Addis Ababa University School of Graduate Studies

Assessing Water Conservation and Demand Management Option For Addis Ababa City

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master Science in Civil Engineering (Hydraulic Engineering)

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DEDICATION

This thesis is dedicated to my wonderful parents; they have raised me to be the person I am today; they have been with me every step of the way, through good times and bad. Thank you for all the unconditional love, guidance, and support that they have always given me, helping me to succeed and instilling in me the confidence that I am capable of doing anything I put my mind to.

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List of Abbreviations

ALC	Active Leakage Control
AWWARF	American Water Works Association Research Foundation
AAWSA	Addis Ababa Water and Sewerage Authority
AUS$	Australia Dollar
BOD	Biological Oxygen Demand
CARL	Current Annual Volume of Real Losses
CII	Commercial, Industrial, Institutional
DMA's	District Meter Areas
DSS	Demand Side Management Least-Cost Planning Decision Support System (model)
ELL	Economic Level of leakage
FAVAD	Fixed Area Variable Discharge
ICF	Infrastructure Condition Factor
ILI	Infrastructure Leakage Index
LCP	Least Cost Planning
IWA	International Water Association
IWMI	International Water Management Institute
LPC	Litre Per Capita
Lpd	Litter (s) per day
Lpf	Litre per flush
Lpm	Litter(s) per minute
MLD	Million Litter per day
NRW	Non- Revenue Water
PRV	Pressure Reducing Valve
PUB	Public
RSF	Single-Family Residential
RMF	Multi-Family Residential
CSA	Central Statistical Authority of Ethiopia
TRC	Total Resource Cost
SFPUC	San Francisco Public Utilities Commission
WC/DM	Water Conservation and Demand Management
UARL	Unavoidable Annual volume of Real Losses
UFW	Unaccounted-for-Water

Abstract

This research develops water demand (end-use) modelling and forecasting, and assesses water conservation and demand management potential for the city of Addis Ababa. The research methodology consists of four steps: 1) data collection, 2) assessing and reducing water distribution system leakage, 3) developing water demand (end-use) modelling and forecasting, 4) water conservation and demand management analysis. International Water Association (IWA)/American Water Work Association (AWWA)'s water loss analysis software and economical leakage reduction model is used for assessing and reducing water distribution system leakage. The Demand Side Management Least Cost Planning Decision Support System or DSS model is developed and used for water demand forecasting and assessing water conservation and demand management measures. DSS model is Microsoft Excel application model. The non-revenue water (NRW) level in the water distribution system in the city of Addis Ababa is found to be 38.2Million m^3/year (39.5% system input volume). The real or physical losses are 26.2Million m^3/year (27%) of the total NRW, the commercial/ apparent losses are 10.1Million m^3/year (10.5%) and unbilled authorized consumptions are1.9 Million m^3/year (2%). The economical leakage reduction model result indicated that 5.7Milion m^3/year or about 10% of the water losses is an ''economical leakage level'. This show about a 29.5% of water losses can be saved through implementation of the recommended water loss reduction programs for the city of Addis Ababa. The water demand (end-use) modeling and forecasting has identified the city average water use in liter per capita per day is 117 and the projected water demand will be 840, 1,502 and 2,735 Million of liter per day by 2020, 2030, and 2040 respectively. With adaption and implementation of the recommended water conservation and demand management program B in the city of Addis Ababa would reduce the future water demand by 66%. This would postpone up to 2020 and downsize of the need for developing new water sources and infrastructures. Furthermore, the benefit-cost analysis result of adapting and implementing the recommended water conservation and demand management program B provides present value benefit of 106,550 million birr and costs present value of 862 million birr to Water and Sewerage Authority of Addis Ababa (AAWSA). The benefit-cost ratio is found to be 120. The cost of water saved is found to be 8,145birr/Million litre which is less than the cost of developing new deep wells and operation and maintenance cost of 300,000birr/Million litres by AAWSA. Therefore, water conservation and demand management provides economically feasible and environmentally sustainable solution for meeting the shortfall supply and projected future water demand in the city of Addis Ababa. The environmental sustainability of water conservation and demand management option is reducing the waste water generated from household and buildings to sewerage system or to the environment.

CHAPTER ONE

1. Introduction

1.1 General

In the recent years, throughout of the world, there has been a clear move away from the traditional approach of water resource development, for meeting the ever growing water demands, to one of water conservation and demand management option. The rapid increasing water demands in many parts of the world cannot be sustained indefinitely and many countries are in a situation of sever and permanent water stress. Other countries face the prospect of prolonged and more frequent period of water shortage as the demand for water outstrips the available water resources. Water conservation and demand management therefore becoming a major issue in many countries and is being promoted by both local governments and many of the international funding agencies.

Recent studies have shown that proposed augmentation schemes can often be postponed for many years, if not postponed permanently and downsized, if the growth in demand can trimmed by only a few percent, target that is certainly achieve in most cases (David & Hirji,2003). The saving associated with postponing and downsizing new water transferred scheme are so large that the measures needed to achieve postpone and downsize are not only environmentally attractive but also very cost effective.

1.2 Background

The city of Addis Ababa has faced with the shortfall supply, increasing water demand, high rate of water distribution system leakage and inefficient water uses.

The present available supply of 263,000m^3/day as compared to the present projected demand of 454,208 m^3/ day for the city, the shortfall water supply is around 42% (Tahal Consulting Engineers, 2005). Over the next 30 years, the city‘s water demand is expected to grow.

Inefficient and ineffective water use of the existing water supplies in Addis Ababa is due to high water loss rate in water distribution system around 40%, older or high flow rate of plumbing fixtures (toilets, shower heads and taps) which are installed at a customer homes and buildings and low water tariff rate that provides an increasing subsidy (Ejigineh,2000).

Furthermore, major problem in changing current supply side management planning practice in the city is that most consultants used by the water supply utility promote the development of infrastructure without adequately reviewing water conservation and demand management measures as alternatives.

Therefore, there is a lack of understanding of principles, scope and the potential of water conservation and demand management as a strategic management tool for developing and implementing by Addis Ababa Water and Sewerage Authority.

Following the trend, by developing a new water sources and infrastructures for meeting the shortfall supply and projected future demand of the city cannot be sustained indefinitely as the costs; environment and climate change impact of the new water sources development is increasing. The challenges can be solved by developing and adapting water conservation and demand management option.

Over the last 15 years new approach of water conservation and demand management option (WC/DM) has emerged from the United State that provide economically feasible and environmentally sustainable solution for meeting the shortfall supply and increasing water demand. Water conservation and demand management option is designed to increase water use efficiency and promote water conservation so that to consumer behaviour is changed and/or changes to the stock of water using equipment is achieved. Increasing water use efficiency can be achieved by replacing water using equipment and appliances (toilets, shower heads and faucet) with more efficient types and by finding and repairing leaks in the water distribution system. Behaviour change in consumers can be promoted via educational campaigns or through economic instruments such as pricing. Replacing or regulating water using equipment and appliances as a conservation strategy is based on the notion that demand for a resource such as water is not in fact a demand for that resource itself but rather for the services that the resource provides, often called end use. Consumers are therefore seen to generate a demand for services, end uses, such as toilets, clothes washing and showers rather than a demand for kilolitres. Water demand or end use modelling enables the amount of conservation from a measure to be estimated. In the this instance, it is assumed that providing the same services with less water resource makes no difference to the consumer.

Therefore, the purpose of this research is to study the scope and potential of water conservation and management alternative in terms of potential benefits from water savings, costs, postponing and downsizing the need of new water sources development and reducing operation and maintenance cost.

1.3 Objectives of Research

1.3.1General Objective

The general objective of this research is to assess water conservation and demand management potential for the city of Addis Ababa.

1.3.2 Specific Objectives

The specific objectives of this research would include:

- ❖ Determine the extent and economic level of water losses in the water distribution system.
- ❖ Developing water demand or end-use modeling and forecasting for Addis Ababa.
- ❖ Analysis the potential benefits and costs of water conservation and demand management measures.
- ❖ Develop and recommend effective water loss and demand management programs for reducing water losses and increasing household water use efficiency.
- ❖ Develop Demand Side Management Least Cost Planning Decision Support System or DSS Model.

1.4 Research Outline

The general structure of the thesis is as follows.

Chapter 1- Introduces the background of study, about the research objectives and contributions.

Chapter 2- Provides a review of the related literature and water conservation and demand management basic principles, case studies and about the water loss management tools.

Chapter 3- Shows a general view of historical background, climate, rainfall, existing water supplies conditions and planned water sources in the study area.

Chapter 4- Describes the methodology, data collection, analysis process and tools used for assessing and reducing water distribution system leakage, developing water demand modelling and forecasting and assessing water conservation and demand management.

Chapter 5- Describes the analysis and a strategy development for assessing and reducing water distribution system leakage

Chapter 6- Provides the water demand modelling and forecasting analysis results.

Chapter 7- Summarizes the structure of the DSS model, development and analysis of water conservation and demand management options and detail description of the recommended water conservation and demand management option programs

Chapter 8- Summarizes the findings of the research and presents conclusions

CHAPTER TWO

2. Literature Review

2.1 Least Cost Planning and Integrated Resource Planning

Least Cost Planning (LCP) and Integrated Resource Planning (IRP) were developed for the electricity industry in the United States in the 1980's (White and Fane, 2007) to compare energy conservation programs to increased generation as sources of supply. The principles of LCP and IRP have been transferred to planning of other large infrastructure systems including water and waste water (White and Fane, 2007). Water conservation or demand side management is central to LCP and IRP. Water conservation and demand management (WC/DM) is a program that modifies (decreases) the level and/or timing of demand for a particular water resource.

Least cost planning involves several steps, including: water demand or end-use modelling , demand forecasting, the design and modelling of water conservation and demand management programs, estimating water conservation from programs, evaluation of costs of conservation and demand management programs, estimating conventional water supply costs, developing and costing alternative supply options if applicable, cost- benefit analysis of all options . Detailed water demand or end-use modelling of how a supplied resource (water) is actually used by customers, provides a much more rigorous basis for demand forecasting, and allows for both the development and evaluation of demand management programs, in particular end-use efficiency. More rigorous demand forecasts also provide better estimates of the future costs of conventional supply augmentation. Results are usually presented in present value terms, often in terms of cost per unit supplied (or conserved) to allow direct comparison of demand management measures relative to increased supply.

Integrated resource planning and least cost planning are often seen as synonymous, however although both involve consideration of demand management for meeting future service needs, IRP provides a broader framework into which LCP fits. Over time, an IRP process should see the iterative reapplication of LCP as part of a cycle of evaluating and assessing options, investing in selected options, assessing conservation and demand management results and demand forecasts and then re-evaluating options, (Figure 2.1). Integrated resource planning also takes into account a range of parameters which go beyond the costs (White and Fane, 2007).

Planning decisions is about demand management need to include a range of other issues including equity, uncertainty of supply/conservation, timeframes for implementation and the potential for changes to rates structures

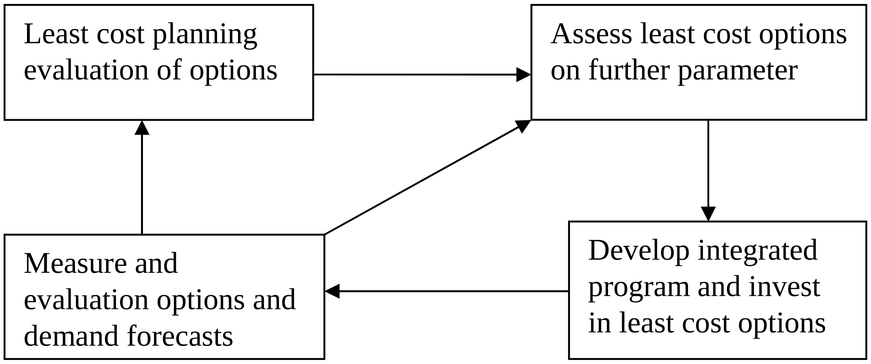


Figure 2.1: Integrated Resource Planning Involves the Iterative Re-evaluation of Option

2.2 Water Demand or End-Use Modelling

End-use or water demand modelling is a methodology that can define the ways that customers use water, to as great a level of disaggregation as possible. This can be achieved by the use of customer surveys of water using appliances (toilets, showers, and taps) and water using practices (frequency of bath and shower use, frequency of clothes washing), through analysis of market research data for large appliances (e.g. clothes washers) or through industry sales statistics provided by manufacturers. End-use or demand models combine the appliance stock and technical data with behavioural/usage data. Demographic and land use data is also needed, including most obviously population data. Housing stock (dwelling type mix) and occupancy (number of persons per dwelling) also strongly influence demand. Modelled demand is correlated to historical demand data, for bulk water production, and metered customer data by sector. Non residential sectors, commercial, industrial and institutional sectors are included to varying degrees of disaggregation dependent on the sectors proportion of total demand.

The importance of end-use or demand modelling in understanding demand is illustrated by the example of the decrease in water demand due to toilets in residential dwellings. The average flush volume of cisterns has decreased significantly from about 11-13 litres in 1980 to less than 4 litres today, due to the development of the dual flush toilet. Today's toilets manufactured is now not more than 6 litres/ 3 litres dual flush (White and Fane, 2007). As older toilets are replaced and new houses are built, the stock of toilets in use changes, and less water is used in toilets per person.

The second stage of end-use modelling involves developing and assessing a range of demand management measures. The end-use model allows potential levels of conservation to be estimated.

2.3 Water Conservation and Demand Management Measures

Water conservation and demand management measures aim to minimise either the overall or peak demand for water (or energy or other resource).

Measures can be categorised as assessing and reducing water distribution system leakage**,** increase end use efficiency and improve the market in resource usage.

2.3.1 Assessing and Reducing Water Distribution System Leakage

No change in water or resource usage by consumers but less system losses. Assessing and reducing water distribution system leakage can be achieved through adapting International Water Association (IWA) standard methodology of assessing and reducing water distribution leakage.

The IWA recommended definition of real losses is ‘the annual volumes lost from transmission and distribution systems through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering’. Real losses can be assessed by any one of two different methods:

- ‘Top-Down’ annual water balance
- Component Analysis or a combination of two or more of these methods. Each of these methods is outlined in the following sections.

2.3.1.1 Top-Down Annual Water Balance

Real/physical /losses can be assessed through the IWA Best Practice ‘Top-Down’ annual water balance (Table 2.1), as the volume remaining after volumes of authorised consumption and apparent losses have been deducted from the system input volume.

<table>
<tr><td rowspan="9">System Input Volume (corrected for known errors)</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Un-metered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non -Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Un-metered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses (Commercial Losses)</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Meter Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses (Physical losses)</td><td>Leakage in Transmission and Distribution Mains</td></tr>
<tr><td>Storage Leaks and Overflows from Water Storage Tanks</td></tr>
<tr><td>Service Connections Leaks up to the Meter</td></tr>
</table>

Table 2.1: IWA 'Best Practice' Standard Water Balance

Because all metered or assessed input data to the water balance are subject to errors and uncertainty, to a greater or lesser extent, these errors accumulate in the calculated volumes of real losses, resulting in uncertainty in the calculated value of real losses. A practical approach to dealing with the uncertainty is the calculation of 95% confidence limits using customized software (Fanner, 2003). This approach to dealing with uncertainty is applicable to each of the methods of evaluating real losses.

The total volume of real losses is determined by the top-down annual water balance; however this analysis does not provide any information on the components of this total volume of real losses. It does not break down real losses into the volume of real losses due to detectable bursts, (that can potentially be managed through speed and quality of repairs, and active leakage control) or real losses due to background losses (that can only be reduced by pressure management or infrastructure renewal). This analysis also provides no information on the volumes of real losses from the various elements of infrastructure, which is required to develop appropriate loss management strategies. For these reasons, it is recommended that, if possible, the top-down annual water balance is undertaken in conjunction with the other two assessment methods.

2.3.1.2 Component Analysis of Real Losses

Annual real losses can also be assessed from first principles using component analysis. This approach uses numbers, average flow rates and average run-times of different types of leaks and bursts (background, reported and unreported) on different parts of the distribution infrastructure (mains, service reservoirs, and different sections of service connections). Other data required to undertake a full component analysis of real losses include basic infrastructure data (mains length, number of service connections, length of the privately owned service line from property boundary to meter); infrastructure condition factor (ICF) for background leakage; numbers of reported and unreported bursts, and their average run-times based on utility policies; average system pressure and pressure/leakage relationships (using appropriate Fixed and Variable Areas Discharge(FAVAD) N1 values.

