

**THE DETERMINANTS OF NON REVENUE WATER IN WATER SERVICES
PROVISION IN KIRINYAGA COUNTY IN KENYA:
A CASE OF KIRINYAGA WATER AND SANITATION COMPANY.**

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DECLARATION

This Research project report is my own original work and has not been presented for a degree or other award in any other university.

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DEDICATION

I dedicate this project to my dear wife Faith and my daughter Joy; you are a great encouragement, a strong source of support and so dear to me. Also to my dad Mr. Eliud who kept on asking me where I have reached and for his moral support.

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ABBREVIATIONS AND ACRONYMS

BCWWA	British Columbia Water and Waste Association
DFID	Department for International Development
IWA	International Water Association
KIRIWASCO	Kirinyaga Water and Sanitation Company
KNWDR	Kenya National Water Development Report
MDGs	Millennium Development Goals
NRW	Non revenue water
O &M	Operations and Maintenance cost.
PPIAF	Public Private Infrastructure Advisory Facility
PVC	Polyvinyl chloride
UFW	Unaccounted for water
WASREB	Water Services Regulatory Board.
WHO	World Health Organization
WSB	Water Services Board
WSP	Water service provider
WSTF	Water Services Trust Fund

ABSTRACT

Kenya is classified as a water scarce country however it losses a lot of water averaging to 47% out of water produced and treated. If ways can be found to prevent this water loss it would not only provide more water to Kenyans but would considerably reduce costs hence promoting sustainability in provision. This study seeks to establish the determinants of Non Revenue Water (NRW) in water service provision in Kirinyaga Water and Sanitation Company (KIRIWASCO). The study was guided by the following objectives; to establish how water infrastructure determines the Non Revenue Water in water services Provision in KIRIWASCO, to find out how pipe leakages determines the Non Revenue Water in water services provision in KIRIWASCO, to establish ways in which metering determines Non Revenue Water in water services provision in KIRIWASCO and to establish how illegal practices determines the Non Revenue Water in water services provision in KIRIWASCO. The study used a descriptive survey design and the theoretical framework of this study was derived from the human economic theory. The target population of the study was 130 members of staff and a sample of 97 staff was picked. The sample was picked using stratified sampling and proportionate sampling. Questionnaires were used to collect data. Ten (10) officers were used for Pilot testing before the commencement of the study. Data analysis was done using Statistical Package for Social Sciences. Descriptive statistics was computed and data is presented using tables. The findings of the study indicated Water infrastructure, pipe leakages, metering and illegal practices determines the Non Revenue Water in water services provision. Non Revenue Water (NRW) is caused by Aged water systems leading to non detected leakages, pipe bursts, Leakages, illegal connections, faulty meters and meter by passes as shown by 64.2% of respondents. It is important that aged pipes be replaced and leak detectors procured since 51.6% of respondents indicated that relocation and maintenance of road reserve reduce bursts. If adaptation of meter installation policy and aged consumer meters are replaced, water losses (NRW) would be reduced by 61.1% as indicated by 58 respondents. The major cases of illegal practices encountered are meter tampering, illegal connection and vandalism and theft as shown by 76.8% of respondents. The generated information will help government departments and the Ministry of Water to come up with interventions which will reduce water losses. The study will also useful to future scholars as it has added to the existing body of knowledge.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Globally, water constitutes about two-thirds of the whole earth surface. However it is limited in its availability as freshwater to man. According to Hu (2006), freshwater constitutes only about 2.76 percent of the total water available on earth, moreover it is only less than one per cent which is readily available to be accessed and used by man. According to Thornton (2002), water is often undervalued in most parts of the world not only is water considered as a free natural gift, but also it is seen as ‘endless’ resource that is always available (World Water Assessment Programme of UN (2003) but this is not the case. According to Thornton (2002), water was seen in the past as an infinitive commodity and this led to failure to consider issues like water loss in the management of water utilities in most countries. While freshwater resource is free natural resource to man, its availability to man at any particular point in time, place and space is limited hence, the necessity for what is called water management (Baumann, 1997).

As stated in the Dublin water conference of (1992) “freshwater is finite and vulnerable resource while the World’s population keeps increasing, freshwater resource remains finite. Again, the conference agreed that freshwater resource has economic value and therefore have to be seen as economic good. Therefore although fresh water is a limited resource but in high demand, its availability can be maintained as long as wastage is avoided and resources protected so that it can be always be available in the quality and quantity needed. The water users should be in the forefront in ensuring water is only put to important use and protected from pouring and also safeguarded from leaking in order to ensure continuity in availability. On the other hand water service providers should carry out inspection to assess the volume of water that reaches the user and how much is lost. This water that gets lost is referred as the Non-Revenue Water (NRW) i.e., the difference between the water produced and the water that reach the consumers’. The reduction of NRW is also a key issue for increasing the performance of water utilities and supplying the population with enough clean drinking water.

The total cost to water utilities caused by NRW worldwide can be conservatively estimated at 141 billion per year, with a third of it occurring in the developing world. In developing countries, about 45 million cubic meters are lost daily through water leakages, all in all some countries have managed to reduce NRW to very low levels. Singapore has reduced its NRW to 5% this in return has resulted to provision and water security this reduction has not been easy but has been due to continuous efforts and investments, In Singapore and Tokyo galvanized iron and polyvinyl chloride (PVC) service connections have been replaced with stainless steel service connections and NRW levels in these cities (5% and 8% respectively) demonstrate the success of this approach World Bank, (2006). Singapore, Tokyo, and other cities also have programs for replacing asbestos cement pipes in distribution systems, as pipe breaks have increased over time.

In South Africa the scarce fresh water is decreasing in quality because of an increase in pollution and the destruction of river catchments, caused by urbanisation, deforestation, damming of rivers, destruction of wetlands, industry, mining, agriculture, energy use and accidental water pollution UNEP (2004) . As the human population increases, there is an increase in pollution and catchment destruction. In South Africa it is estimated that the current level of Non-Revenue Water for the country as a whole is 36.8%.This figure is similar to the estimated world average of 36.6% but is on the higher side when compared to other developed countries and low when compared to the developing countries.

According to (vision 2030) of Kenya, The global climate is changing drinking-water services have to prepare for the impact. If the widely anticipated flood and drought consequences of climate change come to pass, then both established water and sanitation services and future gains in access and service quality will be at risk. The vision 2030 study of WHO set out to increase our understanding of how anticipated climate change may affect drinking-water and sanitation services and what can be done to optimize resilience of technologies, infrastructure and services. One major way is to reduce losses and wastage of water.

In Kenya Water supply and sanitation is characterized by low levels of access, in particular in urban slums and in rural areas, as well as poor service quality in the form of intermittent water supply. Only 9 out of 55 water service providers in Kenya provide continuous water supply (WASREB 2008). Seasonal and regional water scarcity exacerbates the difficulty to improve

water supply. Although urban water tariffs are high (US0.46 per m³ on average in 2007) the level of cost recovery was low due to a high level of non-revenue water (average of 47%) and high costs. Costs of water services are high due to the need to tap distant water sources for example Mombasa is supplied from a source located 220 km from the city and due to high levels of staffing of 11 workers per 1000 connections or more than twice the sector benchmark. For both urban and rural providers water coverage has improved, showing that there is progress in the water services sector. Thus, an increasing number of people have access to drinking water in line with the human right to water and sanitation. This positive development is also supported by an increase in Hours of Supply and a slight reduction in Non-Revenue Water (WASREB, 2012). However, NRW levels remain unacceptably high. At a total billing of KSh 600 million for rural WSPs and KSh 12.6 billion for urban WSPs, and average NRW levels of 57% and 44% respectively, the total amount lost in 2011/12 can be estimated at a staggering KSh 10.6 billion, slightly more than one third of the development budget of the water services sector (WASREB, 2012).

Kirinyaga Water and Sanitation Company has a high NRW position of 73% WASREB (2012) this means more water out of that produced and treated is lost. This reflects a more poor scenario and poorer than the sector average of 47%. Among the main problems cited by WASREB are poor governance, poor infrastructural management and illegal connections. KIRIWASCO covers a large area of about 520 square kilometers in water services provision in Kirinyaga County. It also has more than eight intakes and an old water service infrastructure which is a major challenge in reducing water losses (WASREB, 2012).

1.2 Statement of the Problem

Kenya is classified as a water scarce country, however it losses about 47% of its piped clean water (WASREB, 2009). This is referred to as Non Revenue Water, if this water that goes to loss can be saved then almost an equal population to that already connected to piped water would be connected this will also be a cheaper way to realize more connections unlike other ways like dam constructions, borehole and funding new water system that the government has invested in year after year. The country continues to face serious challenges related to water, although the Ministry of Water has a vision to make water accessible to all citizens , many people are yet to

be connected with clean and piped water, in some localities people travel for long distances travel to fetch water (UNICEF, 2012). Moreover most serious issue is that many people have continued to die from water borne diseases and the government using a lot of money for drugs and medical facilities (UNICEF, 2012). This can be stopped with little effort by only reducing the water losses. This study therefore sought to identify the determinants of Non Revenue Water in water services provision in order to suggest what can be done to reduce these losses and expand accessibility of water to unserved population.

1.3 Purpose of Study

The purpose of study is to identify the determinants of Non Revenue Water in water services provision in Kirinyaga Water And Sanitation Company in Kirinyaga County in Kenya.

1.4 Objectives of Study

The objectives of the study are:

1. To establish how water infrastructure contributes to Non Revenue Water in water services Provision in KIRIWASCO.
2. To find out how pipe leakages determines the Non Revenue Water in water services provision in KIRIWASCO.
3. To establish ways in which metering determines Non Revenue Water in water services provision in KIRIWASCO.
4. To establish how illegal practices determines the Non Revenue Water in water services provision in KIRIWASCO.

1.5. Research Questions

The study sought to answer the following research questions:

1. How does the infrastructure contribute to the Non Revenue Water in KIRIWASCO?
2. To what extent do pipe leakages determine the Non Revenue Water in KIRIWASCO?
3. What is the influence of metering on the Non Revenue Water in KIRIWASCO?
4. How do the illegal practices influence Non Revenue Water in KIRIWASCO?

1.6 Significance of Study

Kenya is classified as a water scarce country and quite a significant population have no access to clean portable water however out of the treated water produced 47% is lost and classified as NRW. This study will help to identify the factors that determine NRW in water services provision. The facts obtained in the study are crucial to the National and County governments, water companies and the citizens in convincing them why investment in NRW reduction is necessary and a viable option. This will also provide a simple solution that can save billions of money which would have been used to provide other sources of water. This study is also important to investors and financial institutions that finance water projects. Research institutions and other researchers would also find this study necessary for further research.

1.7 Delimitation of Study

This study was carried out in Kirinyaga Water And Sanitation Company which provides domestic water to four of the five Sub-Counties in Kirinyaga County. The other sub county which is Kirinyaga East is served by Gichugu Water and Sanitation Trust (GWAST).The study focused on how the water infrastructure, pipe leakages, metering and illegal practices affect NRW in water services provision. KIRIWASCO is divided into 9 areas which are divided into 64 zones which are all easily accessible. The target population was the members of staff of Kirinyaga Water and Sanitation Company.

1.8 Limitations of the Study

NRW management is a broad and complex issue. Given the limitations of time, it was impossible to go into details of all its aspects to travel and cover the whole area of KIRIWASCO. This study was also self-financed hence there was limitation of money which would facilitate travelling and meeting the required budget. KIRIWASCO also covers a large area hence not possible to cover the whole area due to the limitation of time.

1.9 Assumptions of Study

The study assumed that the respondent would give honest answers during the research. The respondent would also be available and accessible during the study. There was significant

contribution of reducing Non-Revenue Water to ensuring water service provision. It was also assumed that the reduction in water losses therefore will result for more water to distribute and lower costs of production and operations and maintenance costs. Non Revenue Water control is an integral component in the water supply system management. NRW can be reduced by applying proper management strategies and controlling the determinants that were studied.

1.10 Definition of Significant Terms

Determinants: In this study these are factors that contribute to water losses and can be controlled.

Metering: This is fixing water meters to customers' connection and service lines.

Non-Revenue Water: This is the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

Pipe Leakages: This is the occurrences of breakages on pipes that result to water losses.

Provision: In this study it means supply of safe and clean water for domestic purposes.

Service Coverage: This is the proportion of the population receiving water services compared to the total population in the whole service area in the jurisdiction of water service provider.

Water Infrastructure: In this study these refers to all valuable resources used in the water system e.g. pipes, tanks and gate valves.

Water service provider: This is the water company that provides the water service.

Water services: This refers to providing piped water to customers by a water company.

