WATER SUPPLY COVERAGE AND QUALITY IN DISTRIBUTION SYSTEM OF SUPPLY (IN CASE OF HAWASSA TOWN)

BY

GUSSA BOLKA

ATHESIS SUBMITTED TO HAWASSA UNIVERSITY DEPARTMENT OF WATER RESOURCE AND IRRIGATION ENGINEERING, SHOOL OF GRADUATE STUDIES OF HAWASSA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER SCIENCE IN WATER RESOURCE ENGINEERING AND MANAGEMENT

MAJOR ADVISOR: Dr. TEWODROS TESFAYE

MAY, 2024

HAWASSA, ETHIOPIA

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HAWASSA UNIVERSITY

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APPROVAL SHEET

Hawassa University Institute of Technology School of Bio system and Environmental Engineering, The Research Entitled "Assessment Of Water Supply Coverage And Quality In Distribution system Of Supply Water A Case Study of Hawassa city, has been approved by the school of Bio system and Environmental Engineering for partial fulfillment of the requirements for the degree of Master's with specialization in Water Resource Engineering and Management.

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EXAMINER'SAPPROVALSHEET

We the undersigned members of the Board of Examiners the thesis open defense by Gussa Bolka Kitessa Have read and evaluated his/her Thesis "Assessment Of Water Supply Coverage And Quality In Distribution system of Supply: A Case Study of Hawassa Town ,Ethiopia" and examined the candidate. This is, therefore to certify that the thesis/dissertation has been accepted in partial fulfillment of the requirements for the M.SC.

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SGS Approval	Signature	Date

Approval and acceptance of the thesis contingent upon the submission of the copy of the dissertation to the school of Graduate Studies through the Department/School Graduate Committee of the candidate's department.

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DEDICATION AND STATEMENT OF AUTHOR

I hereby declare that this M.Sc thesis my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: Gussa Bolka Kitessa

Signature: ______________________________

Date of submission: ______________________________

LIST OFABBREVATIONS /ACRONMYS

ADD	Average Day Demand
AWW	American Water Work Association
CSA	Central Statistical Agency
DWD	DOMESTIC WATER DEMAND
FIG	Figure
GIS	Geographical Information System
GPS	Global Positioning System
GTP	Growth Transformation Plan
HH	House Hold
ILI	Infrastructure Leakage Index
IWA	International Water Association
KM	Kilo Meter
MDG	Millennium Development Goal
M/S	Meter per second
MDD	Maximum Day Demand
MHD	Maximum Hourly Demand
MERV	Main Ethiopia Rift valley
MWR	Ministry of Water Resource
MDGs	Millennium Development Goals
NDWD	None-Domestic Water Demand
NMA	National Metrological Agency
NRW	Non-revenue Water Loss
PHD	Peak Hourly Demand
RL	Real Loss
UNDP	United Nation Development Program
UNICEF	United Nations Children's Emergency Fund
UFW	Unaccounted for Water
WDM	Water Demand Management
WHO	World Health Organization
HTWSSE	Hawassa Town Water Supply and Sewerage Enterprise

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ABSTRACT

Water supply in distribution system is the key problems of water authorities in developing countries including Ethiopia. Water consumption has been increasing significantly in most towns due to increasing number of population and other factors. This study assess Hawassa town water supply system based on main performance indicators namely Demand and supply water coverage, water production, water consumption, distribution system water loss, water quality and operation and maintenance. High water loss, customer complaints and operation and maintenance problems indicates that there are deficiencies on the quality of the service. To conduct this research, data of water production and consumption, some water supply system data were obtained from the water utility records and primary data were collected through field survey and structured checklist administered to the water consumers and key personnel of Hawassa Town Water Supply and Sewerage Enterprise (HTWSSSE) . The existing water supply source of locations was analyzed using software ARC GIS Map version10.1 and the data from HTWSSSE and households were analyzed descriptive methods. As found out, Hawassa town water supply service could not meet water demands of the town with existing capacity. The total demand of the town for the year of 2022/23 is 90,388 m^3/day but the production is 30,976.56 m^3/day which have only 30% coverage of the demand. Sufficient water scheme development that fulfills town demand is the major question to date. Even though there are a number of water sources in the area, chemical content is the main problem as confirmed during this work. The town situated in the rift valley where there is problem due to natural chemical content which undermines the quality of water. Assessment was made on all available ground and surface water sources to verify chemical content that can causes adverse effect on human health. In this regard, 24 samples were collected from all available sources in the town and nearby surroundings area of the town and tested in Hawassa Town Water Supply and Sewerage Service Enterprise, Water Quality Laboratory. According to the test result, most of sources are safe for drinking purpose except calcium, magnesium a little bit higher or out range, however ,the bit increase do not cause adverse effect for human health and fluoride and iron which are more than admissible range of WHO but some sources have allowable range. On the other hand, all boreholes and rivers capacity measured during this work. The analysis of the storage capacity of existing reservoirs which have 10,400m3/day the recommended range was 27,116.4 m^3/day to 45,194.15 m^3/day , the results shows less than the recommended range, so the Hawassa city water scheme is not safe regarding to storage capacity. In conclusion, the town's water supply system is poor in managing water loss, water access, operation and maintenance with the continuous generation of water from source continuously into balancing reservoir. It is recommended that the water utility develop a strategy and work hard on the indicate system deficiencies especially on operation and maintenance to improve the water supply system performance and provide customers with good quality service.

***KEY WORDS**: Water supply, Water Loss, water coverage, Water* Demand, Water Quality *, Hawassa town, Ethiopia.*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Water scarcity affects all social and economic sectors and threatens the sustainability of the natural resources base. Addressing water scarcity requires an inter-sartorial and multidisciplinary approach to managing water resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Integration across sectors is needed. This integration needs to take into account development, water supply, and to place the emphasis on people, their livelihood and the ecosystems that sustain them. On the demand side, enhancing water productivity (the volume of production per unit of water) in all sectors is paramount to successful programs of water scarcity alleviation. Furthermore, protecting and restoring the ecosystems that naturally capture, filter, store and release water, such as rivers, wetlands, forests and soils, is crucial to increasing the availability of water of good quality (UN-Water, 2007).

There are several ways of defining water scarcity. In general, water scarcity is defined as the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully. Water scarcity is a relative concept and can occur at any level of supply or demand. Scarcity may be a social construct that is a product of development, customary behavior or the consequence of altered supply patterns stemming from climate change for example. Scarcity has various causes, most capable of being remedied or alleviated. Water scarcity usually affects the development and sanitation of the society. However, scarcity often has its roots in water shortage, and it is in the arid and semi-arid regions affected by droughts and wide climate variability, combined with high population growth and economic development, that the problems of water scarcity are most acute (UN Water, 2007).

Potable water scarcity also occurs by the presence of high salt or chemical concentration more than the admissible range for human health. Some dissolved chemicals are very toxic and easily changes the odor, color and taste of water. People lives nearby sea and ocean water cannot use directly the water due to excess salt concentration.

According to the United Nations Millennium Development Goals Report, 783 million people, or 11 percent of the global population, remain without access to an improved source of drinking water. Such sources include household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collections. The world has set the MDG drinking water plan but work is not yet completely done. Furthermore, there are regions particularly delayed such as Sub-Saharan Africa where over 40 percent of all people live without improved drinking water (UN, 2012).

Large amount of earth's water that estimated about 97% is salt water. However, only 3% is fresh water; slightly over two thirds of this fresh water is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is found mainly as groundwater, with only a small fraction present above ground or in the air (Global Concern Classroom, 2012; FAO, 2012).

Fresh water is a renewable resource, yet the world's supply of clean, fresh water is steadily decreasing. Water demand already exceeds supply in many parts of the world as the world population continues to rise. Water covers about 70 percent of the earth's surface, and is the most common liquid. Without water, there would be no life on the planet. Humans can live for weeks without food, but only a matter of days without water. It is hard to imagine what it is like not having clean water to drink. Water is not evenly divided around the world. Some places have lots and others have very little. Water supply is a big problem in some countries in Africa. Some people in Africa carry water from a hole that is bored or dug into the ground. This water source might not even be in their town and they will have to travel to get it. In some countries children have to walk for kilometers every day just to get enough water for their family to drink and even then it is often dirty and contaminated, but they have no choice unless they drink it (Global Concern classroom, 2012).

The need for water and sanitation in Ethiopia is severe. Only 42% of the population has access to an improved water supply, and only 11% of the population has access to adequate sanitation services. In rural areas, these numbers drop even further. One of the major problems that Ethiopia faces is that large number of population is without a clean water supply, instead being forced to drink from rivers, streams, lakes and even puddles to survive. These sources are often contaminated and animals can frequently be seen urinating in the same water at upstream while people collect from lower area. The health risks from drinking from an unprotected or untreated water source are severe, with water-related deaths occurring incredibly often, as well as Ethiopians suffering from illnesses such as bronchitis, tonsillitis, diarrhea, vomiting, eye and respiratory infections as well as the deadly malaria on a far too regular occurrence (Water org's project in Ethiopia, 2012).

Drinking water quality in Ethiopia varies in different places. The most comprehensive picture of drinking water quality are the results of a national statistically representative survey of piped water supply, boreholes, dug wells and springs carried out by the WHO and UNICEF in 2005 (WHO and UNICEF,2005). It shows that 72% of samples complied with the values for coli form bacteria in the Ethiopian drinking water standard (ES 261:2001) and the WHO guidelines for drinking water. In the case of piped water supply by utilities compliance was highest at 88%. Open wells and unprotected springs were not included in the survey. Besides bacterial contamination, natural contamination with fluoride is an issue in the Rift Valley (Riemann et al, 2003, Tewodros et al, 2008).

Ground waters in unconsolidated aquifers are usually of excellent quality; being naturally filtered. The water is normally clear, colorless, and free from microbial contamination and thus requires minimal treatment. As a consequence of the slow travel times in the flat plains and due to the long contact time with the sediment, the groundwater often contains significant quantities of minerals in solution. This solute content varies and depends on the resident time of water in the aquifer and the mineral composition of the aquifer itself as seen in the flood plains of the alluvial aquifers in the Rift Valley. After many years of use of drinking water from drilled wells in the Rift Valley, Ethiopia, dental and skeletal fluorosis has become a serious medical problem (Tekle-Haimanot 1990).

Even if there are abundant surface and ground water sources in and around Hawassa, it is not yet used for drinking purpose. So this research paper was assessing the Water Supply System Analysis of Hawassa Town, the main performance indicators are conduct an assessment of the challenges of existing water supply sources to determine the quantity of water demanded by the Town, to examine the amount of water consumed by the Town, to identify component of non-revenue water (NRW) in the water supply system and to evaluate the total loss of water and to verify chemical content of each source against WHO water quality guidelines to assure why it is no potable source.

1.2. Statement of the Problem

Towns are centers for social, political and economic activities. Nowadays, lack of sufficient Water Supply is the major problem of Ethiopian towns. Particularly, Hawassa is one of the towns with water shortage problem due to lack of sufficient potable water sources (Takele, 2010).

The existing water supply system of the Hawassa town is inadequate to meet the demand of rapidly growing population. The distribution network systems of the water do not cover fringed areas or the extremities of the town. At this moment, the Design Period of the existing water system seems to long overdue as it is also postulated by Abay Engineering (2011).

Expansion of the town, rapid population growth, establishment of governmental and private institutions, and a number of small scale industries are putting pressure on the existing water Supply system. Even if, there are a number of surface and ground water resources around Hawassa town, the portability issue is the major problem that causes the water scarcity in the town. Fluoride and iron contents are serious problems that make the water quality beyond the range of WHO guidelines since the town is situated in the Rift Valley.

Therefore, specifically investigated the potable water supply and demand; the water consumption pattern of households; the water loss in the system the quality of water sources, the gap related with water scarcity, and will initiate intervention measures to address the mentioned problems in Hawassa town.

1.3 Objectives of Study

1.3.1. General Objective of the study

The overall objective of the study is to examine the coverage of existing water by supply-demand scenarios and water quality controlling management to indicate the measures to be taken to meet the current and future water demand of rapidly growing town of Hawassa.

1.3.2. Specific objectives

- ✓ To evaluate the current status of existing water supply coverage and demand analysis of Hawassa Town.
- ✓ To estimate the total loss of water from distribution system of supply water in the Town of Hawassa.
- ✓ To assess the portability of drinking water quality parameters in existing supply sources of water quality problems of Hawassa Town in the references to established standards by WHO and Ethiopian guidelines.

1.4. Research Questions

1. Do the current existing water supply sources of Hawassa Town meet the demand?
2. How much water is lost in distribution system when compared to production and what are causes for water losses from supply system and loss impacts of in the Town?
3. What are the drinking water quality problems in current existing supply system of water in the Town?

1.5. Significance of the Study

The significance of the study will be primarily to identify the status of water supply system Analysis, distribution and demand analysis of water supply. It will be expect that to identify the water supply system analysis which covers from the sources of water to distribution of water to community and the estimate of unaccounted water and Non-revenue water (NRW) management allows utilities evaluation and efficiency improvement of urban water distribution systems in the Hawassa Town.

The results help decision makers and especially the town water utility (water supply service office) in planning of future expansions and, improve coverage, service reliability and clear water production and consumption and annual water consumption & average daily water consumption and to set the data (coordinate from the water sources to distribution system) so as to make the system more efficient and increase water supply service level and also this study examines entire water supply system from sources to water taps. Quantities of water being supplied from sources to the system verses targeted consumers water need shall be examined and to gives a clue for further research.

1.6. Scope of the Study

Based on the information from HTWSSSE, the scheme meant to supplies water for Hawassa Town for 42,061 house connections and 296 water taps. Besides the scheme has got twenty-one balance and service reservoirs with a capacity ranging from 4000m^3to50$m^3$and the length of transmission and distribution line is more than 830km with the diameter ranging from 600mm to 50mm. This study examines entire water supply system analysis from sources to end users. Quantities of water being supplied from sources to the system verses targeted consumers water need shall be examined.

1.7. The Thesis Contents

This thesis comprises five chapters, which are organized as follows.

- Chapter one: Contains general background, the problem statement, the research objective, research question, significance of the research.
- Chapter two: Discussion literature related to water loss and leakage
- Chapter three :Discussion about the methodology the data collection and preparation
- Chapter four :Results and discussions
- Chapter five: summary and conclusions.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. International concern in Water Supply

The MDGs distinguished between "improved" and "unimproved" water and sanitation services. Today, the SDGs propose a more ambitious vision for service delivery, using new indicators that are more refined and stringent. The baseline estimates developed by the Joint Monitoring Programmed (JMP) for Water Supply and Sanitation6 provide a stark picture of the challenges Reducing Inequalities in Water Supply, Sanitation, and Hygiene in the Era of the Sustainable Development Goals 3and opportunities over the next 15 years: 4.5 billion people lack access to safely managed sanitation, and 2.1 billion to safely managed water.

This report focuses on three SDG targets:

- By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
- By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
- By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse globally.9

This report provides a picture of the implications of shifting from the MDGs to the SDGs. In 2016, Hutton and Varghese estimated that $28 billion a year would be needed to provide the unserved with just basic services (MDG standards), and estimates run well over a $100 billion a year to provide safely managed services (SDG standards) for all. This report acknowledges that while more money is required to reach the new targets, it is even more critical that effectiveness and efficiency in the allocation and the use of resources be prioritized. Focusing on these priorities would improve targeting and reduce the waste of scarce public resources.

The top level of quality for water supply and sanitation is "safely managed."

The United Nations (UN) Member States agreed to raise standards by committing to the SDGs. This in itself is an acknowledgement that the previous standards were not sufficient to ensure that assets were fully delivering the social or public good benefits intended. For example, under the MDGs a household could still be considered to have access to improved drinking water even if it took over an hour to obtain, decreasing the volume of water consumed and increasing the risk of contamination during transport. Where piped supply is intermittent, the risk of water becoming contaminated increases greatly. A toilet with a slab may adequately protect users from contact with human feces, but what happens when a latrine or septic tank fills up? And what if sewage is left untreated? The SDGs attempt to comprehensively close existing gaps in access to basic services, and to ensure that improvements are sustained over the long term.

Whenever standards are raised, some countries will struggle more than others to achieve them. The SDG parameters are applied. Specifically, it compares Ethiopia, the 17-country average, and Ecuador.10 While coverage will decline across all countries, it will do so to varying degrees. Also, countries that do not collect data on the parameters of the new SDG baseline, "safely managed," will find it particularly difficult to even consider how best to address the comprehensive WASH needs of their citizens, or to demonstrate any progress they do make toward the 2030 goal of universal access.

Water quality and the continuity of water supply appear to be key drivers that lower the baselines for safely managed water (where data are available). For instance, while Ecuador and Bangladesh have achieved their MDGs for water, the new SDG standards have recalibrated their baselines down by 22 and 44 percentage points, respectively, largely due to water quality issues. Moreover, piped water on household premises was found to be equally or more contaminated (source: Era of the Sustainable Development Goals) .

Half a century of efforts by WHO, UNICEF and other international organizations to improve water and sanitation conditions around the world have contributed to global awareness, the establishment of international programs and the strengthening of national institutions (WHO and UNICEF, 2000).

In 2000, world leaders at the United Nations Millennium Development Goals (MDGs) Summit set a target to cut in half the proportion of people without access to clean water by 2015. In 2002, at the World Summit on Sustainable Development, access to basic sanitation was included. Recognizing the critical need to meet the water and sanitation target and its impact on all the other MDGs, 2005–2015 was designated as the 'Water for Life' decade (Global Concern Classroom, 2012).

Nearly 800 million people do not have access to safe drinking water, about one in every eight people. The global consumption of water is doubling every twenty years, twice the rate of population growth, and it is estimated that in 2025, at least 3 billion people will be living in areas where it will be difficult or even impossible to meet basic water needs. There are increasing demands on the world's water supply. Population growth, water-intensive agriculture and economic development are using water faster than it can be replenished. In addition, freshwater resources are in danger due to increasing pollution and climate change (Global Concern Classroom, 2012).

Water is essential to our lives. We need water to drink, to bathe and to cook foods. For most of us, the supply of water seems to be endless. We can simply turn on the faucet any time of the day, any day of the year. Throughout the world, however, millions of people must walk for hours each morning to bring water to their homes.

In developing countries like Africa, lack of clean water is a devastating and often deadly problem (WHO, 2006). Many times people are forced to draw water from a dirty pond or contaminated river, contributing to poor health and disease. Drinking unclean water causes millions of deaths each year from diseases such as diarrhea, hepatitis, cholera, typhoid and parasites (*Global Concern Classroom, 2012*). Access to safe water is a basic human right. It can improve the health, economy and social well-being of a community. We must use water wisely and responsibly to ensure that in the future everyone will have access to drinking water that is affordable and safe.

Most of the Earth's water is undrinkable. Although 70 percent of the planet's surface is water, almost all of it is saltwater in the oceans. Only 3 percent of the worlds' freshwater is safe for drinking, and 97 percent of that is frozen in glaciers. That leaves us with less than 1 percent usable water from lakes, rivers and underground sources. Removing salt from ocean and sea water, called desalination or reverse osmosis process, would greatly help with the world's water needs, yet because it is so expensive and requires a large amount of energy, most countries cannot afford to do it. But with water shortages threatening populations, desalination may become a necessity in the future (Global Concern Classroom, 2012).

Some countries have abundant, untapped stores of water to support population growth, while others are already using most of their available water. Water is also becoming increasingly polluted and although several countries have the technology and can afford to clean their water, the majority of the world cannot (Global Concern Classroom, 2012).

Water supply service quality has many dimensions: continuity, water quality, pressure, and the degree of responsiveness of service providers to customer complaints. Continuity of water supply is taken for granted in most developed countries, but is a severe problem in many developing countries, where sometimes water is only provided for a few hours every day or a few days in a week. It is estimated that about half of the population of developing countries receive water on an intermittent basis.

On the other hand the water quality is the crucial issue in the world. Nowadays, surface and ground water pollution by effluents from different factories is major problem. Fluoride and iron content is another problem of Africa.

2.2. Urban Water Supply and Sanitation in Ethiopia

In contrast to the experience of rural areas, urban water and sanitation services have delivered real benefits—but not equitably or sustainably. With over 10 million people gaining access to water from a piped source on premises, significant time savings have been realized in urban areas. However, these savings have been disproportionally captured by relatively well-off households (that is, those in the top 60 percent of the wealth distribution), who are nearly four times more likely to have access to piped water on premises than poorer households (those in the bottom 40 percent of the wealth index). The reasons for this inequitable uptake are twofold. For about a third of households that are not connected, mainly in smaller towns, there is a lack of infrastructure to connect to. For the remainder, mainly in large urban centers, the infrastructure exists but households can’t pay or utilities simply aren’t making the connection .(Source: World Bank forth coming(a)).

Access to water supply and sanitation in Ethiopia is amongst the lowest in Sub-Saharan Africa and the entire world (World Bank, 2011). The water distribution systems in the country are generally inadequate. The problem is associated partly with unfavorable topography, seasonal fluctuation of the water reservoirs, low capital investment and lack of efficient water governance among concerned authorities. While access has increased substantially with funding from external aid, much still remains to be done to achieve the Millennium Development Goal of having the share of people without access to water and sanitation by 2015, to improve sustainability and to improve service quality (World Bank, 2011).

In 2001 the Ethiopian government adopted a water and sanitation strategy that called for more decentralized decision-making; promoting the involvement of all stakeholders, including the private sector; increasing levels of cost recovery; as well as integrating water supply, sanitation and hygiene promotion activities (World Bank, 2011).

In 2005 the government announced highly ambitious targets to increase coverage in its Plan for Accelerated Sustained Development and to end poverty for 2010. In 2010 the government presented the equally ambitious Growth and Transformation Plan (GTP) 2011-2015 that aims at increasing drinking water coverage, from 68.5% to 98.5% (World Bank, 2011

Water supply systems in urban areas are often unable to meet existing demands and are not available to everyone rather some consumers take disproportionate amounts of water and the poor is the first victim to the problem. The water supply utilities should fulfill the water condition quantitatively and qualitatively. One of the main problems affecting waters supply systems in developing countries is the problem of water losses, which includes apparent water losses and real water losses (M.E.Fontana, 2016). Leakage can be defined as unintentional or accidental loss of water from the pipe distribution network. Leaking pipes are a major concern for water utilities around the globe as they constitute a major portion of water losses. One of the primary reasons for leakage in pipes is aged and deteriorated networks. Leakage rates are also related to length of pipes and number of connection s(Melaku,2015)**.**

A water distribution system consists of a complex combination of components, including pipes, fittings, pumps, reservoirs, valves, hydrants, meters and backflow preventers that are all critical in maintaining physical integrity. At the same time, the distribution system is constantly changing through aging, replacement of components and the addition of new extensions (Krynauw, 2014). Improper connections can sometimes result in continuous escape of water from the distribution pipes. Water supply systems in urban areas are often unable to meet existing demands and are not available to everyone rather some consumers take disproportionate amounts of water and the poor is the first victim to the problem. The developing cities have great difficulty both financial and technical to develop and expand water supply projects and one of the difficulties among the others is managing and reducing losses of water at all levels of a distribution system. As a result of the overall shortage of water many cities are faced a problem in distributing the available water impartially among the residents. Beside to this poor management of the existing infrastructural asset increases the level of water losses in water supply system (Mebet, 2007). As this research deals with over all coverage of water supply and water losses and quality in water supply systems, issues related to water loss and leakage like identifying and reducing was reviewed in this chapter.

2.3. Trend Analysis of Hawassa Town Water Supply

Hawassa Town water supply system project started on1975 at Ethiopian calendar (name of project is kedo treatment plant by Italian company (HTWSSSE).Hawassa City Water Supply and Sewerage Service Enterprise has been established according to ProclamationNo.40/2002 of the Regional State, and has also been re-established as Class 1 city water service. At present, the Hawassa City Water Supply and Sewerage Service Enterprise is organized as an autonomous public organization under the Hawassa City Administration monitored by Water Board. The Hawassa City Water Board (HTWB) is the higher level organ mainly responsible for Policy formulations and strategic management including budget approvals for the Hawassa City Water Supply and Sewerage Service Enterprise(ABAY, 2013).

The top executive is the head of the Water Supply and Sewerage Service Enterprise of Hawassa City with Water Supply and Scheme Administration, Purchasing, Finance and Property Administration and Human Resources Administration being directly responsible to him. Hawassa City Water Supply and Sewerage Service Enterprise have a total of 117 staffs (2003ethc). The Enterprise has five sub branches namely Tabor Alamura, Dato-Odahe, Gudumale, Halade, and Tula water services. The water supply status is below the minimum level set for such cities. The supply average divide by the current population irrespective of service mode and types gives a little over 20 liters per head(ABAY, 2013).

