yeka	Gurd Shola	7				Commercial	Endale Tafesse	M	G+6	Variable
47	Arada	Ararda	10				Domestic	Reshid Nasir	M	Villa	7
48	Kirkos	Arada	10				Commercial	Selam Dejene	F	G+10	Variable
49	Yeka	Megenagna	10	476470	997191	2378	Domestic	Tiztaye Eshetu	F	Villa	8
50	Yeka	Megenagna	7	476290	997845	2418	Institutional	Sintayehu Anjiso	M	G+4	Variable
51	Yeka	Megenagna	8	476127	996422	2377	Domestic	Tigist Sisay	F	Condo	2
52	yeka	Megenagna	7	476146	997698	2415	Domestic	Haymanot Solomon	F	Condo	2
53	Bole	Gurd Shola	7	479968	994943	2350	Institutional	Hana Simie	F	Villa	variable
54	Bole	Gurd Shola	10	480344	994460	2356	Domestic	Emebet Worku	F	G+2+b	3
55	Bole	Gurd Shola	8	483489	995606	2367	Domestic	Fikirte Assefa	F	G+1	5
56	Bole	Gurd Shola	7	476109	994632	2365	Domestic	Rishan Fiwi	F	Villa	5
57	Bole	Gurd Shola	7	480271	994531	2321	Domestic*	Pawlos Shiferaw	M	G+1+b	variable
58	Bole	Gurd Shola	9	481140	993785	2332	Institutional	Abera Lemma	M	G+2+b	variable

59	Bole	Gurd Shola	8	483322	995234	2366	Domestic	Biruk Tadesse	M	G+1	7
60	Bole	Gurd Shola	8	482622	996829	2387	institutional	Nitsuh Workneh	F	Villa	variable
61	Yeka	Gurd Shola	11	482404	997195	2393	Domestic	Wudie Tadesse	F	Condo	8
62	Yeka	Gurd Shola	11	482438	997239	2414	domestic*	Meron Fekadesilassie	F	Condo	14
63	Yeka	Gurd Shola	13	486870	999988	2449	Domestic	Firehiwot Eshetie	F	Condo	6
64	Yeka	Gurd Shola	13	485951	1000158	2498	Domestic	Aster Tadesse	F	Condo	4
65	Yeka	Gurd Shola	13	486873	999988	2459	Domestic	Urgie Cheru	F	Condo	7
66	Add. Ket	Addis Ketema	6	70981.837	999295.98		Institutional	Ameha Berhe	M	G+b	variable
67	Add. Ket	Addis Ketema	6	70828.069	999706		Institutional	Netsanet Tesfaye	M	G+4	variable
68	Bole	Gurd Shola	11	481454	993274	2328	Domestic	Firehiwot Belay	F	Villa	11
69	Bole	Gurd Shola	13	478596	994283	2343	Domestic	Mekides Haile	F	Villa	4
70	Bole	Gurd Shola	14	478460	994657	2336	Domestic	Ahmed Hashim	M	Villa	8
71	Bole	Gurd Shola	13	477996	994718	2351	Domestic	Ashenafi Tesfaye	M	G+1	7
72	Kirkos	Gurd Shola	2				Domestic	Mekides Tadesse	F	Villa	6
73	Arada	Arada	1	472639	997528	2397	Commercial	Eshetu Abebe	M	G+12+b	variable
74	Arada	Arada	2	472942	996801	2369	Domestic	Meymuna Abidela	F	Villa	9
75	Gulelele	Gulele	3	473289	1000334	2509	Domestic	Yoseph Mengistu	M	Villa	8
76	Arada	Gulele	7	475132	998378	2436	Domestic	Etetu Bishaw	F	Villa	4
77	Arada	Gulele	7	474783	998788	2465	Domestic	Sahle Zewdie	M	Villa	25
78	Gulelele	Gulele	2	474017	999680	2475	Institutional	Lemma Yimer	M	G+6	variable

79	Gulelele	Gulele	1	473930	1004718	2984	PF	Ayichew Girma	M	Villa	12
80	Gulelele	Gulele	2	473875	1001735	2586	Domestic	Haymanot Birhanu	M	Villa	18
81	Gulelele	Gulele	1	473071	1003171	2707	Domestic	Yemane Mihretu	M	Villa	5
82	Yeka	Gulele	2	477085	1001288	2603	Domestic	Afework Dereje	M	Villa	13
83	Yeka	Gulele	3	475234	1000871	2529	Domestic	Teshome Mamo	M	Villa	4
84	Yeka	Gulele	3	475878	999199	2460	Domestic	Zewditu Abebe	F	Villa	13
85	Yeka	Gulele	1	475192	1001359	2538	Domestic	Aragie Asmare	M	G+1	15
86	Yeka	Gulele	3	476334	999593	2485	Domestic	Ejigayehu Asbu	F	Villa	8
87	Gulelele	Gulele	6	472723	1002011	2624	Commercial	Aliyou Seid	M	Villa	9
88	Yeka	Gurd Shola	10	477816	1001192	2611	PF	Almaz Alemu	F	Villa	5
89	Yeka	Gulele	1	476144	1002188	2627	YC(s)	Tesfaye Zeleke	M	Villa	15
90	Yeka	Megenagna	7	476290	997850	2404	Institutional	Tezera Moges	F	G+4	variable
91	Yeka	Megenagna	5	477018	998121	2474	Domestic	Wederyelsh Yoseph	F	Villa	10
92	Yeka	Megenagna	7	475856	998065	2398	Domestic	Bekele Gurumu	M	Villa	17
93	Yeka	Megenagna	5	475920	998669	2428	Institutional	Haymanot Akalu	M	G+3	variable
94	Yeka	Megenagna	4	475461	998931	2424	Domestic	Muluemebet Tafesse	F	Villa	17
95	Bole	Megenagna	12	476311	989989	2278	Domestic	Baysa Getu	M	G+2+b	7
96	Bole	Megenagna	1	474913	992392	2306	commercial	Shewalem Girma	M	Villa	variable
97	Bole	Megenagna	1	475133	992994	2306	Domestic	Semira Ayalew	F	Villa	10
98	Bole	Megenagna	12	475841	989141	2211	Domestic	Workinesh Abate	F	Villa	6
99	Bole	Megenagna	2	475472	993704	2303	Domestic	Hikma Getu	F	Villa	5

