ASSESSMENT OF THE PERFORMANCE OF SMALL-SCALE WATER INFRASTRUCTURE (SWI) FOR MULTIPLE USES IN NEBO PLATEAU, SEKHUKHUNE DISTRICT, SOUTH AFRICA

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ABSTRACT

South Africa is ranked the 30th driest country in the world and water is regarded as a scarce resource in the country. Limited availability of good quality water has resulted in urban areas receiving more water at the expense of rural areas. This is due to the fact that urban areas have a more reliable and well-maintained water infrastructure, while rural communities use unreliable and dysfunctional small-scale water infrastructure (SWI). Enhancing the performance of SWI (which are technical hardware used by rural communities to supply water for their day-to-day activities such as domestic, irrigation and rural development) used by the rural communities can enhance their rural livelihoods. The SWIs are designed and operated either as single use systems (SUS) that cater for only one water-use or multiple water systems (MUS) that cater for more than one water-use. These SWI are usually dysfunctional due to a number of reasons. Investment into SWI development, operation and maintenance (O&M), rehabilitation and modernization is limited by the lack of knowledge of the types of SWI in a given area and their functional status. This study sought to assess the performance of SWI in Nebo Plateau, Limpopo Province, South Africa by (a) identifying their types, distribution, ownership, water-use and status using a survey tool administered to the rural communities, (b) assessing their condition using modified technical and risk of failure evaluation tool, (c) investigating their causes of failure using a qualitative research approach and network analysis, and then (d) propose best management practices (BMPs) that are specific to the study area.

The study found 202 SWI, which comprised of the following: unequipped boreholes (59%), equipped boreholes (hand pumps (10%), electric-driven pumps (6%), diesel-driven pumps (1%) and windmills (4%)) and small reservoirs (11%). The overall water uses were 65% SUS, 22% MUS and 13% other. The government owned 54% of the SWI, communities owned 22%, private sector owned 11%, and schools owned 2%. The government was responsible for the maintenance of 49% of the SWI. It was found that 71% of the identified SWI were non-functional

It was found that windmills had minor defects and met rural community needs above satisfactory level. On the other hand, small reservoirs and hand pumps required major maintenance and benefited the rural communities below the minimum level. The major causes of failure were found to be lack of proper operation and maintenance (O & M), lack of O & M strategies, inadequate funds, no monitoring strategies, lack of technical skills at municipality and community level, and lack of strong leadership from the policy regulating institutions, Water Service Authority, water service provider and rural communities.

It was proposed that for improved water supply to the rural communities of Nebo Plateau, there was a need to decentralize the current District municipality water service providers (WSP), establish Village Water Committees (VWC) in the rural communities, link policy with technology used, consider the effects of environment on technology, ensure availability of spare parts locally, provide technical training for both WSP and rural communities, and allocate funds for operation and management of the SWI.

The study concludes that there are different SWI used by the rural communities in the study area and operated as SUS and MUS. The rural communities used water mainly for domestic and irrigation of back yard gardens. Water from small reservoirs was mainly used for livestock watering. The government owned most of the SWI and were also responsible for their maintenance. Most SWI assessed during this study were non-functional thus depriving rural communities of improved standards of living. The factors that caused the poor performance of SWI were interdependent and resulted mainly from the lack of strong institutional capabilities. The proposed BMPs were suitable for the rural communities of Nebo Plateau. It is, therefore, recommended that stakeholders involved in SWI management use the information on the status of SWI presented in this document to address areas with poor performing SWI and adopt or apply the proposed BMPs to improve their performance.

PREFACE

I **Doctor Calvin Sambo**.................................... declare that

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DECLARATION 2 – PUBLICATIONS

Details of contribution to publications that form part of this dissertation, which include papers in preparation, are given in each paper.

Publication 1 – Chapter 2

Sambo DC, Senzanje A, and Dhavu K. 2014. The identification of small-scale water infrastructure in Nebo Plateau, Limpopo, South Africa. *Paper in preparation.*

Publication 2 – Chapter 3

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Publication 3 – Chapter 4

Sambo DC, Senzanje A, and Dhavu K. 2014. Proposal of situation based best small-scale water infrastructure management practices in Nebo Plateau, Limpopo, South Africa. *Paper in preparation.*

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LIST ABBREVIATIONS

AHP	Analytic Hierarchy Process
ASWCC	Arkansas Soil and Water Conservation Commission
AWWRF	American Water Works Research Foundation
BMP	Best Management Practices
CPWF	Challenge Program for Water and Food
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWD	Directorate of Water Development
FAO	Food and Agriculture Organization
FF	Fully functional
GDP	Gross Domestic Product
GfWD	Growth for Water Development
HESET	Health, Environment, Social and Economic Tool
IDP	Integrated Development Plan
IWRM	Integrated Water Resource Management
MAUT	Multi-Attribute Utility Theory
MAVT	Multi-Attribute Value Theory
MCDM	Multi-Criteria Decision Making
MDGs	Millennium Development Goals
MUS	Multiple Use Services/Multiple Use Systems
NF	Non-functional
NGO	Non-Governmental Organization
NRF	National Revenue Fund
RDP	Reconstruction and Development Programme
RRWPPHHE	Rehabilitation of Rural Water Points and Participatory Health and Hygiene Education
RSA	Republic of South Africa
RWSN	Rural Water Supply Network
SAICE	South Africa Institute of Civil Engineers

SF	Sub-optimally functional
SUS	Single Use Service/ Single Use Systems
SWI	Small-scale Water Infrastructure
UNESCAP	United Nations Social and Economic Commission for Asia and Pacific
UNICEF	United Nations Children Education Fund
USA	United States of America
VWC	Village Water Committee
WEDC	Water, Engineering and Development Centre
WHO	World Health Organization
WPC	Water Point Committees
WSP	Water Service Providers

GLOSSARY OF KEY TERMS

(a) **Condition assessment:** the process of evaluating the condition of the different components of a SWI.

(b) **Maintenance:** the act or process of preserving the condition of a water supply infrastructure.

(c) **Operation**: the act of which a water supply infrastructure is functional.

(d) **Ownership**: the right, whether formal or informal, of possessing a water supply infrastructure by an individual or community or an institution.

(e) **Sustainability**: the process of maintaining SWI condition to ensure a reliable and adequate supply of water to the rural communities over a long period of time (Harvey and Reed, 2004; Hoko and Hertle, 2006).

1. INTRODUCTION

1.1 Background

An improved water supply is vital for human, animal and plant life, and contributes to economic and social development (Dungumaro and Madulu, 2003). An inadequate provision of an improved water supply not only affects the rural communities in the poor and developing countries, but it is also a dilemma for developed countries (Hunter *et al*., 2009). It is estimated that sub-Saharan Africa has the lowest rates of improved water supply in the world, with approximately 278 million people in the rural communities without a good quality water source to meet their daily needs (Marks and Davis, 2012). The use of unsafe drinking water sources results in water-borne diseases, which are harmful to the human population. It was estimated by the World Health Organization (WHO, 2007) that water-borne diseases cause 800 000 annual deaths of children under the age of five in the world, which means that there are more deaths in this age group than from malaria and HIV combined. Therefore, there is a need to reduce the number of deaths and improve the quality of life of the human population through improved water supply systems that provide good quality water and a sufficient quantity of water.

