PROJECT REPORT

On the Evaluation of Water Loss Control Practices in Ethiopian Cities, the Case of Mekelle Water and Sewerage Service Enterprise.

Submitted to the Registrar (SED)
School of Management Studies
INDIRA GANDHI NATIONAL OPENE UNIVERSITY
IGNOU, Maidean Garhi, New Delhii -110 068

By: Mehari Desta Abraha
Enrolment No.079102919

For the Partial Fulfillment of the Requirements for Masters of Business Administration (MBA)
(MS-100 Course)

Advisor: Dr Yassin Ibrahim
Mekelle University, Faculty of Business and Economics, Ethiopia

Mekelle **May 2013**

CERTIFICATE OF ORIGINALITY

This is to certify that the project titled "Evaluation of Water loss Control Practices in Ethiopian Cities, the Case of Mekelle City Water and Sewerage Service Enterprise" is an original work of the student and is being submitted in partial fulfillment for the award of Master's Degree in Business Administration of Indira Gandhi National Open University. This report has not been submitted earlier either to this university or to any other University/Institutions for the fulfillment of the requirement of a course of study.

SIGNITURE OF SUPERVISOR	SIGINITURE OF STUDENT
Place:	Place:
Date:	Date:

ACKNOWLEDGEMENT

This dissertation would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

First and foremost my utmost I would like to thank my supervisor, Dr Yassin Ibrahim for excellent support, time and critical ideas, without which this work would not have materialized.

I extend my gratitude to Mr Gidena Abebe, General Manager of Mekelle Water & Sewerage Service Enterprise for his assistant in providing me all necessary data without delay.

I also put forward my deepest regard and blessing to, Mr Eyasu Kiros and Mr Mehari Mebrahitu for their sincerity and encouragement which has motivated me throughout the completion of this thesis and which I shall never forget.

Last, but not least, my gratitude is extended to my wife Roman Nuguse and my wonderful sons and daughters, who are the source of my strength and life. Without their assistance and support, pursuing my education would not have been possible; and I would like to express my appreciation for their persistent and robust support along with a very great patience.

List of Figures

List of Tables

Acronym and Abbreviations

AC	Authorized Consumption
AL	Apparent Losses
BAC	Billed Authorized Consumption
BMC	Billed Metered Consumption
BMC	Billed Metered Consumption
BPR	Business Process Reengineering
BUMC	Billed Unmetered Consumption
CARL	Current Annual Real Losses
CSA	Central Statistical Agency
ENA	Ethiopian News Agency
ET / et	Ethiopia
Gov / gov	Government
ILI	Infrastructure Leakage Index
IWA	International Water Association
LAOF	Leak and over flows
LOSC	Leak on Service Connection
LOTODM	Leakage on Transmutation or Distribution Mains
MI	Metering Inaccuracies
MOFAED/mofaed	Ministry of Finance and Economic Development
MOWR /mowr	Ministry of Water Resources
MWSSE	Mekelle Water & Sewerage Service Enterprise
N/A	Not Available

No.	Number
m^3	Meter Cube
NRW	None Revenue Water
NUPI	National Urban Institute of Ethiopia
Proc.	Proclamation
Q_a	Quantity of apparent water loss
Q_l	Quantity of water loss,
Q_r	Quantity of real water loss
RW	Revenue Water
SIV	System Input Volume (SIV)
UAC	Unauthorized Consumption
UAC	Unbilled Authorized Consumption
UARL	Unavoidable Real Loss
UBMC	Unbilled Metered Consumption
UBUMC	Unbilled Unmetered Consumption
UFW	Unaccounted - For Water
UN	United Nations
UNICEF	United Nations Children Fund
WHO	World Health Organization
WB	Water Balance
WL	Water Loss

ABSTRACT

Following the review of the literature with regard to water loss control and reduction practice of different types of urban water supply organizations or enterprises, this project paper focuses on the evaluation of water loss control practice in Water and Sewerage Service Enterprises of Ethiopian Cities taking the case of Mekelle Water and Sewerage Service Enterprise. Both primary and secondary data on the amount of water losses, causes of water losses , efforts made by the leadership to reduce loss, and the challenges ahead have been collected and analyzed taking the international association best practice of water loss control and it has been reached to conclude that the water control system was not properly practiced as it has been a focus for several years by other organization in developed nations. The leadership has gained full understanding to the problem of water losses and yet been given attention to take measures to reduce the loss significantly. Mekelle Water and Sewerage Service Enterprise will gain advantage from the enhancement of water loss control system in many ways including increase safe drinking water coverage, enhance revenue, etc… It is evident that these advantages could also be equally applicable to other urban water supply enterprises in Ethiopia.

Table Contents

CHAPTER 1: INTRODUCTION

1.1. Background

Water is crucial for sustainable development. Water quality and availability is the most challenging issues in Ethiopia. According to the Central Statistics Agency Report on Ethiopian Population Development Indicators 2008, access to safe drinking water at national level has reached 62.5% for both urban and rural and the access for urban alone is 82% in the year 2007.

Currently, the demand for water is increasing not only for safe drinking water but also, as a utility demand, for construction, industry, hotel service etc…, in proportion to the overall economy growth. The economy of the country is experiencing a significant growth; on average more than 10% yearly growth has been registered for the last seven years since 2005 (www.mofaed.gov.et). Definitely, the demand for water has been growing parallel as it is the major input for the construction, industry, hotel, and house hold etc…, purposes.

The increase in the water utility demand, further, has been triggering a huge investment request in the urban areas as population growth is high and industrialization in all aspects is concentrating in these areas.

Huge investment projects in water supply are undergoing with the assistant

of World Bank, UNICEF and others in selected urban areas of Ethiopia (www.mowr.gov.et). The investment from foreign as well as domestic sources flowing into this utility supply is so large that it is supposed to raise the current water supply to world standard level in country. New and some expansion projects are now under study and under construction (www.mowr.gov.et, Water Supply & Sanitation Projects).

In the other side, operation and maintenance of the water systems is under question. There are several schemes and networking systems under sever operation problems around the country (www.mowr.gov.et). As a result excessive leakages and water losses are observed due to low level of operation and maintenance management practices.

As one of the most crucial efficiency measures for urban water utilities around the globe is improvements on water losses (both real and apparent), therefore, this study will focus on The Evaluation of Water Loss Control in Ethiopian Urban Water Supply Enterprises by taking the case of Mekelle Water & Sewerage Service Enterprise (MWSSE) Water Loss Control and Management Practices.

Mekelle is one of the most important cities of Ethiopia found in the northern part, in-Tigray National Regional State. Astronomically, Mekelle is located at 13^0 32' N latitude and 39^0 33' E longitudes. It is about 780 km north of Addis

Ababa. The maximum elevation of Mekelle is 2200-meter above sea level. The mean maximum temperature of the city is 24.4^0C.

The rainfall characterizes of the city is bio-modal type where the minimum rainfall and maximum rainfall occur in autumn and summer (Keremt) respectively. The mean annual rainfall is 579mm where the highest occurs in August (222.7 mm) and the lowest in December (0.8mm)

It is believed that Emperor Yohannis IV founded Mekelle as a capital of Ethiopian in 1877, before 128 years ago (Mekelle City Profile report 2011) Later when Emperor Yohannis IV died, the capital of the Empire moved to Addis Ababa and since then Mekelle has remained the capital of Tigray Province.

One of the very dynamic phenomena of Mekelle is the population growth. In 2001 the total population of Mekelle had been estimated at 132, 643, and now in 2012, it is estimated at 273,453 (CSA of Ethiopia, 2012 Estimates). This shows that the population has doubled with in 10 years time.

Moreover, in the field of trade, a significant change had taken place. Shops, hotels, groceries and cinema halls were widely flourished in the city. The construction of many buildings for various purposes (including for administrative purposes) had been undertaken.

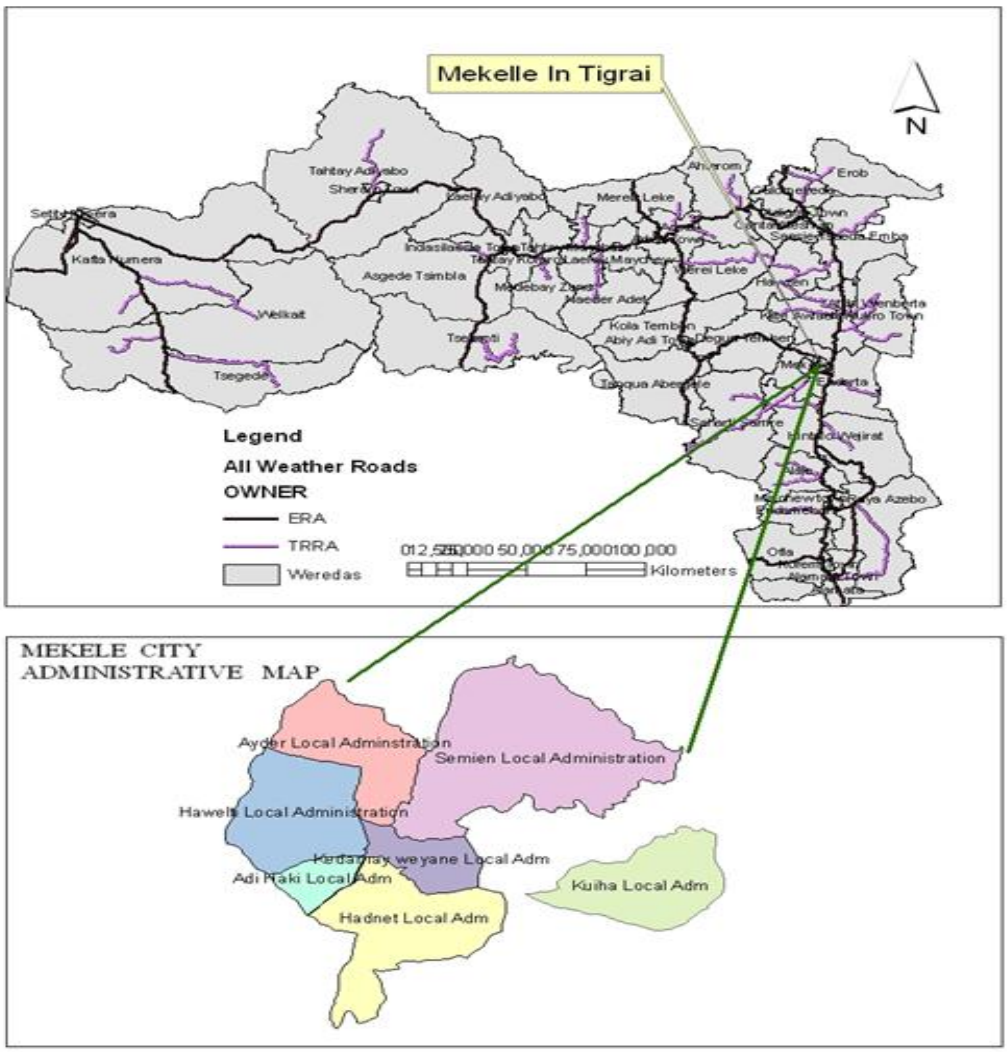

Fig 1. Map of Mekelle

Source: ***Mekelle City Profile Report 2011***

Administratively, Mekelle, currently the capital of the National Regional State of Tigray, has stood as a special zone on its own right. The Special Zone of Mekelle has been divided into 7 Local Administrations (sub cities) including Quiha, Hawilty, Adihaki, Hadnet, Kedamy Weyane, Ayder, and Semyen and the total area of the City has reached 644km^2.