100	Bole	Megenagna	2	475477	993090	2337	Domestic	Aster Aragie	F	Villa	10
101	Aka. Kal	Akaki	3	476057	979275	2065	Domestic	Siyitie Tirunesh	F	muddy	14
102	Aka. Kal	Akaki	2	476200	978776	2068	Domestic	Almaz Takele	F	Villa	8
103	Aka. Kal	Akaki	3	476338	980195	2075	Domestic	Abenezer Nigussie	M	Villa	14
104	Gulelele	Gulele	8	470493	1001626	2628	Domestic	Akilele G/Michael	M	G+3	3
105	Gulelele	Gulele	7	471009	1002281	2670	Domestic	Alem Gessesse	F	Villa	37
106	Gulelele	Gulele	7	471622	1002067	2669	Domestic*	Bogalech Etissa	F	G+2	variable
107	Gulelele	Gulele	6	473245	1002445	2642	Institutional	Missa Mekunint	F	G+5	variable
108	Gulelele	Gulele	5	472553	1001774	2595	Domestic	Emiyou Tefera	F	Villa	8
109	Gulelele	Gulele	3	473646	1001165	2559	Domestic	Amelework W/Tensay	F	Villa	7
110	Yeka	Megenagna	8	477542	996767	2374	commercial	Senay Zenamarkos	M	G+2	variable
111	Kolfe-Ker	Mekanisa	9	468625	996156	2341	Domestic	Yeshi Tefera	F	Villa	5
112	Kolfe-Ker	Mekanisa	9	468725	995555	2338	Domestic	Abebech Demisie	F	Villa	5
113	Kolfe-Ker	Mekanisa	5	468472	993849	2298	Domestic	Migbar Wondimu	F	Villa	12
114	Lideta	Addis Ketema	2	468643	997792	2423	Domestic	Ejigayehu Worku	F	Villa	15
115	Addis Ketema	Addis Ketema	3	469089	997675	2419	Domestic	Tekola Abebe	M	Villa	4
116	Add.Ket	Addis Ketema	3	469396	997525	2429	Domestic	Azeb Getachew	F	G+3	4
117	Kirkos	Nefas Silk	3	473527	993334	2340	Domestic	Enanu Zeleul	F	Villa	38
118	Kirkos	Nefas Silk	3	474038	993510	2338	Domestic	Meskel Flower	F	G+4	7
119	Kirkos	Nefas Silk	2	474296	993663	2337	Institutional	Beletu Assefa	F	G+3	variable
120	Kirkos	Nefas Silk	2	474956	993753	2367	Institutional	Birhanu Atomsa	M	G+4	variable

121	Kirkos	Nefas Silk	2	474852	994285	2403	Domestic	Elsabeth Beshah	F	G+4	5
122	Kirkos	Nefas Silk	1	474798	994767	2342	Domestic	Zenebech Wudineh	F	Villa	21
123	Kirkos	Megenagna	1	474675	995751	2347	Domestic	Workinesh Kifle	F	Villa	14
124	Yeka	Arada	6	475384	997489	2402	Domestic	Bethelhem Tilahun	F	Villa	6
125	Yeka	Arada	6	474767	997218	2390	Domestic	Addis Sisay	M	Villa	9
126	Arada	Gulele	7	475095	997767	2409	Domestic	Andargachew Demissie	M	Villa	20
127	Arada	Arada	8	474676	997631	2394	Domestic	Aynalem Bezabih	F	Villa	3
128	Arada	Arada	8	474352	997233	2411	Institutional	Meseret Tadesse	F	Villa	variable
129	Kirkos	Arada	8	474823	996636	2378	Domestic	Chanyalew Tegegn	M	Villa	3
130	Kirkos	Arada	8	474172	997126	2410	Domestic	G/Mariam Yohannis	M	Villa	5
131	Kirkos	Nefas Silk	2	474331	994550	2369	Domestic	Hussien Fereja	M	Villa	7
132	Kirkos	Nefas Silk	9	473571	995528	2362	Domestic	Eartro Abo	M	Villa	5
133	Kirkos	Nefas Silk	9	474063	994793	2360	Domestic	Solomon Demissie	M	Villa	18
134	Kirkos	Nefas Silk	2	474414	994970	2392	Institutional	Mehbuba Adem	F	G+6	variable
135	Kirkos	Nefas Silk	1	474648	995405	2345	Institutional	Beletech Gobere	F	Villa	variable
136	Aka.Kal	Akaki	8	475348	983273	2172	Domestic	Tena Aklile	F	G+4	3
137	Aka.Kal	Akaki	4	474551	982445		industrial	Birhanu Gebre	M	Villa	4
138	Aka.Kal	Akaki	4	473337	982237	2145	Domestic*	Mebrat Haile	F	Villa	7
139	Aka.Kal	Akaki	4	474405	981423	2065	Domestic	Zinetu Hassen	F	G+4	6
140	Kolfe- Ker	Addis Ketema	9	468177	996984	2361	Institutional	Afework Gorfu	M	Villa	variable
141	Bole	Megenagna	3	476959	995353	2354	Domestic*	Enguday Munye	F	Villa	variable

142	Bole	Megenagna	5	477670	996066	2362	Institutional	Yabsira Baye	F	Villa	variable
143	Bole	Gurd Shola	13	478015	994714	2351	Domestic	Tsehay Gobena	F	G+4	variable
144	Bole	Megenagna	5	477181	995675	2337	Domestic*	Eden Atrsaw	F	Villa	19
145	Add.Ket	Addis Ketema	4	469124	998687	2472	Institutional	Gezali Mohammed	M	G+4+b	variable
146	Gulelele	Addis Ketema	9	470084	999671	2511	Domestic	Jemila Hussien	F	Villa	10
147	Addis Ket	Addis Ketema	5	470420	999268	2496	Bonno	Maritu Tilahun	F	Villa	5
148	Addis Ket	Addis Ketema	7	470480	998662	2477	Domestic	Anguach Mohammed	F	Villa	5
149	Addis Ket	Addis Ketema	5	469575	999315	2482	Commercial	Getahun Tamene	M	G+1	variable
150	Addis Ket	Addis Ketema	9	469505	998913	2491	Domestic	Amarech G/Mariam	F	Villa	17
151	Gulelele	Arada	2	471618	998845	2450	Domestic	Sadia Ibrahim	F	Villa	8
152	Addis Ket	Addis Ketema	7	471311	998620	2456	Institutional	Nuri Abdusiraj	M	Villa	variable
153	Addis Ket	Arada	8	470795	998388	2464	Commercial	Aynalem Yemane	M	Villa	variable
154	Addis Ket	Arada	2	470480	997788	2481	Domestic	Gizachew Teklu	M	Villa	14
155	Addis Ket	Addis Ketema	8	470433	998077	2467	Domestic	Sindu Nigussie	F	Villa	3
156	Addis Ket	Arada	1	471328	997696	2443	Domestic*	Redwan Mohammed	M	Villa	variable
157	Arada	Arada	9	473688	998216	2439	Domestic	Shibirua G/Kidan	F	G+2	2
158	Arada	Arada	1	472368	998045	2428	Institutional	Kiflu Aklilu	M	G+4	variable
159	Aka.Kal	Akaki	8	476314	982689	2145	Domestic	Tirngo Degefa	F	Villa	12
160	Aka.Kal	Akaki	8	476287	983380	2148	Domestic	Aynaddis Mekonnen	F	Villa	9
161	Aka.Kal	Akaki	7	475153	984229	2133	Bonno	Amina Ahmed	F	Villa	9
162	Aka.Kal	Akaki	7	474723	984959	2129	Domestic	Solome Teka	F	G+4	3