As per the United Nation's Millennium Declaration of 2000, countries committed themselves to eradicating extreme poverty by 2015 through the adoption of eight Millennium Development Goals (MDGs), as shown in Appendix A. These goals recognize the need to improve water supply challenges and conditions by ensuring that, by 2015, countries will halve the proportion of people without sustainable access to safe drinking water and basic sanitation (Sachs, 2005; UNICEF, 2012). In South Africa, substantial progress has been made towards the achievement of this target, as 95% of the population is reported to have access to an improved basic water infrastructure (Statistics South Africa, 2013). Although access to infrastructure has improved, the functionality of this infrastructure is not considered and somewhat limited and therefore is a cause for concern.

In 2011, the South African Institute of Civil Engineering (SAICE) conducted an assessment of the water infrastructure in South Africa (Makhethu, 2011). The assessment resulted in a SAICE Infrastructure Report, which indicated that many of the water infrastructures in the country are dysfunctional and deteriorating due to poor maintenance, while some of the facilities have surpassed their expected life-span. The assessment also reported that some of the infrastructure is over 39 years old and requires replacement or an upgrade. Other challenges highlighted include the lack of skilled technical staff to supervise maintenance work, the siltation of farm dams and the lack of funds for maintenance (Weiskel *et al*., 2007; Boshoff, 2009). According to Makhethu (2011), the condition of water infrastructure in urban areas is satisfactory for now and those that are in rural areas are at risk. The risk is because they are not coping with the increasing demand for water and are poorly-maintained. Despite this, rural communities continue to use the poorly-maintained water infrastructure regardless of its condition and the poor quality of the water. In this context water infrastructure is defined as technical hardware used to develop and manage water resources (Hak-su, 2006, Senzanje *at el*., 2012).

The focus of the SAICE Infrastructure Report was on piped water supply systems in urban and rural communities. Water infrastructure used by rural communities, such as hand-pumps, windmills, wells, boreholes and small reservoirs were not considered by most studies addressing water issues in the country, as they are considered rudimentary (Department of Water Affairs, 2000). These water infrastructure were not considered in the report yet they are key to improving access to water by rural communities. Rudimentary water supply systems are water supply infrastructures that do not comply with the basic water supply standards mentioned in the Water Service Act of 1997. However, these rudimentary water supply systems are used by the rural communities on a daily basis. Therefore, they are ensuring that the rural communities have access to water supply.

There are no known databases on the current condition of the rudimentary water supply infrastructure used by the rural communities. This is mainly due to the existence and development of tapped water systems in the rural communities that are sometimes unreliable (Majuru *et al*., 2012). In the face of these rudimentary structures, the rural communities in Nebo Plateau, Sekhukhune District, Limpopo Province, South Africa, still use water from small reservoirs, boreholes, hand pumps and windmills, which are in poor condition (Integrated Development Plan, 2012). Their poor condition has resulted in 47% of the population in Nebo Plateau receiving water below the standards stipulated in the Water Service Act of 1997 (Water Service Act, 1997). Stipulated standards indicate that water infrastructure in the rural communities must be designed to supply 25 litres per capita per day, with an additional 10% allowance for losses, at a maximum distance of 200 meters away from households.

1.2 Small-scale Water Infrastructure (SWI)

A literature review has shown that there is no precise definition of "water infrastructure" used in the rural communities. This was also admitted by the WHO (2006). The definition varies from country to country. Hunter *et al*. (2009) state that it may be advisable to base the definition on the population size and type of water supply. It is often the location and management of the water infrastructure that sets community water supply systems apart.

Hak-su (2006) defines water infrastructure "as a stock of facilities and installations needed to develop and manage water resources, including the delivery, treatment, supply and distribution of water to its users, as well as for the collection, removal, treatment and disposal of sewage and wastewater". This definition refers to all infrastructures, both urban and rural, that handle water for all purposes. In the context of this study, the definition by Senzanje *et al*. (2012) is preferred, as it defines rural small-scale water infrastructure (SWI) as "any technical hardware that is used by farmers in managing water resources for both domestic and agricultural use, and is operated on a small-scale, as well as by rural smallholder farmers" (see examples in Figure 1.1). The definition is based mainly on where the SWI is located, whether it is in a rural community or urban set-up. Senzanje *et al*. (2012) chose to use 'small-scale' to define the water infrastructure that is in a rural community. This definition does not consider the size of the water infrastructure, but where the water infrastructure is located and how it is used. The term SWI will be used in this document to refer to water infrastructure in the rural communities.

SWIs can be categorized in terms of their use by rural communities. Senzanje *et al*. (2012) categorized SWIs in terms of domestic, agricultural and rural development (brick-making, cultural events and schools), as shown in Figure 1.2. This study focuses on water for domestic and agricultural water-use. The agriculture category is divided into two water-uses: irrigation and livestock water-use. However, SWIs in rural communities can supply water for all the water-uses mentioned, or for one or two water-uses. SWI that cater for one water-use are called a Single Use System (SUS). These types of SWI can either supply water for domestic, irrigation or livestock use. SWI that caters for two or more water-uses are categorised as Multiple Use System (MUS). These types of SWI can either supply water for domestic and irrigation only, or domestic, irrigation and livestock use, or irrigation or livestock.

(a) Hand-pump used by rural community

(b) Windmill used for irrigation and livestock watering by rural community

(c) Small reservoir

(d) Water storage tank

Figure 1.1 Types of small-scale water infrastructure (SWI) used by rural communities

MUS is defined by van Koppen *et al.* (2006) as a "participatory, integrated and poverty-reduction focused approach in poor rural and peri-urban areas, which takes people's multiple water needs as a starting point to providing integrated services, moving beyond the conventional sectorial barriers of the domestic and productive sector". MUS take into account rural water needs when planning to design or rehabilitate SWI. This kind of approach is believed to be more sustainable than the single-use approach (van Koppen *et al*., 2006; Schreiner *et al*, 2010).

The MUS approach exists at different levels, as shown in Table 1.1. The MUS approach can be achieved by changing the existing SUS type of SWI to MUS. This can be done through the adaptation of current irrigation and domestic SWI to multiple water-uses in rural communities. The adaptation of irrigation SWI can involve, for example, the supply of water for household use and bathing, the construction of steps in canals for laundry and bathing, the addition of pipes to supply water to the rural community when an irrigation system is not irrigating and adding a place for livestock watering (Williams and Carriger, 2006). Furthermore, SWI used for domestic water activities can be adapted by adding livestock drinking troughs to supply points, as well as, storage tanks to supply water for multiple water-uses and micro-irrigation systems (Williams and Carriger, 2006). SWIs that are used for rainwater harvesting can also be adapted for the multiple water-uses of rural communities.

Use of water from SWIs for domestic, irrigation and livestock purposes can improve the rural livelihoods of communities (Adank, 2006; Senzanje *et al.,* 2012). Through adequate water supplied by a SWI, rural communities can improve food security in their households, create employment and generate income from agricultural and other productive activities. This can be achieved by using the produce harvested from the irrigated field or backyard gardens for household consumption and the extra produce can be sold to the communities or available markets for income. The increase in income can result in the farmer needing to employ other community members to assist in the field. De Regt (2005) states that 75% of the rural communities rely on agricultural activities, which is the largest economic activity in rural communities. Income can also be generated through the selling of bricks, livestock and beer in the community, or available markets. The availability of good quality water from the SWI for domestic use can improve the health of the rural communities and prevent water-borne diseases.

This can be achieved by having SWIs that are consistently supplying good quality and quantity water that fully caters for the rural communities.

