UNIVERSITY OF NAIROBI

THE IMPACT OF NON-REVENUE WATER ON WATER UTILITIES AND THEIR CUSTOMERS: A STUDY OF NAIROBI CITY WATER AND SEWERAGE COMPANY

By

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Abstract

The purpose of this study was to find out how Non-Revenue Water (NRW) affects water utilities and their customers, by studying the case of the Nairobi City Water and Sewerage Company (NCWSC). NRW is the water produced by a water utility that is lost and does not earn any revenue for the utility. The NCWSC is estimated to lose about 40% of the water it produces annually.

These losses affect the NCWSC by denying it a significant portion of the revenue it should earn from the sale of water. It also prevents it from adequately serving its customers' water needs, and subsequently leading to loss of reputation and goodwill from the customers.

The losses also affect the customers. This is because water losses lead to rises in price of water as the water utility tries to recover the lost revenue by charging a premium on the paying customers. Inadequate water supply also forces customers to look for other water sources such as donkey cart vendors and water bowsers (trucks), which leads to a further increase in expenditure for their water needs. In addition, such alternative sources are not subjected to proper water quality standards, meaning that they pose a health risk.

Due to the negative effects, water utilities worldwide employ measures to ensure that water losses are minimal. The NCWSC, in its Strategic Master Plan (2015/16-2018/19), plans to invest KShs 3.2 billion to reduce NRW from 40% to 16%. This will be through improving its water networks and revenue collection mechanisms, while continuously monitoring performance to ensure that gains are being made.

This study found that by carrying out the master plan, the NCWSC would not only reduce its losses, but would also earn about KShs 2.8 billion after recovering the costs of reducing water losses. This significant increase in revenue would be beneficial to the NCWSC as it could reinvest it in programmes which improve its capacity to provide water to Nairobi residents. This would in turn reduce the problem of inadequate water supply, benefitting the NCWSC and its customers. The study therefore concluded that there is need for a sustained effort and strategy to reduce NRW.

Dedication

This dissertation is dedicated to my family and friends for being my main source of inspiration and support throughout my endeavours.

Acknowledgements

I would like to express my gratitude to all that made this project possible. Special thanks go to my supervisor, Dr. Peter K. Ndiba for his insight, suggestions, and help in accessing some of the data needed in the study.

I would also like to thank the staff at the Nairobi City Water and Sewerage Company for their immense help in data collection, especially Mr. Anthony Muchiri of the Non-revenue Water Department. Their warm welcome during my many visits there, their valuable insight into the subject matter, and their patience during my interruptions of their working hours have been of immense help during this study.

I would also like to thank my family and friends who helped me in administering the questionnaires needed in the study, both as subjects, and as a link to the other customers. With their help, the study took much less time and resources to carry out.

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Chapter One: Introduction

1.1 Background Information

Water Service Providers (WSPs), or Water Utilities, are entities charged with the provision of water and sewerage services in many countries including Kenya. Their main mandate involves acquiring the water from the source, treating it to make it potable and fit for human usage, storing it, transporting it to the end-users, then billing the users based on usage tariffs and amounts used. This being a money-intensive endeavour, WSP's depend on income from billing to carry out most of their functions.

The operations of these water utilities are however affected by inefficiencies, because not all of the water that they produce translates into revenue through billing. This unbilled water is termed non-revenue water (NRW). NRW consists of both water provided for free to some consumers like firefighting departments, and water whose usage cannot be accounted for. Water utilised by firefighters and hydrants is easily tracked and logged through meters, and has been found to account for a very small percentage of NRW. The bigger percentage of NRW is thus caused by the unaccounted for water, or water losses.

Water losses are classified into two main components; namely, physical and commercial losses. Physical losses are those caused by leakages of water throughout the utility's physical infrastructure, from the storage reservoirs to the pipes. Commercial losses are those caused by inaccurate billing caused by metering inaccuracies. Water losses are usually expressed as a percentage of the total water produced by the utility over a certain time period. These represent both a loss of revenue for the water utilities, and lower level of service for their customers due to inadequate water provision.

The Nairobi City Water and Sewerage Company, NCWSC, is the utility tasked with water provision in Nairobi. Some estimates place the level of NRW in Nairobi at about 40% (NCWSC, 2014). This is much higher than the best practice levels of below 25% recommended by World Bank. The aim of this study was to establish the causes of these high levels of NRW, and to assess its impact on both the NCWSC and its customers.

1.2 Problem Statement

Non-revenue water is a serious issue for water service providers (WSPs). Because WSPs require money to run, it is important that their costs are recouped, and if possible exceeded, through the revenue they earn by billing the water they produce to their users. The higher the NRW, the less the revenue collected, which seriously impacts the operations of WSPs.

For example, in 2012/13, NCWSC produced about 190 million cubic metres of water (NCWSC, 2014). 40% of this translates to about 76 million cubic metres of water lost. This loss could be considered in several ways:

(i) Lost revenue for the NCWSC.

(ii) The reduced level of service as there is less water to supply to consumers.

(iii) Reputation loss for NCWSC due to failure to satisfy water demand.

The customers of the water utility also suffer because of these water losses. Since there is less water being supplied, many of them are unable to get adequate water for their needs from the water utility. This leads to them seeking alternative water sources such as donkey vendors and water bowser suppliers, which are expensive and whose water is of dubious quality standards. In addition, the water they get from the utility is more expensive as the utility tries to recover its losses by overcharging the paying customers in their bills.

Non-Revenue Water therefore has a steep financial impact on water utilities and their customers, and needs to be studied extensively and managed effectively in order to reduce its negative effects.

1.3 Objectives of the study

The overall aim of this study was to evaluate the impact of the problem of Non-revenue water in Nairobi County, on both the NCWSC and its customers. The specific objectives of the study are:

1. To find out the extent of Non-revenue water experienced by NCWSC.
2. To establish the causes of NRW, and classify them into physical and commercial losses.
3. To evaluate the impact of these losses on both the NCWSC and its customers.

1.4 Scope of the study

The study focused primarily on data from the Nairobi City Water and Sewerage Company, (NCWSC). The company has divided Nairobi area into seven zones, namely: Northern, Eastern, Southern, Western, North-Eastern, Central, and Informal Settlements. The data analysed was on water production, billed volume, and billed revenue amounts for the months of July to December 2015. At the time of the data compilation by NCWSC, the Informal Settlements Region was not yet formed, so the data was from the other six regions.

A number of customers, 10 from each region (totalling 60), were interviewed by means of a questionnaire. The questionnaire focused on issues the customers go through with regards to obtaining enough water for their daily needs, and their opinion on how the NCWSC is carrying out its mandate. It also sought to find out the level of awareness of the issue of water losses and Non-Revenue Water among the customers.

Chapter Two: Literature Review

2.1 Introduction and legal framework

Provision of water services in Kenya is governed by the Water Act of 2002. The Act separated the functions of water policy formulation, water resources management, and the provision of water and sewerage services and gave separate entities to manage each. The Ministry of Water was left to manage policy, while water resources were to be managed under the Water Resources Management Authority (WRMA). The Water Services Regulatory Board (WASREB) was mandated to regulate the provision of water and sewerage services. In order to do this, WASREB licences all public and private entities providing water and sewerage services in Kenya.

Each region in Kenya was placed under a water services board, which is licenced by WASREB to provide water and sewerage services. Nairobi County was placed under the Athi Water Services Board. Water services boards are allowed to contract out their functions to bidders who then provide the services to customers on their behalf. The Athi Water Services Board contracts the function of service provision in Nairobi to the Nairobi City Water and Sewerage Company (NCWSC). NCWSC is a wholly owned subsidiary of the Nairobi City County. As a water service provider, the NCWSC is contracted to:

- Provide water and sewerage services.
- Operate and maintain their facilities.
- Ensure that they comply with quality standards and service levels.
- Billing and revenue collection for the services rendered.

2.2 Overview of the activities of NCWSC in water provision

Out of Nairobi's three million residents, only about 50% have direct access to tap water. The rest, usually the poor in informal settlements, usually get their water from illegal piped connections (spaghetti networks), water kiosks, and water vendors (mostly donkey cart vendors) (NCWSC, 2014).

Some residents have access to private means of water supply. In Runda, the private Runda Water Company provides water to residents in the area (Wikipedia, n.d.). Some residents and entities also sink boreholes to supplement their water supply, for example the University of Nairobi. The rest of the residents are wholly served by the NCWSC. However, water supply is erratic, and only about 40% of them receive water on a 24-hour basis (NCWSC, 2014).

To achieve its mandate, the NCWSC has to source the raw water, transport it to a treatment plant, treat it to make it potable, and store it in reservoirs and tanks, from where it is distributed to consumers via pipes. This is then followed by the billing process, involving meter reading and revenue collection. On the other end, the utility also collects wastewater through the sewer line, and treats it before releasing it to the environment. These steps are outlined in detail below.

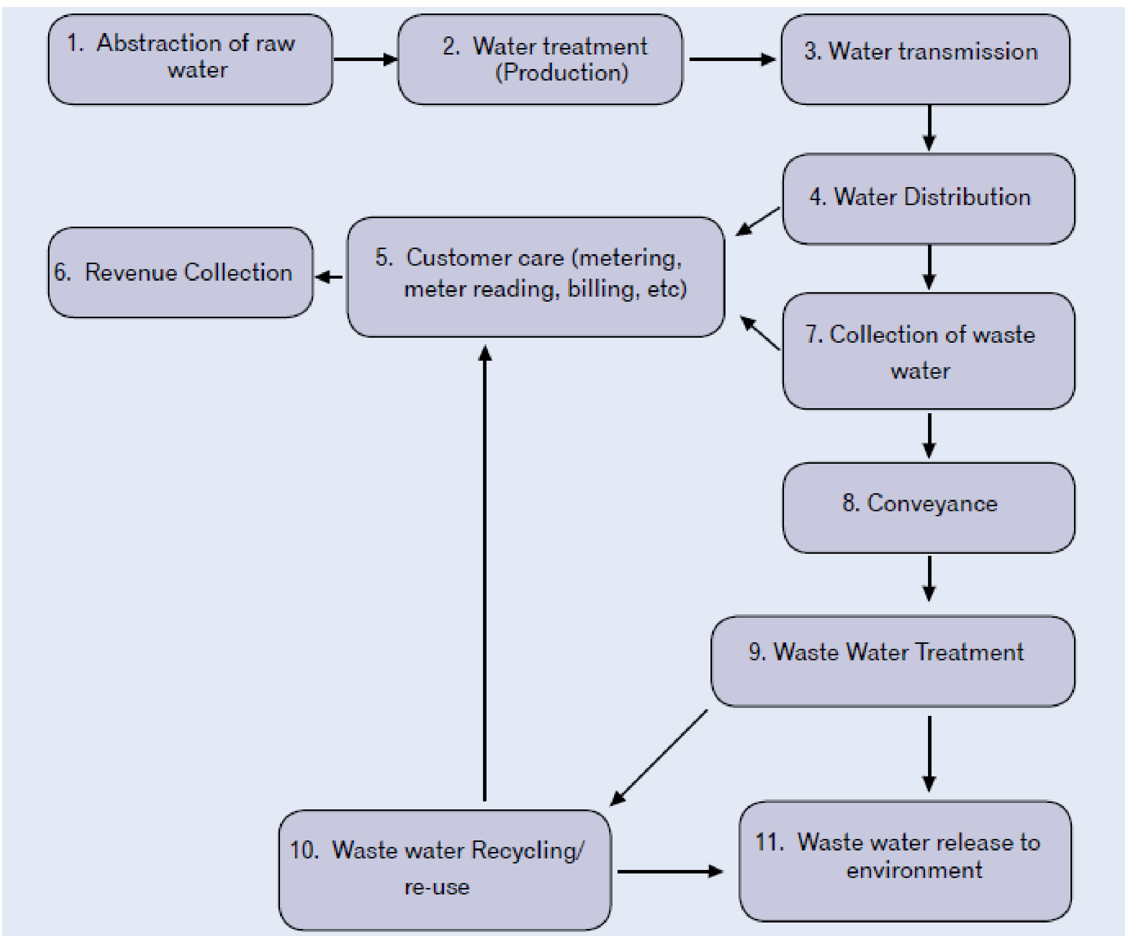

Figure 2.1: Overview of a water utility's main functions (NCWSC, 2014)

2.2.1 Sources of water

Water in Nairobi comes from both surface and underground sources. NCWSC wholly relies on surface water, while the underground water is accessed through boreholes by mostly private entities, some of whom have access to the mains water supply from NCWSC but also use the boreholes as a backup source of water due to erratic supply.