163	Aka.Kal	Akaki	5	475679	985602	2173	Commercial	Filmon W/Gebriel	M	Villa	5
164	Aka.Kal	Akaki	5	474581	986910	2185	Bonno	Alemtsehay Yitbarek	F	Villa	
165	Aka.Kal	Akaki	5	473755	986563	2192	Domestic	Tsigeowoina Abreha	F	Villa	10
166	Arada	Gulele	5	472744	999580	2487	Domestic	Demekech Mamaru	F	Villa	3
167	Lideta	Arada	5	471395	997001	2404	Domestic	Mahlet SahleMichael	M	Villa	55
168	Gulelele	Addis Ketema	9	471064	1000103	2516	Commercial	Amelu Redi	F	Villa	8
169	Arada	Gulele	4	471799	1000372	2544	Domestic*	Tigist Alemu	F	Villa	6
170	Arada	Gulele	1	473032	999248	2460	Domestic	Ayele Feeke	M	Villa	16
171	Arada	Gulele	6	473570	999097	2471	Domestic	Mekedash Banti	F	Villa	4
172	Arada	Gulele	4	472304	1000424	2547	Domestic	Wosen Gebreab	M	G+4	5
173	Gulelele	Gulele	4	472721	999957	2510	Domestic	Zewude Awulachew	F	Villa	4
174	Lideta	Arada	9	472458	996458	2366	Commercial	Temesgen Kuyite	M	G+3	variable
175	Lideta	Arada	6	471953	997020	2371	Domestic	Bizunesh Fersha	F	Villa	7
176	Lideta	Arada	6	471614	997633	2422	Domestic	Workyantifu Mulugeta	F	Villa	5
177	Addis Ket	Arada	1	471166	997506	2422	Domestic	Zehara Mustefa	F	Villa	6
178	Lideta	Arada	5	471266	997434	2439	Commercial	Meliha Bediru	F	Villa	variable
179	Lideta	Arada	9	471689	996753	2368	Domestic	Fasika G/Egiziabher	F	Villa	6
180	Lideta	Arada	9	471971	996036	2365	Domestic	Kirubel Moges	M	Villa	12
181	Lideta	Arada	8	471690	996279	2350	Domestic	Helen Michael	F	Villa	7
182	Kirkos	Mekanisa	7	472353	995818	2367	Commercial	Selamawit Tamiru	F	Villa	variable
183	Kirkos	Mekanisa	7	473063	998929	2352	Domestic	Amina Elias	F	Villa	8

184	Kirkos	Mekanisa	7	472838	996336	2368	Domestic	Almaz Manbegrot	F	Villa	21
185	Kirkos	Mekanisa	10	472309	995495	2381	Domestic	Adanech Yeserah	F	G+4	5
186	Kirkos	Mekanisa	7	472948	995707	2365	Domestic	Mahlet Kiflu	F	Villa	8
187	Kirkos	Mekanisa	6	471976	995525	2347	Institutional	Teshome Dissasa	M	Villa	variable
188	Kirkos	Mekanisa	6	471827	995141	2329	Domestic	Zerihun Kinfe	M	Villa	5
189	Kirkos	Mekanisa	11	472657	995214	2334	Commercial	Tigist Ambaw	F	G+3	variable
190	Kirkos	Mekanisa	10	473040	995438	2371	Domestic	Hirut Temesgen	F	G+1	6
191	Addis Ket	Addis Ketema	9	469648	998759	2487	Domestic	Tilahun Birhanu	M	Villa	7
192	Addis Ket	Addis Ketema	5	468751	999648	2469	Commercial	Abebe Mengistu	M	Villa	12
193	Addis Ket	Addis Ketema	10	468415	999545	2520	Domestic	Fantu Berawork	F	Villa	7
194	Addis Ket	Addis Ketema	10	468797	999108	2456	Domestic	Ayelech Melka	F	G+1	16
195	Addis Ket	Addis Ketema	10	468709	998733	2448	Domestic	Meron Teka	F	Villa	8
196	Addis Ket	Addis Ketema	4	469224	998865	2445	Domestic	Abate Chekol	M	Villa	11
197	Addis Ket	Addis Ketema	5	469378	999924	2518	Domestic	Habitamu Fekadu	M	Villa	5
198	Gulelele	Addis Ketema	8	469304	1000456	2542	Commercial	Birhanu Shibabaw	M	Villa	variable
199	Nefas SL	Nefas Silk	1	470024	988928	2241	Commercial	Varnero PLC	M	G+4	variable
200	Nefas SL	Nefas Silk	12	470814	988356	2232	Commercial	Zebenay Shiferaw	F	G+2+b	variable
201	Nefas SL	Nefas Silk	1	470235	987375	2270	Domestic	Aster Mengistu	F	G+4	5
202	Nefas SL	Nefas Silk	1	470661	985815	2236	Institutional	Ergana Ebisso	M	G+4	variable
203	Kolfe- Ker	Addis Ketema	10	467139	997189	2371	Domestic	Lemma Ferrsha	M	Villa	30
204	Kolfe- Ker	Addis Ketema	10	467754	998274	2410	Domestic	Mustefa Mohammed	M	Villa	9

