# SUPPLYING WATER TO UNPLANNED LOW INCOME SETTLEMENTS: IMPLICATIONS ON WATER UTILITY PERFORMANCE – THE CASE OF LILONGWE WATER BOARD, MALAWI

**MSc. INFRASTRUCTURE DEVELOPMENT AND MANAGEMENT THESIS**

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**UNIVERSITY OF MALAWI**

**THE POLYTECHNIC**

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# SUPPLYING WATER TO UNPLANNED LOW INCOME SETTLEMENTS: IMPLICATIONS ON WATER UTILITY PERFORMANCE – THE CASE OF LILONGWE WATER BOARD, MALAWI

**MSc. Infrastructure Development and Management Thesis**

**By**


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Submitted to the Department of Mechanical Engineering, Faculty of Engineering, in partial fulfilment of the requirements for the degree of Master of Infrastructure Development and Management

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## DECLARATION

I confirm that this is my own work and the use of all materials from other sources has been properly and fully acknowledged. No part of it has been submitted previously for a degree at any other university. I am responsible for the research and its articulation alone. In no way do any of the persons mentioned in the acknowledgement bear any direct responsibility for this work.

**Candidate: Ephraim Banda**

**Signature:**

**Date : December, 2016**

## CERTIFICATE OF APPROVAL

The undersigned certify that they approved for examination by the University of Malawi, Polytechnic this thesis entitled Supplying Water to Unplanned Low Income Settlements: Implications on Water Utility Performance – The Case of Lilongwe Water Board, Malawi.

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# DEDICATION

Dedicated to Odala Banda.

**ACKNOWLEDGEMENTS**

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# ABSTRACT

While most studies have acknowledged growth of unplanned low income settlements and challenges associated with the settlements in developing countries, there have not been studies to assess their impacts on performance of water utilities in these countries. One of the main challenges facing water utilities in Africa, is an increase in unplanned low income settlements which are associated with various physical, social, economic and political challenges. Understanding the impact of the unplanned low income settlements on performance of a water utility is key to development of strategies and sustenance of initiatives being undertaken to improve performance of utilities in the midst of rapid urbanisation. This study assessed performance of Lilongwe Water Board (LWB) in the unplanned low income settlements of Kauma (Area 41), Mgona (Area 50) and Mtandire (Area 56) using selected indicators and benchmarking the performance with the water utility's overall performance. The performance was measured using Non-Revenue Water, Revenue Collection Efficiency and Efficiency of Maintenance and Operation (Repair cost per km and Repair cost per connection). NRW was established based on a water balance, where volumes of water supplied to each of the settlement under study was compared with the total consumptions recorded by water meters in the area. Data on water sales and collected amount for each of the settlements was obtained from the water utility. A comparison was conducted to calculate Revenue Collection Efficiency for each of the settlement and for the entire supply area. Data on cost of pipe repair materials was collected for each of the study settlements and for the entire supply area. The cost of repairs per km and cost of repair per connection was then calculated for the settlements and benchmarked with the cost of repair per km and per connection for the entire utility. Results from the study indicate that the average NRW for LWB is 37% (656m$^3$/km/month). This is higher compared with NRW for Kauma, 26% (395m$^3$/km/month) and Mtandire, 27% (377m$^3$/km/month). Only NRW for Mgona, 42% (872m$^3$/km/month) is higher than the value for LWB. Revenue collection efficiency for LWB (58%) is less than the collection efficiency for Kauma (75%) and Mgona (69%). Collection efficiency for Mtandire (57%) is however less than that for LWB. The cost of network repair materials per km and per connection is high in the unplanned low income settlements compared to the overall cost for LWB (US$59, US$127, US$164, US$57 for Mgona, Mtandire, Kauma and LWB respectively). The study suggests that unplanned low income settlements do not have a significant impact on the performance of LWB measured through NRW and Revenue Collection Efficiency but might have an impact in network repair costs.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AC | Asbestos Cement |
| BWB | Blantyre Water Board |
| CE | Collection Efficiency |
| CRWB | Central Region Water Board |
| DI | Ductile Iron |
| DMA | District Metered Area |
| EIB | European Investment Bank |
| GIS | Geographical Information System |
| IWA | International Water Association |
| KPI | Key Performance Indicator |
| LIA | Low Income Area |
| LWB | Lilongwe Water Board |
| NRW | Non-Revenue Water |
| NSO | National Statistical Office |
| NWDP | National Water Development Programme |
| OEI | Overall Efficiency Indicator |
| PVC | Polyvinyl Chloride |
| SPR | Sector Performance Report |
| SPSS | Statistical Package for Social Scientists |
| SRWB | Southern Region Water Board |
| UARL | Unavoidable Real Losses |
| UFW | Unaccounted for Water |
| WB | World Bank |
| WUA | Water User Association |

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# 1. INTRODUCTION

## 1.1 Background

There is a variation in performance of water utilities globally with utilities in developed countries having a better performance in contrast to utilities in developing countries. For instance Tynan and Kingdom (2002) reported an average Non-Revenue Water (NRW) level of 16% for utilities in developed countries compared to an average of 35% for African utilities. Similarly service coverage of as low as 18% has been reported for utilities in developing countries mostly dominated by Africa, whereas in developed countries the coverage rates exceed 99%.

The water services sector in Africa continues to suffer from poor performance of its public water utilities compared to utilities in developed countries. Although there is variation in performance, it is noted that the performance of African water utilities is low (Banerjee et al., 2008). The prominent challenges in the sector include high level of Non-Revenue Water often averaging between 40% and 60%, low water supply service coverage of less than 60%, high overstaffing and no financial sustainability due to a combination of low tariffs, poor consumer records and inefficient billing and collection practices (Schwartz, 2007). According to Jacobsen (2012), African water utilities often deliver poor continuity of water service and inadequate water quality. Hove and Tirimboi (2011), describe African water utilities as inefficient and the problem being magnified in urban areas due to limited alternatives.

The performance of the utilities is further deteriorating with the rapid urbanisation being experienced in their service areas. At 3.9% per year, urban population growth rates in Africa have been and will continue to be the highest in the world (Jacobsen, 2012). Urban population growth is however highly correlated to growth of informal settlements and in African countries this has put enormous pressure on water utilities (Banerjee et. al, 2008). While there is an increase in number and population of the unplanned low income settlements and hence an increase in demand for water supply services, on the other hand there is a decline in performance of water utilities serving urban areas in Africa. According to Hove & Tirimboi (2011), existence of unplanned low income settlements is the main cause of water utilities failure to achieve 100% service coverage. Inadequate water and sanitation service provision remains a serious problem in these settlements (Water Operators Partnership [WOP], 2009).
The current state of service delivery to unplanned low income settlements is a lose – lose situation for both end-consumers and for utilities (Castro & Morel, 2008). The levels of

unaccounted-for water are exorbitant and customers are paying high prices for low levels of service from off-network providers (Tremolet and Halpern, 2006). Water supply to these unplanned low income settlements has a lot of constraints and challenges. Solo, Perez & Steven (1993) categorise the constraints as; physical and technical constraints, economic and financial constraints, institutional constraints and structural constraints. The physical and technical constraints include difficult site terrains and complicated site layouts. An example on economic and financial constraints is the cost of water against low family incomes in the informal settlements while susceptibility to corruption and politicisation of service delivery form part of institutional and structural constraints. A study in the unplanned low income settlements of Nairobi in Kenya, support the economic constraints by citing potential existence of high levels of water theft and low revenue collection in the informal settlements (Athi Water Services Board [AWSB] and Nairobi Council Water and Sewerage Corporation [NCWSC], 2009). The study further attributes the challenges to social characteristics of the informal settlements.

Challenges and constraints imposed on water utilities by unplanned low income settlements would better be understood through segregated utility performance assessment. While for instance a water utility's performance could be reported based on its level of Non-Revenue Water (NRW), segregating such values of NRW in terms of contributions from unplanned low income settlements and planned settlements would assist the utility in addressing the problem. However in most cases, water utility performance measurement has been generalised. Performance measurement indicators such as Non-Revenue Water (NRW), Revenue Collection Efficiency and operational costs have been reported on a global level. This has neglected the varying challenges and constraints posed by different types of settlements on water utilities. This study hence focused on assessing performance of a water utility (Lilongwe Water Board) at a micro level (selected unplanned low income settlements) and benchmarking the performance with the water utility's macro (overall) performance using selected performance indicators. Consequently establishing how unplanned low income settlements affect water utility performance.

## 1.2 Problem Statement

Lilongwe Water Board (LWB), Malawi is one of the water utilities in Africa facing financial and operational challenges. According to the water utility's 2014 – 2015 Annual Report (LWB, 2015), Non-Revenue Water (NRW) is at 35% which according to Tynan and Kingdom (2002) is higher than the recommended maximum level of 23% for best performing water utilities in developing countries. The water utility collects less than 70% of revenue for the water that has been billed which combined with the NRW translates to the water utility having an overall operational efficiency of less than 50% (LWB, 2015).

The City of Lilongwe of which LWB has mandate to supply water has the highest urban population growth rates amongst the cities of Malawi at 4.3% per year (National Statistical Office [NSO], 2008). This is above Africa's urban population growth rate of 3.9%, making it one of the fastest urbanising cities in Africa and hence one of those susceptible to growth of unplanned low income settlements. According to United Nations Habitat [UN-Habitat] (2011), approximately 76% of Lilongwe City's population resides in informal settlements. About 70% of the city's population has access to water supplied by LWB either through direct household connections, shared yard connections and communal water points (Lilongwe Water Board [LWB], 2014). With 76% of Lilongwe City's population residing in informal settlements and over 70% of the population accessing water through the services of Lilongwe Water Board it means the water utility is threatened by the physical, technical, economic, financial, institutional, and structural constraints as cited by Solo et al (1993). The unplanned low income areas within the supply area are a potential challenge similar to the informal settlements of Nairobi (AWSB et al., 2009). The constraints according to Solo et al., (1993) and the challenges reported by AWSB et al., (2009) would have an impact on the performance of the water utility in terms of revenue collection, supply coverage, non-revenue water, high operational costs and many others. However no study has been conducted to ascertain this.

Studies on water supply in unplanned low income settlements in Malawi have mostly focused at the end user; access to potable water and coverage, affordability of services and mode of supply and service delivery (Water Aid Malawi, 2007; Zeleza-Manda, 2009; Kosamu and Mughogho, 2012). When considering the options for improving water service delivery to unplanned low income settlements in African cities, it is essential to understand both the problems facing residents and the problems facing utilities (Castro & Morel, 2008). Addressing only one or the other is a losing game for achieving sustainable service. However, as observed in Malawi, the water utility perspective has mostly been ignored. On the other side, studies on water utility performance in Malawi have placed emphasis on overall utility performance using non-revenue water as a performance indicator (Chiipanthenga, 2008; Chipwaila, 2009; Kafodya, 2010; Kalulu and Hoko, 2010; Harawa, 2015). Water utility performance assessments have not regarded the potential challenge of unplanned low income settlements. While rapid rate of informal settlements growth for cities like Lilongwe has been acknowledged, performance assessments for water utilities serving such cities has not considered the challenges imposed on the utilities by the unplanned low income settlements. Neglecting this aspect may lead to further deteriorating level of water utility performance in the presence of increasing demand for water supply services in both planned and informal settlements. The aim of this study was therefore to establish the linkage between water utility performance and water supply service provision to unplanned low income areas.

## 1.3 Objectives of the Study

### 1.3.1 Main Objective

The main objective of this study was to measure implications that water supply service delivery to unplanned low income settlements has on the overall performance of Lilongwe Water Board.

### 1.3.2 Specific Objectives

Specific objectives of the study were:

i. To determine sources of water for the households in the selected unplanned low income settlements and growth of water supply services in the settlements through network extensions and water connections;

ii. To establish level of Non-Revenue Water (NRW) in the selected unplanned low income areas; factors contributing to the NRW and compare with overall trends of NRW for Lilongwe Water Board;

iii. To establish revenue collection efficiency for the selected unplanned low income settlements and compare with the collection efficiency trends for the entire LWB;

iv. To estimate the cost of network maintenance per unit length of network and per connection in the study areas and compare with similar costs for the entire supply area;

## 1.4 Significance of the Study

This study is expected to increase the knowledge and information on water utility performance and its interaction with types of settlements. The study will also serve as a guiding document to policy makers in the water sector, town planning authorities, the general public, project financing partners and civil society. The study will set benchmark data for any further investigation on water utility performance and water supply in unplanned low income areas. Additionally it will broaden literature on water supply and unplanned low income areas and could hence be used for academic purposes.

## 1.5 Thesis Outline

**Chapter 1 – Introduction**

The chapter provides the research background, problem statement, aim and objectives of the study. It highlights scope of the study in relation to what other scholars have done.

**Chapter 2 – Literature Review**

This is the theoretical part of the research focusing on what other scholars have covered on characteristics of informal settlements and water utility performance. Focus areas being gaps, theories and concepts to be used in the study.

**Chapter 3 – Methodology**

The chapter gives a description of Lilongwe Water Board's operations and the general characteristics of the water supply area. This includes explanation on how the areas selected for the surveys were identified. The chapter describes the entire data collection and analysis process (type of data collected, sampling methods, and size of sample, and validation techniques).

**Chapter 4 – Results and Discussion**

The chapter undertakes an analysis of the collected data. The data is analysed and presented using graphs, charts and tables from which interpretations and discussions are made.

**Chapter 5 – Conclusions and Recommendations**

The chapter gives conclusions and recommendations based on the findings in chapter four (Results and Discussion) and in relation to the gaps, theories and concepts identified in literature review. The chapter outlines areas for future research and limitations of the study.

# 2. LITERATURE REVIEW

## 2.1 Unplanned Low Income Settlements

### 2.1.1 Definition

The term “unplanned low income settlement” has been used interchangeably with other terms such as slum, peri-urban, informal and squatter settlements. A number of definitions exist for these settlements. Njamwea (2003) defines unplanned low income settlements as residential areas for the urban poor more often in the cities of the developing world. On the other hand Banda (2013) defines unplanned low income settlements (also referred to as peri-urban areas or slums) as settlements within an area of jurisdiction of a local authority characterised by high population density, high density of poorly constructed sub-standard housing units with inadequate basic services such as water supply, sewerage, solid waste disposal and collection, access roads and storm water drainage. The settlements are further defined as settlements whereby persons assert land rights or occupy for exploitation of land which is not registered in their names, or government land, or land legally owned by other individuals (Hurskainen, 2004).

Slums are the most deprived and excluded form of informal settlements characterized by poverty and large agglomerations of dilapidated housing often located in the most hazardous urban land. In addition to tenure insecurity, informal settlement dwellers lack formal supply of basic infrastructure and services, public space and green areas, and are constantly exposed to eviction, disease and violence (UN-Habitat, United Nations Office for Project Services [UNOPS] and Office of the United Nations High Commissioner for Human Rights [OHCR], 2015). Despite a number of terms being used to refer to almost similar types of settlements, in Malawi the commonly used terms include; low income areas, informal settlements and peri-urban areas.

Regardless of their location and legal status, unplanned low-income settlements have several characteristics in common. Their residents often lack access to adequate and affordable basic water supply and sanitation services, lack adequate housing and have limited or no access to other infrastructure and services such as solid waste, storm water drainage, street lighting, roads and footpaths (Water and Sanitation Program [WSP], 2003). In addition to these physical characteristics, Hurskainen (2004) adds social aspects of informal settlements which include unemployment and poverty. Thus unplanned settlements are characterised by both physical and social aspects.

There are numerous underlying causes of informal settlements development. They include: rapid urbanisation; severe shortage of affordable housing opportunities provided by the public and private formal sector; sporadic and non-comprehensive upgrading initiatives; lack of resources and strategies for upgrading at large-scale and prevention of new unplanned developments; and inappropriate institutional and regulatory frameworks for land use planning, infrastructure provision and housing and the dominance of informal and customary land delivery systems (UN-Habitat, 2010). In Malawi, growth of unplanned low income settlements is associated with rapid urbanisation. While Malawi's urban population remains low at around 20%, strong urban growth is taking place in the country's four key cities, Lilongwe, Blantyre, Mzuzu, and Zomba. For instance according to NSO (2008) the population for Lilongwe City the capital of Malawi, is projected to be over 1.3 million residents in 2020, representing a doubling of the population from the most recent population census conducted in 2008. Much of this population growth is projected to occur in the city's poor settlements (Lindstrom, 2014). While the city as a whole is expected to grow at around 4-5% per year, population growth in informal settlements is projected at over 8% (UN-Habitat, 2011).

It can be concluded that in Malawi unplanned low income areas are on the increase in terms of size and number of residents in these areas. This growth should hence correlate with expansion of water supply services in these settlements.

## 2.2 Water Supply in Unplanned Low Income Settlements

### 2.2.1 Management of Water Supply Services

Different modes of water supply services delivery exist in the informal settlements. According to Banda (2013), there is a similarity in the way water is provided to urban areas globally especially amongst developing countries. This similarity even exists in the unplanned low income areas. A study by AWSB et al., (2009) in the City of Nairobi, Kenya found that, most of the informal settlements residents consume piped water with the majority purchasing water from water kiosks. The findings of this study are collaborated by Manda (2009) whose study found that 53% of the households in the informal settlements of the cities of Blantyre, Lilongwe and Mzuzu were relying on water kiosks as a water source. Similarly there exists a proportion of population with household connections in these settlements (22% in Nairobi and 26% in the informal settlements of Malawi).

### 2.2.2 Challenges

**Physical challenges**

Across the African continent, the informal or unplanned nature of many low-income settlements is perhaps a bigger constraint to service delivery than land tenure, and remains the key bottleneck to service delivery in all countries. According to WSP (2003), while the actual nature of the service problem differs from country to country, haphazard layout, lack of road access, high densities and overcrowding are also closely associated with the difficulty of service delivery to these areas. Nair (2010), further cites geographical and environmental conditions as factors rendering service provision in these settlements a practical challenge. These physical conditions common to informal settlements can increase costs and limit infrastructure investment (Dagdeviren and Robertson, 2009).

The haphazard layout of the settlements leads to another challenge which is clandestine connections (Capstone and Banks, 2009). These clandestine connections lower the water pressure in the system. As such, when pipes crack, they are prone to contamination from any pollutants, such as waste water, which is a common sight in informal settlements.

Another challenge imposed on water supply service delivery imposed by unplanned low income settlements is location (Nair, 2010). These settlements are usually on the periphery of cities or in previously uninhabited land including flood plains and hills. This makes the extension of standard water supply network technically difficult (Dagdeviren et al., 2009). Associated with location is the lack of roads. This physical problem of unplanned settlements also limits the viability of infrastructure. Roads are a crucial part of infrastructure, both in the primary function they serve, as well as providing channels for other infrastructure. In planned settlements infrastructure such as water pipes, electricity cables is often buried under a central roadway with residential connections branching off (Dagdeviren et al., 2009). Because residents of informal settlements lack a technical understanding of urban planning, these areas are often developed haphazardly, without space being provided to install infrastructure lines (Solo et al., 1993). Whereas water utilities in planned areas may be arranged by construction under a central roadway with residential connections branching off this, such a conventional approach is impractical in informal settlements that have a random and haphazard development pattern (Solo et al., 1993).

The physical challenges imposed on water service provision make the most standard water supply systems to be inappropriate as a result utility companies may opt for basic systems which would eventually have higher costs on investment as well as operation and maintenance. These systems may not operate at standard requirements as such undesired levels of performance such as leakages and pipeline exposures could be encountered.

**Social-economic challenges**

Providing sustainable, affordable and safe water to the poor while embracing a full service cost recovery calls for greater consideration of the livelihood aspect of the poor in the urban areas who have to survive under a strict and often harsh cash economy (WaterAid, 2008). Most of the informal settlement dwellers have low levels of income. For instance AWSB et al., (2009) established an average monthly income of US$40.00 in the informal settlements of Nairobi which was leaving little room for savings or investments. In Malawi, a similar study by Manda (2009) in the informal settlements of Blantyre, Lilongwe and Mzuzu, established household incomes in the range US$14.00 – US$50.00. The low levels of income are further linked to inability to pay for water supply services that consequently jeopardises performance of water utilities (Mughogho and Kosamu, 2012). On one side, Solo et al., (1993) argue that whatever the cost of water, families will sacrifice food, heat, and shelter to pay for minimum water consumption. This would mean water consumed by these communities is always paid for using the available income. These two schools of thought could be valid in different context. The claim by Mughogho et al., (2012) would be valid for the low income households who have water connections from a utility while the second school of thought would apply where the low income households are buying water from vendors or private owned water points. Thus revenues collected by a water utility could be higher in the Solo et al., (1993) finding. This however would also depend on the willingness to pay by the water retailers or the management system for the water supply in the unplanned low income areas.

Despite these socio-economic challenges studies have shown that informal settlement residents are paying higher fees per cubic meter of water compared to households with own connections (Manda, 2009; AWSB et al., 2009; Water Aid, 2008). The studies however have not addressed how this would directly or indirectly affect water utility performance as focus has been on the water users.

### 2.2.3 Cost of Water Supply to Unplanned Low Income Settlements

Two of the main factors contributing most significantly to the price of supplying water in unplanned settlements are; the size of the slum and the physical conditions of the slum (Dagdeviren et al., 2009). High population density is also seen to increase prices (Abiko et al., 2010). In order to mitigate these high costs, development agencies tend to use low standards for infrastructure. This results in rapid deterioration, and a need for constant maintenance (Dagdeviren et al., 2009). This can raise the costs of infrastructure in the long run.

## 2.3 Measuring Water Utility Performance

As with all other service providers, the water industry's objective is to achieve the highest level of consumer satisfaction and service quality within the prevailing regulatory framework and available resources (Sibanda, 2002). For a utility to achieve this goal, it needs to measure its performance in the various fields of the business. Reporting of performance allows utility managers, policy makers, regulators, and the general public to assess whether utilities are fulfilling their mission, and to form a view on their ability to do so in the future (WSP et al., 2012). According to Baietti, Kingdom and Van Ginneken (2006), many public utilities in developing countries find themselves locked in the vicious cycle from which they cannot escape due to poor performance. On the other hand Tynan and Kingdom (2002), developed a framework for analysing the performance of water utilities. They concluded that performance of water utilities can be assessed using four broad measures: efficiency of investment (measured through Non-Revenue Water), efficiency of operations and maintenance (measured using input to output ratios), financial sustainability (measured using working ratio, collection period), and responsiveness to customers (coverage and affordability).