Besides such low level of service, the supply is intermittent and a recent study has shown that there are kebeles and villages without piped water for three to weeks of days. Peripheral kebeles are the most hit by the absence. The problem of Hawassa water is not only of supply management due to shortages as a result low production capacity. The most concerning issue is also the NRW level reaching to 45% as indicated in the report. The town pipe distribution grid is out dated and needs redesign. Pressures are not proportional to the discharge at most points. Old lines are left unnoticed of bursting flow for hours. The use of piped water for city beatification is another problem adding the depth of the grave (ABAY Engineering plc, 2013)

2.4. Urban Water Supply demand and coverage

A sustainable urban water supply system covers all the activities related to provision of potable water. Sustainable development is of increasing importance for the water supply to urban areas.

Water is an essential natural resource for human existence. It is needed in every industrial and natural process, for example, it is used for oil refining, for liquid-liquid extraction in hydro-metallurgical processes, for cooling, for cleaning in the iron and the steel industry and for several operations in food processing facilities. It is necessary to adopt a new approach to design urban water supply networks that fit with environmental regulations for water utilization and waste-water disposal are increasingly stringent.

To achieve a sustainable water supply network, new sources of water are needed to be developed, and to reduce environmental pollution. Potable water is not well distributed in the world. Deaths about 1.8 million are attributed to unsafe water supplies every year. Many people do not have any access, or do not have access to quality and quantity of potable water. Poor people in developing countries can be close to major rivers, or be in high rainfall areas, yet not have access to potable water at all. There are also people living where lack of water creates millions of deaths every year (WHO, 2010).Where the water supply system cannot reach the slums, people manage to use hand pumps, to reach the pit wells, rivers, canals, swamps and any other source of water. In most cases the water quality is unfit for human consumption. The principal cause of water scarcity is the growth in demand. Water is taken from remote areas to satisfy the needs of urban areas. Another reason for water scarcity is climate change that causes the change of precipitation patterns as result, rivers have decreased their flow; lakes are drying up; and aquifers are being emptied.

When we come to current situation of Urban Water Supply and Sanitation Services of Ethiopia towns, depletion or exhaustion of ground water potentials, longer time period required for construction of Urban water supply and sanitation, majority of the existing urban water supply and sanitation water systems designs have been phased out, however, on the other hand the rate of rehabilitation and expansion has been lagging behind, poor maintenance and rehabilitation, poor water quality control are a few problems that can be mentioned in the urban water supply system. Most urban water utilities do not fulfill the requirement or the principle of cost recovery and self-reliance (MOWE, 2010).

To provide safe water there is a need to ensure that the quality of drinking water is assessed and monitored (UNEP, 2008). Quality is defined by certain physical, chemical and biological characteristics. Even a personal preference such as taste is a simple evaluation of acceptability. Drinking water quality is assessed by comparisons of water samples to drinking water quality guidelines or standards. These guidelines and standards provide for the protection of human health, by ensuring that clean and safe water is available for human consumption (WHO, 2008 and Abraham, 2012).

Most of the Towns in Ethiopia are not well developed and laid with sufficient distribution network from end to end (MOWE, 2010). Extremities of the town of Hawassa are not fully supplied with water except scattered water points. The diameters of laid pipes are small and not supply enough water that fulfills the demand of community which arises due to development of the town.

2.4.1. Urban Water Demand

Water demand is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water consumption, although conceptually the two term do not have the same meaning (Wallingford,2007).In most developing countries, that theoretical water demand considerably exceeds the actual consumptive water use. Urban water demand is classified in to different category that domestic water demands that included in-house-use and out-of-house-use is among the others. In-house-use includes demands for cooking sanitation, house cleaning, laundry and car washing while out-of-house-use includes like garden watering, swimming pools, public stand pipes for public uses and fountains etc.

Urban water demand is usually quoted in terms of liter per capita per day

(1/capita/day).Despite the variation in residential in door water use from house hold to house hold, a typical pattern (referred to as the water use profile) can be developed to provide a reasonable representation of indoor water use, based on the different in door water use components (kitchen, bathroom, laundry, and toilet) and household occupancy (Kanakoudis, 2011).

2.4.2. Urban Water Coverage

Water supply coverage provides a picture of the water supply situation of one specific country or city and helps to compare one country with others and the inter and intra city distribution with in specific country. The percentages of population with or without piped water connection are a relevant indictor to compare the coverage of water supply in urban areas. Although the water supply coverage is better in urban areas while compared with the rural, the actual water supply coverage in cities of developing countries in general and African cities in particular is very low while compared to the demand. According to the Global Water Supply and Sanitation assessment 2000 Report, the African capital cities are having 43% house connection or yard tap,21% served by public tap while 31% of the populations are un-served (WHO, 2011). A household is considered to have access to improved drinking water if it has sufficient amount of water (20liters/person/day) for family use, at an affordable price (less than 10% of the total household income), available to household members without being subject to extreme effort (less than one hour) a day for the minimum sufficient quantity), especially to women and children) (Habital,2003).During 2019/20,the proportion of people having access t o

Potable water supply improved to79.3 percent (82.7 percent rural and 66.5 percent urban population); relative to 75.9 percent (78.7 percent rural and 65.5 percent urban people) a year earlier (Table2.1).In the other words, rural areas had relatively better access to water than urban areas.

Table.2.1.National water supply coverage

Regions	2018/19			2019/20		
	Rural	Urban	Total	Rural	Urban	**Total**
Tigray	60.5	60.0	60.4	60.2	69.7	**62.9**
Afar	62.9	51.1	60.6	70.1	57.2	**67.5**

Amhara	90.1	71.1	86.7	94.8	70.8	**90.3**
Oromia	66.5	64.6	66.2	72.6	63.8	**71.2**
SNNPR	58.4	81.0	62.3	59.8	81.5	**63.6**
Somali	80.1	81.5	80.3	83.1	84.4	**83.3**
B.Gumuz	67.1	48.7	63.0	68.1	50.2	**64.0**
Gambella	75.6	61.2	70.6	76.7	68.4	**73.7**
Harar	85.2	64.1	73.4	87.2	63.5	**73.9**
D. Dawa	82.7	86.2	84.9	87.2	83.5	**84.8**
AA	-	63.5	63.5	-	63.9	**63.9**
Total	**78.7**	**65.5**	**75.9**	**82.7**	**66.5**	**79.3**

Source: Ministry of Water, Irrigation and Energy and NBE Staff Computation 2020 report

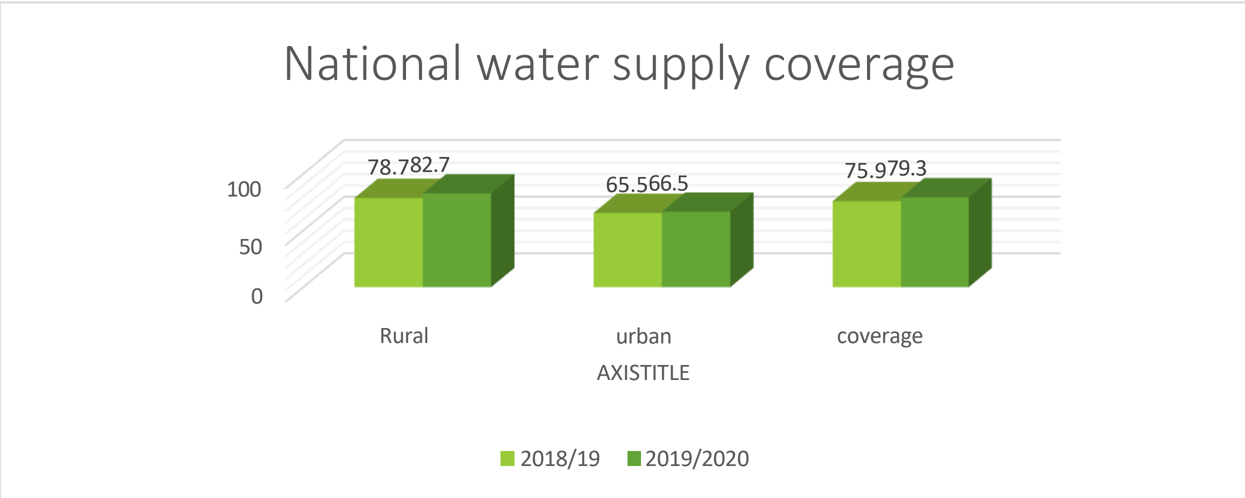


Figure 2.1: National water supply coverage

2.4.3. Water demand Management

Broadly, there are three ways to solve a water shortage problem: one is to find new sources to increase supply; a second is to manage demand within the existing water supply system; and a third is to combine supply and demand side planning in what is referred to as integrated water resource planning (Beecher, 1995).

Water resource development and management can be grouped into supply-oriented and demand-oriented management techniques. Supply-oriented management focuses on considering a range of water supply options which are cost effective to meet the overall water requirements. Hence, it mainly focuses on technical elements and public service delivery (Mani, 2000).

Demand-oriented management is complementary to engineering solutions that seek to supplement water supplies. It ensures that available water is used efficiently and wisely. A demand orientation with a focus on service consumers' needs and willingness to pay full costs of services, competitive markets, and broader participation of the private sector, non-governmental organizations (NGOs) and community-based organizations (Assefa,2006).

Water resource planning is a way to ensure that social, economic, environmental and technical issues are considered in the management and development of our water resources (Gbadegesin and Olorunfemi, 2009). It is a continuous process with ever changing variables, public involvement is critical to the success, and the water industry must embrace integrated water resource planning to be successful. There is a growing policy emphasis on the involvement of stakeholders and the public in water resource planning and decision making (GWP, 2000).

Water management can be considered as a human-environment system that transforms inputs of natural resources into desired outputs of water services (Porter, 1978). The planning process deals with the questions: given a goal for water management, what is the best way to accomplish it, and can approval and support be gained? Finding the best plan is technical in the sense that financial, institutional, economic, legal, and engineering aspects are all called "technical". Gaining approval requires dealing with the public, politicians, and regulatory processes. Planning requires finding the best alternatives, given societies goals, objectives and preferences. Planning methods that combine public participation with decision making functions are therefore increasingly in demand (CEC, 2002).

2.4.4. Domestic Water Demand

It is the amount of water which is used for varies domestic purpose, such as for drinking, bathing, cooking, cleaning utensils, toilets, lawn sprinkling etc. greatly influenced by availability and type of supply. Taking the number of projected population, average per capita domestic demand for all modes of service can be estimated for the year of design period. The water production required for a day can be calculated after adjustment for all modes of services for the required year (Letta et al, 2008).

Table2.2. Domestic water demand for the following categories of consumer:

	Stage1	Stage2
House connection (HC)	50 l/c/day	**70 l/c/day**
Yard connection, own(YCO)	25 l/c/day	**30 l/c/day**
Yard connection, shared(YCS)	30 l/c/day	**40 l/c/day**
Public tap supplies (PT)	**20 l/c/day**	25 **l/c/day**

2.4.5. Non -domestic water demand

Water required for institution, commercial centers, public and sanitary facilities, public gardens, Can be categorized under non domestic needs. To compute such water demands, the actual figure of public service, institutions and commercial centers consumption data were collected from HTWSSSE. The recommended value of non domestic demand by cost effective design guideline for urban water supply presented by Ministry of Water Resource (2006), is 20 to 40% of the domestic water demand, the study adopted 25% of the domestic demand for this scenario.

A. **Commercial and institutional water demand**

The water requirements for both demands depend on the user of building, number of employees and or residents, and number of user of the service delivery. To calculate the commercial and institutional water demand, the real figure of institutions and commercial areas should be known. As data collected from the Hawassa Town Administration shows the formal and informal businesses undertaken in the town by different categories include large to petty trading activities (Eyob, 2008).

B. Industrial water demand

A water demand for industries will be considered separately from commercial demand. Actually, the water requirement of either small scale industries or large scale industries will be more and more from the other demand requirements of the town. When industrial water demand is considered, take into account only the workers sanitation consumption and minor production processes demands. But for major production purpose the industry owners should prepare their own source different from town water supply.

C. Losses and wastes (unaccounted water)

Unaccounted for water (UFW) is expressed as a percentage of water loss against the total water produced for the system. Unaccounted for water arises from system leakage, water theft by illegal connections, inaccuracies in metering, overflowing, and flushing (Abreham, 2012). UFW cannot be assessed easily without adequate and reliable metering. To account the losses strong control of illegal connections and overflow during the operation time, control the leakage with leakage detection equipment and installation of bulk water meter at production site and at the outlet of service reservoirs.

D. Firefighting water demand

Water demand for firefighting purpose depends up on the existence of equipment to the capacity of any fire service. Even if there is not as such equipped fire service exist in the town, due to the expansion of schools shops, hospitals, fuel stations and different large business centers, the town needs a safeguard water to protect human life's, Properties and buildings from fire. This demand is taken by increasing the volume of the domestic water demand by 5% or 10% of the reservoir storage (Tropics Engineers, 2002).

Table.2.3.Institutional and Commercial Demand

S/N	Institutions	Consumption
1	Restaurants	**10 l/Seat**
2	Boarding school	**60 l/Pub**
3	Day schools	**5Lit/Pub**
4	Public offices	**5 l/employee**
5	Workshop/shops	**5 l/employee**
6	Mosques &Church	**5 l/worshipper**
7	Abattoir	**150 l/cow**
8	Hospitals	**50-75l/bed**
9	Hotels	**25-50l/bed**
10	Public Bath	**30 l/visitor**

11	**Public latrines**	**20 lit/seat**

Source: Design Criteria Guide Line of MoWR (2006)

2.4.6. Factors Affecting Per Capita Demand

Per capita demand is the annual average amount of daily water required by one person and including domestic uses. According (Santosh, 2012) to per capita demand depends on the following factors:-

Pressure in distribution system:-The rate of water consumption increase in the pressure of the building and even with the required pressure of the farthest point, the consumption will automatically increase.

Size of the city: - Per capita demand for big city is generally large as compare to the smaller town because of in big cities huge quantity of water required for different purpose.

Climate conditions:-The quantity of water required in hotter and dry places are more than cold places because of the uses of air coolers, air conditioners, sprinkler of water in lawn garden washing of rooms.

Types of gentry and habits of people:-Rich and upper class community generally consume more water due to their affluent living standards. Middle class community consume average amount while the poor slum dweller consume very low amounts therefore,(Santosh,2012) states that the amount of water consumptions is directly depend up on the economic status of the consumers.

Industry and commercial activities:-The pressure of industry and commercial activities at a particular place increases the consumption by amount. Many industries requires really huge amount of water and as such increase a water demand considerably.

Quality of water:-if water is aesthetically (artistic) and medically safe, the consumption will increase as people will not opt to private walls, hand pump etc.

Cost of water:-The cost of water directly affects its demand. If the cost of water is more, less quantity of water will be used as compared when the cost is low.

Policy of metering and charging methods:-Water tax is charged in two different ways, on the bases of meter reading and on the bases of certain fixed monthly rate. Water demand varies seasonally with the lowest usage in winter months and the highest usage during summer month. Variations in demand also occur with respect to time of a day. Diurnal peaks typically occur during the morning early evening periods, while the lowest usage occurs during night time hours (Willem, (2009).

2.5. Water Loss and Leakage

The term *"water loss"* is generally adopted to indicate the difference between the overall amount of water supplied in the network and the sum of the water volumes corresponding to the customer consumption recorded by the flow-meters (Lambert, , 2009). The first and foremost cause of water loss is leakage. Water put to inappropriate or excessive uses may also be considered as loss. Water that is unaccounted for because of measurement errors, including inaccurate meters, forgotten users, and unmeasured uses, are also some of the causes for evaluating the water losses. Leakage can be defined as unintentional or accidental loss of water from the pipe distribution network. Improper connections can sometimes result in continuous escape of water from the distribution pipes. These water losses can be divided in to two groups: the Commercial (apparent) losses, which consist of water volumes actually consumed but not accounted for, and the Physical (real) losses, that are caused by large damages that may have occurred to the network pipes or by the deterioration of the pipe junctions or the hydraulic devices (Malcolm, 2008).

Regardless of the magnitude that greatly varies from town to town or from one area to another area, water loss is a problem experienced in all water distribution systems. The first and foremost cause of water loss is leakage. Water put to inappropriate or excessive uses may also be considered as loss. Water that is unaccounted for because of measurement errors, including inaccurate meters, forgotten users, and unmeasured uses, are also some of the causes for water losses. Unaccounted for water (UFW) is one of the commonly used methods for evaluating the water loss that is usually defined differently by different writers that some of the definitions indicated here: There is no universally applied or accepted definition of unaccounted-for water. Water losses in the water supply distribution system, illegal connections overflow from reservoirs and improper unaccounted for water. Metering (meter err), poor maintenance, etc. are referred to as unaccounted for water.

Table.2.4.Components of Water Loss

Water Loss

Physical loss(Real loss)	Commercial loss (Apparent loss)
Pipe breaks and leaks	Metering Errors
Storage over flows	Water Theft
House connection leaks	Billing Anomalies

2.5.1. Commercial Losses (Apparent loss)

Commercial losses, sometimes called „apparent losses", include water that is consumed but not paid for by the user. In most cases, water has passed through the meters but is not recorded accurately. In contrast to leaks or reservoir overflows, the lost water is not visible, which leads many water utilities to overlook commercial losses and concentrate instead on physical losses. Commercial losses can amount to a higher volume of water than physical losses and often have a greater value, since reducing commercial losses increases revenue, whereas physical losses reduce production costs. Commercial losses can be broken down into four fundamental elements and those are :-(1) customer meter inaccuracy, (2) unauthorized consumption, (3) meter reading errors and (4) data handling and accounting errors (Malcolm, 2008).

1. Customer meter inaccuracy

Inaccurate meters tend to under-register water consumption leading to reduced sales and therefore reduced revenue. Only very rarely do meters over-register consumption. Utilities should focus initially on large customers, such as industrial or commercial users, since they consume a larger volume of water and often pay a higher tariff. Using data from accurate meters to bill customers, rather than charging them based on an assumed per a pita basis, ensures that customers are charged according to their actual consumption and encourages them to preserve water (Malcolm, 2008).The paragraphs below discuss common problems with customer meter accuracies and solutions for utilities. The common possible solutions to address customer meter inaccuracy are describing as below;

a. Installing meters properly

Meters should be installed properly according to the manufacturer's specifications. For example, some meters require a specific straight length of pipe upstream and downstream of the meter. Therefore a standard meter stand should be designed and constructed on site. Utilities should purchase the meter on the customers‟ behalf, so that only standard, high quality meters are used. Meters should also be installed where meter readers can easily read them, and where it is easy to identify each property's meter.

b. Sizing meters properly

Customer meters work within a defined flow range, with the maximum and minimum flows specified by each manufacturer. Large meters will not register low flows when the flow rate is lower than the specified minimum. Therefore, utilities should conduct customer surveys to understand the nature of each customer's water demand and their likely consumption. This information helps to determine the proper meter size for households and businesses. For customers with a high demand, checking the flow pattern and the newly installed meter verifies whether the correct meter size is used. Problems with low flows can occur when a storage tank, with the water flow controlled by a ball or float valve, is installed on the customer's premises. These valves operate by slowly closing as the water level in the tank rises, which has the effect of reducing the flow through the meter, often below the minimum flow specification. This problem is compounded even further if the size of the storage tank is large in comparison to the customer's consumption because the ball or float valve will never fully open and the flow through the meter was continually low.

c. Using the appropriate class and type of meter

Choosing the appropriate meter helps to ensure the accuracy of customer consumption data. Class B meters are a good choice where water quality is low, as the sediments will not greatly affect the meter. Class D meters are more preferable where roof tanks are used and water quality is good, since they have a lower minimum flow specification and will measure the roof tank inflow more accurately. Class C meters are a suitable compromise in most situations, since they can measure low flows better than Class B meters and are not as expensive as Class D meters. Common types of meters include positive displacement (PD), multi-jet, single-jet, turbine, and electromagnetic. The most common type of meter for domestic and small commercial installations is the15 mm and 20 mm PD meter. Single-jet and multi-jet meters are more accurate for small commercial and industrial installations that require 20 mm to 50 mm sizes. Electromagnetic meters are the best choice for sizes 100 mm and above.

d. Maintaining and replacing meters properly

All meters should be installed aboveground and located where they can be audited easily including by the meter readers during their regular rounds. The utility should replace the meters systematically, beginning with the oldest meters and those in the worst condition. Poor maintenance will not only encourage inaccuracy but may shorten the life span of the meter. Meter servicing is essential, especially in areas of poor water quality. The accuracy of mechanical meters changes over time as the mechanical bearings wear down, causing friction to increase and thus the meters to under- register. These changes will occur over a number of years, depending on the quality of manufacture. The water utility should regularly test a sample of its customer meters, including a range of meter brands and ages, using a calibrated meter test bench. This testing will determine the optimum age at which customer meters should be replaced.

2. Unauthorized consumption

Unauthorized consumption includes illegal connections, meter by passing, illegal use of hydrants, and poor billing collection systems Illegal connections involve the physical installation of a connection to water distribution pipelines without the knowledge and approval of the water utility. The common problems and possible solutions are describing as below.

a. Finding and reducing illegal connections

Illegal connections can occur during the installation of a new supply connection, or sometimes the customer’s supply is cut off after non-payment and the customer cannot afford, or does not want to pay, to be reconnected. During customer awareness programmers, customers should been courage to report illegal connections, and regulations should be in place to penalize the water thieves. Meter readers should also report cases of direct connections without accompanying meters that they see during their rounds

b. Tackling meter by passing

Some customers try to reduce their water bills by using a meter bypass, which is an additional pipe installed around the meter. This bypass pipe is often buried and very difficult to detect. This type of unauthorized consumption is usually committed by industrial and commercial premises, where only a small volume of the consumption goes through the meter and the rest through the bypass pipe. Because large customers tend to steal large volumes of water, the discrepancy will show up when the utility conducts a flow balance analysis. The utility should then undertake customer surveys and leakage step tests to determine where the missing flow occurs.

C.Preventing illegal use of fire hydrants

Although the only legal use of fire hydrants is for firefighting, some use them illegally to fill tankers (normally at night) or to provide water supply to construction sites. The utility staff can detect these flows, often high volume over a short period of time, through appropriate flow measurements at DMA meters. Such high flows are not only incidences of water theft, but also a detriment to the pipe network and water quality, which affects the service to the customer. Through customer awareness programs, the utility staff should encourage customers to report cases of illegal uses of fire hydrants. In addition, the utility manager needs to cooperate with relevant local agencies or departments to identify owners of tankers suspected of drawing water illegally and without proper permission. Developing and enforcing regulations to penalize water thieves together with local agencies will also deter unauthorized consumption.

D.Actively checking the customer billing system

Sometimes connections are made legally, but the billing department is not notified of the new connection; therefore, the customer is never billed. These unregistered customers can be detected during the regular meter reading cycle when diligent meter readers find meters that are not in their reading book. However, this process may not identify all of the errors in the billing system.

e. Avoiding corrupt meter readers

Corrupt meter readers can significantly impact a utility's monthly billed consumption. For instance, the same meter reader who walks the same route for an extended period of time, thus becoming familiar with the customers and their monthly billed consumption, may collude with those customers to record lower meter readings in exchange for a monetary incentive. To reduce this risk, the utility manager needs to rotate meter readers to different routes on a regular basis.

3. Meter reading errors

Errors can be easily introduced through negligence, aging meters, or even corruption during the process of reading the meters and billing customers. In competent or in experienced meter readers may read the meter incorrectly or make simple errors, such as placing a decimal in the wrong place (Malcolm,2008).The ages of pipes. Ages of meters also has an impact of the increase of water loss.

Customer meter errors include errors due to under or over registration of the meter (Lambert, 2003). Dirty dials, faulty meters, and jammed meters can also contribute to meter reading errors. The meter readers should immediately report any observed problems, and the maintenance team should take action to remedy the problem immediately. If remedial action is too slow, meter readers may become demoralized and less inclined to report problems. Because meter readers are the utility’s frontline in liaising with customers, their activities have an immediate impact on cash flow. Utility managers should therefore invest in training and motivating.

2.5.2. Physical loss (Real Losses)

Real losses are water volumes lost within a given period through all types of leaks, bursts and overflows. Physical losses, sometimes called real losses or leakage includes the total volume of water losses minus commercial losses .However, the water balance process indicates that commercial losses are estimated and therefore the resulting leakage volume may be incorrect (Malcolm, 2008). Can be classified according to (a) their location within the system and (b) their size and runtime.

a. Based on Location

1. Leakage from the Transmission and Distribution Mains

May occur at pipes (bursts due to extraneous causes or corrosion), joints (disconnection, damaged gaskets) and valves (operational or maintenance failure) and usually have medium to high flow rates and short to medium runtimes. And causes of leaks will vary depending on the nature of the soil, the quality of the construction, the materials used, the pressure levels and the utilities.

2. **Leakage from service connections: -** up to the point of the customer meter: service connections are sometimes referred to as the weak points of water supply networks, because their joints and fittings exhibit high failure rates. Leaks on service connections are difficult to detect due to their comparatively low flow rates and thus often have long runtimes.

2. **Leakage and overflows from storage tanks:-**are caused by deficient or damaged level controls. In addition, seepage may occur from masonry or concrete walls that are not water tight. Water losses from tanks are often underestimated and, though easy to detect, repair is usually elaborate and expensive.