In 2011 there are 85 primary and secondary schools, 63,403 students and 1,653 teachers. There is one Government University- Mekelle University, one private University Collage and more than 5 private colleges (mekelleadministration.gov.et)

As regards to the health facilities, there is one referral hospital- part of Mekelle University-the Ayder Campus, one zonal hospital; three privately owned medium level hospitals, 9 health centers and 40 private clinics including higher clinics and special ones. About 48 pharmaceutical retail outlets and 16 pharmaceutical whole sellers are found in the city. (mekelleadministration.gov.et)

Mekelle is fast growing city in the financial sector. There are 26 financial institutions out of which 17 are banks and 9 insurances both private and government holdings (mekelleadministration.gov.et)

With regard to information and mass media development, there are different newsletters and radio stations in the city. Three FM Radio and one Short Web Radio stations are located in the city.

Mekelle can be accessed by air and land transport. There are one international air port, one bus station and one truck vehicle station, and about 800 taxes are working in different directions of the city.

With regard to utility coverage, the City's electric coverage has reached 91%, and telecommunication coverage 68% (Source: Mekelle City Profile 2011)

Finally, the economic overview of Mekelle indicates that there are considerable numbers of establishments that can have a direct impact on the quantity demand of water. In 2011 there were about 368 wholesales, 4,767 retails and 3,284 services. Among the service giving establishments, 8 were star hotels, 39 pension, and 52 restaurants. Moreover, in 2011 Fiscal Year, there were about 74 industries in the city. (Source: Mekelle City Profile 2011)

As it has been indicated in the development plan of the city, the scarcity of water has been one of the severe problems of the city. There have no adequate sanitation facilities as well. As a result the people are used to use dug-wells in their compound which have significant consequences on the quality and on the health condition of the people of the city. In 2011, water coverage of the city has reached 69.3% taking 40liter per capita domestic water consumption per day(source: 2011 Annual Report of MWSSE)

Mekelle Water and Sewerage Service Enterprise is a government establishment. It was established back to 50 years ago. Several restructuring activities had been carried out at different times during the 50 years time. It had been mandated to serve the city as water supply service office until 2006. Following Proclamation No.122/1999, during year 2007, for the

Establishment of Urban and Rural Water and Sewerage Service of National Regional State of Tigray, it has been established as Mekelle Water and Sewerage Service Enterprise (MWSSE).

According to the new proclamation, the Enterprise is governed by a board for strategic directions and by General Manager and Functional Heads for its daily works. The enterprise has 4 Service Zones to facilitate its services close to the customers. The General Manger is dually accountable to the Board and to City Mayor. Currently the enterprise has around 260 permanent employees, out of which more than 160 are operational staffs.

1.2. Statement of the Problem

The investment in the water sector is very essential as the economic growth, urbanization, and industrialization, and Millennium development goals, is very demanding. Therefore, studying the operation and management of Mekelle Water and Sewerage Service Enterprise was found necessary as it is experiencing more than 21% water losses every year. This water loss is classified as high according to the studies made in different countries. As a result, the municipality is losing significant revenue, and is limiting the residents', to access to safe drinking water, and as well, limiting the business holdings (industries, construction, hotel etc…) to get connected to these utility services on time. This definitely limits the development endeavors of the city in particular and the region in general.

Therefore, this study project addressed the water loss management practice in Mekelle city. The study further evaluated the current water loss control procedures of the water supply to be in compliance with their sustainable strategy. In general the study is designed to give an answer to following four basic questions:

- What is the amount of water being lost every year?
- What are the causes of water loss?
- What measures does the leadership use to reduce water losses and improve performance?
- What challenges does the leadership face in managing water loss?

1.3. Objective of the Research

The general objective of the research project was to investigate the water loss control management practices along with its corresponding challenges observed in the water supply management of municipalities with regard to the best practices designed by International Water Association (IWA) taking a case of Mekelle Water and Sewerage Service Enterprise (MWSSE). Therefore, the specific objectives of the study include:

- To evaluate the amount of water being lost during the last 5 years ,
- To identify the different sources and causes of water losses,
- To find out measures taken by the enterprise to reduce water losses, and

- To provide appropriate recommendations on how to design and implement water loss control best practices and sustain achievements.

1.4. Significance of the Study

Nowadays, the demand for water is growing significantly. This has triggered the request of huge investment into the urban water supply rehabilitation and expansion of the country. This needs to be supported with proper water loss control strategies, operation, and management. Water loss management will definitely help municipalities to optimize water services revenue and cost recovery. Controlling water loss is not just only enhancing revenue, it is also about conserving water, reduction of production cost and energy, limiting health hazards, and improving the supply of safe drinking water to the municipality citizens.

The significance of this research is, therefore, to contribute its part in building effective water loss control strategies on sustainable ground so that the municipality would be able to attain better satisfaction from citizens, industry, construction, hotel and other services giving sectors of the city .

Since the project addresses the water loss management practice and its problems in urban water supply, the findings of this research would also contribute to the enhancement of knowledge of management. On top of that,

the study may initiate other scholars to further look into the subject, as this study is almost one of the new interventions.

Different stakeholders like the World Bank, UNICEF, and other NGOs working in water and sanitation areas need such study to use as an input or as reference to extend their interventions to support the citizens in the urban areas.

1.5. Scope of the Study

The scope of the study has been limited to examining the water loss management practices in the water transmission and distribution networks (outdoor water losses) taking the case of Mekelle Water and Sewerage Service Enterprise. And due attention was given to consider real and apparent water loss determinants out of the water management practices.

1.6. Definition of Terms

The basic terms in the water loss control systems are defined here in this section.

The basic abbreviated definitions of important components / parts of the IWA water balance are as follows:

System Input Volume (SIV) is the amount of water produced or treated annually from water sources and ready to be realized as input to the water supply system or network. It may include imported amount if the water supply uses imported water through its mains.

Authorized Consumption (AC) is the amount of water metered and /or non-metered water taken by officially registered customers, the water distributers and others who are implicitly or explicitly authorized to do so. It includes water exported (if any), and leaks and overflows beyond the point of customer metering.

Non - Revenue Water (NRW) is the difference between System Input Volume (SIV) and Billed Authorized Consumption (BAC). NRW consists of Unbilled Authorized Consumption (UAC) and Water Losses

Water Losses (WL) is the difference between System Input Volume (SIV) and Authorized Consumption (AC), and consists of Apparent Losses (AL) and Real Losses (RL)

Apparent Losses (AL) consists of Unauthorized Consumption (UAC) and all types of errors including metering inaccuracies and accounting errors

Real Losses (RL) are the annual volumes lost through all types of physical networks including pipe-leaks, bursts and overflows on mains, service

reservoirs and service connections, up to the point of customer metering.

Birr is official currency of Ethiopia; it is estimated to be one US Dollar is equivalent to 18 Ethiopian Birr.

1.7. Outline of the Thesis

The study paper has five Chapters which includes introductory chapter that gives the overall picture of the study, Chapter 2 presents a review of the literature relating to water loss control or reduction, Chapter 3 describes applicable research methodology, Chapter 4 provides a detailed study results obtained from Mekelle Water and Sewerage Service Enterprise and an analysis of these results in terms of the literature presented, and Chapter 5 presents conclusions and recommendations.

CHAPTER 2: LITRATURE REVIEW ON WATER LOSSES CONTROL

This chapter would outline water losses control practices including its historical context, purpose and criticisms, as well as consideration of its applicability in developing countries. Discussions of developmental issues, a review of the water balance and the basic methods of effective water leak control management system including an example of the successful implementation of a water leakage control best practices around the globe, were addressed.

2.1. Water Losses Control and Management

This section presents an overview of Water Losses Control. It will follow by addressing descriptive background information on water losses control, hereafter, the main aim of water loss control and its varied criticisms are discussed. As this research is focusing on urban water supplies, this section also presents an introduction to the applicability of operations management in a service giving organizations. The section also addresses the role of leadership in urban utility supplies with focus to the water supply management.

Water losses control has been a necessary part of water supply management in water supply systems and part of the life of the system as long as there have been organizations operating this urban utility. It is important to note the Chinese proverb to clearly understand the importance of water management in

today's world scenario, "We will not know the worth of water, 'til the well is dry".

On average 26% treated water has been lost from water distribution networks from around the globe due to pipe - breaks, damages / failure, poorly designed infrastructure design, and illegal line connections or consumptions every year. This has resulted in lost of $14 billion in profit from the non-revenue water. However, reducing or controlling water loss not only enhances revenue but also conserving water and energy, limiting carbon footprints, and supplying safe drinking water to the world population (Zheng Yi Wu al .. 2006)

Different studies have been made around the world on urban water supply problems and challenges around the world with special emphasis on developing countries. According to study by UN-HABITAT 1999, the problem of water shortage in most of the nations in developing countries is not only due to limitation on the sources but also as a result of inefficiency on distribution networks -of -cities. High -rate -of water losses from the distribution systems is one the significant factors for such inefficiency in the water utility performance. According to the several studies conducted in the world, water losses in cities of developing countries is estimated to be 40- 60% out of the treated amount or the difference between water produced and water consumed (Arlosoroff, 1999). This water loss figures reflect the inefficacy of water supply

management. The strategy to be framed for any water losses reduction requires proper understanding about the action to be taken including technical, operational, institutional, planning, financial, administrative, and above all leadership commitment issues (WHO, 2000)

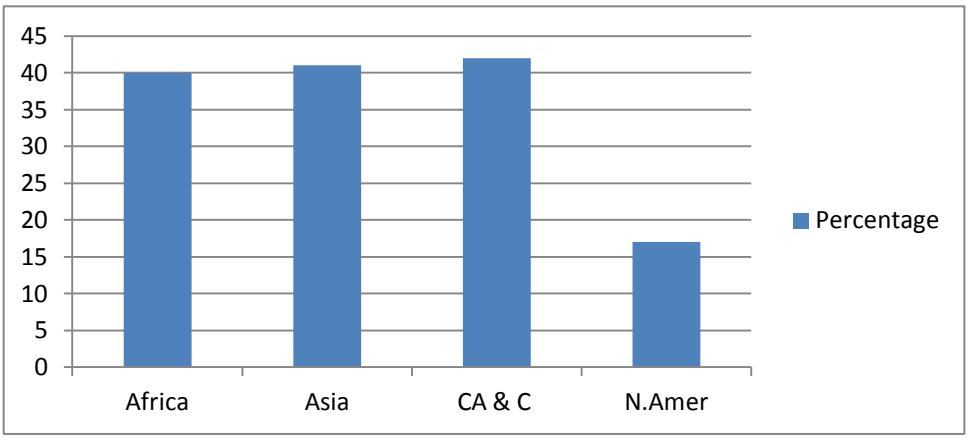

Fig.2: Mean Unaccounted-for Water in Large Cities

Source: WHO, 2000

According to the news release by Ethiopian News Agency 2011, an official figure tells that 30-35 percent of water in the Addis Ababa city would be misused, wasted or non-accounted for charge. A strategy has been designed to address significantly the wastage to 20 percent. As part of the efforts, old pipe lines are being replaced by new ones (ENA, Apr 26, 2011).

