

**QUANTITATIVE ASSESSMENT OF NON-REVENUE WATER PREVALENCE IN
NYARWODHO GFS IN UGANDA**

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Certification

The undersigned attests to having read the dissertation, "Quantitative Assessment of Non-Revenue Water Prevalence in Nyarwodho Gravity Flow Scheme," and recommends it for Kyambogo University to accept it as part of the requirements for the Masters of Science in Water and Sanitation Engineering degree.

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Declaration

I declare that this dissertation is my original work and has not been submitted to any institution of higher learning for the award of a diploma, degree, or any certificates in any discipline.

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Sign.....

Date.....

Acknowledgment

I wish to acknowledge the contributions of Kyambogo University, specifically the Head of the Department of Civil and Building Engineering, for providing essential moral and academic support during my studies.

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Dedication

With great love and appreciation, I dedicate this dissertation to God who is my provider and defender, my Brother Richard Bob opio, and the entire Ademi family.

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List of Acronyms

NRW:	Non-Revenue Water
UN:	United Nations
MDG:	Mileneum Development Goals
SDG:	Sustainable Development Goals
MWE:	Ministry of Water and Environment
NWSC:	National Water and Sewerage Corporation
NUWS:	Northern Umbrella of Water and Sanitation
RGCs:	Rural Growth Centres
WSS:	Water Supply System
GFS:	Gravity Flow Scheme
NUWS:	Northern Umbrella of Water and Sanitation
O&M:	Operations and Maintenance
NDP III:	National Development Plan three
UPMIS:	Utility Performance Monitoring and Information System
WOVs:	Wash Out Valves
ARVs:	Air Release Valves
BPT	Break Pressure Tank
DVs:	Dependent Variables
IVs:	Independent Variables
IWA:	International Water Association
RL:	Real Losses
AL:	Apparent Loss
NGOs:	Non-Governmental Organizations
PSPs:	Public Stand Posts
uPVC:	unplasticized polyvinyl chloride
HDPE:	High Density Polyethylene

UNDP:	United Nations Development Program
US\$:	United States Dollars
Mm ³ /day:	Megalitres per cubic meter
CPVC:	Chlorinated polyvinyl chloride
PEX:	Cross-linked polyethylene
IWA:	International Water Association
JICA:	Japan International Cooperation Agency
PSPs:	Public Stand Posts
G.I:	Galvanized Iron
D.I:	Ductile Iron
LDPE:	Low-density polyethylene
MDPE:	Medium-density polythene
LLDP:	Linear low-density polyethylene
MPa:	Mega Pascal
O&M:	Operations and Maintenance
GFRP:	Glass Fibre Reinforced Polymer
PE:	Polyethylene
PRVs:	Pressure release valves

ABSTRACT

Studies that were conducted reported on impacts of Non-Revenue Water (NRW) on the sustainability of piped water supply systems. Millennium development goal No.7 (MDG 7) and sustainable development goal No. 6 (SDG 6) are among the many strategies adopted globally to ensure access to safe water by the global population and particularly developing countries including Africa. However, water utilities across nations have their efforts hampered by Non-Revenue Water prevalence. Narwodho GFS is a gravity flow system that abstract water from the river Namrwodho at the border between DRC and Nebbi District, and a conventional treatment facility with 4000m³/day treatment capacity before transporting to the 9 supply zones in Nebbi and Pakwach Districts. The system is experiencing high NRW prevalence which affects service delivery. An investigation was conducted to assess and quantify NRW prevalence in the scheme in order to understand the causes of NRW hence develop mitigating strategies. Field surveys were conducted to evaluate the real situation hence develop strategies for mitigation. Billing data were obtained from the records of scheme operator while water production records were obtained from the treatment plant superintendent. Pipes were inspected to understand their characteristics including the pressure ratings and the trenching depths and their contribution to NRW prevalence in the scheme. Hydraulic modeling and analysis was conducted to understand the pipe flow behavior in contributing to NRW, and amongst the software's used were; AutoCAD Civil 3, EpaCAD, and EPANET 2.2 for data manipulations and analysis. The employees of the scheme and water users were interviewed in order to understand the impacts of NRW on them. The findings revealed that the NRW trend in Nyarwodho GFS were; 2018 (93.36%), 2019 (80.25%), 2020 (77.79%) and 2021 (75.34%) contrary to the 39% reported by the scheme through Utility Performance Monitoring information system (UPMIS) portal, with an 18% NRW reduction was recorded in a period of four years. Pipe bursts on the transmission pipeline was observed to have contributed the most to NRW in the scheme, and this was particularly exuberated by; over supply at night, installation of low pressure rating uPVC pipes in some sections, and shallow trenching that has been made even shallower by soil erosion amongst others. Users reported intermittent supply where they spend days or weeks without water, while the scheme staffs have low remunerations due to low revenue collections. Mitigation measures were recommended to water utility providers which among others include but not limited to; regulating night supply, financial support to the utility, adopting preventive measures, good asset management, timely supply of repair materials, replacing pipes of low pressure ratings, staff capacity building, motivation of employees, rewards for reporting vandalism, regular user sensitization and engagements, involvement of local leadership and users in the affairs of water supply, and creating customer what sup group for reporting breakdowns.

CHAPTER ONE: INTRODUCTION

1.1 Background

Water is considered a fundamental necessity and a right Clayton (2015). The high frequency of water losses known as Non-Revenue Water (NRW) frequently hinders international attempts to satisfy the population's water demands. According to Lymphate (2019), NRW is the difference between the amount of water that is invoiced to customers and the amount that is placed into the distribution system. In other words, it is water that is generated and delivered but lost without bringing in any money for the water utility. In order to meet these needs, the Sustainable Development Goal No. 6 (SDG 6) has developed strategies to ensure environmental sustainability, particularly with regard to the proportion of water resources that focus on ensuring the availability and sustainable management of water and sanitation for all UNECA (2017), which is hindered by water losses despite established efforts. In order to meet the constantly increasing water demands brought on by population growth in both urban and rural growth centers, the Ugandan government, acting through the Ministry of Water and Environment (MWE), has constructed and renovated a number of water infrastructures throughout the nation that are both affordable and easily accessible. After these projects are finished, they are turned over to the Umbrella of Water and Sanitation (UWS), which works in small towns and rural growth centers (RGCs), or the National Water and Sewerage Corporation (NWSC). Whereas NWSC has a single standard rate for all of its schemes due to its profit-driven nature, UWAs employ Pro-Poor tariffs that are determined by each individual water supply scheme (WSS) based on the economic standing of the local community.

The Nyarwodho Gravity Flow Scheme (GFS), one of the MWE's schemes, has significantly reduced the use of hazardous water sources by water-stressed residents in the two districts of Nebbi and Pakwach. However, the scheme faces operational challenges with regard to NRW,

which may compromise sustainability and cause some intermittency in the supply to customers.

The incidence of NRW is estimated to be 246 million cubic meters per day worldwide, or 126 billion m³ of treated water, with an estimated yearly loss of US\$ 39 million, according to Liemberger and Wyatt (2018). Additionally, according to NRW, 16 billion m³ of water generated annually are given to customers without being billed.

Notwithstanding the financial difficulties and the remarkable rate of economic growth, an estimated 14Mm³/day, or 64 liters per capita per day, are wasted through NRW in Sub-Saharan Africa, amounting to around \$1.4 billion annually (World Bank, 2018). Water utilities' ability to effectively and efficiently supply a larger population with safe, inexpensive, and clean water as needed has been impacted by the predominance of NRW growth, especially in Africa and other developing nations.

Many Sub-Saharan African towns experience water loss as a result of their outdated water supply distribution networks, which are marked by high non-revenue water (NRW) levels that significantly beyond the limitations advised for sustainable urban utilities. NRW has hindered Uganda's water companies' ability to provide water to all consumers as needed, with almost 33.5% of provided volumes failing to reach the intended users. 39.1% of the treated water intended for customers in Kampala Metropolitan alone was lost (MWE, 2017).

1.2 Statement of Problem

The rapid increase of non-revenue water (NRW), which has a direct impact on revenue collection and system development, hinders the efforts made by water utilities worldwide to provide consumers with clean and reasonably priced water.

One of the biggest and most intricate schemes built by MWE is Nyarwodho GFS, which was turned over to Northern Umbrella of Water and Sanitation (NUWS) for direct management and upkeep.

Due to its extensive coverage and complexity, the system is facing operational issues, particularly with regard to pipe breaks from a portion of transmission mains. This is generating a very significant water loss and inconsistent supply to the consumers, which might potentially compromise sustainability. Since of its predominance, customer needs are occasionally not sufficiently satisfied, which leads to low revenue collection since customers often refuse to pay water bills because they were not provided with the service they anticipated.

If the causes of this prevalence are not sufficiently addressed, the utility's ability to conduct efficient operations and maintenance may be impacted, and user communities may be persuaded to turn to unsafe sources that pose a risk of water-related illnesses brought on by frequent supply outages. The operationalization of SDG agenda 2030 and National Development Plan (NDP) III will suffer, O&M expenditures will be excessive, and service delivery would inexorably fall as a result of low revenue collection. As a result, this was the main reason this study was carried out.

1.3 Objectives of the Study

The following were the Study objectives;

1.3.1 General Objectives

The main objective of the study was to assess water losses in Nyarwodho GFS in Nebbi district.

1.3.2 Specific objectives

1. To quantify NRW prevalence in Nyarwodho GFS in Nebbi District
2. To investigate the sources of NRW in Nyarwodho GFS in Nebbi district.
3. To evaluate the relationship between pipe material characteristics and NRW in Nyarwodho GFS in Nebbi district.
4. To investigate the hydraulic performance of a 15.9km section of the transmission mains in Nyarwodho GFS in Nebbi District.
5. To investigate the impacts of NRW to the scheme employees and the water users.

1.4 Research Questions

1. To what magnitude is NRW prevalence in Nyarwodho GFS?
2. What is the sources of NRW prevalence in Nyarwodho GFS?
3. To what contribution is pipe materials characteristics to NRW prevalence in Nyarwodho GFS?
4. What is the contribution of pipe hydraulics to NRW prevalence in Nyarwodho GFS?
5. To what extent is the impact of NRW to the scheme staff and the water users?

1.5 Research Justification

With the average prevalence of NRW in Nyarwodho GFS from the period of March 2018 to June 2021 is 78.5%. This prevalence is way beyond the acceptable national minimum standard of 35% MWE, (2017) design manual and World Bank maximum NRW level of 25%

World Bank, (2018). NRW causes intermittent supply to customers and affects operations and maintenance which negatively impacts on systems' sustainability in line with Sustainable Development Goal (SDG7) and Uganda's National Development Plan (NDP III). The study therefore is justifiable because it aims to get to the bottom of the prevalence and hence provide workable strategies to safeguard the scheme's sustainability.

1.6 Significance of the Study

Mitigating NRW is a collective responsibility of all stakeholders of interest in the water sector since NRW affects all aspects of day to day life of humanity as water is in itself life. Emphasis put on situational analysis as was conducted by this study to provide water utilities with the preventive knowledge of mitigating the real cause of NRW as opposed to the commonly practiced corrective measures. The Study will provide water utilities with the required information needed to control & regulate the prevalence of NRW in schemes to reduce on resource wastages. The Study will further, in line with the world of academia be able to contribute to the general body of knowledge particularly in the field of piped water operations and maintenance.

1.7 Scope of the Study

The scope of this investigation was divided into three different sub categories as;

1.7.1 Content Scope

The Study focused on factors contributing to NRW (Physical losses) specifically on the systems hardware components. It was majorly oriented to understanding the characteristics of pipe materials such as; (Diameter, type of pipe, pipe thickness pressure ratings, and installation depths) in order to ascertain their contributions to NRW. The Study also investigated the possible contributions to NRW by pipeline fittings at the installations of Wash out valves (WOVs), flanges and Air valves (ARVs), and Break Pressure Tanks (BPT).

1.7.2 Geographical Scope

The Study was conducted in Nyarwodho GFS located in Nebbi district but serving Pakwach District as well. These two Districts are located in the west Nile region of Uganda bordering the Democratic Republic of Congo from the west and South Sudan from the North. For identifying the general sources and causes of NRW in the scheme, the study was done in all supply areas, but to get an understanding of the causes of the actual specific points of physical losses along the transmission pipeline, Four Sub Counties of Nebbi where transmission lines passes was covered which includes; Nebbi, Ndheu, Atego, and Nyaravur respectively. The map of the study area is presented in Figure 1-1 below.

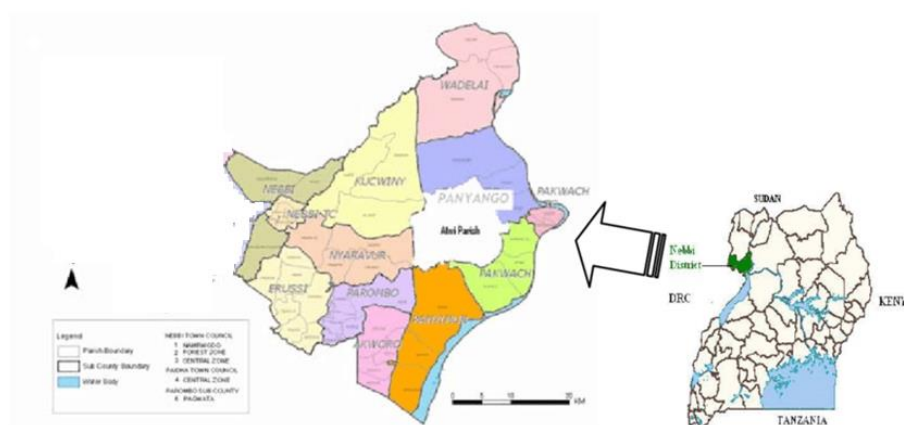


Figure 1-1: Map of the Project Area from Uganda

1.7.3 Time Scope

The study was conducted for a period of 10 months from April 2021 to February 2022. This was the time designed and allocated to cover data collection, data analysis and presentation.

1.8 Theoretical Framework

The study reviewed the following theories in the process of conducting the study: three theories were adopted as key to this study which includes;

1.8.1 The theory of competitive advantage

The theory of competitive advantage was developed by Michael Porter in 1985. The porter's theory of competitive advantage postulates that businesses should undertake ventures that are creating and sustaining superior performance in business which is the basis of success for every organization Grant, (1991). The Porters theory also combines three strategies that include; cost leadership, differentiation and focus which are very important in ensuring that organizations are achieving superior performance and remaining competitive. The WSPs that have managed to reduce NRW to the minimum levels and within the sector benchmark of 25% have fully implemented majority of the NRW reduction strategies to the later while those that have not been able, have not properly focused on the NRW reduction strategies or have other Challenges. WSPs according to application of the Porter's (1985) theory need to minimize NRW Losses using cost leadership strategy, where they reduce their operational costs to the lowest levels through minimization of NRW losses if they have to succeed in achieving sustainable water supply to the citizens of Uganda and Africa at large.

1.8.2 Managerial Efficiency Theory of profits

The Managerial Efficiency Theory of Profit was proposed by Timothy Scott Archer in 2010. The Archer Managerial Efficiency theory stipulates that “if an average firm tends to earn only a normal return on its investment in the long run, then firms that are more efficient than the average would earn above-normal returns and (economic) profits.” The theory further expounds that high profits will provide the incentive for organizations to expand output Arbelo, Arbelo-Pérez and Pérez-Gómez, (2020). This theory denotes the importance of efficiency in controlling water losses in order to increase on the revenue profit generated by water sales. This leads to an understanding on why most WSPs are inefficient and making losses or very little profits that hamper their ability to grow and increase water service delivery to the supply areas allotted them. According to this theory, the study feels that most

WSPs who are currently incurring high NRW losses are not able to grow because they earn very little return on investment hence unsustainable.

1.8.3 The Theory of Constraints (TOC)

The theory of constraints (TOC) was developed by Eliyahu M. Goldratt in 1984. This Theory of Constraints is a methodology for identifying the most important limiting factor (i.e., constraint) that stands in the way of achieving a goal and then systematically improving that constraint until it is no longer the limiting factor Lean Production, (2021). Water utility companies struggle to perform in accordance with meeting their performance objectives but non-revenue water has always and continued to remain a serious bottleneck for them. This theory applies to the water sector in Uganda both NWSC and UWSA where NRW is the biggest constraint for the success of all WSPs in Uganda significant amount of water does not generate revenue as expected reduce their capacity to have a reliable surplus which can be re-invested in furtherance of water supply.

1.9 Conceptual Framework

Two key variables were studied as factors as influencing the occurrence of NRW; Independent Variable (IV) and the resultant NRW as Dependent variable (DV). The IV was broken down into operational variables namely; (a) sources of NRW which includes pipe bursts, leaks, overflows, illegal connections, and metering errors, (b) causes of NRW which includes weak materials, shallow trenching, over supply, poor workmanship, (c) Pipe materials characteristics which includes type of pipe, diameter, thickness, pressure ratings, fittings, and age of pipes, (d) Pipe hydraulics which includes Pressure, Velocity, head loss and Topography which are contributing factors to NRW in Nyarwodho GFS. Since this was a technical investigation on behavior of pipe hydraulics, other sources and causes of NRW such as Commercial losses and human factors were not be deeply considered for the Study much

as they are known contributors. The relationship between these variables is presented in (Figure 1-2).

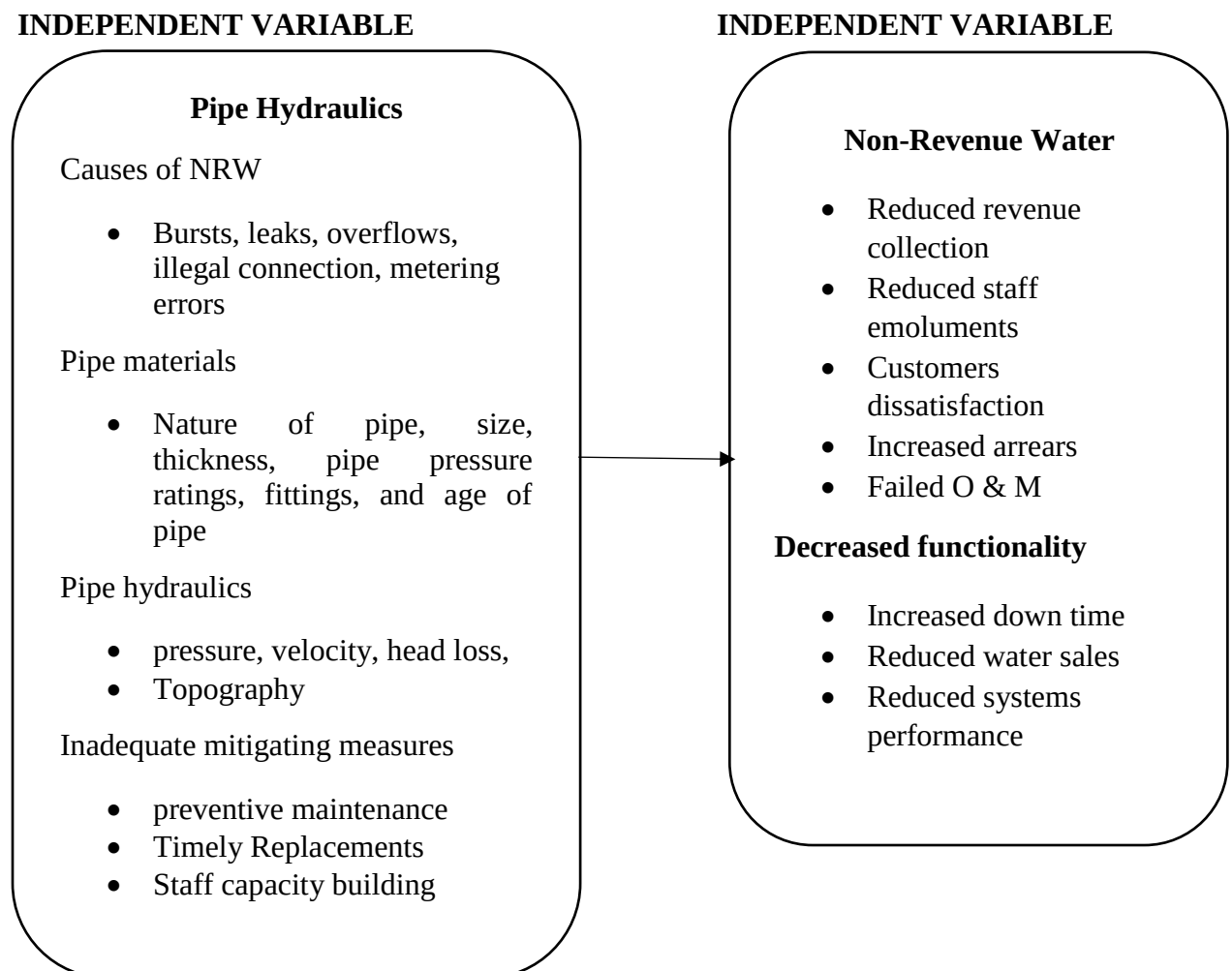


Figure 1-2: Conceptual framework for Non-Revenue Water

Source: Author (2021)

1.9.1 Definition of key Operational terms

Independent variable

Causes of NRW: Causes of NRW are locations contributing or leading to occurrence of water losses, which includes; pipe bursts, leakages, overflows from reservoirs, illegal connections and metering errors

Pipe materials: This denotes the materials composition of a given pipe used for plumbing operations such as; galvanized steel, copper, galvanized steel, plasticized polyvinyl chloride (uPVC), chlorinated polyvinyl chloride (CPVC) and cross-linked polyethylene (PEX).

Hydraulic modelling: Hydraulic modeling is an application of mathematical tools in the model of a fluid flow system to analyze hydraulic behavior with the purpose of understanding, predicting, and managing water resources.

Mitigating measures: These are actions undertaken to prevent or reduce the occurrence of water losses in a system which includes preventive, regulative and corrective measures.

Dependent Variables

Non-Revenue water: water that has been supplied to consumers but has not generated any revenue.

Reduced revenue collection: Is a decline in water bill collection leading to growth in arrears.

Declined Staff motivation: these refer to rewards, wages, incentives, or motivation that is given to staffs or employees of an entity for the work done.

Accelerated Customer dissatisfaction: Customer dissatisfaction is a situation a product or service fails to meet the expectations of customers. Efforts to reduce on NRW in schemes has the potential of increasing.

Increased arrears: the amount of money not paid from the water bill issued to customers.

Reduced systems down time: this denotes a reduction on the number of non -supply hours/days in a water supply system.

Increased water sales: This denotes the increase in billing and revenue collection in water system due to reduced down time.

Improved systems performance: This denotes the total improvement of systems functionality which includes; reduced NRW, increased staff motivation, satisfied & motivated customers etc.

1.9. 2 Study Gaps

Several studies have been conducted on NRW including pumped motorized systems. However limited studies have been conducted on NRW in large gravity systems, and particularly since the problem of the scheme begun in 2018, no study was conducted on this system to ascertain the NRW prevalence rate in the scheme. It is therefore against this gap that the study was conducted.

CHAPTER TWO: LITERATURE REVIEW

2.1 Understanding NRW

Team (2019) states that "NRW is the difference between the amount of water billed to consumers and the amount of water put into the distribution system." Simply put, it refers to water that is generated and delivered but lost without bringing in any money for the water company. The persistent growth in NRW is a global trend in the developed and developing countries especially considering the current climate change that is contributing to global warming. Safe and drinking water availability becomes a challenge even more than ever before now that water gets scarce across the globe. NRW in a nutshell is “the difference between System Input Volume and Authorized Consumption”, quantified from equation (1) according to Lymphate Infra, (2019);

NRW = Water produced – Water billed.....(1).

AWWA (2016) further defines NRW as the difference between the amount of water put into a distribution system and the amount of water billed to consumers.

2.2 Trends in NRW

Over the years there has been an improving trend in water and sanitation development with the increase in the construction of several water and sanitation facilities to meet the ever growing population UNICEF & WHO, (2019). As a result of negative effects of climate change on our environment, the prevalence in water losses have been reported as the hallmark of water utilities in most parts of the world over recent decades”, and continues to be such a global threat especially due to the high growth in world population leading to growth of towns and cities which means there is less water available for the current and future world consumption than in the past Liemberger and Wyatt, (2018). Non-Revenue water is a global challenge that happens in developed and developing countries alike, though at different prevalence rates due to the different knowledge, expertise, and technology

adopted in the construction and maintenance of the systems. According to a study conducted by ADB (<https://www.adb.org>), Utilities in Asia loses up to 65% of their production daily, with most utilities averaging a 30% loss. Liemberger and Wyatt, (2018) provided an extract of the global level of NRW as of IWA as presented in the (Figure 2-1)

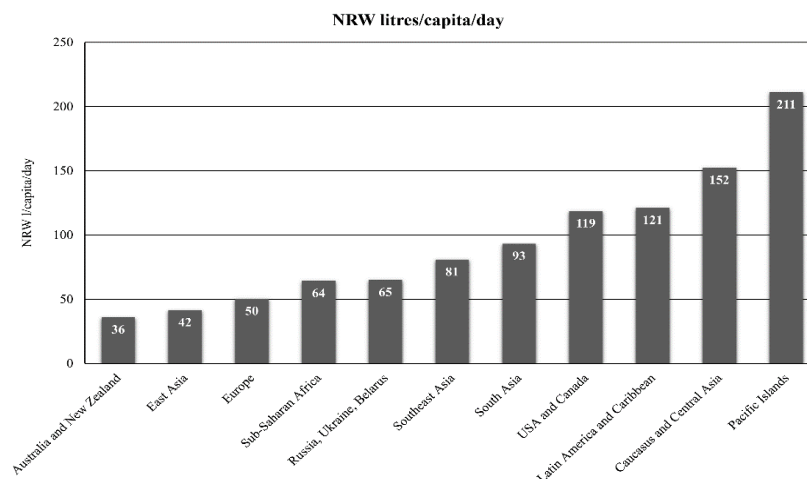


Figure 2-1: Global non-revenue water problem.).

Source: ResearchGate, (2019)

A further study conducted by See and Ma, (2018) approximated NRW prevalence in Malaysia to 38 percent in 2012, which was considered to be higher than is the case in other developing countries like the Philippines which had 11% in 2011, and Thailand 25% in 2012. A study conducted by AVK (www.avkvalves.com) revealed that NRW prevalence was highest in a number of countries which includes; Indonesia (51%), India 50%, Brazil (38%), Kenya (34%), USA (24%), Norway (22%), Denmark (4%) and Australia (3%). The same study reported a very high NRW of 61% in Bulgaria followed by Romania (53%), and least NRW prevalence of 10% in Germany as presented in (Figure 2-2) and (Figure 2-3) of NRW prevalence in Europe..

