Onsite greywater reuse as a water conservation method: A case study of Lepelle-Nkumpi local municipality, Limpopo province of South Africa.

By

Karabo Mashabela

DISSERTATION

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Supervisor: Dr. M.H.N Mollel

Co-Supervisor: Mrs J.M Letsoalo

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ABSTRACT

Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. Growth in population and economic activities have contributed to water scarcity, which is a frequent challenge in rural and township communities in South Africa. This study aimed at investigating onsite greywater reuse as a water conservation method in Lepelle-Nkumpi local municipality, Limpopo province. The study described the socio-economic characteristics, assessed the accessibility and availability of water supply, and ascertained the coping mechanisms for water scarcity as well as the perceptions and reuse of greywater. Four percent respondents each were selected from two settlements, namely, Mashite village and Lebowakgomo township (Zone F). Mashite village had a population size of 5314 people (1231 households) and Lebowakgomo Zone F had 5903 people and (1924 households). A systematic random sampling method was used to select the required households from the two settlements. Both open and close ended questionnaires were used. A Geographical Positioning System was also used to collect the absolute location of available taps in the study area. Data collected were analysed using SPSS version-22 and Arc GIS 10.1.

The study found out that the socio-economic characteristics of importance on onsite greywater reuse included highest qualification, household size and employment status, but they varied in these two areas. In Mashite village the majority of the respondents went to secondary school (59%) as compared to Lebowakgomo Zone F where the majority (72%) attained tertiary qualification. Household size mean in Mashite is 6.18 as compared to Lebowakgomo Zone F (2.77). Sixty four percent of respondents in Mashite village were unemployed, whereas in Lebowakgomo 69% were employed. Water usage in the two areas differed; in Mashite village where they use less water (250 to 840 litres) as compared to Lebowakgomo Zone F, where more water is used (5900 to 8001 litres). In Mashite village, 87% of the respondents could not access water due to inaccessibility of taps and unavailability of water as compared to Lebowakgomo zone F (100%). It was also found that the Mashite community sometimes go for a period of two to three months without tap water whereas in Lebowakgomo water was comparatively regular. As a result both communities resorted to rainwater harvesting and greywater reuse. Seventy six percent (76%) of respondents in Mashite village and 30% of the respondents in

Lebowakgomo Zone F harvested rainwater as a coping mechanism of water scarcity. Perceptions of greywater reuse were higher (76%) in Lebowakgomo Zone F compared to Mashite village (49%). A higher percentage of Mashite village respondents (98%) reuse greywater compared to Lebowakgomo Zone F respondents (59%). Both areas use greywater as water conservation method. These results reinforce the potential of domestic greywater reuse as an alternative for freshwater requirement. Greywater reuse as a water conservation method especially in villages can be used to alleviate the extent of water scarcity.

DECLARATION

I declare that the dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Geography and Environmental Science has not previously been submitted by me for the degree at this or any other university; that it is my own work in design and in execution, and that all material contained herein has been duly acknowledged.

Surname, Initials (title): _____   Date: _____

DEDICATION

To Aunt Georgina Hlungoane for all you have been, I will always love you.

ACKNOWLEDGEMENTS

LIST OF ACRONYMS AND SYMBOLS

ARC — Agricultural Research Council

ASP — Agricultural Support Programme

CSIR — Council for Scientific and Industrial Research

DEM — Digital Elevation Model

DWA — Department of Water Affairs

DWAF — Department of Water Affairs and Forestry

EDRC — Energy and Development Research Centre

FAO — Food and Agricultural Organization

GDG — Gender Development Group

GIS — Geographic Information System

HRD — Human Resource Development

IDP — Integrated Development Plan

NWRS — National Water Resource Strategy

RDP — Reconstruction and Development Programme

RSA — Republic of South Africa

SANSA — South African National Space Agency

SARVA — South African Risk Variability Atlas

SAWS — South African Weather Service

SBC — Session Border Controller

UTM — Universal Transverse Mercator

WHO — World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1 Background

Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment (DWAF, 2004). In spite of its importance, freshwater distribution across the globe varies. There are regions with plenty of freshwater while others are water scarce countries. More than half of the global freshwater runoff is concentrated in the tropical areas of Africa, Asia and South America (Bernstein, 2000). Whereas, portions of Northern Sub-Saharan Africa and western Asia receives small amount of rain (Jeanerette & Larsen, 2006). Water scares countries have less than $1000m^3$ per year per person, the water is not enough to provide for basic needs and economic activities (Bernstein, 2000; Abusam, 2008). South Africa is one of the water scarce countries, with an average annual rainfall of approximately 500 mm. Much of this rainfall is seasonal, which is way below the world's annual average of 860 mm as shown (Figure 1) (DWAF, 2004; SAWS, 2014). There is high variability on rainfall pattern, and high level of evaporation due to the hot climate, and increasing challenges from water pollution. A growing economy and social development is giving rise to increasing demands for water in South Africa. South Africa is the thirtieth driest country in the world and has less water per person than countries widely considered being much drier, such as Namibia and Botswana (NWRS, 2013). The total average annual available surface water in South Africa is 49 200 million m^3. This includes the inflow from Lesotho and Swaziland (DWAF, 2002).The discharge of the Nile River alone is six times higher than the available surface water resources from all South African rivers together (DWAF, 2004).The distribution of rainfall in South Africa is uneven, with some regions in the north west receiving less than 200 mm per year while much of the eastern highveld receives 500 mm to 900 mm. In Limpopo province some areas receive less than 400 mm of rain while others get more than 800 mm per year (Pieterse, du Toit & Associates, 1998; SAWS, 2014).

South Africa is geologically characterised by hard rock with limited groundwater storage capacity. Groundwater is the only dependable source of water for many users but it is available in varying quantities depending upon the hydrogeological

characteristics of the underlying secondary aquifers (Van Schalkwyk & Vermaak, 2000). Groundwater makes greater contribution to the nation's water supplies now and in future as surface water gets closer to the limits of its development and availability (DWAF, 2004). It provides reliable, drinking water supplies to rural areas and many towns in South Africa. Even large cities such as those in the Tshwane Metropolitan Municipality are dependent partly on groundwater. South Africa uses between 2 000 million m^3 and 4 000 million m^3 of groundwater for domestic and other industrial uses (DWAF, 2004; EDRC, 2013). Surface water and groundwater play a central role in most of the national initiatives, such as agricultural development, energy security, tourism and recreation, mining, industry and municipal water supply (NWRS, 2013). This is because harmful microbiological pathogens such as bacteria and viruses usually cannot survive for long in aquifers (DWAF, 2004).

Limpopo province receives summer rainfall between October and March reaching its peak in January. About 2.3% of the province receives less than 400 mm of rain while only 6% receives more than 800 mm and the remaining 91.7% receives between 400 mm and 800 mm of rain (Figure 1) (Pieterse, du Toit & Associates, 1998; DWAF, 2004; SAWS, 2014). The province is traversed by two major rivers (Limpopo and Olifants) which are shared by neighbouring countries. The Limpopo river supplies water to other countries such as Botswana, Zimbabwe and Mozambique, however in South Africa the supply from this river is extremely limited. The Olifants river (Figure 13) supplies water for domestic and industrial (mining) use in the province (DWAF, 2004). Groundwater plays an important role in rural water supplies, 75% of communities in Limpopo Province rely on groundwater (EDRC, 2013). Water in Limpopo province is mainly used for irrigation, domestic, industrial and mining requirements.

Mashite village and Lebowakgomo Zone F are settlements of Lepelle-Nkumpi Local municipality, Limpopo Province. The two areas lie in the summer rainfall region and have a warm climate. The mean annual precipitation for the Mashite village is 478 mm and for Lebowakgomo Zone F is 520 mm. Most of the precipitation falls between the months of October and March with the peak period being December/January. Rainfall between the months of May and September is generally low with the average precipitation rate for the period of June to August being 4.6 mm (SAWS,

2014) (Figure 2). Apart from rainfall, several minor rivers (Figure 4) pass through Lepelle-Nkumpi Local municipality, and they are sources of water in that area.
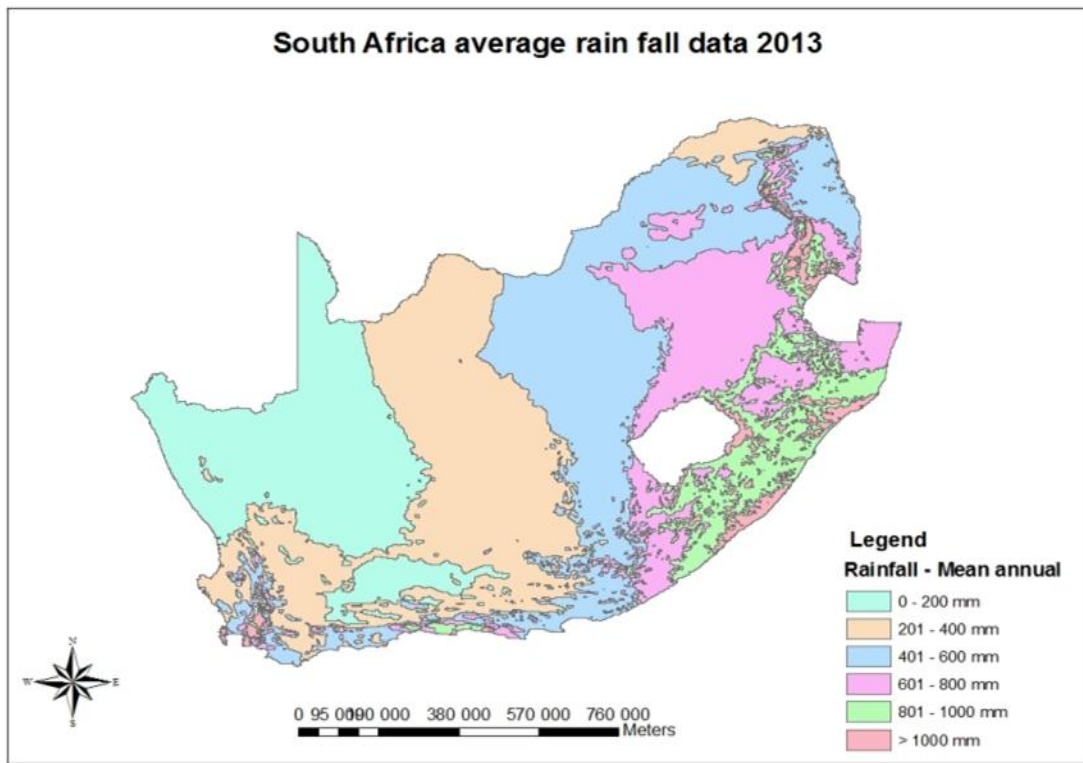
Figure 1: South Africa average rainfall in 2013

Source: (SARVA, 2014)
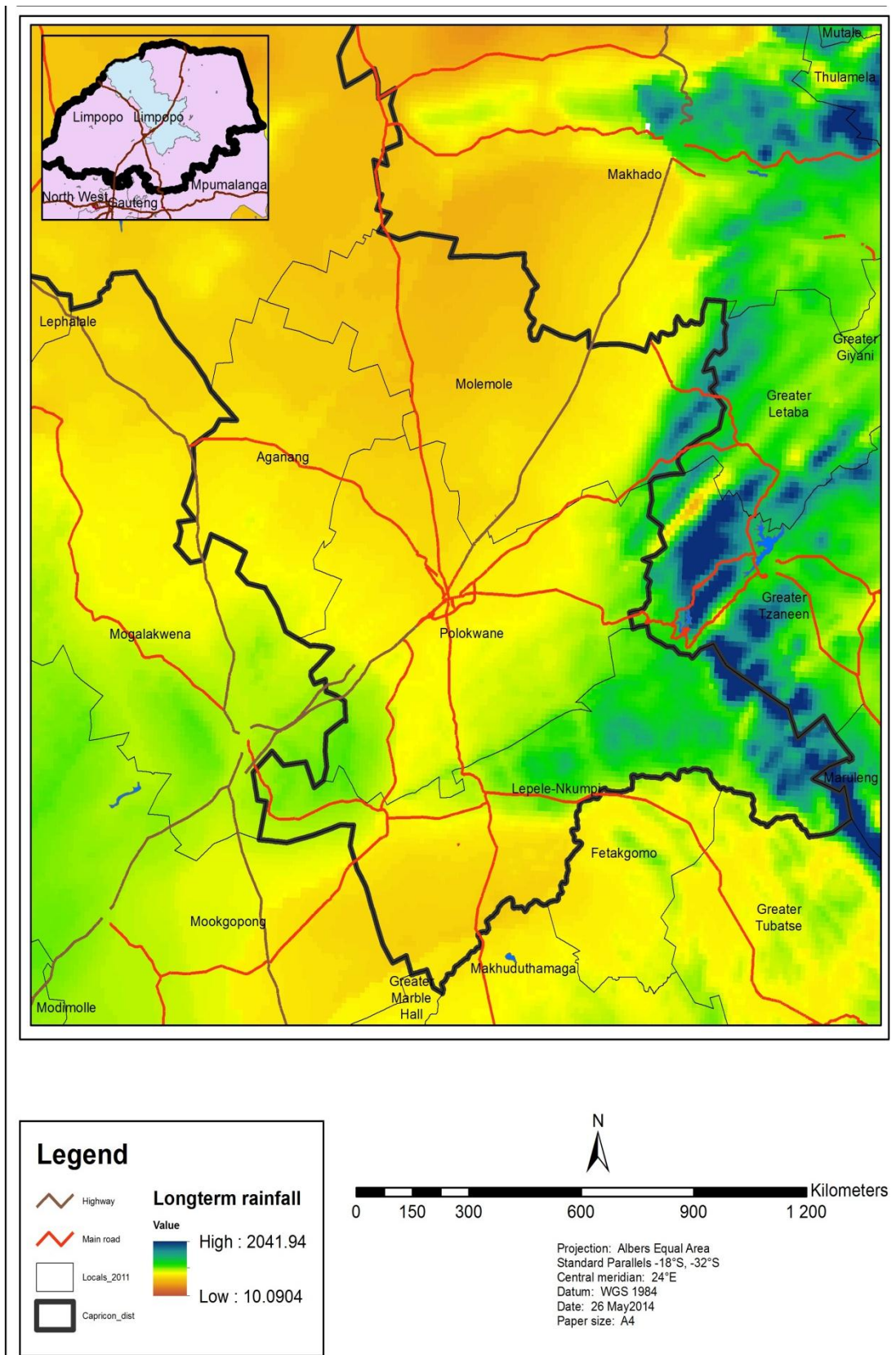
Figure 2: Capricorn District Municipality long-term rainfall

Source: (ARC, 2014)
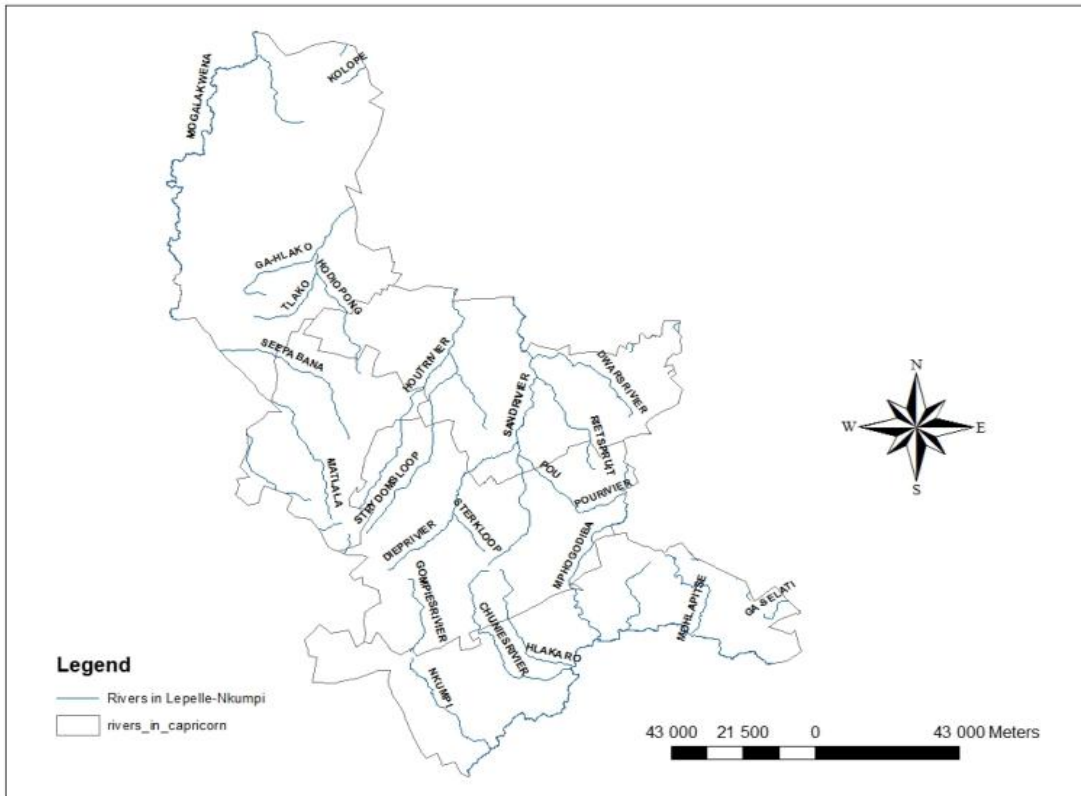
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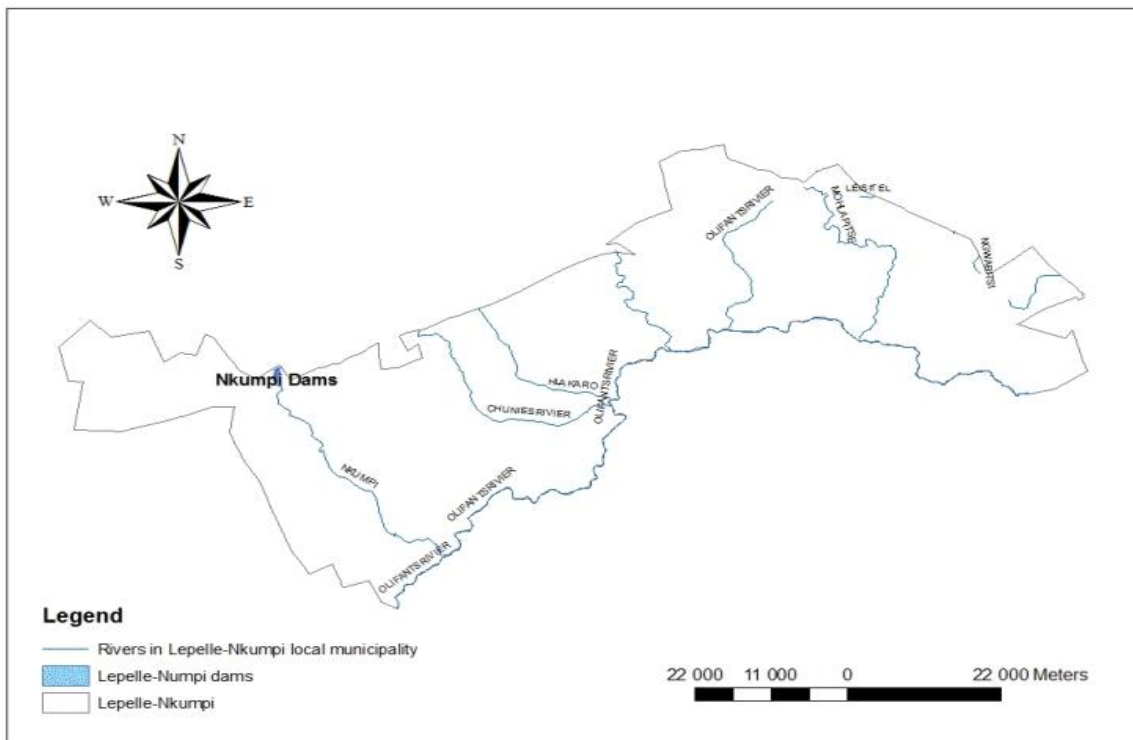
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According to Adewumi *et al* (2009), many communities in South Africa struggle to access reliable and adequate quantities of potable water for diverse water requirements such as drinking. DWAF (2005) reported that South Africa's public stand pipe water supply of not more than 200 metres away from dwellings has not reached many villages such as those in Lepelle-Nkumpi local municipality and other villages in South Africa. The current free basic potable water provision in South Africa is 6000 litres per household (Berger, 2005). Due to the poor service level, residents queue for long periods at water points, which may have slow or irregular supply and carry water home, typically in 20 litre plastic drums on a wheelbarrow. In the households, water is usually stored in these containers or open metal drums. The difficulty of getting water from stand pipes makes people to resort to any available surface water like rivers (Figure 3 and 4), which is highly contaminated and thus increase the risk of water borne diseases. Further sufficient water is not available to sustain households' vegetable garden, thus weakening household food security and nutritional status. The mounting demand on this finite and invaluable resource has inspired creative strategies for freshwater conservation, such as greywater recycling and rainwater harvesting (DWAF, 2005).