These four broad measures have been used to evaluate utility performance in a number of studies. Kalulu and Hoko (2010) in their study on performance of Blantyre Water Board (BWB) adopted the four broad measures and assessed performance using working ratio, revenue collection ratio, tariff and NRW. Similarly based on the four broad categories, Hove and Tirimboi (2011) in their study on water service delivery in Harare City, Zimbabwe used nine indicators (production and consumption, NRW, coverage, continuity of service, connection fees, response to customers and cost recovery) in the assessment of water service delivery for the city. Other studies have introduced operational efficiency indicators in measurement of water utility performance. Another perspective according to Marin (2009) is that the overall efficiency of a water utility can be broadly captured by three main indicators:

NRW, bill collection, and labour productivity. NRW is a key cost element in most water utilities in developing countries. Controlling NRW is a priority for any well-run utility. NRW also referred to as water losses capture the efficiency of both the distribution network and of commercial management. The bill collection ratio directly affects the cash flow of the utility and captures a large portion of the efficiency of commercial management (Wambui, 2013).

It is observed that NRW is a key indicator in measurement of water utility performance. Other indicators widely adopted include financial indicators (collection ratio, collection period and working ratio). Utility performance is also assessed based on efficiency measures which are mostly determined using ratios.

### 2.3.1 Non-Revenue Water

Kingdom, Liemberger, and Marin (2006) define Non-revenue water as the difference between the volume of water put into a water distribution system and the volume that is billed to customers. NRW is an indicator of a water utilities' operating efficiency and reducing NRW increases both financial resources and the water available to utilities (Farley et al., 2008). According to Kingdom et al., (2006), NRW comprises two components: physical (or real) losses and commercial (or apparent) losses. Physical losses include the volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering. Commercial (apparent) losses consists of unauthorised consumption (theft of water in various forms), metering inaccuracies and billing/data handling errors (Lambert, 2003). Real losses are caused by poor operations and maintenance, the lack of active leakage control and poor quality of underground assets.

NRW is expressed in a number of ways. The most common one is the difference between water supplied and water sold expressed as a percentage of net water supplied (Balkaran and Wyke, 2002). OFWAT (2002) indicates that percentages can be used for 'internal benchmarking'. Two other volumetric indicators for expression of NRW also exist. According to Balkaran and Wyke (2002), NRW can be expressed as the difference between water supplied and water sold expressed as a volume of water 'lost' per km of water distribution network per period of time ($m^3$/km/yr; $m^3$/km/month; $m^3$/km/day) and as the difference between water supplied and water sold expressed as volume of water 'lost' per water connection ($m^3$/connection/yr; $m^3$/connection/month; $m^3$/connection/day). These two volumetric indicators can easily be used to baseline and track performance of an individual water supplier's loss management efforts

(Chipwaila, 2009). Expressing NRW using the volumetric indicators makes it easy to turn the volumes into values for simple and more complex economic calculations (Thornton and Lambert, 2005).

Level of NRW has been used as a performance indicator for benchmarking of water utilities from different countries (Baietti et al., 2006; WSP, 2009; WSP et al., 2012). Specific studies have also been conducted at utility level to establish NRW and its causes in Malawi (Kalulu et al., 2010; Msuku et al., 2010; Kafodya, 2010). Other studies have gone further to establish level of NRW at District Metering Area (DMA) level within the supply area of a water utility (Chiipanthenga, 2008; Chipwaila, 2009; Harawa, 2015). Reporting NRW at DMA or settlement level is one of the key tools in reduction of NRW. According to Farley et al., (2008) the concept of monitoring NRW at DMA or zone is now an internationally accepted and well-established technique to determine where leak location activities should be undertaken. The quicker the operator can analyse DMA flow data, the quicker bursts or leaks can be located. This, together with speedy repair, limits the total volume of water lost. It can be concluded that much as NRW can be reported at various levels with varying interests, reporting NRW at a subsystem level is key to reduction of NRW.

### 2.3.2 Collection Efficiency (Collection Ratio)

Revenue collection efficiency also referred to as collection ratio is defined by Wambui (2013), as the total amount collected by a water service provider compared to the total amount billed in a given period. Similarly, WSP (2009) defines collection ratio as the ratio of a utility's actual revenues collected and total billed revenues, expressed as a percentage. Utility managers know very well that billing customers and getting paid are two different things (WSP, 2009). As such collection ratio is an important performance indicator of a water utility as it gives an indication on the effectiveness of the revenue management system in place and consequently the amount of resources available to the utility (Wambui, 2013). This ratio is one of the five main indicators (revenue collection efficiency, operating cost ratio, debt-service ratio, value of gross fixed assets per connection, and average operating revenue) used to evaluate the financial performance of water utilities (Banerjee et al., 2008). Collection ratio, along with average tariff and operating cost coverage ratio, impact on the financial health of a utility (WSP, 2009). The indicator also reflects customers' willingness to pay, which is closely related to customer satisfaction (WASREB, 2012).

Low or poor cost recovery will negatively affect the quest to provide good quality water services (Banda, 2013). It is common for poorly performing utilities to have low bill-collection rates because of lax enforcement and the fact that people often resent paying for poor services (Wambui, 2013). Financial sufficiency is achieved by carefully balancing all aspects of financial management with utility's anticipated future needs. Financial management consists of effectively generating sufficient revenue while appropriately managing costs (American Water Works Association (AWWA), 2010). According to Wambui (2013), effective billing and collection systems and high billing and collection rates are key tools for enhancing the revenue base of the utility, achieving financial viability, and sustainability and hence registering improvements in services delivered.

Studies have been conducted to establish collection efficiency for water utilities in Africa and Malawi (Kalulu et al., 2010; Msuku et al., 2010; WSP, 2009; WSP et al., 2012; Wambui, 2013). In a study by Banerjee et al., (2008) on selected water utilities in Africa, more than half of the utilities collected tariff revenue from fewer than 50 percent of their customers. However, on average, most African utilities are only able to collect about 73 percent of their billed amounts, and it takes an average of eight months to collect outstanding revenues (WSP, 2009). The challenge with reporting of collection ratio is that it has mostly been reported at utility level. However just as District Metering Areas (DMAs) have been used in addressing the challenge of NRW, DMAs or similar blocks within utility operation areas could be used in tracking collection ratio within demarcated areas.

### 2.3.3 Efficiency of Operations and Maintenance

Operational efficiency is defined as the lowest cost use of inputs such as labour, energy, water, and materials in the daily operation of a utility (Tynan and Kingdom, 2002). According to Marques and Monteiro (2001), operational indicators are suitable to describe the water utilities' behaviour and working characteristics, such as the way their operation and maintenance are carried out and their main problems. The most efficient combination of inputs depends in part on local input prices and past capital investment decisions. To measure operational efficiency, analysts use ratios of inputs to outputs (Tynan and Kingdom, 2002). One such ratio is staff per 1,000 connections. A high ratio may indicate inefficient use of staff. A second indicator of operational efficiency is staff per 1,000 people served, which eliminates the distortion caused when single water connections serve multiple households. A third measure combines wages and staffing to give personnel costs as a share of total operating costs. According to Banerjee

(2008), the rate of bursts per kilometre of water main provides some indication of the condition of the underlying infrastructure, and hence the extent to which it is being adequately operated and maintained.

## 2.4 Performance of Water Utilities in Africa

Studies have been conducted on performance of water utilities at Africa level (Baietti et al., 2006; Banerjee et al., 2008; WSP, 2009; Jacobsen, 2012; WSP et al., 2012). Although there is variation in performance it is noted that the performance of African water utilities is low (Banerjee et al., 2008). For instance, Jacobsen (2012) reports variation of continuity of water service from 6 to 24 hours daily and water consumption per capita from 7 litres per capita per day to 240 litres per capita per day. Banerjee et al., (2008), in their study on urban water supply in Africa, found NRW averages of around 30 percent, compared to a good-practice benchmark of 23 percent for developing countries. Labour productivity averages just over six employees per thousand connections, compared to a good-practice benchmark of five for developing countries. On average utilities just cover their operating costs, with an operating-cost-coverage ratio of 1.0, compared to a good practice benchmark of 1.3 for developing countries. Collection efficiency is estimated at just over 70 percent.

The utility performance studies conducted at continental level have in most cases been used for benchmarking of utilities across Africa. It is noted however that water utility and service delivery performance studies have also been conducted at utility or supply area level (Simon et al., 2008; Kalulu et al., 2010; Msuku et al., 2010; Hove et al., 2011; Muturi, 2013). These studies have focused on measurement of service delivery for individual utilities as well as performance in line with usually adopted indicators for water utility performance. According to Steers (1975) and Otley (1980), performance may be analysed at the micro or macro level, or by combining the two. Here the micro level analysis refers to the analysis of an individual component of a system or at sub-system level. At the macro level, organization-wide phenomena are analysed within the organisation, within the industry, or between industries as they relate to performance (Kihn, 2005). Thus utility performance measurement in Africa has generally focused at the macro-level. This approach addresses the question “how well did we do?” and is often viewed in the context of institutional performance as a whole (Nerenz and Neil, 2001). Micro-level measures, on the other hand, encourage a prospective focus on how the individual components of an organization are working together to produce a macro-result, as in “where do we need to focus our efforts in order to do better?” The context for these measures tends to be specific to smaller work-units, interested stakeholders are internal, and the motivation for change is local (Nerenz and Neil, 2001). These units in a water utility could be service delivery at settlement or DMA level. Thus unlike the current trend of measuring and reporting performance at macro-level (whole system) performance measurement at sub-level is key to improvement of overall performance goals.

From the literature it is observed that performance assessments for water utilities in Malawi and Africa have placed emphasis on macro level (entire system) and in most cases the performance is below the requirements. There is an information gap within utilities on performance at specific micro level systems for example per settlement/location and little or no studies have been conducted. This is in the midst of rapid growth of unplanned low income settlements which are micro systems for the water utilities as despite supplying water to the entire supply area the water utilities should supply the informal settlements regardless of potential challenges which could be imposed on water supply services by these settlements. It is from this background that this study has been initiated.

# 3. METHODOLOGY

## 3.1 Study Area

### 3.1.1 Location

The study was conducted in Lilongwe City, the administrative capital of Malawi (Figure 3-1). The City lies at latitude 13.59 south and longitude 33.47 east with a total surface area of 393 km². The topography is mostly flat with an elevation ranging from 1,000 m to 1,200 m above sea level. The northern part of the City is relatively hilly with several small streams flowing southward. The southern part of the City, where Lilongwe River is running through to the north eastern direction, is rather flat.

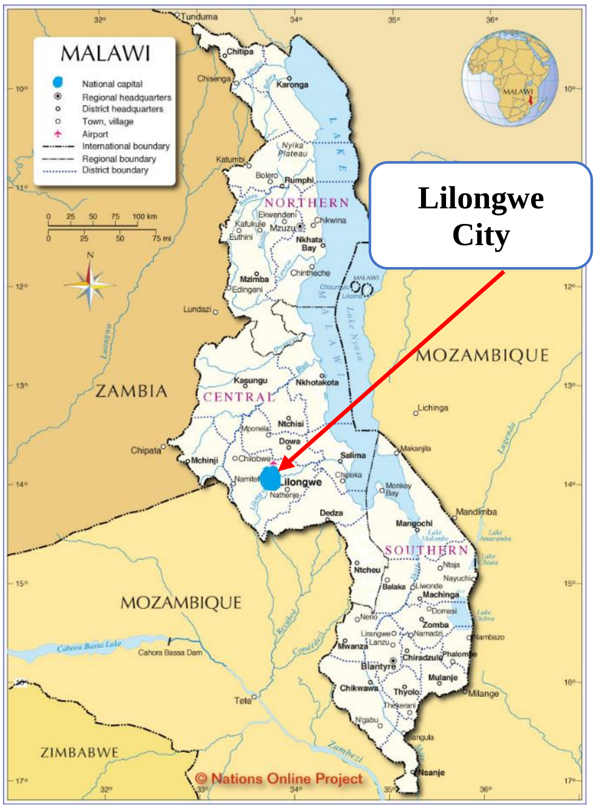


Figure 3-1: Map of Malawi indicating location of Lilongwe city

### 3.1.2 Economic and Social Characteristics

Lilongwe City is one of the most urbanized and rapidly growing cities in Malawi. The 2015 projected population for the City is 1,037,294 (NSO, 2008). The population of the City was 19,425 in 1966, an indication that it has grown by more than 50 times in the last 50 years. Together with the population growth, the population density has also increased from 43 persons/km² in 1966 to 1,702 persons/km² in 2008 (NSO, 2008). The informal settlement (Unplanned low income areas) population has grown from 82,180 in 1987 to 277,762 in 2005.

Currently, approximately 76 percent of the city's population lives in informal settlements (UN-Habitat, 2011).

The city has witnessed a high urbanisation rate ever since the Government administrative functions were relocated from Zomba in 1975. This has further been accelerated by the relocation of most government head offices from Blantyre to Lilongwe from 2005. Lilongwe is situated at the centre of a large agricultural area and there are many economic activities taking place in the city. Tobacco processing is the city's major industry.

### 3.1.3 Land Use Category

According to Japan International Corporation Agency [JICA], (2010) (Table 3-1), agricultural land use occupies 216 $km^2$ which is more than 55% of the city. Majority of the agricultural land is seasonally used as arable land for agriculture. It is used for agriculture during the rainy season but unutilized in the dry season.

Table 3-1: Land use category for Lilongwe city

| | Land use category | Area ($km^2$) |
|---|---|---|
| 1 | Residential | 93.2 |
| 2 | Industrial | 4.6 |
| 3 | Commercial | 3.4 |
| 4 | Government | 9.3 |
| 5 | Institutional | 8.8 |
| 6 | Transport | 5.6 |
| 7 | Infrastructure and Utilities | 1 |
| 8 | Water Bodies | 27.5 |
| 9 | Reserve and Green Areas | 17.5 |
| 10 | Leisure and Sport | 1.5 |
| 11 | Agriculture | 216.5 |
| 12 | Cemetery | 3.1 |
| 13 | Other Open Space | 1.5 |

Source: JICA (2010)

With reference to the breakdown of the residential land (Table 3-2), unplanned settlements occupy the largest share (approx. 39.7%), followed by traditional housing area (THA) sometimes referred to as Unplanned Traditional Housing Area (UTHA) at 18.9%, indigenous village (14.4%), low density permanent (13.9%), medium density permanent (9.1%) and high density permanent (3.7%).

Table 3-2: Residential land for Lilongwe city

| Land use category | Sub category | Area ($km^2$) |
|---|---|---|
| Residential | Low density housing | 13.4 |
| | Medium density housing | 8.5 |
| | High density permanent housing | 3.5 |
| | High density traditional housing | 17.6 |
| | Unplanned Settlements | 37 |
| | Indigenous Village | 11 |
| | Institutional Housing | 2.3 |

Source: JICA (2010)

### 3.1.4 Selected Low Income Settlements

The study was conducted in three unplanned low income settlements of Kauma, Mgona and Mtandire. Lilongwe Water Board has about 60 DMAs. The locations of the settlements in the context of Lilongwe City are highlighted in Figure 3-2. The settlements were chosen as suitable for the study based on their distinct characteristics that included:

- Demarcated District Metering Areas where water balance could be conducted.
- These DMAs are complete areas as established by the Lilongwe City Council.[1]
- Lilongwe Water Board supplies water to the areas.
- The areas are in different administrative zones which enabled matching of results.
- The areas are purely unplanned low income areas compared to other unplanned settlements which have mixed characteristics.

[1] In other cases an area/settlement has more than one DMA

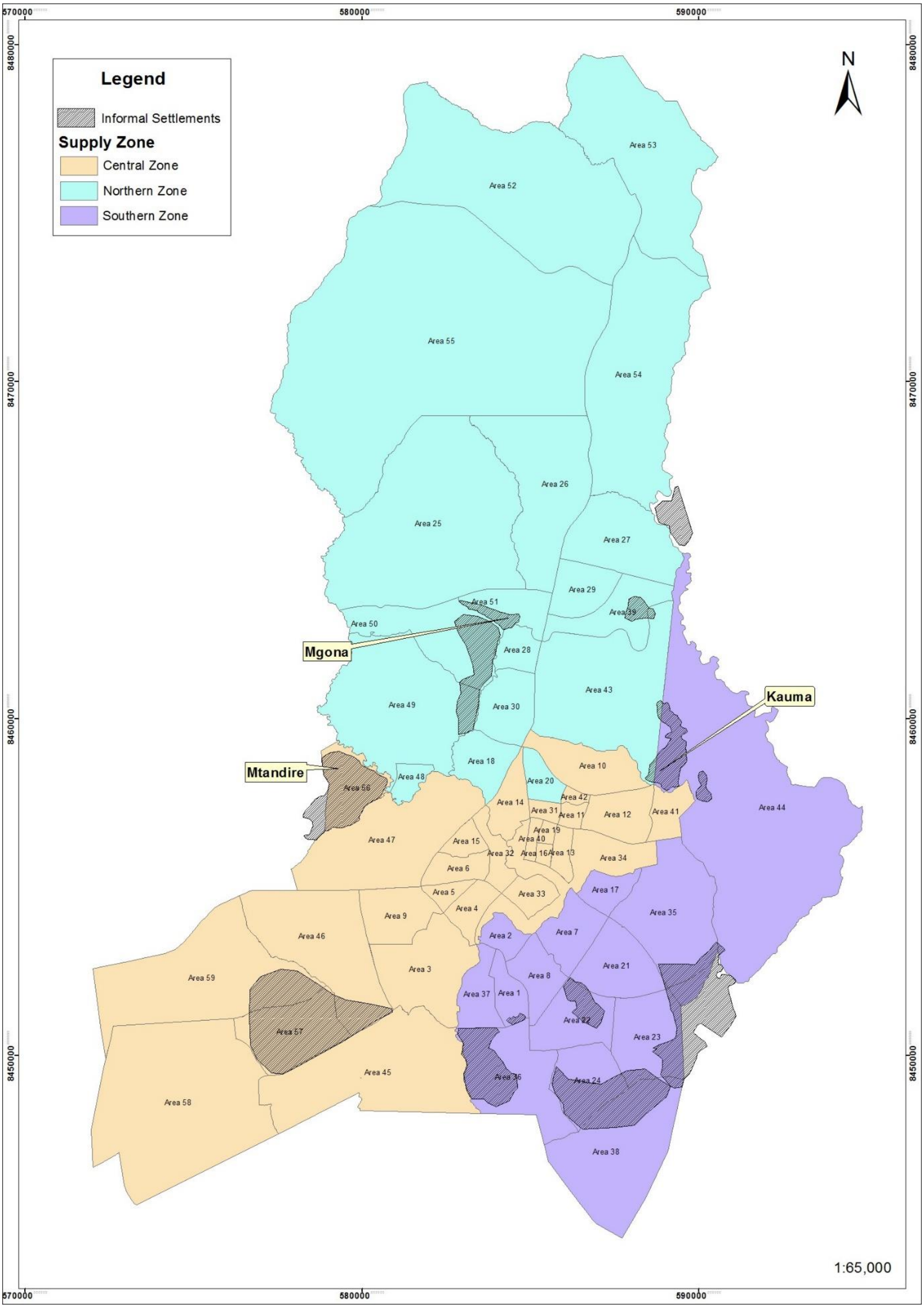


Figure 3-2: Location of the selected unplanned low income areas

***Kauma (Area 41)***

Kauma also referred to as Area 41 is an unplanned low income settlement located in the central eastern side of Lilongwe City. The settlement boarders' three low density residential settlements: Area 10, Area 12 and Area 43. The settlement is within the Central Zone[2] of Lilongwe Water Board.

***Mgona (Area 50)***

Mgona also referred to as Area 50 is an unplanned low income settlement located north of the Central Business District of Lilongwe City falling under the Northern Zone of Lilongwe Water Board.

***Mtandire (Area 56)***

Mtandire (Area 56) is an unplanned low income settlement located on the western side of Lilongwe City. The settlement lies on the western side of Area 47 a low density area and south of Area 49, a rapidly developing medium density residential area. The settlement falls under Central Zone of Lilongwe Water Board.

## 3.2 Lilongwe Water Board

Lilongwe Water Board is a government owned water utility established in January 1947 and reconstituted by an Act of Parliament, Water Works Act No.17 of 1995 (LWB, 2015). Under the Waterworks Act No. 17 of 1995, the Lilongwe Water Board (LWB) is mandated to provide potable water within the urban and peri-urban areas of the City of Lilongwe. The utility operates on a commercial basis with no subvention from the government.

## 3.3 Study Design

The study used historical data review, literature review, field measurements and household surveys. The data collected was mainly quantitative, however qualitative data through unstructured interviews was also collected to validate some of the quantitative data. This study was carried out in Lilongwe City, an area under the water supply jurisdiction of LWB, from October 2015 to February 2016. Data collection over this period enabled accessing water consumption data for the season where there is high water consumption, leading to high demand (April to November) and the season which corresponds with low water consumption

[2] Lilongwe Water Board operations are demarcated into three administrative zones (North, Central and South).

which leads to low water demand (December to March). This accommodation of seasonal variations increased the validity and reliability of the study results. The components studied included coverage of water supply services in the selected unplanned low income areas, non-revenue water and its causes, billed amounts and corresponding collected revenues, and the cost of network maintenance.  In addition to the three specific study areas some components (Non-Revenue Water, Revenue Collection Efficiency, and Cost of network maintenance) were also studied for the whole Lilongwe Water Board supply area.

### 3.3.1 Indicators Selected for the Study

The following indicators were selected for the study:

**Non-Revenue Water**

- Water losses are a key cost element in most water utilities in developing countries. This indicator captures the efficiency both of the distribution network (physical losses) and of commercial management (commercial losses due to metering and billing problems). This indicator was selected for the study as it is the main indicator used in assessment of water utility performance and it captures both technical and financial aspects.

**Revenue Collection Efficiency**

- The revenue collection efficiency directly affects the cash flow of the utility and captures a large portion of the efficiency of commercial management. Revenue collection efficiency was selected for the study in line with literature findings where unplanned low income settlements are associated with low levels of income which could have a bearing on collection efficiency.