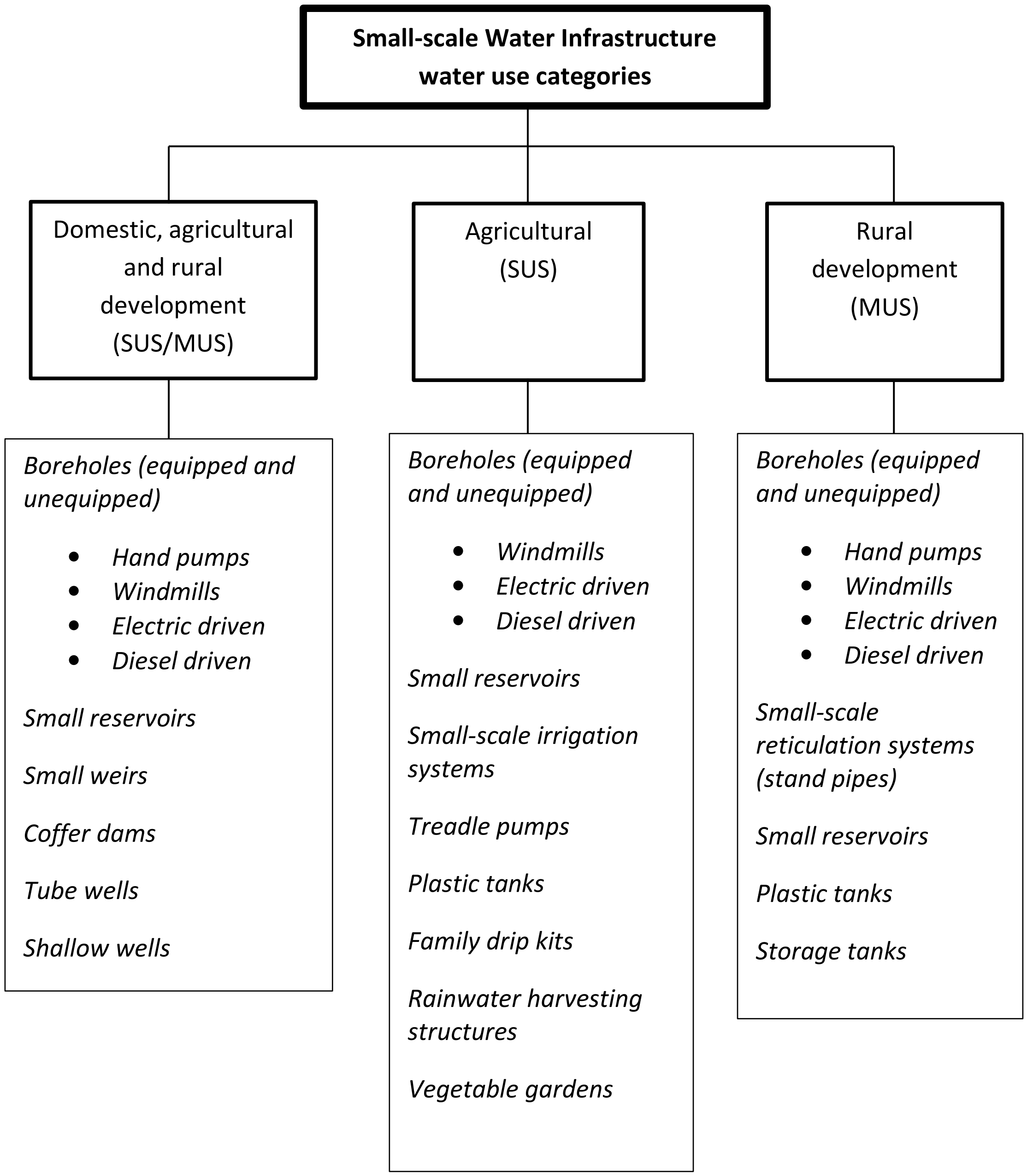

Figure 1.2 Categories of small-scale water infrastructure (SWI) in terms of water-use (adapted from Senzanje *et al*., 2012)

Table 1.1 Different multiple use systems (MUS) levels (adapted from FAO, 2009)

Level of MUS	Description of level	Examples of SWI
Household or homestead level	Involves the use of water for domestic use and small-scale productive uses (backyard gardens, livestock and micro-enterprise	Hand-pumps, small reservoirs and shallow wells
Water system level	Involves SWI whose water is used for different purposes along its course.	Conveyance canal
Community level	Involves overlapping different SWI, which provide water for different uses within the community	Hand-pumps, irrigation systems and small reservoirs.

1.3 Issues Related to Small-scale Water Infrastructure Management

Mann (2003) states that Southern Africa is "polluted" with SWIs that are breaking or broken down and emphasises that simply drilling a borehole and equipping it is not adequate. Therefore, stakeholders involved in water supply need to assess whether the technology used is appropriate for the rural communities. It is also important to consider factors, such as the availability of spare parts, funding, technical skills, ownership and responsibility for operation and maintenance (O & M), as well as institutional capabilities of relevant water service providers (WSP) (Kleemeier, 2000; Mann, 2003; Marks and Davis, 2012). Addressing these issues will result in the rural communities obtaining sufficient and good quality water to enhance their rural livelihoods.

In some parts of South Africa, such as in Mukhudutamaga local municipality (Nebo Plateau), it is reported that 47% of the population do not have access to proper functioning SWIs that meet their minimum water requirements (domestic use) and only 8% has full access to functional SWIs (IDP, 2012). This clearly indicates that more work still needs to be done to ensure that rural communities in Nebo Plateau receive water that is in line with the requirements of the law.

1.4 Research Problem

It was reported in the Integrated Development Plan (IDP) (2012) Report of Sekhukhune District municipality that almost half of the rural population living in the rural communities of Nebo Plateau receive water below the design standards stipulated in the Water Service Act of 1997 of South Africa. This indicates that almost half of the population in Nebo Plateau have non-functional or dysfunctional SWIs that do not supply adequate water for domestic, irrigation and livestock watering. It is reported in the 2012 IDP Report that the inadequate water supply can be blamed on a number of factors, namely: technical, environmental, community-related, institutional and financial. Little has been done to conduct a detailed investigation to establish the causes of SWI failure in the area. An investigation of the causes of failure is critical to improve water supply in Nebo Plateau. Furthermore, the WSP in the area does not have a complete record of the existing SWI types, their distribution, water-use and status. As a result, the WSP cannot allocate funds to conduct the proper maintenance of the SWI. The lack of these records raised the need to identify the different types of SWI used by the rural communities to assess their condition and functional status. Furthermore, an investigation of the causes of failure of the SWI is critical, so as to improve the system, as well as make recommendations on the proposed BMPs. In doing so, the WSP can use the results obtained from the study to relieve rural communities without an adequate water supply and to enhance their livelihoods.

1.5 Objectives

The main objective of this study was to assess the performance of small-scale water infrastructure (SWI) for multiple uses in Nebo Plateau, Limpopo Province, South Africa. The specific objectives of the study were as follows:

(a) To document the existing SWIs in Nebo Plateau in terms of their types, distribution, water use, ownership, maintenance, and functional status.
(b) To assess the performance of SWIs in Nebo Plateau (with respect to maintenance requirement and benefit to the rural communities).
(c) To investigate the causes of failure or sub-optimal performance of selected SWIs in Nebo Plateau.

(d) To propose or suggest the best management practices (BMP) model to maximise the SWIs benefits to the rural community of Nebo Plateau.