WORLDWIDE DIFFERENCES IN NRW LEVELS

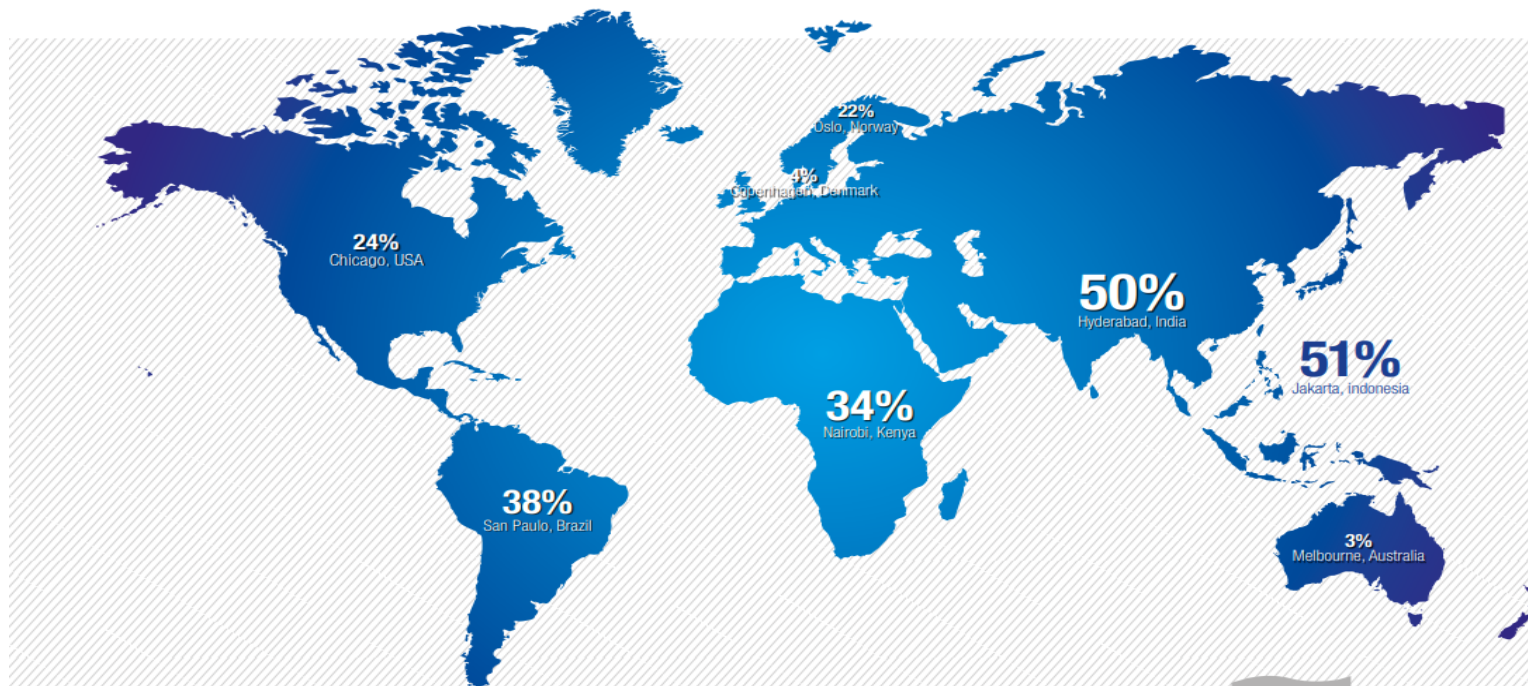


Figure 2-2: Global NRW Levels

Source: AVK, (2019)

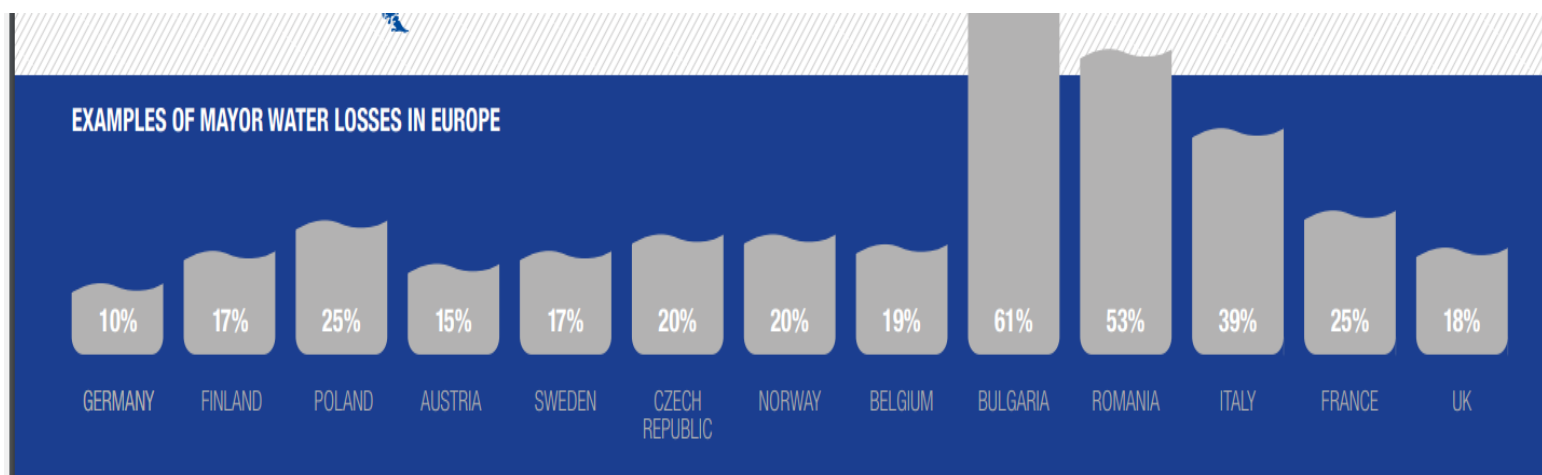


Figure 2-3: Major losses in Europe

Source: AVK, (2019)

In order to develop an understanding of the magnitude of NRW in Africa, a report from (USAID & AfWA, (2015) indicated that 45 million m³ of water was lost each day in Africa, which represents a total annual cost of over 6 billion US\$. 16 billion m³ loss per year not

invoiced (USAID & WBI, 2010). This tremendous increase shows that the problem of NRW needs to be tackled with seriousness across these developing countries with clear implementable strategies. According to Zeraebruk. Et al, (2014), this trend could be due to the fact that many Sub-Saharan African cities have old water supply distribution network which are characterized by high NRW in excess of the recommended limits for sustainable urban utilities. Torres, (2019) reported an increase in the rate of urbanization in African continent which stood at 15% - 60% in the 1960s to a whopping 50% in the year 2010 which unfortunately was predicted to soar up to 60% by 2050, yet old water infrastructures continue to be used dealing utilities a daunting struggle to reduce NRW prevalence to ensure systems sustainability amidst the challenges. A Study conducted by Eberhard (2019) reported that most urban water utilities in Sub-Saharan Africa have NRW values higher than 23% with a national NRW average of 38%; which is much higher than the set national benchmark of 20% for Tanzania. The same study suggested that Sub Saharan Africa was has an average NRW prevalence of 38%, with; Uganda 28%, Burkina Faso 18%, Kenya 18%, and Senegal 20% respectively. This however is not a true representation of reality on ground as the prevalence could be much higher than reported to be the case in Uganda as presented in (Table 2-1).

Table 2-1: Utility Performance in Sub-Saharan Africa

Utility (country)	SDE (Senegal)	Nyeri (Kenya)	ONEA (Burkina Faso)	NWSC (Uganda)	Median (SSA)
Access to pipe water	97%	91%	90%	78%	68%
Hours of supply	24	24	23	18	18
Operating cost coverage ratio	1.39	1.39	1.18	1.28	0.93
Cash collection efficiency	98%	-100%	97%	-100%	91%
Non-revenue water	20%	19%	18%	28%	38%
Staff productivity	3	3	4	6	10

Source: Eberhard (2019)

Due to the prevalence of NRW, most water utility companies in Africa are unable to recover operating costs, hence remain heavily dependent on support from government and other development agencies in the form of subsidy and loans (World Bank, 2017). In relation to meeting the operational costs, World Bank, (2017) reported that only 17% of the 605 utilities in developing country utilities are able to cover their Operation and Maintenance costs and create a surplus. Reducing NRW prevalence within these utilities can reduce on operations

and maintenance costs hence increased water sales and revenue collection, efficiency and effectiveness can be guaranteed.

NWSC and Umbrella water authorities being government agencies mandated with the responsibilities of providing water citizen.go.ug, (n.d) but however keeps encountering high NRW prevalence in different schemes which could be caused by factors such as; size of scheme, terrain, materials availability, methods of construction, operations and maintenance, the staff, and climatic conditions among others. According to NWSC, NRW in the Kampala Water jurisdiction currently stands at 43.7%, contributing to the highest number of losses in the Corporation which has been attributed to illegal water usage on a monthly basis and calls for new strategies.

A review conducted by (MWE, 2017) on the performance of NWSC Contract for the period 2015-2017 reported a 39.1% NRW prevalence for Kampala supply area that accounted for a performance shortfall of 7.1% against the annual target of 32%. This translates into a financial losses estimated at 77.5 Billion Uganda Shillings. The review further suggests adopting several implementable strategies to reduce NRW to best practice of less than 25% would significantly improve the overall performance to realize a revenue of 188 Billion UGX annually. Details are presented in Figure 2-4

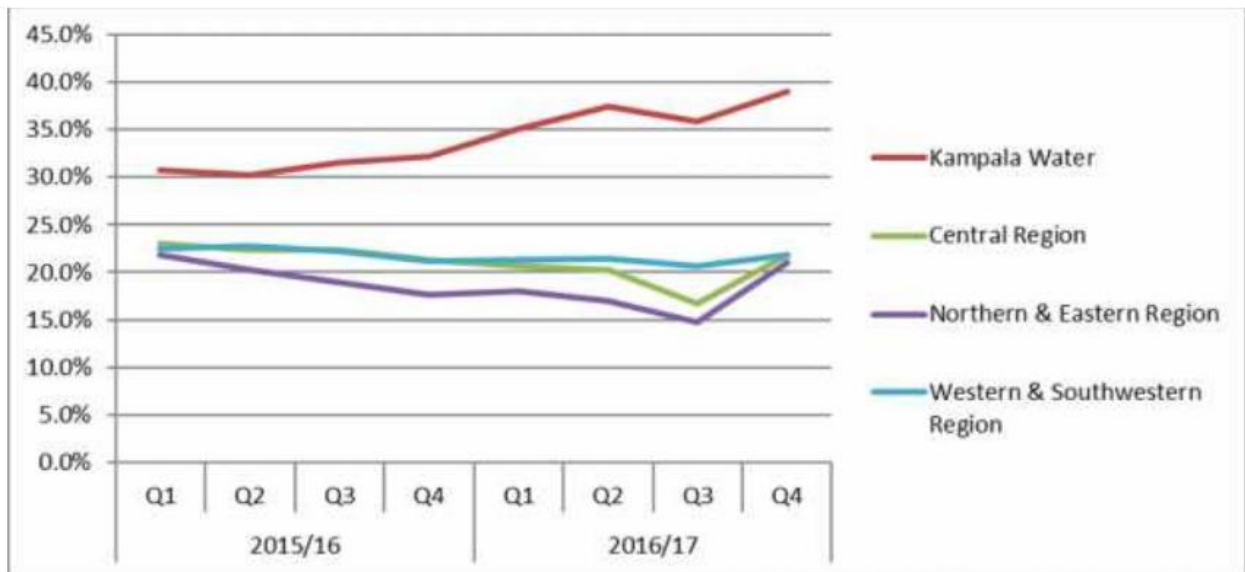


Figure 2-4: NWSC Countrywide level of NRW in Uganda

Source: Ministry Of Water and Environment Water Utility Regulation Department, (2017)

However, from (UPMIS, 2022) which tracks different performance indicators of the schemes managed by umbrella of water and sanitation authorities, the average NRW vary per scheme due to their sizes and complexities.

2.2.1 Components of NRW

Tabesh et al., (2018) describes NRW as consisting of physical and commercial losses. Physical losses consist of leaks, pipe bursts, and overflow from storage reservoirs, while apparent loss consists of unauthorized water consumption such as; all forms of water theft and metering inaccuracies. Real losses emanate from a number of components in a water supply system including but not limited to; transmission and distribution pipelines, storage reservoirs, treatment plant, pumping stations and customer tap stand Al-Washali et al., (2020). According to Kanakoudis et al., (2016), any failure in these components can cause significant NRW growth in the system resulting in high operations and maintenance in terms of lost revenue

2.3 Estimating NRW

Liemberger and Wyatt, (2019) presented various methods exist that can aid in obtaining NRW such as; the percentage of water produced, minimum night flow (MNF) analysis and water balance analysis. Van den Berg,(2015) presented other NRW estimation methods which could be adopted by water utilities to mitigate the high growth of NRW which includes; Leakage Index (ILI) for obtaining data on the system pressure, length of different pipe categories, number of service connections, and the water balance. However, Tabesh et al., (2018) elaborates that the most observed factors to high NRW prevalence are; “poor management, poor training of workers and experts, lack of timely replacement of devices, and inappropriate quality selection of pipes and devices”.

2.4 Concept of water IWA’s balance

According to Liemberger and Farley, (2019), developing an understanding of NRW requires a holistic knowledge of water balance taking into account all the components of a water supply system. This process helps in identifying the occurrences, causes as well quantifying NRW in a system as illustrated in (Table 2-2) of Internationally recognized best practice approach to calculate water balance according to IWA

Table 2-2: Water Balance sheet based on IWA Definition

System Input Volume (SIV)	Authorized Consumption	Billed Authorized Consumption	Billed metered water consumption Billed unmetered water consumption (Water meter not installed, estimated water consumption due to water meter failure)	Revenue Water
		Unbilled Authorized Consumption	Unbilled metered water consumption (Settled water consumption) Unbilled unmetered water consumption (Free water from public tap, pipeline cleaning water from water utility)	Non- revenue Water (NRW)
	Water Losses (Unaccounted For Water: UFW)	Apparent Losses (Commercial Loss)	Unauthorized water consumption (Unknown water, illegal connection water) Customer metering inaccuracies	
		Real Losses (Physical Loss)	Leakage on transmission and distribution mains Leakage and overflows at distribution reservoir Leakage on service connections up to point of customer metering	

Source: JICA, (2020).

2.4.1 System Input Volume

This is the overall volume of treated water that has been supplied from the treatment plant's clear water tank to the supply areas or that which is pumped from the ground and supplied into elevated storage reservoirs and consequently distributed to the consumers. This is therefore that quantity from which other components of water balance are computed.

According to Mastaller and Klingel, (2017), authorized consumption is the volume of metered and/or unmetered water consumed by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. Authorized consumption therefore, include water consumed in firefighting and training, flushing of pipeline and sewers to remove sediments, street cleaning, public fountains, frost protection, building water, etc., which may be billed or unbilled, metered or un-metered. Most utility offices in developing countries don't pay water bills yet use water for daily office maintenance leading to an un-quantifiable amount of NRW.

Billed and unbilled authorized consumption is the Metered Consumption from users including Unmetered Legitimate Consumption such as which but not billed leading to loss in revenue Mastaller and Klingel, (2017).

According to Alegre et al., (2016), billed metered and unmetered consumption refers to all those consumption that are able to produce revenue for the utility. This includes domestic, commercial, industrial or institutional connections. According to the same study, Billed unmetered consumption is calculated through estimation for the period of time when the customer's meter is malfunctioned but can be the key contributor to NRW. Billed unmetered consumption is obtained from the utilities billing system such as water connected under emergencies like those found in refugee settlements and other emergency resettlements. This category mostly covers connections under small water systems constructed by Non-Governmental organizations (NGOs) or other international agencies for rural growth centers, where connections are in Public Stand Posts (PSPs) or kiosks for the community. These generally have high amount of NRW since consumption is not regulated because it does not have standard billing plan but based on estimates. Unbilled metered connections include water used by the utility itself in facilities such as; offices, toilets, cleaning, drinking, shower, etc. or water provided to institutions free of charge, including water transferred across operational boundaries both metered but unbilled. According to Vermersch et al., (2016), this category is a small component of the water balance, and the volume should be established similar to billed metered consumption. Therefore, NRW is computed using the equation 2&3 below;

$$NRW = \text{Systems Input Volume} - \text{Billed authorized consumption} \dots\dots\dots (2)$$

$$NRW(\%) = \frac{\text{System Input Volume} - \text{Billed Volume}}{\text{Systems Input volume}} \times 100 \dots\dots\dots (3)$$

Apparent losses are the quantities of water consumed by customers but has not generated financial benefits, such as water theft, inaccurate customer meter dials, wrong data recording and handling, and billing errors. Apparent losses also include other authorized uses by the utility but is not billed, such as water used for washing network pipes or for the fire department AL-Washali & Kennedy, (2019). This category of losses includes all types of inaccuracies associated with customer metering, data handling and billing errors, and illegal water consumption from unauthorized connections/water theft.

2.4.2 Causes of Real/Physical losses

There are several causes of NRW in water supply systems which are categorized under physical and apparent losses. Physical losses occur from bursts and leaks from transmission, distribution and service lines up to the customer taps stand. They are regarded as physical losses because they are observable and repaired within a short period of time. Leakages can occur from broken pipes, fittings and joints and connections from sanitary facilities like sinks and toilet basins, etc. these losses are further exuberated through poor operations and maintenance of the system in situations where there is non-active leak control, poor pipes laid, substandard fittings etc. one other contributing factor to the growth of NRW and the dangers it poses to the community's sustainability Chan et al., (2017). Another common observable cause of NRW is vandalism by the community members especially people who have not been connected.

2.4.3 Loss from transmission and distribution mains

Large losses emanate from transmission and distribution pipeline through pipe bursts, leaking pipes from cracks or sockets, joints, air valves wash out valves, and other fittings used in the pipeline. Some of the losses are caused by aging materials used in the installation, substandard materials, poor workmanship emanating from poor supervision, and to some extent from extreme climatic conditions. Water losses on distribution and transmission mains

especially in large systems also occur from break pressure tanks (BPTs) which generate a new level of water and creating a pressure zone within the operating limits of the pipe Aymar, (2020), and in any event of blockage downstream, there is uncontrolled overflow leading to massive unquantifiable loss. Air release valves are installed at highest points along the pipeline at convenient intervals especially in large water systems to regulate high pressures generated during supply hence reducing the hydrostatic pressure to zero or local atmospheric. In the process of performing their functions, a lot of water is lost from these orifices due to damaged rubbers. Wash out valves (WOVs) are installed at low points along the pipeline to facilitate the draining off water for the purpose of flushing and repair can contribute to water losses especially from water theft if adequate protection to the manhole covers are not provided. NRW also occur as a leakage on user connections (fittings of a tap stand) such as male adaptor, straight connectors, water meter, gate valve, tap, or from other Galvanized Iron (G. I).

2.4.4 Losses from reservoirs and storage tanks

Leakage occur from between the loose joints of reservoir plates while overflows from reservoirs and storage tanks occur when the supply overwhelms the demands. In most cases it occurs when pumping operation is continuous and the reservoir /tank is filled. The observation from both gravity and pumped systems showed that when the pump attendant starts the pump and goes on errands or when water is pumped at night and the attendant falls asleep then an unquantifiable amount of water is lost through overflow. While, most overflows occur at night when demands are low, it is essential to undertake regularly night observation either physically or by installing a data logger which record reservoir levels automatically at preset intervals. NRW also occur at the storage Reservoirs from the leakages in the plate joints which are not properly sealed or those with damaged rubbers seals. Loss from overflows from the utility's storage reservoirs results from continuous pumping even

when the reservoir is full as a result of negligence on the part of the attendant. There are scenarios where pump attendant switches on the pump and moves out to do his or her personal errands far away from the source, the generator runs until either it runs out of fuel and stops or until the inverter auto stops Author, (2022).

2.5 Customer Metering Inaccuracies and Data Handling Errors

Apparent water losses are caused by customer meter inaccuracies and data handling errors in the meter reading and billing system Ncube and Taigbenu, (2019).

2.5.1 Under-billing of unmetered registered customers.

According to Vermersch et al., (2016), Authorized Billed Unmetered Consumption is one big challenge of water utilities as many are given estimated water bills. A scenario where connections are made during construction but without focusing on the business model aspects of O&M. This practice is quite common in water schemes constructed and handed to the village leadership and those constructed in the refugee settlement. Households pay standard monthly set out tariff regardless of the number of persons per household and the consumption levels. For example, many households under such arrangements are found in schemes in Northern Uganda, particularly in schemes donated to the refugees host communities where each household pays UGX 1000 per month (\$3.6). The rate of NRW in such systems are too immense to break even, and in most cases has to rely on politicians and well-wishers for repairs and replacement of broken components.

Meter reading errors are situations where billing clerks record wrong reading either intentionally through collusion with the user with a customer to record low consumption for corrupt tendencies or unintentionally as a result of negligence.

Meter under-registration occurs when a consumer meter counts only a fraction of the total water amount that has passed through the consumer meter. This so often occur under the following conditions; meter wear and tear, incorrect installation practice, lack of maintenance

or calibration, defective meters, quality of the meter, and incorrect meter sizing to some extent.

Illegal connection is one big contributor of NRW because of water theft which mainly occur when some consumers deliberately bypass the water meter to get water for a period of time until they are detected and disconnected, metered, or fined and billed. Some causes of water theft are as a result of water scarcity, poor management practices, inadequate user sensitization and awareness, high tariff that does not conform to the purchasing power of the community, delayed connection of applicants, and users that don't qualify during promotional connections during construction. Some of the common factors that pose obstruct utility companies in their efforts to eliminate illegal connections are;

1. Users fixated mindset that water is from government and should be made available without charges
2. Political interference from local politicians especially in RGCs for political capital at the expense of water utilities (Author, 2022)

The other reasons for illegal connections are; lack of knowledge in the operations of piped water systems, inappropriate water tariff system and the inability of individuals from making connections due to financial constraints or those applicants who fail to qualify for promotional connections. Also the delays in connections of new applicants by the water utility creates favorable conditions for illegal connections to prevail especially during dry seasons when the water demand tends to outweigh the supply. Other challenges faced by water utilities are;

Billing error is a scenario where the meter reader incorrectly reads or records the customer consumption leading to the customer being billed the wrong amount due to those errors of omission and commission by the utility's billing office. The factors contributing to billing

errors include; A computerized system that estimates the consumption of inaccessible premises, Meter readers recording wrong figures, Inefficiencies and flaws in the billing systems especially in the calculation and correction, and Clogged micro meters that obstruct clear calibrations of consumption Zavašnik, Šestan and Škapin, (2022)

Studies have been conducted over 63 countries, and the findings are that the key drivers of water losses are linked to the physical characteristics of the water system and environmental factors like urbanization and land settlement patterns Van den Berg, (2015). Furthermore, high NRW rates may be caused by poor management skills, inadequate training of workers and experts, lack of timely replacement of devices, and inappropriate selection of pipes Tabesh et al., (2018).

2.6 Relationship between pipe materials characteristics and Non-Revenue water

Transmission mains consist of pipes that convey large amounts of water over great distances to the storage reservoirs and subsequently to the distribution pipelines. Transmission mains are constructed from a number of materials such as; Galvanized Iron, Ductile Iron, Steel, unplasticized polyvinyl chloride (uPVC), High Density Poly Ethylene (HDPE) pipes etc, of different sizes depending on the demand patterns. These pipes have different sizes, properties, and installation requirements to fit the design purpose, and are prone to failures when certain properties have deteriorated hence leading to water losses. Water loss is a common phenomenon in nearly all water transmission network but with varying levels per countries, and from one distribution system to the other Duffy, (2019)

Different studies have shown that NRW is influenced by leakages due to aged and corroded underground assets Tabesh et al., (2018), which can be improved with pipe replacement and immediate repairs to prevent NRW prevalence rates. It is therefore very crucial to assess the piping materials and laying operations adequately supervised throughout construction phase

to prevent future occurrence of regular breakdowns. According to CUDRC, (2020), 50% of pipes break annually as a result of using asbestos–cement pipes, while (DIPRA, 2016) made comparisons between cast iron pipes and ductile iron pipes, and found that the ductile iron exhibited increased resistance to breakage as a result of rough handling during shipping and installation, and occasioned by greater margin of safety against service failures due to ground movements and beam stresses than cast iron pipes. The study further illustrated that ductile iron pipes provides a clean tapping process using specialized tools and techniques using polyethylene encasement along with a convenient spigot and socket joint which provides an enhanced toughness, impact strength, and resistance towards corrosion than cast iron pipes.

Folkman, (2018) conducted a study on pipe durability and reported that corrosion is one of the significant factor in the service life of pipe yet 28% of all pipe failures are caused by its impacts on pipes. Despite the improved strength and corrosion resistance in comparison with cast iron, Wang, (2018) found that graphitic corrosion is still observed in ductile iron pipes. A further study conducted by (Ruchti, 2016) confirmed the fact that Graphitic corrosion is a deterioration that mainly occurs in gray cast iron where metallic constituents are selectively leached and the graphite is left behind, where the thin wall of metal pipes makes them more susceptible to corrosion. In order to reduce corrosion in metal pipes such as ductile iron and mild steel Ruchti, (2017). The same study suggested that pipe linings (inside the pipe) and coatings (outside the pipe) be used with cement mortar lining so that the metal pipes create more resistance to chemical degradation.

The issue of corrosion and leakages remains prominent, and in this regard, traditional iron and steel pipelines were initially believed to have a long service life expectancy in the application of water distribution systems but in recent times its life expectancy has been reduced due to corrosion effects, especially in acidic soil environments due to the soil

properties where the deterioration of both ductile iron and steel pipe are highly influenced by corrosive soil Hou et al., (2016).

In order to have an understanding on the influence of pipe characteristics on strength, Kowalska et al., (2016) described polyethylene pipes as having a pressure resistance of 23 MPa in tensile strength making it weaker than steel pipes with a tensile strength range of 400~650 MPa. The study further illustrates that Polyethylene pipes can deteriorate under specific conditions such as exposure to organic chemicals from chlorinated water and polluted soil despite the fact that they have corrosion resistivity. In summary, Holder et al., (2019) concluded that the soil pollutants can diffuse through the polyethylene pipe which affects the quality of drinking water, implying that the practice of adopting inappropriate selection of piping materials for the water supply system can lead to an early failure of the water pipes leading to high NRW prevalence.

The pipe burst comes along with the risks of accidents leading to enormous economic losses, and have a significant impact on the environment. Therefore, the pipe burst should be prevented and reduced to a larger extent as much as possible by all stakeholders involved in management of water supply system. The frequency of failure of pipes in water distribution networks is increased over time mainly due to deterioration and subsequently increases on operation and maintenance costs while impairing the quality of services of hydraulic integrity of network. This is because the original properties of the pipe during manufacture has deviated due to excess stresses that have beyond the its capacity to cope, hence compromising the design lifespan of the pipe.

Additionally, proper budgetary allocations should be provided for O & M with regards to replacement of all aging infrastructures. Wu and Liu, (2017) also conducted an analysis on the relationship between non-hydraulic factors and pipe failures, and discovered two factors

deemed responsible for pipe failures which includes; (a) the type of material from which the pipes are made, and (b) the diameter of the pipeline. The different types of pipes used in the water distribution system are; galvanized pipes, glass fibre reinforced polymer (GFRP) pipes, polyethylene (PE), other plastics, ductile cast iron, gray cast iron, steel, multi-layer steel-plastic pipe and concrete pipes because they all have different properties that if not properly installed can contribute to adverse post construction failures. However, Alzabeebee et al., (2017) reviewed and refuted these findings and provided a counter explanation that the scholarly literature does not provide clear conclusions about the effect of the pipe diameter and pipe mounting depth on the pipeline behavior, and that most studies have focused on certain types of pipes, certain pipe diameters and certain pipe mounting depths which are not ideally conclusive. The findings however were predominantly focused on the pipeline installation with regards to impacts caused by road traffic but not failures solely dependent on water supply system with its pipe routing environment. Wu and Liu, (2017) also conducted a Study to have an understanding of the relationship between pipe bursts and piping materials using galvanization, glass-fiber-reinforced, polyethylene(PE), other plastics, nodular cast iron, ordinary cast iron, steel tube, steel-plastic composite pipe, and concrete pipe and reported that the percentage number of pipe bursts were observed in galvanized pipes with burst ranging from; 39.29%, 48.86%, 45.36%, 50.73%, 48.95%, and 47.13%, followed by plastic pipes.

2.7 The contribution of pipe properties to Non-Revenue water

The hydraulics of any fluid system is defined by the static and dynamic pressures level that permit the system to function through fluid in motion. A pipe water supply system transmits water through the pump to the service reservoirs through transmission pipes and finally to the consumers through the distribution and service lines which are all made possible through an element of active pressure.

A study conducted by Jun and Kwon, (2019) on the Optimum Monitoring Location of Pressure in Water Distribution System revealed that real-time pressure monitoring is important to detect leakage and abnormal pressure changes for the efficient management of water distribution systems, where water pressure in a distribution system should be cautiously monitored for effective operations and maintenance of the system. In many water distribution systems, leakage through pipes generally evolve into burst type of leakage and background type leakages characterized by quick pressure surge easily detected by measuring instruments like pressure sensors stationed at specific locations along the length of the pipe. Pressure related background leakage in water distribution networks is hidden and runs continuously along the length of the pipes and can be controlled by reducing pressures at the pipe nodes. A study conducted by Adedeji et al., (2018) on Leakage Detection and Estimation Algorithm for Loss Reduction in Water Piping Networks reported that most background leakages are not detectable by measuring instruments and do not surface on the ground yet can go unreported for a very long period of time posing a major threat to water utilities in terms of NRW and contamination. Gravity flow system being designed to operate for 24 hours a day develops high pressures at night during low demand because the reservoirs get filled up and the valves closes hence the pressure keeps building up in the transmission mains due to constant causing pipe bursts. In ideal situations, the system should remain equilibrium state (no supply) which is not the case when ball valves are defective. In other instances, the systems functionality is affected by several factors which include the installed pipeline components and fittings like malfunctioned ARVs and WOVs.

2.7.1 High pressure during low demand conditions

High pressure during low demand conditions have the potential to cause pipe bursts or leakage leading to large amount of water losses through the network where dealing with such occurrences necessitates the use of pressure release valves (PRVs) to reduce and regulate

pressure in the system. A study conducted by Muler, (2018) on the effects of high pressure on systems components reported series of pipe breaks and leaks that caused significant disruption in the system as a result of unnecessarily high water pressures in the pipeline as a result of low demand due to a series of water rationing measures.