**Repair Costs per Km of Network and Per Connection**

- Repair costs per km of network is an improvement on the widely used indicator number of bursts/leakages per km. The number of leakages per km provides an indication on condition of the pipe infrastructure. Repair costs per km attaches a cost element to the technical indicator. According to literature there is a lot of vandalism in unplanned low income settlements. Repair cost per km or connection measures the extent of the vandalism (frequency) and attaches a financial implication.

## 3.4 Data Collection and Analysis

To achieve the specific objectives under the study, various data was collected specific to the objective with varying tools for data collection and sampling techniques.

### 3.4.1 Sources of Water and Trends in Expansion of Water Supply Services in the Study Areas

***Water Connections***

Historical data on number and categories of connections for the entire supply area was collected from Lilongwe Water Board's Billing Section for the period July 2008 to February 2016. Similarly the historical data for the selected unplanned low income settlements, Kauma, Mgona and Mtandire was collected for the period October 2015 to February 2016.

***Length of Pipe Network***

Data on length of pipe network in the selected unplanned low income settlements and for the entire supply area was collected from Lilongwe Water Board's Geographical Information System (GIS). The data included installation dates for the pipes to provide trends on network expansion that has been implemented over the years.

***Population in the Study Areas***

The 2008 Population and Housing Census Report was used as a basis for population projections in the selected informal settlements and determination of sample sizes for the household surveys.

***Sources of Water Supply***

A household survey was conducted in the selected areas to determine the sources of water for the households. The survey used a questionnaire as a tool for data collection. The information captured by the questionnaire among others included sources of water for the households, household sizes, whether a household has a Lilongwe Water Board water connection and number of households using one connection (Appendix 2). The survey used random sampling technique. The sample size for the household surveys was determined using a formula according to Stattrek (2015). This sample size determination formula was used as it is suitable in cases where a current estimate of the proportion of a population that has a trait being studied is available based on past surveys or general knowledge. In this study the proportion estimate was based on the Population and Housing Census Report (2008).

$$n = \frac{\{(z^2 \times p \times q) + ME^2\}}{[ME^2 + z^2 \times p \times q / N]} \text{……………………………………………………………….....} \textit{Equation 3-1}$$

Where: n = sample size, z = critical standard score, p=larger population proportion, q=smaller population proportion, ME = Marginal Error and N=total population.

For this equation to be valid, the following assumptions were made:

- The Margin of Error, ME, is plus or minus 5% or 0.05
- The confidence level is 95% or 0.95, Thus, alpha = 1 - 0.95 = 0.05.
- The critical standard score (z) is the value for which the cumulative probability is 1-alpha/2 = 1 - 0.05/2 = 0.975. Thus for cumulative probability of 0.975, critical standard score (z) = 1.96 (Stattrek, 2007)
- 95% of the households have access to LWB water in Kauma, (thus p=95% and q= 5%)
- 95% of the households have access to LWB water in Mgona, (thus p=95% and q= 5%)
- 95% of the households have access to LWB water in Mtandire, (thus p=95% and q= 5%)

The required sample sizes for the selected areas were established as in Table 3-3.

Table 3-3: Sample sizes for household surveys

| Settlement | Number of Households | Sample size |
|---|---|---|
| Kauma | 7,500 | 73 |
| Mgona | 8,237 | 73 |
| Mtandire | 11,226 | 74 |

The data on connection trends in the selected settlements was analysed using Microsoft Excel while SPSS was used to analyse household survey data obtained from the household survey.

### 3.4.2 Non-Revenue Water Trends and Factors Contributing to NRW

***System Input Volume***

Historical data on volumes of water produced for the entire water supply area of LWB was collected for the period July 2008 to February 2016[3] on a monthly basis. The data was collected to establish the trend for system input and hence an input in calculation of NRW which enabled

[3] Available historical data is from July 2008 while February 2016 corresponded with data collection period

an understanding of the entire system. For Kauma, Mgona and Mtandire ultrasonic clamp-on flow meters were installed at entry points into a settlement and recordings conducted over a period of three days to determine daily inflows into an area. The daily average flow rate was used to calculate monthly system input volume.

***Billed Volume***

Historical data on volumes of water billed for the entire water supply area of LWB was collected for the period July 2008 to February 2016 on a monthly basis. The data was collected to establish the trend for billed volume and hence an input in calculation of NRW which enabled an understanding of the entire system. In the informal settlements all connected customer meters were read on a monthly basis for the period October 2015 to February 2016 to determine monthly consumptions for individual connections and the entire area.

***Calculation of NRW***

The NRW trends for the selected unplanned low income areas and the corporate levels was analysed based on a water balance method in which the difference between water produced (system input) and water billed was calculated as recommended by Farley (2001), Lambert (2003) and Motiee et al., (2007). According to Motiee et al., (2007), the water balance in a water network system can be defined as:

$$Q_P = Q_C + Q_L \quad \textit{Equation 3-2}$$

Where:
$Q_P =$ Water produced/supplied or system input ($m^3$/year, $m^3$/month)
$Q_C =$ Water consumption/Billed Volume ($m^3$/year, $m^3$/month)
$Q_L =$ Total water losses ($m^3$/year, $m^3$/month)

Using *Equation 3-2* NRW trends for the selected unplanned low income settlements and overall trend for LWB was established. Microsoft excel was used to plot the corresponding NRW trends.

***Causes of Non-Revenue Water in the Unplanned LIAs***

The study established causes of NRW in the LIAs through an estimation of the commercial water losses and assigning the remaining amount to physical water loss (leakages). The commercial losses included: meter errors, data transfer and billing errors, and illegal connections.

**Water Loss Due to Meter Inaccuracies**

Meters were randomly uninstalled in the study areas and tested for accuracy at the Lilongwe Water Board meter Laboratory. Volume of water losses due to meter errors ($E_{FM}$) was calculated as follows:

$$E_{FM} = ER_{FM} \times N_a \times Q_a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 3-3}$$

Where $N_a$ is the number of active connections in the study areas obtained from Billing Section, and $Q_a$ is the mean monthly consumption of each connection (Tabesh et al., 2009). $ER_{FM}$ is the average meter error. The mean monthly consumption for each connection is calculated as:

$$Q_a = \frac{M_c}{N_a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 3-4}$$

Where $M_c$ is the monthly billed consumption and Na is the number of active connections.

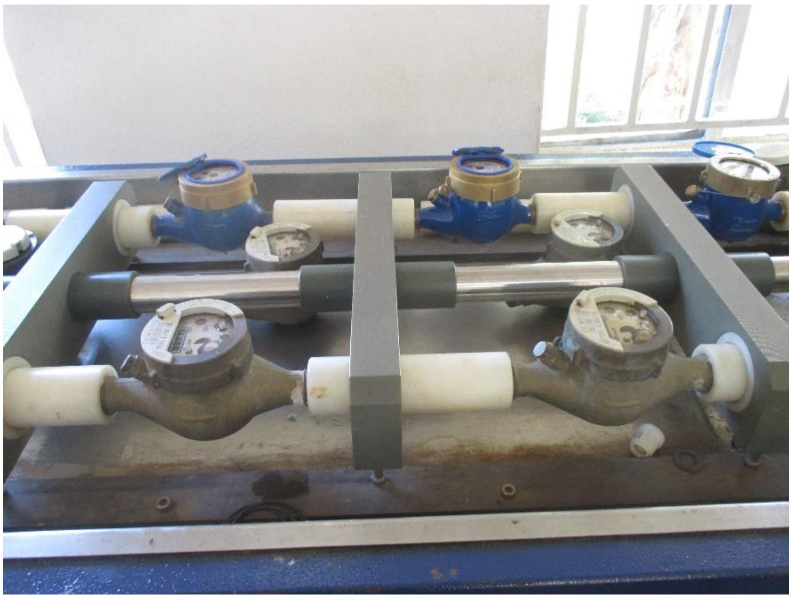

Figure 3-3: Meter testing at the meter laboratory

**Water Loss Due to Data Transfer and Billing Errors**

Meter reading data for selected customers was collected from meter reading books for the selected low income settlements. The data was collected for the month of January 2016. Data for the readings registered in the Billing system for the same period was also collected. The sample size for customers whose meter readings were analysed was determined using (Stattrek, 2015) formula for sample size determination as given in Equation 3-1. Volume of water losses due to data transfer and billing errors was calculated using Equations 3-3 and 3-4.

**Water Loss Due to Illegal Connections**

From the meter validation survey done by Kamnkhwani et al., (2014) number of illegal connections ($N_x$) within the study areas was estimated. Using this information volume of water losses due to illegal connections was calculated as:

$$E_x = N_x \times Q_a \quad \text{......Equation 3-5}$$

Where $E_x$ is volume lost, $N_x$ is number of illegal connections and $Q_a$ is the mean monthly consumption of each connection calculated using Equation 3-4.

**Water Loss Due to Leakages (Physical Losses)**

The volume of water loss due to leakages was established as follows:

$$NRW_L = Q_L - E_{FM} - E_{TM} - E_x \quad \text{......Equation 3-6}$$

Where $NRW_L$ is the volume of water loss due to leakages (visible and background) in $m^3$/year or $m^3$/month. $Q_L$ ($m^3$/year; $m^3$/month) is the total water loss in the study area calculated using Equation 3-2, $E_{FM}$ ($m^3$/year; $m^3$/month) is the water loss due to meter errors, $E_{TM}$ ($m^3$/year; $m^3$/month) is the volume of water loss due to billing and data transfer errors and $E_x$ ($m^3$/year; $m^3$/month) is the volume of water loss due to illegal connections.

### 3.4.3 Revenue Collection Efficiency and Factors Affecting Revenue Collection

***Billed Revenue***

Historical data on monetary value of water billed for the entire water supply area of LWB was collected for the period October 2015 to February 2016 on a monthly basis. The data was collected to establish the trend for billed amounts and hence an input in calculation of collection ratio which enabled an understanding of the entire system. In the unplanned low income areas all connected customer meters were read on a monthly basis for the period October 2015 to February 2016 to determine monthly consumptions and corresponding billed amounts. Ultimate data was collected from LWB Revenue section.

***Cash Collected***

Data on revenue collections for the entire supply area and the low income settlements under study was collected on monthly basis from the Revenue Section of LWB for the period October 2015 to February 2016. The revenue collection efficiency for the entire LWB and in the selected study areas was calculated using a formula by IBNET, which is defined as:

$$CR = \frac{CI}{BR+AR} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 3-7}$$

Where:

$CR$ = Collection Ratio (%)

$CI$ = Cash Income (MK/year, MK/month)

$BR$ = Billed Revenue (MK/year, MK/month)

AR = Opening Arrears (MK/year, MK/month)

***Factors Affecting Revenue Collection***

A customer survey was conducted in the informal settlements to determine factors that would affect revenue collection. The survey used a questionnaire as a tool for data collection. Information corrected included average monthly bills, levels of income, whether customer have ever been disconnected, reasons for non-timely payment of bills and customer's opinion on the water tariff (Appendix 2). The survey used random sampling technique specifically targeting existing LWB customers. Minimum sample size for the customer surveys was determined using a formula according to Stattrek (2015) (Equation 3-1). The required sample sizes for the selected areas were established as in Table 3-4.

Table 3-4: Sample sizes for customer surveys

| Settlement | Number of Customers | Sample size |
|---|---|---|
| Kauma | 259 | 58 |
| Mgona | 866 | 68 |
| Mtandire | 1,007 | 69 |

The data collected through the customer survey was analysed using SPSS and excel to determine factors affecting bill payments and revenue collection in the study areas.

### 3.4.4 Network Maintenance Cost Per Unit Length of Network

***Monthly Cost of Network Repair Materials***

Historical yearly data on cost of network repair materials was collected for the entire water supply covering the period 2011 to 2015. Monthly data on cost of network repair materials for the entire supply area was also collected for the period October 2015 to February 2016. In the selected unplanned low income settlements, data was collected on network repair materials used on a monthly basis covering the period October 2015 to February 2016 using a specially designed form *(Appendix 9).* A price list *(Appendix 8)* of repair materials was obtained from LWB. The cost of the repair materials for the study areas was computed as:

$$C_R = \sum_{i=1}^{n} F_i \times C_i \quad \textit{Equation 3-8}$$

Where:

$C_R$ = Total cost of repair materials (MK/year, MK/month)

$F_i$ = Number of type "*i*" fittings used on repair work

$C_i$ = Unit cost for type "*i*" fitting (MK)

*n* = Types of fittings used on a repair work

***Length of Pipe Network for the Supply Area and the Study Areas***

Data on length of pipe network for the entire supply area and the selected low income areas was collected from Lilongwe Water Board's Geographical Information System (GIS). The data included types and number of fittings for the supply area and the study areas.

**Computation of Repair Costs per Km and Per Connection**

The network maintenance cost per unit length of network was calculated as:

$$N_c = \frac{C_R}{L} \quad \textit{Equation 3-9}$$

where *Nc* is the cost of network repair per unit length of pipeline (MK/km), $C_R$ is the cost of repairs calculated using Equation 3-8 and L is the length of network in a study area in km. The network maintenance cost per connection was calculated as:

$$N_c = \frac{C_R}{n} \quad \textit{Equation 3-10}$$

where *Nc* is the cost of network repair per unit length of pipeline (MK/km), $C_R$ is the cost of repairs calculated using Equation 3-8 and n is the number of connections in a study area.

# 4. RESULTS AND DISCUSSION

## 4.1 Sources of Water for the Households in the Unplanned Low Income Settlements

Figure 4-1 presents a breakdown on water sources for the households in the unplanned settlements of Kauma, Mgona and Mtandire.

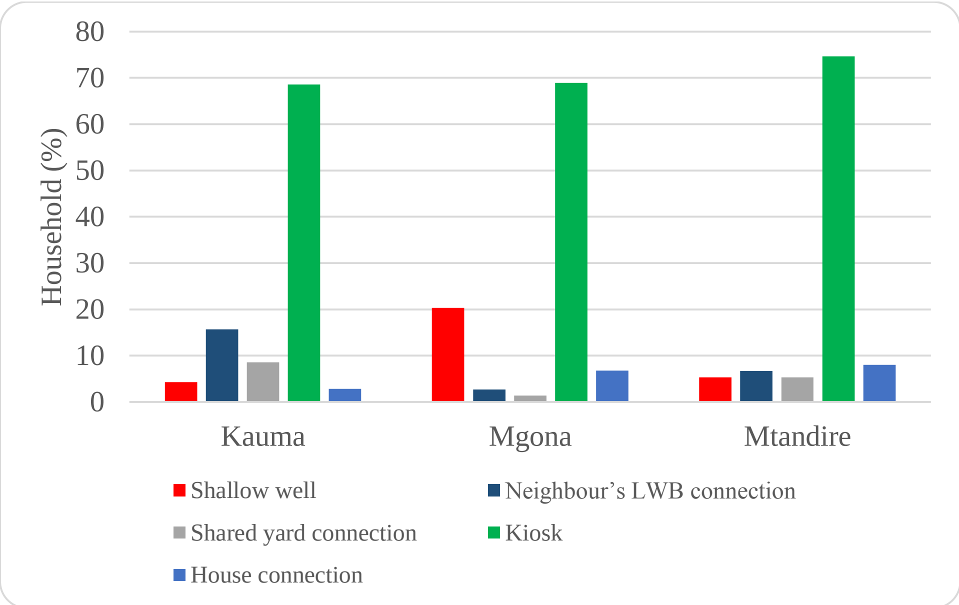


Figure 4-1: Sources of water for households at Kauma, Mgona and Mtandire

From Figure 4-1 it is observed that water kiosks are the main source of water for the households in the low income areas since they are being used by 71% of the sampled households. The other water sources include; shallow wells (10%), buying from neighbours with LWB connection (8%), shared yard connections (5%) and with own house connections (6%). Mtandire has the highest proportion (75%) of households relying on communal water points compared to 69% for both Kauma and Mgona. Other water sources include shared yard connections (highest in Kauma at 9%), individual house connection (highest in Mtandire at 8%), buying water from neighbour with an LWB connection (highest in Kauma at 16%) and shallow wells (highest in Mgona at 20%). Overall 90% of the sampled households are dependent on Lilongwe Water Board's water supply through the various available modes of supply.

The high use of shallow wells at Mgona could be attributed to the households' perception on cost of piped water as 39% of the households in Mgona were of the view that the water tariff is expensive or very expensive compared to 33% for Kauma and 32% for Mtandire as established in the household survey.

Compared to a study by AWSB et al. (2009), results suggest that the proportion of households accessing piped water in the study settlements is lower than the proportion in the informal settlements of Nairobi City which was 97%. In contrast, Muturi (2013) found that the proportion of households using piped water, supplied by the water utility in Nyeri Municipality, Kenya was 16% which is far much less than the situation in the study areas. In a similar water supply system in Malawi, Mughogho et al., (2012) estimated the proportion of households in the informal settlements of Blantyre City accessing piped water at 70% which is lower than that for the informal settlements in Lilongwe City. The findings in this study are not remarkably different from those of Manda (2009) in a study on water and sanitation in the informal settlements of the cities of Blantyre, Lilongwe and Mzuzu where 92% of the households were found to have access to piped water. However whereas the study by Manda (2009) found that households accessing water through kiosks in Lilongwe City was 53% the current study found 71% which could be as a result of investments in construction of additional kiosks in the informal settlements. It can be concluded that coverage of piped water supply in the informal settlements of Lilongwe City is high and that the households highly rely on water supply services delivered by Lilongwe Water Board.

## 4.2 Growth of Water Supply Services

### 4.2.1 Trends in Pipe Network Expansion

Figure 4-2 presents the trends in pipe installations in the study settlements over the period 1999 to 2016 while Figure 4-3 indicates the change in pipe network length for the entire supply area over the same period.

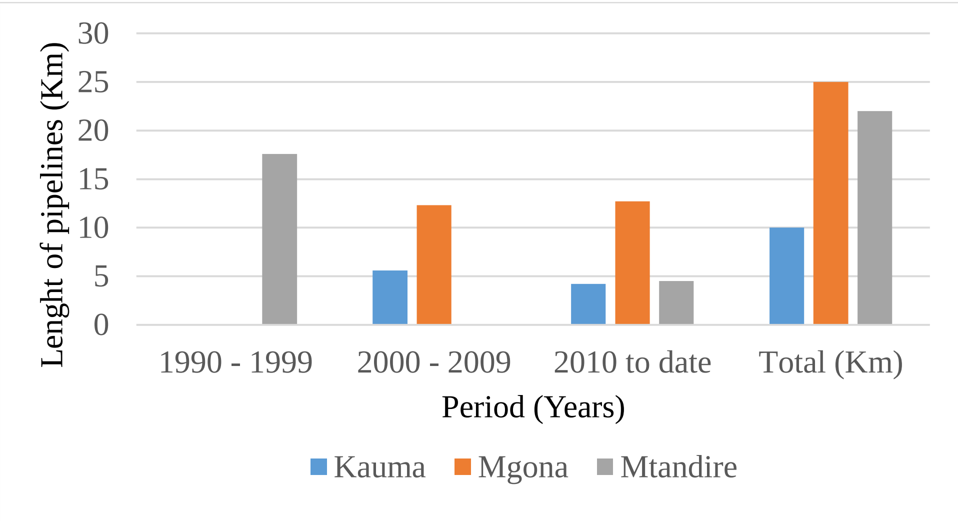


Figure 4-2: Pipe installation trends in the unplanned low income settlements

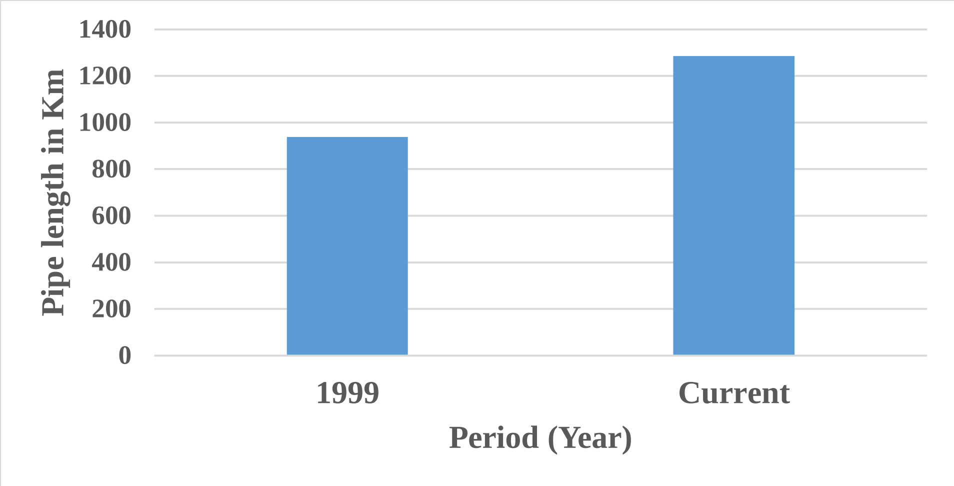


Figure 4-3: LWB pipe installation trends

From Figures 4-2 and 4-3, there is an increase in the length of pipelines in the informal settlements and in the whole supply area. The length of pipe network in the three settlements has grown from 17 Km in 1999 to 57 Km in 2016 (235%). The overall pipe network length for the entire supply area has increased from 938 Km in 1999 to 1,286 Km in 2016 (37%). In Mtandire the network length has been expanded from 17 Km in 1999 to 22 Km in 2016 while for Kauma and Mgona network length has been expanded from 0 to 10 Km and 25 Km, respectively. The results indicate that the water utility is expanding reticulation system in informal settlements including those settlements previously not reticulated.

A study by Banerjee (2008), found that general coverage of utility water in Africa is on the decline at 75% in the period 1990 – 1995 to 63% in the period 2001 - 2005. This is contrary to the expansions in network and connections in the informal settlements of Lilongwe City. The high rate of network expansion in the informal settlements could be attributed to the recent initiatives in improvement of water supply services in these areas. This includes implementation of the Malawi Peri-urban Water Supply and Sanitation Project, financed by the European Union (EU) and the European Investment Bank (EIB) in which network extensions were implemented in informal settlements as well as construction of 372 communal water kiosks (LWB, 2014). This could also be as a result of a new connection subsidy programme implemented by LWB under the second National Water Development Programme (NWDP II).

### 4.2.2 Connection Trends in the Unplanned Low Income Settlements and Overall LWB

Figure 4-4 presents the connections trend over a five year period (2011 – 2016) for the unplanned low income settlements. A similar trend for the entire supply area is presented in Figure 4-5.