There are several ways to cope with water scarcity such as rainwater harvesting and greywater reuse and these need implementation of an effective and equitable management practice that requires knowledge, expertise and investment in political, institutional and technical levels.

Addressing water scarcity requires actions at local, national and river basin levels. It also requires strategies and programmes for integrated river basin, watershed and groundwater management. Water volumes must be measured to improve the efficiency of water use and to reduce losses and to increase recycling of water in a way that gives priority to the satisfaction of basic human needs while preserving or restoring ecosystems and their functions (WHO, 2006).

Rainwater harvesting is the process of intercepting storm-water runoff and putting it to beneficial use. It is the primary source of water in agriculture. It is a way to cope with water scarcity and also it has been used successfully to augment water for industrial and domestic purposes, while being an essential element in the functioning of natural ecosystems. However, rainwater harvesting is rarely integrated into water

management strategies, which usually focus exclusively on surface water and groundwater (WHO, 2006).

Armitage *et al* (2011) found that most greywater in South Africa is disposed onto surfaces as a matter of convenience and largely because the vast majority of people reject the practice of reusing or recycling greywater. The majority of the people think that greywater is dirty and cannot be reused. It was perceived as a resource if it could help control dust, keep ants, flies and other insects away or if it could be used to irrigate harder varieties of shrubs and trees. In a household context, greywater is the leftover water from baths, showers, hand basins, washing machines and kitchen sink water. Greywater is named after its cloudy appearance and its status as being between fresh, potable water known as white water and sewage water known as black water. Any water containing human faecal waste is considered black water. Nonetheless, greywater contains microorganisms but the microorganism loads are substantially lower as compared to microorganism loads found in blackwater (Dimitriadis, 2005).

1.2 Problem statement

We are now entering an era where abundant, clean freshwater is no longer guaranteed, even in developing countries like South Africa. Growth in population and economic activities have contributed to the increase in the use of water adding more pressure on the scarce water resources. Water scarcity is a frequent challenge in rural and township communities in the country. Many water supply systems are too small to work efficiently and as such, water conservation is a well-timed area of research. Greywater reuse as a conservation method may be considered to reduce the costs as well as the extent of water scarcity. The bulk of household wastewater is greywater which is being produced on a daily basis. Reusing greywater may provide many litters per day, which can be used for non-potable water needs such as outdoor use and toilet flushing. However, the potential of domestic greywater reuse as an alternative for freshwater requirement, need to be explored. Therefore this study intended to find out the uses of onsite greywater as a water conservation method by rural and township communities in the Lepelle-Nkumpi Local Municipality.

1.3 Hypothesis/Assumption

The onsite greywater reuse can be a coping mechanism for water scarcity.

1.4 Research questions

i. What are the socio-economic characteristics of the selected households in Mashite and Lebowakgomo, Lepelle-Nkumpi Local Municipality?

ii. What is the status of the accessibility and availability of water supply in the selected communities in Lepelle-Nkumpi Local Municipality?

iii. What are the coping mechanisms for water scarcity by the selected communities in Lepelle-Nkumpi Local Municipality?

iv. What are the perceptions of greywater reuse by households in the selected communities in Lepelle-Nkumpi Local Municipality?

1.5 Motivation of the study

Clean fresh water scarcity in South Africa is a reality. This is, among others, due to growth in population and increased economic activities as well as inadequate water supply systems. This has lead to the need for research in water conservation methods such as greywater reuse. Onsite greywater reuse will provide for non-potable water needs and hence reduce the amount of freshwater requirements.

This study is based on the following theories of human social systems that are basic to most geographic studies human environment system, population and environment and human interactions. These theories identify the various causal chains of links between human activities and environmental degradation where human activities increase or mitigate pressure on the environment. The driving forces which initiate human activities are mainly socio-economic and socio-cultural forces population size, social organization, values, technology, wealth, education, knowledge and many more. Water scarcity, besides being a natural phenomenon that occurs in some areas is the result of most of the above mentioned forces that drive human activities. Its conservation, using methods like greywater reuse, is one of the measures to reduce pressure on the environment. This study is therefore in line with these theories since it reflects on the interaction between the human population and the environment which lead to water scarcity and the need for its conservation for the future.

1.6 Purpose of the study

1.6.1 Aim

The aim of this study was to investigate the onsite reuse of greywater in Lepelle-Nkumpi Local Municipality as a water conservation method.

1.6.2 Objectives

i.   To describe the socio-economic characteristics of the selected communities in Lepelle-Nkumpi Local Municipality.

ii.   To assess the accessibility and availability of water supply in the selected communities of Lepelle-Nkumpi Local Municipality.

iii. To ascertain the coping mechanisms for water scarcity by the selected communities in Lepelle-Nkumpi Local Municipality.

iv.   To describe the households perception of greywater reuse in the selected communities in Lepelle-Nkumpi Local Municipality.

1.7 Ethical considerations

Permission to undertake the research in Mashite village was sought from the village Headman and for Lebowakgomo Zone F it was obtained from the Lepelle-Nkumpi Local Municipality. The participants' information was treated confidentially. Voluntary participation by the participants was guaranteed by the researcher. This meant that the respondents were not forced to take part in the interviews. The permission from village authority was granted to allow the researcher to interview the Mashite village Induna.

1.8 Significance of the study

The information obtained from the study will be useful in providing a more informed and well-structured water conservation plan for communities in Lepelle-Nkumpi local Municipality especially in Mashite village where the Induna was interviewed. The results will also add on existing knowledge on greywater reuse.

1.9 Limitations of the study

The limitations of the study were that, some of the people were not willing to participate thinking that the survey was for political reasons. The researcher had to produce her student card for them to believe since others could not read. Many households were not able to read their meter boxes to monitor water usage and the

researcher herself had to read it and explain why they owe huge amounts of money to the municipality which is because they used water beyond 6000 litres. Furthermore, it was difficult for the respondents to estimate the quantity of greywater they are producing. This limitation was overcome by the researcher looking at containers they used to store greywater and estimated their volume. The last limitation was the difficulty to get permission from Capricorn District Municipality to interview the water service manager since the Lepelle-Nkumpi local municipality referred the researcher to them. As a result, the interview never took place.

1.10 Definition of operational terms

For the purpose of facilitating and common understanding, the following key terms are defined as they relate to the study. A few other terms are defined to demarcate some differences where possible.

1.10.1 Greywater

Greywater is household wastewater that originates from: showers, baths, laundry, kitchen and untreated spa (Queensl, 2003).

1.10.2 Reuse

To reuse is to use an item again after it has been used (Adewimi *et al.*, 2010)

1.10.3 Water conservation

Water conservation refers to reducing the usage of freshwater, recycling of wastewater for different purposes and rainwater harvesting (Bandyopadhyay, 2012).

1.10.4 Water scarcity

Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region (Kharraz et al., 2012; Varghese *et al.,* 2013).

1.10.5 Groundwater

Groundwater is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations (DWAF, 1994).

1.10.6 Surface water

Surface water is water on the surface of the earth such as water in a stream, river, lake, wetland, or ocean (FA0, 2012).

1.11 Summary

This chapter commenced with the background information on water resources. It further emphasized on the accessibility and availability of water supply. It then touched on the ways to cope with water scarcity such as onsite greywater reuse. Other aspects covered in this chapter include statement of the research problem, objectives of the study, the research questions, significance of the study and the limitations of the study. The next chapter focuses on literature review related to the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Due to the decline in the availability of freshwater sources, it is important to look for affordable, implementable and safe solutions to alleviate water problems. The World Health Organization's (WHO) guidelines for safe use of wastewater, excreta and greywater emphasize the importance of greywater as an alternative water resource. Greywater can contribute to this as it makes up the largest volume of the waste flow from households. It has nutrient content although low, but can be beneficially used for crop irrigation and can also be used to reduce the demand for the use of water (WHO, 2006).

In this chapter onsite greywater reuse as a water conservation method is reviewed. Literature sources related to the reuse of greywater, water scarcity, accessibility and availability of water supply, water conservation and coping mechanism, community awareness and legal issues, are discussed.

2.2 Water scarcity

Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region (Kharraz *et al.,* 2012; Varghese *et al.,* 2013). It is driven by two converging phenomena: growing freshwater use and depletion of usable freshwater resources. It involves water stress, water shortage or deficit and water crisis (Schwerdtner *et al.,* 2012). Water scarcity can be defined as water stress, which is the difficulty of obtaining fresh water sources for use during a period of time and may result in further depletion and deterioration of available water resources (Binns *et al.,* 2001; Kharraz *et al.,* 2012). It already affects every continent and around 2.8 billion people in the world at least one month out of every year lack access to clean drinking water (Hanjra & Qureshi, 2010). Water scarcity can either be physical or economic (Jiang, 2009; Varghese *et al.,* 2013; Zhang *et al.,* 2013).

2.2.1 Types of water scarcity

The physical water scarcity is the situation where there is not enough water to meet all demands (Kharraz *et al.,* 2012), including the water needed for ecosystems to function effectively. Arid regions frequently suffer from physical water scarcity. It also occurs where water seems abundant but resources are over-committed (Rijsberman, 2005). Economic water scarcity is a type of water scarcity caused by a lack of investment in water or insufficient human capacity to satisfy the demand of water in areas where the population does not have the means to utilise an adequate source of water (Rijsberman, 2006; Jiang, 2009; Daniell, 2012). Symptoms of economic water scarcity include a lack of infrastructure, with people often having to fetch water from rivers or lakes for domestic and agricultural uses (Binns *et al.*, 2001).

2.2.2 Causes of water scarcity

Water scarcity may be caused by climate change, such as altered weather patterns including droughts or floods, increased pollution, and increased human demand and overuse of water (Rijsberman, 2005). It may be due to the available potable, unpolluted water within a region being less than that region's demand (Binns, 2001). In Africa, more than 38% of the population do not have access to a safe water supply, whereas 40% do not have access to adequate sanitation services. The causes of water scarcity are varied. Some are natural and others are a result of human activities (Varghese *et al.,* 2013).

Physical causes of water scarcity: In most cases these are: drought, climate change, land use and land cover changes, earthquakes as well as evapotranspiration.

➢ Drought can be defined as a prolonged period of unusually dry weather in an area. Low rainfall leads to low water in aquifers and the pattern may lead to water shortages even for the households. It causes negative impacts such as famine, epidemics and land degradation (Bandyopadhyay *et al.,* 2012). Sub-Saharan Africa for example, accounts for 80% of loss of life and 70% of economic losses. A balance must be maintained between the water supplied and the surface run-off to replace it (Fabris *et al.,* 2008).

➢ Earthquakes and other natural disasters may cause water shortage in that, they may destroy a variety of infrastructures including those of water supply.

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The water service may be disrupted for days, weeks, months or even for longer periods depending on the seriousness of the damage (Uitto & Biswas, 2000).

➢ Evapotranspiration is the key part of the hydrological cycle as 75% of the annual precipitation returns to the atmosphere due to evaporation and transpiration (Twort *et al.,* 2000). According to this source, a lot of water goes back to the atmosphere as a result of evapotranspiration which is a combination of the two processes, namely, evaporation and transpiration. Through these processes water is lost from any open water source, e.g. dams, reservoirs, rivers and the vegetation (Twort *et al.,* 2000).

➢ Land use and land cover changes: Land use and land cover changes have a variety of impacts on water resources. Whilst reduction of vegetation cover may result in greater runoff, it reduces groundwater infiltration and the storage capacity of dams and lakes through siltation. The draining of large scale wetlands or large scale deforestation may change the micro-climate of a region (Binns *et al.*, 2001).

➢ Another cause of physical water scarcity is climate change. It has caused receding glaciers, reduced streams, river flow, shrinking lakes and ponds. Many aquifers have been over-pumped and are not recharging quickly. Although the total fresh water supply is not used up, much has become polluted, salted, unsuitable or otherwise unavailable for drinking, industry and agriculture (Binns *et al.*, 2001).

Economic causes of water scarcity: The main cause of economic water scarcity is the growing demand resulting from population increase and economic activities, which often lead to contamination. Lack of maintenance of ageing water infrastructure and the threat posed by invading alien plants also play an important role in economic water scarcity.

➢ Fresh water supplies can be polluted by a variety of sources, such as, industrial effluent; agro-chemical run-off fields; the causal disposal of human excreta and also poorly treated sewage from municipal works. All these may result with insufficient safe/clean water for domestic use (FAO, 2006).

➢ Water is often moved through pipes for longer distances. This is due to the fact that dams are not always conveniently located. In these instances, pipes

may start leaking due to age and this will lead to insufficient water reaching the desired destination. This situation calls for strategies to detect leakages or complete replacement of the leaking pipes (Hunaidi & Wang, 2006).

➢ Alien plants are species that do not occur naturally in an area and are not indigenous. Various species of alien plants have been brought into South Africa, either deliberately as commercial plants or as ornamental garden plants, or accidentally through seed (Enright, 2000; Le Maitre *et al.,* 2000). These plants use more water than indigenous ones. Alien trees result in reductions of 350 mm of runoff per annum (Le Maitre *et al.,* 2000). In Cape Town for example, the impact of these include the reductions on the yield of the Theewaterskloof Dam, a major reservoir for water supply (Enright & Spratt, 1999).

2.3 Water availability and accessibility

Water accessibility and availability constraints have been a worldwide challenge (Adewumi *et al.*, 2012). As a basic need, it is there for certain purposes such as domestic use as in drinking, washing, bathing and to some extent, water may be used to earn an income such as cultivating a garden, field crops and livestock, and brick-making in the rural and semi-urban areas. Prosperity for South Africa and other countries depends upon sound management and utilization of many resources, with water playing a pivotal role. The industrial growth of any country depends on accessibility and availability of adequate water resource (Basson *et al*, 1997; Pinto *et al.,* 2010).

2.3.1 Water availability

One of the natural resources available in nature is water, however, it is not always available for millions of people across the globe for domestic use. The amount of water available for use on the planet is finite, and out of the available water, only 3% is fresh water, 2% of the freshwater is frozen in glaciers and polar ice caps and only 1% is useable water (NASA, 2007). In South Africa, like everywhere else in the world, water is becoming a scarce resource and a crucial one particularly because both people and industries need water for their survival (Masibambane, 2006).

The total surface water available in South Africa averages about 49 200 million m^3 per year, of which about 4 800 million m^3 per year originates from Lesotho. A portion

of this runoff, known as the Ecological Reserve, needs to remain in the river in order to maintain the natural environment along the watercourse. The desired quantity varies from river to river, depending on the requirement to maintain the current environmental condition (Sebola, 2000).

Groundwater also has an important role to play in rural water supplies, but few major groundwater aquifers exist that can be utilised on a large scale due to high salinity in most parts of the country and geologically South Africa is characterised by a hard rock. It is estimated that about 5 400 million m^3 of water a year could be obtained from underground sources (DWAF, 1994).

It is anticipated that climate change will impact water availability globally (DWAF, 2000; Jenerette & Larsen, 2006; Abusam, 2008; Adenjini-Oloukoia, 2013). The net effect of climate change for South Africa will be a reduction of water availability, although impacts will be unevenly distributed, with the eastern coastal areas of the country becoming wetter. In the interior and the western parts of the country, climate change is likely to lead to more intense and prolonged periods of drought. In general, climate change will probably lead to weather events that are more intense and variable, such as sudden high volumes of rainfall, leading to flooding (DWAF, 2004).