2.7.2 Low pressure during high demand

According to Vermersch et al., (2016), low pressure in the pipeline occur from negative flow which results in the deterioration of water quality as the surge can disturb deposits in the pipe or on the pipe wall. The study further suggested that Pressure losses are caused by the action of friction at the pipe wall whose magnitude is dependent on; the water demand, properties of the fluid that is passing through the pipe, the speed at which water is flowing, the internal roughness of the pipe, pipe length, gradient and diameter of the pipe. The study recommends that water utilities should achieve a high degree of hydraulic integrity through a combination of proper system design, and operation & maintenance along with good preventive maintenance as opposed to corrective measures. On the relationship between pressure and new leaks developing. Vermersch et al., (2016) explains that the frequencies in the pipe bursts vary with pressure for individual district metered areas and for large supply systems.

2.7.3 Pressure Change due to Velocity Change

A study conducted by (Jeff, 2018) noted that fluid velocity changes with the changes in the internal flow area of the pipes, where the reduction in the size of pipe undergoes increment in velocity which in return decreases the static pressure. In the event that the pipe diameter is constant, the Study suggested that the velocity remains constant and no change is observed in pressure due to a change in velocity which can be computed using Bernoulli Equation 4

$$p_1 - p_2 = \frac{\rho}{144} \left\{ \frac{V_1^2}{2g} - \frac{V_2^2}{2g} \right\} \dots\dots\dots (4)$$

To determine the total change in the static pressure of a fluid as it flows along a pipeline, the study recommends full adoption to analyze pressure in the oscillations pipeline. A further study conducted by (Alawee et al., 2019) reported that the static pressure in the fluid increases from inlet to outlet with the changes in elevation or velocity which eventually increases the pressure greater than the decrease resulting from head loss.

2.7.4 Hydraulic modelling in pipeline

A hydraulic modelling uses the application of a versatile tool that are used both at the stage of designing a new network and during the operation of an already existing network Kapa, (2021). The tools involve the use of information technology and available software that offers a range of unlimited possibilities to solve problems related to water distribution that would not be possible with conventional methods, and offers the possibility of simulating the quality and properties of water supplied in the network to guide in decision making process on the current operations in a water supply utility company. Hydraulics uses a range of software and Technologies to measure, analyze and investigate water current, water quantity, water pressure, water velocity and other items in pipes. It guides water utilities such as NWSC and UWAs to maintain their water systems and plan for future growth with the purpose of identifying any existing deficiencies and determine the type of intervention to ensure that the system can provide the required flow and pressure to the consumers. Most GFSs like Nyarwodho GFS are designed for water to flows under gravity without any application of external energy to deliver water from source to the consumers. In order for a GFS to work effectively, the pipes have to run full bore to deter air locks through providing ARVs at convenient locations along the transmission and distribution pipelines Bogna, (2021). For longer lines, series of break pressure tanks are constructed to cut pressure to atmospheric with the objective of minimizing construction cost of materials as pipes of higher pressure ratings would be used. This method works for as long as the spring tank is at the highest point in the

system where there is adequate height difference between the spring tank and the reservoir tank to permit a sufficient flow rate once friction losses have been taken into account. Gravity flow systems so often encounter situations where the flow experiences opposition to gravitational flow due to change in topography hence contributing significantly to non-steady flow in the pipeline.

2.7.5 Topography

According to Wannapop et al., (2018) who conducted a study on effects of elevation on Urban Water Distribution Model using EPANET software with calibrations performed on the basis of pressures measured during 24 hours conducted field measurements of water pressure at different points of the MWA network using flexible pressure transmitters. According to (BigSprinkler.com, 2018), elevation can change the pressure both positively or negatively depending on the direction of the flow and the elevation at the different points, which requires pressure build-up in the pipeline to push water uphill. The study concluded that for every 10 feet of rise there is a pressure of -0.03N/mm^2 was lost while for every 10 feet of fall in elevation, Positive pressure of $+0.03\text{N/mm}^2$ was gained

2.7.6 Pressure change due to head loss

Jeff (2019) conducted a theoretical study on pipe flow and reported that head loss in itself does not reduce the fluid velocity and does not affect the elevation head of the fluid. The study further suggested that basing on Daniel Bernoulli theoretical equations of fluids, the total energy of a fluid remains constant along a streamline on assumption that no work is done on or by the fluid and no heat is transferred into or out of the fluid. The study implied that the total energy of the fluid is the sum of the energy the fluid possesses due to its elevation head, velocity head, and static pressure head as illustrated in the (Equation 5).

Total Energy = Elevation Head + Velocity Head + Pressure Head.

$$TE = Z + v^2 + \frac{144P}{\rho} \dots\dots\dots (5)$$

2.7.7 Pressure Change due to change in elevation

Jeff (2021) further discussed the positivity and negativity of change in elevation and reported that the upstream location can be at higher elevation than the downstream location which is for the ideal flow, and that the energy conversion acts to decrease the static pressure if a given fluid is flowing up to a higher elevation, the study suggests that whenever the fluid flows down to a lower elevation, the change in elevation head acts to increase the static pressure at a given temperature as presented in (Equation 6).

$$(P_1 - P_2) = \frac{\rho}{144} (Z_1 - Z_2) \dots\dots\dots (6)$$

Where; TE = Total fluid energy (feet of fluid), Z = elevation of the fluid measured from a reference plane (feet), v = fluid velocity (feet/sec), g = gravitational constant (32.2 ft/sec²), P = static pressure (psi, or lb/in²), ρ = fluid density (lb/ft³), and 144 = conversion from in² to ft²

2.8 Strategies of Reducing Non-Revenue water

Reducing NRW prevalence in piped water supply system is a key requirement for any utility company to achieve break-even and sustainability for the purpose of effective service delivery and profit maximization. Various NRW control measures have been suggested which includes Aiming for efficient leakage recovery, Dividing the water network into sections, Quick assessment and repairs, Monitoring network activities, controlling network pressure, Setting an NRW limit and follow up, tackling illicit consumption, using Quality products and solutions, Training and education, Using all the available data among others. Controlling and mitigating the effects of non-revenue water calls for concerted efforts by all key stakeholders in the water sector by developing a holistic set of strategies that can be adequately operationalized by water utilities Reis et al., (2023).

2.8.1 Pressure Management

According to Vermersch et al., (2016) Pressure Management involves both increases and decreases in pressure, at different times of the day or year”. The study further elaborates that pressure management is one of the fundamentals of effective leakage management policy which should be adopted by water all utilities as part of their leakage management strategies. The importance of maintaining consistent pressures with minimal variations is to understand the relationships between maximum pressure and rate at which new leaks occur, the relationships between pressure and rates of flow from existing leaks, Predicting the effects of pressure management on leakage rate, consumption and income, influence of minimum standards of service, and topography respectively.

2.8.2 NRW Reduction Dependent Factors

Reducing NRW plays an important achievement by water utilities due to a number of benefits. According to World Bank (2016), NRW reduction provides the following benefits;

- financial gains from increased water sales or reduced water production, including possibly the delay of costly capacity expansion;
- increased knowledge on the distribution system;
- increased service coverage due to increased pressure;
- reduced risk of contamination due to reduced points of contamination
- reduce energy consumption due to reduced pumping duration

2.9 Gap in the literatures

In as far as several studies were conducted on NRW in piped water systems, the focus were primarily on pumped systems. Not much attention has been put on investigating the NRW in Gravity flow systems like Nyarwodho GFS under varying topographic conditions and coverage areas. The typical 100% gravity flow systems functions 24 hours and have

significant challenges on the hydraulic integrity of the transmission pipeline such as pressure oscillation that negatively or positively impact on the consumers and hampers the sustainability of such systems such as Nyarwodho GFS. No study has ever been undertaken on the performance of this gravity flow system which, just like any other GFS do experience operational challenges which impacts on its sustainability hence the need for the study.

CHAPTER THREE: METHODOLOGY

3.1 Description of the Study area

The study was carried out in the present Nyarwodho gravity flow scheme supply area, which is situated in the districts of Nebbi and Pakwach. The transmission mains in the Nebbi district, from the Break Pressure Tank 1 at coordinates 2°24'37.35"N, 31° 3'10.52"E to the Nyaravur storage reservoir at coordinates 2°26'36.72"N, 31°11'14.37"E, were the specific focus region.

However, in order to have a deeper understanding of the sources of water losses in the scheme, losses emanating from; water usage at the treatment plant including staff consumption at treatment plant, usage at water offices, the storage tanks, distribution mains and service lines, and tap stands were studied.

The River Nyarwodho, which is situated near the border between Uganda and the Democratic People's Republic of the Congo at coordinates 2°22'42.15"N, 31° 2'35.77"E, provides the raw water utilized by the residents of Nebbi and Pakwach Districts. Because of the area's low water table, which makes ground water abstraction challenging, the supply regions are totally dependent on surface water.

Hence the government of Uganda constructed the system in two phases; from 2014 to 2019, to bring water to the stressed communities at relatively very affordable tariff of an equivalent of UGX 2,200 an equivalent of \$0.60 per cubic meters of water. The system currently has 1850 user connections of different service levels and serving a population of 30,000 people. The Map of the study area as it appears on map of Uganda and google map are presented in (Figure 3-1) while the surveyed pipe routing of the study focus is presented if Figure 3-2 below.

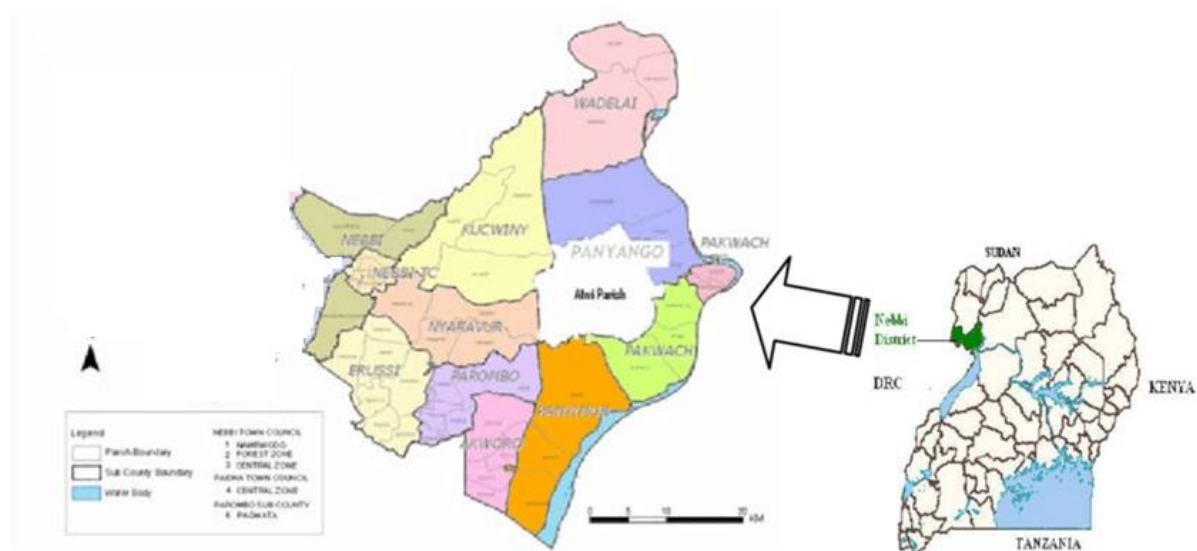


Figure 3-1: Map of the Project Area from Uganda

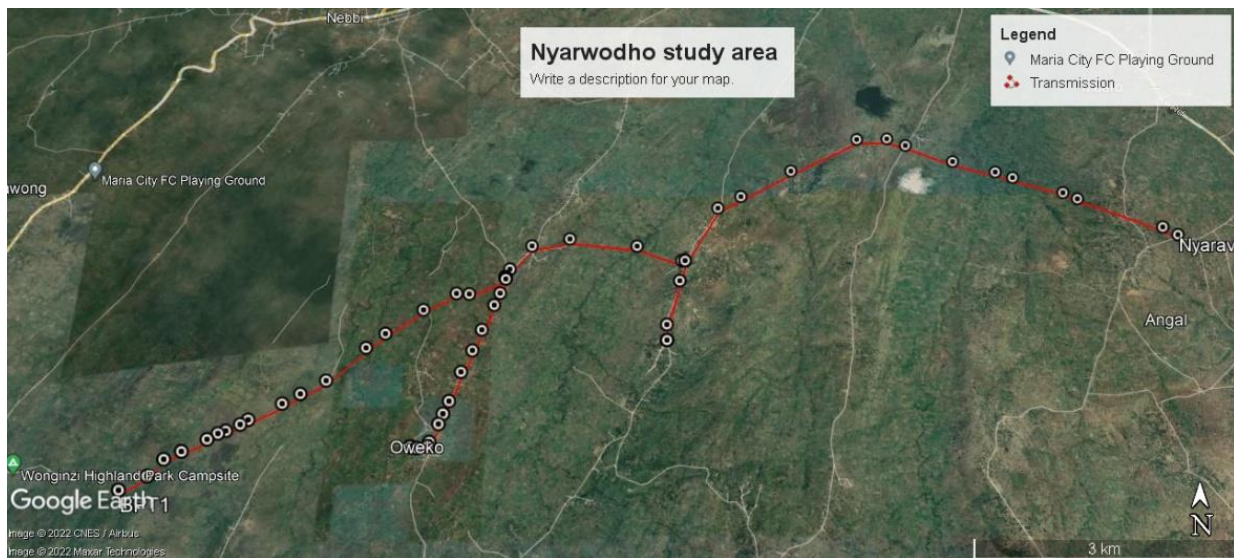


Figure 3-2: Google Map of Study area

3.2 Research design

This Study adopted descriptive methodology to perform both qualitative and quantitative analysis. Field survey and mapping was used to assess possible causes for NRW prevalence/ phenomenon in in the identified study area.

3.3 Research approach

The study adopted different methods/ techniques for data collection, analysis, and interpretation for each specific objective as elaborated.

3.3.1 Study population.

The study population included; 65.45Km of transmission mains and some sections of distribution pipeline which had records of persistent failures together with their installed fittings, Six (6) storage reservoirs that had high records of overflows, section of service lines and the assorted fittings, 4 water offices, 1 treatment plant, 16 plumbers, 1 scheme operator, 1 commercial officer, 1,760 domestic consumer households, 40 institutions, 30 commercial households, and 20 yard tap attendants. A period of four (4) years have been studied from April 2018 to December 2021 for a comprehensive tracking and understanding of the level of water losses prevalence in the scheme. All these were analyzed to ascertain the average level of water losses in the scheme.

3.3.2 Sampling technique

To determine the required sample sizes for the section of transmission, a 15.39 Kilometers stretch from Break Pressure Tank one (BPT1) to Nyaravur main reservoir was covered out of the total 65.45 Km length of the transmission line, all 16 plumbers spreading in the six supply zones were chosen, 1 scheme operator, 1 commercial officer were selected to understand the impact of NRW on scheme employees. To understand the impact of NRW on water users, 141 domestic consumer households out of 1,760 connections, 13 (32.5%) institutional connections, 10 commercial connections (33.3%), and 20 (100%) Public taps attendants were adopted. The targeted a sample size was for the registered user connections from 9 supply zones to avoid bias. This was to minimize costs of movements, as well as avoided the biasness associated with small samples that may lead to non-representativeness of samples leading to re-doing the work.

3.3.3 Sampling strategy

Because they had the much-needed knowledge derived from extensive O&M expertise on the scheme's operations, the research used a purposive sample approach for the Scheme staff, interviewing 16 plumbers, 1 scheme operator, and 1 commercial officer. This was due to the fact that these groups are fully aware of the strategy and are prepared to supply the necessary information. Since they were limited in number in comparison to the water consumers, all of the scheme's technical and commercial staff were questioned. To provide a more representative and fair likelihood of research participation, water customers in their respective connection groups were chosen via purposeful sampling. With the primary goal of boosting efficiency in population homogeneity, four user types were taken into consideration in order to comprehend the influence of NRW on scheme employees and water customers. Since primary data came straight from the source, it was presumed that it was more trustworthy and that decision-making based on the trusted analysis had a direct connection to the real occurrences. Field surveys, observations, questionnaires, interviews, and photographs were used to gather these data, while the scheme operator's desk review yielded secondary data from the project design report, as-built drawings, and monthly operations and maintenance report, which included information on staffing levels, breakdowns, and repairs. The commercial officer provided the billing data, which comprised daily bulk production records from the treatment plant, records of water billed, and bulk water supplied to consumers from the reservoirs. Details about the various user types and scheme staff are included in Table 3-1.

Table 3-1: Sampling frame adopted for different categories

S/n	Stratum	Population	Respondents	Sample Technique	% tage
(a) Scheme staffs					
1	Scheme Operator	1	1	Purposive	100
2	Commercial Officer	1	1	Purposive	100
3	Plumbers	16	16	Purposive	100
	Total	18	18		
(b) User connections					
1	Domestic	1760	141	Purposive	8
2	Institutional	40	13	Purposive	32
3	Commercial	30	10	Purposive	33
4	PSPs	20	20	Purposive	100
	Total	1850	184		

Hence the total samples used in the study for the categories of water users was 184.

3.3.4 Data Sources

The study used primary and secondary data sources to answer the specific objectives.

Since primary data was gathered directly from the source, it was seen to be more trustworthy and to have a higher degree of confidence in decision-making when paired with a credible analysis that had a direct connection to the real occurrences. Information gathered by observation, photography, interviews, and questionnaires was especially gathered using primary data gathering. Secondary data came from the scheme operator's desk review, which included information from the project design report, the operations and maintenance report, which contained records of repairs and breakdowns, the commercial officer's billing records, which included invoices for water billed to customers and bulk water supplied from the reservoirs, and the treatment plant

3.4 Data collection Techniques

3.4.1 Field survey

A field study was carried out to give geographical coordinates of the various installations along the pipeline, such as air valves, washouts, elevations, and junctions, in order to gather primary data on the causes and sources of NRW, hydraulic modeling, and pipe characteristics. The position coordinates of the various key elements throughout the transmission pipeline study section, including BPT, ARVs, WOVs, Junctions, and the linear distance between successive places, were gathered using a handheld etrex 20 GPS (iEduNote, 2020).

3.4.2 Questionnaire

Questionnaire is a tool or technique used by researchers to gain access to primary data from original sources, where the researcher designs questions of particular relevance to field under investigation Brannen, (2018). A questionnaire was employed in this study to collect detailed first-hand information from participants. Water users and scheme staff were given questionnaires to complete in order to gain a comprehensive understanding of how NRW affects water users. The researcher provided full guidance to each respondent in the event that they were unsure about a particular section of the questionnaire. The average monthly number of pipe bursts and leaks on the transmission line, the average monthly number of pipe bursts and leaks on the distribution line, the frequency of pipe bursts on the service lines, the time it takes to repair the bursts or leaks, whether the materials are readily available for the repair, the time it takes to deliver the materials from the secretariat, the actions taken whenever the system is down and the repair materials are not available, and suggestions on how to reduce the occurrence of NRW in the scheme were all given to the staff in order to better understand the impact of NRW on the scheme's employees.

3.4.3 Interviewing

Interview is an environment where a researcher provides an honest free discussion with an individual or group of individuals to extract particular information of interest for use in an investigation without any coercion Wang, (2018). Through questioning and evaluating phenomena, interviews allowed the researcher to gain new insights, stay up to date on the current working environment and its potential role in the scheme's NRW prevalence, and give interviewees a chance to bring up issues that the researcher had not anticipated but had been ignoring. Because women are frequently the ones most impacted by water-related issues in the home, and because some men are typically in charge of paying the household's water bills, the majority of the users in this study were women who were interviewed at their homes. They received guarantees that their answer was not motivated by malice but rather by improving the supply. As a result, users voluntarily provided the information that was requested of them and offered suggestions for improving the supply. During the interview, they were asked if they save water and what container they use, how many days a week they receive water, how long it takes for the taps to run empty again, and if they have any complaints or ideas for the water supplier. The outcomes were provided and they were administered appropriately.

3.5 Data analysis

Data Analysis is the process of systematically applying statistical and/or logical techniques to describe and illustrate, condense, recap, and evaluate data to ensure data integrity is the accurate and appropriate analysis of research findings. Qualitative and quantitative data analysis two data analysis methods were adopted for the study. Data obtained from water supply records including records of; water supplied and water billed was analyzed to obtain the annual NRW in the entire scheme. In order to comprehend the connection between pipe material properties and NRW, survey data from the field study was also examined.

Descriptive analysis was used in the study to characterize the main variables and the closest indicator items associated with the study's goals. Microsoft Excel was used to evaluate the quantitative data that was extracted from the main data.

For this study, the relationship between water supplied and NRW was analyzed using water sold to customers in order to understand whether there was significant connection between water losses to the system performance. The act of methodically looking through and organizing observation notes, interview transcripts, and other non-textual information that the researcher gathers in order to better comprehend the dominant phenomena is known as qualitative data analysis. AlDahdouh (2018). The conclusions were supported by the triangulation of quantitative data from questionnaires, observations, interviews, and report records using qualitative data analysis. The study used content and theme analysis, which focuses on identifying, analyzing, and documenting patterns in data, to examine qualitative data. The CSV survey data was created and modified from Excel to an EpaCAD-compatible format using a variety of software programs, including Microsoft Excel and AutoCAD Civil 3D. The hydraulic properties of the pipeline, including pressure, flow, velocity, head loss, etc., were then simulated using data sent from EpaCAD to EPANET. Examining the connection between NRW prevalence and hydraulic integrity in Nyarwodho GFS was part of the investigation.

3.6 Ethical Clearance

The researcher considered the Research values of voluntary participation, maintaining the principle of anonymity and protection for respondents.

Thus the researcher introduced the purpose of the Study as purely academic in nature and not for any other sinister motive. Hence the Researcher requested respondents to voluntarily participate in the Study, and any respondent was given absolute freedom to decline at will. Each respondent was assured of strict adherence to their privacy including protection for their privacy and any possible harm, which eventually earned their trust and brought about their confidence to give audience since the findings would be strictly and only used for the academically intended purpose. Relevant citations and references were compiled to whenever work from the previous studies was added with the objectives of eliminating tendencies of plagiarism.

3.7 Quantifying NRW in Nyarwodho GFS

Total real losses were computed from the record of bulk supply from the treatment plant and cumulative billed water from the customers. The difference was the result of water losses in the scheme which included; real loses and commercial losses. Current annual water losses from 2018 to 2021 was computed using IWA water balance method with 95% Confidence according to Limit Lambert & Liemberger (2018) as presented in equations 7-17 below;

$$\text{Water Loss} = \text{water supplied in m}^3 - \text{water billed in m}^3 \dots\dots\dots (7)$$

Confidence limits for NRW, water losses, and real losses was calculated from the formulas;

$$\text{Confidence Interval (C.I) will be computed from Equation } C.I = [SD/V/0.5 \dots\dots\dots (8)$$

Where; SD = Standard deviation, V = input volume.

$$SD = V*CL*0.5 \dots\dots\dots (9)$$

Where V = input volume, CL = Confidence limit.

$$\text{Variance } V_a = SD^2 \dots\dots\dots(10)$$

$$\text{Unbilled authorized consumption (UAC)} = 0.5\% \text{ of Billed Metered Consumption (B)} \dots\dots(11)$$

$$\text{Unauthorized Consumption (UC)} = 0.1\% \text{ of Billed Metered Consumption (BMC)} \dots\dots(12)$$

$$\text{Customer metering error (CME)} = 2\% \text{ of Billed metered Consumption (BMC)} \dots\dots\dots (13)$$

$$\text{Water Loss} = \text{NRW} - \text{Unauthorized Consumption (UC)} \dots\dots\dots(14)$$

$$\text{Apparent Loss (AL)} = (\text{UC}) + (\text{CME}) \dots\dots\dots(15)$$

$$\text{Real Losses (RL)} = \text{Water Loss} - \text{Apparent Loss} \dots\dots\dots (16)$$

Hence NRW was computed using the equation (17)

$$NRW(\%) = \frac{\text{System Input Volume} - \text{Billed Volume}}{\text{Systems Input volume}} \times 100 \dots\dots\dots (17)$$

3.7.1 Causes of NRW in Nyarwodho GFS

Causes of NRW were identified by inspecting the performance of the system's components which included; Supply situation at the treatment plat, Break pressure Tanks, types of pipes laid and their pressure rating and their assorted fittings which included; JV couplers, flanges, joints, installation workmanship, conditions of wash out and air valves, fittings at Air valves & washouts, storage reservoirs and Break pressure tanks. Detail analysis of the NRW prevalence were obtained through objective 3 and 4.

3.7.2 Relationship between Pipe Characteristics and NRW

In order to understand the relationship between Pipe characteristics and NRW, the following procedures were undertaken;

- (i) Excavation was conducted on a section of buried PVC pipes at convenient intervals to observe for the diameter, manufacturer's pressure rating, pipe age, & installation depth
- (ii) Joints were observed for washout and air valves tightness which included; JVC couplings, flanges, and gaskets and comparison made with the design specifications

3.7.3 Hydraulic modeling on transmission mains

- (i) The pipeline was Surveyed at convenient chainages along the identified 15.39Km section of transmission mains and data from the following installations recorded; the location coordinates, elevations, and description of strategic components like BPT, AVs, WOs, Junctions and storage reservoirs,
- (ii) Data (location coordinates, elevation, and description) were entered into excel workbook in (csv) file format and exporting to civil 3D, manipulated and saved in DFX file format.
- (iii) The DFX file from AutoCAD was exported to EpaCAD which converted it into a readable file and saved in inp file format to make it readable into EPANET software.
- (iv) The inp file was then imported and then subsequently imported as a network to EPANET software for analysis and simulation,
- (v) A pipeline network was generated for the components on transmission section and storage reservoirs,
- (vi) Different parameters including; base demands, pipe diameter and length of pipe, node elevation, tank diameter, tank height, pipe roughness coefficient and other properties of the pipeline were edited in accordance with the specific demands and the supply areas.

- (vii) Hydraulic analysis model was run to understand the hydraulic behavior of the pipeline and reservoir which included; pressure, velocity and the flow.
- (viii) Viewed and observed the current flow behaviors of the study section of transmission mains and compared with the design parameters to check for compliance in terms of velocity, pressure, head loss and elevation.

CHAPTER FOUR: PRESENTATION AND DISCUSSION OF RESULTS

4.0 Answering the objectives

The objectives of the study were answered as described in the (Table 4-1) below;

Table 4-1: Objectives tackling frame

Item	Objective	Data source	Timeline	Purpose
1	To quantify NRW prevalence in Nyarwodho GFS	• Monthly production record • Monthly Billing record	March 2018-December 2021	To get the actual cumulative volume of NRW in Nyarwodho GFS
2	To identify the causes of NRW in Nyarwodho GFS	• Observation • Repair records	Study period	To clearly understand the causes and sources of NRW in Nyarwodho GFS
3	To investigate the relationship between pipe materials and NRW in Nyarwodho GFS	• Records of pipe bursts • Material of the pipe • Age of installation	Study period	To understand the frequency of pipe bursts and leakages in Nyarwodho GFS
3	To conduct hydraulic modeling of a selected transmission mains	• Field survey report • design report	Study period	To compare the designed pressure and the investigated pressure

Sources and causes of NRW was categorized in to two ways under real losses and apparent losses

4.1 To quantify NRW prevalence in Nyarwodho GFS

The treatment plant's monthly supply data and the total monthly invoicing from various customer meters were used to calculate NRW. Tables 4–2 below provide a summary and presentation of the results collected.