3. **Size and runtime**

a. **Reported or visible leaks:-**primarily come from sudden bursts or ruptures of joints in big mains or distribution pipes. Leaking water will appear at the surface quickly depending on water pressure, leak size as well as on soil and surface characteristics. Special equipment is not required to locate the leak.

b. **Unreported or hidden leaks** by definition have flow rates greater than of the order of 250l/h at 50 m pressure but due to unfavorable conditions do not appear at the surface (WHO,2011).The presence of hidden leaks can be identified by analyzing trends in water consumption behavior within a defined water supply zone.

c. **Back ground leakage** comprises water losses with flow rates less than of the order of 250l/h at50 m pressure, which do not appear at the surface. These very small leaks (seeping or ripping water from leaky joints, valves or fittings) can not be detected using acoustic leak detection methods. Therefore it is assumed that many background leaks are never detected and repaired but leak until the defective part is eventually replaced. Background leaks often cause a major share of real water losses due to their great number and their long runtimes.

2.5.3. Non-Revenue Water (NRW)

Non revenue water (NRW) in a water distribution network is the water lost from unbilled authorized consumption, apparent losses, and real losses compared to the total system input volume (Yang, 2018)**.** Non revenue water is an important parameter for prioritizing water distribution network improvement intervention planning, and it is necessary to identify the affecting parameters. factor classification system has been developed based on the factors suggested by major institutions and researchers to propose an effective NRW classification system in a water distribution network .Factor classifications used include physical, operational, and socio economic factors that could affect NRW. Appropriate standards are required when classifying water main parameters. It must be possible to quantify selected parameter data. Whether the collected data are numerically valid and whether it can be used as a standard for assessment or comparison between regions must be examined. Quantification portion of the qualitative data in managing NRW is important and needs to be used in accordance with reasonable standards.

Table.2.5.Level of Non-Revenue Water in Towns of Ethiopia

S/N	Town	Level of leakage
1	Assosa	**48%**
2	Burayu	**23%**
3	Butajira	**22%**
4	Hossaena	**51%**
5	Miza-Aman	**61%**
6	Sebeta	**21%**
7	**Wolkitie**	**43%**

Source. Case Study Report of Water Aid Ethiopia (2010**)**

2.6. Causes of Water Losses

There are multiple causes for loss of water in transmission pipelines which include leakage, metering errors, public usage such as fire fighting, and theft (El-Abbasy, 2016)**.**The most critical route for losses is a leak, as they are considered to contribute an estimated of 70% of water loss in water transmission systems, this value is expected to become higher in undermanaged networks (Clayton, 2007). Comparatively, gas pipeline networks suffer from similar fates, yet the outcomes of leaks in gas pipelines can be more Water losses occur in every water distribution network (WDN) in the world. For economic and technical reasons, it has to be accepted that real water losses cannot be entirely eliminated. Nevertheless, there has been a large increase in the knowledge and development of state- of-the-art equipment, allowing us to manage water losses within economic limits. According to the WHO leakage management manual (2010). Leakage is usually the major components of water loss in developed countries, but this not always the case in developing or partial developed countries, where illegal connections, meter error or an accounting error are often more significant (Farley., 2010).The other components of total water loss are non-physical losses, e.g..meter under registration, illegal connections and unknown use (WHO,2006).Four key factors influence the degree of leakage within a utility's pipe network these are:-

- Availability of water, financial and personnel resources
- Infrastructural conditions regarding materials, system pressure and renewal policy
- Leakage control policy: activity, perception, technical expertise

- Institutional attitude with respect to structure, regulation ,politics

2.6.1. Causes of Real (Physical losses)

Pipes and fittings of different dimension, material and age are installed below ground, where they are subject to a multiplicity of factors which cannot be registered and controlled on a regular basis. Additionally, specify four key system-specific factors for real water losses, namely the length of the mains, the number of service connections, the location of the customer's meter and the average operating pressure in the system (when the system is pressurized).These factors vary from system to system (Lambert a. T., 2010). The multitude of active and passive interactions between pipes and their environment frequently lead to damage and leaks. In simple terms, the assets of water distribution networks comprise (a) pipes and joints, (b) valves and fittings and (c) storage tanks and pumps. The causes and factors influencing water losses thus can be classified according to the type of asset.

a) Defective pipe sand joints

❖ **Material ,condition and age of the pipe**

1. **Material:-**Besides material failures caused during manufacturing (insufficient wall thickness, absence of corrosion protection on steel pipes, poor reinforcement cover on concrete pipes), damage is also brought about by inappropriate use of certain materials: soft water (especially untreated water from dams) with a high carbonic acid (CO2) content and low calcium concentrations, or with high sulphate concentrations are known to affect concrete aggressively. Reinforced concrete pipes as well as the internal and external cement mortar lining of cast iron pipes are affected.
2. **Condition:-**Allmetallicpipesareexposedtophysicalandelectro-chemicalcorrosion.Corrosion will reduce the wall thickness and decrease the pipe's ability to withstand water pressure and external stress. The most common causes of corrosion are aggressive water and soil as well as stray current.
3. **Age of pipe:-**Many factors influencing leakage are age-dependent. Consequently, the age of a pipe section can appear to be the most significant factor for leakage. Nevertheless, age is not necessarily a factor, if the pipe has been carefully designed and installed, maintenances carried out at regular intervals and external conditions are favorable. Pipes age and material are important factors contributing to the burst probability of pipes that as a result cause of loss of water loss.

- **Design and installation, workmanship**

1. Design:-Mistakes made during the planning phase may influence leakage from pipes, such as the incorrect material choice, insufficient dimensioning for the actual pressure, inadequate corrosion protection measures or incorrect alignment (e.g. along slopes prone to land slides or adjacent to tree roots).

2. Storage and lying of pipes: -improper storage may damage pipes even before installation. Grass roots can penetrate the bituminous coating of steel pipes. Dragging PE pipes over concrete surfaces or stones was cause chamfers which are more susceptible to future leakage. Extended sunlight exposure causes PE pipes to become brittle. Heavy machinery used for transport and installation may also cause damage.

3. Bedding:-the selection of inappropriate material for pipe bedding is a frequent cause of damage: Course or rocky bedding material spoil external coatings on steel or cast iron pipes and support corrosion. Longitudinal and spiral cracks may appear in PE and PVC pipes as a result of stony bedding materials. Insufficient back fill and compaction of the pipe trench may cause subsidence. These uncontrolled soil movements can also trigger socket disconnection or pipe ruptures.

4. Joints:-Unprofessional execution of pipe joints is a further reason for leakage. Welded steel pipes often lack proper internal and external corrosion protection along the weld seam. If unskilled or poorly trained welders execute the relatively new technique of welding PE pipes, it frequently contains defects due to insufficient heating and pressing of the pipe ends. Leakage can also occur if socket pipes exceed the maximum permitted angular bending or if water hammer and high pressures affect joints that are not force locked.

- **Pressure**

1. Highpressure:-Increasingpressurewasresultinahigherflowratefromexistingleaksandan augmented occurrence of new pipe bursts and leaks. Aged valves and fittings may lack sufficiently robust dimensioning for high pressures.

2. Poor pressure:-Poor pressure may complicate leak detection efforts because the water is less likely to reach the surface. Furthermore, decreased noise levels from the leak impede acoustic leak location methods and may cause longer leak runtimes.

3. Pressure variations: marked variations in pressure within the system may lead to material fatigue and thus to leakage, mainly in plastic pipes.

4. Pressure surges: pressure surges (water hammer) mainly arise from inappropriate control mechanisms and can cause pipe fractures, disconnect joints and damage valves and fittings, hence leading to leakage.

- ❖ **Soil and ground water**

1. **Soil type:** The prevailing soil type has significant effect on the runtime of leaks. While water escaping into cohesive soils (e.g. clay or silt) may soon appear at the surface, leaks into non cohesive soils (e.g. sand or gravel) tend to drain away below ground, making leaks more difficult to detect.

2. **Soil Aggressiveness:** most non-cohesive soils are not aggressive. Cohesive soils may negatively affect the external corrosion of metallic pipes due to differing levels of dissolved salts, oxygen, moisture, pH and bacterial activity.

3. **Soil movement:** soil movement is caused by changes in the temperature and moisture content (changing groundwater levels cause cohesive soils to contract or expand), heavy frost as well as subsidence prompted by incorrect pipe bedding, mining activities or earthquakes. Construction work, increased surface loads or pipe repair works may also trigger soil movement. Soil movement may cause pipe joints to disconnect and pipes to rupture.

- ❖ **Traffic**

1. **Traffic load:** many pipes that were originally laid underneath pavements are now situated under the roads as traffic and road widths have increased. More vehicles and the high axle loading of modern trucks place an additional burden on the pipes.

2. **Pavement:** the water outlet may appear far away from the damage due to concrete and tarmac pavements, thus hampering leak location efforts.

3. **Stray current:** 1ampere erodes approximately10kg of iron each year. Stray currents from DC-powered railway systems (trams) and reinforced concrete foundations thus aggravate the external corrosion of metallic pipes. (Oppinger P., 2009)

(b) Third-party influence:-the absence of infrastructure documentation (e.g. as-built drawings) or improper execution of construction work may damage pipes, either directly through excavators or indirectly through vibrating construction machines or heavy vehicles. Damage may be detected instantly or after a delay, making the cause harder to detect.

(c) **Defective valves and fittings**:-Leaks from valves and fittings include breakage, deformations or material failures at the valve body as well as leaking gaskets at joints, bonnets or stems. Rough handling or an absence of maintenance often causes these leaks. Defective valves and fittings may contribute significantly to real water losses in spite of rather slow leak rates. These deficits often remain undiscovered for a long time without a regular servicing program. Considerable water losses may also occur from defective fire hydrants and public water standpipes.

(d) **Defective storage tanks and pumps:-**Water losses from storage tanks are caused both by structural damage and by operational failures, such as faulty or lacking system controls which may result in overflow. Structural damage involves cracks, holes or delaminating at tank walls or floors, leakage due to inferior concrete quality, as well as sealing's and pipe penetrations that are not watertight. Water losses from tanks are often underestimated and, though easy to detect, repairs are usually elaborate and expensive. Water losses from pumps are usually caused by defective pump shaft seals. The amount of leakage is negligible in most cases, but flooding pump chambers and electric equipment is a nuisance and should be avoided by undertaking proper maintenance.

2.6.2. Causes for Commercial loss (Apparent losses)

Apparent water losses are caused by (a) water meter inaccuracies, (b) data handling errors and(c) any form of unauthorized consumption. Apparent losses should not be underestimated, because they do not generate revenue for water that has already been produced, treated, transported and delivered to the customer. Reasons for apparent losses can be grouped as described on the next :(Thornton, 2008.)

b. **Meter Inaccuracies:-**Metering losses are frequently the most common form of apparent losses. Experience shows that a small percentage of water is not metered or metered incorrectly due to measuring errors or creeping losses in water meters. This affects both customer meters and bulk water meters, and may be caused by selecting unsuitable meters, over sized meters, incorrect installation and uncelebrated meters as well as many meters' deteriorating performance over time.

c. **Data Handling Errors:-**Meter-reading personnel may make meter-reading errors. Water consumption data may get lost or changed due to systematic errors in data processing and billing procedures. Unmetered consumption (own needs and free supplies for firefighting, watering of greens, Street cleaning, etc.) may be under estimated while unmetered production may be over estimated. Flat- rate tariffs may cause excessive domestic water consumption that by far exceeds the budgeted amount.

d. **Unauthorized consumption:-**Unauthorized water extraction represents a considerable source of losses in many countries and appears in many different ways, for example illegal connections, vandalized, manipulated or bypassed customer meters, illegal water abstraction from fire hydrants as well as bribery and corruption of meter-readers or other utility personnel.

2.7. Water Loss Management

Water loss reduction should be the aim of every water utility since it leads to improved economic and ecological efficiency and better service for clients.(Thornton,2008.)Before developing a water loss reduction strategy, decision-makers should be aware of why it makes sense to provide financial and personnel resources to reduce water losses. From the perspective of a water utility, there are at least ten reasons that may justify increased expenditure on water loss management:

- **Operating cost efficiency:-**A well-maintained water distribution system was requiring fewer repairs, lower production costs and prevents compensation payments.
- **Capital cost efficiency:-**A lack of maintenance and intermittent operation increase wear and tear on pipes valves and meters. Improved supply will extend the service life of the system components and lead to lower fixed costs for the water utility in the long run.
- **Improved metering and billing:-**Fewer leaks and an improved supply situation may also have positive effects on apparent water losses because air inside the distribution system can cause metering errors.
- **Reduced health risks:** Sewage and other pollutants can infiltrate the pipe system through leaks and trigger water-borne diseases in low-pressure systems or in the case of intermittent operation.
- **Increased security of supply:** A well-maintained system with fewer leaks and bursts will increase the supply guarantee.
- **Less infrastructural damages:** Leakage might create voids below ground which can lead

roads and buildings to collapse.

- **Reduced loads on sewers:** Infiltration of water lost to sewers places an additional load on sewer pipes and wastewater treatment plants.

2.8. Consequences of Water Loss & Leakage

Improved consumer satisfaction:-In addition to poor water quality, in adequate quantity and health risks, leakages also decrease the pressure at customers' appliances. Enhancing the supply service will improve customer satisfaction and willingness to pay.

Publicity and willingness to pay:

Fewer bursts, increased security of supply and hygienic conditions was enhance the public's perception of the water utility. This may also positively affect the consumers' willingness to pay.

Reduced ecological stress:-Finally, the development of a water loss reduction strategy makes sense from an ecological point of view.In the case of scarce or over-exploited water sources, water losses should be reduced to decrease the stress on these resources.

The primary consequence of leaks in distribution system is financial. Reduction in water loss enables water utilities to use existing facilities efficiently. Alleviate shortage of water supply. When it comes to operating water supply systems, water losses are a clear obstacle to sustainability, as the following list of potential impacts shows:

- **Economic impacts:** Costs for exploiting, treating and transporting water which is lost on its way to the customer without generating any revenue for the water utility. Pipe bursts and leaks necessitate expensive repair works and may also cause considerable damage to nearby infrastructure.

- **Technical impacts:** Leakage leads to reduced coverage of the existing water demand, possibly so much so that the system can no longer operate continuously. Intermittent supply will cause further technical problems by air intruding into the pipes and will tempt customers to install private storage tanks.

- **Social impacts:** Water losses result in customers being adversely affected by supply failures, such as low pressure, service interruptions and unequal supply, but also by health risks which may arise from the infiltration of sewage and other pollutants into pipe systems under low pressure or intermittent supply.

- **Ecological impacts:** Compensating water losses by further increasing water extraction places additional stress on water resources and require.

Additional energy and thus causes carbon dioxide emissions that could have been avoided. These few examples impressively demonstrate that water loss impairs all aspects of operating a water supply system sustainably. Thus strive to analyses, quantify, combat and reduce physical and apparent water losses from their water supply systems .A successful and sustainable reduction in water losses requires apolitical and financial frame work that encourages water loss reduction activities by means of binding Regulations, incentives, benchmarking and setting leakage targets.

2.9. Leakage Monitoring and Control

The losses of water are inevitable in the process of supplying thousands of customers spread over a large area started from reservoirs at the treatment plants. Through complex network to the individual customer. It is there for important to ensure that leakage monitoring and control is given the attention it deserves by all waters supply authorities and consumers (MULafu.et al., 2003).

2.9.1. Identifying Leaks through Visual Inspection

In this method a leak may be self-evident because of water shows on the surface or may become so upon investigation flowing consumer complaints such as poor pressure or noise in the plumbing system (Walling ford HR., 2003).

2.9.2. Identifying Leaks through Using Detection Equipment

Most of the water is lost through numerous small holes, which are very difficult to locate, as the pipes are laid underground that usually need special equipment to locate the leak and repair. The leak noise detected will depend upon the position at which a sounding is made

2.9.3. Location of Large Leaks by Pressure Control

A large leak in a small network can be located by measuring the pressure during the time of minimum water supply especially during the night. This can be done by shutting of the valves in successive election of the distribution starting from the supply. Pressure control is a necessary tool for the technical management of the system and combined with any other methods of water loss estimation could give very useful information in order to identify the cause of water loss through leakage (Walling ford HR., 2003).

2.10. Distribution Network

The distribution network is responsible for delivering water from the source or treatment facilities to its consumers at service able pressures and mainly consists of pipes, pumps, junctions (nodes), valves, Fittings and storage tanks. Water distribution networks play an important role in modern societies being its proper operation directly related to the population's well-being. A completely satisfactory water distribution system should fulfill its basic requirements such as providing the expected quality and quantity of water during its entire lifetime for the expected loading conditions with the desired residual pressures (Misirdali, 2003).Water distribution systems can be either looped or branched. Looped systems are generally more desirable than branched system because, in the looped system, breaking of pipe can be isolated and repaired with little impact on consumers outside the immediate area. On the other hand, in the branched system, all the consumers downstream from the break will have their water supply interrupted until the repairs are finished (Atiquzzaman, 2004). Water supply and distribution systems serve many critical functions and play a large part in achieving human and economic health. Despite this, the performance of these systems often goes unnoticed until there is a major disruption or operational failure. While failure events are likely inevitable, often dramatic and costly, day- to-day, inefficient performance of WDS also entails great economic, social and environmental burdens. The most common challenges in water distribution networks include water quality degradation, capacity shortages, infrastructure aging and deterioration, and increasing demand (Jalal, 2008).

2.10.1. Water Distribution

For efficient distribution, it is required that water should reach end use with required flow rate with needed pressure in the piping system. There are three main types of distribution system that can be adopted in villages/towns:

Gravity Fed Distribution:-When the ground level of water source/storage is sufficiently raised than the core village/town area, such system can be utilized for distribution.

Pumping System;-In such system, water is supplied by continuous pumping. Treated water is directly pumped into the distribution main with content pressure without intermediate storing. Supply can be affected during power failure and breakdown of pumps. Hence, diesel pumps also in addition to electrical pumps as stand by to be maintained. Such system works only in condition where there is continuous power supply, reliable water source and where intermediate storage system cannot be installed.

Dual/Combination:-in such system, both gravity as well pumping systems are used. Such systems are used where there are variations in topography in town/village.

2.10.2. Pipe line Distribution Networks

Pipeline distribution networks are aimed at design of suitable routes for piping. It is very important for proper water pressure, capital cost and operation and maintenance cost. Different types of networks are adopted looking to the pressure requirement, operation and maintenance (O&M) strategy adopted, cost parameter and overall length of distribution system (Maharashtra Jeevan Pradhikaran, 2012).

- **Dead end distribution system**:-in such system, sub main pipes are connected at right angles from main pipeline and branch pipes are connected to sub mains at right angles.
- **Grid Iron System:-**in such system; main, sub main and Brach pipes are interconnected to each other. A grid system is laid. Here, total length of pipeline required is high, but this helps in equitable water pressure.
- **Circular or Ring System:-**The whole system is enclosed by main pipeline in radial or rectangular shape. Smaller areas are enclosed by sub main pipeline.
- **Radial System:-**the area is divided into different zones. The water is pumped into the distribution reservoir kept in the middle of each zone and the supply pipes are laid radically ending towards the periphery.

2.11. Drinking Water Quality

Water quality is a term used to express the suitability of water to sustain various uses or processes (WHO, 2006).Water quality is affected by anthropogenic activities and natural processes. In order to prevent and reduce the problems associated with water, there are national and international standards or guidelines to be followed for water quality suitable for Different purposes (drinking, personal hygiene, irrigation, etc).Components of water quality include microbial or biological, chemical, and physical aspects.

2.11.1. Microbial Aspects

Drinking water should be free of all pathogenic micro-organisms. It should also not contain bacteria that would indicate excremental pollution, the primary indicator of which are coli form bacteria that are present in the feces of warm-blooded animals. By using specified treatment techniques, the Microbial quality of drinking water is controlled and the presence of coli form bacteria is monitored (Mark and Mark, 2005). Chlorine is the usual disinfectant.

2.11.2. Chemical Aspects

Chemical contamination of water sources may be due to certain industries and agricultural practices, municipal solid waste, urban runoff or from natural sources. When toxic chemicals are present in drinking water, there is the potential that they may cause either acute or chronic health effects. After exposure of chemicals in drinking water for extended years rather than months they become of health concern (WHO, 2006). Chronic health effects are more common than acute effects because the levels of chemicals in drinking water are seldom high enough to cause acute health effects. There are many evidences that chemical contaminants created adverse human health problems in urban water sheds (EPA, 2005).

2.11.3. Physical Aspects

Water for drinking should be free of objectionable taste, odor, color and suspended materials. These are often called aesthetic parameters. Aesthetic parameters are those detectable by the senses, namely turbidity, color, taste, and odor. They are important in monitoring community water supplies because they may cause the water supply to be rejected and alternative (possibly poorer-quality) sources to be adopted, and they are simple and inexpensive to monitor qualitatively in the field. Physical Parameter of water includes also such parameters as pH, TDS, salinity and hardness. The chemical quality influences also the physical quality. The appearance, taste, odor, and feel of water determine what people experience when they drink or use water and how they rate its quality; other physical characteristics can suggest whether corrosion and encrustation are likely to be significant problems in pipes or fittings .The measurable characteristics that determine these largely subjective qualities are: true color(i.e. the color that remains after any suspended particles have been removed), turbidity(the cloudiness caused by fine suspended matter in the water),hardness(the reduced ability to get a lather using soap), total dissolved solids(TDS), pH, temperature, taste, odor and dissolved oxygen(ADWG, 2006).

2.11.4. Biological aspects

Water naturally contains a diverse population of living organisms, such as aquatic plants, animals, algae, bacteria, parasites and viruses. Some of these organisms are harmless and others can be harmful to humans. Those of greatest concern to us are pathogens, or disease causing organisms. We sometimes refer to these pathogens as microorganisms, microbes or bugs, depending on the local language and country. In the 21st century, contaminated water is the world's second biggest killer of children. Every year some 1.5 million people die as a result of diarrhea and other diseases caused by unclean water and poor sanitation. Close to half of all people in developing countries suffer at any given time from a health problem caused by water and sanitation deficits (UNDP, 2006). The WHO Guidelines for Drinking Water Quality highlight that infectious diseases caused by pathogenic bacteria, viruses, protozoa and helminthes are common in drinking water and inflict wide spread health effects. Although there are several contaminants in water that may be harmful to humans, the first priority is to ensure that drinking water is free of microorganisms that cause disease (WHO, 2006).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Site Description

Hawassa town is the capital for the Southern Nations, Nationalities and Peoples Regional Government (SNNPRG), Hawassa City Administration and Sidama zone. It is located at a distance of 275 km South of Addis Ababa.. It is located at a distance of 275 km South of Addis Ababa. The geographic coordinates of the town is between latitude 6°48'45"- 7°14'49"N, and longitude 38°16'34"- 38°43'26"E. The average altitude of 1700m.a.s.l and the town has got plain topography of urbanized area.