South Africa depends mostly on rivers, dams and underground water for water supply. The country does not get a lot of rain. To make sure that there is enough water to drink, to grow food and for industries, the government builds dams to store water (DWAF, 2003).

These dams make sure that communities do not run out of water in times of drought. About half of South Africa's annual rainfall is stored in dams. Dams can also prevent flooding when there is an overabundance of water. There are more than 500 government dams in South Africa, with a total capacity of 37 000 million m^3 (about 15-million Olympic-sized swimming pools). Gariep Dam is the largest storage reservoir in South Africa with a total storage capacity of 5 341 million m^3 when full (DWAF, 2003).

2.3.2 Water accessibility

Research conducted by Mainganye (2006) indicated that, there was a disparity in the way the villages in South Africa received water. The fact that water accessibility may

result from unequal distribution among the residents is also supported by the White Paper on Water Supply and Sanitation Policy (1994). The introduction of the White Paper on Water Provision (1997) was as a result of unequal sharing of this resource. For example, South Africa experienced disparities in water distribution towards the end of the 19th century. On the one hand, the whites, indians, and the coloureds were receiving between 95% and 100% of piped water to their houses whereas 57.7% of the black community did not have piped water to their houses (The White Paper on Water Supply and sanitation Policy, 1994).

Water accessibility can be influenced by human behaviour, for example, the amount of water that is deemed enough at present, can at some time in the future become inaccessible due to growth in population, economic activities and incomes (Mainganye, 2006).

Lack of water accessibility leads to diseases, death and inconvenience to women and children who are responsible for household chores such as fetching water. Thirty percent of children deaths are as a result of poor water and sanitation conditions. Apart from health problems, people, especially women and children compromise their social time looking for water when it is not available in or near their homes (Masibambane, 2006).

Provision of clean water to the community can reduce the outbreak of water related diseases such as cholera, since people will refrain from using water drawn from streams and contaminated rivers (Masibambane, 2006). The Reconstruction and Development Programme (RDP) adopted by the Government of National Unity is more than a list of the services required to improve the quality of life of the majority of South Africans. It is not just a call for South Africans to unite to build a country free of poverty and misery, but it is a programme designed to achieve integrated and principled manner (Masibambane, 2006).

In 2004, Limpopo Province recorded 871 783 households that received potable water from municipalities and 539 640 out of 871 783 that received free basic potable water from municipalities. There was an increase in household's water accessibility by 6.4% (Statistics South Africa, 2004). Limpopo Province had recorded an increase of 1 124 911 consumer units that received free basic water from the municipalities and with an average increase of 575 005 (Statistics South Africa,

2007). An average increase of households that received free basic water from municipalities and other service providers in South Africa is reported to be 10 345 797 households (Statistics South Africa, 2007). When analysing the water supplies in Limpopo Province, according to Statistics South Africa (2007) one can deduce that there was a remarkable increase from 2004 to 2007.

2.3 Coping mechanism and water conservation

Coping mechanism and water conservation can be understood as all preconditions that enable actions and adjustments in response to current and future external changes, which are dependent both on social and biophysical elements. Common coping strategies during water scarcity are: development of water schemes, rainwater harvesting, greywater reuse and use of less water intensive sanitation techniques. Coping strategies are location specific and dependent on the availability of the necessary social, economic and technical resources to take advantage of water resources (Adeniji-Oloukoia *et al.,* 2013).

Water schemes are man-made conveyance schemes which move water from one river basin where it is available, to another basin where water is less available or could be utilized better for human development. The purpose of such designed schemes can be to alleviate water shortages in the receiving basin, to generate electricity, or both. An example of a large water scheme is the Lesotho Highlands Water Project, which is an on-going water supply project with a hydropower component, developed in partnership between the governments of Lesotho and South Africa. It comprises a system of several large dams and tunnels throughout Lesotho and South Africa. In Lesotho, it involves the rivers Malibamatso, Matsoku, Senqunyane and Senqu. In South Africa, it involves the Vaal River. It is Africa's largest water transfer scheme. The purpose of the project is to provide Lesotho with a source of income in exchange for the provision of water to the central Gauteng province where the majority of industrial and mining activities occur in South Africa, as well as to generate hydroelectric power for Lesotho (Hoover, 2001).

Ghisi & Ferreira (2007), conducted a study to evaluate the potential for potable water savings by using rainwater and greywater in a residential building located in Florianopolis, southern Brazil. The findings showed that the average potential for potable water savings (using non-potable water for toilet flushing, clothes washing

and cleaning) ranged from 39.2% to 42.7%. By using rainwater alone, potable water savings ranged from 14.7% to 17.7%. When greywater was used alone, potable water savings were higher, ranging from 28.7% to 34.8%. As for 25% the combined use of rainwater and greywater, actual potable water savings ranged from 36.7% to 42.0%. These findings show that water can be conserved using greywater and rainwater harvesting.

Water conservation plan encompasses the policies, strategies and activities to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future need (Adewumi *et al.*, 2010). Water conservation has gained priority all over the world, especially in countries experiencing serious water stresses like most African countries (DWAF, 2004). Population, household size, growth and affluence all affect how much water is used. Factors such as climate change increases pressures on natural water resources especially in manufacturing and agricultural irrigation (Adeniji-Oloukoia *et al.*, 2013). Well-structured water conservation plan also include monitoring of Illegal connections, leakage and unmetered connections (Adeniji-Oloukoia *et al.*, 2013).

2.4.1 Rainwater harvesting

Rainwater harvesting is the collection of runoff from the earth's surface, paved surfaces and other surfaces, and storing it for future use. Harvested water can include stormwater, surface runoff, and water from swales, cooling towers, air conditioning systems and other drainage structures, which is directed to a catchment basin or detention pond. The harvested water can be used for irrigation, thus conserving fresh water from being used (NASA, 2007).

Rainwater harvesting can further be defined as a technique of collecting rainfall runoff for domestic use and agricultural production (Frasier, 1983; Reij *et al.,* 1988). The demand of increasing population and widespread droughts since the 1980s, made people aware of the potential of rainwater harvesting to solve water shortage problems (Li *et al.,* 2002) and begun to integrate rainwater harvesting with modern agricultural techniques (Xiao & Wang, 2003). Owing to simple operation, high adaptation and low cost, modern rainwater harvesting systems have been widely built for household use and for agriculture under the government support since the 1990s (Li & Chu, 2003). The systems consist of a catchment, a conveyance and a

storage tank. Rainwater catchment includes a concrete yard, roof, earthy and asphaltic road surface. Water storage tank made from concrete or red-clay is usually distributed alongside the yard or in the field approaching the road. Rainwater harvesting techniques combined with efficient irrigation techniques such as drip irrigation has been used for crop, orchard and vegetable production (Gao & Li, 2005).

Jiang *et al* (2013) in his study on the water and energy conservation of rainwater harvesting system in the Loess Plateau of China reported that, rainwater harvesting proved to be very helpful for water and energy conservation by assessing the water use efficiency and energy consumption for agricultural production. On the other hand March *et al* (2003) reported that toilet flushing in hotels can be carried out with non-potable water which is an important water saving strategy.

2.4.2 Greywater reuse

According to Rodda *et al* (2010) domestic wastewater should be seen as a potential resource for further use to recover water and plant nutrients which would otherwise be lost through discharge to the environment. Using greywater sustainably for irrigation in small-scale agriculture and in gardens is one possible way of alleviating water stress. Since greywater contains some nitrogen and phosphorus it is also a potential source of nutrients for plant growth, particularly for users who cannot afford fertilisers. In the same vein, the soapy nature of greywater means it has some pest repellent properties, again of particular significance to users who cannot afford pesticides.

In view of seasonal water restrictions in many parts of the country, and perennial poverty in low-income communities, the use of greywater to supplement irrigation water is attractive. It is already practiced on an informal basis in urban gardens in middle to upper income suburbs in times of drought, or in food gardens in lower income informal, peri-urban and rural areas. Greywater irrigation holds the potential to contribute significantly to food security in poor communities by providing a source of both irrigation water and nutrients for crop plants. Where crops are produced in excess of household needs, they can be sold or exchanged for other goods or services, which further hold the potential for informal employment (Rodda *et al.,* 2010).

Greywater in South Africa is reused for irrigating crops at the formal housing community (Wyebank near Hillcrest) and an informal housing community (Mandela Park) that did not have any drainage systems in place. Other examples include the collection, sieving, disinfection and reuse of greywater (bathroom and kitchen wastewater) from about 110 sewered and non-sewered households in Carnarvon in the Northern Cape for lawn and vegetable garden irrigation and the direct application of greywater from washing machines for irrigating lawns (Ilemobade *et al.,* 2012).

Al-Jayyousi (2004) indicated that in Jordan, families that adapted to greywater reuse were able to reduce food expenditures by consuming garden produce. Al-Jayyousi (2004) further reported that there was little evidence of negative health impacts due to greywater irrigation, while positive impacts in terms of improved plant nutrition is likely to increase growth. The project on greywater reuse knowledge and management for sustainability helped improve the home gardening and irrigation skills of the recipients. Furthermore, it increased the environmental awareness of the community in terms of water conservation.

Greywater typically breaks down faster than blackwater and has lower levels of nitrogen and phosphorus. Greywater should be applied below the surface where possible (e.g., through drip line on top of the soil, under mulch or in mulch-filled trenches) and not sprayed, as there is a danger of inhaling the water as an aerosol. Greywater reuse presents a potential option for water demand management and it contributes to reducing fresh water use for irrigation (Al-Jayyousi, 2004).

Recycled greywater from showers and bathtubs can be used for flushing toilets. Such a system could provide an estimated 30% reduction in water use for the average household. The danger of biological contamination is avoided by using a cleaning tank, to eliminate floating and sinking items. This is an intelligent control mechanism that flushes the collected greywater if it has been stored long enough to be hazardous; this completely avoids the problems of filtration and chemical treatment (Al-Jayyousi, 2004).

Mandal *et al* (2010) conducted a study on water conservation. The findings of the study were that greywater is less contaminated and water charges can be saved, if treated recycled greywater is used for gardening, irrigation and for toilet flushing.

According to Domènech *et al* (2014), in Barcelona, greywater sources typically involve reusing water from the shower or the bath for toilet flushing purposes.

➢ **What is greywater?**

Greywater is usually defined as all wastewater produced in households, except toilet wastewater (black water). Typically, this includes water from bathroom sinks, baths, and showers and may also include water from laundry facilities and dishwashers (Queensl, 2003). Greywater is also defined as untreated household effluent from baths, showers, kitchens, hand wash basins and laundry (i.e. all non-toilet uses). More than half of indoor household water is normally used for these purposes and can potentially be intercepted by the householder for additional beneficial uses (Rodda *et al.,* 2010). Greywater or sullage is defined as wastewater generated from hand wash basins, showers and bathtubs, which can be recycled on-site for uses such as flushing and landscape irrigation. Greywater often includes discharge from laundry, dishwashers and sinks (Ilemobade *et al.,* 2012).

Greywater may be disaggregated into two sub-categories (i.e. light greywater and dark greywater) based on organic strength or the levels of contaminants contained in the water. Light greywater typically consists of wastewater from bathrooms, hand basins, bathtubs, showers, and laundry. Light greywater generally has lower concentrations of contaminants than dark greywater. Dark greywater is a combination of light greywater and wastewater from kitchen sinks, dishwashers, or other sinks involving food preparation. Food waste, grease, oils and cleaning products contribute significantly to increased contaminant loading and disease-causing microorganisms as compared to light greywater (Ilemobade *et al.,* 2012; Ukpong & Agunwamba, 2012).

➢ **Characteristics of greywater**

The characteristics of greywater depend firstly on the quality of the water supply (Eriksson *et al* 2001), secondly on the type of distribution systems (Eriksson *et al.*, 2001; March *et al.*, 2013) for both drinking water and the greywater (leaching from piping, chemical and biological processes in the biofilm on the piping walls) (Queensl 2003) and thirdly from the activities in the household (Rodda *et al.*, 2010). The compounds present in the water vary from source to source, where the lifestyles, customs, installations and use of chemical household products will be of importance.

The composition will vary significantly in terms of both place and time due to the variations in water consumption in relation to the discharged amount of substances. Furthermore, there could be chemical and biological degradation of the chemical compounds, within the transportation network and during storage (Queensl, 2003).

Physical parameters of relevance are temperature, colour, turbidity and content of suspended solids. High temperatures may be unfavourable since they favour microbial growth. Food particles and raw animal fluids from kitchen sinks and soil particles, hair and fibres from laundry wastewater are examples of sources of solid material in the grey wastewater (Eriksson *et al.*, 2001).

Greywater that originates from the laundry is alkaline and generally has pH-values in the range 8-10, while the other types of grey water generally had somewhat lower pH-values. The pH in the greywater depends largely on acidity and alkalinity in the water supply. However, the higher pH value observed in greywater from laundry shows that uses of chemical products are of importance as well (Eriksson *et al.*, 2001).

> **Sources of greywater**

Greywater is household wastewater that originates from the following: showers, bath tubs, hand basins, toilet (basin) water, laundry water and untreated spa (Queenls, 2003). Greywater from the kitchen sink contains grease and food particles, which can cause clogging and slow infiltration into the soil if not irrigated properly (Eriksson *et al.*, 2001). March *et al* (2003) also added that there are different sources of greywater which are bathtubs, showers, hand-washing basins, laundry machines and kitchen sinks which in general, have a low content of organic matter and pollutants (Domènech *et al.*, 2014).

> **Greywater storage**

In rural and informal settlements, greywater is stored in tanks and buckets. A model for predicting quality changes in stored greywater, based on observed processes of settlement of suspended solids, aerobic microbial growth, anaerobic release of soluble settled organic matter, and atmospheric re-aeration was tested by (Finley & Lyew, 2008).The study suggested that storage of greywater for 24 hours could potentially improve water quality. Storage for more than 48 hours could seriously deplete dissolved oxygen levels and lead to what they call aesthetic problems,

including anaerobic processes and associated smells (Finley & Lyew, 2008). Finley & Lyew (2008) concurred with WHO (2006) that due to bacterial contamination of greywater, untreated greywater should not be kept longer than one day. WHO (2006) further indicated that adding two tablespoons of chlorine bleach per gallon of water will extend storage time. Greywater should be used the day it is collected otherwise the high bacteria count will cause objectionable odour (WHO, 2006). Thus storage of greywater prior to reuse is discouraged because it can affect the pathogen load of both raw and treated greywater. Greywater is therefore pumped immediately to a garden. If greywater needs to be stored, a water purification system must be added to clean the water (Finley & Lyew, 2008).

Chaggu (2011) found out that people of Mwanza City, especially those residing in the study wards, are already separating the greywater (17.4% and 8%) in Igoma and Mbugani wards respectively, due to inadequate pit volume for excreta disposal.

> **Uses of Greywater**

Greywater from households is used differently. Its use is practiced on an informal basis to supplement irrigation water. It also holds the potential to contribute to food security in poor communities by providing a source of both irrigation water and nutrients for crop plants (Domènech *et al.*, 2014).

In arid areas where there is dry grass, greywater is ideal for irrigating firebreaks, because it contributes plant nutrients in the process. Greywater may be used to irrigate gardens during drought periods and also to irrigate golf courses, food crops, parks, playgrounds, school yards, business parks, freeways, landscaping and pasture for animals (Andreson, 2007; Domènech *et al.*, 2014).

In the USA, a trend of increasing acceptance of reuse of greywater has been noted, with some 7% of households practicing some form of reuse. Most households used greywater from the washing machine for garden irrigation (Rodda *et al.,* 2010).

Use of grey wastewater for urinal and toilet flushing is one of the possibilities since the water that is used for toilet flushing in many countries today is of drinking water quality. It has been estimated that 30% of the total household water consumption could be saved by reusing greywater for flushing toilets (Karpiscak *et al.,* 1990). Reuse of greywater from bathrooms has been successfully used in Germany where

it has been shown that it is technically feasible and health requirements can be met (Domènech *et al.*, 2014).

According to Rodda *et al* (2010), the middle to upper income households usually dispose greywater to the sewer, although greywater use does occur, especially in times of drought when water restrictions are imposed. Then the cleaner fractions of the greywater, e.g. bathwater, may be used for car washing or watering the garden.

Rodda *et al* (2010) further reported that the lower income households in South Africa are dependent on the free basic potable water supply or on standpipes situated beyond the boundaries of the properties, shortage of water drives minimisation of water uses other than drinking and cooking. In these groups it is usual for greywater to be used several times before it is discarded. For example, water used to bath adults may thereafter be used to bath their children, wash clothes and finally wash the floors.

Reusing greywater provides a number of benefits including: reducing potable water consumption and the amount of sewage discharged to the ocean or rivers. It also reduces water bills. Greywater has effective nutrients for plant life and less strain on septic tanks. Lagoons or ponds containing greywater can grow algae to feed fish in a separate pond, or provide food for ducks and other waterfowl. In South Africa where home irrigation supplies are limited, rainfall is low, and evapotranspiration is high, greywater reuse is an effective alternative to save potable water (Anderson, 2007).

> **Perceptions on the use of greywater**

The acceptability of greywater reuse is heavily influenced by what it is used for. For example use in golf courses, parks and industry is relatively well accepted, but reuse in people's houses is less popular. Furthermore, acceptability is lower for water uses where contact with the reused water is greater (e.g. in washing machines) than it is for water uses where contact is minimal, for example, toilet flushing (Jeffrey & Jefferson, 2002).

Studies into people's perceptions of communal recycling schemes have found that users prefer to reuse their own greywater rather than someone else's (Jeffrey & Jefferson, 2002). On the contrary Po *et al* (2003) suggested that where communal systems are installed, people prefer larger city wide schemes where the source of

the water is anonymous and not more local schemes where they may know many of the people involved.