1.6 Outline of Dissertation

The thesis is written in the form of individual papers, which provides appropriate and necessary details on the study site and methodology. Furthermore, the writing style separates results from discussion. Chapter 1 gives a brief introduction and puts the study into its context. Chapter 2 discusses the type, distribution, status, water-use, ownership and maintenance of SWI (in general, and in Nebo Plateau). Chapter 3 addresses the performance of SWIs and the maintenance requirements using the risk of failure evaluation tool (Mufute, 2007), and the modified Rietveld *et al*. (2008) technical tool and the Stephenson *et al*. (2001) condition assessment ranking approach. In addition, Chapter 3 also presents the causes of failure of SWIs, using the theme and domain network approach. Chapter 4 proposes BMPs that can be used to manage SWIs in Nebo Plateau and Chapter 5 summarises, concludes and gives recommendations from the research.

1.7 Scientific Relevance and Contribution of the Study

The performance assessment of SWI is necessary, since a relatively newly installed SWI can also be in a poor condition (Rietveld *et al*., 2008). The assessment helps stakeholders that are involved in water supply to acquire solid evidence of the performance of the SWI. The data collected can help inform investors on the type of SWI to invest in and to provide funds for O & M. The causes of SWI failure are investigated, which then inform the proposal of the BMPs suitable for Nebo Plateau. The flow diagram of the study is shown in Figure 1.3.

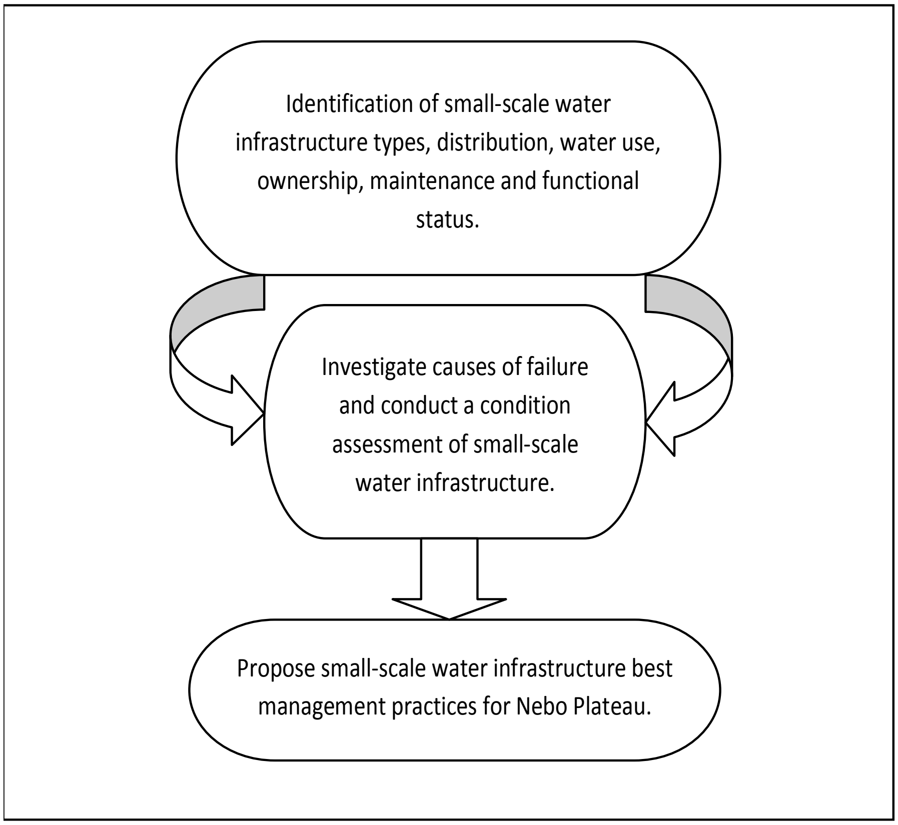

Figure 1.3 Study outline

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2. THE IDENTIFICATION OF SMALL-SCALE WATER INFRASTRUCTURE (SWI) IN NEBO PLATEAU, LIMPOPO PROVINCE, SOUTH AFRICA

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Abstract

Nebo Plateau is located in the Sekhukhune District, Limpopo Province, South Africa, where 47% of the population does not have an adequate water supply. This is mainly due to the low functional status of small-scale water infrastructures (SWIs), which are defined as technical hardware used by the rural communities to supply water for their day-to-day activities. The poor functionality is caused by lack of records of the SWI inventory, which would enable the allocation of resources to sustain maintenance of the SWI. This study aimed at identifying the types, distribution, ownership, responsibility for maintenance and status of the SWIs that exists in Nebo Plateau. Rapid Rural Appraisal techniques were used to undertake the study and these included questionnaires and key informant interviews. The questionnaires were administered to rural community members (202) only. The study identified different types of SWIs in Nebo Plateau and these comprised of the following; boreholes (59%), electric-driven boreholes (6%), hand-pumps (10%), small reservoirs (11%), windmills (4%), most of which (64%) were operated as single-use systems (SUS). The overall water-uses from the SWIs were 33% domestic, 23% irrigation and 9% livestock, with the least being 5% for combined domestic and livestock. About 54% of the SWI was owned by government, while the community owned 22%, the private sector 11% and schools owned 2%. Government was responsible for the maintenance of 49% of the SWI, but this study found that 71% of the SWI was non-functional. This study concluded that

improved-record keeping and the monitoring of the existing SWIs could improve the chances of investment in their operation and maintenance (O & M), which will enhance rural livelihoods. It is recommended that water service providers (WSP) use the inventory of SWIs compiled in this study to identify the population without adequate water in Nebo Plateau. Furthermore, the SUS must be upgraded to multiple-use systems (MUS), because rural communities do not require water for single-use only.

Keywords: borehole, maintenance, ownership, small reservoir, sustainability

2.1 Introduction

It was reported in the 2012 progress-update that the Millennium Development Goals (MDG) target, which was to halve the number of people without access to water and sanitation, has been met in the world (UNICEF, 2012). Despite meeting the target, it is estimated that 780 million people in the world do not have improved water supply systems (Graciana and Nkambule, 2012). Most of the people live in the rural communities of Africa, with some regions, particularly Sub-Saharan Africa lagging behind, with only 61% of the population having access to improved water supply. Furthermore, it was reported that only 19 (including South Africa) out of 50 countries in Sub-Saharan Africa are still committed to meeting the target by 2015 (UNICEF, 2012). According to Statistics South Africa (2013), South Africa has already met the target, with 95% of the population having access to water supply infrastructure. Despite this, rural communities in South Africa are still without proper functioning Small-scale Water Infrastructures (SWIs) that can cater for their day-to-day water-uses (Makhethu, 2011). The government has put more emphasis on supplying sufficient water and increasing investment in new SWIs, neglecting Operation and Maintenance (O & M) (Rietveld *et al*., 2008). Most SWIs are designed for single-use, but rural communities use them for more than one water-use. SWI that cater for single-use are called single-use systems (SUS). SWI that cater for more than one water use are called multiple-use systems (MUS). van Koppen *et al*. (2006) state that rural communities value MUS more than SUS, as a result they are more willing to maintain them.