Surface water is mainly sourced from the Tana River Basin, from the reservoirs at Thika Dam (Ndaka-ini), the Sasumua Dam along Chania River, and the Chania-B Dam. This accounts for 94% of the water. The remaining 6% comes from the Athi River Basin, namely the Kikuyu Springs and the Ruiru Dam. (Wikipedia, 2010)

2.2.2 Treatment of water

Water obtained from the various sources is then taken to a treatment plant. The largest water treatment plant is at Ng'ethu. In Kenya, water standards for what constitutes potable water are set by the Water Services Regulatory Board (WASREB). The World Health Organisation (WHO) guidelines on water quality form the basis for the Kenyan standards. The main parameters for assessing water quality are:

1. **Turbidity –** turbidity measures the extent to which the intensity of light passing through water is reduced by the suspended solids in the water. Water should have an acceptably low level of turbidity.
2. **Alkalinity and pH –** this is a measure of the pH of the water. Water should have a pH close to 7 (neither acidic nor alkaline).
3. **Suspended solids –** solids are measured as residue from evaporating the water. They consist of dissolved and suspended solids, and must be kept to a minimum after treatment.
4. **Dissolved oxygen (D.O.) –** this is a measure of the concentration of oxygen in the water.
5. **Hardness –** this is the property of water that prevents lather formation with soap. There is carbonate hardness and non-carbonate hardness.
6. **Residual chlorine, chlorides, iron and other ions –** ions are dissolved in water from the environment.

7. **Bacteria –** this involves the determination of possible faecal contamination of water.

In order to achieve the above standards, a water treatment plant generally subjects the raw water to many treatment processes. The processes generally consist of:

1. **Physical processes –** these are used to remove solid matter in the water. These include sedimentation, screening, filtration, and coagulation and flocculation.
2. **Chemical processes –** these are employed to remove the chemical matter not removable by physical means, like manganese, iron, and hardness. They include chlorination, addition of lime, and alum.

In doing all the above treatments, the water utility incurs costs. Such costs are from power charges, purchase of the chemicals, and maintenance of the equipment/machinery in the treatment plant (Kamau, 2015).

2.2.3 Storage and transportation of water

The other major element of the water provision process is the storage and transportation. Treated water is stored in reservoirs and tanks in Nairobi. The major challenge facing storage facilities is siltation, which decreases their capacity. This capacity reduction results in increased incidences of water overflows, leading to loss of water. Regular desilting is done at the cost of the water utility.

In all the processes, water has to be transported, whether raw water from the source to the treatment plant, or processed water from the treatment plant to the final storage tanks and reservoirs. NCWSC is fortunate, in that the relief of Nairobi is such that the water sources are at a higher altitude than the end users. This means that water flows in the pipes freely by gravity without requiring the use of pumps, which saves a lot on costs. The main challenges facing transportation include aging pipes, which are now prone to leakages and bursts due to weakening over time. The pipes also suffer from sedimentation and other sources of impurities, which affect the quality of the water. NCWSC does not have a proper mechanism of promptly locating and fixing bursts, which leads to excessive losses of water during bursts. Poor pipe security means that along the pipeline, people easily tamper with the pipes to form illegal water networks (spaghetti networks) (WSP, 2005) especially near informal settlements. Such networks affect the quality of water in the mains pipe, while also reducing the pressure of the water required for delivery to customers further on along the grid.

The other major function in transportation of the water is distribution. Distribution networks are designed by engineers and ensure that all regions are served based on water amount requirements (calculated on the basis of population and the income level in the area), adequate pressure to serve areas with many high-rise buildings, and also the relief characteristics of the area, for instance in some areas which are higher than the source location of the water, enough pressure (head) must be provided to ensure the water reaches the people. Distribution requirements also affect parameters such as pipe diameters and material.

2.2.4 Billing and revenue collection

Billing of the water to consumers is the main way water utilities recover their costs. In NCWSC and almost all water utilities in the world, water is a post-paid service. Customers are billed according to how much water they have used. Water usage is determined by meters, which are normally placed at the sites of the water usage (mostly residences). A utility worker goes round reading the bills and recording them monthly. These are then compared to the previous readings and the difference is the usage for the month. In practice, sending people to read bills monthly is difficult, so the utility estimates usage based on previous use patterns. The discrepancies between the estimates and the actual usages are then reconciled periodically.

Once the usage has been determined, the bills are typically sent via post. Recently, one can also check for their bill amount on email and through M-PESA services. The customer then pays a tariff, which is based on the usage. The bill amount typically increases the more the water is used. In June 2009, the first 10 m^3 of water was charged KShs 18.71 per m^3, then the next 20 m^3 (between 11 and 30 m^3) was charged KShs 28.07 per m^3. Above 30 m^3 up to 60 m^3 was charged at KShs 42.89 per m^3. This progressive billing ensures that heavier users pay more as they tend to be better-off financially, reducing the pressure on the poorer consumers. If the residence has a sewer connection, this is billed pegged on the usage of the water, typically at a rate of 75% of the water usage (Wikipedia, 2010).

Revenue collection after billing used to be mainly done at NCWSC offices in the region. However, the advent of mobile payments in Kenya like M-PESA has revolutionised the way consumers pay for their water services. This has also made revenue collection easier as the money goes directly into the accounts, providing easy monitoring of revenue. Serial bill defaulters generally get disconnected, and have to pay an additional reconnection fee, in addition to the arrears, before reconnection. (NCWSC Website, 2015)

2.2.5 Sewerage services

In addition to water provision services, NCWSC also provides sewer services. Not all buildings with a water connection are connected to the main trunk sewer line, which is due to regulation gaps in the county building approvals process, and also reduced capacity of the NCWSC to provide sewers in all locations. From the buildings, raw water is transported to either of the two main wastewater treatment plants in Dandora (which uses the conventional method of treatment), and Ruai (which uses stabilisation ponds). In both these plants, focus is on reducing the biochemical oxygen demand of the water to sufficient levels as agreed with the National Environment Management Authority (NEMA) before discharging it into the Nairobi River. However, the two plants have an arrangement of negotiated compliance, because they are currently not able to meet the required targets for the treated wastewater. Notwithstanding this, the discharge into the river actually dilutes it: this is because the level of effluent in the river is so high, due to uninhibited dumping of wastes by people and industries. NEMA is however working on a programme to improve the river.

Wastewater treatment has many similarities with treatment of water to make it potable, the difference being that the initial quality of wastewater is so poor that it would be too costly to treat it until it is good enough for human use. This is why it is discharged into the rivers, as a way of recharging it into the natural hydrological cycle.

2.3 Water Losses

It was noticed that many water utilities were suffering financially, yet all the water they were producing seemed to be used up. Upon investigation, it was discovered that some of the water produced did not end up bringing in revenue for the utilities, even though they were billing their customers monthly. The International Water Association, IWA, termed this water that could not be accounted for as ‘water losses’.

Non-revenue water is all the water that has been produced but has not earned any revenue for the utility. Water utilities are required to provide water free of charge for some services of social good like firefighting services, and to always have fire hydrants with adequate pressure always ready. Because this water does not earn any revenue for the utility, it is also non-revenue water. However, studies have shown that most of the non-revenue water is caused by water losses, and that the water provided free of charge is normally insignificant in its impact on the revenue collection levels.

2.3.1 The IWA Water Balance

The International Water Association has found that water losses come from many sources. It came up with the water balance technique, where water utilities track their entire distribution systems so as to discover where the losses are occurring.

The table has standard components so that it is easy to compare with worldwide best practice levels. It is a simple table, and shows which figures should add up to which. It assumes relative accuracy in the tracking techniques employed by the utility, such that discrepancies are low. The table consists of the following components:

The system input volume – this is the annual (or other period) total water produced and put into the utility’s distribution networks. It is composed of:

1. **Authorised consumption –** this is the amount of water whose end usage was what was intended (authorised) by the water utility. The water in this component may be billed or unbilled, and metered or unmetered. It consists of:

a. **Billed authorised consumption –** this is the water which was billed, and brought in revenue for the water utility. It can either be metered or unmetered. Metered consumption is where the meter was read, and unmetered consumption is usually due to the usage of estimates in calculating the water bill. Revenue water is equal to this billed consumption. All other components are part of NRW.

b. **Unbilled authorised consumption** – this is all water consumption, metered or unmetered, for which the utility has authorised usage without charges. This is usually in the case of provision of water for fire hydrants and other public services. It is part of NRW, but normally accounts to an insignificant percentage of it.

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Commercial losses	Unauthorized Consumption	
			Customer Metering Inaccuracies and Estimations	
		Physical losses	Leakage on transmission and/or distribution mains	
			Leakage and overflows at utility storage tanks	
			Leakage on Service connections up to point of customer use	

Figure 1.2: The IWA Water Balance Table (IWA/AWWA, 2012)

2. **Water losses –** this is the component of the total input volume whose usage was not according to the intentions of the water utility. It is also called the unaccounted for water, or unauthorised usage. This portion contributes the most to non-revenue water, and is divided into:

a. **Commercial losses** – these are all losses that occur due to metering issues. They are also termed ‘apparent losses’, because the water is found to have gotten to the end user, but there was no payment for it. These losses are usually caused by metering inaccuracies (where the meter underestimates the usage), meter tampering, and outright water theft along the distribution line. This mainly happens near slum areas, where the utility’s pipes are exposed and it is difficult to properly secure them.

b. **Physical losses** – these are all the losses of water from the distribution network. They are considered ‘real’ losses, because they are caused by physical problems in the infrastructure. They consist of losses in the storage reservoirs, either due to overflows or leakages, and losses in the distribution mains pipes caused by leakages and bursts. A certain component of these losses also comes from customer distribution networks before the metering point, due to leaks and sometimes poorly done pipe joint connections.

As standard practice, NRW is expressed as a percentage of the total water produced. From the above table, a simple equation to calculate the level of NRW in the system is:

$$NRW = System\ Input\ Volume\ - Billed\ Authorised\ Consumption$$
$$= Total\ water\ supplied - water\ sold$$

Expressed as a percentage,

$$NRW = \frac{Total\ water\ supplied - water\ sold}{Total\ water\ supplied} \times 100$$

2.3.2 Calculating Water Balance Components (Water Audit)

Finding out where the losses are occurring is the first step in the NRW reduction strategy. In order to track the losses, data is collected from the water supply network and the various components of the water table are determined. Tracking of water usage requires the utility to perform extensive data collection throughout its network, as well as using estimation methods to determine the other components of the water balance table to a reasonable level of accuracy. The indicator of NRW as a percentage of total system input could be misleading, because not all losses are the same (Wyatt, 2010).

The determination of the losses involves the following steps, as suggested by the NRW Manager's Handbook (Farley, 2008). The steps include:

1. **Determination of the system input volume** – this involves identification of all the sources of the water that the utility supplies. In the case of NCWSC, this is the total output of water from their treatment plants, because it does not import any water. Meter accuracy must be ensured by checking the manufacturer's manuals, and setting up additional meters downstream in order to confirm the readings. The data collected should be subjected to statistical analysis and confidence limits of 95%.

2. **Determination of authorised consumption** – the billed metered consumption can be determined from the consumption indicated by the meter readings. Allow for meter reading time lag (because the reading is always done after consumption). Unbilled metered consumption should be determined in the same way as billed metered consumption.

   For the unmetered consumption, extract usage data from the connections so as to get a good estimate. Some of these connections could also be installed with meters in order to get more accurate figures.

   Unbilled unmetered consumption should also be carefully estimated. This component usually involves water used by the utility for flushing its water systems e.g. desilting of tanks. The water used should be carefully logged. Many utilities tend to overestimate this portion so as to make water losses seem less than they really are. This is because it is part of NRW.

3. **Estimation of commercial losses** – estimating unauthorised consumption is a difficult task. The best way of improving the accuracy of such estimation is intimate knowledge of the distribution network. This can be done through regular surveys, sampling of portions of the network, and using statistical methods in order to improve the confidence limits of the estimations.

   Meter inaccuracies and data handling errors can be estimated through sampling of the meters. Use of software is useful in this regard because software can detect when usage patterns vary widely from the expected. Faulty meters should also be promptly replaced. Data handling errors can also be handled by using database software, so as to detect discrepancies. Such errors arise from mistakes during input by the meter reader.

4. **Calculation of physical losses** – this is done using simple arithmetic, i.e.

$$Physical\ losses = result\ 1 - result\ 2 - result\ 3$$

5. **Estimating physical losses components** – in order to accurately determine each component of physical losses, a detailed component analysis of the system should be done. This can be preceded by estimates.

   For leakages on distribution mains, the reported bursts can be used based on the repair records. The invisible leakages, for instance those that occur slowly over a long time, can then be estimated based on parameters like the ages of the pipes. The amount of water lost in a leak is the product of the leak flow rate and the leak duration.

   For leakages and overflows from the storage tanks, this component is easily quantifiable if the utility logs all its data. This is done using level drop tests when the outflow valves are closed.

   For leakages on connections up to the customer meter, these can be estimated by taking the physical losses determined in (4) above and subtracting the mains and storage facility leakages.

2.4 Effects of Water Losses

Water losses affect all the water sector stakeholders, namely the water utilities and their customers.