205	Kolfe- Ker	Addis Ketema	11	467747	999199	2446	Domestic	Shitaye Nuru	M	Villa	8
206	Kolfe- Ker	Addis Ketema	12	468088	999364	2484	Commercial	Ahmed Sani	M	G+b	6
207	Kolfe- Ker	Addis Ketema	12	468150	998410	2433	Domestic	Sadia Jemal	F	Villa	9
208	Kolfe- Ker	Addis Ketema	11	467620	998372	2413	Domestic	Zulfa Ahmed	F	Villa	8
209	Addis Ket	Addis Ketema	10	468277	999462	2485	Commercial	Wondwosen Seifu	M	Villa	variable
210	Kolfe- Ker	Addis Ketema	13	468019	1000233	2509	Domestic	Emebet Assefa	F	Villa	8
211	Gulele	Gulele	9	470597	1001267	2602	Domestic	Henock Dessie	M	Villa	10
212	Gulele	Addis Ketema	10	469814	1001797	2597	Domestic	Tigist Adane	F	Villa	22
213	Gulele	Addis Ketema	10	469270	1001984	2606	Domestic*	Meseret Getachew	F	Villa	8
214	Gulele	Addis Ketema	10	468952	1002276	2602	Domestic	Assefa Tadesse	M	G+4+b	20
215	Gulele	Addis Ketema	10	468569	1001162	2566	Domestic	Tewodros Asfaw	M	Villa	3
216	Addis Ket	Addis Ketema	10	468403	1000809	2546	Domestic	Addisalem Demissie	F	Villa	12
217	Kolfe- Ker	Addis Ketema	13	468114	1000436	2552	Domestic*	Koreb Tereda	M	Villa	9
218	Arada	Gulele	7	474512	998453	2425	Commercial	Ansuar Jemal	M	Villa	10
219	Nefas SL	Mekanisa	1	468180	990097		Domestic*	Adugna Habitie	M	G+1	variable
220	Nefas SL	Mekanisa	2	469186	991087	2237	Institutional	Dr. Nigatu Zeleke	M	G+3	variable
221	Nefas SL	Mekanisa	1	465882	990066	2257	Domestic	Selamawit Tadesse	F	G+4	2
222	Nefas SL	Mekanisa	2	469603	991753	2259	Commercial	Elias Ahmed	M	Villa	6
223	Nefas SL	Mekanisa	2	469184	992185	2286	Institutional	Let Col. Fekadu Tadesse	M	Villa	variable
224	Aka Kal	Akaki	7	474874	987949		Domestic	Mikias kebede	M	G+4	variable

225	Nefas SL	Nefas Silk	9	474489	989872	2231	Domestic	Wagaye Amere	F	G+2+b	5
226	Aka Kal	Akaki	6	474614	988955	2207	Domestic	Birhane Birara	M	Villa	32
227	Kolfe- Ker	Mekanisa	2	467687	992310	2292	Commercial	Kelem Bekele	F	Villa	10
228	Nefas SL	Mekanisa	1	467349	991251	2298	Bonno	Fentanesh Alemu	F	Villa	5
229	Kolfe- Ker	Mekanisa	2	466902	991827	2335	Domestic *	Masresha Mesele	F	Villa	variable
230	Nefas SL	Mekanisa	3	466668	992279	2311	Domestic	Anwar AbaMecha	M	Villa	5
231	Kolfe- Ker	Mekanisa	1	466520	992432	2298	Institutional	Hussien Abdu	M	Villa	variable
232	Kolfe- Ker	Mekanisa	4	466266	992766	2331	vendor	Brdilu Alemu	M	Villa	variable
233	Kolfe- Ker	Mekanisa	1	466982	992706	2313	Domestic	Gebrekirstos Lutu	M	Villa	9
234	Kolfe- Ker	Mekanisa	6	468201	994501	2317	Domestic	Zenebech Worku	F	Villa	15
235	Kolfe- Ker	Mekanisa	6	467988	995051	2364	Domestic	Mulu Dendir	F	G+4	5
236	Kolfe- Ker	Mekanisa	5	467775	993941	2313	Domestic *	Kassahun Deneke	M	Villa	variable
237	Kolfe- Ker	Mekanisa	5	467436	993188	2316	Domestic	Woinitu Eshetu	F	Villa	13
238	Kolfe- Ker	Mekanisa	1	467920	992768	2311	Domestic	Aynalem Demissie	F	Villa	3
239	Kolfe- Ker	Addis Ketema	7	466130	995120	2501	Institutional	Samuel Anteneh	M	G+4	variable
240	Kolfe- Ker	Addis Ketema	11	466474	996226	2431	Domestic	Lieila Nur	F	Villa	9
241	Kolfe- Ker	Addis Ketema	11	466757	999423	2447	Domestic	Yoseph W/Mariam	M	Villa	5
242	Kolfe- Ker	Addis Ketema	14	466288	999559	2438	Domestic	Birznesh Timerga	F	Villa	4
243	Kolfe- Ker	Addis Ketema	8	466179	997010	2420	Domestic	Adanech Tulu	F	Villa	33
244	Kolfe- Ker	Addis Ketema	7	464809	995167	2451	Commercial	Juhar Sherif	M	Villa	6
245	Kolfe- Ker	Addis Ketema	8	467273	996549	2372	Domestic	Kedir Jemal	M	Villa	11

246	Kolfe- Ker	Addis Ketema	6	466504	995768	2423	Domestic	Aregawi G/Michael	M	Villa	4
247	Arada	Gulele	4	471470	1000116	2525	Commercial	Mustefa Dagnachew	M	Villa	variable
248	Kolfe- Ker	Addis Ketema	13	467011	999890	2501	Domestic	Birhanu Sifir	M	Villa	6
249	Kolfe- Ker	Addis Ketema	13	466644	1000112		Domestic	Wegayehu Yeshitila	F	G+4	4
250	Kolfe- Ker	Mekanisa	3				industrial	Yibelu Workineh	M	factory	variable
251	Kolfe- Ker	Mekanisa	2	464522	992040	2332	vendor	Zinash Belete	F	Villa	5
252	Kolfe- Ker	Mekanisa	2	469214	991417	2325	Domestic	Aster Mergia	F	G+4	3
253	Kolfe- Ker	Mekanisa	3	463162	992553	2451	Domestic	Yeshiwork Lealem	F	G+2	4
254	Kolfe- Ker	Mekanisa	3	463721	994092	2454	Domestic*	Shemsu Mohammed	M	Villa	variable
255	Kolfe- Ker	Mekanisa	4	464119	995026	2483	Domestic	Genet Birhanu	F	G+2	4
256	Kolfe- Ker	Addis Ketema	14	466052	1001145	2539	Domestic	Abebe Andargie	M	G+4	3
257	Kolfe- Ker	Mekanisa	15	468081	1001051	2515	industrial	Elias Hailu	M	G+3+b	variable
258	Kolfe- Ker	Addis Ketema	13	467381	1001121	2549	industrial	Yohannis George	M	G+2	variable
259	Kolfe- Ker	Addis Ketema	15	466202	1002257	2600	Institutional	Desssie Adamu	M	Villa	variable
260	Kolfe- Ker	Addis Ketema	14	466278	1001647	2573	Institutional	Hiwot Yassin	F	Villa	variable
261	Kolfe- Ker	Addis Ketema	13	467046	1001097	2536	Domestic	Beletu Gebre	F	Villa	17
262	Arada	Arada		473227	997893	2388	Domestic	Zifan Ali	F	G+4	4
263	Kirkos	Megenagna	2				Domestic	Tamir Kinfu	F	Villa	6
264	Kirkos	Nefas Silk	1	475046	995640	2346	Domestic	Nigatua Hunde	F	Villa	7
265	Bole	Megenagna	3				Domestic	Geremew Debisaa	M	G+1	6
266	Bole	Megenagna	3	477195.17	993758.7		Domestic*	Henock Tsehay	M	Villa	variable