The study made by consultant Malcolm Farley 2010 indicates that throughout the world, the demand for water is increasing from time to time and the resources are diminishing. The losses of water from the water systems or pipe-networks, has been, for a very long time, a headache to engineers working in

this utility operation. This problem exists even in nations that -are -having modern infrastructures and well developed operating practices. In developing countries, this problem has however a new dimension, where a low level of infrastructure, low level sanitation, and low level supplies always brings serious health risk. Some practice show mixing of -both treated and untreated water by water scarce countries, taken as a solution to satisfy the demand for short term.

The study further described that the source of water losses are not all the results of poor infrastructure and leakages from pipes in the networks. There have been always apparent losses or water misuses from the networks as a result of local customs, not well developed tariff structures, and absence of proper metering policies.

It is fully understood that the formulation of polices and strategies to minimize all types of water losses; being it is apparent or real water losses is necessary and critical. Without clear policies and strategies on water management, it would be impossible to tackle water losses and improve the efficiency and performance of supply networks. Therefore, a strategy for reducing the significant lost treated water is expected from the leadership that focuses on the introduction of water supply management and water development initiatives.

Beside to the commitment from the leadership, the key input to design and develop a strategy for water reduction or loss control is gaining a clear understanding of the causes for water losses and the factors that influence to happen. Hence, it is possible to tailor specific techniques and procedures as per the requirements, nature and makeup of the networks, and local influences, and financial requirements in order to track each cause depending on magnitude and on priority.

Reducing water losses is possible but how much to reduce is not as such an easy question. The recent practice of UK water industry, in this regard, could be taken as a good lesson. They have developed regulators to develop very clear and detail procedures for analyzing, tacking and controlling losses. Different techniques have been developed by practitioners from the water utility industry for understanding, measuring, tracking and monitoring losses within the distribution networks which includes appropriate technology and skill upgrading techniques.

The model developed by United Kingdom -National -Leakage -Initiative -(1991-1994) provided the concept for understanding losses and developing solutions. This experience could help the international water industry to develop strategies customized to local characteristics and infrastructure conditions, in any urban in the world; in addition to this, water supply enterprises would be able to introduced programmers to encourage urban citizens or water users to use economically optimal water.

All water distribution systems, whether small or large, simple or complex, are having water losses however the level and magnitude of loss varies significantly. The main sources for such variations are the material nature of the pipe network, local factors, operational practice of the water enterprise, the expertise and type of technology used to control water losses. The amount of water being lost also varies significantly from country to country and from region to region within each nation or continent around the world. The water losses components and their relative significance would vary among nations and regions.

Above all, proper understanding of the relative importance of each of the parts or components of water loss controls strategy is most critical aspect; making sure that each is quantified or estimated as accurately as possible, so that a series of action plans, on priority basis can be prepared.

Internationally, Water Loss (WL) and Non-Revenue Water (NRW) are accepted expressions and makes inter-country comparisons very easy. These expressions have replaced the traditional expressions such as Unaccounted-for Water (UFW) which are weak to address consistently inter-country comparisons in the world. It is very easy practice to know water loss by subtracting water consumed from water produced or treated. And in accounting terms, it is the difference between water produced and water billed or consumed (IWA, 2010)

There is quite difference between water loss and leakage. Therefore, it is important to differentiate these two to calculate their significant magnitude over a period. According to the International Water Association, water loss is defined as real losses plus apparent losses Mathematically the expression can be put as $WL(Q_l) = RL(Q_r) + AL(Q_a)$. Where: Q_l is total quantity of water loss, Q_r is quantity of real water loss, and Q_a is quantity of apparent water loss.

Accordingly, the expression of Physical Losses has been replaced by Real Losses (RL) and Non -Physical Losses (NPL) has been replaced by Apparent Losses (AL). Real losses are the leakage from pipes, joints and fittings. It also consists leakage through service reservoir floors and walls, and from reservoir overflows. Sometimes, real losses are difficult to track and could be more severe, and may go untraced for longer period beyond months and even years.

The amount water lost would largely depend on the nature and makeup of the pipe network and the policy and procedure used or practiced by the water supply enterprise or organizations in the urban areas to detect and repair leakage in the whole network. Among others the following need much attention from the enterprises: The Pressure Management which deals with the pressure in the network, the frequency and typical flow rates of new leaks and bursts; Active Leakage Control which deals with the proportions of new leaks reported, the awareness time (how quickly the loss is observed), and the level of background leakage (undetectable small leaks); and Speed and Quality of

Repairs which deals with the location time (how quickly each new leak is identified) the repair time (how quickly it is maintained or shut off).

The United Kingdom National Leakage Initiative has acknowledged all the above influences by its research program undertaken on the water industry.

There is a significant difference in the volume or quantity of water losses or leaks from the different parts of the water supply systems, transition mains and distribution lines. In developed countries, water leakage takes the lions share from the total water losses but in developing countries apparent losses including illegal connections and measurement or calculation errors are more significant.

According to International Water Association (IWA), the water balance calculation helps the professionals in the water supply sector to know the volume of water being lost and the source of the water being lost from.

Different water supply enterprises in a country and around the world used to use widely diversified approaches and definitions for water balance calculations which came up with a need for a common and international terminology. Accordingly, the International Water Association (IWA), by studying the best practice from several water supply enterprises around the world has designed an international best practice standard approach for water balance calculations. Figure 3 below describes the details of water balance components.

According to German National Report on Water Loss Management and Techniques produced -by: D.Weimer, 2001, water loss is classified as minimal (8% and below), medium (8%-15%), and highest (more than 15%).

Now days, water supply enterprises in the world, are taking active water loss management as their primary interest. It has been recognized as significant saves. As a result, further investments in new water resources holdings can be justified only if appropriate action is done to minimize loss from the water supply networks. In the last decade, IWA Task Force has made great efforts to develop new way of performance measuring and benchmarking in this regard. The study paper by the task force, presents the basic principles, methodology and the results of the first step in attempt to approach Serbian water mains to the new standards" (Technical Performance Indicators, IWA Best Practices for Water Mains and the First Step in SERBIA, 2007)

Since the level of water losses, including its real and apparent components, is one of the most critical efficiency and performance issues for water utilities around the globe, this research will focus on the evaluation of water loss management and the leadership role in the Ethiopian urban water supply by taking the case of Mekelle City Water Supply, water loss control and management practices.

<table>
<tr><td rowspan="9">System Input Volume (SIV) (corrected for known errors)</td><td rowspan="3">Authorized Consumption (AC)</td><td rowspan="2">Billed Authorized Consumption (BAC)</td><td>Billed Metered Consumption (BMC)</td><td rowspan="2">Revenue Water (RW)</td></tr>
<tr><td>Billed Unmetered Consumption (BUMC)</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumptions (UAC)</td><td>Unbilled Metered Consumption (UBMC)</td><td rowspan="7">Non Revenue water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption (UBUMC)</td></tr>
<tr><td rowspan="6">Water Losses (WL)</td><td rowspan="2">Apparent Losses (AL)</td><td>Unauthorized Consumption (UAC)</td></tr>
<tr><td>Metering Inaccuracies (MI)</td></tr>
<tr><td rowspan="4">Real Losses (RL)</td><td>Leakage on Transmission and/or Distribution Mains (LOTODM)</td></tr>
<tr><td>Leakage and Overflows (LAOF) at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections (LOSC) up to point of Customer metering</td></tr>
</table>

Fig. 3: IWA 'Best Practice' for Water Balance

Source: IWA, Best Practice of Water Losses Control.

2.2 The Purpose of Water Losses Control Systems

Water losses control is designed by water utility enterprises to improve the efficiency and performance of their water supply systems. Water loses control is meant to be critical that an organization applies to improve its total water supply effectiveness. The leadership assists the organizations in providing strategies for managing the water losses control and achieves results by enabling individuals the nature of the

problem and individuals role to solve it.

2.3. Approaches Applicable to Developing Water Losses Control System

For many years in the past, the volume of water lost has been expressed as a percentage of the volume produced or treated. And it was believed by all stockholders, including politicians and above all the media people that this is correctly and the real measure of performance for NRW and all its constituent parts. Accordingly, water loss plans and targets (being it short or long terms) are often put, at national/enterprise level in percentage terms.

It has a meaning to put water losses/NRW in terms of percentages; definitely, it is better than putting no targets at all, it shows the differences between water supply utilities that are with low losses and with high losses. It can also show differences on consumption (low system loading), higher than average operating pressures due to topography, and NRW calculations which include leakage on customers' private pipes.

When expressed in terms of % (percentage), the same magnitude or amount of real losses could, be based on the consumption per service

connection, be somewhat from 40% to 2.5%. Accordingly, countries with relatively lower consumption, such as Malta, England / Wales, and other developing countries, can show to have much losses when put in percentage (%) terms; on the contrary, percentage (%) losses for municipalities from developed countries with higher consumptions can be definitely misleading.