2.4.1 Effects on water utilities

All businesses survive on sale of their marketable products. If a big portion of it is lost, the business loses money and its capacity to produce its marketable product reduces. This leads to lower quality of the product and less of it produced, which further affects profitability. In water utilities, the marketable product is treated water. The above challenge leads to a vicious circle, as illustrated below:

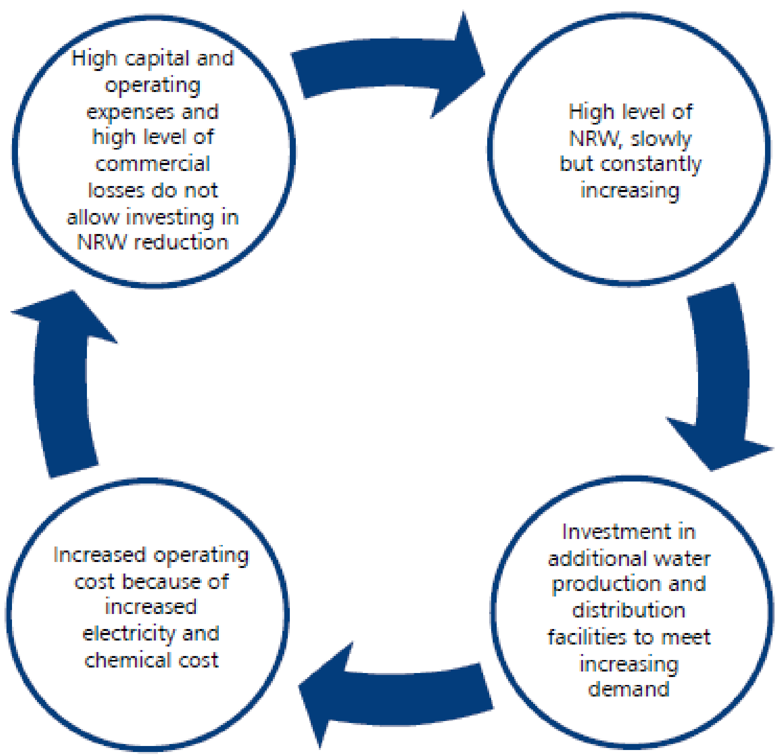

Figure 2.3: The vicious NRW cycle (ADB, 2010)

If left to occur at a high rate, NRW leads to reduced capacity of the water utility to perform its functions due to the worse financial position. This means that functions like water abstraction, treatment and transportation are impacted. Water utilities require money to run and maintain their infrastructure like pipes and machinery at the treatment plants. With the diminished finances, the utility is less able to do this, leading to a reduction in the amount of water it can treat, or poor quality of its treated water, or both. This means that its capacity to serve its customers is reduced even further. This leads to even more NRW losses, and the vicious cycle goes on and on.

2.4.2 Effects on customers

The main objective of a water utility is to satisfy customer demand. The NCWSC total system input volume is not enough to satisfy all the demand in Nairobi area. If NRW is added to this, it results in an even more diminished capacity to provide water to its customers. The main effect of this diminished capacity to satisfy demand is intermittent water supply. On their website, NCWSC admit that only 40% of their customers receive water on a 24 hour basis (About NCWSC, 2015).

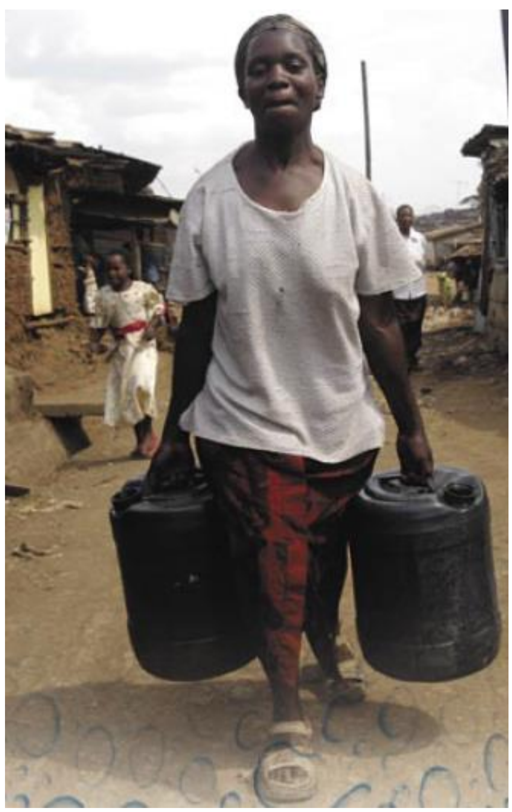

Figure 2.2: The problem of water supply impacts the poor the most (NCWSC, 2014)

Erratic water supply disproportionately affects the poor. Most of the zones with 24 hour supply are the high-income zones of Nairobi. Areas like Eastlands which are known to attract the lower middle class are highly affected by the erratic supply. However, in poor informal settlements like Kibera, there is almost no piped water supply to households. Most of the people depend upon donkey cart vendors, who sell water in 20 litre jerry cans. This water is sold at disproportionately high prices. A 20 litre can of water going for KShs 10 translates into KShs 500 per cubic metre of water, way higher than the standard NCWSC price of about KShs 12 per cubic metre (WSP, 2005). This is being solved by the emergence of water kiosk vendors, but there is still a long way to go.

Erratic water availability affects customer relations with water utilities, leading to less willingness to pay. In addition, the utility, on trying to recover losses from NRW, usually resorts to higher tariffs for their water supply. This affects paying customers unfairly, as they subsidise the rates for those stealing the water. These conditions further contribute to the vicious NRW circle.

The urban poor are normally blamed for theft of water from mains pipes through the establishment of spaghetti (illegal) networks. However, because they do not have water intensive appliances like washing machines, the poor tend to have a much smaller effect on NRW than previously thought. The highest incidences of commercial losses, studies show, are caused by meter tampering and theft by the more well-off residents, and industrial users who typically use a lot of water (ADB, 2010).

2.5 NRW management and reduction strategies

2.5.1 Justification for NRW reduction

NRW reduction strategies should always be carefully formulated to ensure their success. Most reduction strategies are money intensive. However, their main justification comes from the fact that they tend to pay off in a big way due to the virtuous NRW cycle.

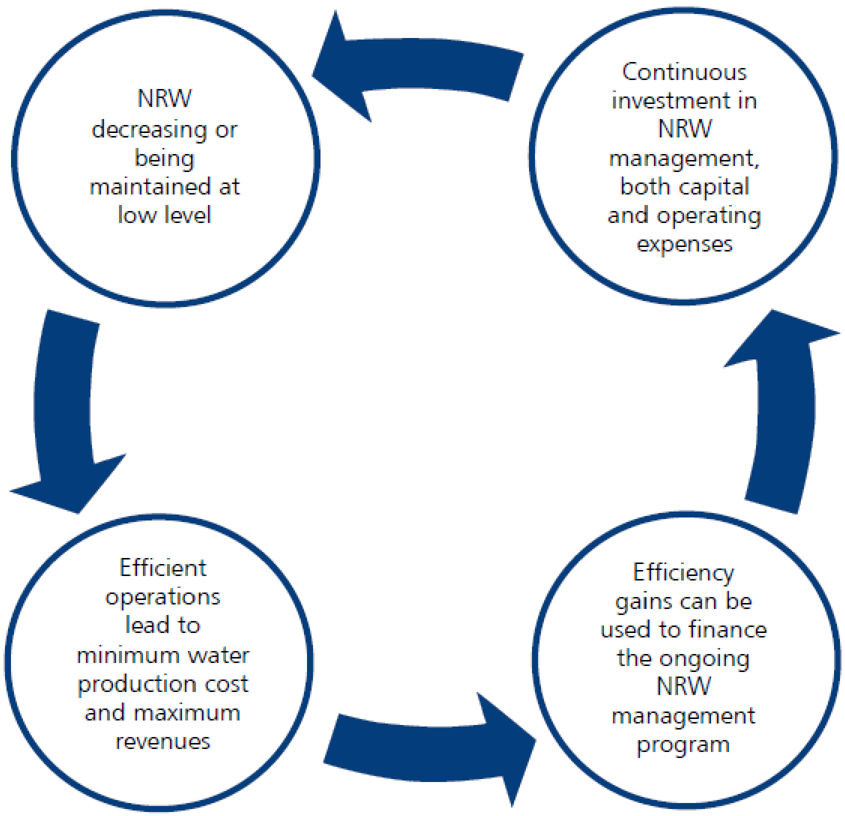

Figure 2.3: The virtuous NRW cycle (ADB, 2010)

As can be seen, efforts to reduce NRW lead to an increased financial capacity for the water utility, which leads to better services and more income, which can further be invested in more NRW reduction, leading to even more benefits. The benefits shown on the virtuous circle form the main justification for a water utility to invest its money in an NRW reduction strategy.

2.5.2 Establishing the NRW reduction strategy

A proper NRW management and reduction strategy can only be formulated after the causes of NRW are determined, and their components formulated (Farley, 2008). This is done by performing a water audit, as demonstrated previously. Establishment of this strategy entails:

1. **Establishment of the strategy development team** – An NRW strategy team should first be constituted. The approach should be holistic, and should consist of members from all departments in the utility, from the customer service, operations department, engineers, and finance departments. Many utilities, the NCWSC included, have a dedicated NRW department. While this is prudent, the other members of the organisation tend to view NRW as the department's problem, rather than the whole utility as a whole.

2. **Setting appropriate reduction targets –** the emergence of Operations Research (OR) showed that the best way to manage a problem is not necessarily by eliminating it, but by reducing it to acceptable levels. Solving problems requires funding, and while a theoretical value of 0% NRW may look optimal, it may be too costly to obtain. Establishing appropriate levels of losses should be done using the available resources taking into account the constraints and other functions of the utility. (Farley, 2008) proposes a graph to obtain what is known as the **economic level of NRW**:

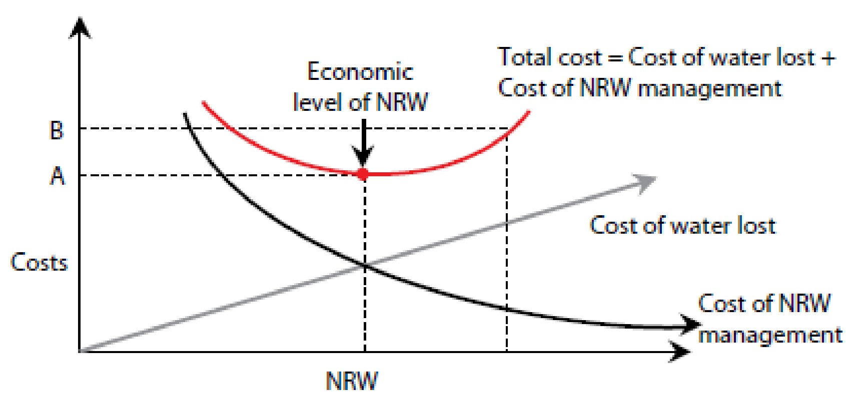

Figure 2.4: Identifying the economic level of NRW (Farley, 2008)

As shown in the graph, utilities should use the cost of water lost (which increases as the level of NRW increases) and the cost of NRW reduction (which reduces as NRW increases). NRW reduction costs proportionately more as the NRW level reduces.

Theoretically, it requires infinite resources to reduce NRW to 0%, which is not feasible. The economic level of NRW is the point where the two curves intersect, representing the maximum NRW reduction for the minimum cost incurred.

3. **Prioritising the NRW components to reduce** – in NRW reduction, the best strategy is to begin with the easiest components to reduce, or the ones that bring the most immediate returns. Using the water table audit, the team should be able to identify the best components to reduce first, taking note that:

   Physical losses – solving physical losses results mainly in the saving of revenue and reduced operation costs. However, solving physical losses generally requires more revenue investment, both in detection of where the losses are occurring and the costs of repairs. However, due to the relatively high volume of water lost this way, reducing them has the greatest impact on the percentage levels of NRW.

   Commercial losses – these losses, while representing a lower volume of water, tend to represent the highest levels of revenue achieved. Solving a problem like faulty meters generally results in immediate returns, because the consumer begins paying fully as soon as the next billing cycle.

   It is up to the team to do all the analysis and to come up with a programme on the components to focus on, taking into account the results expected in solving each.

		Cost		
		High	Medium	Low
Volume	High	Leakage on mains (P) Leakage on service connections (P)	Unauthorised consumption (C)	Unbilled metered consumption (U)
	Medium	Customer meter replacement (C)	Customer metering inaccuracies and data handling errors (C)	Pressure management (P)
	Low	Reservoir leakage (P)	Unbilled unmetered consumption (U)	Reservoir overflows (P)

Figure 2.5: Volume and cost analysis for NRW management activities (Farley, 2008)

4. **Awareness, location, and repair (ALR) in NRW reduction** – once the individual reduction activities have been determined in the step above, the strategic team should use the concept of awareness, location, and repair as it carries out the activities identified. All NRW losses have these three components.

   Awareness – this is the time required for the utility to become aware of the loss, whether in the form of a leak, or a faulty customer meter.
   Location – this is the time required to locate the problem, e.g. finding out where the leak is occurring, or where the faulty or tampered meters are.
   Repair – this is the time required to mobilise resources and repair the problem.

