JIMMA UNIVERSITY, JIMMA INSTITUTES OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING,

HYDRAULIC ENGINEERING MASTER PROGRAM

ASSESSING WATER SUPPLY COVERAGE AND LOSS ESTIMATION IN DISTRIBUTION SYSTEM: A CASE STUDY ON ADAMA CITY

A THESIS PROPOSAL SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF JIMMA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN HYDRAULIC ENGINEERING

BY: GIRMA FEYE

November 2015

Jimma, Ethiopia

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November 2015

Jimma, Ethiopia

Declaration

I, the undersigned, declare that this thesis:

Assessing water supply coverage and loss estimation in distribution system is my original work, and it has not been presented for a degree in Jimma University or any other University and that all sources of materials used for the thesis have been fully acknowledged.

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This thesis has been submitted for examination with my approval as University Supervisor

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ABSTRACT

Losses in water distribution system is an important issue that could affect water companies and their consumers worldwide. Losses could be caused by various factors and be considered as the amount of potable water loss from a supply source in transmission and distribution system. The need to manage water loss in pipe networks of most municipalities became urgent in recent years due to water shortages. The aim of this study was estimation of the water supply coverage of Adama City and total water loss in the distribution system. Surveys, key informant interviews, focus group discussion, and direct observation was used to triangulate the findings of the quantitative survey. The sampling techniques was utilized by clustered and software such as WaterCADV8i and GIS map10 to analysis. SPSS software was also used to analysis primary data. The study was carried out in nine Kebele and the population which water used in current 245,000 and the study would identify and analysis the water supply coverage and total water loss in distribution system in Adama City. The finding of this study showed that water supply coverage and water loss in Adama estimated in the order of 70% and 24.7% respectively. The coverage of the city water supply declines over time from 2009-2013. However, floating population who shares from the daily water proceed, additional number of University and college students, hospitals, and health centers contributed to the water shortage of the city. In 2014 water supply coverage were increases comparing with 2013, because drilling five different boreholes to be utilized the coverage. The water loss trend of the city was fluctuated from year to year. This could be due to road, and star-hotels construction in Adama and breakage of pipes was occurred, and this maximized water loss. Water loss was increases in 2014 comparing with 2013 because expansion of construction. This study found out average per capita consumption was much lower as compared with some water supply standards. Uneven distribution of water and the spatial distribution of the pipe network system do not satisfy the demand of the public. The water loss in Adama city was intermediate and loss was increase and decrease, depending on time of construction and awareness creation between people. Recommendations on better water supply coverage and water loss management for Adama would be operation and maintenance strategy, drilling additional borehole and Proper sized pipes during the implementation of the project.

Key words: *Consumption: Water loss: Water production: Water supply coverage:*

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ACRONYMS

ADB	African Development Bank
AWSSE	Adama Water Supply and Sewerage Enterprise
AWWA	American Water Works Association
CSA	Central Statistics Agency
DCI	Ductile Iron
DMA	District Meter Area
EC	Ethiopian Calendar
ETB	Ethiopian Birr
GC	Gregorian calendar
GIS	Geographical Information System
GPS	Global positioning System
IWA	International Water Association
JiT	Jimma Institute of Technology
Km	Kilometer
l/c/d	litter per capita per day
l/h/d	litter per house per day
l/s	litter per second
l/p/d	litter per person per day
m	meter
m^3	cubic meter
mm	millimeter

MDG	Millennium Development Goal
MNF	Minimum Night Flow
MoWR	Ministry of Water Resources
NRW	Non-Revenue Water
OWWDSE	Oromia Water Works Design and Supervision Enterprise
PWS	Public Water System
SI	System International
SPSS	Statistical Program for Social Science
UFW	Unaccounted For Water
UK	United Kingdom
UNDP	United Nation Development Programs
UNICEF	United Nations Children’s Fund
uPVC	Unplasticized polyvinyl chloride
US	United State
WB	World Bank
WHO	World Health Organization

Definition of key terms and water loss concept

The following are standardized definition and performance indicators used in the IWA/AWWA Water Audit Methodology. Some definitions may vary slightly between water providers based on political decision and internal billing policies.

- **Water losses:** The different between System Input Volume and Authorized Consumption, consisting of Apparent Losses plus Real Losses.
- **Apparent Losses:** Unauthorized Consumption, all types of customer metering inaccuracies and systematic data handling errors in customer billing operations.
- **Real Losses:** The annual volumes lost through all type leaks and breaks in water mains and service connection, up to the point of customer metering. Real losses also include overflows from treated water storage tanks or reservoirs.
- **Authorized Consumption:** The annual volume of metered or unmetered water consumption by registered customer, the water suppliers, and others who were billed and produced revenue.
- **Revenue Water:** components of the System in put volume that were billed and produce revenue.
- **Non-revenue water (NRW):** The sum of Unbilled Authorized Consumption, Apparent Losses and Real Losses. The term of Nonrevenue Water should be used instead of the term imprecise term Unaccounted for water. It was recognized that some of this component water of Nonrevenue water was authorized consumption (unbilled).
- **Unaccounted for water (UFW):** Represents the difference between "net production" (the volume of water delivered into a network) and "Consumption" (the volume of water that can be accounted for by legitimate consumption, whether metered or not).
- **Water Supply Coverage:** Refers to the proportion of people served with the adequate levels of water supply.

CHAPTER ONE

INTRODUCTION

Sufficient potable water supply was one of the basic urban service, which highly affects the economic progress of towns and the health of their people. However, many urban centers around the world were facing serious problem of water supply. The problem in most of the third world countries, including Ethiopia, was particularly worst and multidimensional (Assefa, 2006).

Access to safe drinking water and sanitation was a global concern, especially as a Millennium Development Goal, and in recent years, it has been increasingly addressed as one of the basic human rights of nations (UNDP, 2006). The other issue inviting attention in water supply and sanitation sector in Ethiopia in general and Adama City in particular was characterized by service deficiency of physical infrastructure as well as by inadequate management capacity to handle policy and regulatory issues and to plan, operate, maintain the service. Inadequate production, together with inequitable distribution system and low quality of water influence the well-being of people in particular and the socio-economic condition of the urban in general.

At the beginning of 2000, one sixth of the world population was without access to improved water supply. The majority of those people live in Asia and Africa, where two out of five African's lack improved water supply. The 2000 GC coverage of water supply for the urban population of Africa and Ethiopia was 85% and 77%, respectively. On the other hand, in Africa largest Cities, only 43% inhabitants have house connection water supply services (Welday, 2005). The main problem that developing countries have been facing to provide access to save water for their citizen's was shortage of resource. Moreover, the capacity of the citizen has to pay for water that fully recovers the cost was very limited. Problem in providing satisfaction water supply to the rapidly growing population especially that of the developing countries were increasing from time to time. Water supply coverage system in urban areas are often unable to meet existing demands were not available to everyone rather some consumer take disproportional amount of water and the poor is the first victim to the problem (Bereket, 2006). Moreover, managing and reducing losses of water at all level of a distribution remains one of the major challenges facing many water utilities in most developing countries including Ethiopia. As a result of the overall shortage of water many water utilities were faced a problem in distribution system. Besides, to this poor management of the existing infrastructure asset increases the level of water losses in water supply (Mebet, 2007). Although there are many reasons for minimizing losses in municipal water distribution networks, perhaps the most important one relates to quality of service. Additional, during drought periods, system with a high losses index cannot be properly manage and may demand frequency service interruption.

Reducing water losses volume has the advantage of diminishing costly expansion of the system through hydraulic works. Water loss was also costly in terms of energy losses and causes high environmental cost. In fact, a lot of time was required in order to detect the loss of water in a wide water supply distribution networks and large amount of water goes waste. Non-revenue water (NRW) in a water distribution networks was determined by deduction of meter and authorize un-meter consumptions from total inflow. Non-revenue water was divided into apparent losses and real losses.

Apparent losses: losses were produced by metering, human and management errors, and lead to consumption of water without charging.

Real losses: real losses include wastewater and could be categorized to pipe system leakage (report and unreported bursts and background losses), reservoir leakage and over flow and finally leakage from valves and pumps.

Losses from a water distribution network can be determined by adopting several approaches. By using a field studies concept of yearly balance and minimum night flow (MNF) assessment, possibly in combination with “burst and background losses estimation”, the total value of leakage in water supply networks (at district meter area, DMA, level) can be evaluated and it’s component was determined (Tabesh et al., 2008)

A more rigorous and refine approach, applicable to the distribution of water losses in the entire network, was to use the earlier approaches (water balance and minimum night flow) in combination with a hydraulic simulation model such as WaterCADV8i. However, most a computer program performs extending period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. Water CADV8i is an extremely efficient tool for laying out a water distribution networks. It was easy to prepare a schematic or scaled model and let

Water CADV8i takes care of the link-node connectivity. In constructing distribution networks for this study, no labels to nodes, because Water CADV8i would assign labels automatically. When creating a schematic drawing, pipe lengths are entered manually. In a scaled drawing, pipe length automatically calculated from the position of the pipes' bends, start, and stop nodes on the drawing pane.

A recent study made by the African Development Bank (ADB, 2006) concluded that the average level of water loss was 30% of the water produced, with wide variations among individual suppliers ranging from 4 to 65%. The World Bank (WB, 2005) study also found that more than 900 utilities in 44 developing countries around the world have approximately 35% in water loss level. The actual figure for overall water loss levels in the developing countries was more in the range of 40-50% of the water produced.

Besides too low coverage, water losses (physical loss) in urban water supply were accounted to more than 50% (Shimeles, 2011) of the supplies that mainly arise from:-

- Leakage from water mains through faulty joints or corrosion
- Leakage from reservoir
- Leakage from in service and fitting inside the consumers' promises
- Leakage through abandoned service pipes
- Leakage of valves

While developed cities have start using on-line continues operation and monitoring service, the developing cities have great difficulty even to collect information on their previously performed operation and maintenance activities that could help them developing a strategy for the future. Many developed countries used water audit procedures to determine the efficiency of the system and to identify the location and magnitude of water losses.

There was also a need for some type of database or information system such as GIS to enable analysis of flows in the networks and provide early warning or indication of leakage. At present, although some cities in developing countries were introduced GIS based information system, many countries were still applying conventional methods for collecting, storing, processing and retrieval of information system, but the good news was that GIS have the ability to use previously collected and stored digital information easily and with less cost.

The International Water Association (IWA) and the American Water Works Association (AWWA) began to finalize standard method to assist water utilities in tracking their distribution system losses in the last several years. The method were the foundation of water auditing and conservation strategies that are new being used success worldwide.

The reduction and control of water loss was become even more vital in this age of increasing demand and changing weather patterns that brought droughts to a considerable number of locations in the world. Many water utilities have been developing new strategies to reduce losses to an economic and acceptable level in order to preserve valuable water resources.

In Adama City, the component of water demand were residential, commercial, industrial, institutional or public water uses and unaccounted system losses and leakages. While all components generate revenue to the utility, the unaccounted system loss and leakages were not associated with total cost revenues, and were a source of wasted production costs. With high today's water production costs and rates, the expense of detecting and mitigating the unaccounted water and leakage was an attractive option for reducing waste.

The water utility benefits by:-

- Saving the production costs of the water
- Increasing revenues through the sales of water saved
- Deferring the system expansion and capital expenditures through the capture of lost water
- Reducing increases in utility rates, and thus maintaining better consumer relations

The annual volume of water loss was an important indicator of water distribution system, both individual years and as trend over a period of years. High and increasing water losses were an indicator of ineffective planning and construction, and low operational maintenance activities. with the above background this study was initiated to estimate water supply coverage and related loss in Adama City so as to identify necessary intervention areas.

1.1 Statement of the problem

Adequate and safe water supply was one of the basic urban service, which highly influence economic progress of the city and the health of the people. The water resource availability was linked to economic and social progress, which suggests that the development was strong influenced by water resource availability and management (Sullivan, 2002).

Adama City has passed through various social and economic progress. However, increasing population, growing urbanization and socio-economic change of the people, have pushed up the demand for water extremely high in terms of quantity and quality. This clearly calls for the expansion and improvement of basic water supply service to give proper and timely response to the city water demand.

Water losses were a large source of unaccounted for water and cause by various influence, especially on the aging pipe networks are essential part of the maintenance strategy for existing water distribution networks. Public water supply system face a number of challenges including aging infrastructure. Leakage was a major problem for water utilities, as they affect the environmental and financial sustainability of urban water service and often a large source of unaccounted for water and was a result of either lack of maintenance or failure to renew ageing systems. Water losses from a utilities distribution system was a growing management problem that was not only confine to losses revenue. Water losses in the distribution system require more water to be treated, which require additional energy and chemical usage, resulting in waste resources and losses revenue. Leakage may also be caused from poor management of presser zones, which result in pipe or pipe joint failure.

Although, some leakage may go unnoticed for a long time, detection of visible leakage also requires good reporting which includes some level of public participation. In different attempts and research, works have been also made in different parts of the counties by different governmental organizations, individuals, and voluntary sectors to identify the causes for failing of adequate and sustainable urban water supply system. Previously conducted studies identified the major causes; however, it is not possible to generalize for other urban areas like those that Adama City where the problem is serious but not such conducted yet. In line with the above assertion and find, a comprehensive way out to the problem there should be detailed studies, which aim at investigating the challenges of potable water supply systems in different urban parts of the country. Therefore, the study on the challenges of water supply in Adama City was an attempt in this dimension.

1.2 Objective

1.2.1 General objective

The main objective of this study was estimation of the water supply coverage and total water loss in the distribution system of Adama City.

1.2.2 Specific objective

- To evaluate water supply coverage of Adama City
- To assess water demand and distribution system of Adama City
- To quantify water loss of Adama City
- To identify the major causes of water loss in distribution system

1.3 Research questions

1. How much was the per capita demand of Adama City?
2. How did we evaluate water demand and distribution system in Adama City?
3. How much water was lost in the entire city?
4. What were the possible causes and consequences of water losses?

1.4 Expected outcomes

A municipality would benefit through reduced water loss and reduced costs to the utility. The importance of prioritizing active leak control practices and procedures in the identification of water loss and the corresponding strategies to reduce leakage cannot be understated. The municipality would also benefit through the extension of sustainable water supplies, reduce operating costs, improved system hydraulics and utility efficiency and this methodology would allow more rational performance measures to be calculated for sub-systems, systems, and utilities for realistic national and international performance comparisons of water loss management.

1.5 Justification

In Adama City, reforms had taken place in the water sector to address irregularities that exist in water resources management which affect water supply coverage and equity in water supply and water loss in distribution around the Kebele. Among some of the reforms which include access to water for primary use for all, all water to be beneficially used, water to be treated as an economic good and consideration to be taken for those unable to pay full price during water tariffing. Constraints to sustainability aggravated by the macro-economic challenges face by Adama during the period 2006-2008 erode capacity of local authorities to operate efficiently. Among some of the water problem associated with service delivery in Adama, which include insufficient coverage of services, water losses, and financial problem. Little has been done to review and analyze the performance of the urban water supply utilities.

1.6 Scope

The first objective of this study was to provide municipalities with a basic common method of accounting for the water used and loss in their water distribution system. The intent was to use standard terms that were recognized internationally, allowing municipality to communicate readily and understand each other. By accounting for the water, municipalities can made operations, maintenance, and capital improvement decisions in the best interests of their local Administrative and the community they serve. This best practice would help municipalities prioritize their capital and operating decisions and better safeguard their system from water loss.

Two leading organizations represent municipalities, water utilities, individuals and other organization, in matters relates to this guide. It was recommended that municipality get involved with the AWWA (American Water Works Association) and the IWA

IWA to pursue the continuous improvement in water use and loss control in distribution system. This, in turn, would allow their knowledge and expertise to be disseminated by these organizations for the benefit of municipalities and potable water suppliers everywhere. The scope of this study were estimation of the water supply coverage of Adama City and total water loss in distribution system.

1.7 Frequency

This water use and loss in water distribution systems should be undertaken on yearly basis, as a minimum. Since many operational and maintenance activities were required, advisable on a seasonal schedule, to allow appropriate planning of seasonal activities within the municipality.

1.8 Limitations

The limitations of data collection completely depend on the municipality. There were some sorts of limitation while this document was prepared. Shortage of relevant data for the compilation of literature review, data would not organized in computerized system. A municipality must consider how it would collect, store and evaluate the data to allow it to make the most informed decisions.

1.9 Significance of the study

This study was expected to increase the understanding and provide up to date information of the city water supply size and its undesirable impacts on the urban community due to shortage of water supply. It would also serve as a working document to decision makers in the water sector and the non-governmental organizations. Moreover, the findings would further serve as reference material for any further investigation in the area.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

Problems in providing satisfactory water supply to the rapidly growing population especially that of the developing countries was increasing from time to time. Water supply system in urban areas were often unable to meet existing demands and were not available to everyone rather some consumers take disproportionate amounts of water and the poor was the first victim (Bereket, 2006). develop and expand water supply projects and one of the difficulties among the other was managing and reducing losses of water at all levels of a distribution system. Because of the overall shortage of water, many cities faced a problem in distributing the available water impartially among the residents. Besides the poor management of the existing infrastructure asset, increase the level of water losses in water supply (Mebet, 2007).

Continuous monitoring and maintenance of the distribution network was the key step in meeting pressure and flow requirements, and water quality standards. A recent drinking water infrastructure needs survey(Shimeles, 2011) estimates an investment of 151 billion dollar over a period of 20 years to provide safe drinking water for US customers. Reducing water losses in pipe networks can minimize the maintenance costs and further improve the performance of pipe networks.

Leakage could be defined as unintentional or accidental loss of water from the pipe distribution network (Shimeles, 2011). Pipe leakages were 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 pipe was age and deteriorated networks. In the globe alone, 50% of supplied water was loss as leakage in some of the older networks (Jowitt and Xu, 1990). Leakage rates were also related to length of pipes and number of connection. Improper connection could sometimes result in continuous escape of water from the distribution pipes.

Adama City had significant problem, especially on the shortage of water supply. Thus after ten years of exhausting services, the water treatment and distribution system of the city of Adama has been critical disturbance where the system could not fully cater for all uses in and around the city.

- Floating population who shares from the daily water processed,
- Additional number of university and college students,
- Hospital and Health centers,
- Gusts and Visitors as a result of conference,
- tourism, marketing, establishment of star-hotels and modernized life style,
- Animal fattening purposes,
- Car washing, garden watering

the design quantity of 330 l/s, which called for critical analysis and decision for supply upgrading works (AWSSE, 2013).

