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DEPARTMENT OF EARTH SCIENCE

EVALUATING TELEMETRY SYSTEM OF THE PHALABORWA WATER TREATMENT WORKS PROCESS IN LEPELLE NORTHERN WATER

A thesis submitted in partial fulfilment of the requirement of the Degree of Master of Philosophy in Integrated Water Resources Management, Department of Earth Science, Faculty of Natural Science, University of Western Cape, South Africa.

By

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2021

DECLARATION

I declare that the thesis entitled ***“Evaluating the Telemetry System of the Phalaborwa Water Treatment Process in Lepelle Northern Water, Limpopo Province”*** is my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

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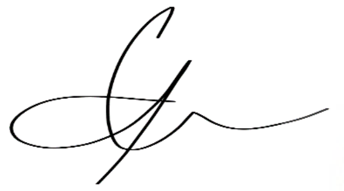

DEDICATION

I dedicate this thesis to my entire family and friends for their love and support during the period I was undertaking my research studies. May their right and time to contribute to water resource management and other related studies be appreciated and respected.

ACKNOWLEDGEMENT

The successful preparation and completion of this thesis titled "*Evaluating the Telemetry System of the Phalaborwa Water Treatment Process in Lepelle Northern Water, Limpopo Province"* has been with input from many people. I understand such undertaking is seldom an individual effort and it is also not possible to mention everyone who deserves recognition. Hence, I thereby acknowledge such people for their contribution. I feel humbled that God has accompanied me on this journey and made all things possible.

The completion of this study would not have been possible without the guidance and contribution of my supervisor Dr Thokozani Kanyerere. His advice as well as guidance provided me with more insight and your encouragement always propelled me to work even harder. I greatly appreciate his kindness, patience, and insightful assistance throughout the research study. I am grateful for all the guidance given. I also recognise the support and contributions received from my family, special thanks to my children Tumi, Laelo and Nolo for being my source of joy and strength. Not forgetting my mother Maria for her love, comfort, support, and prayers.

I would like to thank my employer, Lepelle Northern Water for the study opportunity given and availing the data used in this study. This study was also made possible by various people whom I hold in high regard and who contributed a range of recommendations, insights, guidance, and assistance. They have been a source of inspiration to me. The support and assistance from the Operations and Maintenance department was extremely valuable for this study. I would like to thank all interviews for their participation and valuable time. I would have never reached the end of my research studies without their support. Furthermore, your expert view, knowledge and experience were extremely beneficial and a great contribution to the results of this study. My earnest appreciation to you.

"*I can only see your back and you seem not stopping to share for no reason*."

ABSTRACT

Water is a strategic resource critical for basic human needs and for sustaining key economic sectors, including various emerging small businesses. The significance of water to everyday life become apparent mainly during periods of acute water shortages because of increasing population, industrial developments, droughts, and natural disasters that threatens the assurance of water supply. With the growing complexity of water supply challenges faced by the Phalaborwa WTW, there is a need to deploy technology and other means available to improve the provision of water and sanitation services. The aim of the study was to evaluate the telemetry system for managing the Phalaborwa WTW water supply process.

The use of technology such as telemetry, a vast amount of data and information including challenges related to volume, variety, velocity, and veracity can be easily monitored and managed. Innovation is one of the critical success factors central to identifying solution for addressing the systemic water challenges and interrelated socio-economic issues, as a result, contributed to the research problem. Hence the focus of this study was on to evaluate the telemetry system on the water treatment works process at the Phalaborwa WTW with specific reference to the Ba-Phalaborwa Local Municipality in Limpopo Province. The study employed a qualitative approach collect and analyse data. Semi-structured interviews and document analysis were conducted with purposely selected individuals employed in the Lepelle Northern Water Operations and Maintenance Department and one external service provider as the could provide first-hand information on the performance of the existing telemetry system.

The results from the study revealed serious concerns in relation to the capability of the existing telemetry system employed by the WTW. The results further indicated the importance of the emerging new telemetry tools that can be used to monitor water demand and supply in a cost-efficient manner. The appropriate telemetry system can be used to monitor the operational performance of water pumps, distribution network, water quality, and communicate information swiftly and cheaply to the control centre. To this end, the study recommended a replacement of the existing telemetry with a compatible and intelligent telemetry system that will be able to improve monitoring and management of delivery of water services.

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CONTRIBUTION TO KNOWLEDGE

The results of this research will assist with the provision of greater insight to the factors impeding delivery of water services and the identified recommended solutions will help to reduce the challenges faced by water and sanitation services providers. Regarding the possible contribution to knowledge of the study the researcher related this work on water and sanitation services delivery to the larger body of the literature and research on telemetry system technology. The research participants highlighted the potential for positive impact from results generated by the study to improve service delivery interventions and provide relevant recommendations to water service utilities. The study results can be shared in conferences, publication and with other researchers.

Participants' expertise in telemetry system contributed positively towards archiving the necessary results for the success of this study. They brought their logical thinking, experience, user-centred approach, collaboration, and knowledge about technologies. The spirit of shared goal effort committed themselves and the wiliness to work together in this study. The results of the study illustrated an overlapping between service delivery and technology. Companies, vendors, and employees will benefit from this study. Therefore, there is potential for these contributions to be combined successfully.

However, it was not common for the researcher to work with experts as most of them normally work with equipment service providers or consultants. This study was welcomed by the expert on the basis that the researcher could help with the review of existing telemetry system and user requirements. Moreover, researcher could provide the knowledge in terms of technology developments and new applications. In addition, the study could provide knowledge about artificial intelligent, engineering designs and techniques, and business requirements that could contribute to the improvement of production and operational performance in the provision of water services. These contributions are particularly relevant for the system designers, vendors, operations and maintenance department, and policy makers to inform their decision-making.

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ABBREVIATIONS

DWS	**Department of Water and Sanitation**
WSP	Water Service Provider
IWRM	Integrated Water Resource Management
LNW	Lepelle Northern Water
WTW	Water Treatment Works
NWA	National Water Act
WRC	Water Resource Commission
NWRS	National Water Resource Strategy
DST	Department of Science and Technology
SCADA	Supervisory Control and Data Acquisition
IoT	Internet of Things
AMR	Automated Meter Reading
WDN	Water Distribution Networks
CMA	Catchment Management Agency
BPM	Ba-Phalaborwa Municipality
MDM	Mopani District Municipality
WMA	Water Management Areas
NRW	Non-Revenue Water
AWARD	Association for Water and Rural Development
TIA	Technology Innovation Agency
NRF	National Resource Foundation
LED	Local Economic Development
WSA	Water Services Authority

KEY WORDS

Reliability	Sustainability	Conservation
Telemetry	Efficiency	Effective
Technology	System	Monitor
Optimization	Distribution	Availability

CHAPTER1: INTRODUCTION

1. General Introduction

1.1 Overview of the study

The study seeks to evaluate the use of telemetry system on water treatment works (WTW) process for monitoring and management. It also outlines the constraints of the telemetry infrastructure. The study also shows why the integrated water resources management (IWRM) is important to provide a set of ideas in managing water holistically because there are many challenges to the effective and efficient operation of the water distribution networks. Therefore, there is a need for stakeholders responsible for producing and distributing water to look for automation and to seek the solutions that encompasses all phases from installation, commission, and operation to system maintenance.

1.2 Background of the study

Water science and management involve a vast amount of data and information including challenges related to volume, variety, velocity, and veracity. With the growing complexity of water systems problems, there is a need to deploy technology and other means available to improve the provision of water services (Stanley & Gunn, 2018). This is in relation with the objective of the National Water Act (Act No. 36 of 1998). The NWA objective is to ensure that South Africa's water resources are protected, used, developed, conserved, managed, and controlled in a sustainable and equitable manner for the benefit of all. The availability of affordable water in South Africa where water is relatively a scarce resource that is distributed unevenly, both geographically and as well as socio-politically, for this reason, water resources need to be managed optimally.

The objectives of the government for managing water resources are clearly set out in the National Water Resources Strategy 2 (NWRS 2). Which include prioritisation of pollution prevention, treatment, and restoration of polluted water bodies; enhance capacity of institutions that are responsible for water quality management and compliance enforcement; and support sustainable use of aquatic ecosystems for sustainable livelihoods in poor rural communities, among others. Most of the times water resources and the WTW process are far away from the consumption points. Therefore, telemetry system is implemented for monitoring and controlling of the network to guarantee availability of water supply at all the times to the satisfaction of the end-users. For this reason, the Phalaborwa WTW followed the same approach.

Pressure from both supply and demand side has resulted in physical water scarcity (Chartres & Verma, 2011). The availability of water is influenced by factors such as climate change and pollution, which affect both the quantity and quality of surface and groundwater. Therefore, if appropriate action is not taken, water scarcity problem will worsen (Jury & Vaux, 2007). Therefore, the current study evaluated the application of the existing telemetry system in managing the WTW process in terms of its relevance, efficiency, effectiveness, impact, implementation, and sustainability. Based on the above description, the application telemetry system was viewed as the appropriate intervention in management of the WTW process.

1.2.1 Historical trend on telemetry system in WTW

Telemetry is derived from Greek, the word tele means remote and metron means measure (Suneel, 2013). Historically, telemetry system has been used for remote data acquisition and control. Wire or wireless communication links are used to connect various elements of the telemetry system. According to Keating (1994) there are many distributed control systems suitable for wireless telemetry such as automated system remote monitoring, factories, inventory management system, security and alarm system, and health care applications.

Telemetering information over wire had its origins in the 19^{th} century. One of the first data-transmission circuits was developed in 1845 between the Russian Tsar's winter palace and army headquarters. Weather and snow-depth sensor was built by the French engineers to transmit the real-time information to Paris. In 1906 a set of seismic stations were built with telemetering to the Pulkovo Observatory in Russia. In 1912 Commonwealth Edison developed a system of telemetry to monitor electrical load on its power grid. From 1913 to 1914 the Panama Canal used telemetry system to monitor locks and water levels. In 1930 Robert Bereau from France and Pavel Mochanov from Russia developed wireless telemetry system (DeweSoft, 2019).

Wireless telemetry has several advantages such as simple installation, improved mobility, easier extension, and reconfiguration as compared to wired telemetry. Data processing is typically managed from a central data acquisition and control application which supports the fact that the telemetry system is less complicated and cheaper (Keating, 1991).

1.2.2 Current debate on telemetry system in WTW

Currently, there are three core partners driving the water research, development, and innovation strategy in South Africa. These partners are the Department of Water and Sanitation (DWS), Department of Science and Technology (DST) and the Water Resource

Commission. There are a range of traditional research role player such as the National Research Foundation (NRF), Technology Innovation Agency (TIA), Research Councils, Units and Universities. There are also other organisations that are pivotal in scaling up, testing, and deploying new innovations to practice. These include utilities, municipalities, private sectors, non-profit organisation, and others. South Africa has a unique global contribution to make and continue to grow capability, capacity, and insight in areas key to water security (National Water and Sanitation Master Plan, 2018).

Nimavat (2015) states that recent advances in communication technology, especially wireless sensor networks have inspired numerous remote sensing and control application. This type of system helps in smart water monitoring, collect, and analyse standard water quality data, visualization, and detection of problems for remedial action and restoring the services of water supply and distribution. Major technical challenges of the system are sensor selection and control over wireless network may arise and for that appropriate algorithm are adopted based on system design requirements. Telemetry system is emerging to be the most recent and appropriate technology being used in many sectors including in WTW processes.

Various monitoring devices are available on the market and the task of optimal design and equipment selection is therefore not easy. Selection of monitoring equipment is typically made after the establishment of the goals and objectives of the monitoring programme. The selected equipment should meet the desired precision and accuracy, and appropriate scale. It must cope with spatial variability of the measured variable and work within on-site environmental conditions. Relevant government requirement and contract agreements should also be checked for possible selection constraints. Contracts agreements for the purchase of measuring devices often dictate required measurement systems. These constraints may be in terms of accuracy, specific comparison of devices and procedures (Fletcher & Deletic, 2007). Therefore, telemetry is one of the appropriate monitoring tools for optimizing the operation processes.

1.2.3 Current practice on telemetry system in WTW

There is a variety of telemetry solutions which the water utilities are using and frequently these solutions are integrated into Supervisory Control and Data Acquisition (SCADA) system. Many SCADA protocols are vendor specific (Stoianovi et al., 2008). According to Chinnusamy et al. (2018) to monitor and control geographically distributed Indian cities water networks, sensors should be placed in appropriate locations and manual valves should be automated. It is proposed that Internet of Things (IoT) can be used for real time water level monitoring of storage reservoirs in Water Distribution Networks (WDN) and remote actuation of valves.

Mutchek and Williams (2014) indicate that water losses and ineffective use in urban water network system stand out as promising areas for applications of smart water grids. However, potential barriers to the adoption of smart water grids include lack of funding for research and development, economic disincentives as well as institutional and political structures that favour the current system. According to the Statistics for South Africa General Household Survey (2016) a lack of data and information resulting to weak monitoring information system poses high risk to decision making and planning and will urgently be addressed by repairing and maintaining measuring infrastructure, adopting new monitoring technologies, and improving data management and distribution. The adoption of telemetry system was viewed as a solution to the weak monitoring information system.

Umgeni Water in their 2016/17 to 2020/21 Corporate Plan indicated that they are using GIS for spatial meters data and capturing of network infrastructure spatial attributes. They further indicated that the investigation in the use of Automated Meter Reading (AMR) is underway for assisting them to be more efficient and almost real time meter reading. In the Sedibeng Newsletter of 2016 February Issue for Water Utilities Corporation, it is stated that telemetry is used for real time data availability in water network system and applications, cost saving in operation, eliminating, or minimizing human errors, prompt responding to failures in the field and for easy generation of reports and use trends as references. Based on such attributes of telemetry system, the current study would like to evaluate its relevance, effectiveness, impact, and sustainability to the WTW process.

According to City of Toppenish Water System Plan (2017) telemetry is installed for monitoring of the source of production, regulating of pumps, reservoir level information, flow meter reading, and issuing of commands. Monatee Country Public Works Standards (2015) states that the telemetry ability is used to control pump alternation, activate, and deactivate local alarms, and communicate with the SCADA system. In the current study the focus will be on evaluating source of production, controlling pumps, reservoir level information, flow meter reading, pipeline pressure information, flow information and surveillance.

According to Stoianovi et al. (2008) there is a growing need for monitoring solutions that can be deployed at much lower cost and faster using in-house expertise while providing much higher spatial and temporal density. These novel monitoring solutions are expected to complement traditional telemetry and SCADA systems while generating a high level of monitoring redundancy. Many sensor vendors have started to offer embedded cellular in their products. The current study will evaluate the efficiency (cost) and effectiveness (fast) aspect of the telemetry system.

Current practice has demonstrated that innovative technology coupled with incentives and education can greatly reduce water demand and use. Implementation of Smart water technologies such as telemetry system is one of the technologies that integrate information technology into water accounting and management, such as leak detection, smart water meters, internet-based water-use solution and software. These innovative solutions enable water service providers to enhance water supply and curb demand simultaneously (Water Research Commission Corporate Plan, 2018/19 – 2022/23). Therefore, the current study assesses the relevance, effectiveness, efficiency, impact, and sustainability of adopting such technology in water resource management.

1.3 Problem Statement

There is a general dissatisfaction with service delivery in the bulk water and sanitation services. This dissatisfaction exists regardless of the adoption of the telemetry system. However, the performance of the telemetry system is not evaluated. It brings a question whether the existing system is appropriately utilised or not. The lack of evaluating the telemetry system in WTW process is a problem, hence the reason for conducting the current study. The study argues that unless the current telemetry system is evaluated, the performance of such system in terms of relevance, efficiency, effectiveness, impact, and sustainability cannot be established to improve service delivery in the bulk water and sanitation services.

It is pointed out that the system is not consistent, interoperable, and suitable to cover all specific needs of the water treatment processes. In the event of problems, sometimes the cause cannot quickly be identified without having to call in high qualified technician. Water consumers often experience frequent water supply interruption due to water supply system failures which happen without being noticed at almost real time. Based on the industrial standards and acquired experience, the current telemetry system is not optimizing investments, reducing operating and maintenance costs. Therefore, the need to evaluate the performance of the telemetry system in WTW remains fundamental hence the focus of the current study.

1.3.1 Research question

The research questions for this study are as follows:

Question 1: How is the performance of the telemetry system in the Phalaborwa WTW process?

Question 2: How water demand and supply is determined using telemetry system at the Phalaborwa WTW?

Question 3: How water quality is assessed by the Phalaborwa WTW using telemetry system?

With reference to this study, unless the telemetry system is evaluated, its performance cannot be established in improving service delivery in bulk water and sanitation services. The study examines the use telemetry in WTW according to South Africa's National Water Act 36 of 1998, namely economic efficiency, equity, and environmental sustainability. The assumption is that the proposed approach of evaluating the telemetry system in the water treatment process of Lepelle Northern Water provides a scientific basis of conditions and recommendations. The assumptions are made about a relationship between the outcome variables and the predictors (Creswell, 2003). The prediction of this study is to establish whether the use existing telemetry system in the water treatment works process is beneficial or not.

1.4. Aim and Objectives of the study

1.4.1 Study aim

The aim of the study is to evaluate the telemetry system for managing the Phalaborwa WTW processes.

1.4.2 Study objectives

The specific objectives of the study are:

Objective 1: To establish the performance of the existing telemetry system in Phalaborwa WTW.

Objective 2: To determine the water demand and supply using the telemetry system at Phalaborwa WTW.

Objective 3: To assess the use of telemetry system in managing water quality produced by Phalaborwa WTW.

1.5 Significance of the study

This refers to the relevance of the study in terms of academic contributions and practical use that might be used of the findings to the organisation in which the researcher is based and the public at large. The significance of the study will focus on knowledge and information sharing through conferences and workshops.

1. Knowledge contribution through conferences and workshop will be as follows:

- A suitable telemetry system for WTW and distribution process.
- Implications for improved telemetry system on WTW and distribution process.
- Feasibility of implementing process-based telemetry system.

2. Developing practical telemetry system plan of action related to WTW process.
3. Capacity development through workshop, conferences, and further research.

It is expected from the decision makers, stakeholders, planners, and water resource managers to know the amount of water supplied and the amount water demanded (Hughes, 2006). It is for this reason that the existing knowledge concerning water requirements must be continuously passed on, adapted, and extended. Therefore, it is important to know whether the current telemetry system is helping in managing water services or not. However, improvements in water management can only succeed as part of multi-level campaign. In this respect, the capabilities of individuals, institutions, and society to appraise, revise and implement the available options are of importance.

1.6 Conceptualization of the study

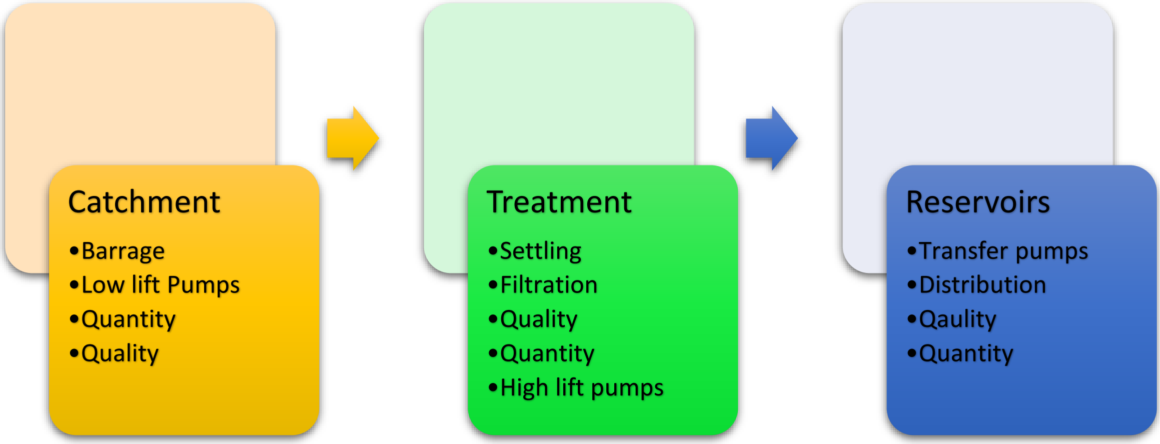
1.6.1 Conceptualization of the study

This study is part of the ongoing project of LNW which adopted the use of telemetry system. The goal is to have a system which performs well in terms of water service delivery. Therefore, there was a need to evaluate the system performance regarding efficiency, effectiveness, reliability, and sustainability. The telemetry system is used to monitor and manage when water is drawn off from the river by abstraction or low lift pumps to the head of works or division box, through the treatment process, disinfected and distributed to various storage tanks.

The process is automated using the telemetry system according to demanding water quantity of high quality for human consumption, industries, and mines and other uses, environmental compliance, and productivity constraints. The telemetry system is installed in all stations for monitoring the water level, for starting and stopping the pumps, positioning of valves, and reservoir level monitoring and flow control. It is also used for radio communication.

The current study seeks to describe the developed conceptual model of the telemetry system, establish how water demand and supply is determined using the telemetry system, and how water quality produced by the WTW process is assessed. Using the telemetry system, the study tries to establish options for managing the available water much better. The water treatment process is explained in figure 1.1.

Figure 1.1: Water treatment process



Source: Researcher, 2019

1.6.2 Scope of the study

The WTW system is consists of the barrage, the low lift pump sets, division box, flocculation channels, clarifiers, sand filters, fore-bay, high lift pump sets, water distribution network (WDN), booster pumps set, distribution reservoirs, transfer pump sets, and tower reservoirs. This study focusses on the telemetry in terms of utilization and capability that is consists of all phases from installation, operation, and maintenance on the WTW process.

The expected functions to be studied among other things include, automatic of events to the SCADA and maintenance operator, transmission of information on incidents, remote monitoring of WTW process and processing of events, access supervision and authorization, management of maintenance team operations at the front-end communication level, data acquisition, mimic diagrams and reports, reduction of maintenance time and costs, and remote diagnosis of the components. This includes, equitable distribution of water, pressure management, positioning of the valves, and surveillance of stations.

1.6.3 Nature of the study

Evaluating the telemetry system on the WTW will require its operational and maintenance information. The information requested includes the installed infrastructure specific constraints relating to its operation, the type of communication available, and the regulation in effect and the cost implications.

Relevant primary and secondary sources such as Lepelle Northern Water (LNW) rules and regulations, reports generated by the telemetry system, callouts and unplanned responses records caused by system failure. Previous reports conducted as well as recorded information on the telemetry system in LNW will be examined. The researcher will also conduct interviews with selected departmental officials to gain adequate and accurate insight into challenges experienced. Field and observation method will also be used.

The other objective is to propose a consistent, interoperable, and suitable solution to cover all aspects of water treatment needs and requirements. The existing telemetry system may perhaps be easily updated without the need for major modifications. There will also be investigate options for easily and quickly identifying the cause of the system failure without having to call a highly qualified technician.

Additional information will be derived from all operational stages such as catchment, purification, transportation, storage, to consumption. The regulation for water quality and quantity for domestic and industrial use will also play a major role. Centralising monitoring of various independent process units will also be taken into consideration. The advantage is that the researcher has been working in Operations and Maintenance Department at Lepelle Northern Water for 20 years.

1.7 Setting of the study area

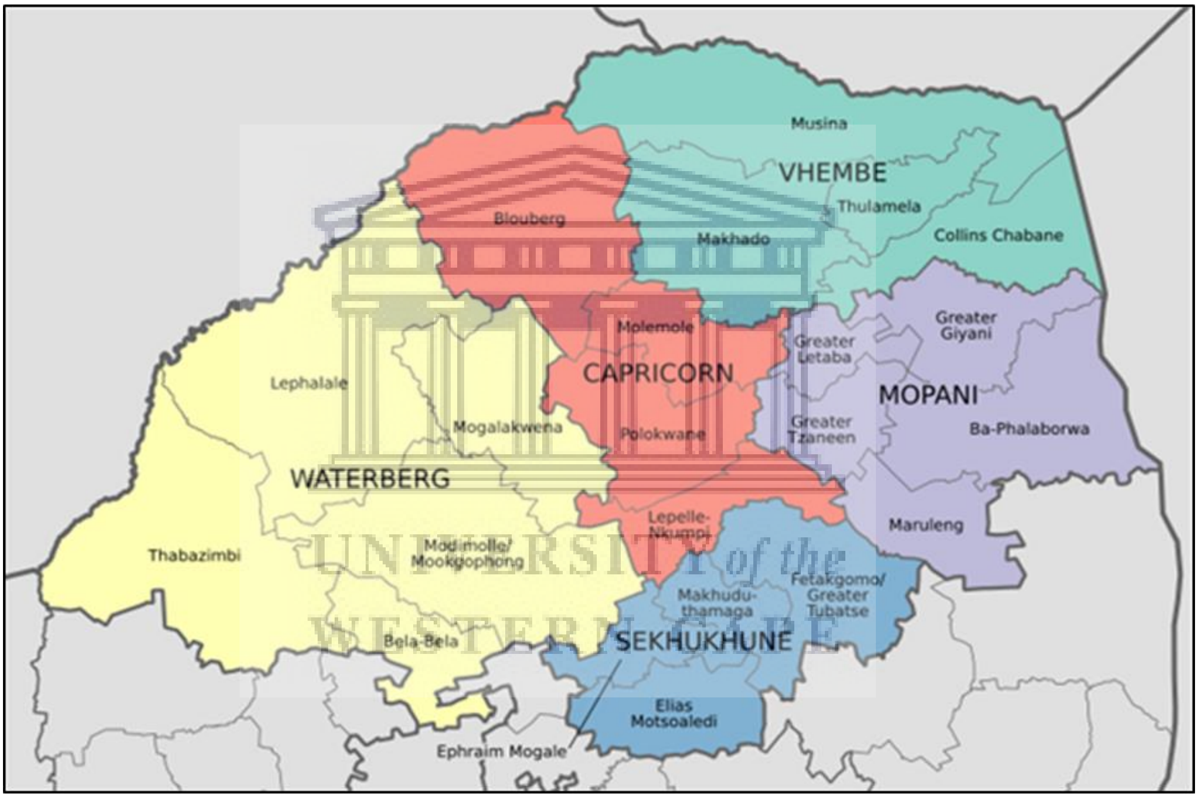
1.7.1 Physiographic features

Physiography relates to relates to the physical features of the earth and it describe the landscapes of the Mopani region in Limpopo province. Ba-Phalaborwa Municipality is one of the local municipalities in the Mopani District Municipality (MDM). The physiographic features of a region commonly affected its climate patterns and tendencies (rainfall intensity and distribution), and water drainage patterns (surface and subsurface). The physiography together with climate forms the basis of agro-ecological zoning.

According to the Constitution, the provision of water services is a municipal competency. However, not all municipalities are authorized to exercise this remit. In fact, water boards like LNW, metropolitan municipalities, district municipalities, and only a group of municipalities are allocated the function. The role to abstract, purify and provide water and manage regional distribution systems is allocated to certain municipalities, categorized as Water Service Authorities (WSAs) and state-owned enterprise like water boards, which are often referred to as Water Service Providers (WSPs). The label also applies to some municipalities that render such services. Limpopo Province is currently divided into five district municipalities are shown in figure 2 below. In this case, Ba-Phalaborwa falls under the Mopani District Municipality (MDM).

Ba-Phalaborwa Local Municipality is situated in the northern-eastern part of Mopani District Municipality (MDM), just less than 1km from the Kruger National Park border. It is about 220km from Polokwane, and Mbombela serves as a central gateway to the Greater Limpopo Trans-Frontier Park through Giriyondo border. It is an entry and exist point to the Mozambiques side of the Xai-Xai beaches. The municipality has a geographical area of 7461.6 km² including the Kruger National Park. The land size of the municipality has doubled from 3001 km² with the inclusion of Kruger National Park in the 2011 demarcation (IDP, 2017). The figure 1.2 below depicts Limpopo Province districts and local municipalities.

Figure 1.2: Limpopo Province districts and local municipalities

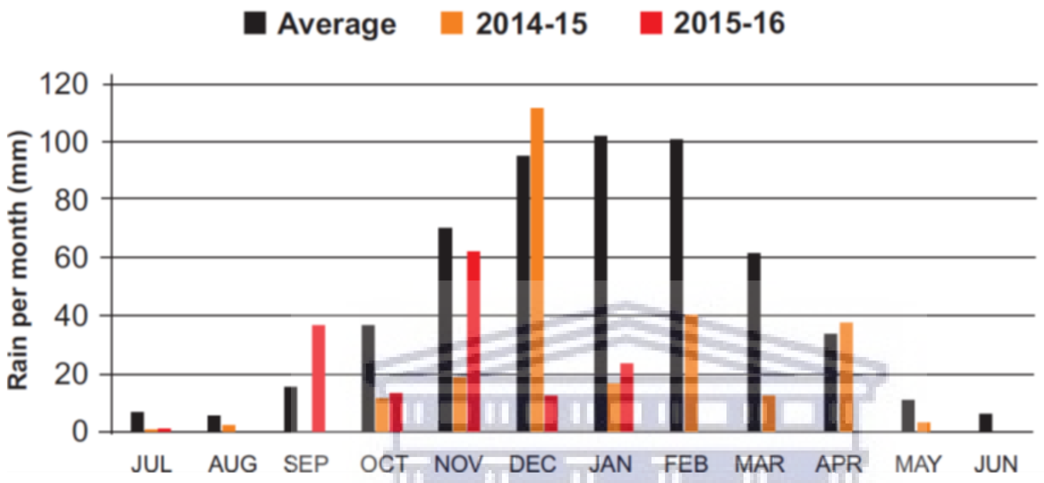


Source: IDP, 2017

There are four key factors determining the availability of water in the Limpopo province are population, climate, economic activities, and upstream impoundments outside the province which result in loss of yield. The rainfall pattern within the province is divided, with the northern portion classified as arid while the majority portion is classified as semi-arid. Western and eastern portion are classified as dry sub-humid and humid, respectively. The variation in topography results in a climate which varies considerably within the Water Management Areas (WMA). As a result, a low rainfall creates a water stressed region (FAOUN, 2005).