Ilemobade *et al* (2012) reported that respondents at the University of Cape Town, Wits University and University of Johannesburg preferred to reuse greywater for toilet flushing compared to garden watering. In comparison to garden watering, most respondents at all institutions preferred toilet flushing but they were concerned of getting sick from greywater reuse for toilet flushing. Furthermore Ilemobade *et al* (2012) reported that toilet flushing was preferred than irrigation. This was due to the perception of possibly lesser contact with greywater if used for toilet flushing than if used for irrigation.

Greywater reuse determined from the qualitative point of view in Igoma and Mbugani wards, indicated that residents were ready to reuse it (Chaggu, 2011). Sixty percent and 28% of respondents from Ingoma and Mbugani wards, respectively, specifically said they wanted to reuse greywater for irrigation (Chaggu, 2011).

➢ **Disadvantages of greywater**

Greywater has the potential for pollution and undesirable health effects if it is not reused correctly. Microbial re-growth and biodegradation of greywater components decrease the concentration of dissolved oxygen in greywater, resulting in the evolution of odours and promotion of mosquito breeding (Athens *et al.,* 1996). Mosquitoes are vectors that spread malaria and other diseases. Greywater has also been shown to contain heavy metals (Athens *et al.,* 1996). Greywater should not be reused if the laundry includes diapers. Greywater containing gasoline, diesel, or similar pollutants, should not be used for purposes other than flushing (Burrows *et al.,* 1991).

The inappropriate use of domestic untreated greywater has the potential to harm the environment in the following ways: Overloading the garden with nutrients or salt; causing degradation to the soil structure, decreasing permeability and changes to soil pH levels; exceeding the site's hydraulic loading; causing runoff of contaminated water into storm-water drains, rivers, streams and other properties; causing the soil to become permanently saturated, preventing plants from growing and causing offensive odours; degrading the soil with contaminants, which affect the soil's ability to assimilate organic material, nutrients and water (Roesner *et al.,* 2006).

There are a number of problems related to the reuse of untreated greywater. The risk of spreading of diseases, due to exposure to micro-organisms in the water, will be a crucial point if the water is to be reused, for example, toilet flushing or irrigation. There is a risk that micro-organisms in the water will be spread in the form of aerosols that are generated as the toilets are flushed (Albrechtsen, 1998). Both inhaling and hand to mouth contact can be dangerous. Growth within the system is another source for micro-organisms and some chemicals.

The risk for pollution of soil and receiving waters due to the content of different pollutants is another question that has been raised concerning infiltration and irrigation with greywater. For instance, Christova-Boal *et al* (1996) stated that infiltration and irrigation may lead to elevated concentrations of pollutants for example in the soil and some plants may suffer due to the alkaline water. These pollutants, originate from the chemical products such as soaps, detergents, etc. that we use in our homes.

The greywater that is going to be reused must also be of satisfactory quality. Suspended solids may cause clogging of the distribution system. Another related problem is the risk of sulphide, which will give offensive odours and thereby cause public nuisance (Eriksson *et al.,* 2001).

2.4.3 Trends on greywater reuse

Water is one of the most important natural resources for human and ecosystem needs, as well as economic development. Sustained growth in human population and economic activity, has led to increasing demand for water.

➢ International studies

Ryan *et al* (2009) reported that female participants and lower income residents were found to be more likely to reuse greywater on their garden, and also lower income residents resort to using greywater as their coping mechanism because they cannot afford other water saving options.

Sondhia *et al* (2007) found out that the community in Victoria, Australia reuses greywater for toilet flushing and watering their gardens as their coping mechanisms due to unavailability of water supply.

Mandal *et al* (2010) conducted a study which aimed at conserving water through greywater treatment and reuse in urban setting with specific context to developing countries such as India. In Nagpur, India, the per capita water availability is reducing day by day due to rapid growth in population and increasing water demand. Greywater treatment and reuse is one of the feasible options in developing countries like India to overcome this problem. A greywater collection, treatment and reuse system was designed and implemented in an urban household having a water requirement of 165 litres per capita per day and a greywater generation rate of 80 litres per capita per day.

Kuntal *et al* (2014) reported that Indian middle-class households if recycled and reused greywater at the site of generation for toilet flushing operations, gardening purposes, it would save a significant quantity of freshwater, thereby saving significant amount of money as well as energy. Santosa *et al* (2012) found out that greywater reuse is a potential method to reduce potable water consumption in buildings and, therefore, to reduce wastewater discharged to public sewage systems and treatment plants. The environmental and economic benefits of such an approach are significant. The study showed that average total greywater production in a typical Syrian urban area was about 46% of the total water consumption. That is, almost half of the domestic water consumption is turned in to greywater. Thus, this amount represents a substantial resource if it can be re-used safely. Toilet flushing on the other hand, consumed about 35% of the domestic water consumption. Therefore, using greywater for toilet flushing can save domestic water consumption (Santosa *et al* 2012).

Faruqui & Al-Jayyousi (2002) conducted experiments on the impact of growing food crops in rural Jordan using greywater to help create food security and generate additional income. His research showed this method hold a great potential. It was reported that the women who participated in this experiment said that they felt empowered by these new skill they have acquired and the ability to better provide for their families. The study did not report any significant adverse effect on the soil.

In a glass house experiment conducted by Pinto *et al* (2010) at the University of Western Sydney, Australia, the study revealed that irrigation of silverbeet with 100% greywater had no significant effects on plant biomass (both root and shoot biomass)

and water use. Also, that the effects of greywater reuse were non-significant for the total nitrogen and total phosphorous contents of soil after the plant harvest.

> ➢ Studies from Africa

The shortage of freshwater resources is an ever-increasing concern worldwide. Particularly in the Middle East and North Africa, the availability of water is reaching crisis levels and chronic water stress is expected to continue to dominate the region (Jury & Vaux, 2007). Madungwe & Sakuringwa (2007); Ukpong & Agunwamba, (2012) found out that greywater comprises 50% to 80% of residential wastewater, which may be used for other purposes, especially landscape irrigation and toilet flushing. Greywater on the other hand was discovered as an important conservation strategy contributing to the maintenance of agricultural production in many parts of the world (Florida DEP, 2006). They further reported that greywater reuse should be possible in African cities such as Harare, where nearly two thirds of the population rely on agriculture for livelihoods. Countries that reuse greywater include among others: Tanzania Chaggu, (2011) reported that respondents in Igoma and Mabugani wards in Mwanza Tanzania reuses greywater for irrigation.

Hyde (2013) conducted a study to evaluate the theoretical potential and practical opportunity for using recycled greywater for domestic purposes in Ghana. The Study found out that treated greywater can be used for domestic cleaning, for flushing toilets where appropriate, for washing cars, sometimes for watering gardens.

ROSA (2010) reported on the use of greywater in tower gardens at household level at Kitgum, Uganda. The research findings were that the effect of greywater application on the soil characteristics was not significant with respect to potassium, organic matter and nitrogen content. However a slight decrease in phosphorus content, possibly due to plant uptake. Tomato and onion grown in the tower gardens thrived with the greywater (ROSA, 2010).

> ➢ Studies from South Africa

In South Africa greywater is suitable for irrigating lawns, trees, ornamentals, and food crops. It is applied directly to the soil, not through a sprinkler or any method that would allow contact with the above ground portion of the plants (Adewumi *et al.*, 2010). Jacobs & Van Staden (2008) found out that garden vegetation and lawn grass seems to thrive well when irrigated with greywater, despite the higher-than-

recommended sodium content in the soil. Plants that thrive only in acid soil are not watered with greywater, which is alkaline (Adewumi *et al.*, 2010). Greywater is used only on well-established plants, not seedlings or young plants. Greywater is dispersed over a large area, and it rotates with fresh water to avoid build-up of sodium salts (Florida DEP, 2006). Adewumi *et al* (2010) conducted a study, which aimed at providing an overview of the South African water resources situation and wastewater generation in order to put the need for greywater reuse into perspective. Potential for broader implementation and parameters influencing wastewater reuse based on local attitudes and experience were discussed to facilitate broader implementation of wastewater reuse. Adewumi *et al* (2010) and Rodda *et al* (2010) further reported that household wastewater reuse involved the collection of wastewater and it is used for non-drinking requirements such as toilet flushing and irrigation.

Carden *et al* (2007) in the study to investigate the use and disposal of greywater in non-sewered areas in South Africa and this included developing options for the management thereof. The research revealed that reuse of greywater in not advised in non-sewered areas unless it is done under controlled conditions. Additional findings have also showed that for settlements densities above 50 dwellings per hectare greywater poses unacceptable risk to the occupants.

Mzini & Winter (2015) reported on irrigation of soils with greywater did not change soil pH and sodium content, compared to soil irrigated with diluted greywater or potable water. Therefore, the greywater used in this study does not appear to cause an accumulation of salts and heavy metals in soil, in the short term.

Ilemobade *et al* (2012) conducted a study on greywater reuse for toilet flushing at a university academic building at the University of the Witwatersrand and at a university residential building at the University of Johannesburg. The study found out that the lower the possibility of contact with greywater, the more acceptable is to potential beneficiaries. Hence, the preference expressed by respondents in this study was for toilet flushing with greywater instead of greywater for irrigation. Non-residential buildings may likely be preferred to residential buildings for greywater. In this study higher percentage of respondents were generally in favour of greywater for

toilet flushing at the university academic building than at the university residential building.

2.5 Legal requirement and water conservation legislations

The Constitution of South Africa (Act 108 of 1996), chapter 2, Bill of Rights section 24, stipulates that everyone has the right to an environment that is not harmful to their health or wellbeing. The objective of the law is to protect human health from the adverse effects of any contamination of water intended for human consumption by ensuring that it is clean.

The Water Conservation and Demand Management National Strategy Framework of the Department of Water Affairs and Forestry (DWAF, 1999) tentatively defines the concept water conservation as comprising the adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

2.5.1 Overview of Legislative provisions

According to the Constitution of the Republic of South Africa (Act 108 of 1996) it is every person's right to have access to clean water. It is from this background that the Department of Water Affairs (DWAF) as a policy formulator and implementer initiated the Water Supply and Sanitation Programme in 1994 in order to achieve a constitutional objective of ensuring that all South Africans have access to sufficient water and healthy environment with the focus on rural areas.

The Free Basic Water Policy was officially launched in July 2001. By March 2004, some 155 of the 170 Water Service Authorities claimed to be providing Free Basic Water. The total number of people receiving Free Basic Water at that stage was estimated at 30,5 million. Through the Free Basic Water Policy, each household receives up to 6000 litres of clean water per month (Berger, 2004).

In 1997, the Water Service Act, 1997 (Act 108 of 1997) was passed. The aim of this Act was to ensure and define the right of access to basic water supply and basic sanitation services, to set out the rights and duties of consumers and those who are responsible for providing services and also to allow the minister of Water Affairs and

Forestry to set national standards (including norms and standards) to ensure sufficient, continuous affordable and fair water services.

2.5.2 National Water Act 1998 (Act 36 of 1998)

The purpose of the above Act is to ensure that the nation water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors meeting the basic human needs of present and future generations.

The National Water Act of 1998 among others, addresses the use and disposal of water in South Africa. The Act makes no specific reference to greywater, but refers to disposal of waste or water containing waste. This may be considered to apply also to greywater.

2.5.3 Regulations and guidelines for water reuse

Access to sufficient water is recognised as a basic human right in the Constitution of South Africa, as is the right to an environment not harmful to health or wellbeing. Seventy six per cent of municipalities have implemented the free basic water policy and supply 6000 litres of water per household free of charge to cater for poor households (DWAF, 2001). National Regulations that briefly address reuse can be found in the latest revision of the Water Services Act of 1997 relating to greywater and treated wastewater (DWAF, 2001) and the latest revision of the National Water Act of 1998, 37(1) relating to irrigation of any land with waste or water containing waste generated through any industrial activity or by a water works (DWAF, 2004).

In the above documents, there is no objection to the reuse of wastewater for different non-drinking water requirements. However, reuse must be permitted and monitored by the relevant Water Services Authority using rigorously developed by-laws.

2.5.4. National Water Resource Strategy (NWRS, 2013) chapter 4: Water reuses.

According to the National Water Resource Strategy (2013), the Department of Water Affairs has developed a National Strategy for Water Reuse, which provides a considered approach to the implementation of water reuse projects. The National Strategy for Water Reuse is a sub-component of, and is consistent with the National Water Resource Strategy. The intention of the National Strategy for Water Resource is to better inform decision-making surrounding this valuable resource through the

development of guidelines for the implementation of water reuse projects. The guidelines will address the choice of wastewater treatment technology, water quality standards, project financing and tariff implications, implementation, and operations and maintenance.

Particular attention is given to public and stakeholder engagement, education and consultation. The Department of Water Affairs (DWAF) reviews water-related laws and regulations to assess the need for amendment to facilitate reuse in cooperation with the Water Research Council and make water reuse technology development a key focus area for research. DWAF explores the use of new technologies for reusing wastewater and for using treated mine water, and will encourage the development of centres of excellence in this regard at selected universities (NWRS, 2013).

Municipalities conduct feasibility studies of water reuse options in all water-scarce areas. Such investigations are planned for eThekwini (treated effluent from eThekwini and KwaMashu), Nelson Mandela Bay, Rustenburg, Mangaung, Buffalo City, George-Mossel Bay, and Mbombela-Bushbuckridge over the next five years. Where the municipality lacks capacity to conduct such a study, the DWAF will provide support. The performance of existing wastewater treatment plants in terms of meeting discharge standards and reliability is critical to the successful integration of water reuse into Reconciliation Strategies and into water supply systems in South Africa. These facilities discharge treated wastewater into the water environment with consequences for the safety, economy and fitness for use of the water resources by downstream users (NWRS, 2013).

2.5.4 Wastewater reuse by-laws in South Africa

In South Africa the by-laws are the local laws established by municipalities and their scope is regulated by the central government of the nation. The examples of South Africa's by-laws on wastewater reuse are; the City of Cape Town Treated Effluent by-law (2010), the Durban Metro Water Supply by-laws (2008) and the Moses Kotane Local Municipality Water and Sanitation by-laws, (2008).

In July 2010, the City of Cape Town promulgated its treated effluent by-law. The City of Cape Town remains the only municipality in South Africa with a by-law specifically addressing treated effluent. The by-law aims to control and regulate treated effluent in the City of Cape Town, and to provide for matters connected therewith. Treated

effluent is broadly defined as wastewater which has been treated at one of the city's wastewater treatment plants. To this end, the by-law does not directly address greywater which differs in character and hazards from treated effluent (Local Municipality Water and Sanitation by-laws, 2008).

The Durban Metro Water Supply by-laws (2008) state that no person shall use or permit the use of water obtained from a source other than the (potable) water supply system, except with the prior consent of the Authorised Officer and in accordance with such conditions as it may impose for domestic, commercial and, industrial purposes as well as filling of swimming pools. The by-law employs the term non-potable which caters for the diversity of non-conventional water resources including greywater.

The Moses Kotane Local Municipality Water and Sanitation by-laws (2008) Section 78 (1) understands greywater to be wastewater excluding "water derived from any kitchen, excluding clothes washing machines, or from toilet discharges" and as such, states the following as regards greywater use:

➢ Section 60. All commercial vehicle washing facilities shall be constructed and operated in such a manner that 50% of the water used by such facility is recycled for reuse in the facility;

➢ Section 61. Any device which entails the recycling or reuse of water shall not make use of water derived from any kitchen, clothes washing machines, or from toilet discharges (The Moses Kotane Local Municipality Water and Sanitation by-laws, 2008).

In Limpopo Province, specifically Capricorn District Municipality and Lepelle-Nkumpi Local Municipality, there are no by-laws on wastewater or greywater reuse. The Lepelle-Nkumpi Local Municipality, in terms of section 13(a) in conjunction with section 75 (1) of the Municipal Systems Act, 2000 (Act No. 32 of 2000), published the Public Amenities by-law for its local municipality which states that no person may misuse, pollute or contaminate any water source or water supply or wastewater in or at any public amenity.

2.6 Summary

This chapter presented an overview of literature on the water scarcity and, availability and accessibility. Further the chapter focused on legal requirements and water conservation. The next chapter focuses on methodology.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This Chapter presents a brief description of the study area and the research methods used to collect and to analyse the data.

3.2 Study Area

The research was conducted in Lepelle-Nkumpi Local Municipality which is one of the 5 local municipalities in the Capricorn District Municipality, Limpopo Province of South Africa (Figure 5). It is geographically located at latitudes 24° 17' 56.76" south and longitudes 29° 31' 58.8" east. The Lepelle-Nkumpi Local Municipality is located 55 km south of Polokwane city and 90 km from the University of Limpopo (Turfloop campus).The municipality is predominantly rural with a population of 230 350 people and covers 3 454.78 km^2, which is 20.4% of the district's total land area. It is divided into 29 wards, which comprise of a total of 93 settlements. Among the 93 settlements there is one urban settlement called Lebowakgomo and 92 rural settlements. About 95% of its land falls under the jurisdiction of Traditional Authorities. All sittings of the Provincial Legislature take place at Lebowakgomo old Parliament for the former homeland and it is one of the Capricorn District Municipality growth points.