Back ground information reveals the number of users in 1975 EC was estimated to 75,000 with a per head satisfaction of 33 l/d and currently users population size of the town has limitlessly increased. The number of daily visitors in the form of passengers, resort fellow, conference participators and many incomers from the surrounding areas add up to the number of usual residents which give rise to above 245,000 people. At the rate of 80 l/c/d, the current per capita satisfaction was therefore, estimated to 46 l/c/d, only 13 l/h/d added upon the supply of 29 years back (AWSSE, 2013). The water supply service office has now about 245,000 registered customers who own a metered water service and it was forecasted that, customers shall rose to over 350,000 in year 2015 and further growth was usually expected (AWSSE, 2013).

The major existing water supply source for the area was Awash River, but the water supply situation was inadequate due to floating population who shares from the daily water processed.

Table 2.1 Progress towards the MDG drinking water target for the most populous developing countries (WHO and UNICEF, 2006)

Drinking water coverage (%)			
Countries with population > 50 million in 2004	1990	Actual	Required to reach MDG target
China	70	77	79
India	70	86	79
Indonesia	72	77	80
Brazil	83	90	88
Pakistan	83	91	88
Bangladesh	72	74	80
Nigeria	49	48	65
Mexico	82	97	87
Vietnam	65	85	76
Philippines	87	85	91
Ethiopia	23	22	46
Egypt	94	98	96
Turkey	85	96	90
Iran (Islamic Republic of)	92	94	94
Thailand	95	99	97
Democratic Republic of the Congo	43	46	60
Myanmar	57	78	70

In 2004, 5.3 billion people used water from improved sources up from 4.1 billion in 1990. However, because of population growth, the number of people unserved has not charged substantially since 1990. About 1.1 billion people of the world population remains without access to improved drinking water and 84% of these live in rural areas (WHO and UNICEF, 2006).

2.2 Urban water demand

Demand of water was the amount of water required to meet all the needs of the people, which the system serves. It was expressed as per capital demand per day (l/c/d). Community growth, the growth of local commerce and industry, and the development of new industries all increases demand for water. Essentially, the analysis of water demand aims at offering all the necessary information and knowledge for designing an effective water demand policy, and specifically a policy that pursues the efficient use of water resources.

According to Linsley et al. (1992), water supply system capable of supplying a sufficient quantity of potable water was a necessity for modern city. The components that make up a modern water supply system includes the sources of supply, storage facilities, transmission (to treatment) facilities, transmission (from treatment) and intermediate storage facilities and distribution facilities.

Urbanization and population growth follow a very complex process and affected by a range of economic, political, social, cultural, and environmental factors. The design of the water supply project was done based on projected population it was the main factors that affects the water supply project. Future population growth can be influenced by affecting birth, death, or migration rates due to social, economic, political, technological, and scientific developments (Lee and Tuljapurkar, 1994).

Chatterje (2005) describes the design was done based on projected population at the end of the design period. Otherwise, a present scheme will be inadequate in the near future.

One of the problems that was related to urban water supply provision was the lack of a potable water supply, it could be stated that quite often, household connection to a piped water were only available for the higher income group of population. The reasons behind this were because the physical availability of water for many cities in developing countries were in areas of heavy rainfall or were close to major rivers. In other words, because of the limited access to a potable water supply then people may decide to consume water of a doubtful quality from a nearby-unprotected river, well or spring (Akbar and Minnery, 2007). This, in developing countries, people that live in poor areas were not concerned with a safe water supply as an adequate source but more on the availability of water.

Table 2. 2 Current situation of water supply coverage of Adama City (AWSSE, 2013)

Daily water production	24,480 m^3/d
Estimated daily water loss	5,190 m^3/d or 21.2 %
Net daily water distribution	19,280 m^3/d
Daily utilizing Communities	373,500 to 400,000
Daily per head supply	48 to 50 l/h/d
Actual demand	80 l/h/d
Shortage	12,720 m^3/d
Service coverage	65.25 %

Therefore, changing the previously used water supply system of Animal fattening purpose and garden watering, replace it by drilling boreholes. Since the animal fattening and garden watering consumes 4213.72m^3/d amount of water from the total production (AWSSE, 2013), so it contributes for the shortage happened in the city. To minimize this problem AWSSE proposed project covers the water demand of animal fattening and garden watering by drilling five boreholes and giving their consumption to the people. Since geological and hydrological of the investigated area has, the potential and accessible ground water source to solve the above problem.

2.3 Water supply situation in Adama City

Adama City was started to get water supply in 1935. Groundwater has been used as the source of water over a long period. The groundwater source near the city has been abandoned since 2003 due to the intrusion of florid. Instead, Awash River (minimum flow was about 15 m^3/s), which is regulated by Koka Hydropower Reservoir, is transported from 15 km distance. It is the potential source of water for Adama City. The water quality of treated water (Awash) is almost satisfactory except for its silt-like taste. There are three reservoir and one pump. Two reservoir distribute water by gravity system to the city and when the altitude is high, the water store in the third reservoir and distribute by pump to the highest altitude.

The volume of water production by the treatment plant is 9,250 m^3/day, on the average. The water transmission line feeds three reservoirs constructed at different locations in the city. The Reservoirs capacity were ranging from 500m^3 to 6000m^3. Adama Water Supply and Sewerage Enterprise, which is a government enterprise that responsible for the supply of potable water and collection, disposal of wastewater and sludge of the city, managed by Adama City water supply system. The enterprise is administrated by a board and directly responsible to the town mayor. The water is delivered to the households, public and business organizations through different sizes of pipes, reservoir and pumping stations.

Water demand analysis of the city has been 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. Beside to the average per capita water consumption, the distribution of number of domestic connection per family has been also evaluated.

Table 2. 3 Adama population, Summaries of water demand and design flows (OWWDSE, 2012)

	2011	2014	2015	2020	Phase I (2025)	2030	Phase II (2035)
Residing in Adama	264,173	299,565	312,147	381,237	461,163	552,496	655,558
Rural and Floating	19,183	22,467	23,411	28,593	34,587	41,437	49,167
Adama University	14,000	15,076	15,453	17,484	19,782	22,381	25,322
Subtotal	**298,000**	**337,100**	**351,000**	**427,300**	**515,500**	**616,300**	**730,000**
Wonji population	75,432	85,538	89,131	108,859	131,681	157,761	187,189
Total population	373,400	422,600	440,100	536,200	647,200	774,100	917,200
Livestock population	100,000	100,000	100,000	100,000	100,000	100,000	100,000

A large population would use more water than a small once and the water use must be income measure related to the population. The various types of water demand may be broken down into the following categories.

- Domestic demand
- Industrial and commercial demand
- Public water demand
- Unaccounted losses
- Recreation and Navigation purpose
- Fire hazard protection

2.3.1 Domestic water demand

In the design of any water supply project, it was necessary to estimate the amount of water that was required to satisfy and serve up to the end of the design period. This involves determining the number of people who would be served and their per capita water consumption, together with an analysis of the factors that may operate to affect consumption. Water demand of households would depend on their income, willingness to pay and understanding of people about the advantage of using treated and potable water. Therefore, it was clear that the future piped water consumption would be closely related to the future water tariff and connection fees to be charged. Water require for drinking, cooking, bathing, gardening, sanitation purpose, it depends on the living standard of the consumer. The domestic water usage range from 20 l/c/d for developing countries like Ethiopia to 350 l/c/d for developed countries (AWSSE, 2013). Average per capita consumption and level of connection per family parameters were used to assess the town domestic water supply coverage.

Data's of individual domestic water consumptions, total water consumption (m^3), total production (m^3), and total number of customers were collected from the town water supply and sewerage enterprise bill documents for analyzing average per capital consumption and connection per family.

2.3.2 Non domestic water demand

Non-domestic water demand was the quantity of water required for Schools, Hospitals, Universities, Government, and non-government office. To compute such water demands, the actual figure of public service, Institutions and commercial centers consumption data were collected from AWSSE. The recommended value of non-domestic demand by cost effective design guideline for urban water supply presented by MoWR (2006), was 20 to 40 % of the domestic water demand.

2.3.3 Industrial water demand

Adama has very large endowment of land, cheap labor those created strong competence to the city. The prevalence of agricultural raw materials and transport infrastructures were contributed their share for the development of industrial establishments in the city. Adama was one of the cities where of industries establishments those largely depend on domestic resources found in concentration. The city characterized by the absence of large-scale manufacturing that could accommodate many employees and generate many employments in the city. The city Administration has installed all necessary infrastructures in this industrial zone to facilitate investment in industry and it provides basic facilities like water, electricity and others.

Industrial water demand was the quantity of water required for factories, Industries, Power station, and the water required in the industries mainly depends on the type of industries, which were existing in the town. The recommended value of industrial demands by effective design guideline for urban water supply presented by MoWR (2006) was 5 to 10 % of the domestic demand. However currently there were big industries in Adama City and require huge volume of water, it was a usual practice to let it has its own water source, such as a borehole.

2.3.4 Water requirement for firefighting

Fire hydrants should be installed at public and municipality interest such as Schools, Shops, Hospitals, Fuel stations and at salient points of distribution network. MoWR (2006) recommends enlarging total reservoir volume by 10 % to the reserve water for firefighting.

As the amount of water required for firefighting was usually taken as small, the trend of the town frequency of the fire breakout was rare and from economical point of view, installing fire hydrant at lower elevated nodes of the distribution system, so that the fire brigade trucks could fill in by the available head was recommended.

Table 2. 4 Adama water consumption excluding un-accounted for water (OWWDSE, 2012)

Consumption	Unit	2011	2014	2015	2020	Phase I (2025)	2030	Phase II (2035)
Domestic demand	m^3/d	10,520	11,929	12,430	18,907	26,051	35,173	46,617
Public and Commercial	m^3/d	3,156	3,579	3,729	5,672	7,815	10,552	13,985
Livestock	m^3/d	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Industrial demand	m^3/d	1,052	1,193	1,243	1,891	2,605	3,517	4,662
Adama University	m^3/d	840	905	927	1049	1,187	1,343	1,519
Total	m^3/d	18,068	20,106	20,829	30,019	40,158	53,085	69,283

2.3.5 Adama average day demand

The average water demand could be determined by adding the five categories of water demands: Domestic water demand, public and commercial, livestock, industrial demand, Adama University and unaccounted for water would be added to this sum. The average day demand represents the daily demand of the city over the year.

Table 2. 5 *Average day demand* (OWWDSE, 2012)

	Unit	2011	2014	2015	2020	Phase I(2025)	2030	Phase II(2035)
Un-Accounted for water	%	34%	34%	15%	20%	25%	30%	35%
Domestic demand	m^3/d	14,097	15,985	14,295	22,688	32,564	45,725	62,933
Public and Commercial	m^3/d	4,229	4,796	4,288	68,06	9,769	13,718	18,880
Livestock	m^3/d	3,350	3,350	2,875	3,000	3,125	3,250	3,375
Industrial demand	m^3/d	1,410	1,599	1,429	2,269	3,256	4,572	6,294
Adama University	m^3/d	1,126	1,213	1,066	1,259	1,484	1,746	2,051

2.3.6 Adama maximum day demand

The daily water consumption varies from day to day. Maximum water demand represents the water consumption in a day that was higher than the normal. Daily water demand changes with seasons and days of the week. The ratio of the maximum day factors usually varies between 1.15 and 1.5. For Adama a maximum day factor of 1.2 has been adopted; because of the population range falls between 0-500,000, which was 245,000 at a target year of 2014. The deviation of consumption from the average day demand was taken care of as per the maximum daily coefficient in Table below. This table was adopted from design guideline, which has been followed by OWWDSE in previous studies.

Table 2. 6 maximum day demand (OWWDSE, 2012)

Description	Unit	2011	2014	2015	2020	Phase I(2025)	2030	Phase II(2035)
Maximum day factors		1.2	1.2	1.2	1.2	1.2	1.2	1.2
Domestic demand	m^3/d	16,916	19,182	17,153	27,226	39,077	54,870	75,520
Public and Commercial	m^3/d	5,075	5,755	5,146	8,168	11,723	16,461	22656
Livestock	m^3/d	4,020	4,020	3,450	3,600	3,750	3,900	4,050
Industrial demand	m^3/d	1,692	1,918	1,715	2,723	3,908	5,487	7,552
Adama University	m^3/d	1,351	1,455	1,279	1,511	1,781	2,025	2,461

2.3.7 Adama peak hour demand

Peak hour demand was meant for peak demand in some hours within a day. It occurs particularly when all the water taps were opened at a particular rush hour. Such an event was likely to happen during morning hours when most people use water for bathing, washing utensils and cooking. Moreover, it could also occur at the end of the day when people need water for the same purpose after working hours. The peak hour demand was greatly influenced by the size of the town, mode of service used and social activity pattern. The ratio of the peak hour demand to the maximum day demand was called peak hour factor. A peak hour factors of 1.6 has been used for Adama City (AWSSE, 2013).

Table 2. 7 peak hour demand (AWSSE, 2013)

<table>
<tr><td>Town Population</td><td colspan="8">Peak hour factors</td></tr>
<tr><td>0-50,000</td><td colspan="8">2</td></tr>
<tr><td>50,001-100,000</td><td colspan="8">1.8</td></tr>
<tr><td>100,000 and above</td><td colspan="8">1.6</td></tr>
<tr><td rowspan="2">Peak hour demand</td><td>Unit</td><td>2011</td><td>2014</td><td>2015</td><td>2020</td><td>Phase I(2025)</td><td>2030</td><td>Phase II(2035)</td></tr>
<tr><td>l/s</td><td>538</td><td>599</td><td>532</td><td>801</td><td>1,116</td><td>1,534</td><td>2,078</td></tr>
</table>

The peak hour demand was greatly influenced by city size, mode of service and social activity patterns. Previous studies on hourly variation of demand show the peak hour factor was greater for a smaller population.

2.3.8 Average daily per capita consumption

The volume of water consumed for domestic purpose has been aggregated to all eighteen Kebele of the town so as to analysis the distribution of the water supply coverage among different localities. The annual consumption data has been converted to average daily per capita consumption using the number of population. The average daily per capita consumption of each district was derived using the following expressions

2.3.9 Level of connection per family

In order to compare the distribution of the water connection among the different districts, the total number of connection per district were converted to connection per family using the population data of the each Kebele.

2.4 Water distribution system

The purpose of a water distribution network was to supply system users the amount of water demand and to supply it with adequate pressure. The pipe materials for distribution networks are uPVC, and DCI pipes. The diameter of the pipes range from 50mm to 600mm.

Water was distributed to the consumer through 1800m long distribution pipe network laid in the city at different times based on availability of water and demand from customers.

Table 2. 8 The ten water distribution zones in Adama City (OWWDSE, 2012)

ID	Supply Zone	Elevation (masl)	Remarks
SAR1-1800	Sire Ababune	1800	New
GAR2-1750	Galma Abba Gada	1750	Existing
WAR3-1715	Western Adama	1715	New
NAR4-1760	Northern Adama	1760	New
DHAR5-1750	Dhaga Adi	1750	Under construction
AUR6-1720	Adama University	1720	Existing
EAR7-1715	Eastern Adama	1715	New
LUR8-1685	Lugo	1685	Existing
EBOR9-1715	Eastern Boku	1715	Under construction
WBOR10-1715	Western Boku	1715	New

2.5 Coverage of the existing and new distribution networks

The major existing water supply source for Adama was Awash River. Adama City has significant problem on the shortage of water supply. Those after about ten years of exhaustive service, the water treatment and distribution system of the city of the Adama has seen critical disturbances where the system could not fully provide for all water users around the city.

Coverage of the existing distribution system has been increased from 50% (2575 ha) to 100% (5018 ha). The master plan area of Adama City as shown in the figure 2.1. The yellow painted central part of the city represents the existing water supply system whereas the light blue one shows the coverage of the new water supply system.

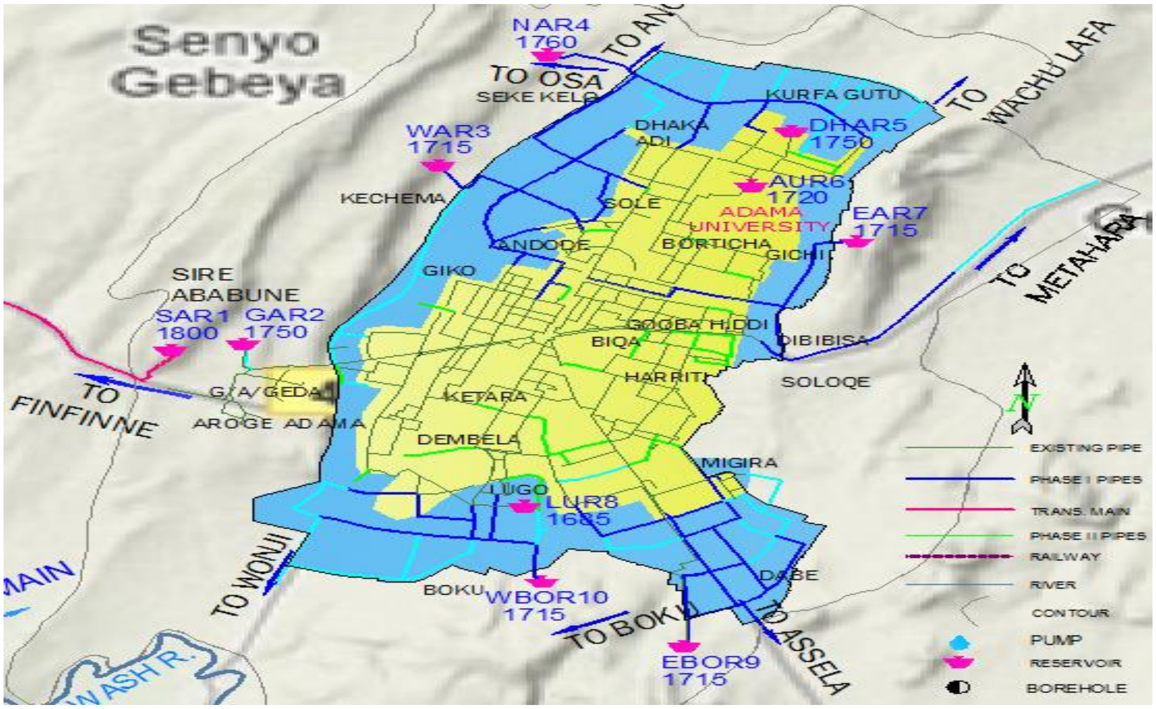

Fig.2. 1 Existing and expanded areas of distribution network of Adama City (OWWDSE, 2012)

Therefore, this project comprises the analysis of the existing situation and design of Adama City water supply system. When complete project phase I and phase II giving their consumption to the people increased the supply from 70 to 79.83% (AWSSE, 2014).