According to WRC (2016) cited by ACE (2019), from a catchment perspective, the mean annual rainfall is about 630 mm, while the escarpment divides the catchment into two portions, orientated approximately north-south. Ba-Phalaborwa Local Municipality, the area where the WTW located is relatively dry, but being downstream of the escarpment, it benefits from this relatively high rainfall region. Figure 1.3 show the rainfall pattern.

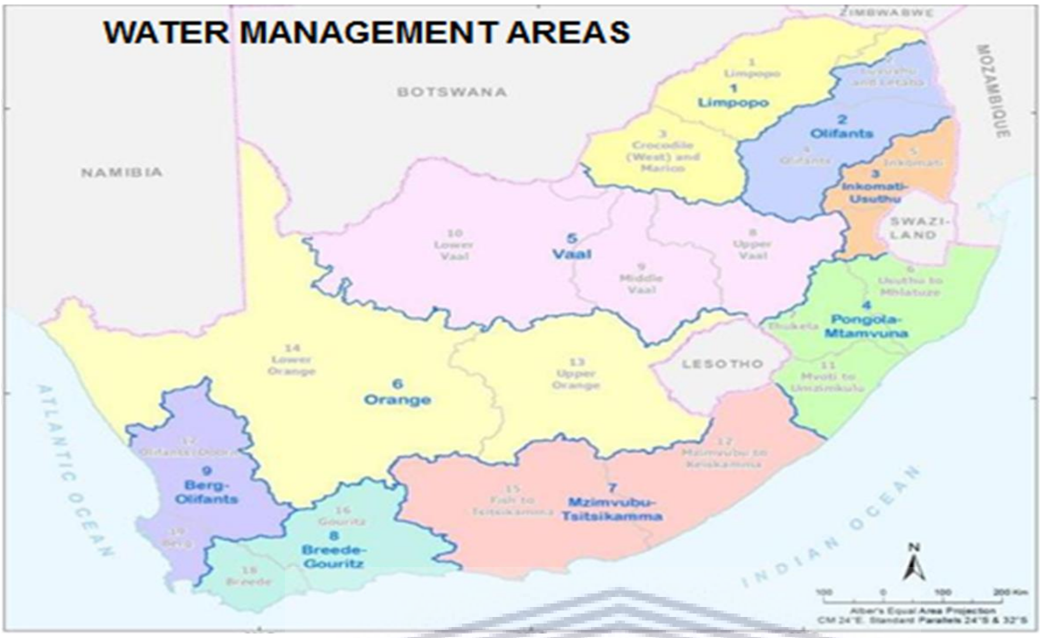
Figure 1.3: Rainfall pattern for Phalaborwa for the years 2014-2016



Source: WRC, 2016

An increase in population, significant growth in the mining and industrial sector, and significant water use by the agricultural sector results in a high need for water abstraction and the need to upgrade water supply and wastewater related infrastructure. There are four WMA in Limpopo province. A WMA is defined as an area as a management unit in the National Resource Strategy within which a catchment management (CMA) conducts the protection, development, conservation, management, and control of water resources (DWAF, 1999). According to the Department of Water and Sanitation (2011) there four WMAs within the Limpopo province, namely the Limpopo WMA, Luvuhvu and Letaba WMA, Crocodile (West) and Marico WMA, and Olifants WMA. Figure 1.4 shows the Limpopo province WMAs.

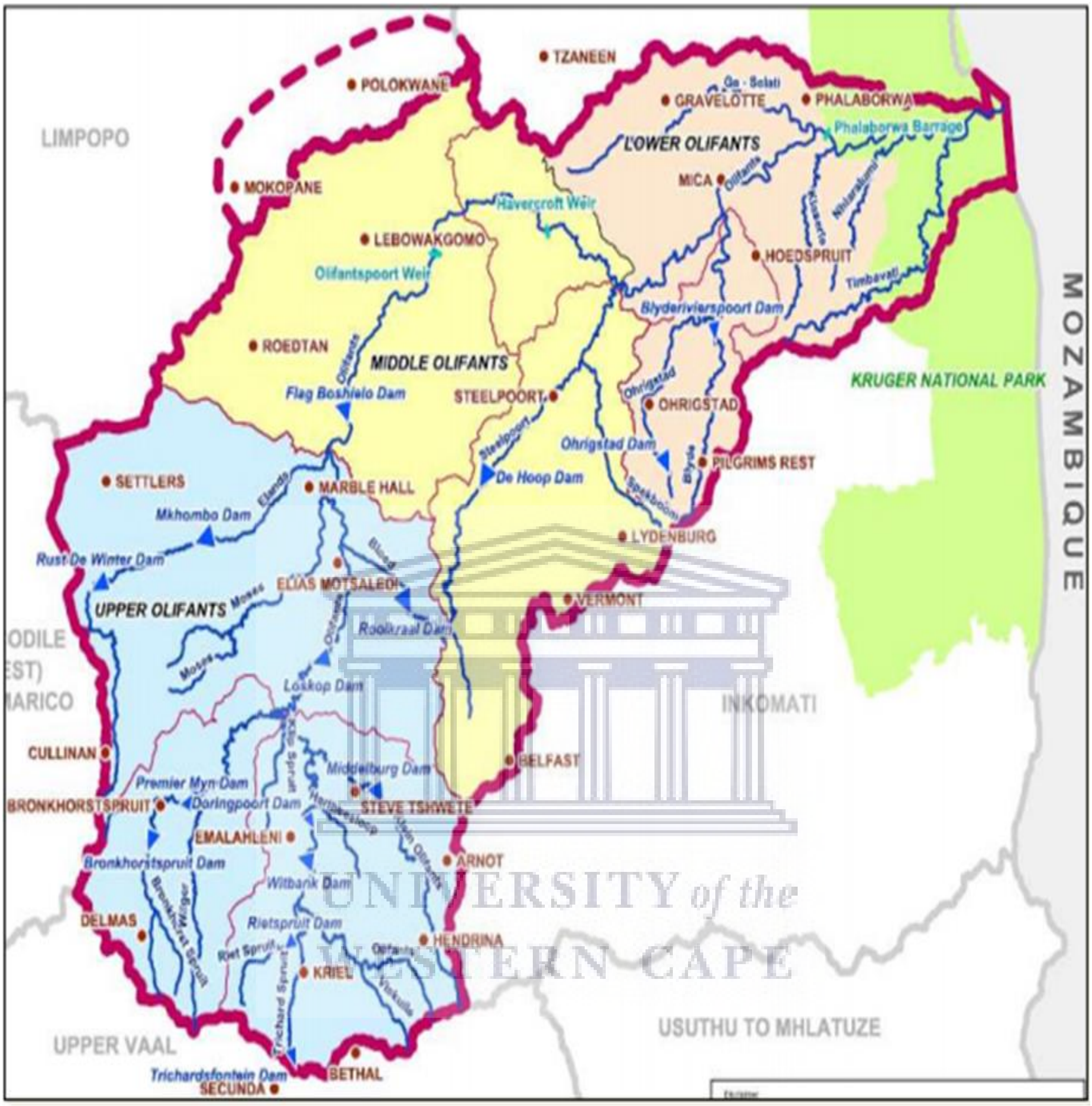
Figure 1.4: Water Management Areas



Source: Limpopo Environmental outlook Report, 2016.

The registered water use in the Limpopo province is 17% of the total registered use in South Africa. The Olifants WMA uses 7%, the Crocodile (West) and Marico 5%, the Limpopo WMA 4%, and Luvuvhu and Letaba 3% (NSWR, 2014). Most rivers have lost parts of their flow regime that are essential for maintaining unmodified and natural conditions (WRC, 2011). Rivers within the Crocodile (West) and Marico WMA are in a largely modified condition and rivers in the Limpopo and Olifants WMA are in a moderately modified condition, and river in the Luvuvhu-Letaba WMA are in a largely natural condition (DWS, 2014). The Olifants River Catchment drains several tributaries of which the most significant on the left bank are the Wilge, Elands and Ga-Selati Rivers and the Steelpoort, Blyde, Klaserie and Timbavati Rivers on the right bank. Figure 1.5 below depicts the Olifants River Catchment.

Figure 1.5: Olifants River Catchment

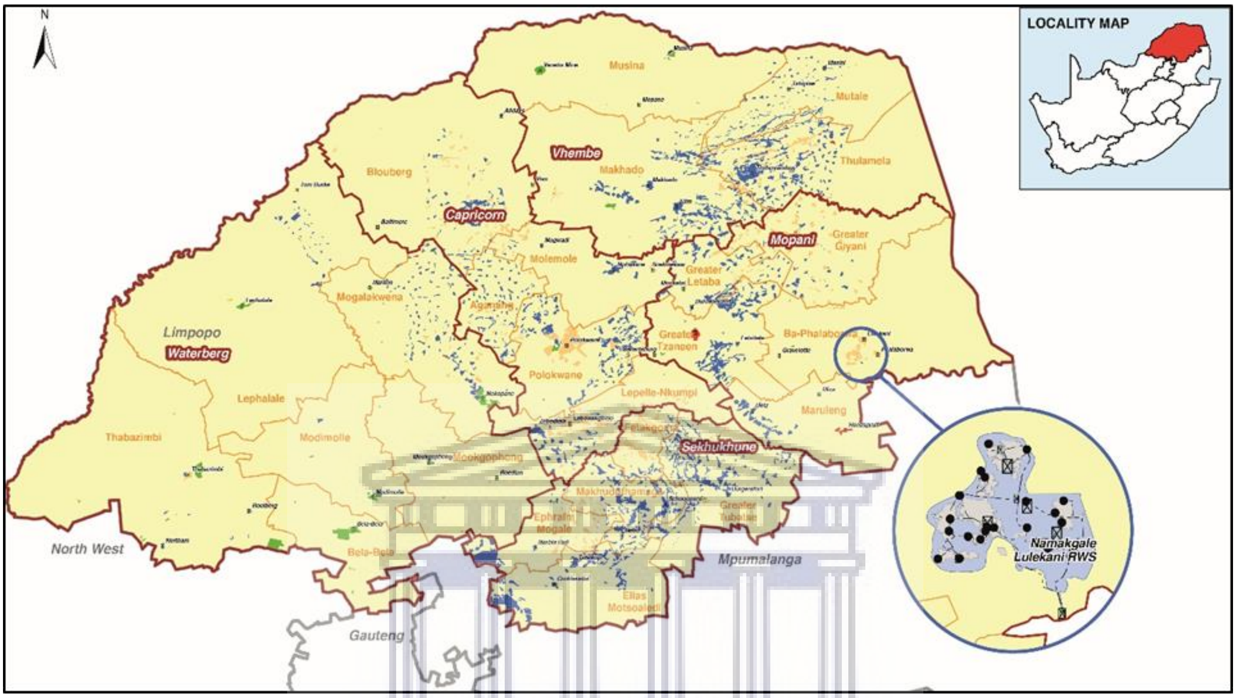


Source: DWS, 2016

As indicated in Figure 5, the local municipality and thus the service of the Phalaborwa WTW are not situated within any of the strategic water source areas. This notwithstanding, it benefits from the Wolkberg and the Mpumalanga Drakensberg precious areas as they located downstream thereof. Specifically, in terms of water resources, the service area of the Phalaborwa WTW is part of the Olifants River Catchment (DWS, 2016).

Lombaard (2016) stresses that it is crucial that water supply is secured and well managed using current technology to address the massive socio-economic challenges, such technologies include telemetry system. LNW depends on the above mentioned four WMA for the provision of bulk water and sanitation services within the Limpopo province. Figure 1.6 below depicts LNW area of supply in Ba-Phalaborwa Local Municipality.

Figure 1.6: Ba-Phalaborwa Local Municipality



Source: LPG, 2016

The water resource in the Olifants River catchment is harnessed through several dams, the largest being in the upper and middle sub-catchments. In the Lower Olifants, there are currently two large dams, namely the Blyderivierpoort Dam and the Ohrigstad Dam, and the barrage in Phalaborwa, which is the source for the service area of the scheme. The barrage has a higher natural mean annual runoff (ACE, 2019).

The yield from a system is the volume of water that can be abstracted at a certain rate over a specified period. For domestic, industrial, and mining use, water is required at a relatively constant rate throughout the year, whereas strong seasonality of use occurs with respect to irrigation and mining activities upstream. However, the organisation is experiencing water availability challenges due to drought, hence the need to have a system that monitors water effectively and efficiently (ACE, 2019).

According to DWAF (2003) quoted by Limpopo Environmental Outlook report (2016), the use of water in the major economic sectors of Limpopo highlights the importance of implementing management responses to ensure the availability of water resources of good quality. The focus of future management is directed towards the more efficient, beneficial, and equitable use of the water resources currently available in the province (Limpopo Green Economy Plan, 2013). Therefore, adoption of the use of telemetry system is one way of implementing management responses.

1.7.2 Socio-economic features

The Ba-Phalaborwa Municipality is predominantly underlain by gneisses of the Goudplaats gneiss and granites of the Lekkersmaak Granites with quartzitic, dioritic, sedimentary and pyroxenitic intrusions which, when combined are known as the Phalaborwa complex. This complex formed for the mining industry in the area. According to the IDP (2017), the most important minerals mined in the Ba-Phalaborwa are copper, phosphate and vermiculite. Moreover, magnetite, zirconium, nickel uranium, iron and gold are by-products mined in smaller quantities. Generally, land within the municipal area is developable. However, the shallow and exposed bedrock occurs in certain area are affecting the installation of infrastructure services (IDP, 2017).

- **Topography**

The municipality area is situated at 840m to the west and 300m with a higher lying ridge that is running from west to east through the centre of the municipality. This ridge complex is characterized by a series of dominant koppies and rock outcrops which form topographical highpoints through the municipal area. However, the influence of the topography on spatial development is minimal (IDP, 2017). Importantly, the topography defines the different water catchment areas with the ridge complex forming the major divide between drainage towards the Letaba River to the north and the Olifants River to the south (IDP, 2017).

- **Climate**

Ba-Phalaborwa is known as the “Town of Two Summers” because of its sub-tropical climate. The town is situated at 405m above sea level. The temperature in the Ba-Phalaborwa area ranges between 23°C and 35°C and higher, with an average annual rainfall of 550mm. Due to this, proper attention be paid to land development planning in terms of orientation as well as the use of appropriate construction material (IDP, 2017). Generally, the temperature in the area contributes much to high water usage.

- **Surface hydrology and Catchment Areas**

Ba-Phalaborwa Local Municipality is situated within the Olifants River primary catchment area, and tertiary catchment water shed between the Ga-Selati River and the Letaba River taken along the topographical ridge line. The potable water supply for the Ba-Phalaborwa Municipality is abstracted from the Olifants River catchment to the Phalaborwa WTW for purification and distribution (IDP, 2017). Groundwater yields within the municipal area are considered low to negligible, and cannot be considered as a source of suitable, reliable, and sustainable potable water due to these low yields as well as poor water quality (IDP, 2017). Hence the adoption of effective and efficient monitoring and management tool such as telemetry system is required for equitable, reliable, and sustainable water and sanitation service provision of the available resource.

- **Fauna and Flora**

The municipal area is mainly comprising of Mopani Bushveld with the indigenous marula as an important economic driver in the area. In addition, several wild animals roam freely in the area given the closeness to the Kruger National Park, however, this is not unexpected as they add attractiveness but also dangerous to the community. Most people living in rural areas do not have electricity and depend on the use of wood. However, the widespread use of wood constitutes a danger to the environment. The other challenge in the area is the alien and invader plants as well as disturbance and destruction of biodiversity is considered problematic (IDP, 2007).

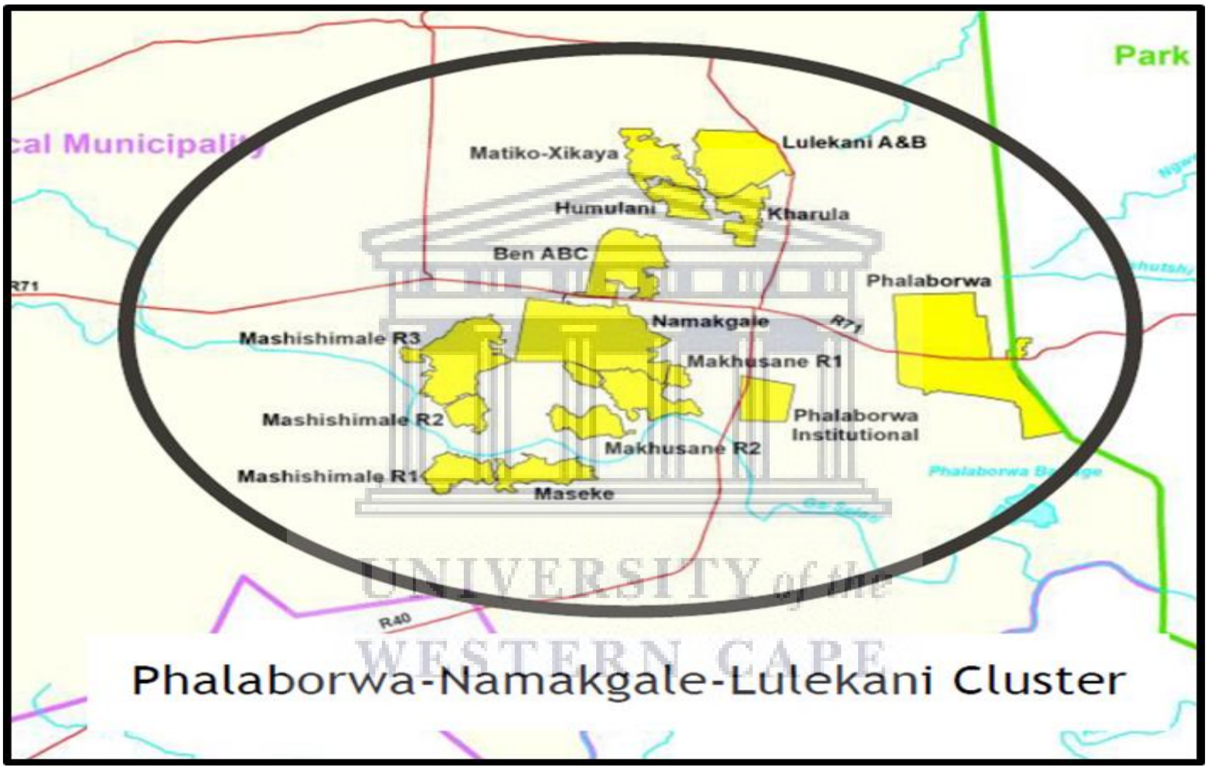
- **Local Economic Development**

According to Ba-Phalaborwa Municipality IDP (2017), the local economic development in Ba-Phalaborwa Municipality has been founded on and guided by the principles and objectives of the National Spatial Development Perspective (NSDP), the National Development Plan (Vision 2030), the Limpopo Employment and Growth Development Plan (LEGDP), the District Local Economic Development (LED) Strategy, and recommendation of the District Growth and Development Summit. However, it is suggested that the development be primarily focused on areas of high population concentration such as Namakgale, Lulekani and Phalaborwa town (IDP, 2017). Based on the above statement, it is evident that Ba-Phalaborwa Municipality is ready and prepared to do more in terms of development that eventually enhance service delivery.

According to the Association for Water and Rural Development (AWARD, 2016), fundamental to all challenges is climate change adaptation, biodiversity, and natural resources management, and supported by a focus on livelihoods, especially of the poor and vulnerable. The estimated non-revenue water (NRW) and l/c/d for Ba-Phalaborwa are 56.3% and 476 l/c/d respectively (AWARD, 2016). According to AWARD (2016) these figures are significantly higher than the national average of 36.7% NRW and 236 l/c/d (WRC, 2012) which suggest there are tremendous scope for water loss reduction and improved water use efficiency.

Although 29% of households are indigent, generally water supply to all households is formal which creates an enabling environment for proper metering, billing, and cost recovery (AWARD, 2016). Based on the information by AWARD, the adoption of monitoring system and management tools for water distribution network need to be prioritised. Figure 1.7 below depicts the Phalaborwa WTW service area and demand centres.

Figure 1.7: Phalaborwa WTW service area and demand centres



Source: ACE, 2017

LNW (2017) states that the goal is to ensure bulk water services within the service area of the scheme remain affordable, equitable, economical, and sustainable going forward. It is thus essential that beyond outlining current water needs there is a sound appreciation of future demand. However, water allocation varies according to the importance attached to water input in a particular sector. In general, domestic, and industrial use are accorded a higher level of assurance (1:100-year assurance) in comparison to agricultural use (1:50-year assurance).

Moreover, the economic value-add per unit of water used is different across the sectors. Against this backdrop, the consideration is now directed to the current water consumption within the service area of the scheme. The sectoral water use for the scheme is currently split between the domestic sector at about 65% and the mining sector the 35%. Therefore, for the WTW requires the correct and reliable tools to manage water distribution successfully.

The National Water Resource Strategy 2 (NWRS2) outlines the key challenges, constrains and opportunities in water resource management and proposes new approaches that ensure a collective and adequate response for the benefit of all people in South Africa. The strategy ensures that the management of water resources contributes towards achieving South Africa's growth, development, and socio-economic priorities in an equitable and sustainable manner (DWS, 2016). However, according to the LNW Corporate Plan (2019) the province of Limpopo is largely rural and suffers from a high level of unemployment. Due to the lack of sufficient disposable income, the sustainability of the water supply service is eroded.

The Department of Water and Sanitation (DWS) Annual Performance Plan for year 2017/18 to 2019/20 shows that as the economy grows, the demand of water also increases, requiring interventions to curtail the high levels of financial losses. Among other things is high water losses; poor infrastructure planning; weak operations and maintenance; insufficient revenue and debt management; and pollution of resources leading to high water treatment costs. Therefore, systems that are put in place to address the above uses need to be evaluated.

1.8 Outline of the thesis

This outline provides an overview of the thesis. It is consisting of chapters with a brief description of the content of each chapter as briefly outlined below:

Chapter 1: (General Introduction) which provides an overview and the background against which the study took place. It describes the research problem, the aim, and the objectives of the study.

Chapter 2: (Literature Review) provides an overview of reviewed literature on the telemetry system during the completion of the study, from both South Africa and international levels.

Chapter 3: (Research design and Methodology) presents the research design and the method used throughout the duration of the study to collect and analyse data to achieve the research objectives.

Chapter 4: (Results and Discussion) presents and discusses the results obtained during the study and provides a brief description of each.

Chapter 5: (Conclusion and Recommendations) provides a summary of the main outcomes of the study. Conclusions and recommendations are also made about the research objectives and results of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Water management in service areas is subject of increasing concern as population grow. Limited water resources conservation and sustainability policies and infrastructure complexity for meeting consumer demands with appropriate flow pressure and acceptable quality levels make water management a challenging problem. The use of technologies play an important role in the effective and efficient water management, distribution and use of water resources. Therefore, monitoring, measuring, metering, and controlling water infrastructure can be performed with great precision by using these technologies. It is for this reason, that many water treatments work network are operated through centralised telemetry system. Telemetry systems are an alternative method of transmitting data from WTW network to the stationary data acquisition system.

2.1.1 Literature review objectives

There are three fields of research objectives relevant to the study and all have independent theories and concepts related to them. The three objectives are telemetry system performance, water demand and supply, and water quality. The overlaps exist to some an extent, to address water service delivery within the study area of supply. The literature review is structured in such a way that all objectives can be analysed individually. Figure 2.2 depicts literature review objectives.

Figure 2.2: Literature review objectives.

Source: Researcher, 2019.

In all three objectives, different types of technologies and tools that can be integrated with the telemetry system on WTW process are going to be explained. The integration of technologies such as Internet of Things (IoT), Artificial Intelligent (AI) or Big Data analytics into the telemetry system on water treatment and distribution process can have immediate and significant impacts. Online sensor mesh network can be integrated into telemetry system to provide real-time data on environmental variables, water conditions and various systems to detect early warning of conditions that can affect human health and environmental integrity and water supply efficiencies (Stanley & Gunn, 2018). There is a complex, multi-dimensional challenges for urban and rural water supply sustainability. Therefore, a new culture of innovation, monitoring and assessment of plans, planning, and design for WTW requires strategies that will ensure the achievement of resilient and sustainable water services (Ahern, 2010).

2.2. Previous studies on the telemetry system

The earliest telemetry system transmitted information through cable such as computer network, telephone lines or fibre optic cables. Telemetry tools allow remote measurement and reporting of system performance are widely used in many sectors (Chaudhri, Borriello & Thies, 2010). Automation has made inroad into traditionally manually controlled WTW processes and water distribution network since mid- seventies. Prior to the seventies WTW used simple alarm panels, dial gauges and panel display such as circular chart recorders as an additional to manual operations.

Later, smart instruments and analysers such as pH meters and turbidity meters were introduced. Eventually, fully automatic operation of the WTW using programmable logic control (PLC) or distributed control system (DCS) which was introduced in the early eighties. After having achieve a level of sophistication at the WTW process, there was a need to carry on and try to achieve the same level of control in the water distribution network system (Buun, 2007). Buun (2007) further state that the early development of telemetry was introduced with doubts of success because of the problem of low data transmission speed, still in the developmental stages, and the unreliability of radio line communication used. This is still a problem today, but largely been overcome using high reliability packet switching networks.

However, using the PLC in the WTW process provided the framework to allow advanced algorithms to be produced, and the implementation of telemetry and SCADA system allowed far more sophisticated management of water distribution network. Then system wide optimization strategies were incorporated into the control system. The combination of field-based remote telemetry units (RTU), the telemetry system, and control system at the WTW unlocked significant cost saving and other benefits for the water utilities. Significant made in the areas of system security, water quality, and energy efficiency. Several historical studies identified events at the Water Treatment Works (WTW) are classified as major or minor sensor fault events. Major events are defined as events that causes impediments to emergency response an interruption of production flow and sometimes led to an unplanned WTW shutdown. For this reason, online monitoring technologies for WTW process have made a significant progress in recent years (Storey et al., 2011; Report card for America's Infrastructure, 2013). Technologies such as telemetry system have provided relief in the management of WTWs supply network.

2.2.1 Application of telemetry system

The previous section examined incentives for, and barriers to innovation and proposed ways to change current practices, investments, risk allocation mechanisms, administrative procedures, and operating efficiencies to broaden incentives and overcome barriers. Many believe, however, that water utilities must go beyond changes of current conditions to arrive at efficient and effective ways of water service delivery, that bold and transformative thinking is in need to effect quantum movement in operating performance, cost efficiency, environmental outcomes, and community involvement in the provision of water services.

The use of telemetry system for real-time monitoring are increasingly used in the decision-making process to provide up-to-date information for flood forecasting, water supply management, irrigation, and hydro-generation (Haeggli, 2009). Telemetry systems operate by sensors measuring parameters, a data logger storing readings and the remote terminal unit (RTU) transmitting a data package containing the readings through an antenna (Sauer, 2002). Therefore, telemetry system can also be used data transmission in the WTW.

The data package is picked up by a receiver and pass it on to a receiving station, which decodes the transmitted data package and sends it to the data management system on a server where it can be processed, stored, analysed, and disseminated. Vries (2008), further mention that telemetry is the term used to describe the logging or reading of information at one site and conveying the information via radio signals to a location remote from the first site. In turn, signals may be sent from the second remote location to the first to activate a device, can either be a pump, valve, water flow, pressure, reservoir level, leak, or camera. Telemetry systems are supplied by various vendors and some modify them for their specific use.

Telemetry systems are key to the success of real time control (RTC) system in WTW network system. These ensure the transmission of information between the various hardware components of a remote station including sensors, actuators, and controllers and possibly a central station where a field data is displayed on Human Machine Interface (HMI). These communications are under the supervision of supervisory control and data acquisition (SCADA) system (USEPA, 2006). Types of telemetry system include terrestrial-based (GSM/GPRS/UMTS) and satellite-based (VSAT). GSM/GPRS relies on mobile phone networks and its limitation is that its range is within the mobile network coverage and the reliability of the mobile network. In general, VSATs are used for networks required to be online during extreme events and thus are the preferred systems for early warning in the WTW (Haeggli, 2009).