In South Africa, the government is responsible for the maintenance and development of SWIs to supply water to rural communities (Cousins *et al*., 2008). However, prior to the democratic era (before 1994), the former government municipalities focused on providing water to urban areas only and neglected rural areas. Post-1994, when the new democratic government took over, the country went through a transitional process of reviewing government's responsibilities for both rural and urban water supply. This transition came into effect in 1995 and this culminated in local councils becoming responsible for water supply in urban and rural communities. After 1998, under the new legislation in the Water Service Act of 1997 (Water Service Act, 1997) and the National Water Act of 1998 (National Water Act, 1998), the District municipalities and local municipalities took over the responsibilities of water supply in their respective areas from the Department of Water Affairs (DWA). The new role of the DWA was planning, coordination, policy development, as well as provision of financial support for the transferred responsibility. However, the transfer of responsibilities to new government arms had its fair share of challenges, including the following (Harvey and Reed, 2004; Boshoff, 2009; Makhethu, 2011; IDP, 2012):

(a) the lack of sufficient capital and technical skills,
(b) the developing private sector providing poor quality work and over charging services,
(c) uncontrollable corruption,
(d) poor communication between municipality and the private sector due to different levels of skills and capacity,
(e) the lack of transparency in public – private partnerships, and
(f) no clear responsibility for ownership, operation and maintenance of SWI.

In the context of this study, ownership refers to the act of rightfully owning the SWI. Therefore, as a result of the challenges mentioned above, it was reported that in Nebo Plateau, Sekhukhune District, Limpopo Province, South Africa almost half of the population do not have access to fully functional SWIs that conforms to the design standards stipulated in the Water Service Act of 1997 (IDP, 2012). Furthermore, there is a lack of records of the SWI used by the rural communities, with regards to their types, distribution, water-use and condition. The availability of such records will promote the proper allocation of funds and human capital for maintenance of the SWI. This will also aid the Water Service Providers (WSPs) to plan better for SWI O & M in the future. WSP refers to stakeholders (government, municipalities, non-government originations, service providers, and individual, etc.) responsible for developing and maintaining SWI. The aim of this study was to identify the SWI used by the rural communities in Nebo Plateau for their day-to-day water-related activities. In addition, it also aimed at identifying their types, distribution, water-use, ownership, maintenance and functional status.

2.2 Materials and Methods

This section presents a brief overview of the study area, data collection methods and analysis.

2.2.1 Study site

The study was conducted in Makhudutamaga local municipality (Nebo Plateau) in the Sekhukhune District of Limpopo Province, as shown in Figure 2.1. The municipality was formed in 2000, after the transition from a local council (Ngwaritsi-Makhudutamaga) to a local municipality. The area is known for its rampant poverty, limited employment opportunities, poor social amenities, such as water infrastructure and access roads, with which to render service to the rural communities (IDP, 2012). The profile of the study area is summarised in Table 2.1.

2.2.2 Data collection

Rapid Rural Appraisal (RRA) techniques were used to collect data in Nebo Plateau. This is because the budget and time allocated for the study was not adequate to use long quantitative survey methods that require substantial financial and time resources. These techniques involve collaboration with community members in all aspects of data collection and analysis (Chambers, 1981). Data is therefore collected, using a diverse set of tools and techniques that facilitate the participation of community members in a more cost-effective and less time-consuming way (Chambers, 1981; Chambers 1990). It is argued that data and results produced are of a better quality than the traditional methods, such as intensive field surveys (Chambers, 1990). Therefore, using RRA enabled the adequate collection of data. This involved ignoring information that is not relevant to the study and focusing on the required information to achieve proportionate accuracy. The study used two RRA techniques, namely; questionnaires and key informant interviews.

2.2.3 Questionnaires

A questionnaire (can be found in Appendix B) was designed to collect data in the study area. The target group for the questionnaire was the rural community members of any age that used the SWIs. The questionnaire enabled collection of data on types, distribution, water-uses, ownership, maintenance and functional status of the SWI. Different types of the SWIs were identified, while travelling around the rural communities.

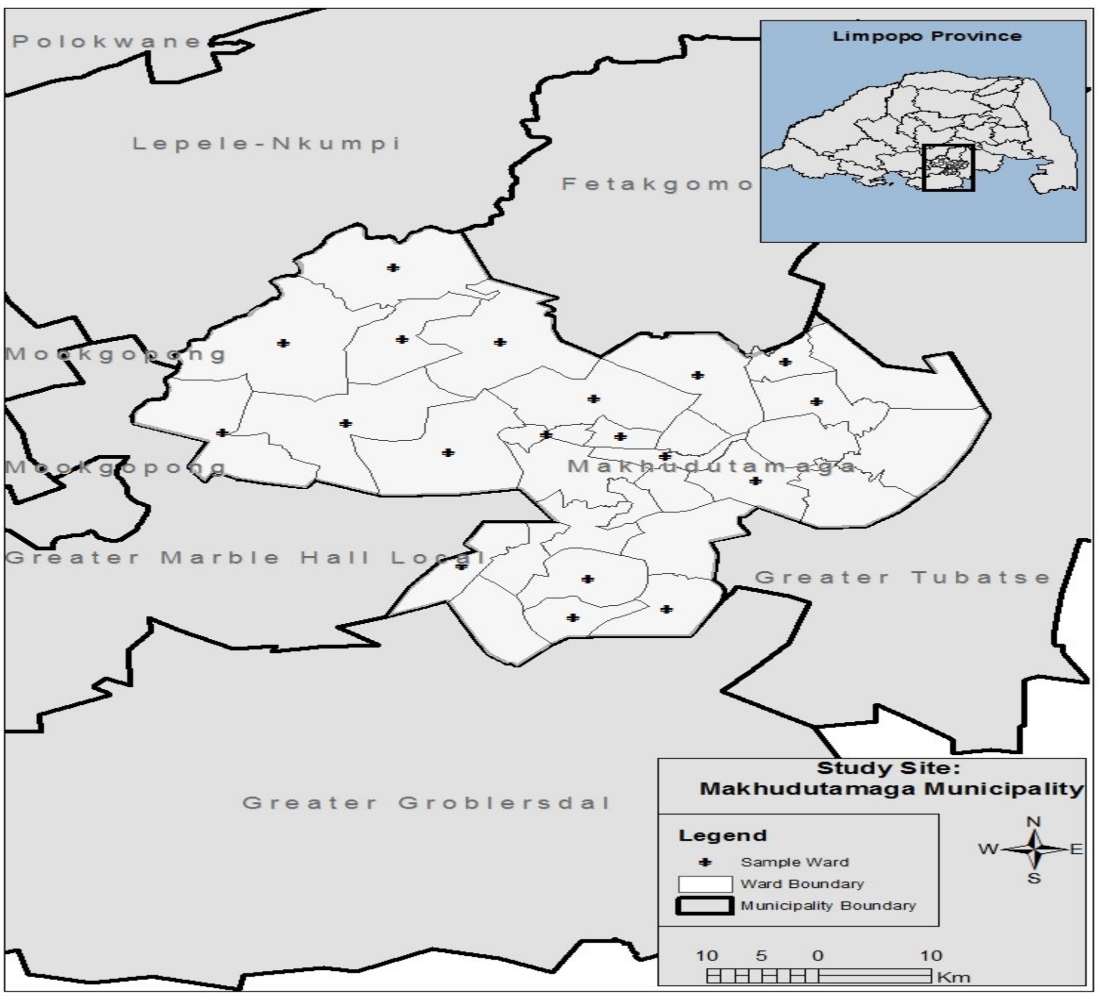

Figure 2.1 Map of the study site

Table 2.1 Profile of the study area (adapted from IDP, 2012)