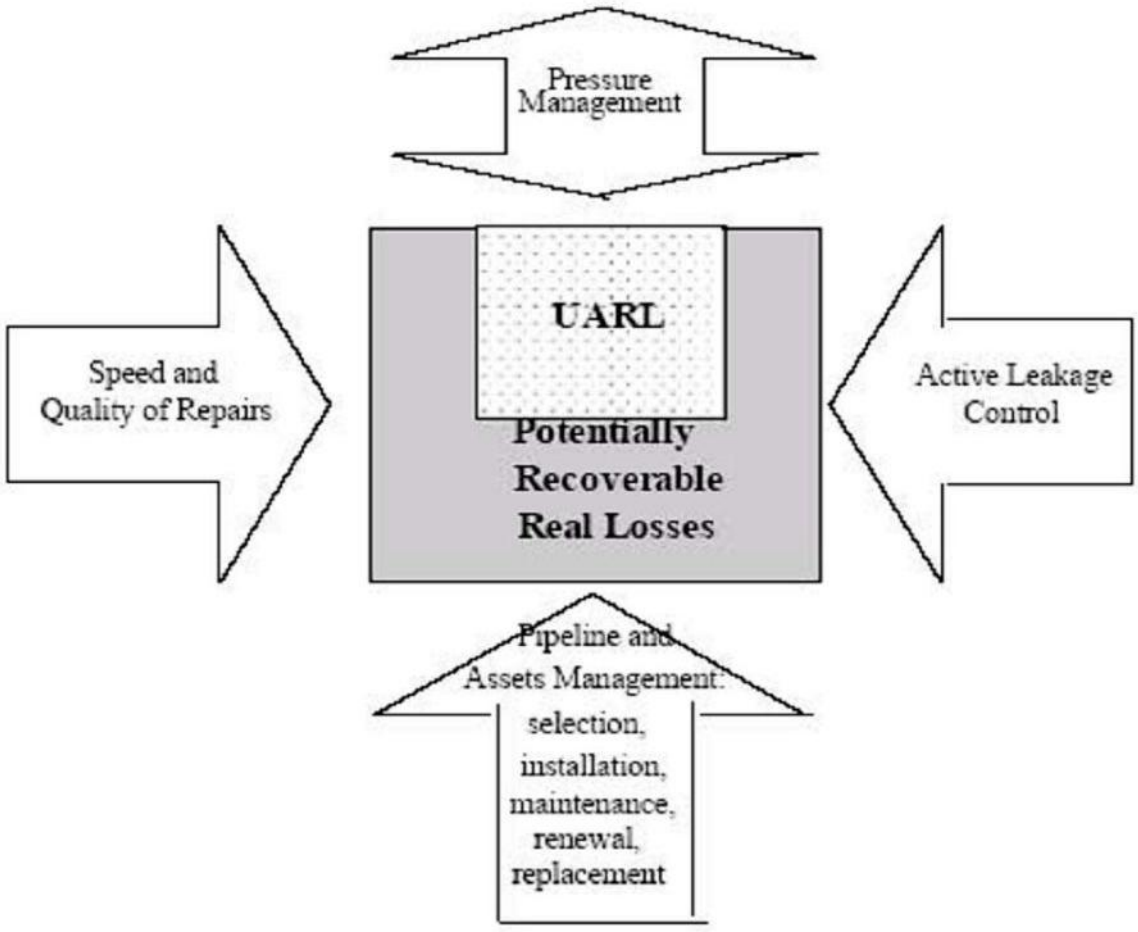

Fig 4: Basic Methods of Managing Real Losses

Source: IWA, Best Practice of Water Losses Control.

Due to demand management measures or when consumption reduces annually or seasonally, the amount or percentage of real losses increases significantly while the real losses remain unchanged. The opposite effect will also occur when consumption increases.

The method of performance comparison which developed by the Water Loss Task Force assigned by International Water Association (IWA) can be used by a water supply enterprise to measure their own success that will support the introduction of a leakage strategy. As a result the taskforce have developed Infrastructure Leakage Index (ILI) that will be used by companies and nations to measure their performance. It also used for inter- company and inter-country comparisons.

This Infrastructure Leakage Index (ILI) performance measure is defined as the ratio of current annual real losses to unavoidable annual real losses. Figure 4 depicted above, shows the result of leakage control and operating practices, which will decrease when more efficient operating practices are used and it could use as the basic foundation for designing, developing, and implementing a leakage management strategy.

The small rectangle in the figure represents Unavoidable Real Losses (UARL) and the large rectangle represents the Current Annual Real Losses (CARL). The difference between Current Annual Real Losses (CARL) and

Unavoidable Real Losses (UARL) results the potentially recoverable Real Losses and the ratio of the Current Annual Real Losses (CARL) to the Unavoidable Annual Real Losses (UARL) is put as the Infrastructure Leakage Index (ILI). If the difference comes to zero, the ratio will reach to one.

If all the activities of the infrastructure including maintenance, active leakage control and infrastructure management are properly managed at current operating pressure, the measure of ILI will show the effectiveness of the practice. It is absolutely true that if ILI shows lower values, it can be said that the utility's performance is good.

According to IWA best practice, there is always some optimal level of investment and activity for each of the four activities indicated in figure 4 above that required to be monitored or assessed, calculated, or evaluated to consider the marginal value in its local currency / m^3, to be placed on the real losses. Considering the local ground and practices, the marginal value may be low or high and this strongly influences the optimal management policies for controlling real losses.

CHAPTER 3: RESEARCH DESIGN AND METHEDOLOGY

3.1. The Research Method

This research will thoroughly examine the water loss control of the urban water supply in Ethiopia by taking the cases of Mekelle Water & Sewerage Service Enterprise which is one of the pioneers' water supply management in the country. The researcher selected and used case study research method to evaluate the amount of water being lost every year, to identify the causes of water losses, and find out the measures taken by the management to reduce water losses. Since water loss control is one aspect of process control in the water supply system, to investigate the losses control process as water management practice, illustrative case study method has been applied.

3.2. Instruments of Data Collection

The researcher of this paper used both primary and secondary data sources. To obtain the primary data, questionnaires and face to face interviews were used. Semi structured questionnaires were designed in such a way that to comprise queries focusing at general understanding & practices of water loss management with regard to Water Balance, the four basic pillars of leakage management, and the four methods of managing of real losses, and how to maintain the strategies or assure sustainability.

Observations on some process and operational systems have been made to collect information on how the system is working by taking some pictures.

The researcher has also referred related proclamations, policy & procedure manuals, strategic planning documents, brochures and other relevant document of MWSSE, Ministry of Water Resource development, Bureau of Water Resources Mining and Energy of Tigray Region, and City Administration of Mekelle, as secondary data sources. On top of that, it had included review of different Operational and Management books, journals and other research materials.

3.2.1 Questionnaire

Questionnaire is one of the data collection methods applied in surveys and research works. It is designed and distributed to individual's respondents to be filled and returned within specified time frame.

In this particular case a questionnaire has been designed and used to collect information from the different staff categories of functional units. 25 semi structured questionnaire that addresses 5 major subjects were distributed to collect information from the staff

employed in MWSSE. Out of which 22 were returned and 2 were fund incomplete. Therefore, 20 have been used for data analysis.

3.2.2. Interviews

Interview data collection method is useful to collect information that are not very clear to the researcher and to further confirm facts collected by questionnaire or statistical figures.

In this particular case 10 senior management members were interviewed focusing on the causes of water losses, measures taken to reduce water losses, and the challenges that the leadership facing to reduce water losses.

3.2.3. Secondary Data

Data on annual water production, water consumption, revenue, expense, line expansion, line maintenance, meter maintenance, and water loss figures has been collected from the MWSS documents and records.

3.2.4. Focused Group Discussion

This method is used to arrive at an agreement on the causes of water losses and the challenges ahead. 10 focused group members participated to cross check the figures and facts collected from questionnaire, interview and secondary sources.

3. 3. Subjects and Sampling

3.3.1 Subjects

In this study Senior Management members and operational staff have been considered as subjects of the study. 10 Management members, 17 team leaders and professionals, and 13 technical and operation staff were taken as samples.

3.3.2 Sampling Technique

Since the research method is case study, the researcher used information-oriented sampling instead of random sampling. All management members are taken in the informants, all team leaders are considered in this study.

3.4. Techniques of Data Analysis

Both quantitative and qualitative data analysis have been applied. The data thus have been tabulated and analyzed on descriptive statistical methods to summarize the understanding, practices and observed challenges in the water loss control practices of the selected enterprise. Percentages, averages, graphs including histograms have been used to interpret and present the data. Focus has been made to compare the data output with the international best practices to arrive at the reliable conclusions. The model of WB and the 4 methods of leakage control have been used to evaluate the current practice of water losses.

The current water losses figures have been compared with the international average, with East African average and with Addis Ababa water loss figures. Accordingly, conclusion has been drawn and recommendation for further study and strategies for appropriate water losses control have been forwarded.

3.5 Ethical Consideration

There were no expected physical and social risks towards the study participants. However, the researcher expected that since dealing with a water problem is sensitive issue the researcher expects some resistance from the sample respondents in answering and filling some of the questions in the questionnaires by forwarding their real opinion.

To avoid or minimize the expected resistance by some of the respondents in filling and describing the questions genuinely the student researcher used the following strategies:

- Describing the objective of the study on the first part of the questionnaire, since this can create positive attitude and also avoid any negative impressions that can be created on the participants.
- Acknowledging participants that the study will serve as for academic purpose only.

- Last but not least, ensuring the participants that the information they will give is kept confidential and as there is no need of writing their name.

3.6. Directions for Future Research

This study was limited to examine the water loss management practices and its challenges taking the case of Mekelle Water and Sewerage Service Enterprise. The result is expected to depict a good deal of the total picture of the water loss management practices and its challenges in the urban water supply of the country and will contribute its own part to the development of knowledge of operation management in the water supply interventions. Further, it will serve as an introduction for other scholars to further deepen the start by considering additional determinants.

CHAPTER 4: RESULTS & ANALYSIS

This chapter presents the basic results and discussions related to water management with major focus to the water losses control practices in Mekelle Water and Sewerage Service Enterprise. Firstly, water production, consumption and water loss figures are discussed to arrive at the amount of water being lost every year from the water supply networks. Secondly, identification of the causes for water losses is being addressed. Thirdly, the measures taken by the leadership to reduce water losses are identified. Lastly the problems or challenges that the leadership is facing to manage water losses are being discussed.

4.1. Amount of Water Lost in the Last Five years

In this section, it is being tried to see the water balance to help us give an answer to the question that what quantity of water being lost during the past 5 years by major sources. Secondary data have been collected and analyzed from the annual report of the enterprises from June 2007 to June 2011. Accordingly, water production and water consumption figures were computed to arrive at the amount of water being lost every year.