The municipality is situated on an elevated plateau with an altitude ranging between 1200 m and 1500 m above sea level. The climate of Lepelle-Nkumpi Local Municipality can be described as a subtropical climate with very hot, humid summers and a cooler, dry and sunny winter season lasting from June to September. The dry season begins from April and extends all the way to October, nearing the beginning of a hot, humid wet season. The annual average sum of precipitations is 489 mm, which indicates the aridity of the region (SAWS, 2012). The maximum amount of rainfall is observed in summer and the minimum amount of rainfall is observed in winter and spring with no rainfall at all (SAWS, 2012). The map (Figure 5) shows the physical location of Mashite village and Lebowakgomo (Zone F) township in Lepelle-Nkumpi Local Municipality.
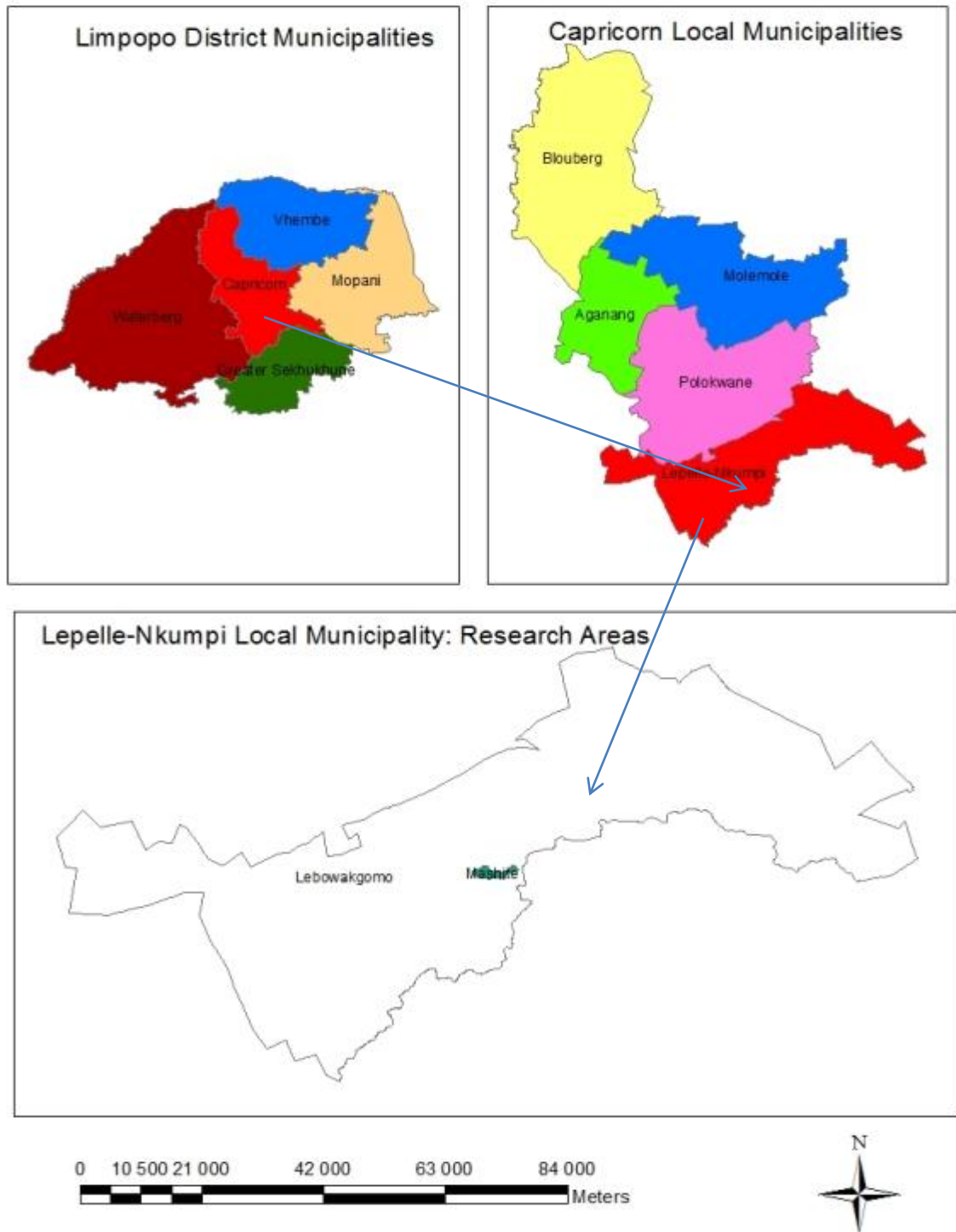
Figure 5: The study area
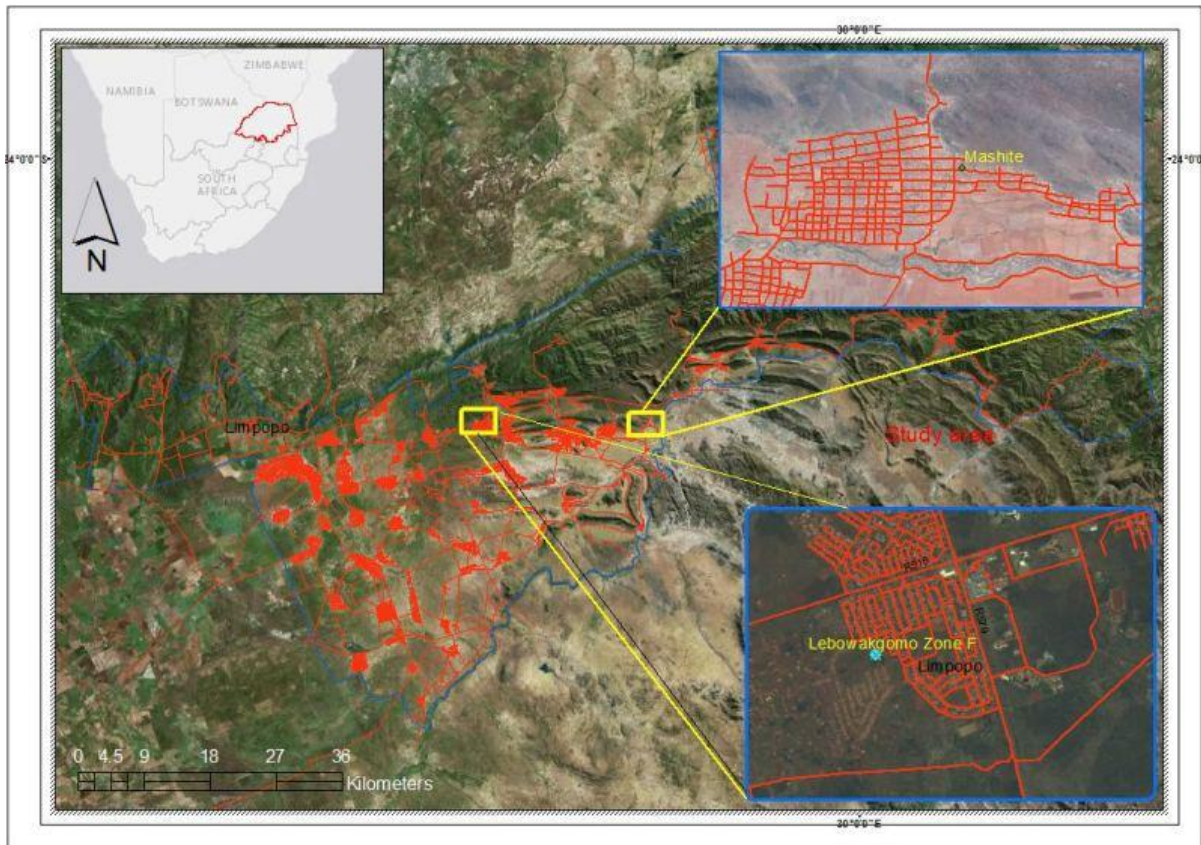
Figure 6: Study area

3.3 Research design

The study adopted both quantitative and qualitative approaches since it involves the measurements of quantitative and qualitative characteristics. The study adopted this research design because of quantifiable data that is presented in the form of graphs and tables. Furthermore, the design is qualitative in that other information from interviews are in a descriptive reporting form.

3.4 Sampling

3.4.1 Study population

The sampling frame was the 93 settlements of Lepelle-Nkumpi Local Municipality, with a population of about 230 350 people, a total of 59 682 households. Population size for Mashite Village was 5314 and 5903 for Lebowakgomo Zone F. According to the Census Report South Africa (2013), the number of households in Mashite village is 1231 and in Lebowakgomo Zone F is 1924.

3.4.2 Research procedure

Purposive random sampling was used to select the Mashite village settlement and the Lebowakgomo Zone F urban settlement. This is because water use characteristics are likely to differ in rural and urban settlements. Consequently, a comparison of the greywater reuse between these two settlements will be useful. Households in Mashite do not have running water unlike Lebowakgomo Zone F which has been identified as a potential growth point with improved service delivery.

Four percent of the total households in each selected community participated in the study. For Mashite with 1231 households, a sample of 49 households was selected. On the other hand, 77 households were selected from Lebowakgomo Zone F with a total number of 1924 households. A systematic random sampling method was used to select the required households from the two settlements. The kth value in this case is the total number of households divided by the sample size in each settlement.

$$k = \frac{N}{n}$$

K: Sampling interval (sometimes known as the skip)

N: Population size

n: Sample size

The kth value in each settlement is 25. The first household was randomly selected for each settlement and thereafter every 25th household was selected.

3.5 Data collection

3.5.1 Secondary data

Secondary data such as the number of households in Lepelle-Nkumpi Local Municipality was acquired from the municipality's Integrated Development Plan (IDP). Furthermore, greywater reuse literatures were obtained from research reports, journal articles, the internet and books. Provincial boundaries were obtained from South African National Space Agency (SANSA, 2014), and the municipal demarcation downloaded from http://www.demarcation.org.za Accessed 14 May 2014.

3.5.2 Primary data

Primary data were collected using the following methods:

> **Questionnaires**

A questionnaire was designed with both open and close ended questions. The questioner consisted of 26 questions of which 16 were close ended and 10 were open ended. The questionnaires were distributed among the sampled households in the selected settlements of Lepelle-Nkumpi Local Municipality. The questionnaires were self-administered to 126 households (49 for Mashite village and 77 for Lebowakgomo Zone F). Only the heads or any older members of the family in each household were required to complete the questionnaire. The questionnaire dealt with the socio-economic characteristics, accessibility and availability of water supply, the coping mechanisms of water scarcity and perception of greywater reuse at Lepelle-Nkumpi Local Municipality.

> **Key informant interviews**

The Induna at Mashite village was interviewed about the strategies which they use for the minimisation of water wastage and its conservation; he was also asked as to whether he sensitizes communities on water conservation by organising awareness campaigns and public participation events.

> **Field observation**

Observation was the most important method of identifying areas where the water is conserved or not conserved. It took three days to observe the physical condition of water conservation or wastage. Photos on water conservation facilities such as water storage tanks, and water wastage such as burst pipes, leaking taps etc. were taken by the researcher in order to show the status of water conservation in Lepelle-Nkumpi Local Municipality.

> **Points collection**

Geographical Positioning System (GPS) was used to collect absolute location of available water taps and the reservoir in the Mashite village. Slope information was obtained from Digital Elevation Model (DEM) using GIS software package ArcGIS 10.1. The source of DEM was from SANSA which was 90 m spatial resolution and point data was through the use of a GPS. All collected points were added into an excel sheet before they were mapped in the GIS software. The polygons rivers data

and the SPOT building count were used as restricted areas to suitable locations. The thematic maps were developed for each of the parameters. All the maps were geo-referenced to the Universal Transverse Mercator (UTM) coordinate system.

3.6 Pilot study

A duration of a week was used to conduct a pilot study at Lepelle-Nkumpi Local Municipality. The purpose of the pilot study was to evaluate the appropriateness and quality of data collection methods. The pilot study also gave an opportunity to practice the interviewing techniques. The outcome of the pilot study assisted to validate the research instruments. After validating the research instrument, then the main study was conducted.

3.7 Data analysis

The data collected from the questions during the study was gathered from two types of questions; the first type was closed ended questions dealing with the socio-economic characteristics of the communities, accessibility and availability of water supply as well as the coping mechanism for water scarcity. The responses were analysed using SPSS version-22 to obtain the interrelationship of responses to different questions in average and graphical forms. Descriptive statistics in the form of frequencies and mean was computed to describe the characteristics of the collected data. The descriptive statistics was also used to ascertain the households' coping mechanisms during water scarcity, to assess the accessibility and availability of water supply and lastly to ascertain the perceptions on greywater reuse by the two communities of the study area. These responses were compared for similarities or differences using Pearson Chi-square test method.

$$X^2 = \sum \frac{(O - E)^2}{E}$$

O = Observed frequency

E = Expected frequency

$\sum$ = Summation

X^2 = Chi Square value

The second type was open-ended questions, which were included in the survey so that the respondents could express their opinions, suggestions and recommendations on the reuse of greywater. These responses were manually analysed to develop suggestions and recommendations to minimize the challenges which are facing the community regarding greywater reuse.

GPS Points collected data were analysed using criteria for accessibility analysis. The following is the formula for suitability criteria.

➢ Formula for suitability criteria

$$S = \sum w_i\, x_i \prod r_j$$

S: Suitability for water accessibility site

W_I: Weight for criteria

X_i: Criteria for suitability

r_j: Restriction

∑: Sum of

∏: Cartesian product of

Two suitability criteria were used for the analysis. The first one was the factor criterion which enhances or detracts from the suitability of a specific alternative for the activity under consideration e.g. distance to water taps (near = most suitable; far = least suitable). The second one was the restriction criteria which serves to limit the alternatives under consideration such as an element or a feature that represents limitations or restrictions and area that is not preferred in any way or considered unsuitable e.g. protected area, water body etc.

➢ Factor Criteria (Accessibility and Suitability)
Distance to the nearest water taps (point layer with taps)

➢ Proximity of SBC to Operational taps (near = most suitable; far = least suitable)
➢ Elevation with best attribute from 1 to 4

Table 1: Criteria suitability

Suitability Source	Minimum Buffer Distance (m)	Maximum Buffer Distance (m)	Accessibility	Analysis Buffer Distance (m)
Water Taps	20	50	Taps & Houses	50
DEM	No buffer	No buffer	Slope	

➢ Restriction criteria

Rivers: Restriction related to river location

Streets: Restriction related to street location

Reservoir: Restrictions related to reservoirs location

Table 2: Criteria restrictions

Restriction Criteria	Minimum Buffer Distance (m)	Maximum Buffer Distance (m)	Analysis Buffer Distance (m)
SPOT Building Count_2006_2012	20	50	50
Street National	100	300	200
NFEPA Rivers	30	200	100

➢ Considerations for Accessibility

Water taps accessibility was analysed by measuring the proximity of water taps to houses using the SPOT 5 building count data sets. The cadastral layer was not used due to lack of data coverage in the study area. Proximity analysis was done by buffering the GPS points (water taps) at a distance of 20 meters and overlay the data together with the houses data to evaluate water accessibility. The closer the spot

building counts to the buffers, the more accessible and the further they are, the least accessible to the taps.

3.8 Summary

This chapter described the method used to collect data and methods used to analyze data that were considered to differentiate the characteristics that matter most to greywater reuse as a water conservation method.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings of the study with a view to address the research questions and hypothesis/assumption raised in chapter one. The results present the demographic characteristics and accessibility and availability of water supply, coping mechanisms of water scarcity and perception of greywater reuse using key informant interviews and field observation. They are provided in the forms of tables and charts, and interpreted in terms of percentages.

4.2 Socio-economic characteristics

Socio-economic status is a measure of individuals' or families' economic and social position based on education, income, gender, employment, household size, marital status and occupation. According to the Municipal Systems Act 32 of 2000, municipalities are given the power to move progressively toward social and economic upliftment of local communities and ensure universal access to essential services that are affordable to all. Important demographic factors identified for this study were age, gender, marital status, household size, education level, employment and level of income.

4.2.1 Age of the respondents

Age plays an important role in enabling the households to participate and apply new ideas and practices such as new water conservation and reuse methods. According to the theory of human capital, young members of a household have greater chance of absorbing and applying new knowledge (Sidibe, 2005).

Figure 7: Shows the age distribution of the respondents in the study areas.
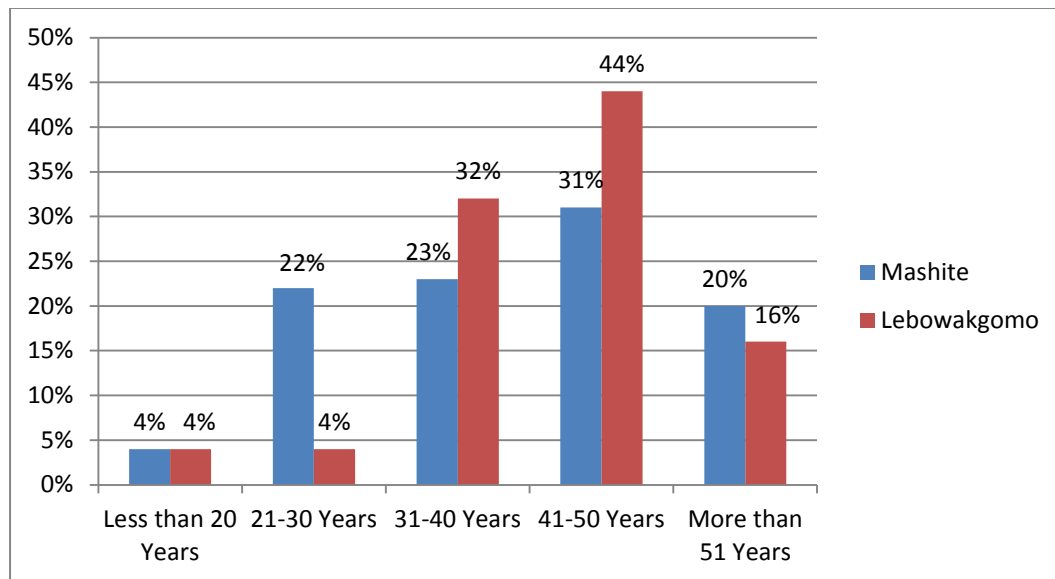
Figure 7: The age of the respondents

The age of the respondents was grouped into five categories as indicated in the figure 7. In Mashite village, most of the respondents (31%) were between 41 to 50 years of age followed by 23% of the respondents aged between 31 to 40 years. The percentage falling under 21 to 30 years age category was 22%, followed by the group in the more than 51 years category (20%). The remaining respondents were younger than 20 years and constituted only 4%. Respondents results on age distribution in Lebowakgomo Zone F had similar sequence for 41 to 50 years, and for 31 to 40 years, 21 to 30 and less than 20 years as in Mashite village. However, the percentages of groups were different, with the exception of the less than 20 years which had the similar percentages (4%) for both areas. Forty-four percent of the respondents in Lebowakgomo Zone F were 41 to 50 years old, followed by 32% (between 31 to 40 years old). Only 16% of the respondents were older than 50 years. The reason Mashite village ranked higher in the age group between 21 to 30 years than Lebowakgomo might be because most of the Lebowakgomo youths are at tertiary institutions or that those who had finished tertiary education are working in towns as compared to Mashite where most of them have families and their own houses. According to Badisa (2011) in a study of Thulamela local municipality, the higher age of the respondents was between 40 to 50 years which is similar to this study.