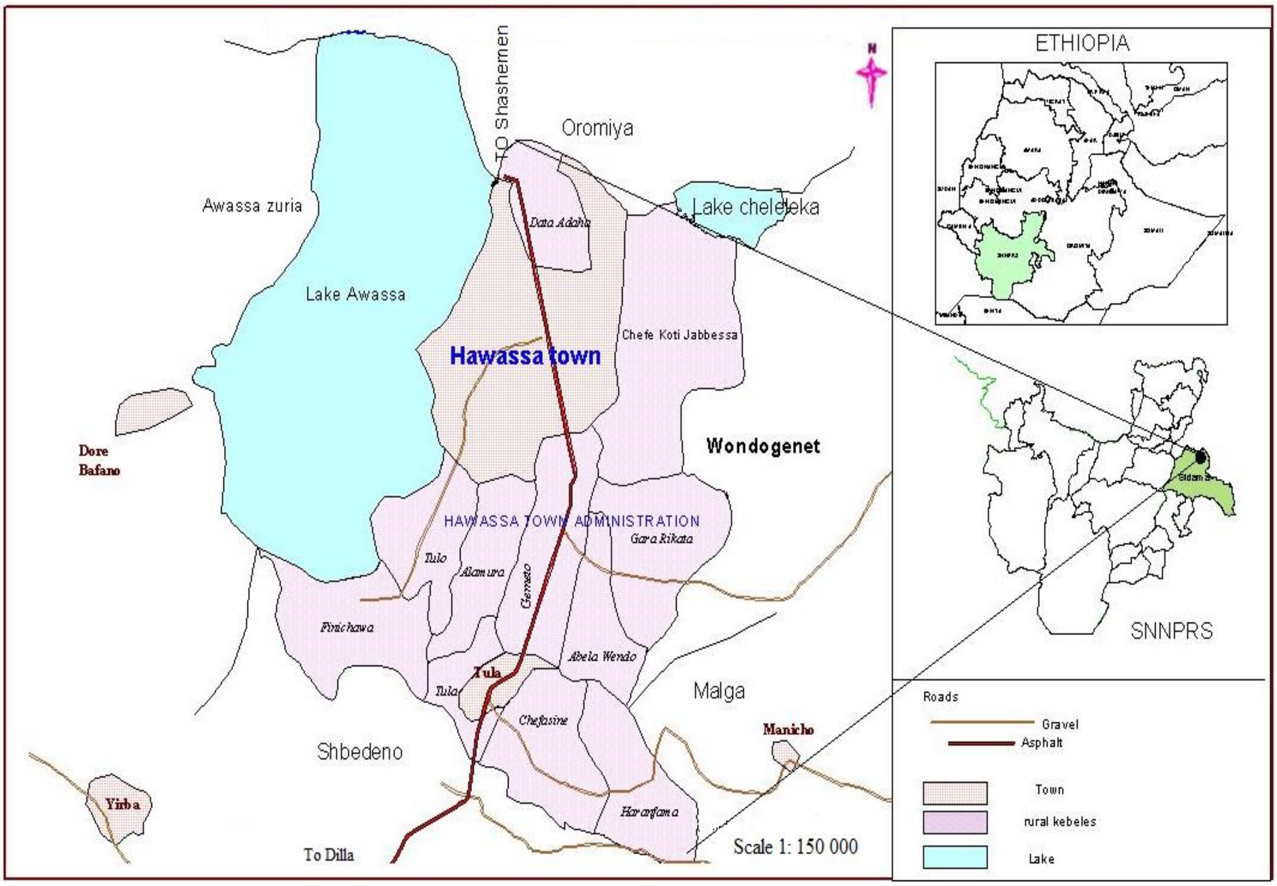


Figure 3.1: Location map of Hawassa Town (SNRGS, Bureau of Finance and Economic development, HC Statistics Department)

The City Administration has an area of 157.2 km^2 and divided into eight sub-cities and 32 kebeles for administrative purposes. These sub-cities are Tabor, Addis-Ketema, Mahal-Ketema, Hayik-Dar, Menaheria, Hawela-Tula, Bahil-Aderash and Misrak (Hawassa Socio-Economic Profile report, Jan. 2013). The city is the economic and cultural hub of the region.

3.1.1. Climate

Hawassa climate is warm temperature which varies between 10ºC in winter and 30ºc in summer. The mean annual precipitation of the city is 956mm. The mean maximum precipitation in rainy season is about 126mm in the month of September. There are daily sunshine hours ranging between 4 hours during rainy season and 9 hours during dry season. The relative humidity varies between 40% and 90% over the year. The average wind speed is recorded between 0.6m/s and 1.1m/s.

Cesen and Ansaldo (1987) estimated that the annual potential Evapo transpiration (PET) to be 1255mm for the station at Hawassa, with minimum of 81mm in the month of July and maximum of 135mm in January. According to the National Meteorological Authority, the annual estimated PET for the station at Hawassa is about 1599mm, with minimum of 102mm in the month of July and maximum of 173mm in December.

Hawassa town is situated at the Eastern shore of Lake Hawassa close to the eastern fault belt of the central part of the Main Ethiopian Rift Valley in a large volcano-tectonic collapse. The town is located on a plain between Lake Hawassa and Lake Chelelaka with general slope towards lake the drainage of the town is towards the lake at present and the lake has submerged some part of the western side of the town due to the continuous rise of the lake level.

A number of streams and rivers such as kedo, Boga, Afina, Wosha and Werka drain into Lake Hawassa basin which covers a Surface area of 1360km^2. The rivers Such as kedo, Afina, Abosa and Boga have minimum flow that ranges from zero (Abosa river)to329l/s for (Kedo River) and the 95% reliable flow ranges from 40l/s (Abosa river) to 190 l/s (kedo river).Based on the precipitation, evapo -transpiration and open-water evaporation data, the total annual recharge into the Lake Hawassa Basin has been estimated about 103,247,040m^3,whichis3270l/s.About38% of the above amount (39, 462, 210m^3 or1250 l/s) recharges the Cheleleka basin East of Hawassa where drilled wells are situated (CES and Tropics consulting Engineers, 2002).

3.1.2. Population

Population projection value under the sub city level which is published in August 2013 has gathered from the Ethiopian Central Statistical Agency (CSA) which is based on at zonal and woreda levels by urban and rural residence. According to this document the total projected value for the Hawassa city on the year of 2018 is taken as 485,816 with a projection rate of 4.8% per year of urban and 2.8% per year of rural. Prior to this as per the data of Hawassa city administration Finance and Economy Department, the study area has a total population of 573,699 with average number of occupants per household 5.5 for the year 2022/23.The detail information is presented.

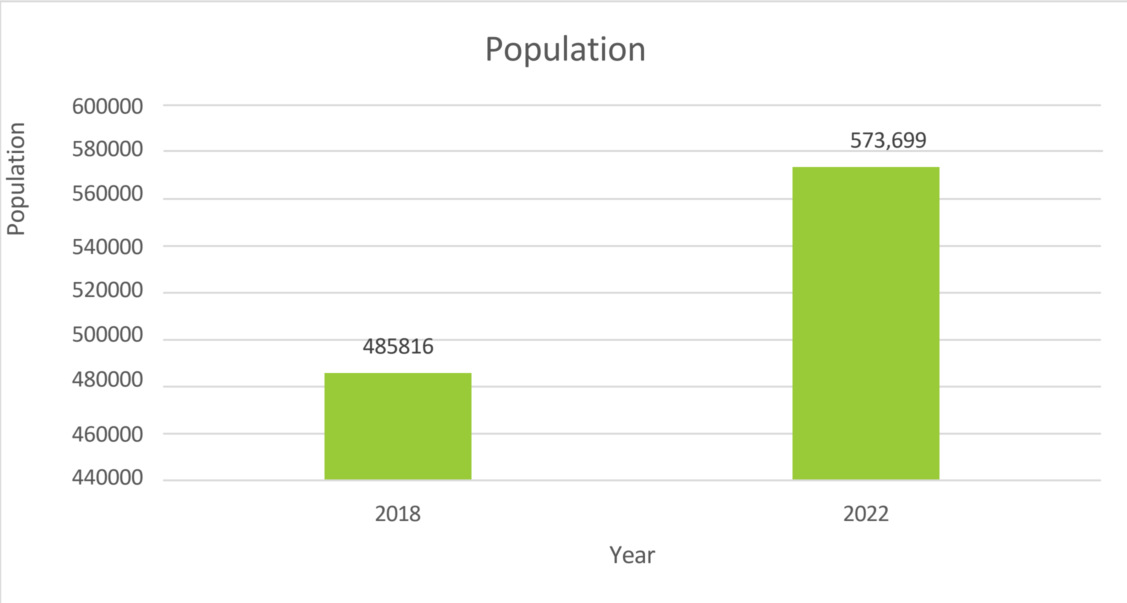


Figure.3.2.population Vs year chart

3.1.3. Socio-economic activities

There are intensive and diversified modern investments activities such as hotels and tourism, social services, real estate development, industries and construction in the town. Hawassa town is the centre for high level education and trainings in the region. There is one university, three Teachers Training Institutes, one Water Technology College, and number of private Health, Engineering and other education colleges (HCA, 2011).

The town fulfills all infrastructural facilities vital for any type of investment. The socio-economic standard of the people in the town depend on diversified small to large business activities, government and non-governmental organization (NGO) employees, and labor works.

Hawassa Town Water Supply and Sewerage Service Enterprise (HTWSSSE) has been established according to Proclamation No. 40/2002 of the Regional Government, and has also been re-established as Class 1 town water service. At present, the HTWSSSE is organized as an autonomous public organization under the Hawassa City administration administered by Water Board. The Hawassa Town Water Board (HTWB) is the higher level organ mainly responsible for Policy formulations and strategic management including budget approvals for the Hawassa Town Water Supply and Sewerage Service Enterprise.

The top executive is the head of the Water Supply and Sewerage Service Enterprise of Hawassa Town with Water Supply and Scheme Administration, Purchasing, Finance and Property Administration and Human Resources Administration being directly responsible to executive. Hawassa Town Water Supply and Sewerage Service Enterprise have a total of 117 staff members. In order to improve the existing water supply service by HTWSSSE, Business Process Reengineering (BPR) has been designed. The BPR clearly defines the duties and responsibilities of each manpower allocated at his/her responsible area. Up on the implementation of BPR, the service given by the office is set to improve in order to satisfy the ever increasing water demand of the town both in terms of quality and quantity.

The Enterprise has five sub branches namely Alamura, Dato-Odahe, Gudumale, Halade and Tula water services. The Hawassa Town Water Supply and Sewerage Service Enterprise, according to the government policy has to function on cost recovery basis. Accordingly, the water supply system that would be developed for the town has to be cost effective and economical so that it would be affordable by the customers.

3.2. Materials

- ✓ ARC Map GIS version10.1: For delineate location of the study area and related work.
- ✓ Auto CAD version 2015: For draw scheme layout of water supply system.
- ✓ Excel Spreadsheet 2013: For data preparation analysis and interpretation of results.
- ✓ Portable Spectrophotometer DR/6000: for chemical analysis test
- ✓ GPS: during the field survey data to collect x, y, and z co ordinates of existing supply source

3.3. Methods

The Stages of the study was divided in to three.

- The first stage of the study was desk study concentrating on literature review and development of data gathering methods.

- The second stage involved data gathering from legal organizations, field data collection from selected area of the Hawassa town and discussions with the local experts of the town water supply authority.
- The third stage is to analyze the collected data, identify problems towards answering the research questions.

The activities in each of these phases are described in the consecutive sub-sections .Finally, from analyzed data problems identified and remedial measures was suggested.

3.4. Data Collection and Preparation

The work plan of the study proposes both primary and secondary data was collected. Secondary data was collected from the town administrative municipality office, the town water supply service and at the field from the distribution system, some supplementary information was also collected from Abay plc Consulting Engineers (MSC) design reports.

During the field visit, other secondary data includes various published and unpublished documents, annual reports and project or design documents etc. This information include source wells, water reservoirs, mains length of pipes , number of service connections, customer meter, average pressure, system input volumes, authorized and unauthorized consumption, tariff, population data, and other related data and information.

3.4.1. Primary Data Collection

The primary data gathering technique include household survey, field visit, key information interviews, customer satisfaction, focus group discussion, and personal observation and informal discussion.

- GPS and Google Earth to obtain a good picture of the research area.

- **Field survey data of existing supply source**

Table.3.1.Number of existing supply source with yield capacity (springs. River and boreholes)

	Water Supply Infrastructure & Water Production								
1									
#	Type of Water Supply Scheme and Water Source	Year of Construction	Yield: Design capacity (ltr/second) (m3/day)[1]	Status (Functional / Non-functional)	Operational capacity (yield) (ltr/sec), (M3/day)[2]	Pumping hours in a day (hr)	Distance from Town (KM)	GPS coordinates	Source of energy
A	**Boreholes**								
1	AbelaWondo # 1	2007E.C	12	Functional	7	18	9	E=446365 N=770929 Z=1724	EEPCo& Standby Generator
2	AbelaWondo # 2	2007E.C	12	Functional	6	18	10	E=447171 N=770245 Z=1745	EEPCo& Standby Generator
3	AbelaWondo school # 3	2013 G.C	13	Functional	12.9	18	10	E=446375 N=770333 Z=1741	EEPCo& Standby Generator
4	Garareketa 1	2002 E.C	30	Functional	31.7	18	14	E=447760 N=771217 Z=1700	EEPCo& Standby Generator
5	Garareketa2	2002 E.C	30	Functional	31.4	18	16	E=448400 N=770948 Z=1715	EEPCo& Standby Generator
6	Garareketa3	2002 E.C	30	Non-functional	0	18	16	E=0448470 N=771190 Z=1709	EEPCo& Standby Generator
7	Gemeto (Mete#1 new)	1999 E.C	13	Functional	8	18	9	E=445603 N=770648 Z=1724	EEPCo& Standby Generator
8	Gemeto (Mete#2 new)	2006 E.C	22	Non-functional	0	18	9	E=445303 N=770493 Z=1727	EEPCo& Standby Generator
9	Awassatreat.plant BH	1992 E.C	7.3	Non-functional	0	18	17	E=447465 N=768772 Z=1721	EEPCo& Standby Generator
10	Yowokebele P1	2004 E.C	50	Functional	18.8	18	15	E=449214 N=771791 Z=1711	EEPCo& Standby Generator
11	Yowokebele P2	2010 E.C	50	Non-functional	0	18	17	E=449360 N=770943 Z=1705	EEPCo& Standby Generator(but know no EEPCO

									power)
12	Yowokebele P3	2010 E.C	50	Functional	34.6	18	17	E=449976 N=771497 Z=1705	EEPCo& Standby Generator
13	Yowokebele P4	2004 E.C	50	Functional	28.9	18	18	E=449926 N=770917 Z=1714	EEPCo& Standby Generator
14	Garariketa P5	2004 E.C	50	Functional	20.2	18	14	E=447977 N=771948 Z=1714	EEPCo& Standby Generator
15	Garariketa P6	2004 E.C	50	Functional	23.3	18	15	E=448528 N=772643 Z=1705	EEPCo& Standby Generator
16	Garariketa P7 (To Ere do)	2007 E.C	50	Functional	51.4	18	15	E=448118 N=772982 Z=1705	EEPCO
17	GemetoP8(To MR)	2007 E.C	50	Functional	67.2	18	7	E=445269 N=773012 Z=1701	EEPCO
18	G3meto P9	2007 E.C	30	Non-functional	0	18	6.5	E=44269 N=773012 Z=1701	No Power
19	Alamura(kerara)	2006 E.C	16.5	Functional	6.4	18	11	E=441352 N=770743 Z=1762	EEPCo& Standby Generator
20	Alamura(Boko)	2013G.C	16.75	Non-functional	0	18	10	E=442184 N=771188 Z=1755	EEPCo
21	Gemeto–FTC	2006 E.C	25	Functional	23.7	18	8	E=443886 N=771378 Z=1719	EEPCO
22	Gemeto Beshema BH	2006 E.C	25	Functional	18.8	18	9.5	E=443886 N=771378 Z=1719	EEPCO
B	**River**								
23	KedoRiver /intake1/ Treatment Plant	1975 E.C	38.8	Functional	20.8	24	17	E=451701 N=766610 **Z= 1578**	Gravity
C	**Spring**								
24	Ambowha Spring 1	2004 E.C	55	Functional	55	12	9	E=453133.8 N=785238 Z=1701	EEPCO
25	Beshema Spring 2		6	Functional	6	18	9.5	E=444669 N=770817 Z=1723	EEPCO
26	Loke Spring 3	1989 E.C	13	Functional	13	24	11	E=436890 N=771918 Z=1694	EEPCo& Standby Generator
	Total production (m3/day)		51,469.56		30,976.56				

3.4.2. Projection of Population

Direct population count and projection based on pre-counted population are two possible approaches to collect population data. However, since direct population count at any time requires a great deal of resource and time, it is not usually preferred. Different population forecasting methods are in fact available and can be used for population projection. But their result varies from one method to another. For fast growing city, where relatively high economic activity is observed and at the same time continuous expansion of city due to various reasons is experienced, exponential method population forecasting is preferably used (Ministry of Water Resources of Ethiopia,2012). According to this document the total projected value for the Hawassa city on the year of 2018 G.C is taken as 485,816 with a projection rate of 4.8% per year of urban and2.8%per year of rural and .Prior to this as per the data of Hawassa city administration Finance and Economy Department, the study area has a total population of 573,699 with average number of occupants per household 5.5 for the year 2022.

$$\mathbf{P_t = p_o\,(1+k)^n} \qquad (3.1)$$

P_t= Future population

P_o= Existing population

K = percentage growth rate

n= the design period in year

3.4.3. Secondary Data Collection

Secondary data was collected from legal organizations, agencies, and literatures, the following secondary data include:-

Table 3.2. Data of functionality status of Existing water supply boreholes

s. n o	Name of boreholes	Amount of yield l/sec	GPS location	Drilling year	Static water level (m)	Dynamic water level (m)	Pump position	Depth of borehole	Diameter Inch (type of Pipe is DCI
1	AbelaWondo#1	7	E=446365 N=770929 Z=1724	2007E.C	22	23	39	70	11
2	AbelaWondo#2	6	E=447171 N=770245 Z=1745	2007E.C	10.8	30.65	30	50	14
3	Abella Wondo school # 3	12.9	E=446375 N=770333 Z=1741	2013 G.C	22	23	53.5	170	10
4	Garareketa1	31.7	E=447760 N=771217 Z=1700	2002 E.C	5.13	24.3	48	107	12"
5	Garareketa2	31.4	E=448400 N=770948 Z=1715	2002 E.C	5.55	13.36	41	50	10
6	Gemeto (Mete#1new)	8	E=445603 N=770648 Z=1724	1999 E.C	5.55	13.36	92	150	14,12
7	YowokebeleP1	18.8	E=449214 N=771791 Z=1711	2004 E.C	10.8	30.65	100.5	55.6	10
8	YowokebeleP3	34.6	E=449976 N=771497 Z=1705	2010 E.C	37.9	39.91	25.7	95	10 "
9	YowokebeleP4	28.9	E=449926 N=770917 Z=1714	2004 E.C	2.87	4.89	71	62.15	14,12
10	Garariketa P5	20.2	E=447977 N=771948 Z=1714	2004 E.C	39.3	41.78	46	100	10 "
11	Garariketa P6	23.3	E=448528 N=772643 Z=1705	2004 E.C	6.5	15.65	73	110	14,12
12	Garariketa P7(To Eredo)	51.4	E=448118 N=772982 Z=1705	2007 E.C	26.6	32.03	54	130	10 "
13	Gemeto P8 (To MR)	67.2	E=445269 N=773012 Z=1701	2007 E.C	37.9	39.91	80	200	13,12

14	Gemeto Beshima	18.8	E=443886 N=771378 Z=1719	2006 E.C	6.6	8.4	107	168	15,11
15	Alamura (kerara)	6.4	E=441352 N=770743 Z=1762	2004 E.C	8.53	9.83	120	175	13,8
16	Gemeto–FTC	23.7	E=443886 N=771378 Z=1719	2007 E.C	6.5	15.65	56	193	16,6

Out of 22 existing drilled boreholes to supply water sixteen (16) boreholes are functional and six (6) are non functional due to shortage of budget and high iron or excessive iron content.

Non functional boreholes they are:-

1. Gara riketa3,
2. Gemeto or mete 2new,
3. Hawassa treatment borehole,
4. Yuwo kebelep2,
5. Gemeto p9 and
6. Alamura (boko) are non-functional bore holes

3.4.4. Existing service Reservoir and booster stations with yield capacity

Table 3.3. Existing service reservoirs and booster stations

	Service Reservoirs	Discharge Capacity of reservoir by volume(m3)	Type of structure	Status of reservoir	year of construction	GPS location	Existing pump head
1	Loke reservoir	200	concrete	functional	1989		
2	SebategnaKampreservoir	500	concrete	functional	1975	N=776,955 E=443,923 Z=1764m	
3	SebategnaKampreservoir	500	concrete	functional	1975		
4	Eredo mountain reservoir	1000	Paioner	functional	2004	N=783,268 E= 461,441 Z=1996m	

5	Sebategna Kamp new reservoir	500	concrete	functional	1997		
6	Sebategna Kamp new reservoir	4000	concrete	functional	2010	N=776,708 E=444,118 Z=1778m	
7	Sebategna Kamp new reservoir	2660	Pioneer	non functional	2008	N=678,540 E=387,234 Z=187m	
8	Zelalem Park Alamura mountain reservoir	50	Masonry /sandwich	functional	1993	N=568,906 E=467,345 Z=165m	
9	Abelawondo Mure reservoir	200	Paioner	functional	2005	N=891,233 E=432,122 Z=179m	
10	Alamura-karara	100	Monsory (sandwich)	functional	2006	N=423,133 E=656,422 Z=189m	
11	Tula- Boko	300	concrete	functional	2006	N=556,221 E=497,465 Z=180m	
12	Tula town	100	concrete	functional	1993	N=446,926 E=670,917 Z=171m	
13	Haranfama reservoir	300	concrete	functional	2005	N=545603 E=670648 Z=174m	
14	Referral reservoir	200	concrete	functional	2009	N=436890 E=771918 Z=169m	
15	Eredo mountain reservoir	1000	concrete	functional	2010	N=449,118 E=372,982 Z=177m	
16	Alamura FM reservoir	300	concrete	functional	2009	N=445,886 E=471,378 Z=179m	
17	Chafasine reservoir	100	concrete	functional	1999	N=435,269 E=371,012 Z=171m	
	Booster station						
18	Abela BS	100	concrete	functional	2005	N=546375 E=470333 Z=174m	
19	Haranfama BS	50	concrete	functional	2005	N=548528 E=672643 Z=178m	

20	Gemeto BS	300	concrete	functional	2011	N=443886 E=771378 Z=179m	
21	Burkito BS	300	concrete	functional	2007	N=555,145 E=355,561 Z=177m	
	Total storage capacity available at the moment	10,400 m^3/day					

3.4.5. Mode of services in water consumption by per service of connections

Table.3.4. percentage of served population of supply water by mode of service with existing water connections

S/N	Connection Type	% of Population By mode of Service	Number of population By connection	Total number Of population
1	Privet house connection	92	42,261	**527,775.48**
2	Public Tap User	8	828	**45893.52**
	Total	**100**	**43,089**	**573,669**

3.4.6. Customer data as per level of connection

These data were collected which used to analysis the coverage. From Hawassa town water supply and sewerage enterprise yearly report collected the yearly customer data are shows in the following table.

Table.3.4.customer data as per level of connection.

Type of customers	Year2015
Domestic	**42,261**
For public	**828**
Commercial	**3384**
Institutions	**276**
Industries	**70**
Total connection (costumer)	**46,819**

3.4.7. Number and type of customers

The number and type of customers with their corresponding meter type has been collected from the town water supply service office that can be used in the determination of real and apparent loss. The length of service connections are also summed up as it is required for the determination of real loss in the distribution system. Meters according to their size and type were also identified.

3.4.8. Existing water supply delivering system of Hawassa town from source to service reservoirs

Table 3.5. The reservoir's data including their capacity &material of construction were also collected.

Reservoir ID	Source Reference	Physical location	Volume (m3)	Type	Remark
001	Loke spring	Loka	200	Con	
002	Treatment/mett#1 ,Abelawondo#1	Sebategna Camp	500	Con	
003	Gemeto Galle	Sebategna Camp	500	Con	
004	Kedo	Sebategna camp	500	Con	
005	Ambowuhaspring	Eredomountain	1000	Con	
006	Mett#2	ZelalemPark	50	Mas	
007	Gararequeta	Sebategna Camp	2660	pioneer	
008	Booster station (8boleholes)	Sebategnareservoir	4000	Con	
009	GemetoFTCwell	Gemeto	100	Con	
010	E1,E2,P1,P2,P3	Booster station new	300	Con	Balance
011	P4,P5,P6,	Booster station new	300	Con	Balance
012	springandBokoAlamura	Referral Hospital	200	pioneer	
013	keraraWater well	Tula sub city	100	Mas	
014	BokoAlamura	Tula sub city	300	Mas	

015	Mette3	Chafasine	100	Con	
016	Boreholes	Tullasub city	100	Con	
017	Abelawondo3	Harenfama	300	Con	
018	AbellaWondowell#2	Tullasub city	1000	Con	
019	Qarara	TullasubcityGutter	300	Con	Balanc e
020	Bashima spring	Tulla sub city	100	Con	
021	Loke spring	Referral Hospital	200	Con	

Sources: HTWSSSE

3.4.9. Actual Water production and Water consumption

Table.3.6.Water production and Water consumption

Year (E.C)	Total production (m3)	Total Water consumption(m3)	Total billed data (in birr)	Total population
2020	8,978,421	8,132,,142	84,984,953	**533,573**
2021	9,576,541	9,010,121	92,110,781	**547423**
2022/23	**9,674,453**	**9,122,113**	**135,535,722**	**573,699**

Source:-HTWSSE

3.4.10. Population data

Population projection value under the sub city level which is published in August 2013 has gathered from the Ethiopian Central Statistical Agency (CSA) which is based on at zonal and woreda levels by urban and rural residence. According to this document the total projected value for the Hawassa city on the year of 2018 is taken as 485,816 with a projection rate of4.8% per year of urban and 2.8% per year of rural. Based on this the current projection populations of the city was (2018) 485,816, (2019) 509,135 (2020) 533,573 (2021) 547423 and (2022/23) 573,699 Prior to this as per the data of Hawassa city administration Finance and Economy Department, the study area has a total population of 573,699 with average number of occupants per house hold 5.5 for the year 2022/23.

3.5. Analysis of existing water supply coverage based on water demand

The domestic water supply coverage of the town was evaluated based on the average per capita consumption and level of connection per family. The average per capita consumption has been derived from the yearly consumption that was aggregated from the individual domestic water meters.

Expressional analysis of Average water supply Demand by mode of service:-.