1.11 Organization of the Study

The study was organized in five chapters as follows;

Chapter One of this research proposal covers the background to the study, statement of the problem, purpose and objectives of the study, research questions, the significance, assumptions, limitations and delimitations of the study, and definition of significant terms. Chapter Two is the literature review of the study with outlook on theoretical framework, conceptual framework and the scholarly works on infrastructure, bursts and leakages, metering and illegal practices.

Chapter Three outlines the research design, target population, sampling technique, data collection method, data analysis, ethical considerations and operational definitions of variables. Chapter four contains data analysis, interpretation, and presentation of the findings. Chapter five contains summary of findings, discussions, conclusions and recommendation as well as contribution to the body of knowledge.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter highlights the relevant literature on the determinants of Non Revenue Water in water services provision. This chapter will review both the theoretical and empirical literature on the determinants of NRW in water service provision. The review will emphasize on exploring, discussing and critiquing the relevant literature on determinants of NRW.

2.2 Global Water Situation

According to the World Health Organization statistics, it is estimated that about 1.1 billion people in the world do not have access to safe water (WHO, 2010). The United Nations' states that by 2025, 1.9 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions (UN, 2009). Seven billion people now depend on the world's finite supply of freshwater to drink every day, to grow our food and, in many cases, to dispose of our excreta, to bathe, and for many other purposes. One billion of us have only unsafe water to drink, and over two billion lack sanitation. Hundreds of millions live in places where water is very scarce and, therefore, a contested resource. Vast numbers are crowding into large, ill-served cities. In a generation's time, not six but eight billion of us will depend on the same amount of water for all the same purposes. That is the nature of the impending crisis, a crisis that is particularly serious for the health and livelihoods of the world's poor people. According to the California Department of Resources, if more supplies aren't found by 2020, the region will face a shortfall nearly as great as the amount consumed today.

Los Angeles is a coastal desert able to support at most 1 million people on its own water; the Los Angeles basin now is the core of a megacity that spans 220 miles (350 km) from Santa Barbara to the Mexican border. The region's population is expected to reach 41 million by 2020, up from 28 million in 2009. The population of California continues to grow by more than two million a year and is expected to reach 75 million in 2030, up from 49 million in 2008 (UN, 2009). But water shortage is likely to surface well before then.

Water deficits, which are already spurring heavy grain imports in numerous smaller countries, may soon do the same in larger countries, such as China and India. The water tables are falling in scores of countries (including Northern China, the US, and India) due to widespread over pumping using powerful diesel and electric pumps. Other countries affected include Pakistan, Iran, and Mexico. This will eventually lead to water scarcity and cutbacks in grain harvest (WHO, 2010). Even with the over pumping of its aquifers, China is developing a grain deficit. When this happens, it will almost certainly drive grain prices upward. Most of the 3 billion people projected to be added worldwide by mid-century will be born in countries already experiencing water shortages. Unless population growth can be slowed quickly, it is feared that there may not be a practical non-violent or humane solution to the emerging world water shortage.

According to a UN(2009) climate report, the Himalayan glaciers that are the sources of Asia's biggest rivers – Ganges, Indus, Brahmaputra, Yangtze, Mekong, Salween and Yellow could disappear by 2350 as temperatures rise. Approximately 2.4 billion people live in the drainage basin of the Himalayan rivers. India, China, Pakistan, Bangladesh, Nepal and Myanmar could experience floods followed by droughts in coming decades (UN, 2009). In India alone, the Ganges provides water for drinking for more than 500 million people. The west coast of North America, which gets much of its water from glaciers in mountain ranges such as the Rocky Mountains and Sierra Nevada, also would be affected. With the world scarcity of fresh water in mind we will have to improve our management of water resources and avoid conflicts over them (UN, 2009).

We must allocate water equitably between different uses and ensure sustainable access to different types of water services. Freshwater is also a mobile resource. It is present as atmospheric moisture, rainfall, soil moisture, surface water (including rivers and lakes) and groundwater, and there are complex relationships between these different parts of the hydrological cycle. All of these forms of water vary over place and time, both seasonally and from year to year. Their distribution is affected by climate and landscape. Water use, and with it the value that people give that water, also varies with place and time according to the people's capacity to modify or capture the resource.

The provision of the quality and quantity of water resources depends on the balance of agricultural, industrial and domestic uses against the prevailing hydrological conditions. At the same time, people are increasingly recognizing that the environment is both the fundamental provider of freshwater and a legitimate user of that water, and that the maintenance of ecosystems demands a range of seasonal water requirements.

2.2.1 Non Revenue Water Situation in Singapore

Singapore like many other countries is classified as a water scarce country. Thus, it imports its entitlement of water from the neighboring Johor state of Malaysia, under long-term agreements (Tortajada, 2006). When Singapore became an independent country in August 1965, the long-term water security was an important consideration for this newly independent nation. Singapore made a special effort to register the Separation Agreement in the United Nations Charter Secretariat Office in June 1966 (Tortajada, 2006). Singapore has developed a new plan for increasing water security and self-sufficiency with increasingly more efficient water management, including formulation and implementation of new water-related policies and other similar actions.

The Public Utilities Board (PUB) has managed the entire water cycle of Singapore since 1 April 2001 (Luan, 2010). The PUB developed a holistic policy, which included protection and expansion of water sources, storm-water management, desalination, demand management, non-revenue water control, catchments management, outsourcing to private sector specific activities, and public education and awareness program (Butler and Memon, 2006). Non-revenue water was 9.5 % of the total water production in 1990 and the PUB managed to reduce NRW to around 5% in the year 2000 and beyond. Unlike other South and Southeast Asian countries, Singapore simply does not have any illegal connections to its water supply systems (McIntosh, 2003). Today, Singapore's NRW management would still be considered one of the best examples in the world (Tortajada, 2006).

The overview of NRW control for Singapore water supply management is that Meter accuracy is very high, Production meters are calibrated every month, domestic consumer meters are replaced every 7 years and industrial meters are in every 4 years.

The volume of water used for firefighting is estimated or measured and fire departments are billed (Luan, 2010). The commercial system is highly reliable and controls are in place to prevent tampering. Billing complaints are dealt with promptly. High and low consumption patterns are investigated. Average water rates are close to the incremental cost of water. The entire distribution system is surveyed for leaks every year. Water districts can be fully isolated to monitor for leaks. Distribution pipes are cement lined to reduce corrosion and are replaced if the number of breaks exceeds three per kilometer per year. House connections are made of stainless steel or copper and Certified plumbers do in-house repairs and installations. Many of these approaches can be adopted by developed and developing countries to improve their water management systems (Tortajada, 2006). Singapore has been very successful in managing its water and wastewater. This can be attributed to its concurrent emphasis on supply and demand management. This includes metering, leak surveillance, proper billing procedures, strong management, and institutional effectiveness. It is also very important to create an enabling environment, which includes a strong political will, effective legal and regulatory frameworks and an experienced and motivated workforce.

The water utility is reclaiming wastewater after secondary treatment by means of advanced dual-membrane and ultraviolet technologies. This treated water is mainly supplied to industries and commercial customers (Wyatt, 2011). The source of water is further expanded by reducing NRW, which is defined as actual water loss due to leaks and apparent losses arising from meter inaccuracies. Singapore has hundred percent metering, leak surveillance, proper billing procedures and strong management in water supply. Demand management Concurrent to the diversification and expansion of water sources, Tortajada (2006) PUB has put in place a well thought out and comprehensive demand management policy. As part of this discussion, it is useful to review the progress of water tariffs for water during the 1997-2000 periods. The water tariff used is the block rate system (Wyatt, 2011). Minimum first rate was 20m³ in 1997 and 40 m³ in 2000. The average monthly household consumption has steadily declined. In 1995, it was 21.7 m³ per month per household but by 2004 was 19.3 m³ per month per household.

The consumption in 2004 was 11 % less than in 1995. This is a positive result of introducing demand management policy in water management at Singapore. However, the Government provides water specially targeted help for the lower income families such as households living in 1 and 2 room flats. These households are eligible to receive social financial assistance. This is a much more efficient policy in socio-economic terms, instead of providing subsidized water to all. Commercial and industrial users are not subsidized.

2.2.2 Non Revenue Water Situation in Kenya

According to the 1992 National Water Master-plan, the annual renewable fresh water resources in Kenya is 20.2 billion cubic meters, comprising of surface water of 19.59 billion cubic meters and ground water of 0.62 billion cubic meters. Assuming that amount of water is still available to the current population of 40 million people; this translates to 505 cubic meters per capita per year. In global standards therefore, Kenya is a water scarce country (Government of Kenya, 1992). During the rainy periods, rain is the main source of drinking water for about 52% of the total drinking water supply. In dry periods the rural population relies on springs, rivers and streams for their drinking water. Urban households have water piped into their compound or dwelling (49%) or get water from public taps. The majority lives within 15 minutes of their water source supply. About 22% of the population in Kenya lives in an urbanized area.

The main population lives in rural territory. Especially in the rural part, source waters are both heavily contaminated and highly turbid. Although there are no health based rules on turbidity, the WHO suggests that drinking water with a turbidity of 5 NTU (Nephelometric Turbidity Unit) is acceptable to consumers. For adequate disinfection however, the turbidity should be below 0. When looking at the urban areas, investigations have shown a decline in improved drinking water sources and a slight increase in sources in rural regions. In the urbanized regions 85% of the population has access to safe drinking water (UN 2009). From all the people who live in rural areas, 53% has access to safe drinking water. Clean and safe water on the other hand requires high capital expenditure for development of water systems, treatment works and it's also costly to operate and maintain. It is therefore a global challenge to offer water services sustainably.

2.2.3 Non Revenue Water in Kirinyaga County

Kirinyaga county losses a lot of water averaging 73% WASREB (2012) this is shows a higher loss of water that which is accounted for. According to WASREB (2012) Nyeri and Malindi are the only two urban WSPs with acceptable NRW levels. By implication, 64 or 97% of WSPs have unacceptably high levels of water losses. Out of these, 16counties lose more water on the way than they actually manage to sell and Kirinyaga County is one of them. These figures are a clear indication of the lack of professional management and good corporate governance in many WSPs. High levels of NRW result from poor infrastructure maintenance WASREB (2012) and above all, poor commercial practices (corruption). At current levels of NRW, urban WSPs are losing approximately KSh 9.9 billion annually, slightly less than one third of the sector budget. This not only threatens the financial sustainability of the sector but also wastes funds which could otherwise be used to increase access and improve service delivery. According to 2009 census Kirinyaga County has a population of 552,175 out of these only 32% have access to piped treated water from either Kirinyaga Water and Sanitation Company or Gichugu Water and Sanitation Company the two water service providers (WSP) in the county.

2.3 Water Infrastructure

Provision of water has remained one of challenges for the government for a long time (Mumma, 2005), With the increasing growth in population and the subsequent socio-economic pursuits, including urbanization, industrial production, tourism and agricultural activities, demand for water has increased rapidly. If not checked, the demand for water may soon surpass the supply not only due to the growing needs of the increasing population, but also limited natural endowment of fresh water as well as serious degradation of water resources (KNWDR, 2006). Kenya, which is considered as a water scarce country faces serious challenges with regard to water services (MWI 2005; Krhoda 2008).

The situation is not any better in the urban areas, meeting the rapidly growing urban demand for safe and affordable water is already a daunting challenge for many communities. Not only are the numbers of people who need better water supplies very large, water itself is becoming scarcer (UN-HABITAT, 2007).

Dilapidated infrastructure, low levels of revenue collection, poor management, and lack of accountability in governance are further obstacles to the sustainable improvement of access to water in the urban areas, and particularly in low-income settlements. Furthermore, Kenya is one of the few countries in the world where urban drinking water coverage from improved sources actually declined during the 1990-2004 period (WHO/UNICEF, 2006). The urban water supply situation in Kenya can be summarised as follows UN-HABITAT (2007) “Water supply in Kenyan cities is highly inequitable. Over 50% of the urban poor, living in slums, have no access to safe drinking water and end up paying vastly more for municipal piped water. Local governments provide water in towns, but their water supply capacity is insufficient to cover the urban needs.

Old and dilapidated infrastructure leaves the water exposed to many leakages and continuous bursts if the repairs are also not done in an appropriate manner the bursts keeps on re occurring. Infrastructural Management is hence a key issue in prevention of NRW, Farley and Trow (2003), if mains replacement is being used as a water leakage reduction strategy, then it would be more beneficial to carry out targeting studies to determine which areas of the water system are more prone to frequent bursts and leaks and which mains within these areas have the highest frequency (number per kilometer per year) and the highest background leakage. If this exercise is carried out effectively, according to Farley and Trow (2003), the initial schemes would be more cost effective than the later ones. Many utilities do not allocate enough funds and resources for operation and maintenance. Leakages and pipe burst are not repaired in time leading to high NRW. A lot of funds and resources are allocated to none priority areas, inflated expenditures are incurred at the expense of the service provision thus denying a lot of people access to adequate water and sanitation. Many utilities ration water supply to consumers due high level NRW caused by poor operation and maintenance. They can hardly supply water for more than 10 hours in a day. The personnel lack most of the basic tools and equipments for performing their work.