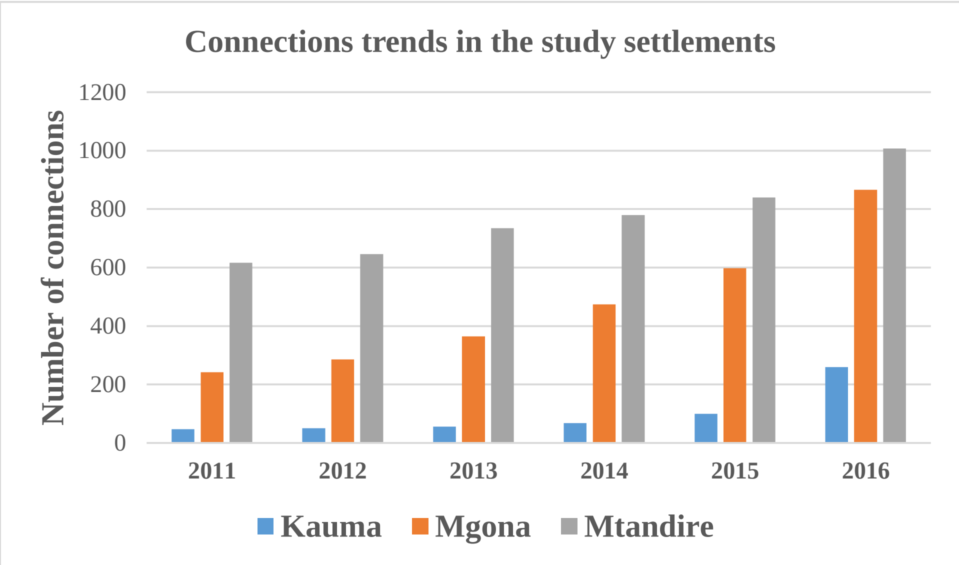


Figure 4-4: Trend of connections in the study settlements

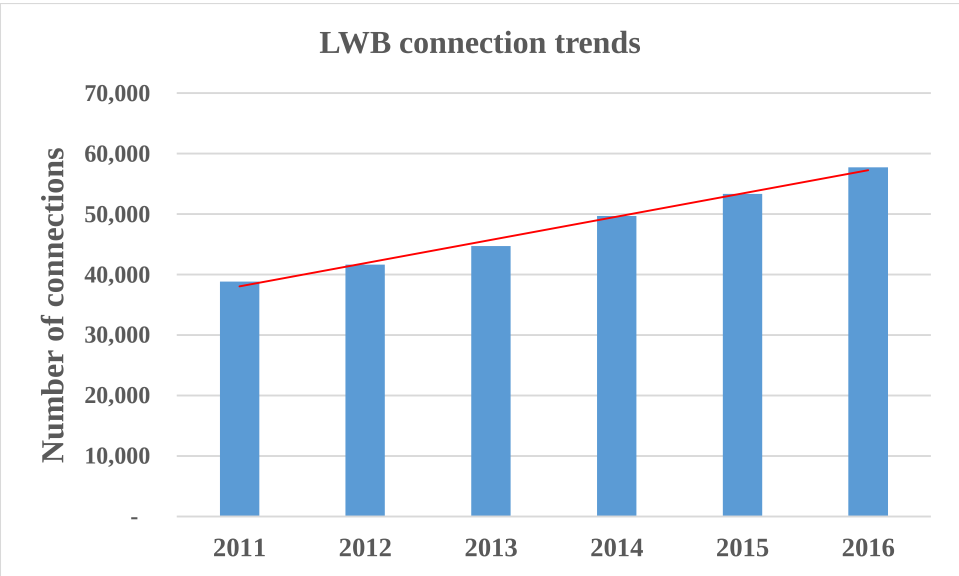


Figure 4-5: Growth in number of connections

From Figures 4-4 and 4-5 it is observed that there is a general increase in number of connections in both the study settlements and the entire supply area. The number of connections in the unplanned low income settlements has increased from 905 in 2011 to 2,132 in 2016 (136%).

Over the same period, the number of connections for LWB has increased from 38,837 in 2011 to 57,728 in 2016 (49%). In Kauma the number of residential connections has moved from 4 (9% of the total connections) in 2011 to 214 (83% of the total) while the number of communal water points has remained at 34 representing a decline from 72% to 12%. Over the five year period, the movement in percentage of residential connections compared to total connections in Mgona and Mtandire is lower compared to Kauma. In Mgona it has moved from 71% to 82% and for Mtandire it has moved from 85% to 87%. The number of communal water kiosks has moved from 64 to 133 in Mgona and 65 to 95 in Mtandire. *(Details on connection trends per customer category are provided in Appendix 3).* It is however observed that number of residential water connections is on the increase in these settlements which may lead to a pattern change on mode of accessing piped water supply for the households.

The general increase in number of connections in the settlements is as a result of expansion of water supply network in these settlements *(Section 4.2.1)* and a new connection subsidy programme implemented by LWB under the second National Water Development Programme (NWDP II). Whereas in most African countries expansion of piped water supply in informal settlements is very slow (Banerjee, 2008; Dagdeviren et al., 2009), the experience in the informal settlements under LWB is different. The case however has similarities with informal settlements of Kampala, Uganda where a large increase in connections was registered as a result of deliberate policies (World Bank, 2014).This indicates that water supply services have been expanded in unplanned low income areas in the past 15 years.

## 4.3 Non-Revenue Water

### 4.3.1 Lilongwe Water Board Trend for NRW (2010 – 2016)

Figure 4-6 presents plots of the total annual Water Produced, Water Billed, NRW (volume) and NRW (%) for Lilongwe City from 2010 to 2016.

From Figure 4-6 it is observed that annual NRW for LWB expressed as a volume has been in the range 11million cubic metres to 13million cubic metres for the six years. Water production has increased by 4million cubic metres, from 30million cubic metres to 34million cubic metres. The increase in production is attributed to the expansion and rehabilitation of the water treatment works by LWB. The highest level of NRW (39%) was recorded in 2011. Over the six year period NRW is in the range 34% - 39%.

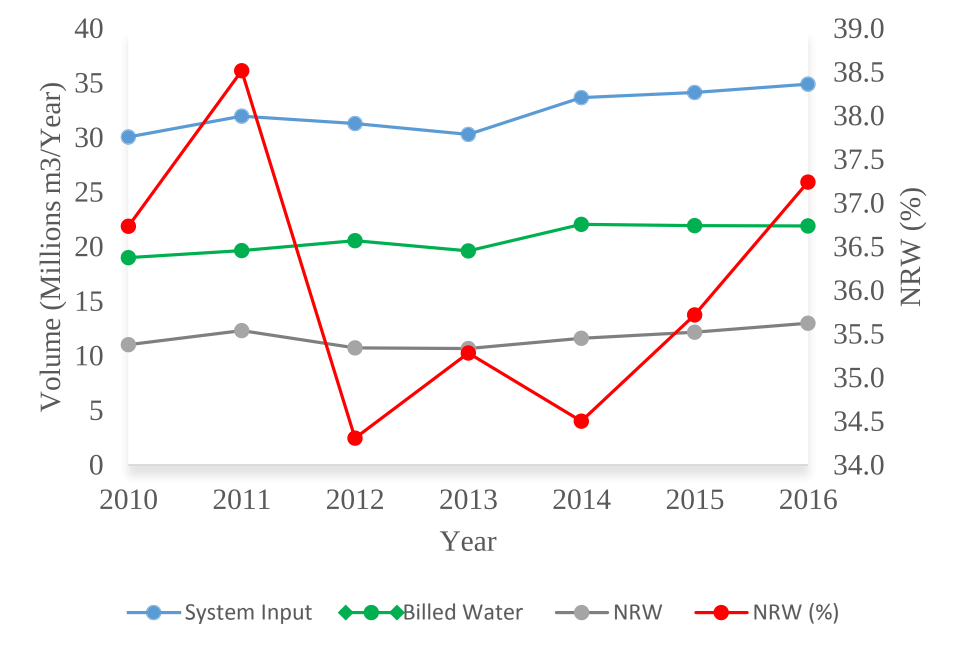


Figure 4-6: Total water produced, water billed, NRW (volume) and NRW (%) for Lilongwe city from 2010 to 2016

A study by Marunga et al., (2006) established NRW levels of 57% in the City of Mutare, Zimbabwe. Gumbo (2004) found NRW level of 20% for the City of Bulawayo. In similar studies in Malawi, Kafodya (2010), established NRW of 50% for Blantyre Water Board (BWB) while Chipwaila (2009) established average NRW of 27.5% for the City of Zomba. In Bangladesh, Dhaka and in the Pacific region average NRW levels of 30% and 51% have been reported respectively (WSP, 2014; PWWA, 2012). The NRW level at LWB over the period 2011 – 2016 is within the levels reported in literature for most utilities (20% - 57%) however it is more than the acceptable level of 23% for developing countries.

The monthly NRW for the entire supply area and for the unplanned low income settlements for the period October 2015 to February 2016 is presented in Figure 4-7.

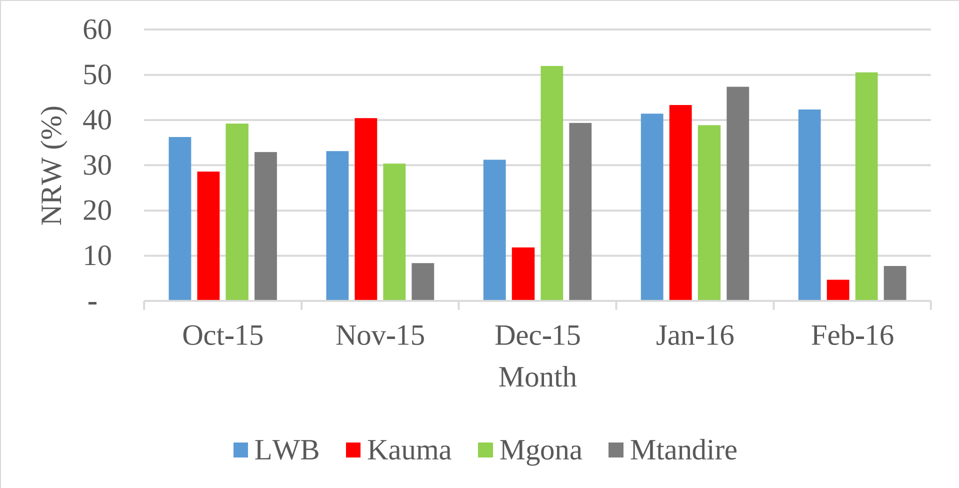

Figure 4-7: Monthly variations in NRW for Lilongwe city (March 2015 – February 2016)

In the study period (October 2015 to February 2016) NRW for the entire supply area ranged from 31.0% to 42.0%, the lowest amount being recorded in December 2015. The average NRW for the study period was 36.6%. This depicts similarities with the five year average NRW of 36% an indication that LWB's NRW as a percentage of system input is almost constant. There is however a bigger variation between the minimum (31.0%) and the maximum (42%) on the monthly percentages compared with the yearly figures for the period 2011 – 2016. This could be as a result of variations in meter reading cycles whose error is eliminated over a longer period of time.

### 4.3.2 Non-Revenue Water Trends in the Unplanned Low Income Settlements

Tables 4-1, 4-2 and 4-3 present system input, billed volume and NRW for Kauma, Mgona and Mtandire for the period October 2015 to February 2016.

Table 4-1: System input, billed consumption and NRW for Kauma (October 2015 – February 2016)

| Month | System Input ($m^3$) | Billed Consumption ($m^3$) | Non-Revenue Water | | | |
|---|---|---|---|---|---|---|
| | | | Volume ($m^3$) | % of water supplied | $m^3$/km/month | $m^3$/connection/ month |
| Oct-15 | 15,520 | 11,083 | 4,437 | 29 | 444 | 17 |
| Nov-15 | 15,019 | 8,952 | 6,067 | 40 | 607 | 23 |
| Dec-15 | 15,520 | 13,678 | 1,842 | 12 | 184 | 7 |
| Jan-16 | 15,520 | 8,799 | 6,721 | 43 | 672 | 26 |
| Feb-16 | 14,518 | 13,838 | 680 | 5 | 68 | 3 |

Table 4-2: System input, billed consumption and NRW for Mgona (October 2015 – February 2016)

| Month | System Input ($m^3$) | Billed Consumption ($m^3$) | Non-Revenue Water | | | |
|---|---|---|---|---|---|---|
| | | | Volume ($m^3$) | % of water supplied | $m^3$/km/month | $m^3$/connection/ month |
| Oct-15 | 52,728 | 32,052 | 20,676 | 39 | 827 | 24 |
| Nov-15 | 51,027 | 35,520 | 15,507 | 30 | 620 | 18 |
| Dec-15 | 52,728 | 25,339 | 27,389 | 52 | 1,096 | 32 |
| Jan-16 | 52,728 | 32,238 | 20,490 | 39 | 820 | 24 |
| Feb-16 | 49,326 | 24,391 | 24,935 | 51 | 997 | 29 |

Table 4-3: System input, billed consumption and NRW for Mtandire (October 2015 – February 2016)

| Month | System Input ($m^3$) | Billed Consumption ($m^3$) | Non-Revenue Water | | | |
|---|---|---|---|---|---|---|
| | | | Volume ($m^3$) | % of water supplied | $m^3$/km/month | $m^3$/connection/ month |
| Oct-15 | 30,719 | 20,608 | 10,111 | 33 | 460 | 10 |
| Nov-15 | 29,728 | 27,238 | 2,490 | 8 | 113 | 2 |
| Dec-15 | 30,719 | 18,626 | 12,093 | 39 | 550 | 12 |
| Jan-16 | 30,719 | 16,172 | 14,547 | 47 | 661 | 14 |
| Feb-16 | 28,737 | 26,516 | 2,221 | 8 | 101 | 2 |

From Tables 4-1, 4-2 and 4-3 it is observed that over the study period, monthly NRW for Kauma was in the range 5% to 43%. The NRW for Mgona was in the range 30% - 52% and for Mtandire 8% to 47%.

A comparison of the average levels of NRW in the study areas and the entire Lilongwe City over the period October 2015 to February 2016 is presented in Figure 4-8. Table 4-4 presents the average NRW for the study areas and the entire supply area expressed as percentage of water supplied, volume per length of pipeline ($m^3$/km/month) and volume per connection ($m^3$/km/connection).

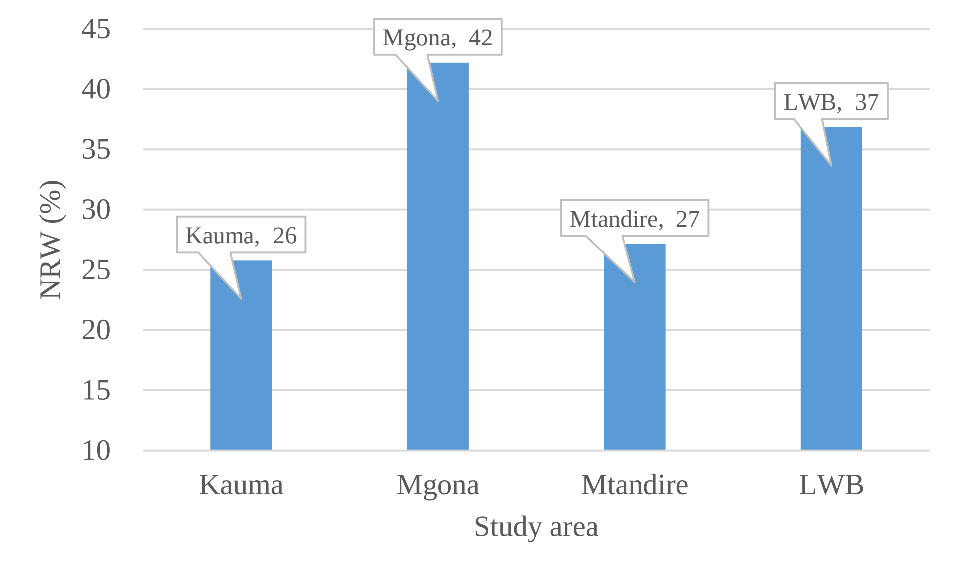


Figure 4-8: A comparison of average NRW for the study areas and entire Lilongwe city for the period March 2015 – February 2016

Table 4-4: Average NRW for the study settlements and the entire supply area for the period October 2015 to February 2016

| Area | Mains Length (Km) | Connections | Average Non-Revenue Water | | | |
|---|---|---|---|---|---|---|
| | | | Volume ($m^3$) | % of water supplied | $m^3$/km/month | $m^3$/connection/month |
| Kauma | 10 | 259 | 3,949 | 26 | 395 | 15 |
| Mgona | 25 | 866 | 21,799 | 42 | 872 | 25 |
| Mtandire | 22 | 1,007 | 8,292 | 27 | 377 | 8 |
| LWB | 1600 | 57,728 | 1,049,695 | 37 | 656 | 18 |

From Figure 4-8 and Table 4-4 it is observed that Kauma had the lowest average NRW of 26% (395m$^3$/km/month or 15m$^3$/connection/month) followed by Mtandire at 27% (377m$^3$/km/month or 8m$^3$/connection/month). Mgona had the highest level of NRW at 42% (872m$^3$/km/month or 25m$^3$/connection/month). This could be due to low network maintenance activities as a result of very few leakages being reported to LWB by the residents. The customer survey established that 48% of the customers in Mgona indicated to have ever reported a leakage to LWB compared to 62% for Mtandire and 70% for Kauma. Key informants at LWB reported that Kauma and Mtandire have vibrant and active Water User Associations (WUA) that facilitate community management of water facilities in the settlements. The average NRW for the entire supply area was 37% (656 m$^3$/km/month or 18 m$^3$/connection/month). In comparison with NRW for the entire supply area, it is observed that the average NRW in two of the study settlements; Kauma (26%) and Mtandire (27%) is less than the average NRW

(37%) for the entire supply area while the average NRW for Mgona (42%) is higher than the NRW for the entire supply area. The NRW levels for the selected low income areas as well as the entire supply area are above the recommended level of 23% for developing countries.

A study by Chiipanthenga (2008) in two DMAs within the supply area of BWB established NRW levels of 42% (Chinyonga) and 50% (BCA). Chipwaila (2009), found NRW levels which were in the range 6% - 62% in four DMAs of Zomba City. High levels of NRW for Blantyre were reported as due to a relatively old pipe network (Kafodya, 2010), while for Zomba high level of water losses was attributed to very high pressures in the system (Chipwaila, 2009). A study by Harawa (2015) within the same LWB' supply area found NRW of 20% (Area 28), 33% (Area 15) and 44% (Area 18). It is evident that the NRW levels for the study areas in this study are within the mid-range of levels established in other water utilities and very close to the NRW levels for other DMAs within the supply area of LWB as found by Harawa (2015).

### 4.3.3 Factors Contributing to Non-Revenue Water

***Water Loss Due to Meter Errors***

Results of the meter errors at normal operating flow rate (high) are presented in Table 4-5 while Table 4-6 provides details of water loss due to meter errors.

Table 4-5: Meter testing results at high flow rate

| Settlement | Number of meters tested | Meters with error | Average negative error (%) | Average positive error (%) | Meters with negative error (%) | Meters with positive error (%) |
|---|---|---|---|---|---|---|
| Kauma | 18 | 14 | 17 | 0.9 | 33 | 44 |
| Mgona | 18 | 15 | 1.7 | 0 | 83 | 0 |
| Mtandire | 18 | 13 | 2.6 | 1.2 | 44 | 28 |

Table 4-6: Water loss due to meter errors

| Settlement | Water loss due to meter errors ($m^3$) | Water loss due to meter errors as a percentage of total water loss (%) | As a percentage of system input (%) |
|---|---|---|---|
| Kauma | 610 | 15.5 | 4 |
| Mgona | 432 | 2 | 0.8 |
| Mtandire | 176 | 2.1 | 0.6 |

From Tables 4-5 and 4-6 it is observed that meter errors contributed 15.5% of the water losses in Kauma, 2.1% in Mtandire and 2.0% at Mgona. A study by Chipwaila (2009), found that meter errors contributed to less than 10% of the water losses in Zomba City. However Harawa (2015) in a study on meter errors in Areas 15, 18 and 28 of Lilongwe City observed that meter errors had minimal contributions to water losses in these areas. For Kauma the results are high compared to the findings in the other studies while for Mgona and Mtandire the findings are in line with the studies by Chipwaila (2009) and Harawa (2015).

***Water Loss Due to Data Handling and Billing Errors***

Results of an assessment of billing errors are presented in Table 4-7 while Table 4-8 gives a presentation of water loss due to billing errors. Details on comparison for meter readings captured in the meter reader books and the billing system are presented in Appendices 5 to 7.

Table 4-7: Billing errors from the sampled accounts in the study areas

| Settlement | Sampled accounts | Accounts with error | Average negative error (%) | Average positive error (%) | Accounts with negative error (%) | Accounts with positive error (%) |
|---|---|---|---|---|---|---|
| Kauma | 58 | 9 | 15 | 7 | 9 | 7 |
| Mgona | 42 | 9 | 17 | 4 | 13 | 7 |
| Mtandire | 46 | 5 | 5 | 3 | 3 | 2 |

Table 4-8: Water loss due to data handling and billing errors

| Settlement | Water loss due to data handling and billing errors ($m^3$) | Water loss due to billing errors as a percentage of total water loss (%) | As a percentage of system input (%) |
|---|---|---|---|
| Kauma | 97 | 2.45 | 0.64 |
| Mgona | 567 | 2.60 | 1.10 |
| Mtandire | 20 | 0.24 | 0.07 |

***Water Loss Due to Illegal Connections***

Table 4-9 provides details on the estimated number of illegal connections, and water loss due to illegal connections in the study areas.

Table 4-9: Estimated number of illegal connections and water loss due to illegal connections in the study areas

| Settlement | Number of connections | Number of illegal connections | Average water loss due to illegal connections ($m^3$) | Water loss due to illegal connections as a percentage of total water loss (%) |
|---|---|---|---|---|
| Kauma | 259 | 2 | 90 | 2.3 |
| Mgona | 866 | 7 | 239 | 1.1 |
| Mtandire | 1007 | 8 | 175 | 2.1 |

***Water Loss Due to Leakages***

The contribution of leakages to NRW in the study areas was calculated using Equation 3-6. The levels of NRW due to leakages (visible and background) in the selected low income areas are presented in Table 4-10 and Figure 4-9 gives details on physical water losses as a percentage of NRW for the study areas.