Characteristic	Description
Population	65 215 households.
Climate	The climate varies between floods and drought with annual rainfall between 500 - 800 mm.
Gender distribution	56.6% females and 43,3% males.
Water access	62% of the household receive water below the RDP level.
Road access	Degraded road infrastructure due to heavy rains.
Distance to closest town	Closest town is Jurne Furse and Lebowakgomo but people prefer Polokwane which is about 150 km away and is more developed.
Health care	There are hospitals and clinics but they need to be revived.
Housing	Delayed commencement of housing development due to the dynamics involved with the list of beneficiaries.
Electricity	Electricity backlogs of 36% households.
Sanitation	The municipality is facing sanitation backlogs of 38,034 households.
Education	High number of students without post matric education due to lack funds. This is influenced by the lack of a tertiary institution in the area and most of the families in the area are disadvantaged as they can not afford post matric education. Only one bursary scheme was established which takes in a few students in the area. Development challenges such as delivery of books, water, sanitation and electricity also influence the level of education.
Agriculture	The communities depend on rainwater for agriculture. The Setlabotswana, Crokodile and Platkip irrigation schemes are the only commercial irrigation schemes equipped with floppy irrigation systems. The primary agricultural nodes are in ward 12, 17, 22, 02 and 05. Agricultural activities employ 6% of the population (Census, 2011) and almost 80% of the farms are under land claims. The most common crops planted are wheat, maize, sunflower, maize, sorghum and vegetables. Some of the community members have back yard gardens but also communal gardens are preferred in the area.
Community Projects	These projects absorb about 19% of the workforce in the area.
Mining	Mining is minimal and provides 1% employment in the area.

In some instances, researchers would request rural community members to assist with the identification of the SWI. The rural community members were more than willing to provide information when asked by one of their own than by an external person. More detailed data was acquired by using the rural community member's assistance, with regards to SWI and the rural communities' water dynamics. Once the SWI was identified, a Garmin eTrex Legend HCx - Global Positioning System (GPS) was used to capture the geographic coordinates of the SWI. The functional status of the SWIs was determined by physical observation and rated, as shown in Table 2.2.

Table 2.2 Description of functional status

Functional status	Condition of Small-scale Water Infrastructure
Fully functional (FF)	Small-scale water infrastructure operating without any defects or dysfunctional and supplying water according to its adjusted purpose.
Sub-optimally functional (SF)	Small-scale water infrastructure operated with minor defects or dysfunctional and supplying minimum water below its original adjusted purpose.
Non-functional (NF)	Small-scale water infrastructure that is not operational due to major defects and not supplying water according to its adjusted purpose.

2.2.4 Key informant interviews

Key informant interviews were conducted with individuals, from various institutions that are involved in water management in Nebo Plateau. The interviews were informal and respondents were asked different questions, depending on their position and responsibility, as well as their knowledge of the study area. Table 2.3 shows the different key informants that were interviewed.

Table 2.3 Key informants

Institution	Representative	Number
Department of Water Affairs (Limpopo)	Director: Groundwater	1
Limpopo Department of Agriculture	Extension officers Researchers	4 5
Sekhukhune District Municipality - Water Services	Technical staff	3
Traditional Authority	Head man	1
Mvula Trust (NGO)	Manager: Water Management	1
Tsogang (NGO)	Director	1
Village water committee (VWC) Member - Wonderboom	Chairman Treasurer	1 1
Community	Community members	5

2.2.5 Data analysis

Analysis of the data was conducted using Statistical Package of Social Sciences version 21.0 (SPSS) (SPSS, 2012) for general descriptive information, such as percentages and the cross tabulation of types, water-use, ownership, maintenance and functional status of the SWIs.

2.3 Results

This section presents results found in the rural communities of Nebo Plateau, Limpopo Province, South Africa. The results are based on the SWIs identified in Nebo Plateau.

2.3.1 Types of small-scale water infrastructure (SWI)

Figure 2.2 shows the distribution of 202 SWI identified in Nebo Plateau. Figure 2.3 shows that boreholes and small reservoirs constituted 77% and 11%, respectively, of the SWI identified in the study area. However, boreholes were categorised according to the technology used to abstract groundwater from the boreholes, as follows: unequipped boreholes (59%), hand-pumps (10%), windmills (4%), electric-driven boreholes (6%) and diesel-driven boreholes (1%). Unequipped boreholes are defined as boreholes without water abstraction mechanism installed to supply water to the rural communities.

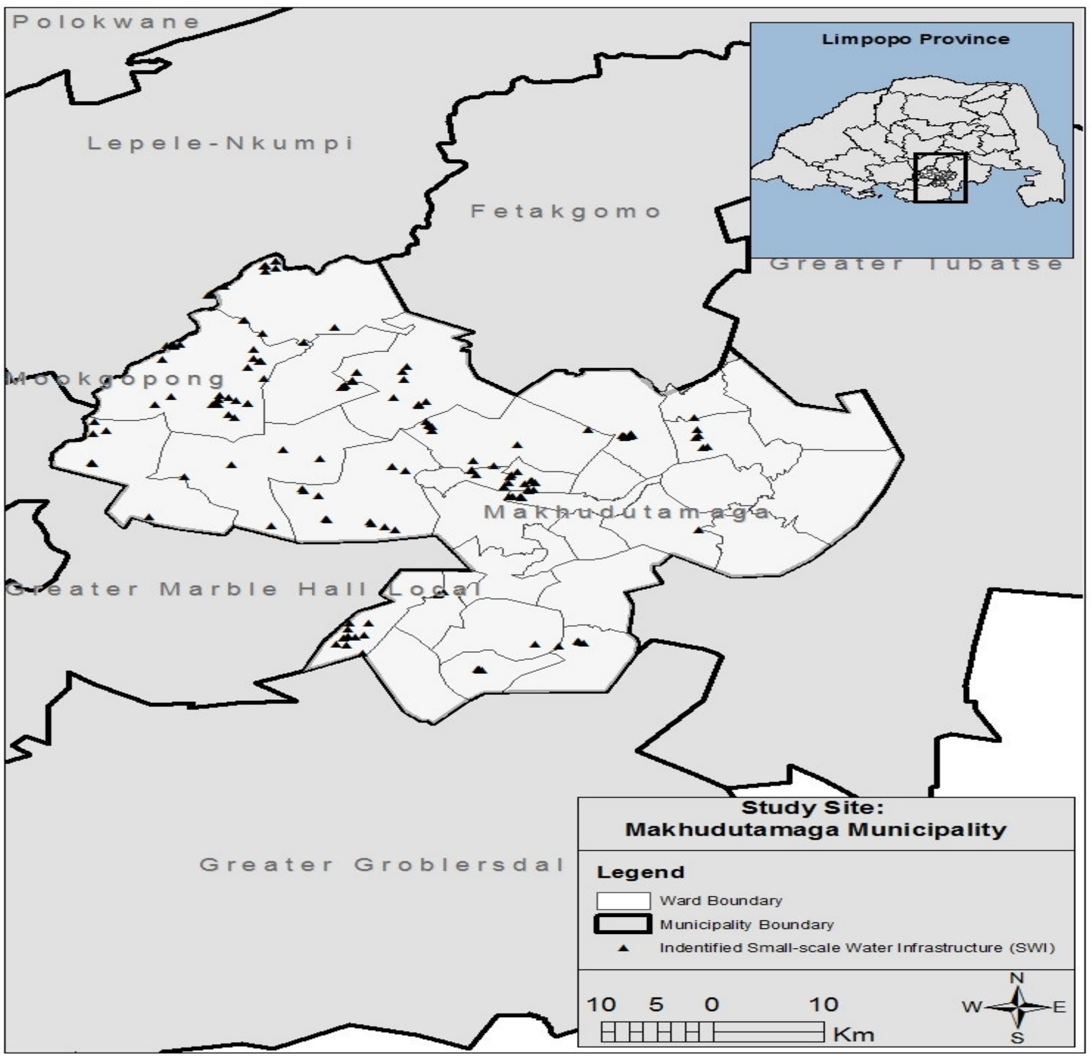

Figure 2.2 A Map showing distribution of small-scale water Infrastructure (SWI) in Makhudutamaga local municipality