The major infrastructural determinants of NRW are poorly constructed household connections Fanner & Lambert (2009), poorly constructed water tanks which leak, poorly build concrete structure at water treatment works and low quality valves and armatures which leak.

Others are poorly laid pipes which do not follow pipeline construction procedures, Random excavation of pipe trenches without following technical designs, random expansion of pipeline network without following technical procedures, none anchoring of pipe bends and Tee-joints causing movement and leaks as well as Covering pipes without conducting pressure tests for leakages in the joints.

2.4 Influence of Pipe Leakages

Pipe leakages results to loss of water and then to less water available for distribution. With less water available rationing has to be done to the customers making every customer to be allocated hours of supply. According to WASREB (2012), hours of supply measure the ‘average number of hours per day that a utility is able to provide water to consumers’. McBain (1985) offered that reliability of service of water utility continuous supply of water in the adequate quantity and quality was a major determinant of the service provision. This is reflected as ability of an enterprise to provide enough value to justify any social costs (Tisdell & Ward, 2003). Shamir & Howard (1981) expresses water supply system reliability in terms of the shortages that result from the failures of a system’s physical components. Intuitively, the system failure affects the capacity which determines the revenue and subsequently financial viability. Increasing capacity involves improving physical facilities storage, pumping capacity and the system pipelines.

Leaks and bursts appear to be a fact of life for water network operators. Pipes, joints, and other parts spring new leaks under the normal wear and tear water network infrastructure is subjected to. The question is: how do you deal with leaks and bursts? Can you delay their onset? How soon can you find and repair them? Water loss control, as its name implies, strives not so much to eradicate this phenomenon, as to restrain it. For example, for a constant rate of occurrence of new leaks, the amount of water lost depends simply on the time it takes for operations staff to find and repair those leaks, so earlier detection and repair means less Non-Revenue Water, Fanner& Lambert (2009). Incidentally, it also means less leaks have time to develop and escalate into large, visible bursts and service interruptions, so keeping water loss under control may improve several distinct measures.

In as much as every water supply system wants to eliminate leakage and for that matter all forms of water losses, there is a limit to which this can be carried up to, after which it would no more be economical to apply resources to reduce leakage. According to Farley and Trow (2003), for majorities of water utilities, leakage cannot be completely eliminated and that “there will always be a level of leakage which has to be tolerated and which has to be managed”. The reason for this is the law of diminishing returns, where returns on investment begin to diminish in relation to the cost of production or investment.

Two major options in bridging the gap between future demand for water and the current level of supply, Farley and Trow,(2003) are; Supply augmentation this refers to addition of reservoir, increase in pumping capacity, treatment plant expansion, and exportation of water from other area; Reducing the future need for water by leakage reduction and demand management. The economic implications of the two methods are different and should be appreciated. Whereas system augmentation has the advantages of economies of scale, leakage reduction has the disadvantages of the law of diminishing returns (Farley and Trow, 2003 “The more effort that is put in leakage reduction programme, the less would be the returns in terms of water saved the non revenue water must be reduced to optimum levels.

2.5 Influence of Metering to NRW

Non revenue water (NRW) is defined as ‘the difference between the volume of water put into a water distribution system and the volume that is billed to customers’ (Kingdom, Liemberger &Marin, 2006). Losses are either physical – leakages mainly due to poor operations and maintenance; commercial – due to customer meter under registration, data-handling errors, and water theft; and unbilled authorized consumption. Non-revenue water negatively affects the financial viability of water utilities through lost revenue, lost water resources, and increased operational costs (Janssens, 2013). Consequently, water utilities’ capacity to expand by increasing connections and service coverage is compromised. Nonrevenue water is a serious problem in developing countries with estimations indicating that water lost through illegal connections for example could account for about 40 per cent of NRW (Kingdom, Liemberger & Marin, 2006).

In a study investigating the non-revenue water levels in the water system in Accra, Yeboah (2008) found out that the NRW within the system was at 57per cent. This leakage led to the 40 per cent reduction in the water utility's profitability. Consequently the water utility's financial viability was negatively affected.

In Kenya NRW had detrimental effect on the provision of water utilities through lost revenue, lost water resources, and increased operational costs Olwa (2012), reducing their capacity to fund necessary expansions of service. According to the International Water Association (IWA) Task Force on Water Loss (IWA, 2003).Non Revenue Water (NRW), is "the difference between system input volume and billed authorised consumption". According to the task force, system input is "the annual input to a defined part of the water supply system" and billed authorized consumption, according to the task force is billed metered consumption including water exported and billed unmetered consumption. The World Bank Group (2006) and its affiliate partners (Water and Sanitation Sector Board and Public Private Infrastructure Advisory Facility -PPIAF) discussing the issue of non revenue water in Developing countries, defined NRW and its components as follows:" non revenue water is the difference between the volume of water put into a water distribution system and the volume that is billed to customers".

NRW has three components: Physical (or real) losses; this comprise leakage from all parts of the system and overflows at the utility's storage tanks. These occur as a result of poor operations maintenance, the lack of active leakage control, and poor quality of underground assets. It is "any leakage downstream of a production source and upstream of the consumer revenue meter"(UNEP/IETC, 1999).

2.5.1 Commercial/Apparent Losses;

These are caused by customer meter under registration, data-handling errors, and theft of water in various forms. Unbilled authorised consumption; these include water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups. System of the water utility would now be obtained, which would then form the basis for the formulation of strategies for dealing with water losses.

Butler and Mamon (2006), suggest that certain questions should be posed about the water utility with regard to the characteristics, the production process, and the operating practices, and using the available tools and mechanisms within the water utility to answer these questions from the first step in the right direction to deal with the prevailing situation. In the process of trying to answer these questions, better understanding of the network system of the water utility would now be obtained, which would then form the basis for the formulation of strategies for dealing with water losses. Butler and Mamon (2006) suggest the following questions: How much water is being lost? Where is it being lost from? and why is it being lost? The first two questions, “how much” and “where from”, according Butler and Mamon (2006) can be answered by conducting water balance. “Which is the difference between system input volume and authorised consumption”), water balance can be conducted. The third question “why is it being lost” can be answered by reviewing the management practices of the water system.

The reviewing processes should identify the policies and procedures that need reviewing and those which are being done well. Having addressed the first three questions, the “how? Where? And why?” of the losses in the system, it then becomes possible to address the last two questions which have to do with issues of strategies, policies and methodologies that need to be formulated and adopted to address the system’s losses and improve performance and water services provision. Many municipalities throughout Canada are experiencing the consequences of inefficient and wasteful water use. Studies focused on water consumption have shown that the Canadian average per capita water use is one of the highest in the world (EC, 2010). Water metering has been accepted as a step towards more conscientious resource use (Infraguide, 2003; BCWWA, 2012). Metering can support the efficient operation and management of the precious resource. As expressed by Salman and Quraeshi (2008) “We measure what we value and we value what we measure”. In British, Columbia, municipalities are close to achieving universal metering for non-residential water consumers (BCWWA, 2012). Though the frequency of metering continues to increase year-by-year throughout Canada, there is no standard in place for successful feedback systems or incentive packages. Encouraging Industry, Commercial and Industrial (ICI) water users to consider and reduce their water consumption is a complex matter. Eliciting these changes requires the appreciation of cultural, habitual and technological knowledge in relation to water use.

Researchers have studied the effects of diverse feedback interventions, however due to variations in experimental groups, climates, income levels, education levels and test group size it can be difficult to generalize results from one study to another. Efforts encouraging municipal water use reduction hold many benefits for a community, as high freshwater withdrawals can lead to environmental degradation and social difficulties in the short and long-term. Consequences include the decreased security of access to safe potable water supplies for future generations (BCWWA, 2012). Water use feedback systems can stimulate feelings of accountability from consumers for their behavior. Feedback analysis can also support governments in finding high and low users and system leakages (Infraguide, 2003). The municipal water users are generally organized into Residential, Industrial, Commercial and Institutional (ICI) and Agricultural users (EC, 2011). Metering is not evenly dispersed throughout each of these segments. Despite the increased connectivity of the ICI sector, the majority of research in the field of water metering is from residential housing (Wilhite 2007; Assen 2010). A review of the literature suggests that testing households is preferable to businesses and organizations. In a household, the consumer with financial responsibility is likely to also receive and pay bills and have a direct influence on other household members.

The household unit is smaller and so less complicated to understand. The diversity of the management structures of ICI reduces the ability to reproduce or develop standards for feedback delivery for that sector of water users. The lack of data has also contributed to the lack of knowledge on successful conservation behavior and if it can be attributed to particular feedback methods.

2.5.2 Quality of water meters

Poor quality water meters cause a lot of error in billing which result in water losses. 100% metering is one of the best practices in the management of NRW. It is only achieved if the installed meters are of good quality and well calibrated to give the right readings. Poor quality meters do not give the right readings and fail to work totally after short time intervals (Kingdom, Liemberger & Marin, 2006). Many suppliers of these meters are middle men with good connections.

They acquire these meters from the black market (stolen reconditioned meters often packed in sacks) or from companies which manufacture counterfeit goods. Water meters can be damaged and deteriorate with age, thus producing inaccurate readings. Inaccurate readings will give misleading information regarding water usage, make leak detection difficult, and result in lost revenue for the system. All meters, especially older meters, should be tested for accuracy on a regular basis. The system also should determine that meters are appropriately sized. Meters that are too large for a customer's level of use will tend to under register water use. Meters should be able to accurately record the full range of expected flow rates.

2.6 Illegal practices

Nonrevenue water is a serious problem in developing countries with estimations indicating that water lost through illegal connections for example could account for about 40 per cent of NRW in developing countries (Kingdom, Liemberger & Marin, 2006) It is estimated that 20-40% of finances in the Water Sector are being lost through corruption and dishonest practices (World Bank report, (Stalgren 2006), the same corruption and illegal practices have adversely affected efforts to reduce NRW. The forms of corruption which are rampant in the water sector of Kenya are misappropriation of resources and funds, doctoring of bills and customers data, extortion of money from consumers, illegal connections, preferential treatment, theft and misuse of property and equipments, financing ghost projects, political manipulations, favoritism, nepotism, none transparent procurement of goods and services (poor quality but high costs) and bribery for illegal services(Good governance in the Kenyan water sector, BMZ, 2012).

The water sector reforms which were initiated in 2003 have brought considerable gains for the sector. The reform achievements would have been much higher if corruption and governance challenges affecting the sector were dealt with effectively. However, corruption and bad governance among some key water sector players has continued to impede the total achievement of the reform objectives. The water sector adopted the human rights approach already by the year 2006 and put policies and strategies in place aimed at gradual realization of this. However, corruption and bad governance has continued to be a stumbling block for the sector to reach the next level of performance. One critical area in water service provision which is affected adversely by corruption and bad governance is the management of Non-Revenue

water (NRW).The national level of NRW water in Kenya has been above 47% since 2006 without any significant improvement despite other areas having shown improvements over the years.

The sustainability and economic viability of the utilities with high NRW levels are therefore at stake. Some utilities are also likely to face legal suits for violating human rights (limiting availability and access) according to the Constitution of Kenya, 2010. The high level of NRW is remaining despite the huge investments brought to the sector by the reforms. In addition, there are many local and international documented best practices on reduction of NRW to the levels below 20% from which the Kenyan water sector can learn. Some of the donor agencies involved in supporting the Kenya water sector have some of the best practices in the world for managing NRW. Among this are JICA (NRW in Japan averages at 6%) and GIZ (NRW in Germany averages at 7%). In addition there are very good best practices in Africa to learn from in countries like Burkina Faso (NRW averages at 16%), Morocco (NRW averages at 20%) and Tunisia (NRW averages at 16%).

Some Utilities in Kenya like Nyeri Water and Sewerage Company has been able to reduce the NRW to about 26%. Some of the worst performing utilities are however having NRW ranging from 60-80%. The high national NRW level in these utilities cannot therefore be attributed to the often stated reasons of lack of knowledge or none availability of required investment for improving infrastructure (the reforms have attracted a lot of investment in the sector over the last 10 years). NRW management in Kenya will only improve significantly if the challenges of corruption and bad governance in the affected utilities are dealt with since availing of the knowledge and resources has brought no significant impacts on NRW. Some of the corruption and governance issues contributing to bad NRW management are described below. Many construction works do not meet the quality standards due to malpractices occurring during the tendering and selection of contractors (KACC, 2011). Wrong contractors are often selected so long as they are able to give kickbacks and bribes. They perform their work with impunity and often produce very low quality works. The works are however approved and paid for, even with higher costs, due to the financial gains derived from bribes and kickbacks (KACC, 2011).Occasionally funds are used on ghost projects (projects on paper only) which are not

implemented at all. Such money is lost at the expense of improving infrastructure. The infrastructure remains therefore in a dilapidated state thus contributing to technical losses.