The enterprise uses 19 water wells to produce safe drinking water and supply this through the water line/networks which is extended around 644 square kilometer areas of the city. At June 2011, which is the fiscal

year of 2011, the annual production of safe drinking water has reached 4,755,351m^3. Its daily production capacity also reached 28,420m^3 per day as a result the water coverage has reached 69.3%. The daily production was 20,500m^3 in year 2010 and the coverage was 51%. However, the daily production could not be attained due to several factors: power interruption, delay in maintenance and dry up of old wells are among others (MWSSE Annual Report, 2011)

Table 1: Water Production of MWSSE, 2011

S.N	Well	Annual Production (m^3)
1	FPW9	745,177
2	PW10	159,954
3	PW3	130,282
4	TW5	220,668
5	Gomata New	309,138
6	FPW1	263,716
7	Dandera	486,325
8	TW1	637,879
9	TW2	149,386
10	PW2	340,465
11	TW4	0
12	PW8	120,349
13	PW7	403,782
14	Lachi	60,516
15	PW4	99,403
16	Gomata Old	26,445
17	Sewhi Nigus	48,179
18	FPW-5	0
19	Feleg daero	7,125
18	Chinferes-1	371,816
19	Chinferes-2	174,750
	Sum	**4,755,351**

Source: MWSSE Annual Report 2011

Among the water produced and supplied to the networks only 77-79% is reached to the customers. This means, about 21-23% of the water produced was lost in the networks during the last five years. Table 2 and Figure 5 present the amount of water produced and lost in the networks from year 2007 to 2011.

Table 2: MWSSE- Water Produced, Consumed and lost in m³ (2007-2011)

Description	2007	2008	2009	2010	2011	Average
Produced	3,460,815	3,780,199	4,207,059	4,630,597	4,755,351	4,166,804
Consumed	2,690,235	2,963,525	3,241,647	3,565,560	3,751,972	3,242,588
Lost	770,580	816,674	965,412	1,065,037	1,003,379	924,216
% lost	22%	22%	23%	23%	21%	22%

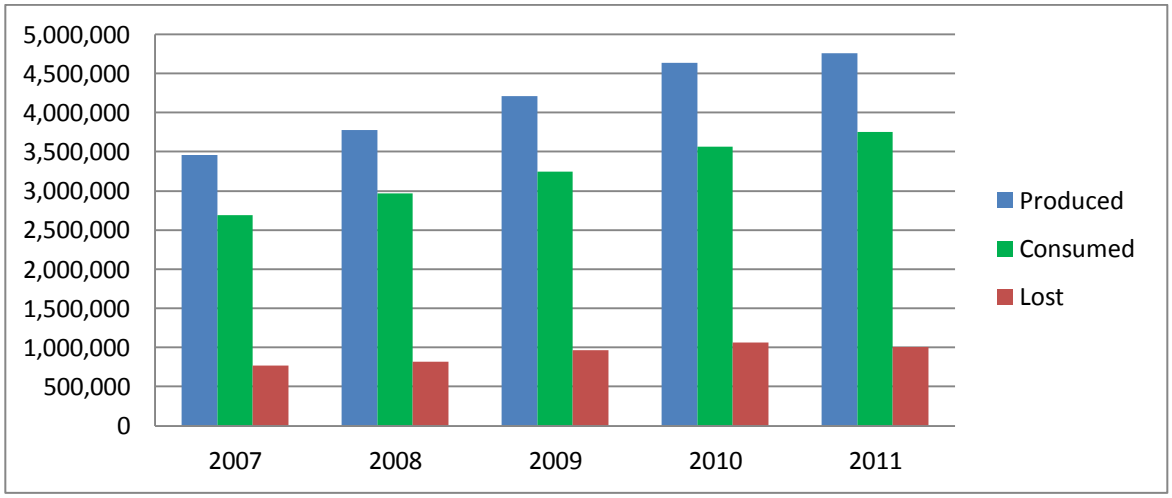

Fig 5: MWSSE-Water Produced, Consumed and lost in m³ (2007-2011)

Source: Annual Report - Mekelle Water & Sewerage Service Enterprise

As it can be observed from the table and graph, the amount of water produced is increasing from year to year and the water loss is proportionally increasing with similar percentage except for the budget year 2011 which showed a decrease from the previous year.

The water loss in Mekelle is lower than the Cities in developing countries which accounts 40-60% (source: Arlosoroff, 1999) and still lower than the loss in City of Addis Ababa which is 30-35% (Source: ENA, Apr 26, 2011). However, it is higher than developed countries. According to the German standard, water losses above 15% are classified as high (Source: D.Weimer, 2001) and therefore the water loss in Mekelle which is 22% (average of the last 5 years) found to be high.

To produce $1m^3$ of water (excluding depreciation cost) it needs from Birr 2.35 to Birr 2.72 when calculated taking the running cost against the total water production and when depreciation cost is added the cost of water will goes higher even more than double.

It is not only the cost implication what matters but the lost revenue that makes a decision maker or the leadership most alert. The amount of revenue lost every year ranges from Birr 2.3 to Birr 7.5 million. It can be observed that, the enterprise/city has lost in total around Birr 25 million in the past 5 years.

The water losses accounted below is purely non revenue water (NRW) which is lost in the networks. This is not only significant revenue lost but it is also customer lost, safe drinking water lost, health lost, etc… to the municipality.

Table 3: MWSSE-Lost Revenue (2007-2011)

Descriptions	2007	2008	2009	2010	2011	Total
Produced m^3	3,460,815	3,780,199	4,207,059	4,630,597	4,755,351	20,834,021
Consumed m^3	2,690,235	2,963,525	3,241,647	3,565,560	3,751,972	16,212,939
Lost Water m^3	770,580	816,674	965,412	1,065,037	1,003,379	4,621,082
Running Cost Birr	10,127,002	7,850,527	15,042,156	14,404,505	11,161,163	58,585,353
Revenue Birr	8,058,594	9,789,898	18,817,209	24,618,048	27,885,284	89,169,033
Cost Birr per m^3	3	2	4	3	2	3
Revenue Birr per m^3	3	3	6	7	7	5
Lost Revenue Birr	2,308,271	2,697,853	5,604,052	7,353,443	7,457,281	25,415,346

Source: Annual Report of the enterprise

When the production and distribution system is evaluated against the water balance the following figures are observed for the year 2011.

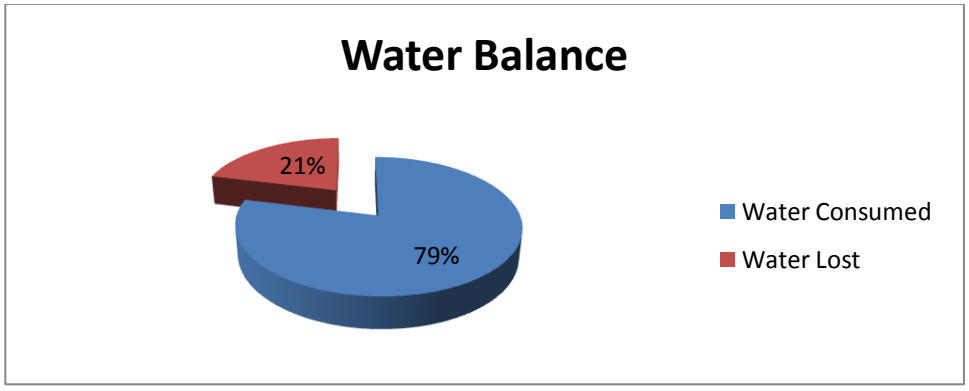

Fig 6: Water Lost and Consumed During 2011

Source: MWSSE, Annual Report 2010/11

<table>
<tr><td rowspan="8">SVI
=
4755351m³</td><td rowspan="4">AC
=
3751972 m³</td><td rowspan="2">BAC
=
3751972 m³</td><td>BMC= N/A</td><td rowspan="2">RW
=
3751972 m³</td></tr>
<tr><td>BUMC = N/A</td></tr>
<tr><td rowspan="2">UAC = N/A</td><td>UMC= N/A</td><td rowspan="4">NRW
=
1003379m³</td></tr>
<tr><td>UUMC= N/A</td></tr>
<tr><td rowspan="4">WL
=
1003379 m³</td><td rowspan="2">AL = N/A</td><td>UC = N/A</td></tr>
<tr><td>MI = N/A</td></tr>
<tr><td rowspan="4">RL = N/A</td><td rowspan="2">LOT/or LODM
=
N/A</td></tr>
<tr><td>LOUST = N/A</td></tr>
<tr><td>LSCUPCM = N/A</td></tr>
</table>

Fig 7: *MWSSE-Water Balance - Year 2011*

Source of Data: Mekelle Water & Sewerage Service Enterprise Annual Report

As it can be easily observed from the Figures above, the system shows the problem of recording data to allocate figures to the different subsystems of the water balance. No records were found to differentiate the water losses into real loss and apparent losses. Similarly no data was found to differentiate the main source of real losses that will help to know where the water is being lost from?

4.2. Causes of Water Losses

This section tries to review network operation practices in order to investigate causes including historical reasons of poor practices, quality management systems, procedures, and poor materials, infrastructures, local influences both cultural and social, institutional and financial limitations. In the other way, the four pillars of leakage management are being addressed in this section to identify the major causes of water losses.

Very limited recorded or secondary data was found to determine the causes of water losses hence the researcher used questionnaire, interview, focused group discussion and limited observation methods for data collection. Since the research method is case study, the researcher used information-oriented sampling instead of random sampling. All management members are taken in the informants, all team leaders are considered in this study.

Based on the structured questionnaire, General Manager, Functional Heads, Branch Heads, Case Team Leaders' and relevant operational staff were considered. Out of the 40 selected staff, 20 filled structured questionnaires, 10 were interviewed, and 10 participated in focused group to enrich the study through discussion which was managed by the researcher, detail participants list and position is attached as appendix 3.

All of the staffs considered in this study are having minimum completion of 12 grade education level. 8 are degree, 8 diploma holders, and the rest 4 have completed grade 12. The degree holders include engineers and social science graduates with considerable years of experience.

The researcher has also observed sample leakages from the distribution lines, construction of a bridge over major water line, and cross points where water pipes, telecommunication cables, and electric cables are passing through.

Operation practice of water systems includes operating and maintaining of wells and reservoirs, constructing new lines and water points, maintaining transmission and distribution lines, generators, water meters, switchboards, handling of new customer application, connecting customers to distribution lines, customer meter reading, customer meter maintenance, changing meter, transfer of meter, change of connection line, installing, rehabilitating, and replacing pipes and equipments as appropriate. Most of these activates directly or indirectly will have effect on water losses or leakages.