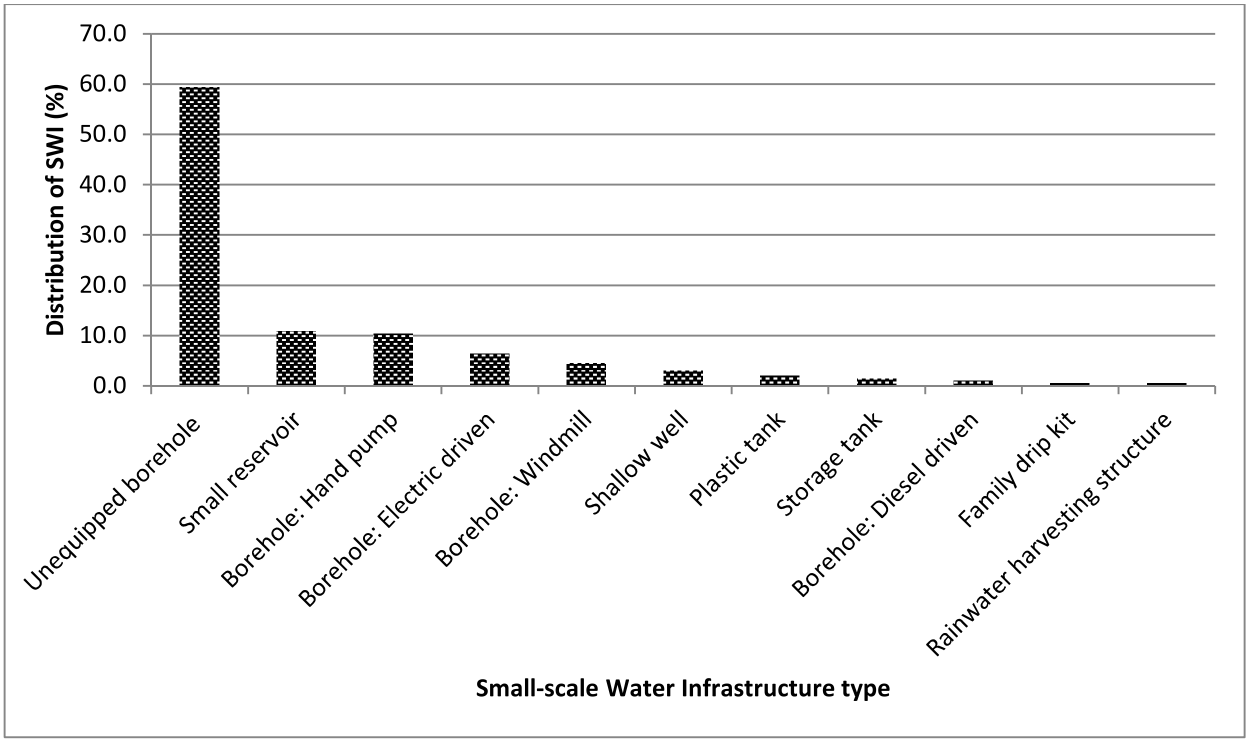

Figure 2.3 Overall distribution of small-scale water infrastructure (SWI) by type in Nebo Plateau, Limpopo Province

2.3.2 Utilization of small-scale water infrastructure (SWI)

The study categorised water-use into seven categories, as defined by Senzanje *et al*. (2012). These include domestic, irrigation and livestock for SUS and domestic and irrigation, domestic and livestock, and domestic, livestock and irrigation for MUS. The seventh category was "other", which refers to water-use other than those mentioned above. The water-uses were the actual water-use, regardless of the functional status of the SWI. For unequipped boreholes, only intended water-use was recorded. Figure 2.4 shows the percentage of water-use in each category, as practised by the community of Nebo Plateau. Figure 2.5 shows the relationship between different SWI types and water-use. Almost 70% of the water used for domestic purposes is collected from boreholes. However, hand-pumps contribute 19% of the domestic water used. Water for multiple-use (domestic, irrigation and livestock) is supplied by hand-pumps (9%), windmills (9%), electric-driven boreholes (22%) and small reservoirs (13%).

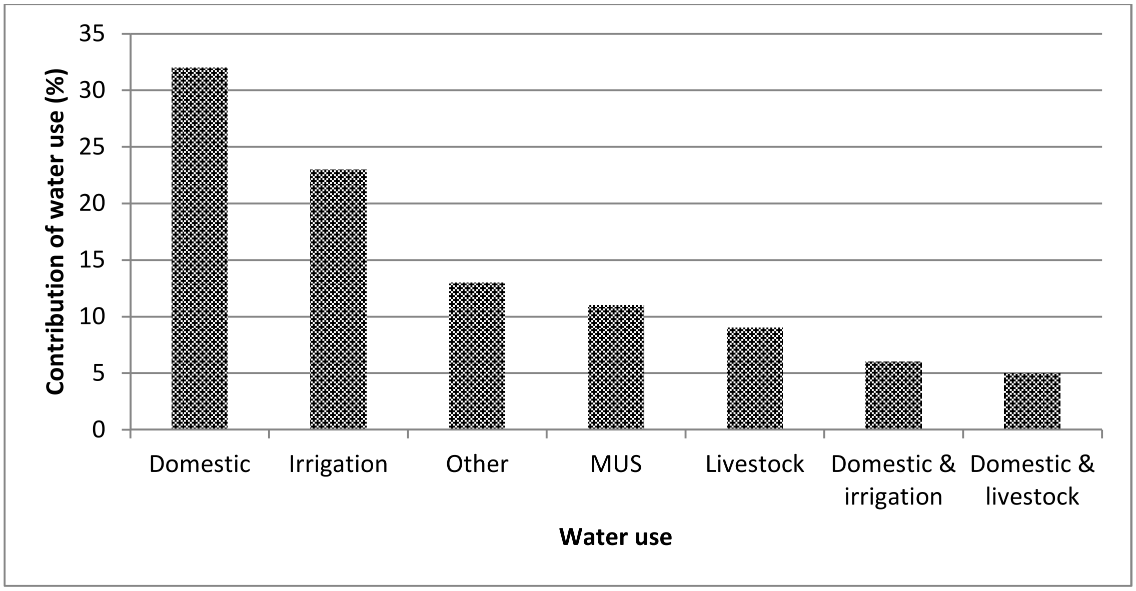

Figure 2.4 Distribution of different water use from the identified small-scale water infrastructure (SWI) in Nebo Plateau, Limpopo Province

2.3.3 Ownership of small-scale water infrastructure (SWI)

Figure 2.6 shows the different ownership arrangements of SWIs identified in Nebo Plateau. The results show that the government owns 54%, community 22%, private sector 11% and family 1% of the SWIs (including unequipped boreholes) in the study area. Furthermore, the results also indicate that government and community have shared ownership of 6% of the SWIs.