2.6 Measuring and comparing water losses

The component of water loss are determined by a field study with investigation of all properties in the study area and all the components of water distribution network such as reservoir, pumps, valves and pipes (Hussien, 2010).

In developed countries, leakage measurement was conducted through detailed field investigation using sophisticated equipment like Sounding, correlation survey, acoustic noise logging, laser beam, ultra-red, and detection by chemicals. However, in developing countries, due to lack of such technologies, the water loss measurement remains to the indirect calculation from the total water production and consumption (Hussien, 2010).

The amount of water loss from differs from country to country, city-to-city and even from network to another networks in the same city. Different countries uses different indicators to evaluate their states in comparison with others and to compare the distribution of water loss from one location to other location of a distribution system in order to take action based on the level of loss. As stated above competition using unaccounted for water (UFW) expressed as percentage had limitation when used for comparison as it highly depends with the volume of water produced.

One of the major issues affecting water utilities in developing world was the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers called "Non-Revenue Water". Current statistical surveys indicated that NRW levels in developing countries was around 45 to 50% (Dighade et al., 2014).

Table 2.9 Water losses in developed and undeveloped countries (WHO and UNICEF, 2006)

Countries	Level of NRW (excluding unbilled authorize consumption) % system input volume	Real losses (%)	Apparent losses (%)	Loss volume (billions of m^3/year)		NRW volume billions of m^3/year
				Real losses	Apparent losses	
Developed countries	15	80	20	9.8	2.4	12.2
Undeveloped countries	35	60	40	16.1	10.6	26.7

The traditional performance indicator of water losses were frequently expressed as a percentage of input volume. However, this indicator fails to take account of any of main local influences. Consequently, it cannot be an appropriate performance indicator for comparison (WHO, 2001). Metered and unmetered billed (revenue water) and lost (non-revenue water) in a distribution system is tabulated from known and calculated volume of water over time as shown in Table 2.10. Where economically feasible, a municipality should meter all water used by customers.

Since the metering of other users may not always be possible, calculated volumes were recommended.

To avoid for the wide diversity of format and definition related to water loss, many practitioner have been identified an urgent need for a common international terminology that among them task forces from the international water association (IWA, 2003) recently produced standard approach for water balance calculation with a definition of all terms involved as indicated below.

System input volume (A1): was defined as the amount of water that was produced and added to a distribution system by a public water system (PWS). It also includes water that may have been purchased from another water supplier to supplement the needs of the PWS.

System input volume = authorized consumption + water losses

Metering the water supplied into the water distribution system was critical if a municipality wants to understand where water was used and lost in the system. The right size and appropriate calibration frequency of the system input meters monitoring the flow to the water distribution system would reduce unregistered water and meter inaccuracies.

Water losses (A2): the quantity of water loss was the difference between the total water supplied to the distribution system less the authorized consumption.

- Water losses = water produced – water billed or consumed (Farley, 2001)
- Water losses = Real losses + Apparent losses (Mathias, 2011)

Apparent losses (A3): losses were produce due to water meter inaccuracies at customer building, accounting procedure error, and lead to consumption of water without charging and unauthorized consumption. Accounting procedure errors may occur due to overlapping billing cycles, misread meter, improper calculations, or computer programming errors. These types of losses were mistakes that could be identified and corrected. The entire billing procedure should be reviewed to make certain all issues were addressed. Apparent losses consist of unauthorized consumption, and all types of metering inaccuracies (Trow and Farley, 2006). Apparent losses include:

- Errors in sources, production and consumption (household) meters
- Theft and Illegal use
- Unmetered public use (council pars and garden)
- Firefighting and Training
- Water used in processing (filter back-washing)
- Water used in infrastructure maintenance (pipe scouring and reservoir cleaning)

Real losses (A4): Real losses are the annual volume lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connection, up to the point of customer metering (Trow and Farley, 2006). Real losses were water that physically disappears from the distribution system through problems such as holes, cracks, and fissures in pipes, joints and fittings, reservoir overflows and leakage through reservoir floor and walls or through evaporation. This water does not disappear from the hydrological cycle obviously. It was water that the service provides has invested in which does not reach the customer. If real losses were reduced, more water would be available for distribution to customers at a much lower economic and environmental cost than augmentation of supplies.

Real losses include:

- Background leakage in pipes, joints and fittings
- Reported and unreported burst in pipes
- Leakage and overflows from reservoirs

Authorized Consumption (A5): Authorized consumption was the annual volume of metered or non-metered water taken by registered customers, the water suppliers and others who implicitly are or explicitly authorized to do so (Trow and Farley, 2006).

Authorized consumption includes:

- Residential properties

- Educational facilities
- Local government/ council operation
- Fire fighting
- Irrigation of public parks

Billed Metered Consumption (A6): was an authorized consumption that was directly measured. There were quantity of water metered and generates revenue through the periodic billing of the consumer.

Billed Un-metered Consumption (A7): was an authorized consumption that was based on an estimate or flat fee. This billing method was used for customers that do not have meters. Estimated use was often based on historical or average use data. The fee may vary for different types of customers such as residential or industrial.

Unbilled Authorized Consumption (A8): consists of known uses, condoned by the utility, for which no revenue was received. Unbilled authorized consumption could be either metered or un-metered.

Billed Authorized Consumption (A9): was that quantity of water that does not generate revenues, which was accounted and not lost from the system. Water used in the treatment process or water provided without charges were example of these quantities.

Revenue Water (A10): was water that was consumed and for which the utility receives payment. Revenue water consumption was measured or estimated. Revenue water includes metered and unmetered billed authorized consumption.

Non-Revenue Water (A11): water that was not billed and no payment was received. It could be either authorized, unauthorized or measured result from water loss.

Unbilled Un-Metered Consumption (A12): was the quantity of water that was authorized for use by the PWS but is not directly measured and creates no-revenues. Water main flushing and firefighting were often example of this category.

Unbilled Metered Consumption (A13): was directly measured water use for which there was no change. This category can include water use at city government offices, street cleaning, or city park irrigation.

Unauthorized Consumption (A14): was that quantity of water that was removed from the system without authorized and presumably without the PWS's knowledge.

Table 2. 10 Water Balance (AWWA /IWA, 2012)

System input volume (A1)	Authorized Consumption (A5 =A8+A9)	Billed Authorized consumption (A9 =A6+A7)	Billed Metered Consumption (A6)	Revenue Water (A10 =A6+A7)
			Billed un-metered Consumption (A7)	
		Unbilled Authorized consumption (A8 =A12+A13)	Unbilled Metered Consumption (A13)	Non-Revenue water(NRW) (A11=A1-A10)
			Unbilled Unmetered Consumption (A12)	
	Water losses (A2 =A1-A5)	Apparent losses (Commercial losses) (A3 =A13+A15)	Unauthorized Consumption (A14)	
			Customer Metering Inaccuracies and Data Handling Error (A15)	
		Real loss (Physical losses) (A4 =A2-A3)	Leakage in transmission and Distribution mains (16)	
			Storage leaks and Over flow from water storage tanks (17)	
			Service Connection leaks up to the Meter(18)	

2.7 Causes of leakage

Water produce and deliver to the distribution system was intended to be sold to the customer, not loss or siphon from the distribution system without authorized. Not long ago, water companies sold water at a flat rate without metering. As water had become more valuable and metering technology had improve, more and more water system in the US meter their customers. Although all customers may be meter in a given utility, a sizable portion of the water most utilities produce does not pass through customer meters. Unmetered water includes unauthorized users, including losses from accounting errors, malfunctioning distribution system controls, thefts, inaccurate meters, or leaks.

Leakage was usually the major components of water loss in developing countries, but this was not always the case in developing or partially developed countries, where illegal connection, meter error, or an accenting error were often more significant (Farley and Trow, 2003). The other components of total water loss were non-physical losses, meter under registration, illegal connections, and unknown use (WHO, 2001).

There were different types of leakage including service line leakage, illegal connection, meter error and valves leakage (Farley and Trow, 2003), but in most cases, the largest portion of unaccounted for water was loss through leaks in the mains. There were many possible causes of leaks and often a combination of factors leads to their occurrence. The material, composition, and age joining methods of the distribution system components could influence leaks occurrence. There were a whole range of factors that were, to varying degrees in space and time, responsible for water loss. The most common ones being briefly describe in the following (Mathias, 2011):

2.7.1 Pipe materials and age

There were several types of pipe materials available for water supply system (lead, cast and galvanized iron, copper (housing), different kinds of plastic and concrete), and they all suffer from different kinds of deterioration that gradually would have a bigger impact with time. When considering the most significant factor creating leakage, age on its own was not necessarily important if the quality of the pipe and workmanship have been good.

2.7.2 Water scheduling

The problem of water scheduling caused by an intermittent supply results in leakage, with a cycling pressure situation created due to having the supply turned on and off, increased levels of leakage are experienced due to stress being inflicted on the pipes causing them to rupture. Due to high levels of water loss, a continuous supply was not available resulting in water scheduling.

2.8 Pressure management

Pressure management can be an effective tool to reduce water loss in a water distribution system. Maximum pressure (including the influence of surges) can significantly affect the rates at which new breaks occur. Water losses through leaks were directly related to the water pressure within the water mains. Pressure management allows municipalities to reduce the water pressure in parts or all of the distribution system, thereby reducing the quantity of water lost through leaks. Pressure control valves were also part of malfunctioning distribution system control, and can have a large impact on water loss. Water pressure has a substantial impact on water loss, as the higher the system pressure, the more water was lost through leaks. Typically, 1 percent reduction in pressure should reduce existing system leaks flow rates between 0.5 percent and 1.5 percent, depending upon pipe materials and type of leaks (Federation of Canadian Municipalities, 2003). In some countries, it was recognized for many years that effective management of pressure was the essential foundation for an effective leakage management strategy. The Spanish National Report considers pressure reduction to be ‘the preventative measure par excellence’. Pressure management could thus be an immediate and cost-effective solution for decreasing real water losses in a distribution network, even at low initial pressure. However, leakage reduction was not the sole benefit. Pressure management also offers water conservation benefits because, some types of water consumption would decline due to reduce average zone pressure. A study by the IWA water loss task force found that pressure reduction result in a significant decrease in new pipe breaks and bursts (Thornton and Lambert, 2007). All of these positive effective of pressure management usually result in high water saving and thus have very short payback time. Pressure management was a relatively new enterprise in the world of water supply, being recognized in Japan and the UK more than 20 years ago, but not until recently seen as the essential foundation for an effective leakage management strategy in most utilities, both in the developed and developing world (Mathias, 2011). The rate of leakage in water supply networks was a function of the pressure applied by pumps or gravity head and there exists a physical relationship between leakage flow rate and pressure. This has now documented through numerous tests both in laboratories and in underground systems (Trow and Farley, 2006). There was also strong evidence that burst rates were functions of pressure as well (Thornton and Lambert, 2006). This evidence now available and the ever-improving reliability, with which technical and economical predictions could be made, were such that progressive water service providers could no longer afford to ignore investigating possibilities of pressure management in their systems and it was the foundation for effective leakage management (Thornton and Lambert, 2005). Some of the pressure management reports by different utilities include:

- Fewer emergency repairs, more planned work.
- Reduced inconvenience to customers extension of the life the distribution infrastructure.
- Reduction of new burst frequencies on distribution mains and service connection
- Reduction of flow rates of all leaks and bursts present in the system at any time.
- Reduction of new leaks on private pipes and overflows at storage tanks.
- Reduction of some components of consumption subject to direct mains pressure.
- Reduction in annual repair cost.

2.9 Water losses in distribution system

Water losses occurs on all the system and it reflects the ability of utility to manage the networks. The water losses consist of real and apparent losses. To understand the reason, why, how and where water was being lost, the managers have to carry out an appraisal of the physical characteristics of the networks and the current operational practice. The condition of the infrastructure and the renewal or rehabilitation perhaps one of the main reasons for the variation in leakage across the world. This problem was more pronounced in the developing countries with the ageing infrastructure (Liemberger and Marin, 2006). A high level of real loss reduces the amount of precious water reaching customers, increase the operating costs of the utility and makes capital investments in new resources schemes larger. Reducing water losses was a special concern of every water supply utility.

2.10 Water loss management

Water encompasses a set of different values in different contexts (ecological, economical, and social). Water users depend upon a steady supply of enough hygienically safe water to be used for drinking, cooking washing. In urban areas, normally a water service provider has the responsibility to cater for these needs. Water loss management thus entails all the efforts a water service provider make in order to account for all the water that was being invested in it through production and distribution. The ultimate goal of this effort was to make sure that water losses were kept at a minimum. There would always be certain amount of leakage to varying degrees in any distribution system, but the key point was to try to get as much as possible of the water supplied to reach its intended users (Mathias, 2011). In order to make the water distribution system more efficient, utmost importance must be placed on water loss management. Independent of the type of method being used for performing a water audit, there would always be an uncertainty while calculating non-revenue water, apparent losses, and real losses.

There were four methods of managing real losses:

- Improve Maintenance, Replacement and Rehabilitation
- Pressure Management
- Improve response time for leak repairs
- Active Leakage Control

Putting a focus on these four management methods could reduce real losses, but at a given average system operating pressure, the total real losses cannot be economically reduced any further than the value of unavoidable real losses. There were four methods for managing apparent losses:

- Unauthorized consumption (theft and illegal use)
- Analysis errors between archived data and data for billing or water balance
- Meter accuracy error
- Transfer errors between meter reading and archived data

Depending upon the amount of attention given to each component related to apparent losses would increase or decrease. A primary purpose of the utility was to keep real and apparent losses at minimum to minimize use of water resources and maximize revenue.

2.11 Pressure and leakage management in water distribution system

Despite operational improvements over the last 10-15 years, water utilities still lose a significant amount of potable water from their networks through leakage. The most effective way to combat leakage was on one hand to locate and physically repair bursts and on the other hand to introduce pressure control to reduce background leakage from connection and joints. Reduction of leakage has two positive impacts on the environment and it minimize clean water losses and energy used for pumping and treatment of water (Hossam, 2011).

Water companies have tried many management strategies, which were general pipe rehabilitation, direct detection, and repair of existing leaks and operational pressure management. Direct detection and repair of existing bursts was one of the most powerful policies that was used to prevent the high-level leakage from bursts. Detecting and reducing burst was an attractive solution, and many algorithms have been developed to predict and detect the location and quantify the leakage in water distribution (Hossam, 2011). Operational pressure management was a cost-effective method for leakage reduction over entire DMAs, and for minimizing the risk of the further leaks by smoothing pressure variations. Many researchers have presented, developed, and implemented various methods and algorithms to optimize the operational pressure, and the results showed that, the leakage could be reduced by up to 60%. Hossam (2011), analyzed the effect of employing pressure management techniques on the operating costs of water distribution systems, which increases the savings by a 20-55% (Girard and Stewart, 2007) described implementation of the pressure. Leakage management strategies on the Gold Coast, Australia, and the results revealed a good opportunity to achieve significant water savings (Hossam, 2011) implemented a pressure management as a leakage reduction, in Zimbabwe. The results showed that an operating pressure reduction from 77m to 50m result in 25% reduction in the total leakage.

2.12 Water loss reduction practices

In order to ensure that the utilization was made of the assets and the water supply itself, it was essential that the water flows were measured within the supply network. The design of the water supply system and construction, management, operation and maintenance must be understood and optimized. This issue would vary for each unique water supply system. There were a series of connected techniques, procedure, and methods to be applied to get a better managed.

A diagnostic approach, followed by the practical by implementation of achievable solutions could be applied to any water company, anywhere in the world, to develop water loss management strategy (Trow and Farley, 2006).

2.13 Controlling water losses

- Water audit or water balance.
- Meter testing repair replacement, improving billing procedure.
- Leak detection and control program.
- Corrosion control.
- Pressure reduction.
- Public education program.
- Rehabilitation and Replacement program

2.14 Leakage monitoring and control

Leakage management could be classified into two groups including passive leakage control and active leakage control. Passive leakage control was reactive to report bursts or a drop in passive, usually report by customer or notes by the company's own staff while carrying out duties other than leaks detection. This method could apply in areas with low cost supplies.

Active leakage control (ALC) was when customer deployed company staff to find leaks, which have no reports. The main ALC methods were regular survey and leakage monitoring.

Leakage monitoring was flow monitoring into zones to measure leakage and to prioritize leaks detection activities. This has now become one of the most cost effective activities for leakage management programs.

The most appropriate leakage control policy would mainly dictate by the characteristics of the networks and local condition, which may include financial constraints on equipment and other resources.

2.15 Activities to reduce water losses

Effective and pro-active infrastructure management could prevent most water losses. The following infrastructure management activities would help to reduce real losses:

- Distribution system operation and maintenance to prevent breakdowns in equipment and the associate leakage.
- Material and construction standards to assure quality of future infrastructure installation.
- Maintain prober inventory to repair all sizes of main breaks or leaks.
- GIS mapping of system components to order quickly find valves to isolates main breaks.
- Increased surveillance in areas with aging infrastructure or reported leaks.
- Periodically checking proper operation and control of pumps used to fill storage tanks.
- Leak detection surveys or studies and leak repair.
- Water main rehabilitation and replacement.
- Pressure management

The following activities would help reduce apparent water losses:

- Metering of all source inputs, water experts or sales and customer accounts (includes billed, authorized use and non-billed authorized)
- If not going to meter hydrants usage, accurately estimate and record the water used for firefighting or flushing.
- Accounting and record keeping practice to improve reliable and accuracy of the water balance; more easily pinpoint areas with water losses (EPD, 2007).

2.16 Acceptable water loss

It is a compromise between the cost of reducing water loss and maintenance of distribution system and the cost of water saved. AWWA leak detection and accountability committee (1996) recommended 10% as a benchmark for UFW.

Table 2. 11 UFW levels and action needed (Saroj, 2008)

<10%	Acceptable, Monitoring and Control
10-25%	Intermediate, could be reduced
>25%	Matter of concern, reduction

CHAPTER THREE

METHODOLOGY

The research method applied in this study was a non-theoretical approach using structural interview schedules (questionnaires) that were developed by discussion and input from the local water supply experts and local community. The survey was designed to gather data about customers' perceptions on water and sewerage service in Adama City and the degree of satisfaction of customers.

The survey was conducted in nine Kebele and AWSSE within Adama City in selected Kebele by using structural interviews. The statistical software SPSS Version 20 was used for data analysis.