MWSSE operates 19 water wells that are dispersed over different locations; within and outside the city boundary. Transmission and distribution mains or the water supply networks, as well, are lying over 664km^2 area of the city. As the city is expanding in all its directions, the water lines need

to be expanding from year to year. As an instant, expansion and maintenance works efforts of the enterprise for 2011 are presented in the following table:

Table 4: MWSSE, Line Expansion and Maintenance Performance 2011

S.N	Descriptions	Unit	Plan	Achievement	
				Actual	%
1	Water Line Expansion Study	No	10	18	180
2	Surveying of new lines for expansion	Km	40	73.644	184.1
3	Lining of 1st and 2nd Pipe lines	Km	30	17.94	59.8
4	Lining of 3rd line by Branch offices	Km	41	50.579	123.3
5	Construction of Assembled Reservoirs	No	1	-	0
6	Construction of large and medium Get valves	N0	40	42	105
7	Construction of Water Points	No	10	6	60
8	Construction of pointer polls	No	50	-	0
9	Distribution lines simple maintenance	Km	3	2.175	72.5
10	Medium water lines maintenance	Km	1	1.42	142
11	Heavy Maintenances of water mains	Km	12	16.45	137.08
12	Site clearance for reservoir and water main lines construction	Km	12	14	116.6
13	Up grading and Rehabilitation of water lines	Km	30	21.131	70.43

S.N	Descriptions	Unit	Plan	Achievement	
				Actual	%
14	Special lines maintenance	Km	15	16.995	113.3
15	Transfer of water lines directions	Km	6.1	6.276	102.9
16	Modification works	No	60	103	171.6
19	Third water line expansion for low income group citizens	Km	21	On study	0
20	Customers' water meter maintenance	No	470	446	94

Source: MWSSE, Annual Report 2010/11

This resulted to increase the size of customers on average by 2460 every year and by 2011 the size of the customers has reached 32,000.

Table 5: MWSSE Customer's Size (2007-2011)

Description	**2007**	**2008**	**2009**	**2010**	**2011**
New Customers	1183	2364	1264	3694	3,799
Total Customers	20879	23243	24507	28201	32,000

Source: Water & Sewerage Service Enterprise Annual Reports

Based on the information collected from the staff, the following major causes for water losses are identified according to their estimated magnitude:

- Leakage from old lines- this problem has been the routine practice in the old sub-city especial in Kedamay Weyane Sub City of Mekelle.

Water lines aging more than 25 years are still serving at this modern age in the sub city. Figure 9 shows sample leakage in one block site of this sub city.

Figure 8: Water Leakage in the Old Sub City of Mekell

Source: Photo Picked by the Researcher on 28/12/2012

- Bursts due to new construction by others- the very significant losses are occurred during road construction and maintenance, underground telephone line and electric lines installation activities due to low coordination in the infrastructure development of the city. During this time water lines are damaged and water is lost due to this missing links among organizations working in the same city.

- Over flows from reservoirs- this is very rare case where operators' mistake makes the reservoirs to over flow treated water.

- Road crossing where loads on pipe exceed design loads- this happens where unexpected size of vehicle using roads above designed capacity. Significant time is required to stop the leakage and replace the damaged pipes in the road because it needs to close the road for some time.

- Meter reading errors and meter faults- this relates to fault meter readings due to technical reasons and carelessness of meter readers

From the interview with management staff, it is found that apparent losses are not significant and could be some meter readers' errors and water meter faults, as all connections and water uses are completely and absolutely metered and authorized. The legal framework regarding this is also easily applicable and tight.

In the other side, it was found that local laws, culture or customs and political influence have no influence on water losses control however institutional and financial limitations have their own influence in limiting the water loss put at the required level. There were serious financial limitations in the past years as it was allotted to other priorities including expansions of other water projects.

From the interview and record checking, the researcher tried to evaluate water losses control practice of the enterprise by using the pillars of

leakage management. Evaluation of these four basic methods of managing real losses is presented as follows:

- **Asset Management**

  Data and records that could show the assets in the ground are not properly known. No proper registration of old lines, medium age lines and new lines in the supply network. The lengths of the water lines are not known classified as transmission mains and distribution lines. There is no proper planning and guideline for managing pipeline, installation, maintenance, renewal and replacement. Calibration systems have not introduced which is critical by quality management system procedures for meters and instruments in the system.

- **Pressure Management**

  The topographic nature of the city is inclined towards the west side with significant slope. As a result the lower areas got continuous water but not always the case in the upper areas. Metering for zonal location was not introduced to control such flows. There is no clear pressure management practice at all in the enterprise.

- **Active leakage control**

  This factor requires different types of water leakage detection procedures and technologies, appropriate information system. There is an introduction of technology to start active leakage control; however,

there is no well developed Standard Operating Procedure (SOP) for its implementation.

- **Speed and quality of repairs**

  Speed and quality of repairs are highly dependent on the availability of qualified technician and engineers, materials, appropriate tools, equipments, information, and procedures. The capacity of the technicians in this regard is limited and the instability of engineers is being seen as higher gap.

4.3. Measures Taken by the Leadership to Reduce Water Losses

In this section the major measures taken by the leadership during the past year is being addressed. Secondary data has been assessed and interview was made with the 10 management members including the enterprise manager.

The major measures taken by the leadership to reduce water losses are classified as system development, introduction of technology and institutional capacity development.

Too much effort has been exerted to reduce water loss from 23% to 21% during 2011 budget year and this result was encouraging that helped the leadership to design water losses control as whole system development project.

The leadership has understood the importance of water losses control as a process defect in the distribution system. It has also well aware of the importance of water balance and the four basic methods leak management. As a result water loss reduction project was designed, fund from World Bank has been secured, and a bid was floated for the system development during 2011.

From the record and interview, it has been found that there were trials to develop standards time for maintaining meters, and water lines of different capacity and size. These all are a good start and supports the water loss reduction, however, monitoring of the implementation has not yet materialized to compare actual results against standard time.

The leadership is strengthening the legal and institutional capacity of the enterprise. Mekelle Water and Sewerage Service Enterprise have been re-established following the new proclamation of Water and Sewerage Service of The National Regional State of Tigray- Proc. No. 122/1999 dated at Feb 2006. The Enterprise, as stipulated in proclamation, has water and sewerage service mandates, and the following will refer to water supply service's mandates:

- Produce and provide clean and adequate water to the city citizens.
- Connect new customs to the water line based on application priority
- Collect tariffs following approved water tariff laws

- Maintain property and finance of the enterprise as per approved systems
- Monitor and evaluate the water system, on regular basis, to avoid losses and contaminations
- Keeps reserve equipments and accessories to help replace immediately damaged ones, maintain damaged parts, replaces as appropriate on own expenses
- Maintains data and records related to equipments, assets, water production, source of water, water storage and distribution, and other necessary data and information as appropriate and necessary to the enterprise
- Based on design standards carried out expansion and rehabilitation works of water sources and network/systems

Currently the enterprise has started the sewerage service but its major focus is on the water supply operations with very limited sewerage function.

The enterprise is one of the city's organs who have introduced Business Process Reengineering (BPR). Accordingly, the Organization structure has been developed to address BPR principles. Operation and Maintenance Department is taken as the core or main process of the enterprise. It has three division or case teams under this main process namely; Sewerage Treatment and Disposal Davison/Case Team, Water

Production and Distribution Division/Case Team, and Installation and Maintenance Division/Case Team. These last two divisions are the focal points of this study.

Recently four service centers have been established to give services to customers around their delineated areas. They have a mandate to connect customers to the distribution lines and to conduct maintenance of the network below 2”1/2 pips.

In 2011 budget year, there were 260 permanent employs and about 20 casual workers. The total size of employees working under the enterprise has reached 280. The size of permanent operational staff accounts about 66% the total staff, Table 6 shows permanent staff size by category.

Qualification wise the Enterprise has more than 100 degree and diploma holders. During the study all approved positions are filled with staff except the senior Auditor Position.

Table 6: MWSSE- Staff Category (2006/7- 2010/11)

Staff Type	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**2010/11**
Operational	67	146	129	156	173
Finance & property Administration	70	83	94	35	35
Adm. Support	18	10	11	50	52
Total	155	239	234	241	260

Source: *Annual Reports 2007-2011, MWSSE*

The enterprise is taking different measures to develop the competency of the staff at different levels. Beside to providing training, continuous staff assessment and feedback sessions are performed and expected to be in place during the next 3 years.

With regard to introduction of technology, materials and instruments that help detect leakage in the networks have been purchased and are readily available for use after trading on the technology. The leadership of enterprise has introduced fully computerized billing system; accordingly monthly bills are prepared and controlled through this system. This has direct impact to control apparent losses.

4.4. Problems Encountered by the Leadership to Reduce Water Losses

In this section the major problems that the current leadership is facing in reducing water losses is presented. An interview method has been employed to collect data with the Manager and Department Heads of the enterprise to identify these problems.

Accordingly, the major problems that the leadership have been facing to reduce water losses in the past are enumerated hereunder, as per their magnitude and priority.

- Absence of appropriate database system or cadastre that shows the type of assets; pipes and fittings, length, age and makeup of by origin and zone registration on the transmission and distribution system that will serve as input for water losses control.

- Absence of coordination among organizations working in infrastructure development of the city including Ethiopian Telecommunication Corporation, Ethiopian Electric Light and Power Corporation, City Road Construction Office, etc… There is limited integration on planning, monitoring and evaluation and exchange of information among these organizations.

Figure 9: Connection Point: Bridge, Pipe Line, Tell & Electric Cables

Source: Photo Picked by the Research on 20/12/12

- Absence of appropriate operating manual to address technical and operational issues. Operation works are more traditional and hardly possible to solve major operational and technical problems. This has also a problem to evaluate technicians employed in the enterprise.

- Absence of appropriate pressure management that relate to the topographic nature of the city which is inclined from east to west.

- Absence of proper information system that could integrate with the public and customers that will help report leakage or bursts of lines or illegal actions on water lines.

Figure 10: Leakage Case Reported After 24 Hours

Source: Photo Picked by the Researcher on 26/12/12

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

In this chapter, conclusion and recommendations will be presented which have been drawn from the research findings. The first section presents conclusion of the MWSSE water losses control practices. The second section will present recommendations to address the strategies that the leadership will introduce to reduce water losses and improve performance and how the enterprise could maintain the strategies and sustain the achievements to be attained in the future.

The recommendation will address further study that could be done into this area, as well as some advice for municipalities that are intending to develop and implement water losses control or reduction.

5.1. Conclusion

In this section the major findings of the study, as an output to the analysis and understanding of the researcher is presented to support the conclusion.

Water leak detection and water loss management have been, for long time, treated as a late addition in network operations and maintenance practices. Water utility supply enterprises, in recent years, are developing a water loss strategy to become one of the major operational tasks of the distribution network throughout the world. This is the

resu1t of combined influences of global water shortages, and the need that increasingly making water supply industries accountable to customers.