   The three components should be kept at a minimum; because the more the time the problem remains unsolved, the higher the volume of the losses incurred:

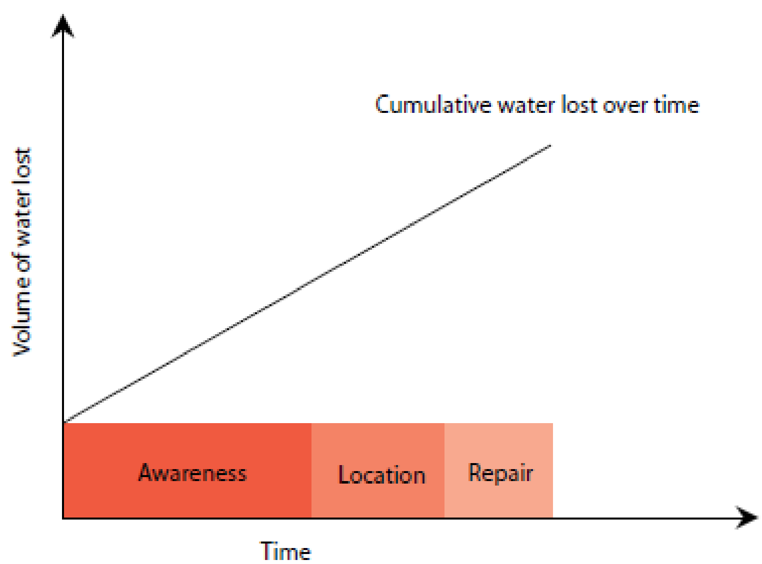

Figure 2.6: Effect of ALR time on losses (Farley, 2008)

5. **Budget considerations for the strategy implementation** – the overall cost of reducing NRW could be very high as it may take many years. Strategies tend to start off at full momentum only to suffer budget cuts over time. It is best to always discuss a long term budget with the stakeholders before starting. Conducting pilot projects to demonstrate the effectiveness of various strategies should also be done so as to convince the management.

2.5.3 Management and reduction of commercial losses

Commercial losses are typically losses of revenue rather than the water itself. This means that the water has been used, but the utility does not receive adequate compensation for it. This happens due to water theft and faulty meters. Thus, commercial losses are also known as apparent losses.

Reducing of commercial losses has a greater value because revenue increase is realised almost immediately (Liemberger, 2005). (Farley, 2008) proposes the division of these losses into four main areas, namely:

- Customer meter inaccuracy
- Unauthorised consumption
- Meter reading errors
- Data handling and accounting errors

(a) <u>Addressing customer meter inaccuracy</u>

Inaccurate meters tend to under-register the consumption. Very rarely to faulty meters over-register, and in such cases, customer reporting of the issue is prompt. In solving this problem, utilities should focus first on commercial and industrial users, who use higher amounts of water and pay higher tariffs. This is where the most returns can be achieved. The main strategies employed to solve such inaccuracies are:

1. **Proper installation and handling of meters** – meters should always be installed properly, as per the manufacturer specifications. Some meters require a certain length of pipe flow upstream or downstream for higher accuracy. Utilities should take it upon themselves to source for trustworthy meters and install them for the customers, in a place where they can be easily read. In a multiple residence area, meters should be properly numbered according to the property they serve, to avoid errors during meter reading.

   In addition to this, meters should be sized properly, and the proper class and type used for every situation. For instance, some larger meters do not register flows of water if the flow rate is below a certain threshold, and should only be installed in parts of the network where the flows justify them. Meters are also classified based on how sediments in the water affect their accuracy. If the water quality is poor, meters whose accuracy is not affected significantly by this should be used.

Sedimentation is a major cause of meter recording inaccuracies.

Figure 2.7: Sedimentation in meters (Liemberger, 2005)

2. **Monitoring water quality and intermittent water supply** – water quality has a great effect on water meters, especially those sensitive to sedimentation. Utilities should regularly monitor their water quality to reduce this. Intermittent water supply, while sometimes necessary in the case of water rationing, tends to reduce the accuracy of meters due to air gaps in the pipes.

3. **Maintenance and repair of meters** – meters should be routinely maintained and replaced. Systematic replacement should be done regularly, beginning with the older meters first. Meter maintenance includes examining the mechanical parts, washing off sedimentation, and calibration to ensure accuracy.

4. **Addressing meter tampering** – some customers insert objects into meters to under-register their usage. The utility should consider using the more tamper-proof meters in the market.

(b) Addressing unauthorised consumption

Unauthorised consumption involves mostly illegal connections, meter bypassing, and errors in the billing system.

1. **Illegal connections** – this is the physical installation of a water connection in the distribution pipeline without the knowledge of the utility. They are normally installed at pipe joints. Such connections also lead to the problem of pressure tampering in the distribution system, leading to further inefficiencies. Customer awareness on the effects of such connections is important, and they should be encouraged to report such incidences. In addition, the water utility should regularly take rounds auditing their pipe networks to detect such connections and rectify them.

2. **Meter bypassing** – some customers install meter bypasses, meaning that they use water without getting metered (this is different from tampering to reduce meter accuracy). Bypass pipes are often hidden underground, and is done by corporate users who then use only a little of the metered water while the rest goes through the bypass pipe. Water utilities should always conduct flow balance analyses, to see whether the bills being paid correspond to the usage levels. This leads to early discovery of the culprits.

3. **Billing system errors** – sometimes consumers are connected to the grid but billing departments are not notified so as to add them to the billing list. Utilities should regularly conduct customer surveys and reconcile the lists to capture these consumers into their systems.

4. **Corruption by meter readers -** this also contributes to the errors. Such readers collude with customers to record a lower usage. One way of reducing this is preventing familiarisation of the meter readers with the customers, by ensuring their routes are changed periodically.

(c) <u>Addressing meter reading errors</u>

These errors can be caused by negligence, aging meters, and corruption. Sometimes the meter readers make errors while taking their readings, or guess values due to low visibility of the meter dials. Meter readers should always be properly trained and motivated so that they can form a better link between the utility and its customers. Frequent spot checks should also be done, and corruption should be punished severely as deterrence. Colluding customers should also be punished through fines, or service suspension.

(d) <u>Addressing data handling and accounting errors</u>

The bill reading process consists of the meter reader taking the readings, recording them, and then taking the readings to the billing office, which inputs the values into the system. Errors occur due to incorrect customers being given the bills, or sending bills to the wrong address. A robust billing database should be used so as to easily detect errors, especially when it notes a big variation in the amounts and the expected usage for the customers.

Utilities also regularly send estimates to consumers, especially where meter reading is not able to be done periodically. Over time, this system develops errors because the estimates are only based on confidence levels. The utility should periodically regularise their readings by sending actual meter readers, so as to reconcile the readings to the actual values.

2.5.4 Management and reduction of physical losses

Physical losses are also termed real losses. This is because they involve real loss of water from the utility's distribution system, and not misappropriation of the water usage as in the case of commercial losses. Physical losses reduce the amount of water in the distribution system.

Reduction of physical losses thus results in an increase of the volume of water in the system, and do not immediately result in revenue. However, the amount of water lost is usually very significant, and should be considered because the water utility needs more water to satisfy the demand.

Physical losses are classified into three main components:

- **Leakage from transmission and distribution mains** – these are usually large events, and get noticed faster. They usually lead to disruptions in the infrastructure, but due to their relatively quick detection times, they are shut off and repaired faster.

Figure 2.8: A mains pipe burst (Liemberger, 2005)

- **Leakage and overflows from the utility reservoirs and storage tanks** – these leakages are easily quantified. Overflows should be observed by the utility managers so that their levels can be estimated. Leakages from tanks can be done by drop level tests by measuring the rate of drop in water levels after shutting off inflow and outflow from the tank.

- **Leakage on service connections up to the customer meter** – unlike mains pipe bursts, these are generally harder to detect as they are not easily visible. They tend to result in the highest losses because they go on for longer. They can be estimated by deducting the leakages from the mains and the storage facilities from the total physical losses.

Figure 2.9: Leakage on service connections (Farley, 2008)

All physical losses are thus leakages; the only thing that varies is the location of the leakage in the system, and their severity and duration. Physical loss management is thus leakage management, but the various characteristics of leakages should be understood so as to come up with a proper strategy to combat the losses.

Based on the ALR (Awareness, Location, and Repair) technique, service connection leakages, though having lower flows, have high losses due to slow detection levels. Mains leakages have higher flows, but due to the faster detection, are stopped before they lose much water. There are three basic types of leakages:

- **Reported bursts** – these are visible, and promptly reported by the public. They have a short awareness time.

- **Unreported bursts** – these mainly occur underground, and are only discovered during leak detection surveys. They have a long awareness time.

- **Background leakages** – these are small leaks, often numerous, that are not cost-effective to repair individually.

NRW managers should thus be aware of these leakage types before coming up with a strategy. There should be active programmes to detect and deal with the leaks.

(Farley, 2008) Recommends the following components in the management of leakages:

(a) Active Leakage Control (ALC)

This involves actively monitoring the system, even when leaks are not reported. Analysis of the distribution network involves a technique called **flow metering**. This technique captures bursts quicker, and enables estimation of small background leakages. It involves data logging and analysis via supervisory control and data acquisition (SCADA) systems, which utilities use in their networks, especially the District Meter Areas (DMAs). (DMAs will be covered in a subsequent section.) After the leaks have been noted, the next step is locating the exact location for repairs. This is done using various techniques, including:

1. **Noise loggers** – these narrow down the localisation of the leakages by analysing the noise characteristics of the pipes. They are placed at intervals in clusters, usually 6, 12, or 18 loggers. Noises that are suspected of being caused by leaks are then noted.

2. **Leak noise correlators** – these instruments locate the leaks using the velocity of sounds

rather than the noise levels.

3. **Ground microphones** – these typically amplify the sound of a leak to make it easier to locate.

4. **Sounding sticks** – these are like doctor's stethoscopes. They consist of a simple rod with a hollow ear piece attached. The logger then listens for any leakage noises. The staff members have to be trained in order to be accurate in doing this.

Figure 2.10: A computerised noise logger in use (Farley, 2008)

Figure 2.11: Use of a sounding stick (Farley, 2008)

(b) Pressure Management

Pressure affects leakages in two ways: it increases the likelihood of a burst, and if a burst occurs, higher pressures lead to higher leakages. The relationship between pressure and leakage is thus one of direct proportionality, i.e. a linear relationship:

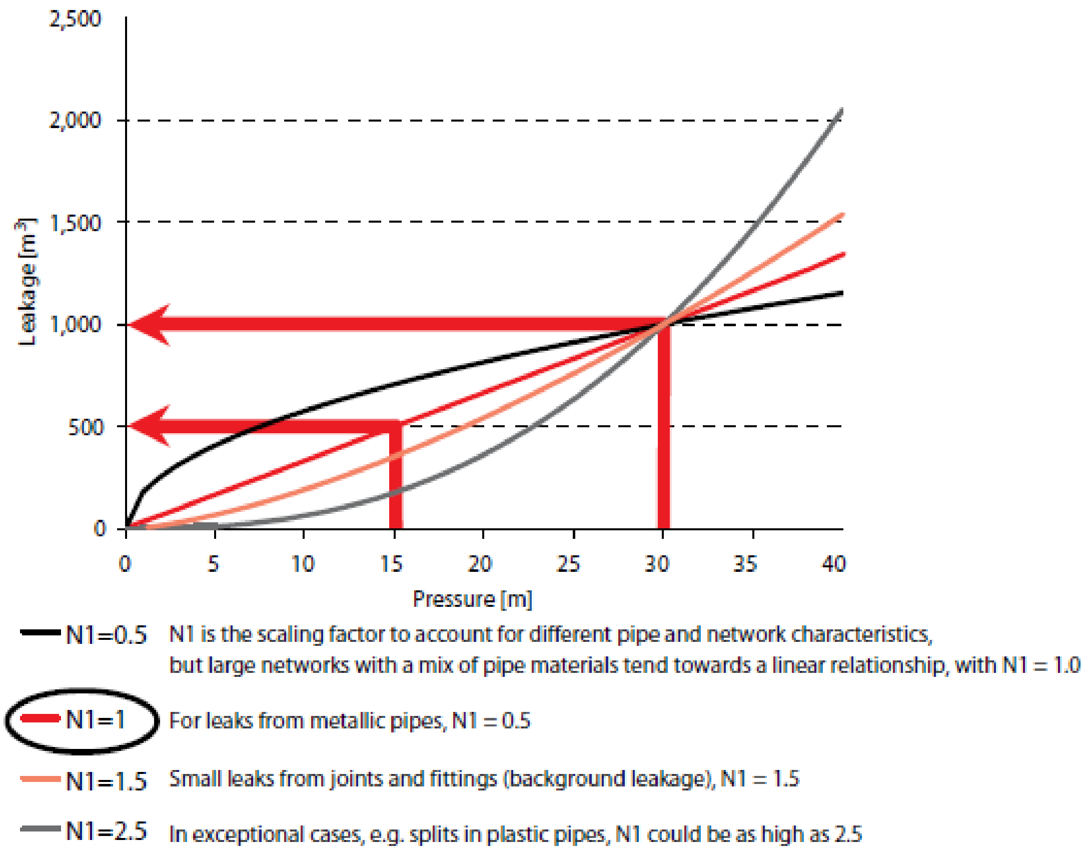

Figure 2.12: Pressure and leakage relationship (Farley, 2008)

The utility must first analyse the needs of the system before embarking on pressure control. Some of the issues to look at include the customer types and needs. High-rise buildings require higher pressure due to water supply in higher floors. After gathering this information, the utility should then model the pressure control system, whether using software or in a pilot project section, so as to clearly understand the costs and benefits. Once this is done, the pressure control apparatus are then installed at the correct points. One of the most cost-effective apparatus for pressure control is the automatic pressure reducing valve (PRV). These vales maintain the same downstream pressure, regardless of the upstream pressure levels.