3.1 Questionnaire

The questionnaire consists of two sections and thirty-six main questions with various sub questions dealing with different issues related to water service such as water supply coverage, water losses, water supply service, and causes of water loss.

3.2 Study area

Adama City was located in the main Ethiopian Rift Valley Region, Oromia Region State. The City stretches between $8^0$33'35" to $8^0$36'36" latitude and $39^0$11'57" to $39^0$21'15" longitude. Altitude ranging from 1600 to 1700 m above sea level and 99 km South East of Addis Ababa. According to population and housing census conducted by Central Statistics Agency (CSA, 2007), the total population of Adama City was 220,212. Adama water Supply and Sewerage Enterprise (AWSSE) was a public authority and organized into Eighteen Kebele and namely; 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14, Boku Shanan, Dabe Soloke, Melka Adama, Dhaga Adi, which provide water service of the city.

Table 3. 1 The three-water distribution reservoir in Adama City (AWSSE, 2015)

ID	Supply Zone	Elevation	X	Y
GAR-1	Galma Abba Gada	1750	527363.325	945410.831
AUR-2	Adama University	1720	527428.287	945373.383
LUR-3	Lugo	1685	533213.369	945161.887

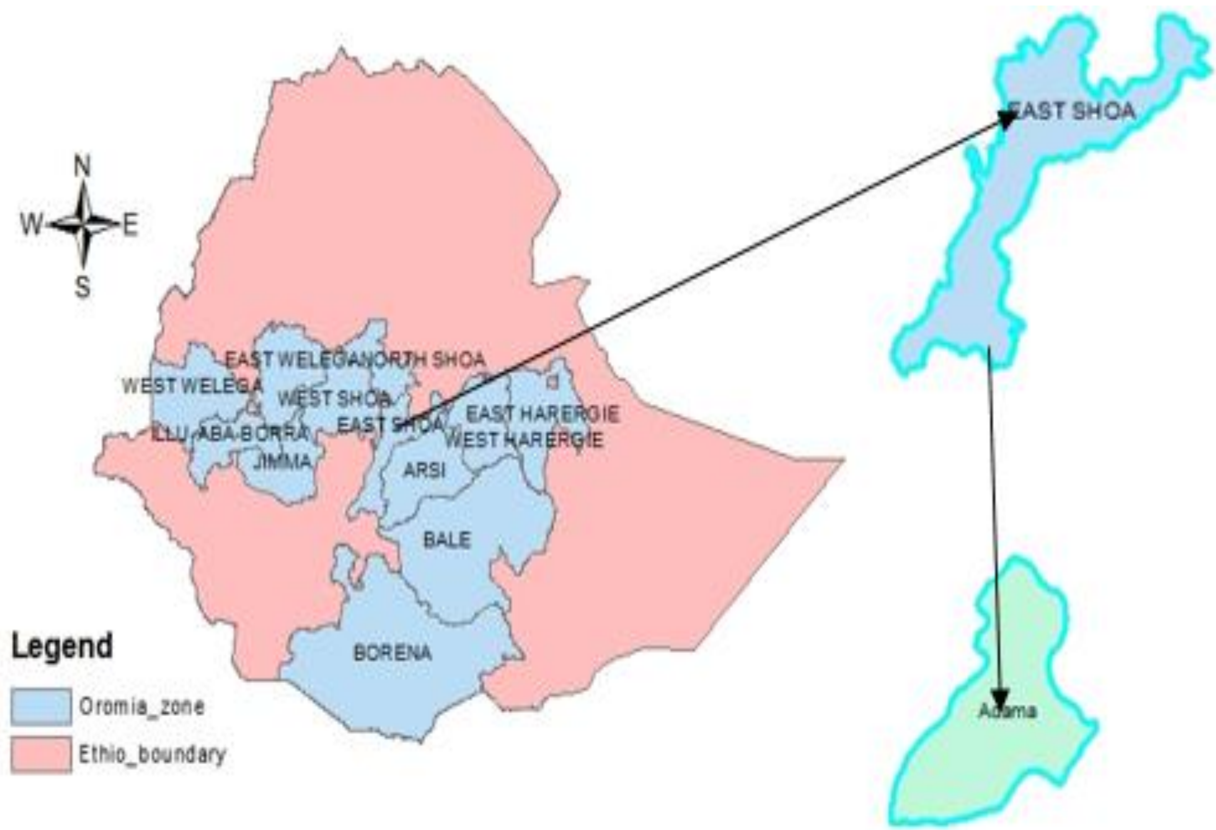

Fig.3. 1 Study area drawn using GIS version 10

3.3 Area coverage

According to the newly revised master plan by Adama City in 2004 G.C., Adama City covers 13,336.5 hectares or 133.6 km^2 the area of the city currently classified into administrative areas, residential areas, commercial areas, storage, playgrounds, infrastructure, market, religious, cemetery, recreation areas, mixed use, social services, manufacturing and other types of development purposes. Residential areas dominate much of the city's area (a brief profile of Adama City, 2014).

3.4 Population size

Adama was the third largest city in terms of population size next to Addis Ababa and Dire Dawa in the country. The last three consecutive censuses conducted in the country show large increases of population in the city. Demographically, Adama was the most rapidly growing city both in terms of population and in terms of physical areas in the region starting from the outside of its establishment. The impacts of population pressure that has placed pressure on public service and tremendous pressure on the city administration as the city's population has swelled and become obstacle to improve welfare of the population in the city. The natural growths of the city in terms of the physical expansion and the increasing number of population have brought about the increasing demand for different infrastructure developments. The mountain unemployment was a chronic problem that was endangered the life of many residents in spite of young and dynamic demographic basis the city possessed. According to the first Ethiopian population and housing census, which held in May 1984, Adama City had a population 77,237. By 1994, the result of the second population and housing census indicated that the population of Adama had reached 127,842. According to 2007 (the most recent year for which data were available), people of whom 108,872 males and 111,340 are females inhabit Adama, an increase of 72.25% over the population recorded in the 1994 census and total population of 220,212 (CSA, 2007). However, according to a brief profile of Adama City in 2015 Adama population was 350,000.

3.5 Study design

Observation and Exploratory survey design was used in this study.

Observation: Site observation was conducted on the causes of leakage on distribution system. Information was collected by two data collectors and distributing questionnaires, structural interviewing for local administrative, local communities and concerning sectors.

3.6 Sampling size and sampling procedures

Since a complete listing of household in the survey area was not available, clustered sampling used for this study. Clustering of Kebele was based on population size, the old and new establishment area of the city. Based on this classification nine Kebele were selected out of eighteen Kebele as the study site. Namely, Kebele 08, 09, 10, 11, 12, 13, 14, Boku Shanan and Dabe Soloke.

Taking into consideration the resources and time available for this research, it was decided to take 32 household heads was included in one cluster. The sample size of household were 288 for 9 cluster and 12 for AWSSE totally 300 respondents. The sample size obtained from the study area just the representative sample size within the systematic sampling collected and measured on peoples and existing water distribution system, Adama Water and Sewerage Authority and on the side of local community.

3.6.1 Sampling procedure

Target Population: The definition of targeting population would be in line with the objectives of water supply coverage and causes of leakage in the distribution system. Specific Sampling unit: All parties become a sampling unit and all contractors engage in water supply construction projects become the sampling elements.

Specific sampling frame: The sampling would be design from the list of participants in water supplies.

3.7 Study variables

The study variables asses in this research were both independent and dependent variables.

Independent variables: independent variables were more related with specific objectives. However, each specific objective was affecting one another. Different problems occurs before and during water supply and distribution stages under construction.

- Joints of pipe
- Sizes of pipe

Dependent variable: dependent variables, which observed and measured to determine the effective of the independent variables, which was directly, related to the general objectives.

- Per capita demand
- Water losses

3.8 Data collection process

The data collection processes exercised in this study were questionnaire, personal observation, structured interview, and reviewing of archived document. Both open ended and close-ended questionnaire employed in this research. The interviews type would be structured where necessary and data were obtained in the form of face-to-face interview or through telephone.

3.8.1 Primary data collection

Primary data were collected from customers through household survey, face-to-face interview with local administrative (AWSSE) and field observations.

3.8.2 Secondary data collection

Secondary data were collected from reviewing of documents from archives of Adama City Water Supply and Sewerage Enterprise, journals, reports, and internet.

3.9 Data processing and analysis

Two data collectors were recruited and they underwent through training on issues such as objective of the survey, methodology of data collection, area would be surveyed including on how to use a GPS to record the geographical coordinate of the household and elevation to be surveyed.

For locating and delineating the study area, Arc GIS version 10 used. The quantitative data was collect from AWSSE coded and processed using Microsoft excel 2013 and SPSS computer program. The survey data for distribution system were evaluated using Water CADV8i, which is used to analysis the quantitative data. The qualitative data was collect through the key informant interviews; Focus group discussion and field observation so as to triangulate the findings of the quantitative survey.

The volume of water consumed for domestic purpose has been aggregated in nine selected Kebeles to analysis the distribution systems of water supply coverage. The annual consumption data has been converted to average daily per capita consumption using the number of population.

$$\text{Per capita consumption (l/p/d)} = \frac{\text{Annual consumption (m}^3\text{)} \times 1000\ \text{l/m}^3}{\text{Population number of the Kebele} \times 365} \qquad (1)$$

In order to compare the distribution of the water connection among different Kebeles, the total numbers of connections per Kebele were converted to connection per family using population data of each Kebele.

$$\text{Connection per family} = \frac{\text{Total number of connection in the Kebele}}{\text{Number of population by Kebele /Average family size}} \qquad (2)$$

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 city.

$$\text{Total water loss (\%)} = \frac{\text{Total water production - Total water consumption}}{\text{Total water production}} \times 100 \qquad (3)$$

3.9.1 Water distribution system network

A water distribution system is a pipe network that delivers water from single or multiple supply source to consumers. There is a general belief arising out of negligence on behalf of service providers, that water supply networks can be expanded indefinitely. Many water supply providers, in a drive to provide wide water supply coverage increase the number of customer connection through a massive network expansion. Because of rapid population growth and high water losses from the distribution network, the total water demand of the system in Adama exceeds available production capacity.

The flow and pressure distributions across a network are affected by the arrangement and sizes of the pipes and the distribution of the demand flows. Since a change of diameter in one pipe length will affect the flow and pressure distribution everywhere, network simulation is not an explicit process. Pipe network analysis involves the determination of the pipe flows and pressure heads that satisfy the continuity and energy conservation equations. According to this study, Hazen-Williams equation was used as it is commonly used in the design, modelling of water distribution network and water distribution systems because of its simple form, and analyzing an entire network in steady state flow.

Table 3. 2 Pipe head loss formula for full flow (Rossman, 2000)

Formula	Resistance Coefficient (A)	Flow Exponent (B)
Hazen-Williams	$4.727\ C^{-1.852}\ d^{-4.871}\ L$	1.852
Darcy-Weisbach	$0.0252\ f(\varepsilon, d, q) d^{-5} L$	2
Chezy-Manning	$4.66\ n^{2}\ d^{-5.33}\ L$	2
C = Hazen-Williams roughness coefficient ε = Darcy-Weisbach roughness coefficient (ft) f = friction factor (dependent on ε, d, and q) n = Manning roughness coefficient d = pipe diameter (ft) L = pipe length (ft) q = flow rate (cfs) According to this study, SI unit could be used		

3.9.2 Initial setup

Throughout the process, International System Unit (SI) has been used. To request the use of these units in WaterCADV8i, the user chooses SI flow unit under the hydraulics option. In this study, liters per second unit was selected for flow, which also defines all other units using the SI system. Hence, lengths, pressure, head, elevations are taken in meters, and diameters of pipes are defined as millimeters. The network element is:

- Reservoir
- Pipes
- Nodes
- Pumps

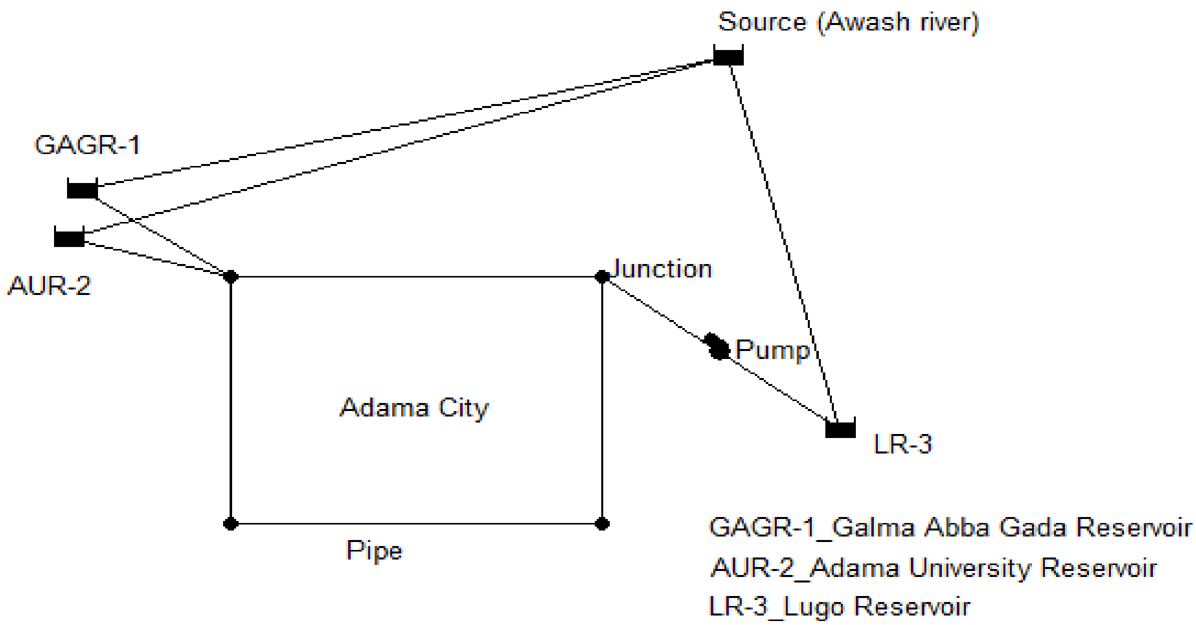

Fig.3. 2 Node- link representation of water distribution network

3.9.3 WaterCADV8i

WaterCADV8i is a powerful, easy-to-use program that helps hydraulic engineers design and analyzes water distribution systems. WaterCADV8i provides intuitive access to the tools you need to model complex hydraulic situations. It can be used for many different kinds of applications in distribution system analysis. In this study, it was used to carry out the hydraulic analysis of the distribution networks in the study area.

WaterCADV8i can be analyze complex distribution systems under a variety of conditions for a typical WaterCADV8i project, it may be interested in determining system pressure, velocity and flow rates under average loading conditions, head loss or under fire flow conditions.

- Perform steady state and water quality simulation
- Analyze multiple time variable demands at any junction node

A simulation of the network was carried out using the Water CADV8i. Water CADV8i views the water distribution system as a network containing nodes and links, where the nodes are connected by links. Data using for WaterCADV8i has x, y coordinate and elevation, junction or node and demand values.

3.9.3.1 Reservoir

Reservoirs are a type of storage node. A storage node is a special type of node where a free water surface exists, and the hydraulic head is the elevation of the water surface above sea level. The water surface elevation of a reservoir does not change as water flows into or out of it during an extended period simulation.

3.9.3.2 Pipes

Every pipe is connected to two nodes at its ends. In a pipe network system, pipes are the channels used to convey water from one location to another. The physical characteristics of a pipe include the length, inside diameter, roughness coefficient, and miner loss coefficient. The pipe roughness coefficient was associated with the pipe material and age. The miner loss coefficient is due to the fitting along the pipe. Pipe length and diameters are then inputted as well as roughness. A roughness of 150 was selected for the uPVC pipes.

3.9.3.3 Nodes

Nodes are the locations where pipe connected. Two types of nodes exist in a pipe networks system. All nodes should have their elevation specified above sea level. Nodes, besides representing the connection point between pipes, can represent the following components in a network:

- Points of water consumption (demand nodes)
- Points of water input (Source nodes)
- Location of Tanks or Reservoirs (Storage nodes)

3.10 Ethical consideration

Letters were written from JiT to the offices directly involving in the provision of data for the success of the study Data collection was carried out after approval was given from the Hydraulic Engineering Chair, JiT, Jimma University, and AWSSE to proceed. Before collecting the data through interview and questionnaire, the objective of the study was clearly explained to the respondents. Then, data collection was conducted after obtaining the full consent of the respondents.

3.11 Data quality assurance

In order to increase the quality of the data, the research prepared a fieldwork manual to check every day progress and assistant was selected and trained to make the data handling good. The researcher has checked the reliability and the accuracy of the data as well.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Water Supply Coverage and Demand

Problem in provision of adequate water supply to the rapidly growing urban population were increasing dramatically. Water demand in the domestic sector of developing cities including Adama City increases through time as a result demand for additional water sources and infrastructure. Adama City has significant problem on the shortage of water supply. Thus after about ten years of exhaustive services, the water treatment and distribution system of the city has been critical disturbances where the system could not fully cater for all users in and around the city. In Adama both household and industry consumption were provided by city water and sewerage authority which was responsible for water treatment and distribution in the city. In order to restore the quality of water, it receives a district water supply from Koka Water Treatment Plant that built on Awash River. The total drinking water demand that required in the city in the year 2014 was around 32,330 m^3/d (3741 l/s). The designed production of the treatment plant was 330 l/s but now reduced to 285 l/s of the total production 88% (249 l/s) was distributed to Adama City and the rest 12% (36 l/s) for Wenji Town.

As described above from the distributed 32,330 m^3/d of water supply was provided for animal fattening and garden watering consumes 4213.72 m^3/d amount of water from the total production, so it contributes for the shortage happened in the city. As information gathered from city's water supply and sewerage office, over all coverage of water service in Adama was 70%. Still shortage of water is not minimize in the case of floating people to the city and more people use public water point.

Fig.4. 1 Photo taken during field observation showing collecting water from public water point

Changing the previous water supply system and increase water distribution system program and a bottleneck to any type of development project for the city. Since all require clean water in one way or the other, that forced the requirement of conducting detailed assessment of the current system capacity, recommend interim and long-term solution for the available of clean and adequate systems.