The introduction of monitoring technologies like telemetry system have reduced operating costs of many organisations. However, producing water of the required quality and quantity by WTW in an effective and efficient way is a challenging task for water utilities. For this reason, WTW require continuous monitoring and automation system to overcome such challenges. Various fault detection and isolating techniques can also be deployed (Venkatasubramanian et al., 2003; Miljkovic, 2011; Maiti and Banerjee, 2012).
In the water industry telemetry system have been defined as the sensing and measuring of information at remote locations and then transmitting it to a central location. The information is then monitored and used to control a process at the remote site. Thus, telemetry can be a thing of remote measuring and data acquisition commonly related to supervisory and control

systems (SCADA) (Vasant, 1999; Mandic, 2002; Rao, 1998; Stankovski et al., 2003; Stephens, 2001), the same is also mentioned by Keating 1994).

It is indicated by Keating (1994) that wired or wireless communication links are used to connect to distributed individual elements of the telemetry system. Many control systems suitable for wireless telemetry such as automated systems in water industries are used for remote monitoring, inventory management, security and alarm system, tracking, health care applications and building access. The system offers professional digital communication for adequate solution for reliable and secure communication between distributed measured and control devices and a centralised control centre.

Keating (1991) further mention that the elements of wireless telemetry system can also be implemented in moving vehicles. However, Schaake and Lai (1969) found out that the water distribution research community has utilised various networks as a baseline for use in comparing different analysis and evaluated different optimization algorithms. This was further cited by Kessler and Shamir (1989) and Geem (2006). It is therefore a need to develop and summarise a classification system as a grid to assist in evaluating the performance of different analysis algorithms to examine if the performance is impacted by the overall topologic structure on the WTW distribution network (Hoagland et al., 2015). However, several softwares are compatible and can be used for hydraulic analysis of water distribution network, especially the open-source software programs that can be easily integrated with an optimization model and telemetry system can be an option.

According to Eren (2005) telemetry system can be either analog or digital. However, nowadays digital telemetry is mostly used because of ease in data transmission and handling. Therefore, selection of the appropriate technological instrument depends on the WTW purpose, presence of existing infrastructure, location, desired data accuracy, water quality, network, access, and cost (Roy & Borden, 2015). However, Grady et al. (1999) mentioned that there are several factors that can affect the cost of a telemetry system link. These include but not limited to modulation type, carrier to noise ratio, transmitter power, receiver sensitivity, and antenna gain. These parameters are important in a detailed link analysis but hold no relevance as a selection tool for the general end-user such as WTW. And as far as operating principles are concerned, telemetry system can be divided into two main categories which are band-based telemetry and multiple-channel telemetry.

There are large investments made in automation and control systems by water utilities over the past 20 years and those investments have produced the necessary WTW infrastructure optimisation strategies for implementation. Recently, water utilities are developing and introducing ever more sophisticated software to improve water resource distribution and usage, reduce leakage, and improve overall water resource management. It further calls for water utilities to acquire even more sophisticated monitoring and management systems to regulate and increase the security concerns (Bunn, 2005).

2.3 Literature review on telemetry performance: Objective 1

Water is an essential commodity required for the substance of life. The demand for water is continuously increasing. However, this ever-increasing demand can be addressed by efficient water distribution network based on advance computing technology systems that include modern hydraulic modelling and designing software (Sonage & Joshi, 2015). Many features like hydraulic and water quality analysis, steady state and extended period simulation are also made to function with enhanced capability, strong data management along with AutoCAD and GIS integration. As previously indicated, hydraulic modelling, designing software, water management technology, tools and equipment which can be integrated to the telemetry system for WTW process monitoring and management are explained in the study.

Online water distribution network simulated can be with the help of AQUAIS 7T by assessing real time data from different sensors in water supply system. The online hydraulic simulation model demonstrated its potential by showing details of a flow event detected in the distribution management area (DMA). It is also indicated that the simulation of various DMA has shown appropriate results for pressure at different nodes. Therefore, it was concluded that the AQUAIS 7T is a very efficient online simulation software which results in realistic benefits for both management and customers alike (Machell et al., 2010). In other studies, efficient water supply was done by Mahapatra et al., (2012) using EPANET and ArcGIS software. Their study on leakages was carried out continuously as well as intermitted water supply system. According to Mahapatra et al., (2012) EPANET has successfully been used for simulation of both intermitted and continuous supply providing conclusion avoiding direct tapping to transmission main line.

However, Ingeduld and Zdenek (2006) argued that emptying and filling of water pipelines makes it difficult to apply EPANET based on hydraulic models because of low pressure and empty pipelines. The intermittent water supply systems are highly influenced by the low pressure and empty pipe situations, hence adjustment in basic EPANET source code has been carried out to design water distribution network. On the other hand, to design hydraulic model roof tanks can be incorporated into the water supply analysis for better formulation and for schematization of the system hydraulics. Results obtained from the hydraulic model of these two cases are incorporated in the algorithm of water distribution software packages, MIKE NET and MIKE URBAN of DHI hydro-informs.

Ramana (2015) also published the efficient design of water distribution network performed by EPANET software. In the publication it was indicated that EPANET is one of the useful tools to determine the head losses due to friction, flow rate and the demand pattern. Waikha (2015) supported Ramana (2015) by discussing the optimization of water distribution network using EPANET because of its ability to deliver the required quantity of water and pressure to the individuals. Therefore, by using EPANET software, water delivery services can be performed easily and fast. As mentioned earlier, Waikha (2015) shared the same sentiments by also indicating that EPANET software can also be used to assess the performance of the water distribution network.

Elsheikh et al. (2013) indicated that the WaterCAD software can be applied to design and optimize the water distribution network considering the severe problem of ageing water pipeline infrastructure as well as to address water quality issues in the WTW. The application of various tools of WaterCAD like Darwin Designer, Pipe catalogue tools are found to be very effective in the overall design and optimization of water distribution network. After the network analysis has been done, Sumithra et al., (2013) noted that LOOP and WaterGEMS software are highly efficient to do various hydraulic and costing analysis. However, WaterGEMS was found to be extremely user friendly with variety of hydraulic and graphical analysis options and it was also found to be less time consuming.

Bentley (2014) shared the same sentiments with Sumithra et al., (2013) by mentioning that the minimum service level in the water distribution network cannot be achieved if there is high head loss. Therefore, WaterGEMS software can be the solution for reducing the cost and as well as the equipment repair time. Puust (2015) stated that WaterGEMS can also be used as a tool for optimizing the water reservoir levels and estimating the influence of network valves on leakage. Clearly, WaterGEMS is a preferred tool because of its simpler way of analysis in the water sector.

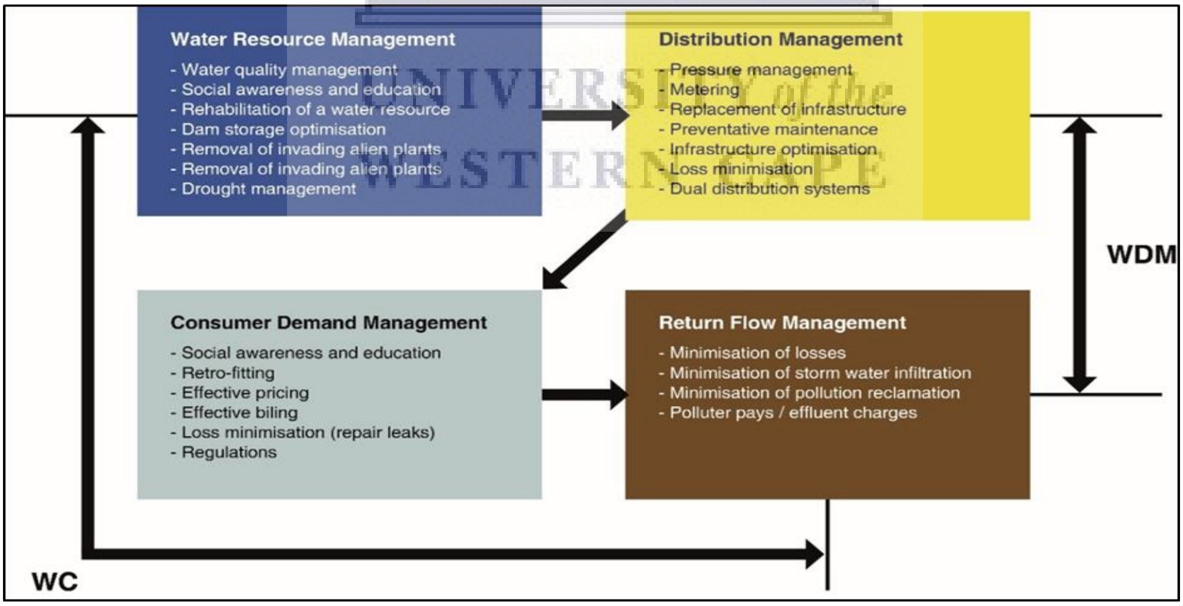
In planning for the Water distribution system, Khadri (2014) used GIS, GPS and RS technology for visualization, network planning, and mapping. The objective was to generate the thematic map, digitizing and mapping of the water distribution system, and survey the water distribution network. It was found that the appropriate softwares to be used were ArcGIS, AutoCAD, GPS and ERDAS 9.1. However, the focus was on the use of remote sensing and GIS in the management of the water distribution system.

2.4 Literature on water demand and supply: Objective 2

South Africa is a water scarce country, and the effective management of water resources is essential for the continued provision of water services to the community. It is therefore an important need for the government to constantly assess the performance of water services authorities (WSAs) and water service providers (WSPs) on the performance of service delivery. Because poor performance in this regard can lead to reduced provisions of water and sanitation services to the receiving community (Brettenny & Sharp, 2017). The use of technology in water monitoring and management can be of assistance in terms of water conservation and demand management.

Water Demand Management (WDM) is generally deemed a subset of Water Conservation (WC), which focuses on the efficient use of water resources. WDM on the other hand concentrates on the achievement of the most beneficial solution for water services from different perspectives, including social and economic considerations. Despite differing, emphasis on WCWDM is shown in Figure 2.3, their components are interlinked and impractical to separate and it is very clear and believe that WC and WDM are treated as a combined concept (WC-WDM).

Figure 2.3: Water conservation and Water demand management



Source: DWAF, 2004

There are many technologies used by water utilities to reduce demand on water supply by increasing the efficiency of their distribution system. Some technologies such as telemetry system and other hardware software tools are merged to form the backbone of a smart water system. Telemetry technologies are designed to help water utilities to reduce the amount of water lost in the distribution network system, through pressure management, energy saving on pumping and purification process, and the optimization of water treatment chemicals can also offer a significant cost saving (United State Government Accounting Office, 2016).

Most of the research have been conducted for optimizing the sensor placement to achieve better monitoring results. Optimizing the placement of pressure sensors is of great significance, especially for understanding the performance of water distribution systems (WDSs). The effective and timely understanding of the performance of the water distribution systems is important for anomaly detection, optimal operation and so on. To this end, telemetry systems have increasingly been applied by many water utilities for collecting near real-time data for water quality, flow, and pressure sensors (Cheng et al., 2016). Chena (2013) has further indicated that in real- world and real-time, the statistically prediction of water demand can be developed by an integrated Time Series Forecasting Framework (TSFF), and the TSFF approach is applicable for interfacing with SCADA infrastructure.

However, Buttler (2014) shared the new approach for water management which allows identification of the role of mitigation and adaption of new strategies. The discussion was to propose that engineering, organisation, and affected parties to develop a degree of resilience and sustainability as an option. The resilience and sustainability options are both vigorous concepts. On the other side, Morosinia (2015) also proposed a new methodology that aimed to improve water demand at the critical node during an emergency condition and effective results were obtained in two case studies with pressure driven analysis (PDA) approach. However, one of the challenges in water supply system management is to achieve demand at the inadequate head of a node.

Castelletti and Soncini-Sessa (2007) quoted by Rasul (2010) stated that the process of formulating and implementing shared vision of planning and management strategies for sustainable water resources development and utilization, with due consideration of all spatial and temporal interdependencies among natural process, human and ecological water uses must be prioritized. Therefore, collaboration of all water users is important to ensure sustainability of the water resources. Traditionally, water distribution systems have been demand-driven in that demands are treated at junction nodes. This is adequate for most purposes; however, water leaves the system through orifices and flow is therefore determined by orifice opening and pressure. Such demands are referred to a “pressure dependent” and in some instances the differences in flows can be attributed to differences in pressure (Walski et al., 2016).

According to Do et al. (2016) water distribution systems (WDS) has been constructed and developed for hundred years across the world. As a result of population growth and urbanization, water distribution systems have expanded, and have become more complex and difficult to operate. However, the introduction of technology such as telemetry system became one of the preferred options for intervention. Water distribution infrastructure are facilities which are structurally designed by engineers and these systems require routine maintenance. Therefore, the use of telemetry system for monitoring and management should be considered. Merchant (2014) also pointed that water management has become more complicated and there is a need to introduce new water management software technology because of a big gap between demand and supply.

2.4.1 Water pressure control and management

Coveli et al. (2016) indicated that water pressure reducing valves are used to reduce water pressure to the minimum level and maximize the service level to meet consumer demands. This is supported by Wright et al. (2014) by saying that water pressure can also be controlled by maintaining the optimal water level in the reservoirs as much as the changes in the water demands by customers permits. However, the challenges of providing pressure management to the network are explained by Kanakoudis and Gonelas (2015) as the installation, maintenance and replacement cost of pressure reducing valves. In addition, there are several approaches to solve the indicated challenges. One of the solutions is the proposed pressure control units which include predictive and feedback control, proportional algorithm based on the pressure measurements at the control nodes and real-time logic control algorithm (Creaco and Franchini, 2013).

2.4.2 Pump scheduling

Ormsbee et al. (2009), stated that pump scheduling is aimed at establishing an optimal set of rules that will enable operators to make decisions on the best approach to minimize pumping cost for the WTW while delivering satisfactory level of service to the consumers. However, the challenge can be formulated as an optimization problem with the decision variable as the actual pump operating times. Optimisation approaches to solve pump scheduling problem include branch and bound algorithm, linearization of system components, interactive linear programming, hybrid algorithms, and dynamic programming. However, Cherchi et al. (2015) mentioned that the application of integrated energy and water quality management would support WTW to achieve real-time optimal pump scheduling energy efficiency, and water quality objectives together with the compatible SCADA systems. Therefore, it is beneficial for the WTW to have the appropriate communication software system in place.

2.4.3 Operational control

Operational control challenge in the water distribution network is concerned with meeting hydraulic performance, storage volume control, improvement of water quality, economic efficiency, and other important operational objectives at a minimum cost (Cembrano et al., 2000). However, Burgschweiger et al. (2009) stated that it is difficult to solve operational challenges due to inherent factors such the size, topology, and types of hydraulic elements of the WTW network. According to Ormsbee and Lansey (1994) it can be achieved by controlling pumps and valves, keeping the reservoir levels within specified limits to meet future and unforeseen demand and this can be possible with the use of technology such as telemetry system.

The approaches to optimal control include dynamic programming, linear programming, hierarchical decomposition optimization, simulated annealing, hybrid optimization methods, genetic algorithm, and integer programs linked to hydraulic solver, and software system that can generate a near-optimal operating plan available for real-time and online operation of WTW network. However, Cembrano et al. (2000) also indicated that there are ongoing studies to develop real-time optimal control of water distribution network to minimize the operational cost and improve the performance of the network system in terms of adequate pressure and flow to meet the demand.

2.4.4 Leak assessment and control

One of the main challenges of the water utility managers in the country is how to minimize water losses to ensure sustainability of finite water resources, protect the environment, improve revenue, and provide high quality service to the customers. The coordinated management activities directed to reduce water loss from the source to the distribution network include speed and quality repairs and rehabilitation of ageing water infrastructure, material management, water pressure management, active and passive leakage control methodologies (Boulos & Aboujaoude, 2011). There are also several approaches to detect and locate leakages in the water distribution networks (WDN). One of the approaches is to ensure that leak detection devices are in place, effective and efficiently communicating any event to the central monitoring control system via the telemetry system.

2.4.5 Sectorization

Sectorization is the process of partitioning a water distribution network into a set of independent districts metered areas. The aim is to achieve a better control over the network system, enhance leakage and burst detection and management, pressure management, control of contamination spread, enhance water security, improve work planning, and support effective monitoring and control of activities and operating of the network (Gomez et al., 2012). The sectorization is linked, among others, with the pressure control and management, operational control, and the sampling design. With the aid of telemetry system, it allows some flow or pressure sensors to be positioned at the discrete meter area (DMA) for real-time measurement of pressure and flow rates.

2.4.6 Modelling water distribution network

Most developments for water distribution network (WDN) modelling purposes refer to optimization approaches for design, operation, or rehabilitation. However, most case studies presented in this study represent only a small simplification of WTW process network (Gama et al., 2015). Mathematical models are some of the tools or approaches used to describe and emulate the behaviour of networks and estimate the states and parameters of the networks for some specific operating and loading conditions in water distribution networks. These mathematical models can be managed using RTU like telemetry.

2.4.7 Demand forecast models

Water demand forecasting is an important tool for the design, operation, and management of WDN. It is based on the past water use, and socio-economic and climate parameters associated with the past water use. These parameters are referred to rain, temperature, seasonality, and evapotranspiration, water price, income, family size and other related factors (Anele et al., 2017). Thus, accurate prediction of peak water demands stems from the need to improve or optimize the operation and management of WDN. Therefore, short-term water demand forecasting is essential for operation and management of the network whereas long-term forecasting is appropriate for planning and design of WDN.

2.5 Literature on water quality: Objective 3

2.5.1 Water quality

Water quality is a very important issue related to human health, however, Tabesh et al. (2015) stated that it is not usually considered in the water distribution network (WDN) design. Water distribution networks are generally composed of pumps, many interconnected pipes, valves, reservoirs, and other hydraulic elements that carry water to demand points from the supply source, with specific pressure levels to provide a good service to consumers. The management and monitoring of drinking water quality in South Africa is governed by policies and regulations based on the national standards (SANS 241) as per the Water Service Act (Act N0. 108 of 1997) (Rivett et al., 2013).

Hence, Oliveira et al. (2017) suggested there is constant need of water utilities to improve water treatment techniques and research on the emergence of new technologies for obtaining and distributing adequate water, both in terms of quality and quantity. Technology is one of the interventions that can be used for monitoring and managing the pollution of water sources and distribution network. It further calls for operational efficiency in water distribution and a reliable in-situ water quality monitoring system (Allen et al., 2011) to be introduced. As mentioned earlier, monitoring water quality is performed for the sole reason of complying with the applicable water service delivery rules and regulations of the country.

Modelling software such as EPANET is one of the in-situ water monitoring system that allows for the user to specify a different reaction rate coefficient (Rossman, 2000) for storage facilities for field sampling to be conducted to identify reaction time rate if warranted (Speight, 2010). All these can be made possible through the integration of the telemetry system to allow human management interface (HMI) display and response to events by the water purification and distribution process operators.

Water quality models are found applicable for tracer studies in WDN (travel time and flow path), determination of sampling locations, analysis of contaminants or disinfectant concentrations, water age simulation, water quality operation optimization, source contaminant detection and location, location and operational optimization of disinfectant booster stations and water quality sensor location design (Kessler et al., 1998). Water quality models are important tools to predict water quality transport and fate in WDN (Contans & Brémond, 2003). In this regard, application of proper monitoring tools like telemetry system can inform and the WTW process operators to promptly take the necessary action accordingly should a need arise.

Generally, for these models to be effective, they must draw on an accurate, continuously updated view of the state of the water distribution network. This can only be achieved by synthesizing SCADA and other real-time telemetry system data with a network model in an automated mode. The real-time telemetry data may be used as boundary conditions such as water reservoir levels and operational statuses such as pump speed or valve settings in the network model. Therefore, the model demands should be continuously updated to reflect network aggregate flow (Hatchett et al, 2010).

Ramotsoela et al. (2018) also pointed that information and communication technologies (ICT) can play a key role to address various challenges associated with water management. Effective realization of water security prospects obliges organizations like LNW to have, amongst other instruments, clearly defined plans of what will be required in the future, so that this can be considered presently and consistently throughout the water supply process. The combination of population growth and increasing stringent water quality standards has prompted the need for increased WTW capacity through upgrades and/or expansion. In many cases, optimization of the WTW process may meet the increased water demands, improve WTW performance and water quality. Optimization techniques are also important for the delivery of quality water in the most efficient manner (Ministry of the Environment, 2014).

There are some technologies utilizing satellite imaging with different wave lengths to determine the water quality. Their main functions are based on the parameters which depend on the optical properties. There are also in-situ sensors using optical water features by emitting a light and measuring the interactive of the light with water. However, limitations with this remote sensing method are the difficulty to take high accurate imaginary with spectral resolution by satellites imaging sensors. As a result, this restricts the wide application of the obtained data for monitoring the quality of water (Ritchie et al., 2003). Dehua et al. (2012) indicated that an automatic on-line monitoring system using GPRS for transmitting data can also be used to determine different water parameters.

Ginsberg and Hock (2004) pointed that water distribution networks are vulnerable to different sources of intentional or accidental attacks of contamination. It is for this reason that Nardo et al. (2015) suggested that the appropriate computer system security measures should be deployed for SCADA systems, and in this case, the telemetry system may be the appropriate tool. Another measure to secure WDN is to provide high level monitoring of water infrastructure, in addition to water quality monitoring systems. Ostfeld (2004) believed that to improve the security of drinking water requires an extensive action. Two methodologies were proposed for extensive action are the Randomized Pollution Matrix (RPM) which provides a representation of pollutant intrusion consequences and specified optimal system for given monitoring station housed in optiMonitor program.

In addition, there are four main methodologies also used for water quality monitoring (Jiang et al., 2009). The four methodologies are:

- The conventional system of sampling on site and analysing in laboratories after following the standard procedures for collection and transportation of water sample (Wagner et al., 2006).
- Detection of water quality parameters by analysing the change in activities of sensitive aquatic organisms in the water body.
- Water quality parameters determination by remote sensing technologies without contacting the water body. This is mainly achieved by detection of the spectrum of some electromagnetic waves.

- Automatic monitoring of water parameters by sensors which then transmit water quality data through wired or wireless online communication system.

2.6 Monitoring, evaluation, and reporting system

Monitoring is defined as a routine process of collecting data and information to track progress towards expected results by the United Institute for Training and Research (Unitar, 2017). Govender and Reddy (2014) agree with Unitar (2017) by defining monitoring as tracking of intervention and using the data collected to timeously fulfil or enhance the achievement of the set targets to the satisfaction of the targeted stakeholders.

2.6.1 7-S Model of service delivery evaluation

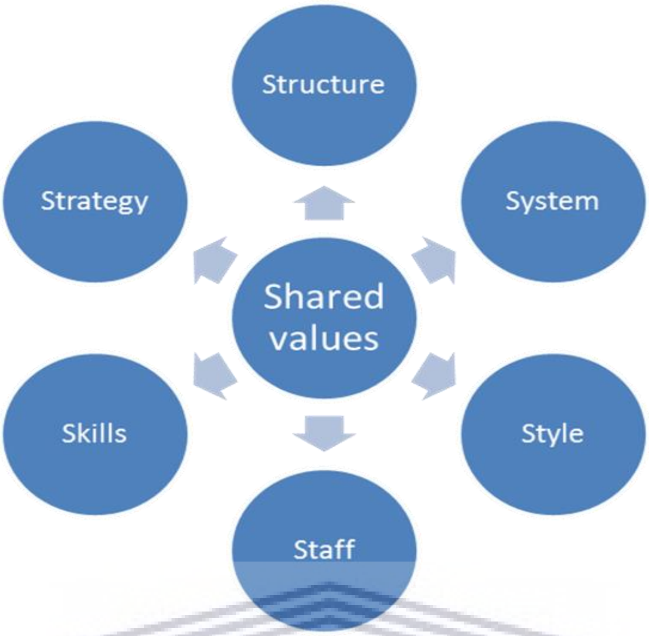
The 7-S model acknowledges interdependencies between individual aspects of the service delivery. According to Peters and Waterman (1982), McKinsey designed a complex model for performance evaluation called the 7-S model and this model considers the seven factors relevant to service delivery success. These seven factors consist of three "hard" factors, namely, strategy, structure, and systems. To make up a total of seven factors, four "soft" factors were also included, namely, style, staff, skills, and shared values (Peter & Waterman, 1982). Hard factors summarize the organizational aspect of the model as they are explained below:

Structure: Structure refers to the hierarchical organisation of a business. The functional division in the departments, team size, and reporting structure fall under this aspect. In many instances, the structure of a business is impractical and not goal orientated and as a result, goals and objectives of the business become difficult to achieve.

Systems: This factor describes processes in place enabling successful delivery of services. Hence, the focus is on how services are delivered (Bryan, 2008).

Strategy: Strategy describes the overall tactical plan of a business or departments within a business. However, the combination of a business structure and strategy often poses a threat to the performance on a business in terms of service delivery. Figure 2.4 below depicts the 7-S Model Framework.

Figure 2.4: The 7-S Model Framework



Source: Peters and Waterman, 1982.

The four soft factors of a business. Soft factors refer to the social aspect of the model which can sometimes be hard to change (Peter, 2011). The four soft factors are explained as follows:

Style: The term style refers to the company culture, including attitudes of employees and leadership styles. While style is an important factor, especially in terms of change management, it is hard to transform. This style is expected to represent the organisation well and positively contribute to the success of service delivery.

Staff: This model includes talent management under the term staff. Staff refers to training, development, or turnover. Diversity of employees in terms of gender, cultural background or professional field also contribute to this factor. This factor has the potential to hamper service delivery if full attention is not paid to it.

Skills: This factor of skills includes both organizational as well as employees' skills. In many instances, the skills of the organization further alignment with the other factors of the 7-S model to achieve better business performance in terms of delivery of services.

Shared values: The term shared value refers to the goal an organisation is trying to achieve, such as an increase in profit. This aspect of shared value is in the centre of the model to symbolise the common impact of all other factors. In this case, overtime other factors also become relevant, such as social responsibility or diversity (Bryan, 2008). It is important to note that all seven factors are equally critical and required to be properly planned for and fostered to maintain a sustainable, efficient, reliable, and a successful business in delivering services without compromising its customers (Peters, 2011).

2.6.2 Monitoring services delivery

Monitoring water service delivery is an important role for the water utility. In doing so, creativity and innovative ideas are required to ensure that basic water services are delivered to the intended beneficiaries. Therefore, a need for authorities to meet, share challenges and come up with new approaches to track, evaluate and review service delivery performance is required. In service delivery reviews, the terms of reference for quality service often tend to reflect the service delivery and customer satisfaction. Service delivery targets as outlined in the service level agreement contract of two or more parties seek to measure performance, which is then judged against predetermined standards of acceptability (Kuzek & Rist, 2004).

The introduction of new technologies in the WTW process, enabled wireless communication system and widening internet access provide new opportunities for water services monitoring systems. Data can be generated and shared much more rapidly and at a lower cost. However, the main financial cost will be associated with the generation of data, with the marginal cost of sharing being minimal. More importantly, it should be noted that the real gains come from the ability to use data to manage things differently and re-engineering systems around the assumption of data being available at a low cost and in a timely fashion. For this to happen, it requires a move from the monitoring and evaluation leading to lessons learned paradigm to a surveillance-response paradigm (Thomson, et al., 2012b). A surveillance-response paradigm is one in which the data are used in a fast feedback loop as key input to operational system.

2.6.3 Evaluating delivery of services

Evaluation is defined as an assessment, conducted as systematically and impartially as possible, of an activity, project, programme, strategy, policy topic, sector, operational area, or institutional performance. It analyses the level of achievement of both expected and unexpected results by examining the results, chain, process, contextual factors, and the relationship between cause and effect using appropriate criteria such as relevance, effectiveness, efficiency, impact, and sustainability (UNEG, 2016).

The evaluation of water service quality levels is critically important in monitoring service delivery that is customer focused. The quality of service can essentially be thought of a measure of the extent to which the service delivered meets customers' expectations. It is, therefore, worth noting that quality service is influenced not only by the service outcome, but also the service process (Ghobadian et al., 1993). According to Madumo (2012), a developmental organisation is identified as an organisation that uses all the necessary mechanisms at its disposal to achieve successful economic intervention in a specific area.

2.6.4 Customer focused service delivery

Most of the water utilities rely on demand-driven approaches. However, the aim of service delivery transformation initiative in South Africa is to improve service delivery and emphasise the criticality of customer focused strategy in service delivery and monitoring. The customer focused service delivery is emphasized in the Batho Pele principles and in organisational values. The term, Batho Pele emanates from the Sesotho language. Batho Pele in English translation is "people first" (Russell & Bvuma, 2001). Hence, the need evaluates the effectiveness and efficiency of technology employed in the WTW.

2.6.5 Matching indicators with service levels

Fuller et al. (2016) found that countries follow non-linear path targets, including fits and starts, accelerations and decelerations when tracking progress towards global drinking water and sanitation targets. This statement suggests that there is no single clear path to be followed by all, the corollary being that different policy responses are required at different stages as countries climb the service delivery ladder. Moreover, tracking, and crediting progress at lower levels on the service delivery ladder, for example, improvements in universal basic water supply coverage, having the more nuanced indicators has another advantage. Along with many others, Hauser, and Katz (1998) show that the metrics influence behaviour as well as measuring outcomes.