Table 4-2: Annual NRW

Month	2018			2019			2020			2021		
	water supplied (m ³)	water sold (m ³)	% sold	water supplied (m ³)	water sold (m ³)	% sold	water supplied (m ³)	water sold (m ³)	% sold	water supplied (m ³)	water sold (m ³)	% sold
Jan	-	-	-	44356	4815	11	44,862	13688	31	45,967	8634	19
Feb	-	-	-	47543	15258	32	48,336	11323	23	34,636	8754	25
Mar	-	-	-	18796	6143	33	39,110	8280	21	37,444	7849	21
Apr	43432	1784	4	41819	7635	18	45,765	8109	18	38,619	9857	26
May	43867	3777	9	42349	5854	14	43,957	8793	20	33,065	8962	27
Jun	43870	3528	8	38210	8213	21	35,867	8687	24	35,043	11203	32
Jul	44652	2735	6	40641	7746	19	41,794	7967	19	36,336	8242	23
Aug	43876	2483	6	38118	6639	17	33,989	8423	25	40,247	9926	25
Sept	45735	1752	4	27772	6832	25	38,915	7282	19	37,264	9284	25
Oct	45890	1848	4	30117	7412	25	33,880	8921	26	40,905	13397	33
Nov	42178	3092	7	27747	6421	23	32,784	7846	24	41,696	9980	24
Dec	48674	6506	13	48974	7622	16	33,186	8341	25	30,788	8407	27
Total	402174	27505	7%	446442	90590	20	472,445	107,660	23	452,010	114,495	25

As presented in Table 4-2 above, the year 2018 exhibited the lowest amount of water sold at 7% from the 402,174m³ of water supplied and only 27,505m³ sold. An increment in sales was observed in the year 2019 with 446,442m³ of water supplied and 90,590m³ sold an equivalent of 20%. 2020 had 23% of water sold from 472,445m³ supplied against 107,660m³ sold. Finally, the year 2021 showed additional progress in water sales with 25% of water sold from the 452,010m³ supplied against 114,495m³ sold to the customers

4.2 Real losses

Records of the bulk water production at the treatment plant, the volume used for backwash, records from the bulk meters of the storage reservoir, and estimates of losses from leaks and bursts from the pipes and their various fittings—BPTs, ARVs, WOVs, flanges, couplings, and losses from the tap stand components—were used to determine the actual losses from various system components. These losses from the various parts of the system were divided

into two categories: unavoidable annual real losses (UARL) and current annual real losses (CARL).

4.3 Annual water losses

The average yearly water loss was calculated by adding the losses from treatment operations, which included backwash losses (water sold to consumers that was taken from micrometers) and losses from water provided to the zones plus staff consumption from the treatment facility. According to data from the report on the system's annual NRW prevalence from April 2018 to December 2021, the operator's first year of takeover (2018) had the highest average NRW percentage (93.16%), followed by 79.71% in 2019 and 77.21% in 2020. The lowest recorded NRW was 74.67% in 2021 as presented in (Figure 4-1).

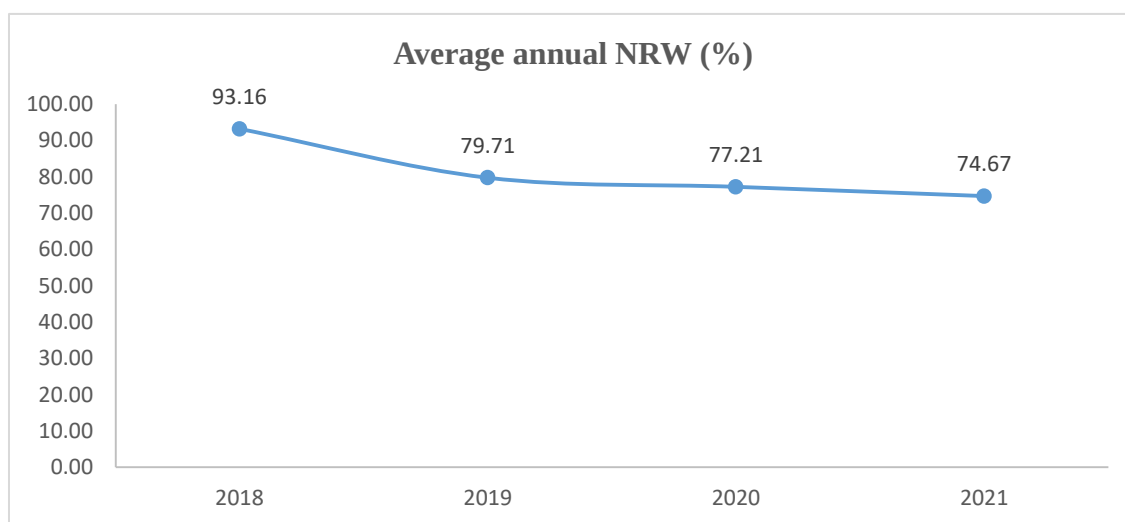


Figure 4-1: Average annual NRW

4.4 Average Current Annual Real Losses (CARL)

The average CARL data from 2018 to 2021 was derived from the water balance calculation utilizing scheme office records, which comprised micrometer consumption and water supply information. These were computed using IWA Water Balance with 95% Confidence Limit, hence the following equations were adopted Lambert & Liemberger (2018)

Confidence limits for NRW, water losses, and real losses was calculated from the formulas;

Confidence Interval (C.I) will be computed from Equation $C.I = [SD/V/0.5 \dots \dots \dots (7)$

Where; SD = Standard deviation, V = input volume.

$$SD = V * CL * 0.5 \dots \dots \dots (8)$$

Where V = input volume, CL = Confidence limit.

$$\text{Variance } V_a = SD^2 \dots \dots \dots (9)$$

$$\text{Unbilled authorized consumption (UAC)} = 0.5\% \text{ of Billed Metered Consumption (B)} \dots (10)$$

$$\text{Unauthorized Consumption (UC)} = 0.1\% \text{ of Billed Metered Consumption (BMC)} \dots \dots \dots (11)$$

$$\text{Customer metering error (CME)} = 2\% \text{ of Billed metered Consumption (BMC)} \dots \dots \dots (12)$$

$$\text{Water Loss} = \text{NRW} - \text{Unauthorized Consumption (UC)} \dots \dots \dots (13)$$

$$\text{Apparent Loss (AL)} = (\text{UC}) + (\text{CME}) \dots \dots \dots (14)$$

$$\text{Real Losses (RL)} = \text{Water Loss} - \text{Apparent Loss} \dots \dots \dots (15)$$

Hence NRW was computed using the equation (16)

$$NRW(\%) = \frac{\text{System Input Volume} - \text{Billed Volume}}{\text{Systems Input volume}} \times 100 \dots \dots \dots (16)$$

The results of average annual water balance for the four years are presented in (Table 4-3).

Table 4-3: Average water Balance for four years

Components of IWA standard water balance	Volume (V) (m ³ /year)			
	2018	2019	2020	2021
System input volume	402174	446442	472445	452010
Billed authorized consumption	27505	90590	107660	114495
Non-revenue water	374669	355852	364785	337515
Unbilled authorized consumption	138	453	538	572
Unauthorized consumption	28	91	108	114
Customer metering error	550.1	1811.8	2153.2	2289.9
Water losses	374641	355761	364677	337401
Apparent losses	578	1902	2261	2404
Real losses	374064	353859	362416	334996

From the Table 4-3 above, it can be observed that physical/real losses contributed the highest cumulative level of NRW in the scheme than the apparent losses.

The average annual water losses were; 374064 m³ in 2018, 353,859m³ in 2019, 362,416m³, in 2020, and 334,996m³ in 2021 respectively. The year 2018 exhibited the highest loss when the system was handed over to the operator which indicates a number of challenges as the scheme was yet new and being such a vast coverage there were so many issues to address.

The cumulative average annual NRW for the four years was computed at 358,205.3m³ out of the systems input volume of 443,267.8m³/year. Water billed and sold only amounted to 19% of the total water supplied. 2020 saw the most annual actual losses, totaling 452,010 m3, while 2021 saw the lowest, totaling 334,996 m3. Details are presented (Figure 4-2)



Figure 4-2: average cumulative Annual Real losses for the four year period

4.5 Relationship between water produced and water sold

To understand the relationship between water billed and water sold, correlation analysis was performed and the findings are on (Table 4-4) with the formula for finding correlation as

$$r = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{N \sum X^2 - (\sum X)^2 * N \sum Y^2 - (\sum Y)^2}}$$

Where; r = correlation, N= Number of years, X = average annual water produced, Y = Average annual water billed

Table 4-4: Computation of correlation between water supplied and NRW

Water produced (X)	Water billed (Y)	XY	X ²	Y ²
414,414	27505	11,398,457,070	171,738,963,396	756525025
458,682	90590	41,552,002,380	210,389,177,124	8206548100
484,685	107660	52,181,187,100	234,919,549,225	11590675600
464,250	114495	53,154,303,750	215,528,062,500	13109105025
1,822,031	340,250	158,285,950,300	832,575,752,245	33,662,853,750

$$r = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{N \sum X^2 - (\sum X)^2 * N \sum Y^2 - (\sum Y)^2}}$$

$$r = \frac{4 * 158,285,950,300 - (1,822,031)(340,250)}{\sqrt{4 * 832,575,752,245 - (1,822,031)^2 * 4 * 33,662,853,750^2 - (340,250)^2}} = 0.0197$$

Therefore, the coefficient of correlation (y) = 0.0197 < 1 hence there is no relationship between water supplied and NRW since water sold is insignificant compared to water supplied.

Coefficient of determination (C.d) was also computed using formula; $C.d = (R^2)$

$C.d = 0.0197^2$. Therefore, $C.d = \underline{0.00039}$.

Coefficient of non-determination (C.n.d) was computed as; $1 - C.d$

$C.n.d = 1 - 0.00039$

Therefore, $C.n.d = \underline{0.999}$ approximately 1 (100%)

From the above results, a lot of water is lost compared to authorized quantities which is water billed. The scheme operates at such a high rate of NRW which requires urgent attention.

4.6 Discussions

The presence of losses emanating from systems components and their assorted fittings such as BPTs, ARVs, WOVs, flanges, couplings, tap stands confirms the findings by Bhagat et al., (2019) which attributed such loss categories Current Annual Real Losses (CARL) and unavoidable Annual Real Losses (UARL). The findings of loss categories using systems water balance has also reflected by a study on non-revenue water previously conducted by Liemberger and Wyatt, (2018), which found that there was a positive trend towards reducing NRW levels in the scheme which indicates that the operator is upping the game towards reducing the prevalence of NRW in the scheme by 18.7% in the last four years. This signifies a little decline in the NRW prevalence but more effort has to be done to reduce it to the acceptable maximum level of 25% for Uganda, and the operator's effort needs to be supported towards achieving a sustainable O & M with even more new strategies.

4.7 Identifying the sources of NRW Water in Nyarwodho GFS

The major sources of water losses in the scheme are presented in (Table 4-5).

Table 4-5: Reported sources of NRW in Nyarwodho GFS

Source	Nature	Avg frequency Per month	water loss
Transmission	Burst	2	unquantified
	Leaks	5	unquantified
Distribution	Burst	7	unquantified
	Leaks	15	unquantified
Air Valves	Leaks	30	unquantified
Reservoirs	Overflow	15	unquantified
service line	Burst	5	unquantified
	Leaks	45	Unquantified
Tap stand	Leaks	58	Unquantified
Water theft	illegal connection	4	Unquantified
	pipe pricks	2	Unquantified

With an average frequency of serious bursts occurring twice in a month, 5 leakages occurring at the joints and sockets per month. The study also found that leaks occurred at least five times per month and that the average minimum frequency of transmission main bursts was twice per month. The distribution pipeline had leaks and bursts on average seven and fifteen times each month, respectively. Because the system serves seven sub counties in the two districts, there are more likely to be bursts and leaks. Because these leaks happen continuously as long as there is water in the pipeline, losses from the air valves have shown a greater frequency and contribute considerably to NRW. The community vandalizes the air valves in an attempt to obtain free water for residential use and animals, which results in some losses and expensive NRW. Due to the seven reservoirs in the project, cases of loss from reservoir overflow were claimed to have happened on average of 15 times each month. The service/intensification pipeline had five bursts from pressure surges, particularly during night flow, and 45 recorded average leaks because of the shallow excavation depth and local vandalism in the form of pipe cuts. As a result, customer tap stands had an extremely high rate of leaks, occurring an average of 58 times each month. This was most likely caused by the large number of leaking taps, gate valves, and water meters that were leaking due to

deterioration. Four instances of illicit connections arose from people evading the regulations and using water in their homes without the water officials noticing. All of these factors combined to cause and still do contribute to the high rate of NRW, particularly physical losses within the program. Details of the findings are presented in Figure 4-3

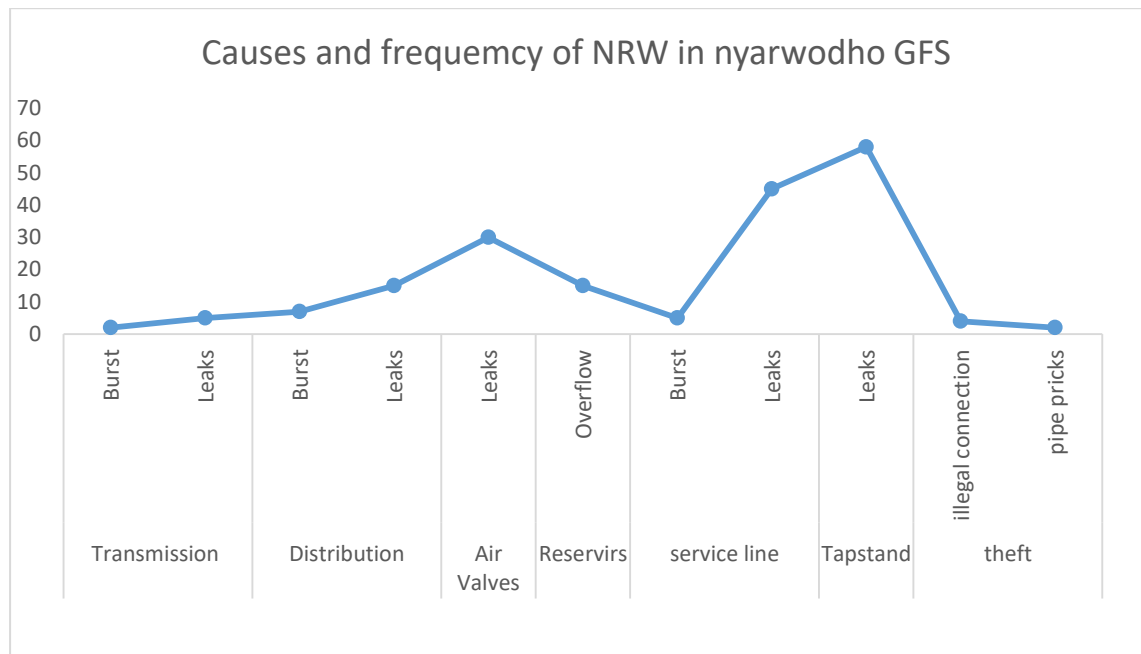


Figure 4-3: Causes and frequency of NRW in Nyarwodho GFS

4.7.1 Losses on transmission mains

The study estimated water losses occurring on transmission mains per a single burst depending on the detection time. According to Table 4-6, the design system flow is 0.044 m³/s, which results in an average water loss of 158 m³/hour and a daily loss of 3,801.60 m³/day.

Table 4-6: Estimated Loss on transmission mains

Hours	NRW (m ³)	Hours	NRW(m ³)
1	158.	13	2,059.20
2	316.80	14	2,217.60
3	475.20	15	2,376.00
4	633.60	16	2,534.40
5	792.00	17	2,692.80
6	950.40	18	2,851.20
7	1,108.80	19	3,009.60
8	1,267.20	20	3,168.00
9	1,425.60	21	3,326.40
10	1,584.00	22	3,484.80
11	1,742.40	23	3,643.20
12	1,900.80	24	3,801.60

This loss is incremental in nature as illustrated by the graphical representation as in figure 4-

4

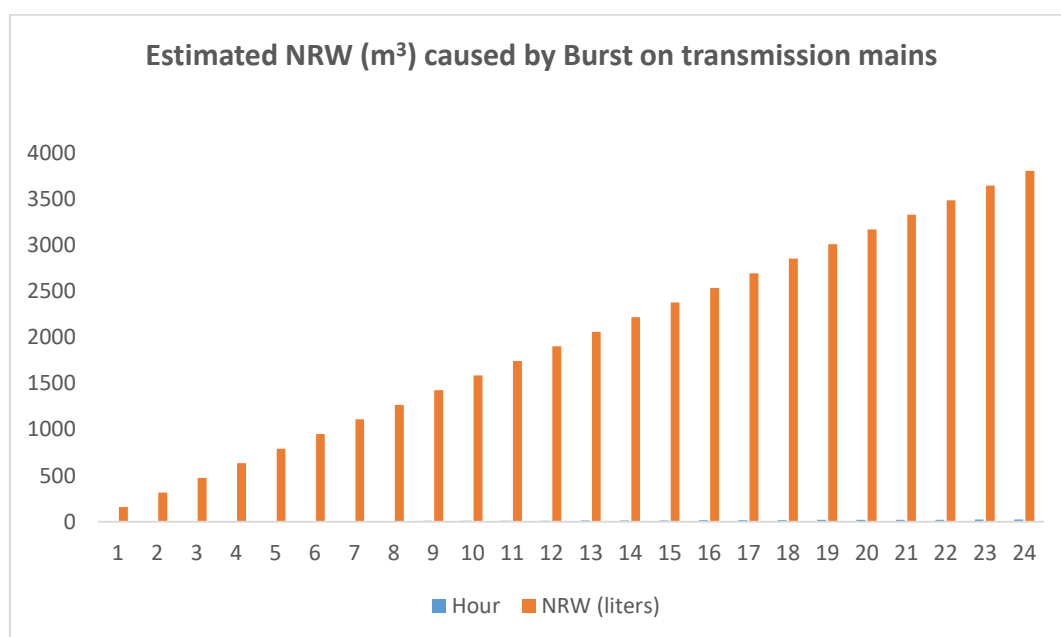


Figure 4-4: Estimated Loss on transmission mains

Pictures of the losses as they happened along sections of transmission mains are presented in

Annex 1.

Discussions

The rate of water loss during a specific time period is directly related to the time it takes for the treatment plant clerk to notice, report, and shut down the systems.

Depending on where the burst occurred, it took different amounts of time to locate the leak along the 15.39 km transmission pipeline segment. While the supply is constant, bursts that happen near the road or in the gardens are reported more quickly than those that happen farther into the uninhabited regions (deep in the jungle), which can take a day or more to be found and reported. The whole pipeline must be drained through the washout in order to repair such a rupture, which results in a significant and incalculable loss of water.

From the scheme records the average twice a month bursts in the transmission mains, massive losses becomes inevitable and unquantifiable as water would be continuously supplied into the pipeline and gets wasted. This finding supports the findings by Duffy, (2016) which attributes physical losses to pipe bursts, leakages and breaks among others which challenges water utilities need to address in order to reduce NRW prevalence.

4.7.2 Loss from Air valves and washouts

Because of the pressure increase in the pipeline, higher losses were also seen coming from the air release valves throughout the transmission network (18 in total). Twelve of these AVs have broken control rubbers, and some of their bolts and nuts have been removed, resulting in a continuous flow of water that the villagers are free to collect and use for laundry.

Due to the pipeline's constant flow, these air valves continuously leak water, which results in an incalculable sum of NRW. Because the manhole for these AVs cannot be locked to prevent unwanted access, vandals may approach the valves, puncture the rubber with a sharp tool, and release water that the nearby communities can freely collect. Additionally, some of these valves have turned into places where livestock get their water, which raises the

possibility of contamination. The majority of washouts have their manhole covers vandalized, much as AVs. Pictures of damages, leakages and vandalism of Air Release and Washout valves presented in **Appendix 2**.

Discussions

Air valves are components meant to reduce high pressures in pipeline yet when they are poorly maintained they can contribute significantly to water losses in the pipeline through flooding. This notion is supported by the findings of c, Karney and Malekpour, (2015) which asserted that among some of the problems associated with air release valves are maintenance problems including but not limited to; inaccessible or confined locations, physical damages to valves, leaks etc. this calls for water utility operators to focus efforts towards regular maintenance of these components.

4.7.3 Loss from Storage Reservoir

Another type of loss was discovered coming from the storage reservoirs. According to the average anticipated losses shown in Table 4-7, the system has reservoirs spread across the seven coverage zones.

It was noted that none of the reservoirs had bulk meters for measuring the amount of water that was supplied to them. The system personnel does not measure the quantity provided to the different supply zones by taking daily meter readings for a few reservoirs with output bulk meters. Even if there was willing scheme workers, no record could be made since some of the outlet bulk meters were discovered to be defective. As a result, it was challenging to precisely quantify the losses resulting from distribution and intensification networks.

Table 4-7: Reservoirs supplied by Nyarwodho GFS

S/No	Reservoir Location	Size(m ³)	Probability of overflow
1	Oweko	33	Low
2	Paminya	33	Low
3	Nyaravur	218	High
4	Alwii	180	High
5	Panyango	115	Medium
6	Pakwach	125	Medium

Source: Scheme operator's report

Although the six reservoirs showed varying degrees of loss, the four main reservoirs recorded the most frequent losses due to overflow since they are mostly fed at night in a system akin to rationing. These happen for the reasons listed below;

- Since there are no attendant residences built in any of the seven reservoirs to monitor and manage any overflow situation, the reservoir attendants do not live at these reservoir locations.
- When the reservoir is full, none of the ball valves that control the flow are working, which leads to overflows.
- Since agriculture is a major source of income in this area, there aren't many attendants hired to monitor and regulate water flows, and some of them leave the reservoir to tend to their gardens. As a result, they can't control overflow by closing the supply junction to redirect water to other supply zones, as is standard procedure in the system.
- Information between the treatment plant clerk and the reservoir attendants can be shared over the limited communication network provided by the several service providers, including MTN and Airtel. Additionally, there is little power in the bushes, which makes it difficult for these attendants to communicate urgently about supplies

on their phones. As a result, some reservoir attendants do not have phones, most likely because they have other domestic-related priorities that interfere with effective communication.

Discussions

Storage reservoirs/tanks are meant to balance the storage of water for some time as water is supplied to the consumers, however, these have instead led to regular losses as a result of constant overfilling, loose inlet and outlets, corrosion of materials, and excessive pressure among others. This study resonates with the findings of Philippines, (2022) and concurred by Asirvatham, (2018) that water system operators should endeavor to ensure they control the quality of materials used for the tank, workmanship and controlled pumping by incorporating the sensors that communicates between the pump station and the reservoir to control overflows. This being a Gravity flow system, it functions 24 hours a day hence supply is continuous both during day and at night to prevent air-lock scenario which require regular and consistent communication by all personnel responsible for the supply. Failure to do this means there is absolutely no regulation of the functionality of the system which ultimately leads to a continuous and more losses.

4.7.4 Losses from distribution and service pipeline

At many supply zones, losses from the distribution pipeline were noted. The service regions of Kucwiny, Angal, and Alwi showed numerous losses as a result of leaks and bursts brought on by excessive pressure. Most of the incidents happened at night since there was little demand, which put a lot of strain on the HDPE pipes, some of which were PN6. Additionally, because of the poor dig depths and placement nearer the access roads, the pipeline was frequently cut by the District local government during road construction and agriculture. The pipe fittings, including male adapters, saddle clamps at the tapping point, and HDPE straight

connections, showed some losses. Appendix 3 contains illustrations of distribution and service pipeline losses.

Discussions

Managing water losses in the distribution system require concerted efforts because it occurs from a number of components that cumulatively if not controlled can significantly contribute to serious losses. This study concurs with a study conducted by Ociepa, Mrowiec and Deska, (2019) which reported that water losses on the distribution system generally result from losses caused by leakages of water from the networks and systems, fittings, materials structures, age of pipe among others which losses are associated with high financial losses. Utility operators should hence focus on the usage of quality pipes of the right pressure ratings during installation, ensure proper workmanship and correct fittings are used during construction and replacements/rehabilitation.

4.7.5 Losses from theft and vandalism

Additionally, it was noted that there were several instances of pipe vandalism, in which individuals willingly cut pipes to obtain free water without the service providers' knowledge. Illegal connections for brick mounding, in-house hookups for restrooms, and for animals were seen in a few instances. These occur especially during the dry season, which lasts from December to April and reaches temperatures of up to 37°C. Appendix 4 provides visual details of the vandalism.

Dissuasion

Losses from vandalism usually occur due to a number of factors such as dishonored connection applications, lack of alternative sources of water, desire for free water even as the distribution line is within one's reach, high poverty level, pastoralism with inadequate access to water for the herds among others. A study conducted by Duffy, (2016) reported that vandalism/water theft are either caused by illegal taps or by the tampering of water meters to

read lower flows than what is actually being used) or unbilled water consumption that is authorized but not properly read or recorded by the utility. This resonates with the findings of this study hence water utility operators should ensure the factors contributing to water theft is addressed to minimize water losses.

4.7.6 Losses from tap stand

The customer tap stand was found to have losses, mostly from leaky fittings, such as taps, gate valves, micrometers, and occasionally the male adapter that was mounted on the tap stand's rise.

In order to reduce on the level of losses from the tap stand, users need to be regularly and consistently sensitized about safe management of tap stands in order to maintain safe water chain. Water is supplied clean and safe from the distribution network to the tap but the way its managed can become a source of contamination through leakages as it attracts animals and a breeding ground for mosquitoes. Users can be motivated to provide simple fencing to prevent access to children and animals, and they should be encouraged to report all leakages/breakdowns of tap stands to the operator for immediate repair and or replacement.

Discussion

A study conducted by tapfaucetadmin6, (2022) attests to the challenges water users face in leakages from taps. It argues that a water leak is a common problem for taps hence getting it fixed is a must because if it is ignored, more problems can be caused especially in the user's month's water bill. The study also recommends that it is important to know the reasons why the tap is leaking in order to know how to properly fix the issue. Leakages can emanate from; the tap's O-ring, cartridge, washer, and other parts that might be loose. Accumulated sediment from water and extremely high water pressure can also cause the water leak of your

taps. Some of these can be an easy fix but it is still better to engage a professional plumber that focuses on tap and faucet to assist you in repairing any leaking taps.

4.7.7 Losses from operational office use

Additionally, it was noted that although the five water offices actually have water connected and being utilized for office cleaning and toiletries, these are not billed. Each office's staffing level is shown in (Table 4-8)

Table 4-8: Reservoirs supplied by Nyarwodho GFS

Office Location	No. of staff	l/c/d	Monthly consumption(m ³)
Nyaravur	10	100	30
Alwii	4	100	12
Panyango	4	100	12
Pakwach	4	100	12
	22	400	66

Given the number of employees using the services, Nyaravur has the highest consumption (30 m³/month), as shown in Figure 4-5. In contrast, the supply areas of Alwi, Panyango, and Pakwach had constant consumption of 12 m³, with an average monthly loss of 66 m³ from staff consumption and an average annual unbilled consumption of 792 m³ from the various offices.

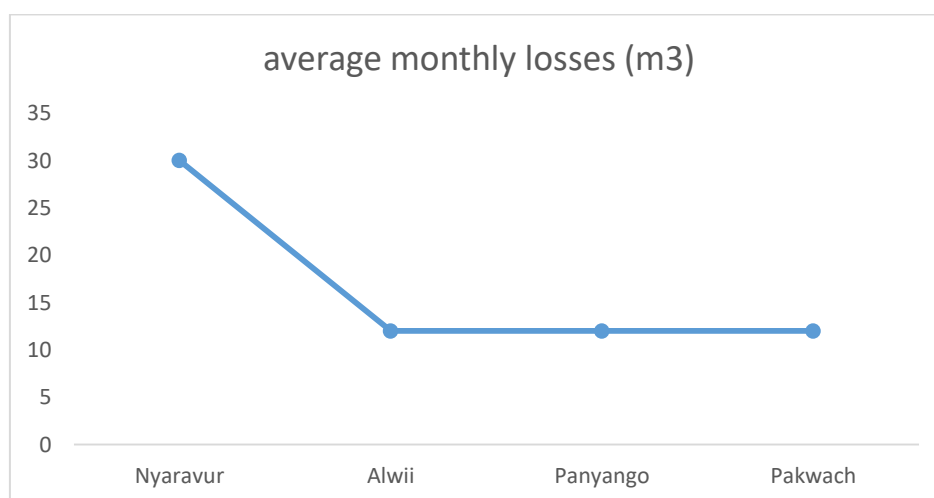


Figure 4-5: Average Monthly losses from water offices

Discussion

In as much as water losses are taken to emanate from other scheme components, consumptions from scheme staffs are so often ignored in many water schemes yet the water usage in those offices may not necessarily be only by the staff but outsiders related to scheme staffs and even their families could be fetching from the taps freely. Visitors and customers who regularly visit water offices also use the same water during visits to the toilet facilities. This means the losses from such offices may be as much as thrice or more than the officially estimated losses. Therefore, all consumptions from scheme offices should be billed and payments made in order to reduce on such recurring losses.

4.7.8 Losses from flushing the end caps

Additionally, the study discovered that cleaning the endcaps of the distribution mains at various supply zones at least every three months results in losses. This is done to remove the settling sediments from the pipes that are caused by contaminated water that enters the pipeline during leaks, bursts, and repair work. When not flushed, water supplied to the customers will be turbid with color and may impair the health of the users. It was however observed that this system does not have provision for firefighting hence there are no losses from fire hydrants.