From the value water supply coverage infrastructure in Adama City in, the estimated water supply coverage of the city:

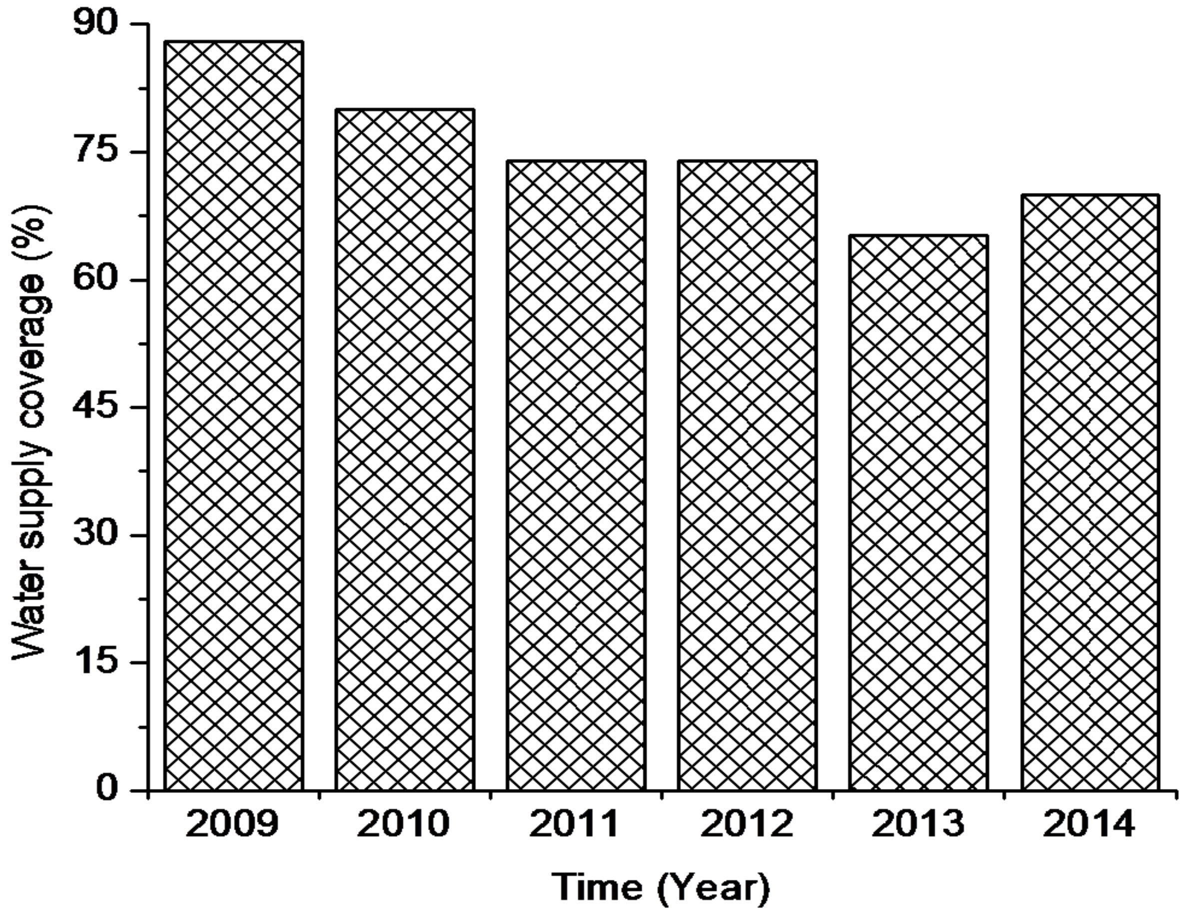

Fig.4. 2 Water supply coverage trends in Adama City

The coverage of the city water supply declines as time goes on from 2009-2013, however floating population who shares from the daily water proceed, additional number of University and college students, hospitals and health centers, gusts and visitors as a result of conference, establishment of star hotels all contributed to the water shortage of the city. In 2014 water supply coverage were increases comparing with 2013, because drilling five different boreholes to be utilized the coverage.

4.1.1 Average daily per capita consumption

The level of water consumed for domestic purpose has been aggregated to all Kebele of the city to analyze the distribution of the water coverage among different localities (Kebele). Evaluating the domestic water supply coverage using volume of consumption may not allow realizing the distribution comparison among the Kebele. For this reason, the annual consumption data has been converted to average daily per capita consumption using the number of population. The average daily per capita consumption of each Kebele for the year 2014 was computed as shown in the Table below.

Table 4. 1 Average daily consumption of selected Kebele of Adama City from bill of 2014

Kebele	Population by Kebele	Annual Consumption By Kebele (m^3)	Per capita consumption (l/person/day)
08	26,946	12,4082	12.62
09	35,856	21,8754	16.71
10	19,465	10,4781	14.75
11	23,123	11,6974	13.86
12	41,796	17,6489	11.57
13	19,468	112648	15.85
14	24,978	121124	13.29
Boku Shanan	29,689	15,4725	14.28
Dabe Soloke	30,635	129753	11.60

As Table 4.1, observed that, the distribution of the water consumption varies among each Kebele. More or less the variation is observed in all Kebele; particularly Kebele 09 has relatively better average consumption as compared to the others.

Taking the mean consumption as shown in Table 4.1, the average domestic water coverage of the city was found as 13.84 l/p/d. According to WHO (2008), the minimum quantity of domestic water required in developing countries in urban areas was taken as 20 l/c/d within a radius of 0.5km. Domestic water supply is categorized as basic level of service, which is higher than the average domestic consumption of Adama City. It only satisfies 70% of the as standard value.

4.1.2 Level of connection per family

Level of water connection was an important element for evaluating the level of coverage. In order to compare the distribution of the water connection among different Kebele of Adama City, the total numbers of connection per Kebele were converted to connection per family using the population data of some Kebele. According to the 2007 and the city administrative finance and economic development, Average family size 2.9 was used for calculating the average number of connection per family.

Table 4. 2 Level of connection per family of Adama City for the year 2014

Kebele	Number of population by Kebele	Average family size	Total number of connection by Kebele	Level of connection
08	26,946	2.9	4356	0.47
09	35,856	2.9	6326	0.51
10	19,465	2.9	3698	0.55
11	23,123	2.9	5689	0.71
12	41,796	2.9	8894	0.62
13	19,468	2.9	4569	0.68
14	24,978	2.9	6345	0.75
Boku Shanan	29,689	2.9	3648	0.36
Dabe Soloke	30,635	2.9	6498	0.61

As can be seen from the Table 4.2, some of the Kebele are found to be having higher level of connection per family while compared with Kebele 11 and 14 have higher value of connection per family as compared to other Kebele. Taking the average connection per family for the entire city was found 0.58. This implies that almost at an average of nine persons are sharing one connection or water tap.

4.1.3 Evaluating distribution system of water supply coverage

As clarified Table 4.1 and 4.2, the water supply coverage of the city in terms of Per capita consumption is very low and relatively good in level of connection. In areas where water supply coverage is sufficient, volume of domestic water consumption is expected to be linearly 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. A detailed demand study in Africa found that average water carried was about 22 l/d per capita over a long distance rising to about 30 l/d per capita where water was obtained from the consumer own stand pipe. Of course, distance is not a big problem in urban areas as compared to rural areas (ADB, 1993). Some areas may have better level of connection that consuming more volume of water, as the possibility of getting the water does not depend only on the location (Kebele 14 has connection per family of 0.75 but has only a per capita consumption of 13.29 l/c/d, which is very far from the value of 20 l/c/d).

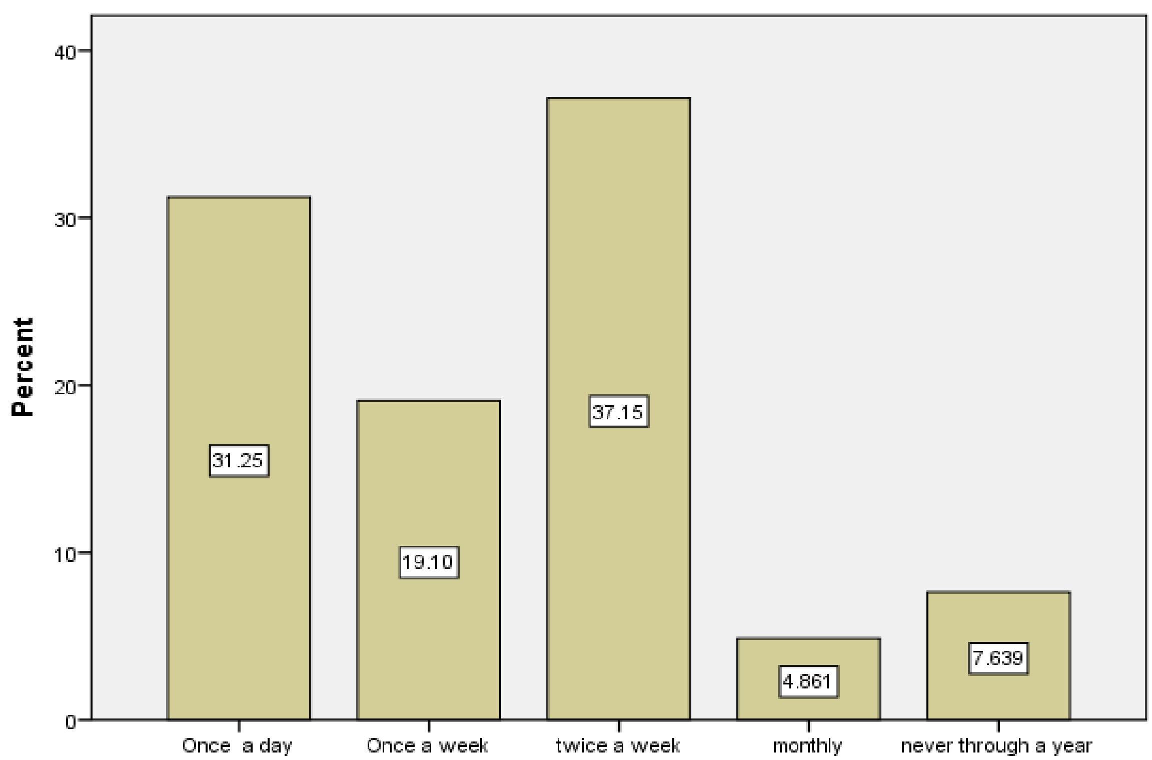

Fig.4. 3 Water supply interruption by responses of the respondents

As observed from Fig.4.3, more frequent occur in twice a week in 37.15% of the respondents justified in this interruption whereas 31.25% of respondents responded that the interruption occurs once a day. High percentage of respondent for twice a week can attribute the fact that shortage of water occurs in the entire city.

Table 4. 3 Problem of water source responses from AWSSE

Are there problems with water source?			
	Frequency	Percent	Cumulative Percent
Yes	11	91.7	91.7
No	1	8.3	100
Total	12	100	

4.2 WATER LOSS ANALYSIS

Globally, water demand was increasing while the recourses were diminish. Water loss from water distribution systems (WDSs) has long been a feature of the WDS operations management. Water loss occurs in all WDSs, only the quantity of loss varies and depends on the physical characteristics of the pipe network, operating factors and parameters, and the level of technology and expertise applied to control this loss.

Reducing and controlling water loss was becoming very important issue in this age of rapidly growing demand and relative abundance to one of relative scarcity of the water resource, and climate changes that bring droughts to many locations over the world (Hossam, 2011). The water resources were subjected to the fluctuations of the nature and were therefore largely beyond the human control. In order to preserve valuable water resources, many water utilities have been developing new strategies to minimize losses to an economic and acceptable level.

Residential, commercial, industrial, public water use, and unaccounted system loss and leakage constitute the overall water demand. While all components create revenue to the water utility, the unaccounted system loss and leakage were not associated with total cost revenues, and are a source of wasted production costs. With today’s high water production, treatment and transmitted costs and rates, the expense of detecting and reducing the unaccounted for water and leakage was an attractive solution for minimizing operating expenditures.

Water distribution networks in all countries around the world encounter water loss, for example, in Addis Ababa, Ethiopia; nearly 50% of the produced water was lost at different levels of the distribution system before reaching the consumers (Welday, 2005).

This study was aimed to propose effective water supply coverage and estimating water loss in Adama City. In the study, in addition to technical loss, some engineering proposals for the effective control of non-technical loss and general water economy were suggested.

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

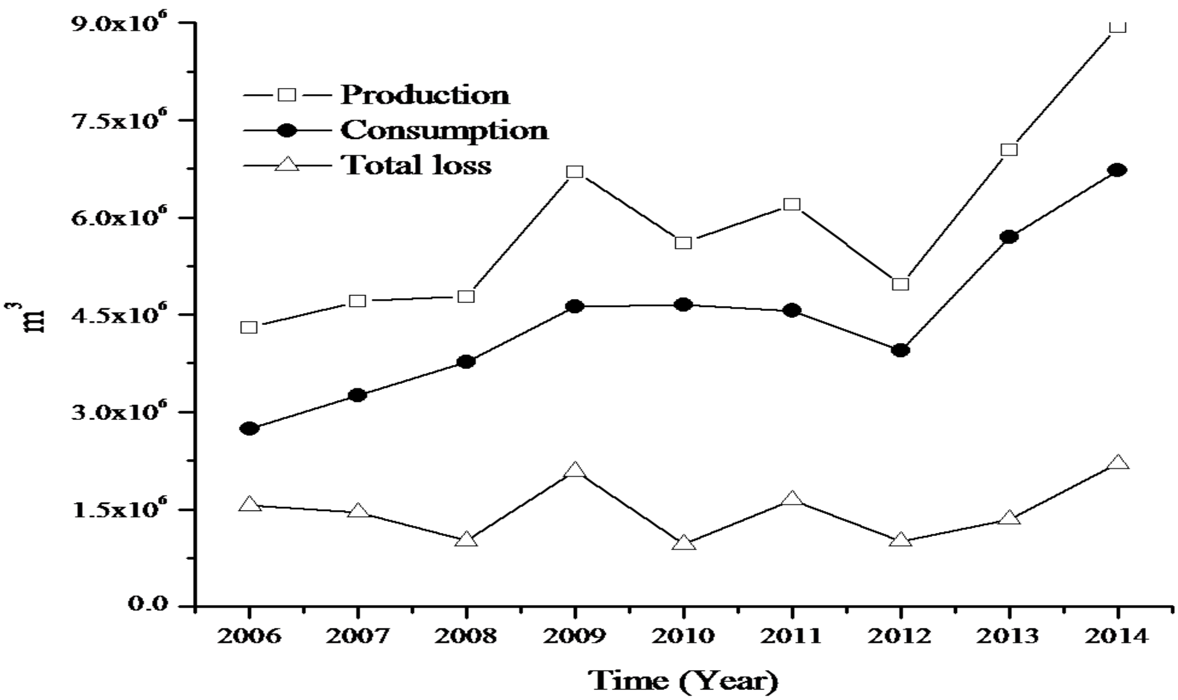

Fig.4. 4 Annual water production, consumption, and loss trends

From the value of water supply coverage infrastructure in Adama City, the estimated water loss was as shown Fig.4.5.

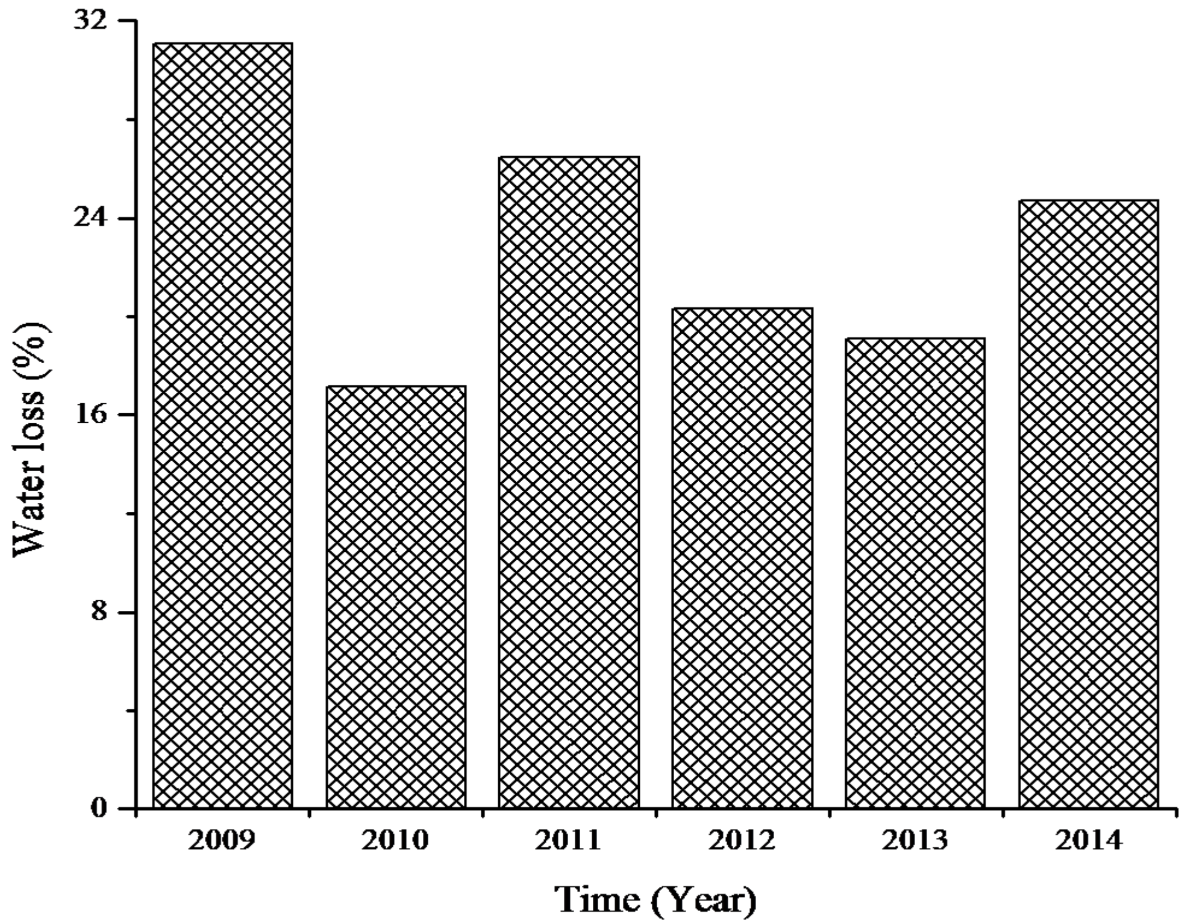

Fig.4. 5 Total water loss trends in Adama City

The water loss trend of the city showing that loss was fluctuated from year to year. This could be due to road, star-hotels construction in Adama and breakage of pipes was occurred, and this maximized water loss. An interview result showing that, once a leak identified and repairs after 74 hour on the average. This implies that, leak was not a timely response and it maximized water loss. However, both water loss increased and decreased depending on time of construction and awareness creation between people. At the end of the year 2014, the annual water produced and distributed to the system was 8,935,200 m^3 and annual water loss as derived using the Fig.4.5 expression was 2,207,300 m^3, which account to 24.7% of the total production and water loss was increases in 2014 comparing with 2013.