2.6.6 Reporting

Reporting involves the regular communication, within defined intervals, of results and findings, and the facilitation of their use. Reporting often follows pre-determined and structured formats to ensure that information gathered is more easily collated and synthesised. While reporting is essential for informing adaptive management that improves implementation methods and the achievement of outcomes, it is equally important in demonstrating commitment and accountability (DWS, 2017).

2.6.7 Service quality

Service standards include continuity (hours per day of service), system reliability, water safety (drinking water standard in terms of SANS 241), and mean time repair of equipment failure. There is an important trade-off between improving the service quality for current customers and expanding the water distribution network. Thus, measures of citizen satisfaction reflect perception regarding the mix of service coverage, tariffs, and quality. Public information regarding service quality is often woefully inadequate, limiting the ability of public input to put pressure of the water utility leadership (Berg, 2013).

2.7 Theoretical framework on water services delivery

2.7.1 Theories for practice

Numerous theories explain actors, relations, and phenomena (Lemert, 2013). However, Rowell (1984) argue that theories are heuristic for generating strategies and dealing with anticipated and empirically encountered problems. It is also mentioned that every strategy has limitations and makes sense in its own context. Theories are circumstance-specific but are all meaningful. It is important to note that, if a theory or set of theories are dominant within a discourse, it can lead to participants to adopt its prescriptions in the form of dogma to guide practice (Rowell, 1984). Therefore, this can have implications for water governance should a certain theory dominate. Based on this, practitioners can be influenced to adopt their prescriptions without considering other ideals.

2.7.2 Regulation theory

Regulation theory is drawn to understand the reorganisation of power and social order in the new form of government (Hubbard et al., 2002). It explores the response of the state to the crisis of capitalism. However, to avert the crisis of capitalism, state scalar configuration should therefore be regulated and attuned to its specific history, political background, institutional organisation, and regulatory activities in maintaining order in its governing architecture and social spectrum (Brenner, 2004). The principles of Regulation theory assume that social, economic, and political systems are not necessarily stable and systematic in their functioning, and therefore need to be regulated (Hubbard et al., 2002).

2.7.3 Institutional theories

It is mentioned that institutional theories emanate from theory of organisations, but they are distinct from each other (Frederickson et al., 2016). Frederickson et al (2016) and Draft (2007), further stress that the modern organisation theory is more concerned with private sector organisations because it draws lessons and practices from privately owned organisations. It is noted that organisation theories may also be unsuited for the multi-layered nature of organisation because in the context of the public sector they are more conducive to a hierarchical bureaucratic organisation.

2.7.4 Network theories

Network theory concerns formal and informal interdependence (Emerson et al., 2015). It leads to networked government that is characterised by coordination between multi levels of government, non-profit organisations, and for-profit organisations (Goldsmith & Eggers, 2014).

2.7.5 Public value theory

Bryson et al (2015) stated three approaches to public value cited by Mark Moore (2014) and Bozeman (2007). Mark Moore (2014) theorised that public leadership can create public value by ensuring that the public interventions benefit citizens economically and socially (Stoker, 2006) to a large extent. Mainly, public value theory advocates for the involvement of stakeholders and government officials (Stoker, 2006) in the spirit of ensuring that public institutions are at the centre of service delivery to guarantee value to the public.

2.7.6 Principal-agent theory

This theory is mentioned to be a useful starting point in trying to understand the influence of ownership on the performance of water utilities. In a principal-agent relationship, the task of the sector is to design a contract that provides the management of the institution with the incentive to choose the strategy that maximises the sector's welfare. However, the challenge for the sector is that the management's effort cannot be monitored, and contracts cannot be enforced without cost implications. A significant issue, in comparing public and private sector is their relative efficacy in providing management of the institutions with incentives to act consistently with sector's goals and objectives (Yarrow, 1989; Hodge, 2000).

2.7.7 Property right theory

This theory argues that private sector, as residual claimant has more clearly defined incentives to push for efficient decision-making for service delivery. The same logic applies to the institution's creditors and to the management or leadership of other institutions considering a potential takeover. In contrast, politicians, senior bureaucrats, and taxpayers have reduced property rights to the gains associated with improved public sector agency performance and, as a result have diminished incentives to push for improvements (Yarrow, 1989; Hodge, 2000).

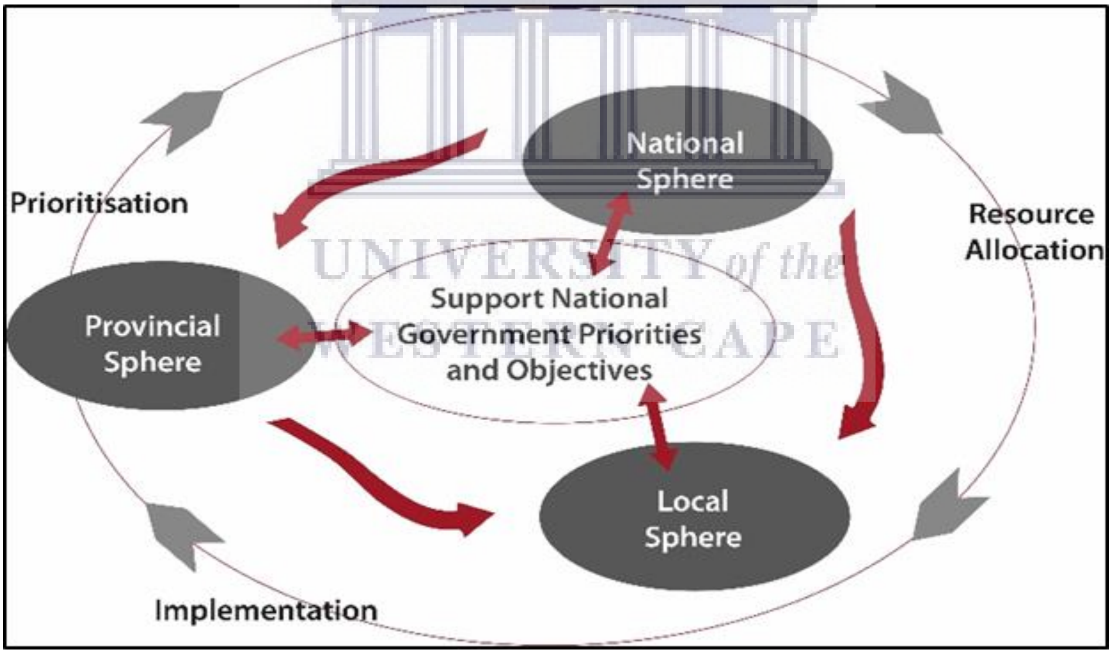
2.7.8 Public choice theory

Public choice theory emphasises the potential inefficient behaviour on the part of public sector leadership since they are assumed to act in their own self-interest, for example, by seeking to expand the size of their own budget. Altogether, these theoretical perspectives predict that the public sector have less incentives to provide oversight and discipline while public leadership have more incentives to pursue goals other than those of their agency. The lack of costless enforceable contracts that anticipate every contingency means that public agencies will exhibit poorer performance compared with their private counterparts. According to Megginson and Netter (2000) these arguments have been challenged on both theoretical and empirical grounds.

2.8 Conceptual model for water services

Service delivery to the public implies providing service as defined in the public policies including the powers and functions allocated to the spheres of government in South Africa (Kanyane, 2010). Service delivery consists of a series of highly localized actions by agents in public agencies or private institution to provide needed goods and services to citizen beneficiaries in a way that meets their expectations (Kim, 2012). This definition draws a literature from a variety of disciplines such as economics, behavioural economics, social science, and engineering to provide a broader perspective to service delivery. Figure 2.5 depicts inter-governmental interaction and coordination.

Figure 2.5: Inter-governmental interaction and coordination



Source: DWAF, 2008.

2.8.1 Services delivery models

There are multiple models that can provide the goods or services such as centralized or decentralized government provision on contracting (Lamothe & Feicok, 2008; DCF, 2009; Alexander & Heard, 2012). For this reason, the Bank Group is increasingly supporting technological development and innovation with reference to digital solutions to promote and support a more citizen-centric approach. The application of new technologies can enable wider, more frequent, more tailored, and less expensive information sharing. Through connected services, technologies can encourage and facilitate citizen input and feedback on an ongoing and real-time basis (Asis & Woolcock, 2015).

The water supply management model refers to the combination of management entity, service provider, service authority and the associated enabling environmental factors support or undermine the functioning of the management entity and the service provider. However, it is important to note that there are often overlaps in the roless and mandates between service authorities, management entities and service providers. For instance, under local government provision of water services. The local government authority is the service authority, and the management entity may house the service provider (WaterAid, 2018).

2.8.2 Factors to consider in the selection of management models

There are factors which commonly have a strong bearing on the selection of management models (WaterAid (2018). However, it is not possible to capture all factors specific to any given local context. Therefore, the decision for selection of the model should consider a number of key principles that underpin the more technical selection process.

2.8.3 Public-private partnership (PPP) model

Many developing coutries need water infrastructure to improve the livelyhoods of their citizens and their quality of life. Therefore, South Africa is no exception. However, there are many constraints to water services delivery, and one of them is cost. Finance is the lifeblood of water service delivery, and in some instances, it is difficult to access. The lack of funding has created a backlog of water services provision and this has forced governments, industries, funders and other stakeholders to come with a new approach. Efficient and productive water services delivery are important inputs for all industries and vital for economic growth and efficiency, productivity and competitiveness (DBSA, 2009; DWAF, 2004, 2008).

Municipalities are facing various challenges such as the lack of technical, planning and management skills, limited financial resources, and lack of operation and maintenance resulting in dilapidating and aging water and sanitation services infrastructure. This has resulted in rapid decentralisation of the responsibility for the provision of water services with massive spending and development to achieve universal access with massive changes in the form and function of local government (DCoG, 2010; DPLG, 2000b; DWAF, 2003)

2.8.4 Public-private partnership (PPP) value chain framework models

Matji (2013) and Ruiter (2011) indicate that there have been attempts to involve the private sector in public-private partnership models for the creation of water services and sanitation infrastructure but not with the commitment, consistency, or legislative protection that would encourage and protect private sector investment and encourage long-term partnership. However, there are several contracts with private operators for water services and sanitation infrastructure provision.

2.8.5 State model

The water services value chain is 100% government funded and owned infrastructure. Government is a key player in infrastructure investment and inefficiencies within the public expenditure management systems are particularly detrimental. Significant problems in spending of infrastructure budget is one of the examples (NT, 2013b; DCoG, 2010; DWA, 2012b).

2.8.6 Hybrid model

In the middle of water service value chain is a hybrid model. This model is between government and the private sector. As a result, an institutional framework was developed to guide this type of development (DCoG, 2010; OECD, 2012; NT, 2000).

2.8.7 Private model

The other extreme of water service value chain is 100% private sector funded and owned infrastructure. Therefore, harnessing the significant potential for capital markets to finance water infrastructure, particularly local bond markets, is contingent on their strengthening and further development. In this case, appropriate institutional investors would be the natural sources of long-term financing for water services infrastructure (World Bank, 2010; TCTA, 2012; Inderst, 2009).

2.8.8 Decentralization

Cheema and Rondellini (2007) advocate that decentralized governance could accelerate economic growth, increase political accountability, and enhance public participation in governance. They mention that it could also reduce the complexity of hierarchical processes and procedures, thereby expediting delivery and affording water services communities. Furthermore, decentralization provides for innovation and empowerment of communities, mobilising private resources for investment in infrastructure and facilities. Similarly, Buccus et al. (2007) observe that the South African government has committed itself to responsiveness, accountability, and transparency in the decentralized governance. However, public participation is predominantly in the form of consultation rather than empowerment of citizens.

2.9 Water services delivery framework

2.9.1 Water Service Act

The Constitution of South Africa affords everyone the right to access sufficient water. The Water Services Act 108 of 1997 (WSA) sets the legislative framework to give effect to this right by regulating institutions that manages the access and delivery of water services. These institutions include Water service authorities, Water service providers, water service intermediaries, water boards and water service committees. However, the national and provincial government also form part of the overall institutional structure of the water services landscape.

2.9.2 National Water Act

This Act deals with water resources and its main purpose is to protect, use, develop, manage, and control water resources. The Act ensures that water for basic human needs and environment is reserved before is allocated for other uses (National Water Act 36 of 1998).

2.9.3 National and Provincial Government

Local government has the responsibility to ensure that every person has access to water services. However, national, and provincial have an important role to play by ensuring that municipalities execute effectively (Section 154 (1) of the Constitution). For this reason, national and provincial government capacitate municipalities to manage and perform their functions in terms of section 139 of the Constitution.

2.9.4 Municipalities

According to the South African Constitution (Section 11 (1) of the WSA), municipalities are obliged to progressively ensure efficient, affordable, economical, and sustainable access to water supply and sanitation services. However, not every municipality is defined a water services authority (Stats SA, 2016). Municipalities may provide these water services, contract these services out to water services providers or enter a joint venture with another water services institution as per section 19 of the WSA. Therefore, municipalities are obliged to develop a water services development plan for its area of jurisdiction. The plan should detail the strategy for providing access to water services at local level.

2.9.5 Water services providers

According to section 19 of the WSA, municipalities may enter a contract with a public or private water services provider to supply water and sanitation services. The regulatory framework provides for a range of institutional arrangements to ensure provision of water services. However, each institutional arrangement has its sets of benefits and restrictions.

2.9.6 Water boards

According to section 28 (1) (a) of the WSA, water boards are organs of state established by the Minister to provide bulk water services as their primary function to other water services institutions within a specific area. However, it may be allowed to carry out other secondary activities which does not interfere with its primary function as per section 32 (a) of the WSA.

2.9.7 Water resources

The key aspect of water services reform process involves defining mechanisms to improve existing services and to allocate water to different stakeholders based on assessments of their minimum water requirement (Soussan et al., 2002). Therefore, water supply side interventions are required to balance available water resources with projected water requirements until 2030 and beyond. Water use efficiency and water conservation and demand management interventions need to be put in practice to ensure reliable and sustainable water service delivery. Failure to implement various water conservation interventions will result in high water shortage.

10. Chapter summary

There was a need to review about other previous studies across the globe. Hence, this chapter reviewed various approaches to service delivery arrangements, from the source through WTW to distribution. The focus of the study was on the use of telemetry system tool used for monitoring and management of water quality, demand, and supply, in attempt to address water management challenges. These in turn form part of a broader technological infrastructure that supports innovation and ability for one technology to be linked to another. This chapter provides a general context on technology development adoption or build on the existing studies. Therefore, technology can be instrumental to enable users as well as policy makers to get a better understanding of technology options available.

Moreover, measurement technology is instrumental to provide much needed water related information which is also essential for informed decision-making at both management and technical decision-making. However, technology solutions require a good understanding of the context in which they are applied. And the solutions need to be based on a holistic approach which goes beyond the identification of quick-fixes and consider cost effectiveness along a life-cycle perspective.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The literature review presented in chapter 2 identified key issues that are relevant to the study of telemetry system. Therefore, an appropriate methodology was developed to collect data on these key issues. The research design and methodology were explained to indicate what was required to answer the research questions and achieve a systematic management of data collection and analysis. Under research design the study area, sampling size, parameters, sampling design were described. In addition, the chapter also addressed the sampling technique used and focused on the selection of participants, ethical, technical, and legal considerations. The aim of the study was to explore the practices, experiences, and perceptions to evaluate the use of telemetry system in WTW.

3.2 Research design

3.2.1 Study design

Christensen (2007) states that research design refers to the outline, plan of strategy specifying the procedure to be used in seeking an answer to the research question. The research design was qualitative in nature. The focus in qualitative research was to understand, explain, explore, discover, and clarify situations, feelings, perceptions, attitudes, values, beliefs, and experiences of a group of people (Kumar, 2014). The source of evidence emerged from the current WTW telemetry system in terms of its performance, water demand and supply management, and monitoring and assessment of water quality.

Exploratory qualitative design was preferred over other methods because of covering previously unexplored phenomenon or very little was known about the subject in question (Mason et al., 2010). Data were collected from Phalaborwa WTW and the focus was on the evaluation of the telemetry system. This study adopted the semi-structured method for data collection in the form of primary and secondary data. As mentioned earlier, there was not previously researched or scientific data of any kind about telemetry system at LNW' WTW, hence the selection of this design method.

This design was used to uncover mainly the features that characterise a phenomenon in each context. According to Mason et al. (2010) these characteristics can in future be studied further to broaden and deepen understanding of the phenomenon. Furthermore, the adoption of this approach was to allow the phenomenon to be described from the perspective of the participants. For this, it gave prominence to the meanings they attach to their experience of the phenomenon (Pope & Mays, 1995).

3.2.2 Research design methods

This subsection describes the research process and the kind of tools and procedures used. Data was collected from interviews and existing official minutes of meetings, reports, archives, manuals, and job cards. In this study, the researcher focused on evaluating the performance of the telemetry system employed on water treatment and distribution process. Secondly, telemetry system was evaluated on how water demand and supply is determined. Lastly, the telemetry system was assessed on monitoring and management of water quality. Data was then analysed with Microsoft Excel tools such as tables, graphs, pie, area, and bar-charts using numbers and percentages.

According to the report by Wilmot (2005), qualitative research provides an in-depth understanding of the world as seen through the eyes of the people being studied. This is supported by Curry, Nembhard and Bradley (2009) when they maintain that qualitative method is typically the preferred method of data collection and analysis in exploratory studies. The study was exploratory in nature and it was deemed relevant to the current research study. The approach was suitable as an in-depth understanding of employees and stakeholders were sought (Shield & Rangarjan, 2013) and the qualitative method was used for data collection and analysis. The study can be characterised as cross-sectional because of time spent to complete. The term cross-sectional describes a research study conducted at a single point in time. It is compared to the researcher taking a slice of the case (Saunder et al. 2016).

3.2.3 Sampling design

There are two sampling design methods to select from, namely, probability sampling or non-probability sampling method. According to Zikmund *et al.* (2013) non-probability sampling works with unknown probabilities. The selection process for participants for this study took place according to the principles of non-probability sampling. The non-probability sampling strategy which is purposive sampling technique was used since it would aid in providing the best information to achieve the objectives the study (Kumar, 2014). According to Dolores and Tongco (2007) purposive sampling technique can be described as a type of non-probability sampling that is most effective when there is a need for the researcher to study a certain cultural domain with knowledgeable experts within.

3.2.4 Data type and their sources

The researcher was granted permission by the LNW management to freely access most of the relevant material and information available for this study. The source of documents was accessed from the operations and maintenance department and other supporting units such as supply chain and finance. Relevant documents attained from the abovementioned units and departments include, type of telemetry system used, telemetry system capacity, functions and performance of the telemetry system, maintenance work orders, reports, records and minutes of meetings, system operating manuals among others became essential for this study.

The sources of literature were also carefully chosen to some cases that implemented the use of telemetry system, considering the level of technology, experience, and the type of the industry. According to Yin (2014) the use of several sources of evidence, or research tools provided a better coverage, reduced bias, and enabled a control to verify the quality of data collected. Based on the aforementioned information, qualitative primary and secondary data were collected and analysed. In this study, the researcher focused on employees who have more than two years of work experience.

According to Stake (1995) documents provide some valuable information that was obtained by others. Yin (1994) supported Stake when he suggests that documentary information is sometimes essential for a case study topic. Therefore, the analysis of LNW document related to the subject of the study provided us with information on various activities related to telemetry system including goals, objectives, and mission in terms of water service delivery. It was further noted that the most important use of documents was to emphasis and increase evidence from other sources (Yin, 1994). It also became important for the researcher to include the production and maintenance crew in the collection of data regarding the telemetry system at the WTW. Managers, engineers, production, and maintenance team poses full knowledge and experience of telemetry system performance characteristics.

3.2.5 Population size

This is the description of the population and its elements from which samples will be drawn. Sampling involves decisions about which people, settings, events, or behaviours to include in the study. Researchers need to decide how many individuals, groups or objects will be observed (Bertram & Christiansen, 2014). Since it is generally impossible to study an entire population in the study area. Generally, the important case was to portray the meaning lived experiences from the people going through the phenomenon under study by collecting data involving 5 to 25 participants (Creswell, 2007).

The study relied on this sampling procedure to acquire a section of the population to participate in the study. The population was chosen based on their experience in the operations and maintenance department for this study. Therefore, experience of the participants in the functioning of the telemetry system was required for the interview. Table 3.1 below depicts the selected participants for the study according to their knowledge and experience.

Table 3.1: Selected participants

Designation	Quantity	Department
Manager	4	Operations & Maintenance
Technician	3	Operations & Maintenance
Training Officer	1	Operations & Maintenance
Service Provider	1	Vendor
Assistant Technician	1	Operations & Maintenance
Trainee	1	Operations & Maintenance

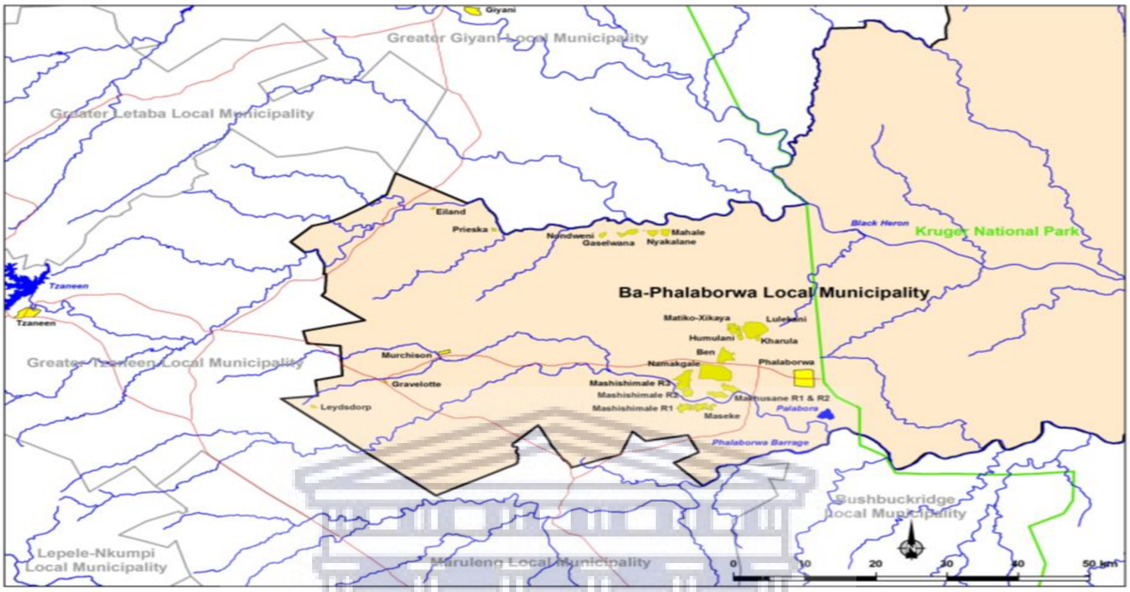
This means that a total of 12 samples of the 53 employees of the Phalaborwa WTW were taken from operations and maintenance department. This sample was found to represent the study in a meaningful manner (Saunders et al., 2012). The vendor used to provide telemetry services at the WTW was also included in the population mainly because of inadequate capacity in certain specialised work. According to Bertram and Christiansen (2014) there is no clear-cut answer to the question of sample size and is also determined by the data collection method and the purpose of the study.

3.2.6 Sampling site

The site of this study was Phalaborwa WTW. The WTW is in the Ba-Phalaborwa Local Municipality (BPM). BPM is a category B municipality and falls under the Mopani District Municipality (MDM) in the Limpopo Province. The MDM has four major towns, namely, Phalaborwa, Ga-Modjadji, Tzaneen, and Giyani. The Ba-Phalaborwa municipality is situated in the northern-eastern part of MDM, about 240km east of Polokwane, and just less than 1km from the Kruger National Park border.

Ba-Phalaborwa Municipality has a mixture of town, rural and industries. According to the South African Statistics Census 2011, the BPM population has increased from 131 089 to 150 637. It must also be noted that the Community Survey 2016 concluded that the population stands at 168 937. According to McMillan and Schumacher (1997) population is a group of elements or cases, whether individuals, objects of events that conform to a specific criterion and to which the research results are generalised. Figure 3.2 below depicts the map of Ba-Phalaborwa municipal area.

Figure 3.2: Ba-Phalaborwa Local Municipality



Source: IDP, 2017.

The mines, industries, township expansions and Kruger National Park contribute to high population increase in the Ba-Phalaborwa area of supply, thus high-water demand. The community residing within the 15km radius of Phalaborwa town is depending mainly on surface water from Phalaborwa WTW. According to Ba-Phalaborwa Municipality IDP (2017) the quality of underground water is not good, especially for human consumption and the yield of most of the boreholes is very low. Hence, the need for new technology for water conservation and demand management.

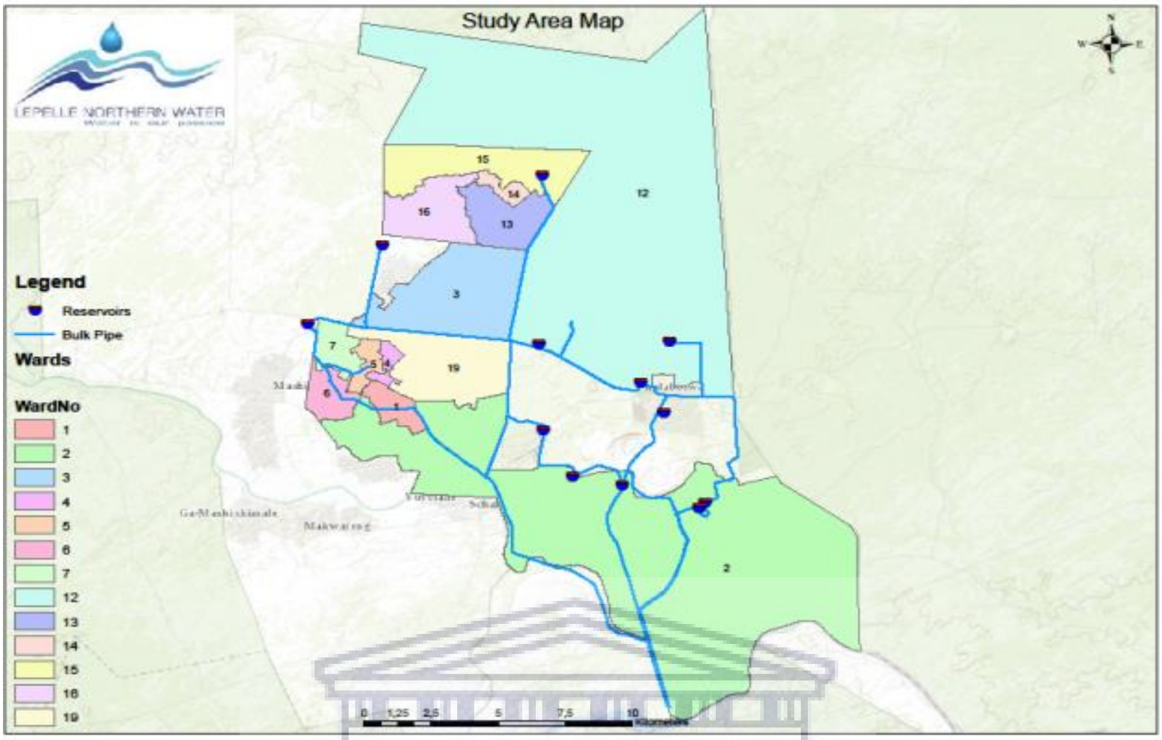
The Phalaborwa WTW is one of the biggest water treatment works situated at the lower end of the Olifants River before it enters the Kruger National Park to Mozambique. Water to the WTW is abstracted from the Olifants River at the barrage through centrifugal pumps to the division box at the head of works. The WTW has a capacity of 148Ml per day, both portable and industrial water included. Figure 3.3 below depicts the barrage.

Figure 3.3: The barrage for Phalaborwa WTW

Source: LNW, 2019

The map below depicts the study area (wards, reservoirs, and the distribution network). The wards, the reservoirs and the pipelines are shown below with different colours. Water scarcity remains one of the municipal service delivery challenges. According to the Ba-Phalaborwa 2017-201/22 IDP, the Township Regeneration Strategy document for Ba-Phalaborwa has identified the centre between Lulekani, Namakgale and Phalaborwa town as a strategic land that should be considered for future residential and business development area. However, this available land is in the control of traditional authorities. For this reason, the municipality, and the traditional authorities to meet and plan for water services provision, especially, with the emphasis of adopting technology for water monitoring and management. Figure 3.4 below depicts different wards for the Ba-Phalaborwa municipality as the researcher's study area.