Discussion

Estimating losses from pipeline flushing is not easily possible however, once the necessary bulk meters are installed at all reservoir inlets and outlets, and after having controlled pipe leakages and reservoir overflows, the quantity of water used for pie flushing could then be easily computed by deducting volume of water consumed by customers in a given month from the total water supplied from the storage tank. These calls for concerted efforts from the operator to address all sources of leakages and bursts on the distribution mains, and this can only be achieved when; materials are provided timely by Umbrella, scheme plumbers are

Committed to the job, there is timely reporting of leakages by the customers and general public, water theft has been stopped, and response time is reduced.

4.7.9 Losses from The Treatment plant

Losses from the treatment plant was observed to emanate from two different categories which include;

4.7.9.1 Loss from staff consumption

The treatment plant contains a total of 10 people which includes treatment plant superintendent, cleaners, and security including their families. These are supplied from the 100m³ storage reservoir raised on 12m stand. Using the MWE design manual (2013), the recommended consumption for this category with water closet (W.C) is 100 liters per capita per day as presented in (Table 4-9).

Table 4-9: unbilled Consumption from treatment plant

Demand category	Population	Demand (l/c/d)
House connection	10 persons	100

As shown in (Figure 4-6), the losses from staff consumption indicated a consistent monthly unbilled consumption of 30m³ per month.

4.7.9.2 Losses from the backwash tank

Rapid sand filter tank was built to make water treatment easier since this device has gravity flow and operates around the clock. Each of the three filter chambers that make up the sand filter is backwashed with 33 m³ from the same storage tank. As indicated in (Table 4-10), each filter compartment is backwashed on different days to ensure supply continuity.

Table 4-10: Backwashing days and losses from the rapid sand filtration

filter 1(m³)	filter 2 (m³)	filter 3 (m³)
33	33	33

The estimated annual water loss was found to be a constant of 360m³ from staff uses at treatment plant per year and 11,880m³ for backwash, which water is has not generated any revenue as presented in the (Figure 4-6).

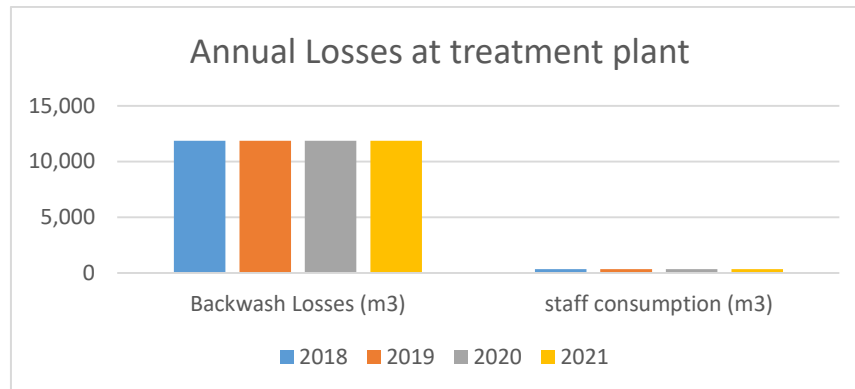


Figure 4-6: Sectorial Annual NRW at treatment plant

Discussions

The design provided 50m³ to backwash 1 filter tank per day, 26-m³/d dilution water and 5 m³ for the other plant uses and attendant staff which totals to 81m³ per day usage at the treatment plant. With the 33m³/day used for backwashing and 1m³/day consumed by staff, hence the losses at the treatment plant is below the 5m³/day as provided for in the design hence acceptable. However, Umbrella should regulate consumption at the treatment plant to prevent unauthorized use by external community members which will minimize on wasteful use of water hence increase on the amount of water sold to bring revenue to the scheme

4.8 Investigating the Relationship between Pipe Material Characteristics and NRW

The following techniques were used to comprehend the connection between NRW and pipe characteristics: (i) To determine the diameter, manufacturer's pressure rating, pipe age, and installation depth, a segment of underground PVC pipes was excavated at appropriate intervals. (ii) Joints, including JVC couplings, flanges, and gaskets at both washouts, air release valves, and junctions,

were observed for tightness. The contractor's compliance was then determined by comparing it with the design requirements. The findings of the investigation into the link between NRW and Pipe Material Characteristics are shown in Table 4-11.

Table 4-11: Pipe characteristics

Point Coordinates		Pipe type	Pipe Diameter(mm)	Pipe pressure rating	Installation depth (mm)	Year of manufacture
Northings	Eastings					
2.41042	31.0531	uPVC	280	PN10	850	2013
2.41042	31.0531	uPVC	280	PN10	653	2013
2.41042	31.0531	uPVC	280	PN10	902	2013
2.41042	31.0531	uPVC	280	PN10	776	2013
2.41042	31.0531	uPVC	280	PN10	856	2013
2.41042	31.0531	uPVC	280	PN10	757	2013

The pipes investigated were the section of uPVC pipes of OD 280mm, which were found to be of nominal Pressure (PN10). The installation depths of all these pipes did not reach the required minimum trenching depth of 1000mm as per the design specifications for trenching. Additionally all the pipes installed were manufactured in 2013 a year before the system construction commenced in 2014.

Discussion

The findings on the pipe material characteristics testifies to the contribution of post construction poor system functionality when adequate and effective supervision is not followed. Trenches are excavated at shallow depths, pipe of low ratings are installed, joints are not properly tightened, back-filling using the specified materials are not done, etc etc.

clients, consultants, contractors and all other stakeholders involved in the water sector should always ensure there are stringent supervision to ensure proper and complete adherence to design specifications throughout project implementation phase and throughout defects liability period so that during the O&M period such that the system functions as per the design.

4.9 Hydraulic modeling of the transmission mains

The following process/steps were used in hydraulic modeling to comprehend the transmission pipeline's behavior and performance: (i) The 15.39 km section of transmission mains that went from BPT1 (located at 2.41042N, 31.0531E) to Nyaravur reservoir (located at 2.44354N, 31.1873E) was surveyed at convenient chainages.

The coordinates and altitudes of important elements such as BPT, AVs, WOs, junctions, and storage reservoirs were recorded from the following installations. (ii) data were exported to Civil 3D for additional management after being loaded into an Excel workbook in csv file format; (iii) AutoCAD data was transferred to EpaCAD, which was then exported to EPANET software for analysis and simulation. (iv) A pipeline network was created for the storage reservoirs and transmission section components. (v) Modifying the pipeline's various parameters and characteristics in accordance with the supply areas and particular requests. (vi) Analyzing the hydraulic model. (vii) Examining the study section of transmission mains' current flow characteristics and comparing them to the design criteria to ensure compliance with regard to elevation, head, pressure, and velocity. A computer software called EPANET simulates the hydraulic and water quality behavior of pressurized pipe networks—which are made up of pipes, nodes, pumps, valves, and storage tanks or reservoirs—over a long period of time. Properties of interest for the study were head loss, length, altitudes, pressure, flow, velocity, and static head. The hydraulic modeling was carried out using the following procedures. Based on the input default characteristics and hydraulic parameters, including node elevations, tank diameter, pipe length, pipe diameter, and pipe roughness coefficient, the analysis was automatically carried out using EPANET software that was acquired from the US EPA, ORD, (2014). Head loss and flow units were the hydraulic characteristics that were employed; location coordinates, base demand, demand pattern, and flow periods were other parameters of importance. Results from a few sections are shown in Table 4-12.

Table 4-12: field Survey data

point	coordinates		Modelled Dynamic pressure (m)	Elevation (m)	Installed pipe rating
	Northings	Eastings			
1	2.423	31.085	109.38	1036	uPVC PN10
2	2.429	31.093	120.7	1023	uPVC PN10
3	2.431	31.095	120.29	1023	uPVC PN10
4	2.436	31.103	107.9	1034	uPVC PN10
5	2.436	31.105	117.68	1024	uPVC PN10
6	2.442	31.124	139.38	999	Steel
7	2.448	31.133	114.3	1022	steel
8	2.449	31.136	135.83	1000	uPVC PN10
9	2.453	31.143	121.82	1013	uPVC PN10
10	2.458	31.155	107.14	1024	uPVC PN10
11	2.454	31.163	135.82	994	uPVC PN10
12	2.453	31.167	130.09	999	uPVC PN10
13	2.452	31.169	124.79	1004	steel
14	2.45	31.175	103.94	1024	steel

Some elevation of the surveyed points are above the 100-meter head with other points as high as 1036 meters which exhibited high pressure above the normal PN 10 pipes used.

The study also considered sections of pipeline from Oweko and Paminya tanks because these are directly connected to the section of transmission line under the study and have influence on the hydraulic performance of the transmission line. The findings were that both tanks do not receive water because the pipes used are of low diameter even as they run long distances to reach the storage tanks. The pipeline to Oweko tank was tapped from OD 280mm pipe using OD 63mm HDPE pipe, and runs a distance of 2,600 meters. There was significant pressure drop as the pipe nears the tank and does not push water into the tank. The same was observed at paminya where an OD 40mm pipe was laid to a distance of 1,100 meters and joined with a riser mains of OD 50mm. hence water does not rise into the tank due to head loss. These are presented in (Figure 4-7)

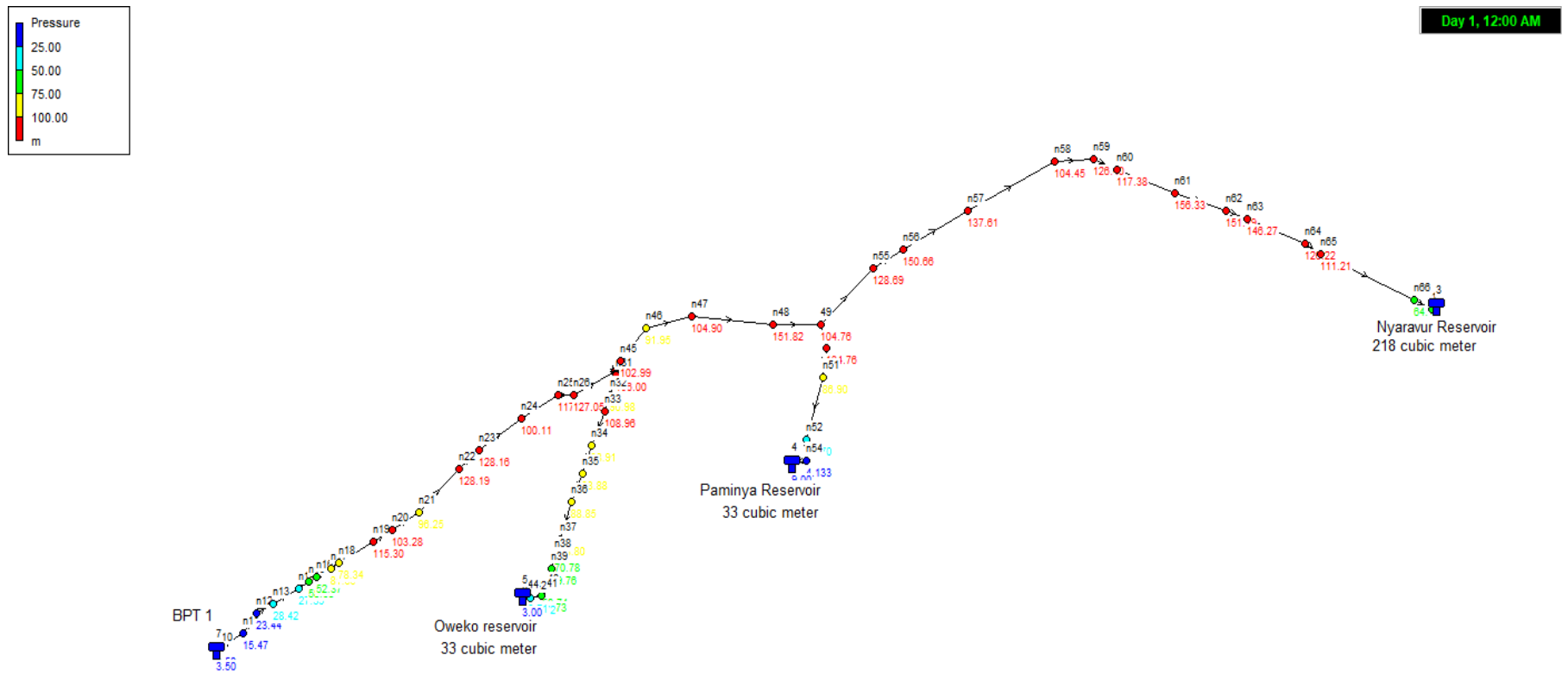


Figure 4-7: Simulated Pressure in the transmission pipeline

4.9.1 Pressure

Red ink was used to identify high pressures exceeding 100 meters, whereas yellow ink was used to identify pressures below 100 meters but above 70 meters. Some areas, which have a history of pipe breaks and significant leaks on transmission pipelines that result in significant water losses, showed high pressure at 0:00 hours that was greater than 100 meters' head. You may see these in (Figure 4-8). The highest recorded pressure at Node 27 was 109.00m at 0:00 and the lowest was 99.22m at 19:00. similar to other nodes. Pressure often falls below 100 meters during the day between 4:00 and 20:00, which PN 10 pipes can help to moderate.

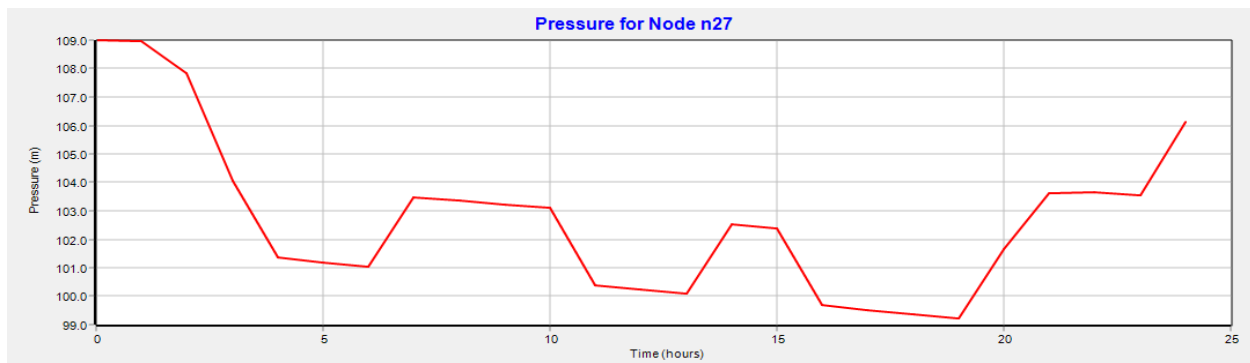


Figure 4-8: Simulated Pressure at nodes 27 for 24-hours supply

The lowest pressure was recorded at 135 meters at 19:00 hours, while the maximum pressure was recorded at node 61, the lowest point of height at 994 meters on coordinates (X 31.163, Y 2.454). When demand was higher, low pressures were seen from 4:00 to 7:00, 11:00 to 2:00, and 15:00 to 19 hours. However, between 0:00 and 3:00 and 21 and 24 hours, considerable pressure was noted at this node. Specifics are shown in (Figure 4-9)

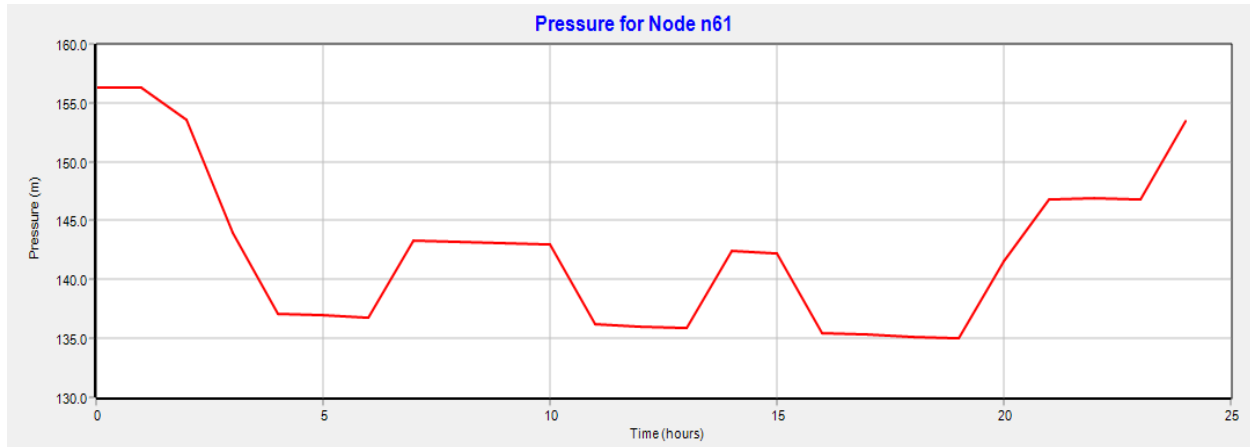


Figure 4-9: Simulated Pressure simulation for Node 61 with highest pressure

4.9.2 The flow

The design maximum day demands (MDD) were used to calculate the transmission system's flow. The flow requirement was 44 liters per second from the Break pressure tank (BPT1) to the Oweko Tee, 1.0 liter per second to the Oweko supply area, 1.0 liter per second to the Paminya supply area, and 42.0 liters per second to the Nyaravur tank from the Tee at Paminya. The lowest peak flow was between 9.95 and 9.75 l/s from BPT 1 to Paminya Tee, and then 8.40 l/s in the direction of Nyaravur tank. Specifics are shown in (Figure 4-10).

As a result, the treatment facility contributes 95% of its intended capacity of 4000 m³/day to the pipeline, with a total discharge of 3,801 m³/day.

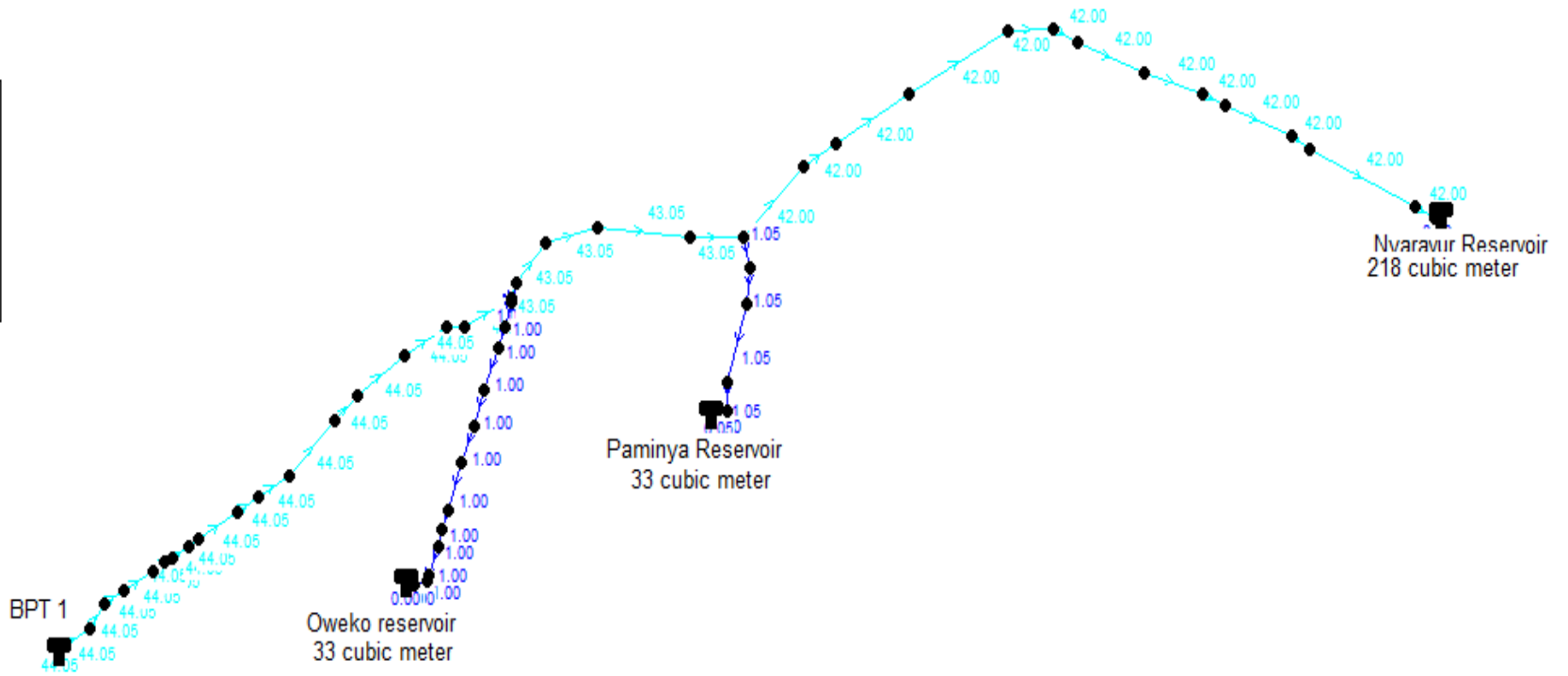


Figure 4-10: Simulated flow in the transmission pipeline

The section of the simulated flow in (Figure 4-11) and the 24-hour flow balance is presented in (Figure 4-12), where little flow is expected at around 11:00 pm or mid night during low demand and increases during dawn when users begin seeking for water. The flow remains relatively constant during day due to the demands when it declines from around 9:00 pm as users begins retiring to bed. No much use of water is needed at night since the area does not have nigh economy and all shops are closed by mid night.

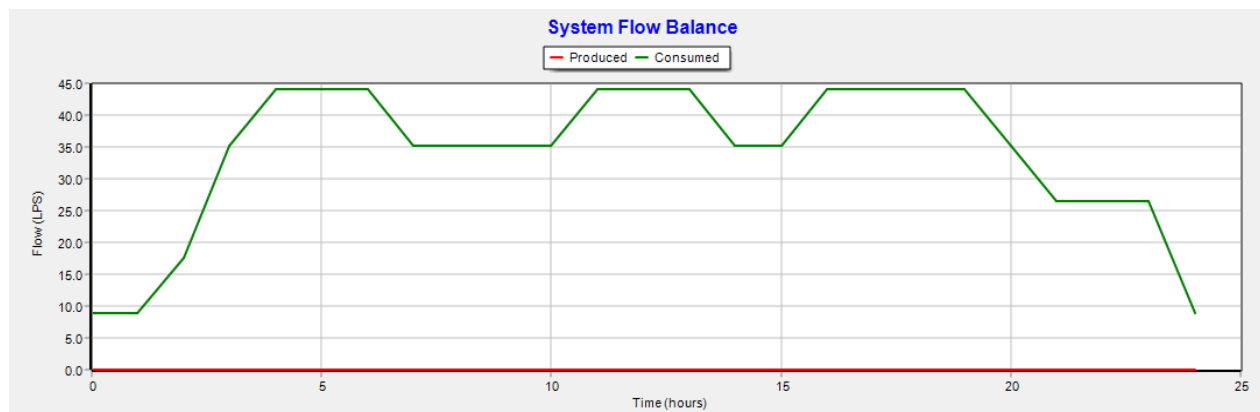


Figure 4-11: Simulated Systems flow balance in 24 hours

4.9.3 Flow Velocity

The simulated velocity for the pipeline during high peak flow at 6:00 hours as illustrated in (Figure 4-12). A velocity of 0.72m/s from BPT 1 to Oweko Tee, 0.70 m/s from Oweko to Paminya Tee, and from Paminya Tee-off to Nyaravur reservoir the velocity is 0.68m/s.

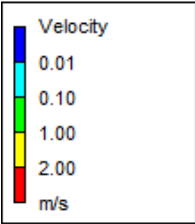


Figure 4-12: peak-hour simulated velocity

However, the velocity for low peak flows at 0:00 hours was simulated at; 0.16m/s from BPT 1 to Paminya Tee, and subsequently reduced to 0.14m/s towards Nyaravur reservoir. Details are presented in (Figure 4-13 and Figure 4-14)

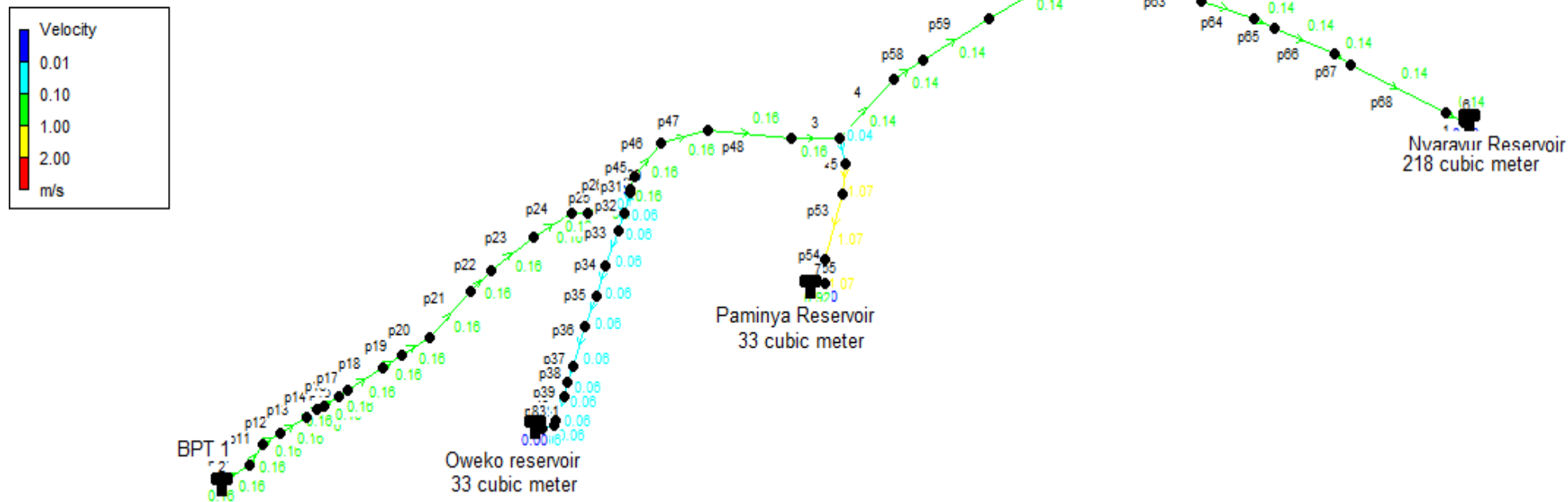


Figure 4-13: Simulated flow velocity for off peak hours

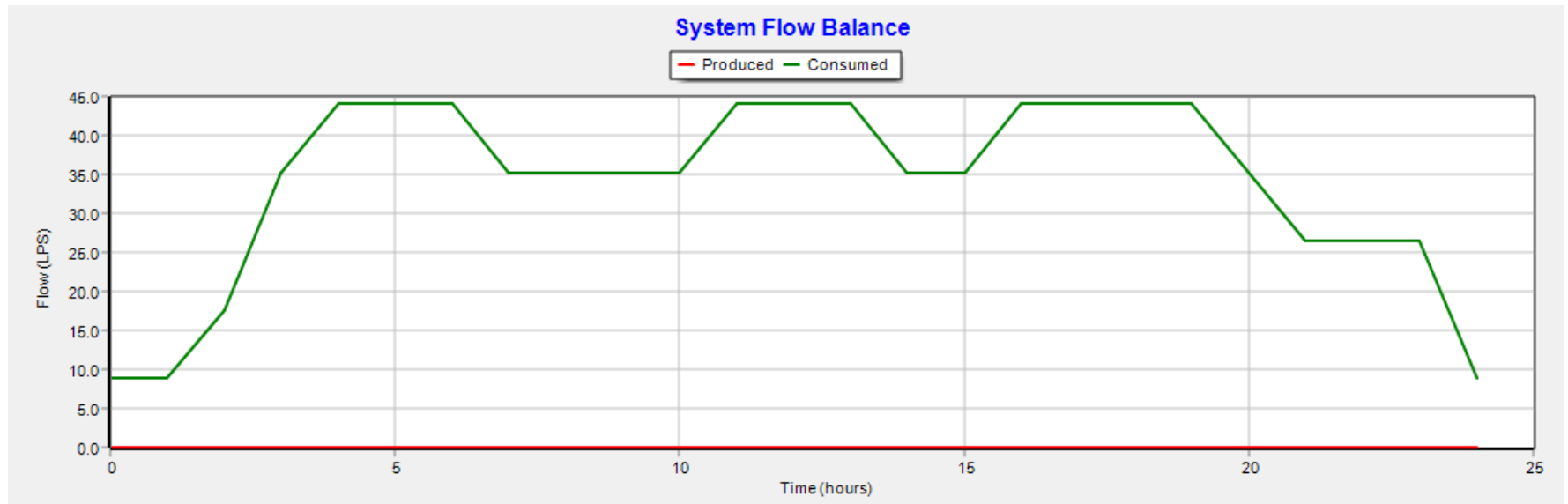


Figure 4-14: simulated systems flow balance in 24 hours

Just like the flow, the flow velocity in (Figure 4-13) above follows the same pattern with pressure and the discharge. Lower velocity is expected during low peak hours and subsequently rises as demand for water soars and the supply is increased. In as much as gravity flow systems should function for 24 hours a day in order to reduce on air locks in the pipeline, Scheme operators should reduce the flow at night as excessive pressure build up is made in the pipe, and coupled with the varying topographic condition of this area as presented in (Figure 4-15), burst are inevitable. This attests to the fact that most bursts happened during night as opposed to leakages during day time.