Illegal connections are a major source of NRW. Most of these connections are done by the utility staff against payment of bribes by those benefitting from these connections. Some are done to favour some politically well connected people. Illegal connections are also done by criminals or cartels often claiming community interest, who exploit on poor metering systems which do not allow detection of such connections easily (Kingdom, Liemberger & Marin, 2006).

Tampering with water meters and Data manipulation is done either by meter readers or billing staff against payment of bribes to induce favour to some customers. The data are manipulated in order to make customers disappear from the billing system or to favour such customers to reduce or waive off their bills at the expense of the utility (Liemberger & Marin, 2006). The concerned staffs are bribed for offering such favours. Purchasing of low quality meters which fail to work promote this malpractice by giving leeway for estimated meter readings.

Customers are supposed to be disconnected as soon as their bills are not paid for more than 2 months unless special arrangements are agreed on. However, some customers continue to enjoy the water services for years without payment. This creates huge debts. This is often achieved by bribing the concerned utility staff to avoid disconnection. Many utilities have debts in millions of shillings. Some of these debts are never paid forcing the utilities to write them off. There are many cases where funds and resources are stolen from the utilities by staff members thus crippling essential areas like operation and maintenance. This is often done through bank frauds and stealing of equipment and materials from stores. Receipts are sometimes stolen and used to obtain money fraudulently from unsuspecting customers. Vehicles also are diverted for private use leaving maintenance personnel with no means to react to emergency repairs such as pipe bursts.

2.7 Theoretical Framework

This study will be guided by the economic theory. Many programs to reduce NRW have failed to achieve their objectives, sometimes from the onset and sometimes only in the long run. Often they focus on real losses without sufficient attention being paid to apparent losses (World Bank, 2006). If programs achieve an initial reduction in NRW levels, they often increase again over the years to the same or even higher levels than before the program. Both apparent and real losses have a natural tendency to increase if nothing is done World Bank(2006) more leakage will occur, there will be more defective meters, and information on customers and networks will become more outdated. In order to sustain NRW at low levels, investments in fixing leaks and replacing meters are insufficient in the best case and ineffective in the worst case (USAID, 2012).

To achieve permanent results, management procedures related to a utility's organization, procedures and human resources have to be changed. Additionally the implementation of an Intelligent Pressure management system is an efficient approach to reduce the total real losses in the long term. It is one of the most basic and lucrative forms of optimizing a system and generally provides fast investment paybacks. There is some debate as to what is an economically optimal level of leakage or, speaking more broadly of NRW. From a financial or economic point of view it is not appropriate to try to reduce NRW to the lowest possible level, because the marginal cost of reducing NRW increases once the cheaper options have been exploited (World Bank, 2006). Once the marginal cost of reducing NRW exceeds the marginal benefits or water savings, an economic optimum has been achieved. Benefits should be measured through reduced production costs if reduction of NRW results in lower water production, through the avoided costs of additional supply capacity if the system is close to the limit of its capacity and demand is growing, or through the value of water sold if reduction of NRW results in additional water sales. The latter can be done by valuing water through water tariffs (financial value) or through the willingness to pay by customers (Trow ,2005). There are fewer financial incentives for a utility to reduce NRW if water production is cheap, if there is no or little metering (so that revenues thus are independent of actual consumption), or if volumetric tariffs are low.

In the United Kingdom the assessment of economic levels of leakage has a long history. The first national study on the topic was published in 1980 setting down a methodology for the assessment of economic leakage levels. This led to the implementation of sectors (District Metered Areas) in most water companies in the UK. The findings were reported in a major national research program in 1994. As a result of a drought in 1995/96 a number of companies initiated major leakage management programmes based on economic assessments. The situation in other parts of the world is quite different from the UK. Particularly in developing countries sectorisation is very rare and proactive leakage control limited. From a public health and drinking water quality point of view it is being argued that the level of real water losses should be as low as possible, independently of economic or financial considerations, in order to minimize the risk of drinking water contamination in the distribution network.

The World Bank recommends that NRW should be "less than 25%", while the Chilean water regulator has determined a NRW level of 15% as optimal in its model of an efficient water company that it uses to benchmark service providers. In England and Wales NRW stands at 19%. In the United States the American Water Works Association's (AWWA) Water Loss Control Committee recommended in 2009 that water utilities conduct annual water audits as a standard business practice. AWWA recommends that water utilities should track volumes of apparent and real losses and the annual cost impacts of these losses. Utilities should then seek to control excessive losses to levels that are economic for the water utility.

2.8 Conceptual Framework

To facilitate studying the determinants of NRW in water services provision, a conceptual Framework is formulated with the aim of showing the directional relationship of various factors. A conceptual framework establishing the determinants of NRW in water service provision is formulated as shown in Figure 1.

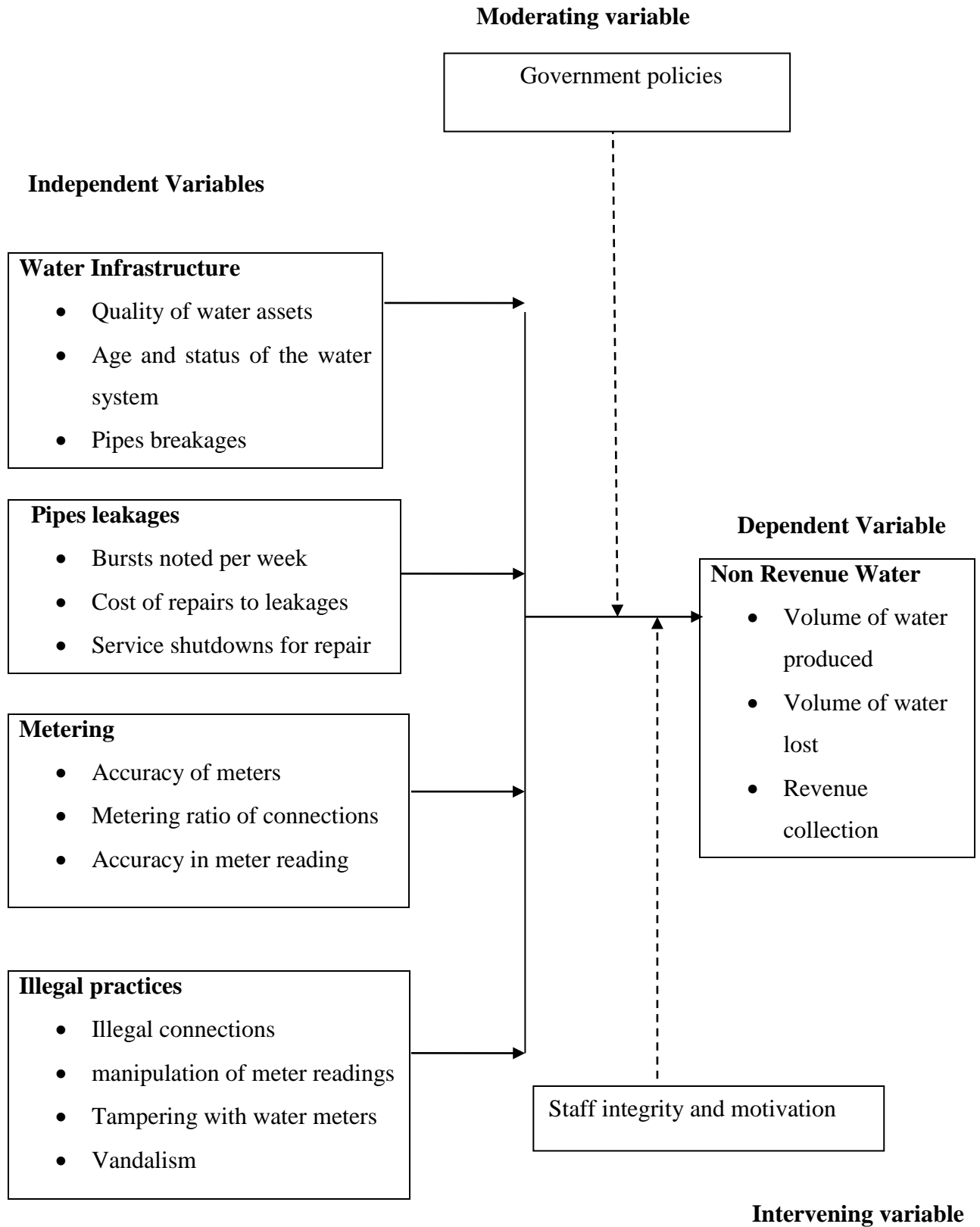


Figure 1: Conceptual Framework

The dependent variable in this study will be Non Revenue Water whilst the independent variables are the major determinants, these are; infrastructure, pipe leakages, metering and illegal practices. The moderating variable is government policies whilst the intervening variables are staff integrity and motivation.

2.9 Knowledge Gap

This study is about the determinants of Non Revenue Water in water service provision; the reduction of Non Revenue Water is a crucial step to improve the financial health of water utilities and to save scarce water resources. In Kenya the level of Non Revenue Water is about 47% in the best performing company like Nyeri Water and Sewerage Company WASREB (2012) it is 24 % although the optimal level should vary depending on circumstances, such as particularly the cost of bulk water supply. From the Literature Review we find that the percentage of physical losses is influenced not only by the deterioration of the piped network, but also by the total amount of water used, system pressure, bursts, illegal practices and the degree of supply continuity. The percentage of administrative losses depends on the degree of effort exerted in identifying illegal connections and in repairing meter. To a large extent, the level of Non Revenue Water is an indicator of how well a utility is managed. The study will find out how water infrastructure determines the Non Revenue Water in water services Provision in KIRIWASCO, how pipe leakages determines the Non Revenue Water in water services provision in KIRIWASCO, establish ways in which metering determines Non Revenue Water in water services provision in KIRIWASCO and to establish how illegal practices determines the Non Revenue Water in water services provision in KIRIWASCO. The study has not considered the role of management in reduction of Non Revenue Water and how the county government can facilitate reduction especially now when the water has become a devolved function under the current constitution. There is hence a gap for further study and a need to carry out further research on the Effect of devolution of water services in reducing the Non Revenue Water.

2.10 Summary of the Chapter

This chapter has given in depth insights into the independent and dependent variables of the Study by basing the literature on published works by other researchers. It has also outlined the Conceptual and theoretical framework which the study was based upon.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research design and methodology that was used in gathering information for purpose of completing the study. This includes introduction, research design, target population, sample size and sampling technique, data collection procedures, methods of data collection, instrument validity, instrument reliability and data analysis.

3.2 Research Design

According to Mugenda and Mugenda, (2003) survey research can be descriptive, exploratory or involving advanced statistical analysis. The study adopted descriptive survey design. According to Orodho (2009) a survey method is ideal for collecting information by administering questionnaires. The design was appropriate because it uses pre-determined population in this case the staff to give information on what causes the water losses.

3.3. Target Population

In this study the target population was the staff of Kirinyaga Water and Sanitation Company (KIRIWASCO). A total of 130 members of staff of KIRIWASCO from Technical and Commercial department were targeted in this study. According to Borg and Gall (1989) a target population is defined as all members of the real set of people, events or objects to which a research wishes to generalize the results of the study. The target population is as shown in Table 3.1.

Table 3.1 Staff in Kirinyaga Water and Sanitation Company.

Department	Number of staff
Technical	99
Commercial	31
Total	130

3.4 Sampling Procedure

Sampling is the process of selecting a number of individuals or objectives from a population such that the selected individuals became representative of the entire population. (Mugenda and Mugenda, 2003). Stratified random sampling and proportionate sampling was used in this study resulting to 97 members of staff. According to Krejcie and Morgan (1970) as shown in Appendix 5, a total of 130 members of staff required a sample of 97 members of staff. Stratified random sampling was suitable in this case because the population is divided into different strata or groups. The aim of stratified sampling was to achieve an even representation of the subgroups of the population in the selected sample (Mugenda and Mugenda, 2003). Proportionate sampling enabled the researcher to achieve greater representativeness in the sample of the population. This was accomplished by selecting individuals at random in proportion to the actual size of the group in the total population (Van Dalen, 1979). The sample is drawn as shown in the Table 3.2.