4.2.2 Gender of the respondents

Gender is defined by FAO (2012) as the difference between men and women, based on their social and cultural differences. Table 3 illustrates the percentage composition of both males and females who contributed to this study.

Table 3: Gender distribution of the respondents

Areas	Male	Female
Mashite	24%	76%
Lebowakgomo	30%	70%

Out of 49 households sampled in Mashite, majority (76%) were female, while 24% were male. In Lebowakgomo Zone F, the majority of the respondents (70%) were female while 30% were male. The reason why most of the respondents were female might be because most of the women are at home, carrying out household chores than men. Another reason could be that most of the household heads are female. Further, the data was collected during the day, where most men were likely to be at work at time of conducting the study. In most instances, women have been regarded as an inferior class until the post-apartheid era when women empowerment started receiving the major attention in South Africa. A study carried out by Al-Khatib *et al* (2009) reported that women participants are more than men which is similar to this study. The reason being that women are responsible for household chores and since the study was conducted during the day, most men were probably at work during that time of the day. According to Census Report South Africa (2011), there are more female than males in South Africa, mostly in rural areas, because of the migrant labour system where men migrate to urban areas in search of work. The Gender Development Group (GDG) (2002) supports the above statement by indicating that women are most often users, providers and managers of water in the rural households. They are the guardians of households' hygiene as well. It is usually women who collect water and carry out households chores.

4.2.3 Marital status

Marital status is one's situation with regards to whether one is never married, married, separated, divorced or widowed. Figure 8 shows the marital status of the respondents in the study area.
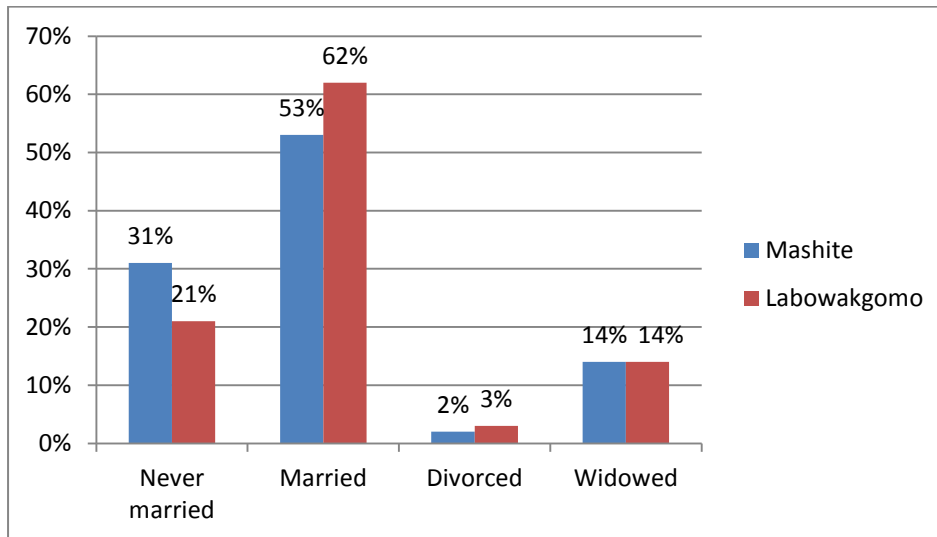
Figure 8: The marital status

From Figure 8 in Mashite village, 53% of the respondents were married, 31% never married, fourteen percent (14%) were widowed and 2% were divorced. For Lebowakgomo Zone F, 62% of the respondents were married 21% never married, fourteen percent (14%) were widowed while 3% said they were divorced. This finding is in line with the Census Report South Africa (2011) which reported that there were more married people than divorcees in South Africa.

4.2.4 The qualification of the respondents

Education plays a very important role in influencing the household perception on adopting new knowledge and technologies of greywater reuse, and how such knowledge is disseminated as well as its sustainability. Thus, it influences the level of understanding and assimilation of the development issues (Agricultural Support Programme, 2004). Figure 8 shows the educational qualification of respondents in the two study areas.
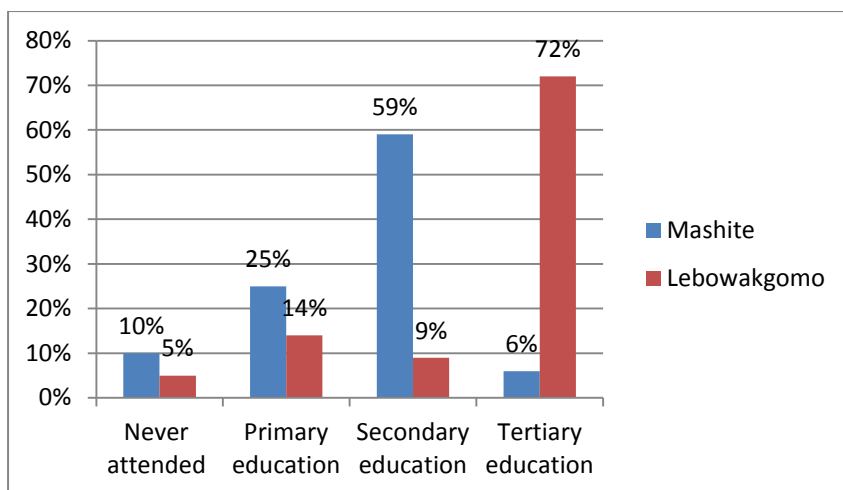
Figure 9: The education qualification of the respondents

In Mashite 59% of the respondents indicated that they have completed secondary education, 25% had primary education, 10% never went to school at all; and only 6% had tertiary education. On the contrary, respondents educational qualification in Lebowakgomo Zone F had a different sequence as compared to Mashite village. Seventy-two percent of the respondents completed tertiary education, 14% only went up to primary level, 9% went to secondary education, while 5% said that they never went to school (Figure 9). The highest educational qualification for Mashite was secondary education as compared to Lebowakgomo Zone F which was tertiary education. The reason might be that in villages most people finish schooling at primary or secondary level and they start searching for jobs or become parents at an early age as compared to townships where the majority study further.

The highest percentage of the respondents with tertiary education at Lebowakgomo Zone F was influenced by government employees who are mostly teachers and nurses. Most of the employees are stationed in Lebowakgomo township which is the administrative town of Lepelle-Nkumpi Local Municipality.

Although education plays a key role in influencing households' perception on adoption of new ideas and their application (ASP, 2004), this is not true in the study areas as indicated in Table 11. In spite of the fact that the majority of Lebowakgomo Zone F respondents (72%) attended tertiary education, their knowledge of greywater was lower (81%) compared to Mashite village where with only 6% of respondents having obtained the highest qualification do have a high number of those who have

knowledge of greywater (94%). Contrary to the role of education towards the knowledge of greywater, it played a role in the interest to reuse greywater (Table 12). Lebowakgomo Zone F respondents (76%) indicated that they would prefer to reuse greywater compared to respondents of Mashite village (49%).

4.2.5 Household size

Household size is the number of people living together in the same house. Table 4 shows distribution of household size. Generally, large households' sizes have more mouths to feed and, as a result, they use more water which, in turn positively affects greywater generation and possibly reuse. In this study, the minimum household size in Mashite was 2 people and the maximum 13 people whereas in Lebowakgomo Zone F the minimum household size was 1 person and the maximum was 4 people, respectively (Table 4).

Table 4: Distribution of household size

Area	Household size			
	Maximum	**Minimum**	**Standard deviation**	**Mean**
Mashite	13	2	2.634	6.18
Lebowakgomo	4	1	1.432	2.77

The average households' size for Mashite village was 6.18 as compared to Lebowakgomo with 2.77. This might be because in Lebowakgomo Zone F most people are educated as compared to Mashite village. Generation of greywater in Mashite village varied from 40 litres to 500 litres. This might be due to household size where large household sizes produce more greywater as compared to small household sizes. As for Lebowakgomo, greywater was not stored.

4.2.6 The employment status

Employment is the state of being employed and earn a salary. Figure 10 shows the employment status of the respondents. In Mashite village, 64% of the respondents were unemployed, 24% were self-employed while the remaining 12% of them were employed. Occupations of the respondents who said they are employed included the following: teachers, nurses, nannies, clerks, police officers, security officers, gardeners and cleaners.
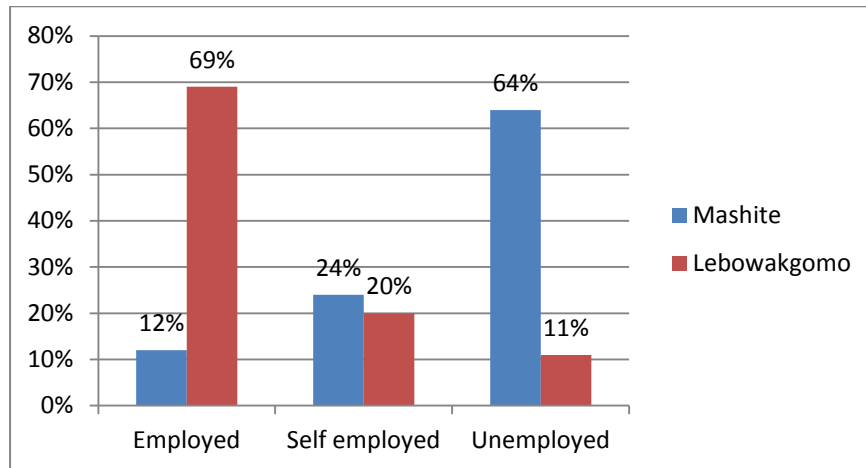
Figure 10: The employment status of the respondents.

Contrary to Mashite village, the majority of the respondents in Lebowakgomo Zone F (69%) said they are employed. Twenty percent were self-employed while 11% were unemployed. Occupations of the respondents who said they are employed include: teachers, nurses, doctors, clerks, police officers, accountants, geologists and cleaners. The employment status of the two areas at the time of the interview differed. This is because Lebowakgomo Zone F is the capital town of Lepelle-Nkumpi Local Municipality.

4.2.7 Level of income of the respondents

The level of income enables households to meet their essential needs as well as investing in other uses such as technology implementation, and it may also encourage the need for greywater reuse as a water conservation method. Studies have shown that the level of income positively influences adoption of new water conservation strategies (Savadogo *et al.,* 1994; Adesina, 1996). Figure 11 shows the level of income per month of the households' in Mashite village and Lebowakgomo Zone F.
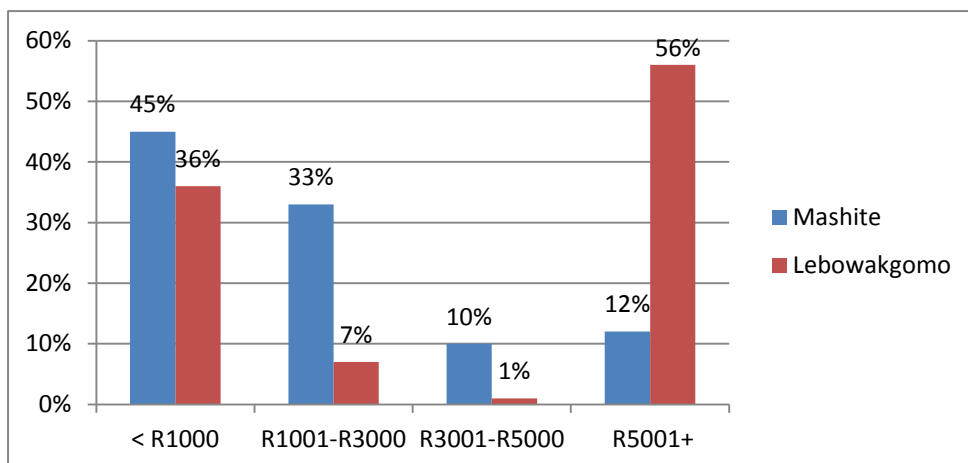
Figure 11: The income of the respondents

The results in Mashite village indicate that 45% of the households earn less than R1000 per month, 33% earn between R1001 to R3000, 12% earn more than R5001, while the remaining 10% earn R3001 to R5000. In Lebowakgomo Zone F 56% of households earn more than R5001 per month, 36% earn less than R1000 per month, 7% earn between R1001 to R3000 per month, while only 1% of the respondents are earning between R3001 to R5000. The reason for the high income level in Lebowakgomo might be because many respondents are working as compared to Mashite village where many are unemployed, and thus depend on old age and child grants. A higher percentage of Mashite village respondents (98%), reuse greywater compared to Lebowakgomo Zone F respondents (59%) (section 4.4.2) in spite of their level of income. In this case the higher level of income did not encourage greywater reuse.

4.3 The accessibility and availability of water supply

The accessibility and availability of water supply is the extent to which people can obtain water at the time it is needed. A municipality as a water service authority must prepare a water service development plan to ensure effective, efficient, affordable, economical and sustainable access to water services that promote sustainable livelihoods and economic development (DWAF, 2003).

4.3.1 Sources of water

Sources of water refer to water from streams, rivers, dams and, taps, which ensure the availability of water to users such as communities, industries etc. Figure 12 shows the water sources for households.
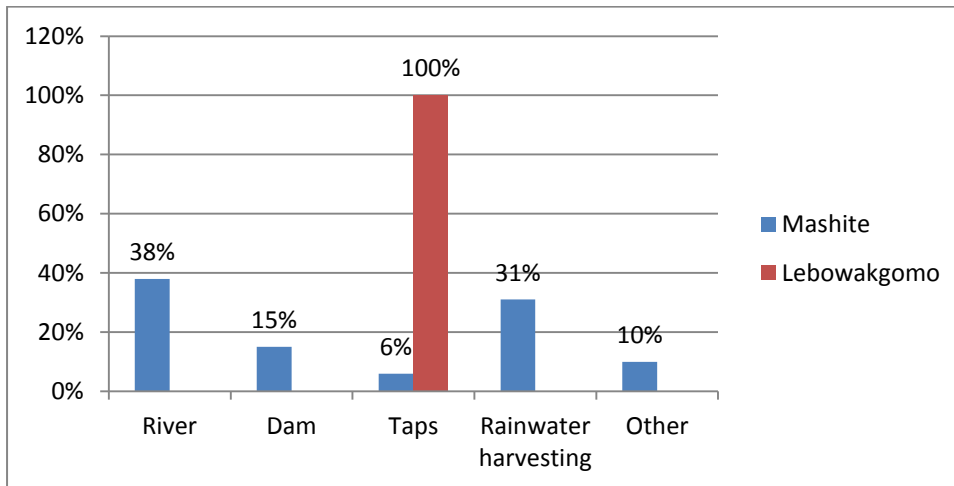
Figure 12: Sources of water

The majority of households (38%) in Mashite get water from the rivers, 31% harvest rainwater, 15% obtain water from the dams, and 6% get water from taps. Lastly, 10% of the respondents buy water from other households where they pay R2 for 20 litre and R20 for a 210 litre tank, while others installed their own borehole taps. Households that depend on social grants are likely to suffer the most due to their lower levels of income Motoboli (2011). All of the respondents in Lebowakgomo Zone F access water from the taps. According to the HDR (1997) and Motoboli (2011), inadequate water supplies are the cause and effect of employment. Similar studies have been done in Thabazimbi local municipality where the community sometimes spend about a month without water. The community is forced to spend R1.50 to get 25 litres of water and many people are not working and those who cannot afford to pay for water resort to using water from the wells, fountains or rivers (Manamela, 2010).

4.3.2 Distance from the water sources

Distance from the water source is the distance one travels to get water, and according to the RDP standard of South Africa it has to be 200 m or less (RSA, 1997).

When the respondents in Mashite were asked how far are the water sources from their homes, 94% of them said less than 1 km, while 6% of them said between 1 km and 3 km. The majority of the respondents said that the nearest water source is found at the corner house which is less than 1 km from their houses while others said the next street which is also less than 1 km. In contrast, Lebowakgomo respondents mentioned that they do not travel to the water sources as they have taps indoors.

Figure 13: The distance from households to the nearest water tap

Proximity analysis was done at a distance of 50 m to 100 m, 100 m to 150 m, 150 m to 200 m, and the data was overlaid together with the houses data to evaluate water tap accessibility. The orange buffer zone is 50 m to 100 m which indicates that houses in these buffer zones are accessible to stand pipes as compared to green and blue buffer zone areas. The green buffer zone is 100 m to 150 m which indicates moderate accessibility and the blue buffer zone 150 m to 200 m indicates low accessibility to stand pipe (Figure 13).
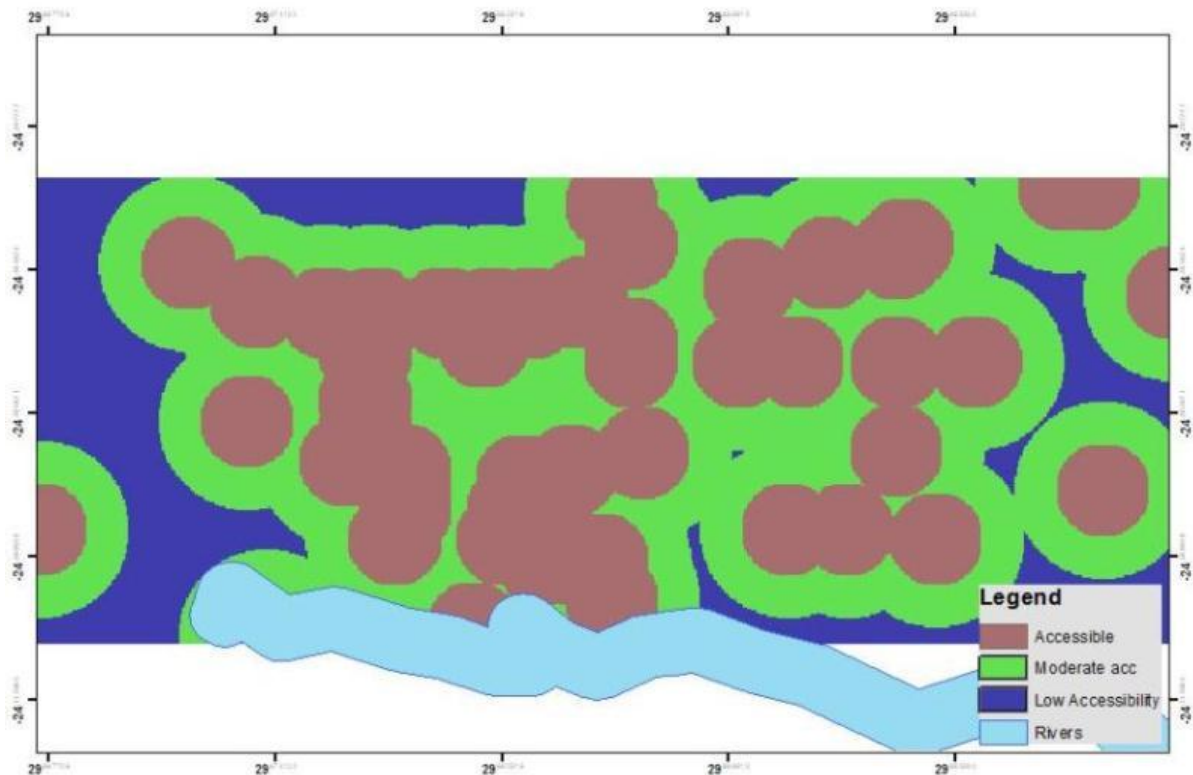
Figure 14: Households with poor access to water

From Figure 14 above households with poor water accessibility are in the blue buffer zone. The present delivery of stand pipes does not adequately meet the needs of the most poor and vulnerable (Figure 14). The figure also shows that stand pipes are not evenly distributed. According to WHO (2006), rural areas in Africa are the ones mostly with limited sources of water. Not only is there poor access to readily accessible drinking water, even when water is available it is not enough. This mostly affects the individuals travelling more distance to the source of water.