A component analysis model breaks down the overall volume of real losses into its constituent components for each element of the system infrastructure, based on their most influential parameters. A calibrated component analysis model is therefore very useful for evaluating alternative options for managing real losses.

2.3.1.3 Unavoidable Real Losses (UARL)

Real losses cannot be eliminated totally. The lowest technically achievable annual volume of real losses for well-maintained and well-managed systems is known as unavoidable annual real losses (UARL). Figure 2.2 shows the relationship between current annual real losses (CARL) from an IWA water balance – represented by the large rectangle - and UARL (the small rectangle).

Using the four methods of leakage management (the four arrows), real losses can be controlled, but (at the current operating pressure) cannot be reduced any further than the UARL. However, although the UARL represents the minimum level of real losses that could technically be reached, for most utilities it will not be economic to reduce real losses to this level. There will be some intermediate economic level of real losses which it is appropriate for a utility to achieve.

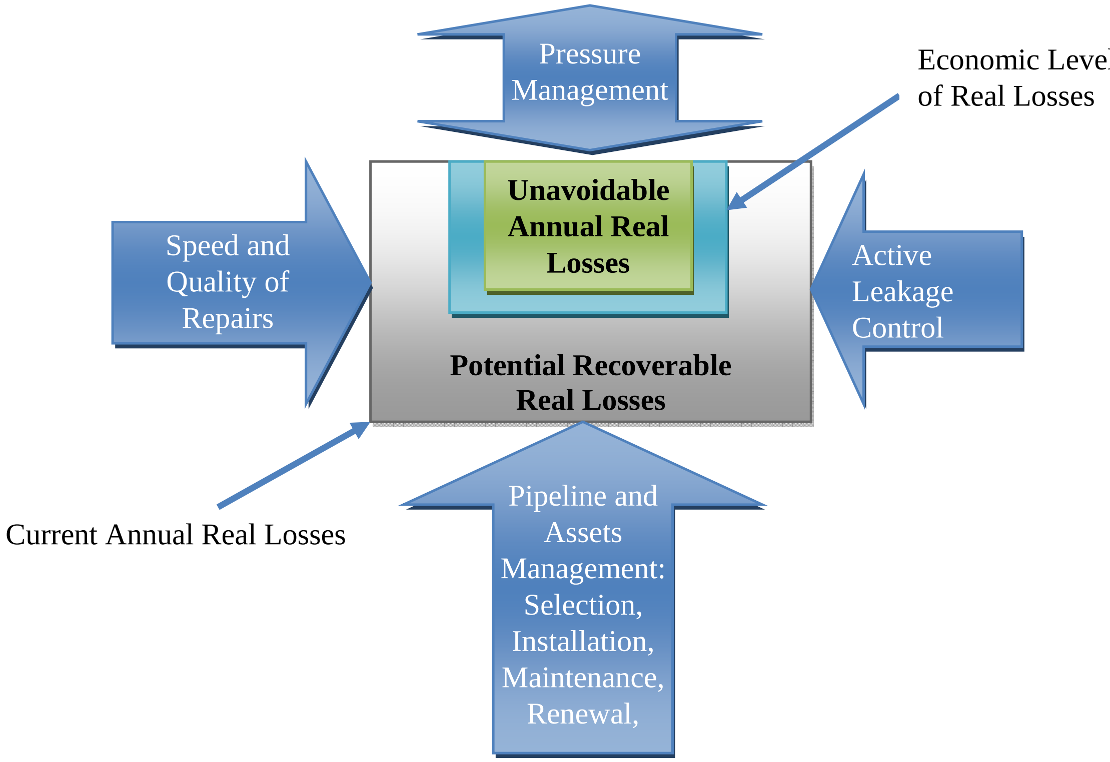


Figure: 2 .2 Four Pillars of Leakage Management Tools Developed by IWA/AWWA

System-specific values of UARL can be assessed using a formula developed by the IWA Water Losses Task Force (Mckenzie.et.al, 2000). Data required for this assessment are the number of service connections Nc, the length of mains Lm (km), the length of private pipes (Lp in km) between the street/property boundary and customer meters, and the average operating pressure (P metres). UARL is used in the calculation of the infrastructure leakage index (ILI), which is the ratio of CARL to UARL.

2.3.1.4 Active Leakage Control

When first undertaking leakage detection and repair work, leaks will be relatively easy to find. A backlog may have built up due to under investment in previous years resulting in fewer leaks being found and fixed than occur in any given year. However, once the more obvious mains and service bursts have been found, then a higher level of effort has to be put in to reduce leakage by a similar volume.

2.3.1.5 Pressure Management

The most cost effective schemes are those which cover a large area, and which make a significant impact on average pressures.

An example would be the installation of a pressure reducing valve on the branch from a trunk main to cover a whole town. Once such schemes have been completed, the next stage may be to install PRVs in conjunction with district metering. In the extreme, some water suppliers have installed PRVs on supplies to districts of less than 200 properties, or even on individual properties. The cost of the scheme reduces much less than the benefit obtained due to the reduction in the area covered, and so the schemes become less cost effective.

2.3.1.6 District Metering

When installing zonal and district metering there is a tendency to favour areas which can be metered without the need for additional facilities to be installed in the network. Areas will be created using natural breaks in the network, along the lines of main roads, rivers and canals, and over undeveloped land.

The aim is to provide single feed district meter areas (DMAs) which are supplied through only one meter installation. This will tend to minimise the number of valves which have to be shut in order to create a discrete area. The number of areas which can be created in this way will depend on the layout of the distribution network. The cost and the benefit will be similar. As the number of properties contained within DMAs increases, there will come a point at which adding further properties incurs a higher unit cost.

2.3.1.7 Mains and Service Renewal

Replacing an old water main with a new installation will reduce leakage on the main. If water mains are being replaced for reasons other than leakage control, for example water quality problems, then the benefit to the leakage engineer should also be taken into account. When mains replacement is being used as a primary measure for leakage reduction, targeting studies should be carried out to determine which areas, and which mains within those areas, have the highest burst frequency (number per kilometre per year) and which have the highest levels of background leakage. If targeting is carried out effectively, it is inevitable that the initial schemes will be more cost effective than the later ones. So, mains replacement will also follow a law of diminishing returns.

2.3.1.8 Speed of Repairs

Reducing the time it takes to repair a leak will reduce the volume of leakage. However, once the repair time is reduced below a certain threshold, the unit repair cost will tend to rise due to standby, call out and overtime payments to staff, or supplementary payments to contractors to make additional repair teams available.

Figure 2.3 shows the generalised relationship between expenditure on leakage management operations, and the unit production costs of water as a function of the level of losses. The key to a successful strategy is to collect sufficient factual data to allow this relationship to be understood for each supply zone (Farley and Trow, 2003)

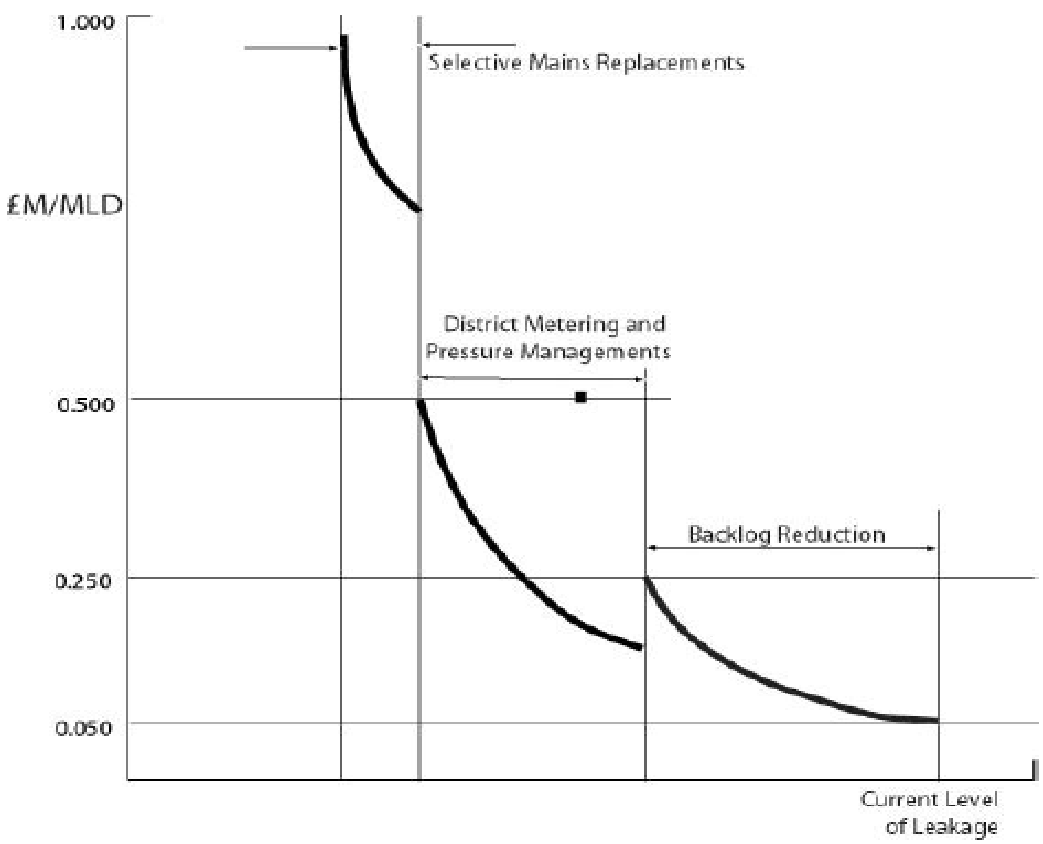


Figure 2.3: Diminishing Returns from Leakage Management Measures

2.3.1.9 Economic Level of Leakage

For any water distribution system there is a level of leakage below which is it not cost effective to make further investment, or use additional resources, to drive leakage down further. In other words, the value of the water saved is less than the cost of making the further reduction.

This point is known as the economic level of leakage (ELL). Leakage targets based on ELL must therefore be specific and dynamic.

In order to understand the estimation of ELL, it is necessary to appreciate how water is valued. ELL will vary from one region to another, and also within areas of the same

In the short term there are a number of key parameters which govern the actual economic level of leakage. These are effectively fixed, and include:

- The average pressure in the system
- The condition of the mains and service pipes
- The facilities available for collecting data (i.e. district metering and telemetry)

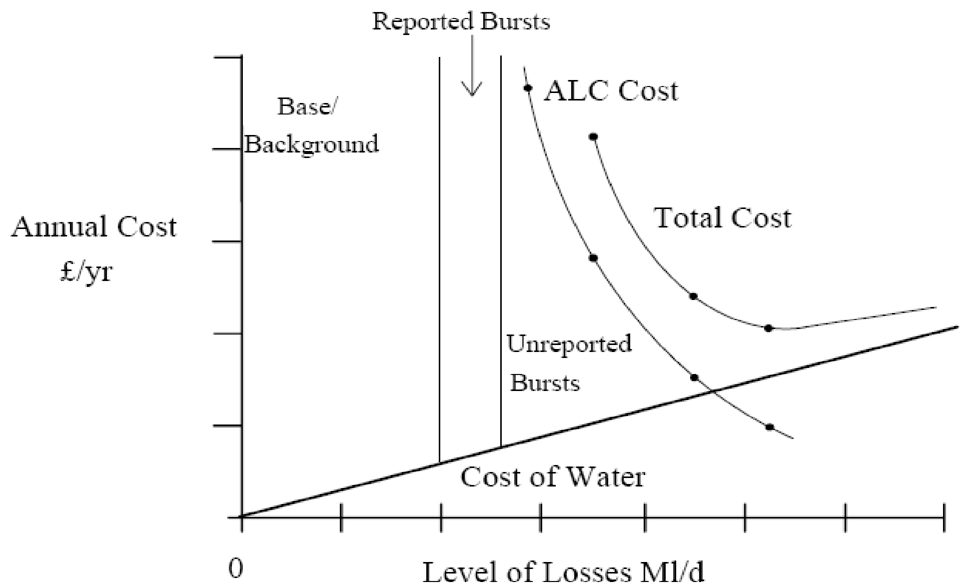


Figure 2.4: General Relationship between Operating Costs and the Level of Losses

So, at any particular time, the only parameter which can be changed quickly to have an impact on the level of leakage is the number of personnel out looking for leaks and then repairing them. Leak location and repair is sometimes called active leakage control (ALC). There is a steady state situation in which the marginal cost of the ALC effort is equal to the marginal cost of the water saved by adopting that ALC policy.

In the longer term, investment in facilities such as district metering, telemetry, pressure management and mains renewal will have an impact on the short term ELL. The reduction in the short term ELL and consequently the savings and costs associated with the change can be compared to the investment cost of making the change. Investment costs are sometimes called transitional costs, i.e. they represent the cost of making the transition from one steady state to another.

Short term ELL is based on an economic analysis which estimates the optimum level of ALC effort taking account of the costs of ALC and the short term value of the water in the supply zone.

Long term ELL is based on a form of investment analysis taking account of the following questions:

- What is the current level of leakage?
- What is the short term ELL?
- How will the short term ELL change with the investment under consideration?
- What is the saving in water losses and the change in ALC resources from the proposed investment compared with the current policy?
- What is the cost of the proposed investment?
- What is the return on the investment?

The answers to these questions will allow the water supplier to decide an investment policy using normal investment decision criteria.

2.3.2 Increase End use Efficiency

Increasing end use efficiency refers to provide the same services with less water makes no difference to the consumer. Examples: Regulating for low flow shower heads and dual flush toilets in new developments; enforce minimum performance standards on new appliances (clothes washing machines); offering financial incentives for water efficient purchase and installation; programs to retrofit efficient equipment into existing buildings.

2.3.3 Improve the Market in Water or Resource Usage

Inform the consumer about the full costs of their water or resource use. Examples: full cost recovery charges for water use; volume-based pricing set at or above the long run marginal cost; providing better feedback on the level and cost of ongoing water usage by universal metering with at least quarterly billing or smart metering with instant feedback; remove perverse incentive for increased resource use such as declining block tariffs; provide comprehensive information on the environmental impacts of water use, run education campaigns; conduct detailed water use analysis (audits) for water customers in key sectors.

2.4 Water and Waste Water Conservation and Management Evaluation

Least cost planning uses an economic evaluation of options, as the aim is to minimise the total social cost of meeting service needs. As a true economic analysis is difficult, evaluation in LCP often uses what is termed a total resource cost (TRC) test to compare direct costs of conservation by demand management programs to the cost of supply. This test includes all costs and benefits to both the utility and its consumers in the analysis. Decreases in consumer bills spent on the conserved water or resource are not included in the TRC test as the utility sees these savings as a cost of foregone revenue. Equity issues between groups are not addressed by the TRC test, and equity between future and current generations is only addressed in relation to the discount rate applied to future costs. Urban water and wastewater conservation has the potential to reduce both the economic cost and the ecological impacts of providing urban water services. Economic cost savings result from eliminating or reducing the size of capacity augmentations as well as the operating and maintenance costs of treating and distributing potable water, and collecting and treating sewage. Some ecological impacts of urban water systems may be included in the evaluation of water and wastewater conservation as costs externalities if monetary values can be agreed on.

The comparison of supply to water conservation is often constructed in terms of unit cost, with conserved water or wastewater being equated to an equivalent increase in supply. This recognises that supply for a new development can be obtained by increases in capacity or by increasing the efficiency of existing and future water users. The preferred cost measure is levelised unit cost which is the present value of all costs of a measure or option over the present value of all water supplied (or conserved). A number of authors, including White and Fane, 2007 have described calculating unit cost by using present value of a physical water flow. They calculated a water supply scheme marginal capacity cost using the term average incremental cost (AIC). This AIC used the present value of a physical water flow in the calculation of a unit cost, but only included future capital costs of supply and corresponding capacity increases. Levelised unit cost (L) as defined by(White and Fane, 2007), is similar but conceptually slightly broader as it can account for all capital and operating expenditure by water or wastewater service providers or their customers in providing for increased flows or for reduced demand, see equation 1.

$L = PV\,(costs)/PV\,(water\ saved\ or\ supplied)$ --- (1)

Demand management measures may affect various parameters other than average volumes that in turn dictate costs in an urban water system (Maddaus, 2005). On the water supply side parameters include: peak day demand, peak hourly demand and amount of potable supply consumed per capita.

On the wastewater side potential parameters other than average dry weather flow include: peak wet weather flow, BOD load and nutrient loads at sewage treatment. Conservation measures might also avoid energy use for hot water, quantities of detergents needed, and storm water infrastructure

2.5 Case Studies

Two case study regions and the programs implemented are described in this section. The case study has been described by White and Fane, 2007.