(c) Speed and quality of repairs

Once leaks are detected, the utility should ensure they are repaired promptly. Delays, as the ALR analysis shows, lead to accumulation of losses. Key to prompt repairs is efficient organisation, sufficient funding, diligent management and staff, and good quality of service connections.

(d) Asset Management

Proper asset management is the key to reducing losses. The assets of a water utility include the entire infrastructure in the whole network, from the reservoirs, pipes, and water meters. A proper asset management policy does the following:

- **Understand their assets** – the utility should always know their assets, in terms of their condition, number, materials, and how they are performing currently.

- **Data collection** – data should be collected on all the assets to determine how well they are performing. It should also be done on the environment and the market. If a better way of doing things comes about, whether due to innovation or changing standards, the utility should be able to come to a decision.

- **Good information systems** – the best way is through computerised logging of their assets. This means that information on when to do replacements, which components in the market to replace them with, and other considerations can be done to make the NRW management easier.

2.5.5 Use of District Meter Areas (DMAs) in NRW management

Water utilities that operate their pipe networks as an open system, where water from many sources is fed into the system and mixed, suffer from problems of water pressure and quality. This led to many utilities dividing up their networks into smaller zones, called district meter areas (DMAs), which made it easier to manage the system in terms of pressure and water quality levels. Each DMA consists of its own intake from the main system, and meters and other data loggers for performance analysis.

It was later noted that the benefits of DMAs go beyond the network improvements, but also make NRW management easier. It is easier to analyse a smaller system and to determine the losses in each, and their causes and mitigation. This means that NRW management could be undertaken actively. Zones may follow either administrative or hydraulic boundaries (Wave Training Kenya, 2010).

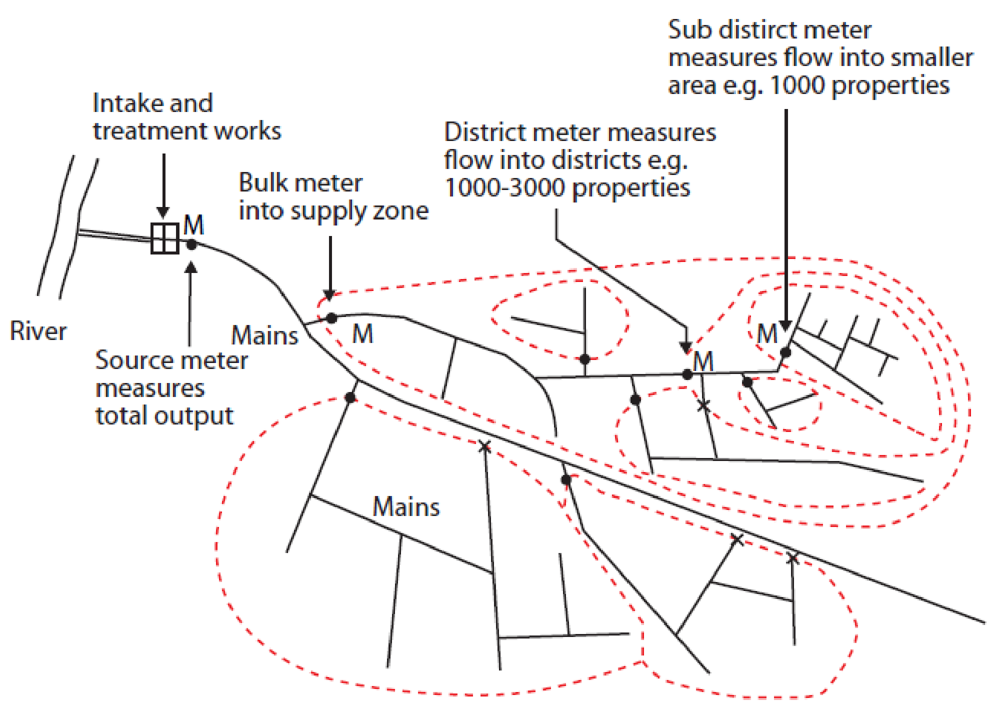

Figure 2.13: Typical DMA layout (Wave Training Kenya, 2010)

DMAs make it easier to isolate problematic areas, determine and reduce NRW, and perform pressure regulations and controls. The following is an outline of how NRW is determined in DMAs:

1. **Physical losses** – because most DMAs do not contain any reservoirs or trunk mains, these components are typically not analysed. Physical losses are typically pipe leakages on the main pipe, and service connections to the customers. This is usually higher at pipe joints.

   Analysis involves leakage monitoring at night, when the customer usage is low. This is because at night, when customer flows are low, the leakage flows, which are constant throughout the day, take up a larger proportion of the flows at night.

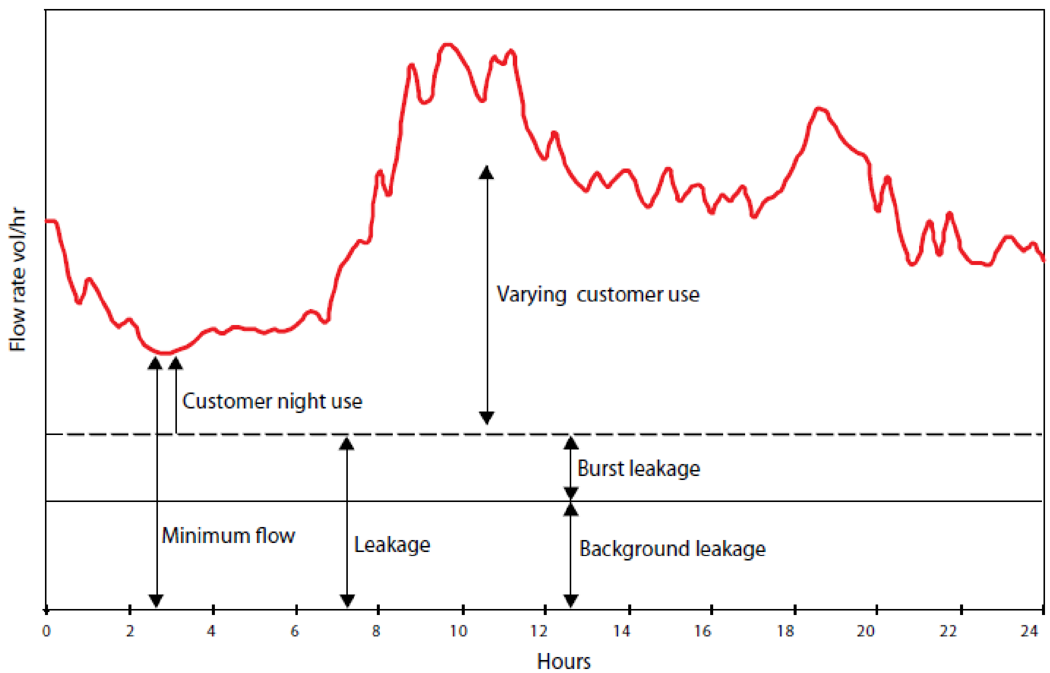

Figure 2.14: Typical DMA flow profile (Farley, 2008)

To estimate the background leakage, the utility analyses the night flow, taking into consideration the flow due to customer night use. The customer night use is termed the legitimate night flow. This level of flow can be estimated using analysis of the expected night usage based on the customer profiles of those served by that DMA, then applying confidence limits. The night background leakage and the burst leakage are then determined by subtracting the estimated customer flows from the total night flows. This procedure is called the Burst and Background Estimate (BABE).

$$Net\ night\ flow\ losses = Minimum\ night\ flow - Legitimate\ customer\ night\ use$$

2. **Commercial losses** – these losses are determined by subtracting the night leakage flows (physical losses) from the total NRW, which is determined by the total inflow less the amount of billed water in the DMA.

$$Commercial\ losses = Total\ NRW\ in\ the\ DMA - Net\ night\ flow\ losses$$

$$Total\ NRW\ in\ the\ DMA = Total\ water\ input - Water\ billed$$

Once NRW has been determined and detected in a DMA, the process outlined before for NRW reduction and management is used.

2.5.6 Monitoring performance of NRW Management strategies

NRW performance indicators are used to rate a utility's performance and operational efficiency against set standards. The major performance indicators used are:

1. **Expressing NRW as a percentage of system input volume** – this is the simplest indicator. It does not tell much about a utility's performance in its reduction strategy, but is useful as it provides an overall feel of the level of losses.

2. **Infrastructure leakage index (ILI)** – this index was developed by the IWA (Wave Training Kenya, 2010). It measures how well the distribution network is maintained and repaired. It is an indicator for physical losses, and has no units:

$$ILI = \frac{Current\ annual\ volume\ of\ physical\ losses}{Minimum\ achievable\ annual\ physical\ losses}$$

Other indicators look at NRW as a percentage of the cost of running the system. To ensure accountability, utilities are required to establish independent auditing teams to measure the indicators, just like they do their financials.

2.6 Emerging issues in NRW

Various scholars and water experts have developed literature on how NRW management can be handled going forward. Some of the emerging issues they have noted are outlined here.

2.6.1 Public-Private Partnerships and outsourcing of NRW management

(Kingdom, 2006) outlines how the private sector, through performance based service contracting, can be involved in the management of NRW in water utilities. Water utilities can subcontract the function of NRW management while they focus on the core function of water provision. The contract should contain clauses on how performance can be monitored, and how the private entity should be paid. Public-Private partnerships have already been used in other sectors of government to streamline service delivery.

2.6.2 Benchmarking and twinning partnerships

Another suggested way of NRW management by (Farley, 2008) is twinning partnerships. This involves the utility identifying a development partner who can help in the management of NRW through peer-to-peer exchanges, benchmarking, financial aid, and exchange programmes.

2.6.3 Financial models for developing countries

Another suggested method is the use of financial models to manage NRW in developing countries. Many utilities use the Economic Level of Leakage (ELL) to determine performance of their networks, but according to (Wyatt, 2010), this indicator is unhelpful to developing countries due to the high commercial losses. He develops a financial model based on Operations Research techniques for utilities in developing nations to use for NRW management.

2.6.4 Engineering curriculum and NRW

According to (ADB, 2010), engineering schools focus on teaching designs of networks, but do not teach a lot of maintenance of the systems they design. NRW is a part of system maintenance. Going forward, training should be done so that the students can appreciate the issue early on.

Chapter Three: Methodology

3.1 Introduction

This chapter outlines the methodology used in carrying out the study so as to achieve the objectives. The study relied on data and other information from the NCWSC and its customers. These data were then analysed as outlined in this section.

3.1.1 Area of Study

The study was in Nairobi County, Kenya, where the NCWSC is mandated to provide water and sewerage services. The County is into seven regions, each with a way of estimating the system input volume of water and the billing information.