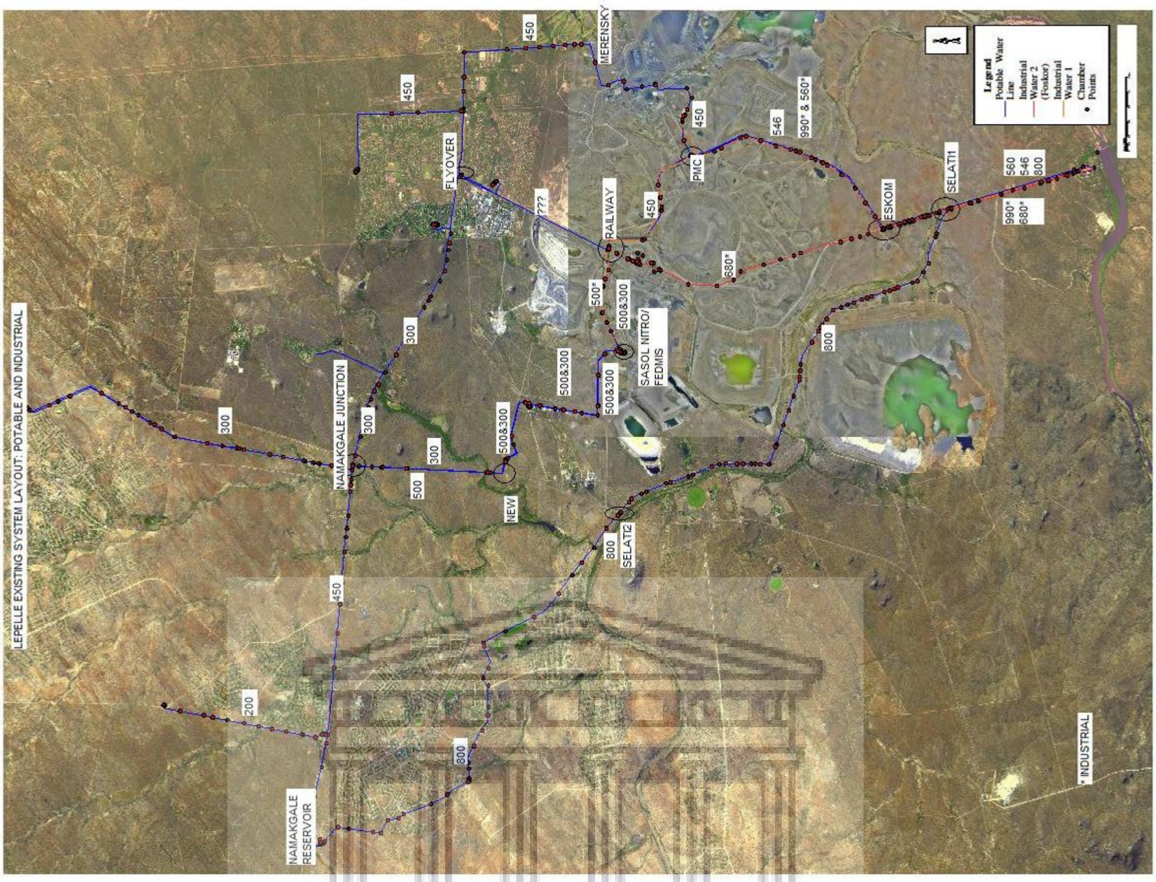
Figure 3.4: Study area map



Source: LNW, 2019

The BPM represents an excellent model of population densification, with 94% of the population staying in the 15km radius of the Phalaborwa urban complex (IDP, 2017). This 94% of population is served by the Phalaborwa WTW which is owned and operated Lepelle Northern Water. The WTW is supplying both portable and industrial water to the municipality and the mines, respectively. The map below depicts the water distribution network. Generally, the responsibility of the WTW is to ensure compliance to both water quality and quantity in adhering to contractual obligations and customer satisfaction. Areas supplied with portable and industrial water are explained below. Portable water is supplied Namakgale town through 800mm diameter pipe, Phalaborwa Town South through 450mm diameter pipeline, Phalaborwa Town North through 450mm diameter pipeline, Extension 8 & 9 through 450mm diameter pipeline, Schiettotch through 325mm pipeline, Ben farm through 200mm diameter pipeline, and Lulekani town through 450mm diameter pipeline. Industrial water is supplied to both PMC and Foskor mines through 990mm diameter pipeline and 680mm diameter pipeline respectively. The map, figure 3.5 below depicts distribution network sizes and areas of supply.

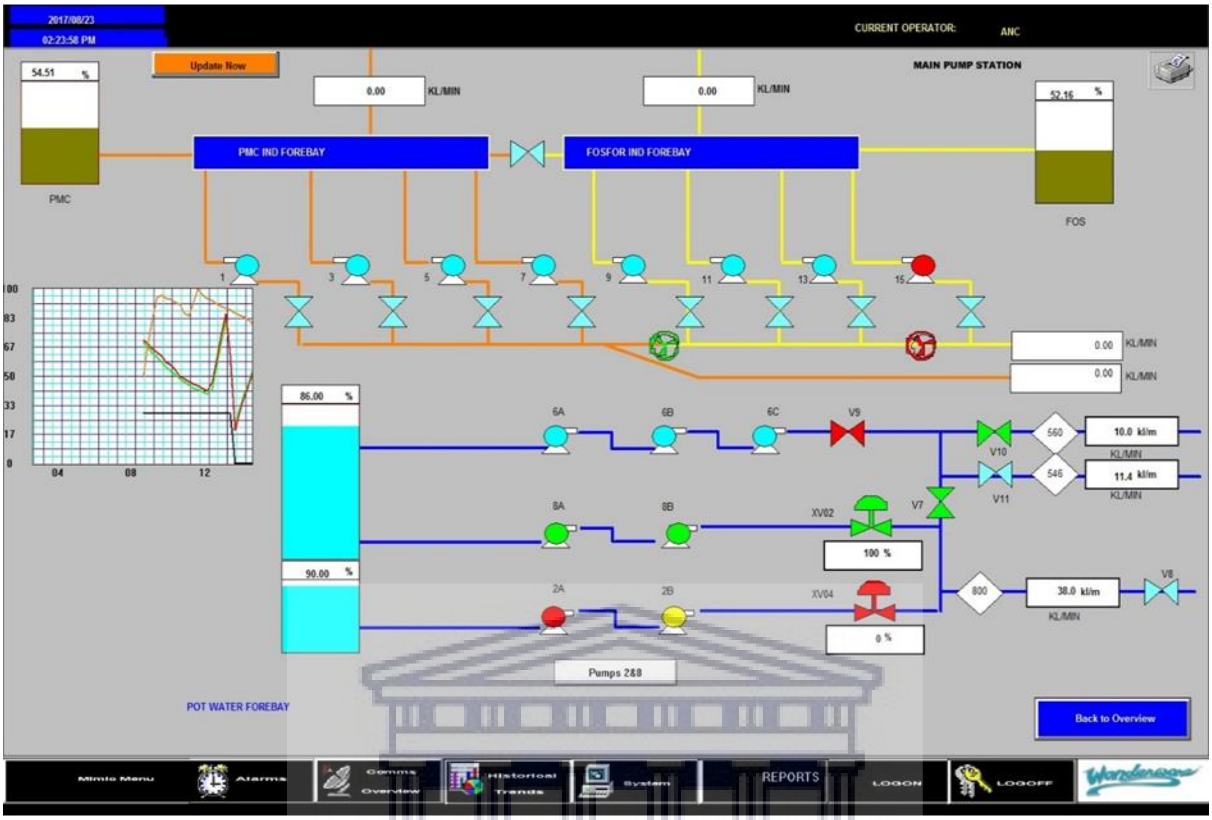
Figure 3.5: Water distribution network



Source: LNW, 2019

Currently, challenges facing both the municipality and Phalaborwa WTW is high water loss through vandalism of water distribution network, illegal connections, and building of concrete structures on top of the water pipelines. This suggest that there are different plans for water service delivery between both the traditional authorities and the Ba-Phalaborwa local municipality. Based on that, water delivery services could be a challenge if the use of new technologies is not embraced for water monitoring and management. Below figure 3.6 depicts the use of PLC and telemetry system for different WTW process and functions.

Figure 3.6: Main pump station overview



Source: LNW, 2019

The current telemetry system is used for only basic functions such as pump starting and stopping, monitoring of reservoir levels, valve positioning, alarms, duty pumps, reservoir water inflow and outflows, pipeline pressure and surveillance.

3.2.7 Time horizon

The research time horizon implemented in this study was cross-sectional as the research would be focusing on completed and ongoing telemetry system infrastructure within the past 5 years. Based on this, it was found to be relevant as it describes the performance of a phenomenon (Saunder et al., 2012).

3.3 Research methodology

3.3.1 Quantitative methodology

The term quantitative usually means the use of some form of numbers of statistics to portray, analyse and draw conclusions on data. Although not exclusively, this is conducted with methodologies rooted in deductivism and positivism (Donaldson, 2005; Kremelberg, 2011). Quantitative research originated in the physical science, particularly, in chemistry and physics (Creswell, 2002). Quantitative research involves the collection of data so that information can be quantified and subjected to statistical treatment to support or refute alternate knowledge claims (Creswell, 2003).

Furthermore, results of quantitative research often rely on data from questionnaire which provide little insight to the subjective experience of participants whereas inferential depend on the subjective interpretation of the researcher (Roer-Stier and Kurman, 2009). However, there are limitations to quantitative research which include the requirement of large samples.

3.3.2 Qualitative methodology

Qualitative research method offers some benefits to a case study, this method also gives the participants the opportunity to share their experiences and opinion on a phenomenon (Guercini, 2014; Onwuegbuzie & Byers, 2014). Researchers either adopt unstructured or semi-structured questions to understand the how, who, why and what of a phenomenon (Salmona *et al.,* 2015). The qualitative research method allows some flexibility in the data collection process because researchers can modify the interview questions as the interview progresses (King *et al*., 2013; SuB & Sayah, 2013).

Additional attributes of the qualitative research method include the reliance on the researcher as the principal instrument for collecting data, allowing multiple perspectives of employees, the use of complex inductive reasoning to organise data, and presenting a composite picture of the problem under study (Lal *et al.*, 2013). Shield and Rangarajan (2013) further indicate that it seeks out unexplored and under-researched phenomenon. The qualitative research method is found to be appropriate for examining problems where the type of data analysed does not require measurement or empirical analysis (Guercini, 2014; Merriam & Tisdell, 2015). For this reason, the researcher chose to use the qualitative research method for this study.

3.3.3 Mixed methodology

Mixed method research is a potentially interesting idea and approach. However, it is also a term that can provoke some confusion. The term mixed method appears to allude to issues relating uniquely to research methods rather than methodologies. However, the term really is concerned with the idea of mixed methodologies (Stoke, 2011). The mixed method integrates both qualitative and quantitative approach in one research setting (King et al., 1994). A mixed method approach has gained more popularity, recognizing the benefits of complementary rather than competitive fashion (Jick, 1979).

It is noted that the process of mixed methods is either sequential or concurrent, whereby applying one research approach dominant over the other or both in an equal manner. However, potential barriers to be considered for mixed method research are highlighted by

Brymann (2007). The barriers are such as different audience, methodological preferences, role of timelines, and nature of the data, skill specialism, publication process and problems of exemplars. Therefore, all these barriers should be considered and compared with the actual setting and if necessary, to be addressed prior to embarking on a mixed method approach.

3.4 Research methods

3.4.1 Methods for assessing performance of the telemetry system.

3.4.1.1 Primary data collection

Primary data was collected by interviewing participants. Primary data is information collected for the specific purpose of the study either by the researcher or by someone else. Sources used to provide primary data are such as interviews, observations, and questionnaires (Kumar, 2014). In this study, data collection consisted of semi-structured interviews describing activities and functions of WTW process and how water distribution network (WDN) is monitored and managed by telemetry system in aid of answering the research question 1. Semi-structured in-depth interviews could cover a broader array of topics within one interview and therefore, are more time-efficient and less costly than unstructured in-depth interviews (Zikmund et al., 2013).

According to Stokes (2011) an interview is a conversation, an interrogation, or an oral exchange with the objective of securing data and ultimately information. The purpose and the relevance of this study was explained to the participants (Kumar, 2014). The perceptions of participants were important especially when complex experiences related to the performance of the telemetry system were explored. In this qualitative research, the researcher was the data collection instrument (Silverman, 2015). Marshall and Kaczynski et al. (2014) stated that qualitative researchers, who conduct interviews are human instruments because all data are mediated through them instead of surveys or statistical instruments. Notes were used to complete the data capturing forms and audio recordings during the interviews. Importantly, the audio recordings were also used for quality and validity checks (Patton, 2002). Recording allowed capturing of exactly what participants said as well as paying close attention to responses and clarifying of questions. Certainly, it was essential to also have interviews audio-recorded (Patton, 2002).

3.4.1.2 Secondary data collection

Secondary data were also used in the study. Secondary data are data collected by others or derived from existing data (Bertram & Christiansen, 2014). For this study, the researcher used various existing documents as the source of data. Data collection consisted of system failure reports, call-out and overtime reports, minutes of the meetings, manuals, and documents describing performance of telemetry system monitoring and management of WTW process and water distribution network (WDN) in aid of answering the research question 1. Other information was obtained from journals, publications, books, and multiple articles and materials from the internet.

Reviewing documents is another qualitative research strategy that offered a few advantages to the researcher. They conveyed a sense of events that began prior to the evaluation, documenting early telemetry system development and implementation stages and the decisions that were made along the way. Documents helped to stimulate questions that might be pursued later through interviews and observation (Patton, 2002). Secondary data further supported the findings of the primary data analysis. The perceptions of participants were important especially when complex experiences in the system performance were explored.

3.4.2 Methods for determining water demand and supply using telemetry system.

3.4.2.1 Primary data collection

The collection of primary data was achieved through interviews. Primary data was used to fill the gap of knowledge from secondary data because the research topic of this study was specific. This is supported by Saunders *et al*. (2016) by defining primary data as information collected and analysed specifically for the purpose of the study. Participants selected for the collection of data with the use of interviews were production personnel, maintenance crew, management officials and instrument technicians from Phalaborwa WTW and some from the operations and maintenance department in LNW. The reason for using the interview research approach was to allow the researcher to understand human beings as they engage in action and interaction within the context of settings and situations (Welman, Kruger & Mitchell, 2012).

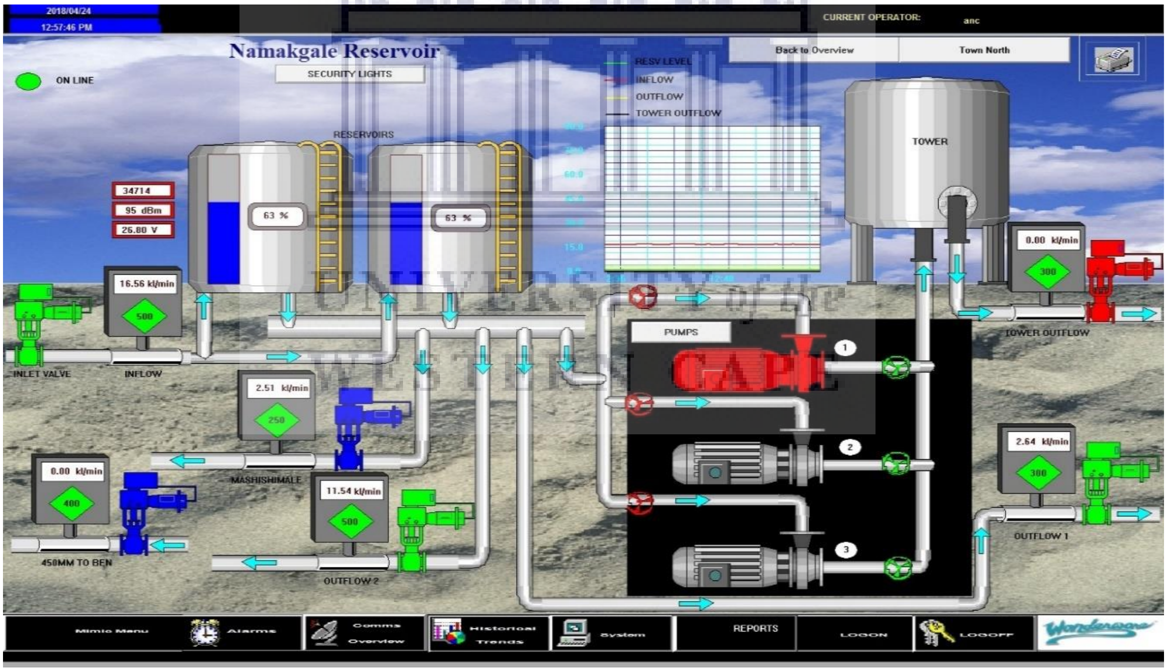
3.4.2.2 Secondary data collection

The collection of secondary data was archived through the collection of existing relevant documentations from operations and maintenance departments within LNW. Data collection approaches in qualitative research include the use of information such as reports, the minutes of the meetings, corporate plan, presentations, complaints records and manuals (Yin, 2014). Yin (2014) further stress that the use of several source of research tools provides a better coverage and enables a control system to verify the quality of the data collected. Books, journals, publications, and multiple articles and materials from the internet were also used to gather information.

According to Zikmund et al. (2013), in this study, secondary data is data that have been collected and recorded by a different researcher for the purpose of the study. This study focused more on the efficient delivery of sustainable and reliable bulk water and sanitation services using the telemetry system. This method was used to collect water demand and supply management data describing the effectiveness, efficiency, impact, and reliability of telemetry system in WTW process and water distribution network to answer research question 2.

Regarding the water demand and supply, this research depended on secondary data as options for primary data were limited. The secondary data further supported the findings of the primary data analysis. For this, the utilized data collection method was relevant to this study as it facilitated exploration of the subjective experience by the WTW employees and the management officials. Based on the statement, the researcher believed this method did not compromise gathering of data. Figure 3.7 below depicts the Namakgale water distribution reservoir, reservoir levels, and water inflow and outflow readings as an example by showing some of the telemetry monitoring and management functions.

Figure 3.7: Namakgale water reservoirs



Source: LNW, 2019.

The monitoring and management of the reservoirs in the Phalaborwa WTW area of supply is done from the central point at the process control room using telemetry system and this application is the same as on other reservoirs and outstations. The only difference is the capacity of reservoirs and the size of population served.

3.4.3 Methods for assessing water quality using telemetry system.

3.4.3.1 Primary data collection

Semi-structured interview method was utilized to collect data from the employee at Phalaborwa WTW, scientific services unit, and the asset management unit which is within the finance department was involved. In qualitative research, the researcher is the data collection instrument (Silverman, 2015). In this study, the researcher used primary data collection method. The researcher probed the participants to describe as precisely and comprehensively as possible their thoughts, actions, feelings, views to gain clarity about the phenomenon in terms of their interpretation. It is indicated that the most appropriate place for the participants to give their view about the phenomenon is where they reside (Leedy & Ormrod, 2014). However, it was not the case for this study.

In this case, participants shared their experiences at the place of work since most of their time was spent at work. Before interviews start on the exact time as agreed between the researcher and the participants, participants were asked to read and understand the consent form. In addition, explanation was given where necessary before the consent forms were accepted and signed. Participants were then allowed to ask questions related to this study and were further requested to elaborate and describe in as much detail as possible on their experience relative to water quality and the use of telemetry system to address question 3.

3.4.3.2 Secondary data collection

Zikmund et al. (2013), describe secondary data is data that have been collected and recorded by a different researcher for the purpose of the study. This study focused more on the efficient delivery of quality and reliable bulk water and sanitation services using the telemetry system. This method was used to answer water quality questions by describing the effectiveness, efficiency, and reliability of telemetry system in WTW process and water distribution network research questions. Water quality monthly and quarterly reports from scientific services unit, minutes of meetings and corporate plans, where water quality monitoring and management issues were discussed and documented. Other information was obtained from journals, publications, books, and multiple articles and materials from the internet.

Collection of data was mainly focused on methods and systems used for monitoring and managing, processing, and distributing quality water complying with SANS 241 and other applicable regulations. Regarding the water quality, this research depended on secondary data as options for primary data were limited in responding to question 3. The secondary data further supported the findings of the primary data analysis. Therefore, the utilized data collection method was relevant to this study as it facilitated exploration of the subjective experience by the WTW employees and the management officials.

3.4.4 Data analysis method

In this section, the focus of this study was based on the tools of analysis that was used to measure the analysis obtained from the data collected. Data analysis involves the processes necessary for the researcher to grasp the wholeness of the phenomenon and search beyond the facts to extract the significant data (Lewis, 2015). It was also explained that data analysis was regarded as studying the organized material to discover the inherent facts (Pandey & Pandey, 2015). In this study, content analysis was selected as a suitable research method because of the systematic quantitative approach employed to analyse qualitative data (Kabanoff, Waldersee & Cohen, 1995)

Data was gathered from different sources through questionnaires and existing telemetry documents. The research questions were answered by using data and information gathered from reviewed company official documents and the interviews conducted with officials and other stakeholders were analysed using themes (Creswell, 2014). According to Payne and Payne (2004) content analysis seeks to demonstrate the meaning of written or visual sources by systematically allocating their content to pre-determined, detailed categories, and then both quantifying and interpreting the text outcomes in a simple, clear, and easily repeatable format. Content analysis was also defined by Krippendorff (1980) as a research technique for making replicable and valid references from data to their context.

As indicated by Payne and Payne (2004), written data were collected from the research participants, structures and patterned regularities in the text made inferences based on these regularities. The meaning of the text was relatively straightforward and obvious, and this made it useful to for looking at frequencies of words and their change of frequency over time. For this reason, content analysis was used to analyse interview texts and counting the use of themes. Furthermore, relationship between themes and codes were identified through co-occurrence Microsoft Excel tables were used to do the exploratory data analysis (EDA). Audio recordings were also used to during the coding stage to check inter-rater reliability, as well as helping to pace the interview (Patton, 2002). Generally, tools such as histogram, barcharts, pie-charts, Pareto charts, metrics, diagrams, etc. were used for data presentation. Table 3.2 depicts summary of data collection and data analysis.

Table 3.2: Summary of data collection and analysis

Research question	Data collection	Data analysis
System performance	Primary	Content
	Secondary	Content
Demand & supply	Primary	Content
	Secondary	Content
Water Quality	Primary	Content
	Secondary	Content

Source: Researcher, 2019.

Therefore, the researcher believed gathering of data was not compromised. The information collected through interviews was a foundation for answering all the questions. For this reason, all three research questions relied mainly on best practices and applicable theories, models, and frameworks for water service delivery. Furthermore, components of secondary literature also contributed to answering research questions. Table 3.3 below depicts interview sources, codes and themes used for the study.

Table 3.3: Interview source, codes, and themes

Interview sources	Codes	Themes
System optimization, improvement, cost saving, performance, reliability and sustainability, challenges, impact on services, other functions.	Remote monitoring, management, and control	System performance
Water management, demand and supply, constraints, water loss, pressure management.	Water conservation and Demand management	Water demand and supply

Water quality monitoring, system limitations, quality management, and water security and improve monitoring.	Water compliance requirements	Water quality
Legislative, regulation and mandated	Theories, models, and Practices	Service delivery
Ability, experience, capability, and competency	Information and knowledge	Training and development

Source: Researcher, 2019.

Microsoft Excel was utilised for exploratory data analysis and the reason for coding during analysis was based on minimizing the risk of misunderstanding research interview questions by the participants.

3.5 Quality assurance

According to Vogt (2005) trustworthiness has been chosen to differentiate the methods of establishing and assessing quality in qualitative studies. The elements mentioned by Given (2007) involved in trustworthiness are dependability, transferability, credibility, and confirmability. Given is supported by Saunder et al. (2012) when citing those who continue to use the concept of reliability and validity, amending them to fit qualitative method designs (Yin, 2009) to demonstrate that their research is of high quality and credible.

Qualitative researchers generally regard quality aspects as inappropriate in establishing the "truth value" of a quantitative research project (AS de Vos *et al*., 2011). Reliability and validity are central to judgements about the quality of research in the natural and social science (Saunders et al., 2016). The relationship between reliability and validity is straightforward and easy to understand. For example, a test can be reliable but not valid, a test cannot be valid without first being reliable.

Reliability is the extent to which the test, measure or instrument can be repeated with the same or a similar group or respondents, and still produces the same results (Bertram & Christiansen, 2017). Validity refers to the appropriateness of the measure used, accuracy of the analysis of the results of the findings (Saunders et al., 2016). Validity is the extent to which data collection method accurately measure what they were intended to measure (Cameron & Price, 2009).

3.5.1 Reliability of the findings on telemetry system: Objective 1

The purpose of the study was to establish the performance of the existing telemetry system on WTW process. The study revealed that various sets of telemetry software and hardware systems can be used to improve performance in the provisioning of water and sanitation services. These various set of tools have been recommended by different researchers for the provision of efficient and effective water and sanitation services. Data was collected through various sources of evidence. Primary and secondary data was gathered through interviews and documents review, respectively. Participants were invited for interview through the telephone and emails. During data collection, adherence to the research methodology and design were followed to ensure reliability (Yin, 2014). As mentioned by Mårtensson et al. (2015), when research design sound is met with proper research data, the answers should lead to comprehensive conclusions and new knowledge that is reliable and transparent.

Reliability evaluation of the engineering system is often performed using simulation tools. It is for this reason that reliability indices of a system be the expected value of a test function applied to a system state to assess whether that specific configuration corresponds to an operating or failed state (Pereira & Pinto, 1991). Generally, to determine the state of the system as a function of its components, it is necessary to evaluate a function that is called system function. WTW process and distribution functions as one unit, from the source to the tap. This mean without any of the links water service delivery may be compromised or completely be dysfunctional. Hence, a suitable and well-maintained infrastructure is preferred to ensure efficient, reliable, and sustainable water services delivery over the system that will even fail to deliver free basic water services.

3.5.2 Reliability of the findings on water demand and supply: Objective 2

This study aimed to determine the utilization of telemetry system on water demand and supply in terms of WTW process and water distribution network monitoring and management. It has been revealed by several researchers that various telemetry system tools can improve the management of water and sanitation services. One of the strategic objectives of LNW is the provision of equitable, sustainable, and reliable, water and sanitation services.

To achieve this, Phalaborwa WTW has raw water abstraction permit issued by DWS, plans are in place for responding to equipment failures, including production related infrastructure technology. WTW process and water distribution network is regularly maintained to ensure its reliability in addressing water demand and supply challenges. Importantly, any water supply interruption is timeously communicated to various stakeholders including the internal Infrastructure planning and maintenance unit for assistance and future planning to ensure water supply reliability. The collected data from the infrastructure planning and maintenance is transparent and auditable.

Where LNW fail to plan and implement strategies for the provision of basic water services (BWS), fail to provide efficient, effective, and sustainable services, the national and provincial government has the constitutional right to intervene. Water service delivery requires responsible service providers, managers, and policy makers to be answerable, to provide enforcement, and to make relevant organizational changes where possible (Caseley, 2006; Asis & Woolcock, 2015) to make service "people-centred" (UNDP, 2013). Data collected from Community Survey 2016 and Statistics for South Africa 2011 access to piped water households in terms of Ba-Phalaborwa population supplied by Phalaborwa WTW is reliable and can be verified.

3.5.3 Reliability of the findings on water quality: Objective 3

The purpose of this study was to assess the use of telemetry system in managing water quality produced by the WTW supplied to the community in an efficient manner. Reliability is used to refer to the time to which a point of source or piped system is free from unplanned interruption due to breakdown or other causes. The lack of reliability and/or continuity in improved water sources can force served community to search for other sources, and the potential of being less safe is high (Pattanvak et al., 2005); Subbaraman et al., 2013). It can also contribute to contamination in piped systems (Lee & Achwab, 2005; Rizak & Hrudey, 2008). Contamination in piped system can be because of unauthorized connections and infrastructure vandalism.

Therefore, regarding water service delivery using technology, reliability dimension of quality service refers to the ability of service providers to perform the promised services as per the service level agreement (SLA) dependably and accurately, and that being so, reflects the consistency and dependability of an organization's performance (Rodriquez et al., 2011). In support, Wilson et al (2008) emphasize this by indicating that reliability means that the service provider delivers on its promise about service delivery, service provision and problem resolution. In this study, data were collected as per water service act (WSA) and the use of IRIS tool for reliability as approved by DWS through the government quality assurance system.

3.5.4 Validity of the findings on telemetry system: Objective 1

Validity is a process of checking with participants concerning the accuracy of the data and interpretations (Tracy, 2010; Creswell, 2007). For this reason, some of the production related equipment are maintained, replaced, and serviced according to the original equipment manufacturer to produce valid results. Furthermore, LNW has entered into contractual agreements for goods and services delivery with various service provider in line with National Treasury requirements to ensure sustainable and reliable service delivery. Furthermore, the study results are valid as the results were compared with those of previous years using the same technology. Therefore, the findings of the study were validated by the results of the previous years for the selected WTW of LNW.

3.5.5 Validity of the findings on water demand and supply: Objective 2

Validity is also called member checking. Selected participants of the sample were given opportunities to review interview questions prior to dissemination of copies of the transcribed data and the results section. The Phalaborwa WTW is depending on the water from the Olifants River and the abstraction permit is in place with DWS. LNW as the water service provider has a service level in place with the Mopani District Municipality (MDM) for potable water and for industrial water with the Palabora Mining Copper (PMC), Foskor, and Bosveld industry. Therefore, the study results were validated by the results of previous years of service level agreement between parties using the same technology to monitor and manage WTW process and distribution network.