The assessment of these programs and recalibration of end use and demand forecasting models over time has not previously been described.

2.5.1 Rous Regional Demand Management Strategy

The Rous Regional Demand Management Strategy was commenced in 1996, with the aim of reducing the demand for water in a region of high population growth. Rous Water is the bulk water supply authority to four local councils in the north coast region of New South Wales, Australia, supplying a population of about 70,000 people.

This strategy, which resulted in a comprehensive water efficiency program outlined below, provides an example of the benefits of deferring capital works. In this case deferral of the adopted schedule of capital works (with a present value in 1996 of AUS$30Million) by one year, results in a financial benefit of AUS$1.4Million. This means that any measure which reliably reduces demand by 1 ML/year provides a financial benefit of more than AUS$3,500. During the Rous Regional Demand Management Strategy many options were identified and implemented that had a cost significantly lower than this.

The program developed included the following components:

- Pricing and billing reform;
- Leakage detection and repair;
- Rebates and give-aways for water efficient shower heads;
- Point of sale rebates for front loading washing machines;
- Discounted residential retrofit;
- Free water audits for non-residential customers;
- A water efficient demonstration house and garden;
- A school education program.

2.5.2 Sydney Water Demand Management Program

In 1997, Sydney Water Corporation, the largest water service provider in Australia, commissioned the institute for sustainable sutures to undertake a major end use modelling and least cost planning study. The study considered over forty different options to reduce demand, covering all water use sectors (residential, commercial, industrial, institutional, unaccounted and non-metered water) and all end uses (e.g. toilets, showers, taps, washing machines, garden and lawn watering). The options also covered the range of possible means of implementing water efficiency measures, including regulation, pricing, education and advisory services, loans, incentives and retrofitting. The options were modelled by estimating the potential demand reduction that would be achieved at different levels of investment in each option. Options were selected on a range of criteria including the cost to the community to implement the option and the ability to provide timely reduction in demand.

Results of subsequent case studies (White and Fane, 2007) in specific sewer catchments indicated that demand management had the potential to reduce potable water consumption, effluent discharge, and nutrient loads to the environment while avoiding costs for system augmentation, ongoing operational costs, pollution licensing fees, energy and chemical usage by Sydney Water, energy and detergent use by customers. The expected effects of options on externalities in the form of carbon dioxide and nutrient releases to waterways were calculated. Table 2.1 Summarises the selected program developed for the Sydney-wide least cost planning study shown below.

Table 2.2: Demand Management Program Designed to Meet Sydney Water's Operating Licence

Measure	Estimated Demand Reduction in 2011(Litres Per Capita Per Day)	Levelised Cost (AUS$/kL)
1. Shower head performance standard	8.6	0.0014
2. Price increase (AUS$0.10/kL over	1.9	0.0018
3. Clothes washer performance	3.5	0.041
4. Outdoor water use restrictions	1.8	0.063
5. Shower head rebate (AUS$10)	0.7	0.14
6. Residential indoor audit &	3.4	0.19
7. As for 6 (free for low-income)	1.5	0.25
8. Active leakage control	7.5	0.3
9. Industrial & commercial audits	2.9	0.42
10. Hotel audits	1.3	0.42
11. Outdoor water use promotion	0.2	0.49
12. Outdoor irrigation system audits	0.3	0.67
13. Washing machine rebate (A$150)	0.4	0.7
Total demand Reduction in 2010	**38**	

Not all options have been able to be implemented. Options 1 and 3 are scheduled for implementation in 2003 for achievement of the 2011 – 35% water consumption reduction targets. The program is ranked in order of levelised cost.

In 1999 Sydney Water began implementing the majority of the programs, costing over AUS$60m, and requiring the participation of more than 10% of the 1.4 million domestic residences supplied by Sydney Water. The response by customers to the residential program in particular has been dramatic. In Shell harbour, where the residential assessment and retrofitting program was piloted, a 25% uptake rate was experienced compared to a 10% estimate. It appears that other programs such as the industrial and hotel audits and the shower head rebate program are under performing. A first year analysis of the program is currently being conducted to evaluate the performance against assumptions and to assess the actual costs and benefits of each program component. This analysis includes statistical comparison of participants versus control groups to assess actual customer demand reduction (White and Fane, 2007).

CHAPTER THREE

3. Description of Study Area

3.1 Historical Background

Addis Ababa has been a center for economic, social and political affairs/activities of the country for over 100 years. Addis Ababa at the moment covers 540 square kilometer land area as obtained from City map. The city lies between 2000 and 3000 meters above sea level, enjoying mild and warm temperature climate. The lowest and highest annual average temperatures recorded are about 10°c and 25°c respectively. Average annual rainfall is around 1250mm.

Since it is establishment, the population is increasing at alarming rate. According to the Central Statistical Authority of Ethiopia (CSA) 1994 and 2006 population census, this gives a population of 2.11 million and 2.738 million in 1994 and 2006 respectively and average annual growth rate of 2.1%. The city is administratively divided into ten sub-cities and 100 kebeles. Figure 3.1 depicts the general location for the study area.

Provision of water supply and sewerage service to the people of Addis Ababa is the responsibility of Addis Ababa Water and Sewerage Authority (AAWSA). AAWSA is a public authority and organized into eight branch offices, namely: Arada, Addis Ketema, Nifase Silik, Mekanisa, Gulele, Megenagna, Gured Shola and Akaki which provide services to all parts of the city.

When the city was first established, the principal sources of water were the numerous springs located at the foot of the Entoto mountain ranges together with a series of hand dug wells within the city itself. In 1938 the Entoto treatment plant was commissioned which provides filtration, sedimentation and chlorination. Increased water demand led to the construction of original Gefersa dam in 1942/43. In 1960 the Gefersa dam was raised, in order to increase its capacity from 20,000 m^3/day to 30,000m^3/day, while the springs were taken out of services. It is interest to note that at this stage the whole of Addis Ababa was served by sources to north and west of the city.

The next major phase of expansion of water supply facilities commenced in 1970 with commissioning of the Legedadi dam and treatment plant, which was located on the Akaki River east of Addis Ababa. The plant’s output of 50,000m^3/day was transmitted via 900mm pipe line to terminal reservoirs on the city’s eastern edge and Mesekel Square in the city’s center. To transfer and distribute these additional water additional reservoirs, pumping stations and pipe line were constructed in the eastern and northern areas of city. The facilities came to be known as Stage I Water Supply Projects.

Furthermore, development of water supply facilities was carried out during the 1980s under the Stage II Water Supply Projects. This phase included expansion of Legedadi treatment plant, construction of new transmission pipe line into the city of, rehabilitation of the Gefersa treatment plant and the construction or upgrading of several reservoirs and pumping stations throughout the city. The second phase included expansion of primary and secondary pipe line installation and improvements to the distribution network. The capacity of supplying facilities, i.e, 150,000 m^3/day and 30,000 m^3/day respectively for Legedadi and Gefersa, were projected to be adequate to serve the need of Addis Ababa up to 1992. Planning for a Stage III water supply commenced in the early 1980's, when a reconnaissance study was undertaken on all potential water supply sources located within a 50km radius. In 1991 feasibility studies and preliminary designs were completed for the development of a number of sources to serve the city to the year 2020.

Meanwhile, due to the population growth and expansion of the city a water shortage problem occurred in mid 1995. To alleviate this shortage AAWSA drilled a number of boreholes in the vicinity of the city.

Furthermore, due to an excessive delay in implementation of Water Supply III project, two water supply projects were designed under an emergency program. These were part of the Akkaki well field and Dire Dam.

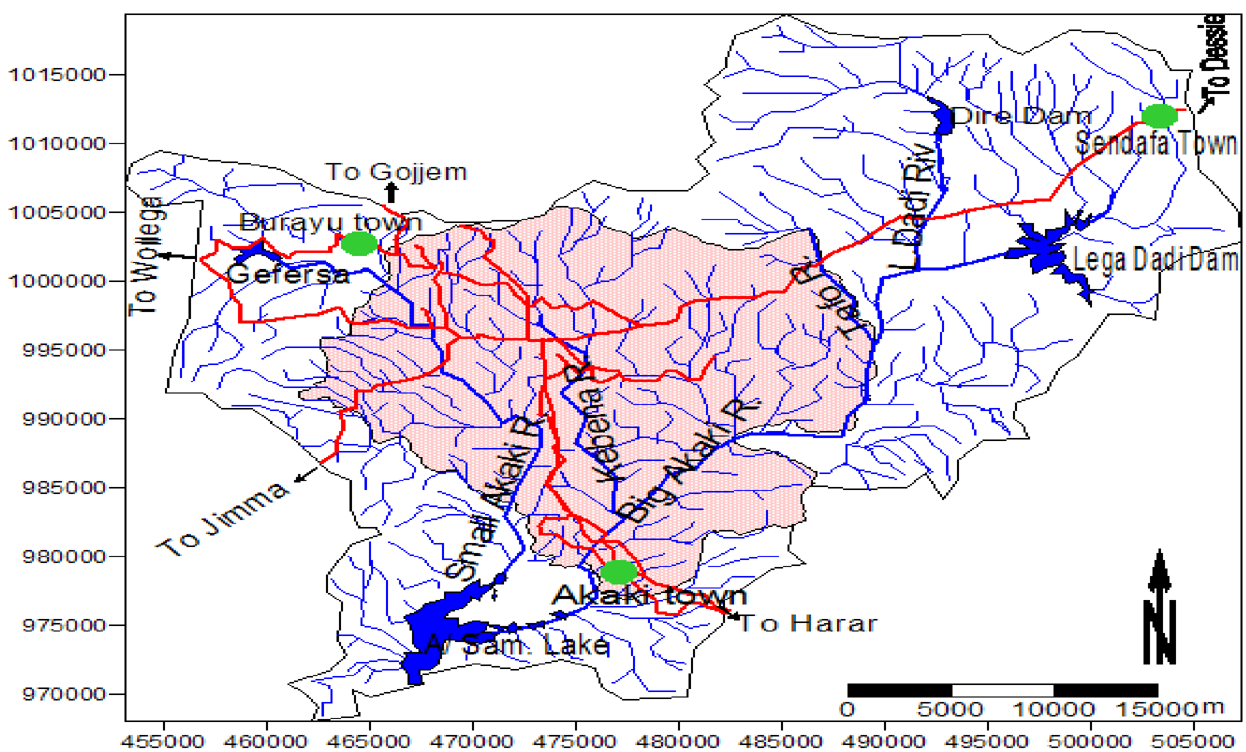


Figure 3.1: General Location Map for the Study Area

3.2 Existing Water Supply and Distribution System

The city of Addis Ababa gets its water from surface and ground water sources. The major sources are two treatment plants that take its water from Gefersa , Legedadi and Deire Dams and the treatment plants is located some 12 km and 30 km to North West and East from the city respectively. The two surface sources provides approximately 192,000 m^3/day(73%) and Akaki ground water source located 25km and other wells located in different parts of the city provides 43,000 m^3/day (16%) and 28,000 m^3/day (11%) respectively, altogether 263,000 m^3/year based on 2009 data provided by AAWSA.

Water distributed to customers through more than 3674 kilometers length of pipe network and serving 301,700 customers connection.

3.3 Planned Water Supply Sources

In 1984 additional five potential water sources were investigated by AAWSA. These are Gefersa IV, Akaki A, Sibilu ,Gerbi and the use of ground water with different well depth.

3.3.1 Surface Water Sources

The city receives an annual average rainfall of about 1250mm (data obtained from Addis Ababa Observatory). The perennial streams within the city include Little Akaki, Bantyktu, kurtume, Kebena, Genflie and Great Akaki. These are almost intermittent streams. However, almost all of these reverse are polluted by industrial effluents and household wastes. The situation necessitates the need to go for other surface water sources out of the city. Thus, AAWSA planed the development of Sibilu and Gerbi rivers.

The project encompasses areas beyond the boundary of the city Government of Addis Ababa which is situated within the national regional state of Oromia. The sources of water and installations will be located in Oromia.

TAHAL Consultancy Engineers Ltd. has made a contract agreement with AAWSA. Additional water quantities planned under this project are: Gerbi 67,200m3/day; Sibilu 618,000m3/day and Sibilu and Gerbi 579,000m3/day. It is observed that the two impounding reservoirs, which are collecting the water from the same catchment area, supply together less than Sibilu only. The advantage of constricting Gerbi Dam is the gravitational supply which has a higher reliability and potential of energy saving.

3.3.2 Ground Water Sources

SEURECA Consulting Engineers has made a contract agreement with AAWSA and conducted water source reconnaissance study of Addis Ababa recommended that one of the possible water supplies for Addis Ababa is ground water in 2007. The detailed feasibility study conducted by SEURECA and subsequent test drilling showed that the areas can readily be developed. These include:- Sebeta area, Koye(south west of Addis Ababa) and Akaki area and minimum of 63,000m^3/day is expected.

Furthermore, AAWSA also has made a contract agreement with an integrated hydro geological and geographical survey conducted in Addis Ababa and the surrounding areas (Geomatrix PLC,2008) shown that the existence of pocket well sites in the upper catchment and other parts of the the city with average yield of 15l/sec at an average depth of 250 and well fields are identified which includes Mekanissa, Alem Gena area, Legedadi, and Gefersa Tatek well field.

CHAPTER FOUR

4. Research Methodology

The methodology of the research consists of four steps :1) data collection, 2) assessing and reducing water distribution system leakage, 3)developing water demand or end-use modeling and forecasting, 4) water conservation and demand management analysis .

4.1 Data Collection

Assessing water conservation and water demand management option for the city of Addis Ababa is based on five main data inputs: 1) Customer water billing and production, 2) Water distribution pipe line data, 3) Population forecasting, 4) Estimates of the current stock of plumbing fixtures and appliance for city, and 5) Planned water sources development, operation and maintenance costs. The first and second input data used to determine the extent of water losses in water distribution, to develop economical leakage reduction and water demand model and build a water use profile by customer category for existing conditions. The third input data is used to project current unit-based demands forwarded through the projection period. The fourth input is used to quantify the expected reduction in current water use trends based on natural conservation of inefficient plumbing fixtures resulting from the national/international plumbing fixtures standard impact. The fifth input data used to determine the water savings benefits from downsizing the need of new water source development and reducing operation and maintenance cost through adapting water conservation and demand management measures. Other demographic and housing unit data used in the model was obtained the 1994 and 2006 Censuses from Ethiopian Central Statistic Authority.

4.1.1 Water Billing and Production Data

Water usage data (2005-2009) was obtained from the water customer billing and water production departments of Addis Ababa Water and Sewerage Authority. This data included water production data, as well as customer water billing data (water use data) by category as shown in Appendix A.

4.1.2 Water distribution Pipe Line Data

Water distributed to customers through more than 3674 kilometers length of pipe network and serving 301,700 customers connection as shown in Table 4.1 below.

Table 4.1: Water distribution Pipe Line Data

Water distribution Pipe Line	Pipe Lengths (km)	Pipe Diameters(mm)
Primary	524	125-1200
Secondary	1,760	50-110
Tertiary	1,414	15-40

4.1.3 Population Forecasting

Population data for the city of Addis Ababa was obtained from Ethiopian Central Statistic Authority, whereas employment data was derived from water billing data that the 2009 estimated service area employment (total jobs in service area) was directly related to the number of 2009 commercial and industrial accounts or connections. Table 4-2 shows the population forecasts for the city of Addis Ababa.