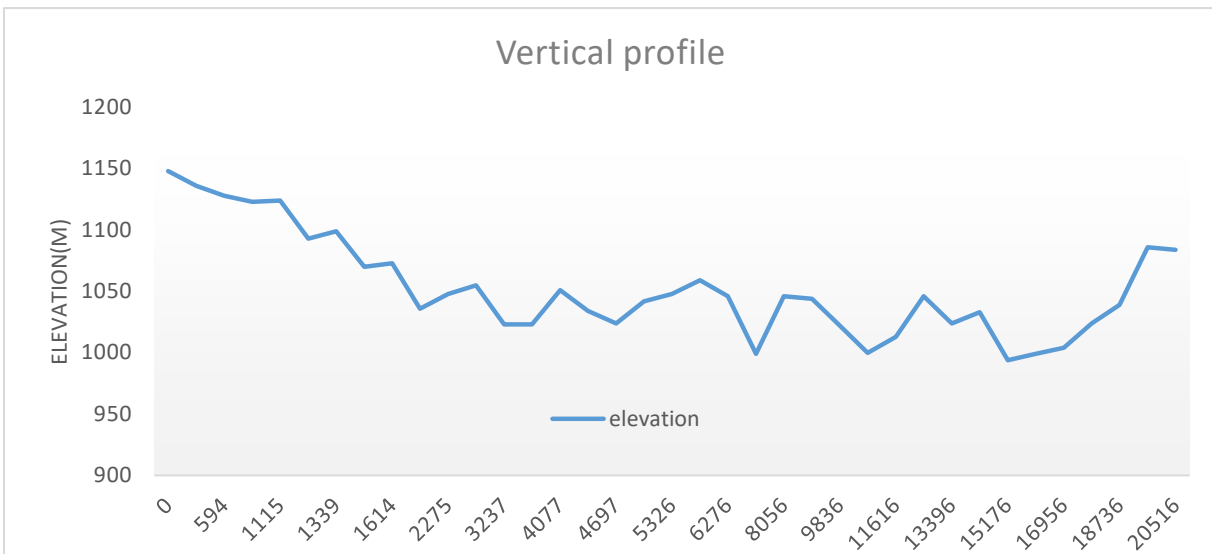


Figure 4-15: Elevation profile in the pipeline

The elevation from BPT 1 to Nyaravur reservoir is 1148 msl to 1092 msl with the lowest point being 994 msl at a distance of 15.176 km of transmission pipeline as illustrated in (Figure 4-15).

The pressure in the pipeline for a period of 24 hours from EPANET simulation as illustrated in (Figure 4-8), while the flow simulation in liters per second is illustrated in (Figure 4-16)

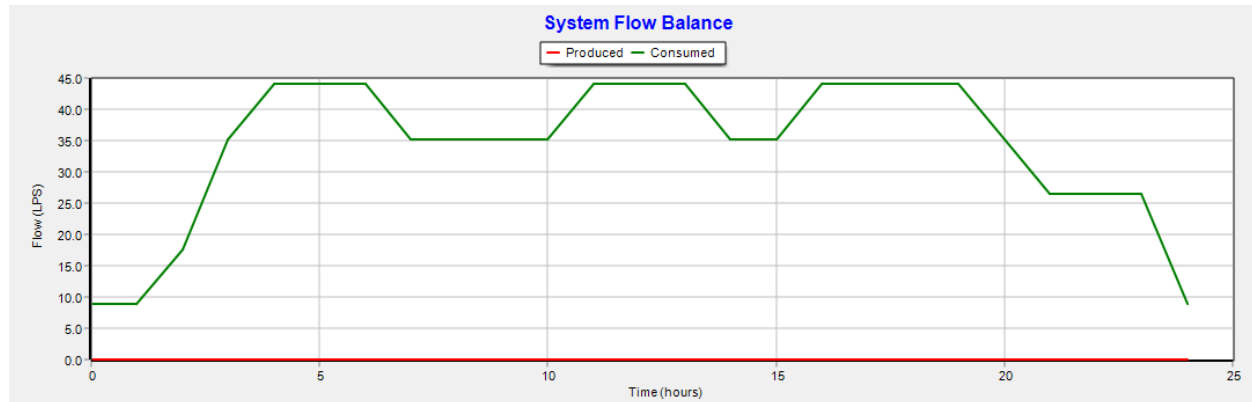


Figure 4-16: Systems flow balance in 24 hours

Discussion

Conducting hydraulic modeling plays a cardinal role in generating scientific conclusions and recommendations. This is because there is no room for assumptions hence providing scientific findings. In this study, pipe sizes and workmanship has contributed to poor system functionality as pipes of low diameter stretched for several Kilometers leading to high level of head loss leaving the installed tanks dummies. Parties involved in system construction need to adhere to the specifications to prevent such occurrences. Pressure in the pipeline is directly proportional to the prevailing elevations that's why certain sections of the transmission pipeline have higher pressures above the pipes installed. This calls for strict supervision during construction phase to ensure only pipes of the pressure rating for a given elevation are laid using relevant supporting technologies to install them. Ideally gravity flow systems should remain in a state of equilibrium during no demand period but bursts is indicative of poor installation.

4.10 Impacts of NRW to the scheme employees and water users.

Regarding the effects of NRW on the scheme personnel, the scheme responders provided the following answers regarding how NRW has improved the operation of the systems, which are shown in (Table 4-13) below.

Table 4-13: Staff response on NRW

	Greater than 5/month	Less than 5/month	Not sure
average nr of pipe bursts/ leakages on the transmission	13	03	02
average nr of pipe bursts/ leakages on the distribution	04	11	03
average nr of pipe bursts/ leakages on the service line	06	07	05
No. of days taken to repair the Burast/leakage	16	02	00
Days taken to deliver the materials from the secretariat	01	14	03

Regarding the effects of NRW on the scheme personnel, the following answers were gathered from the scheme respondents regarding the ways in which NRW has improved the operation of the system. In response to the question about the average frequency of transmission main breakdowns, 72.2% of respondents said that breakdowns happened more than five times per month, especially three to four times per month; 16.67% said that breakdowns happened fewer than five times per month; and 11.11% were unsure of the transmission main breakdown situation. Regarding the distribution mains, 22.22% of respondents said that the breakdown happened more than five times a month, 61.1% said that the distribution line broke down five to ten times a month, and 11.11 percent were unsure. Regarding the average frequency of leaks on the service mains, 33.33% of respondents concurred that the failures happened more frequently than five times per month, 38.89% disagreed, and 27.78% were unsure.

When asked how long it took to remedy a burst or leak whenever it happened, 88.89% of respondents said it took five to ten days, assuming resources were available, while 11.11% said it took fewer than five days to fix breakdown.

0.1% of respondents agreed that it took less than five days, 16.67% were unsure of the number of days it took to deliver materials to the scheme, and 77.8% of respondents acknowledged that it took more than five days to receive major repair materials to respond to breakdowns, particularly the 280mm uPVC pipe and the various fittings of the same size. Details of this are presented in (Figure 4-17)

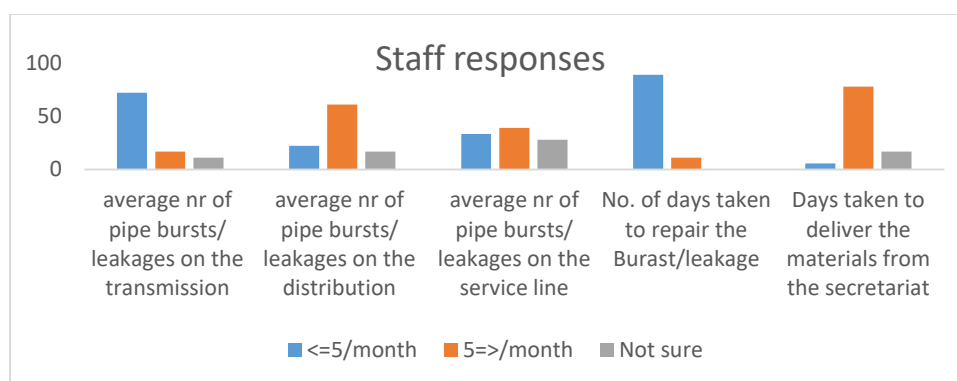


Figure 4-17: Staff responses towards NRW

Regarding the availability of materials and tools to manage breakdowns, responses from the different staff on availability of materials and tools are presented in (Table 4-14)

Table 4-14: Materials and tools availability

Actions	Response			
	Agree	Disagree	Not sure	
materials availability for the repair/replacement	5	3	8	
Tools availability for repair	16	01	01	
Action taken when repair materials are not available	Wait for delivery	improvise	Not sure	
	8	3	7	
Action to reduce NRW occurrence	Timely repairs	Stock materials	Communicate	Rewards
	10	03	04	01

Regarding the availability of equipment to respond to crises, 88.7% of respondents agreed that there are tools accessible to remedy repairs, while 5.6% disagreed and were unsure. As shown in (Figure 4-18), 16.7% completely disagreed, 27.8% agreed that certain materials were always accessible to react to repair, and 44.4% were unsure regarding the availability of supplies.

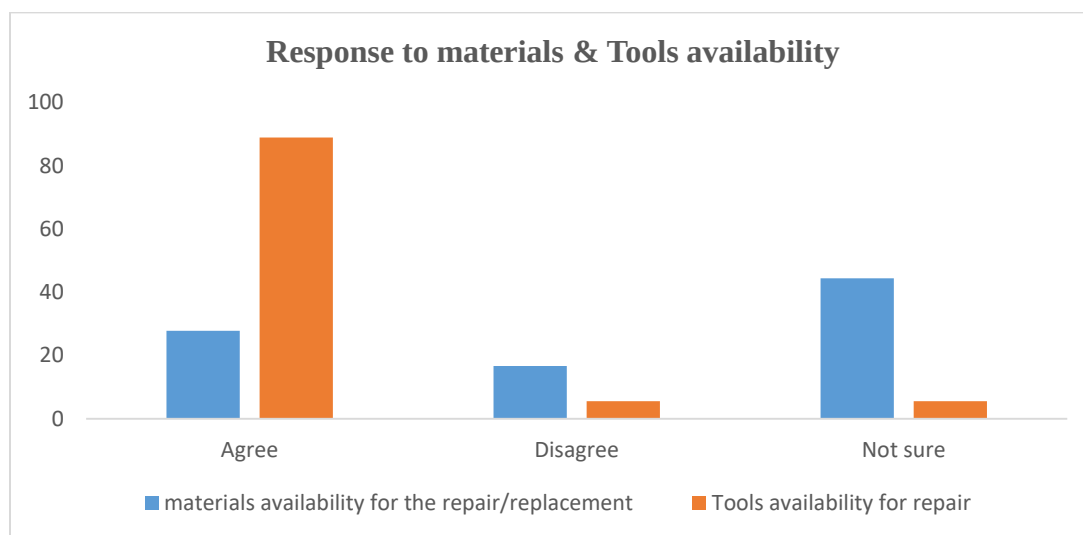


Figure 4-18: Availability of Tools and equipment

Regarding the steps they would take to fix leaks or bursts when supplies were unavailable, 44.4% acknowledged that they would wait for the materials to arrive, while 38.9% were unsure of what they would do in the event that materials were unavailable to handle the breakdown. As seen in (Figure 4-19) below, just 16.7% of respondents said they would improvise a temporary solution to deal with the breakdown while materials were being obtained.

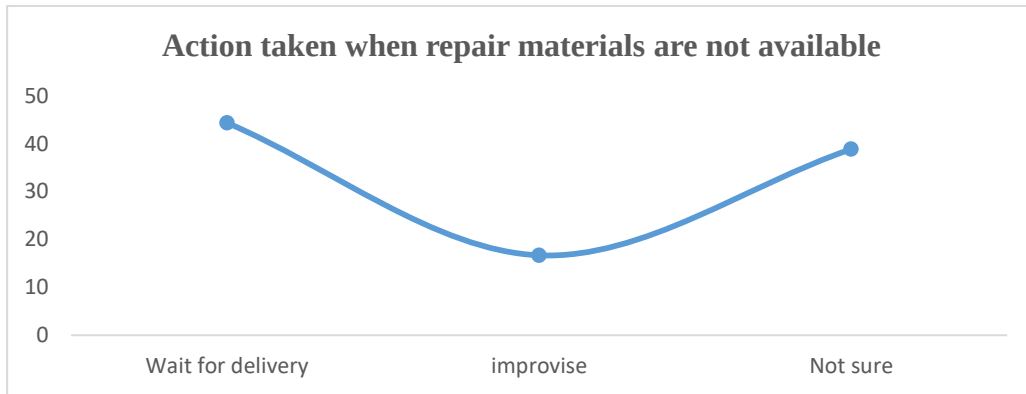


Figure 4-19: Actions taken when materials are unavailable

As shown in (Figure 4-20), 55.6% of respondents supported prompt repairs as the most effective way to reduce NRW, 22% would prefer that staff members communicate well in order to react to breakdowns more quickly, and 16.7% supported material stockpiling in order to facilitate faster reaction. In order to deal with breakdown, 5.6% of respondents preferred incentives as a motivation.

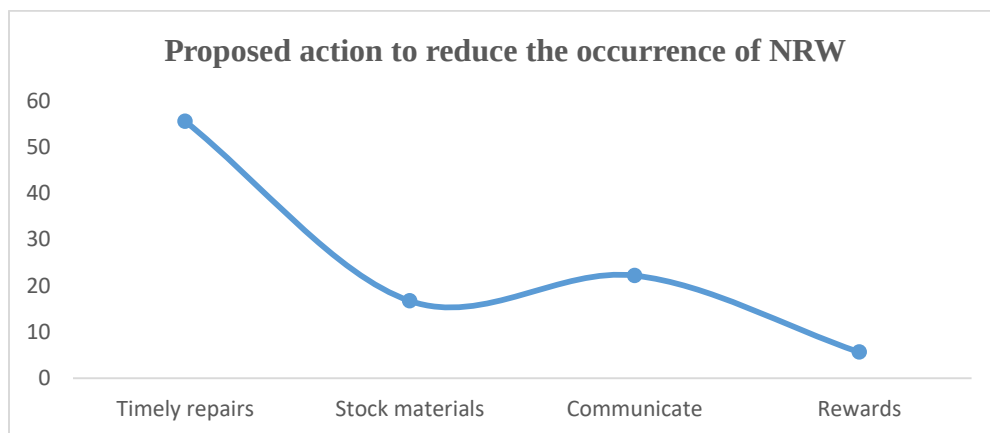


Figure 4-20: Mitigation strategy for NRW

4.10.1 Responses from water users

Responses from the users on the water situation were sought and the results are presented in (Table 4-15)

Table 4-15: Responses from users of water supply situation

	Strongly disagree	Disagree	Agree	Strongly agree	Not sure
I receive water daily	79	45	36	16	8
the supply is adequate and affordable	56	71	32	22	3
Improved standards of life achieved	19	34	84	43	4
Down time is communicated prior	107	24	21	15	17
Water is restored as early as possible	36	16	67	43	22
Water related infections reduced	7	27	95	47	8

Regarding how frequently the customers received water, 28.26 percent acknowledged that they received water every day, however 67.39% said they did not receive it as frequently as they would have anticipated. Due to spending more time away from home, just 4.35% of respondents were unsure if they had a daily water supply. Although 29.35% of respondents acknowledged that the supply is sufficient and reasonably priced, 69.02% of respondents disagreed. Just 1.63% of respondents in this category were unsure about the affordability and sufficiency of the supply. Respondents in this category are regarded as not having any knowledge of water connections or helping to pay water bills. While 28.8% of respondents disputed that the water had raised their level of life, 69.02% of respondents said it has, particularly the female respondents who said they have had to go several kilometers to find water. Accordingly, 2.17% of respondents were unsure if this method had enhanced their quality of life. 71.20% of respondents disagreed with the statement that all reported breakdowns are conveyed to users, while 19.57% agreed that users—who are the members who were added to the What's Up customer group—are informed to some extent. When there was a breakdown, 9.24% of respondents were unsure if there was any contact at all. In response to the question of whether water was restored. 59.78% agreed that water was restored in time while 28% disagreed.

11.96% of respondents were unsure if the water was promptly restored. When asked if there has been a significant decrease in the number of water-related illness cases since the system was put into service in 2018, 77.17% of respondents agreed, while 18.48% disagreed. Of those in this category, 4.35 percent were unsure if the number of water-related illness cases had decreased. These are shown in detail in (Figure 4-21).

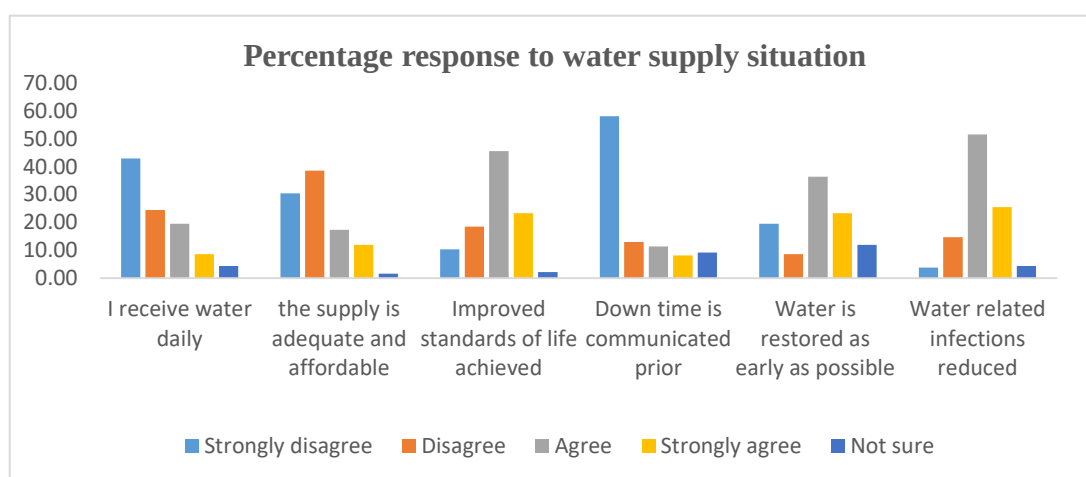


Figure 4-21: Percentage response to water supply

Discussion

On the impacts of NRW to the scheme crew, and particularly regarding average number of breakdowns on transmission mains where 72.2% of the respondents reported that it occurred less than 5 times in a month particularly between 3-4 times a month, there is still need to reduce this figure to below zero due to the fact that a single burst on transmission can cause such a huge loss more than any other breakdown could. Utility providers also should ensure that these breakdowns are addressed immediately as they occur so that the customers get the services they deserve as from the intentions for which the system was designed. Additionally, any large system should expect systematic vandalism however, water utilities should try as much to

understand the reasons behind such persistent vandalism. It could be that there are no alternative sources of

water, low coverage that requires pipe extensions to unserved areas, could be the community is poor and cannot afford yard connections to their individual homes hence the need for public stand points, could be there was limited sensitization etc. the secretariat is responsible to ensure there is regular supply of repair materials, tools and equipment in schemes so as to cut short the response time. Leaving schemes without such repair fittings leads to customer dissatisfaction and low morale from the scheme staff hence poor performance and bad image to the entity. When laying distribution, intensification and service lines, care should be taken to ensure the recommended depth has been achieved. This is because shallow excavations are susceptible to exposure due to so erosion hence during farming and roadworks they are easily cut either on purpose or accidentally, but also it makes vandalism much easier than when the required depth have been reached.

On the frequency of how the users received water, and by the fact that 67.39% of respondents reported not receiving water on a daily basis as they would have expected is an indicator of disapproval rating on the part of the water utility company, meaning the community is dissatisfied with the services being rendered to them. Functional measures need to be put in place and together to ensure the communities do not revert to the pre-project unsafe sources otherwise the system loses the purpose for which it was initiated. Additionally, with 69.02% of the respondents disagreeing that the supply is adequate and affordable yet at the same time 69.02% of respondents affirmed that the water system has improved their standard of living especially the female respondents who reported to have had to travel several miles away in the pursuit of water, utility companies should strive to meet the demands of the customers so that the negative

compliments are out performed by quality service delivery. 71.20% of respondents who disagreed that they are officially informed of any systems shutdown or breakdowns is a testament that the community require effective communication to enable them prepare for alternative sources either through water storage or other sources for the downtime period. On the other hand, having 59.78% of respondents testifying that water was restored in time after the repair is an assurance that the community is supportive of interventions made by the operator hence the need to continue building their trust by ensuring that they are continuously updated on whatever transpires in the system because they are the permanent stakeholders of the system. Finally, the testimony from the 77.1% who admitted that the water system has reduced on the number of cases of water related infections since it's commissioning in 2018 is an indicator that the efforts of the operator is being recognized and appreciated say for the hiccups that are sometimes inevitable. The operator should regularly conduct Strength, Weakness, Opportunity, and Threat (SWOT) analysis and convert the challenges into opportunities because among the several strength they have is the support of the community and the local leadership. Thus bringing water users on board can offer some functional solutions to the operator to provide lasting solution to the intermittent supply that is currently the prevailing status of the system.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

5.1.1 Quantifying NRW prevalence in Nyarwodho GFS

The year 2018 exhibited the lowest amount of water sold because out of the 402,174m³ of water supplied to the customers; only 27,505m³ was sold which is an equivalent of 7%. An increment in sales was observed in the year 2019 in which 446,442m³ of water supplied and out of which 90,590m³ was sold an equivalent of 20%. 2020 had 23% of water sold from 472,445m³ supplied against 107,660m³ sold. Last but not least, 2021 saw more growth in water sales, with 114,495m³ sold to clients, or 25% of the 452,010m³ delivered. Although the current average NRW in the scheme is 86.70%, which is significantly higher than the maximum recommended of 25% from the MWE design manual (2013), this shows a reduction trend of about 18% of NRW in four years, which may not be convincing enough but indicates efforts are being made to improve performance.

5.1.2 Sources of NRW in Nyarwodho GFS

The sources of NRW was experienced more as occurring from physical losses emanating from pipe bursts on transmission, distribution and service lines and their assorted components such as ARVs, WOVs, JV couplers, straight connectors etc, where water leaks were continuously unchecked. A 24-hour leak from 200 user tap stands is sufficient to produce a substantial physical loss to the system, even if leaks from user tap stands seem to have contributed very little to NRW. It was determined that the perceived losses had little bearing on NRW.

Other losses were observed emanating from treatment plant, storage reservoir, pipe flushing, staff consumption, vandalism, and water theft/illegal connections. Implying that there is need for a serious mitigation measures put in place to regulate losses.

5.1.3 The relationship between pipe materials and NRW in Nyarwodho GFS

The study established that some pipes laid for the transmission line were of low pressure ratings of PN10 instead of the recommended PN16 or higher. Additionally, the trenching depth in some sections were shallow hence due to soil erosion they became even shallower to accommodate and resist the lifting/overturning force due to the flow pressure in pipe. Also the connectivity of some joints and pipe ends were not accurate in some sections leading to leaks.

5.1.4 Hydraulic modeling of a section of transmission mains

The study established that the static pressure in the pipeline at some point was as high as 156.5m yet the pipes laid in most sections were of PN10 which certainly are unable to resist the high pressures hence bursting which mostly occurred at night. The study also found that an uncontrolled, round-the-clock supply puts stress on the pipes' ability to withstand pressure since the flow time pattern has not been closely monitored to control demand, resulting in less water being delivered at night when demand is low.

5.1.5 Recommendations

The results, gaps, difficulties, and requirements found from the schemes are the basis for the following suggestions and actions, which are made in light of the aforesaid predominance of NRW and specifically to enhance performance for the system's self-sustainability:

5.2 Measures to mitigate NRW

5.2.1 General Measures

- Northern Umbrella of water and sanitation authority being government agency responsible to operate water supply systems in small towns and RGCs in Uganda should

focus more on preventive maintenance of infrastructure rather than corrective maintenance being conducted

- In order to adequately assist the Utility's efforts, water customers and local leaders should report and work together to detect and report any instances of leaks, bursts, vandalism, or illegal connections.
- All parties involved in the construction of water supply systems should be able to access funding from NUWS to assist NRW reduction plans or initiatives. These might include the utility in the front line, governments, municipal governments, and development partners.
- Staff attempts to lower NRW should get sufficient management support from NUWS, which may be achieved by supplying fittings and supplies for prompt replacement and repair.
- Regular in-house training to comprehend the definition of non-revenue water and the extent of its occurrence in the transmission, distribution, and service pipe network within the scheme is one way that MWE, through NUWS, should enhance the ability of scheme workers.
- In order to address commercial losses, NUWS's sociologists and commercial officers should carry out commercial operations by educating and training billing clerks and users on the importance of accurate water meter readings and the necessity of functional meters at all installations, including the source, reservoir, and every metered connection.
- Since water losses only happen through water assets, the NUWS secretariat and scheme staff should practice sound asset management to handle non-revenue water incidents at all levels.

5.2.2 Technical measures:

- To track the amounts of water provided to the various zones, the plan should include bulk water meters at each reservoir's intake and exit. By doing this, the operator will be able to recognize and detect the typical reasons for losses, whether they are caused by distribution pipelines or overflows. Under the direction of the scheme operator, the system's technical team, including plumbers, can do this.
- When the reservoir reaches its full capacity, the operator should install high pressure-resistant ball valves in each intake to control and regulate the flow. By doing this, overflow losses from the four main reservoirs that serve various zones will be avoided. Scheme plumbers are capable of doing this as long as the necessary fittings are made accessible.
- NUWS in close collaboration with the scheme staffs should conduct the replace all faulty components of air release valves particularly the rubber and gaskets. This will control losses emanating from 24/7 supply from the numerous air release valves.
- Low pressure uPVC pipes that have been put in areas with high pressures should be replaced by the operator. Examples include places where PN10 was inserted even though PN16 was intended. This measure will lower NRW and the frequency of pipe breaks.
- Since there have been instances of severe fractures on uPVC sockets as a result of excessive pressure on pipe ends, the operator ought to think about implementing flanged fittings at pipe ends that are pressure-resistant.
- The NUWS scheme operator ought to think about using locks to secure the manhole lids for the washouts and air valves. This will stop illegal water fetching from the WO pipes and vandals from entering the chamber and damaging the rubber stoppers at the AVs.

- In order to inform reaction decision-making, the operator should install pressure sensors at strategic points along the transmission line that would transmit abrupt pressure surges or drops.
- Before the need for corrective action becomes unavoidable, the operator should regularly examine the transmission line to find leaks in the fittings and pipes and take preventative action.
- To enable prompt reaction to malfunctions whenever they arise, NUWS will provide the scheme stores with a steady and reliable supply of high-quality repair materials. Customers would be more satisfied, have more faith in the operator, and be able to pay their payments on time.

5.2.3 Operational issues for O & M

The following social measures are generated;

- Regular user awareness training should be carried out by the operator to safeguard and maximize the system's functionality, including reporting any malfunctions, emergencies, or vandalism for prompt resolution.
- The NUWS/Scheme operator should think about implementing a program that offers incentives to those who spot and report vandalism. This might include material or financial incentives.
- NUWS should consider Motivating scheme staffs to enable them ever ready to respond to breakdown. This is because a happy workforce is a performing entity. This motivation could be monetary, material, capacity building, promotions, demotion for poor performers etc.

In summary, management of large gravity flow systems should adopt the strategies that have been recommended. Regular technical audit of the system be in terms of the implementation of these strategies will promote sustainability of the systems.

Finally, further study be conducted on other factors beyond the scope of this study which may be causing the failures in the systems hydraulics.