4.3.3 Availability of water

According to the Water Service Act, 1997 (Act 108 of 1997) availability of water is the right of access to basic water supply. Table 5 shows percentages of respondents to availability of water. The communities, when asked if the water is always available, gave the following answers, in Mashite village all respondents (100%) said no, whereas, in Lebowakgomo Zone F, 73% of the respondents said yes and 27% of the respondents said no (Table 5).

Table 5: Percentages of responses to availability of water

| Area | Is water always available? | |
	Yes	No
Mashite	0%	100%
Lebowakgomo	73%	27%

The Mashite community emphasised that they wanted the water taps to be erected inside their yards and not in the street. According to the municipality, the decision to erect the taps on the street was part of phase 1 of a larger water project. Their plan was that stand pipes would be followed by the erection of the water taps in the yards as well as providing for water meters. The supply of water from the street taps/stand pipes is not done on a daily basis. The number of taps varies per street as others have none, one, two, four, five, six and ten but they also included the ones which are not working. Respondents in Lebowakgomo said that they do not have stand pipes.

Availability of water from stand pipes varied across Mashite village. Some sections had stopped drawing water from the taps, whereas some sections received stand pipe water after every two days per month while in other sections running stand pipe water was available during the day only. The new stands do not receive stand pipe water at all because the water is unable to flow to these sections due to the weak water pressure from the main supply. The quantity of water supply to the villagers is below the RDP standard. The villagers often stand in long queues to fetch water from the taps. The flow rate is at 25 litres of water per 20 minutes. This is contrary to the RDP standard which is 10 litres of water per minute (200 litres per 20 minutes). The scramble for water supply at Mashite village is still visible and it is a common feature. Sometimes water taps run dry while people are still in the queue. This is a physical water scarcity since there is no enough water to meet all demands.

The expectation of the villagers is that water supply should be done on a daily basis. Villagers fetching water from the river do not drink it; they use it for washing clothes, bathing, cleaning and irrigation.

4.3.4 Uses of water

Water as an essential natural resource is required to meet several human water needs such as domestic, agricultural, industrial etc. Water uses in the study area include domestic use, irrigation and animal watering. Figure 15 shows the uses of water by the respondents.
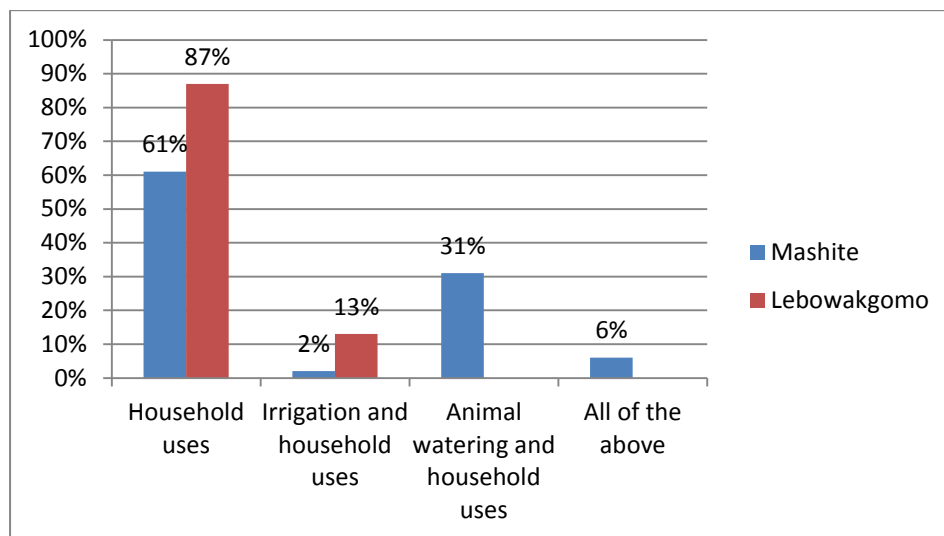
Figure 15: uses of water

In Mashite village, 61% of the respondents use water for household needs only and the other 31% of the respondents use water for animal feeding and household requirements, 2% of the respondents use water for household purposes and irrigation and the remaining 8% of the respondents use water for all of the above mentioned uses. Most people have animals and that is why there is a small percentage on household uses and irrigation. In Lebowakgomo Zone F 87% of the respondents use water for household purposes only and the other 13% of the respondents use water for irrigation and household uses. The reason for not using water for animal feeding might be because in a township people do not have livestock. According to the urban by-laws, due to the possibilities of pollution and health risks of keeping animals in close proximity to people and the competition with other sectors (for space and resources), planners and policy makers suggest that they better be shifted to larger specialized units outside the city (CSIR, 2012).

4.3.5 Water sufficiency

Water sufficiency is the availability of water resources to meet the demands of water usage. Table 6 shows if the available water was adequate/enough for the people needs or not.

Table 6: Percentages of respondents water sufficient needs

Area	Is water sufficient for your needs	
	Yes	No
Mashite	35%	65%
Lebowakgomo	77%	23%

Thirty-five percent of Mashite village respondents said water is sufficient, while 65% said it is not. The majority of the respondents said that they queue long lines for water and they only take home three 20 litre containers (60 litres) and by the time they go back the water is no longer available. When Lebowakgomo respondents were asked whether the water is sufficient for their needs, 77% said it is enough, while 23% said it is not sufficient. The majority of the respondents said the water is sometimes less or not enough in the morning while others said that water is sometimes less or not sufficient in the evening.

Table 7: Pearson Chi-Square tests on water sufficiency

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	66.779[a]	1	.000		
Continuity Correction[b]	63.822	1	.000		
Likelihood Ratio	80.881	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	66.249	1	.000		
N of Valid Cases	126				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 23.33.

b. Computed only for a 2x2 table

A Pearson Chi-Square test was conducted to assess whether townships and rural areas have an impact on water sufficiency for the respondents needs. The Pearson Chi-Square value for the association between region and water sufficiency was obtained as 66.779 with 1 degree of freedom and significance probability less than 0.001, indicating a very highly significant result. Based on this data analysis (Table7) there would appear to be an association between region and water sufficiency. Thus, it can be concluded that people in rural areas lack sufficient water as compared to those in townships. This might be because in townships people pay for water services unlike rural areas where water is free. According to Census Report South Africa (2011) many rural areas in South Africa still lack sufficient water.

4.3.6 Perception of the quality of water

Perception of the quality of water is the way which people appreciate/perceive the quality of water they use. Table 8 shows the respondents level of satisfaction with the quality of water.

Table 8: Satisfaction of the water quality

Area	Is the quality of water satisfactory	
	Yes	No
Mashite	33%	67%
Lebowakgomo	88%	12%

In Mashite village 33% of the respondents indicated that they are satisfied with the quality of water, while 67% said that the quality of water is not satisfactory. The majority (67%) of the respondents said that the water is somehow salty and it looks brownish, because it is not treated. In Lebowakgomo Zone F when the respondents were asked whether the quality of water is satisfactory, 88% responded in the affirmative yes, and 12% in the negative no. The reason for this sharp difference in the responses between the two study areas might be that Mashite village get water from boreholes, rainwater harvesting and rivers and this water is not treated as compared to Lebowakgomo Zone F respondents who all have taps in their homes and the water is treated.

Table 9: Pearson Chi-Square test on the satisfaction of the water quality

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	41.744[a]	1	.000		
Continuity Correction[b]	39.277	1	.000		
Likelihood Ratio	42.953	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	41.413	1	.000		
N of Valid Cases	126				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 16.33.

b. Computed only for a 2x2 table

A Pearson Chi-Square test was conducted to assess whether region impact water quality. The Pearson Chi-Square value for the association between region and water quality satisfaction was obtained as 41.744 with 1 degree of freedom and significance probability less than 0.001 indicating a high significant result. According to this result (Table 9), there is an association between the region and water quality satisfaction.

4.3.7 Quantity of water used

The quantity of water used depends on the number of people using water in the household. According to the World Health Organisation (2006), the minimum quantity of water needed for survival is 25 litres per person per day. This includes water for drinking, cooking and personal hygiene (Children Institute, 2009). The quantity of water used by respondents from the study area varied, and it ranged between 250 litres to 8001 litres, per month per household. When the respondents in Mashite village were asked how much water they use per month, they mentioned: 1500 litres, 840 litres, 810 litres, 500 litres, 420 litres and 250 litres, and they store

water in large containers and tanks (Figure 16). For Mashite village, 56% of the respondents used 250 litres per household per month (8.3 litres per day per household), 21% of the respondents used 1500 litres per household per month (50 litres per day per household), 16% of respondents used 500 litre per household per month (16 litres per day per household) and the remaining 7% of respondents used 840 litres per household per month (28 litres per day per household).

In Lebowakgomo the metre boxes were evaluated and it was discovered that majority (61%) of the households used between 5900 litres to 6000 litres per month. This might be because this quantity is free as prescribed by the free basic water (RSA, 1997). Thirty two percent of the respondents use between 6001 litres and 8000 litres per month while the remaining 7% used more than 8001 litres of water per month. The respondents who used more than 8001 litres are business owners who own hair salons, carwashes and other water consuming businesses. The results thus suggest that households with improved water access consume more water which is more than the minimum standard for the Free Basic Water in South Africa, while households with unimproved water access consume less than the minimum standard as stated in the Free Basic Water in South Africa, which states that 6000 litres per household of 8 people per month or 200 litres per household per day which is 25 litres per person per day within 200 metres from the house at a flow of not more 10 litre a minute (RSA,1997).

Figure16: Water storage containers in Mashite village

4.3.8 Community perceptions on underlying reasons for the water delivery constraints.

The researcher interviewed the respondents in Mashite village and Lebowakgomo Zone F on what they thought were the underlying reasons for the poor water situation. From the responses, a number of issues were raised. They are summarized below:

> **Lack of community participation and consultation in water services provision**

The issue of poor community participation and consultation is one of the constraints to water delivery. The respondents explained that, in their view, the level of participation of the community in water management issues at the municipality was minimal. They cited the failure of the ward councillors to convene regular meetings to discuss water issues with the community. When the communities were asked what challenges they are facing in ensuring water conservation strategies, they said the following: illiteracy, lack of awareness campaigns, alien plant species and funds. They also indicated that illiteracy and lack of funds have negatively impacted on water service delivery.

➢ **Poor local governance**

Villagers attributed the poor delivery of water services to the quality of local governance such as local municipality. In particular, the governance structures which are supposed to assist them appeared to be either dysfunctional or unprepared to handle the tasks at hand. They raised a concern about their ward committee. They were not satisfied with the fact that the committee was not residing in Mashite and that most of their stand pipes are broken (Figure 17) others are not working, some are leaking (Figures 18;19;20 and 21) which end up damaging their roads (Figure 20 and 21) and encourage kids to play with water (Figures 22). This situation discourages the community from addressing the challenges of water shortage. When the respondents were asked how they address the challenges of water shortage they replied: by informing the chief and the municipality while other respondents said that they do nothing.

➢ **Rioting**

The Mashite community described poor water service delivery as severe because they went for three months without tap water. In May to July 2014, the water shortage issue in Mashite village turned into a crisis where tyres were burned in the streets causing them to close the roads and, school children did not go to school. Rioting sensitized the municipality to restore water supply immediately.

Figure 17: Broken tap

Figure 18: Leaking tap (a) in Mashite village

Figure 19: Leaking tap (b) in Mashite village

Figure 20: Leaking tap (c) in Mashite village causing damage to the road

Figure 21: Leaking tap (d) in Mashite village causing damage to the roads

Figure 22: School children playing with water

4.4 Coping mechanisms of water scarcity

Coping mechanisms of water scarcity is an adaptation to water shortages using various methods such as rainwater harvesting and greywater reuse.

4.4.1 Rainwater harvesting

Rainwater harvesting practice is the collection of raindrops or runoff water from the roof tops or the earth surface. Rainwater harvesting as a coping mechanism of water scarcity was practiced in the study areas. Table 10 illustrates proportions of respondents who harvest rainwater.

Table 10: Rainwater harvesting practices

Area	Do you practice rainwater harvesting?	
	Yes	No
Mashite	76%	24%
Lebowakgomo	30%	70%

In Mashite village, when asked whether they practice rainwater harvesting, 76% of the respondents answered in the affirmative, while 24% said they do not harvest rainwater. The majority of the respondents said that since they are facing water shortage and water scarcity, and they go for a period of two months without water supply from the municipality they resort to rainwater harvesting. On the other hand, in Lebowakgomo Zone F 30% of the respondents said they practice rainwater harvesting while 70% said they do not practice rainwater harvesting. The majority of the respondents in Mashite village said that they do not need to conserve water since it is scarce. Although respondents in Mashite village said they do not need to conserve water, indirectly they were conserving water through rainwater harvesting, because the majority (76%) practiced rainwater harvesting. Hensley *et al* (2000) reported that rainwater harvesting reduces total runoff and also reduces surface

evaporation, whereas Ghisi & Ferreira (2007) indicated that water can be conserved through reusing of greywater and rainwater harvesting.

4.4.2 Greywater reuse

➢ **Knowledge of greywater**

Greywater is usually defined as all wastewater produced in households, except toilet wastewater (black water). Typically, this includes water from bathroom sinks, bath tubs, showers and may also include water from laundry facilities and dishwashers (Queensl, 2003). Table 11 show the respondents knowledge of greywater.

Table11: Respondents knowledge on greywater

Area	Do you know what greywater is?	
	Yes	**No**
Mashite	94%	6%
Lebowakgomo	81%	19%

The majority (94%) of the respondents in Mashite village when asked whether they know what greywater is, responded that they know what it is, while 6% of the respondents said they do not know (Table 11). In Lebowakgomo Zone F township 81% responded in the affirmative "Yes" to the same question, while 19% indicated that "No" (Table 11). The results seem to be influenced by educational qualifications due to fewer percentages of respondents who never went to school (section 4.2.4) and yet know about greywater. Although fewer people of Mashite completed tertiary education compared to Lebowakgomo Zone F with more who completed tertiary education, they seem to have knowledge of greywater. The reason might be because in Mashite village due to lack of reticulated water indoors, the respondents resort to other ways of meeting their water needs such as rainwater harvesting and reuse of greywater unlike Lebowakgomo Zone F where water is always available.

➢ **Sources of greywater**

The amount of greywater generated depends to a greater extent on the amount of water used by the households which is a function of the number of people in the household or household size. All the respondents from the two study areas said that the sources of greywater in their homes are from: kitchens, bathtubs, laundry and showers. This is in line with Queensl (2003) and Rodda *et al* (2010), who opined that greywater includes water from bathroom sinks, bathtubs, and showers and may also include water from laundry facilities and dishwashers. Where water is available in-house (tap water), the generation of greywater will be higher relative to those who need to walk longer distances (Chaggu, 2011). This is similar to findings of this study, where Mashite village generates small amounts of greywater since they walk long distances and they queue for water unlike Lebowakgomo where the water is available in their houses, in spite of Mashite village having larger household size compared to Lebowakgomo Zone F (section 4.2.5).

➢ **Drainage and storage of greywater**

The availability or unavailability of a sewerage disposal system dictates whether used water is drained or stored. Generally in towns and townships where there is a sewerage system, used water drains directly into the system, compared to rural areas which do not have sewerage systems and where people reuse greywater directly or store it.

With regard to where the generated greywater directly drained to, 96% of the respondents in Mashite village, said that the generated greywater is used for irrigation. Four percent (4%) of the respondents in Mashite village said they drain greywater into storage containers. No one mentioned anything about greywater being drained in cesspool or through the drainage system. When the respondents in Lebowakgomo were asked where the used water from bathtubs, showers and kitchen is drained to, they all mentioned that it goes to the sewerage system except for greywater from laundry.

The sampled households in Mashite village were asked to store greywater for a period of one week where the researcher was self-monitoring it looking at the quantity of the containers they used to store greywater. From the 49 households, 28% of the respondents stored 40 litres of greywater a week, 18% of the

respondents stored 210 litres of greywater for a week, 16% of the respondents stored 500 litres of greywater a week. Fourteen percent (14%) of the respondents stored 60 litres of greywater a week, 8% of the respondents had no storage containers and they were not willing to participate in storing greywater, 6% of the respondents stored 120 litres of greywater a week, 4% of the respondents stored 105 litres of greywater a week and the other 4% stored 80 litres of greywater for a week and lastly the remaining, 2% of the respondents stored 1680 litres of greywater a week.