Table 4-2: Population and Employment Forecasting for City of Addis Ababa

Population Forecasting (number of People)			
2010	2020	2030	2040
2,975,339	3,662,637	4,508,700	5,550,201
Employment Forecasting (number of Employees)			
2010	2020	2030	2040
661,399	769,774	895,913	1,042,730

Source: DSS Model and Census data

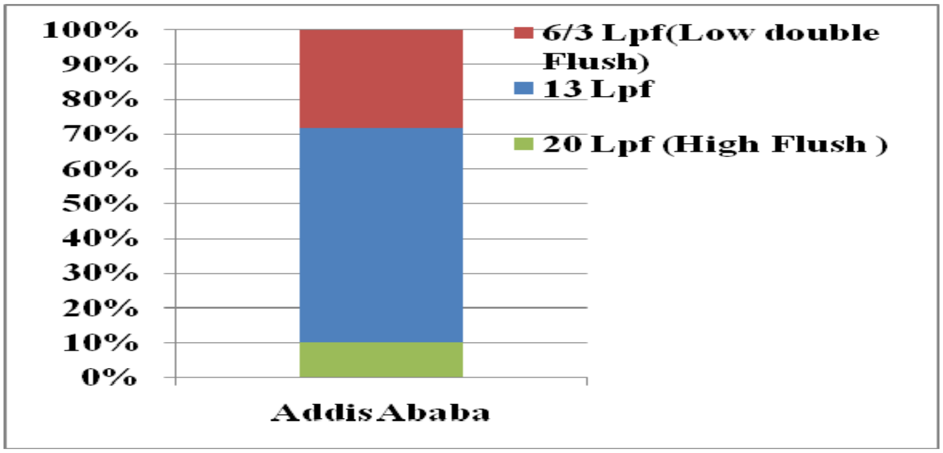
4.1.4 Plumbing Fixture Stock

Plumbing fixture stock was inferred the housing units derived from the water customer billing data and the 1994 city's census data. Estimates of housing age provided from the 1994 and 2006 G.C Census that were adjusted based on a projected replacement rate to more efficient fixtures.

The types of plumbing fixtures installed in houses and other buildings play a large role in current internal use as well as forecasted use in the future. Homes and business built in or prior to 1995 may contain inefficient toilets.

Before the 1950s, toilets typically used 25 litres or more for each flush. By the end of the 1960s, toilets were designed to flush with 20 litres, and in the 1980s the new toilets being installed were using only 13 litres. Today, a new toilet uses no more than 6/3 litres of water. Toilets are the largest water users inside the home; in the city there is large percentages of high flush toilets therefore a higher water savings potential in the future from the natural replacement of fixtures due to plumbing code. Estimates for existing types of toilet fixtures for city is provided in Figure 4-1.

Figure 4-1: Toilet Fixture Estimates for City of Addis Ababa, Year 2009



4.1.5 Planned Water Sources Development, Operation and Maintenance Costs

Information on current planned water sources development and operation and maintenance costs obtained by Addis Ababa Water and Sewerage Authority as provided below in Table 4-3.Current planned water sources development, operation and maintenance costs include planned 40 deep wells development, current pumping/electricity, and current water treatment/chemical , current staff salary in the year 2010.

Table 4-3: Current Planned Water Source Development, Operation and Maintenance Costs Data

Item . no	**Planned water sources development, operation and maintenance costs**	
1	Total current annual operation and maintenance cost (Million birr)	100
2	Average annual water production (ML)	95,995
3	Unit cost of operation and maintenance (birr/ML) (2÷3)	1,042
4	Annual planned deep wells development cost (Million birr)	50,000
5	Planned deep wells development (40 wells produces a safe yield of 100 l/second for 20 years period (ML)	126,144
6	Unit cost of deep wells development(birr/ML) (4÷5)	396,372
7	**Total unit cost of operation, maintenance and deep wells development (birr/ML)** (3+6)	**397,414**

4.2 Assessing and Reducing Water Distribution System Leakage

International Water Association/American Water Work Association (IWA/AWWA)'s two combination of leakage management methods are used, shown in Figure 4-2 below: 'Top-Down' annual water balance and economical leakage reduction analysis.

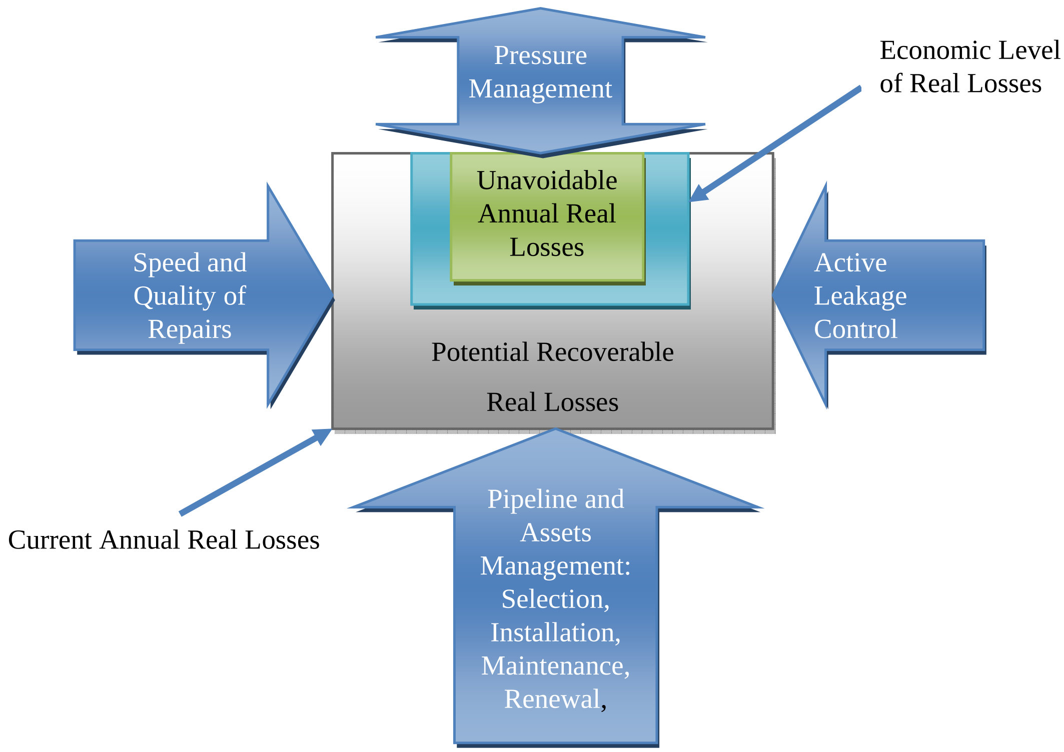


Figure 4-2: Leakage Management Tools Developed by IWA/AWWA

4.2.1'Top-Down' Annual Water Balance Analysis

IWA/AWWA's water loss analysis software was used to estimate the current water losses level in water distribution system of the city, can be download free from AWWA's website. The Analysis provides physical losses or the current Annual real (CARL), unavoidable real losses (UARL), apparent/commercial losses and infrastructure leakage performance index.

The collected data for the year 2009 and assumptions in Table 4-4 below is used to make an initial water loss assessment.

Table 4-4: Basic Data and Assumptions used for IWA/ AWW's Water Loss Analysis Software

Data	Source and Assumption	Accuracy
System Input Volume	AAWSA , largely based on estimates because of non-working or non-existing meters, accuracy ranges assumed as follows: Legedadi 7% Gefersa 5% Akaki 1% Other wells 10%	Statistical overall accuracy:5.1%
Billed Consumption (metered and un metered)	AAWSA Billing Department	Supposed to be okay
Un Billed metered Consumption	AAWSA Billing Department Unbilled Metered Consumption is directly measured water use for which there is no charge.	AAWSA office use missing : otherwise supposed to be okay
Un Billed unmetered Consumption	Fire protection Agency Unbilled Un-metered Consumption is the quantity of water that is authorized for use by the AAWSA s not directly measured and creates no revenues. Fire fighting are often examples of this category.	AAWSA office use missing : presumed to be (+/-10%)
Number of illegal connection	Real assumption; it is said that illegal connection are not a problem, provisionally a figure of 1,000 has been used.	unknown (+/-50%)
Meter tapering, Bypasses	Real assumption; it is said that meter tapering, by passes etc. are not a problem, provisionally a figure of 3,000 has been used (1% of all connection).	unknown (+/-50%)
Customers meter under-registration	Real assumption; seems to be a problem, partly because of over-aged and presumably often over-sized meters and especially the problem of under registered low flow because of roof tank, low consumption and low pressure;10% meter under registration has been used.	Uncertain guess (+/-50%)

Meter reader's "inaccuracies"	Meter reader corruption presumably also exists but is not assumed to be a major issue. Real estimate (2% of billed consumption)	unknown (+/-50%)
Meter reading and data transferred error	Meter reading and data transferred error is assumed to be a major problem; real estimate (4% of billed consumption)	Unknown (+/-50%)
Length of primary and secondary pipes	From AAWSA Water distribution and leakage control department : ,524km +1,760km=2,228km	Unknown (+/-50%)
Length of Tertiary pipes that are not individually service connection	From AAWSA Water distribution and leakage control department:3,000km	Unknown (+/-50%)
Number of house connection	From AAWSA Billing Department:300,000	Seem to be reasonable (+/-5%)
Average pressure	From AAWSA Water distribution and leakage control department:20-30m	(+/-10%)
Average Supply time	From AAWSA Water distribution and leakage control department 35% of area have 24 hour/day, 12% of area between 12-20 hours/day ,3% of area have 4-10 hours/day and 50 % of area have 2hours/day	(+/-20%)

4.2.2 Economical Leakage Reduction Analysis

Based on the assessment of current water losses level in the water distribution system of the city and the principles of the leakage management tools developed by IWA/AWWA, shown by Figure 4-1 above, the following combinations of water loss management options are recommended and optimized using the economical leakage reduction model for reducing the water distribution system leakage in the city of Addis Ababa:

- Improvement of operational sub-systems – water distribution modelling or restructuring to hydraulically isolated sub system, align AAWSA branch boundaries with new sub-system boundaries, improve operational network capability to better distribute water the areas that can hardly supplied at present, installation of bulk meters to measure inflow/out flow to from the sub-systems.
- Designing and establishing of small hydraulically isolated parts of the distribution network (District Meter Areas- DMAs) consists of 1,000 – 1,500 customer connections each and monitored routinely to produce a pattern for night flow. DMAs enable the identification and location of unreported pipe break and leakage or real losses .Each DMA shall be equipped with an inflow meter, a pressure reducing valve and pressure logger. Totally 300 numbers of DMAs is required to design and established for the whole water distribution system of the city. The costs for design and establishment of one DMA estimated about 675,000 birr. One fifth of the water distribution system in the city or 60 number of DMA (District meter areas) assume to be established, leakage detection and repair carry out over each year.
- Use leak detection equipment (sonar) and software to identify leaks. There are several different types of leak detection equipment on the market, ranging from hand- held listening devices to permanent and semi-permanent devices that are placed within the system to record leaks at low demand times (such as early morning hours, 3 am). Proactive leak detection programs have been successful in the leakage management pilot areas launched by Addis Ababa Water and Sewerage Authority in finding minor leaks that are not usually found, and has resulted in significant water losses reduction.
- Establish a strategy for prioritizing leak repairs. Although main breaks require swift response time, losses on smaller lines deserve as much or more attention, as small losses over long periods of time may result in significant losses.
- Conduct meter calibration and/or replacement program. Older meters should routinely be checked for accuracy. Faulty meters almost always underestimate the amount of water used, resulting in significant amounts of non-billed water.

- Manual meter reading and data transfer is anticipated to be a major source of errors .the introduction of electronic, hand-held meter reading device is essential. A barcode that will be clued on each customer meter must be scanned by the meter reader and only then it is possible to enter the reading. Office fabricated reading will not be possible anymore. Data transfer from the device to the billing system is done electronically another source of error is eliminated. Change the present, billing software with new billing software that has interface and compatible with the software of the meter reading equipment.
- Maintain an asset management program to track aging pipes and meters with a schedule for planned replacement.

The economic leakage reduction model is used to identify when or at what frequency AAWSA should send leak detection and repair crew to an area to find unreported burst/invisible leaks and to determine an ‘’economical level/volume’’ of leakage for AAWSA, since leakage cannot be totally eliminated. The model was developed by South Africa Water research commission, can be download free from own website. Based on the economical leakage reduction model result target was set for reducing real water loss assumed to be achieved /maintained over the next five years.
Economic leakage reduction model used the data provided in Table 4-5 that associated with loss through all types of leaks, breaks and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

Table 4-5: Data used for Economical Leakage Reduction Model

Description	Units	value
Number of service connection	number	300,000
Length of transmission line	km	524
Length of distribution main	km	2,000
Average system pressure	m	25.5
Unavoidable connection losses at 25.5 m of pressure (90%)	Litres/connection/hr	1.2
Unavoidable main losses at 25.5 m of pressure (10%)	Litres/km/hr	21
Leakage from service reservoirs	As % of volume per day	0.1

Leakage through main burst	m^3/hr at 50m pressure	12
Leakage from connection pipe burst	m^3/hr at 50m pressure	1.6
Average running time of main burst	days	0.5
Average running time of connection pipe burst	days	8
Costs of DMA Establishment	60 (DMA)/year	45 Mill. birr
Average cost of repairing main pipe burst	birr	10,000
Average cost of repairing connection pipe burst	birr	5,000
Annual water supplied to the distribution	Million litre/year	76,999.
Estimated annual real losses	Million litre/year	26,353.
Purchase price of water	Birr/m^3	30
selling price of water	Birr/m^3	2.3
Frequency of service connection burst per 1000 connection at 50 m of pressure	Burst/1000 connection/year	2.5
Annual frequency of main burst per km main at 50m of pressure	Number/km of main/year	0.15
Pressure exponent for flow through main and connection leaks		0.7
Power exponent for calculating number of main leaks for different pressure (cubic relation is normal adapted)		3
Costs of basic sounding per km of mains	Birr/km main	1,400
Cost of leak noise correlator per km of mains	Birr/km main	2,800
% of mains requiring leakage noise correlator to detect leaks	%	20

4.3 Developing Water Demand or End-Use Modelling and Forecasting.

The “Demand Side Management Least Cost Planning Decision Support System” (DSS) model is developed and used to forecasts water demand. DSS model is Microsoft excel application model. The model uses current water production and customer water billing data obtained from Addis Ababa Water and Sewerage Authority, along with population forecasts, to estimate water demand through 2040.

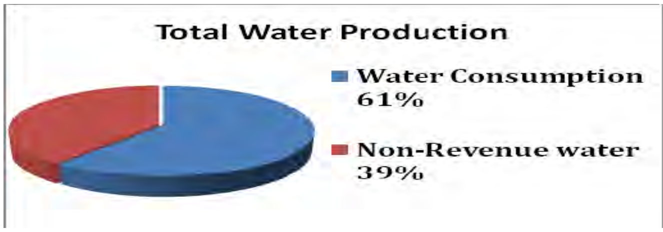
4.3.1 End-Use Modeling Methodology

Using two district approaches, “Top-down” and “bottom-up”, approach the model calculates indoor and outdoor anticipated demand for each of the customer categories: Single family residential, multi-family residential, Commercial, Industrial, Institutional and other categories as established by the water utilities. The “Top-down analysis” approach breaks overall water usage by total consumed/billed, by customer category, by indoor and outdoor usage. The “bottom-up analysis” approach examines the frequency of water use for a particular end use (such as toilets, showers, faucets, clothes washing etc.) and aggregates them to total water usage for each customer category. To calibrate the model, the two approaches are adjusted and reconciled as needed. For the city’s specific conditions is calibrated using this approach, and then the model is used to forecast future water demand. Figure 4-3 shows below the graphical representation of the water demand or end-use modeling methodology.

Figure 4.3: Water Demand or End-use Modeling Methodology

<u>"Top Down Analysis"</u>

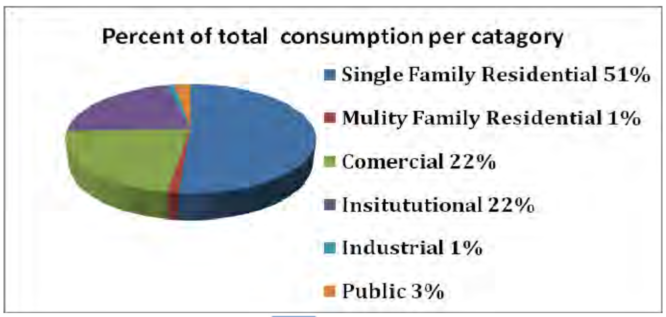
NRW=Production –Consumption



Internal/External:

Seasonal variation in water
Production records

Customer Billing Data by Catagory



<u>Estimate Internal/External:</u>

Derived from seasenal varation in
customer billing data

<u>Comparision and Adjustement</u>

Census data
Pluimbing fixture stock
Water use frequency
Natural replacement

<u>"Bottom up Analysis"</u>

4.3.2 Assumptions

Certain assumption and adjustments are made to the customer water billing data collected from AAWSA in order to account for current shortfall supply or suppressed demand and for certain data that was not available.

General assumptions in the model include the following:

- The base year for the water use forecast is 2009. The adjustment is base on the last 10 years of weather data looking at water use during both wet and dry year's records, long term permanent change in water use behavior as result of water shortage/drought, and the benefits of natural conservation in reducing historical demand. The deference in per capita demand between the actual and the adjusted demand essentially reflects demand suppression resulting from emergency water shortage or drought response actions.