3.5.6 Validity of the findings on water quality: Objective 3

In qualitative study validity refers to the credibility, transferability, dependability, and confirmability of the findings. Often validity involves triangulation, acknowledgement of bias and the inclusion of archival documents to establish the truth and legitimacy of research outcome (Cope, 2014; Yin, 2014). Under normal condition, Phalaborwa WTW takes water sample to ensure the provision of quality water in compliance to SANS 241. The laboratory instruments are regularly calibrated, and the water sample results are accurately interpreted to ensure credible results are produced. Credibility refers to ensuring that the water quality results are believable from the perspective of the consumers and in compliance to the relevant regulations (Roulston & Shelton, 2015).

The WTW ensured the credibility of the water quality results by representing an accurate interpretation of water produced to which people can relate (Houghton *et al.*, 2013; Noble & Smith, 2015). The WTW established dependability by providing an audited trail of methods and procedures for water quality compliance. In this study, dependability was established by an audit trail to track water quality process.

3.6 Research integrity

In considering what is good for self and others, and can be expressed in terms of golden rule, to treat others as one would like to be treated. In the context of the organisations, ethics refer to the ethical values applied to decision-making, conduct, and the relationship between the organisation, its stakeholders, and the broader society (McKinsey & Global Institute, 2017).

3.6.1 Ethical considerations on telemetry system: Objective 1

Monitoring water service delivery is an important role for the water utility. In doing so, creativity and innovative ideas are required to ensure that basic water services are delivered to the intended beneficiaries. Therefore, a need for authorities to meet, share challenges and come up with new approaches to track, evaluate and review service delivery performance is required. Generally, the implementation of technology in the water services delivery value chain will help in addressing customer complaints timeously and effective communication.

This has prompted a great deal of research and effort put into solving the problem of scheduling production, pumps, and valves with technology such as telemetry system in the water distribution systems (Bunn, 2005). According to McKinsey and Global Institute (2017) there is a growing concern about whether there will be enough jobs for workers given remote monitoring and management of WTW process using technologies such as telemetry system. However, with sufficient economic growth, innovation, and investment, there could be enough newer jobs to offset the impact of automation.

The main challenge would be to ensure that workers have the skills and support needed for transition to new jobs. Therefore, countries that fail to manage this transition could experience high unemployment and depressed wages (McKinsey & Global Institute, 2017). The practice of engineering exists in an environment of many competing interests, cost and schedule pressures, changes in operational threats, requirements, technology, laws and policies, and changes in the emphasis on tailoring policies in a common-sense way (DoD, 2001). Therefore, in such environment application of effective communication technique, transparency and declaration of interest should be emphasized to a large extent.

3.6.2 Ethical considerations on water demand and supply: Objective 2

The Constitution of South Africa affords everyone the right to access sufficient water and the Water Services Act 108 of 1997 (WSA) also sets the legislative framework to give effect to this right by regulating institutions that manages the access and delivery of water services.

Importantly, it further emphasized by the DWS that water is life and sanitation is dignity. Therefore, water use efficiency and water conservation and demand management interventions need to be put in practice to ensure reliable and sustainable water service delivery for preservation of human life and dignity. Failure to implement various water conservation and water demand management interventions would result in high water shortage challenges.

The use of technologies such as telemetry system approaches would assist in the provision of effective and efficient water and sanitation services. Efficient and productive water services delivery are important inputs for all industries and vital for economic growth and efficiency, productivity and competitiveness (DBSA, 2009; DWAF, 2004, 2008).

It is therefore the responsibility of intitutions vested with authority and capacity to ensure provision of sustainable water of acceptable quality to the communities. Most of the water utilities rely on demand-driven approaches. However, the aim of service delivery transformation initiative in South Africa is to improve service delivery and emphasise the criticality of customer focused strategy in service delivery and monitoring (Russell & Bvuma, 2001).

3.6.3 Ethical considerations on water quality: Objective 3

Water quality is a very important issue related to human health, but Tabesh et al. (2015) state that it is not usually considered in the water distribution network (WDN) design. However, there is variety of stakeholders involved in water quality monitoring programmes and the alternative methods and processes used, challenges the current understanding of information system designs as well as the notion of developing a single national information system.

Oliveira et al. (2017) suggested the constant need of water utilities to improve water treatment techniques and research, the emergence of new technologies for obtaining and distributing adequate water, both in terms of quality and quantity. However, drought and pollution of water sources make water purification process one of the main cost drivers for many water utilities to maintain and improve service standards including continuity (hours per day of service), system reliability, and water safety requirements (water standard in terms of SANS 241). According to Water Service Act 108 of 1997 (WSA), access to water of good quality is a constitutional right for all.

The purpose of water quality determination is to provide authorities and affected stakeholders with the needed valuable information to make informed decisions (Azzuni, 2014). Rivett et al. (2013) noted the management and monitoring of drinking water quality in South Africa is governed by policies and regulations based on the international standards to be fit for human consumption. In service delivery reviews, the terms of reference for quality service often tend to reflect the service delivery and customer satisfaction.

According to Ostfeld (2004) measures to secure water distribution network is to provide high level monitoring water infrastructure, in addition to water quality monitoring systems and believed that to improve the security of drinking water requires an extensive action to ensure provision of high-water quality to the deserving communities. Therefore, effective realization of water security prospects obliges organizations like LNW to have, amongst other instruments, clearly defined plans of what is required now and, in the future, so that this can be considered consistently throughout the water supply process.

3.6.4 Technical considerations on telemetry system: Objective 1

Many new technologies are continuously being developed. It is therefore important to research and consider new technologies coming into the market and consult with a specialist in this regard. It should, however, be noted that there are risks associated with new and emerging technologies. Before implementing any new or emerging technology, the organisation should go through a process to evaluate the applicability, compatibility, practicality, and sustainability of such a technology (DWAF, 2007).

In addition, system technical designs should provide for basic operation and maintenance to be carried out at local level with consideration for the levels of technical expertise. However, it cannot be over emphasised that standardisation of the system operation orientation is critical, for example, different transmitters at a given site, with different controls could be an invitation for errors or difficult for parts acquisition and replacement. All buttons and controls should therefore be of the same configuration throughout the site (Workplace Safety North, 2012). Telemetry system projects should include training of the end-users and capacitate them through skill transfers.

Moreover, selection of telemetry system should be based on reliable and available when required. Its performance results must be able to satisfy the end-user even under difficult conditions. Water services authorities should find a creative and innovative model that can assist in responding to water services infrastructure delivery in a positive manner. The model should be maintainable, serviceable, calibrated for accurate measurement data, safe to operate, replaceable or upgradeable and able to be integrated with other available systems used for measuring data in the water utilities. It is important to ensure that the monitoring and measurement equipment in an operational site are verified at a regular interval to provide confidence that data that being collected is correct (ECC, 2009).

The transfer of new technologies, especially from foreign counties, can be treated with suspicion if the local communities have had previous negative experiences, lack of knowledge and skills, and inappropriate technologies that were misguided and resulted in job losses or created unintended social consequences (OECD, 2010). It is important to ensure that great care is taken in both the choice and international transfer of technology to avoid potential hazards and ensure the technology system is adapted to local conditions (Alli, 2008).

The end-users should be provided access to information to get a better understanding of the services and goods or technology options available, including the respective cost-efficiency system. In addition, measurement, monitoring, and management technology should be instrumental to provide much needed water related information, which is also an important element good for both policy and technical decision-making (OECD, 2010). Therefore, thorough research needs to be undertaken to assist in decision-making. One of the decisions to make by senior management is training and development of the workforce on new changes on process of provisioning of water and sanitation services.

3.6.5 Technical considerations on water demand and supply: Objective 2

Water service provision is a complex business activity requiring thorough planning which includes all aspects of the service delivery to the communities. Therefore, operational control challenges in the water distribution network should be concerned with meeting hydraulic performance, storage volume control, improvement of water quality, economic efficiency, and other important operational objectives at a minimum cost (Cembrano et al., 2000). In considerations, water conservation and water demand and management should be exercised together with water infrastructure planning and maintenance. Planning for infrastructure should be an ongoing activity in the provision of water services and related activities such as operation, administration, maintenance, revenue collection, governance, and support from other departments within the organisation.

Generally, the provision of water services should be considered as a technical activity and appropriate application of technical standards should play a crucial role in ensuring efficient, sustainable, and reliable services. Sustainability of available water infrastructure should be defined by continuity of water supply, functionality of equipment and reliability of the infrastructure (Harvey & Reed, 2004; Prokopy, 2005) cited by Selala, Senzanje and Dhavu (2019). This is the reason why South Africa has adopted various practices and technologies to improve the reliability of water supply services (Kahinda et al., 2007).

Availability of the infrastructure's ability to provide the required amount of water per capita per day and that water must be of good quality. In this regard, operation, maintenance, and rehabilitation should be ways to minimize or avoid lack of continuity of water demand and supply services. The infrastructure planning and maintenance effort should result in a management document covering the implementation of program requirements for system upgrade of replacement, it should also include technical approaches for subsequent phases of the life cycle. As a result, assurance of supplying sustainable water services of good quality will be improved (DoD, 2001).

3.6.6 Technical considerations on water quality: Objective 3

It is essential that the quality of water supplied to the communities is consistently monitored to enable any deviation to be timeously identified. Water quality is for ever changing, it is therefore essential that monitoring processes are established at all appropriate locations to provide early warning of failures outside the set water quality standard. Monitoring should therefore be part of structure which critical for the sustainable maintenance of water quality.

Water quality monitoring should be as simple a process of gathering information, however, it can be of little value if the information is not evaluated and if there is also no process in place for acting on the outcome of the analysed water samples. Rivett et al. (2013) stressed the importance of management and monitoring of drinking water using technology to ensure the processing of real-time information to the central location for the process controller to act accordingly. Therefore, the RTU designed for water quality compliance monitoring should have the capacity to perform water sampling with the correct separation between data records and could store data records locally until they are transferred to the Master station.

According to Oliveira et al. (2017) there should a constant need of water utilities to improve water treatment techniques and research, the emergence of new technologies for obtaining and distributing adequate water, both in terms of quality and quantity. The adopted technology should have system-wide health and performance as well as operational visibility on elements and equipment that makes up the complete telemetry system to ensure system efficiency and reliability in terms of information gathering and dissemination (Abbey, 2015).

The telemetry system should have the ability to retrieve, store and protect the integrity of the water quality measurement data. Therefore, applicable tools and formatting should enable the manipulation and presentation of raw data to make sense of it. Specifications and system description should be sufficiently detailed, and the implementation of instrumentation devices should be outsourced in many cases to ensure validity of instrument warrantee (Abbey, 2015).

3.6.7 Legal consideration on telemetry system: Objective 1

The emergence and potential impact of telemetry technologies for provisioning of equitable and sustainable water services should be considered in relation to the National water Act (NWA), N0. 36 of 1998) (DPW, 2012). There are also legislations that may apply to the planning, design, construction, and operation of WTW using technology for effective and efficient management and control of service delivery. For this reason, the designer and operator of WTW should determine the applicable regulations, statutes, guidelines, and procedures for the proposed suitable telemetry system tools to be employed and ensure familiarity with water treatment and distribution process and other legal requirements (DPW, 2012).

The application of legal requirements implies adherence to a range of issues including some which are directly regulatory policy such as legal transparency, accessibility, and clarity for both technical and management, and maintenance and operations decisions. Failure to which, legal issues will be undermined and that will result in compromising water service delivery responsibilities (DWS, 2003). In an environment dominated by ongoing convergence of water services infrastructure and water service delivery, regulatory interventions should as far as possible be technologically neutral to stimulate innovation and facilitate the development of innovative new product and service offerings (DoTPS, 2014).

According to Menon and Fink (2019), it is important for the water authorities to adopt a different set of guiding principles. The principles that should be adopted by authorities are:

- The flexibility to respond to changing circumstances without losing sight of the overarching goal and values the legislation has designed to support WSAs and the ability to correct their course in real-time.
- Recognition of the process of making rules and setting standards appropriate to WSAs and service providers to keep up with technological shifts.
- The need to develop ideas quickly and implement them in experimental settings without affecting water service delivery.
- Considering views and of all stakeholders involved in the water sector. Stakeholders include technology firms, environmental experts, insurers, and consumer group, health and safety experts and ethics advisors.
- Prepare and guard against the vulnerability to increasing cyber-attack. The potential for damage and service disruption from cyber-attack is rising significantly.
- Support from the government in setting cross-border standards and streamlining regulations.

It should be noted that specified technology targets typically take the form of recommendations concerning technologies applicable in certain circumstances. Therefore, selection of technologies should be based on qualitative assessments of source water type and quality. The requirement for their high availability and proper functioning requires the protection of this critical infrastructure from both intentional and unintentional incidents that can impact their operation negatively (CPNI, 2010).

3.6.8 Legal consideration on water supply and demand: Objective 2

Meeting the needs of the community for domestic water and productive use on the demand at the border of their yards where it is practical, affordable, financially viable and sustainable in an integrated manner while making the most efficient use of water resources (DWS, 2017). Water is an essential commodity for human life, and indeed all life on earth depends upon it. In addition, this essential commodity is also a critical input to production in several economic sectors. For this reason, every sector of the economy is influenced in some way by water (EPA, 2013). According to the South African Constitution (Section 11 (1) of the WSA), municipalities are obliged to progressively ensure efficient, affordable, economical, and sustainable access to water supply and sanitation services. Therefore, municipalities are obliged to develop a water services development plan for its area of jurisdiction. The plan should detail the strategy for providing access to water services at local level.

According to DWS (2017), the provision of water should be made in compliance with one of the following guidelines:

- A water service authority shall ensure that adequate bulk water is available to enable water services.
- Water shall be made available for 635 days per year and not interrupted for longer than 24 consecutive hours.
- The water provided shall comply with the SANS 241 quality standards.
- The Minister responsible for water reserves the right to impose water restrictions when necessary but not less than 25 litres per person per day.
- All water uses and/or supply shall be metered and tariffed.
- The water shall be made available at a high pressure of not exceeding 9 bar/ 9 kPa.
- All fire installations pipework shall be constructed in accordance with the relevant requirements of SANS 2001-DP2 and shall have a pressure rating of not less than 1200 kPa.
- The supply of bulk water shall follow the Guidelines for the Design of Water Supply Systems and the relevant standards as set out by the SABS for pipes, valves, and connections.
- Water loss and leaks detection shall be implemented to reduce water demand.
- Maintenance of water infrastructure within the boundary of the yard shall be the responsibility of the owner.
- All water use shall be metered and tariffed.
- Asset management shall be implemented.
- Users shall be educated in effective water use and hygiene.

In addition, all aspects related to water provision should support the objectives of sustainable and equity which underpin the National water Act (NWA), N0. 36 of 1998 as central guiding principles in the protection, use, development, conservation, management, and control of water resources. Measures to conserve the environment should also be employed to support economic growth and social welfare without affecting, overstraining, or irreversibly damaging the natural environment and natural resources in the process of providing bulk water and sanitation services (DPW, 2012). management, and control of water resources. Measures to conserve the environment should also be employed to support economic growth and social welfare without affecting, overstraining, or irreversibly damaging the natural environment and natural resources in the process of providing bulk water and sanitation services (DPW, 2012).

3.6.9 Legal consideration on water quality: Objective 3

Water is essential to sustain life, and a satisfactory supply must be made available to all. This resulted to the DWS's legislative mandate to seek to ensure that water resources are protected, managed, used, developed, conserved, and controlled through regulating and supporting the delivery of effective, efficient, and sustainable water supply and sanitation services. The mandate is executed in accordance with the requirements of water related policies and legislation in the country which are critical to delivering on the right to access to sufficient water and food, transforming the economy and eradicating poverty (DWS, 2003).

The World Health Organisation guideline for drinking water quality recommended that water service providers should develop and implement Water Safety Plans (WSPs) to proactively maintain safe public water provision and reduce health impacts from water contaminants. For this reason, WSPs are required by many countries as compliance to national legislation (WHO, 2004). The WSPs should be developed to organize and systematize a long history of management practices applied to drinking water and to ensure the applicability of these practices to the management of drinking water quality (WHO, 2017). Therefore, effective plans and programmes to control drinking water quality should specify the quality of water to be supplied to the consumers, the practice to be followed, treatment processes and distribution systems (WHO, 1997).

The WSAs should continually ensure potable running water because access to safe drinking water that complies with South African National Standard (SANS) 241 specifications is a basic human right and essential to people's health. According to the Water Service Act (N0. 108 of 1997), the WSAs have a legal responsibility to monitor the quality of drinking water supplied to the public, compare water quality results to the national drinking water standards and communicate any health risk to the public and appropriate authorities (DWS, 2006). Therefore, every effort should be made to achieve a drinking water quality that complies with the national safety standards regarding microbiological, chemical, and physical quality.

3.7 Study limitation

The research was based within the WTW process context, which might have not fully reflected the general view of the organisation. Technically, the study only covered water treatment process, pump stations, water distribution network and reservoirs for the Phalaborwa WTW out of all LNW's operated and owned schemes. The number of participants was just a fraction of the entire population. Due to the limitations in the participation of the individuals having the expertise, some sections that were supposed to appear in the study were omitted, hence the participants could not fully represent the views of all the departments in the organisation.

The evaluation of statements expressed by maintenance crew and operators, was to a certain extent affected by the knowledge and experience and was somewhat subjective. Therefore, process of interpretation of results was also subjective despite best efforts made to be open as much as possible. It would be preferred for the data of the study to be obtained from all LNW operated and owned schemes. In addition, the other limitation of the study was the lack of review data of the existing technology system meant towards improving water service delivery. Therefore, it was suggested that the data be an analysis on which further studies can be built upon.

Limitation in the research approach was based on the type and availability of documents to be reviewed. These documents were provided while the research study was at various stages of completion. Therefore, limited the ability of the researcher to compare some of the information especially in relation to the presentation of results and shared activities. It was difficult for the researcher to conduct the interviews as scheduled with a reasonable number of participants due to matters pertaining to operational reasons and end of business financial year activities. It was also not easy to assess issues related to telemetry system and that contributed to the researcher's experience in the operations and maintenance department influences on the study in relation to data collection and within the process of reviewing documents. Therefore, information leading to critical reflection on the assumptions, ideas, and ethical principles in the performance of activities related to this research were limited.

3.8 Chapter summary

This chapter outlined the research methodology and research design that the research used to expand on the phenomena. It articulated the data collection technique and data analysis used, namely qualitative approach. For the qualitative data, primary data were collected through in-depth interviews and secondary data were sourced from variety of documents of the organisation (LNW) and literature review. Permission was requested and authorization was granted for all sources that were considered in the secondary data. This chapter also outlined the study area, reliability, and validity of objectives central to the telemetry performance, water demand and supply and water quality judgements. Ethical, legal, and technical considerations were also explained for each study objective, including the research study limitations.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from analysis and interpretation of the research data which was collected through qualitative approach guided by the research design and methodology explained in chapter 3. The purpose of the study was to evaluate the telemetry system on WTW process. The data in this study was collected by using semi-structured interviews. The aim of this study was to evaluate of the telemetry system on the water treatment process in Phalaborwa. The study seeks to evaluate the capacity of the telemetry system in terms of its performance for service delivery.

The result of the study presented aimed to evaluate the practices, knowledge and experiences, and perceptions regarding the use the existing telemetry system on WTW process focusing on efficiency, effectiveness, impact, reliability, and sustainability. In this chapter, the statistics of the demographics are presented followed by analysis and the discussion of the main findings. The second section presents data collected from the interview questions and secondary data from the Operations and Maintenance Department in relation to the three objectives the study. The three-specific objective of the study were:

Objective 1: To establish the performance of the existing telemetry system in Phalaborwa WTW.
Objective 2: To determine the water demand and supply using the telemetry system.
Objective 3: To assess the use of telemetry system in managing water quality produced by WTW.
The study consisted of 5 chapters and most participants were the employees of Lepelle Northern Water. The source of data was collected from the interviews and documents.

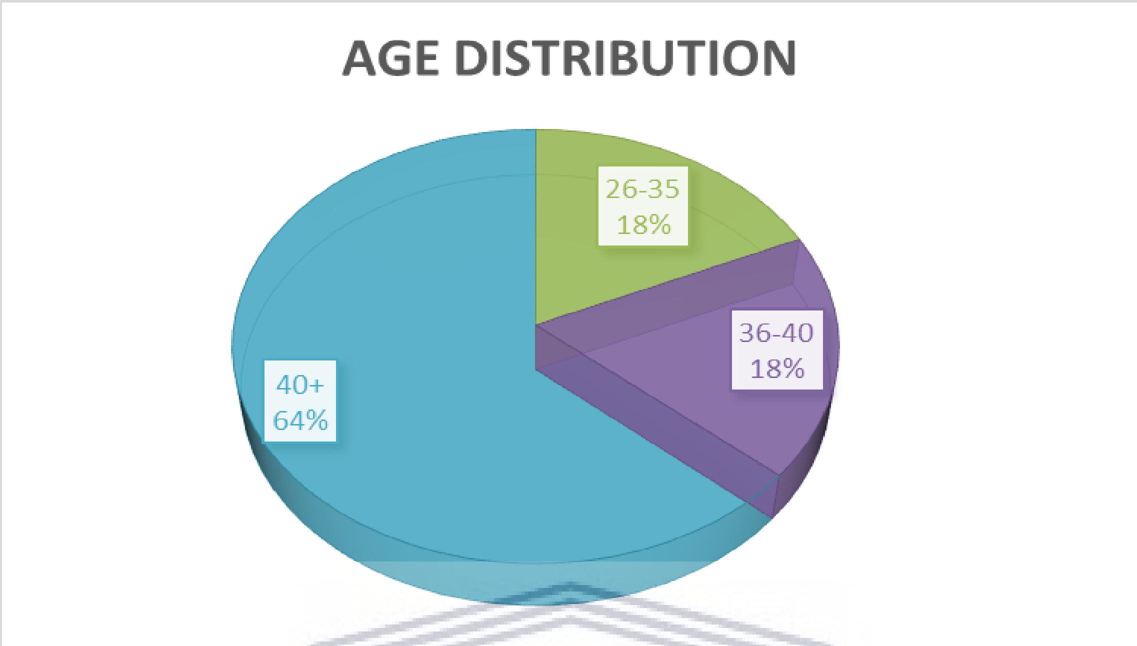
4.2 Descriptive analysis

This section focuses on presenting the biographical information of the respondents followed by the interpretations. The biographical information covers gender, age group, qualification, years of service, and occupation. However, this was not part of the purpose of the study but was used to assess for any influence on the evaluation of the telemetry system employed on the water treatment works.

4.2.1 Age distribution of the participants

Frequency distribution in terms age of the respondents is presented in figure 4.1.

Figure 4.1: Age distribution



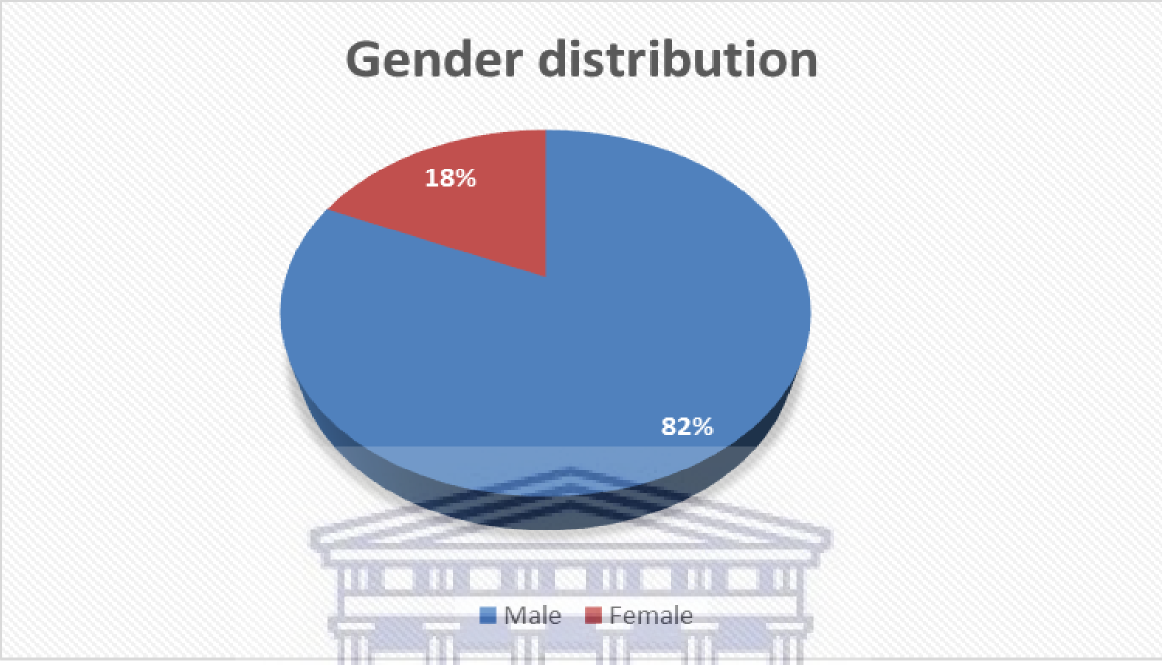
Source: Researcher, 2019.

Referring to figure 4.1, we can see that only 18% (n=2) of the respondents is falling within the 26 – 35 years of age range, another 18% (n=2) of the respondents falling within the 36 – 40 years of age range, while 64% (n=7) of respondents is falling within 40 years and above of age range. The age distribution range and the number of respondents per group, suggests that most of the respondents are in their middle age and above. Based on the age ranges, the researcher feels that the right targets were obtained to provide valid responses to make solid and logic conclusion from the study research interviews. Generally, plans for including young generation in the engineering field should be considered, especially for the sustainability of water and sanitation services.

4.2.2 Gender distribution of the participants

Frequency distribution in terms of gender of the respondents is illustrated in Figure 4.2.

Figure 4.2: Gender distribution



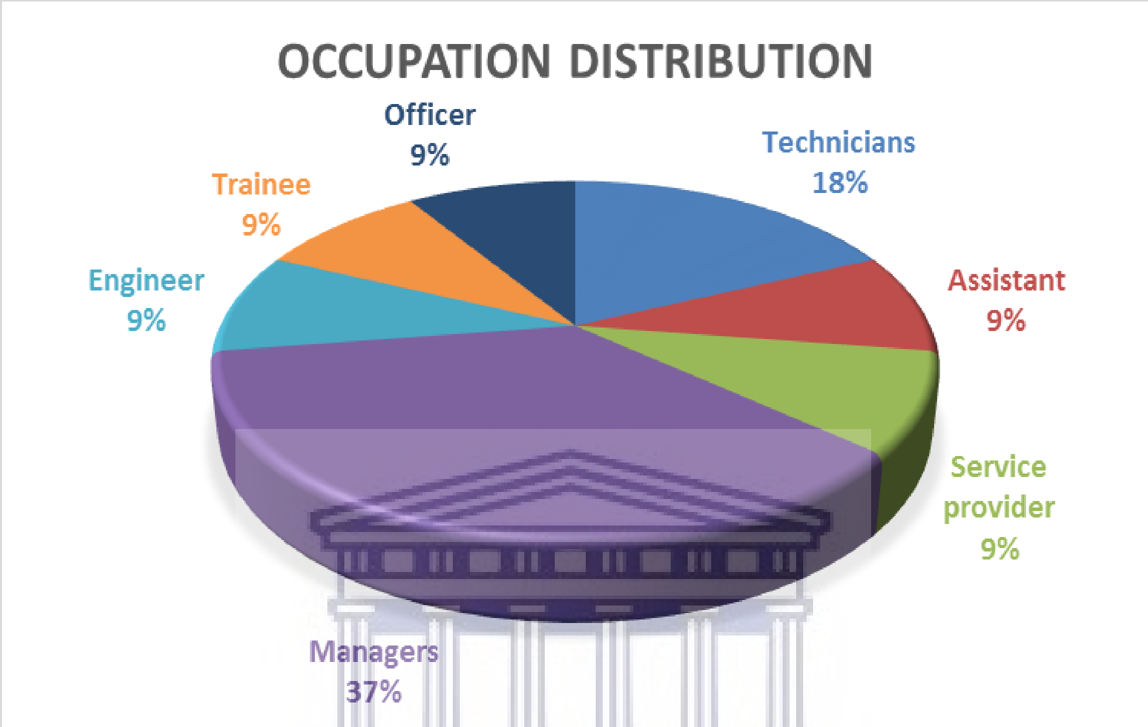
Source: Researcher, 2019.

Gender is an important factor in a social setting as it affects many socio-economic issues such as participation in various activities including decision-making. Gender based issues mostly affect women negatively, especially when coming to access to water and sanitation services. However, it was with a great disappointment that their contribution in this study was only 18% (n=2). As seen in figure 4.2, most of the respondents were males who accounted for 82% (n=9) of the population interviewed. According to the researcher, the results of the study indicates that most of the telemetry system experts are predominantly males in the water and sanitation services in the area understudy.

4.2.3 Occupation distribution of participants

Frequency distribution in terms of occupation of the respondents is presented in figure 4.3.