This research tried to evaluate water loss practices of MWSSE following the stages for developing a water loss control models presented in IWA best practices, the detail steps required to design and implement such control has been evaluated and found no such practice are followed by the Mekelle Water and Sewerage Enterprise (MWSSE). The enterprise has no clear strategy to control water losses though it has been experiencing high water losses for several years in the past.

Therefore, the enterprise need to adopt the requirements of the strategy and set policies and implementing procedures that will help for accurately assessing the volume of Non Revenue Water (NRW). An appropriate, achievable and practicable polices geared for the network characteristics, shall be put in place that would enable to draw action plans to reduce water loss to an economical level. This will definitely help enterprise to see water losses control as one source of conserving water before further investment on other water supply sources or holdings.

It is possible that MWSSE and the other cities not having these procedures, or framed strategy for developing same, are getting difficulty in estimating current losses and forecasting future losses or evaluating trends.

MWSSE water network and any urban water supply enterprises in Ethiopia can use the water loss control models developed by the IWA for understanding, measuring, monitoring and comparing losses, and the mechanisms for supporting it, however, it needs limited modification to be based on the nature of the network structures, customs and social frameworks. Major emphasis shall be made on training of engineers and technicians before implementing the new system to change the mind set of traditional way of doing things.

5.2 Recommendations

The recommendation section tried to address the question how the leadership would maintain the new water loss control system? Once the operational activities in Figure 4 have been addressed - and how to sustain the improvements gained from it. This will require some changes to policies, and will almost certainly need the introduction of modern operation and maintenance programmers.

- The water losses of MWSSE are observed to be moderately low when comparing with the East African countries and the City of Addis Ababa. However, it needs water meters calibration both at the input and output sides, the researcher therefore recommends the case for further study.

- It observed that MWSSE lacks appropriate information on lines lied

over 644 square kilometers of the city, the efforts to be made to reduce water losses has to be supported through proper information management and monitoring systems in order to sustain it, therefore it is recommended the development of proper database and cadastre system to enable the enterprise, locate sites, keep age of asset, record and retrieve historic data on installation and maintenance.

- There is no clear understanding by MWSSE on water balance and the four Basic Methods of Managing Real Losses (pressure management, active leakage control, pipeline and asset management, speed and quality of repairs), therefore these methods has to be developed and implemented. The water balance model is recommended to be adopted by the enterprise and the initiative of the management to seek fund from neither the World Bank nor other donors shall be continued to make the project of water loss control realistic.

- Percentage of lost water is reported every time but it has to be supported by an analysis on monetary value of the amount of revenue lost every year to aware the leadership, this will help to see water losses control as one option of water source before deciding further investment. The reporting mechanism shall include lost revenue loss in terms of its percentage of revenue collected from water service and its absolute value.

- Quality management system helps enterprise, inspect, control, document, and audit every process, sub process, system, and sub system; it also puts calibration method by internal and external bodies therefore introduction of such systems is recommended to support the water losses control systems.

- The current basic institutional setup of MWSSE is considered good, but considering the expansion of the water supply system and with the introduction of the modern way of addressing sustainability of water losses strategy, it will be most necessary to understand fully the criticality of water loss. The demand for water-as critical resource will grow not only due to population growth but also growth in the per-capita of water use. Therefore, it is recommended to give focus on training and development of technicians and engineers, improve awareness and motivation of the workforce, and improve community and customers awareness on water conservation and in providing information on leakages and related damages on the networks.

- One of the performance improvement measures of real losses or leakage control is Infrastructure Leakage Index (ILI), MWSSE and the other urban water supply services in Ethiopia shall set targets on how to reduce losses of water out of the current leakage amount till they reach at reasonable or Unavoidable Real Losses (UARL). Since water

loss could be minimized but not eliminated, it is not good to go beyond the reasonably economical level of leakage control, therefore it is recommended to determine the cost value side of the system following the best practices using the ILI performance measures before putting further targets.

- The leadership of MWSSE (the management and the board), has considered the water losses control as one of water source, and designed a project that will evaluate and develop water losses control, this could be a good practice to other cities to consider water losses

6. REFERENCES

1. Zheng Yi Wu (Author), al, (2011) “Water Modeling and Water Losses Reduction” Electronic Book, First Edition, Bentley Institute Press, www.bentley.com/Books.
2. Malcolm Farley (2010) “Non-Revenue Water – International Best Practice for Assessment, Monitoring and Control”, idswater.com
3. Farley, M. and Trow, S (2003) 'Losses in Water Distribution Networks - A Practitioner's Guide to Assessment, Monitoring and Control”. London: IWA Publishing http://www.iwapublishing.com/template.cfm?name=isbn1900222116
4. Operation and Maintenance of Water Supply Systems, Central Public Health and Environmental Engineering Organization, Ministry of Urban Development, New Delhi, and World Health Organization, Systems Vision Printing, January 2005.
5. Dipl.-Ing. D. Weimer, Gerlingen (2001) “Water Loss Management and Techniques”, German National Report
6. Technical Performance Indicators, IWA Best Practices for Water Mains and the First Step in SERBIA, 2007
7. Central Statistics Agency, “Report on Ethiopian Population Development Indicators”, 2008.
8. Annual Performance Report (2011), Mekelle Water Supply Office
9. Proclamation 2006 for the establishment of water and sewerage service enterprises in the national regional state.

10. www.mofaed.gov.et
11. www.mowr.gov.et
12. Ethiopian News Agency, ENA, 2006, News on Addis Ababa City Water Management and Achievement
13. Mekelle City Profile, 2011, Talent Development Consultants, Mekelle.

7. Appendix

Appendix 1: Structured Questionnaire

Note: This questionnaire is only for academic purpose. You may fill only considerable to you.

1 – General Information

1.1 Some **general information** about your water distribution network:

Number of connected citizens	[-]
Total network length	[km]
Number of service connections	[-]
Average length of service connection *(exact data or best estimate)*	[m]

Total amount of water fed into the network (= water production)	[m³/day]
(please chose most appropriate unit)	[m³/month]
	[m³/year]

Water is abstracted from the following sources:

□ Underground water resources	[%]
□ Surface water	[%]

The distribution network is mainly operated as:

□ continuous supply (24h/day)	Yes	No
□ intermittent supply	Yes	No

1.2 Does your utility use **computerized tools** / information systems, such as a:

□ Billing system	Yes	No
□ Hydraulic network simulation software	Yes	No
□ Geographical Information Systems (GIS)	Yes	No
□ Cadastral register for system assets	Yes	No
□ Register for repairs, defects, rehabilitation works	Yes	No
□ Real time measurement & supervision system (SCADA)	Yes	No

2 – Finances

2.1 Some information about **your finances**:

Amount of water which is billed for	[m³/day]
(chose most appropriate unit)	[m³/month]
	[m³/year]
Average water sale price	[$/m³]
Production costs for water delivered to the customer	[$/m³]
Annual total operating costs of the water supply system*	[$/year]
Annual investment costs for maintenance and rehabilitation	[$/year]

**Total costs include all expenses for operation, maintenance and rehabilitation of the water supply system*

3 – Water Losses

3.1 What was the **percentage of water losses** of your utility in the given years?*

	2007	2008	2009	2010	2011
Non-Revenue Water (NRW)	%	%	%	%	%
Real Water Losses	%	%	%	%	%
Apparent Water Losses	%	%	%	%	%

** Water losses according to IWA standard water balance, as illustrated in the graphic below*

3.2 Please tick which of the following statements **apply to your utility**:

A national water policy exists which aims at reducing water losses Yes No

A water loss reduction program is implemented Yes No

Benchmarks for reducing water losses exist and are followed up Yes No

Is your utility using performance indicators for water losses Yes No

System flow meters are installed to measure the system input Yes No

Approx. ----------% of the service connections are metered

The network is subdivided in District Metered Areas (DMAs) Yes No

Pressure Management is used to reduce water losses Yes No

A network maintenance/ rehabilitation program is implemented Yes No

Preventive network inspections are done Yes No

A leak detection program is implemented Yes No

Measures to fight illegal connections are applied Yes No

Meter reading and billing is performed □ Monthly □ Quarterly □ Yearly

4 - Deficiency Analysis / Needs Assessment

4.1 **Obstacles** for fighting water losses are:

□ Political situation Yes No

□ Institutional situation Yes No

□ Lack of financial means Yes No

□ Lack of appropriate technologies Yes No

□ Maintenance system Yes No

□ Personnel capacities Yes No

□ Personnel awareness Yes No

4.2 What do you consider to be the best solution **to improve your water supply situation**?

Please **prioritize the measures** according to their efficiency (1 = very high, 4 = very low)

□ Development & exploitation of new resources (e.g. desalination) Yes No …….

□ Water loss reduction Yes No……..

□ Rehabilitation Yes No …….

□ Reducing wastage of water (e.g. by metering, customer awareness) Yes No …….

5 – Space for your own comments and recommendations

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Thank you for your cooperation!

Appendix 2: Interview Questions

Note: the interview results will be for academic purpose and will be kept confidential

Measures taken to reduce water control by the leadership

Do you have full understanding of water loss control? Do you know the IWA Best practice of water loss control? You may state the modules and leak control procedures

_____

_____

_____

_____

_____

_____

To what extent the current loss could be reduced? And How?

_____

_____

Your annual reports/statistics shows 21-23% water loss every year, how do you arrive at this figures?

_____

_____

If you fully understand the water control, what measures did you taken to reduce water losses? You may classify as technical and non technical.

What did you achieve from water loss reduction? If you are really implementing it

What are the problems you face to reduce water losses? You may list them according to their magnitude.

What solutions do you suggest for the future?

_____

_____

_____

Thank you for the information and for giving me your considerable time.