Table 3.2: Sample Population from Kirinyaga Water and Sanitation Company Staff

Department	Number of staff	Sample	Percentage(%) of Sample
Technical	99	74	76.3
Commercial	31	23	23.7
Total	130	97	100

3.5 Methods of Data Collection.

A structured questionnaire was used to collect data. The questionnaire was administered to the sample of 97 respondents with help of one research assistant. They were administered and left with the respondents to fill in before being collected a day later. The data for this research was collected from both primary and secondary sources. The secondary sources include records, past research and documents. The primary sources are the subjects of the study who gave actual data collected from the field. The use of questionnaire method is supported by Burns (2000) as appropriate when dealing with many respondents. The use of a questionnaire allows every participant to get a similar assessing tool to complete which may result in standardized responses. During the questionnaire completion process, if any problem arises, the researcher or

the assistants are available although they remain in the background (De Vos, 2001). The use of a questionnaire also eliminates a situation where the researcher is available but the respondent to be interviewed is not available as when using an interview in a qualitative study (Burns, 2000).

3.5.1 Piloting of the instruments

The researcher carried out pilot testing with 10 employees who were not part of the main study. The instruments were then edited and corrected.

3.6 Validity of the Instruments

According to Mugenda and Mugenda (2003), validity refers to the accuracy and meaningfulness of inferences which are based on the research results. It is also the degree to which the results obtained from the analysis of the data represents the phenomenon under the study. Validity of the research is asking the right questions framed in the least ambiguous way (Sommer, 2007).

An instrument is valid when it measures what it purports to measure (Robson, 2002). In this study the Validity of the questionnaire was measured to ascertain all the areas necessary for the study were covered in the instrument. The validity of the questionnaire was validated through help of the University supervisor and classmates as suggested by Robson (2002). Their comments were used to design the questionnaire to the required standards.

3.7 Reliability of the Instruments

The reliability of a measuring tool is the consistency it has in providing similar results from the same population when administered at different times (Currier 1984). This research study used test-rest method which involves administering the same scale or measure to the same group of respondents at two separate times. Shuttleworth (2009) stated that in test retest method, the instrument was administered at two different times and then the correlation between the two sets of scores computed. This was after a time lapse of one week. Reliability of the instruments was computed using Pearsons Product Moment correlation coefficient. A correlation coefficient of 0.7 was found and therefore the questionnaire was reliable.

3.8 Data Analysis techniques

The questionnaires were edited to check on completeness, clarity and consistency in answering research questions. The data was coded, tabulated and analysed using Statistical Package for Social Sciences (SPSS) version 19 based on study objectives. Descriptive statistics and correlations were computed and study findings were presented using tables and percentages and interpretations made and report written.

3.9 Ethical Considerations.

This study observed confidentiality when handling the information given on questionnaires. The respondent's information was not passed to any third party. The respondent's names were also not written on the questionnaires. The Respondents consent was sought before administering or conducting interviews. The researcher identified himself to the respondent and explain his mission.

3.10 Operational Definition of Variables

Operational definition is a description of a variable, term or object in terms of the specific process or set of validation tests used to determine its presence and quantity. Variables described in this manner must be publicly accessible so that persons other than the definer can independently measure or test for them at will (Kish, 2011). Operationalization refers to the translation of concepts into tangible indicators of their existence (Saunders, 2009). Table 3.3 summarizes the operational definition of variables that were used in this study.

Table 3.3 Operational Definition of Variables in the Study

Objective	Type of Variables	Indicator(s)	Measure(s)	Measurement scale	Type of analysis tools
To establish how the water infrastructure determines the Non Revenue Water in water services Provision in KIRIWASCO.	Independent	Age of network	Number of years	Ratio	Percentages and means
	Infrastructure	Type of material used	Length in KM	Ratio	Percentages and means
		Pipe broken	Number of pipes broken	Ratio	Percentages and means
To establish how pipe leakages determines the Non Revenue Water in water services provision in KIRIWASCO.	Independent variable pipe leakages	Bursts reported	Number of bursts	Ratio	Correlation
		Cost of repairs done	Number of repairs	Ratio	Percentages and means
		Service shutdown for repair	Number of shut down	Ratio	Percentages and means

<p>To establish how metering determine Non Revenue Water in water services provision in KIRIWASCO.</p>	<p>Independent Variable Metering</p>	<p>Master meters Metered connections Metering ratio</p>	<p>Number of master meters Number of metered connections Percentage of metered connections</p>	<p>Ratio Ratio Ratio</p>	<p>Correlation Percentages and means</p>
<p>To establish how illegal practices determines the Non Revenue Water in water services provision in KIRIWASCO.</p>	<p>Independent variable Illegal practices</p>	<p>Illegal connections Manipulation of meter readings Meters tampered with Vandalism cases</p>	<p>Number of illegal connections reported Number of meters manipulated No of meters tampered No.of cases reported</p>	<p>Ratio Ratio Ratio Ratio</p>	<p>Percentages and means Percentages and means Percentages and means</p>

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

This chapter presents data analysis, presentation and interpretation of findings collected from Kirinyaga Water and Sanitation Company's staff based on determinants of non revenue water in water services provision in Kirinyaga County in Kenya. The study sampled 97 Kirinyaga Water and Sanitation Company. The data was interpreted as per the research questions. The analysis was done through descriptive and inferential statistics. The findings were presented in form of frequency tables and percentages.

4.2 Questionnaire Return Rate

The questionnaire return rate was 98% out of the 97 questionnaires used. This was possible since the questionnaires were administered by trained research assistants who administered questionnaires, waited for the respondent to complete and collect immediately.

4.3 Demographic characteristics of the respondents

This section presents the respondents' gender, age and education background. These social attributes were relevant to the study since they enabled the respondent to provide information that is valid, reliable and relevant to the study.

4.3.1 Study responses by gender, age and level of education of the respondent

The study sought to establish the social characteristics of the respondents. The responses are shown in Table 4.1.

Table 4.1 Social characteristics of the respondents

	Age bracket	Secondary level	Tertiary level	University	
Male	Below 30 years	0	0	0	0
	31-40 years	7	37	1	45 (71.5%)
	41-50 years	2	10	0	12 (19%)
	51-60 years	2	4	0	6 (9.5%)
Total		11	51	1	63
		17.5%	80.9%	1.6%	100.0%
Female	Below 30 years	0	1	0	1 (3.1%)
	31-40 years	1	12	0	13(40.6%
	41-50 years	0	12	1	13(40.6%)
	51-60 years	0	5	0	5 (15.7%)
Total		1	30	1	32
		3.1%	93.8%	3.1%	100.0%
Total		11	51	1	63
		17.5%	80.9%	1.6%	100.0%

The findings indicate that 71.5% of the male respondents are in the age bracket 31-40 years of age while 81.2% of female respondents are in the age bracket 31-50 years of age. However, 93.8% of female respondents have attained tertiary level of education while 80.9% of male respondents have attained tertiary level of education. This implies that the most female employees have attained technical skills from technical colleges.

4.3.2 Work experience of the respondents in KIRIWASCO.

The respondents were asked to indicate their gender and the number of years they have worked. Table 4.2 show results.

Table 4.2 Gender and work experience at KIRIWASCO

	Years of work at KIRIWASCO			Total
	Less than 1 year	1-5 years	6-10 years	
Gender of the respondent				
Male	27	25	11	63(66.3%)
Female	16	11	5	32(33.7%)
Total	43(45.3%)	36(37.9%)	16(16.8%)	95(100%)

The findings indicate that 45.3% respondents have worked for less than 1 year. Majority of male workers 27 males (42.9%) and female workers 16(50%) have worked for less than 1 year. This implies that there is high turnover in the water company.

4.4 Water Infrastructure in Determining Non Revenue Water in KIRIWASCO

4.4.1 Main causes of Non Revenue Water in KIRIWASCO.

The respondents were asked to indicate the main causes of Non Revenue Water. Table 4.3 shows the main causes of Non Revenue Water.

Table 4.3 Main causes of Non Revenue Water

Marital status	Frequency	Percentage
Aged water systems leading to Non detected leakages	61	64.2
Bursts and Leakages,	18	18.9
Illegal connections, faulty meters and meter bypasses	16	16.8
Total	95	100.0

The findings indicate that majority of the respondents 61 respondents (64.2%) indicated that non revenue water was caused by Aged water systems leading to non detected leakages, 18 respondents (18.9%) indicated that it was caused by pipe bursts and 16 respondents (16.8 %) indicated that it was caused by Illegal connections, faulty meters and meter by passes. It is therefore important aged pipes be replaced and leak detectors procured.

4.4.2 Ways of reducing Non Revenue Water

The respondents were asked to suggest ways of reducing Non Revenue Water. Table 4.4 shows the suggested ways of reducing Non Revenue Water.

Table 4.4 Ways of reducing Non Revenue Water

Ways of reducing NRW	Frequency	Percentage
Replacement of old meter and water systems(aged)	47	49.5
Calibration of all meters	13	13.7
Immediate repair of bursts	21	22.1
Sealing of all meters	2	2.1
Changing of staff attitude especially meter readers	12	12.6
Total	95	100.0

From the study, 47 respondents (49.5%) indicated that NRW can be reduced by replacement of old meter and water systems(aged), 21 respondents (22.1%) said that NRW can be reduced through immediate repair of bursts and 12 respondents (12.6%) said that NRW can be reduced through Changing of staff attitude especially meter readers and operating and maintenance (O&M). This implies that NRW can substantially be controlled through replacement of old meter and water systems (aged).

4.4.3 Area of coverage

The respondents were asked to indicate area of coverage. Table 4.5 shows the respondents area of coverage.

Table 4.5 Area of coverage

Area of coverage	Frequency	Percentage
Less than 1 Km	9	9.5
1-20km	37	38.9
21-40km	20	21.1
41-60km	3	3.2
61-80km	19	20.0
81-100km	3	3.2
Above 100km	4	4.2
Total	95	100.0

The study shows that 38.9 % of respondents cover 1-20KM in the course of their work, 21.1% respondents cover 21-40KM and only 7.4% respondents cover from 81 KM and above in the course of their work. That is 60.0% cover 1-40KM in the course of their work. This shows that the staff capacity is adequate in the water company.

4.4.4 Age of main service lines, type and class

The respondents were asked to indicate the age of main service lines, type and class. Table 4.6 shows the results.

Table 4.6 Type, class and age of the main service lines

		Type and class of the main pipes					Total
		Ductile iron	Galvanized iron class B,C,D (PVC)	Galvanized iron max. size 3"	PVC Class D	ALL	
How old is your main service lines	11-20 years	13	9	3	4	0	29 30.5%
	21-30 years	11	5	6	4	1	27 28.4%
	31-40 years	17	10	2	5	0	34 35.8%
	Above 40 years	2	1	0	1	1	5 5.3%
Total		43 45.3%	25 26.3%	11 11.6%	14 14.7%	2 2.1%	95 100%

From the study, 45.3% of respondents indicated that the highest proportion of main service line was ductile iron pipes followed by PVC pipes class B, C, D as indicated by 26.3%) of respondents. Majority of the main pipes are 31-40 years as indicated by 35.8% of respondents. This implies that most main lines have quality pipes; however most service lines are old and may be leaking leading to NRW.

4.4.4 Class of plastic pipes one use and the pipe experience most bursts

The respondents were asked to indicate the class of plastic pipes used. Table 4.7 shows the responses.

Table 4.7 Class of plastic pipes one use and the pipe experience most bursts

		Which pipe experience most bursts			Total
		Class A	PVC Class B downward to class A	Class C (plastic pipe)	
Which class of plastic pipes do you use	Class B,C,D	12	28	0	40(42.1%)
	Class B and C	2	41	0	43(45.3%)
	Class C	1	7	1	9(9.5%)
	not applicable	0	3	0	3(3.2%)
Total		15(15.8%)	79(83.2%)	1(1.1%)	95(100%)

The study showed that 45.3% of respondents indicated that Class B and C of plastic pipes are mostly used. Majority of respondents (83.2 %) indicated that PVC pipes of Class B downwards to class A experience most bursts. This implies that most plastic pipes are of low quality (class B and C) since the best quality is class D and E. PVC Class B downward to class A should be replaced since they experience most bursts that contributing to NRW.

4.5 Pipe Leakages in Determining Non Revenue Water IN KIRIWASCO

Pipe leakage contributes to Non Revenue Water in the water company.

4.5.1 Extent of pipe leakages in determining NRW and time taken to repair bursts

The respondents were asked to indicate to what extent pipe leakages determine NRW and how long does it take to repair bursts. Their responses are in table 4.8.