267	Bole	Megenagna	3	8.99251	38.791461		Commercial	Hailemeskel Bekele	M	G+3	variable
269	Lideta	Arada	7					Radia Mohammed	F	G+4	5
270	Kirkos	Arada	1				Domestic	Tamir Kinfu	F	Villa	6
271	Bole	Megenagna	4	9.012	38.777629		Domestic	Asegedech Kebede	F	Villa	2
272	Yeka	Megenagna	5	477018	998121	2474	Domestic	woderyelesh Yoseph	F	Villa	10
272	Kolfe- Ker	Mekanisa	3	464063	994349	2548	Bonno	Rehima Kemal	F	Villa	5
272	Kolfe- Ker	Addis Ketema	13	466916	999639	2466	**Bonno**	Munteha Hussien	F	Villa	5

Note: Addis. Ket = Addis Ketema, Aka Kal= Akaki Kality; and Nefas SL= Nefas Silk Lafto

Appendix A- 5- I: English version of the interview questions for the water customers

A1. General profile of the responding water customer

Interviewer Name____

Sex of the respondent: Male ______ Female_______

Respondent's residence: Sub City ______________________Wereda ______________

House number _____________water supplying branch ______________________________

Date of interview ________________________Respondent's responsibility _____________

2. Specific interview questions for interviewing water customers

1. How do you evaluate the service provided by AAWSA in terms of water quantity, water quality, proximity, incoming water pressure, service quality?
2. How do you rate your satisfaction level?

Excellent, very good, good, poor, very poor, other (please specify)

3. In a given months' time, what is the frequency of water supply interruption/failure?

Never every hour every day every week every month other (specify)

4. Once water supply is interrupted, for how long water remain unavailable during each interruption?

Never _______ hours _____days ____weeks other /specify

5. In the past one year, what was the worst case of water supply failure /interruption related problem and how long water was unavailable

________hours_______ days ______months, ________ weeks other (please specify)

6. How do you evaluate the quality of water with respective the following physical water quality parameters? Good ______ Satisfactory _________ Poor _________
7. Based on your observation
   a. Which of the colors listed below best describe the color of your water supply? colorless, blue, green, black, dark brown, brown, red, orange, yellow, milky white, cloudy other (please specify)
   b. How do you rate the temperature of this water?

Cold ____ warm ______ normal/acceptable _____ hot ______

   c. Which odor below resembles the odor of the water you are supplied with?

Sulfur/rotten egg, moldy, musty, earthy, grassy, fishy, other (please specify)

d. How do you rate the taste of your water?

Tasteless, metallic taste, chlorine taste, Medicine/chemical taste, other (please specify)

e. How do see the amount of suspended matter in your water supply?

Crystal clear, clear, slightly turbid, highly turbid

8. Are these problems

i. Existent in the past or are they a recent phenomenon

ii. Continuous since long time?

9.What do you use this water for?

a. without any treatment process

Bathing cooling drinking cleaning house animals

Gardening launder other (please specify

b. What measure do you take to ameliorate this water and make fit for drinking?

10. What is the monthly water consumption for the whole family in units of liter?

11. If conditions are fulfilled and allow do you want to save water or use much more water than this volume?

12. If you the interest to get improved water quantity, water quality, enhanced water pressure and better service

a. How will your water use pattern change with water tariff changes?

13. If the current water price is going to increase by 5%, 10%, 15%, and 20% 25% or 30%, what price per month can you afford (are you willing) to pay have a better water supply service?

In your opinion, at each stage of the entire supply network, what things should AAWSA improve to enhance its service and how do you think water quantity, water quality, water pressure and water price should be corrected or managed?

Appendix A-5-II: The Amharic version of interview questions prepared for water customers

የዉኃ አጠቃቀም መጠየቅ ለዉኃ ተጠቃሚዎ / ደንበኞች

1) አጠቃላይ ሁኔታወች

ቃለ ምልልሱን ያካሄደዉ ጠያቂ ሥም ____

የደነንበኛዉ አደራሻ ክ/ከተማ ____

ቀበሌ__________የቤት ቁጥር______________________ የቤቱ ዓይነት ______________________

የቤቱ መገኛ አመለካቾች ____

የቤት ባለቤትነት ሁኔታ ____

ጥያቄና መልሱ የተካሄደበት ቀን ____________________ሠዓት ________________

የቤተሰብ በዛት ________________የመልሠጭዉ ጾታ ወንድ ______ ሴት; ______

ለቃለ መጠይቁ የተዘጋጁ ጥያቄዎች

1. የአዲሰስ አበባበ ዉኅና ፍሳሽ ባለሥልጣንን አገልግሎት አሰጣጥ ከሚያቀርበው የዉኃ መጠን ፤የዉኃ ጥራት ፣ የዉኃ መገኛዉ ከመኖሪያ ቦታዎ ዉጭ ከሆነ ያለው እርቀት ፣ የዉኃ ግፊት/ የመፍሰስ ጉለበት እንጻር እንዴት ይገመግሙታል?
2. በአገልግሎቱ የሚሰማዎትን የርካታ መጠን ምን ደረጃ ይሠጡታል?