It is a compromise between the cost of reducing water loss and maintenance of distribution system and the cost of water saved. AWWA leak detection and accountability committee (1996) recommended 10% as a benchmark for UFW. Saroj (2008) gives classification and descriptions of UFW as acceptable, which could be monitored and controlled, when the loss is < 10%, as intermediate, which could be control when the loss is 10-25% and as a matter of concern that reduces the water supply when the loss is > 25%. According to this study, water loss in Adama City was 24.7% in the year 2014, showing that the loss in the city was intermediate, according to the description given by Saroj (2008). Thus, the loss could be controlled and monitored.

4.2.1 Major factors contributing to high levels of water loss in Adama City

There were several reasons for the high level of water loss in Adama. Such as illegal connections, pressure build up, poor construction and backfilling mention in detail below.

4.2.1.1 Illegal connections

There are a significant number of illegal uses of water within distribution system in Adama City. The number of households who do not pay water rates but receive water from its distribution system without knowledge of the Authority. Consequently, they contribute significantly to apparent losses and revenue loss to the authority. These connections were poorly laid just a few meters below the surface and break resulting in real losses taking placed in the form of leakage. Illegal connections are therefore significant concern of water utilities.

Fig.4. 6 Illegal connection (AWSSE, 2014)

4.2.1.2 Pressure

The pressure needed to supply water through the pipe network itself cause water loss in several ways through increased leakage because of increased pressure. increased burst frequency as a consequence of increased pressure; pressure cycling from frequent on/off switching by pumps of faulty pressure reducing valves can cause fatigue in plastic pipes. On the other hand, higher pressure will result in more water leaking from holes in the pipeline. All pipes have specific pressure within which they should serve; once the pressure is exceeded, the pipes naturally give way. This is worsened if the fittings were lower pressure rating as well. Excessive pressure should be avoided, if possible serve water under minimum acceptable residual pressures.

Fig.4.7 Photo taken during field observation showing effect of pressure on distribution system

4.2.1.3 Poor construction and backfilling

Faulty laying of pipes and incorrect backfilling will cause rapid pipe failure. Storage of plastic pipes in the sun and damage during handling will shorten their durability. On the customers, side there will be faulty tap washers, ball valves, poor seals that cause loss.

To compliment a good design quality worker should be observed if not then significant leaks at joints and fitting become evident.

Fig.4. 8 Photo taken during field observation showing poor construction and backfilling

4.2.1.4 Unaccounted for water

Not all the water that goes in the distribution pipe reaches the consumers. Some portion of this water wasted in the pipelines due to defective pipe joints, cracked and broken pipes, flood hazard, fault valves, and fittings. On the other hand, Adama City is severely suffering from seasonal floods. There is no enough drainage systems in the city. Besides, to this, some quantity of water was lost due to unutilized and illegal connections. The losses, or uncontrolled for water are expressed as a percentage of the total production.

Fig.4. 9 Photo taken during field observation showing problem of fitting and flood hazard

4.3 Water Distribution System Modeling

Analysis of water distribution network provides the basis for the design of new systems, the extensions, and control of existing systems. The flow and pressure distributions across a network are affected by the arrangement and sizes of the pipes and the distribution of the demand flows. The objective of this modeling was not to predict the exact time at which different users get water, but to develop a simplified model, node demand is dependent on the pressure at the junction nodes to reduce the water loss and maximize the flow rate at the tap. Galma Abba Gada, Adama University, and Lugo reservoirs are sub-components of the sub-system.

WaterCADV8i could show pressure, demand, and hydraulic grade in different nodes as well as flows, velocities, head-loss gradient and head-loss in different pipes throughout the distribution system.

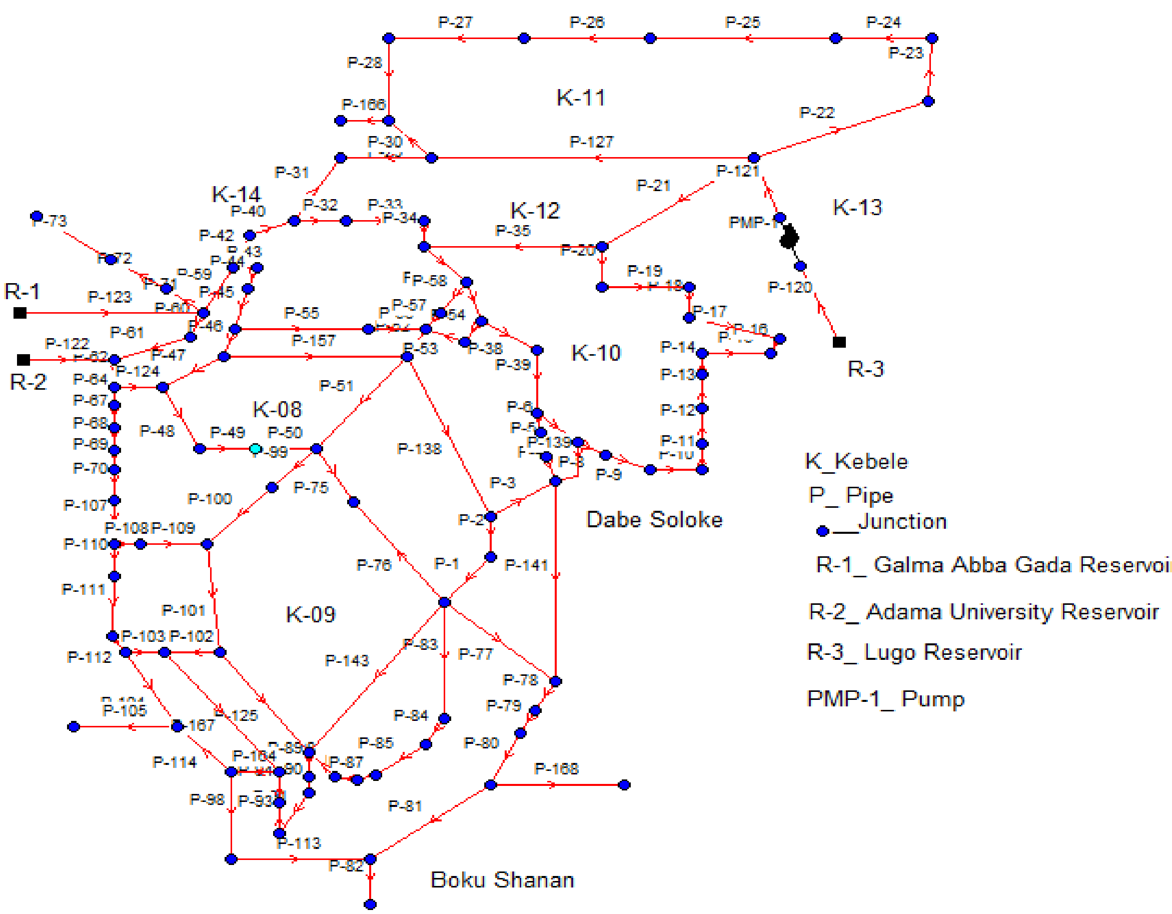

Fig.4. 10 Water distribution network analysis of pressure zone

4.3.1 Pressure

There are extremes of low and high pressure throughout the system mainly due to topography of area and the elevation of the distribution reservoirs. Galma Abba Gada and Adama University Reservoirs are marked by high elevation. As a result, water was distributed to the system by gravity system. However, Reservoir at Lugo is low pressure and water was distributed to the system using pump system to reach at the higher elevation where the gravity system is not reached.

The pressure in water distribution system is at a minimum when the flow and subsequent head losses in the pipes are at peak demand. On the other hand, the pressure is a maximum when the flow is at minimum, normally at night time while most consumers were sleep and institutions were shut down. The low-pressure nodes were normally those nodes, which are located relatively at high elevations and far from the supply points.

Ethiopian guideline criteria for the minimum and maximum operating pressure value in the distribution network were 15m to 70m respectively (MoWR, 2006). Maximum pressure limitation are required to reduce the additional cost of the pipe, strengthening necessary due to the high pressure. The guideline further states that water velocity shall be maintained at 0.6 to 2m/s. Maximum and minimum velocity limitation was necessary because:

- Velocity is not be lower than 0.6m/s to prevent sedimentation
- Velocity is not be more than 2m/s to prevent high head loss

According to this study, pressure ranges full fill the criteria of Ethiopian guideline for selected study area, but velocity was below and above as compared to the standard at some pipe. Table 4.4 shows, velocity ranges that count below, above and fill the criteria of Ethiopian guideline.

Table 4. 4 Velocity range from WaterCADV8i analysis

Velocity range (m/s)	Count	Count (%)	Effect
0. – 0.6	18	10.71	Sedimentation occur
0.6 - 2	149	88.69	Acceptable
>2	1	0.60	Head loss occur
total	168	100	

4.3.2 Pump

The most common input of energy into a system was through pumping. Pumps were crucial to any distribution system that cannot supply acceptable pressure to consumer through the sole use of gravity flow. A pump was an element that adds a head to the system as water passes through it. Pump were an integral of much pressure system and add energy to head gains to the flow to counteract head losses and hydraulic grade differences within the system.

4.3.3 Pump capacity curve

A pump curve represents the relationship between the head and flow rate that a pump can deliver at it nominal speed setting. Pump head is the head gain imparted to the water by the pump and plotted on the vertical of the curve in meter. Flow rate is plotted on the horizontal in litter per second. A valid pump curve must have decreasing head with increasing flow. An efficiency curve determines pump efficiency in vertical percent as a function of pump flow rate in horizontal flow.

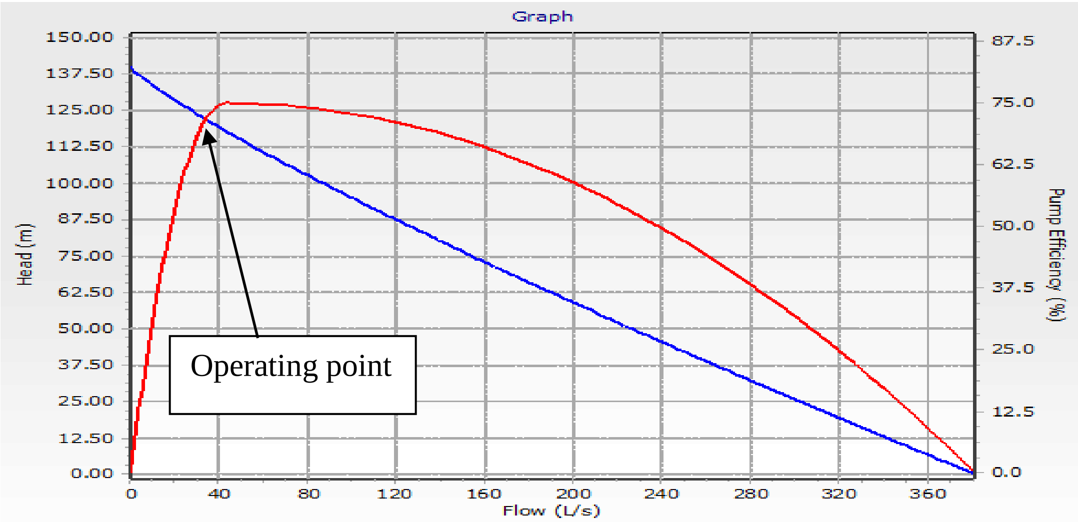

Fig.4. 11 Pump head-flow curve

4.3.4 Flow

The flow arrow symbol on the pipe in the plan view always indicates the direction of flow, and the “Start node” and “Stop node” fields in the pipe properties indicate the orientation of the pipe itself. If water is flowing from the “start node” to the “stop node”, the flow arrow will point that way and the flow result value will be positive. If water is flowing from the “stop node” to the “start node”, the flow arrow will point that way and the flow result value will be negative. A negative flow indicates orientation of flow with regard to the orientation of the pipe itself. The reason why this behavior occur is because in some system (mainly water distribution), flow can often reverse direction over the course of a day. Showing the negative sign in front of the calculated flow value is one way for the user to distinguish the current direction of flow.

4.3.5 Demand

As far as distribution of water is concerned, it seems that more consumption in the afternoon of the sub-system and decreases at morning. However, some area did not totally get water.

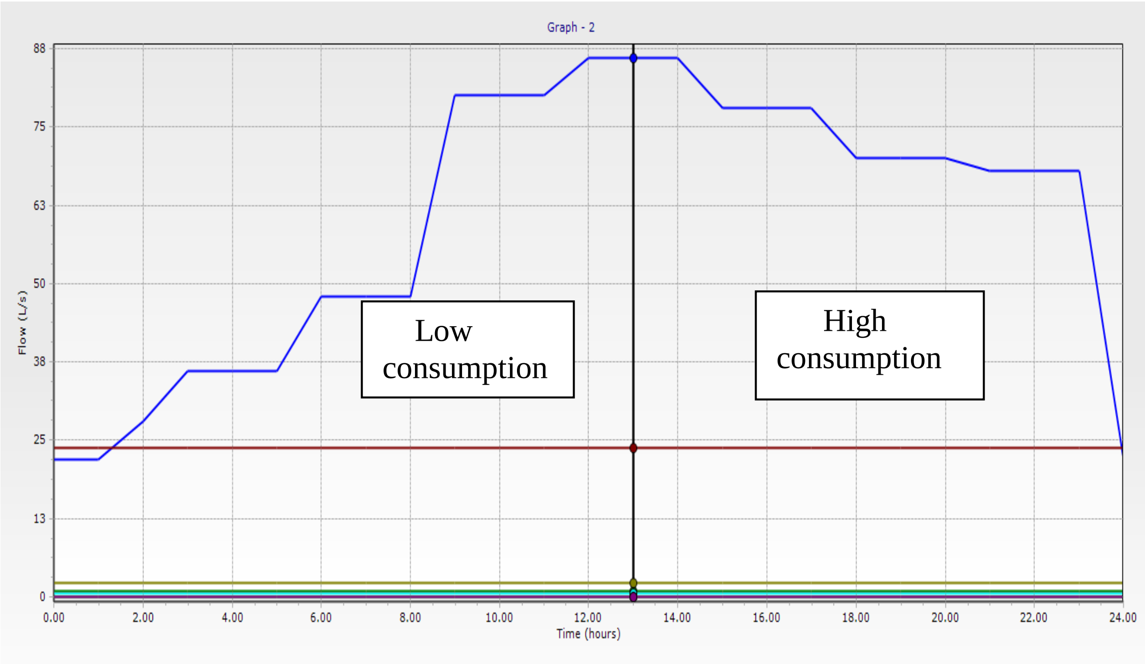

Fig.4. 12 System flow balance in some selected areas

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Both the average domestic water supply coverage and distribution were evaluated based on the daily per capita consumption and level of connection using the population data of the Adama City for the year 2014. The average water supply coverage of the city is 13.84 l/p/d. This average per capita consumption was much lower as compared with some water supply standards set by WHO (2008), the minimum quantity of domestic water required in developing countries in urban areas 20 l/c/d within a radius of 0.5 km. In this regard, the city domestic water supply satisfies about 70% of the standard value. Although the distribution of water supply coverage within the city (among each Kebele) has variation, the amount of each Kebele average per capita water consumption is still below the standard. The existing pipes of the distribution pipe system do not cover all areas of the city. Uneven distribution of water and the spatial distribution of the pipe network system fail to satisfy the demand of the public. In addition, some part of the city that are located at higher elevation and those areas located closer to the reservoir site do not get the minimum required water pressure.

The coverage of water supply declines as time goes on from 2009-2013. However floating population who shares from the daily water proceed, in additional to the increase in the number of University and college students, hospitals and health centers, gusts and visitors as a result of conference, establishment of star hotels all contributed to the water shortage of the city. In 2014 water supply coverage were increases comparing with 2013, because drilling five different boreholes to be maximized the coverage.

Water loss include leakage in the pipe due to breakage of pipes, improper fitting of pipe, illegal connection, back washing, flushing, wastage at public taps and poor fitting in the house connection. For Adama City from the production and consumption data, it was found that loss was 24.7% in 2014. According to AWWA leak detection, accounting committee recommended, as 10% as a benchmark for UFW, so Adama City water loss was intermediate. Thus, the loss can be controlled and reduced. From the existing system, it was expected that there would be a considerable amount of loss. This loss will be reduced with the replacement of old component of the system by new ones and proper sized pipes during the implementation of the project.

Loss would be minimal at the beginning of the design period and would increase gradually with time in the expected service life of the new system unless intermediate leakage detection and subsequent remedial work is carried out. Because leakage detection requires skilled manpower, equipment and strong organization that is unlikely to be established in Ethiopia in general and in Adama City particular. At the city, there are many star hotels and several road constructions activities, which could result in the breakage of pipes, and this maximized water loss. However, loss was increase and decrease, depending on time of construction and awareness creation between people.

The main reason was the under-capacity of operation and maintenance, the team did not have necessary materials and equipment to make proper repairs, and due to large area coverage did not maintain at time.

There are several reasons for the high level of water loss in Adama. Major causes of these losses were listed as follows:

- Unnecessarily high pressure in some area resulting pipe damage
- Illegal connection
- Backwashing
- Flood hazard
- Improper fitting of pipe

5.2 RECOMMENDATIONS

In order to improve the water supply services of the city in terms of coverage, water demand and reducing water loss the following actions should be undertaken.

The first and actual information will be collect and assess the problem. Therefore, this study work specifically investigated the potable water supply and demand, the existing water supply quantity, reducing water loss; the gap associated with water scarcity and suggested possible measurer.

The predominant approach towards meeting increasing water demand of the city is towards supply augmentation schemes. This includes developing new sources or expanding existing sources. Therefore, the city water supply authority have to look seriously into water demand management. To satisfy continuous rising of water demand several measures will be take.

Such as:

- Construct additional borehole in order to increase water supply coverage
- Increase reservoir
- Awareness creation to the community
- Updating existing network data, measuring and evaluating water loss
- Operation and Maintenance strategy in order to decrease leakage
- Proper sized pipes during the implementation of the project.

The available quantity of water from all sources of supply will be distribute to all people on equitable and fair distribution system. Therefore, a planned and scheduled rationing system as well as boosting stations can be implement to supply water to higher elevated area.