Water coverage = quantity of water supply/quantity of demand*100…

Average of water supply Demand for Town=Number of Population*Per Capita Demand…3.5

3.5.1. Average Daily Per Capita Consumption

The average daily per capita consumption of the town was computed using this expression.

$$\text{Average per capita consumption (l/person/day)} = \frac{\text{annual consumption m3*1000l/m3}}{\text{Population number of each kebeles*365}} \quad \text{----3.7}$$

3.5.2. Level of Connection per Family

Level of water connection per family is one mechanism to evaluate the level of water coverage.

$$\text{Level of Connection per family} = \frac{\text{Total number of annual Connection by each kebe}}{\text{Number of Population by Keble /Average family size}} \quad \text{..............3.8}$$

3.5.3. Factors Affecting Per Capita Demand

Per capita demand is the annual average amount of daily water required by one person, and include the domestic uses, industrial uses, public use, wastes, thefts it was expressed as:-

$$\frac{\text{(Total yearly water requirement of the city in liter}}{(m^3)\ \text{designpopulation} * 365} \quad \text{..................................3.9}$$

Per capita demand depends on, size of the city, climate conditions, habits of people, industrial and commercial activities, quality of water, pressure in distribution system & cost of water (Santosh K, 2012).

- **Water demand:-**The water use/demand in the distribution network classified in to three:- Domestic, Industrial and Other use (Alkhatib, 2012).

Table.3.7.Recommended Water Demand Based on Number People in the Town.

Categories	Number of people	Demand lit/c/day
Town-1	Over1,000,000	**100**
Town-2	100,000 -1,000,000	**80**
Town-3	50,000 – 100,000	**60**
Town-4	20,000-50,000	**50**
Town-5	**Less than 20,000**	**40**

Source; (GTP-2)2016-2020

Domestic water use is the quantity of water required for various domestic usage such as bathing, drinking, cooking, food preparation, washing clothes etc.

Expressed as:-

$$D= \quad dn \times N \times 365 \times 10^{-9} Mm^3/\text{year} \ldots \quad 3.10$$

Where D=domestic use

dn=per capita consumption(L/cd),

N = population served

Industrialwater demand:−

$$I = Av \times N \times 365 \times 10^{-9} Mm^3/\text{year} \quad 3.11$$

Where N=Total population served at n[th] yea

Av = average industrial consumption

Other use:-the water demand for other use(O) is computed as :-

$$O = On \times N \times 365 \times 10^{-9} Mm^3/\text{year} \quad 3.12$$

Where N =Total population served at n[th] yea

On=Average other use consumption L/c.d at n[th] yea

The total water demand (WD) in to the distribution network is given by:-

WD=D+I+O… 3.13

Where WD=water demand

D=domestic water demand

I = Industrial water demand

O = other uses

3.5.4. Sample size determination

In order to ensure the generalization of the findings to larger population, the study was considered adequate sample respondents for selection through appropriate techniques. The sample size of this study was determined on assumption of HTWSSSE that the water supply coverage of Hawassa town is 78 percent and Fink and Kosecoff (1995) have presented the following formula to determine the sample size:

$$N = \frac{Z^2}{e^2} * (p) * (1 - p) \quad (3.3)$$

Where: N: the sample size

P: Expected water supply coverage of the area = 78 %,

$Z_{\alpha/2}$: 95% confidence level corresponds to the value 1.96

e: proportion of sampling error tolerated at 0.07 (to increase the accuracy)

Accordingly, the sample size (N) of the study was 287 and the researcher also considered 10% non response rate.

3.5.5. Sampling technique

The most commonly used probability and multistage sampling techniques were used to select the sample respondents. In the first stage of sampling, the total eight Kifle-Ketemas of the town were stratified into three groups based on distance from the service reservoir and water coverage. In the second stage of sampling, three kifle-Ketemas were selected by simple random sampling technique. Thirdly, probability proportional sampling technique was used to select a total of 32 households from each kifle-Ketemas.

The administration of the questionnaires has helped to get the residents' views on water supply and demand in the area. To represent people from all the social strata and different location of the area adequately and equally, purposive sampling methods were employed and the transect walk across and along the Kefile-Ketemas were carried out. This was complimented by detailed field observation of the area, and interview with concerned officials of HTWSSSE.

3.6. Water Loss Analysis

3.6.1. Statistical Analysis of Water Losses

1. Evaluation of water loss (unaccounted for water) analysis at town level.

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water loss for the entire town.

The 12 months water production and consumption was derived using the following expressions (Mebet, 2007).

$$\text{Total water loss\%} = \frac{\text{Total water produced} - \text{Total water billed})}{\text{Total water produced}} * 100 \qquad \text{3.14}$$

2. Water loss as per number of connection

Water loss expressed as a percentage could be an appropriate means to show the extent of the loss within a given environment, but it is not a good indicator for comparing the loss from one area to another. According to some literature comparison of water loss between different areas is recommended to be done using the water loss per service connection per day. Taking the total number of connection in the town and annual consumption for the similar duration was derived the following expiration, (Mebet, 2007).

Water loss=Annual total loss*1000/(Number of connection*365)… 3.15

3. Water loss expressed as per length of pipes and age

Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non-densely populated areas using the total pipe length of the entire city, the water loss per kilometer length of main pipes will be derived to be evaluated for the following expiration (Mebet, 2007).

$$\text{Water loss per pipe age } \frac{m3}{km/day} = \frac{\text{Annual Consumption } (m^3)}{\text{Total pipe length of each year (km)} * 365} \qquad \text{3.16}$$

3.6.2. Analysis of Water Loss Components and Performance Indicators

3.6.2.1. Water Loss Components

1. Water loss (Real and Apparent losses)

This volume of water lost in the system was evaluated by taking the difference of the system input volume and the authorized consumption.

2. Unavoidable Annual Real Losses (UARL)

UARL can be assessed using a formula developed by the IWA water losses task force. Data required for this assessment are the number of service connections (Nc), the length of mains (Lm in km), the length of private pipes (Lp in km) between the street: property boundary and customer meters, and the average operating pressure (P meters).

UARL values have now been calculated for several hundred diverse systems worldwide. The general equation for UARL is:

UARL (liters/day) =18xLm+0.8xNC+25xLP) x P 3.17

Where,

Lm= Mains length (km)
NC= number of service connection
LP = total length of private pie, property boundary to customer meter (km)
P = average pressure (m).

3.3. Apparent losses

Apparent loss= Total NRW– UARL...3.18

3.4. Customer Metering Inaccuracies

Customer metering inaccuracies are defined as the discrepancy between the amount of water actually consumed and the amount of water reportedly consumed due to under or over registering meters (Sarah, (2006)). This type of error can be beneficial or detrimental to the utility, although typically meters tend to under-register more often than over-register.

A general expression for estimating this metric is:

M Error=V (1-A)3.19

Where

M, error=Apparent losses due to meter errors (m^3/year).
V=Billed metered consumption (m^3/year),
A = Average meter accuracy

3.4.1. Infrastructure Leak Index (ILI)

It is the ratio of the current annual real losses (CARL) to the unavoidable (technical minimum) annual real losses (UARL).

It is calculated as follows (Liem berge r& Farley, 2004)

ILF =CARL/UARL..3.20

3.4.2. Performance indicator Assessment

There are different measures for assessing the water supply system performance yet they have not been subjected to comparative interpretation over a range of different water utility condition worldwide (Mutikanga et al., 2010).

1. Financial Performance Indicators (FPI)

1.1. **Non-Revenue Water: as% of system in put volume**

This volume was described as the water which does not provide any revenue to the utility. It should not be used for assessing any aspect of operational performance management of water losses ((Liemberger& Farley, 2004). It is given by the Expression:

NRW (%)= $\frac{Qin - Qrevenue}{Qin}$ *100%..3.21

Where

Q in=annual system input volume
Q revenue=annual billed volume

1.2. **Non-Revenue Water:** as % of cost of running system:-the detailed financial PI for non-revenue water is based on the percentage by value of the water, rather than the percentage by volume (Mutikanga et al., 2010). A general expression for estimating this metric is:

NRW (%)= $\frac{\text{cost of Non Revenue water}}{\text{Cost of operating system}}$ *100...3.22

2. Operational efficiency Performance Indicators (OPI)

2.1. **Apparent loss per service connection**

The purpose of this operational indicator was to evaluate the volume of apparent losses per service connection in the utility system. This is a useful indicator to compare between utility systems ((Sarah, (2006)).

It is calculated as equation:-

Apparent loss (L/Connection)/day=V Apparent /Nc...3.23

Where:

VApparent=Volume of apparent loss per day (m^3/day)

NC = Number of service connections

2.2. **Real Losses per service connection**

The objective of this performance indicator is to measure the efficiency of the water supply system (Wallingford &Mebet, 2003,2007) it is given by the expression

$$\text{Real loss (l/con/day)} = \frac{VReal}{Nc} \qquad 3.24$$

Where

VReal is the volume of real loss per day(m^3/day

3.7. Drinking Water quality

Hawassa city is very rich in ground water but still not used for drinking purpose. The basic quality parameters or chemicals of all available sources will be tested for their concentration following standard procedures and compared with the limits given by WHO.

Surface and ground water for drinking should meet drinking water quality standard of WHO (2008) and Ethiopia (2010).To help for verification of physico-chemical characteristic of drinking water standard the guideline is tabulated in the Table 3.7.

During this research to assure the water quality problem of the town, sixteen (16) samples from ground water sources collected to be analyzed in the water quality laboratory. Based on this expected result of water quality test and measuring the capacity or discharge of the sources the future water supply source will be mitigated to fulfill future water demand of the town.

Table .3.8.Essential physico-chemical characteristics of drinking water

S. No	Constituents	Unit	WHO guidelines	Ethiopia standard
1	Fluoride (F^-)	mg/l	1.5	**1.5**
2	Iron (Fe^{+2})	mg/l	0.3	**0.3**
3	Sulphate ($SO4^{2-}$)	mg/l	250	**250**
4	Nitrate ($NO3^-$)	mg/l	50	**50**
5	PH	units	6.5-8.5	**6.5-8.5**
6	Total Hardness as (CaCo3)	mg/l	300	**300**
7	Calcium(Ca^{2+}) as CaCO3	mg/l	75	**75**
8	Magnesium (Mg^{2+}) as CaCO3	mg/l	50	**50**
9	**Total alkalinity as CaCO3**	**mg/l**	**200**	**200**

3.8. Summary of Methods Followed

The water supply coverage of the town was evaluated before analyzing the water loss. In evaluating the water supply coverage focused on the volume of consumption and level of water connection as these are highly related to the issue of water loss. Analyzing the actual water production rate with the design document variability was stated.

CHAPTER FOUR

4. RESULT AND DISCUSSIONS

4.1 .Water Supply demand Coverage in distribution system

The main objective of the research was evaluate the water supply coverage and loses by assessing the distribution system in the town and to recommend mitigation measure for the above causes to increasing the water supply coverage and to reduce NRW of the town.

Water supply coverage is usually evaluated based on the quality, quantity, paying capacity of the people, distance, etc. but the intention of this research is not to evaluate all those but related to the quantity of the supply and level of connection that are related to the water loss. In this part of the analysis, the number of domestic connection per family and the average daily per capital consumption is used to analysis the domestic water supply coverage for the Town. The level of coverage has been also compared with other town or city of developing countries. Beside on the population and connection data the analysis for distribution of the average daily per capital consumption and connection per family has been evaluated.

The average water supply coverage of the town was evaluated based on the daily per capital consumption and level of connection using the population data of the town.

Generally, in the old settlement areas of the town low level of connections per family and per capita water consumption was observed. Hence, it is concluded that the low financial capacity of the inhabitants, the topographic nature (higher elevation) of the areas and the available traditional pond as the main reasons for the low coverage in the areas

Three approaches were used to compare the loss among the systems:-

(i) The UFW expressed as a percentage.

(ii) Loss per-length of pipes and.

(iii) Loss per connection.

(iv) ILI

4.2. Analysis of Existing Domestic Water Supply Coverage

Town Population is dramatically increasing from year to year more than the expected growth rate of the town. Infrastructure construction and the investment of Small scale industries, high standard hotels and resorts are increasing with attraction of skilled manpower throughout the country. Civilization of the town increases the great awareness of using pure and potable water. The development of town draws more attention and causes the flow of tourists throughout the year. This all situation increases the town water demand that led for more development of water schemes before expected time of design period.

At the base year 2022/2023, the population of the town is 573,699 which will increase rapidly with in twenty years to 1,065,644. The study shows that the total demand of the town for the year 2022 is 90,613.4m^3/day and for the year 2023 is 94,575 m^3/day. The current actual production of water in the town measured during this study is359l/s (30,963m^3/day),which covers only 30% of the demand of the town for the year 2022/2023. This shows that the supply is much lower than actual demand.

Therefore, the key problem is to manage the demand from available surface and ground sources due to excess amount of natural chemical content. The flows of supply rivers are varying seasonally and highly harvested for irrigation and make the rivers undependable for water supply. Not only over harvest and chemical content of the rivers and ground water, but also the polluted water release from small scale industry and factories release the water with toxic chemicals. Due to this reasons it is big challenge for the town to fulfill the demand within short period of time (http://www.technoserve.org).

The number of customers increases very rapidly with the increase of town population and investment. Investment work in small and large scale industry, resorts and standard hotels draw skilled and unskilled manpower which contributes for population increase. Investment needs water for construction and production or for work and again contributes for rapid demand increase. The data collected from HTWSSSE ICT data management section shows that there is high increase of customers with size increase of the town for more than 2200 customers per year is highly considerable.

As projection shows the water demand after twenty years by 2040 reaches 156,836.3,492 m^3/day production is required. Therefore, new substantial, free from adverse chemicals, and potable source identification and development is inevitable measure to be taken.

During this work 12 checklists questioner distributed to water customers or users, out of which only 57 responded. Out of the respondent 60% complain about the interruption of water supply because most of them do not have individual tankers. 10% of the respondents indicate the water shortage highly slow down the individual commercial activities. 30% of Fringed area people, specially, the people live in Hitata, Tilte and Farra kebele residents complain about water interruption around water points that make their children queuing for long time to fetch water and make late them for school. In addition to that they respond sometimes they feel bad odor and requested the enterprise to assess for occasional problem.

Out of 10 HTWSSSE officials 9 of them respond stating that there is shortage of water against the demand of the town. Existing sources are no sufficient to meet the demand. Sometimes the interruption of electric power increases water shortage. HTWSSSE has shortfall to make consultation discussion with water users regarding the quality and shortage problem. Finally, the ideas summarized to solve water supply problem against the demand are educate or train the community how to use and save the available water, progressing tariff mechanism to discourage water over use, and looking for new sources to develop without any delay to satisfy rapidly growing population.

The water supply coverage of the Town has been evaluated based on the average per capital consumption and level of connection per family. The average per capital consumption has been derived from the yearly consumption of the Town that has been aggregated from the individual domestic water meters. Beside to the average per capital water consumption, the distribution number of domestic's connection per family has been also evaluated Number of population as forecasted to the year 2042 has been used to evaluate the average per capital consumption

Access to water supply may be evaluated using the amount of water consumed and the level of Connection .For evaluating the amount of water consumption ,the annual water consumption is Converted to average daily per capita consumption using the population data of the city. The number of domestic connection per family has been also used for analyzing the level of connection as elaborated below. Taking the total number of connection in the town and annual consumption for the similar duration was derived the following expiration**,**(Mebet,2007).The volume of water consumed for domestic purpose has been distributed for all beneficiaries of the town to analyze the distribution of the water supply coverage. The average daily per capita consumption of the town was computed using this expression

Per capital Consumption $\left(\frac{L}{person\ /Day}\right) = \frac{AnnualConsumption\ (m3)*1000L/m3}{Population\ Number\ each\ Kebele*365\ day}$

$$(2021) = \frac{9010121m3*1000L/M3}{547423*365\ Day}$$

= 45.5 L/Person/Day

$$2022) = \frac{9122113*1000L/M3}{573699*365\ Day}$$

= 43.5 L/Person/Day

Table.4.1.Average Daily per Capita Consumption of the Town

Year	Total production(m^3)	Total Billed data(m^3)	Total population	production ($^l/_{person/day}$)	Consumption ($^l/_{person/day}$)
2020	8,978,421	8,132,142	533,573	46	41.75
2021	9,576,541	9,010,121	547,423	47	45.09
2022	9,674,453	9,122,113	573,699	46	43.5

The distribution of the domestic water coverage has been evaluated using the above statistical tools. The distribution of the production has been first reviewed using the descriptive statics. Taking the mean production as shown in above the average domestic water production of the Hawassa city is found to be 46 L/per/day and the consumption of the towns are 43.5 L/per/day in 2022/23. The average daily per capita production of the town is low b/c from yearly water production, while an over view of GTP- 2 Provide urban water supply access with minimum service level of 100 l/c/day for category-1 towns/cities, 80 l/c/day for category 2 towns/cities (towns/cities with a population in the range of 100,000-1million), 60 l/c/day for category 3 towns/cities (towns/cities with a population in the range of 50,000 -100,000),according to the standard set by MoWR, Hawassa city was second level city. Based on the above results Hawassa city water supply consumption and productions are less than46% compare to GTP2 standards, so it shows there is a high gap in the city water production and consumption.

Per-capita consumption @2022/2023 = 43.5 l/person/day

$$\text{Water supply coverage based on demand (2022/23)} = \frac{\text{AnnualProductionx100\%}}{\text{Total Annual demand}}$$

$$\frac{9674453*100}{\mathbf{32991937}/\text{m}^3\mathbf{year}}$$

= 30

The analysis of water coverage as per domestic and non-domestic demand. The result shows as the total average demand is 90,388 m^3/day. However, the amount of water production in 2021 shows as 32,991937m^3/year, which have only 30% coverage of the demand. Therefore, the result shows there is high gap between demand and supply. And also The First Growth and Transformation Plan (GTP- I),which aims at increasing drinking water coverage, rural 98%andurban 100%.Incomparisonwith this plan, the water supply coverage is behind the plan. As clarified earlier the water supply coverage of the town, both in quantity and level of connection is low accordingly in GTP-1 the water supply access coverage has reached to75.5%,84.1%and76.7%inurban,rural,and national respectively but

Hawassa still now less than and half of the GTP-1 coverage . In areas where water supply coverage is sufficient, volume of domestics water consumption is expected to be linear related to the level connection. Areas having better level of connection are expected to consume more water as they can easily get it within their building or compound. On the other hand in areas having insufficient supply, some areas may have better level of connection but may not necessarily mean they are consuming more volume of water as the possibility of getting the water does not depend only on the location. There are number of places that get low volume of water due to their topographic location. As the town mainly uses gravitational supply system, topography has a great impact on the per capital consumption

4.2.1. Population of the Town

To provide standard services, it is important to know the number of current population projects for future based on census data. Population estimation process uses different methods to update population data gathered from the last census to approximate the current situation or for future. Population projections indicate what changes might occur, given assumptions inherent in the projection method and data since projections refer to the size of the population at some point in the future.

Population growth estimated for twenty years using **Geometric Increase Method** taking initial population of 2022 as projected from census data is 573,699 and annual growth rate for urban and rural 4.8% and 2.8% respectively (Hawassa Socio-Economic Profile, 2013).

$$\mathbf{P_t = p_o (1+k)^n} \quad \ldots\ldots \quad (3.1)$$

P_t= Future population

P_o= Existing population

K = percentage growth rate

n= the design period in year

CSA's Country Level urban Population Growth Rates 2007 report

Table.4.2. population projection of Hawassa city

Year	Urban Growth rate %	population projection
2022	4.8	**573669**
2023	4.06	**596991**
2025	3.95	**645084**
2030	3.72	**774334**
2035	3.42	**916117**
2040	**3.07**	**1,065,644**

The above results it shows that at the end of 20th years (2042), the number of population boosts surprisingly with the increase of water demand.

4.2.2. Current Water Demand Analysis with existing supply water

- **Domestic water demand**

It includes water finished to in- house purpose such as drinking, cooking ablution washing utensil washing clothe, washing toilets, watering animal. The amount of water used for domestic purpose varies depending on the life style living standard, climate mode of service and all the price of water and affordability of users.

- **Demand Computation by mode of service**

The most common mode of domestic service in Ethiopia and are used in Hawassa town.

Table.4.3.supply Demand Computation by mode of service

S/N	Connection Type	% of Population By mode of Service	Number of population by connection	Total number of population
1	Privet house connection	92	42,261	527,775.48
2	PublicTapUser	8	828	45893.52
	Total	100	43,089	573,669

4.2.2.1. Average Demand by Mode of Services in the Town

According to the current standard of the country the second level towns like Hawassa have the following per capital demanded and the calculated average demand is shown in table below.

Average Demand for Town =Number of Population*Per Capita Demand

Table.4.4. Domestic water demand categories of consumer:

	Stage1	Stage2
Private House connection (HC)	50 l/c/day	**70 l/c/day**
Private Yard connection, own(YCO)	25 l/c/day	**30 l/c/day**
Yard connection, shared(YCS)	30 l/c/day	**40 l/c/day**
Public tap supplies (PT)	**20l/c/day**	**25/c/day**

4.2.2.2. Analysis of Average Domestic Demand

According to the MoWR standard the Hawassa city was first level towns like have the following per capital demanded and the calculated average demand is shown in table below.

Average D Demand for Town=Number of Population*Per Capita Demand

PHC =527,775.48*70=36,944,283.6l/c/day) =36,944.3(m^3/day) PT = 45893.52 *25 =1,147,331.25 l/c/day = 1147.3 m^3 /day

Table.4.5.Analysis of Average Domestic Demand

Connection Type	Per Capita Demand(l/c/day)	No. of population per service(2022/15)	Average Demand (l/c/day)	Average Demand(m^3 /day)
Private house connection	70	527,775.48	36,944,283.6l	36,944.3
For public	25	45893.52	1,147,331.25	1147.3
Total		573,669	**38,091,600**	**38,091.6**

4.2.3. Non-Domestic Water Demand

Non-Domestic demand is a quantity of water required for various non- domestic needs, Non – domestic demands are:-

Table.4.6. Non-domestic water demand standards set by (MoWR2006)

1	Restaurants	10 l/Seat
2	Boarding school	60 l/Pub
3	Day schools	5Lit/Pub
4	Public offices	5 l/employee
5	Workshop/shops	5 l/employee
6	Mosques & Church	5 l/worshipper
7	Abattoir	150 l/cow
8	Hospitals	50-75l/bed
9	Hotels	25-50l/bed
10	Public Bath	30 l/visitor
11	**Public latrines**	20 lit/seat

Source: Design Criteria Guide Line o f MoWR (2006)

4.2.3.1. Institutional demand

The water demand for educational institutes:- in Hawassa city there are 59 college, 8 university with 3,368 number of teachers, 113,249 students, and 423 number of staffs. (Hawassa city administration education office 2022). In Hawassa there is one University and Collage the maximum number of student's trainee staff and supporting staff around 117,040.

$$D = dn \times N \times 365 \times 10^{-9}\ Mm^3/Year$$

$$D = 5L/stu) \times 117040 \times 5 \times 365 \times 10^{-3}\ m^3/Year$$

$$= 5852\ M^3/year$$

There are 58 governmental and 86 non-governmental, in general 144 schools. These schools accommodate total of 132,106 students served by 3,448 teachers according to the Hawassa City Administration Finance and Economic Development Department. The demand calculated including teachers was =680.5m^3/year

- **Health institutes**

Health institution there is11 hospital,13 health center and 58 private clinics with a total of about 18,450 beds and number of public toilets 270 (Hawassa city health office, 2022).

$$D=18,450 * 50l/bed * 10^{-3} m^3/year$$

$$=922.5 m^3/year$$

- **Public and governmental offices**

According to Hawassa City Administration Finance and Economic Development Department. There are12,112 permanents and 2,250 temporary employees in governmental organizations, and there are 1,340 employees in NGOs and 16,576 employees in small scale enterprises. The recommended consumption for each employs. 161.39m3/day=161,390l/c/day

4.2.3.2. Commercial demand

According to Hawassa city Administration Finance and Economic Development Department Hawassa town is fast growing commercial center. It has 273,687 potential local and foreign tourists per annum that mean 786 visitors per day. And also has 4070 beds for transit and polite pass. Commercial demand transit visitors total demand of 205,90m3/day. According to the second hand data from Hawassa City Tourism Department most of the commercial institutes such as low standard hotels, inns, pensions, have no access to water supply service to the maximum of the demand standard.=205,90m3/day

4.2.3.3. Industrial water demand:-

Hawassa is the one of the most important and selected industrial centers of the country and its core industrial and commercial activities include food processing and other consumer's goods those are public and privately owned. According to recent survey undertaken in by Abay PLC (2014) the existing industrial demand is 39.5m^3/d. From existing yield industry share demand of billing data on year 2022 was 180,980 Ethiopian birr and Total industrial demand.is2,528,000l/c/day

Table.4.7.current Analyzed result of Non-Domestic water Demand in the town

S/N	Institutions	Demand (M^3/day)
	Health Institution	**922.5**
1	Day School	**680.5**
2	University and Collage	**5852**
3	Fire demand	**703.9**
4	Public and Government office	**161.39**
5	Commercial demand	**205,90**
6	Industrial Demand	**2,528**
Total Sum		**31,438.3**

Table.4.8.Domestic and Non-Domestic Demand (2022/23)

S/N	Item	Demand (M^3/Day)(L/Day)
1	Domestic	**38,091.6(38,091,600)**
2	Non-Domestic	**31,438.3(31438300)**
	Subtotal	**69529.9 (69529900)**
3	30%loss(forschemehaving10yearservice)	**20,858.97 (20,858,970)**
	Total Sum	**(90,388.87) (90,388,870)**

4.2.3.4. The total water demand

(WD) in to the distribution network is given

By: - WD = D+ND+O

Where, WD = water demand

D=domestic water demand

ND=non domestic water demand and

O= Others

=90,388.870 m^3/year

4.2.3.5. Average water demand

There are several mathematical methods of estimating the water demands of a given town; including extrapolating historical trends and correlating demand with the socio economic variables of the town. But, the most common means of forecasting future water demand is estimating current per-capital water consumption, and multiply this by the projected population figure. Therefore, the average water demand for Hawassa city (2022/23) was calculated to be 38,091.6 m3/d and the total demands are 90,388.870 m3/day.