- Once per-account unit or person /employee- based demands for each of customer category were established, the number of accounts or connections is used to estimate the total demand for the city. The numbers of accounts/connections are taken directly from the water customer billing data.

- The estimated non-revenue water from chapter five is used.

4.4 Water Conservation and Demand Management Analysis

The methodology used for the water Conservation and demand management analysis involves, shown in Figure 4-4: 1) Identification of potential water conservation and demand management measures, 2) benefit-cost analysis.

4.4.1 Identification of Potential Water Conservation and Demand Management Measures

Important step in assessing the water conservation and demand management measures was the review and identification of the current water conservation practices from other water utilities implemented across other countries that may be appropriate for the city of Addis Ababa and the screening of these water conservation measures to a short-list for detail evaluation (benefit-cost analysis using DSS Model). To accomplish this process, a list of 10 potential water conservation measures were identified and evaluated.

Each of potential conservation measures was ranked against three qualitative criteria, listed below. Scores for each criteria were based on a scale of 1 to 5, with 5 being the most acceptable .measures with low scores are eliminated from further consideration, while those with high scored were passed into the next evaluation phase(Cost-effective analysis using DSS Model). The three qualitative criteria are:

- Technology/ market Maturation: Is required technology available in commercially and supported by the local water utility? For example, a water-saving device would score very low if it is not yet commercially available in area.

- Service area Match: Is technology appropriate for the area's climate, building stock, or lifestyle? For example, promoting efficient gardening for multifamily may not be appropriate where water use analysis indicates relatively little outdoor irrigation. Customer

- Acceptance/Equity: Are customers willing to implement to implement measures? If not, the water saving would be too low to be significant. Measures should be also equitable to ensure that one customer category does not benefit while another pays the costs without receiving benefits. Customer acceptance may be based on convenience, economics, perceived fairness or aesthetics.

The screening process resulted in a short-list of 6 potential water conservation measures for the city of Addis Ababa. These conservation and demand management measures were assessed quantitatively using a cost-benefit DSS model.

4.4.2 Benefit-Cost Analysis

Least Cost Planning Decision Support System or DSS model is developed and used to maximize the cost-benefit of the water conservation and demand management measures. DSS is Microsoft excel based computer model.

Because of interaction between measures when assembled into conservation and demand management measures, each current as well as potential new measure was modeled individually as well as in combining into packages or programs (multiple measures) to assess the overall water savings.

An economic screening analysis was performed, as illustrated in Figure 4-4. First, the DSS model evaluated each of these 6 water conservation and demand management measures individually, simulating them as if they are implemented alone. The DSS model evaluated potential water savings based on conditions specific to the city of Addis Ababa. Information of each water use sector was used to evaluate potential savings for each of conservation and demand management measure. For instance, the DSS model calculated the water savings for toilet replacement for city based on the number and age of the single-family housing stock as well as the percentage of single-family use of water for toilet flushing. Based on existing information, and forecasted demands, potential savings for each measure were quantified. Next, the individual water conservation and demand management measures are ranked based on the cost of the water saved (cost / million Litre saved) and the best water conservation and demand management measures are selected.

Combinations of the best individual water conservation and demand management measures are then placed in several different “option packages” or programs.

Three water conservation packages were identified for the city of Addis Ababa, each with varying degrees of water savings and costs. The current adopted water conservation measures provided the backbone for each of these packages. Package A was composed of the 3 current water conservation measures to provide a benchmark for the analyses. Package B is composed of Package A plus two additional water conservation measures. Package C is comprised of all 6 evaluated water conservation measures. Finally, the option packages are evaluated to determine how much water savings could be obtained when these water conservation measures were combined.

The time value of money was explicitly considered. The value of all future costs and benefits was discounted to 2009 (the base year) at the real interest rate of 3.0%. The DSS model calculates this real interest rate, adjusting the current nominal interest rate (assumed to be approximately 6 %) by the assumed rate of inflation (3%). Cash flows discounted in this manner refer to as "Present Value" sums herein, and is used in order to properly make comparisons of water conservation measures.

Benefit-cost analyses can be performed from several different perspectives, based on who is affected. For planning water conservation programs for the Water and Sewerage Authority of Addis Ababa, the perspectives most commonly used for benefit-cost analyses include the water utility and the community.

The "Water utility" benefit-costs are based on the benefits and costs to the Addis Ababa Water and Sewerage Authority.

Benefits include reduction in operation and maintenance cost and windfalls from downsizing and postponing of new water sources development projects (lower demand means smaller infrastructure). Costs include the cost of implementation incurred by water utility or AAWSA for planning, administrations and education campaign and additional investment required by water utility or AAWSA for water efficient fixtures and appliances and water loss management.

The "community" benefit-costs includes the local water provider or AAWSA benefit and costs together with account owner/customer benefits and costs. These include customer reduced water bill benefits and costs of implementing the water conservation and demand management measure, beyond what the Addis Ababa Water and Sewerage Authority pays.

The water utility or AAWSA perspective offers two advantages for this analysis. First, it considers only the program costs that will be directly borne by the Addis Ababa Water and Sewerage Authority. This enables the Addis Ababa Water and Sewerage Authority to fairly compare potential investments for conserving and supplying water.

Second, because revenue shifts are treated as transfer payments, the analysis is not complicated with uncertainties associated with long-term rate projections and rate design assumptions.
Because of the local water provider's paramount role in Addis Ababa city's water conservation and demand management program, water utility perspective is primarily used to evaluate elements of the water conservation and demand management measures.

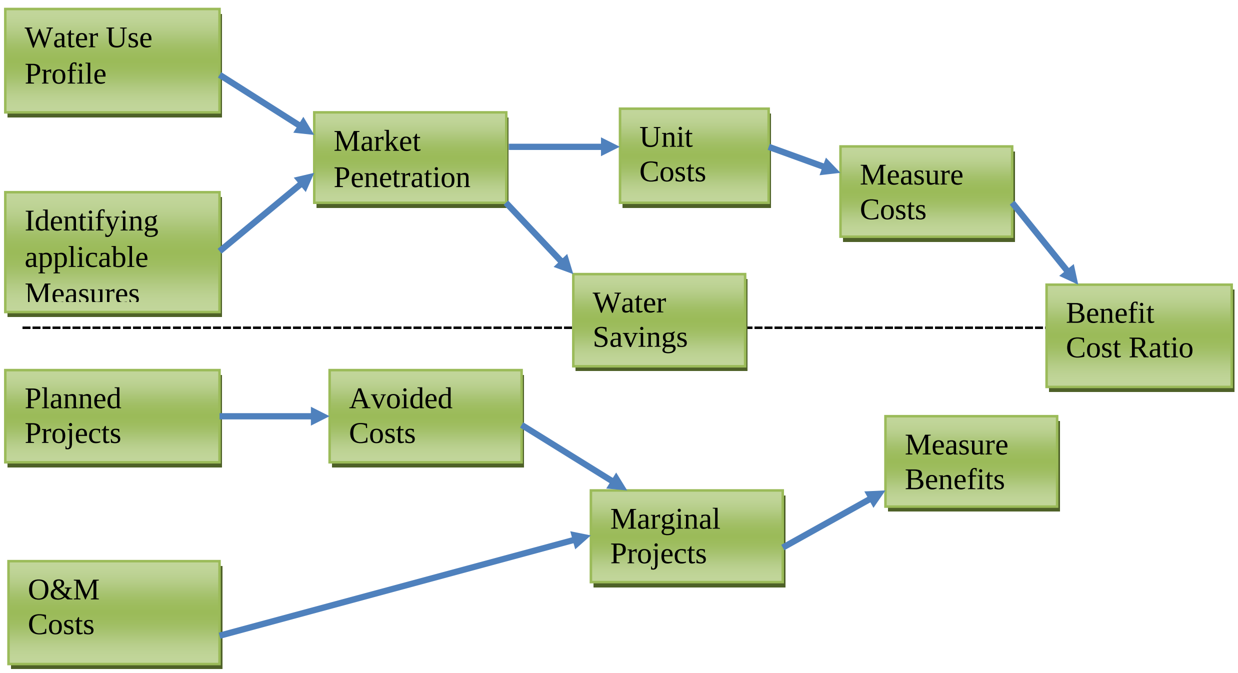


Figure 4-4: Analysis Processes of WC/DM Measures

4.4.3 Data Used and WC/DM Measure Assumptions

In addition to understanding the market potential for each of measure, several variables associated with cost and implementation of each measures are identified. These variables include:

- Targeted water user
- The market penetration goal for measures
- Potential water savings from implementing a measure.
- Cost associated with implementing the measure

These variables are described below. Following the description, Table 4-6 provides specific assumption related to these variables for each of water conservation and demand management measures.

4.4.3.1 Targeted Water User

Each water conservation and demand management measure targets a particular water use such as indoor single-family were use. Target water uses are categorized by water user group and by end use. Target water user groups could include Single-Family Residential (RSF); Multi-Family Residential (RMF); Commercial, Industrial, and Institutional (CII); and public (PUB). Measures may apply to more than one water user group. Target end use includes indoor and outdoor use. The targeted water user group and end use is indicated in Table 4-6 for each water conservation and demand management measure. The targeted water use is important to identified because the water saving are generated from reduction in water use for the targeted end use. For example, distribute low flow shower heads and faucet aerators (measure 2, Table 4-6) targets single family and multi-family residential indoor uses, specifically shower and faucet uses. When considering the water savings potential generated by a low shower heads and faucets retrofit one considers the water saved by installing low-shower heads and faucet aerators in single and multi-family homes.

4.4.3.2 Market Penetration Goal

The market penetration goal for a measure is the extent to which the product or service related to conservation occupies the potential market. In essence, the market penetration goal identifies how many fixtures, rebates, surveys; etc the retail customer would have to offer or conducted over a period of time to reach its water savings goal for each of measure.

The potential for errors in market penetration goal estimates for each of measure can be significant because they are based on previous experience, chosen methods, projected utility efforts and fund allocated to implement the measure.

The potential error can be corrected through re-evolution of measure as the implementation of the measure progresses. For example if the market penetration required to achieve specific savings turnout to be more or less than predicted, adjusted to the implementation efforts can be made. Larger rebates or additional promotion are often used to increase the market penetration and needed savings area achieved regardless of future variance between estimates and actual conditions.

In contrast, market penetration for mandatory ordinance can be more predictable with the greatest potential for error occurring in implementing the ordinance change.

4.4.3.3 WC/DM Measure Water Savings

Water savings for each water conservation and demand management measure are considered in terms of end-use water reductions. Each water conservation and demand management measure evaluated in this study targets a particular customer category (i.e., single-family residential, multi-family residential, and commercial, institutional and industrial) and a particular water use within that customer category (i.e., toilets, showerheads).

Water savings are expressed as a percent reduction in water use per end use. The percent reductions are only applied to amount of water identified for end use, not the entire category use. For example, distribute low flow shower head and faucet aerator (measure 2, Table 4-6) target replacing shower heads and faucet in single-family and multi-family residential sector accounts, therefore the savings is applied as a percentage of shower and faucet use in both single-family and multi-family residential sector. Table 4-6 indicates the target use for each measure.

4.4.3.4 Benefits and Costs of WC/DM Measures

Benefits and costs are included:

- *Utility benefits and costs*: Those benefits and costs that the utility would receive or spend.
- *Community benefits and costs*: Community benefits equal utility benefits plus customer billed water reduced benefits. Community costs include utility and customer costs.
- *Water savings benefits*: Based on assigning a typical unit value for avoided new water sources development, treated and distributed water supply at a cost of birr 300,000/ML. The 300,000/ML is the typical cost for development of 40 deep wells as well as operations and maintenance costs per million litres by AAWSA.
- *Costs for the utility*: Includes measure set-up, annual administration, and payment of rebates or purchase of devices or services as specified in the measure design.
- *Customer costs*: Includes costs of implementing the measure and maintaining its effectiveness over the life of the measure.

Table 4-6: Water Conservation and Demand Management Measures, Costs and Assumptions

Measures	**Target Water User group; End use**	**Market Penetration Goal[1]**	**Measure Water Savings(as percent of the total water usage(per end use) on each account to which the measure is applied)**	**Water Utility cost for contractor**	**Retail Customer Unit cost**	**Water Utility Administration cost (percent per participant)**
1.Replace Older Inefficient Toilet Fixtures	RSF,RMF; Indoor	25% of target water user group account with home built before 2000 with applicable end use	Water Savings 64% end use is Toilet varies with the current toilet stock Savings based on DSS Model toilet fixture models, which were based on housing age and adjusted with a modest natural replacement rate,	1,400 birr/fixture	700 birr/ fixture	25%
2.Distributing Low Flow Showerheads and Faucet aerators	RSF,RMF; Indoor	75% of existing high flow rate devices with home built before 2000 in a target user group accounts with applicable end use	Water Saving 20% end use is showers varies with the current low flow shower head	405birr/RSF,203birr/RMF		10%
3.Water Loss reduction (assessment & Leak Detection /Repair)	NRW	One fifth of the water distribution system or 60 number of DMA(District meter areas) targeted each year for the leakage detection and repair	Reduce leakage up to economic leakage level (25% of the current water loss level). Impact of leakage reduction will last 5 years.	Average cost for design, establishment and commissioning of one DAM is 675,000 birr		25%

4.Conservation Water Pricing and improving billing system	RSF,R MF,CII; outdoor	75% of target user group account with applicable end use at end of ten year	A 6-point increasing block-water tariff rate was developed as shown in chapter 7; section 5 that increase average price of 25% for RSM&RMF and 100% for CII and charge customers more per unit for higher used. 0.1 price elasticity.	70 million birr required for changing the billing system		
5.Installing Low flow Toilets and Urinals	CII; Indoor	100%	Water Savings are variable percentage of Toilet use, varies with current toilet stock which is 56% end use is Toilet varies with the current toilet stock	2,500 birr/fixture	1,350 birr/fixture	25%
6. efficient clothes washer rebate	CII ,indoor	50%of target user groups accounts by the year 2007	35% water savings end use is cloth washing	4,050 birr/washer	1350	25%

1: derived from water customer billing and census data

CHAPTER FIVE

5. Assessing and Reducing Water Distribution System Leakage

5.1 Top-Down Water Balance Analysis

The IWA/AWWA's water loss analysis result has shown that the current non-revenue water (NRW) level in the city of Addis Ababa is 38.2Million m^3/year (39.5% system input volume). Of the total NRW, the physical losses are 27%, the commercial/ apparent losses 10.5% and unbilled authorized consumption 2%. IWA/AWWA's water loss analysis output result is shown below in Figure 5-1

Figure 5-1: IWA/AWW's Water Loss Analysis Software Result

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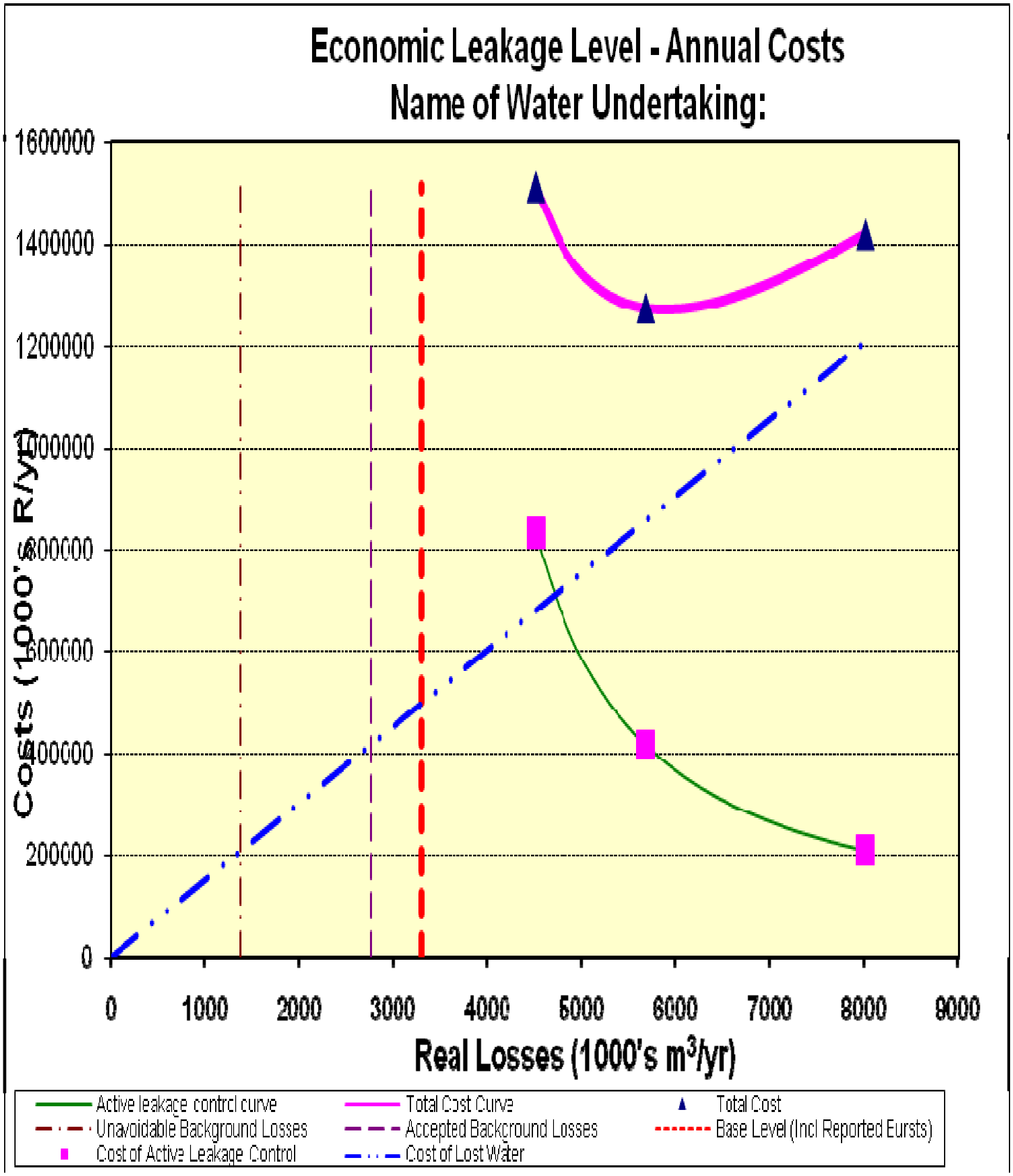
5.2 Economical Leakage Reduction Model Analysis

The economical leakage reduction model result has shown about 5.7ML/year or 10% of the water losses is an ‘’economical leakage level’’ or 29.5% of savings by the implementation of the recommended water loss reduction programs for the city and identified intervention of once every year is economical to AAWSA to find and repair the leaks as shown below in Figure 5-2. This economical leakage level is set to be achieved or maintained over the next five years through implementing a combination of the recommended leakage reduction programs in the city.