እጅግ በጣም ጥሩ ________ ዝቅተኛ ________

በጣም ጥሩ ________ በጣም ዝቅተኛ ________

ጥሩ መካከለኛ ________ ሌላ ከለ ይገለፅ ________

3. የዉኃ አቅርቦቱና ሥርጭቱ በአንድ ወር ጊዜ ዉስጥ ለሥንት ጊዜ ተቋርጦ ይቆያል?

ምንም አይቋረጥም __________

በየሠዓቱ __________

በየቀኑ __________

በየሳምንቱ __________

ሌላ ካለ ይግለጹ ____________________

4. ዉኃ አንድ ጊዜ ሲቋረጥ ለምን ያህል ጊዜ ተቋርጦ ይቆያል?

ዉኃ አንድ ጊዜ ሲቋረጥ ለምን ያህል ጊዜ ተቋርጦ ይቆያል?

ምንም አይቋረጥም ______ ለ ________ ቀናት

ለ _______ ደቂቃ ለ ________ሳምንታት

ለ ________ሠዓት ሌላ ካለ ይገለጽ _______

4. ባለፈዉ ዓመት,
   a. ከፍተኛዉ የገጠማችሁ የዉኃ ችግር ምንድን ነበር? ____________________
   b. ለምን ያህል ጊዜስ ያለ ዉኃ አቅርቦትና ስርጭት ቆያችሁ? ___________________
5. የአዲስ አበባ ዉኃና ፈሰሽ ባለስለጣን ባለስልጣን የሚያቀርብላችሁን የዉኃ ጥራት ከሚከተሉት ፊዚካዊ መለኪያዎች አንጻር እንዴት ደረጃ ትሠጡታለችሁ?

   ጥሩ _______ መካከለኛ _______ የማያረካ ________
6. በዘሁ መሠረት
   a. የዉኃዉ ቀለም ከሚከተሉት የትኛውን ይመሥላል? _____________________________

ቀለም አልባ፣ ሠማያዊ፣ አረንጓዴ፣ጥቁር፣ ጥቁር ቡናማ፣ ቀይ፣ብርቱካናማ፣ቢጫ፣ ተትማ ነጭ፣ ሌላ ካለ ይጠቀስ

   b. የዉኃን መጠነ ሙቀት ከየትኛዉ ይመደባል? ቀዝቃዛ መደበኛ/ የተለመደ ለብያለ ሞቃት
   c. የዉኃዉ ጣዕምስ?

ጨዋማ ___________ ጣዕም የለሽ __________

የብረት ጣዕም __________ የክሎሪን ጣዕም__________

የመደሀኒት/ የኬሚካለ ጣዕም _______ ሌላ ካለ ይገለጽ _______________

   d. የዉኃዉ ሽታ ከየትኛዉ ቀራረባል?

ደኝ/ የበሰበሰ አንቁላል _______ የሽከላ ሽታ ____________

እምክእምክ የሚል __________ የአፈር ሽታ __________

የሳር ሽታ __________ የዓሣ ሽታ __________

ሌላ ካለ ይገለጽ ________

   e. በዉኃዉ ዉስጥ የሚገኙ ተንሳፋፊ ጠጣር ነገሮቸ/የውኃዉ ድፍርሰነት

ኩልል ብሎ የጠራ _________ በጣም ድፍርሥ __________

የጠራ ___________ በመጠኑ የደፈረሠ __________

ሌላ ካለ ይገለጽ ________________

7. እነዚህ ችግሮች

   a. ቀደም ሲልም ነበሩ ወይስ የቅርብ ጊዜ ክስተቶች ናቸዉ? ______________________________

   b. ችግሮቹስ ቀጣይነት አላቸዉ ወይስ የአነደ/አጭር ጊዜ ክስተቶች ናቸው? _________________

8. ይህን ውኃ ያለምንም ዓይነት ሂደት ለምን ለምን ተግባራት ትጠቀሙበታላችሁ?

ለእጥበት፣ ለምግብ ማብሰል፣ ለመጠጥ፣ ቤት ለማጠብ፣ ቤተ እንሰሳትን ለማጠጣት፣ለላውንደሪ እጥበት፣

ሌላካለ ይገለጽ _____________________________________

9. ይህን ዉኃ ለመጠጥ ለመጠቀምና ጥራቱን ለማሻሻል ምንምን መግትሄ ትሠጣላችሁ?

____

10. በአንድ ወር ጊዜ ዉስጥ ምን ያህል ሊትር ዉኃ ቤተሰባቸሁ ይጠቀማል?

____

11. ሁኔታዎች ቢመቻቹ/ቢፈቅዱ ዉኃን ለመቆጠብ/ ከዚህ የበለጠ መጠን ያለዉ ዉኃ መጠቀም ይፈልጋሉ?

____

12. አሁን ያለዉ የዉኃ አቅርቦት መጠንና ጥራት፣የዉሃዉ መገኛዉ ከመኖሪዎ ዉጭ ከሆነ ያለዉ እርቀት፣ የዉኃዉ ግፊት ሁኔታ ና የአገልግሎት አሠጣጡ እንዲሻሻል ፍላጎት አለዎት?

አዎ____________ የለ –ም________________ ___________________

   a. አሁን ያለዉ የዉኃ ታሪፍ ቢሻሻል የዉኃ አጠቃቀመዎ እንዴት ይለወጣል/ይቀየራል?

____

____

   b. ለተሻለ የዉኃ አቅርቦትና ስርጭት አገልግሎት **አሁን** ያለዉ ታሪፍ በ 5% 10% 15% 20% 25% 30% ቢጨመር በየዎሩ ምን ያህል የመክፈል አቅም/ፍላጎት አለዎት?

____

13. በአርስዎ እስተያየት የአዲስ አበባ ዉኃና ፍሳሽ ባለስልጣን የዉኃ አቅርቦቱንና ስርጭቱን ለማሻሻል ከዉሃዉ መገኛ አንስቶ እስከ ተጠቃሚዉ ድረስ በየ ዋናዋና ከፍሎች ምንምን ጉዳዮችን ማሻሻል አለበት ይላሉ?

አሁን ባለዉ የዉሃ አቅርቦትና ሰርጭት ስርዓት ዉሰጥ የሚሰራጨዉን የዉኃ መጠን ፣ የዉሃዉን ጥራት፣የዉሃዉ ግፊት ና የአገልግሎቱን ጥራት እንዴት ማሻሻል ይቻለል ይላሉ?