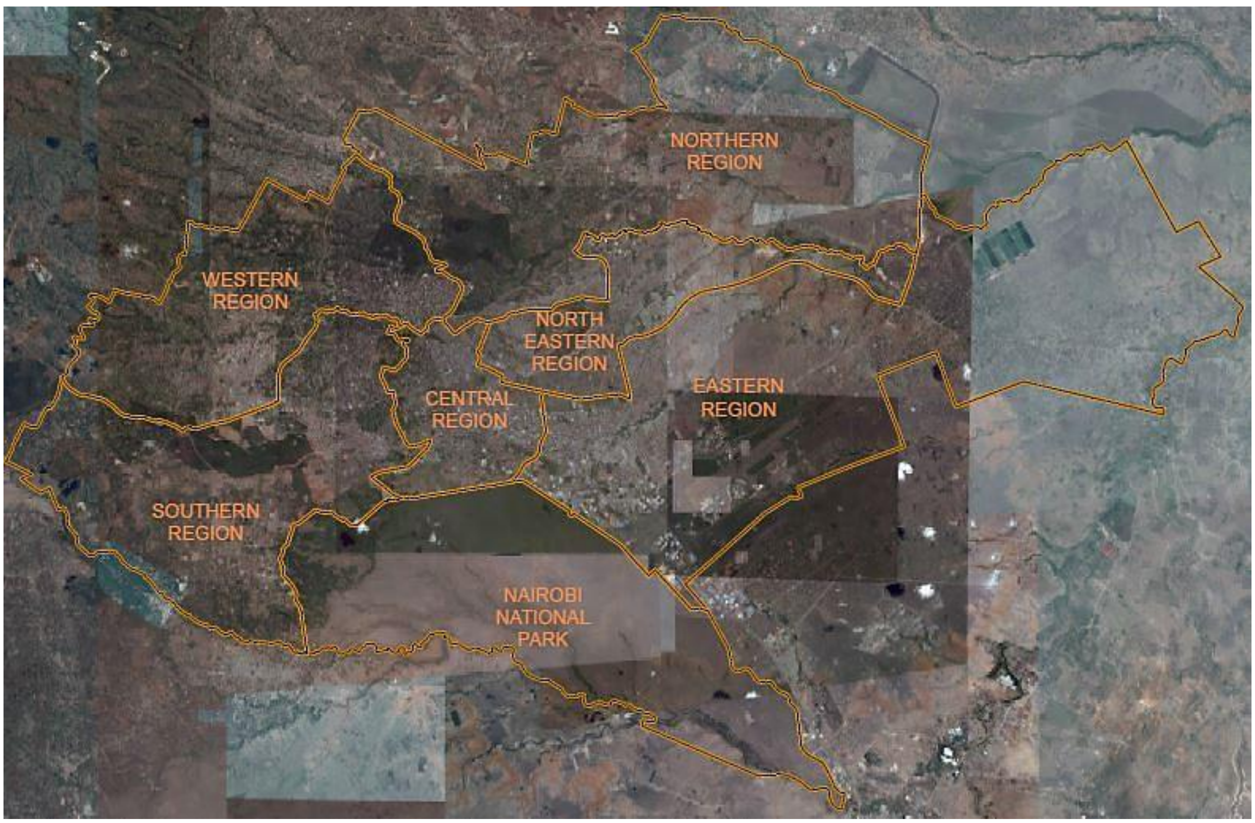

Figure 3.1: NCWSC Regions (NCWSC, 2016)

The areas are as follows:

1. **Northern Region** – this area consists of areas around Thika Road from Kasarani, Zimmerman, Githurai, Kahawa and environs.
2. **Eastern Region** – this consists of Eastlands area, from Embakasi along Mombasa Road, along Outer Ring Road, through estates like Buru Buru and Umoja, and Komarock up to Ruai along Kangundo Road.
3. **Southern Region** – this area consists of Lang'ata Constituency, all the way through to Karen and bordering Dagoretti.
4. **Western Region** – this region consists of Westlands area along Waiyaki Way up to Kangemi, Loresho, and along Ngong Road, including Riruta, Lavington, and Kawangware areas.
5. **Central Region** – this region consists of the Central Business District of Nairobi, and outskirts like Upper Hill, Parklands area in the north, and along Landhies Road, Gikomba Market, and Makongeni area.
6. **North-Eastern Region** – this region consists of Eastleigh area, Kamukunji, Mathare, Kariobangi, Racecourse and Kariokor, up to Murang'a Road and Ngara areas.
7. **Informal Settlements Region** – this zone was created in December 2015. Unlike the rest, it is not geographical in nature. This means that the zone is classified by the socioeconomic status, not its geographical location within Nairobi. Informal areas and slums were found to have unique problems of their own, including spaghetti networks and inadequate provision of services like sewerage (hence the 'flying toilets' phenomenon). Most slum areas, including Kibera and Mukuru slums are in this zone. This enables the NCWSC to better serve the poor by considering their unique needs in a zone of their own.

3.1.2 Nairobi Water Distribution Network

The Nairobi Water Utility has four main sources of water system input, namely the Ng'ethu, Sasumua, Ruiru and Kikuyu Springs. This water is then stored in the main water tanks/reservoirs at Kikuyu, Dagoretti, Uthiru, Kabete, Karen, Kyuna, Gigiri, Hill Tank, Wilson Airport, Kiambu, and Kasarani. The largest tank is at Gigiri, with a capacity of 61,000 cubic metres.

From the main tanks and reservoirs, it is then distributed to smaller water tanks, and then to customers. The nature of the networks in Nairobi is such that there are many instances of water from various sources mixing in the network, making the task of determining the system input volumes into each region difficult. For instance, the Kabete Tank receives water from both Sasumua and Ruiru. In addition, some of the areas depend on historical data to estimate the inflows because there are currently no master meters installed to accurately measure the inputs. This is being remedied by the use of zero-pressure tests to isolate the networks, after which the master meters will then be installed. The exercise of conducting zero pressure tests is being carried out in 2016 in Kahawa (Northern Region) and Loresho (Western Region).

The water distribution network is simplified and shown in the schematic diagram shown below:

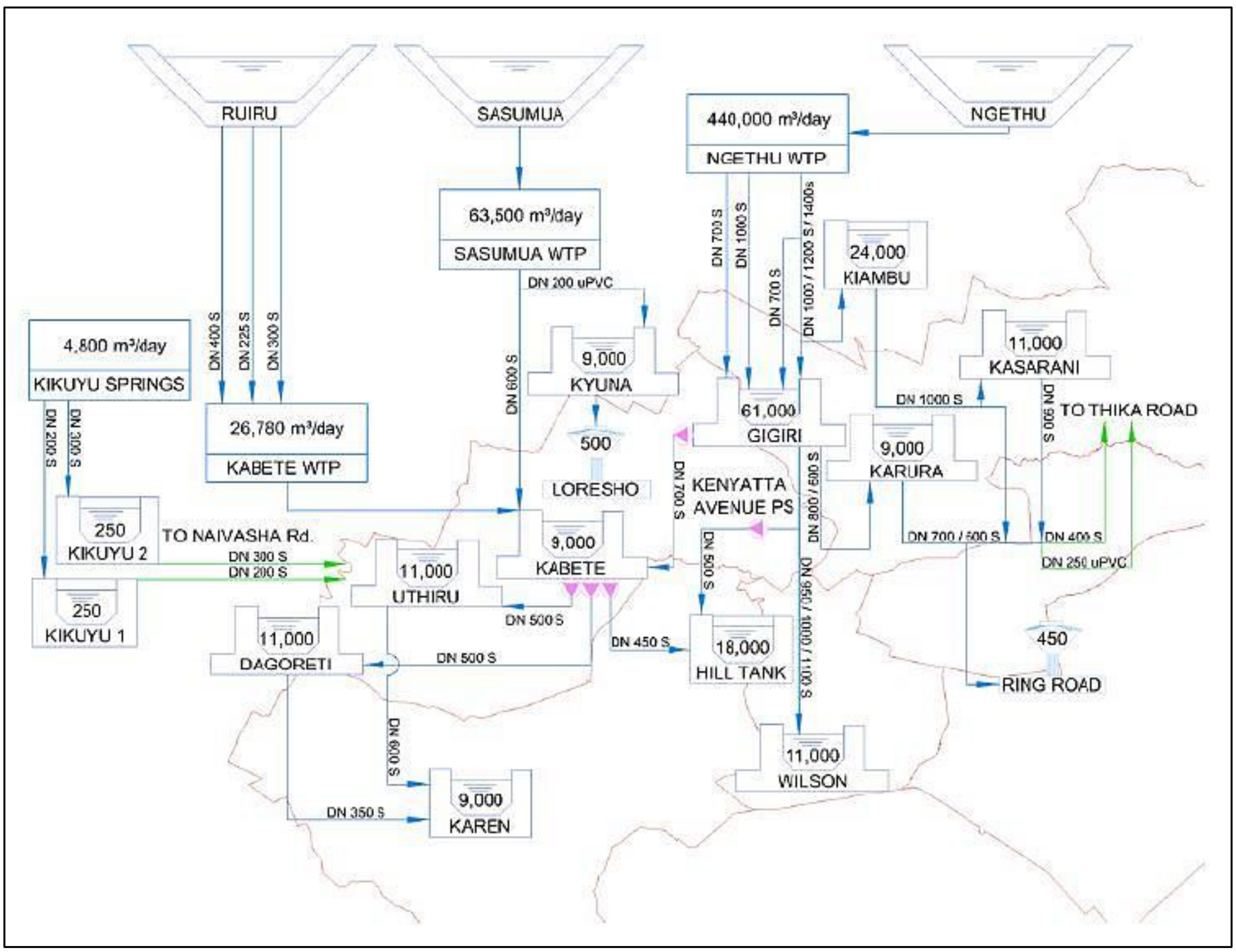

Figure 3.2: Schematic diagram of NCWSC water distribution network (NCWSC 2016)

3.2 Data Collection

Data for the study was collected from both the NCWSC and its customers.

3.2.1 Data from NCWSC

The Nairobi City Water and Sewerage Company has a Non-Revenue Water office. It is mandated to regularly keep track of NRW levels in the distribution networks and take measures to manage and reduce it.

The NRW office provided primary data on water production for the last six months in 2015, from July to December, together with data on amount of water sold, and the billing amounts. This data was in the form of an Excel Sheet and was based on the data they collect monthly. In order to determine the system input volumes of the regions, a mixture of estimates based on historical water usage, together with data from master meters, are used. Being a new region, there was no data from the Informal Settlements Region.

3.2.2 Data from Customers

To find out how NRW affects the customers of water utilities, a questionnaire was used. The questionnaire focused on the perception that customers have of the water utility, the challenges they think it faces, and the awareness levels of the issue of NRW.

The questionnaire was administered to 10 customers from each of the regions, amounting to 60 respondents overall. Some customers were reached through door-to-door visits of places of work in the Central Business District. This yielded more customers from the Eastern region than others, because that is where most Nairobi residents live. For other regions like Northern and Western, personal acquaintances from such areas were used in the administration of the questionnaires to some of the residents there. The response rate was 100%, because only a few customers (ten from each region) were required to answer.

3.3 Data Analysis

3.3.1 Data from NCWSC

The data from NCWSC included the system input, billed volume, and the billed value of the water in shillings. This was from six regions. For each, the amount of NRW was simply the system input less the billed volume. This was then expressed as a percentage of the total input volume:

$$NRW = \frac{System\ Input\ Volume - Billed\ Volume}{System\ Input\ Volume} \times 100$$

For the components of the losses, the NCWSC used information from a water audit it conducted in 2013 through a hired consultant. The audit had determined that the NRW level was 40%, of which 22% was physical losses and 18% was commercial losses. Thus, for all subsequent years, the losses were assumed to be distributed in the 22:18 ratio for physical to commercial losses. This ratio was used to determine the amount of each component in the total NRW volume.

The billed amount in shillings was used to calculate the total hypothetical revenue that would have been earned where water had not been lost (an NRW level of 0%). This was done using the following equation:

$$Total\ potential\ revenue = \left(\frac{100}{100 - NRW\ (percentage)}\right) \times actual\ revenue$$

3.3.2 Data from Customers

The data from customers was principally the questionnaire answers. The customers were grouped based on the region where their reported residences fell. Due to time and resource constraints, the data collected was not meant to be statistical in nature, but to serve as a way of roughly gauging the customers' feelings on Non-Revenue Water and how it affects water services from the NCWSC.

The main parameters measured in the questionnaire were:

1. Price of the water, and the affordability of the bills.
2. The regularity and adequacy of the water supply.
3. Whether other means of sourcing water have been applied e.g. water tanks and donkey vendors.
4. Dirty water from the taps.
5. The concept of NRW and water losses, and what they thought was the main cause of this problem and their suggestions for remedial action.

3.4 Limitations and constraints

The main limitation was the range of the data acquired. The data available from NCWSC was only on the unaccounted for water after the billing cycle. More data would have been needed in order to make proper analysis. A more thorough analysis of the network, including age of pipes, their diameters, the pressures they carry, and the frequency of bursts and repairs should be done in order to know more about physical losses and their effects. Additionally, the conditions of the meters, the effect of storage tanks on supply, and informal networks should also be analysed in order to know more about commercial losses and their effects.

The main constraints of this study were time and resources. The NRW is carrying out zero-pressure tests at Loresho and Kahawa to isolate networks and put in place meters at strategic points. This is in order to be able to accurately measure the losses wherever they occur in the network and aid in quicker detection and remedying of the problem. However, the exercise was to take longer than 6 months and it was not possible to do so within the study period.

Chapter Four: Results and Discussion

4.1 Introduction

This chapter outlines the results obtained from the data collection. The explanations and implications of the data are discussed.

4.2 NCWSC Data

The data provided was on the system input, billed volume, and billed value from the six regions for a period of six months from July to December 2015. The ratio of physical losses to commercial losses was assumed to be 22:18 throughout as established by a previous water audit.

The data on actual revenue collection from the billing was not available. However, it was assumed that the revenue collection rate is 100%; hence, the data on billing amounts could be used to determine the economic value of the losses.

For each region, the volumes of the system input, billed amount, and losses were added up over the six months to get the totals. For the Non-Revenue Water column, the total NRW over the six months was found as an average. In the grand totals, the overall level of NRW for all the regions was **30%**. The levels however ranged from 5% (Northern Region, July) to 49% (Western Region in November and December).

The Central, Western, and North-Eastern regions had the highest levels of NRW at around 40% each, while the Northern, Eastern, and Southern regions had levels of 18%, 24%, and 22% respectively. The reason for these discrepancies is mainly the errors caused by estimations. Another reason could be the fact that because there is better and more regular supply to the Central, Western, and North-Eastern regions, there is an increased chance of water being lost especially due to leaks. Areas where water does not flow often in the pipes have less chance of the little water that flows being lost.