4.3. Evaluating of Existing Domestic Water Supply coverage in the Town

The water supply coverage of the city has been evaluated based on the average per capita consumption and level of connection per family. The average per capital consumption has been derived from the yearly consumption of the town that has been aggregated from the individual domestic water meters. Beside to the average per capita water consumption, the distribution number of domestic's connection per family has been also evaluated.

4.3.1. Actual Water Production

The existing water sources for the supply of Hawassa town currently measured during the study are surface water from Kedo River treatment plant with the capacity of 20.8l/s, sixteen Bore holes with the capacity of 264.2l/s, and three spring sources with the capacity of 74 l/s. The current total production of potable water is 359 l/s. To verify the ambiguity and to know the current total production capacity of the city, each source such as bore holes, springs and treatment plant are measured using flow meters and water meters during this research work. This actual situation enables us to carry out the analysis of water supply and demand.

Table.4.9.water supply infrastructure and actual water production Existing supply sources and actual production

#	Type of Water Supply Scheme and Water Source	Year of Construction	Status (Functional / Non-functional)	Operational capacity (yield) (ltr/sec), (M3/day)[3]	Pumping hours in a day (hr)	Distance from Town (KM)	GPS coordinates	Source of energy
A	Boreholes							
1	AbelaWondo # 1	2007E.C	Functional	7	18	9	E=446365 N=770929 Z=1724	EEPCo& Standby Generator
2	AbelaWondo # 2	2007E.C	Functional	6	18	10	E=447171 N=770245 Z=1745	EEPCo& Standby Generator
3	AbelaWondo school # 3	2013 G.C	Functional	12.9	18	10	E=446375 N=770333 Z=1741	EEPCo& Standby Generator
4	Garareketa 1	2002 E.C	Functional	31.7	18	14	E=447760 N=771217 Z=1700	EEPCo& Standby Generator
5	Garareketa2	2002 E.C	Functional	31.4	18	16	E=448400 N=770948 Z=1715	EEPCo& Standby Generator
6	Garareketa3	2002 E.C	Non-functional	0	18	16	E=0448470 N=771190 Z=1709	EEPCo& Standby Generator
7	Gemeto (Mete#1 new)	1999 E.C	Functional	8	18	9	E=445603 N=770648 Z=1724	EEPCo& Standby Generator
8	Gemeto (Mete#2 new)	2006 E.C	Non-functional	0	18	9	E=445303 N=770493 Z=1727	EEPCo& Standby Generator
9	Awassatreat.plant BH	1992 E.C	Non-functional	0	18	17	E=447465 N=768772 Z=1721	EEPCo& Standby Generator
10	Yowokebele P1	2004 E.C	Functional	18.8	18	15	E=449214 N=771791 Z=1711	EEPCo& Standby Generator
11	Yowokebele	2010 E.C	Non-	0	18	17	E=449360	EEPCo&

	P2		functional				N=770943 Z=1705	Standby Generator(but know no EEPCO power)
12	Yowokebele P3	2010 E.C	Functional	34.6	18	17	E=449976 N=771497 Z=1705	EEPCo& Standby Generator
13	Yowokebele P4	2004 E.C	Functional	28.9	18	18	E=449926 N=770917 Z=1714	EEPCo& Standby Generator
14	Garariketa P5	2004 E.C	Functional	20.2	18	14	E=447977 N=771948 Z=1714	EEPCo& Standby Generator
15	Garariketa P6	2004 E.C	Functional	23.3	18	15	E=448528 N=772643 Z=1705	EEPCo& Standby Generator
16	Garariketa P7 (To Eredo)	2007 E.C	Functional	51.4	18	15	E=448118 N=772982 Z=1705	EEPCO
17	GemetoP8(To MR)	2007 E.C	Functional	67.2	18	7	E=445269 N=773012 Z=1701	EEPCO
18	G3meto P9	2007 E.C	Non-functional	0	18	6.5	E=44269 N=773012 Z=1701	No Power
19	Alamura(kera ra)	2006 E.C	Functional	6.4	18	11	E=441352 N=770743 Z=1762	EEPCo& Standby Generator
20	Alamura(Bok o)	2013G.C	Non-functional	0	18	10	E=442184 N=771188 Z=1755	EEPCo
21	Gemeto–FTC	2006 E.C	Functional	23.7	18	8	E=443886 N=771378 Z=1719	EEPCO
22	GemetoBeshe ma BH	2006 E.C	Functional	18.8	18	9.5	E=443886 N=771378 Z=1719	EEPCO
B	River							
23	KedoRiver /intake1/ Treatment Plant	1975 E.C	Functional	20.8	24	17	E=451701 N=766610 Z=	Gravity
C	Spring							

24	Ambowha Spring 1	2004 E.C	Functional	55	12	9	E=453133.8 N=785238 Z=1701	EEPCO
25	Beshema Spring 2		Functional	6	18	9.5	E=444669 N=770817 Z=1723	EEPCO
26	Loke Spring 3	1989 E.C	Functional	13	24	11	E=436890 N=771918 Z=1694	EEPCo& Standby Generator
	Total production (m3/day)			359 l/s or 30,976.56 m^3/day				

4.3.1. Actual Water Production and per capita Water Consumption

The annual water supply production for Hawassa town is obtained from one surface source, three water springs and sixteen boreholes .The annual water production from the water supply service is collected on the monthly base and then converted to yearly base for the evaluation purpose. The production of the water for distribution purpose is from the boreholes and the spring sources. Here below are presented the production for the year 2020-2022/23 both in tabular and in chart form. The annual water consumption from the water supply service is collected on the monthly base and then converted to yearly base for the evaluation purpose. The consumption of water is combined consumption of private, commercial, Government & public, and industry consumption. Here below are presented the consumption for the year 2020-2022/23 both in tabular and in chart forms. Statistical analysis was used to evaluate the distribution of the supply coverage in the town and the domestic water supply coverage is evaluated using the annual consumption data and the result has been converted to average daily per capital consumption using the number of population.

4.3.2. Comparison of water billed consumption and population based on actual water production

It is necessary to evaluate consumption with population .This has been evaluated using the correlation between the water billed consumption & number of population based on actual existing water production. Water consumption by number of population graphically illustrates are shown below Figure 4.6 volume of water consumption increase and number of population also increase.

Table: 4.10. Comparison of billed consumption and Population based on and actual water production

Year	Total Actual water production (m^3)	Total Billed consumption data (m^3)	Total population
2020	8,978,421	8,132,142	533,573
2021	9,576,541	9,010,121	547,423
2022/23	9,674,453	9,122,113	573,699

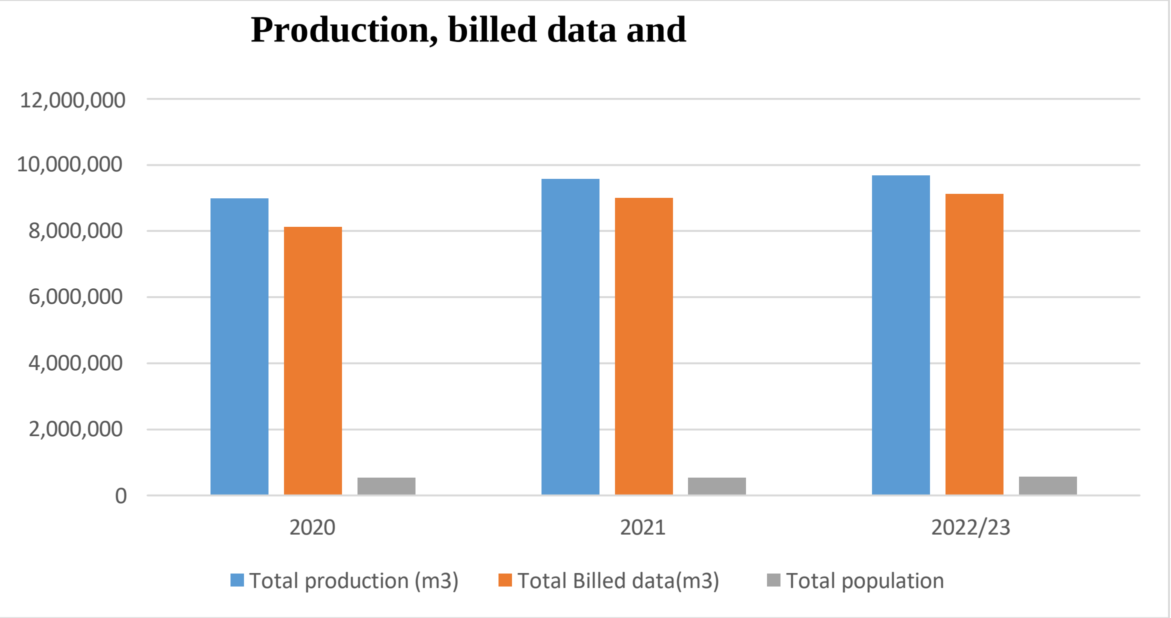


Figure .4.10. Correlation of billed water consumption and population base on existing actual water production (2020-2022/2023)

The annual water production rate in 2020-2022/23 was 8,978,421m^3, 9,576,541 and 9,674,453 m^3 respectively and the annual population number in 2020-2022 was 533,573,547423 and 573,699 respectively.

4.3.3. Coverage Based on Average daily Per Capita consumption

The level of water consumed for domestic purpose has been aggregated to the town so as to analysis the distribution of the water coverage. Statistical analysis was used to evaluate the distribution of the supply coverage of the town. Evaluating the domestic water supply coverage using volume of consumption may not allow realizing the distribution comparison. For this reason the annual consumption data has been converted to average daily per capital consumption using the number of population. The average daily per capital consumption of the city was derived using the following expressions.

$$\text{Per capital Consumption } \left(\frac{L}{person\ /Day}\right) = \frac{AnnualConsumption\ (m3)*1000L/m3}{Population\ Number\ each\ Kebele*365\ day}$$

$$(2021) = \frac{9010121m3*1000L/M3}{547423*365\ Day}$$

= 45.5 L/Person/Day

$$2022) = \frac{9122113*1000L/M3}{573699*365\ Day}$$

= 43.5 L/Person/Day

Table: 4.10.1. Average Daily per Capita Consumption of the Town

Year	Total production (m^3)	Total Billed data (m^3)	Total population	production ($^l/_{person}/_{day}$)	Consumption ($^l/_{person}/_{day}$)
2020	8,978,421	8,132,142	533,573	46	41.75
2021	9,576,541	9,010,121	547,423	47	45.09
2022	9,674,453	9,122,113	573,699	46	43.5

The distribution of the domestic water coverage has been evaluated using the above statistical tools. The distribution of the production has been first reviewed using the descriptive statics. Taking the mean production as shown in above the average domestic water production of the Hawassa city is found to be 46 L/per/day and the consumption of the towns are 43.5 L/per/day in 2022/23. The average daily per capita production of the town is low b/c from yearly water production ,while an over view of GTP- 2 Provide urban water supply access with minimum service level of 100 l/c/day for category-1 towns/cities, 80 l/c/day for category 2 towns/cities (towns/cities with a population in the range of 100,000-1million), 60 l/ c/day for category 3 towns/cities (towns/cities with a population in the range of 50,000 -100,000), according to the standard set by MoWR , Hawassa city was second level city. Based on the above results Hawassa city water supply consumption and productions are less than 46% compare to GTP2 standards, so it shows there is high gaps in the city water production and consumption.

4.3.4. Coverage Based on Level of Connection per family

Level of water connection is an important element on the one hand for evaluating the level of water coverage that was the focus of this section and on the other hand it has a direct impact on the water loss that was detail separately. The total numbers of connection or water meter in the Hawassa city supplies are 46,819 connections among those, for domestic 43,089 use. In order to compare the distribution of the water connection among the different parts of city, the total numbers of connection are converted to connection per family using the population data. According to the census of the 2018, average family size of 5.5 is used for calculating the average number of connection per family using the following expression.

$$\text{Level of Connection per family} = \frac{\text{Total number of annual Connection by each kebele}}{\text{Number of Population by kebele /Average family size}}$$

Similar to the per capita consumption, the distribution of the connection of the connection per family has been evaluated.

Table: 4.10.2.Level of Connection per family

Year	Total population	Average family size	Total number of connection	Level of connection
2020	533,573	5.5	43,844	0.45
2021	547,423	5.5	44,966	0.452
2022/23	573,699	5.5	46,819	**0.46**

$$\text{Level of Connection per family} = \frac{43844}{97013.3} = 0.45$$

In this analysis the per capita consumption after evaluating for outliers, the average connection per family for the entire Hawassa city is found to be0.46.This implies that at average above one families and or 9 persons are sharing one connection or water tap. In other words the average in- house or yard connection of the town is about 46%. Similar to the per capita consumption, the distribution of the level of connection per family shows variation among districts and this has been evaluated using the above table.

Table: 4.10.3. Domestic Water Supply Coverage

Year	Consumption (m^3)	Population	production m^3/pers/year	consumption (l/person/day)	Production (M^3)	Annual demand	% of coverage
2022/23	9,122,113	573,699	46	43.5	9,674,453	32991937	30

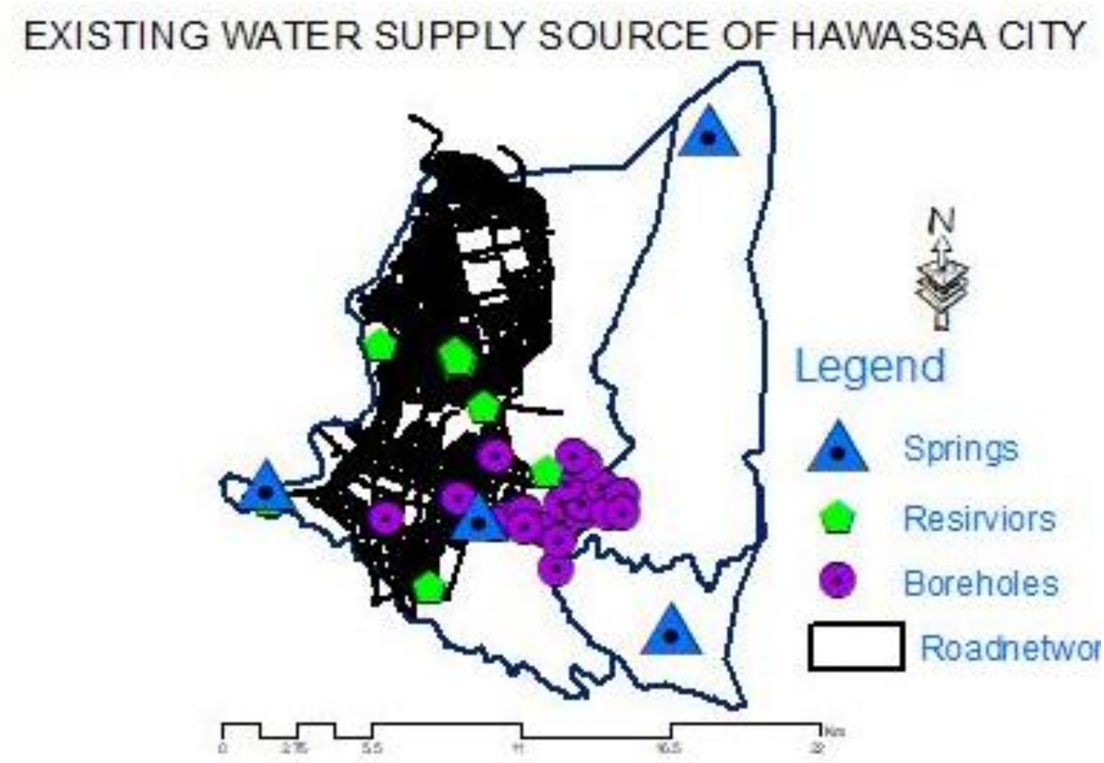
$$\text{Water supply coverage based on demand (2022/23)} = \frac{\text{Annual Production x 100\%}}{\text{Total Annual demand}}$$

$$\frac{9,674453*100}{32,991937m^3/year} = 30\%$$

The analysis of water coverage as per domestic and non-domestic demand. The result shows as the total average demand is 90,388 m3/day. However, the amount of water production in 2021 shows as 32991937m^3/year, which have only 30% coverage of t he demand. Therefore, the result shows there is high gap between demand and supply. And also The First Growth and Transformation Plan (GTP- I),which aims at increasing drinking water coverage, rural 98%andurban 100%.Incomparisonwith this plan, the water supply coverage is behind the plan. As clarified earlier the water supply coverage of the town, both in quantity and level of connection is low accordingly in GTP-1 the water supply access coverage has reached to75.5%,84.1%and76.7%in urban, rural and national respectively but Hawassa still now less than and half of the GTP-1 coverage . In areas where water supply coverage is sufficient, volume of domestics water consumption is expected to be linear related to the level connection. Areas having better level of connection are expected to consume more water as they can easily get it within their building or compound. On the other hand in areas having insufficient supply, some areas may have better level of connection but may not necessarily mean they are consuming more volume of water as the possibility of getting the water does not depend only on the location. There are number of places that get low volume of water due to their topographic location. As the town mainly uses gravitational supply system, topography has a great impact on the per capita consumption.

4.3.4. Water distribution network analysis

In the modern water supply system, clear water shall be delivered to the service reservoirs directly through the transmission main and which is completely isolated from the distribution system. But, existing Hawassa water supply system which was constructed before 35 years ago and as it was the old system; water is pumped simultaneously into the distribution network and service reservoir. So, the impact of this network configuration and the capacity of distribution system components were described as below.



Scale of map 1: 50,000

Figure 4.4 current existing source locations and supply / distribution pipe networks

4.3.5. Storage capacity of existing Reservoirs

In order to provide for security of supplies above the need for balancing purposes it is recommended that the minimum total reservoir storage capacity be in the range of 30% to 50% of the average daily demand .When determining the level of storage wit in the above range, the following criteria will be considered:

- Reliability of pumping arrangements at the source works,
- Reliability of electricity supplies if 100% stand by generation capacity is not provided,
- socio-economic status of the town (or an indicator of the level of qualified staff available for system operation),

The capacities of reservoirs in the water supply system were determined using different methods (MoWR D. M., 2006).The peak hour and Maximum day factor varies inversely with the size of the consumer base.

Table: 4.10.4.Peak hour and Maximum day factor

Population Range	Peak hour factor	Maximum day factor
<20000	2	1.3
20001 to 50000	1.9	1.25
50001 to 100000	1.8	1.2

Source:-Design Manual of MoWR (2006)

4.3.7.1. Maximum daily demand

The maximum day demand (MDD) represents the maximum consumption during anyone day of the year. The ratio of the maximum daily consumption to the mean annual daily consumption is the maximum day factor .This demand is used to design source capacity, riser mains, and service reservoir.

Maximum Day Demand= ADD *MDF

ADD=90,388 m^3/day

90,388m^3/daym^3/dayx1.2

=108,465.6m^3/day =1255.4 L/s1883 L/s

4.3.7.2. Peak Hour Factor

Water demand varies greatly during the day. The distribution system must be designed to cope with the peak demand, which is taken in to account by the use of a peak hour factor .The peak hour demand is one of the highest demands within any one hour over the year and estimated taking in to account the possible water collection hours and amount collected by each demand category. Previous studies and experiences clearly demonstrate that peak hour factor is greater for a smaller population. According to water supply design criteria prepared by ministry of water resource and tropics studies the proposed maximum day and peak hour factor are summarized below.

Peak Hour Demand (PHD) =ADD* PH

90,388m^3/dayX1.8

162698.4 m^3/day =1883L/s

In order to provide for security of supplies above the need for balancing purposes it is recommended that the minimum total reservoir storage capacity be in the range of 30% to50% of the average daily demand (MoWR, 2006).

The Hawassa city Have 21 functional reservoirs, which have a total of 10,400 m^3 reservoir.

To check this capacity enough or not the total average day demand as per computed above is 90,388m^3/day & the level of existing storage computed as:-

Table 4.10.5.: Existing functional service reservoirs and booster stations

	Service Reservoir	**Discharge Capacity of Reservoir by volume (m^3)**	**Type of structure**	**Status of reservoir**	**year of construction**
1	Loke reservoir	200	Concrete	Functional	**1989**
2	Sebategna camp reservoir	500	Concrete	Functional	**1975**
3	Sebategna camp reservoir	500	Concrete	functional	**1975**
4	Eredo mountain Reservoir	1000	Paioner	functional	**2004**
5	Sebategna camp New reservoir	500	Concrete	functional	**1997**
6	Sebategna camp New reservoir	4000	Concrete	functional	**2010**
7	Sebategna camp New reservoir	2660	Pioneer	non functional	**2008**
8	Zelalem Park Alamura mountain reservoir	50	Masonary /sanduch	functional	**1993**
9	Abela wondoMure Reservoir	200	Paioner	functional	**2005**
10	Alamura-karara	100	Monsory (san dwisch)	functional	**2006**
11	Tula-Boko	300	Concrete	functional	**2006**
12	Tulatown	100	Concrete	functional	**1993**

13	Haranfama reservoir	300	Concrete	functional	**2005**
14	Referral reservoir	200	Concrete	functional	**2009**
15	Ere do mountain Reservoir	1000	Concrete	Functional	**2010**
16	Alamura FM Reservoir	300	Concrete	Functional	**2009**
17	Chafasine reservoir	100	Concrete	Functiona	**1999**
	Booster station				
18	Abela BS	100	Concrete	functional	**2005**
19	Haranfama BS	50	Concrete	functional	**2005**
20	Gemeto BS	300	Concrete	functional	**2011**
21	Burkito BS	300	Concrete	functional	**2007**
22	Burkito BS	300	Concrete	functional	**2007**
	Total storage Capacity	**10,400m^3/day**			

30%*ADD to 50%*ADD

30% x 90,388 m^3/day 50% x90,388 m^3/day

= 27,116.4 m^3/day = 45,194.15 m^3/day

From the analysis shows the storage capacity of existing reservoirs are below half of the recommended range, so the Hawassa city water scheme is not safe regarding to storage capacity and to recommend the city should be construct additional reservoir.

4.4. Discussion I

From the above analysis of average per capital consumption of the Hawassa city found to be 43.5L/person/day, while an overview of GTP-2 Provide urban water supply access with minimum service level of 100 l/c/day for category-1 towns/cities,(with a population in the range of 500,000 - 1,000,000), according to the standard set by MoWR Hawassa city was second level and average per capital consumption is lower while compared with the minimum requirement of domestic demand which is 100 L/c/day. Based on the above results Hawassa city water supply consumptions are very less. The average domestic water production of the town is found to be 46 l/per/day; the result shows that an average daily per capital production of the town is low compare to the standard.

In the analysis, the average connection per family for the entire Hawassa city is found to be 0.46.This implies that at average above one families or 9 persons are sharing one connection or water tap. In other words the average in-house or yard connection of the city is about 46%.Similar to the per capita consumption, the distribution of the level of connection per family shows variation.

The other issue that has been addressed was analysis of water coverage as per domestic and non-domestic demand. The result shows as the total average demand is 90, 388 m^3/day. However, the amount of water production in 2022/23 shows as 9,674,453 m^3/year, which have only 30% coverage of the demand. Therefore, the result shows there is high gap between demand and supply and also The (GTP-I),which aims at increasing drinking water coverage ,rural 98% and urban 100%.In comparison with this plan, the water supply coverage is behind the plan.