Figure 4.3: Occupation distribution



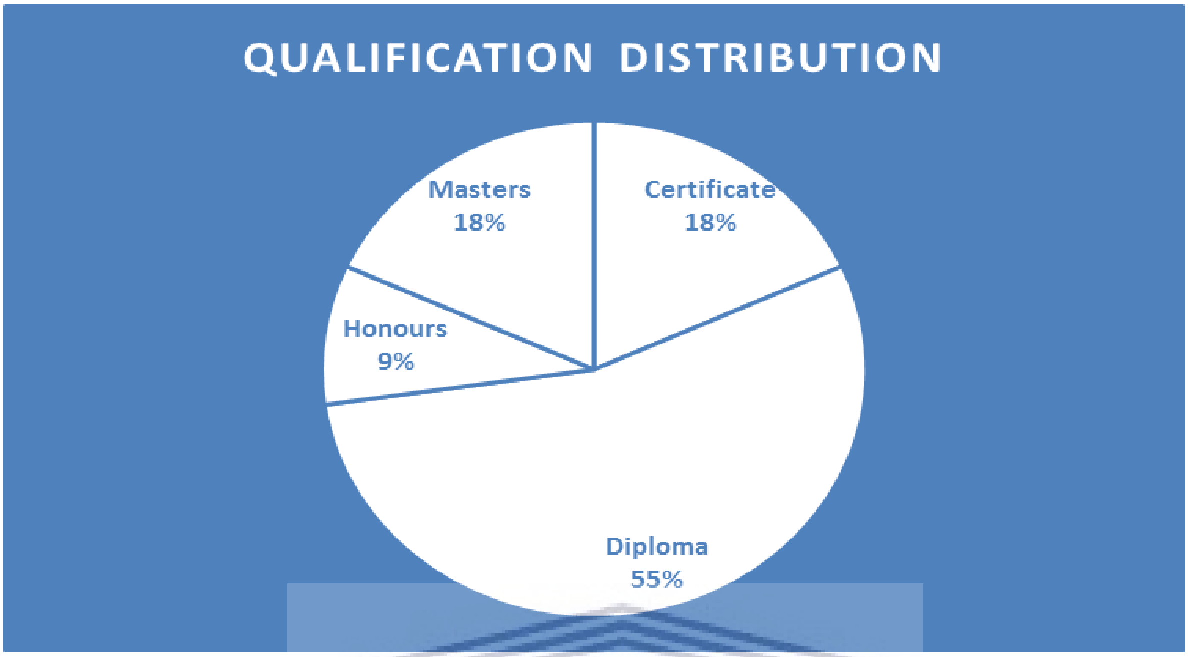
Source: Researcher, 2019.

The occupation level distribution of the participants as indicated in figure 4.3 reveals that the contribution of the technicians amounts to only 18% (n=2), 9% (n=1) for the assistants, 9% (n=1) of the service providers, 37% (n=4) of the managers, and 9% (n=1) for the trainee, 9% (n=1) for the officer and the engineer also contributed 9% (n=1). The occupational distribution indicates that managers contributed more than other occupations and followed by technicians in this study. The occupation categories of the participants were important in ascertaining the quality of responses in relation to decision-making about the effectiveness, efficiency, and reliability of the telemetry system with regard to provisioning of sustainable water and sanitation services to the deserving community.

4.2.4 Qualifications distribution of the participants

Frequency distribution in terms of qualification of the respondents is presented in figure 4.4. In the research study, education is regarded as an important variable in answering the research interview questions and it also influence the quality of the data collected. The study has established that most of the respondents have obtained their tertiary qualifications.

Figure 4.4: Qualification distribution



Source: Researcher, 2019.

The results in figure 4.4, shows that 55% (n=6) of respondents obtained diploma qualifications, 18% (n=2) with certificates qualifications, 18% (n=2) with master's degree qualifications, and only 9% (n=1) of respondents with honours degree qualification. The result from the study indicates that most of the respondents are bordering within the diploma qualification level. Certificates and master's degrees qualifications are second followed by honours degree qualification on the chart. The interpretation suggest that the organisation needs to develop its employees to the degree qualifications level, especially technicians in the field of instrumentation technology. In addition, contribution towards continuous improvement of employees' performance through training and development has long term rewards for the organisation.

4.2.5 Number of years' experience of the participants

Frequency distribution in terms of years of experience is presented in figure 4.5. The experience of the respondents was required to test is they are skilled and experienced in engineering field.

Figure 4.5: Years of service experience

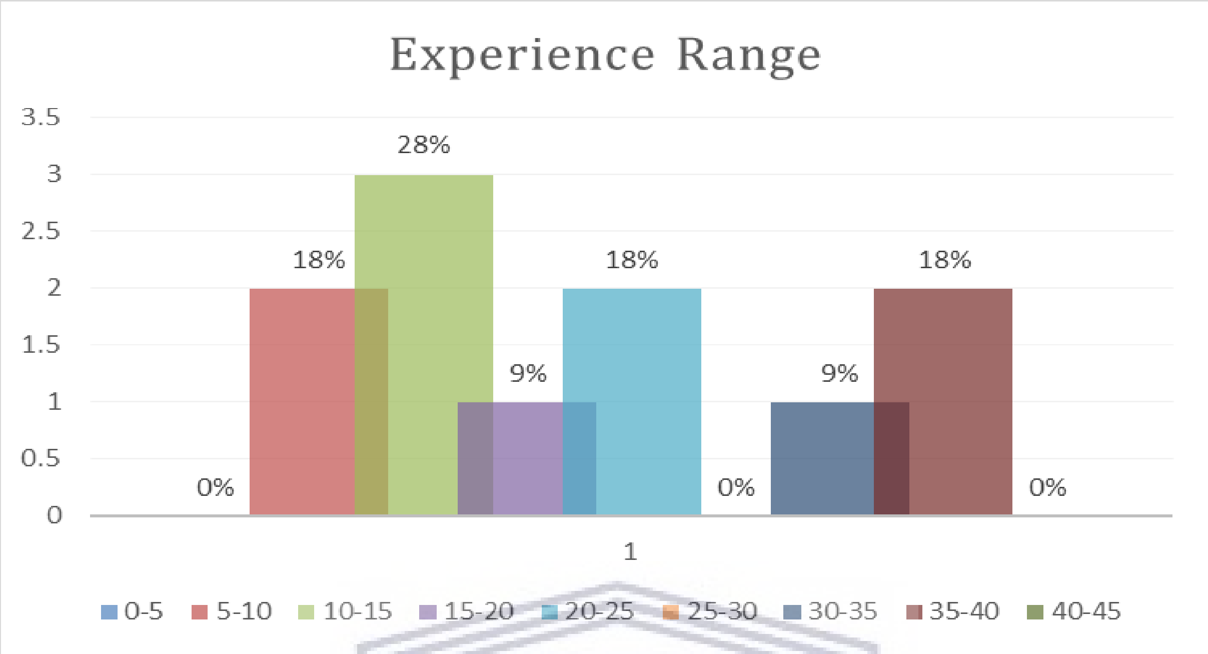
Source: Researcher, 2019.

The years of service experience distribution level of the respondents in figure 4.5 reveals that engineer trainee has only 6 years of experience, assistant with only 9 years of experience, manager with 37 years of experience, technician with 12 years of experience, the second manager with 17 years of experience, the third manager with 15 years of experience, fourth manager with only 11 years of experience, engineer with 21 years of experience, the second technician with 35 years of experience, the officer with 22 years of experience and the service provider who is mostly offering his instrumentation services to the WTW has 39 years of experience. The picture suggests that there is a need for young and experienced technicians in the field of instrumentation to ensure effective, efficient, reliable, and sustainable services.

4.2.6 Work experience range of the participants

The results in figure 4.6 reveals that greater number of respondents in this research study with experience ranging from 10 -15 years contributed 28% (n=3), from 5-10 years contributed 18% (n=2), from 15-20 years is 9% (n=1), from 20-25 years is 18% (n=2), from 30-35 year is 9% (n=1) and 18% (n=2) ranges between 35-40 years of experience.

Figure 4.6: Experience range



Source: Researcher, 2019.

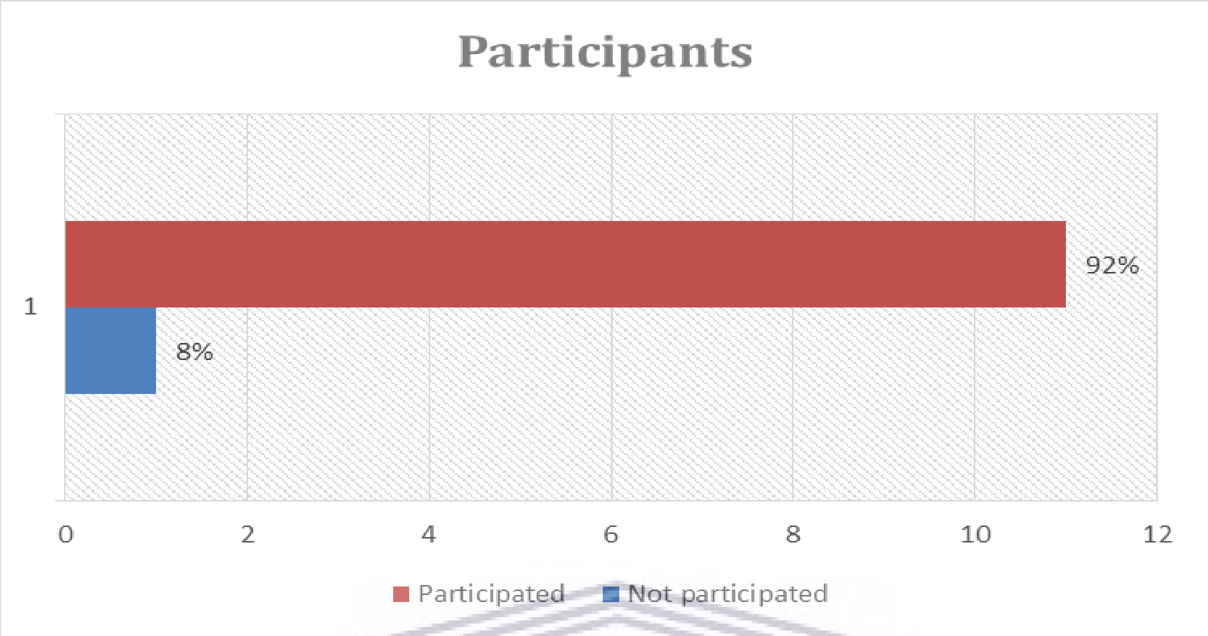
The results show that all respondents make up a joint percentage of 100% have more than 5 years of experience in engineering field. Employees in the operation and maintenance department contributed 91% while the service provider contributed only 9%.

4.3 Discussion and interpretation of results

4.3.1 Performance of the existing telemetry system: Objective 1

Interview questions were used for research data gathering, permitting further exploration of the research topic, expanding on the qualitative findings, clarifying vague statements, and yielding a more in-depth experiential account of the extent of telemetry system expects for responding to questions according to the research purpose. Ninety-two percent, 92% (n=11) of respondents availed themselves for the interview as planned while only eight percent, 8% (n=1) could not make it due to various operations reasons. Referring to figure 4.7, the researcher is confident that the study representation was adequate and satisfactory.

Figure 4.7: Participants



Source: Researcher, 2019

The researcher observed that some of the respondents seemed not being quite certain about responses given but showed some dissatisfaction regarding the performance of existing telemetry system. The interview revealed that most of the respondents brought the idea of replacing the existing system with the latest model that will be able to cover most requirements and functions of the WTW.

- **Existing telemetry system.**

The results indicated four respondents out of seven felt that the current telemetry system is not delivering to what was expected and suggested that some improvement on the system should be considered. This was followed by two respondents who believed that the system is giving what is meant for. While one respondent could not share his opinion. The views of most the respondents are shared below:

"Some of the WTW telemetry systems have been in use since 1985 and offer only basic operational needs though still very limited and requires a lot of human interaction as it fails a lot on communications which compromises water services delivery. Spares and replacement parts are no longer readily available due to the age of the hardware system and influences performance when compared to more recent systems. However, there is always a room for improvement in the world of technology since is always trending."

The interpretation of the responses from the participants is that the existing telemetry system infrastructure needs to be assessed on its performance in terms of relevancy and impact on service delivery.

- **Existing telemetry system software.**

Most respondents responded by describing the existing telemetry system as outdated and decentralised. One participant explained how the components of the existing telemetry system functions and another one felt the existing system is performing according to how was required for. Their general opinion is that the current system needs to be reviewed.

"The telemetry part is outdated but the software (SCADA) system is current and adequate in fulfilling its function because LNW has subscribed to a continuous software updating license package to staying in line with worldwide developments, provided that the hardware is compatible with the new developments. It is not flexible nor adaptable to integrate with other developing systems like androids. However, the software has limited operational capabilities as the reports generated are not user friendly because cannot filter the historical pump performance results as needed to give operations team the opportunity to analyse them and take beneficial decisions, it lacks intelligence of the current artificial intelligence."

In considering the responses from the participants, the option for upgrading the existing telemetry system might be a waste of the available resources because is an outdated system which will not be possible for it to be with the latest technology.

- **Challenges experienced with the existing telemetry system.**

Most of the respondents indicated that theft, vandalism, and electricity failure contribute a lot to unreliability of the current telemetry system. The remaining participants had various differing views and none of them was in favour of the performance the current system.

"The telemetry system does not have commercial support anymore from the manufacture (limited spares available). Consistency and reliability especially on metering, is vulnerable to interference and vandalism due to constant communicating failures, incorrect information or delay signal transmissions which complicates and frustrate efficient operations. On the other hand, advantages of the current system to spread over a large geographical area has been under-utilized due to rapid technological changes, lack of knowledgeable and skilful maintenance and operations personnel who are not conversant in the use of the system."

The indication from the responses is that there is a high risk of interrupting the existing telemetry system, therefore, legal considerations need to be intensified including safe keeping of the infrastructure and capacitating the current technicians to ensure equipment availability.

- **Optimizing the existing telemetry system.**

Most respondents suggested that the current telemetry system should be upgraded to perform better under different conditions without compromising service delivery. While others think it will be difficult to upgrade the current system and good maintenance strategies and equipment redundancy should be considered.

"Upgrade the system for effectiveness by linking the stand-alone system to a central server through a network to share information for operational, engineering, and general business users. It is also recommended that a centralized control room be put in place where all the data can be transmitted via wireless devices, captured, and converted into information to the benefit of the organization such as dam and reservoirs levels, night flows, running hours for maintenance purposes to name a few. However, for any system to be effective and efficient requires developed and dedicated workforce".

As indicated, the existing telemetry system is decentralised and the views of most of the respondents is to centralise it to ensure quick reaction to events and improved management and control for the benefit of all stakeholders concerned.

- **Improvement on the existing telemetry system.**

Three out of seven respondents suggested that the current telemetry system should be modified to improve its performance by encompassing all the phases from operations to maintenance. Two respondents suggested that the system should be upgraded by incorporating GPRS to the existing SCADA. This is supported by suggestions that the organisation should embrace the latest trending technology.

"It is proposed that software and hardware system be replaced with equipment and technology that can propel the organization into the new era such as the Internet of Things and the 4th Industrial Revolution through partnerships with more advanced systems and telecommunication networks for more reliability on communication. Complete review exercise is required and then retrofit upgrade where in security at the remote area is enhanced and solar power is considered using battery as backup for GPRS units to ensure real-time monitoring of flows and of instrumentation at remote sites where there is no AC power supply available and incorporate it in the existing SCADA."

Generally, the feeling is that the existing telemetry system is not reliable, and its capacity is also questionable, hence, the suggestion for replacement.

- **Impact the existing telemetry system have on operation.**

Most of the respondents indicated that the current telemetry system can save operational costs significantly. However, there are also indications that the system is not effective and reliable, and it is expensive because technology keeps on changing with time.

"The impact is very significant since it reduces manual operation and gathering information from remote area which reduces the cost of operation by avoiding call outs and overtime. Information such as water flows and levels of remotely situated reservoirs can be checked."

On the basic function, the system is still relevant and offers a little help in terms of operational cost saving.

- **Efficiency of the existing telemetry system on service delivery.**

The indication from the respondents is that the system is inefficient and requires to be upgraded. However, some think the system is performing according to its intended purpose of alerting the control centre of any event around the clock.

"It has a positive impact on reduction of unnecessary overtime for regulating supply however it also has a huge risk factor of incorrect information on metering and water levels which this might result in a devastating financial implication or loss. The system can be improved through data acquisition of equipment status and process condition, time tagging of events and alarms, and publication of real-time and historical trends. Failures will be controlled and minimised, equipment's expected lifespan will be realised, and water loss will reduce, and more water will be supplied to communities."

- **Functions offered by the existing telemetry system.**

The respondents indicated the system can also be used to detect equipment failures, for automated meter reading (AMR), leak detection and pressure monitoring and for turning fault alarms into work orders for the maintenance crew for taking corrective action. However, the other respondent argued that the current telemetry system is limited in its functions because is not an intelligent system.

"*The existing system can be used to record and trend graphs, and pump sets running hours that can be used by the Planned Maintenance Division to develop service intervals for key* *production equipment. It can be also used to report pump performance, for leak detection and pressure monitoring, automated meter reading, create automatic job request on suspected failures and give warning alarm on detected failures".*

The existing is unable to perform critical functions such as leak detection, automated meter reading, monitoring, and generating production related equipment performance history record.

- **Impact of the existing telemetry system on water service delivery**

There is a balance of arguments here because half of the respondents indicated that the telemetry system is responding positively to service delivery issues while others held their believe that the system has a negative impact on service delivery because it only performs up to its minimum functions.

"Telemetry has improved waters service delivery because operators can manage complicated and extensive water networks far more efficiently than before. Operators can be able to balance the various reservoir levels and thereby ensure that the available water is equally distributed. Without it, service delivery would be much more difficult, and you would need operators at all outstations to control and monitor plant conditions. However, overtime and maintenance can be management by turning all those fault alarms into work orders and giving reports on breakdowns and equipment condition. Strain relationship with municipalities when failed pumps are not available for a long period to supply enough quantity can be improved".

The opinion of many respondents is that the existing telemetry is offering some benefits to both the water service provider and the community. However, much is expected from the existing system in terms of its reliability and relevancy in water services and all this can be made possible through the introduction of the latest technology.

- **Opinion of participants on the existing telemetry system.**

Most of the respondents indicated that the telemetry system should be upgraded or replaced and partnership through other developed and advanced systems offered and enter a long-term contract with reputable service providers to ensure system reliability and reductions of operational costs.

"*There is a lot of gaps in terms of controls and monitoring, it can offer functions such as pipeline pressure monitoring equipment vibration and thermal monitoring status with all this, it is also very inconsistent as we suffer most breakdowns due to those and we lack the predictive which this should offer. However, to upgrade it is not possible therefore standardized replacements back-up redundancy for all the SCADA computers is required. Training should be provided to* *the relevant operations and maintenance personnel in the uses and advantages of telemetry systems to ensure that the instrument technicians keep the systems well maintained."*

There is a strong view from the respondents that the best option is to replace the existing telemetry rather than upgrading it. The reason for that is upgrading might not be cost effective or even improve the current situation of water service delivery. For this reason, replacement will give the end-user the option to select the latest preferred suitable and compatible technology. The challenge coming with new technology was highlighted, as a result, training and development of employees was proposed as a solution to ensure reliability and sustainability of the system.

4.3.2 Determine water demand and supply: Objective 2

The objective two of the study was to determine whether the capacity of the current telemetry system is effectively and efficiently addressing water demand and supply services challenges faced by the WTW or not. With the use of current technology, it was expected that water provisioning process will be improved and optimized, especially with the use of tools made available. This section is consisting of five research questions answered by the participants during the research interview sessions. During the interviews research participants gave their different individual views to give positive response to questions. The research questions and the responses from the participants are indicated below.

- **Requirements to ensure equitable water distribution.**

Most of the respondents indicated that the system needs to be upgraded and highlighted that the current system is not user-friendly and is only providing limited information. The respondents felt the installation of leak detector and pressure management tools could be the answer to the current water challenges. Lastly, the emphasis was put on the development of personnel to understand how to manage the water distribution network and distribute water equitably.

"*Telemetry system must be effective and user friendly and give required results to ensure that expected output is realised. System upgrade will broaden the application as well as the monitoring scope and personnel development in understanding the effective use of applications available on offer. Personnel must be able to understand and interpret the information received via the telemetry system and take the necessary steps to ensure that water is distributed equitably, especially when large consumers have peak consumptions."*

It was clearly noted that employees need to be trained and capacitated to perform effective maintenance and operation of any applicable system. Hence, the applicable system should be user-friendly and produce the required results.

- **Telemetry system assisting in reduction of water loss.**

Most respondents stated that the reduction of water loss can be managed through the improvement of system reliability, pressure management and flow monitoring, and installation of high- and low-level indicators in reservoirs. However, one respondent had a varying view and argued that communication between remote stations is not effective. Through their responses, it came out clearly that the current system is not quite assisting much in optimizing water distribution network.

"Effective communication between main pump stations, outstations and reservoir should be working and assist with availability of infrastructure. By installing flow meters in strategic places, mass balance can be done continuous and should tolerance levels for water losses be exceeded, should be reported to the maintenance department for action. Reduction of water losses can be performed through consistent monitoring of pipeline pressure and improved water metering through automation, and by comparing the plant outlet volumes with the consumer billing meter volumes for pipeline losses."

Water pressure management and installation of zonal meters in strategic location was mentioned as some of the solution for reducing water loss which could be because of ageing infrastructure, vandalism, or illegal water connections. However, effective, and consistent monitoring of these points with a compatible telemetry system will be required.

- **Requirements for water demand and supply management.**

In this question, most respondents have indicated that the existing system need to be upgraded and one responded by saying the new system is required. It clearly shows that the system should either be upgraded or be replace of which the results would pretty much be the same. Leak detection and water distribution network monitoring was also put forward. One of the respondents suggested that the system need to be programmed accordingly and emphasized on personnel development in the field of instrumentation.

"Introduce and incorporate technologies to optimize distribution, pump pressure and PRV controls. By adding "rate of change" functionality to reservoir levels, operators can assess demand better and thus allow for timeous changes to plant processes, historical information in the form of trends and graphs consumption patterns can be evaluated, where high night

flows occur in communities it can point towards system leaks. Through better programming, feeding the right and correct information to the system, train our people and improve the monitoring capabilities of the current system"

Pump scheduling and system optimization, water demand management through pressure control valves and other applicable tools are required to be incorporated into the acquired telemetry system.

- **Addressing water demand and supply constraints.**

In respond to the question regarding water demand and supply most respondents pushed for the current system to be upgraded to be able to address the experienced water services challenges. Installing of intellectual system (e.g., data loggers, process variable & early warning system, pump energy saving) was one of the solutions suggested by the respondents.

"*The upgrading and maintenance can assist with water supply constraints. Better programmes to control and monitor flow pressure automatically so that it can cut off or reduce pressure as per incident. Installing intellectual instruments, data loggers, etc. all over the distribution network, to also acquired data to monitor and control the process variables and secure assets, early prevention of events and continuous service to our customers."*

Effective and efficient monitoring of water treatment and distribution network process through compatible applicable telemetry system software and hardware tools can offer great assistance for the WTW to provide sustainable water services to the community.

- **Water pressure management in the distribution network.**

During the interview, most participants responded by mentioning pressure management and leak detection as the answer to distribution network challenges, especially water loss due to ageing infrastructure. Automating the water distribution process in order save operational cost was also highlighted by the some of the respondents.

"Telemetry systems can measure the line pressures in various zones of a bulk or reticulation network. By reducing the pressure at night by means of pressure regulating valves that can be activated by the telemetry system. Pipeline pressure can also be managed by installing water pressure monitoring instruments for early detection of leaks and pipe burst and improve energy efficiency. This will lead to a decrease in losses and can also save on electricity costs when booster pumps are switched off. Technological range of Data Loggers, GSM Monitoring Systems, and SMART PRV Control Systems are one of the best products available in the

market. ZEDNET can also be incorporated with Google Maps, which allows positioning of the monitoring point to be plotted and makes it easy for identification from a "bird-eye" view."

Pressure management in the water distribution system is one of the common effective control measures applied by most of the water utilities and preference is given to various monitoring tools depending on their advantages and of the installed telemetry system.

4.4 Water quality assessment: Objective 3

The objective three of the study was to establish whether the capacity of the current telemetry system has been utilized for assessing water quality during water treatment process and in the distribution network. With the use of the current technology, it was also expected that water quality monitoring and control will be improved. This section is consisting of five research questions answered by the participants during the research interview sessions. During the interviews research participants gave their different individual views to respond to the best of their knowledge and experience. The research questions and the responses from the participants are explained below.

- **Water quality assessment.**

Answering questions, most respondents mentioned about upgrading the existing telemetry system, installing the online sensors so that water quality can be monitored and control on an on-going process. Generally, online water quality system monitoring system has not yet been effectively introduced to our WTW process and distribution network. Therefore, automation of water quality monitoring and control will give assurance of healthy drinking water to our stakeholders and adherence to water quality legal requirements.

"With the current telemetry we cannot monitor water quality, it will need upgrade for us to connect online instruments. Online water analyzers can be connected to telemetry systems that can notify operators well in advance should there be adverse changes in parameters such as turbidity, residual chlorine, and pH. Water quality measuring monitors that support major communications process such as Modbus, Profibus, EPANET, etc. are required and with telemetry system enabling remote communication to the central station".

Acquisition for the latest telemetry system with sufficient online capacity to accommodate and monitor various water quality compliance parameters will minimize the chances of human errors during water sample taking analysis and interpretation of results. Therefore, there is a need to first investigate for a suitable system for WTW.

- **Managing water quality in the water supply process.**

The management of water quality during the purification process and in the distribution, network is not yet provided for on the existing telemetry system and most respondents raised the need for upgrading the system capacity so that technology can be utilized to the benefit of all stakeholders involved. Some of the respondents brought the idea of installing early warning monitoring system that can be able to assist the operators.

"The current system cannot assist in the management of water quality and upgrading is required. Management of water quality can be made by incorporating online water quality analyzers into the existing telemetry system for data acquisition and control of the process. Water quality can be managed by reading data on the existing monitoring point of the current system and displaying in on a SCADA. The system can be set up in such a manner that bulk water delivery pumps are automatically stopped should certain parameters be outside acceptable norms."

For the WTW to benefit from the latest installed technology it will require competent and committed workforce to be able to swiftly react to water quality failure events to ensure system efficiency and reliability from the source to the tap.

- **Software for water quality monitoring and assessment.**

Respondents indicated that the installation of on-line monitoring system in the supply network can improve the monitoring of water quality through timeous response to any failure detected in the water supply system.

"Software is available that can be linked to the telemetry and GIS systems to evaluate reticulation systems to determine whether there are areas where the water may become stagnant for instance in dead ends. Telemetry software system will assist in timeous response to any detected failure of water quality standard. By providing constant timeous quality analysis information to the controller at pre-determined intervals to effectively effect urgent controls beforehand. The system can give alarm if water quality is poor, and measures be taken to rectify before it enters the reservoirs."

Effective and efficient online water quality monitoring and analysis system will require a compatible telemetry system to be incorporated with to ensure healthy and safe drinking water supply to communities.

- **Existing telemetry system for managing water quality.**

Most participants responded by indicating that the current system is outdated, and the software system does not have the capacity to the extent that flexibility cannot be possible. Therefore, upgrading or replacing the existing telemetry system was an option for creating an enable environment for some improvements.

"The existing system is not suitable to be used for water quality management because its hardware is outdated, and the current software package doesn't have the necessary features. It is weak due to the lack of flexibility on our telemetry current setup and stagnant technology base on its design or blueprint. Interfacing the water quality with the current system might need a serious upgrade or improvements on the system or get a completely new system that will come with the package. The system can be very helpful in managing water quality so that the product is monitored and protected from contamination or failures."

As indicated earlier, replacement of the existing telemetry with the latest and relevant technology in WTW water quality will be advantageous in terms of system warrantee and the availability of maintenance spares in the market.

- **Limitation on the existing telemetry system.**

The respondents shared the same view in that the current telemetry system has limitations and cannot be interlinked to other systems due to the lack of capacity and unavailability of spares because it has been phased out and there is also no support services or service level agreement entered with any of the service providers to ensure the system performance is according to what has been expected.

"Limitations of the current telemetry system is outdated software and technical personnel knowledge, and the understanding of system infrastructure which it operates on or controls. The system is only used for the very basic functions such as the stop start of pumps, levels and flows monitoring and control. It is not compatible with most recent developments such as geo-referencing or link to the planned maintenance system for issuing of job cards. Drawbacks are that most of telemetry service providers are in Cape Town and when support service is required on-site it becomes expensive"

Regarding the limitations on the existing telemetry system, it became clear that the system cannot offer much of assistance to the benefit of the end-user. The sooner the replacement with a compatible system is done the better for the WTW. The WTW will then be able to utilize the newly installed technology to the fullest with minimum drawbacks if any.