Figure 5-2: Economical Leakage Reduction Model Result



6. Water Demand or End-Use Modeling and Forecasting

6.1 Adjusted Base Year profile

As 2009 water use was unnaturally depressed as result of the ongoing water shortage/drought, the water use data was adjusted to create an adjusted base year profile that reflect normal water use condition. For long term city water conservation and demand management programs and water supply planning, normal water conditions provide a more responsible estimate of future needs than drought or shortage-impacted actual water usage.

Table 6-1 shows the adjusted base year per capita and per employee use for single residential and multi-family as well as all other non-residential uses, including indoor or outdoor use.

Table 6-1: Adjusted Base Year Water Use Profile for City of Addis Ababa

	overall (Lpcd) Note[2]				Single-family Residential (Lpcd) Note[3]				Multi -family Residential (Lpcd) Note[3]				Non- Residential (Lpd/ employee) Note[3]			
Total System Use	Total consumption	Indoor	outdoor	% outdoor	Total	indoor	outdoor	% outdoor	Total	indoor	outdoor	% outdoor	Total	indoor	outdoor	% outdoor
159	123	97.2	26	21.0	123	103	20	16.2	119	108	10.7	9	124	98	26	21

1. Total adjusted per capita use (total adjusted demand including non-revenue water divided by population) shown in Lpcd

2. Does not include non-revenue water

3. Publicly supplied water and population

4. Outdoor use is defined as all use above the winter minim level

Lpcd=Liter per capita(person) per day

6.2 Top-Down Analysis

The total adjusted demand for the city of Addis Ababa is estimated based on the per-account unit-based demand for each customer category and the number of customer accounts or connection. Since there is no a standard billing category system in place in Addis Ababa Water and sewerage Authority, common categories are used for comparative purposes. The main categories are as follows:

- Single Family Residential
- Multi Family Residential
- Commercial
- Industrial
- Institutional
- Public

Based on these account categories and customer billing data obtained from Addis Ababa Water and sewerage Authority, the number of accounts or connections per customer category is determined.

Top-down analysis also looked at housing stock information to estimate the percentage of water use by plumbing fixtures. The makeup of plumbing fixtures in the city is based on housing age (derived from the 1994 and 2006 census) and adjusted with a modest natural replacement rate, shown in Table 6-3.

The natural replacement converts existing less efficient plumbing fixtures with more efficient fixtures as they are damaged or due to change in style. The national or international plumbing fixture standards codes ensure that older fixtures are replaced with more efficient fixtures. Over time, the plumbing code will gradually reduce per capita demands, as percentage of efficient fixtures in homes and building increases. This demand, which includes water saving due to efficient fixtures, is referred to as 'the baseline' demand.

6.3 Bottom-up Analysis

The American Water Works Association Research Foundation (AWWRF, 1999) study, "Residential End uses of water" provided the initial bottom-up estimate for plumbing fixture use frequencies and quantities. Table 6-3 shows the average water end uses and frequency factor for a single family account, based on the AWWRF study. The initial water end use estimate are compared in the model to existing stock of plumbing fixtures in the city, based on the top-down analysis.

The top-down and bottom-up are adjusted until they mach to assure calibration of model, with preference to the more accurate top-down generated numbers shown in Table 6-2 and 6-4.

Table 6-2: Single Family Water End Use (AWWARF)

End Use	Unit	Likely Range Value	Average Value	Value Used in Model for A.A City
Toilet Flushing Volumes	Liters /flush	6 to 30	13.8	11
Frequency of Toilet Flushing	Flushes/person/Day	2 -to 8	5.05	2.5
Showering Frequency	Showers/person/day	0 - 1	0.65	0.25
Shower Flow Rates	Liters/minute	5.7 -19	9.5	7.6
Duration of Average Shower	Minutes	5 - 15	8.2	8.2
Bathing Frequency	Baths/person/ day	0 - 0.2	0.1	0.067
Volume of Water	Liters/bath	113 -189	151	15
Clothes Washing Machine use	Loads/person/day	0.2 -0.5	0.37	0.167
Volume of Water	Liters/load	170 - 1 89	153.2	107
Dish Washing	Loads/person/day	0.1 - 0.3	0.1	0
Volume of Water	Liters/load	38 - 57	38	38
Kitchen Faucet Use	Minutes/person/day	2.5 - 10.5	6.6	2.5
Faucet Flow Rates	Liters/minute	7.6 -11	5.1	5.8
Bathroom Faucet Use	Minutes/person/day	0.5 -2.5	1.5	1
Faucet Flow Rates	Litres/minute	7.6 - 11	9.5	5.2
Leak and Drips	Liters/person/day	0 -37.8	35.9	15
Total Indoor Use (Liters /person/day)			**279.7**	**97**

Source: (AWWA, 1999)

Table 6-3: Natural Plumbing Fixture Conversion

End Use	Current Standards Plumbing Code	Natural Replacement Rate
Toilets	6 Liters per flush	2% per year
Shower heads	9.5Liters per minute	4% per year
Faucets/Taps	9.5Liters per minute	4% per year
Urinals	3.8 Liters per flush	2%

Table 6-4: Single Family Residential Water End Use Model Result for City of Addis Ababa

End Use	Percentage Share	Liters /person/day
Toilets 28%	28%	27.5
Clothes Washing 19%	19%	17.9
Shower 16%	16%	15.58
Faucets 20%	20%	19.7
Baths 1%	1%	1.0
Leaks and Other 16%	16%	15
Total Indoor	**100%**	**96.7**
Outdoor	**16%**	**20**
Total End-Use		**117**

Specific water saving resulting from the Standards plumbing code depended on the demographics of the city and its current share of low, medium, and high flow fixtures in existing dwellings and businesses buildings.

6.4 Baseline Water Demand Forecasting

The without conservation trend forecasting water demand is without water saving due to the existing plumbing fixture standards code ,while the baseline water demand forecasting incorporates future reduction in indoors use as a result of continued implementation of the existing plumbing fixture standards code. The natural replacement of efficient plumbing fixtures is expected to reduce future water demands by 7% in 2040. Figure 6-1 and Table 6-5 provides comparison of the demands considered "baseline" and this demand based on trend without conservation and demand management. Additional information regarding the water demand forecasting by customer categories is provided in DSS model computation for water demand forecasting in Appendix B.

Figure 6.1: Baseline Water Demand Forecasting

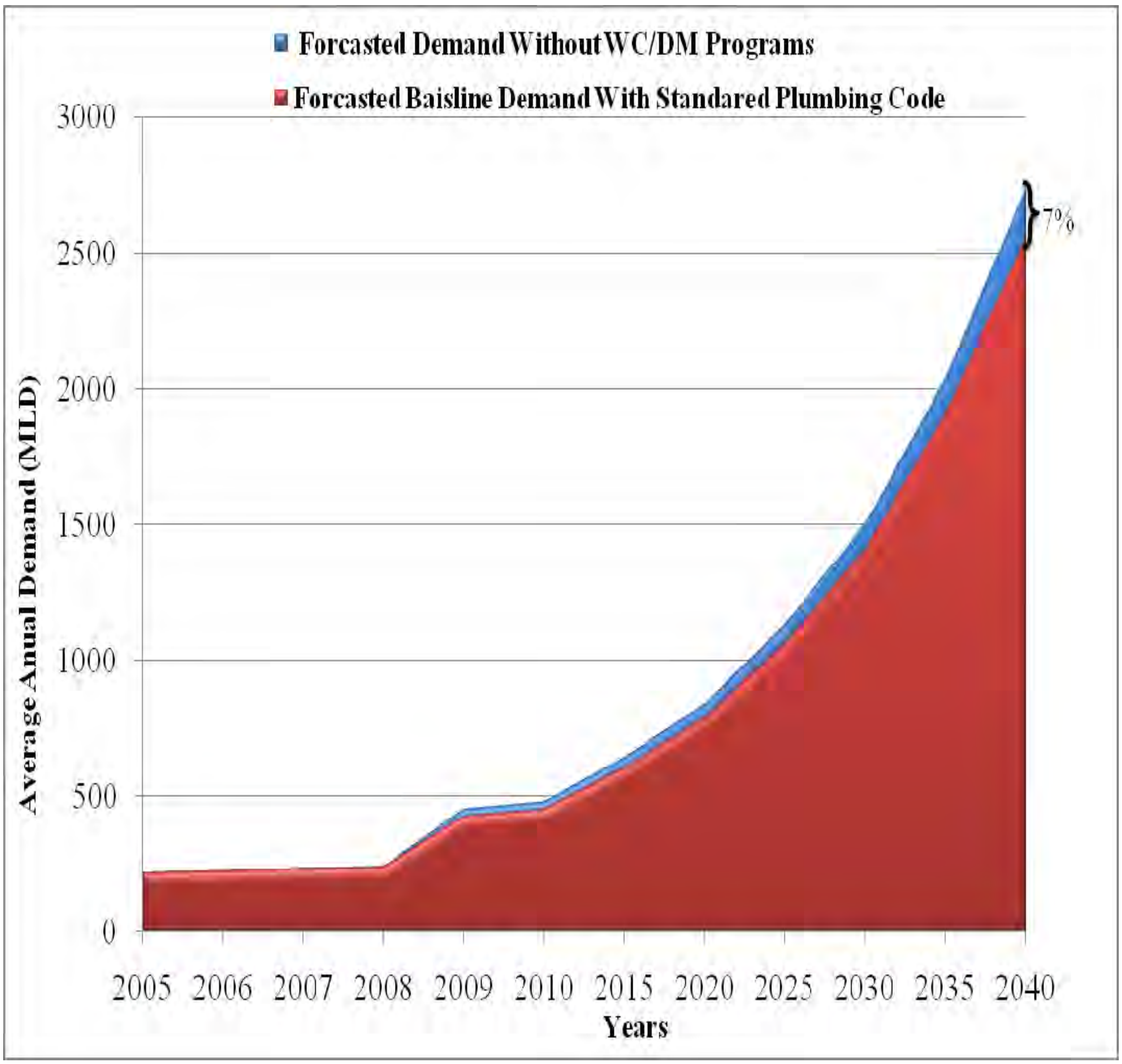


Table 6-5: Baseline Water Demand Forecasting

Years	Forecasted Demand Without Conservation and Demand Management (MLD)	Forecasted Baseline Demand (MLD)
2009	454	430
2010	481	455
2015	643	607
2020	840	791
2025	1132	1065
2030	1502	1409
2035	2038	1910
2040	2735	2559

CHAPTER SEVEN

7. Water Conservation and Demand Management Analysis

7.1 Structure of DSS Model

The Least Cost Decision Support System (DSS) model, as described in chapter4, is developed and used to analysis the quantitative water conservation and demand management measures.

The DSS model utilizes the market potential data and the variables associated with implementation and water savings for each conservation and demand management measure. In addition to these data, the DSS model also uses data generated by the water demand forecasts for retail customer to arrive at the costs and benefits of implementing the individual conservation measures. The data include information on projected water use for customer-billing categories (water user groups) and end-use assumptions. The end-use assumptions provide estimates on how much future water will be consumed by different indoor plumbing fixtures and outdoor use. These assumptions are based on a 2009 base-year water demand for retail customer. In essence, water use for the base year 2009 is broken down into indoor and outdoor use and then by end use (i.e., toilets, showers, clothes washing, etc.) as described in detail in Chapter 6.

These data are important to the water conservation and demand management analysis, as the data provide a baseline from which water saving form that each water conservation and demand management measure can be estimated. Using these three types of data, the DSS model estimates the potential for water savings in the future as a result of a specific water conservation and demand management measure and calculates associated costs and benefits through the following key steps:

- Calculate the water savings for each year that the water conservation and demand management measure is implemented. This is accomplished by using the end-use estimates in the water demand forecast, the unit water savings and market penetration.

- Calculate the cost of the measure for each year the measure is implemented. This is based on the number of participating accounts and the unit costs.

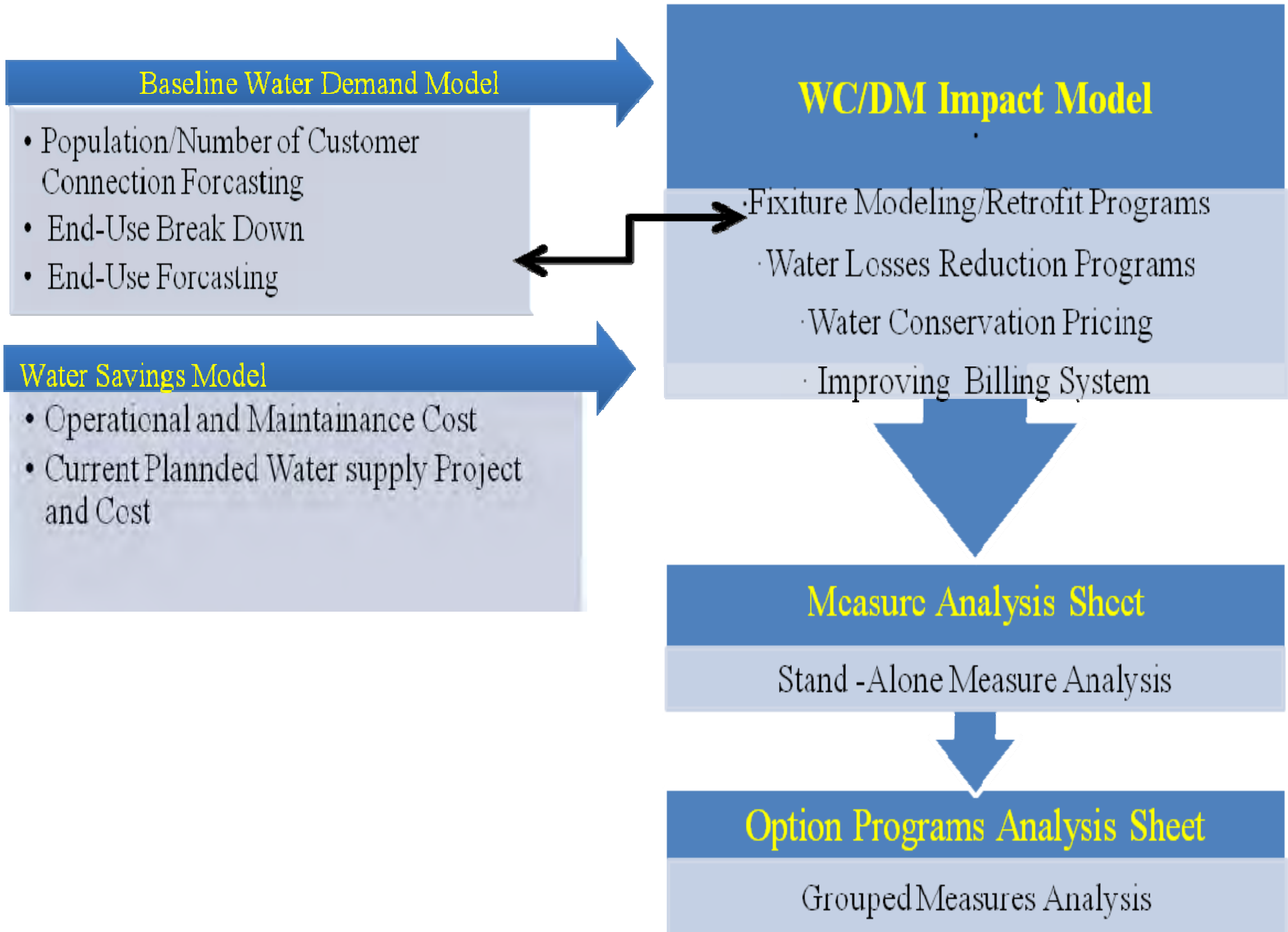


Figure 7.1: Structure of DSS Model

7.2 Benefit-Cost Analysis

Table 7-1 shows the analysis result of individual water conservation measures for the Addis Ababa City. This table presents the estimated water savings for each conservation measure, how much each would cost and the benefit-cost ratios for each of the measures considered on a stand-alone basis, i.e. without interaction or overlap from other measures that might affect the same end use(s). Note that water conservation measures with benefit-cost ratios less than 1.0 have a negative Net Utility Benefit. Water savings shown are averaged over the 30-year analysis period. Other key statistics include the cost of water saved in birr per million litre (birr/MG), and the benefit-cost ratios.