Region	Month	System Input (m^3)	Billed Volume (m^3)	NRW (m^3)	Physical Losses (m^3)	Commercial Losses (m^3)	NRW (%)	Billing (KShs)
Central	July	3,132,766	1,787,742	1,345,024	739,763	605,261	43	126,096,699
	Aug.	2,985,198	1,920,142	1,065,056	585,781	479,275	36	132,876,237
	Sept.	3,117,954	1,757,412	1,360,542	748,298	612,244	44	122,542,237
	Oct.	2,805,208	1,816,784	988,424	543,633	444,791	35	126,015,783
	Nov.	2,790,935	1,852,242	938,694	516,282	422,412	34	162,974,248
	Dec.	2,793,392	1,667,760	1,125,632	619,098	506,534	40	114,708,928
Total		**17,625,453**	**10,802,082**	**6,823,372**	**3,752,855**	**3,070,517**	**39**	**785,214,132**
Northern	July	3,533,865	3,356,863	177,001	97,351	79,650	5	137,451,092
	Aug.	3,678,386	2,753,136	925,250	508,887	416,362	25	139,788,099
	Sept.	3,562,813	2,475,164	1,087,649	598,207	489,442	31	124,080,880
	Oct.	3,610,808	2,767,504	843,304	463,817	379,487	23	142,258,856
	Nov.	3,568,571	2,694,651	873,921	480,656	393,264	24	174,152,814
	Dec.	3,737,600	3,677,262	60,338	33,186	27,152	2	189,078,269
Total		**21,692,043**	**17,724,580**	**3,967,462**	**2,182,284**	**1,785,357**	**18**	**906,810,010**
Western	July	1,776,974	1,252,848	524,126	288,269	235,857	29	68,849,332
	Aug.	1,983,910	1,371,999	611,911	336,551	275,360	31	74,705,010
	Sept.	2,049,061	1,351,344	697,716	383,744	313,972	34	77,263,298
	Oct.	2,533,103	1,335,053	1,198,050	658,927	539,123	47	73,139,626
	Nov.	2,477,726	1,259,966	1,217,760	669,768	547,992	49	90,660,438
	Dec.	2,533,103	1,303,543	1,229,560	676,258	553,302	49	63,933,930
Total		**13,353,877**	**7,874,753**	**5,479,123**	**3,013,517**	**2,465,606**	**40**	**448,551,634**
Eastern	July	2,414,105	1,977,043	437,062	240,384	196,678	18	95,047,463
	Aug.	2,653,551	2,072,538	581,014	319,558	261,456	22	105,938,628
	Sept.	2,513,645	1,974,250	539,395	296,667	242,728	21	111,627,961
	Oct.	2,578,805	1,953,501	625,303	343,917	281,386	24	98,868,318
	Nov.	2,538,315	1,690,000	848,315	466,573	381,742	33	128,191,423
	Dec.	2,578,805	1,920,771	658,033	361,918	296,115	26	65,650,874
Total		**15,277,226**	**11,588,103**	**3,689,122**	**2,029,017**	**1,660,105**	**24**	**605,324,667**
Southern	July	1,320,927	981,163	339,765	186,871	152,894	26	55,162,575
	Aug.	1,518,194	1,145,380	372,814	205,048	167,766	25	69,217,527
	Sept.	1,328,327	1,213,300	115,027	63,265	51,762	9	78,877,352
	Oct.	1,384,127	996,987	387,141	212,927	174,214	28	58,328,346
	Nov.	1,321,235	1,005,827	315,407	173,474	141,933	24	110,217,407
	Dec.	1,384,127	1,098,930	285,198	156,859	128,339	21	59,990,302
Total		**8,256,937**	**6,441,587**	**1,815,352**	**998,444**	**816,908**	**22**	**431,793,509**
N. Eastern	July	2,301,109	1,321,348	979,761	538,869	440,892	43	76,155,644
	Aug.	2,298,542	1,475,558	822,984	452,641	370,343	36	85,503,221
	Sept.	2,438,449	1,364,056	1,074,393	590,916	483,477	44	78,230,701
	Oct.	2,359,249	1,424,651	934,598	514,029	420,569	40	89,046,526
	Nov.	2,359,249	1,494,190	865,059	475,782	389,277	37	126,220,464
	Dec.	2,359,249	1,428,787	930,462	511,754	418,708	39	81,856,334
TOTAL		**14,115,847**	**8,508,590**	**5,607,257**	**3,083,991**	**2,523,266**	**40**	**537,012,890**
GRAND TOTAL		**90,321,383**	**62,939,695**	**27,381,688**	**15,060,108**	**12,321,759**	**30**	**3,714,706,842**
Hypothetical Revenue								**5,306,724,060**
Lost Revenue								**1,592,017,218**

Table 3.1: NCWSC Data July to December 2015

The total amount received from billing was **KShs 3,714,706,842**. Considering this to be 70% of the total revenue that would have been achieved had there been no losses, it was found that the losses in water would have earned an extra **KShs 1,592,017,218**.

In the strategic plan 2014/15-2018/19, NCWSC has identified areas it would like to improve in its operations in order to increase revenues and customer satisfaction (NCWSC, 2014). One of the improvement areas is reducing NRW from 40% to 16% by 2019. This reduction exercise will be at an estimated cost of KShs 3.2 billion, which comes to about KShs 800 million spread over 4 years. This exercise will involve improved leak detection, installation of proper meters at residences, and master meters in each zone so as to monitor the water more accurately.

Other areas the utility plans to improve on include water quality by ensuring the treatment plants are equipped and modernised, improved water distribution by upgrading the existing network and increasing the household water connections from 280,000 to 400,000. This exercise is projected to cost approximately KShs 5 billion.

To improve their services; the NCWSC has to reduce NRW. By investing KShs 3.2 billion to reduce NRW to 16%, this would increase the revenues considerably. In the last half of 2015, the total revenue gained, accounting for 70% of total potential revenue, is KShs 3.7 billion. This translates to KShs 7.4 billion a year and KShs 30 billion over 4 years, assuming no revenue growth over the years. KShs 30 billion represents the scenario of 30% losses. By reducing losses to 16%, the maximum revenue earned over 4 years rises to approximately KShs 36 billion:

$$\frac{(100-16)\%}{(100-30)\%} \times 30\ billion = 36\ billion$$

The extra 6 billion represents returns on the KShs 3.2 billion spent on NRW reduction, giving extra earnings of KShs 2.8 billion. This extra money leaves adequate revenue for other company initiatives like improving their networks, customer relations, and employee satisfaction. When taking into consideration the normal revenue growth, the returns in practice are even higher. Thus, the impact of NRW on a water utility is not just the absolute revenue lost, but also the missed opportunities that that revenue would have realised.

4.3 Results of the Customer Survey

The questionnaire consisted of thirteen questions. There were 60 respondents, 10 from each of the 6 Regions of Nairobi. The questionnaire, results, and detailed discussions can be found in Appendices 1 and 2.

All the interviewed respondents were customers of NCWSC. However, due to inadequate supply, many of them had a supplementary source of water. Such sources included donkey vendors and water bowsers (lorries delivering fresh water). Since the supply is erratic throughout the day, customers have also invested in storage tanks at home to act as a buffer so that there is water to use even when NCWSC water is not flowing.

In the case of non-revenue water, while the level of awareness of the term NRW was low, more people seemed to understand the concept of water losses. They also thought the main reason for water losses was incompetence, and to a lesser extent, lack of funding. Seemingly, the low opinion some of them have of NCWSC due to erratic supply led them to blame NRW on incompetence more than inadequate capacity and funding.

Most of them felt that increased awareness was the key to solving the problem of NRW. While utilities can focus on the technical issues that lead to water losses, it is also important to involve the customers as stakeholders. Customers who are aware of the importance and costliness of water are more likely to report any cases of leaks and water theft promptly.

Chapter Five: Conclusions and Recommendations

5.1 Conclusions

The conclusions of the study were:

1. The Non-Revenue Water experienced by the Nairobi City Water and Sewerage Company does have an impact on both the NCWSC and its customers.
2. The NCWSC suffers mainly financially and reputation-wise due to NRW.
3. The customers suffer due to inadequate supply, forcing them to seek other water sources, and also financially, since water becomes expensive due to the wastage caused by the losses.
4. To control NRW levels requires heavy financial and labour investment by NCWSC.
5. The best strategy around reducing NRW is one focuses on achieving economic levels of NRW, not eliminating it to 0% entirely.
6. When developing an NRW reduction strategy, initial focus should be on reducing the components which lead to a more immediate financial return, so as to provide additional funding to reduce the other components.

5.2 Recommendations

The recommendations of this study are:

1. More detailed analysis of the entire network of NCWSC should be done, including age and condition of pipes and meters, general water demand in various areas and regions, and the profiles of the customers. This is to enable a sound NRW reduction and management strategy to be put in place.
2. As stakeholders, customers should be educated and engaged by NCWSC in matters of water management, so as to encourage compliance and reporting of any issues that they notice such as theft and leakages.
3. NRW management in water utilities should be treated as a culture of the whole organisation instead of a small department.

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APPENDICES

Appendix 1: Questionnaire for NCWSC customers

1. Which area of Nairobi do you live?
2. Where do you get your water supply from?
    - Nairobi Water (Council)
    - Cart/Donkey vendors
    - Borehole
    - Other (specify)
3. How would you rate Nairobi Water's services?
    - Good
    - Average
    - Bad
4. Do you think the water bill is too high?
5. How often do you get water supply in your house?
    - 24 hour supply
    - Irregular supply
    - Morning and evening
6. Is the water supply sufficient for your needs?
7. Do you have a water tank at home?
8. Have you ever gotten dirty/brown water from your taps?
9. Have you ever heard of the term non-revenue water?
10. Did you know that the Council loses almost half (40%) of the water it produces?
11. What would you say, in your opinion, is the cause for this?
    - Corruption
    - Incompetence
    - Lack of funds
12. As a customer, how do you think this affects you?
    - Makes water expensive
    - Inadequate supply
    - Dirty water from tap
    - Other (specify)
13. How do you think this issue should be dealt with in your opinion?
    - Increased awareness
    - Increased funding for the Council
    - Other (specify)

Appendix 2: Customer questionnaire results

The questionnaire consisted of thirteen questions. This section tabulates the answers received for each, and attempts to explain the results.

1. Which area of Nairobi do you live?

Region	Northern	Eastern	Southern	Western	Central	N. Eastern
Number	10	10	10	10	10	10

Table A2.1: Number of respondents from each region

There were ten respondents from each region who answered the questionnaire. The regions were deduced from the residential areas in their answers. For instance, a customer from Umoja in Eastlands was placed in Eastern Region.

2. Where do you get your water supply from?

	Northern	Eastern	Southern	Western	Central	N. Eastern
NCWSC	10	10	10	10	10	10
Cart	1	2	2	0	0	1
Borehole	2	1	3	4	1	2
Other (specify)	0	0	3 (water tanker)	2 (water tanker)	4 (water tanker)	0

Table A2.2: Sources of water

All the respondents depended on NCWSC water, but supplemented it with various means. Based on the regions, which generally show the income levels of the respondents, some customers supplemented their supply using cart vendors (especially in slum areas), boreholes, and water tankers for the higher income areas. In areas like Runda, the respondents also had supplementary supply from water utilities like Runda Water Company.

3. How would you rate Nairobi Water's services?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Good	2	1	3	4	7	1
Average	3	5	4	4	2	6
Bad	5	4	3	2	1	3

Table A2.3: Customer ratings of NCWSC services

Most customers rated the services average or poor, except in Western and Central Regions. This is because in high-rise regions like Western the customers have almost 24 hour supply, which is supplemented and hence almost never experience dry taps. In Central Region, the NCWSC also provides close to 24 hour usage.

4. Do you think the water bill is too high?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Yes	6	7	5	3	4	7
No	4	3	5	7	6	3

Table A2.4: Customer opinion on water bill

In this, the respondents were also divided along socioeconomic lines. There was a correlation between the ratings of the services and the views on the water bill. Customers who received less than satisfactory supply were also more likely to think that the bill was too high.

5. How often do you get water supply in your house?

	Northern	Eastern	Southern	Western	Central	N. Eastern
24 hour	0	0	1	3	6	0
Irregular	5	8	6	7	4	7
Morning/evening	5	2	3	0	0	3

Table A2.5: Frequency of supply

Very few customers said they got 24 hour supply. For those who did, most were in Central (CBD). There was also the fact that where water tanks and other supplementary supply sources like boreholes are available, the customers were unlikely to know when the mains water supply was not available. Most of the places with morning and evening supply were rental houses where the owner has a tank in place, and opens the water for use in such hours.

6. Is the water supply sufficient for your needs?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Yes	7	6	8	9	10	7
No	3	4	2	1	0	3

Table A2.6: Sufficiency of Water Supply

Most customers overwhelmingly felt that the supply was sufficient in almost every region, with a few differences. This was because most customers had a way of ensuring that when supply was there, enough water was stored to do most of the activities that require water. This was done using tanks and storage cans.

7. Do you have a water tank at home?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Yes	9	7	8	10	7	8
No	1	3	2	0	3	2

Table A2.7: Number of home water tanks

Most Nairobi residents have a water tank at home. They range from the big overhead tanks, to which all water supply to the building is pumped and then utilised from the tank, to the small indoor tanks of approximately 100 litres which store just about enough water for two days in the lower income areas. Very few people depended on the direct tap supply without a means of storing it for when taps are dry.