On the other hand the analysis shows as the maximum day demand is 108,465.6 m^3/day(1255.4 L/s) and peak hour demand is 162698.4m^3/day(1883L/s).The analysis of the storage capacity of existing reservoirs which have 10,400m^3 the recommended range was27,116.4m^3/dayto45,194.15m^3/day, the results shows less than the recommended range, so the Hawassa city water scheme is not safe regarding to storage capacity, to recommend the city should be construct additional reservoir. Therefore, to satisfy the demand the pressure main pipe line and the capacity of the pump existing pump should have ability to meet the maximum day demand 1255.4 L/s However, the existing ump has a capacity to lift

355.6 l/s which is 28% of the maximum day demand. This show as possible to need of more pump, mostly need more reservoir.

4.4.1. Water Loss Analysis

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water loss for the sub city. One of the major challenges of water utilities is high volume of water loss in their distribution networks. If a large quantity of supplied water is lost; it is difficult to meet the required quantity to demands, and correspondingly made challenges to keep the water tariffs in the system at a reasonable level. Water loss for Hawassa city was assessed and discussed as below;

4.4.1.1. Evaluation of water loss analysis at town level

Water losses in the water supply distribution system, illegal connections, overflow from reservoirs and improper metering etc. referred to as uncounted for water. Unaccounted for water (losses) was expressed as percentage of domestic plus public water demands and is calculated the difference between water produced and water consumed or sold .The total annual water produced and distributed to the distribution system and the water billed data was aggregated from the individual customer meter readings were used to quantify the total water loss for the entire town.

They early water production, consumption and Loss based on using the following expressions (Mebet, 2007) is shown in the Table.4.10.6.

$$\text{Total water loss \%} = \frac{\text{Total water produced} - \text{Total billed data}}{\text{Total water produced}}$$

Table.4.10.6.The total water loss of the city

Year	Production(m^3)	Total Billed data (M^3)	Yearly Loss
2020	8,978,421	8,132,142	**846,279**
2021	9,576,541	9,010,121	**566,420**
2022/23	**9,674,453**	**9,122,113**	**552,340**

The total water loss has been evaluated based on cumulative production and consumption of the years. Generally based on the analysis results in the above Table 4.12 the total annual water produced and distributed to the system within the specified year has been 9,674,453 cubic meters and the annual total water loss from the system is 552,340 m^3/year. The analysis shows towns have high loss of water.

4.4.1.2. Total Water Loss Expressed As Percentage

The total annual water produced and distributed to the system within the specified year (2022/23) has been 9,674,453 M^3 and the annual total water loss as derived using the expression was 552,340 M^3.

- Existing Hawassa city Water Tariff =10.45Birr=0.21 USD

Taking the average tariff of water in the city as 10.45 Ethiopian Birr (1 USD=60 Eth. Birr) the water loss estimated to be 115,991.4 USD every year (7 million Ethiopian Birr) lost every year. However, the real loss is beyond this as the water tariffs like other developing countries are usually subsidized.

4.4.1.3. Water Loss as Per Number of Connection

Water loss expressed as a percentage could be an appropriate means to show the extent of the loss within a given environment, but it is not a good indicator for comparing the losses from one area to another. According to some literatures, comparison of water loss between different areas is recommended to be done using the water loss per service connection per day. Taking the total number of connection in the Hawassa city in 2022/23 is 43,844 and the water loss per connection for the similar duration was calculated as 34.5 liter/connection /day. This shows as litters per service connection per day increase water losses also increases.

❖ **Guideline for Water Loss Level**

For systems with per capita consumption of less than 150l / day the general rule for water loss level is:

- Good condition of system <250 Liter/connection/day

- Average condition 250-450Liter/connection/day
- Bad condition of system > 450Liter/connection/day

➢ Another guide line for the water loss level is the "Benchmark "Liter/km mains/day:

- Good condition of system <10,000 Liter/km main/day
- Averagecondition10,000 –18,000 Liter/km main/day
- Bad condition of system>18,000Liter/km main/day Guideline for Water Loss Level

Source: (UNESCO-IHE, April 2008) Gerhard Zimmer (Experiences from kfw funded programs).

Taking the total number of connections in the city as 43,844Km, the water loss per connection for the similar duration was expressed as,

Water loss = Annual total loss*1000 / (Number of connection*365)

=552,340 m^3x1000/ 43,844x365 =552340000/16003060

= 34.5 L/connection/day

4.4.1.4. Water Loss Expressed as per Length of Pipes

Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss .This indicator is usually recommended for non-densely populated areas using the total pipe length of the entire city, the water loss per kilometer length of main pipes was derived to be evaluated for the following expiration (Mebet, 2007).

Table.4.10.7.Pipe line Length and materials

Age category	All pipes category		Main pipe category		Secondary pipes category	
	Total length(km)	%from total	Pipe lengt h	%from mai n total	Pipe length	%from secondary total
10yearsand less	187	19%	84	63%	103	12%
10-20years	639	65%	26	19%	613	72%
20-30years	150	15%	23	17%	127	15%
Total length of main pipes	976 (main and distribution total in km)		133(main total transmission pipe line in km)		843(distribution total pipe line in km)	

The other good indicator of water loss in the distribution network is determining loss as per pipe length (liters per kilometer of pipe line per day, l/km/d). Evaluating the water loss as per kilo meter of main pipe is one way to indicate the loss. The total length of pipes ar 843km and these total pipe length used to the water loss per kilometer length of main pipes was express .Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non- densely populated areas. Using the total pipe length of the entire sub city, the water loss per kilometer length of main pipes was calculated as 1.8 m^3/ km/day or 1800 L/Km/day depending on total water loss and total pipe length. This shows that as length of the pipe increases the amount of water losses per day increases.

Water loss=Annual loss / (Length of pipe Km *365)

$$552{,}340\ m^3/\ 843Km\ x365 = 552{,}340m^3/307{,}695$$

$$=1.8m^3/km/day$$

4.4.1.5. Analysis of Real and Apparent Loss

Water Losses (WL) volume is obtained by deducting Unbilled Authorized Consumption from Non- Revenue Water. Systematic inaccuracies associated with production metering should be identified and corrected before bulk metered volumes are entered into the Water Balance; otherwise they will influence the calculated NRW and Water Losses volumes. Water Losses consist of two components: Apparent Losses (AL) and Real Losses (RL).

4.4.1.6. Customer Metering Inaccuracies

Customer metering inaccuracies are defined as the discrepancy between the amount of water actually consumed and the amount of water reportedly consumed due to under or over registering meters (Sarah, (2006)). This type of error can be beneficial or detrimental to the utility, although typically meters tend to under-register more often than over-register. Based on AWWA acceptable standards of average accuracy range is 0.98-1.015 of any water meters. Billed metered consumption the city 2022/23 year is 9, 122,11 m^3/year.

A general expression for estimating this metric is:

M (Error) = V (1-A)…… (Equation 3.15) (Sarah, (2006))

Where M, error =Apparent losses due to meter errors (m^3/year).

V=Billed metered consumption (m^3/year),

A = Average meter accuracy

M (Error) =9,122,113m^3/year (1- 0.98)=182,442.23m^3/year

=499.8 m^3/day = 182,442.23m^3/year

4.4.1.7. Infrastructure Leak Index (ILI)

The ILI indicators are defined as a ration of real losses (RL) and unavoidable annual real losses (URAL). It is a new indicator of water supply systems expressing the technical condition of the system from the point of view of water loss. This indicator is proposed and recommended by the international water association IWA(Lambert,2008).The ILI calculation uses simplified values of non- revenue water (NRW) as

ILI=NRW/UARL

Where, NRW = non-revenue water (m^3/year =552,340 m^3/year

UARL=unavoidable annual real loss (m^3/year=50,713.1M^3/Year

ILI=552,340 / 50,713.1=10.9 m^3/year

The infrastructure leakage index for the Hawassa city distribution system is calculated as10.9m^3/year and this shows us that the current annual real losses are assessed as being around eleven times as high as the unavoidable annual real losses for the system.

4.4.1.8. Evaluating Possible Causes of the Water Loss

There are several reasons for the high level of water loss generally in Hawassa city. These factors are given below, and some advisory solutions were briefly proposed in next sections.

4.4.1.9. Age of Pipe Network

Pipe age is one of the factors that affects the magnitude of the loss specially that of physical loss. Aged pipes are more likely having more water loss through leakage than newly installed pipes .It is estimated that nearly above 65% of the main pipe network in the Hawassa city was 10-20 years age and the total pipe length of the city was less than 30 years age. The main duties which made more than half a month is checking of each customer (door to door water connection) by sounding rod .In this time, it was found so many invisible & visible leakages both on the private connection & also on the main line. Water Loss Expressed as per Length of Pipes age analysis result shows 25.6m^3/km/day or 25600L/ km/day Therefore, this analysis shown that if distribution line is expanded, the age of pipe increase the water loss also increases in the pipe network.

Table.4.10.8.Hawassa city pipe length and age categories

Age category	All pipes category		Main pipes category		Secondary pipes category	
	Total length (km)	%from total	Pipe length	%from main	Pipe length	**%from secondary**
10years&less	187	19%	84	63%	103	**12%**
10-20years	639	65%	26	19%	613	**72%**
20-30years	150	15%	23	17%	127	**15%**
Total length Of main pipes	**976 (main and distribution in km)**		**133 (main total Transmission pipe in km)**		**843 (distribution total pipe line in km)**	

$$\text{Water loss per pipe age } (m^3/Km/day) = \frac{\text{Annual Billed data } (m^3)}{\text{Total pipe length of each year (Km)}*365}$$

$$= 9,122,113 / 976*365$$

$$= 25.6m^3/Km/day$$

4.4.1.10. Poor Maintenance of Networks

Water authorities has performed a maintenance program for distribution system, the areas have high leakages due to poor maintenance of network and poor man power management for maintenance, it is so difficult to find financial support to renew the water distribution system. Thus, the lack of finance to proper materials and poor construction materials resulted in increased leakage in the system.

4.4.1.11. Customer Side Leakage

Many water institutions do not give enough attention for water losses caused as a result of metering errors but it has a considerable impact unless due attention is given like to that of the pipe networks. As per the feedback from the local experts, until recently the water authority was not checking the customer meters by itself unless the customers apply for checkup. However, customers apply most probably when the problem were over-registration rather than under registration.

4.4.1.12. Illegal Connections

There are a significant number of illegal users of water within distribution system in Hawassa city from field survey especially in the Main line areas. As a consequence, they contribute significantly to apparent losses and revenue loss to the water authority. These connections are often poorly laid just a few meters below the surface and will break easily resulting in real losses taking placed in the form of leakage. Illegal connections are therefore of significant concern of water utilities.

4.4.1.13. Damage due to Utility Construction

In the Hawassa city there are many construction of utility like roads, sewer line, Telecommunication line, were worked from time to time. During those utility was constructed water line including main line and customer lines were broken and water lose is highly occurred up to the authority technician came and maintain. As it was tried to observe, any contractor or the client of those utility do not care about water line during excavation. Even though when broken the water line and water is highly lose do not report for the authority. Hawassa city water supply and sewerage enterprise were significantly concern this issue and communicate with the owner of those utility before starting excavation or construction and also ready to stand by during excavation on the site especially during excavation of main and secondary of line at different sites.

4.5. Possible Solution to reduce water loss and leakage

Knowing the magnitude and the spatial distribution of the loss greatly helps to intervene giving priority to those areas with higher magnitude of loss with regard to the leakage index usually fixed based on local condition. Nevertheless, identification is not by itself an end in reducing the water loss. Identifying the causes of the losses might help where to focus with probably limited resources that the city is having. This study somehow gave an indication that the predominant causes of the water loss in the city leakage and losses due to meter errors. Once the spatial distribution and the characteristics of the loss are identified; it is possible to see alternative solutions to reduce the water loss. Therefore, an appropriate long and short term strategy is necessary. Shortage of water is a crucial problem in the Hawassa city, great attention is given to the issue of water loss by the water authority. Furthermore, Hawassa city water supply sewerage enterprise one of its responsibilities is to reduce water loss. Generally the following may be considered to be possible solution to be taken to reduce water loss and leakage in a distribution system.

4.5.1. Improving billing system and meter readings

Improving a billing system is one step forward for improving the overall demand management of the city and helps to a great extent to better evaluate the water balance and water loss. The most important part of determining how much water is being lost in a system is to accurately quantify the volume of water which is entering that system. Metering of input volumes and in flows in to zone distribution systems is essential for water balance calculations. But Customer meters also require careful management of water loss if representative and significant results are to be obtained. Billing system can be reviewed and updated for the integrity and quality of the data. The location and the historical records like ages of the meter, periods of calibration, etc. need also be integrated with the billing systems.

4.5.2. Calibration and replacement of customer meters

One of the main causes for the water loss is the under-recording of customer meters. The usage of poor material quality also holds true for the customer meters. Unless meters are regularly calibrated and those not functioning well are either maintained or replaced the water loss reduction programmed will not be effective. Until recently, the water authority was checking the customer meters only if it is requested by the customers themselves, but this might only help the customer not to pay more as such requests are usually for over registration. Therefore systematic checkup of the customer meters is important not only to identify the magnitude of the loss but also to maintain and replace when necessary.

4.5.3. Proper maintenance and renewal

The major causes for the increase of water loss are the usage of poor quality materials and poor workmanship. In spite of the many pipe networks in the city seem to have below 30 year ages. The main reason for this might be the usage of poor quality of material and poor workmanship .Therefore care should be taken while maintaining existing networks and installation of new ones. While rehabilitation of any mains is planned due to attention should be given to maintain as well the service connections fed from the mains. Replacing an old water main with anew installation will undoubtedly reduce on the main. Most leakage occurs on service connections and, unless the service connections are also renewed, the benefit may not be a great as the first estimated (Farley, 2010).

4.5.4. Improving organizational management and provision of training

Effective management of water supply service in general water loss and leakage in particular water supply providing institutions must have an appropriate organizational management. The organizational aspect related to the water loss management is well addressed in the organizational structure of Hawassa city water supply sewerage enterprise, but lack of qualified and experienced personnel is the major problem of the country in general and HTWSSE in particular. Capable management and technical staff are paramount take training regarding to water loss management in order to achieve better performance. Offering a continuous theoretical and practical training based on the need is also important.Due to the complex nature of water loss and leakage commitment of staffs at all level is also very important. Effective leakage management requires an input from a number of different personnel and unless,they are all committed ,the implementation of any water loss reduction program will not be efficient, it may then be difficult to maintain the infrastructure which has led to lower leakage levels (Farley., 2010).

4.5.5. Establishing of Information Disk

Water was loss at different place by different cases as mentioned in previous section in the causes of water loss. Those water loss were continues to loss for one day or two day some time above until the authority technician HTWSSE. So in order to arrive automatically when water is loss and make a possible solution HTWSSE has established afree telephone service not only Hawassa city customers also especially pressure mains in rural areas from balancing reservoir that can support to get information from the community in case of leakage and breakage of pipes immediately.

4.6. Discussion II

From Analysis of water loss and leakage needs a detail data due to its complex nature. The data are usually scarce in developing countries that the case of Hawassa city is also similar. Due to limited data the analysis was focusing on evaluating the total water loss and un avoidable real loss on different pressure. Based on the result of the analysis the following conclusions and findings:-

From the Hawassa city water loss analysis in different location of the water supply system, higher water loss is found relatively on gravity flow main line from balancing reservoir to service reservoir than other distribution system lines. This line have low pipe length and small number of connection compared to the distribution system but have relatively higher unavoidable real loss as a result of high pressure and illegal connections found in this location. The total annual Hawassa city water produced and distributed to the system within the specified year (2022/23) has been 9,674,453 M^3 and the annual total water loss as derived using the expression was 552,340 M^3, the analysis shows Hawassa city have high loss of water.

Taking the average tariff of water in the city as 10.45 Birr=0.21 USD (1 USD=60 Eth. Birr) the water loss in the Hawassa city estimated to be 115,99.4 USD (7millionEthiopianBirr) every year. However, the real loss is beyond this as the water tariffs like other developing countries are usually subsidized.

Taking the total number of connection in the Hawassa town in 2022/23 is 43,844 and the water loss per connection for the similar duration was calculated as 34.5 liter/connection /day. This shows as litters per service connection per day increase water losses also increases.

Evaluating the water loss as per kilo meter of main pipe is one way to indicate the loss. The total length of the city pipes are 843 km from total length of pipes ,Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non- densely populated areas. Using the total pipe length of the entire city, the water loss per kilometer length of main pipes was calculated as 1.8 m^3/ km/day or 1800 L/Km/day depending on total water loss and total pipe length. This shows that as length of the pipe increases the amount of water losses per day increases.

The value of Unavoidable Average Real Losses **(**UARL) is 50,713m^3/year. This value is represents the unavoidable annual real losses (UARA)is the 90% of technically achievable volume of real losses which is 552,340 m^3/year of the total loss computed by using production and consumption data and the apparent plus avoidable real loss covers 10%. However, this proportion is not logical because unavoidable real loss is should be much less than avoidable plus real loss.

Apparent Customer Metering Inaccuracies losses due to meter errors are499.8m^3/dayor82,442.23 m^3/year. The infrastructure leakage index for the Hawassa city distribution system is calculated as10.9 m^3/year and this shows us that the current annual real losses are assessed as being around two times as high as the unavoidable annual real losses for the system.
The total pipe age categories are estimated that nearly above 65% of the main pipe network of the Hawassa city was 10-20 years age and the total pipe length of the town was less than 30 years age. And Water Loss Expressed as per Length of Pipes age analysis result shows 25.6m^3/km/day or 25600L/ km/day Therefore, this analysis shown that if distribution line is expanded, the age of pipe increase the water loss also increases in the pipe network.

4.6.1. Projected Demand (2022 –2042)

Water production data along with present and future population data were repeatedly reviewed. Accordingly, the two mentioned data were primarily used for water demand analysis. Prior to assigning project water demand , it was required to establish average use of water per person. Per capita water demand was taken as average water use. Maximum water use and minimum water use usually related to average water use by multiplication of peaking factors Results of water demand projection analysis to satisfy maximum day demand until the end of design period needs a discharge of 1255.4 l/s and to satisfy the peak hour demand needs 1883l/sec .This means, the pressure main pipe should have a capacity to deliver 1255.4 L/sec and the pump should have a capacity to lift 1255.4 L/sec. In addition the main distribution pipe should have a capacity to deliver 1883 l/sec.

Table.4.10.9.Forecasting of Hawassa city population

Year	Urban Growth rate %	population projection
2022	4.8	**573669**
2023	4.06	**596991**
2025	3.95	**645084**
2030	3.72	**774334**
2035	3.42	**916117**
2040	**3.07**	**1,065,644**

Table.4.10.10.Hawassa city Projected Demand (2022–2042)

	Unit	Year					
		2022	2023	2025	2030	2035	**2042**
Hawassa city population	No.	573669	596991	645084	774334	916117	**1,065,644**
Domestic Demand							
Privet house connection		92%	93%	94%	95%	96%	**97%**
Public Tap User		8%	7%	6%	5%	4%	**3%**
Number of Population per service level							
Privet house connection	No.	527,776	555,201	606,378.9	735,617	879,472	**1,033,674**

Public Tap User	No.	45,894	41,789	38,705	38,716.7	36644.7	**31,969**
Per capita water demand by Categories							
Privet house connection	L/c/day	70	72	74	76	80	**85**
Public Tap User	L/c/day	30	32	34	36	40	**42**
Water demand Categories							
Privet house connection	M^3/day	36,944.32	39,974472	44,872,038	55,906,892	70,357,760	**87,862,290**
Public Tap User	M^3/day	1,376.82	1,337248	1,315,970	1,393801	1465787	**1342711**
Total Domestic water Demand	M^3/day	38,321.14	41,311.7	46,188	57,300.7	71,823.5	**89,205**
Non domestic Water Demand	M^3/day	31,438.3	31,438.3	31,438.3	31,438.3	31,438.3	**31,438.3**
Average Day Demand	M^3/day	69,759.4	72,750	77,876.3	88,739	103,261.8	**120,643.3**
Losses and Leakage (30%)	M^3/day	20,858.9	21,825	23,362.9	26,621.7	30,978.5	**36,192.9**
Average Day Demand With Loss(ADD)	M^3/day	90,613.41	94,575	101,239	115,360.7	134,240.3	**156836.3**
Total Maximum day demand (ADD*1.2)	M^3/day	108,736.09	113,490	121,487	138,432.8	161,088.4	**188,203.5**
Total Maximum Day Demand	L/sec	1258.5	1313.5	1,406	1,602	1864.4	**2178.3**
Peak Hour Demand (ADD*1.8)	M^3/day	163,104.1	170,235	182,230	207,649	241,632	**282,305**
Peak Hour Demand	L/sec	1887.7	1970.3	2109.1	2403.3	2796.7	**3267.4**
Storage Capacity (33*MDD)		**3588289.9**	**3,745,170**	**4,009,071**	**4,568,282.4**	**5,315904**	**6,210,715.5**

4.6.2. Analysis of supply water Distribution Networks

In the modern water supply system, clear water shall be delivered to the service reservoirs directly through the transmission main and which is completely isolated from the distribution system. But, existing Hawassa city water supply system which was constructed before 35 years ago and as it was the old system; water is pumped simultaneously into the distribution network and service reservoir. So, the distribution network configuration and the reservoirs capacity of supply water system components were described as below.

4.6.3. Type of main Transmission and Distribution Pipe Line

It is discussed that the transmission main was not isolated from the distribution network and it gives water to distribution line before entering to service reservoir. The service reservoir is found at the highest point in the town and the supply is done by gravity force from reservoir to the lower points. However, the system is also interconnected that water directly enters the distribution system when necessary. Nineteen water sources and three springs and one surfaces water fed the water main,15 with pump and the other with gravity system. The transmission main from "Buriqito" Booster Station to 4000m^3 service reservoirs, from Gemeto Galle & Kedo river to 500 m^3 each two services reservoir, Abella 1, Mette 1, and treatment bore holes to 500 m^3services reservoir and from Mette2,Abela2to50 m^3services reservoirs has no distribution network and but transmission main from Boreholes spring source, and surface sources (river). The transmission main was laid among 8(eight) service reservoirs along the water main from source to end point. Generally, the pipe main covers a total of 97km. The Hawassa town distribution network, which was initially designed by German Water Engineersin1985, consists of DCI,GI ,uPVC and HDPE pipes with a diameter ranges between1.5 inch to12 inch with a length of 30kms.But the size and length of the distribution network has dramatically changed with the development of the town following the initial construction of the treatment plant. Now the total length of the distribution network is more than 830km and the pipes type consists of uPVC,GI, DCI, and HDPE, and their sizes are ranges from 25mm – 600mm, 1" – 6". In Hawassa city the nodes were located close to each other and based on distribution of village. Generally, there are 97km main nodes and distribution main line in the total length of distribution line was 496km with a pipeline diameter varying from 600 to 30 millimeters. The maximum and minimum water pressure at a junction points varies at different flow scenarios.

4.6.4. Storage capacity of existing Reservoirs

The capacities of reservoirs in the water supply system were determined using different methods. The most appropriate and economical approach of determining storage volume of reservoir is the24 hours supply demand simulation mass curves. In order to develop such type of curves ,it requires reliable recorded historical data of hourly water demand figures of the town .But ,in the absence of such type of data, to determine the size of reservoirs, it was adopted the commonly practiced in many water supply systems and based on the urban water supply design criteria of the ministry of water resources ;it was used for sizing the reservoir volume as one third of the maximum daily demand. In order to provide for security of supplies above the need for balancing purposes it is recommended that the minimum total reservoir storage capacity be in the range of 30% to 50% of the average daily demand (MoWR, 2006).

The Hawassa city Have 21 functional reservoirs, which have a total of 10,400 m^3 reservoir. To check this capacity enough or not the total average day demand as per computed above is 90,388 m^3/day & the level of existing storage computed as:-The analysis of the storage capacity of existing reservoirs which have 10,400 m^3 the recommended range was 27,116.4 m^3/day to 45,194.15 m^3/day, the results shows less than the recommended range, so the Hawassa city water scheme is not safe regarding to storage capacity, to recommend the city should be construct additional reservoir.

4.6.5. Drinking Water Quality

Water quality is a term used to express the suitability of water to sustain various uses or processes (WHO, 2006).Water quality is affected by anthropogenic activities and natural processes. In order to prevent and reduce the problems associated with water, there are national and international standards or guidelines to be followed for water quality suitable for Different purposes (drinking, personal hygiene, irrigation, etc).Components of water quality include microbial or biological, chemical, and physical aspects. A few chemical contaminants can cause adverse health effects in humans as a consequence of prolonged exposure through drinking- water. However, very small proportion of the chemicals that may reach drinking-water from various sources can affect the quality of water. Water gathers impurities from both natural and anthropogenic sources, and these cause the physical and chemical parameters of drinking-water to vary over time and by location. Natural and anthropogenic sources of water contamination include (WHO,2004); naturally occurring chemicals and other substances ,chemicals from industrial sources and human dwellings ,chemicals from agricultural activities ,chemicals used in water treatment or from materials in contact with drinking-water, and pesticides used in water for public- health purposes. Many chemicals found in drinking-water sources may be the cause of adverse human health effects (e.g. arsenic, fluoride), affect the acceptability of water (i.e. turbidity, iron, conductivity, taste, color, and odour) and lower the effectiveness of water treatment.