Table 4.8 Extent of pipe leakages in determining NRW and time taken to repair bursts

		How long it takes to repair bursts					Over	Total
		1-3 hrs	4-6hrs	7-9hrs	10-12hrs	12hrs		
To what	0-20%	12	2	0	1	1	16(16.8%)	
extent do	21-40%	36	6	13	0	1	56(58.9%)	
pipe leakages	41-60%	7	1	4	0	0	12(12.6%)	
determine	61-80%	5	5	1	0	0	11(11.6%)	
NRW								
Total		60	14	18	1	2	95	
		(63.2%)	(14.7%)	(18.9%)	(1.1%)	(2.1%)	(100%)	

From the study, 63.2% of respondents indicated that it takes 1-3hrs to repair a burst while 58.9% of the respondents indicated that pipe leakages contribute to 21-40% of NRW. The pipe bursts should be repaired promptly to reduce NRW since pipe leakages contribute significant amount to NRW.

Using percentages of pipe leakages and time taken to repair a pipe, a Pearson product moment correlation test was conducted and table 4.8 shows the results.

Table 4.9 The relationship between the extent of pipe leakages and determining NRW in Water Services Provision (N=95)

		To what extent do pipe leakages determine NRW		How long does it take to repair bursts
To what extent do pipe leakages	Pearson	1	.031(**)	
determine NRW	Correlation			
	Sig. (2-tailed)		.762	
	N	95	95	

**** Correlation is significant at the 0.01 level**

The results indicate a positive relationship but no significant association at 99% level of confidence between the extent of pipe leakages in determining NRW and the time taken to repair a burst ($r = 0.031$ $N=95$ and $p=0.762$) and that the differences between the scores could be by a chance.

The study also sought to find what can be done to reduce bursts and it showed that 51.6% of respondents indicated that relocation and maintenance of road reserve reduce bursts, 30.5% of respondents indicated that replacement of aged system reduce bursts while 17.9% of respondents indicated that Regular patrol reduce bursts. Reduction of bursts will reduce NRW.

4.6 Metering In Determining Non Revenue Water in KIRIWASCO

The water in the distribution system requires to be metered in order to control water losses.

4.6.1 Total volume of water produced and channeled to the distribution system

The respondents were asked to indicate the total volume of water produced and channeled. Their responses are in table 4.10

Table 4.10 Total volume of water produced and channeled

Total volume of water produced and channeled	Frequency	Percentage
0-10000 cubic meters per day	36	37.9
10001-20000 cubic meters per day	36	37.9
20001-30000 cubic meters per day	17	17.9
More than 30000 cubic meters per day	6	6.3
Total	95	100.0

From the study, 36 respondents (37.9%) indicated that 0-10000 cubic meters per day is the total volume of water produced and channeled to consumers, 36 respondents (37.9%) indicated that 10001-20000 cubic meters per day per day is the total volume of water produced and channeled to consumers. Therefore 72 respondents (75.8%), indicated that 0-20000 cubic meters per day per day is the total volume of water produced and channeled to consumers. Thus the amount expected to be billed is from 0-20000 cubic meters per day, however, it is expected to be lower than 0-20000 cubic meters per day because of NRW.

4.6.2 Volume of water billed to all customers

The respondents were asked to indicate the total volume of water billed. Their responses are in table 4.11.

Table 4.11 Total volume of water billed to all customers

Total volume of water billed	Frequency	Percentage
0-10000cubic meters per day	59	62.1
10001-20,000 cubic meters per day	26	27.4
20001-30000 cubic meters per day	10	10.5
Total	95	100.0

From the study, 59 respondents (62.1%) indicated that the total volume of water billed was 0-10000cubic meters per day. The billed water is lower than what was channeled (0-20000cubic meters per day). The losses were due to NRW.

4.6.3 Steps WSP has taken to reduce losses

The respondents were asked to indicate the steps which WSP has taken to reduce losses. Their responses are shown in table 4.12.

Table 4.12 Steps WSP has taken to reduce losses

Trainings	Frequency	Percentage
Replacement of aged consumer meters	28	29.5
Adaptation of meter installation policy	30	31.6
Gradual replacement of GI pipe with PVC	4	4.2
Replacing of faulty meter	9	9.5
Be proactive to issues apertaining to NRW	15	15.8
Istallation of leak detectors	9	9.5
Total	95	100.0

From the study, 30 respondents (31.6%) indicated that adaptation of meter installation policy would reduce losses while 28 respondents (29.5%) indicated that replacement of aged consumer meters would reduce losses. If adaptation of meter installation policy and aged consumer meters are replacement, they would reduce losses by 61.1% as indicated by 58 respondents.

4.6.4 Metered connection

The respondents were asked to indicate the percentage of their metered connection. Their responses are shown in table 4.13.

Table 4.13 Percentage of metered connection

Trainings	Frequency	Percentage
0-20%	5	5.3
21-40%	16	16.8
41-60%	4	4.2
61-80%	15	15.8
81-100%	55	57.9
Total	95	100.0

From the study, 55 respondents (57.9%) indicated that the percentage of metered connection is 81-100%. This implies that much of the water channeled is metered. Metering enables giving of accurate and reliable data for water sold, control losses and increases revenue collection.

4.6.5 Main ways that efficiency of meters can be ensured

The respondents were asked to indicate the main ways that efficiency of meters can be ensured. Their responses are shown in table 4.14.

Table 4.14 Main ways that efficiency of meters can be ensured

Ways of ensuring efficiency of meters	Frequency	Percentage
Having meter supervisors	31	32.6
Adaptation of meter installation policy	23	24.2
Provision of meter reading equipment	17	17.9
Introduction of data logger and short courses for meter readers	24	25.3
Total	95	100.0

From the study, 31 respondents (32.6%) indicated that having meter supervisors would ensure efficiency of meters while 24 respondents (25.3%) indicated that introduction of data logger and short courses on meter readers would ensure efficiency of meters. Efficiency of meters will enable giving of accurate and reliable data for water sold, control losses and increases revenue collection.

4.7 Illegal Connections in Determining Non Revenue Water in KIRIWASCO

Illegal connections lead to increased NRW and hence loss of revenue collection.

4.7.1 Major Cases of Illegal Practices Encountered

The respondents were asked to indicate the major cases of illegal practices encountered .Their responses are shown in table 4.15.

Table 4.15 Major Cases of Illegal Practices Encountered

Major Cases Of Illegal Practices	Frequency	Percentage
Meter tampering, illegal connection and vandalism and theft	63	66.3
Meter reversing	9	9.5
By passing	11	11.6
Self-reconnection	12	12.6
Total	95	100.0

From the study, 63 respondents (66.3%) indicated that the major cases of illegal practices encountered are meter tampering, illegal connection and vandalism and theft while 12 respondents (12.6%) indicated that the major cases of illegal practices encountered is self-connection.

4.7.2 Penalties of Illegal Practices

The respondents were asked to indicate whether attended trainings on rabbit production had any influence on adoption. Their responses are shown in table 4.16.

Table 4.16 Penalties of Illegal Practices

Penalties Of Illegal Practices	Frequency	Percentage
Surcharged	47	49.5
disconnection	30	31.6
prosecution in the court of law	5	5.3
Warning to consumers	5	5.3
Enshrined in the gazetted tariff	8	8.4
Total	95	100.0

From the study, 47 respondents (49.5%) indicated that the main penalties of illegal practices are surcharging while 30 respondents (31.6%) indicated that disconnection is the main penalty of illegal practices. Penalties deter illegal connections and hence reduce NRW.

4.7.3 Main Illegal Practices

The respondents were asked to indicate whether attended trainings on rabbit production had any influence on adoption. Their responses are shown in table 4.17.

Table 4.17 Main Illegal Practices

Main Illegal Practices	Frequency	Percentage
Meter tampering, vandalism and tampering with water system-25%	73	76.8
Installation of bypass and damaging main line 15-30%	22	23.2
Total	95	100.0

From the study, 73 respondents (76.8%) indicated that the main illegal practices are meter tampering, vandalism and tampering with water system and contribute to 25% of water losses while 22 respondents (23.2%) indicated that the main illegal practices are installation of bypass and damaging main line contributes to 15-30% of water losses. These water losses contribute to NRW.

4.7.4 How to mitigate illegal practices

The respondents were asked to indicate whether attended trainings on rabbit production had any influence on adoption. Their responses are shown in table 4.18.

Table 4.18 How to Mitigate Illegal Practices

Mitigate Illegal Practices	Frequency	Percentage
Efficiency in metering water system, sealing of all meters, penalties to community and improve supervision	44	46.3
Impose heavy penalties to offenders	36	37.9
Improve supervision by creating strong audit team	15	15.8
Total	95	100.0

From the study, 44 respondents (46.3%) indicated that efficiency in metering water system, sealing of all meters, creating awareness of illegal practices and penalties to community, improve supervision by creating strong audit team mitigate illegal practices while 15 respondents (15.8%) indicated that improving supervision by creating strong audit team will mitigate illegal practices. If illegal practices are controlled, NRW will decrease and revenue collection is improved.

4.8 Summary of the Chapter

The data collected was analysed using Statistical Package for Social Sciences and tables were used to present data in APA table format. The response rate was 98 %,(95 questionnaires were received back) from staff of Kirinyaga Water and Sanitation Company. The data interpretation focused on the determinants of Non Revenue Water in Water Services Provision. This study shows that water infrastructure, pipe leakages, metering and illegal practices determine the Non Revenue Water in water services Provision in Kirinyaga Water and Sanitation Company (KIRIWASCO).

CHAPTER FIVE
SUMMARY OF FINDINGS, DISCUSSION, CONCLUSIONS AND
RECOMMENDATIONS

5.1 Introduction

This chapter focuses on the summary of findings of the study which formed the foundation for discussions. The discussions provided a firm basis upon which conclusions and recommendations were advanced to address the determinants of Non Revenue Water in Water Services Provision in Kirinyaga Water and Sanitation Company (KIRIWASCO). It also includes suggested areas for further research and contribution to the body of knowledge.

5.2 Summary of Findings

The summary of findings is presented based on the four objectives of the study.

5.2.1 How water infrastructure determines the Non Revenue Water in water services

Provision in KIRIWASCO.

The findings indicate that 45.3% respondents have worked for less than 1 year. That is 42.9% of male workers and 50% of female workers. This shows that there is high turnover of employees in the water company. From the study, 64.2 % of respondents indicated that aged water systems leading to non detected leakages are the main cause of NRW and 49.5% of respondents indicated that NRW can be reduced by replacement of old meter and water systems(aged). It is therefore important that aged pipes be replaced and leak detectors procured.

The study shows that 38.9 % of respondents cover 1-20KM in the course of their work, 21.1% respondents cover 21-40KM and only 7.4% respondents cover from 81KM and above in the course of their work. That is 60.0% of the respondents cover 1-40KM in the course of their work. This shows that the staff capacity is adequate in the water company. From the study, 45.3% of respondents indicated that the main service line was ductile iron pipes followed by PVC pipes class B, C, D as indicated by 26.3% of respondents. Most main pipes are 31-40 years as indicated by 35.8% of respondents and therefore require replacement. This implies that most

main lines have quality pipes; however most service lines are old and may be leaking leading to NRW. The study showed that PVC pipes of Class B downwards to class A experience most bursts as indicated by 83.2 % of the respondents. This implies that most plastic pipes are of low quality (class B and C) and likely to cause bursts and water leakage.

5.2.2 How pipe leakages determine the Non Revenue Water in water services provision in KIRIWASCO.

From the study, 63.2% of respondents indicated that it takes 1-3hrs to repair a burst while 58.9% of the respondents (58.9%) indicated that pipe leakages contribute to 21-40% of NRW. The pipe bursts should be repaired promptly to reduce NRW since pipe leakages contribute significant amount to NRW. The results indicated a positive relationship but no significant association at 99% level of confidence between the extent of pipe leakages in determining NRW and the time taken to repair a burst ($r = 0.031$ $N=95$ and $p=0.762$) and that the differences between the scores could be by a chance.

The study also sought to find what can be done to reduce burst and it showed that 49 respondents (51.6%) indicated that relocation and maintenance of road reserve reduce bursts, 29 respondents (30.5%) indicated that replacement of aged system reduce bursts and 17 respondents (17.9%) indicated that regular patrol reduce bursts and consequently reduce NRW.

5.2.3 Ways in which metering determines Non Revenue Water in water services provision in KIRIWASCO

From the study, 75.8% of respondents indicated that 0-20000 cubic metres per day is the amount of water produced and channeled to the distribution system but 62.1% of the respondents indicated that only 0-10000 cubic metres per day are billed to consumers. Therefore, the billed water is lower than what was channeled because of NRW. A pearson product moment correlation test was conducted to examine whether there is a relationship between total volume of water channeled to the distribution system and total volume billed to customers.