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Appendix

Appendix 1: Photos of breakdowns on transmission mains



Burst on the PVC and G.I interlink



Leakage on the pipe joint



Burst on the mains



Repair works on PVC pipes

Appendix 2: Loss on Air valves and washout chambers



Continuous losses at the air valve

Loss from the air valve



Loss from Washout

Appendix 3: Pictures of Loss from service lines



Locals fetch from a burst point



Repair works on burst



Repair works on Distribution line



Pipe exposure to facilitate repair

Appendix 4: Loss from vandalism



Losses from a vandalized pipe



Losses from a pipe that has been cut

Appendix 5: Water supply and NRW records for 2018 - 2021

Water supply and NRW record for 2018

Month	Water supplied (m ³)	Water sold (m ³)
April	43,432	1784
May	43,867	3777
June	43,870	3528
July	44,652	2735
August	43,876	2483
September	45,735	1752
October	45,890	1848
November	42,178	3092
December	48,674	6506
Total	402,174	27,505

Water supply and NRW record for 2019

Month	Water supplied (m ³)	Water sold (m ³)
January	44,356	4815
February	47,543	15258
March	18,796	6143
April	41,819	7635
May	42,349	5854
June	38,210	8213
July	40,641	7746

August	38,118	6639
September	27,772	6832
October	30,117	7412
November	27,747	6421
December	48,974	7622
Avg total	446,442	90,590

Water supply and NRW record for 2020

Month	Water supplied (m ³)	Water sold (m ³)
January	44,862	13688
February	48,336	11323
March	39,110	8280
April	45,765	8109
May	43,957	8793
June	35,867	8687
July	41,794	7967
August	33,989	8423
September	38,915	7282
October	33,880	8921
November	32,784	7846
December	33,186	8341
Total	472,445	107,660

Water supply and NRW record for 2021

Month	Water supplied (m ³)	Water sold (m ³)
January	45,967	8634
February	34,636	8754
March	37,444	7849
April	38,619	9857
May	33,065	8962
June	35,043	11203
July	36,336	8242
August	40,247	9926
September	37,264	9284
October	40,905	13397
November	41,696	9980
December	30,788	8407
Total	452,010	114,495

Appendix 5: Records for water produced and billed

Date	Initial meter reading	final meter reading	water supplied (m³)
18/03/2019	1649	3596	1,947
19/03/2019	3596	4745	1,149
20/03/2019	4745	6083	1,338
21/03/2019	6083	7376	1,293
22/03/2019	7376	8721	1,345
23/03/2019	8721	10137	1,416
24/03/2019	10137	11583	1,446
25/03/2019	11583	12884	1,301
26/03/2019	12884	14258	1,374
27/03/2019	14258	15655	1,397
28/03/2019	15655	17166	1,511
29/03/2019	17166	18409	1,243
30/03/2019	18409	19815	1,406
31/03/2019	19815	20445	630
TOTAL			18,796
APRIL			
01/04/2019	20445	22331	1,886
02/04/2019	22331	23755	1,424
03/04/2019	23755	24936	1,181
04/04/2019	24936	26116	1,180
05/04/2019	26116	27866	1,750
06/04/2019	27866	29472	1,606
07/04/2019	29472	31146	1,674
08/04/2019	31146	31724	578
09/04/2019	31724	32856	1,132
10/04/2019	32856	34599	1,743
11/04/2019	34599	36025	1,426
12/04/2019	36025	38038	2,013
13/04/2019	38038	39675	1,637
14/04/2019	39675	41611	1,936
15/04/2019	41611	43582	1,971
16/04/2019	43582	45576	1,994
17/04/2019	45576	47516	1,940
18/04/2019	47516	49472	1,956
19/04/2019	49472	49650	178
20/04/2019	49650	50653	1,003
21/04/2019	50653	51478	825
22/04/2019	51478	52622	1,144
23/04/2019	52622	53280	658

24/04/2019	53280	54544	1,264
25/04/2019	54544	55685	1,141
26/04/2019	55685	56936	1,251
27/04/2019	56936	58277	1,341
28/04/2019	58277	59488	1,211
29/04/2019	59488	60716	1,228
30/04/2019	60716	62264	1,548
TOTAL			41,819
MAY			
01/05/2019	62264	63707	1,443
02/05/2019	63707	65282	1,575
03/05/2019	65282	66868	1,586
04/05/2019	66868	68482	1,614
05/05/2019	68482	69147	665
06/05/2019	69147	70410	1,263
07/05/2019	70410	71590	1,180
08/05/2019	71590	73115	1,525
09/05/2019	73115	74421	1,306
10/05/2019	74421	75745	1,324
11/05/2019	75745	76842	1,097
12/05/2019	76842	78249	1,407
13/05/2019	78249	79842	1,593
14/05/2019	79842	80907	1,065
15/05/2019	80907	82536	1,629
16/05/2019	82536	84242	1,706
17/05/2019	84242	85782	1,540
18/05/2019	85782	87102	1,320
19/05/2019	87102	88499	1,397
20/05/2019	88499	89922	1,423
21/05/2019	89922	91311	1,389
22/05/2019	91311	92900	1,589
23/05/2019	92900	94287	1,387
24/05/2019	94287	94809	522
25/05/2019	94809	95701	892
26/05/2019	95701	97073	1,372
27/05/2019	97073	98623	1,550
28/05/2019	98623	100017	1,394
29/05/2019	100017	101493	1,476
30/05/2019	101493	103063	1,570
31/05/2019	103063	104613	1,550
TOTAL			42,349
JUNE			
01/06/2019	104613	105850	1,237

02/06/2019	105850	107175	1,325
03/06/2019	107175	108668	1,493
04/06/2019	108668	110108	1,440
05/06/2019	110108	111306	1,198
06/06/2019	111306	112340	1,034
07/06/2019	112340	113615	1,275
08/06/2019	113615	115038	1,423
09/06/2019	115038	116608	1,570
10/06/2019	116608	118212	1,604
11/06/2019	118212	119590	1,378
12/06/2019	119590	121234	1,644
13/06/2019	121234	123045	1,811
14/06/2019	123045	124543	1,498
15/06/2019	124543	125887	1,344
16/06/2019	125887	127090	1,203
17/06/2019	127090	128311	1,221
18/06/2019	128311	129526	1,215
19/06/2019	129526	131071	1,545
20/06/2019	131071	132725	1,654
21/06/2019	132725	134399	1,674
22/06/2019	134399	134399	-
23/06/2019	134399	135174	775
24/06/2019	135174	136179	1,005
25/06/2019	136179	137580	1,401
26/06/2019	137580	138840	1,260
27/06/2019	138840	140275	1,435
28/06/2019	140275	141487	1,212
29/06/2019	141487	142823	1,336
30/06/2019	142823	142823	-
TOTAL			38,210
JULY			
01/07/2019	142823	144205	1,382
02/07/2019	144205	145686	1,481
03/07/2019	145686	146921	1,235
04/07/2019	146921	148260	1,339
05/07/2019	148260	149475	1,215
06/07/2019	149475	150898	1,423
07/07/2019	150898	152605	1,707
08/07/2019	152605	154096	1,491
09/07/2019	154096	155653	1,557
10/07/2019	155653	157273	1,620
11/07/2019	157273	158782	1,509
12/07/2019	158782	160270	1,488

13/07/2019	160270	161575	1,305
14/07/2019	161575	163032	1,457
15/07/2019	163032	164624	1,592
16/07/2019	164624	165839	1,215
17/07/2019	165839	167095	1,256
18/07/2019	167095	168370	1,275
19/07/2019	168370	169804	1,434
20/07/2019	169804	171223	1,419
21/07/2019	171223	172649	1,426
22/07/2019	172649	174141	1,492
23/07/2019	174141	175577	1,436
24/07/2019	175577	176202	625
25/07/2019	176202	177209	1,007
26/07/2019	177209	178029	820
27/07/2019	178029	178677	648
28/07/2019	178677	179726	1,049
29/07/2019	179726	180774	1,048
30/07/2019	180774	182204	1,430
31/07/2019	182204	183464	1,260
TOTAL			40,641
AUGUST			
01/08/2019	183464	184907	1,443
02/08/2019	184907	186404	1,497
03/08/2019	186404	187416	1,012
04/08/2019	187416	188646	1,230
05/08/2019	188646	190016	1,370
06/08/2019	190016	191373	1,357
07/08/2019	191373	192630	1,257
08/08/2019	192630	193968	1,338
09/08/2019	193968	195319	1,351
10/08/2019	195319	196753	1,434
11/08/2019	196753	197994	1,241
12/08/2019	197994	198483	489
13/08/2019	198483	199077	594
14/08/2019	199077	199880	803
15/08/2019	199880	200808	928
16/08/2019	200808	201672	864
17/08/2019	201672	202637	965
18/08/2019	202637	204286	1,649
19/08/2019	204286	205861	1,575
20/08/2019	205861	207034	1,173
21/08/2019	207034	208031	997
22/08/2019	208031	208843	812

23/08/2019	208843	210246	1,403
24/08/2019	210246	211470	1,224
25/08/2019	211470	212845	1,375
26/08/2019	212845	214256	1,411
27/08/2019	214256	215908	1,652
28/08/2019	215908	217435	1,527
29/08/2019	217435	218884	1,449
30/08/2019	218884	220184	1,300
31/08/2019	220184	221582	1,398
TOTAL			38,118
SEPTEMBER			
01/09/2019	221582	223269	1,687
02/09/2019	223269	224347	1,078
03/09/2019	224347	225499	1,152
04/09/2019	225499	226686	1,187
05/09/2019	226686	227647	961
06/09/2019	227647	228761	1,114
07/09/2019	228761	229983	1,222
08/09/2019	229983	231065	1,082
09/09/2019	231065	232087	1,022
10/09/2019	232087	233366	1,279
11/09/2019	233366	234826	1,460
12/09/2019	234826	236390	1,564
13/09/2019	236390	238058	1,668
14/09/2019	238058	239721	1,663
15/09/2019	239721	241228	1,507
16/09/2019	241228	242924	1,696
17/09/2019	242924	243513	589
18/09/2019	243513	243513	-
19/09/2019	243513	243513	-
20/09/2019	243513	243513	-
21/09/2019	243513	243513	-
22/09/2019	243513	243513	-
23/09/2019	243513	243513	-
24/09/2019	243513	244435	922
25/09/2019	244435	245644	1,209
26/09/2019	245644	246704	1,060
27/09/2019	246704	247373	669
28/09/2019	247373	248157	784
29/09/2019	248157	248850	693
30/09/2019	248850	249652	802
TOTAL			28,070
OCTOBER			

01/10/2019	249652	250546	894
02/10/2019	250546	251821	1,275
03/10/2019	251821	253253	1,432
04/10/2019	253253	253474	221
05/10/2019	253474	254415	941
06/10/2019	254415	255521	1,106
07/10/2019	255521	256880	1,359
08/10/2019	256880	258405	1,525
09/10/2019	258405	258888	483
10/10/2019	258888	258888	-
11/10/2019	258888	259707	819
12/10/2019	259707	260797	1,090
13/10/2019	260797	261866	1,069
14/10/2019	261866	262966	1,100
15/10/2019	262966	264151	1,185
16/10/2019	264151	264651	500
17/10/2019	264651	265910	1,259
18/10/2019	265910	266712	802
19/10/2019	266712	267705	993
20/10/2019	267705	268902	1,197
21/10/2019	268902	269484	582
22/10/2019	269484	270633	1,149
23/10/2019	270633	271691	1,058
24/10/2019	271691	271691	-
25/10/2019	271691	272309	618
26/10/2019	272309	273792	1,483
27/10/2019	273792	275057	1,265
28/10/2019	275057	276495	1,438
29/10/2019	276495	277866	1,371
30/10/2019	277866	279220	1,354
31/10/2019	279220	279769	549
TOTAL			30,117
NOVEMBER			
01/11/2019	279769	280938	1,169
02/11/2019	280938	282156	1,218
03/11/2019	282156	283099	943
04/11/2019	283099	284285	1,186
05/11/2019	284285	285575	1,290
06/11/2019	285575	286962	1,387
07/11/2019	286962	287746	784
08/11/2019	287746	287746	-
09/11/2019	287746	287746	-
10/11/2019	287746	289512	1,766

11/11/2019	289512	290745	1,233
12/11/2019	290745	291222	477
13/11/2019	291222	292300	1,078
14/11/2019	292300	293638	1,338
15/11/2019	293638	295041	1,403
16/11/2019	295041	296447	1,406
17/11/2019	296447	296717	270
18/11/2019	296717	296717	-
19/11/2019	296717	296717	-
20/11/2019	296717	296717	-
21/11/2019	296717	296717	-
22/11/2019	296717	296717	-
23/11/2019	296717	296717	-
24/11/2019	296717	297734	1,017
25/11/2019	297734	299185	1,451
26/11/2019	299185	300389	1,204
27/11/2019	300389	301932	1,543
28/11/2019	301932	303824	1,892
29/11/2019	303824	305723	1,899
30/11/2019	305723	307516	1,793
TOTAL			27,747
DECEMBER			
01/12/2019	307516	309297	1,781
02/12/2019	309297	311485	2,188
03/12/2019	311485	313480	1,995
04/12/2019	313480	313971	491
05/12/2019	313971	315191	1,220
06/12/2019	315191	317144	1,953
07/12/2019	317144	318937	1,793
08/12/2019	318937	320682	1,745
09/12/2019	320682	322575	1,893
10/12/2019	322575	323691	1,116
11/12/2019	323691	324733	1,042
12/12/2019	324733	326617	1,884
13/12/2019	326617	326617	-
14/12/2019	326617	328234	1,617
15/12/2019	328234	329895	1,661
16/12/2019	329895	331477	1,582
17/12/2019	331477	333233	1,756
18/12/2019	333233	334974	1,741
19/12/2019	334974	336601	1,627
20/12/2019	336601	338395	1,794
21/12/2019	338395	339884	1,489

22/12/2019	339884	341517	1,633
23/12/2019	341517	343259	1,742
24/12/2019	343259	344944	1,685
25/12/2019	344944	346558	1,614
26/12/2019	346558	348241	1,683
27/12/2019	348241	349814	1,573
28/12/2019	349814	351231	1,417
29/12/2019	351231	352812	1,581
30/12/2019	352812	354571	1,759
31/12/2019	354571	356490	1,919
TOTAL			48,974
JANUARY			
01/01/2020	356490	358468	1,978
02/01/2020	358468	360304	1,836
03/01/2020	360304	361753	1,449
04/01/2020	361753	363011	1,258
05/01/2020	363011	365037	2,026
06/01/2020	365037	366676	1,639
07/01/2020	366676	368691	2,015
08/01/2020	368691	370734	2,043
09/01/2020	370734	372632	1,898
10/01/2020	372632	374318	1,686
11/01/2020	374318	375778	1,460
12/01/2020	375778	376192	414
13/01/2020	376192	376192	-
14/01/2020	376192	376902	710
15/01/2020	376902	378581	1,679
16/01/2020	378581	379656	1,075
17/01/2020	379656	381240	1,584
18/01/2020	381240	382611	1,371
19/01/2020	382611	384205	1,594
20/01/2020	384205	385412	1,207
21/01/2020	385412	386656	1,244
22/01/2020	386656	388318	1,662
23/01/2020	388318	389778	1,460
24/01/2020	389778	391507	1,729
25/01/2020	391507	393212	1,705
26/01/2020	393212	394866	1,654
27/01/2020	394866	396226	1,360
28/01/2020	396226	397525	1,299
29/01/2020	397525	398317	792
30/01/2020	398317	399569	1,252
31/01/2020	399569	401352	1,783

TOTAL			44,862
FEBRUARY			
01/02/2020	401352	403289	1,937
02/02/2020	403289	405372	2,083
03/02/2020	405372	407080	1,708
04/02/2020	407080	409159	2,079
05/02/2020	409159	410607	1,448
06/02/2020	410607	411882	1,275
07/02/2020	411882	412924	1,042
08/02/2020	412924	414586	1,662
09/02/2020	414586	416620	2,034
10/02/2020	416620	417860	1,240
11/02/2020	417860	419009	1,149
12/02/2020	419009	420005	996
13/02/2020	420005	421441	1,436
14/02/2020	421441	423081	1,640
15/02/2020	423081	424777	1,696
16/02/2020	424777	426427	1,650
17/02/2020	426427	428125	1,698
18/02/2020	428125	429778	1,653
19/02/2020	429778	431560	1,782
20/02/2020	431560	433500	1,940
21/02/2020	433500	435128	1,628
22/02/2020	435128	436721	1,593
23/02/2020	436721	438380	1,659
24/02/2020	438380	440320	1,940
25/02/2020	440320	442428	2,108
26/02/2020	442428	444547	2,119
27/02/2020	444547	446618	2,071
28/02/2020	446618	448121	1,503
29/02/2020	448121	449688	1,567
TOTAL			48,336
MARCH			
01/03/2020	449688	450574	886
02/03/2020	450574	450574	-
03/03/2020	450574	451799	1,225
04/03/2020	451799	451972	173
05/03/2020	451972	452972	1,000
06/03/2020	452972	454805	1,833
07/03/2020	454805	456268	1,463
08/03/2020	456268	458018	1,750
09/03/2020	458018	459690	1,672
10/03/2020	459690	461716	2,026

11/03/2020	461716	462263	547
12/03/2020	462263	463560	1,297
13/03/2020	463560	465637	2,077
14/03/2020	465637	467254	1,617
15/03/2020	467254	468508	1,254
16/03/2020	468508	470470	1,962
17/03/2020	470470	471413	943
18/03/2020	471413	472384	971
19/03/2020	472384	473356	972
20/03/2020	473356	474982	1,626
21/03/2020	474982	476413	1,431
22/03/2020	476413	476994	581
23/03/2020	476994	478191	1,197
24/03/2020	478191	479527	1,336
25/03/2020	479527	480564	1,037
26/03/2020	480564	482158	1,594
27/03/2020	482158	482475	317
28/03/2020	482475	483643	1,168
29/03/2020	483643	485388	1,745
30/03/2020	485388	487051	1,663
31/03/2020	487051	488798	1,747
TOTAL			39,110
APRIL			
01/04/2020	488798	490877	2,079
02/04/2020	490877	492527	1,650
03/04/2020	492527	494190	1,663
04/04/2020	494190	495836	1,646
05/04/2020	495836	497561	1,725
06/04/2020	497561	499433	1,872
07/04/2020	499433	500833	1,400
08/04/2020	500833	502500	1,667
09/04/2020	502500	503800	1,300
10/04/2020	503800	505080	1,280
11/04/2020	505080	506626	1,546
12/04/2020	506626	508063	1,437
13/04/2020	508063	509397	1,334
14/04/2020	509397	510616	1,219
15/04/2020	510616	511926	1,310
16/04/2020	511926	513193	1,267
17/04/2020	513193	514979	1,786
18/04/2020	514979	516417	1,438
19/04/2020	516417	517798	1,381
20/04/2020	517798	519168	1,370

21/04/2020	519168	519168	-
22/04/2020	519168	519740	572
23/04/2020	519740	521512	1,772
24/04/2020	521512	523645	2,133
25/04/2020	523645	525743	2,098
26/04/2020	525743	527983	2,240
27/04/2020	527983	529697	1,714
28/04/2020	529697	531057	1,360
29/04/2020	531057	532793	1,736
30/04/2020	532793	534563	1,770
TOTAL			45,765
MAY			
01/05/2020	534563	536630	2,067
02/05/2020	536630	537985	1,355
03/05/2020	537985	539414	1,429
04/05/2020	539414	541302	1,888
05/05/2020	541302	542871	1,569
06/05/2020	542871	544535	1,664
07/05/2020	544535	546337	1,802
08/05/2020	546337	548069	1,732
09/05/2020	548069	550173	2,104
10/05/2020	550173	552147	1,974
11/05/2020	552147	553770	1,623
12/05/2020	553770	555289	1,519
13/05/2020	555289	556716	1,427
14/05/2020	556716	558272	1,556
15/05/2020	558272	559768	1,496
16/05/2020	559768	561261	1,493
17/05/2020	561261	562701	1,440
18/05/2020	562701	564072	1,371
19/05/2020	564072	565480	1,408
20/05/2020	565480	565822	342
21/05/2020	565822	566788	966
22/05/2020	566788	567328	540
23/05/2020	567328	568817	1,489
24/05/2020	568817	569338	521
25/05/2020	569338	570363	1,025
26/05/2020	570363	571783	1,420
27/05/2020	571783	572448	665
28/05/2020	572448	573219	771
29/05/2020	573219	574714	1,495
30/05/2020	574714	576676	1,962
31/05/2020	576676	578520	1,844

TOTAL			43,957
JUNE			
01/06/2020	578520	580007	1,487
02/06/2020	580007	581448	1,441
03/06/2020	581448	582800	1,352
04/06/2020	582800	584182	1,382
05/06/2020	584182	585110	928
06/06/2020	585110	586958	1,848
07/06/2020	586958	588511	1,553
08/06/2020	588511	590267	1,756
09/06/2020	590267	591251	984
10/06/2020	591251	592901	1,650
11/06/2020	592901	594434	1,533
12/06/2020	594434	595668	1,234
13/06/2020	595668	595668	-
14/06/2020	595668	596653	985
15/06/2020	596653	597722	1,069
16/06/2020	597722	598973	1,251
17/06/2020	598973	600632	1,659
18/06/2020	600632	602189	1,557
19/06/2020	602189	603988	1,799
20/06/2020	603988	605287	1,299
21/06/2020	605287	606957	1,670
22/06/2020	606957	608612	1,655
23/06/2020	608612	610122	1,510
24/06/2020	610122	610122	-
25/06/2020	610122	611506	1,384
26/06/2020	611506	613263	1,757
27/06/2020	613263	614387	1,124
28/06/2020	614387	614387	-
29/06/2020	614387	614387	-
30/06/2020	614387	614387	-
TOTAL			35,867
JULY			
01/07/2020	614387	615329	942
02/07/2020	615329	615539	210
03/07/2020	615539	616785	1,246
04/07/2020	616785	618090	1,305
05/07/2020	618090	619406	1,316
06/07/2020	619406	621067	1,661
07/07/2020	621067	622621	1,554
08/07/2020	622621	624153	1,532
09/07/2020	624153	625684	1,531

10/07/2020	625684	627440	1,756
11/07/2020	627440	628812	1,372
12/07/2020	628812	630311	1,499
13/07/2020	630311	631907	1,596
14/07/2020	631907	633373	1,466
15/07/2020	633373	634624	1,251
16/07/2020	634624	634624	-
17/07/2020	634624	636079	1,455
18/07/2020	636079	637168	1,089
19/07/2020	637168	638030	862
20/07/2020	638030	639542	1,512
21/07/2020	639542	641003	1,461
22/07/2020	641003	642327	1,324
23/07/2020	642327	643921	1,594
24/07/2020	643921	645634	1,713
25/07/2020	645634	647293	1,659
26/07/2020	647293	648985	1,692
27/07/2020	648985	650431	1,446
28/07/2020	650431	652076	1,645
29/07/2020	652076	653668	1,592
30/07/2020	653668	655166	1,498
31/07/2020	655166	656181	1,015
TOTAL			41,794
AUGUST			
01/08/2020	656181	657232	1,051
02/08/2020	657232	658633	1,401
03/08/2020	658633	659993	1,360
04/08/2020	659993	661353	1,360
05/08/2020	661353	661767	414
06/08/2020	661767	663121	1,354
07/08/2020	663121	664538	1,417
08/08/2020	664538	665832	1,294
09/08/2020	665832	666970	1,138
10/08/2020	666970	668031	1,061
11/08/2020	668031	668386	355
12/08/2020	668386	668386	-
13/08/2020	668386	668902	516
14/08/2020	668902	668902	-
15/08/2020	668902	670357	1,455
16/08/2020	670357	671352	995
17/08/2020	671352	672522	1,170
18/08/2020	672522	674162	1,640
19/08/2020	674162	675998	1,836

20/08/2020	675998	677716	1,718
21/08/2020	677716	679007	1,291
22/08/2020	679007	680488	1,481
23/08/2020	680488	681686	1,198
24/08/2020	681686	683146	1,460
25/08/2020	683146	684526	1,380
26/08/2020	684526	685792	1,266
27/08/2020	685792	687153	1,361
28/08/2020	687153	688826	1,673
29/08/2020	688826	690170	1,344
30/08/2020	690170	690170	-
31/08/2020	690170	690170	-
TOTAL			33,989
SEPTEMBER			
01/09/2020	690170	691767	1,597
02/09/2020	691767	693189	1,422
03/09/2020	693189	695033	1,844
04/09/2020	695033	696922	1,889
05/09/2020	696922	698482	1,560
06/09/2020	698482	700493	2,011
07/09/2020	700493	702260	1,767
08/09/2020	702260	703872	1,612
09/09/2020	703872	704737	865
10/09/2020	704737	706350	1,613
11/09/2020	706350	707669	1,319
12/09/2020	707669	708308	639
13/09/2020	708308	709847	1,539
14/09/2020	709847	710703	856
15/09/2020	710703	712230	1,527
16/09/2020	712230	713625	1,395
17/09/2020	713625	715106	1,481
18/09/2020	715106	716844	1,738
19/09/2020	716844	718207	1,363
20/09/2020	718207	719496	1,289
21/09/2020	719496	720704	1,208
22/09/2020	720704	722226	1,522
23/09/2020	722226	723464	1,238
24/09/2020	723464	724278	814
25/09/2020	724278	724988	710
26/09/2020	724988	724988	-
27/09/2020	724988	725203	215
28/09/2020	725203	726536	1,333
29/09/2020	726536	727944	1,408

30/09/2020	727944	729085	1,141
TOTAL			38,915
OCTOBER			
01/10/2020	729085	729933	848
02/10/2020	729933	729933	-
03/10/2020	729933	730625	692
04/10/2020	730625	730933	308
05/10/2020	730933	732580	1,647
06/10/2020	732580	734058	1,478
07/10/2020	734058	735184	1,126
08/10/2020	735184	736488	1,304
09/10/2020	736488	737616	1,128
10/10/2020	737616	737616	-
11/10/2020	737616	738613	997
12/10/2020	738613	739885	1,272
13/10/2020	739885	740614	729
14/10/2020	740614	741496	882
15/10/2020	741496	742493	997
16/10/2020	742493	743891	1,398
17/10/2020	743891	745376	1,485
18/10/2020	745376	746846	1,470
19/10/2020	746846	748200	1,354
20/10/2020	748200	749649	1,449
21/10/2020	749649	750581	932
22/10/2020	750581	751094	513
23/10/2020	751094	751818	724
24/10/2020	751818	753441	1,623
25/10/2020	753441	755071	1,630
26/10/2020	755071	756751	1,680
27/10/2020	756751	758387	1,636
28/10/2020	758387	759224	837
29/10/2020	759224	760773	1,549
30/10/2020	760773	762085	1,312
31/10/2020	762085	762965	880
TOTAL			33,880

NOVEMBER

01/11/2020	No daily record	No daily record	no data
02/11/2020	No daily record	No daily record	no data
03/11/2020	No daily record	No daily record	no data
04/11/2020	No daily record	No daily record	no data
05/11/2020	No daily record	No daily record	no data
06/11/2020	No daily record	No daily record	no data
07/11/2020	No daily record	No daily record	no data

08/11/2020	No daily record	No daily record	no data
09/11/2020	No daily record	No daily record	no data
10/11/2020	No daily record	No daily record	no data
11/11/2020	No daily record	No daily record	no data
12/11/2020	No daily record	No daily record	no data
13/11/2020	No daily record	No daily record	no data
14/11/2020	No daily record	No daily record	no data
15/11/2020	No daily record	No daily record	no data
16/11/2020	No daily record	No daily record	no data
17/11/2020	No daily record	No daily record	no data
18/11/2020	No daily record	No daily record	no data
19/11/2020	No daily record	No daily record	no data
20/11/2020	No daily record	No daily record	no data
21/11/2020	No daily record	No daily record	no data
22/11/2020	No daily record	No daily record	no data
23/11/2020	No daily record	No daily record	no data
24/11/2020	No daily record	No daily record	no data
25/11/2020	No daily record	No daily record	no data
26/11/2020	No daily record	No daily record	no data
27/11/2020	No daily record	No daily record	no data
28/11/2020	No daily record	No daily record	no data
29/11/2020	No daily record	No daily record	no data
30/11/2020	No daily record	No daily record	no data
TOTAL			32,784
DECEMBER			
01/12/2020	No daily record	No daily record	no data
02/12/2020	No daily record	No daily record	no data
03/12/2020	No daily record	No daily record	no data
04/12/2020	No daily record	No daily record	no data
05/12/2020	No daily record	No daily record	no data
06/12/2020	No daily record	No daily record	no data
07/12/2020	No daily record	No daily record	no data
08/12/2020	No daily record	No daily record	no data
09/12/2020	No daily record	No daily record	no data
10/12/2020	No daily record	No daily record	no data
11/12/2020	No daily record	No daily record	no data
12/12/2020	No daily record	No daily record	no data
13/12/2020	No daily record	No daily record	no data
14/12/2020	No daily record	No daily record	no data
15/12/2020	No daily record	No daily record	no data
16/12/2020	No daily record	No daily record	no data
17/12/2020	No daily record	No daily record	no data
18/12/2020	No daily record	No daily record	no data