Table7.1: Analysis Results of Individual Water Conservation and Demand Management Measures

Conservation Measures	Present Value of Water Utility cost (Million Birr)	Present Value of Total Community cost (Million Birr)	Average Water Saving (MLD)	Present value of Water Savings (cost) Birr/ML	Present Value of Utility Benefits (Million Birr)	Present Value of Total Community Benefits (Million Birr)	Water Utility-Benefit-cost Ratio	Total Community Benefit-cost Ratio	2040 Water Savings
1.Replace Older Inefficient Toilet Fixtures	165	231	5	2,976	290	319	1.8	1.4	153
2.Water Loss reduction(Assessment & Leak Detection/ Repair	68	68	25	245	1,447	1,447	21.3	21.3	192
3.Distributing Low flow Showerhead and Faucets	37	37	2	1,773	110	121	3	3	21
4.Instaling low flow Toilets and Urinals	522	691	15	3,105	878	2390	2	3	152
5.Establishing Conservation water Pricing and improving billing system	70	70	139	46	7,930	7,930	114	114	1,261
6.Cloth Washer Rebate	88	202	3	3,036	152	183	2	1	25

1. Present Value Calculated Using 3% Interest Rate
2. Annual Water Savings Average Over 30 Year Study Period.
3.2040 Water Savings Represent Water Savings Realized in the Year 2040

7.3 Water Conservation and Demand Management Option Programs

Table 7-2 provides a short description of the 6 water conservation and demand management measures option programs in which they were placed. Three option packages were designed to accomplish an increasing level of water savings. The DSS model is used to quantify the interaction between measures in terms of water savings and benefits to estimate the combined savings and benefits from the three best option packages. This analysis was performed at the city level and then aggregated to the city level

Table 7-2: Descriptions of the WC/DM Measures Evaluated Quantitatively

WC/DM Measures		Applicable Category	Distribution Method and Incentives	Description	Programs A	Programs B	Programs C
1	Replace older, Inefficient toilets fixtures	Existing Indoor - Residential	City/Addis Ababa Water and Sewerage Authority	To speed the conversion of older, inefficient toilets towards current lower flow models, Addis Ababa Water and Sewerage Authority will be required to implement a program targeting the replacement of older plumbing fixtures. Low flow fixtures are defined according to current plumbing fixture standards of double flush toilet 6/3 or 4 litre per mine	✓	✓	✓
2	Water loss reduction	City Water and Sewerage Authority	Addis Ababa Water and Sewerage Authority	Addis Ababa Water and Sewerage must identify methods to reduce leakage in their systems, and to reduce unbilled water. AAWSA should perform a distribution system water audit based on the International Water Association/American water work Association (IWA/AWWA) methodology, in order to maintain uniform assessments of leakage and set targets at the economic level of leakage.	✓	✓	✓
3	Distribute Low flow showerheads & aerators	Existing Indoor - SF Water	Addis Ababa Water and Sewerage Authority	Addis Ababa Water and Sewerage Authority will distribute low-flow Retrofit kits to customers. These kits could include low-flow showerheads, faucet aerators, and other applicable retrofit items. The kits would be distributed to the portion of the service areas that have pre-2000 G.C built homes.	✓	✓	✓
4	Establish Conservation water pricing and improving billing system	City / Addis Ababa Water and Sewerage Authority	City/ Addis Ababa Water and Sewerage Authority	Rates Implement or modify rate structures to provide increasing block-water tariff rate as shown in chapter 7; section 5 that charge customers more per unit for higher use. New billing system is required to update existing billing software of AAWSA		✓	✓

5	Installation of low flow toilets and urinals in business and institution buildings	Existing Indoor - CII	Addis Ababa Water and Sewerage Authority	Addis Ababa Water and Sewerage Authority will Install low toilets and urinals in business and institution Buildings Replacements would include urinals flushing with double flush toilet 6/3 or 4 litre per mine and 3.8Lpf for urinal		✓	✓
6	Efficient Clothes Washer rebates	Existing Indoor – RSF,RMF &CII	Addis Ababa Water and Sewerage Authority	Addis Ababa Water and Sewerage Authority would offer a rebate for the purchase of an efficient Clothes Washer until such time as they are required to be sold in the market			✓
Total					3	5	6

Lpm= Liter per minute

Lpf=Liter per flush

RSF= Residential Single Family

RMF=Residential Multi-Family

CII=Commercial, Industrial, Institutional

Selection criteria for the water conservation and demand management measures in each option package included the following, by program:

- Program A includes the current water conservation and demand management measures practices from other water utilities
- Program B includes Program A measures plus two new additional measures
- Program B is designed to be the midpoint program and includes cost effective measures that are able to conserve significant amounts of water.
- Program C includes all the quantitative measures presented in Table 7-2.

7.4 Analysis Results of WC/DM Option Programs

Table 7-3 presents key evaluation statistics compiled from the DSS models.

Assuming all measures are successfully implemented, projected water savings in MLD are shown for 2040, as are the costs to achieve this water demand reduction. The costs are expressed in two ways: total present value over the 30-year period and the cost for each million litre of water saved. The benefits are calculated based on the avoided costs from downsizing and postponing the need of developing new water sources and infrastructure through implementation of the recommended water and demand management measures B .The present value of benefit of 106,550 million birr (from Table7.3) is compared to the present value of cost of 862 million birr (from Table7.3) that required for implementing the recommended water conservation and demand management program B.

This shows the present value of benefits from water conservation and demand management would be significantly more than the present value of water utility /AAWSA costs. Benefit-cost ratio for the water conservation and demand management is 120. Cost of water saved is 8,145birr/ML which is less than the cost of developing new deep wells of 300,000birr/ML by AAWSA.

Table 7-3: Analysis Results of Option WC/DM Programs

Conservation Option programs (includes plumbing code)	2040 Water Savings (MLD)[1]	Water Savings as a percent of 2040 Without Conservation Trend	Present value of Water Utility Costs (Million birr)	Present Value of Utility Benefits (Million Birr)	Cost of Water Saved (biir/ML)	Water Utility Benefit-Cost ratio
Program A	366	14%	270	18,470	4,994	70
Program B	1,779	66%	862	106,550	8,145	120
Program C	1,805	66%	950	108,070	1,1181	110

Present Value is determined using an interest rate of 3%
Programs A, B and C include plumbing code savings
Cost of water saved is present value of water utility cost divided by total 30-year water savings.
1. Includes non-revenue water reduction savings

The 66 percent water savings in Table 7-3 reflects only conservation and demand management beyond 2009. Figure 7-2 shows the cost of the three option programs versus the amount of water saved for each water conservation and demand management program.

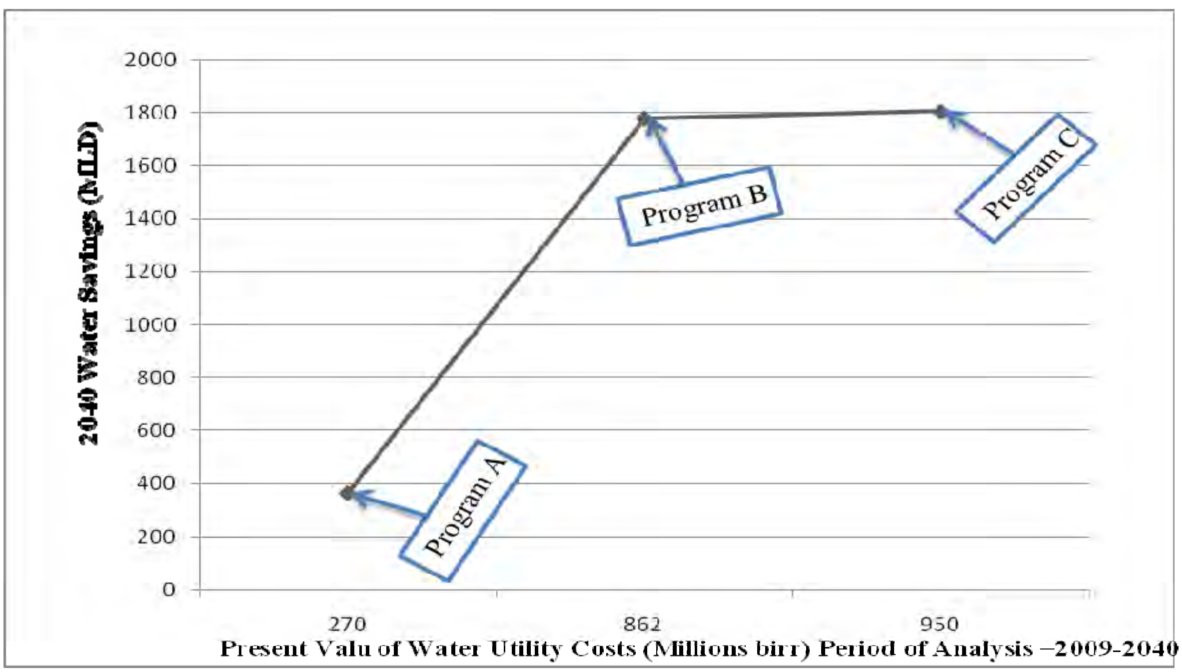


Figure 7-2: Present Value of Three Water Conservation and Demand Management Option Programs

7.5. Recommended Water Conservation and Demand Management Programs

Water Conservation and Demand Management Program B was selected as the recommended program. Although all three water conservation programs were evaluated as cost effective for the Water and Sewerage Authority of Addis Ababa, Program B represented an approach that would be widely accepted. This aggressive water conservation program will achieve significant savings and maximize returns on investments in the program. Implementation of Program B realizes the majority of the water savings available while Program C requires spending 10% more (or 88M birr) to gain less than 26MLD of additional water savings. Implementing the measures in Program B provides additional water conservation benefits on the foundation provided by the current measures without exceeding the number of measures that Addis Ababa Water and Sewerage Authority can realistically implement. However, the additional measures in Program C may be held in reserve for implementation as substitution measures if one or more of the measures in Program B is determined to either be too difficult to implement, or if expected water savings do not materialize.

The following five measures are included in the recommended water conservation and demand management program B. A description of each of measures is provided below.

7.5.1 Replacing Older, Inefficient Toilets Fixtures

Homes built in or prior to 1995 may contain inefficient toilets. Before the 1950s, toilets typically used 25 litres or more for each flush. By the end of the 1960s, toilets were designed to flush with 20 litres, and in the 1980s the new toilets being installed were using only 13 litres. Today, a new toilet uses no more than 6/3 litres of water. Replacing an inefficient toilet with a low flow model will conserve water.

Addis Ababa water and sewerage Authority should offer a program to convert older, inefficient toilets to 6/3 litres per flush (lpf) models within their community. AAWSA should implement a strategy to distribute, install, or provide incentive to replace higher flow fixtures on accounts owning pre-1995 built homes. The program must specifically address toilet replacement rather than provide toilet retrofit devices and implementation should begin no later than 2011. Examples of such programs include:

- Rebate incentive program – Customer receives a credit to water bill, cash, or voucher offsetting the cost for a new low-flow toilet.
- Direct install program – Customer exchanges older toilet for a low-flow toilet with discounted installation through the local water provider.

- Other – Any program that provides at least the same rate of replacement as the above examples.

7.5.2 Assess and Reduce Water Distribution System Leakage

AAWSA must identify methods to reduce leakage in their systems, and to reduce unbilled water. The first step is to determine the extent of water losses in the distribution system using the International Water Association (IWA) and American Water Works Association (AWWA) methodology herein referred to as the IWA / AWWA method.

The IWA / AWWA methodology is recommended to quantify and classify non-revenue water because it addresses some of the major problems in estimating system water loss. The commonly used percentage of "unaccounted-for water" method of determining system water loss does not provide a standard for measurement of water use and water loss. The IWA / AWWA methodology defines all uses and losses and is designed to function with different units and measures using a water balance format.

The methodology uses an Excel spreadsheet and is more comprehensive and accurate than previously available tools for water loss calculations. Within IWA/AWWA methodology, no water is considered "unaccounted for", as it is allocated as either a consumption or loss. Water loss programs can then target the most significant categories of losses. The spreadsheet provides benchmark information and allows utilities to easily set performance targets.

AAWSA must establish a goal for reducing the "real" water losses, or those associated with loss through all types of leaks, breaks and overflows on mains, service reservoirs and service connections, up to the point of customer metering. The goal for reducing the real component of water loss will be based on existing water loss, the specifics for the distribution system and the water loss program. The goal for real water loss established by AAWSA will be achieved over the next five years.

The IWA/AWWA identifies the areas of biggest water losses as well as their financial impact.
Based on water loss data, obtain from AAWSA water loss reduction programs are developed that will be beneficial to their particular water distribution system in the city of Addis Ababa.
The following combination of water loss management options programs are recommended to reduce water losses in water distribution of Addis Ababa.

- Improvement of operational sub-systems – water distribution modelling or restructuring to hydraulically isolated sub system, align AAWSA branch boundaries with new sub-system boundaries, improve operational network capability to better distribute water the areas that can hardly supplied at present, installation of bulk meters to measure inflow/ of flow to from the sub-systems.
- Designing and establishing of small hydraulically isolated parts of the distribution network (District Meter Areas- DMAs) consists of 1,000 – 1,500 customer connections each and monitored routinely to produce a pattern for night flow. DMAs enable the identification and location of unreported pipe break and leakage or real losses .All DMAs shall be equipped with an inflow meter, a pressure reducing valve and pressure logger. Totally 300number of DMAs is required to design and establish for the whole water distribution system of the city of Addis Ababa. The costs for designing and establishment of one DMA estimated about 675,000 birr. One fifth of water distribution system or 60 numbers of DMAs (District Meter Areas) assume to be established, leakage detection and repair carry out over each year.
- Use leak detection equipment (sonar) and software to identify leaks. There are several different types of leak detection equipment on the market, ranging from hand- held listening devices to permanent and semi-permanent devices that are placed within the system to record leaks at low demand times (such as early morning hours, 3 am). Proactive leak detection programs have been successful in the leakage management pilot areas launched by Addis Ababa Water and Sewerage Authority in finding minor leaks that are not usually found, and can result in significant water losses reduction.
- Establish a strategy for prioritizing leak repairs. Although main breaks require swift response time, losses on smaller lines deserve as much or more attention, as small losses over long periods of time may result in significant losses.
- Conduct meter calibration and/or replacement program. Older meters should routinely be checked for accuracy. Faulty meters almost always underestimate the amount of water used, resulting in significant amounts of non-billed water.
- Manual meter reading and data transfer is anticipated to be a major source of errors .the introduction of electronic, hand-held meter reading device is essential. A barcode that will be clued on each customer meter must be scanned by the meter reader and only then it is possible to enter the reading. Office fabricated reading will not be possible anymore. Data transfer from the device to the billing system is done electronically another source of error is eliminated. Change the present, billing software with new billing software that has interface and compatible with the software of the meter reading equipment.