Table 4-10: Composition of the water losses in the study areas

| Settlement | Total water loss ($m^3$/month) | Water loss due to meter errors ($m^3$/month) | Water loss due to billing errors ($m^3$/month) | Water loss due to illegal connections ($m^3$/month) | Water loss due to leakage ($m^3$/month) | Leakage as percentage of total water loss (%) |
|---|---|---|---|---|---|---|
| Kauma | 3,949 | 610 | 97 | 90 | 3,152 | 80 |
| Mgona | 21,799 | 432 | 567 | 239 | 20,562 | 94 |
| Mtandire | 8,292 | 176 | 20 | 175 | 7,921 | 96 |

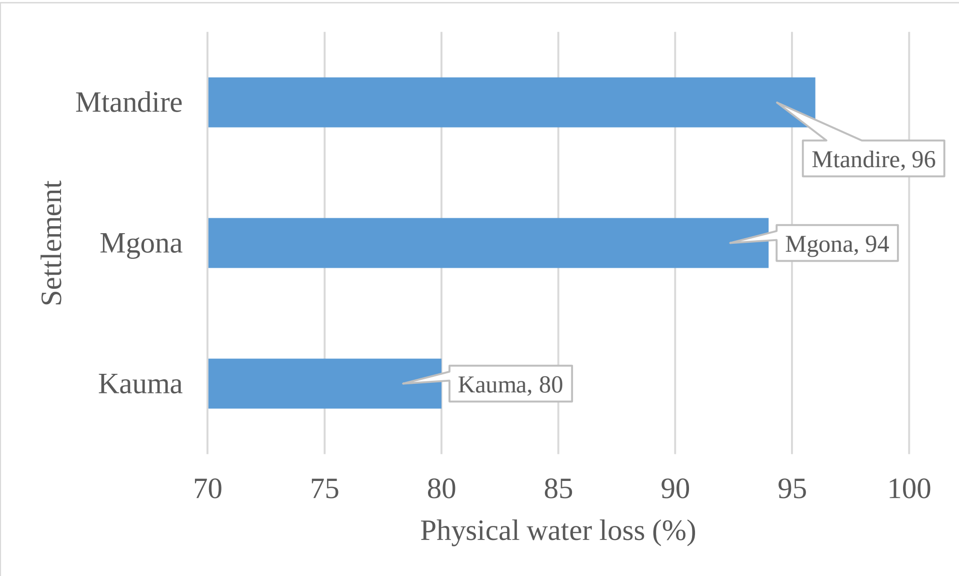


Figure 4-9: Physical water losses as a percentage of total NRW for the study areas

From Table 4-11 and Figure 4-9, pipe leakages (visible and background) have highest contributions to NRW in all the settlements under study (96% for Mtandire, 94% for Mgona and 80% for Kauma). This is consistent with the findings by Harawa (2015) where physical water losses contributed to 80% - 90% of the NRW in Areas 15 and 18. Whereas Harawa (2015) attributed the high levels to the age of the pipe network, on the contrast network in the selected informal settlements is relatively new. The household survey results however indicate that households in these settlements attributed the frequent leakages to vandalism and poorly laid network (Figure 4-10).

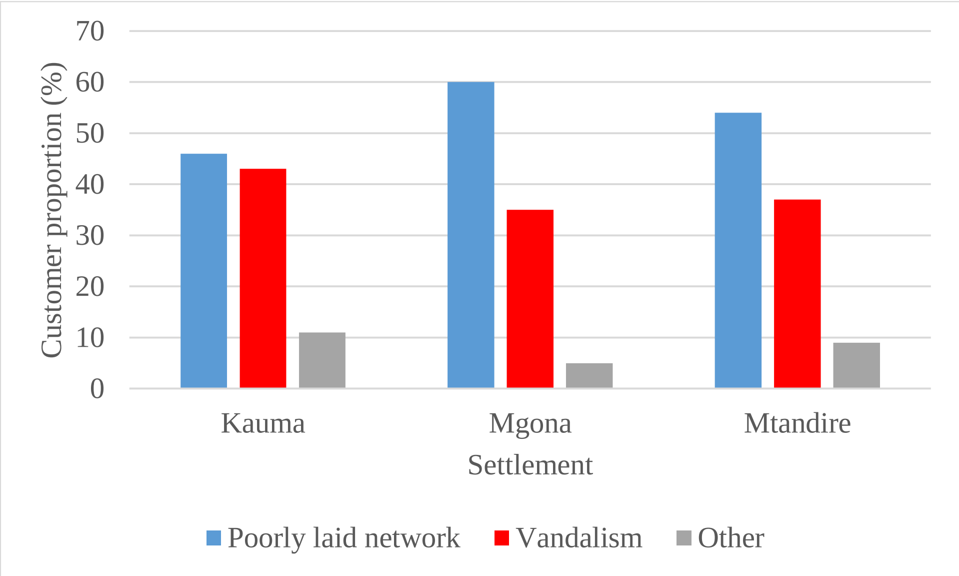


Figure 4-10: Customer opinion on causes of pipe bursts and leakages in the study areas

Figure 4-11: An exposed pipeline prone to vandalism and damage – Mtandire

Figure 4-12: A leakage on an exposed pipe at Mgona

## 4.4 Revenue Collection Efficiency

### 4.4.1 LWB Revenue Collection Trends

Figure 4-13 presents the value of water sold, actual amount of revenue collected and the collection efficiency covering the eight months period (May 2015 – March 2016).

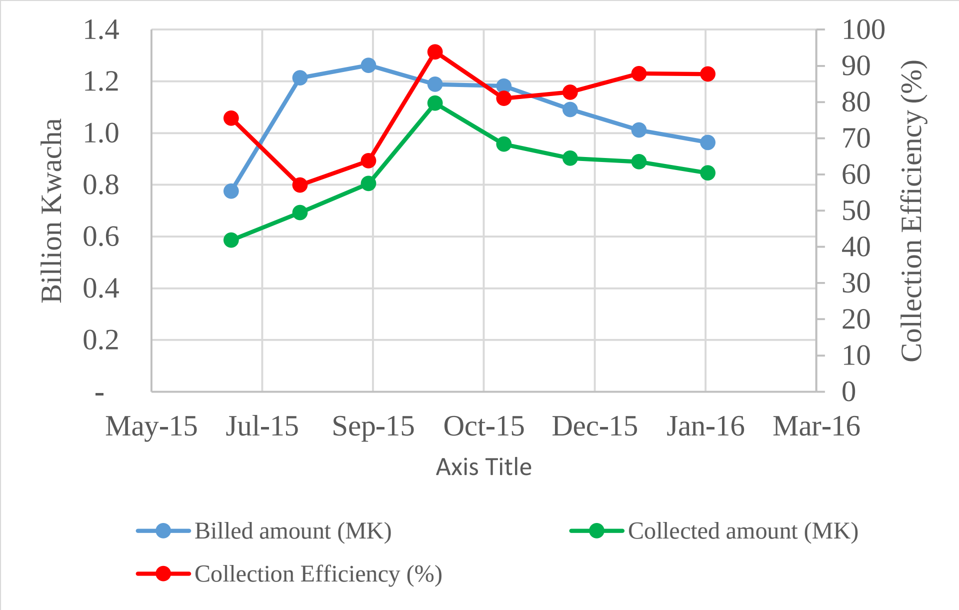


Figure 4-13: Billed amount, collected amount and collection efficiency for LWB (July 2015 – February 2016).

From Figure 4-13 it is observed that the collection efficiency for LWB over the eight months period has been in the range 57% (August 2015) to 94% (October 2015).

### 4.4.2 Revenue Collection Trends in the Unplanned Low Income Settlements

The billed amounts, collected amounts and collection efficiency for the unplanned low income settlements are presented in Table 4-11.

Table 4-11: Billed amount, collected amount and collection efficiency (Kauma, Mgona and Mtandire)

| Settlement | Kauma | Mgona | Mtandire |
|---|---|---|---|
| Billed amount (MK) | 33,746,327.56 | 81,838,509.94 | 79,598,957.32 |
| Collected amount (MK) | 25,323,511.54 | 56,383,429.00 | 45,373,624.00 |
| Collection Efficiency (%) | 75 | 69 | 57 |

A comparison of collection trends in the unplanned low income settlements and the entire LWB over the study period is shown in Figure 4-14.

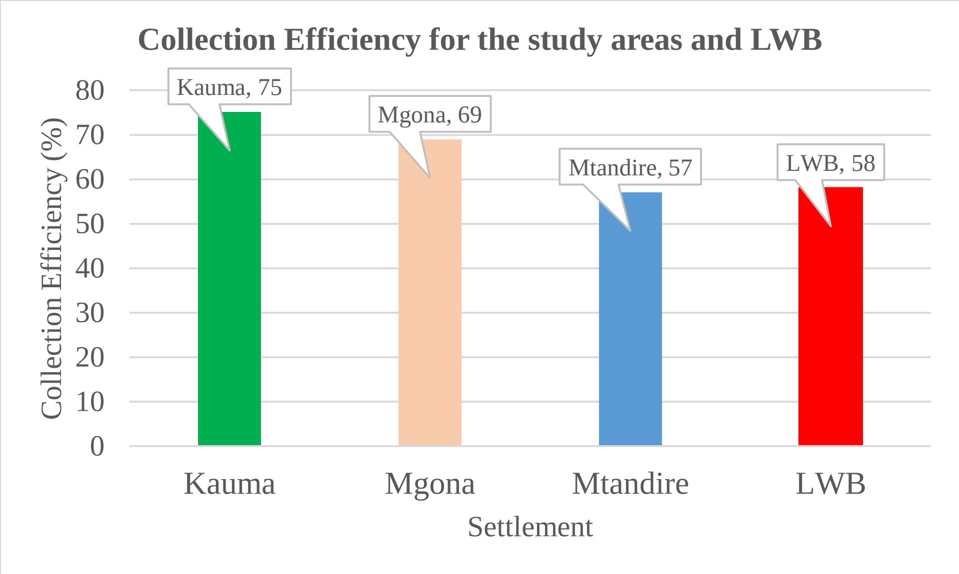

Figure 4-14: A comparison of collection efficiency for the study areas and entire LWB

From Figure 4-14, it is noted that Mtandire had the lowest collection efficiency (57%). This is less than the overall collection efficiency for the entire LWB (58%). Kauma and Mgona had collection efficiencies of 75% and 69% respectively, all higher than LWB. Overall the average collection efficiency for LWB over the study period is less than the average collection efficiency for the study settlements (68%). According to LWB (2015) the targeted collection efficiency for the water utility is 95%. A higher collection efficiency in the unplanned settlements is due to the main mode of piped water supply in these settlements where majority of the households buy piped water on cash basis from the WUAs and the money is channelled to the utility. The collection efficiency in these settlements is however less than 100% as there is still a presence of households, institutions and commercial customers with own connections and paying bills using the traditional approach. From the customer survey 36.5% of customers in Mtandire which reported the lowest collection efficiency (57%) had reported to have been disconnected for non-payment of bills compared to 7.9% in Kauma and 5.8% at Mgona (Figure 4-15). This is an indication of presence of a non-payment of bills culture in these settlements. At the entire water supply area level, key informants at LWB linked the overall low collection efficiency for the utility to non-payment of bills by Government institutions.

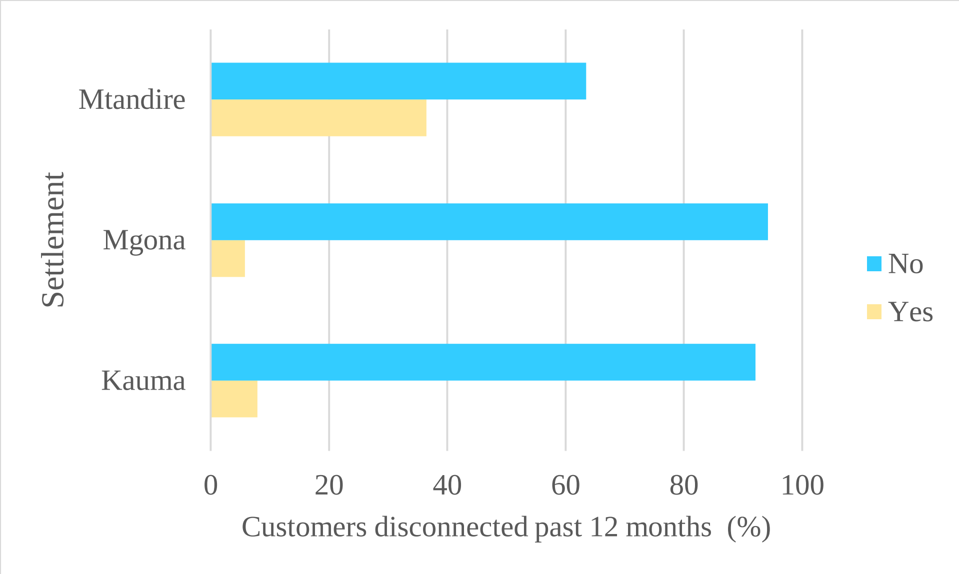


Figure 4-15: Proportion of customers that have had disconnections in the past 12 months

All the collection efficiencies established in the unplanned low income settlements as well as for the entire LWB are less than the averages for most other water utilities in both Africa and other regions. For instance in Dhaka, Bangladesh collection ratio of 83% is reported and similarly 85% is reported as average for utilities in the Pacific region (WSP, 2014; PWWA, 2012). The collection efficiencies are less than 77% an average for Southern Africa WOP (2009) and 84% for Kenya as reported by Wambui (2013). The average collection efficiency (68%) for the study settlements is slightly less than the collection efficiency of 70% established for BWB in a study by Kalulu et al., (2010) while the overall collection efficiency is far much less than that for BWB. It can be concluded that the collection efficiency for LWB is less than efficiencies reported within the region however the average collection efficiency in the unplanned settlements is comparable to the regional figures.

### 4.4.3 Factors Affecting Collection Efficiency in the Study Areas

Factors affecting collection efficiency in the study areas are presented in Figure 4-16. From Figure 4-16 it is observed that lack of finances ranked high (42%) on the reasons for non-payment of water bills by customers in the study areas. The other reasons included; customers not receiving the bills (16%) and inconvenient bill paying options (16%). 26% of the customers did not provide a specific reason for not paying of bills in time.

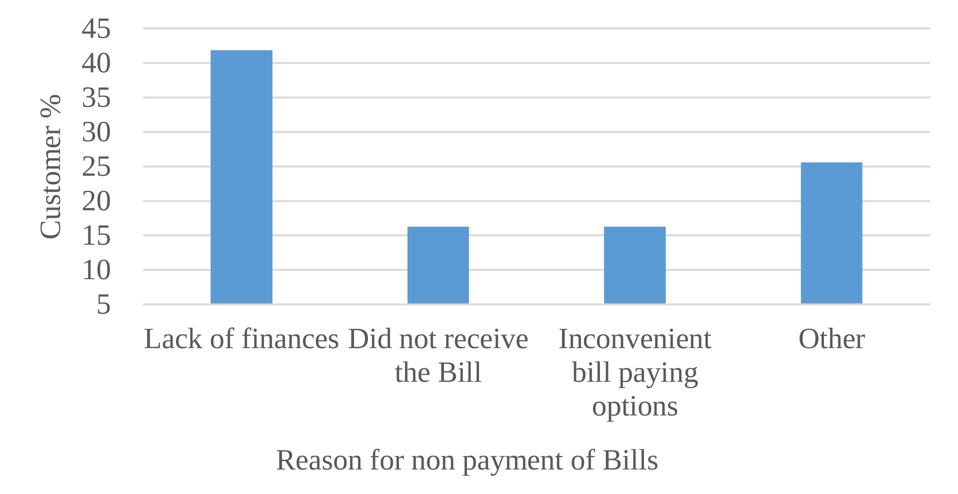

Figure 4-16: Reasons for non-payment of bills

## 4.5 Cost of Network Maintenance in Informal Settlements and the Entire LWB Supply Area

### 4.5.1 Maintenance Cost Historical Trends for the Entire Supply Area

Figure 4-17 shows trends in amount spent on repairs for the five year period (2010 – 2015).

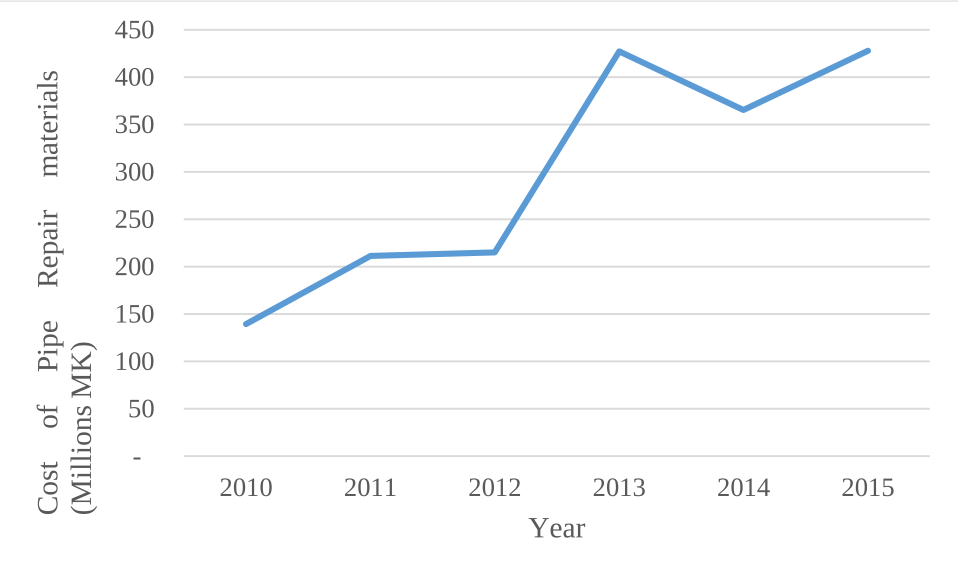


Figure 4-17: Trends in cost of pipe repair materials (2010 – 2015)

### 4.5.2 A Comparison of Cost of Network Repair Materials in the Unplanned Low Income Settlements and Entire LWB Over the Study Period

Comparisons for the cost of repair materials per km and per connection for the unplanned low income settlements and the entire water supply area for LWB are presented in Figure 4-18 and 4-19.

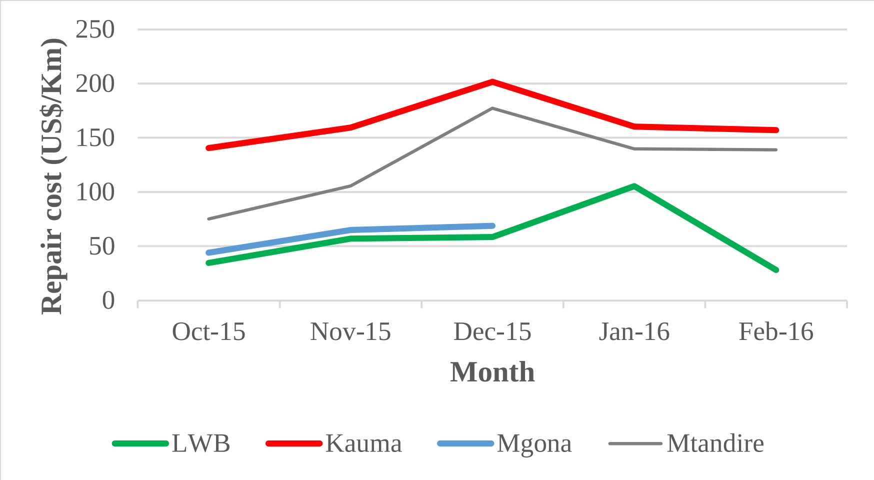


Figure 4-18: Repair cost per km for the unplanned low income settlements and entire LWB (Oct 2015 – February 2016)

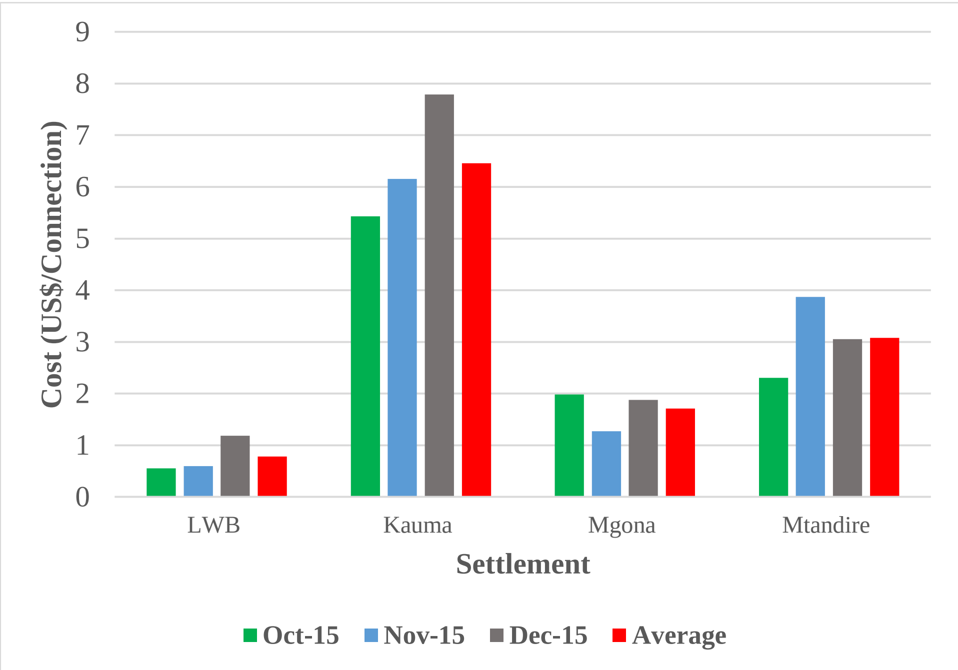


Figure 4-19: Repair cost per connection for the study areas and entire LWB (Oct 2015 – February 2016)

From Figures 4-18 and 4-19, it is noted that the cost of network repair materials per unit length of network in all the settlements was higher than the overall cost of network repair for LWB (US$57/km). Mgona (US$59/km), Mtandire (US$127/km), Kauma (US$164). The average cost of network repair materials per connection for LWB was US$0.78 compared with an average of US$3.75 for the study areas. In terms of efficiency of operation and maintenance it is observed that the cost of operation and maintenance is higher in the study areas compared with the overall cost for LWB. The high cost in the study areas is due to frequent pipe repair works in these study areas as a result of the poorly laid network and vandalism. The household survey results indicate that 53% of the customers attribute frequent leakages in the study areas to poorly laid network and 38% to vandalism. This is in line with observations made in literature on physical and social challenges associated with water supply in these types of settlements (Solo et al., 1993). Field observations undertaken over the study period confirmed this observation as a lot poorly laid and vandalised pipes were identified (Figure 4-20).