4.4 Interpretation of results

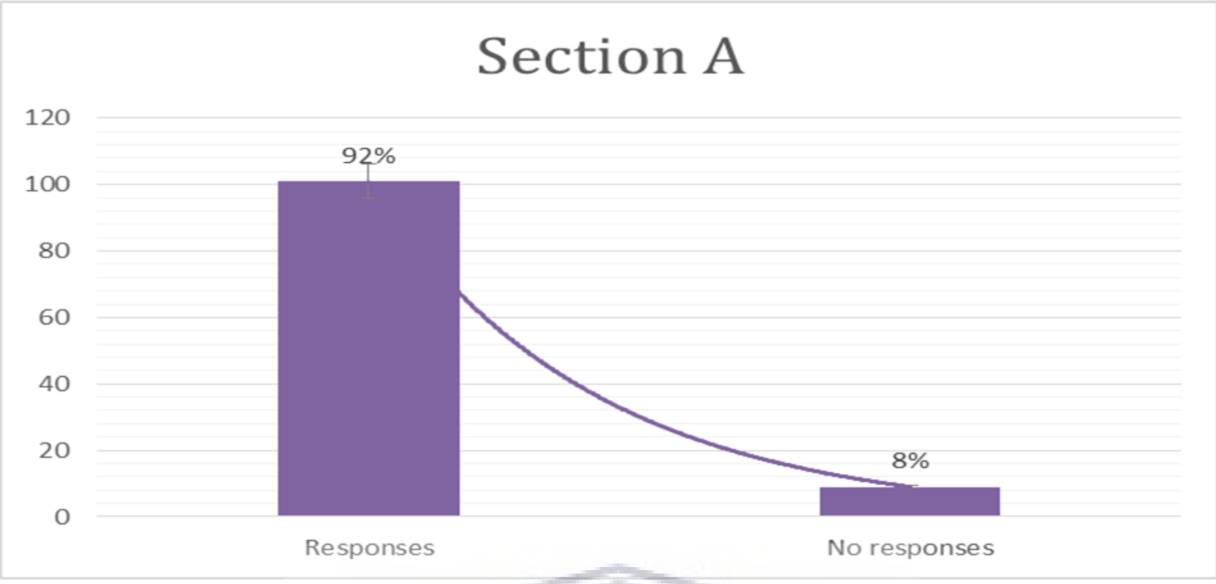
4.4.1 Existing telemetry system: Objective 1

In this section of the research objective, one evaluated the extent to which the existing telemetry system is capable of in management of the provision of water and sanitation services. Several conclusions can be drawn from the results presented in this chapter in which objectives are outlined. The sample from which the data was collected was small. However, the researcher believed the results still provide meaningful findings because most of the respondents agreed that the existing telemetry system need to be upgraded. The understanding is that the findings could be generalised to day-to-day practices carried out by the average WTW in the organisation.

The primary data revealed that the use of telemetry system within the organisation is mostly for a strategic purpose. Therefore, the researcher was of the view that the acquisition of the applicable and relevant technological tools that are specific to the WTW process would require further research. Consideration could also be given to upgrading or modifying fit for purpose some of the existing remote monitoring and control systems unless service delivery is not going to be compromised. Without monitoring and control, water treatment and distribution process of WTW process cannot be effectively and efficiently managed.

Responses given in this section by 11 participants who contributed to 92% of the 10 interview questions of which only 8% of them could not be answered are presented. This suggests the participants have knowledge and experience of the telemetry system. Their knowledge and experience assisted a lot in the interpretation of the research objective one. Figure 4.8 below represents contribution of the respondents to this study on telemetry system performance.

Figure 4.8: Telemetry system performance responses



Source: Researcher, 2019.

Interpretation of the findings has become a very important and essential process because of some of the following factors:

- Enabled the researcher to have an in-depth knowledge about telemetry system performance, especially after having discovered that the existing system is outdated and limited to only basis functions.
- Understanding and knowledge was obtained with the assistance of primary and secondary data. Data obtained from the literature, documentations, and participants.
- The researcher was able to understand the study findings and the reasons for their existence. The understanding was that the existing telemetry system should be reviewed accordingly.
- Provided a good guidance in the study related to the research project. This enabled the researcher in choosing the correct sampling method based on the knowledge and experience of the selected participants.
- The data revealed that the study participants recognized the important of the telemetry system in the provision of water and sanitation services. Hence, the suggestion that replacement with the latest system in the market should be considered.

Some the findings from the literature review and which readers should take note of can be summarised as follows:

- Sonage and Joshi (2015) highlighted the importance of addressing increasing demand by efficient water distribution network based on advance computing systems. The use of the tool can also optimise the operations and management of WTW.
- Mahapatra *et al.,* (2012) studied the efficient of water supply using EPANET and ArcGIS software and noted the importance of carrying out continuous leakages monitoring as well as intermitted water supply system. The application of the software would significantly reduce water loss and sustain the business.
- Sumithra *et al.,* (2013) noted that LOOP and WaterGEMS software are highly efficient to do various hydraulic and costing analysis. The software can be used for pressure management in the water distribution network.
- Ramana (2015) published the efficient design of water distribution network performed by EPANET software. Same as the statement by Mahapatra *et al.,* (2012)
- Puust (2015) stated tools for optimizing water reservoir levels and estimating the influence of network valves on leakages using WaterGEMS. The system can be used for reservoir levels and pressure management.
- Elsheikh et al. (2013) indicated the application of WaterCAD software for designing and optimizing the water distribution network. Same as the tools recommended by Puust (2015).
- Khadri (2014) mentioned the importance of GIS, GPS and RS technology for visualizing, network planning, mapping, and digitizing of the water distribution system. Same as the tools recommended by Sonage and Joshi (2015).

The performance of the telemetry system was identified by most of the respondents as an area of concern and requires some improvements. It has been highlighted that it has limited functions hence the need for upgrade or replacement with the intelligent telemetry system infrastructure. It has been further indicated that the existing telemetry system is only capable executing minimum functions which include viewing of water reservoir levels, reservoir inflows and outflows, alarms, and monitoring of pipeline pressure.

4.4.2 Determine water demand and supply: Objective 2

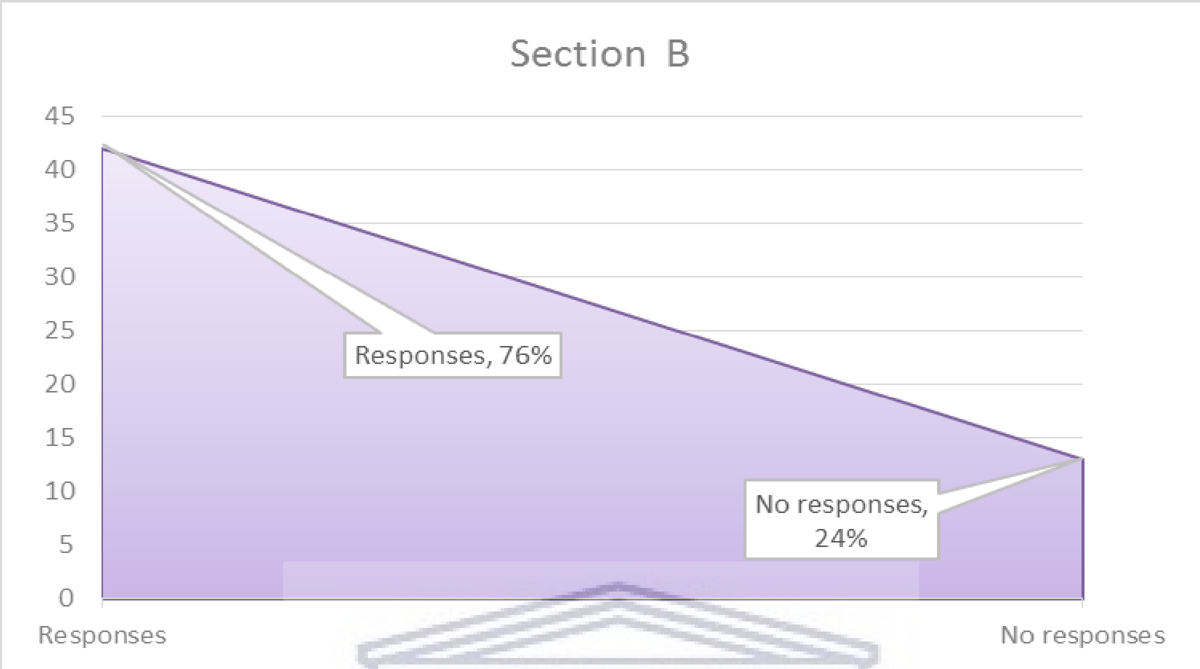
In this section most of the respondents indicated some of the challenges and possible solutions for better management of water demand and supply. The respondents further mentioned the telemetry system as one of the reasons for challenges in the provisioning of sustainable and reliable water services. It was suggested that possible solution is to look beyond the current system model and consider options such as intellectual infrastructure that can be perform functions such as leak detection and pressure monitoring, Sectorization, pump optimization, automated meter reading to achieve a better control over the network system.

According to Boulos and Aboujaoude (2011), one of the main challenges water utility managers faced with is how to minimize water losses to ensure sustainability of finite water resources, protect the environment, improve revenue, and provide high quality service level to the customers. The coordinated management activities directed to reduce water loss from the source to the distribution network include speed and quality repairs and rehabilitation of ageing water infrastructure, material management, water pressure management, active and passive leakage control methodologies.

According to the research respondents it requires a developed and competent workforce to read and interpret the data provided by new system and act accordingly. Pressure in the WDS can be managed easily with the use of pressure control valves (PCVs) and variable speed pumps (VSPs) in response to real-time pressure measurements at various remote nodes (Campisano, Creaso & Modica, 2010). Respondents also mentioned energy cost as one of the challenges faced by the WTW of which it is not possible to be saved with the current telemetry system and they suggested pressure management as one of solution for optimizing energy.

In this section, responses given by 11 participants who contributed to 76% of the 5 interview questions. This suggest that the participants have knowledge and experience of the telemetry system. However, in terms of software tools for managing water demand and supply was found a bit challenging, hence the 24% of questions that could not be answered in this section. Their knowledge and experience assisted a lot in the interpretation of the research objective one. Figure 4.9 depicts how interview responses on water demand and supply were distributed.

Figure 4.9: Water demand and supply responses



Source: Research, 2019.

Interpretation of the findings has become an essential process because of some of the following factors:

- Enabled the researcher to have an in-depth knowledge of managing water demand and supply with the aid of telemetry system.
- Understanding and knowledge was obtained with the assistance of primary and secondary data. The understanding of how different software system functions was important in terms of providing options for the users.
- The researcher was able to understand the study findings and the reasons for their existence. The understanding was that the existing telemetry system should be reviewed such that various tools for water distribution network can be integrated.
- The data revealed that the study participants recognized the importance of efficient, reliable, and sustainable water services. Hence, the suggestion that replacement of the existing telemetry system with the latest compatible system in market should be opted for.
- It was further discovered that training and development of the workforce plays a major role in the management of water demand and supply with the use of sophisticated technology system.

Some of the findings from the literature review and which readers should take note of can be summarised as follows:

- Merchant (2014) stressed the importance of managing water demand and supply using technology.
- Hoagland et al. (2015) mentioned many compatible softwares that can be used for hydraulic analysis of water distribution network and can be easily integrated with an optimization model.
- Buttler (2014) indicated the importance of sharing new approach for water management which allows identification of the role of mitigation and adaption of new strategies.
- Cheng et al. (2016) cited that most research must be conducted for optimizing the sensor placement for better monitoring results.
- Gomez et al. (2012) highlighted the importance of partitioning a water distribution network into a set of independent districts metered areas.
- Flath (2012) mentioned that for organizations to match water supply to water demand on real-time basis should implement dynamic water pricing schemes to influence customer consumption behaviour.
- Kalogridis et al. (2015) supported Laspidou (2014) by indicated that advances in water sensor communications and ICT integration of smart technologies are key drivers for managing water networks better.

According to Ormsbee et al. (2009), pump scheduling is aimed at establishing an optimal set of rules that will enable operators to make decisions on the best approach to minimize pumping cost for the WTW while delivering satisfactory level of service. Above all, staff development was also mentioned as one of the areas that requires urgent attention to be able to utilize and manage the acquired intelligent technology.

4.4.3 Water quality assessment: Objective 3

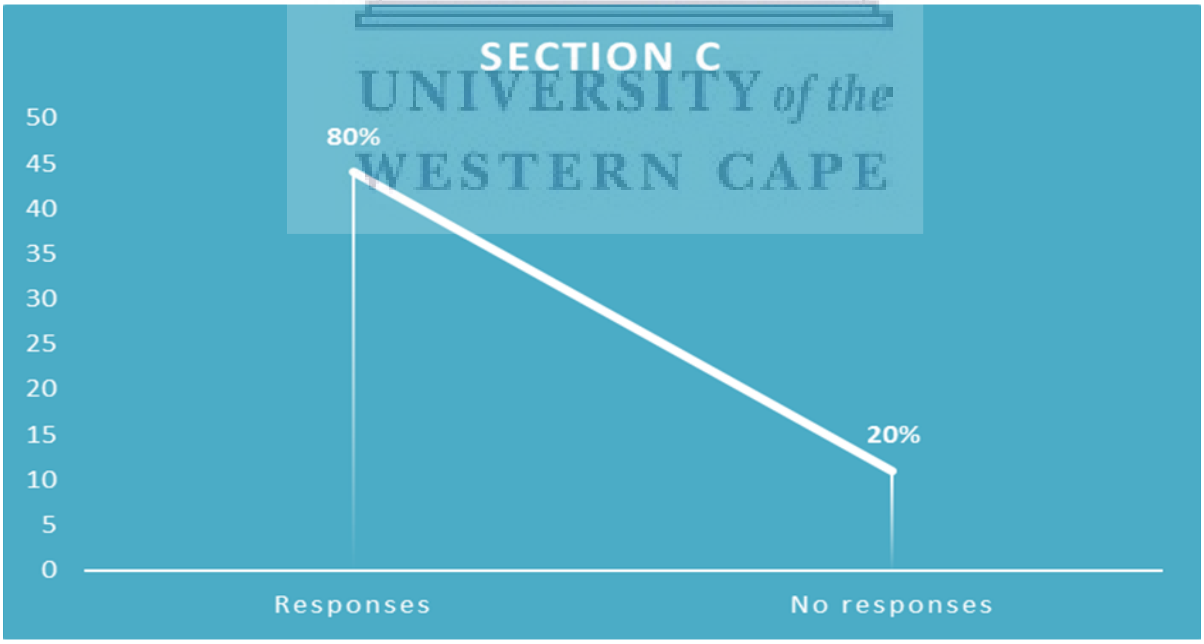
Water quality is a very important issue related to human health, however, Tabesh et al. (2015) state that it is not usually considered in the water distribution network (WDN) design. According to most of the respondents what Tabesh et al (2015) had indicated is almost what is experienced with the current telemetry system. They have pointed out that the system is outdated and there is no support care that can be provided for in case of emergency situations. It was further indicated that is also not compatible to accommodate the current technological developments.

Given the current practice, respondents pointed that these limitations make it difficult to interlink software systems that can provide flexibility and the necessary information to the central location for monitoring and controlling of water quality. They further stressed that assessment and analysis of water quality will require some upgrade or complete replacement of the current system with the one that can be compatible with the trending technology.

The literature provided some of the useful software tools used to monitor and measure water quality are models. According to Contans and Brémond (2003) water quality models are important tools to predict water quality transport and fate in WDN. Ginsberg and Hock (2004) pointed that water distribution networks are vulnerable to different sources of intentional or accidental attacks of contamination. His assertion is supported by Nardo et al. (2015) suggesting that the appropriate computer system security measures should be deployed for SCADA systems.

This section presents responses given by 11 participants who contributed to 80% of the 5 interview questions of which 20% could not be answered. This suggest that most participants have knowledge and experience of the telemetry system used. However, in terms of software tools for managing water demand and supply was found a bit challenging. Their knowledge and experience assisted a lot in the interpretation of the research objective one. Figure 4.10 below shows how interviewed participants contributed to water quality questions.

Figure 4.10: Water quality responses



Source: Researcher, 2019.

Interpretation of the findings has become a very important process because of some of the following factors:

- Information obtained from primary and secondary data provided the researcher with the understanding of different software systems advantages.
- The data enabled the researcher to have an in-depth knowledge of managing water quality from the source to the tap.
- The understanding from the data collected was that the existing telemetry system is not compatible and cannot be upgraded for the integration of water quality tools.
- The data revealed that the online analysers are required for managing water quality effectively and efficiently.
- The study confirmed that competent workforce plays a major role in ensuring proper management of water quality with the aid of the latest technology.

Some the findings from the literature review and which readers should take note of can be summarised as follows:

- Oliveira et al. (2017) noted the importance of constant need of water utilities to improve water treatment techniques with the use of new technologies.
- Rivett et al. (2013) indicated the management and monitoring of drinking water quality in South Africa as governed by policies and regulations based on the international standards.
- Contans and Brémond (2003) stressed the importance tools to predict water quality transport and fate in water distribution network.
- Kuzek and Rist (2004) outlined that service delivery targets in the service level agreement contract seek to measure performance which is judged against predetermined standards of acceptability.
- Thomson, et al. (2012b) mention that it requires a move from monitoring and evaluation leading to lessons learned paradigm to a surveillance-response paradigm.
- Fuller et al. (2016) found that countries follow non-linear path targets, including fits and starts, accelerations and decelerations when tracking progress towards global drinking water and sanitation targets.

Nardo et al. (2015) further mention that another measure to secure WDN is to provide high level of monitoring water infrastructure, in addition to water quality monitoring systems. The same sentiment was share by Ostfeld (2004) who believed that to improve the security of drinking water requires an extensive action. It is therefore important to investigate about a suitable water quality monitoring system that can monitor and measure all compliance parameters.

4.5 Comparative analysis of the results.

A comparative analysis of water service delivery for the WTW was carried out based on the existing telemetry system. This comparative analysis focuses on four objectives, namely, establishing the performance of existing telemetry system, determining the water demand and supply using telemetry system, and assessing the use of telemetry system in managing water quality produced by the WTW. These research objectives made assessment and evaluation possible to garner the study results. The content analysis revealed that there is some degree of alignment between primary and secondary data.

The analysed data further revealed that the WTW emphasized more the need to monitor and manage the efficiency, reliability, quality, and sustainability of water delivery services. As a result, responses from both employees and external service provider shared the same sentiments particularly regarding the performance of the existing telemetry system and water services delivery, as much as water quality, and demand and supply is concerned. This reflected the need for the WTW to be more responsive to the needs of the stakeholders in relation to water services of high quality. Most of the respondents highlighted the inefficiency the existing telemetry system in relation to water services monitoring and management.

Comparative analysis of the existing and proposed telemetry system is supported by the analysed primary and secondary data. Responses from the research participants are reflected in this chapter on figure 4.8 to 4.10. Comparison of the study results and the collected data is explained as follows:

- Results from the study revealed the importance of monitoring and management of both water quality, and water demand and supply using the latest technology.
- Replacement of the existing telemetry system with the latest intellectual system will provide the benefits of gathering and storing large operational data for now and future use, for example demand forecast, consumption trend, etc.
- The ultimate purpose of a suitable telemetry monitoring system of water provision is to provide authorities with the needed valuable real-time information to take informed decisions as quick as possible without compromising the quality of service expected by the customers.
- The existing conventional on-site sampling method with laboratory-based analysis of water quality parameters has several defects. As compared with the application of online water quality monitoring system, there are benefits such as the reduction of workforce to complete water quality monitoring and assessment functions.

- Data collection process of the water sampling method is slow, and the amount of information is very small. With the online water monitoring system, real-time data can urgently be provided to trigger the required operational responses.
- The conventional monitoring method poses a determined financial implication which may affect the whole process of ensuring efficient and reliable provision of water services hence the suggestion for installing the latest technology.
- The existing telemetry system is limited to only basic functions and it mostly depends on human interaction hence the need for replacement with the system that has sufficient operating capacity. Adding more functions required for efficient and effective in monitoring and management of water services will minimize some of human errors.
- Remote surveillance is the alternative to reading electronic measuring equipment and collecting the data of sensors in person. Physical collection of data is slow and expensive as compared to electronic data collection and transmission.
- Sensing and detection of event in the water distribution network and changes in quantities or qualities is the basis of water service delivery monitoring. This function will ensure efficient and sustainable provision of water services.
- Local and remote sensing is possible by placing the sensor in the location of interest without direct contact, depending on the type and transmission of the emitted signal to be detected, for example water pressure, water quality or water leaks, low or high reservoir level, etc.
- The result of this study further confirmed the compatibility and the applicability of the telemetry system required for the WTW and the ability to actively account for the complex interactions between water requirements and socio-economic parameters.

4.6 Evaluation of the study based on the results.

This is a descriptive type of research specifically aims to move beyond “just getting the facts” to make sense of countless people, politician, social, cultural, and contextual elements involved (Walliman, 2011). About quality of water service provision, the study revealed that there are few if none of the research done on assessment of the telemetry system. The following are considered the evaluation of the study results by the researcher:

- The framing of the study within the exploratory design, firmly addresses the issue of evaluating the existing telemetry system on WTW process. WTW process includes water abstracted from the source by pumps, purification process, storage, and distribution.
- There was consistency of evaluating the telemetry system across the respondents as most of them supported idea of replacing the existing telemetry system with the latest technology. The results revealed that the research can be valued because of its

incremental advance in the use of technology for provisioning of water services. This might also enhance the ability to generalize a study by extending the original research results to a new population of water services context.

- The evaluation questions for the study were carefully selected for relevance throughout all the research chapters. However, the assessment of whether the research questions were relevant is based on the subjective opinion.
- The researcher, who was also the employees of LNW has operational and technical knowledge and experience of the telemetry system employed in WTWs. These insights were brought into the study and as a result, valuable contribution was made.
- A further evaluation on telemetry system for effectiveness, reliability, impact, relevance, and provision of equitable and sustainable was highlighted in the study.
- The results reflected the comparison of the socio-economic benefits on equitable and sustainable water supply to the operational cost of production. The operational cost can be explained by the frequency of human interaction in WTW process and in water distribution network.
- The study results correlated with the predictions set out in the introduction. They were supported by the expert responses from the participants and there were no differences did the researcher find that refute the research hypotheses.
- Different types of graphs formats emphasized the sizes of effects, and different analysis methods for different results. Study results were protected from bias through a well-established hierarchy of study designs; however, the presence of bias does not imply a preconception on the part of the researcher, but rather means that the results of the study deviated from the truth.
- The researcher was able to decide which expert to be invited to participate in the study and whether certain operational occurrences should be reported as adverse event. The results showed that these decisions required the researcher to act with integrity and not for personal or institutional gain.

4.7 Implications of the results for practice and policy.

In this section, several implications for practice relates the knowledge gained from the research study to the provision of water services with the aid of technology. This knowledge can be used by technicians, technologist, researchers, businesses, practitioners, and policy makers to confirm the capability and competency to produce the intended results by the existing telemetry system, to upgrade the existing telemetry system, and to design or research for a suitable telemetry system. This study has also implications for those who implement, coordinate, and advocate for innovative community engaged in water service strategies in the water sector. Moreover, the general picture derived from this study also stimulates some further research.

- The research study in evaluating the existing telemetry system is naturally basic and as a result there may be few, if any, direct links to practice and policy. However, most research studies in the technology and sciences environment have some links to the existing practice and policy.
- The knowledge gained from the study results can be used to research for a suitable telemetry system used on WTW and water distribution process.
- Innovative water services delivery interventions that have been shown in this research study to be effective can be added to the existing telemetry system, upgrade or replace the existing telemetry system.
- Innovative water services delivery interventions that have been shown in this research study to be effective can provide a rational for maintaining existing interventions as well as providing accountability data.
- Innovative water services delivery interventions that have been shown in this research study to be effective can be the catalyst funding to deliver effective interventions to the existing telemetry system, upgrade or replace the existing telemetry system.
- Technological service interventions to relationships among variables may indicate that problems or potential problems exist in the delivery of water services. This awareness of problems may lead to a reconsideration and revision technological standards, water service delivery standards, ethical codes, and standards of practice for professionals, certification, and licensure requirements as well as accreditation standards for technology designs and implementation.

4.7 Chapter Summary

This chapter constituted the research results. Although the respondents indicated that they preferred the review of existing telemetry system, the results revealed evidence of ineffective of this telemetry system. The strength and weakness of the existing telemetry system and the challenges faced by the WTW have been reiterated in the results and discussion sections. It has been indicated that since the system is not intellectual is limited to only basic functions such as alarms, valve positioning, stop and start of pumps, pipeline pressure monitoring only at some certain points, monitoring of reservoir levels, and surveillance at remote stations. According to the respondents, limitations of the system is not assisting, especially when coming to the operational cost optimization. Generally, as mentioned above, its performance is not up to the expected standard given the trending technologies.

The respondents in this study indicated some of the challenges experienced and possible solutions for better management of water demand and supply. The respondents further mentioned telemetry system as one of the reasons for challenges in the provisioning of sustainable and reliable water services. As mentioned earlier, it requires a coordinated management activity directed to reduce water loss from the source to the distribution network that include speed and quality repairs and rehabilitation of ageing water infrastructure, material management, water pressure management, active and passive leakage control methodologies using the recent available intellectual technologies in the market.

Literature has indicated that water quality is a very important issue related to human health and should be considered in the water treatment process and in the distribution network (WDN) design. This has brought up the question of how water quality is monitored and measured from the source to the tap. The research respondents pointed out the challenge in monitoring water quality on-line as the outdated telemetry system and not compatible to accommodate the current technological developments. Moreover, it has been captured that there is no support care on the existing telemetry system that can be provided for in case of emergency situations, another reason being the location of most of the service providers. It was further emphasised that the intellectual telemetry system that would provide all the necessary functions will competent workforce be able to operate, manage and maintain.

CHAPTER 5: RECOMMENDATIONS

5.1 Introduction

In this chapter, conclusion and recommendations grounded on the research study results and the literature are going to be made in relation to the three objectives. Given the nature of the research objectives, there will be a multiple recommendation for a given purpose. Recommendations are suggestions for action that are based upon the results and the applicable literature with consideration for the limitations of both. The recommendations are for upgrading or replacing the existing telemetry system with the latest compatible system in line with new initiatives in theory, practice, and policy. Recommendation can also be for future research on the telemetry system about its technological capability and functions on emerged weaknesses that have become apparent, new questions raised by the results, and conceptual framework and methodologies that seem to hold promise in the future.

5.2 Conclusion and recommendations on objective 1

In conclusion, the study for this objective revealed that the existing telemetry system capacity is limited thus performing only basic functions. Therefore, there is a need to review its performance in relation to efficiency, relevancy, capability, and impact on water service delivery before decisions to replace it can be made. It has been discovered that the existing telemetry system is outdated and its reliability also questionable. The proposed review exercise will be able to provide possible solutions to the challenges currently experienced by the WTW. Generally, it is recommended that the existing telemetry system need to be replaced with the latest compatible telemetry technology system available in the market to ensure provision of efficient, reliable, and sustainable water services.

5.3 Conclusion and recommendations on objective 2

In conclusion, the study for this objective revealed that it is not possible to manage water demand and supply using the existing telemetry system. The existing telemetry system is not capable of performing pressure management in the water distribution network system because of its limited system capacity. Managing water demand and supply requires a compatible telemetry system for water leak and pipe burst detection, pressure reducing valves, pump scheduling, water distribution system optimization, and support effective and water management activities to achieve a better control over the distribution network system. Therefore, it is recommended that the existing telemetry system to be replaced to realise the expected benefits. As a result, it will provide a significant improvement for the WTW in the provision of efficient, equitable and sustainable water services delivery to the deserving community.

5.4 Conclusion and recommendations on objective 3

In conclusion, the study for this objective have shown that the existing telemetry system is not an intelligent system for monitoring and management of water quality. In considering of the limitations on the existing telemetry system, clearly, the system cannot offer many options to the benefit of the end-user and the consumers. The sooner the replacement with a compatible system is done the better for all stakeholders. It requires a compatible telemetry system to be incorporated with water quality monitoring tools to ensure healthy and safe drinking water to the community. Some of the tools to be considered is online water quality monitoring and management system. It is therefore recommended that a compatible intelligent telemetry system be acquired. The acquired latest telemetry technology system must have the capability and functions to accommodate various water quality compliance parameters through online mode of communication.

5.5 Conclusion and recommendations on results

The tone of recommendations ranged from tentative to advisory, however, it is in the best interest of both the researcher and the reader to take note of challenges coming with the new or advanced technology. The challenge would largely be experienced from both maintenance and operations side of the WTW. It was noted with great interest to acknowledge that training and development of the workforce is required to ensure that the newly acquired system is offering the desired results. It was surprising to learn that the existing telemetry system is outdated and getting maintenance spare is not possible or comes with unreasonable cost to the end-user.

Surprisingly, high risk of interrupting the installed and commissioned telemetry system through theft, vandalism, and interference was also highlighted. System downtime due to human factors and inconsistent availability of the system was viewed in serious light considering the impact of interruption on water service deliver. Therefore, legal considerations need to be intensified including safeguarding of the telemetry infrastructure and capacitating the technician, engineers, and managers responsible for WTW. The installation of intelligent telemetry system to be able to monitor and analyse water quality was not expected. Much can be learned about the existing and proposed latest telemetry technology system.

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