Appendix A-6-I: English version of the interview questions for branch Professionals

General questions about the profile of the professional and the branch s/he is working

Interviewer Name______________________ Name of the institution ______________________

Location of the institution: ________Date______ Respondent: Male: ____ Female: ________

Responsibility of the respondent: ____

Specific questions to be asked during the interview

1. What are the main components of Addis Ababa city water supply system?
2. What are the major technical, institutional, and financial challenges that AAWSA is facing to meet Addis Ababa water demand? Why?
3. In each Addis Ababa City's water supply system components mentioned above,
    a. What are the major problems and what are their known and possible causes?
    b. What do you think are their quantitative and /or qualitative effects?
    c. How do these problems affect water quantity, water quality, pressure and service quality?
4. Which problems are user related and which others are utility related and how do these problems affect water quantity, water quality, pressure and Service quality?
5. To solve each problem raised earlier,
    d. What has been done so far (earlier)? Describe the success story and quantify your output in monetary, water quantity, and water quality and water pressure and service level improvement terms.
    e. What is being done? Quantify each output in relation to water quantity, water quality, pressure, service level
    f. What is planned to solve the problems? Quantify each output in relation to water quantity, water quality, pressure, service level
    g. What more should be done (what do you suggest further for the utility to do at each component and quantify the possible outputs of each measure in relation to water quantity, water quality, pressure, service level
6. What are the policies and principles that AAWSA is following when allocating for water for prioritizing users at times of supply deficit (emergency and shortage)?
7. How do you rate the service provided by AAWSA with respective to each main component?

Appendix A-6-II: Amharic version of the interview questions for branch professionals

ለመሥክ ጥናት የቀረቡ ጥያቄወች

A1. ለውኃ በአቅራቢዉ ባለሥልጣን መስሪያ ቤት የሚቀረቡ ጥያቄወች

የጠያቂው ሥም__________________

የመልስ ሠጭዉ ተቋም ሥም ___________________________

ተቋሙ የሚገኝበት ቦታ ___________________________

ተቋሙ ያለበት አካባቢ መጠሪያ______________________________

ጥያቄና መልሱ የተካሄደበት ቀን________________________________

የመልስ ሰጭዉ ጾታ: ወንድ: ______   ሴት: ____________መልስ ሠጭው በተቋሙ ያለዉ ኀላፊነት:

____

A2. ለቃለ መጠይቁ የተዘጋጁ ጥያቄዎች

1. የአዲስ አበባ የዉሃ አቅርቦትና ስርጭት ሥርዓት ዋናዋና ክፍሎች ምንምን ናቸዉ;
2. የአዲስ አበባ ዉሃና ፍሳሽ ባለስጣንን እያጋጠሙት ያሉት ቴክኒካዊ፣ተቋማዊ ና ኢኮኖሚያዊ ተግዳሮቶች ምንምን ናቸው?
3. ከላይ በተጠቀሱት የአዲስ አበባ የዉሃ ስርጭት ሥርዓት ዋናዋና ክፍሎች,
   h. ለሚስተዋሉት ችግሮች መንስኤዎቻቸዉ ምንድን ናቸዉ/ ለምን የተከሰቱ ይመስለዎታል?
   i. እነዚህ በየክፍሎች የተስተዋሉ ችግሮች ያመጧቸው አይነታዊ ና መጠናዊ ተፅኖዎች ምንምን ናቸው?
   j. እነዚህስ ዉጬቶች/ ተጽኖዎች የሚሰራቸጨዉን የዉሃ መጠን፣ጥራት፣, ዉኃዉ የሚፈስበት የግፊት መጠን, ና የአገልግሎት ደረጃ እንዴት ጉዳት ያደርሱባቸዋል?
4. በሚሰራቸጨዉን የዉሃ መጠን፣ጥራት፣, ዉኃዉ የሚፈስበት የግፊት መጠን, ና የአገልግሎት ደረጃ ላይ ጉዳት/ተጽዕኖ የሚያደርሱትን መንስኤዎች ዉስጥ
   k. ከተጠቃሚዎች ጋር የሚዛመዱት የትኞች ናቸው?
   l. ከባለስልጣኑ ጋር የሚዛመድስ የትኞች ናቸው?
5. እነዚህን በአዲስ አበባ የውሃ እቅርቦትና ስርጭት ስርዓት ዋናዋና ክፍሎች ያሉ ችግሮች/ ተግዳሮቶች ለመቅረፍ,
   a. ከአሁን በፊት ምንምን ሥራዎች/ የመፍትሔ እርምጃዎች ተወስደዋል?
   b. በዚህስ እርምጃ በየ ልየልዩ ክፍሎች ምንምን ዓይነታዊና መጠናዊ ዉጤቶች ተመዝግበዋል?

ስኬቶቹ ከገነዘብ ቁጠባ፣ ከዉሃ መጠን ቁጠባ//ምርት መጨመር፣ ከዉሃ የመዉረድ ግፊት ሁነቴ መሻሻል አኳያ፣ ከአገልግሎት ጥራት መሻሻሽል አንጻር በቁጥር እንዴት ይገለጻሉ?

c. በአሁኑ ሰዓትስ ባለሥልጣን መስሪያ ቤቱ ችግሮችን ለመፍታት ምንምን የመፍትሄ እርምጃዎችን/አማራጮችን እየወሰደ ነዉ?

ስኬቶቹ ከገነዘብ ቁጠባ፣ ከዉሃ መጠን ቁጠባ//ምርት መጨመር፣ ከዉሃ የመዉረድ ግፊት ሁነቴ መሻሻል አኳያ፣ ከአገልግሎት ጥራት መሻሻል አንጻር በቁጥር እንዴት ይገለጻሉ?

d. ለወደፊቱ ባለሥልጣን መስሪያ ቤቱ ችግሮችን ለመፍታት ምንምን የመፍትሄ እርምጃዎችን/አማራጮችን ለመዉሰድ አቅዷል?

በዚህ አቅድ መሠረት ይገኛሉ ተብለዉ የሚገመቱት ዉጤቶች ከገነዘብ ቁጠባ ከዉሃ መጠን ቁጠባ/ምርት መጨመር ከዉሃ የመዉረድ ግፊ ከአገልግሎት ጥራት መሻሻል አንጻር በቁጥር እንዴት ይገለጻሉ?

e. ከዚህስ ባሻገር ምንምን ተጨማሪ የመፍትሄ እርምጃዎች ቢዎሰዱ የሚሰራጨዉን የዉኃ መጠን ጥራት የሚወረድዉን የዉኃ ግፊት የአለግሎቱ ጥራት በምን ያህል መጠን ያሻሽለዋል?