Figure 4-20: Visible leakage along a main road at Mtandire

Data on average cost of repair per km of network and the calculated NRW was plotted to establish the relationship between level of NRW and repair costs. Figure 4-21 presents the relationship between NRW and repair costs.

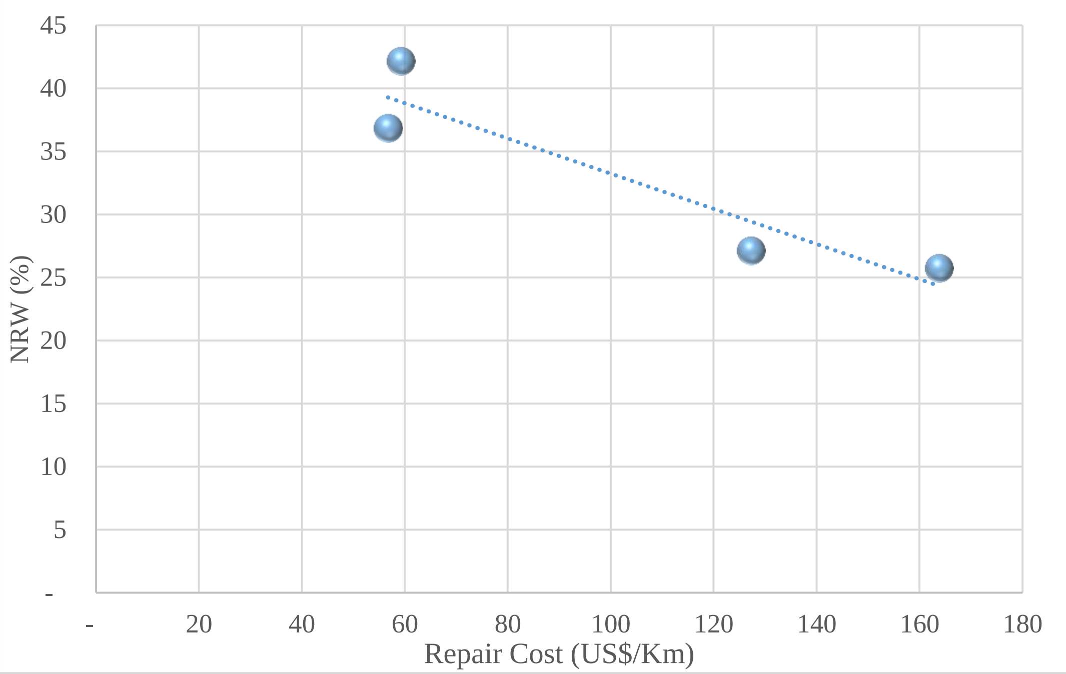


Figure 4-21: Relationship between NRW and network repair costs

From Figure 4-21 it can be concluded that there is a negative correlation between NRW and the network repair costs. NRW (%) is lower in settlements where higher costs of network repair materials is being incurred. NRW for Kauma is lower (26%) compared to Mtandire (27%) and Mgona (42%) however the repair cost is high in Kauma (US$164/km) compared to Mtandire (US$127km) and Mgona (US$57/km). The frequencies (Figure 4-22) for the pipe bursts/leakages as identified by customers were also plotted against the cost of repairs (Figure 4-23).

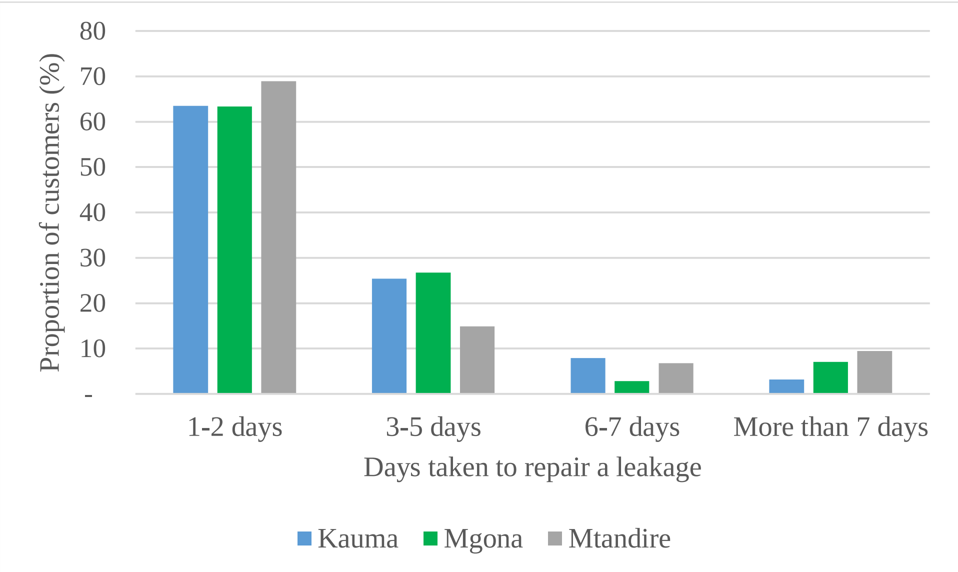


Figure 4-22: Cases of pipe breakages identified by customers in the study areas

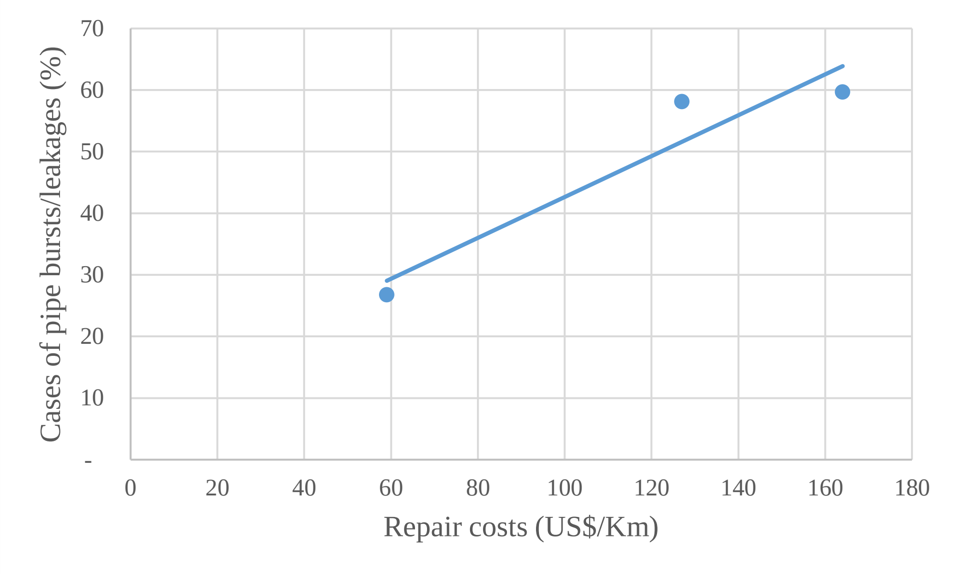

Figure 4-23: Relationship between frequency of pipe breakages and repair costs

Figure 4-22 indicates that very few cases of leakages or pipe bursts are identified by customers in Mgona (73% of customers identified 1 – 2 cases in a month, 25.4% identified 3-5 cases in month and 1.4% identified 6-10 cases in a month). In Mtandire (41.9% of customers identified 1 – 2 cases in a month, 47.3% identified 3-5 cases in month, 9.5% identified 6-10 cases in a month and 1.4% identified of 10 cases in a month). For Kauma (40.3% of customers identified 1 – 2 cases in a month, 41.9% identified 3-5 cases in month, 4.8% identified 6-10 cases in a month and 12.9% identified of 10 cases in a month). Figure 4-23 indicates that there is a positive correlation between number of identified cases per month and the cost of network maintenance.

Data from the household survey was used to determine relationship between proportions of customers (%) reporting pipe leakages/bursts against repair costs. Figure 4-24 provides details on customers who have ever reported a leakage or pipe burst in the study areas while Figure 4-25 gives a plot of repair costs against proportion of customers who have reported leakages to LWB.

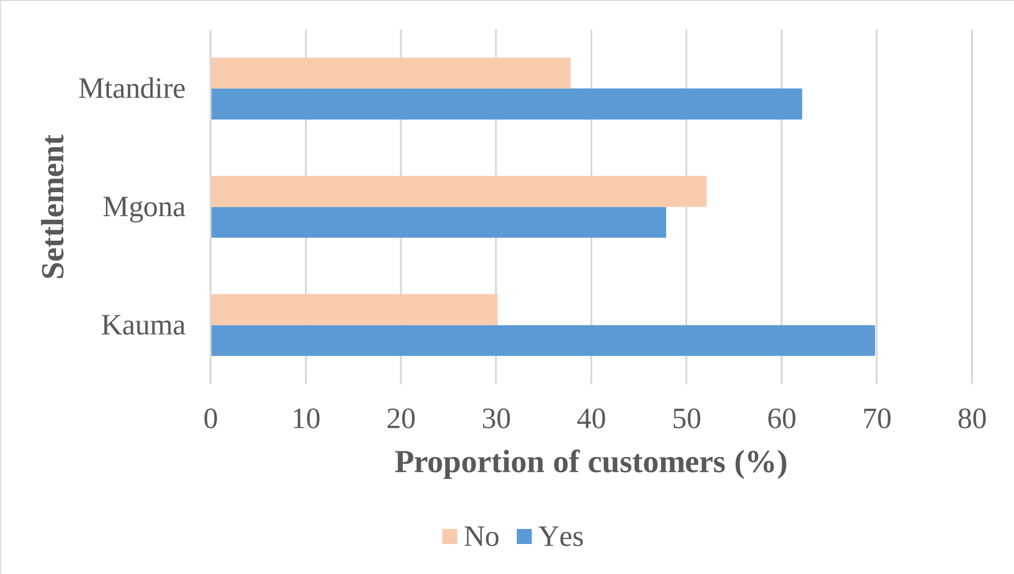


Figure 4-24: Customers who have ever reported pipe burst/leakage in the study areas

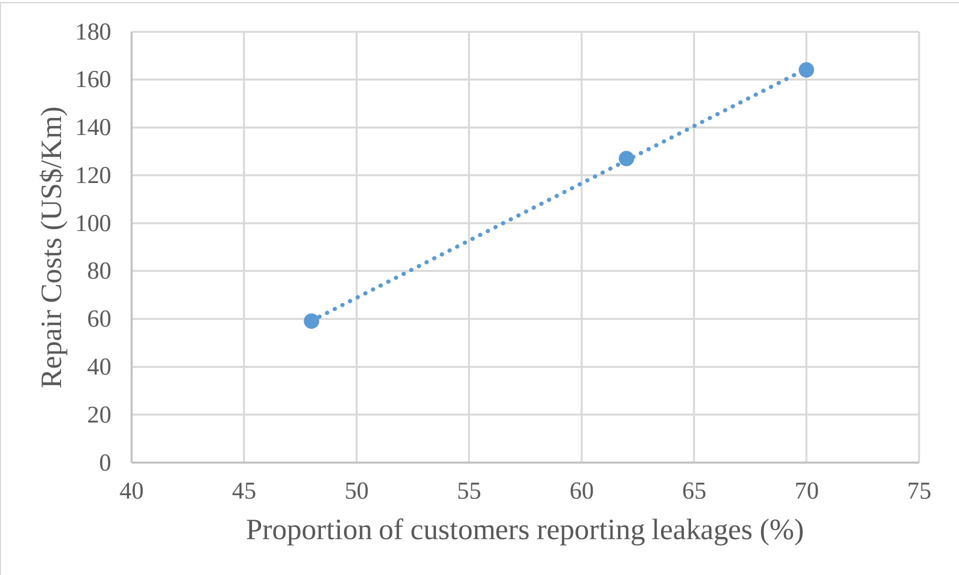


Figure 4-25: Relationship between proportion of customers reporting leakages and the cost of repairs

From Figure 4-24 it is observed that a high percentage of customers at Kauma (70%) had ever reported leakages or pipe burst to LWB by the time of the survey, compared to Mtandire (62%) and Mgona (48%). Figure 4-25 depicts a positive correlation between proportion of customers reporting leakages to LWB and the cost of network maintenance.

# 5. CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions and Recommendations

The main objective of this study was to compare overall performance of LWB with its performance in selected unplanned low income settlements. While most studies have acknowledged growth of unplanned low income settlements and challenges associated with the settlements there have not been studies to assess their impacts on performance of water utilities in developing countries. Prior to this study, performance of utilities has been measured at the entire utility level and this has missed out opportunities for addressing actual challenges being faced by the water utilities. This study has managed to segregate measurement of LWB's performance at the macro level (entire organisation) and at micro level (selected settlements) using selected performance indicators. The study used Non-Revenue Water, Revenue Collection Efficiency and Efficiency of operations and maintenance.

From this study the following conclusions and recommendations were made:

1. There is an effort to increase delivery of piped water supply services in unplanned low income settlements located in the supply area of LWB. The network length has been extended by 235% in the unplanned low income settlements compared to 37% for the entire LWB in a period of 15 years. In the same settlements the number of connections has increased by 257% compared to 49% for the entire LWB over a 5 year period.
2. The unacceptable level of NRW (37%) or $656m^3$/km/month for LWB is not being influenced by the unplanned low income settlements as the average NRW of 32% ($597m^3$/km/month) in these settlements is less than the overall level for the supply area. However NRW for both the entire supply area of LWB and the unplanned settlements is higher than the recommended (23%) for developing countries. It is recommended that the water utility should enhance efforts to reduce physical water losses in the unplanned low income settlements as physical losses constitute a high proportion of the total NRW. LWB should develop strategies to enhance revenue collection at both the entire supply area level as well as in the low income settlements.
3. Performance of LWB on revenue collection efficiency is higher in the unplanned low income settlements where on average 67% of revenues on billed water is being collected compared to 58% for the entire LWB. Delegated management of communal water kiosks to the Water User Associations in the low income settlements has a positive impact on revenue collection efficiency. The revenue collection efficiency for

both the entire LWB and the specific study areas is less than the target for LWB (95%). It is recommended that LWB should enhance capacity of the Water User Associations and maintain this approach of water supply management in the informal settlements. In addition, the water utility should install pre-paid water meters in Public institutions.

4. The cost of network repair is higher in the unplanned settlements (Kauma – US$164, Mgona – US$59, Mtandire US$127) compared to the entire LWB's supply area (US$57). The high cost in these areas is due to high level of pipe vandalism and poorly laid network which is exposed to damages. There is an inverse relationship between cost of repairs per km and NRW (%). This entails that the higher the amount spent on repairs the lower the NRW. There is need for innovative solutions in supplying water to the unplanned low income settlements in order to overcome challenges of vandalism and frequent damages to poorly laid pipelines which is as a result of the layout of the settlements.

It is evident from the study that unplanned low income settlements do not have a significant impact on the overall performance of LWB measured using NRW and revenue collection efficiency. However the cost of network repair may have a significant impact on the performance of LWB.

## 5.2 Limitation of the Study

The following were the limitations of this study:

1. The cost of repair only considered the cost of materials whereas the actual cost has other variables including labour, transport and time.
2. The research only focused on cost of network repairs, however full lifecycle costing including capital costs would have been preferred. This was limited by the available data.

## 5.3 Future Areas of Research

The following are areas of future research:

1. This study has established that the performance of the water utility on NRW and collection efficiency is currently better in the unplanned low income settlements compared to the overall performance. Further evaluation should however be conducted using other performance measurement indicators.

2. The study has established that unplanned low income settlements do not have significant impact on the current level of NRW and collection efficiency for LWB. Further research however can establish the point at which these unplanned settlements will have a significant impact on the performance of LWB.
3. Infrastructure vandalism is a challenge in the informal settlements. Further research should be conducted on how infrastructure vandalism can be reduced.
4. It has been established that physical layout of the unplanned low income settlements is contributing to poorly laid pipe networks which are exposed and prone to frequent damage and vandalism. Future research should assess how network installation can be improved in unplanned low income settlements.

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## APPENDICES

**Appendix 1: Detailed data collection process**

| Objective | Data Required | Methodology | Frequency | Purpose of Data |
|---|---|---|---|---|
| 1. To establish coverage of utility water supply services in informal settlements and categorise sources of water in the settlements | • Number of water connections per selected informal settlement | • Review of records from Lilongwe Water Board billing system | • One month | • Input for estimation of number of people having access to piped water |
| | • Length of pipe network in the selected informal settlement | • Records from Lilongwe Water Board's network GIS, as built drawings | • One month | • To establish proportion of pipelines in relation to size of an informal settlement |
| | • Area ($Km^2$) for each of the selected settlement | • Records from Lilongwe Water Board's GIS | • One month | • To establish proportion of pipelines in relation to size of an informal settlement |
| | • Projected population in the informal settlement | • Census Data from NSO | • One month | • Input in estimation of percentage people served with piped water |
| | • Sources of water for households in the informal settlement | • Administer Questionnaires | • 3 Weeks | • Secondary data |
| 2. To establish revenue collection efficiency in informal settlements and compare with overall collection efficiency for Lilongwe Water Board | • Billed amounts (monetary) for the informal settlements | • Review of billed consumption/sales records for the selected areas | • Monthly Data (July 2015 to February 2016) | • Input for calculation of revenue collection efficiency in the informal settlements |
| | • Collected revenue from water sold in the informal settlements | • Review of collected revenue records | • Monthly Data (July 2015 to February 2016) | • Input for calculation of revenue collection efficiency in the informal settlements |

| Objective | Data Required | Methodology | Frequency | Purpose of Data |
|---|---|---|---|---|
| | • Billed amounts for Lilongwe Water Board | • Review of billed consumption/sales records for Lilongwe Water Board | • Monthly Data (July 2015 to February 2016) | • Input for calculation of overall revenue collection efficiency for Lilongwe Water Board |
| | • Collected revenue from water sales for Lilongwe Water Board | • Review of collected revenue records | • Monthly Data (July 2015 to February 2016) | • Input for calculation of overall revenue collection efficiency for Lilongwe Water Board |
| | • Drivers of revenue collection efficiency | • Administer Questionnaires | • 3 Weeks | • To establish factors that affect bill payments in the informal settlements |
| 3. To establish a trend for Non-Revenue Water for Lilongwe Water Board and corresponding Non-Revenue Water values in selected informal settlements; | • Water supplied into the system and corresponding billed volume | • Review of water production and consumption records | • Yearly (2011 – 2015) and monthly data (January to March 2016) | • To establish overall NRW trends for Lilongwe Water Board |
| | • Water supplied to the informal settlement (DMA) and Billed volume for the informal settlement | • Bulk meter readings (DMA) and review of billed volume for the informal settlement (DMA). | • Monthly Data (January to March 2016) | • To establish NRW trends for the informal settlements |
| | • NRW drivers in the informal settlements | • Review records on leakages, faulty meters and illegal connections | • Monthly Data (July 2015 to February 2016) | • To establish factors contributing to NRW |

| Objective | Data Required | Methodology | Frequency | Purpose of Data |
|---|---|---|---|---|
| | | | | in the informal settlements |
| 4. To establish the cost of network maintenance in informal settlements and compare with overall network maintenance cost for Lilongwe Water Board; | • Cost of network repair materials for Lilongwe Water Board | • Review of records on issued maintenance materials | • Monthly Data (July 2015 to February 2016) | • To calculate overall amount spent on materials for network maintenance |
| | • Number of overall network failures (leakages and pipe bursts) | • Review of records on leakages and pipe bursts | • Monthly Data (July 2015 to February 2016) | • To establish overall intensity of pipe failures for Lilongwe Water Board |
| | • Cost of network repair materials in the selected informal settlements | • Review of records on issued maintenance materials for the selected informal settlements | • Monthly Data (July 2015 to February 2016) | • To calculate amount spent on materials for network maintenance in the selected informal settlements |
| | • Number of network failures (leakages and pipe bursts) in the selected informal settlements | • Review of records on leakages and pipe bursts | • Monthly Data (July 2015 to February 2016) | • To establish intensity of pipe failures in the selected informal settlements |

**Appendix 2: Questionnaire for household surveys**

**UNIVERSITY OF MALAWI**

**QUESTIONNAIRE FOR HOUSEHOLD/CUSTOMER SURVEYS**

**Supplying Water to Unplanned Low Income Areas: Implications on Water Utility Performance – The Case of Lilongwe Water Board, Malawi**

This study is being conducted by Ephraim Banda a Master of Science in Infrastructure Development and Management, postgraduate student at the Malawi Polytechnic. The study intends to study "How the performance of a Water Utility is affected through supply of water to unplanned low income areas (LIAs)". Although the results of this study are for academic purposes, an examination of the water supply will provide insights into the existence and extent of gaps relating to water provision in Malawian cities. Further, the study will contribute to raising awareness to responsible authorities on how to optimally integrate the attributes of "best practice" in water provision within our institutions. Please note that the information provided will be used for education purposes only, unless otherwise authorized by yourselves.