- Maintain an asset management program to track aging pipes and meters with a schedule for planned replacement

7.5.3 Distribute Low-Flow Shower Heads and Faucet Aerators to Residential Users

Retrofit kits are intended to target portions of the service area with homes built before 1995. AAWSA may advertise the availability of retrofit kits, direct mail, distribute at festivals, or other forms of distribution. A low-flow retrofit kit is a package of water saving devices that can assist residents to save water at home and typically includes low-flow showerheads, faucet aerators, and other applicable retrofit items. It is important to promote water conservation in the home due to the fact that 31percent of water used in the city occurs in the home. The distribution of low-flow retrofit kits can accelerate the natural conversion of less efficient plumbing fixtures.

The recommended water conservation retrofit kit currently contains 5 products including a low flow showerhead, a kitchen aerator, a low-flow faucet aerator, leak detection dye tablets and a flow meter bag. AAWSA should tailor their kits toward their customer base.

Detailed product descriptions are provided below.

Low-Flow Showerhead: A highly efficient showerhead uses7.6 litres/min. The showerhead uses air pressure instead of extra water to provide water at a comfortable rate. Low flow showerheads provide an even spray pattern and may also offer a variety of spray patterns.

Kitchen Faucet Aerator: A highly efficient kitchen aerator provides an even spray pattern at 7.6 litres/ minute.

Low-Flow Lavatory Faucet Aerator: A highly efficient faucet aerator provides an even spray pattern at 3.8 litres s/min.

Leak Detection Dye Tablets: The leak detection dye tablets provide a way to check for leaks in toilets.

Flow Meter Bag: The flow meter bag helps with measuring the flow from a showerhead or faucet.

7.5.4 Conservation Water Pricing and Improving Billing System

7.5.4.1 Conservation Water Pricing

Payment for water services is an important issue and one that causes problem in many areas. Without a reasonable level of payment for water, water supplier will eventually fail and the water system will fall into disrepair, require massive injection of capital. Customer must therefore pay for water services to ensure sustainable and equitable development, as well as efficient and effective management thereof.

The water tariff structure should be realistic and generate adequate revenue to fund operations, capital expenditure and repayment of loans and should be structured to include, amongst others, the following:

- Recovery of the cost of water purchases;
- Recover of overheads including operational and maintenance costs
- Provision for the replacement, upgrading and expansion of water services

The old water tariffs in Addis Ababa are perverse, providing an increasing subsidy as more water is used. Under the proposed new tariff structure, an “assurance of supply charge” was instituted to deliver the message that a tariff was needed to cover the fixed costs arising from having a supply of water on tap. This charge was levied as a three-tiered tariff because of city’s great disparity between rich and poor. The average winter use, which is the basis of the conservation tier, is calculated by the billing system for the residential customer category. Outdoor water is typically not used during the winter months so the average winter use reflects baseline indoor water use. The lowest tier was calibrated against average winter single-family residential water use numbers.

As estimated in the water demand or end-use modelling part in chapter 6, a typical single-family winter use of 130 litres per capita per day or $20m^3$ per single-family account per month, internationally, is common for conservation water use estimates. Once the winter use baseline is determined for the residential customer category, the first tier rates was established.

The rate of 30 birr per month was levied for the period 2030–2040 for the typical consumer (called economic tariff). The charge of 3 birr per month was levied for those indirect financial situations (called the indigent tariff), while an intermediate rate of 12 birr per month was charged for sub-economic households.

A 6-point increasing block-rate tariff is developed, based on the principle that those who tend to drive the marginal cost of water upwards should be charged at the marginal rate (Table 7.4). While the assurance-of-supply tariff depended on the income level of the household, the block tariff did not. However, in keeping with the overall national goal of using the water sector to promote social stability, the lower end of the tariff scale (the life-line tariff) was set to be affordable to all consumers.

Table 7.4: Proposed New Water Tariff for Addis Ababa City

Cubic Meter Range	Cost (birr) Per Cubic Meter	Total Cost*
0-7	2	0-14
8-20	3	14-39
21-100	6	39-519
101-300	9	519-2,319
301-500	12	2,319-4,719
Over 501	12^{+}	4,719-

**Note:* (Add birr 3.00, 12.00, 30.00 assurance-of-supply charge for indigent, sub-economic and economic users respectively

7.5.4.2 Improving Billing System

New billing software is required to update existing billing software of AAWSA, as existing billing software is replaced it should include certain functionality to facilitate conservation.

Functionality that should be available in new billing system packages in the city of Addis Ababa include:

- Ability to sub-divide customers into the following customer categories; single-family residential, multi-family residential, commercial, industrial and institutional.
- Include both current and historical water use information on bills.
- Include an explanation of the conservation pricing. This information will allow the customer to set goals for water use to avoid the top pricing tier.
- Clearly identify the billing units, with preference given towards cubic meter-based units. Most customers are familiar with cubic meter as a unit of measure and less familiar with other units.

The increased billing functionality over time will provide water customers in the city of Addis Ababa with more information to make water use choices. Additionally, the proper classification of customer categories will assist with future forecast updates as well as the future evaluation of the benefit of the city conservation program.

7.5.5 Install Low-Flow Toilets and Urinals in Government and Business Buildings

AAWSA should demonstrate leadership in practicing water conservation and demand management. Replacing inefficient fixtures with high efficiency fixtures in government and business buildings not only conserves water for the local government, it provides an opportunity for public awareness and education. High efficiency replacement fixtures include HET toilets, 6/3 lpf double flush or less, and high-efficiency urinals, 3.8 lpf or less.

This measure focuses on government and business buildings and includes public administration buildings, AAWSA's administration buildings, public libraries, and court buildings.

7.6. Future Water Demand and Supply Forecasting With Recommended WC/DM Program

By 2040, the city's water demand without and with the implementation of the recommended water conservation and demand management program B will approach 2,735MLD and 903MLD respectively. The 2009 available water supply is 263MLD; therefore, to meet the shortfall and the projected future water supply needs in the city of Addis Ababa through 2040 about 2,435MLD and 630 MLD additional water sources will be needed without and with the implementation of the recommended water conservation and demand management program B respectively.

This shows, adaption and implementation of the recommended water conservation and demand management measures B would reduce the city's future water demand or water saved by 66%, postpone up to 2020 year and downsize the need for developing new water sources and infrastructure for meeting the shortfall supply and projected future water demand through 2040. Figure 7-3 and Table 7-5 shows a graphical representation of how the recommended water conservation and demand management option programs B would reduce overall water demands, downsize and postpone the need for developing new water sources and infrastructure in the Addis Ababa City through 2040. Additional information regarding the water demand forecasting that includes the effects of the recommended water conservation and demand management is provided in DSS model computation for water demand forecasting in Appendix B.

Figure 7-3: Addis Ababa Annual Average Day Demand and Supply Forecasting With Recommended WC/DM Program (2009-2040)

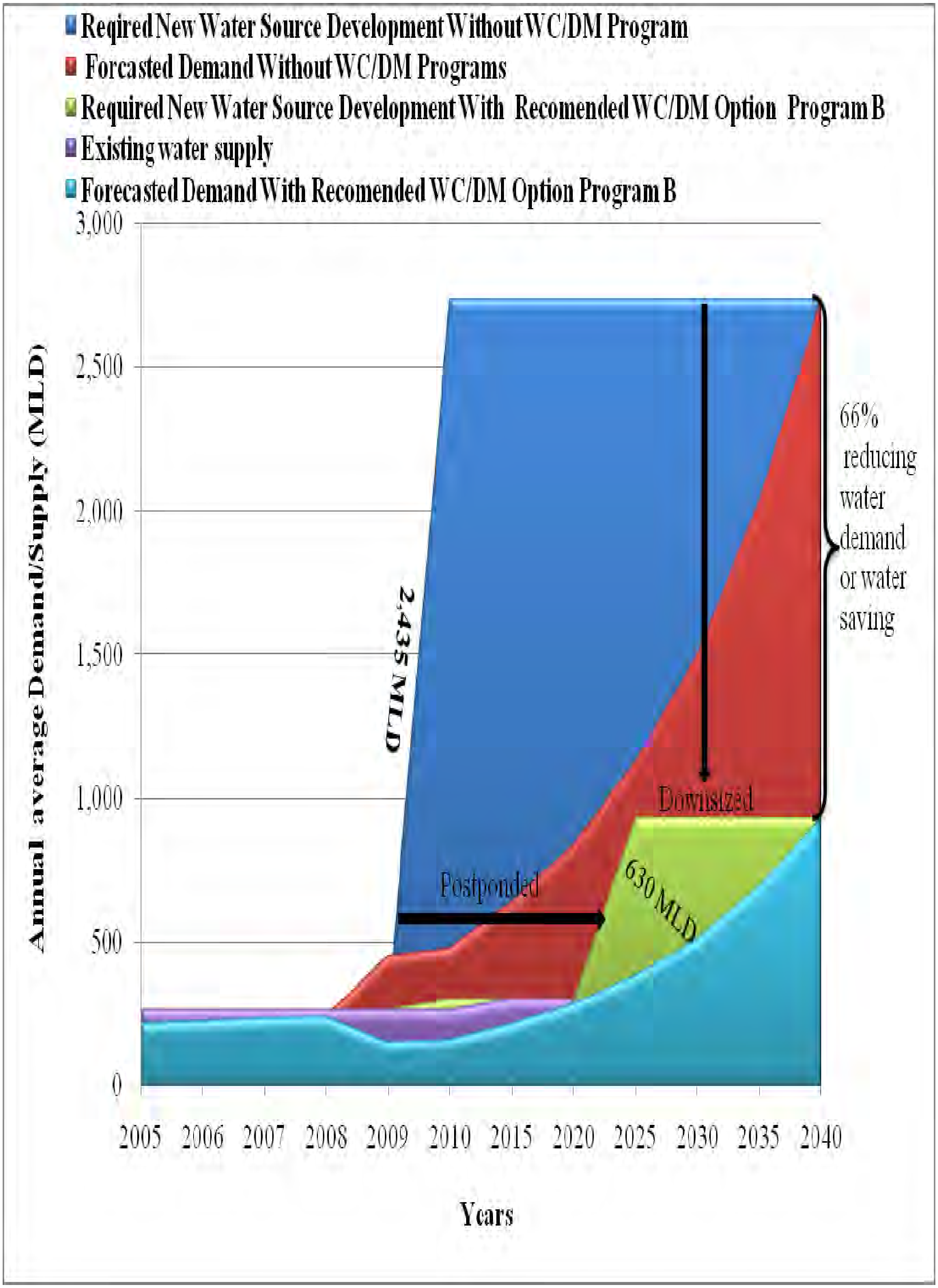


Table7-5 provides the 2009-2040 average annual day water demand and supply forecasting for the city of Addis Ababa including the effects of the recommended water conservation and demand management program B

Table 7-5: Annual Average Day Water Demand and Supply Forecasting With Recommended WC/DM Program for City of Addis Ababa (2009-2040)

Years	Forecasted Water Demand Without WC/DM (MLD)	Forecasted Baseline Water Demand (MLD)	Forecasted Water Demand With Recommended WC/DM Program B (MLD)	Required New Water Source Development Without WC/DM (MLD)	Required New Water Source Development With Recommended WC/DM Program B (MLD)
2009	454	430	154	191	
2010	481	455	164	181	
2015	643	607	219	343	
2020	840	791	286	540	
2025	1132	1065	385	832	85
2030	1502	1409	511	1202	211
2035	2038	1910	693	1738	393
2040	2735	2559	930	2,435	630

Water conservation and demand management provides economically feasible and environmentally sustainable solution for meeting the shortfall supply and projected future water demand in the city of Addis Ababa. By the year 2040 the implementation of recommended water conservation and demand management could reduce water demand by 1779 AAD-MLD or 66% water savings. This can be achieved by replacing older plumbing fixtures with efficient one, reduction of water losses through system leakage detection and elimination programs and establishing water conservation and improving billing system.

The environmental sustainability of water conservation and demand management option is reducing the waste water generated from household and buildings to sewerage system or the environment.

CHAPTER EIGHT

8. Conclusions

This research develops water demand or end-use modeling and forecasting and assesses the water conservation and demand management potential for the city of Addis Ababa.

To achieve the goal, IWA/AWWA's water loss analysis software is used to determine the extent water losses in the water distribution system of the city and economic leakage reduction model software used to identify when or at what frequency AAWSA should send leak detection and repair crew into an area to find unreported or invisible leaks and to determine an ''economical leakage level'' or the saving achieved from implementation of the recommended water loss reduction program.

The ''Demand Side Management Least Cost planning Decision Support System'' (DSS) model is developed and used for water demand forecasting and assessing water conservation and demand management potential in the city of Addis Ababa. DSS model is Microsoft Excel based application model.

Instead of following the trend, by developing a new water sources, adapting and implementing water conservation and demand management provides economically feasible and environmentally sustainable solution for meeting the shortfall supply and projected future water demand for the city of Addis Ababa.

The water losses assessment conducted in this research has shown that the current non-revenue water (NRW) level in the water distribution system in the city of Addis Ababa is 38.2Million m^3/year (39.5% system input volume). Of the total NRW, the physical losses are 27%, the commercial/ apparent losses 10.5% and unbilled authorized consumption 2%.

The economical leakage reduction model result is indicated that 5.7ML/year or 10% of the water losses is an ''economical leakage level'' or a 29.5% of savings by the implementation of the recommended water loss reduction programs in city of Addis.

The end-use modeling and forecasting has identified the city average water use in per person per day of 117 and projected water demand of 840, 1502 and 2735 MLD by 2020,2030, and 2040 respectively.

Three water conservation and demand management programs are identified for the city of Addis Ababa, each with varying degrees of water savings and costs. The current adopted water conservation and demand management measures provided the backbone for each of these programs. Program A was composed of the 3 existing water conservation measures to provide a benchmark for the analyses. Program B was composed of Program A plus 2 additional water conservation measures. Program C is comprised of all evaluated water conservation measures.

Water conservation and demand management program B is selected as the recommended program. Although all three water conservation and demand management programs are evaluated as cost effective for the Water and Sewerage Authority of Addis Ababa, Program B represented an approach that would be widely accepted. This aggressive water conservation and demand management program will achieve significant savings and maximize returns on investments in the program. Implementation of Program B realizes the majority of the water savings available while Program C requires spending 10% more (or 88Million birr) to gain less than 26 MLD of additional water savings. Implementing the measures in program B provides additional water conservation benefits on the foundation provided by the current measures without exceeding the number of measures that Addis Ababa Water and Sewerage Authority can realistically implement. However, the additional measures in program C may be held in reserve for implementation as substitution measures if one or more of the measures in program B is determined to either be too difficult to implement, or if expected water savings do not materialize.

With adaption and implementation of the recommended water conservation and demand management program B (replacing older or inefficient toilet fixtures and distributing low flow shower heads and faucet aerators for residential water user, finding and repairing water distribution system leakage, installing efficient toilets and urinals in commercial and governmental buildings and establishing water conservation pricing and improving billing system) in the city of Addis Ababa would reduce the city's future water demand by 66%. This will postpone up to 2020 year and downsize of the need for developing new water sources and infrastructures.

Furthermore, benefit-analysis result of adapting and implementing the recommended water conservation and demand management program B in city provides present value benefit of 106,550 million birr and costs present value of 862 million birr to Water and Sewerage Authority of Addis Ababa (AAWSA). The benefit-cost ratio is found to be 120. The cost of water saved is 8,145birr/ML which is less than the cost of developing new deep wells and operation and maintenance cost of 300,000birr/ML by AAWSA.

Therefore, water conservation and demand management provides economically feasible and environmentally sustainable solution for meeting the shortfall supply and projected future water demand in the city of Addis Ababa. The environmental sustainability of water conservation and demand management option is reducing the waste water generated from household and buildings to sewerage system or to the environment.

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Materials available on line

http://WWW.waterloss2007.com/Leakage2005.com

http://www.awwa.org.

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Appendix A: Water Billing and Production Data

Appendix B: DSS Model Computation for Water Demand Forecasting