Appendix 3: Respondents Background

S.No	Position	Size	Education	Quest.	Interview.	Group Disc.
1	Manager	1	MBA		x	
2	Public Relations Office	1	BA	x		
3	Auditor	1	BA	x		
4	Core Process Owner	1	BSc		x	
5	Case Team Coordinator	1	BSc		x	
6	Branch System Supervisor and Branch Head	4	BSc			x
7	Water Meter Inspector	2	Dip		x	
8	Junior Plumber	2	Dip		x	
9	Meter Reader	4	12 Complete	x		
10	Design & Installation Mant. Team Case Coordinator	1	BSc		x	
11	Design Engineer	1	BSc			x
12	Electromechanical Engineer	1	BSc			x
13	Database and GIS Expert	1	BSc			x
14	Senior Mechanic	1	Dip	x		
15	Senior Plumber	2	Dip	x		
16	Production& Dist Case Team Coordinator	1	BSc			x
17	Hydrologist	1	BSc		x	
18	Water Quality Control	1	BSc	x		
19	Main System and Water Losses supervisor	2	BSc			x

S.No	Position	Size	Education	Quest.	Interview.	Group Disc.
20	Support Work Process Coordinator	1	BA			x
21	Planning Process Owner	1	BA	x		
22	Budget Expert	1	BA	x		
23	Information Analyst	1	BA	x		
24	Monitoring & Evaluation Expert	1	BA	x		
25	Finance & property Adm. Process Owner	1	BA	x		
26	Senior Accountant	1	BA	x		
27	Finance Adm. Officer	1	BA	x		
28	Property Adm. Expert	1	BA	x		
29	HR Process Owner	1	BA		X	
30	Training Officer	1	Dip	x		
	Total	40		20	10	10

Appendix 4: MWSSE Job Positions by Education Requirements

S.No	Position	Size	Education
1	**Office of the Manager**		
1.1	Manager	1	MBA
1.2	Public Relations Office	1	BA
1.3	Legal Advisor	1	LLB
1.4	Executive Secretary	1	Diploma
1.5	Light Vehicle Driver	1	10 Grade Complete
1.6	Messenger	1	10 Grade Complete
2	**Support Work Process Internal Audit**		
2.1	Senior Auditor	0	BA
2.2	Auditor	1	BA
3	**Work Proceeds Water plants Administration**		
3.01	Core Process Owner	1	BSc
3.02	Service Vehicle Driver	2	10 Grade Complete
3.03	Office Assistant	1	Diploma
3.1	**Branch Case Team**		
3.1.1	Case Team Coordinator	1	BSc
3.1.2	Branch System Supervisor and Branch Head	4	BSc/BA
3.1.3	Customer Case worker	4	Diploma
3.1.4	Water Meter Inspector	4	Diploma
3.1.5	Junior Plumber	24	Diploma

S.No	Position	Size	Education
3.1.6	Meter Reader	25	10 Grade Complete
3.1.7	Bill Distributer	4	10 Grade Complete
3.1.8	Bill Seller	7	12 Grade Complete
3.1.9	Office Administrator	4	Diploma
3.1.10	Service Vehicle Driver	2	10 Grade Complete
3.2	**Study, Design, expansion and Maintenance Case Team**		
3.2.1	Team Case Coordinator	1	BSc
3.2.2	Design Engineer	1	BSc
3.2.3	Electromechanical Engineer	1	BSc
3.2.4	Database and GIS Expert	1	BSc
3.2.5	Senior Mechanic	1	Diploma
3.2.6	Construction Foreman	1	Diploma
3.2.7	Assistant Construction Foreman	1	Diploma
3.2.8	Senior Plumber	4	Diploma
3.2.9	Welder	1	Diploma
3.2.10	Crain Operator	1	10 Grade Complete
3.2.11	Service Vehicle Driver	2	10 Grade Complete
3.3	**Production and Distribution Case Team**		
3.3.1	Case Team Coordinator	1	BSc
3.3.2	S.C.A.D.A. Expert	3	BSc
3.3.3	Senior Electrician	1	Diploma

S.No	Position	Size	Education
3.3.4	Junior Electrician	1	Diploma
3.3.5	Hydrologist	1	Diploma
3.3.6	Water Quality Control	1	BSc
3.3.7	Main System and Water Losses supervisor	2	BSc
3.3.8	Bill Preparation Worker	2	Diploma
3.3.9	Water Pump Operator	60	10 Grade Complete
3.3.10	Service Vehicle Driver	3	10 Grade Complete
	Sub Total	**180**	
4	**Support Work Process**		
4.1	Support Work Process Coordinator	**1**	BA
4.1.1	Service Vehicle Driver	2	10 Grade Complete
4.1.2	**Support Work Process Development plan**		
4.1.3	Process Owner	1	BA
4.1.4	Budget Expert	1	BA
4.1.5	Information Analyst	1	BA
4.1.6	Monitoring & Evaluation Expert	1	BA
4.1.7	Office Assistant	1	Diploma
4.2	**Support Work Process for Finance & Property Administration**		
4.2.1	Process Owner	1	BA
4.2.2	Senior Accountant	2	BA

S.No	Position	Size	Education
4.2.3	Finance Administration Officer	6	BA
4.2.4	Cashier	5	Diploma
4.2.5	Archives Clerk	1	Diploma
4.2.6	Purchase Expert	1	BA
4.2.7	Purchase Officer	2	Diploma
4.2.8	Property Administration Expert	1	BA
4.2.9	Property Administration Officer	2	Diploma
4.2.10	Secretary	1	Diploma
4.2.12	Storekeeper	5	Diploma
4.3	**Support Work Process for Human Resources**		
4.3.1	Process Owner	1	BA
4.3.2	Personnel	2	Diploma
4.3.3	Training Officer	1	BA
4.3.4	Record & Archives Officer	1	Diploma
4.3.5	Office Administrator	1	Diploma
4.3.6	Duplicator	1	12 Grade Complete
4.3.7	Post person	1	12 Grade Complete
4.3.8	Telephone Operator	1	12 Grade Complete
4.3.9	Gardener	2	4 Grade Complete

S.No	Position	Size	Education
4.3.10	Guard	24	4 Grade Complete
4.3.11	Cleaner	10	4 Grade Complete
Sub Total		**80**	
Total		**260**	

Appendix 5: Secondary Data Figures from MWSSE, 2007- 2011

Item	Unit	Fiscal Year End of June				
		2007	2008	2009	2010	2011
Water Production (m3)	m^3	3,460,815.00	3,780,199.00	4,207,059.00	4,630,597.00	4,755,351.00
Water Consumption	m^3	2,699,435.70	2,963,525.00	3,241,647.00	3,565,559.69	3,751,971.94
Water Loss	m^3	761,379.30	816,674.00	965,412.00	1,065,037.31	1,003,379.06
% of water loss	%	22%	22%	23%	23%	21%
Unauthorized Consumption (if any recorded amount)	m^3	NA	NA	NA	NA	NA
Metering inaccuracies and Data Handling Errors (if recorded)	m^3	NA	NA	NA	NA	NA
Leakage on transmission and/or distribution mains (if recorded)	m^3	NA	NA	NA	NA	NA
Leakage and overflows at utility's storage tanks (if recorded)	m^3	NA	NA	NA	NA	NA
Leakage on service connections up to point of customer metering (if recorded)	m^3	NA	NA	NA	NA	NA
Number of Customers	No	20,879	23,243	24,507	28,201	32,000
Population Size	No					

Item	Unit	Fiscal Year End of June				
		2007	2008	2009	2010	2011
		237,930	249,110	260,820	273,080	273,453
New Customers	No	1,183	2,364	1,264	3,694	3,799
Revenue	Birr	8,058,593.93	19,789,897.50	18,817,209.23	24,618,048.00	27,885,284.05
Running cost	Birr	10,127,001.69	17,850,527.39	15,042,155.82	14,404,505.03	11,161,163
Deprecation (if any)	Birr					
Investment Cost (**Project Name) 1. Constriction of Reservoirs, 2. Constriction Borehole at Chinferance**	Birr				70,254,952.93	
Total Employee's size	No	155	239	234	241	260
Operational Staff (Meter reading)	No	67	146	129	156	160
Support Staff	No	88	93	105	85	100
Time standard to maintain distribution line per case	**½ inch** 15-20Sec., **¾ inch** 20-30 Sec.,**1 inch** 30-40 Sec., **1½ inch** 40-50 Sec.,**2 inch** 60 mint					
Actual time observed to maintain distribution line per case		NA	NA	NA	NA	NA
Number of cases observed for line maintenance	No	NA	NA	NA	NA	NA
Average time for line per case	Minuit	NA	NA	NA	NA	NA
Number of observed for meter	No	411	457	496	471	446

Item	Unit	Fiscal Year End of June				
		2007	2008	2009	2010	2011
maintenance						
Average time for meter maintenance	Minuit	10-15	10-15	5-10	5-10	5-10

Appendix 6: Water Production of MWSSE, 2011

S.N	Well	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb	Mar.	April	May	June	Annual
1	FPW9	68035	48467	57991	63895	67194	64446	61694	49344	72450	62935	64839	63887	745,177
2	PW10	9849	5609	1995	14308	12199	15327	17843	14299	15180	17654	17909	17781.5	159,954
3	PW3	5008	4289	9753	9322	13209	12650	13530	12776	13800	12872	11091	11981.5	130,282
4	TW5	19644	13640	7377	18432	20751	20809	20507	18601	20010	20386	20212	20299	220,668
5	Gomata New	20942	23705	24876	26124	27311	24598	24724	23983	28980	27957	27973	27965	309,138
6	FPW1	36430	36953	37342	34872	15020	13734	14353	13653	24150	12699	12107	12403	263,716
7	Dandera	38401	14718	63870	51216	52318	50797	20481	32093	41400	33183	47504	40343.5	486,325
8	TW1	51163	51107	56215	57868	57580	55009	59281	61490	60720	57219	27745	42482	637,879
9	TW2	4283	6865	16258	15356	12902	9843	8051	15216	15180	14789	15499	15144	149,386
10	PW2	23419	22203	23001	34426	33600	32536	33100	24277	28980	28201	28414	28307.5	340,465
11	TW4	0	0	0	0	0	0	0	0	0	0	0	0	0
12	PW8	13042	13264	0	0	0	0	0	0	16422	24210	27537	25873.5	120,349
13	PW7	31103	36852	42190	37593	36071	32868	33582	33626	35880	29128	26883	28005.5	403,782
14	Lachi	4274	4303	5828	5240	8425	5240	6304	8467	8280	1385	1385	1385	60,516
15	PW4	6342	5652	5824	8911	9071	8866	8465	9390	8280	9483	9585	9534	99,403
16	Gomata Old	0	0	0	1433	482	3347	3512	3871	13800	0	0	0	26,445
17	Sewhi Nigus	3188	759	1020	4611	4482	4535	2624	5241	12356	3181	3061	3121	48,179
18	FPW-5	0	0	0	0	0	0	0	0	0	0	0	0	0
19	Feleg daero	0	0	0	0	0	0	0	0		1398	3352	2375	7,125
18	Chinferes-1								136800	136800	35957	29520	32738.5	371,816
19	Chinferes-2	0	0	0	0	0	0	0	0	30424	46117	50100	48108.5	174,750
	Total	**335,123**	**288,386**	**353,540**	**383,607**	**370,615**	**354,605**	**328,051**	**463,127**	**583,092**	**438,754**	**424,716**	**431,735**	**4,755,351**