The water supply network of Adama City can be update using GIS and this need to be integrated with the land information system (LIS) of the city as well as information on hydraulic flow of the water network. Operation and maintenance data including pressure records need also be integrate spatially with the network. Therefore, introducing geographical information system is timely as it may facilitate the updating of the networks and support to perform related spatial analysis.

Some suggestions are proposed for further studies in applying water supply coverage and estimating water loss for improving per capita demand and water loss management. Due to the limited time and resources, this study is not adequately addressing all Kebeles despite their significance. The recommendation studies are as follows:

1. Kebele 01, 02, 04, 03, 05, 06, 07, Dhaga Adi and Melka Adama are not included in this study.
2. The study did not focus on water quality analysis and standardize urban water quality.

These recommendations are indicative of what can be follow up, but they are no means exhaustive list of possible directions for further research.

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Appendix A: Pipe Table

Current Time: 0.000 hours

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?
131	P-1	567	J_59	J_48	150.0	uPVC	150.0	False
132	P-2	373	J_48	J_65	150.0	uPVC	150.0	False
133	P-3	630	J_65	J_49	50.0	uPVC	150.0	False
134	P-4	242	J_49	J_50	100.0	uPVC	150.0	False
135	P-5	220	J_50	J_51	100.0	uPVC	150.0	False
136	P-6	197	J_51	J_52	50.0	uPVC	150.0	False
137	P-7	429	J_52	J_66	200.0	uPVC	150.0	False
138	P-8	262	J_66	J_88	200.0	uPVC	150.0	False
139	P-9	394	J_88	J_87	200.0	uPVC	150.0	False
140	P-10	416	J_87	J_54	150.0	uPVC	150.0	False
141	P-11	235	J_54	J_55	150.0	uPVC	150.0	False
142	P-12	337	J_55	J_53	150.0	uPVC	150.0	False
143	P-13	314	J_53	J_56	150.0	uPVC	150.0	False
144	P-14	209	J_56	J_57	50.0	uPVC	150.0	False
145	P-15	566	J_57	J_22	50.0	uPVC	150.0	False
146	P-16	152	J_22	J_13	50.0	uPVC	150.0	False
147	P-17	771	J_13	J_41	50.0	uPVC	150.0	False
148	P-18	283	J_41	J_42	50.0	uPVC	150.0	False
149	P-19	709	J_42	J_40	50.0	uPVC	150.0	False
150	P-20	382	J_40	J_23	50.0	uPVC	150.0	False
151	P-21	1,502	J_23	J_21	100.0	uPVC	150.0	False
152	P-22	1,529	J_21	J_77	200.0	uPVC	150.0	False
153	P-23	597	J_77	J_73	200.0	uPVC	150.0	False
154	P-24	787	J_73	J_83	200.0	uPVC	150.0	False
155	P-25	1,521	J_83	J_80	200.0	uPVC	150.0	False
156	P-26	1,037	J_80	J_20	200.0	uPVC	150.0	False
157	P-27	1,106	J_20	J_14	200.0	uPVC	150.0	False
158	P-28	775	J_14	J_79	200.0	uPVC	150.0	False
159	P-29	492	J_79	J_19	50.0	uPVC	150.0	False
160	P-30	744	J_19	J_71	50.0	uPVC	150.0	False
161	P-31	710	J_71	J_37	50.0	uPVC	150.0	False
162	P-32	417	J_37	J_38	150.0	uPVC	150.0	False
163	P-33	647	J_38	J_39	150.0	uPVC	150.0	False
164	P-34	241	J_39	J_82	150.0	uPVC	150.0	False
165	P-35	1,456	J_82	J_23	50.0	uPVC	150.0	False
166	P-36	476	J_82	J_29	200.0	uPVC	150.0	False
167	P-37	394	J_29	J_31	250.0	uPVC	150.0	False
168	P-38	530	J_31	J_58	150.0	uPVC	150.0	False
169	P-39	587	J_58	J_52	150.0	uPVC	150.0	False
170	P-40	392	J_37	J_36	250.0	uPVC	150.0	False
172	P-42	334	J_36	J_35	150.0	uPVC	150.0	False
173	P-43	200	J_35	J_10	350.0	uPVC	150.0	False
174	P-44	211	J_10	J_11	350.0	uPVC	150.0	False

Continued

Current Time: 0.000 hours

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?
178	P-48	663	J_81	J_18	350.0	uPVC	150.0	False
179	P-49	453	J_18	J_44	250.0	uPVC	150.0	False
180	P-50	499	J_44	J_43	150.0	uPVC	150.0	False
181	P-51	1,145	J_43	J_34	50.0	uPVC	150.0	False
182	P-52	291	J_34	J_33	50.0	uPVC	150.0	False
183	P-53	342	J_33	J_32	100.0	uPVC	150.0	False
184	P-54	242	J_32	J_31	100.0	uPVC	150.0	False
185	P-55	1,087	J_12	J_24	100.0	uPVC	150.0	False
186	P-56	474	J_24	J_33	50.0	uPVC	150.0	False
187	P-57	205	J_33	J_30	50.0	uPVC	150.0	False
188	P-58	352	J_30	J_29	50.0	uPVC	150.0	False
189	P-59	495	J_35	J_7	450.0	uPVC	150.0	False
190	P-60	247	J_7	J_78	100.0	uPVC	150.0	False
191	P-61	656	J_78	J_4	50.0	uPVC	150.0	False
192	P-62	261	J_4	J_3	300.0	uPVC	150.0	False
195	P-64	180	J_3	J-1	200.0	uPVC	150.0	False
196	P-65	203	J-1	J_1	200.0	uPVC	150.0	False
197	P-66	203	J_1	J-1	50.0	uPVC	150.0	False
198	P-67	203	J-1	J_1	250.0	uPVC	150.0	False
199	P-68	209	J_1	J_2	200.0	uPVC	150.0	False
200	P-69	196	J_2	J_60	200.0	uPVC	150.0	False
201	P-70	287	J_60	J_72	200.0	uPVC	150.0	False
202	P-71	386	J_7	J_6	200.0	uPVC	150.0	False
203	P-72	525	J_6	J_5	50.0	uPVC	150.0	False
204	P-73	730	J_5	J_9	100.0	uPVC	150.0	False
206	P-75	582	J_43	J_26	50.0	uPVC	150.0	False
207	P-76	1,202	J_26	J_59	50.0	uPVC	150.0	False
208	P-77	1,177	J_59	J_90	100.0	uPVC	150.0	False
209	P-78	324	J_90	J_91	100.0	uPVC	150.0	False
210	P-79	237	J_91	J_69	100.0	uPVC	150.0	False
211	P-80	555	J_69	J_68	100.0	uPVC	150.0	False
212	P-81	1,210	J_68	J_89	50.0	uPVC	150.0	False
213	P-82	424	J_89	J_86	50.0	uPVC	150.0	False
214	P-83	1,097	J_59	J_67	150.0	uPVC	150.0	False
215	P-84	292	J_67	J_64	150.0	uPVC	150.0	False
216	P-85	502	J_64	J_93	150.0	uPVC	150.0	False
217	P-86	151	J_93	J_63	150.0	uPVC	150.0	False
218	P-87	188	J_63	J_62	100.0	uPVC	150.0	False
219	P-88	313	J_62	J_27	100.0	uPVC	150.0	False
220	P-89	229	J_27	J_75	100.0	uPVC	150.0	False
221	P-90	159	J_75	J_100	100.0	uPVC	150.0	False
222	P-91	447	J_100	J_28	100.0	uPVC	150.0	False
224	P-93	283	J_28	J_99	150.0	uPVC	150.0	False
175/225	P-45/P-94	406/287	J_11/J_99	J_12/J_61	350.0/50.0	uPVC	150.0	False
176/228	P-46/P-98	268/848	J_12/J_97	J_80/J_84	300.0/200.0	uPVC	150.0	False
177/230	P-47/P-99	585/513	J_70/J_43	J_81/J_85	100.0/150.0	uPVC	150.0	False

Continued

Current Time: 0.000 hours

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?
231	P-100	762	J_25	J_45	100.0	uPVC	150.0	False
232	P-101	1,024	J_45	J_46	100.0	uPVC	150.0	False
233	P-102	464	J_46	J_47	100.0	uPVC	150.0	False
234	P-103	316	J_47	J_96	100.0	uPVC	150.0	False
235	P-104	819	J_96	J_92	50.0	uPVC	150.0	False
236	P-105	847	J_92	J_17	100.0	uPVC	150.0	False
238	P-107	405	J_72	J_85	200.0	uPVC	150.0	False
239	P-108	212	J_85	J_94	100.0	uPVC	150.0	False
240	P-109	545	J_94	J_45	50.0	uPVC	150.0	False
241	P-110	300	J_85	J_76	100.0	uPVC	150.0	False
242	P-111	561	J_76	J_95	100.0	uPVC	150.0	False
243	P-112	184	J_95	J_96	100.0	uPVC	150.0	False
244	P-113	1,146	J_89	J_84	100.0	uPVC	250.0	False
245	P-114	622	J_92	J_97	50.0	uPVC	150.0	False
255	P-120	877	R-3	PMP-1	400.0	uPVC	150.0	False
256	P-121	1,006	PMP-1	J_21	400.0	uPVC	150.0	False
257	P-122	313	R-2	J_4	400.0	uPVC	150.0	False
258	P-123	743	R-1	J_7	600.0	uPVC	150.0	False
260	P-124	394	J_3	J_81	400.0	uPVC	150.0	False
262	P-125	1,189	J_46	J_27	50.0	uPVC	150.0	False
265	P-127	2,645	J_19	J_21	100.0	uPVC	150.0	False
287	P-138	1,654	J_34	J_65	200.0	uPVC	150.0	False
288	P-139	518	J_66	J_49	50.0	uPVC	150.0	False
291	P-141	1,888	J_49	J_90	100.0	uPVC	150.0	False
294	P-143	1,798	J_59	J_27	50.0	uPVC	150.0	False
325	P-157	1,502	J_70	J_34	200.0	uPVC	150.0	False
338	P-164	395	J_61	J_97	50.0	uPVC	150.0	False
342	P-166	392	J_79	J-29	150.0	uPVC	150.0	False
343	P-167	1,479	J_47	J_61	50.0	uPVC	150.0	False
345	P-168	1,097	J_68	J-30	50.0	uPVC	150.0	False

Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss (m)	Headloss Gradient (m/km)	Has User Defined Length?
0.000	-32	1.83	10.13	17.86	False
0.000	-33	1.89	7.03	18.84	False
0.000	2	0.82	9.15	14.52	False
0.000	-3	0.33	0.28	1.17	False
0.000	-3	0.33	0.26	1.17	False
0.000	-3	1.30	6.76	34.36	False
0.000	12	0.40	0.32	0.75	False
0.000	11	0.34	0.15	0.56	False
0.000	11	0.34	0.22	0.56	False
0.000	11	0.60	0.95	2.28	False
0.000	11	0.62	0.56	2.39	False
0.000	11	0.62	0.81	2.39	False
0.000	11	0.61	0.73	2.31	False

Continued

Current Time: 0.000 hours

Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss (m)	Headloss Gradient (m/km)	Has User Defined Length?
0.000	3	1.46	8.90	42.53	False
0.000	1	0.70	6.14	10.85	False
0.000	-1	0.65	1.45	9.57	False
0.000	-1	0.76	9.64	12.51	False
0.000	-2	0.90	4.92	17.41	False
0.000	-2	1.16	19.54	27.56	False
0.000	-3	1.52	17.29	45.30	False
0.000	-11	1.37	25.06	16.68	False
0.000	53	1.69	16.73	10.94	False
0.000	53	1.69	6.53	10.94	False
0.000	31	0.98	3.18	4.05	False
0.000	30	0.95	5.81	3.82	False
0.000	18	0.59	1.61	1.55	False
0.000	18	0.59	1.72	1.55	False
0.000	16	0.51	0.94	1.21	False
0.000	-2	0.79	6.60	13.43	False
0.000	2	0.80	10.25	13.77	False
0.000	-1	0.48	3.78	5.32	False
0.000	25	1.44	4.79	11.48	False
0.000	25	1.44	7.43	11.48	False
0.000	25	1.43	2.71	11.25	False
0.000	-2	0.92	26.26	18.03	False
0.000	27	0.85	1.47	3.08	False
0.000	25	0.51	0.36	0.91	False
0.000	19	1.05	3.38	6.38	False
0.000	15	0.86	2.60	4.43	False
0.000	-28	0.58	0.46	1.17	False
0.000	-28	1.61	4.69	14.05	False
0.000	146	1.52	0.94	4.69	False
0.000	135	1.40	0.85	4.06	False
0.000	122	1.26	1.36	3.35	False
0.000	111	1.16	0.75	2.84	False
0.000	53	3.01	26.24	44.88	False
0.000	87	0.90	1.19	1.79	False
0.000	63	1.28	2.30	5.09	False
0.000	32	1.81	8.75	17.56	False
0.000	-2	1.02	24.94	21.79	False
0.000	2	1.12	7.52	25.86	False
0.000	-6	0.70	1.67	4.89	False
0.000	-6	0.77	1.39	5.74	False
0.000	10	1.31	16.70	15.36	False
0.000	1	0.70	5.11	10.78	False
0.000	0	0.16	0.15	0.71	False
0.000	-1	0.64	3.28	9.30	False
0.000	-185	1.16	1.06	2.14	False
0.000	8	0.98	2.20	8.93	False

Continued

Current Time: 0.000 hours

Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss (m)	Headloss Gradient (m/km)	Has User Defined Length?
0.000	3	1.46	27.70	42.25	False
0.000	96	1.36	1.19	4.56	False
0.000	45	1.44	1.48	8.21	False
0.000	16	0.51	0.24	1.18	False
0.000	0	0.21	0.24	1.18	False
0.000	29	0.58	0.24	1.18	False
0.000	44	1.40	1.61	7.73	False
0.000	36	1.16	1.07	5.45	False
0.000	32	1.02	1.24	4.33	False
0.000	15	0.47	0.39	1.01	False
0.000	1	0.48	2.88	5.47	False
0.000	0	0.00	0.00	0.00	False
0.000	2	1.11	14.76	25.35	False
0.000	-1	0.73	13.95	11.60	False
0.000	3	0.38	1.79	1.52	False
0.000	9	1.10	3.63	11.22	False
0.000	7	0.86	1.66	7.00	False
0.000	6	0.73	2.90	5.22	False
0.000	2	1.14	32.62	26.95	False
0.000	1	0.44	1.96	4.62	False
0.000	26	1.49	13.42	12.23	False
0.000	26	1.49	3.57	12.23	False
0.000	23	1.32	4.91	9.78	False
0.000	11	0.63	0.37	2.45	False
0.000	8	1.08	2.03	10.77	False
0.000	6	0.76	1.77	5.64	False
0.000	6	0.76	1.29	5.65	False
0.000	5	0.64	0.65	4.10	False
0.000	5	0.64	1.83	4.10	False
0.000	2	0.09	0.02	0.07	False
0.000	1	0.49	1.58	5.51	False
0.000	0	0.01	0.00	0.00	False
0.000	11	1.40	8.94	17.44	False
0.000	3	0.45	1.59	2.09	False
0.000	5	0.69	4.79	4.68	False
0.000	4	0.52	1.31	2.82	False
0.000	-6	0.83	2.08	6.57	False
0.000	3	1.65	43.50	53.10	False
0.000	5	0.68	3.86	4.56	False
0.000	26	0.83	1.20	2.95	False
0.000	13	1.68	5.18	24.48	False
0.000	2	0.97	10.86	19.92	False
0.000	12	1.52	6.11	20.38	False
0.000	12	1.47	10.77	19.19	False
0.000	11	1.39	3.18	17.25	False
0.000	0	0.03	0.01	0.00	False

Continued

Current Time: 0.000 hours

Minor Loss Coefficient (Local)	Flow (L/s)	Velocity (m/s)	Headloss (m)	Headloss Gradient (m/km)	Has User Defined Length?
0.000	-2	1.06	14.64	23.53	False
0.000	95	0.76	0.98	1.11	False
0.000	95	0.76	1.12	1.11	False
0.000	109	0.87	0.45	1.43	False
0.000	220	0.78	0.54	0.72	False
0.000	44	0.35	0.11	0.27	False
0.000	1	0.66	11.55	9.71	False
0.000	-9	1.11	29.92	11.31	False
0.000	35	1.13	8.60	5.20	False
0.000	2	0.79	6.98	13.47	False
0.000	6	0.73	9.80	5.19	False
0.000	2	0.82	26.06	14.49	False
0.000	48	1.52	13.54	9.01	False
0.000	2	1.18	11.17	28.31	False
0.000	15	0.86	1.73	4.41	False
0.000	1	0.69	15.61	10.55	False
0.000	3	1.78	66.78	60.89	False

Appendix B: Junction Table

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
194	J-1	1,695.17	08	<Collection: 1 items>	1	1,717.93	23
341	J-29	1,689.00	08	<Collection: 3 items>	15	1,741.44	52
344	J-30	1,609.00	08	<Collection: 2 items>	3	1,628.59	20
30	J_1	1,695.17	08	<Collection: 1 items>	1	1,717.67	22
42	J_2	1,672.72	08	<Collection: 1 items>	8	1,715.89	43
53	J_3	1,659.60	08	<Collection: 1 items>	6	1,719.55	60
64	J_4	1,699.99	08	<Collection: 1 items>	16	1,719.86	20
75	J_5	1,687.96	08	<Collection: 1 items>	1	1,746.20	58
86	J_6	1,689.46	08	<Collection: 1 items>	14	1,749.08	59
97	J_7	1,679.00	08	<Collection: 1 items>	12	1,749.47	70
119	J_9	1,698.89	08	<Collection: 1 items>	0	1,746.20	47
31	J_10	1,687.49	09	<Collection: 1 items>	11	1,747.50	60
33	J_11	1,678.48	09	<Collection: 1 items>	13	1,746.66	68
34	J_12	1,679.40	09	<Collection: 1 items>	0	1,745.33	66
35	J_13	1,661.00	09	<Collection: 1 items>	0	1,703.20	42
36	J_14	1,699.83	09	<Collection: 1 items>	2	1,744.11	44
39	J_17	1,615.00	09	<Collection: 2 items>	5	1,645.79	31
40	J_18	1,676.71	09	<Collection: 1 items>	7	1,719.36	43
41	J_19	1,699.47	09	<Collection: 1 items>	6	1,749.74	50
43	J_20	1,695.37	09	<Collection: 1 items>	0	1,745.82	50
44	J_21	1,710.00	09	<Collection: 1 items>	23	1,779.63	69
45	J_22	1,652.42	09	<Collection: 2 items>	3	1,701.76	49
46	J_23	1,696.23	09	<Collection: 2 items>	6	1,754.45	58
47	J_24	1,663.89	09	<Collection: 1 items>	9	1,728.64	65
48	J_25	1,646.12	09	<Collection: 1 items>	8	1,703.90	58