4.6.6. Ground water Chemical Analysis

Some of the chemicals can easily dissolve in the ground water and affects quality. It would be difficult and largely unnecessary to test for all chemicals that might be of concern in drinking-water and so the chemical parameters to measure have to be prioritized. Priority is given to parameters that have the greatest impact on the health of the general population, and on infants and young children. People who are debilitated, sick or elderly, or who live under unsanitary conditions may be particularly vulnerable to dissolved chemicals in drinking-water (WHO, 2010)). To verify the ground water chemical concentration condition in Hawassa Administrative area, all available sources of ground water sample collected and tested in the laboratory and the chemical analysis result is tabulated in the following table

Table.4.11.Chemical analysis of ground water

S.No	Name of source	Type of source	Fluoride (mg/l)	Iron (mg/l)	Phosphate(mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	PH	Total Hardness as $CaCO_3$ (mg/l)	Ca as $CaCO_3$ (mg/l)	Mg as $CaCO_3$ (mg/l)	Alkaline as *$CaCO_3$* (mg/l)	GPS coordinate		Elevation (m)
													Northing	Easting	
Acceptable limit of WHO			1.5	0.3	-	250	50	6.5-8.5	300	75	50	200			
1	Karara	Borehole	1.43	0.06	0	4	0.7	7.4	105	60	45	150	441352	770743	1762
2	Mete1	Borehole	0.35	0.03	0.57	1	0.4	7.6	110	60	50	150	445607	770648	1722
3	Mete2	Borehole	0.42	0.10	0.73	1	0.4	7.0	120	90	30	150	445303	770493	1727
4	Abelawondo 1	Borehole	0.12	0.02	0.57	4	1.2	7.1	120	80	40	141	446393	770925	1729
5	Abelawondo 2	Borehole	0.64	0.04	0.40	13	1.1	7.6	260	140	120	180	447130	770258	1750
6	Gararikata 1	Borehole	1.05	0.03	0.35	20	1.1	7.4	140	100	40	160	447761	771220	1723
7	Gararikata 2	Borehole	0.53	0.2	0.60	19	0.73	7.4	120	60	60	126	448405	770950	1723
8	Gararikata 3	Borehole	0.51	0	0.4	2	1.5	7.6	110	54	56	160	448467	771909	1721
9	Treatment	Borehole	0.18	0.03	0.64	2	2.2	7.5	110	100	10	130	447465	768772	1721
10	Yuwop1	Borehole	0.63	0.08	0.17	3	2.64	7.55	130	68	62	480	449154	771808	1716
11	Yuwop4	Borehole	0.80	0.04	0.17	3	7.0	7.35	110	60	50	146	449924	770916	1718
12	Yuwop5	Borehole	0.66	0.26	0.06	5	4.81	7.35	70	36	34	160	448023	771921	1719
13	Gararikata p6	Borehole	0.71	0.30	0.2	5	6.16	7.65	104	66	38	150	448538	772649	1712
14	BGI1	Borehole	3.9	0.04	0.63	23	6	7.9	140	62	78	510	445273	777317	1725
15	BGI2	Borehole	2.6	0.03	0.65	22	7	8.1	139	59	80	490	445136	776765	1724
16	Haile resort	Borehole	3.6	0.09	0.27	1	1.0	8.2	140	120	20	520	442472	782304	1700

4.6.7. Chemical Contents of Existing Water Source

The most effective means of consistently ensuring the safety of a drinking –water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from the source to consumer (WHO, 2004). During the study period, the water sample of each existing source collected and checked in the laboratory to identify the quality against WHO standard. When we see some water supply sources of fluoride content, karara borehole (1.43mg /l), Ambowuha spring (1.05mg/l) and Gara-Rikata borehole (1.05mg/l) are a little bit larger value but it is not more than the upper range of WHO guideline which is 1.5mg/l. Let's compare, some drinking water samples collected from Hawassa Water supply schemes that are tested in HTWSSSE laboratory, with WHO guidelines.

Table 4.12:.Comparison of physico-Chemical characteristics of Hawassa drinking water with WHO water quality standard

Drinking water quality standard	Physico-chemical characteristics of drinking water								
	Fluoride, (F^-) Mg/l	Iron (Fe^{2+}) mg/l	Sulphate (SO_4^{2-}) mg/l	Nitrate (NO_3^-) Mg/l	PH	Total Hardness ($CaCO_3$) Mg/l	Ca as	Mg as	**Total Alkalinity as $CaCO_3$**
WHO standard	1.5	0.3	250	50	6.5 - 8.5	300	75	50	**200**
Treatment Plant water	0.1	0.21	24	3.5	7.0	37	21	16	**25**
Loke spring1	0.35	0.03	1.0	0.4	7.6	110	40	30	**130**
Ambowuha spring	1.02	0.22	5	1.5	7.2	90	60	30	**120**
Gara-riqata1 BH	1.05	0.03	20	1.1	7.4	140	100	40	**160**
Gara-rikata 3 BH	0.51	0.0	2	1.5	7.6	110	54	56	**160**
Mete1	0.35	0.03	1	0.4	7.1	120	60	50	**150**

Beshima spring	**0.29**	**0.53**	**3**	**0.4**	**6.9**	**80**	**50**	**30**	**110**

When we come to overall water quality of the water that is supplying to the town is very potable. The water that comes from every source not directly supplied, but it mixed in the reservoir and dilute fluoride and other chemical concentration and finally the chlorine is injected before its' supply to the consumers. After dilution, chemical concentration is in range of WHO standard as shown below in the table 4.19 except Calcium and Magnesium a little bit higher or out of range, however, the bit increase do not cause adverse effect for human health.

Table.4.13.Mixed water test result before supply to consumer

Drinking water quality standard	**Physico -chemical characteristics of mixed water in the reservoir**									
	Fluoride, (F^-) Mg/l	Iron (Fe^{2+}) mg/l	Phosphate Mg/l	Sulphate (SO^{2-}_4) mg/l	Nitrate (NO_3^-) Mg/l	PH	Total Hardness ($CaCO_3$) Mg/l	Ca as $CaCO_3$	Mg as $CaCO_3$	**Total Alkalinity as $CaCO_3$**
WHO standard	1.5	0.3		250	50	6.5-8.5	300	75	50	**200**
Mixed water from each source in the reservoir	**0.64**	**0.01**	**0.33**	**18**	**2.3**	**7.3**	**140**	**80**	**60**	**150**

4.7. Managerial structure of Town Water Supply organization

4.7.1. Town Water Boards (TWBs)

Town Water Boards were responsible for planning and managing their town water supply systems. The Water Boards will enter in to performance agreements or contracts with utility operators to handle routine operations and maintenance and improve efficiency and expand their system over time .Board members are in most cases representatives of government organizations from municipality, water bureau, health, education and representatives of the user community.

4.7.2. The Town Water Supply Enterprises

The town water supply enterprises are concerned mainly with the scheme expansion and rehabilitation, operation and maintenance, financial and human resources management of the water supply scheme in the urban areas. The enterprises, depending on the size of the city are autonomous in terms of city water supply development operation and maintenance. The enterprises are managed by boards and the executive body of the enterprise leads the activities of the utility and its management.

CHAPTER FIVE

5. SUMMARYAND CONCLUSIONS

5.1 .SUMMARY

The main objective of the research was to evaluate the water supply coverage, explore the water loss and water quality in the water supply distribution system of the Hawassa city. The analysis focused on the evaluation of the existing water supply coverage of town based on the billed consumption and population of town, projection of demand for next 20 years, evaluating the total water loss and exploring the possible causes of the water loss with their remedial measurement.

- From the above analysis of average per capital consumption of the Hawassa city found to be 43.5L/person/day, while an overview of GTP-2 Provide urban water supply access with minimum service level of 100 l/c/day for category-2 towns/cities according to the standard set by MoWR Hawassa city was second level and average per capital consumption is lower while compared with the minimum requirement of domestic demand which is 100 L/c/day. Based on the above results Hawassa city water supply consumptions are very less.
- The average domestic water production of the town is found to be 46l/per/day ,the result shows that an average daily per capital production of the city is low compare to the standard.
- In the analysis, the average connection per family for the entire Hawassa city is found to be 0.46. This implies that at average above one families or 9 persons are sharing one connection or water tap. In other words the average in-house or yard connection of the city is about 46%. Similar to the per capita consumption, the distribution of the level of connection per family shows variation.
- The other issue that has been addressed was analysis of water coverage as per domestic and non-domestic demand. The result shows as the total average demand is 90, 388 m^3/day. However, the amount of water production in 2022/23 shows as 9,674,453m^3/year, which have only 30% coverage of the demand. Therefore, the result shows there is high gap between demand and supply and also The(GTP-I),which aims at increasing drinking water coverage ,rural 98% and urban 100%.In comparison with this plan, the water supply coverage is behind the plan.
- On the other hand the analysis shows as the maximum day demand is108,465.6m^3/day (1255.4L/s) and peak hour demand is 162698.4 m^3/day (1883 L/s).

- The analysis of the storage capacity of existing reservoirs which have 10,400 m^3 the recommended rangewas27,116.4m^3/dayto45,194.15m^3/day, the results shows less than the recommended range,

- The total annual Hawassa city water produced and distributed to the system within the specified year (2022/23) has been 9,674,453 M3 and the annual total water loss as derived using the expression was 552,340 M3, the analysis shows Hawassa city have high loss of water.
- Taking the average tariff of water in the city as 10.45 Birr=0.21 USD (1 USD=60 Eth. Birr) the water loss in the Hawassa city estimated to be 115,991.4USD every year (7million Ethiopian Birr) every year.However,the real loss is beyond this as the water tariffs like other developing countries are usually subsidized.
- The water loss per kilometer length of main pipes was calculated as 1.8 m^3/ km/day or 1800 L/Km/day depending on total water loss and total pipe length. This shows that as length of the pipe increases the amount of water losses per day increases.
- The value of Unavoidable Average Real Losses **(**UARL) is 50,713m^3/year. This value is represents the unavoidable annual real losses (UARA) is the 90% of technically achievable volume of real losses which is 552,340 m^3/year of the total loss computed by using production and consumption data and the apparent plus avoidable real loss covers 10%. However, this proportion is not logical because unavoidable real loss is should be much less than avoidable plus real loss.
- Apparent Customer Metering Inaccuracies losses due to meter errors are 499.8m^3/day or 82,442.23 m^3/year. The infrastructure leakage index for the Hawassa city distribution system is calculated as 10.9 m^3/year and this shows us that the current annual real losses are assessed as being around two times as high as the unavoidable annual real losses for the system.
- The total pipe age categories are estimated that nearly above 65% of the main pipe network of the Hawassa city was 10-20 years age and the total pipe length of the town was less than 30 years age. And Water Loss Expressed as per Length of Pipes age analysis result shows 25.6m^3/km/day or 25600L/ km/day Therefore, this analysis shown that if distribution line is expanded, the age of pipe increase the water loss also increases in the pipe network.

- Hawassa is situated in the Great Rift Valley; potable water is a problem in the area where it has natural impact on the drinking water and a number of studies were carried out to verify the quality problem.

- During the study period, the water sample of each existing source collected and checked in the laboratory to identify the quality against WHO standard. When we see some water supply sources of fluoride content ,karara borehole (1.43mg/l),Ambowuha spring (1.05mg/l) and Gara-Rikata borehole (1.05mg/l) are a little bit larger value but it is not more than the upper range of WHO guide line which is 1.5mg/l To make awareness creation with concerned farmers of stakeholders to use natural composite from access able area surrounding environment and from different animal manure association (city municipal)

5.2. CONCLUSIONS

The following conclusions in relation to water coverage, water loss and water quality and operation and maintenance have been proposed respectively to improve the performance of existing Hawassa city water supply system.

❖ There should be structured operation and maintenance practice in order to improve the whole pipe water system in the town.

❖ The analysis of the storage capacity of existing reservoirs which have 10,400 m^3 the recommended range was 27,116.4 m^3/day to45,194.15 m^3/day, the results shows less than the recommended range, so the Hawassa city water scheme is not safe regarding to storage capacity, to recommend the city should be construct additional reservoir.

❖ The analysis shows low water supply coverage, low customers, low production, poor construction, quality of material and ageing of the system are the main cause's infant stage to enhance the existing water supply system, increase the water supply coverage, per capital consumption, connection per family level, customers and production.

❖ It is demonstrated that the existing water supply system do not meet the demand of the town since the Population growth is high with size increase of the town. Continuously growing population of the town, fast growing investment, and industries in the city necessitated urgent water sources development.

❖ To meet the demand by developing sufficient water schemes, these, gathered and acknowledgedinformationmayhelpthewaterutilityandTownAdministrationtocometo the decision, which source could be the future source for the town to attain current and future demand. The results obtained both in terms of discharge and quality assessment

- ❖ The water utility should respond immediately to maintenance requests of customers to avoid water loss and complaints from customers and need to regular discussions with the customers. The water utility should also conduct a regular survey to know customers satisfaction level and the service deficiencies and should make improvements on its service to increase the customer's satisfaction.
- ❖ There is rapid growing of population and expansion of Hawassa city the supplied water to the system could not satisfy the current as well as the future water demand of the people living in the city. Therefore, it is necessary to upgrade the system by increasing the water production by using the potential of water sources shall be considered to meet existing and future water demand of the people.
- ❖ Taking the average tariff of water in the city as 10.45 Birr=0.21 USD (1 USD=60 Eth. Birr) the water loss in the Hawassa city estimated to be 115,991.4 USD every year (7 million Ethiopian Birr) every year..However, the real loss is beyond this as the water tariff like other developing countries are usually subsidized, So the town should minimize loss.
- ❖ It is recommended that Bacteriological and chemical water quality test be conducted periodically at least four times a year .And as it is indicated on the Ethiopian guideline for drinking water quality the bacteriological test should be accompanied with turbidity and free residual chlorine and pH where chlorination is applied**.**

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APPENDICES

Appendix-1.Check list for discussion

1. What are the main sources of water in the city? Are there any water sources that are not included to the distribution system? Where and how much?
2. Is there any difference in level of water distribution among different localities? If yes, how do you manage to balance the supply?
3. Is there any seasonal difference in amount (volume) of water supplied particularly in rainy season and dry season? If yes to what extent?
4. Are there any non-metered water consumptions? If so for what purpose and how do you estimate the volume of water consumed?
5. How do you estimate the residential water demand? Do you have any standard?
6. How do you identify leakage or breakage of water pipes ?How do the residents/communities Support in reporting leakage or breakage of pipes?
7. How frequent do water meters become defective? Do the customers report on time in case of defective water meter? If yes, do they report equally for both in case of the defect causing over readings and under readings? In case they didn’t report how do you monitor it?
8. Have you encountered with illegal water connections? If yes how frequent? Do you think that all customers pay for all water they have consumed? If not why?
9. From your experience, does leakage and breakage of pipes have significant relation with age of pipes
10. From your experience does the ground elevation difference of the city have a significant impact on pressure and distribution of water? How do you manage the pressure with the big elevation difference of the city?
11. Do you have a plan to replace aged pipes and water meters? What major criteria do you use for prioritization of replacement?
12. Do you have any plan regarding operation and management in general and leakage reduction in particular? If so what are the main components?

Appendix-2.Hawassacity water supply source data

S. No	Source	Depth(m)	Yield (lps)	Construction year	Distance (Km)	Supply area
1	Kedo River		38.8	1981	17	Hawassa city
2	19 boreholes					
2.1	Mettewell#1	50	12.8	2006	9	Hawassa city
2.2	Mettewell#2	59	7.3	2005	9	Hawassa city
2.3	Treatment well	107	7.7	2005	12.8	Hawassa city
2.4	AbellaWondo#1	58	7	2005	9	Hawassa city
2.5	Gara-Riquat#1	96	30	2010	10	Hawassa city
2.6	Gara-Riquat#2	107	30	2014	10.7	Hawassa city
2.7	Gara-Riquat#3	125	30	2010	9.2	Hawassa city
2.8	Gara-Riquat-P5	176	50	2014	8.5	Hawassa city
2.9	Gara-Riquat-P6	200	50	2014	9.3	Hawassa city
2.1	Gara-Riquat-P7	185	50	2010	10	Hawassa city
2.11	Gemeto-P8	193	50	2008	6	Hawassa city
2.12	Yuwo -P1	200	50	2012	10	Hawassa city
2.13	Yuwo-P2	200	50	2014	10.7	Hawassa city
2.14	Yuwo-P3	200	50	2014	11.5	Hawassa city
2.15	Yuwo-P4	200	50	2014	12	Hawassa city
2.16	AbelaWondo#3	163	13	2014	11	Tullasub-city
2.17	Abella Wondo well #2	53	6	2014	10	Tulla sub-city
2.18	Qarara	204	7	2014	10.2	Tullasub-city
2.19	Boko– Alamura	160	16.75	2014	9.8	Tulla sub-city
3	Lokespring		13	1985	11	Hawassa city
4	Ambo wuha Spring		12	2014	15	Hawassa city
5	Beshima Spring		6	2012	7	Tulla sub-city
	Total Production		637.35			

Appendix-3.Hawassa city water reservoir

Source Reference	Physical location	Volume (m^3)	Type	Remark
Loke spring	Loka	200	Con	
Treatment/mett#1,Abelawondo#1	Sebategna Camp	500	Con	
Gemeto Galle	Sebategna Camp	500	Con	
Kedo	Sebategna camp	500	Con	
Ambo wuha spring	Eredo mountain	1000	Con	
Mett#2	Zelalem Park	50	Masonry	
Gara riketa	Sebategna Camp	2660	pioneer	
Booster station(8boleholes)	Sebategna reservoir	4000	Con	
Gemeto FTC well	Gemeto	100	Con	
E1,E2,P1,P2,P3	Booster station new	300	Con	Balance
P4,P5,P6,	Booster station new	300	Con	Balance
Loke spring and Boko Alamura	Referral Hospital	200	pioneer	
Kerara Water well	Tula sub- city	100	Masonry	
BokoAlamura	Tula sub -city	300	Masonry	
Mette3	Chafasine	100	Con	
Bore Holes	Tulla sub- city	100	Con	
Abelawondo3	Harenfama	300	Con	
AbellaWondowell#2	Tulla sub -city	1000	Con	
Qarara	Tulla sub -city/Gutter	300	Con	Balance
Bashima spring	Tulla sub -city	100	Con	
Loke spring	Referral Hospital	200	Con	

Appendix-4.Hawassa city demand projection (2022-2042)

	Unit	Year					
		2022	2023	2025	2030	2035	2042
Hawassa city population	No.	573669	596991	645084	774334	916117	1,065,644
Domestic Demand							
Privet house connection		92%	93%	94%	95%	96%	97%
Public Tap User		8%	7%	6%	5%	4%	3%
Number of Population per service level							
Privet house connection	No.	527,776	555,201	606,378.9	735,617	879,472	1,033,674
Public Tap User	No.	45,894	41,789	38,705	38,716.7	36644.7	31,969
Per capita water demand by Categories							
Privet house connection	L/c/day	70	72	74	76	80	85
Public Tap User	L/c/day	30	32	34	36	40	42
Water demand Categories							
Privet house connection	M^3/day	36,944.32	39,974472	44,872,038	55,906,892	70,357,760	87,862,290
Public Tap User	M^3/day	1,376.82	1,337248	1,315,970	1,393801	1465787	1342711
Total Domestic water Demand	M^3/day	38,321.14	41,311.7	46,188	57,300.7	71,823.5	89,205
Non-domestic Water Demand	M^3/day	31,438.3	31,438.3	31,438.3	31,438.3	31,438.3	31,438.3
Average Day Demand	M^3/day	69,759.4	72,750	77,876.3	88,739	103,261.8	120,643.3
Losses and Leakage (30%)	M^3/day	20,858.9	21,825	23,362.9	26,621.7	30,978.5	36,192.9
Average Day Demand with Loss (ADD)	M^3/day	90,613.41	94,575	101,239	115,360.7	134,240.3	156836.3
Total Maximum day demand (ADD*1.2)	M^3/day	108,736.09	113,490	121,487	138,432.8	161,088.4	188,203.5
Total Maximum Day Demand	L/sec	1258.5	1313.5	1,406	1,602	1864.4	2178.3
Peak Hour Demand (ADD*1.8)	M^3/day	163,104.1	170,235	182,230	207,649	241,632	282,305
Peak Hour Demand	L/sec	1887.7	1970.3	2109.1	2403.3	2796.7	3267.4
Storage Capacity (33*MDD)		3588289.9	3,745,170	4,009,071	4,568,282.4	5,315904	6,210,715.

Appendix- 5: Mixed Water Test Result in the Reservoir Before Supplied to Consumers.

Drinking water quality standard	Physico-chemical characteristics of mixed water in the reservoir									
	Fluor ide, (F^-) Mg/l	Iron (Fe^{2+}) mg/l	Phosphate Mg/l	Sulphate (SO_4^{2-}) mg/l	Nitrate (NO_3^-) Mg/l	PH	Total Hardness ($CaCO_3$) Mg/l	Ca as $CaCO_3$	Mg as $CaCO_3$	Total Alkalinity as $CaCO_3$
Mixed water from each source in the reservoir	0.64	0.01	0.33	18	2.3	7.2	140	80	60	150

Appendix-6: Chemical analysis of borehole

Appendix 6: Mixed Water Test Result in the Reservoir Before Supplied to Consumers.

Drinking water quality standard	Physico-chemical characteristics of mixed water in the reservoir									
	Fluoride, (F^-) Mg/l	Iron (Fe^{2+}) mg/l	Phosphate Mg/l	Sulphate (SO_4^{2-}) mg/l	Nitrate (NO_3^-) Mg/l	PH	Total Hardness ($CaCO_3$) Mg/l	Ca as $CaCO_3$	Mgas $CaCO_3$	Total Alkalinity as$CaCO_3$
Mixed water from each source in the reservoir	0.64	0.18	0.27	3	8.8	7.2	98	72	26	170

Appendix 7 : Chemical analysis of borehole

S. No	Name of source	Type of source	Fluoride (mg/l)	Iron (mg/l)	Phosphate (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	PH	Total Hardness as $CaCO_3$ (mg/l)	Ca as $CaCO_3$ (mg/l)	Mg as $CaCO_3$ (mg/l)	Alkalineas $CaCO_3$ (mg/l)	GPS coordinate		Elevation (m)
													North ing	Easting	
Acceptable limit of WHO			1.5	0.3	-	250	50	6.5-8.5	300	75	50	200			
1	Karara	Borehole	0.65	0.01	1.57	4	11.9	7.8	53	30	23	156	441352	770743	1762
2	Mete1	Borehole	0.45	0.08	0.45	2	11.5	7.6	100	60	40	162	445607	770648	1722
3	Mete2	Borehole	0.42	0.10	0.73	1	0.4	7.0	120	90	30	150	445303	770493	1727
4	Abelawondo 1	Borehole	0.38	0.02	0.59	4	2.6	7.5	106	90	16	163	446393	770925	1729
5	Abelawondo 2	Borehole	0.64	0.06	0.33	3	2.3	7.6	86	70	16	180	447130	770258	1750

Borsamo Roka   Matiyos Azage   Esayas Sebsibe

6	Gararikata 1	Borehole	0.81	0.05	0.40	27	3.9	7.4	132	90	42	175	447761	771220	1723
7	Gararikata 2	Borehole	0.61	0.15	0.66	8	0.017	7.3	120	80	40	152	448405	770950	1723
8	Gararikata 3	Borehole	0.51	0	0.4	2	1.5	7.6	110	54	56	160	448467	771909	1721
9	Treatment	Borehole	0.18	0.03	0.64	2	2.2	7.5	110	100	10	130	447465	768772	1721
10	Yuwop1	Borehole	1.06	0.07	0.39	8	3.5	7.5	110	70	40	100	449154	771808	1716
11	Yuwop4	Borehole	0.59	0.08	0.56	4	2.8	7.3	110	70	40	145	449924	770916	1718
12	Yuwop5	Borehole	0.66	0.26	0.06	5	4.81	7.35	70	36	34	160	448023	771921	1719
13	Gararikata p6	Borehole	0.95	0.08	0.45	9	10.4	7.6	130	89	41	190	448538	772649	1712
14	BGI1	Borehole	3.9	0.04	0.63	23	6	7.9	140	62	78	510	445273	777317	1725
15	BGI2	Borehole	2.6	0.03	0.65	22	7	8.1	139	59	80	490	445136	776765	1724
16	Haile resort	Borehole	3.6	0.09	0.27	1	1.0	8.2	140	120	20	520	442472	782304	1700

Analyzed by water quality control chemists :-

- Borsamo Roba
- Signature [signature] Date 24/may/2024
- Esayas Sebsibe
- Signature [signature] Date 24/may/2024

Approved by (Quality control team leader) : -

- Matiyas Azage
- Signature [signature] Date 24/may/2024

Sidaamu Dagoomu Qoqqowi Mootimma Hawaasi Quchchumi Wayinna S/Owaante Interprayize