➤ **Uses of greywater**

Uses for greywater include gardening, washing vehicles, and flushing toilets. All of these uses save freshwater which could have been used for such purposes. Figure 23 presents the different uses of greywater in the study areas.
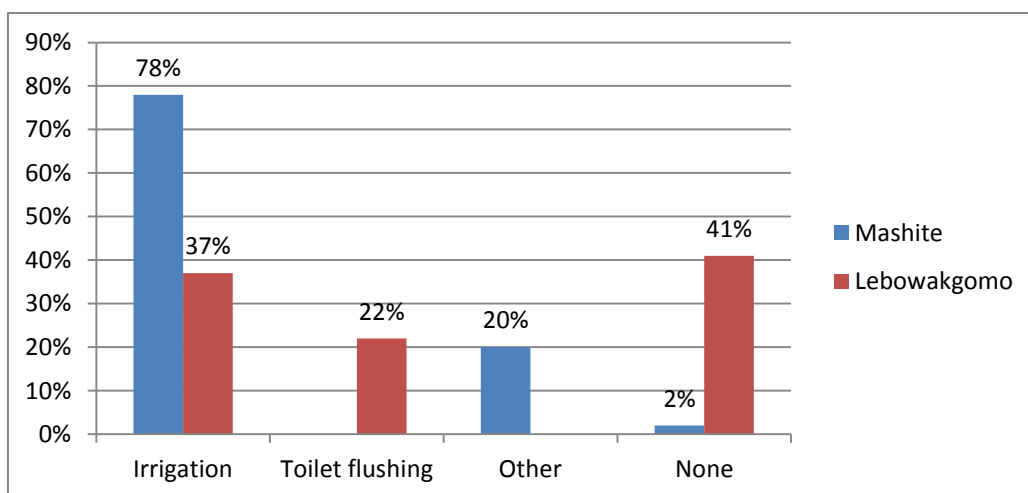
Figure 23: The uses of greywater

With regard to the uses of greywater by the respondents in Mashite, 78% of them use it for irrigation. Figures 24, 27, 28, 29 and 30 show some respondents irrigating gardens with greywater. Two percent (2%) of the respondents do not use greywater at all and no one uses it for toilet flushing, while 20% use it for other purposes such as: building mud houses, house pavements, paving the yards and mixing cow dung for decorating (Figure 25). Lebowakgomo Zone F respondents obtained greywater from laundry. Forty one percent (41%) of the respondents in Lebowakgomo said that they do not use greywater whereas 37% of the respondents use greywater for irrigation (Figure, 23) and 22% of the respondents said that they use it for toilet

flushing (Figure 23). Figure 26 shows toilet flushing using greywater. The reason for not using greywater for toilet flushing in Mashite village is because their toilets are pit toilets and they do not need water to operate. According to Salukazana *et al* (2004) in a study comparing crop yield irrigated with greywater and tap water in rural, informal and peri-urban area, crops irrigated with greywater were consistently significantly taller than crops irrigated with tap water. He further reported that greywater has nutrients which are good for plant growth. In areas experiencing water shortage, greywater is becoming an important water resource for irrigation. Irrigating crops with greywater as part of a reuse and disposal system allows households the opportunity to grow plants during times when water is not readily available, leading to less water stress and increased food security (Madungwe and Sakuringwa, 2010).

Figure 24: Irrigating a young tree with greywater

Figure 25: Greywater used to make cow dung mixture for decorating a house

Figure 26: Toilet flushing with greywater

When the respondents in Mashite and Lebowakgomo were asked which plants they irrigate if they do use greywater for irrigation they mentioned the following: fruit trees, flowers, tomatoes and grass (Figure 24; 27; 28; 29 and 30). Those respondents who use greywater for irrigation when asked whether the used households' water has any effect on the environment, 63% of them in Mashite said that they do not know, 20% said greywater has effects on the environment and 17% said greywater does not

have effects on the environment. In Lebowakgomo Zone F 36% of the respondents said that they do not know if greywater has effects on the environment, 24% agreed that greywater has effects while 40% disagreed that greywater does not have effects on the environment.

According to Rodda *et al* (2010) the use of greywater in agriculture fits in well with the concepts of Ecological Sanitation which seek to prevent pollution and disease by managing human urine as a resource rather than a waste. The soap and other residues in the water can provide useful sulphates and nitrates, when diluted and in some instances it can act as a fertilizer and therefore be beneficial to the garden. This type of application therefore has the potential to improve the amenity of the environment. Al-Jayyousi (2004) reported that in Jordan, families that adapted to greywater reuse were able to reduce food expenditures by consuming garden produce. This is similar to Mashite village, where community members also sell their vegetables, trees and fruits to other rural communities, and at Lebowakgomo central business area to make a living.

Figure 27: Irrigating an orange tree with greywater

Figure 28: Irrigating a guava tree with greywater

Figure 29: Irrigating a peach tree with greywater

Figure 30: Irrigating flower with greywater

4.5 Perception of grey water reuses

Perception of grey water reuses is the way in which greywater is regarded, understood, or interpreted by people.

4.5.1 Preference on greywater reuse

Preference on greywater reuse is the greater liking and commitment to reuse greywater. Table 12 presents the preference on greywater reuse in the study area. With regards to preference on reusing greywater, in Mashite village 49% of the respondents said they prefer to reuse greywater and most (51%) of the respondents said they do not prefer to reuse greywater. In Lebowakgomo Zone F 76% of the respondents prefer to reuse greywater and 24% do not prefer to reuse greywater (Table 12).

Table 12: Preference to reuse greywater

| Area | Do you prefer to reuse greywater? | |
	Yes	No
Mashite	49%	51%
Lebowakgomo	76%	24%

In spite of the fact that in Mashite village the majority of the respondents went to secondary school as compared to Lebowakgomo where they went to tertiary education (section 4.2.4) and the majority earn less than R1000 as compared to Lebowakgomo Zone F where majority earn more than R5001, in Mashite village the majority know what greywater is as compared to Lebowakgomo Zone F, but the preference to reuse is less. This is contradictory since the results show that Mashite village reuse greywater more than Lebowakgomo Zone F. The respondents in Mashite village indicated that they do not have a choice not to reuse greywater despite the low level of preference as they do not have running water in their yards.

According to the respondents of this study, the reasons for preference of reusing greywater included the fact that it saves money and it is good for plants. Those who do not prefer to reuse greywater said that it is dirty and they also mentioned the effects of water logging, causing of diseases and drying the grass/crops. The respondents, who preferred to reuse greywater, indicated that if well-handled and disposed, greywater is easily absorbed by land and seep into the ground. According to Al-Jayyousi (2004) greywater reuse presents a potential option for water demand management and it contributes to reducing fresh water use for irrigation, it also holds the potential for informal employment (Rodda *et al.,* 2010). Rodda *et al* (2010) further reported that families that adapted to greywater reuse were able to reduce food expenditure by consuming garden produce.

4.6. Strategies to promote water conservation

The strategies to promote water conservation are the plans of action designed to promote water conservation.

4.6.1 Respondents view on water conservation

When the respondents were asked in both study areas what strategies they think must be applied to promote greywater reuse as water conservation in their area, 32% of the respondents in Mashite village and all respondent in Lebowakgomo Zone F said awareness campaigns, competitions and workshops. The rest of the respondents in Mashite village (68%) had nothing related to strategies for promoting water conservation. Instead they said they want taps in their homes and others commented that since the municipality is not delivering they need sponsors. Whereas others said how can they conserve water while they go for a period of two months without it.

4.6.2 Key informant interviews on water conservation

The village Induna raised a concern about the level of co-operation between the villages and the Ward Councillor. He further emphasised that the counsellor should stay in Mashite in order to experience what the community is experiencing. The expectation of the village Induna was that the local ward councillor should interact with the community by attending meetings convened by the community. This would afford him the opportunity to understand the real issues that need to be addressed with regard to water service delivery and water conservation methods such as rainwater harvesting and greywater reuse. He also mentioned that if people start conserving the little water they get or harvest it, this will stop rioting in the Mashite community.

4.6 Summary

This chapter provided the results and discussions on socio-economic characteristics, accessibility and availability of water supply, coping mechanisms such as onsite greywater reuse and rainwater harvesting and perceptions on greywater reuse. The next chapter focuses on summary, conclusions of the study and recommendations.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary and conclusions of the findings on the socio-economic characteristics, accessibility and availability of water supply and community's knowledge, and perceptions on greywater reuse as a water conservation method. It also covers a summary of findings on the respondents and local leaders view on water conservation. Furthermore, the chapter provides recommendations based on the conclusions.

5.2 Summary

The results show that although water is an important natural resource it is very limited in the study areas more especially in Mashite village. As a result, water conservation should be practiced on a regular basis. Although these could not be quantified the research also confirmed that there is a problem of water quality in Mashite village as compared to Lebowakgomo Zone F.

5.2.1 Socio-economic characteristics

The Mashite village and Lebowakgomo Zone F communities generally consist of pensioners, middle aged and young people. The literacy level, household size, employment and household monthly income of these two areas varied. In Mashite village the literacy level of the community is very low where the majority of respondents (59%) went to secondary school compared to Lebowakgomo Zone F where the majority (72%) went to tertiary institutions. Household size mean in Mashite village is 6.18 compared to Lebowakgomo Zone F with a household size mean of (2.77). Mashite village contributed to a high rate of unemployment (64%), leading to the majority of respondents' (45%) monthly household income being less than R1000. In comparison Lebowakgomo Zone F contributed high employment (69%) and the majority of the respondents (56%) earn more than R5000.

5.2.2 Accessibility and availability of water supply

The findings clearly show that in Mashite village there is a problem of water availability and accessibility as compared to Lebowakgomo Zone F where water is

accessible and available regularly. In Mashite village water is insufficient, stand pipes are leaking as compared to Lebowakgomo Zone F with indoor taps water supply. The perception on water quality differed. In Lebowakgomo Zone F water quality was seen as satisfactory (88%) as compared to Mashite village where it was not satisfactory (67%).

Water usage in these two areas differed. In Mashite village they use less water (250 litre to 840 litre) since it is not always available as compared to Lebowakgomo Zone F where more water is used (5900 litre to 8001 litre). The sources of water varied in these two areas. In Lebowakgomo Zone F the source of water is from taps only as compared to Mashite village where the source of water is from rivers, dams, stand pipes and rainwater harvesting. The distance to the source of water differed. In Mashite village people walk 1km or more to stand pipes and in Lebowakgomo Zone F people have taps in their homes.

5.2.3 Coping mechanisms of water scarcity

Both communities including the Mashite Induna adapt to water shortages by using rainwater harvesting and greywater reuse as a coping mechanism and they do have knowledge of greywater. Their source of greywater is bath tubs, showers, kitchen sinks and laundry. Uses of greywater included irrigation and toilet flushing.

5.3.4 Community knowledge and perception on greywater reuse

The Lebowakgomo Zone F community preferred to reuse greywater more as compared to Mashite community. The respondents think the strategies to promote water conservation in their areas were awareness campaigns, competitions and workshops.

5.3 Conclusions

Four main stakeholders were identified at this level of onsite greywater reuse as a water conservation method: communities of Mashite village and Lebowakgomo Zone F, the traditional leader for Mashite village and the municipality that manage and supply water. The conclusions from the study are:

➢ Socio-economic characteristics such as education and household size affect greywater reuses.

- ➢ Accessibility and availability of water supply was a challenge in Mashite village compared to Lebowakgomo Zone F due to water not being available regularly in Mashite village and the use of stand pipes instead of indoor taps.
- ➢ The coping mechanisms for water scarcity for both settlements were rainwater harvesting and greywater reuse.
- ➢ There are different perceptions on greywater reuse in this study. In Mashite the preference to use greywater is less compared to Lebowakgomo Zone F.

The communities need water authorities in the local municipality to encourage public participation and awareness campaigns, and research implications drawn from these results can provide useful insights for formulating strategies to intensify onsite greywater reuse in rural, semi-urban and urban areas. Therefore, this study concludes that greywater could be one of the methods used to alleviate water scarcity.

5.4 Recommendations

The information will help prioritize the factors that affect greywater reuse decisions and provide insight on pathways to increase the water conservation method. The study recommends the following:

- ➢ There should be a campaign to educate the people so that they may be able to know how to conserve water to minimise water scarcity.
- ➢ There is need for the government to give each household in Mashite village a metre tap and potable water should be available daily. The government should appoint a water service manager at Lepelle-Nkumpi Local Municipality.
- ➢ Regular review and visits by the, municipal officials, researchers and specialists, to make sure villagers do not go a period of two months or more without water. This will also help to avoid destroying of roads and government infrastructure due to rioting for supply water in Mashite rural area.
- ➢ The National Department of Water Affairs and sanitation should establish a new policy to provide financial assistance to greywater recycling projects for irrigation and toilet flushing. The results also suggest the need for greater political and institutional input into onsite greywater reuse projects.

- The municipality should provide water to all regions following the RDP standards where each household in spite of rural or urban should get 6000 litres of water per month.
- The researcher hopes that the findings of this study will form a basis for future research on service delivery. Furthermore, the study should focus on understanding modalities to foster greater cooperation between municipalities, communities and their respective leadership with regard to finding lasting solutions to the challenge of poor service delivery.
- Future research should be done on methods to improve greywater quality and mechanisms to capture large quantities of greywater.

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APPENDIX A

ONSITE GREYWATER REUSE AS A WATER CONSERVATION METHOD: A CASE STUDY OF LEPELLE-NKUMPI LOCAL MUNICIPALITY LIMPOPO PROVINCE, SOUTH AFRICA.

My name is Karabo Mashabela. I am studying for a Master of Science in Geography and Environmental studies in the Department of Geography and Environmental studies, School of Agricultural and Environmental Sciences, Faculty of Science and Agriculture, University of Limpopo (Turfloop campus).

I have identified you as participants in this survey. Your answers will be treated confidentially. You do not need to reveal your identity. The information obtained will be used for research purposes and is subject to ethical rules of research at the University of Limpopo (Turfloop campus).

Please answer all questions. If questions are left blank, it will unfortunately render your completed questionnaire unusable. If you have any query, you are welcome to contact me at;

Enquiries: Karabo Mashabela

Cell phone: 0760117841

Email: karabomashabela@webmail.co.za

Questionnaire

A. Socio-economic characteristics data.

1. Age

<20 years	21-30 years	31-40 years	41-50 years	51+

2. Gender

Male	Female

3. Marital status

Never married	Married	Divorced	Widowed

4. Highest qualification

Never went to school	Primary education	Secondary education	Tertiary education

5. How many are you in the family currently?

…………………………………………………………………………………………………...

6. Employment status

Employed	Self employed	Unemployed

7. Monthly salary household income

<R1000.00	R1001-R3000	R3001-R5000	R5001+

B Accessibility and availability of water Data:

8. Where do you get water from?

☐ River

☐ Dam

☐ Municipality

☐ Rainwater harvesting

☐ Other specify …………………………………………………………………………………

9. How far is the water source from your home?

…………………………………………………………………………………………………

10. How many public taps / stand pipes do you have in your area?

………………………………………………………………………………………………

11. Is the water always available?

Yes	No

12. Give reasons for your answer above (question 11)

……………………………………………………………………………………………………
……………………………………………………………………………………………………

13. What are the main uses of your water?

☐   House hold uses (such as Drinking, washing, laundry)

☐   Agricultural irrigation (trees and vegetables)

☐ Animal feeding

☐ All of the above

Others…………………………………………………………………………………

14. Is the water sufficient for your needs?

Yes	No

15. Is the quality of water satisfactory?

Yes	No

16. How much water do you use per month?

…………………………………………………………………………………………………..

C. Coping mechanism for water scarcity data:

17. Do you practice rainwater harvesting?

Yes	No

18. Do you know what greywater is?

Yes	No

19. What are the sources of greywater in your household?

………………………………………………………………………………………………

………………………………………………………………………………………………

20. Where is the used water from the kitchen drained to?

☐ Cesspool

☐ Storage containers

☐ Agricultural irrigation

☐ Drainage

21. How much is the greywater generated from your household?

……

……

22. What do you use your greywater for?

☐ Flushing

☐ Irrigating

Other
specify………………………………………………………………………………………………….

23. If you use greywater for irrigation, what do you irrigate?

……..

D. Perception of greywater reuses data:

24. Do you prefer to reuse greywater?

Yes	No

25. Give reason for the above (question23)

………………………………………………………………………….......................................

……

……

26. What do you think must be done to promote greywater reuses as a water conservation method in your area?

……

……

……

APPENDIX B

ONSITE GREYWATER REUSE AS A WATER CONSERVATION METHOD: A CASE STUDY OF LEPELLE-NKUMPI LOCAL MUNICIPALITY LIMPOPO PROVINCE, SOUTH AFRICA.

My name is Karabo Mashabela. I am studying for a Master of Science in Geography and Environmental studies in the Department of Geography and Environmental studies, School of Agricultural and Environmental Sciences, Faculty of Science and Agriculture, University of Limpopo (Turfloop campus).

I have identified your area as the study area for this research. The information obtained will be used for research purposes and is subject to ethical rules of research at the University of Limpopo (Turfloop campus).

Please answer all questions. If questions are left blank, it will unfortunately render your completed questionnaire unusable. If you have any query, you are welcome to contact me at;

Enquiries: Karabo Mashabela

Cell phone: 0760117841

Email: karabomashabela@webmail.co.za

What do you think lead to water scarcity?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

What do you think about the situation of water scarcity in this area?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

How has the situation affected the community?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Do you reuse greywater?

…………………………………………………………………………………………………
………………………………………………………………………………………………….

What other strategies are you employing to ensure sustainable water management within your community?

…………………………………………………………………………………………………
………………………………………………………………………………………………....

How effective are these strategies?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

What challenges do you face in an effort of ensuring sustainable water management in your communities?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

How do you address these challenges?

…………………………………………………………………………………………………
………………………………………………………………………………………………..