6. ባለ ሥልጣን መሥሪያ ቤቱ የዉሃ እጥረት በሚያጋጥምበት ሰዓት ዉኃን በቅደምተከተል ለማሠራጨት የሚከተላቸዉ ፖሊሲዎቸና መርሆዎች አሉት ወይ?

ካሉትስ ፖሊሲዎቹና መረሆዎቹ ምንምን ይላሉ?

7. ከላይ ከተዘረዘሩት የአዲስ አበባ የዉኅ ሥርጭት ሥርዓት ዋናዋና ክፍሎች አንጻር የባለሰለጠኑን መሥሪያ ቤት የአገልገሎት አጠባጠ ደረጃ እንዴት ይገመግሙታል? የግምገማዎን ዉጤት

a. በፐርሰንት እንዴት ይገልጹታል? ______________________________%

b. በቃላዊ ደረጃዎች (እጅግ በጣም ጥሩ፣ በጣም ጥሩ ፣ ጥሩ መካከለኛ ፣ ዝቅተኛ ፣ በጣመ ዝቅተኛ) እንዴት ይገልጹታል?

Appendix A-7: Branch professionals who participated in the interview

Branch	Date	Name	sex	Responsibility	Telephone
Megenagna	29/4/2016	Medina Yimam	F	Engineer	913948120
Megenagna	29/4/2016	Tamirat W/Senbet	M	Water supervisor	912159034
Megenagna	29/4/2016	Henok Manaye	M	Water leakage control case team leader	91791049
GurdShola	29/4/2016	Mohammed Kasew	M	Branch Manager	927729819
GurdShola	29/4/2016	Genene Regassa	M	Water Customer service process owner	929040533
GurdShola	30/4/2016	Ermias Shume	M	Engineer II	910417159
Akaki	15/4/2016	Belete Dinku	M	WCS sub process owner	913601254
Akaki	15/4/2016	Asfaw Meskele	M	Engineer I	
Gulele	42679	Kifle Abebe	M	Water customer service leader (dep’t head)	
Gulele	42679	Saleamlak Muluken	M	Distribution and line Installation case manager	973409721
Gulele		Kifle Abebe		Acting Branch Manager	
Arada	13/5/2016	Yenehareg Bekele	F	Water customer service sub process owner	913067780
Arada	13/5/2016	Debere Tujo	M	Arada Branch Manager	911407481

Appendix B: Raw data and assumptions used for analysis

Appendix B-1: Water infrastructure distribution among branches in 2010

Branch	Area (km^2)	population	Density (km^2)	Customer No.	Pipe length	Valve	Fire hydrant
Arada	15.25	480,162	15.25	45,123	285	1049	42
Gulele	44.45	480,162	44.45	49,865	435	1148	5
Addis Ketema	44.69	480,162	44.69	50,675	550	1256	25
Nwfas Silk	45.75	480,162	45.75	57,930	510	1426	13
Megenagna	54.94	480,162	54.94	29,744	375	1506	21
Mekanisa	63.94	480,162	63.94	67,928	415	810	29
Akaki	121.23	480,162	121.23	23,387	395	732	18
Gurd Sholla	129.21	480,162	129.21	64,655	610	1483	11
Total	**519.46**	**3,841,296**	**519.46**	**389,307**	**3,575**	**9,410**	**164**

Appendix B-2: Projected system input volume, 2015-2020 (m^3/d)

Year	2015	2016	2017	2018	2019	2020
Existing capacity	373000	373000	373000	373000	373000	373000
Akaki WF02 deep wells	0	70,000	70,000	70,000	70,000	70,000
Akaki WF03 deep wells	0	0	70,000	70,000	70,000	70,000
Legedadi Deep wells	0	40,000	40,000	40,000	40,000	40,000
Legedadi Treatment Plant expansion	0	30,000	30,000	30,000	30,000	30,000
Gerbi Water supply scheme	0	0	38,000	76,000	76,000	76,000
System input volume(m^3/d)	373,000	513,000	621,000	659,000	659,000	659,000
system input volume (m^3/year)	136,145,000	187,245,000	226,665,000	240,535,000	240,535,000	240,535,000

Appendix B-3: Projected population for the period 1994- 2030 using miscellaneous scenarios

Year	AAWSA's three growth scenarios for 1994-2030			CSA projection for 1984-2037	Data used by AAWSA
	Low scenario	medium scenario	High scenario		
1994	2.112737	2.112737	2.112737	2.112737	
1995	2.157	2.157	2.157	2.157	
1996	2.222	2.222	2.222	2.22	2.109
1997	2.287	2.286	2.291	2.286	2.15
1998	2.354	2.354	2.362	2.354	2.19
1999	2.423	2.424	2.437	2.424	2.23
2000	2.493	2.495	2.516	2.495	2.2738
2001	2.565	2.57	2.599	2.57	2.32
2002	2.638	2.646	2.686	2.646	2.36
2003	2.712	2.725	2.777	2.725	2.4
2004	2.788	2.805	2.87	2.805	2.44
2005	2.864	2.887	2.969	2.887	2.48
2006	2.94	2.973	3.071	2.973	2.52
2007	3.02	3.059	3.177	2.739551	2.57
2008	3.099	3.147	3.288	2.792555	2.967
2009	3.179	3.237	3.401	2.851862	3.051
2010	3.257	3.328	3.517	2.914245	3.136
2011	3.336	3.418	3.637	2.979481	3.224
2012	3.415	3.512	3.759	3.049043	3.314
2013	3.494	3.605	3.885	3.121654	3.407
2014	3.572	3.699	4.012	3.19721	3.503
2015	3.647	3.792	4.143	3.275348	3.601
2016	3.722	3.883	4.274	3.355791	
2017	3.794	3.975	4.408	3.43809	
2018	3.866	4.067	4.544	3.521687	
2019	3.935	4.157	4.68	3.606497	
2020	4.003	4.246	4.817	3.691652	
2021	4.068	4.332	4.952	3.776917	
2022	4.131	4.416	5.088	3.862386	

2023	4.193	4.499	5.225	3.947433
2024	4.254	4.581	5.362	4.03231
2025	4.312	4.664	5.503	4.116545
2026	4.37	4.748	5.645	4.200429
2027	4.426	4.831	5.789	4.283889
2028	4.482	4.914	5.935	4.366851
2029	4.536	5	6.084	4.449715
2030	4.589	5.087	6.236	4.532594