Continued

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
49	J_26	1,636.00	09	<Collection: 1 items>	4	1,696.31	60
50	J_27	1,616.00	Boku_Shanen	<Collection: 1 items>	3	1,679.83	64
51	J_28	1,607.00	Boku_Shanen	<Collection: 1 items>	3	1,676.18	69
52	J_29	1,679.46	Boku_Shanen	<Collection: 1 items>	1	1,726.93	47
54	J_30	1,683.78	Boku_Shanen	<Collection: 1 items>	1	1,723.70	40
55	J_31	1,657.36	Boku_Shanen	<Collection: 1 items>	0	1,726.57	69
56	J_32	1,676.00	Boku_Shanen	<Collection: 1 items>	1	1,725.21	49
57	J_33	1,687.00	Boku_Shanen	<Collection: 1 items>	9	1,723.56	36
58	J_34	1,667.00	Boku_Shanen	<Collection: 1 items>	8	1,731.06	64
59	J_35	1,679.12	Boku_Shanen	<Collection: 1 items>	11	1,748.42	69
60	J_36	1,697.00	Boku_Shanen	<Collection: 1 items>	0	1,743.74	47
61	J_37	1,691.00	Boku_Shanen	<Collection: 1 items>	2	1,743.28	52
62	J_38	1,670.58	Boku_Shanen	<Collection: 1 items>	0	1,738.51	68
63	J_39	1,664.55	10	<Collection: 1 items>	0	1,731.10	66
65	J_40	1,667.18	10	<Collection: 1 items>	1	1,737.20	70
66	J_41	1,649.43	10	<Collection: 1 items>	0	1,712.81	63
67	J_42	1,660.06	10	<Collection: 1 items>	1	1,717.71	58
68	J_43	1,656.95	10	<Collection: 1 items>	7	1,715.14	58
69	J_44	1,689.74	10	<Collection: 1 items>	6	1,718.88	29
70	J_45	1,651.43	10	<Collection: 1 items>	0	1,700.88	49
71	J_46	1,629.00	10	<Collection: 1 items>	0	1,694.36	65
72	J_47	1,630.13	10	<Collection: 1 items>	9	1,692.53	62
73	J_48	1,645.00	10	<Collection: 1 items>	2	1,715.02	70
74	J_49	1,660.00	10	<Collection: 1 items>	0	1,713.25	53
76	J_50	1,668.00	10	<Collection: 1 items>	0	1,713.53	45

Continued

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Demand Collection		Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
77	J_51	1,681.00	11	<Collection: items>	1	0	1,713.79	33
78	J_52	1,684.83	11	<Collection: items>	1	0	1,720.58	36
79	J_53	1,649.08	11	<Collection: items>	1	0	1,717.57	68
80	J_54	1,668.23	11	<Collection: items>	1	0	1,718.94	51
81	J_55	1,663.02	11	<Collection: items>	1	0	1,718.38	55
82	J_56	1,659.73	11	<Collection: items>	1	8	1,716.85	57
83	J_57	1,649.45	11	<Collection: items>	1	1	1,707.93	58
84	J_58	1,668.00	11	<Collection: items>	1	3	1,723.19	55
85	J_59	1,645.30	11	<Collection: items>	1	0	1,705.24	60
87	J_60	1,655.75	11	<Collection: items>	1	4	1,714.69	59
88	J_61	1,606.00	11	<Collection: items>	1	0	1,674.88	69
89	J_62	1,615.00	11	<Collection: items>	1	3	1,681.46	66
90	J_63	1,634.11	Dabe_Soloke	<Collection: items>	1	3	1,683.38	49
91	J_64	1,650.89	Dabe_Soloke	<Collection: items>	1	3	1,688.55	38
92	J_65	1,658.00	Dabe_Soloke	<Collection: items>	1	1	1,722.21	64
93	J_66	1,670.09	Dabe_Soloke	<Collection: items>	1	0	1,720.26	50
94	J_67	1,647.00	Dabe_Soloke	<Collection: items>	1	0	1,692.06	45
95	J_68	1,670.00	Dabe_Soloke	<Collection: items>	1	0	1,695.37	25
96	J_69	1,646.00	Dabe_Soloke	<Collection: items>	1	1	1,698.23	52
98	J_70	1,678.00	Dabe_Soloke	<Collection: items>	1	10	1,744.59	66
99	J_71	1,713.00	Dabe_Soloke	<Collection: items>	1	3	1,739.50	26
100	J_72	1,643.00	Dabe_Soloke	<Collection: items>	1	9	1,713.27	70
101	J_73	1,699.00	Dabe_Soloke	<Collection: items>	2	22	1,756.43	57
103	J_75	1,630.00	12	<Collection: items>	1	1	1,678.58	48
104	J_76	1,643.00	12	<Collection: items>	1	0	1,706.68	64

Continued

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
105	J_77	1,699.00	12	<Collection: 1 items>	0	1,762.96	64
106	J_78	1,680.13	12	<Collection: 1 items>	5	1,747.27	67
107	J_79	1,679.00	12	<Collection: 1 items>	3	1,743.16	64
109	J_80	1,686.00	12	<Collection: 1 items>	12	1,747.44	61
110	J_81	1,666.00	12	<Collection: 1 items>	11	1,719.56	53
111	J_82	1,689.00	12	<Collection: 1 items>	0	1,728.40	39
112	J_83	1,692.00	12	<Collection: 1 items>	1	1,753.24	61
113	J_84	1,612.00	12	<Collection: 1 items>	0	1,663.75	52
114	J_85	1,642.00	12	<Collection: 1 items>	1	1,712.17	70
115	J_86	1,636.00	12	<Collection: 2 items>	1	1,661.78	26
116	J_87	1,683.00	13	<Collection: 1 items>	0	1,719.89	37
117	J_88	1,659.00	13	<Collection: 1 items>	0	1,720.11	61
118	J_89	1,631.00	13	<Collection: 1 items>	2	1,663.74	33
120	J_90	1,639.00	13	<Collection: 1 items>	0	1,703.48	64
121	J_91	1,678.00	13	<Collection: 1 items>	2	1,699.87	22
122	J_92	1,618.00	13	<Collection: 1 items>	0	1,649.65	32
123	J_93	1,632.00	13	<Collection: 1 items>	12	1,683.74	52
124	J_94	1,653.00	13	<Collection: 1 items>	11	1,707.33	54
125	J_95	1,638.43	13	<Collection: 1 items>	1	1,697.04	58
126	J_96	1,634.00	14	<Collection: 1 items>	1	1,694.21	60
127	J_97	1,631.26	14	<Collection: 1 items>	0	1,663.75	32
129	J_99	1,649.11	14	<Collection: 1 items>	1	1,676.17	27
32	J_100	1,639.00	14	<Collection: 1 items>	0	1,677.95	39

Appendix C: Pump Definition Detailed Report: PMP-1

Element Details

ID	259	Notes	
Label	PMP-1		

Pump Definition Type

Pump Definition Type	Standard (3 Point)	Design Head	118.00m
Shutoff Flow	0L/s	Maximum Operating Flow	50L/s
Shutoff Head	140.00m	Maximum Operating Head	115.00m
Design Flow	43L/s		

Pump Efficiency Type

Pump Efficiency Type	Best Efficiency Point	Motor Efficiency	80.0%
BEP Efficiency	75.0%	Is Variable Speed Drive?	False
BEP Flow	43L/s		

Transient (Physical)

Inertia (Pump and Motor)	0.000kg·m²	Specific Speed	SI=25, US=1280
Speed (Full)	0rpm	Reverse Spin Allowed?	True

Pump Table

Current Time: 0.000 hours

ID	Label	Elevation (m)	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (m)	Hydraulic Grade (Discharge) (m)	Flow (Total) (L/s)	Pump Head (m)
254	PMP-1	1,692.72	PMP-1	On	1,684.02	1,780.77	95	96.74

Appendix D: Reservoir Table

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Flow (Out net) (L/s)	Hydraulic Grade (m)
246	R-1	1,750.00	Galma Abba Gada Reservoir	218	1,750.00
247	R-2	1,720.00	Adama University Reservoir	59	1,720.00
248	R-3	1,685.00	Lugo Reservoir	95	1,685.00

Appendix E: input parameters for WaterCADV8i

Node	X	Y	Z	Demand
J_1	527158.672	944635.411	1695.168	26.68
J_2	527201.691	944604.888	1672.716	7.54
J_3	527327.28	944779.733	1659.599	6.24
J_4	527383.482	945045.481	1699.994	15.99
J_5	527658.944	945379.277	1660.783	21.19
J_6	527739.431	945377.145	1655.654	23.71
J_7	527997.547	945359.799	1644.004	0
J_8	527538.622	945633.159	1686.235	2.75
J_9	527489.435	945411.819	1700.01	12.44
J_10	528419.725	945874.795	1655.841	1.28
J_11	528365.084	945670.281	1649.477	0.95
J_12	528262.046	945294.036	1638.681	0
J_13	532717.632	945199.097	1661.002	17.94
J_14	530101.556	948026.566	1699.834	4.45
J_15	527967.617	946337.198	1671.689	1.61
J_16	527117.993	941051.747	1614.31	0
J_17	527386.712	941162.396	1614.202	8.04
J_18	527987.376	944268.462	1625.71	0.5
J_19	529820.983	947105.811	1676.467	7.35
J_20	530548.103	948299.236	1695.368	13.73
J_21	532476.551	946647.409	1699.601	0
J_22	532646.427	945064.849	1652.419	0.28
J_23	531255.415	946051.905	1662.23	6.87
J_24	529333.992	945282.634	1634.21	4.14
J_25	528559.451	943773.069	1620.12	2.19
J_26	529227.295	943664.397	1625.324	0
J_27	528891.836	941301.403	1640.403	0
J_28	528821.583	940917.353	1666.746	9.42
J_29	530148.091	945726.131	1649.949	0.5
J_30	529904.546	945442.776	1640.43	0.95
J_31	530276.888	945354.228	1639.899	0.33
J_32	530134.625	945158.617	1634.201	0.5
J_33	529778.969	945265.314	1634.146	9.42
J_34	529636.706	944891.875	1629.707	8.05
J_35	528231.863	945869.93	1655.117	10.14
J_36	528374.126	946172.238	1663.491	0
J_37	528765.348	946243.369	1671.047	0
J_38	529156.57	946350.066	1670.575	0.5

J_39	529458.878	946421.197	1664.547	0.28
J_40	531397.206	945763.233	1657.182	16.14
J_41	531895.125	945389.794	1649.43	18.29
J_42	531930.691	945674.319	1660.062	0.5
J_43	528978.742	944162.779	1619.945	0.48
J_44	528427.474	944109.43	1619.744	0
J_45	528018.469	943255.855	1621.429	0
J_46	527733.944	942455.628	1618.592	4.61
J_47	527503.767	942544.542	1623.134	9.25
J_48	530348.019	943149.158	1609.225	0.95
J_49	530881.504	943860.471	1610.207	0.5
J_50	530810.373	944091.647	1614.343	0
J_51	530757.024	944305.041	1618.63	0
J_52	530739.241	944500.652	1624.833	0.35
J_53	531841.777	944678.481	1625.084	10.5
J_54	531752.862	944322.824	1615.229	0
J_55	531752.862	944447.304	1619.021	0
J_56	531752.862	944802.96	1626.731	7.86
J_57	531752.862	944927.44	1631.45	1.5
J_58	530757.024	945105.268	1641.055	3.32
J_59	529974.58	942722.37	1624.558	0
J_60	527079.318	944301.821	1655.753	4.25
J_61	528642.604	941056.42	1656.482	15.69
J_62	529021.971	941024.806	1656.361	6.87
J_63	529222.193	940982.654	1634.106	0
J_64	529591.022	941551.705	1614.89	0
J_65	530349.756	943522.305	1615.18	4.2
J_66	531066.338	944228.349	1615.087	10.5
J_67	530086.306	941636.009	1603.952	11.04
J_68	530349.756	940993.192	1605.148	0
J_69	530571.053	941499.015	1600	4.14
J_70	528165.371	945025.283	1633.348	0.25
J_71	529118	946902	1684	23.71
J_72	526965	944007	1643	15.99
J_73	533916	948626	1696	13.12
J_74	528590	940953	1659	1.28
J_75	528907	941059	1654	0.95
J_76	527021	942995	1643	9.38
J_77	532838	948417	1699	0
J_78	527882	945216	1647	0.5
J_79	529509	947246	1693	9.24

J_80	531395	948630	1698	21.53
J_81	527655	944721	1636	14.1
J_82	529828	946235	1652	20.19
J_83	532779	948873	1692	6.24
J_84	528229	940294	1648	7.14
J_85	527058	943405	1642	0.92
J_86	529439	940041	1640	7.78
J_87	531664	943968	1606	0
J_88	531233	944015	1611	0
J_89	529331	940311	1631	7.35
J_90	530741	941981	1600	0
J_91	530677	941718	1601	0.33
J_92	527782	941548	1610	7.86
J_93	529395	941070	1612	8.27
J_94	527468.882	943389.163	1632.765	11.3
J_95	527215.971	942440.745	1628.428	1.65
J_96	527352.964	942251.062	1624	3.15
J_97	528425.782	941099.049	1641.262	5.82
J_98	528473.348	941019.773	1650.405	5.77
J_99	528706.298	940996.6	1659.106	0.95
J_100	528836.8	940986.843	1661.109	6.45

Appendix F: Questionnaires for Local Administrative and Local Community Survey

Hello! My name is________________. I am assisting an on-going research by ***Girma Feye***, in partial fulfillment of his MSc degree at Jimma University. We are talking to selected sample households in Adama City about the water supply coverage and water loss in distribution system. The information collected from this questionnaires survey will be used for research purpose only. Please be frank and open-minded in your evaluations and opinions. All information obtained will be kept strictly confidential. Your kind cooperation is highly appreciated.

Questionnaire No.:____ Name of Interviewer: _______________ Date of interview: ___________

I. Personal Information of Respondents

1. Name of Kebele_____ 2. House No: _____ 3. Sex: (1) Male (2) Female

4. Age: (1) Under 14 years (2) 15-39 years (3) 40-64 years (4) above 65 years

5. Educational attainment

(1) None (2) Read- Write (3) Elementary school (4) Secondary school

(5) High School (6) College (7) Graduated (8) Higher education (9) Others_____

6. Occupation: (1) Government Sector (2) Retired (3) Private Sector (4) Housekeeper

(5) Other (specify) ____________

7. How many persons live in your household? __________________

Infants (less than 1 year old) ( ) persons

Children (1-18 years old) ( ) persons

Adults (more than 18 year old) ( ) persons

8. House holding: (1) Private (2) Rent (3) Government (4) private (5) other (specify) ________

II. Local Administrative (AWSSE)

9. Is your Unaccounted-for-Water below 10%?
   1) Yes
   2) No
10. Are there problems with the water source (s)?
    1) Yes
    2) No
11. Is water available year round?
    1) Yes
    2) No
12. What causes water loss in distribution system?
    1) Pipe damage
    2) Heavy track
    3) Illegal connection
    4) Ageing pipe
    5) I don't know
13. Do you conduct an annual water audit of your system?
    1) Yes
    2) No
14. Do you think that poor connection causes leakage on distribution system?
    1) Yes
    2) No
    3) I don't know
15. Are the type of material used and leakage on distribution system related?
    1) Yes
    2) No
    3) I don't know
16. Do think your current method of calculating water loss fairly and accurately reflects the amount of water loss in the system?
    1) Yes 2) No 3) I don't know

17. Do you conduct a full leak detection program for your distribution system every two years?
    1) Yes
    2) No
    3) I don't know
18. Is your system 100% metered?
    1) Yes
    2) No
    3) I don't know
19. Do you use an automatic or radio-read meter reading system?
    1) Yes
    2) No
    3) I don't know
20. Are all public-sector facilities billed for their water use?
    1) Yes
    2) No
21. Are any accounts not billed?
    1) Yes
    2) No
22. Do you bill based on actual meter readings, not estimated use?
    1) Yes
    2) No
    3) I don't know
23. Is the volume of water used stated in gallons on the bill?
    1) Yes
    2) No
24. Do you have a meter repair/replacement program that services meters based on the AWWA (American Water Work Association) standards?
    1) Yes
    2) No

25. Is your meter repair/replacement program funded through an annual budget appropriation?
    1) Yes
    2) No
26. Are water supply system operations fully funded by water supply system revenues?
    1) Yes
    2) No
27. Was your rate structure developed to promote water conservation and/or control demand (that is, do you charge more for water when demand is higher – for example, in the summer)?
    1) Yes
    2) No
28. Do any of your customers have a second meter for outdoor water use?
    1) Yes
    2) No
29. How much water is consumed by consumer?
    1) Once a day
    2) 24 hr
    3) In a week
30. Does your water supply system provide assistance to your public-sector users in conducting water-use audits?
    1) Yes
    2) No
    3) I don't know
31. Do you have a public education plan on water conservation?
    1) Yes
    2) No
32. Does your utility have any specific programs or procedures where you fix leaks on the customer service?
    1) Yes
    2) No

III. Local Community

33. Do you have secondary source of water for drinking?
    1) Yes
    2) No
    3) I don't know
34. Are there any leaks in the household pipes?
    1) Yes
    2) No
35. Is water point secure?
    1) Yes
    2) No
36. During dry season distance of water source from your home
    1) Meter
    2) Kilometer
37. Time required to the nearest alternative source of water
    1) Minutes
    2) Hours
38. How much water get in a month?
    1) Once in a day
    2) Once a week
    3) Twice a week
    4) Monthly
    5) Never through a year
39. Does the water line distribute in your home?
    1) Yes
    2) No
40. Where do you get water

1) Borehole

2) Public tap/ stand pipe

3) Water point

41. Do you think shortage of water occur in Adama?

1) Yes

2) No

3) I don’t know

42. What causes shortage of water?

1) There is no enough source of water

2) Problem of distribution

3) I don’t know

43. Do you think pipe damage causes water loss?

1) Yes
2) No
3) I don’t know

44. Do you think illegal connection occur in your area?

1) Yes
2) No
3) I don’t know