The results indicated a significant and positive relationship ($r = .456$ $N=95$ $P=.000$) implying that the amount of water produced and channeled to the distribution system is associated with the amount of water billed to consumers. The higher the amount of water produced and channeled to the distribution channel, the higher the amount of water billed to customers. From the study, 31.6% respondents indicated that adaptation of meter installation policy would reduce losses while 29.5% respondents indicated that replacement of aged consumer meters would reduce losses. If adaptation of meter installation policy and aged consumer meters are replaced, they would reduce losses by 61.1% as indicated by 58 respondents. The results indicated a negative relationship ($r = -0.5$ $N=95$ $P=.628$) and the results did not yield a statistically significant association. This shows that as the percentage of metered connection increases the percentage of NRW decreases and vice versa. Therefore the percentage of metered connection should be increased in order to control NRW.

5.2.4 How illegal practices determines the Non Revenue Water in water services provision in KIRIWASCO.

From the study, 76.8% of respondents indicated that the major cases of illegal practices encountered are meter tampering, illegal connection and vandalism and theft while 49.5% of respondents indicated that the main penalties of illegal practices are surcharging. Therefore Penalties deter illegal connections and hence reduce NRW.

5.3 Discussion of Findings

The study identified some of the issues associated with Non Revenue Water in water services provision in Kirinyaga Water and Sanitation Company in Kirinyaga County. The findings illuminated the research questions in line with the research objectives proposed in chapter one. This chapter discusses some of the major themes emerging from the study namely water infrastructure, pipe leakages, metering and illegal connections and their contribution to Non Revenue Water. The findings are discussed and elaborated further with the assistance of the supporting literature.

5.3.1 How water infrastructure determines the Non Revenue Water in water services

Provision in KIRIWASCO.

From the study, 64.2% of the respondents indicated that Non Revenue Water was caused by Aged water systems leading to non detected leakages, pipe bursts, Leakages, illegal connections, faulty meters and meter by passes. This agrees with study by Fanner & Lambert (2009) who reported that the major infrastructural determinants of NRW are poorly laid pipes which do not follow pipeline construction procedures, random excavation of pipe trenches without following technical designs, random expansion of pipeline network without following technical procedures, none anchoring of pipe bends and Tee-joints causing movement and leaks as well as Covering pipes without conducting pressure tests for leakages in the joints. NRW can also be reduced by immediate repair of bursts and changing of staff attitude especially meter readers and operating and maintenance (O&M). This implies that NRW can substantially be controlled through replacement of old meter and water systems (aged) as indicated by 64.2% of the respondents. This collaborates study by Farley and Trow (2003), who said that infrastructural management is a key issue in prevention of NRW, if mains replacement is being used as a water leakage reduction strategy, then it would be more beneficial to carry out targeting studies to determine which areas of the water system are more prone to frequent bursts and leaks and which mains within these areas have the highest frequency (number per kilometer per year) and the highest background leakage.

The main service line was 21-40 years as indicated by 61 respondents (64.2%). This indicates that the service line is old especially in areas where it is of low quality and may be leaking leading to NRW. This agrees with Farley and Trow (2003) who indicated that the kind of infrastructure used determines the level of NRW. They further observed that old and dilapidated infrastructure leaves the water exposed to many leakages and continuous bursts if the repairs are also not done in an appropriate manner the bursts keeps on re occurring. The study showed that 43 respondents (45.3%) indicated that Class B and C of plastic pipes are mostly used and 79 respondents (83.2 %) indicated that PVC pipes of Class B downwards to class A experience most bursts. This implies that most plastic pipes are of low quality (class B and C) since the best quality is class D and E. PVC Class B downward to class A should be replaced since they

experience most bursts that contributing to NRW. This agrees with WHO/UNICEF (2006) who reported that dilapidated infrastructure, low levels of revenue collection, poor management, and lack of accountability in governance are further obstacles to the sustainable improvement of access to water in the urban areas, and particularly in low-income settlements.

5.3.2 How pipe leakages determine the Non Revenue Water in water services provision in KIRIWASCO.

From the study, 60 respondents (63.2%) indicated that it takes 1-3hrs to repair a burst while 56 respondents (58.9%) pipe leakages contribute to 21-40% of NRW. The pipe bursts should be repaired promptly to reduce NRW since pipe leakages contribute significant amount to NRW. This agrees with Fanner & Lambert (2009) who reported that for constant rate of occurrence of new leaks, the amount of water lost depends simply on the time it takes for operations staff to find and repair those leaks, so earlier detection and repair means less Non-Revenue Water. Pipe leakage determine 21-40% of NRW as indicated by 56 respondents (58.9%).

This shows that pipe leakage contribute greatly to NRW resulting to less water available for distribution. This agrees with WASREB (2012), who reported that Pipe leakages results to loss of water and then to less water available for distribution. With less water available rationing has to be done to the customers making every customer to be allocated hours of supply. Reduction of bursts reduces NRW. From the study, 48 respondents (50.5%) indicated that the best way of controlling bursts and leakages is replacement of aged pipes. A Pearson product moment correlation test was conducted and The results indicate a positive relationship but no significant association at 99% level of confidence between the extent of pipe leakages in determining NRW and the time taken to repair a burst ($r = 0.031$ $N=95$ and $p=0.762$) and that the differences between the scores could be by a chance. The aged pipes replacement can control a lot of NRW and hence meet water demand. This collaborates study by Farley and Trow (2003) who observed that two major options in bridging the gap between future demand for water and the current level of supply is by leakage reduction and demand management.

5.3.3 Ways in Which Metering Determines Non Revenue Water in Water Services

Provision in KIRIWASCO.

The findings indicate that if meter installation policy is adapted and aged consumer meters replaced, they would reduce losses by 61.1% as indicated by 61% of the respondents. The water in the distribution system requires to be metered in order to control water losses. This agrees with Kingdom, Liemberger & Marin (2006) who reported that poor quality water meters cause a lot of error in billing which result in water losses. They further stated that 100% metering is one of the best practices in the management of NRW and poor quality meters do not give the right readings and fail to work totally after short time intervals. Water meters can be damaged and deteriorate with age, thus producing inaccurate readings. From the study, 75.8% of the respondents indicated that 0-20000 cubic meters per day is the total volume of water produced and channeled to consumers but the water billed is 0-10000 cubic meters per day. The losses were due to NRW and reduce revenue generated. The results indicate a negative relationship ($r = -0.5$ $N=95$ $P=.628$) and the results did not yield a statistically significant association. This shows that as the percentage of metered connection increases the percentage of NRW decreases and vice versa.

Therefore the percentage of metered connection should be increased in order to control NRW. This agrees with Janssens (2013) who stated that Non-revenue water negatively affects the financial viability of water utilities through lost revenue, lost water resources, and increased operational costs. Therefore a lot of water (21-60%) which would otherwise serve many customers is lost through NRW. If adaptation of meter installation policy and aged consumer meters are replacement, they would reduce losses by 61.1% as indicated by 58 respondents This collaborates study by Kingdom, Liemberger & Marin (2006) who stated that Nonrevenue water is a serious problem in developing countries with estimations indicating that water lost through illegal connections for example could account for about 40 per cent of NRW. This leakage led to the 40 per cent reduction in the water utility's profitability. Consequently the water utility's financial viability was negatively affected. The study indicated that if adaptation of meter installation policy and aged consumer meters are replaced, they would reduce losses by 61.1%.

From Pearson product moment correlation tests the percentage of metered connection increases as the percentage of NRW decreases and vice versa. Therefore the percentage of metered connection should be increased in order to control NRW. Metering enables giving of accurate and reliable data for water sold, control losses and increases revenue collection. This agrees with Olwa (2012) who found that NRW had detrimental effect on the provision of water utilities through lost revenue, lost water resources, and increased operational costs, reducing their capacity to fund necessary expansions of service. This further agrees with BCWWA (2012) who reported that water metering has been accepted as a step towards more conscientious resource use and metering can support the efficient operation and management of the precious resource.

5.3.4 How Illegal practices determine the Non Revenue Water in water services provision in KIRIWASCO.

From the study, 76.8% of respondents indicated that the major cases of illegal practices encountered are meter tampering, illegal connection and vandalism and theft while 49.5% of respondents indicated that the main penalties of illegal practices are surcharging. Therefore Penalties deter illegal connections and hence reduce NRW. This agrees with BMZ (2012) who stated that the forms of corruption which are rampant in the water sector of Kenya are misappropriation of resources and funds, doctoring of bills and customers data, extortion of money from consumers, illegal connections, preferential treatment, theft and misuse of property and equipments, financing ghost projects, political manipulations, favoritism, nepotism, none transparent procurement of goods and services (poor quality but high costs) and bribery for illegal services.

This also agrees with Stalgren (2006) who indicated that 20-40% of finances in the Water Sector are being lost through corruption and dishonest practices and the same corruption and illegal practices have adversely affected efforts to reduce NRW. From the study, 46.3% of respondents indicated that efficiency in metering water system, sealing of all meters, creating awareness of illegal practices and penalties to community, improve supervision by creating strong audit team mitigate illegal practices. If illegal practices are controlled, NRW will decrease and revenue collection is improved.

Penalties deter illegal connections and hence reduce NRW. This corroborates study by Kingdom, Liemberger & Marin (2006) who indicated that Illegal connections are a major source of NRW. They further indicated that most of these connections are done by the utility staff against payment of bribes by those benefitting from these connections. Illegal connections are also done by criminals or cartels often claiming community interest, who exploit on poor metering systems which do not allow detection of such connections easily. From the study, 46.3% of respondents indicated that efficiency in metering water system, sealing of all meters, creating awareness of illegal practices and penalties to community, improve supervision by creating strong audit team mitigate illegal practices. If illegal practices are controlled, NRW will decrease and revenue collection is improved.

5.4 Conclusion of the Study

It can be concluded that water infrastructure determines the Non Revenue Water in water services provision. Non Revenue Water (NRW) is caused by Aged water systems leading to non-detected leakages, pipe bursts, Leakages, illegal connections, faulty meters and meter by passes. NRW can be reduced by immediate repair of bursts and changing of staff attitude especially meter readers and operating and maintenance (O & M) staff. The main causes of pipe leakages are Corroded pipes, GI pipe damage due to high pressure and acid corrosion. Pipe leakage contributes greatly to NRW resulting to less water available for distribution. The aged pipes replacement can control a lot of NRW and hence meet water demand. Two major options in bridging the gap between future demand for water and the current level of supply is by leakage reduction and demand management. Old meters should be replaced for accurate and reliable water data to increase water sold and revenue collection. The major cases of illegal practices encountered are meter tampering, illegal connection and vandalism and theft which lead to loss of revenue. To mitigate illegal practices, there should be efficiency in metering system, sealing of all meters, creating awareness of illegal practices and penalties to community and improving supervision by creating strong audit team.

5.5 Recommendations

On the basis of the results of this study the recommendations are as follows

1. The water and sanitation companies should detect pipe leakages, pipe bursts, illegal connections, faulty meters and meter by passes in order to reduce NRW and hence improve the volume of water available for distribution and revenue collection.
2. The corroded pipes and damaged GI pipe should be replaced with quality pipes which are non corrosive and can hold more water volumes (pressure).
3. The water and sanitation companies should install master meters and leak detectors to control bursts and leakages. This will reduce NRW and improve revenue collection.
4. To mitigate illegal practices, efficiency in metering water system, sealing of all meters, creating awareness of illegal practices and penalties to community for meter tampering and other illegalities as well as improving supervision by creating strong audit team should be implemented.

5.6 Suggested areas for further Research

The following areas are suggested for further studies from the results of this study

1. Carry out research on an investigation of the determinants of non-revenue water in water services provision in other parts of the country.
2. Carry out a study to establish the factors that influence illegal practices in water and sanitation companies in the country.
3. Carry out a Study to find out how illegal connections can be detected by officers while in the office.