8. Have you ever gotten dirty/brown water from your taps?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Yes (Rare)	3	2	1	0	2	3
No	7	8	9	10	8	7

Table A2.8: Dirty water from taps

Not many complained of dirty tap water, and the few who did all said it happened very rarely. Dirty water in pipes mostly occurs after a pipe burst, where the dirt seeps through the damaged sections of pipe. It is thus correlated with physical losses. Periods of low pressure flow in pipes also cause dirt to be sucked into the pipes. Other reasons could be excessive siltation and sediments in tanks.

9. Have you ever heard of the term non-revenue water?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Yes	1	0	1	2	3	2
No	9	10	9	8	7	8

Table A2.9: Awareness of NRW among respondents

There was overwhelmingly a low rate of awareness of the term Non-Revenue Water. This is probably because it is a technical term. The few who did had come across the term in the media whenever water supply issues were being discussed.

10. Did you know that the Council loses almost half (40%) of the water it produces?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Yes	3	5	6	6	7	5
No	7	5	4	4	3	5

Table A2.10: NCWSC water losses awareness

In this case, the awareness levels were higher. This was because a lot of people were witnesses to water theft and pipe bursts at some point. For some customers, however, they answered 'yes' because that is what they expected of NCWSC, and not because of witnessing any incident that could cause losses. Due to the low opinion they already have of NCWSC, they were not surprised that it loses so much of its water.

11. What would you say, in your opinion, is the cause for this (NRW)?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Corruption	3	2	0	0	2	2
Incompetence	9	10	10	9	10	10
Lack of funds	0	0	1	2	1	0

Table A2.11: Customer thoughts on causes of NRW

In this question, customers were allowed to make more than one choice. Overwhelmingly, many chose incompetence as the main reason for NRW. Corruption is a major cause for complaint in Kenya especially in public institutions, but very few thought it was the cause. Even fewer considered that the reason could be lack of funds. This shows that most customers feel that the main reason for NRW is that the NCWSC is just not doing enough to combat the issue.

12. As a customer, how do you think this affects you?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Expensive water	4	6	3	3	4	5
Inadequate supply	8	9	8	10	10	9
Dirty water	0	1	0	0	0	2
Other	0	0	0	0	0	0

Table A2.12: Customer opinion on effects of NRW

In this question, more than one answer could be selected. Most customers felt that the main effect of NRW was inadequate supply. This could be because of deduction that if water is being lost then of course some customers will go without. Others felt that it causes water to be more expensive, especially the same customers who had complained that the bills are too high.

13. How do you think this issue should be dealt with in your opinion?

	Northern	Eastern	Southern	Western	Central	N. Eastern
Increased awareness	9	10	10	9	9	10
Increased funding	2	3	2	5	4	1
Other (specify)	0	1 (fire incompetent staff)	0	0	1 (more policing of their networks)	2 (deal with illegal connections; reduce corruption)

Table A2.13: Customer suggestions

Many customers felt that increased awareness would be the most effective in dealing with NRW, possibly because most were not aware of the issue before the questionnaire. They also felt like stakeholders in water matters, and understood that awareness and involvement of every stakeholder is important in solving most problems. Quite a number also felt that funding should be increased to NCWSC so as to deal with the problem. For those specifying other remedies, two of them felt that there should be more policing of the NCWSC pipe networks to reduce theft. Another felt that the incompetent staff should be replaced, while one felt that the main strategy should be to fight corruption.

From the responses, there was a feeling of pervasive customer dissatisfaction with the services of NCWSC. The inadequacy of the supply is a constant cause for frustration. It is clear that with the cost-benefit analysis of NRW reduction being done, the returns would not only be financial, but also reputation-wise.

Appendix 3: EasyCalc Water Balance Software

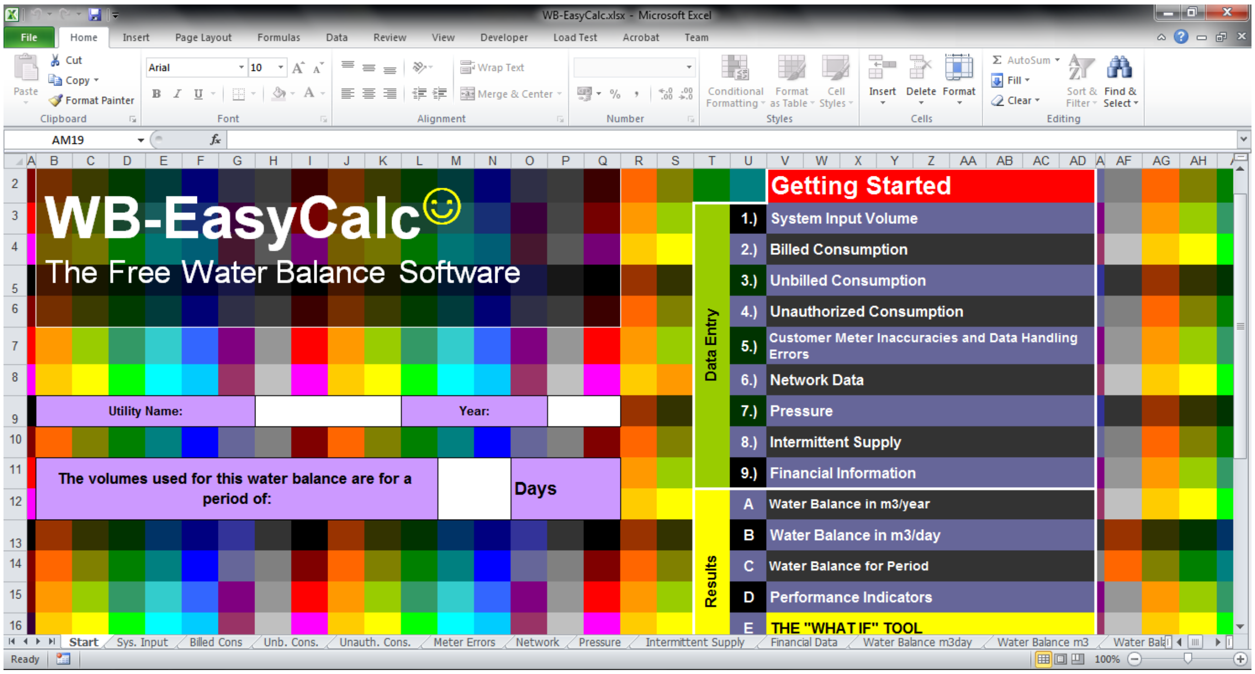

Figure A3: EasyCalc Water Balance

The EasyCalc Water Balance is a free tool developed by Liemberger. It is based on Microsoft Excel. It is a useful tool for water utilities in calculating and estimating non-revenue water using the water balance table. It is available as a free download on www.liemberger.cc/.

It asks for various data such as production, the relative ages of pipes and meters, the amount of maintenance done on the infrastructure, among others. Based on the level of accuracy specified by the user, it then calculates NRW and its components to the maximum possible accuracy levels.

Appendix 4: Leakage on service connection

Figure A4: Leakage on service connections, Ngara Road

Leakages on service connections such as this lead to huge background losses, especially with underground pipes, since they only become visible after so much water has leaked that it starts seeping to the surface. This is as opposed to leakages from transmission mains, which are dramatic bursts and quickly detected.

Appendix 5: Spaghetti networks

Figure A5: Spaghetti Connections (wikiwater.fr)

Spaghetti connections are so called because they are essentially many pipes meeting up in one spot like spaghetti. This means that it is difficult for the water utility to determine which pipe or meter serves which building, and makes it easy to hide illegal connections. The utility should prevent such scenarios by placing meters and pipes in an organised manner.

Appendix 6: NCWSC Strategic Plan on NRW

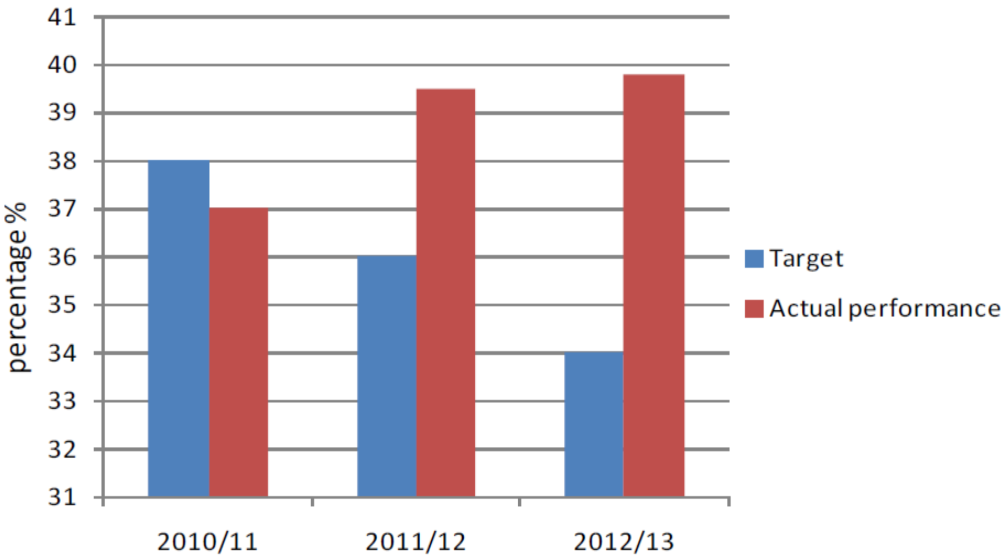

Figure A6.1: NCWSC NRW performance vs targets over the years (NCWSC, 2014)

S.NO.	Strategy	Expected output(s)	Proposed actions	Output indicator(s)	Implementing actors	Time frame	Cost estimates (Kshs million)
1.	Active leak detection	Reduction of NRW (physical) 22% to17%	i. Carry out leak scouting for physical leaks identification and documentation	Documented leaks	TD, NRWM	continuous	2
			ii. Carry out pilot studies in, Loresho, Plot 10, Ruai and CBD	Study reports	TD, NRWM	December 2015	25
			iii. Repair all reported and visible leaks within stipulated response times	Leak repair reports	TD, O&MM NRWM	Continuous	750
			iv. Review and implement work procedures and instruction for new connections and leak repairs	Documented work procedures and instruction	O&MM NRWM	June 2014	0
2.	Pressure management	Reduction in leakages	i. Evaluate performance of existing pressure zones	Evaluation report	NRWM, O&MM	June 2019	57
			ii. Conduct network pressure survey to inform active leakage detection and implement the findings	Pressure survey reports	NRWM, O&MM	June 2019	203
3.	Asset management	Reduction of water losses	i. Procure and operationalize GIS and employ qualified staff	Operational GIS	TD, NRWM	December 2015	21
			ii. Develop Asset Management Policy, Systems and Plans	Asset management policy	TD, EM, NRWM	December 2015	4
			iii. Procure Asset Management System	Asset Management System	TD, EM, NRWM	December 2015	106
			iv. Conduct asset valuation	Valuation report	TD, EM, NRWM	December 2019	250
4.	Quantify the water distributed into the zones	Incremental sales growth	i. Installation of District Meters	No. of District meters installed	CD, TD, NRW-M	June 2015	157

Figure A6.2: NRW Strategy and costing (NCWSC, 2014)

S.NO.	Strategy	Expected output(s)	Proposed actions	Output indicator(s)	Implementing actors	Time frame	Cost estimates (Kshs million)
5.	Improve meter accuracy	Incremental sales growth	i. Meter right sizing	No. of meters right sized.	CD, NRW-M	June 2019	12
			ii. Replace all faulty meters	No. of meters replaced	CD, RMs	Continuous	840
			iii. Meter testing and calibration	No. of meters tested & Calibrated	CD, NRW-M,	Continuous	3
			iv. Secure New connection materials	Materials available	CD, SCM	continuous	100
			v. Replace all meters 10 years and older	No. of meters replaced	CD, RMs	Continuous	300
			vi. Install AMRs for large consumers	AMRs installed	CD, NRWM	continuous	130
			vii. Seal all customer meters	No. of meters sealed	CD, RMs	Continuous	20
			viii. Install 4,000 Prepaid meters in Informal settlements	No of meters installed	TD	continuous	60
			ix. Install additional MT Benches	No. of MT benches installed	CD, NRW-M	Dec-16	20
			x. Install meter repair bench and commence meter repairs	Installed repair bench	CD, NRW-M	Dec-15	8
			xi. Training and bench marking for NRW reduction staff	No. of staff trained	CD, DHRA, NRW-M	Continuous	47
6.	Develop authentic customer data base	Incremental sales growth	i. Develop acceptable data gathering procedures and processes for adoption	Available Procedures	CD, RMs, ICT-D	December 2014	0
			ii. Data clean up	No. of cleaned customer records	CD, RMs, TD	Continuous	100

Figure A6.3: NRW Strategy and costing (continued) (NCWSC, 2014)

The strategy is budgeted to cost KShs 3.215 billion, to reduce NRW from 40% to 16%.