**Name of Customer/Interviewee (Optional):________________________________**

**Location: ____________________________________________________________**

**Tick where applicable**

1. What is your household size?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1 – 4** | | **5 – 7** | | **8 – 10** | | **Over 10** | |

2. Do you have a Lilongwe Water Board water connection?

| | | | |
|---|---|---|---|
| **Yes** | | **No** | |

3. If **"yes",** what do you use the water connection for?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Domestic** | | **Commercial** | | **Institutional** | | **Kiosk** | |

4. If **"No",** what is your source of water?

| | |
|---|---|
| **Shallow well** | |
| **Buy piped water from Neighbour** | |
| **Shared yard connection** | |
| **Kiosk** | |
| **River/Stream** | |
| **Other** | |

5. How many households use your LWB water connection?

| | |
|---|---|
| **1** | |
| **2** | |
| **3** | |
| **4** | |
| **5** | |
| **Over 5** | |

6. What is your average monthly water bill?

| | |
|---|---|
| **MK 0 – 4,999.00** | |
| **MK5,000.00 – 9,999.00** | |
| **MK10,000.00 – 14,999.00** | |
| **MK15,000.00 – 19,999.00** | |
| **MK20,000.00 – 30,000.00** | |
| **Over MK30,000.00** | |

7. What is your monthly average income

| | |
|---|---|
| **MK 0 – 10,000.00** | |
| **MK10,000.00 – 20,000.00** | |
| **MK20,000.00 – 30,000.00** | |
| **MK30,000.00 – 40,000.00** | |
| **Over MK40,000.00** | |

8. Have you ever had a water disconnection by Lilongwe Water Board due to non-payment of bills in the past one year?

| | |
|---|---|
| **Yes** | |
| **No** | |

9. How many times in the past one year?

| | |
|---|---|
| **Once** | |
| **Twice** | |
| **Three times** | |
| **Four times** | |
| **Over four times** | |

10. Why did you not pay the water bills in time?

| | |
|---|---|
| **Lack of finances** | |
| **Did not receive the Bill** | |
| **Inconvenient bill paying options** | |
| **Other** | |

11. What is your opinion on the water tariff for Lilongwe Water Board?

| | |
|---|---|
| **Very Cheap** | |
| **Cheap** | |
| **Fair** | |
| **Expensive** | |
| **Very expensive** | |

12. In your observations, how many pipe burst cases occur in a month in this area?

| | |
|---|---|
| **1 – 2 Cases** | |
| **3 – 5 Cases** | |
| **5 – 10 Cases** | |
| **Over 10** | |

13. Have you ever reported any pipe burst case to Lilongwe Water Board?

| | |
|---|---|
| **Yes** | |
| **No** | |

14. How long does it take for Lilongwe Water Board to fix pipe bursts from the day it starts?

| | |
|---|---|
| **1 – 2 days** | |
| **3 – 5 days** | |
| **6 -7 days** | |
| **More than 7 days** | |

15. What do you think could be the cause of the frequent pipe bursts?

| | |
|---|---|
| **Vandalism** | |
| **Poorly laid network** | |
| **High Pressure** | |
| **Aged infrastructure** | |

*Thank you very much for providing the information.*

**Appendix 3: Historical data on customers per category (Kauma, Mgona, Mtandire and LWB supply area)**

| | Kauma | Mgona | Mtandire | LWB supply area |
|---|---|---|---|---|
| **Year** | **Residential connections** | | | |
| 2011 | 4 | 172 | 525 | 35,267 |
| 2012 | 6 | 194 | 527 | 37,802 |
| 2013 | 8 | 235 | 599 | 40,501 |
| 2014 | 20 | 324 | 641 | 45,351 |
| 2015 | 54 | 440 | 701 | 48,785 |
| 2016 | 214 | 706 | 873 | 53,072 |
| | | | | |
| | **Kauma** | **Mgona** | **Mtandire** | **LWB supply area** |
| **Year** | **Kiosks** | | | |
| 2011 | 34 | 64 | 65 | 483 |
| 2012 | 34 | 85 | 90 | 548 |
| 2013 | 35 | 116 | 94 | 610 |
| 2014 | 37 | 130 | 95 | 659 |
| 2015 | 33 | 133 | 98 | 758 |
| 2016 | 32 | 133 | 95 | 774 |
| | | | | |
| | **Kauma** | **Mgona** | **Mtandire** | **LWB supply area** |
| | **Commercial/Industrial connections** | | | |
| 2011 | 6 | 4 | 10 | 2,395 |
| 2012 | 6 | 4 | 12 | 2,559 |
| 2013 | 6 | 8 | 18 | 2,782 |
| 2014 | 4 | 12 | 16 | 2,833 |
| 2015 | 4 | 14 | 15 | 2,933 |
| 2016 | 4 | 14 | 12 | 2,971 |
| | | | | |
| | **Kauma** | **Mgona** | **Mtandire** | **LWB supply area** |
| | **Institutional connections** | | | |
| 2011 | 3 | 2 | 16 | 690 |
| 2012 | 4 | 3 | 17 | 725 |
| 2013 | 7 | 6 | 24 | 791 |
| 2014 | 7 | 8 | 27 | 861 |
| 2015 | 8 | 11 | 26 | 862 |
| 2016 | 9 | 13 | 27 | 910 |

## Appendix 4: Meter testing results

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lilongwe Water Board** | | | | | | | | | | | |
| **Meter accuracy testing (Area 56)** | | | | | | | | | | | 10-May-16 |
| ID | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| **Water Meter Information** | | | | | | | | | | | |
| Meter Type | | CM | CM | CM | CM | Multimag | CM | MSD | CM | CM | XNP |
| Size (mm) | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Serial No. | | 11C0002 | 11C0039 | 11C00051 | 11C0003 | A095420555 | 11C0038 | 04/447179 | MTS/9697 | 14831898 | 39256214 |
| **Water Meter Testing Results** | | | | | | | | | | | |
| 3. High Flow Rate Test (1500l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 1221 | 598 | 678 | 804 | 919 | 680 | 817 | 1170 | 1314 | 1009 |
| | Reading 1 | 1035 | 399 | 484 | 609 | 722 | 482 | 614 | 970 | 1110 | 808 |
| | Difference | 186 | 199 | 194 | 195 | 197 | 198 | 203 | 200 | 204 | 201 |
| 2. Medium Flow Rate Test (750l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 1035 | 399 | 484 | 609 | 722 | 482 | 614 | 970 | 1110 | 808 |
| | Reading 1 | 848 | 196 | 289 | 414 | 524 | 283 | 414 | 770 | 905 | 605 |
| | Difference | 187 | 203 | 195 | 195 | 198 | 199 | 200 | 200 | 205 | 203 |
| 1. Low Flow Rate Test (30l/h) | | | | | | | | | | | |
| 10l | Reading 2 | 848 | 196 | 289 | 414 | 524 | 283 | 414 | 770 | 905 | 605 |
| | Reading 1 | 838 | 185 | 278 | 403 | 514 | 272 | 403 | 759 | 905 | 597 |
| | Difference | 10 | 11 | 11 | 11 | 10 | 11 | 11 | 11 | 0 | 8 |
| | | | | | | | | | | | |
| Reading at start | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 25 | 10 | 10 | 10 |

| Lilongwe Water Board | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Meter accuracy testing (Area 56)** | | | | | | | | | 9-May-16 | | |
| ID | | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | | |
| **Water Meter Information** | | | | | | | | | | | |
| Meter Type | | PSM | PSM | PSM | PSM | PSM | PSM | PSM | PSM | | |
| Size (mm) | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | |
| Serial No. | | C-TAI0490 | C-FAF0936 | C-FAA2545 | C-FAF0809 | C-FAF0933 | 12002046 | C-EGA3319 | 11C0020 | | |
| **Water Meter Testing Results** | | | | | | | | | | | |
| 3. High Flow Rate Test (1500l/h) | | | | | | | | | | | |
| 100l | Reading 2 | 1083 | 1200 | 1112 | 668 | 367 | 1058 | 343 | 286 | | |
| | Reading 1 | 983 | 1099 | 1013 | 567 | 267 | 958 | 243 | 190 | | |
| | Difference | 100 | 101 | 99 | 101 | 100 | 100 | 100 | 96 | | |
| 2. Medium Flow Rate Test (750l/h) | | | | | | | | | | | |
| 100l | Reading 2 | 983 | 1099 | 1013 | 567 | 267 | 958 | 243 | 190 | | |
| | Reading 1 | 882 | 998 | 913 | 466 | 166 | 857 | 142 | 93 | | |
| | Difference | 101 | 101 | 100 | 101 | 101 | 101 | 101 | 97 | | |
| 1. Low Flow Rate Test (30l/h) | | | | | | | | | | | |
| 10l | Reading 2 | 882 | 998 | 913 | 466 | 166 | 857 | 142 | 93 | | |
| | Reading 1 | 872 | 988 | 902 | 456 | 156 | 847 | 132 | 83 | | |
| | Difference | 10 | 10 | 11 | 10 | 10 | 10 | 10 | 10 | | |
| | | | | | | | | | | | |
| Reading at start | 10 | 10 | 10 | 12.5 | 10 | 10 | 25 | 10 | 10 | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lilongwe Water Board** | | | | | | | | | | | |
| **Meter accuracy testing (Area 41)** | | | | | | | | | 11-May-16 | | |
| ID | | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | | |
| **Water Meter Information** | | | | | | | | | | | |
| Meter Type | | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | | |
| Size (mm) | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | |
| Serial No. | | 5970590 | 3798103 | 3798956 | 3802676 | 3799145 | 5969322 | 3797876 | 3798102 | | |
| **Water Meter Testing Results** | | | | | | | | | | | |
| 3. High Flow Rate Test (1500l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 906 | 250 | 1180 | 628 | 1050 | 1363 | 572 | 780 | | |
| | Reading 1 | 705 | 250 | 982 | 427 | 849 | 1162 | 372 | 582 | | |
| | Difference | 201 | 0 | 198 | 201 | 201 | 201 | 200 | 198 | | |
| 2. Medium Flow Rate Test (750l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 705 | 250 | 982 | 427 | 849 | 1162 | 372 | 582 | | |
| | Reading 1 | 505 | 250 | 785 | 226 | 649 | 962 | 173 | 384 | | |
| | Difference | 200 | 0 | 197 | 201 | 200 | 200 | 199 | 198 | | |
| 1. Low Flow Rate Test (30l/h) | | | | | | | | | | | |
| 10l | Reading 2 | 505 | 250 | 785 | 226 | 649 | 962 | 173 | 384 | | |
| | Reading 1 | 495 | 250 | 775 | 216 | 639 | 951 | 162 | 374 | | |
| | Difference | 10 | 0 | 10 | 10 | 10 | 11 | 11 | 10 | | |
| | | | | | | | | | | | |
| Reading at start | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | |

| Lilongwe Water Board | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Meter accuracy testing (Area 41)** | | | | | | | | | 11-May-16 | | |
| ID | | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| **Water Meter Information** | | | | | | | | | | | |
| Meter Type | | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan |
| Size (mm) | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Serial No. | | 06/322831 | 3798881 | 3797591 | 3801955 | 3803365 | 3801959 | 3800629 | 6998143 | 37985/3 | 3797808 |
| **Water Meter Testing Results** | | | | | | | | | | | |
| 3. High Flow Rate Test (1500l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 1272 | 444 | 1032 | 1015 | 589 | 1259 | 515 | 641 | 996 | 1253 |
| | Reading 1 | 1067 | 244 | 834 | 815 | 387 | 1058 | 313 | 441 | 797 | 1055 |
| | Difference | 205 | 200 | 198 | 200 | 202 | 201 | 202 | 200 | 199 | 198 |
| 2. Medium Flow Rate Test (750l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 1067 | 244 | 834 | 815 | 387 | 1058 | 313 | 441 | 797 | 1055 |
| | Reading 1 | 863 | 44 | 636 | 616 | 185 | 857 | 110 | 241 | 596 | 856 |
| | Difference | 204 | 200 | 198 | 199 | 202 | 201 | 203 | 200 | 201 | 199 |
| 1. Low Flow Rate Test (30l/h) | | | | | | | | | | | |
| 10l | Reading 2 | 863 | 44 | 636 | 616 | 185 | 857 | 110 | 241 | 596 | 856 |
| | Reading 1 | 859 | 33 | 627 | 604 | 182 | 846 | 103 | 230 | 585 | 845 |
| | Difference | 4 | 11 | 9 | 12 | 3 | 11 | 7 | 11 | 11 | 11 |
| | | | | | | | | | | | |
| Reading at start | 10 | 25 | 10 | 20 | 18 | 35 | 10 | 25 | 10 | 10 | 10 |

| Lilongwe Water Board | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Meter accuracy testing (Area 50)** | | | | | | | | | 13-May-16 | | |
| ID | | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | | |
| **Water Meter Information** | | | | | | | | | | | |
| Meter Type | | PSM | PSM | PSM | PSM | PSM | PSM | PSM | PSM | | |
| Size (mm) | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | |
| Serial No. | | 13004312 | C-FAA3061 | 12001435 | 13002631 | 13002623 | C-TAF6856 | 13001339 | C-FAA1798 | | |
| **Water Meter Testing Results** | | | | | | | | | | | |
| 3. High Flow Rate Test (1500l/h) | | | | | | | | | | | |
| 100l | Reading 2 | 424 | 642 | 788 | 732 | 1084 | 1157 | 395 | 719 | | |
| | Reading 1 | 325 | 543 | 688 | 640 | 986 | 1060 | 297 | 621 | | |
| | Difference | 99 | 99 | 100 | 92 | 98 | 97 | 98 | 98 | | |
| 2. Medium Flow Rate Test (750l/h) | | | | | | | | | | | |
| 100l | Reading 2 | 325 | 543 | 688 | 640 | 986 | 1060 | 297 | 621 | | |
| | Reading 1 | 225 | 442 | 588 | 551 | 887 | 961 | 198 | 522 | | |
| | Difference | 100 | 101 | 100 | 89 | 99 | 99 | 99 | 99 | | |
| 1. Low Flow Rate Test (30l/h) | | | | | | | | | | | |
| 10l | Reading 2 | 225 | 442 | 588 | 551 | 887 | 961 | 198 | 522 | | |
| | Reading 1 | 215 | 432 | 577 | 542 | 876 | 951 | 189 | 515 | | |
| | Difference | 10 | 10 | 11 | 9 | 11 | 10 | 9 | 7 | | |
| | | | | | | | | | | | |
| Reading at start | 10 | 12.5 | 20 | 12.5 | 20 | 12.5 | 12.5 | 12.5 | 12.5 | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lilongwe Water Board** | | | | | | | | | | | |
| **Meter accuracy testing (Area 50)** | | | | | | | | | 13-May-16 | | |
| ID | | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 |
| **Water Meter Information** | | | | | | | | | | | |
| Meter Type | | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan | Baylan |
| Size (mm) | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Serial No. | | 15M005415 | 6999461 | 3795979 | 3801069 | 3799255 | 5129630 | 3802431 | 3796230 | 3795897 | 3795323 |
| **Water Meter Testing Results** | | | | | | | | | | | |
| 3. High Flow Rate Test (1500l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 913 | 913 | 766 | 931 | 1258 | 969 | 1246 | 506 | 514 | 1053 |
| | Reading 1 | 713 | 715 | 567 | 733 | 1059 | 771 | 1048 | 307 | 314 | 856 |
| | Difference | 200 | 198 | 199 | 198 | 199 | 198 | 198 | 199 | 200 | 197 |
| 2. Medium Flow Rate Test (750l/h) | | | | | | | | | | | |
| 200l | Reading 2 | 713 | 715 | 567 | 733 | 1059 | 771 | 1048 | 307 | 314 | 856 |
| | Reading 1 | 513 | 515 | 368 | 535 | 861 | 575 | 851 | 108 | 113 | 659 |
| | Difference | 200 | 200 | 199 | 198 | 198 | 196 | 197 | 199 | 201 | 197 |
| 1. Low Flow Rate Test (30l/h) | | | | | | | | | | | |
| 10l | Reading 2 | 513 | 515 | 368 | 535 | 861 | 575 | 851 | 108 | 113 | 659 |
| | Reading 1 | 503 | 504 | 360 | 525 | 852 | 566 | 841 | 98 | 102 | 649 |
| | Difference | 10 | 11 | 8 | 10 | 9 | 9 | 10 | 10 | 11 | 10 |
| | | | | | | | | | | | |
| Reading at start | 10 | 10 | 10 | 20 | 10 | 10 | 25 | 10 | 10 | 10 | 10 |

**Appendix 5: A comparison of meter readings in meter reader books and the billing system for Kauma**

| ID | ACCOUNT # | January 2016 | | | Error (%) |
|---|---|---|---|---|---|
| | | Reading | | Variance | |
| | | Meter Reader Book | Billing System | | |
| 1 | 2151127 | 625 | 625 | 0 | 0% |
| 2 | 2159721 | 107 | 215 | 108 | 101% |
| 3 | 2160636 | 565 | 656 | 91 | 16% |
| 4 | 2163914 | 373 | 373 | 0 | 0% |
| 5 | 2165492 | 410 | 410 | 0 | 0% |
| 6 | 2166625 | 733 | 733 | 0 | 0% |
| 7 | 2167755 | 565 | 565 | 0 | 0% |
| 8 | 2168652 | 263 | 263 | 0 | 0% |
| 9 | 2169029 | 932 | 108 | -824 | -88% |
| 10 | 2169807 | 70 | 70 | 0 | 0% |
| 11 | 2169924 | 322 | 322 | 0 | 0% |
| 12 | 2169925 | 68 | 68 | 0 | 0% |
| 13 | 2170082 | 93 | 93 | 0 | 0% |
| 14 | 2170189 | 279 | 279 | 0 | 0% |
| 15 | 2170660 | 480 | 480 | 0 | 0% |
| 16 | 2170802 | 141 | 141 | 0 | 0% |
| 17 | 2170888 | 569 | 79 | -490 | -86% |
| 18 | 2171123 | 176 | 176 | 0 | 0% |
| 19 | 2171208 | 400 | 400 | 0 | 0% |
| 20 | 2171453 | 151 | 151 | 0 | 0% |
| 21 | 2171500 | 321 | 321 | 0 | 0% |
| 22 | 2171716 | 112 | 112 | 0 | 0% |
| 23 | 2171769 | 282 | 282 | 0 | 0% |
| 24 | 2171775 | 152 | 152 | 0 | 0% |
| 25 | 2171793 | 152 | 152 | 0 | 0% |
| 26 | 2171876 | 76 | 76 | 0 | 0% |
| 27 | 2171904 | 157 | 157 | 0 | 0% |
| 28 | 2171931 | 27 | 27 | 0 | 0% |
| 29 | 2172566 | 113 | 113 | 0 | 0% |
| 30 | 2173361 | 162 | 162 | 0 | 0% |
| 31 | 2173461 | 225 | 225 | 0 | 0% |
| 33 | 2174622 | 71 | 71 | 0 | 0% |
| 34 | 2174729 | 42 | 42 | 0 | 0% |
| 35 | 2174730 | 30 | 30 | 0 | 0% |
| 36 | 2174740 | 59 | 59 | 0 | 0% |
| 37 | 2174879 | 29 | 29 | 0 | 0% |
| 38 | 2175196 | 33 | 33 | 0 | 0% |

| ID | ACCOUNT # | January 2016 | | | Error (%) |
|---|---|---|---|---|---|
| | | Reading | | Variance | |
| | | Meter Reader Book | Billing System | | |
| 39 | 2175198 | 61 | 61 | 0 | 0% |
| 40 | 2175214 | 94 | 94 | 0 | 0% |
| 41 | 2175313 | 138 | 138 | 0 | 0% |
| 42 | 2175347 | 69 | 67 | -2 | -3% |
| 43 | 2175366 | 3 | 3 | 0 | 0% |
| 44 | 2175728 | 55 | 55 | 0 | 0% |
| 45 | 2175842 | 98 | 98 | 0 | 0% |
| 46 | 2175956 | 341 | 341 | 0 | 0% |
| 47 | 2175991 | 116 | 116 | 0 | 0% |
| 48 | 2176016 | 53 | 53 | 0 | 0% |
| 49 | 2176078 | 26 | 26 | 0 | 0% |
| 50 | 2176324 | 82 | 82 | 0 | 0% |
| 51 | 2176545 | 73 | 77 | 4 | 5% |
| 52 | 2176773 | 67 | 114 | 47 | 70% |
| 53 | 2177102 | 106 | 5 | -101 | -95% |
| 54 | 2177359 | 73 | 75 | 2 | 3% |
| 55 | 2177656 | 70 | 255 | 185 | 264% |
| 56 | 2178071 | 241 | 109 | -132 | -55% |
| 57 | 2178494 | 100 | 57 | -43 | -43% |
| 58 | 2178849 | 51 | 249 | 198 | 388% |

**Appendix 6: A comparison of meter readings in meter reader books and the billing system for Mgona**

| ID | ACCOUNT # | January 2016 | | | Error (%) |
|---|---|---|---|---|---|
| | | Reading | | Variance | |
| | | Meter Reader Book | Billing System | | |
| 1 | 2139419 | 551 | 551 | 0 | 0% |
| 2 | 2140901 | 585 | 585 | 0 | 0% |
| 3 | 2145904 | 1006 | 1006 | 0 | 0% |
| 4 | 2147044 | 788 | 788 | 0 | 0% |
| 5 | 2148914 | 52 | 52 | 0 | 0% |
| 6 | 2148971 | 58 | 58 | 0 | 0% |
| 7 | 2150938 | 668 | 668 | 0 | 0% |
| 8 | 2151036 | 856 | 856 | 0 | 0% |
| 9 | 2153687 | 983 | 983 | 0 | 0% |
| 10 | 2155545 | 266 | 266 | 0 | 0% |
| 11 | 2156518 | 1633 | 1633 | 0 | 0% |
| 13 | 2159574 | 5743 | 5743 | 0 | 0% |
| 14 | 2160579 | 353 | 353 | 0 | 0% |
| 15 | 2162035 | 258 | 258 | 0 | 0% |
| 16 | 2162778 | 755 | 755 | 0 | 0% |
| 17 | 2162970 | 676 | 676 | 0 | 0% |
| 18 | 2163260 | 187 | 187 | 0 | 0% |
| 19 | 2163708 | 266 | 266 | 0 | 0% |
| 20 | 2163856 | 123 | 123 | 0 | 0% |
| 21 | 2164283 | 453 | 453 | 0 | 0% |
| 22 | 2164541 | 176 | 176 | 0 | 0% |
| 23 | 2165428 | 260 | 260 | 0 | 0% |
| 24 | 2165594 | 535 | 535 | 0 | 0% |
| 25 | 2167115 | 177 | 177 | 0 | 0% |
| 26 | 2167350 | 385 | 385 | 0 | 0% |
| 28 | 2169172 | 250 | 250 | 0 | 0% |
| 29 | 2169425 | 58 | 68 | 10 | 15% |
| 30 | 2169543 | 204 | 204 | 0 | 0% |
| 31 | 2170144 | 74 | 74 | 0 | 0% |
| 33 | 2170362 | 148 | 148 | 0 | 0% |
| 34 | 2171134 | 69 | 69 | 0 | 0% |
| 35 | 2171142 | 48 | 48 | 0 | 0% |
| 36 | 2171610 | 100 | 100 | 0 | 0% |
| 37 | 2171674 | 73 | 63 | -10 | -16% |
| 38 | 2172112 | 92 | 92 | 0 | 0% |
| 39 | 2173008 | 47 | 47 | 0 | 0% |
| 40 | 2173829 | 10 | 11 | 1 | 9% |

| ID | ACCOUNT # | January 2016 | | | Error (%) |
|---|---|---|---|---|---|
| | | Reading | | Variance | |
| | | Meter Reader Book | Billing System | | |
| 41 | 2173925 | 12 | 12 | 0 | 0% |
| 42 | 2173939 | 16 | 14 | -2 | -14% |
| 44 | 2174193 | 9 | 9 | 0 | 0% |
| 45 | 2174239 | 39 | 39 | 0 | 0% |
| 46 | 2174260 | 9 | 6 | -3 | -50% |