19/12/2020	No daily record	No daily record	no data
20/12/2020	No daily record	No daily record	no data
21/12/2020	No daily record	No daily record	no data
22/12/2020	No daily record	No daily record	no data
23/12/2020	No daily record	No daily record	no data
24/12/2020	No daily record	No daily record	no data
25/12/2020	No daily record	No daily record	no data
26/12/2020	No daily record	No daily record	no data
27/12/2020	No daily record	No daily record	no data
28/12/2020	No daily record	No daily record	no data
29/12/2020	No daily record	No daily record	no data
30/12/2020	No daily record	No daily record	no data
31/12/2020	No daily record	No daily record	no data
TOTAL			33,186
JANUARY			
01/01/2021	839029	840316	1,287
02/01/2021	840316	841746	1,430
03/01/2021	841746	843019	1,273
04/01/2021	843019	844417	1,398
05/01/2021	844417	845877	1,460
06/01/2021	845877	847521	1,644
07/01/2021	847521	848827	1,306
08/01/2021	848827	849652	825
09/01/2021	849652	850566	914
10/01/2021	850566	851512	946
11/01/2021	851512	852880	1,368
12/01/2021	852880	854551	1,671
13/01/2021	854551	856246	1,695
14/01/2021	856246	858030	1,784
15/01/2021	858030	859550	1,520
16/01/2021	859550	861190	1,640
17/01/2021	861190	863032	1,842
18/01/2021	863032	865032	2,000
19/01/2021	865032	866923	1,891
20/01/2021	866923	869093	2,170
21/01/2021	869093	870946	1,853
22/01/2021	870946	872581	1,635
23/01/2021	872581	874209	1,628
24/01/2021	874209	875839	1,630
25/01/2021	875839	876573	734
26/01/2021	876573	877969	1,396
27/01/2021	877969	879733	1,764
28/01/2021	879733	881111	1,378

29/01/2021	881111	882551	1,440
30/01/2021	882551	883523	972
31/01/2021	883523	884996	1,473
TOTAL			45,967
FEBRUARY			
01/02/2021	884996	886426	1,430
02/02/2021	886426	887655	1,229
03/02/2021	887655	888919	1,264
04/02/2021	888919	890521	1,602
05/02/2021	890521	892093	1,572
06/02/2021	892093	893601	1,508
07/02/2021	893601	894404	803
08/02/2021	894404	895166	762
09/02/2021	895166	896379	1,213
10/02/2021	896379	897488	1,109
11/02/2021	897488	898813	1,325
12/02/2021	898813	899800	987
13/02/2021	899800	901212	1,412
14/02/2021	901212	902602	1,390
15/02/2021	902602	904007	1,405
16/02/2021	904007	904914	907
17/02/2021	904914	906297	1,383
18/02/2021	906297	907040	743
19/02/2021	907040	908405	1,365
20/02/2021	908405	909280	875
21/02/2021	909280	910631	1,351
22/02/2021	910631	911895	1,264
23/02/2021	911895	913137	1,242
24/02/2021	913137	914315	1,178
25/02/2021	914315	915300	985
26/02/2021	915300	917014	1,714
27/02/2021	917014	918271	1,257
28/02/2021	918271	919632	1,361
TOTAL			34,636
MARCH			
01/03/2021	919632	920951	1,319
02/03/2021	920951	922361	1,410
03/03/2021	922361	923716	1,355
04/03/2021	923716	925139	1,423
05/03/2021	925139	925432	293
06/03/2021	925432	926914	1,482
07/03/2021	926914	928450	1,536
08/03/2021	928450	930146	1,696

09/03/2021	930146	931916	1,770
10/03/2021	931916	933764	1,848
11/03/2021	933764	935425	1,661
12/03/2021	935425	936476	1,051
13/03/2021	936476	938246	1,770
14/03/2021	938246	940080	1,834
15/03/2021	940080	941689	1,609
16/03/2021	941689	942371	682
17/03/2021	942371	943536	1,165
18/03/2021	943536	944540	1,004
19/03/2021	944540	945163	623
20/03/2021	945163	946046	883
21/03/2021	946046	946461	415
22/03/2021	946461	947388	927
23/03/2021	947388	948400	1,012
24/03/2021	948400	949892	1,492
25/03/2021	949892	951438	1,546
26/03/2021	951438	953046	1,608
27/03/2021	953046	953774	728
28/03/2021	953774	954599	825
29/03/2021	954599	955738	1,139
30/03/2021	955738	956163	425
31/03/2021	956163	957076	913
TOTAL			37,444
APRIL			
01/04/2021	957076	958383	1,307
02/04/2021	958383	959664	1,281
03/04/2021	959664	961089	1,425
04/04/2021	961089	962187	1,098
05/04/2021	962187	963701	1,514
06/04/2021	963701	965181	1,480
07/04/2021	965181	966613	1,432
08/04/2021	966613	968010	1,397
09/04/2021	968010	969411	1,401
10/04/2021	969411	970503	1,092
11/04/2021	970503	971951	1,448
12/04/2021	971951	973437	1,486
13/04/2021	973437	974397	960
14/04/2021	974397	976830	2,433
15/04/2021	976830	977842	1,012
16/04/2021	977842	979323	1,481
17/04/2021	979323	980784	1,461
18/04/2021	980784	982335	1,551

19/04/2021	982335	983767	1,432
20/04/2021	983767	984907	1,140
21/04/2021	984907	986361	1,454
22/04/2021	986361	987757	1,396
23/04/2021	987757	989157	1,400
24/04/2021	989157	990562	1,405
25/04/2021	990562	991833	1,271
26/04/2021	991833	992830	997
27/04/2021	992830	993783	953
28/04/2021	993783	994628	845
29/04/2021	994628	994875	247
30/04/2021	994875	995695	820
TOTAL			38,619
MAY			
01/05/2021	995695	996548	853
02/05/2021	996548	997572	1,024
03/05/2021	997572	998709	1,137
04/05/2021	998709	999999	1,290
05/05/2021	0	724	724
06/05/2021	724	858	134
07/05/2021	858	1776	918
08/05/2021	1776	2629	853
09/05/2021	2629	3572	943
10/05/2021	3572	4486	914
11/05/2021	4486	5334	848
12/05/2021	5334	6326	992
13/05/2021	6326	7372	1,046
14/05/2021	7372	8454	1,082
15/05/2021	8454	8966	512
16/05/2021	8966	9980	1,014
17/05/2021	9980	10060	80
18/05/2021	10060	10737	677
19/05/2021	10737	12210	1,473
20/05/2021	12210	14008	1,798
21/05/2021	14008	15979	1,971
22/05/2021	15979	17777	1,798
23/05/2021	17777	19340	1,563
24/05/2021	19340	20169	829
25/05/2021	20169	21546	1,377
26/05/2021	21546	23103	1,557
27/05/2021	23103	24313	1,210
28/05/2021	24313	25743	1,430
29/05/2021	25743	27065	1,322

30/05/2021	27065	28118	1,053
31/05/2021	28118	28761	643
TOTAL			33,065
JUNE			
01/06/2021	28761	30420	1,659
02/06/2021	30420	31950	1,530
03/06/2021	31950	32824	874
04/06/2021	32824	34283	1,459
05/06/2021	34283	35455	1,172
06/06/2021	35455	36640	1,185
07/06/2021	36640	38059	1,419
08/06/2021	38059	39799	1,740
09/06/2021	39799	41158	1,359
10/06/2021	41158	41374	216
11/06/2021	41374	42683	1,309
12/06/2021	42683	43976	1,293
13/06/2021	43976	45307	1,331
14/06/2021	45307	46449	1,142
15/06/2021	46449	47433	984
16/06/2021	47433	48305	872
17/06/2021	48305	49541	1,236
18/06/2021	49541	50718	1,177
19/06/2021	50718	51769	1,051
20/06/2021	51769	52948	1,179
21/06/2021	52948	54029	1,081
22/06/2021	54029	55064	1,035
23/06/2021	55064	56240	1,176
24/06/2021	56240	57282	1,042
25/06/2021	57282	58400	1,118
26/06/2021	58400	59418	1,018
27/06/2021	59418	60574	1,156
28/06/2021	60574	61493	919
29/06/2021	61493	62646	1,153
30/06/2021	62646	63804	1,158
TOTAL			35,043
JULY			-
01/07/2021	63804	64992	1,188
02/07/2021	64992	66493	1,501
03/07/2021	66493	68029	1,536
04/07/2021	68029	69506	1,477
05/07/2021	69506	70928	1,422
06/07/2021	70928	71753	825
07/07/2021	71753	72072	319

08/07/2021	72072	72994	922
09/07/2021	72994	73366	372
10/07/2021	73366	74758	1,392
11/07/2021	74758	76253	1,495
12/07/2021	76253	77390	1,137
13/07/2021	77390	77390	-
14/07/2021	77390	77390	-
15/07/2021	77390	77390	-
16/07/2021	77390	77390	-
17/07/2021	77390	79404	2,014
18/07/2021	79404	81209	1,805
19/07/2021	81209	82713	1,504
20/07/2021	82713	84093	1,380
21/07/2021	84093	85425	1,332
22/07/2021	85425	86871	1,446
23/07/2021	86871	88306	1,435
24/07/2021	88306	89768	1,462
25/07/2021	89768	91081	1,313
26/07/2021	91081	92464	1,383
27/07/2021	92464	93941	1,477
28/07/2021	93941	95366	1,425
29/07/2021	95366	96744	1,378
30/07/2021	96744	98397	1,653
31/07/2021	98397	100140	1,743
TOTAL			36,336
AUGUST			
01/08/2021	100140	102053	1,913
02/08/2021	102053	103889	1,836
03/08/2021	103889	105268	1,379
04/08/2021	105268	106829	1,561
05/08/2021	106829	108487	1,658
06/08/2021	108487	110256	1,769
07/08/2021	110256	111281	1,025
08/08/2021	111281	112956	1,675
09/08/2021	112956	114146	1,190
10/08/2021	114146	115662	1,516
11/08/2021	115662	117070	1,408
12/08/2021	117070	117345	275
13/08/2021	117345	118834	1,489
14/08/2021	118834	120184	1,350
15/08/2021	120184	121444	1,260
16/08/2021	121444	122778	1,334
17/08/2021	122778	124198	1,420

18/08/2021	124198	125619	1,421
19/08/2021	125619	126826	1,207
20/08/2021	126826	127826	1,000
21/08/2021	127826	128303	477
22/08/2021	128303	129329	1,026
23/08/2021	129329	130507	1,178
24/08/2021	130507	131750	1,243
25/08/2021	131750	133019	1,269
26/08/2021	133019	133476	457
27/08/2021	133476	134069	593
28/08/2021	134069	135067	998
29/08/2021	135067	136958	1,891
30/08/2021	136958	138734	1,776
31/08/2021	138734	140387	1,653
TOTAL			40,247
SEPTEMBER			
01/09/2021	140387	142213	1,826
02/09/2021	142213	143938	1,725
03/09/2021	143938	145865	1,927
04/09/2021	145865	147084	1,219
05/09/2021	147084	148409	1,325
06/09/2021	148409	149584	1,175
07/09/2021	149584	150892	1,308
08/09/2021	150892	151406	514
09/09/2021	151406	152374	968
10/09/2021	152374	153239	865
11/09/2021	153239	154073	834
12/09/2021	154073	155137	1,064
13/09/2021	155137	156759	1,622
14/09/2021	156759	157126	367
15/09/2021	157126	158011	885
16/09/2021	158011	159333	1,322
17/09/2021	159333	160491	1,158
18/09/2021	160491	161775	1,284
19/09/2021	161775	162955	1,180
20/09/2021	162955	164319	1,364
21/09/2021	164319	165432	1,113
22/09/2021	165432	166647	1,215
23/09/2021	166647	167990	1,343
24/09/2021	167990	169305	1,315
25/09/2021	169305	170670	1,365
26/09/2021	170670	172047	1,377
27/09/2021	172047	173356	1,309

28/09/2021	173356	174710	1,354
29/09/2021	174710	176246	1,536
30/09/2021	176246	177651	1,405
TOTAL			37,264
OCTOBER			
01/10/2021	177651	179136	1,485
02/10/2021	179136	180659	1,523
03/10/2021	180659	181981	1,322
04/10/2021	181981	182996	1,015
05/10/2021	182996	184420	1,424
06/10/2021	184420	185776	1,356
07/10/2021	185776	187056	1,280
08/10/2021	187056	188368	1,312
09/10/2021	188368	189560	1,192
10/10/2021	189560	190870	1,310
11/10/2021	190870	192250	1,380
12/10/2021	192250	193661	1,411
13/10/2021	193661	195107	1,446
14/10/2021	195107	196563	1,456
15/10/2021	196563	197556	993
16/10/2021	197556	198497	941
17/10/2021	198497	199713	1,216
18/10/2021	199713	200922	1,209
19/10/2021	200922	202208	1,286
20/10/2021	202208	204121	1,913
21/10/2021	204121	205275	1,154
22/10/2021	205275	206468	1,193
23/10/2021	206468	207746	1,278
24/10/2021	207746	208967	1,221
25/10/2021	208967	210171	1,204
26/10/2021	210171	211671	1,500
27/10/2021	211671	213297	1,626
28/10/2021	213297	214579	1,282
29/10/2021	214579	215928	1,349
30/10/2021	215928	217284	1,356
31/10/2021	217284	218556	1,272
TOTAL			40,905
NOVEMBER			-
01/11/2021	218556	219805	1,249
02/11/2021	219805	221098	1,293
03/11/2021	221098	222470	1,372
04/11/2021	222470	223882	1,412
05/11/2021	223882	225256	1,374

06/11/2021	225256	226467	1,211
07/11/2021	226467	227394	927
08/11/2021	227394	228979	1,585
09/11/2021	228979	230672	1,693
10/11/2021	230672	232322	1,650
11/11/2021	232322	233994	1,672
12/11/2021	233994	235724	1,730
13/11/2021	235724	237067	1,343
14/11/2021	237067	238336	1,269
15/11/2021	238336	239715	1,379
16/11/2021	239715	241000	1,285
17/11/2021	241000	241624	624
18/11/2021	241624	243107	1,483
19/11/2021	243107	244596	1,489
20/11/2021	244596	246063	1,467
21/11/2021	246063	247849	1,786
22/11/2021	247849	249506	1,657
23/11/2021	249506	250719	1,213
24/11/2021	250719	251981	1,262
25/11/2021	251981	253396	1,415
26/11/2021	253396	254784	1,388
27/11/2021	254784	256131	1,347
28/11/2021	256131	257574	1,443
29/11/2021	257574	258923	1,349
30/11/2021	258923	260252	1,329
TOTAL			41,696
DECEMBER			-
01/12/2021	260252	261647	1,395
02/12/2021	261647	262975	1,328
03/12/2021	262975	264299	1,324
04/12/2021	264299	265685	1,386
05/12/2021	265685	267074	1,389
06/12/2021	267074	268141	1,067
07/12/2021	268141	269492	1,351
08/12/2021	269492	270401	909
09/12/2021	270401	271564	1,163
10/12/2021	271564	272689	1,125
11/12/2021	272689	273753	1,064
12/12/2021	273753	275271	1,518
13/12/2021	275271	276744	1,473
14/12/2021	276744	278206	1,462
15/12/2021	278206	279597	1,391
16/12/2021	279597	280346	749

17/12/2021	280346	280979	633
18/12/2021	280979	281641	662
19/12/2021	281641	282319	678
20/12/2021	282319	283919	1,600
21/12/2021	283919	283919	-
22/12/2021	283919	284601	682
23/12/2021	284601	285395	794
24/12/2021	285395	286218	823
25/12/2021	286218	287002	784
26/12/2021	287002	287695	693
27/12/2021	287695	288536	841
28/12/2021	288536	289374	838
29/12/2021	289374	290203	829
30/12/2021	290203	290989	786
31/12/2021	290989	291040	51
TOTAL			30,788

Appendix 6: Survey Data sheet

Points	Coordinates		Elevation (m)	Distance (m)	Remarks
	Northings	Eastings			
1	2.41267	31.07003	1148	0	BPT1 to oweko Tee
2	2.41420	31.07262	1136	342	AV, TM2
3	2.41605	31.07394	1128	252	TM2
4	2.41695	31.07559	1123	208	TM2
5	2.41830	31.07803	1124	313	AV, TM2
6	2.41899	31.07903	1093	133	TM2
7	2.41933	31.07978	1099	91	AV, TM2
8	2.42009	31.08114	1070	172	TM2, 280mm Steel
9	2.42064	31.08189	1073	103	AV, TM2
10	2.42257	31.08519	1036	424	WO, 280mm PVC
11	2.42372	31.08699	1048	237	AV, 280mm PVC
12	2.42525	31.08962	1055	339	AV
13	2.42928	31.09349	1023	623	bridge point, TM2
14	2.43102	31.09547	1023	292	280 Steel, TM2
15	2.43390	31.09952	1051	548	AV, TM2
16	2.43606	31.10308	1034	459	TM2
17	2.43601	31.10455	1024	161	WO, TM2
18	2.43813	31.10855	1042	503	OWEKO T-OFF 280-210-280 PVC
19	2.43915	31.10905	1048	126	Air valve

20	2.44217	31.11149	1059	445	Air valve
21	2.44324	31.11588	1046	505	PT
22	2.44247	31.12376	999	890	Wash out
23	2.44036	31.12895	1046	671	AV Paminya 280mm steel
24	2.44035	31.12932	1044	15	Tee-off paminya 280-210-280
25	2.44766	31.13345	1022	940	Air Valve
26	2.44934	31.13629	1000	372	Wash out
27	2.45292	31.14255	1013	803	Air Valve
28	2.45740	31.15096	1046	1061	PT
29	2.45761	31.15474	1024	311	PT
30	2.45659	31.15690	1033	384	PT
31	2.45447	31.16252	994	664	PT
32	2.45293	31.16749	999	577	Air valve
33	2.45212	31.16947	1004	239	Air valve
34	2.44983	31.17508	1024	669	NP
35	2.44888	31.17658	1039	197	Air valve
36	2.44468	31.18562	1086	1115	Air Valve
37	2.44368	31.18719	1084	206	T-off nyaravur

weko Tee off to Oweko Reservoir

1	2.43810	31.10859	1043	6	210mm, PVC, TM3
2	2.43800	31.10862	1043	6	160mm, PVC, TM3
3	2.43795	31.10864	1044	6	90mm, HDPE, TM3
4	2.43786	31.10864	1045	6	75mm HDPE, TM3
5	2.43604	31.10809	1054	221	AV, 63mm hdpe TM3
6	2.43452	31.10750	1042	175	TM3
7	2.43141	31.10629	1052	371	TM3
8	2.42887	31.10540	1057	295	TM3
9	2.42627	31.10432	1062	366	AV, 63mm hdpe TM3
10	2.42281	31.10328	1072	401	TM3
11	2.42134	31.10274	1080	173	AV, 63mm hdpe TM3
12	2.42016	31.10236	1081	133	Exposed Pipe, 63mm HDPE, TM3
13	2.41811	31.10156	1092	242	TM3
14	2.41763	31.10144	1094	60	Bend to Oweko Tank
15	2.41741	31.10031	1101	119	Church
16	2.41754	31.0996	1108	78	End line / Rising Main
17	2.41754	31.0996	1112	0	Inlet oweko tank

Tee- off to Paminya Tank

1	2.44035	31.12932	1044	0	Tee-off paminya Tank 280-210-280
2	2.43766	31.12864	1053	307	PT
3	2.43197	31.12704	1079	656	PT
4	2.43002	31.12702	1090	140	40mm pipe
5	2.43002	31.12702	1105	9	Inlet at paminya tank

Appendix 7: epanet results

Node ID	Elevation m	Head m	Pressure m
Junc n10	1148	1151.50	3.50
Junc n11	1136	1151.47	15.47
Junc n12	1128	1151.44	23.44
Junc n13	1123	1151.42	28.42
Junc n14	1124	1151.39	27.39
Junc n15	1093	1151.38	58.38
Junc n16	1099	1151.37	52.37
Junc n17	1070	1151.35	81.35
Junc n18	1073	1151.34	78.34
Junc n19	1036	1151.30	115.30
Junc n20	1048	1151.28	103.28
Junc n21	1055	1151.25	96.25
Junc n22	1023	1151.19	128.19
Junc n23	1023	1151.16	128.16
Junc n24	1051	1151.11	100.11
Junc n25	1034	1151.06	117.06
Junc n26	1024	1151.05	127.05
Junc n27	1042	1151.00	109.00
Junc n28	1043	1151.00	108.00

Node ID	Elevation m	Head m	Pressure m
Junc n29	1043	1151.00	108.00
Junc n30	1044	1151.00	107.00
Junc n31	1045	1151.00	106.00
Junc n32	1054	1150.98	96.98
Junc n33	1042	1150.96	108.96
Junc n34	1052	1150.91	98.91
Junc n35	1057	1150.88	93.88
Junc n36	1062	1150.85	88.85
Junc n37	1072	1150.80	78.80
Junc n38	1080	1150.78	70.78
Junc n39	1081	1150.76	69.76
Junc n40	1092	1150.74	58.74
Junc n41	1094	1150.73	56.73
Junc n42	1101	1150.72	49.72
Junc n43	1108	1150.71	42.71
Junc n44	1112	1150.71	38.71
Junc n45	1048	1150.99	102.99
Junc n46	1059	1150.95	91.95
Junc n47	1046	1150.90	104.90

Node ID	Elevation m	Head m	Pressure m
Junc n48	999	1150.82	151.82
Junc n50	1046	1150.76	104.76
Junc n51	1053	1139.90	86.90
Junc n52	1079	1116.70	37.70
Junc n53	1090	1109.13	19.13
Junc n54	1105	1109.13	4.13
Junc n55	1022	1150.69	128.69
Junc n56	1000	1150.66	150.66
Junc n57	1013	1150.61	137.61
Junc n58	1046	1150.45	104.45
Junc n59	1024	1150.40	126.40
Junc n60	1033	1150.38	117.38
Junc n61	994	1150.33	156.33
Junc n62	999	1150.29	151.29
Junc n63	1004	1150.27	146.27
Junc n64	1024	1150.22	126.22
Junc n65	1039	1150.21	111.21
Junc n66	1086	1150.13	64.13
Junc 1	1084	1150.12	66.12
Junc 49	1046	1150.76	104.76
Tank 7	1148	1151.50	3.50
Tank 3	1092	1100.00	8.00
Tank 4	1100	1109.00	9.00
Tank 5	1112	1115.00	3.00

Link ID	Length m	Diameter mm	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor
Pipe p10	342	280	86.00	1.40	5.22	0.015
Pipe p11	252	280	42.00	0.68	1.38	0.016
Pipe p12	208	280	42.00	0.68	1.38	0.016
Pipe p13	313	280	42.00	0.68	1.38	0.016
Pipe p14	133	280	42.00	0.68	1.38	0.016
Pipe p15	91	280	42.00	0.68	1.38	0.016
Pipe p16	172	280	42.00	0.68	1.38	0.016
Pipe p17	103	280	42.00	0.68	1.38	0.016
Pipe p18	424	280	42.00	0.68	1.38	0.016
Pipe p19	237	280	42.00	0.68	1.38	0.016
Pipe p20	339	280	42.00	0.68	1.38	0.016
Pipe p21	623	280	42.00	0.68	1.38	0.016
Pipe p22	292	280	42.00	0.68	1.38	0.016
Pipe p23	548	280	42.00	0.68	1.38	0.016
Pipe p24	459	280	42.00	0.68	1.38	0.016
Pipe p25	161	280	42.00	0.68	1.38	0.016
Pipe p26	503	280	42.00	0.68	1.38	0.016
Pipe p27	6	200	1.00	0.03	0.01	0.048
Pipe p28	12	160	1.00	0.05	0.02	0.024
Link ID	Length m	Diameter mm	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor
Pipe p29	6	90	1.00	0.16	0.35	0.025
Pipe p30	10	90	1.00	0.16	0.39	0.028
Pipe p31	210	90	1.00	0.16	0.39	0.028
Pipe p32	180	90	1.00	0.16	0.39	0.028
Pipe p33	371	90	1.00	0.16	0.39	0.028
Pipe p34	295	90	1.00	0.16	0.39	0.028
Pipe p35	310	75	1.00	0.23	0.95	0.027
Pipe p36	400	75	1.00	0.23	0.95	0.027
Pipe p37	176	75	1.00	0.23	0.95	0.027
Pipe p38	137	75	1.00	0.23	0.95	0.027
Pipe p39	244	75	1.00	0.23	0.95	0.027
Pipe p40	52	75	1.00	0.23	0.95	0.027
Pipe p41	130	75	1.00	0.23	0.95	0.027
Pipe p42	77	75	1.00	0.23	0.95	0.027
Pipe p43	4	75	0.00	0.00	0.00	0.000
Pipe p45	126	280	41.00	0.67	1.32	0.016
Pipe p46	445	280	41.00	0.67	1.32	0.016
Pipe p47	505	280	41.00	0.67	1.32	0.016
Pipe p48	890	280	41.00	0.67	1.32	0.016

Link ID	Length m	Diameter mm	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor
Pipe p49	671	280	41.00	0.67	1.32	0.016
Pipe p53	656	75	1.00	0.23	0.95	0.027
Pipe p54	214	75	1.00	0.23	0.95	0.027
Pipe p55	15	280	0.00	0.00	0.00	0.000
Pipe p58	372	280	40.00	0.65	1.26	0.016
Pipe p59	803	280	40.00	0.65	1.26	0.016
Pipe p60	1061	280	40.00	0.65	2.68	0.035
Pipe p61	311	280	40.00	0.65	2.68	0.035
Pipe p62	384	280	40.00	0.65	1.26	0.016
Pipe p63	664	280	40.00	0.65	1.26	0.016
Pipe p64	577	280	40.00	0.65	1.26	0.016
Pipe p65	239	280	40.00	0.65	1.26	0.016
Pipe p66	669	280	40.00	0.65	1.26	0.016
Pipe p67	197	280	40.00	0.65	1.26	0.016
Pipe p68	1115	280	40.00	0.65	1.26	0.016
Pipe 24	940	280	-40.00	0.65	1.26	0.016
Pipe 25	307	75	1.00	0.23	0.95	0.027
Pipe 2	2	280	86.00	1.40	5.21	0.015
Pipe 1	206	280	40.00	0.65	1.26	0.016

Appendix 8: Questionnaire

Questionnaire for the scheme staff

The following will be the questionnaire for the scheme staffs

General background

1. Name.....Position.....

Year of service..... Salary scale.....

2. What is the average number of pipe bursts & leakage on the transmission line?

Leakages per week/month Bursts per week/month

3. What is the average number of pipe bursts & leakages on the distribution line?

Leakages per week/month Bursts per week/month

4. What is the frequency of pipe bursts on the service lines?

Leakages per week/month Bursts per week/month

5. How many days does it take to repair the Buras and leakage above?

Days for burst days for leakage

6. Are the materials readily available for the repair/replacement?

Yes for leakage/Burst No for leakage /burst

7. How long does it take to deliver the materials from the secretariat in Lira?

Days/weeks/Months

8. What do you do when the system is down and the repair materials are not available?

.....

9. In your opinion, what should be done to reduce the occurrence of NRW in this scheme?

Appendix 3: Interview

For customer

The following questions will be asked from the scheme staffs

Questionnaire for Customers

The following questionnaire will be used for the customers

Interview question by the interviewer	Interviewee answer
What is your age?	
When were you connected to the network?	
How many people are in your household?	
What is your average monthly consumption?	
How many days in a week do you receive water	
How many hours does it last before disappearing?	
Do you store water? If yes, in what container?	
Do you have any comment for the water provider?	

Interview for staff

The following interview will be conducted with the staffs of the scheme

Position in the scheme	☐ Plumber ☐ operator ☐ Commercial officer
Major roles and responsibilities in the scheme?	☐ Managing the scheme affairs ☐ Keeping the scheme's commercial transactions ☐ Day to day repairs, meter readings and revenue collections
Number of years in the service	☐ 0-1 ☐ 1-2 ☐ 2-3 ☐ 3-5 ☐ 4-5
Average monthly earning Ugx (000s)	☐ 100 to 300 ☐ 300 to 500 ☐ 500-1000
Are you happy with your work?	☐ Yes ☐ Fairly ☐ No

Are you contented with your salary	☐ Yes	☐ Fairly	☐ No
Time taken discover a breakdown	☐ < week	☐ a week	☐ a week
Time taken repair a breakdown	☐ < week	☐ a week	☐ a week
Means of transport for response	☐ Bicycle	☐ motorcycle	☐ Vehicle

What are the challenges you face when responding to the emergencies?

In your opinion what could be done to reduce on systems down time?