5.7 Contribution to the body of knowledge

Objective	Contribution to knowledge
<p>To establish how water infrastructure determines the Non Revenue Water in water services Provision in KIRIWASCO.</p>	<p>From the study, majority of the respondents 61 (64.2%) indicated that non revenue water was caused by Aged water systems leading to non detected leakages. Other causes of Non Revenue Water (NRW) are due to pipe bursts, Leakages, illegal connections, faulty meters and meter by passes. It is therefore important aged pipes be replaced and leakage detectors be installed. NRW can also be reduced by immediate repair of bursts and changing of staff attitude especially meter readers and operating and maintenance (O&M). This implies that NRW can substantially be controlled through replacement of old meter and water systems (aged). Majority of respondents, 79 (83.2%) indicated that PVC Class B downward to class A experience more bursts.</p>
<p>To find out how pipe leakages determines the Non Revenue Water in water services provision in KIRIWASCO.</p>	<p>Majority of the respondents 66 (69.5%) indicated that the main causes of pipe leakages are Corroded pipes, GI pipe damage due to high pressure and acid corrosion. Pipe leakage determine 21-40% of NRW as indicated by 56 respondents (58.9%). From the study, 48 respondents (50.5%) indicated that the best way of controlling bursts and leakages is replacement of aged pipes. The aged pipes replacement can control a lot of NRW.</p>
<p>To establish ways in which metering determines Non Revenue Water in water services provision in KIRIWASCO.</p>	<p>From the study, a lot of water (21-60%) as indicated by 62 respondents (65.3%) indicated which would otherwise serve many customers is lost through NRW. Metering enables giving of accurate and reliable data for water sold, control losses and increases revenue collection. The study showed that having meter readers officers ensured efficiency of meters, as indicated by 31 respondents (32.6%). Efficiency</p>

Objective	Contribution to knowledge
	of meters will enable giving of accurate and reliable data for water sold, control losses and increases revenue collection.
To establish how illegal practices determines the Non Revenue Water in water services provision in KIRIWASCO.	From the study, 63 respondents (66.3%) indicated that the major cases of illegal practices encountered are meter tampering, illegal connection and vandalism and theft. The main illegal practices are meter tampering, vandalism and tampering with water system and contribute to 25% of water losses as indicated by 73 respondents (76.8%). These water losses contribute to NRW. From the study, 44 respondents (46.3%) indicated that efficiency in metering water system, sealing of all meters, creating awareness of illegal practices and penalties to community, improve supervision by creating strong audit team mitigate illegal practices.

REFERENCES

- BCWWA (2012). *Position Statement for Water Metering*. British Columbia Water and Waste Association, Burnaby, Canada.
- Brandes, M., Maas, T and Reynolds, E (2006) *Thinking Beyond Pipes and Pumps; Top 10 Ways Communities can save Water and Money*. University of Victoria, Victoria, British Columbia.
- Blackburn, J., & Holland, (1998). *Institutionalizing participation in Development*.
- Borg and Gall (1989); *Population in scientific Research*, Paris. Citizen's Report Card (2007),
- Burn, R.B. (2000). *Introduction to research methods fourth edition*. London: Sage.
- Citizens Report Card (2007) *.Urban Water, Sanitation and Solid Waste Services in Kenya. :* World Bank, Washington D.C.
- City of Seattle (2011) *Saving Water Partnership 2010 annual report; & ten year program review* Seattle Water Supply System Regional 1% Water conservation Program.
- Cooper R. and Schindler P. (2000). *Business Research Methods*. McGraw-Hill, New York
- Davis, J., A. Kang, J. Vincent & D. Whittington (2001), *How important is improved water infrastructure to micro enterprises?* Evidence from Uganda.
- Day, G. (Ofwat, UK) (2010, January). *Leakage now and in the future*. Paper presented at the 4th Global Water Leakage Summit. London, England.
- Dinar, A. (2000), *The political economy of water pricing reforms*. Washington D.C.: World Bank.

DFID (2001; *Addressing the Water Crisis - Healthier and more Productive Lives for Poor People*

Ellis, F. (2000), *Rural livelihoods and diversity in developing countries*: Oxford University Press.

Foeken, D. (2006), *“To subsidise my income” : Urban farming in an East African town.*
Leiden: Brill.

Farley, M. and Trow, S., (2003), *“Losses in Water Distribution Networks”*, A Practitioner’s Guide to Assessment, Monitoring and Control, IWA Publishing.

Farley, M., and Liemberger, R., (2005), *“Developing a non-revenue water reduction strategy: planning and implementing the strategy”*, Water Science and technology: IWA publishing.

Fischer, C. (2008). *Feedback on household electricity consumption: a tool for saving energy?*

Infraguide (2003) *Potable Water; Establishing a Metering Plan to Account for Water use and Loss*, National Guide to Sustainable Municipal Infrastructure National Research Council Issue No. 1.0 Ottawa, Canada.

Kenya, Government of (1986), *Sessional Paper No. 1 of 1986 on Economic Management for Renewed Growth*. Nairobi: Government Printer.

Kenya, Government of (1999), *Sessional Paper No. 1 of 1999 on National Policy on Water Resources Management and Development*. Nairobi: Government Printer.

Kenya, Government of (2002), *The Water Act 2002*. Nairobi: Government Printer. Nairobi.

Kenya, Government of (2003), *Economic Recovery Strategy for Wealth and Employment Creation*. Nairobi: Government Printer.

Kenya, Government of (2006), *The National Water Resources Management Strategy (NWRMS)*
Nairobi: Ministry of Water and Irrigation.

Kenya, Government of (2006), *Kenya National Water Development Report: A Report Prepared for the UN World Water Development Report II*. Nairobi: Ministry of Water and Irrigation.

Kimani-Murage, E.W. & A.M. Ngindu (2007), *Quality of water the slum dwellers use: The case of a Kenyan slum*. Journal of Urban Health. 58, 706-715.

Kombo C.R (1991) *Research methodology; methods and Technology* (2nd Edition) New Delhi; W.Prakasha

Metering (2007) *Compulsory water meters for Prince George* <http://www.metering.com/>

Ministry of Water and Irrigation (MWI) (2005), *Strategic Plan of the Ministry (2005-2009)*.
Nairobi: Ministry of Water and Irrigation.

Morel, A. (2006), *A delegated management model to improve water supply delivery within informal settlements: Lessons learnt from Nyalenda, Kisumu*. Paper presented at the “Africities Conference”, Nairobi, Kenya, September 18-22, 2006.

Mumma, A. (2005), *Kenya's new water law: An analysis of the implications for the rural poor*. Paper presented at the international workshop on “African water laws: Plural legislative frameworks for rural water management in Africa”, Johannesburg, S.A

Mwangi, S.W. (2000), *Partnerships in urban environmental management: An approach to solving environmental problems in Nakuru, Kenya*.

Mugenda and Mugenda A (2003) *research methods. Qualitative and Quantitative Approaches*. Nairobi, Act Press . Kenya.

- Odhiambo, W. & D.K. Manda (2003), *Urban poverty and labour force participation in Kenya*. Paper presented at the “World Bank urban research symposium”, Washington D.C., December, 2003.
- Ombogo, P.L. (2006), *Strategy for access to water and sanitation services in informal settlements: The Kisumu experience*. Paper presented at the “Africities Conference”, Nairobi, Kenya.
- Onjala, J.O. (2002), *Managing water scarcity in Kenya: Industrial response to tariffs and regulatory enforcement*. Roskilde: Roskilde University, Department of Environment, Technology and Social Studies (PhD thesis).
- Otiego, L.A. (2006), *Commercialization of water services in informal settlements: Case study of Manyatta in Kisumu municipality, Kenya*. Nairobi: University of Nairobi, Department of Urban and Regional Planning (MA thesis).
- Shiklomanov, I.A., (1993). “*World Fresh Water Resources, In Water in Crisis*”, a guide to the world’s fresh water resources, ed. P. H. Gleick. Oxford University Press. New York.
- Serageldin, I., (1995), “*Toward Sustainable Management of Water Resources*”, The World Bank.
- Shiklomanov, I.A., (1993). “*World Fresh Water Resources, In Water in Crisis*”, a guide to the World’s fresh water resources, ed. P. H. Gleick. Oxford University Press. New York:
- Stein M. Robert, (1990), “*Urban Alternatives: Public and Private Markets in the Provision of Local Services*”, University of Pittsburgh Press, Pittsburgh, London.
- Suzuki, K. (2005). Measures against NRW (Relations with Management. Workshop of Water Supply Management , May 26, 2005, in Hue City ,Viet Nam.

Trow, S. (2007). *Alternative approaches to setting leakage targets*. Proceedings of Water Loss Conference Bucharest, Romania: International Water Association.

Trow, S., & Pearson, D. (2010). *Setting targets for non-revenue water reduction*. Water21

WASREB, (2009) . *Water and Sanitation Coverage in Kenya*. Impact report, Nairobi, Kenya

WHO/UNICEF(2005) “*Joint Monitoring Programme for Water Supply and Sanitation Coverage Estimates 1980-2000*”

World Health Organization & United Nations Children’s Fund- Joint Monitoring Programme (JMP). (2008). *Water Supply and Sanitation*. Retrieved from <http://www.wssinfo.org>.

World Health Organization & United Nations Children’s Fund- Joint Monitoring Programme (JMP). (2010). *Water Supply and Sanitation*. Retrieved from <http://www.wssinfo.org>.

Vermersch Michel-Seuz-Environment, (2005).“*The reduction and control of UFW*” UNESCO-IHE. Institute for water education. Delft, Netherlands.

APPENDICES

APPENDIX 1: INTRODUCTION LETTER

Isaac Murimi Kangangi.
P.O. BOX 828,
Kerugoya.

Dear Sir/Madam,

RE: REQUEST FOR PARTICIPATION IN A RESEARCH STUDY

I am a final year Masters of art student at the University of Nairobi. My area of specialization is Project Planning and Management. I am currently undertaking a research on “The determinants of non-revenue water in water services provision in Kirinyaga County in Kenya: a case of Kirinyaga Water and Sanitation Company. I will be grateful if you could spare sometime from your busy schedule and complete the enclosed questionnaire. All the information provided will be used purely for academic purposes only and your identity will be treated with utmost confidentiality.

Thank you for your cooperation.

Yours faithfully,

Isaac Murimi Kangangi.
L50/65746/2013

APPENDIX 2: RESEARCH QUESTIONNAIRE FOR KIRIWASCO STAFF

Section A: General information

1. Gender
A) Male () B) Female ()
2. Which year were you born? -----
3. Education background
A) Primary () B) Secondary () C) College ()
D) University () E) Post graduate ()
4. Which is your department/area-----
5. How long have you worked in KIRIWASCO? -----
6. What are the main causes of Non Revenue Water -----

7. State three ways of reducing Non Revenue Water. -----

Section B: Water Infrastructure

8. What is your area of coverage in square Km? -----
9. How many sources of water do you have? -----
10. How old is your main service lines? -----

11. What is the type and class of the main pipes? -----

12. Do you use plastic pipes?
Yes () B) No ()
13. If yes what class? -----
14. Which pipes experiences more bursts in your opinion? -----

28. Do you have NRW department / section?

- A) Yes () B) No ()

29. Have you noted any improvement in reducing the NRW?

30. In your opinion which are the best ways to reduce bursts and leakages-----

Section D: Metering

31. Do you have master meters in your system?

- A) Yes () B. No ()

32. What is the total volume of water produced and channeled to the distribution system?----

33. What is the total volume of water billed to all consumers?_____ m3

34. What was the percentage of non-revenue water in March 2014? _____ (%)

35. What steps has your WSP taken to reduce these losses?

36. What is the percentage of your metered connection?

37. What is the benefit of metering to you? -----

38. Do you have customer complains on meter accuracy?

- A. Yes () B. No ()

39. How frequent are such complains?

- A) Very frequent () B) Average () C) rare ()

40. Do you have problems of poor meter reading?

- A) Yes () B. No ()

41. How does it affect the NRW? -----

42. State three main ways that the efficiency of meters can be ensured. -----

Section E Illegal Practices

43. Which are the major cases of illegal practices you usually encounter ?-----

44. State three major causes of illegal connections?-----

45. Has vandalism increased or decreased in the last two years? -----

46. Which penalties do you have for illegal practices ?-----

47. Have the penalties helped to reduce the illegalities? -----

48. What percentage of meters was subject to manipulation of meter readings in the last three months? -----

49. What percentage of meter were illegally tampered with in the month of April?-----

50. Kindly state three main illegal practices and the approximate contribution to water losses in the month of April.-----

51. What would you suggest to be done to do away with illegal practices?-----

APPENDIX 3

DETERMINATION OF SAMPLE SIZE FOR A GIVEN POPULATION BY KREJCIE AND MORGAN

Table for Determining Sample Size for a Given Population

N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	246
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	351
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	181	1200	291	6000	361
45	40	180	118	400	196	1300	297	7000	364
50	44	190	123	420	201	1400	302	8000	367
55	48	200	127	440	205	1500	306	9000	368
60	52	210	132	460	210	1600	310	10000	373
65	56	220	136	480	214	1700	313	15000	375
70	59	230	140	500	217	1800	317	20000	377
75	63	240	144	550	225	1900	320	30000	379
80	66	250	148	600	234	2000	322	40000	380
85	70	260	152	650	242	2200	327	50000	381
90	73	270	155	700	248	2400	331	75000	382
95	76	270	159	750	256	2600	335	100000	384

Note: "N" is population size
"S" is sample size.

Source: Krejcie & Morgan, 1970