**Appendix 7: A comparison of meter readings in meter reader books and the billing system for Mtandire**

| ID | ACCOUNT # | January 2016 | | | Error (%) |
|---|---|---|---|---|---|
| | | Reading | | Variance | |
| | | Meter Reader Book | Billing System | | |
| 1 | 2139540 | 1511 | 1511 | 0 | 0% |
| 2 | 2139919 | 131 | 131 | 0 | 0% |
| 3 | 2143352 | 1766 | 1766 | 0 | 0% |
| 4 | 2143878 | 351 | 351 | 0 | 0% |
| 5 | 2144176 | 578 | 578 | 0 | 0% |
| 6 | 2144736 | 378 | 378 | 0 | 0% |
| 7 | 2145418 | 227 | 277 | 50 | 18% |
| 8 | 2151108 | 62 | 664 | 602 | 91% |
| 9 | 2154281 | 730 | 730 | 0 | 0% |
| 10 | 2154745 | 1366 | 1366 | 0 | 0% |
| 11 | 2154829 | 761 | 761 | 0 | 0% |
| 12 | 2155717 | 849 | 849 | 0 | 0% |
| 13 | 2156167 | 653 | 2113 | 1460 | 69% |
| 14 | 2158104 | 645 | 645 | 0 | 0% |
| 15 | 2159689 | 321 | 321 | 0 | 0% |
| 16 | 2159698 | 410 | 410 | 0 | 0% |
| 17 | 2160645 | 419 | 419 | 0 | 0% |
| 18 | 2161210 | 161 | 161 | 0 | 0% |
| 19 | 2161211 | 389 | 389 | 0 | 0% |
| 20 | 2161251 | 367 | 367 | 0 | 0% |
| 21 | 2161470 | 208 | 208 | 0 | 0% |
| 22 | 2161762 | 256 | 256 | 0 | 0% |
| 23 | 2162516 | 458 | 458 | 0 | 0% |
| 24 | 2162763 | 380 | 380 | 0 | 0% |
| 25 | 2162780 | 70 | 70 | 0 | 0% |
| 26 | 2162976 | 492 | 492 | 0 | 0% |
| 27 | 2162978 | 151 | 151 | 0 | 0% |
| 28 | 2164062 | 289 | 289 | 0 | 0% |
| 29 | 2164768 | 1032 | 1032 | 0 | 0% |
| 30 | 2165368 | 297 | 297 | 0 | 0% |
| 31 | 2165659 | 54 | 54 | 0 | 0% |
| 32 | 2165747 | 501 | 501 | 0 | 0% |
| 33 | 2167049 | 252 | 252 | 0 | 0% |
| 34 | 2168066 | 240 | 240 | 0 | 0% |
| 35 | 2168069 | 217 | 217 | 0 | 0% |
| 36 | 2168159 | 78 | 78 | 0 | 0% |
| 37 | 2168188 | 310 | 310 | 0 | 0% |

| ID | ACCOUNT # | January 2016 | | | Error (%) |
|---|---|---|---|---|---|
| | | Reading | | Variance | |
| | | Meter Reader Book | Billing System | | |
| 38 | 2168743 | 61 | 61 | 0 | 0% |
| 39 | 2168758 | 39 | 43 | 4 | 9% |
| 40 | 2168763 | 254 | 280 | 26 | 9% |
| 41 | 2169149 | 398 | 398 | 0 | 0% |
| 42 | 2169734 | 117 | 117 | 0 | 0% |

**Appendix 8: Lilongwe Water Board price list for repair materials**

| | Item description | Unit of measure | Unit Price (2015 - 2016) US$[4] |
|---|---|---|---|
| 1 | 15mm M&F Bends | each | 0.84 |
| 2 | 20mm M&F Bends | each | 1.75 |
| 3 | 25mm M&F Bends | each | 2.06 |
| 4 | 32mm M&F Bends | each | 2.51 |
| 5 | 40mm M&F Bends | each | 2.86 |
| 6 | 50mm M&F Bends | each | 6.71 |
| 7 | 15mm G.I. Elbows | each | 0.53 |
| 8 | 20mm G.I. Elbows | each | 1.20 |
| 9 | 25mm G.I. Elbows | each | 1.30 |
| 10 | 32mm G.I. Elbows | each | 2.51 |
| 11 | 40mm G.I. Elbows | each | 3.21 |
| 12 | 50mm G.I. Elbows | each | 4.07 |
| 13 | 15mm G.I. Hex Nipples | each | 0.74 |
| 14 | 20mm G.I. Hex Nipples | each | 0.78 |
| 15 | 25mm G.I. Hex Nipples | each | 0.86 |
| 16 | 32mm G.I. Hex Nipples | each | 2.17 |
| 17 | 40mm G.I. Hex Nipples | each | 2.42 |
| 18 | 50mm G.I. Hex Nipples | each | 2.83 |
| 19 | 15mm G.I. Plain Sockets | each | 0.63 |
| 20 | 20mm G.I. Plain Sockets | each | 0.81 |
| 21 | 25mm G.I. Plain Sockets | each | 1.25 |
| 22 | 40mm G.I. Plain Sockets | each | 1.53 |
| 23 | 50mm G.I. Plain Sockets | each | 1.79 |
| 24 | 20x15mm G.I. Red. Sockets | each | 1.07 |
| 25 | 25x15mm G.I. Red. Sockets | each | 1.79 |
| 26 | 50x40mm G.I. Red. Sockets | each | 2.43 |
| 27 | 15mm Tap Washers | each | 0.09 |
| 28 | 20x15mm G.I. Red. Bushes | each | 0.89 |
| 29 | 25x15mm G.I. Red. Bushes | each | 1.08 |
| 30 | 25x20mm G.I. Red. Bushes | each | 1.09 |
| 31 | 32x20mm G.I. Red. Bushes | each | 1.35 |
| 32 | 50x15mm G.I. Red. Bushes | each | 3.38 |
| 33 | 50x20mm G.I. Red. Bushes | each | 3.47 |
| 34 | 40x25mm G.I. Red. Bushes | each | 2.51 |
| 35 | 50x25mm G.I. Red. Bushes | each | 1.13 |
| 36 | 50x40mm G.I. Red. Bushes | each | 1.21 |
| 37 | 15mm G.I. Tees | each | 0.39 |

[4] 1.00$US=MK721.00 (February 2016)

| | Item description | Unit of measure | Unit Price (2015 - 2016) US$[4] |
|---|---|---|---|
| 38 | 20mm G.I. Tees | each | 0.35 |
| 39 | 25mm G.I. Tees | each | 0.43 |
| 40 | 32mm G.I. Tees | each | 0.23 |
| 41 | 40mm G.I. Tees | each | 0.95 |
| 42 | 50mm G.I. Tees | each | 1.30 |
| 43 | 75mm G.I. Tees | each | 0.38 |
| 44 | 15mm G.I. Plugs | each | 0.21 |
| 45 | 20mm G.I. Plugs | each | 0.28 |
| 46 | 25mm G.I. Plugs | each | 0.18 |
| 47 | 40mm G.I. Plugs | each | 0.24 |
| 48 | 50mm G.I. Plugs | each | 1.99 |
| 49 | 50mm G.I. Flat Flanges | each | 11.62 |
| 50 | 75mm G.I. Flat Flanges | each | 11.86 |
| 51 | 100mm G.I. Flat Flanges | each | 18.22 |
| 52 | 150mm G.I. Flat Flanges | each | 33.20 |
| 53 | 250mm G.I. Flat Flanges | each | 65.74 |
| 54 | 15mm G. I. Unions | each | 0.47 |
| 55 | 20mm G. I. Unions | each | 0.58 |
| 56 | 25mm G.I. Unions | each | 0.42 |
| 57 | 2"x3/4" Bolts & Nuts | each | 0.19 |
| 58 | 2 1/2"x1/2" Bolts & Nuts | each | 0.13 |
| 59 | 6"x3/8" Bolts & Nuts | each | 0.17 |
| 60 | 2 1/2"x5/8" Bolts & Nuts | each | 0.99 |
| 61 | 3"x3/16" Bolts & Nuts | each | 0.20 |
| 62 | 3"x3/8" Bolts & Nuts | each | 0.10 |
| 63 | 3 1/2"x1/4" Bolts & Nuts | each | 0.07 |
| 64 | 3"x1/2" Bolts & Nuts | each | 0.23 |
| 65 | 3"x7/16" Bolts & Nuts | each | 1.04 |
| 66 | 5"x3/4" Bolts & Nuts | each | 4.09 |
| 67 | 3"x5/8" Bolts & Nuts | each | 3.52 |
| 68 | 3 1/2"x1/2" Bolts & Nuts | each | 0.17 |
| 69 | 2"x1/2" Bolts & Nuts | each | 0.50 |
| 70 | 4"x1/2" Bolts & Nuts | each | 0.41 |
| 71 | 4"x5/8" Bolts & Nuts | each | 0.39 |
| 72 | 5"x1/2" Bolts & Nuts | each | 0.46 |
| 73 | 5"x5/8" Bolts & Nuts | each | 1.91 |
| 74 | 5 1/2"x1/2" Bolts & Nuts | each | 0.29 |
| 75 | 7"x5/8" Bolts & Nuts | each | 2.08 |
| 76 | 6"x5/8" Bolts & Nuts | each | 1.91 |
| 77 | 8"x1/2" Bolts & Nuts | each | 0.35 |

| | Item description | Unit of measure | Unit Price (2015 - 2016) US$[4] |
|---|---|---|---|
| 78 | 7"x1/2" Bolts & Nuts | each | 0.49 |
| 79 | M24x100mm Bolts & Nuts | each | 3.38 |
| 80 | 3"x3/4" Bolts & Nuts | each | 3.74 |
| 81 | 8"x5/8" Bolts & Nuts | each | 5.48 |
| 82 | 15mm cobra Bib Cocks | each | 3.81 |
| 83 | 20mm cobra Bib Cocks | each | 4.80 |
| 84 | 15mm cobra Gate Valves | each | 3.99 |
| 85 | 20mm cobra Gate Valves | each | 4.58 |
| 86 | 25mm cobra Gate Valves | each | 4.74 |
| 87 | 32mm cobra Gate Valves | each | 9.49 |
| 88 | 40mm cobra Gate Valves | each | 15.87 |
| 89 | 50mm cobra Gate Valves | each | 25.44 |
| 90 | 15mm cobra Stop Cocks | each | 3.51 |
| 91 | 20mm cobra Stop Cocks | each | 5.41 |
| 92 | 15mm Basin Taps | each | 8.24 |
| 93 | 20mm Basin Taps | each | 11.03 |
| 94 | 40mm G. I. Unions | each | 1.41 |
| 95 | 50mm G. I. Unions | each | 1.91 |
| 96 | 20mm Swivel Ferrules | each | 18.86 |
| 97 | 25mm Swivel Ferrules | each | 20.52 |
| 98 | Thread Tapes | each | 0.42 |
| 99 | 4 x3/4 Bolts & Nuts | each | 3.78 |
| 100 | 50mm Stab [CW] B. Ring | each | 28.02 |
| 101 | 25mm Air Valves | each | 98.40 |
| 102 | 50mm Air Valves | each | 151.80 |
| 103 | 80mm Air Valves | each | 450.07 |
| 104 | 100mm Air Valves | each | 578.99 |
| 105 | 2 x 5/8 Bolts & Nuts | each | 5.62 |
| 106 | 8 X 65 Bolts & Nuts | each | 5.62 |
| 107 | 32 x 25 G I Red Bus | each | 5.62 |
| 108 | 25mm N/Return Valves | each | 5.58 |
| 109 | 50mm N/Return Valves | each | 8.46 |
| 110 | 50mm F/Strainers | each | 52.94 |
| 111 | 100mm F/Strainers | each | 471.90 |
| 112 | 150mm F/Strainers | each | 312.76 |
| 113 | 80mm F/STRAINERS | each | 133.50 |
| 114 | 6x1/2 Bolts & Nuts | each | 2.15 |
| 115 | 500ml Solvent Cement | 500ml | 4.61 |
| 116 | 500ml Cleaning Fluid | 500ml | 0.92 |
| 117 | 63mm PVC Valve Sockets | each | 6.25 |

| | Item description | Unit of measure | Unit Price (2015 - 2016) US$[4] |
|---|---|---|---|
| 118 | 110mm PVC Double valve sockets | each | 3.26 |
| 119 | 63mm PVC Equal Tees | each | 2.01 |
| 120 | 110x63mm PVC Tees | each | 197.57 |
| 121 | 110 PVC Equal Tees | each | 8.53 |
| 122 | 110mm Stub Flange | each | 2.01 |
| 123 | 160mm PVC Double Socket | each | 2.01 |
| 124 | 63x900 PVC Bends | each | 1.04 |
| 125 | 63mm x 45 degrees PVC Bend | each | 1.04 |
| 126 | 110mm x 90 degrees PVC Bend | each | 2.57 |
| 127 | 110mm x 63mm PVC Reducer | each | 3.54 |
| 128 | 32mm PVC End Caps | each | 0.42 |
| 129 | 63mm PVC End Caps | each | 2.91 |
| 130 | 110mm PVC End Caps | each | 0.90 |
| 131 | 15mm PSM Meters | each | 42.64 |
| 132 | 1/8 Insertion Rubber | each | 45.69 |
| 133 | 20mm PSM Meters | each | 51.72 |
| 134 | 25mm PSM Meters | each | 60.95 |
| 135 | 50mm PSM Meters | each | 24.25 |
| 136 | 40mm Flostar M Meters | each | 10.89 |
| 137 | 80mm Flostar M Meters | each | 40.07 |
| 138 | 100mm Flostar Meters | each | 47.99 |
| 139 | 20mm Couplings | each | 2.06 |
| 140 | 25mm Couplings | each | 2.52 |
| 141 | 20mm HDPE Pipe CL 1 | metre | 0.35 |
| 142 | 25mm HDPE Pipe CL | metre | 0.55 |
| 143 | 63x32mm Saddles | each | 4.27 |
| 144 | 160x32mm Saddles | each | 15.18 |
| 145 | 160mm PVC stub flange | each | 45.54 |
| 146 | 110x63mm PVC saddle | each | 14.49 |
| 147 | 20x20mm Fads | each | 1.14 |
| 148 | 63mm Couplings | each | 8.39 |
| 149 | 63mm Mads | each | 7.25 |
| 150 | 63mm Fads | each | 7.55 |
| 151 | 160 x 63mm Saddle | each | 18.23 |
| 152 | 32mm HDPE Coupling | each | 2.28 |
| 153 | 32mm HDPE MAD | each | 1.98 |
| 154 | 32mm HDPE FAD | each | 1.91 |
| 155 | 32mm HDPE Pipe | metre | 0.76 |
| 156 | 110 x 32mm PVC SADD | each | 11.44 |

| | Item description | Unit of measure | Unit Price (2015 - 2016) US$[4] |
|---|---|---|---|
| 157 | 25x25mm Fads | each | 1.52 |
| 158 | 63mm HDPE Pipes | metre | 3.81 |
| 159 | 63mm Valve sockets | each | 1.08 |
| 160 | 20x20mm Mads | each | 1.21 |
| 161 | 25x25m Mads | each | 1.37 |
| 162 | 150mm A.C Pipes CL D | 6 metre length | 110.95 |
| 163 | 200mm A.C. Pipes D | 6 metre length | 41.81 |
| 164 | 250mm A.C. Pipes CL D | 6 metre length | 32.39 |
| 165 | 300mm A.C. Pipes CL D | 6 metre length | 60.90 |
| 166 | 375mm A.C. Pipes CL B | 6 metre length | 65.60 |
| 167 | 375mm A.C. Pipes CL C | 6 metre length | 65.60 |
| 168 | 600mm A.C Pipes CL B | 6 metre length | 79.33 |
| 169 | 350mm A.C. Pipes CL C | 6 metre length | 64.84 |
| 170 | 400mm A.C. Pipes CL D | 6 metre length | 14.29 |
| 171 | 525mm A.C Pipes CL B | 6 metre length | 15.14 |
| 172 | 600mm A C Pipe Cl D | 6 metre length | 23.46 |
| 173 | 100mm A.C Pipes CL D | 6 metre length | 12.35 |
| 174 | 300mm VJ Couplings Class 18 | each | 807.84 |
| 175 | 300mm VJ Couplings Class 24 | each | 460.67 |
| 176 | 300mm C I JOINTS CLASS 20 | each | 460.67 |
| 177 | 300mm V J Coupling Class 22 | each | 684.64 |
| 178 | 350mm V J Coupling Class 16 | each | 335.19 |
| 179 | 350mm V J Coupling Class 20 | each | 340.83 |
| 180 | 350mm V J Coupling Class 22 | each | 351.66 |
| 181 | 300mm V J Coupling Class 20 | each | 560.68 |
| 182 | 300mm V J Coupling Class 16 | each | 456.93 |
| 183 | 350mm C I Joints Class 18 | each | 560.68 |
| 184 | 100mm C.I. Joints | each | 45.69 |
| 185 | 150mm C.I. Joints | each | 56.37 |
| 186 | 200mm C.I. Joints | each | 211.69 |
| 187 | 225mm C.I. Joints | each | 234.95 |
| 188 | 250mm C.I. Joints | each | 252.12 |
| 189 | 300mm C I. Joints Class 16 | each | 380.65 |
| 190 | 375mm C.I. Joints | each | 402.77 |
| 191 | 400mm C.I. Joints | each | 402.77 |
| 192 | 350mm C.I. Joints | each | 602.64 |
| 193 | 500mm C.I. Joints | each | 739.94 |
| 194 | 525mm C.I. Joints | each | 1045.08 |
| 195 | 600mm C.I. Joints | each | 755.20 |
| 196 | 100mm V.J. Couplings | each | 27.54 |

| | Item description | Unit of measure | Unit Price (2015 - 2016) US$[4] |
|---|---|---|---|
| 197 | 150mm V.J. Couplings | each | 36.54 |
| 198 | 250mm V.J. Couplings | each | 224.04 |
| 199 | 300mm V.J. Couplings | each | 533.22 |
| 200 | 350mm V.J. Coupling | each | 456.93 |
| 201 | 600mm V.J Couplings | each | 746.81 |
| 202 | 50mm C.I. Flanged Adaptors | each | 85.82 |
| 203 | 100mm C.I. Flanged Adaptors | each | 54.16 |
| 204 | 150mm C.I. Flanged Adaptors | each | 57.21 |
| 205 | 200mm C.I. Flanged Adaptors | each | 228.09 |
| 206 | 225mm C.I. Flanged Adaptors | each | 286.06 |
| 207 | 250mm C.I. Flanged Adaptors | each | 304.37 |
| 208 | 300mm C.I. Flanged Adaptors | each | 350.14 |
| 209 | 375mm C.I. Flanged Adaptors | each | 390.57 |
| 210 | 75mm Fire Hydrants | each | 84.83 |
| 211 | 160x63mm PVC Hydrant Tee | each | 42.62 |
| 212 | 110x63mm PVC Hydrant Tee | each | 18.53 |
| 213 | 350mm Sluice valves | each | 1359.74 |
| 214 | 80mm Sluice valves | each | 83.91 |
| 215 | 100mm Sluice Valve | each | 197.57 |
| 216 | 150mm Sluice Valve | each | 259.29 |
| 217 | 200mm Sluice Valve | each | 455.79 |
| 218 | 250mm Sluice Valve | each | 596.91 |
| 219 | 300mm Sluice Valve | each | 902.05 |
| 220 | 375mm Sluice Valve | each | 2250.35 |
| 221 | 400mm Sluice Valve | each | 2287.73 |
| 222 | 150mm None Return Valves | each | 273.86 |
| 223 | 100mm M.I. Saddles | each | 24.33 |
| 224 | 150mm M.I. Saddles | each | 30.13 |
| 225 | 200mm M.I. Saddles | each | 67.05 |
| 226 | 225mm M.I. Saddles | each | 96.04 |
| 227 | 250mm M.I. Saddles | each | 150.66 |
| 228 | 300mm M.I. Saddles | each | 56.17 |
| 229 | 15mm G.I. Pipes | 6 metre length | 10.60 |
| 230 | 20mm G.I. Pipes | 6 metre length | 14.42 |
| 231 | 25mm G.I. Pipes | 6 metre length | 27.39 |
| 232 | 40mm G.I. Pipes | 6 metre length | 44.02 |
| 233 | 50mm G.I. Pipes | 6 metre length | 91.46 |
| 234 | 40mm PVC Pipe Class 10 | 6 metre length | 2.44 |
| 235 | 90mm PVC Pipe Class 12 | 6 metre length | 9.35 |
| 236 | 63mm PVC Pipes Class12 | 6 metre length | 12.24 |

| | Item description | Unit of measure | Unit Price (2015 - 2016) US$[4] |
|---|---|---|---|
| 237 | 63mm PVC Pipes Class16 | 6 metre length | 15.29 |
| 238 | 110mm PVC Pipes Class 12 | 6 metre length | 25.05 |
| 239 | 110mm PVC Pipes Class 16 | 6 metre length | 29.25 |
| 240 | 160mm PVC Pipes Class 12 | 6 metre length | 23.58 |
| 241 | 160mm PVC Pipes Class 16 | 6 metre length | 27.54 |
| 242 | 200mm PVC Pipes Class 10 | 6 metre length | 38.98 |
| 243 | 250mm PVC Pipes Class 12 | 6 metre length | 139.75 |

**Appendix 9: Form for capturing repair materials used on a leakage/pipe burst**

| Date | Location | Pipe size (mm) | Date Reported | Date Repaired | Materials Used | Requisition No. | Issue No. |
|---|---|---|---|---|---|---|---|
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