Figure 2.7 shows the SWI types identified in the study area and their ownership. The results indicate that the government owns the highest percentage of the SWIs. The government owns unequipped boreholes (43%), hand-pumps (76%), windmills (78%), electric-driven boreholes (77%), diesel-driven boreholes (100%) and small reservoirs (77%).

The community owns unequipped boreholes (27%), electric-driven boreholes (8%) and small reservoirs (18%). The results also show that government and community shared ownership of unequipped boreholes (5%), hand-pumps (19%), windmills (16%) and electric-driven boreholes (18%). The private sector owns the least number of windmills (12%).

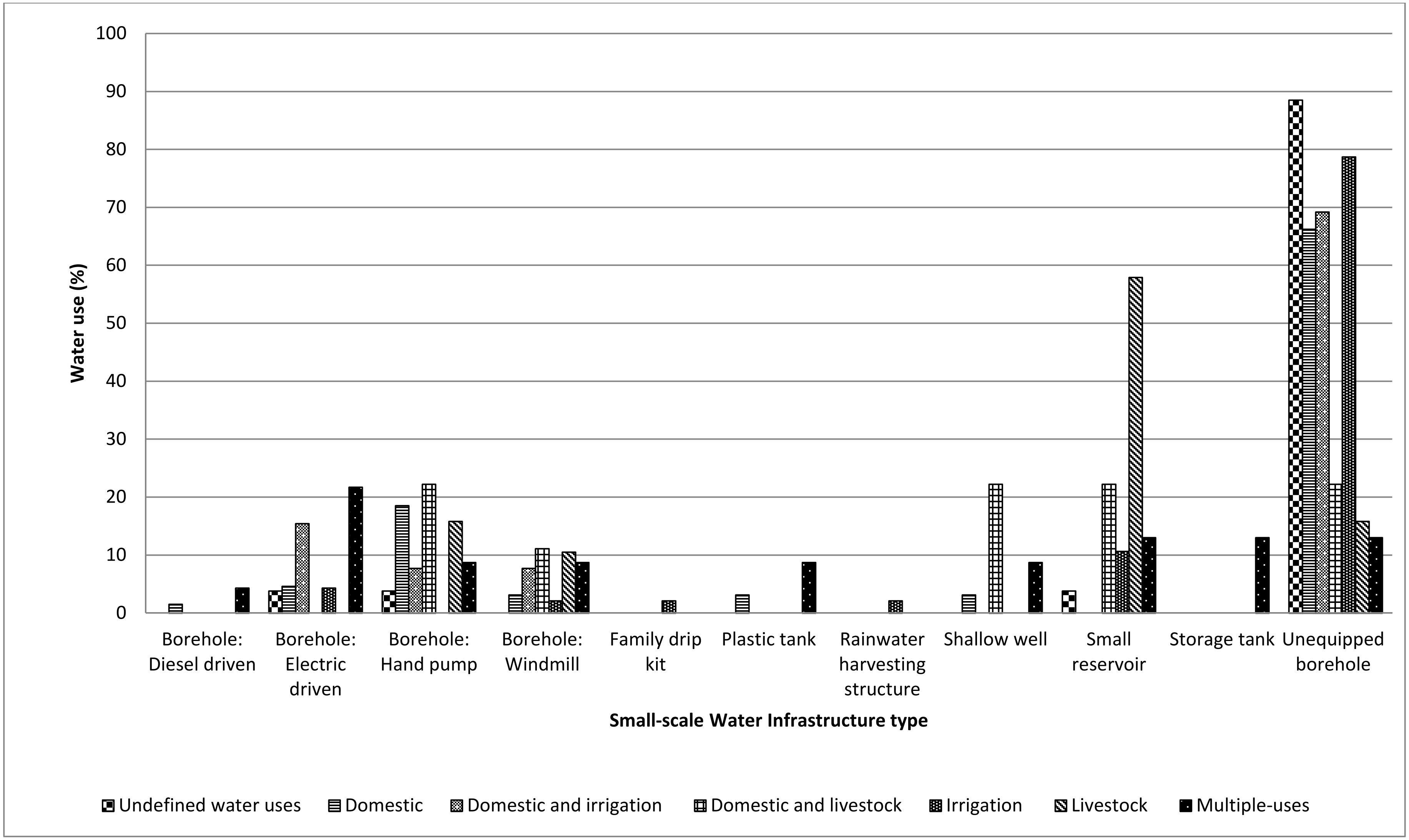

Figure 2.5 Water use from the different types of small-scale water infrastructure (SWI) in Nebo Plateau, Limpopo Province

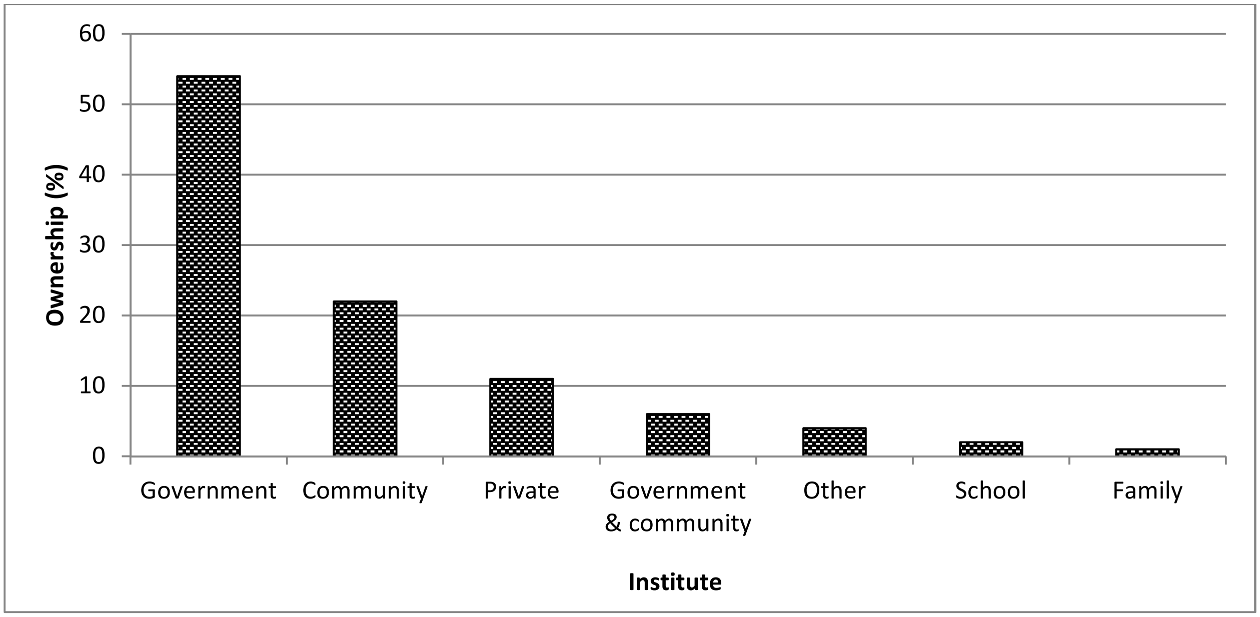

Figure 2.6 Ownership of small-scale water infrastructure (SWI) in Nebo Plateau, Limpopo Province

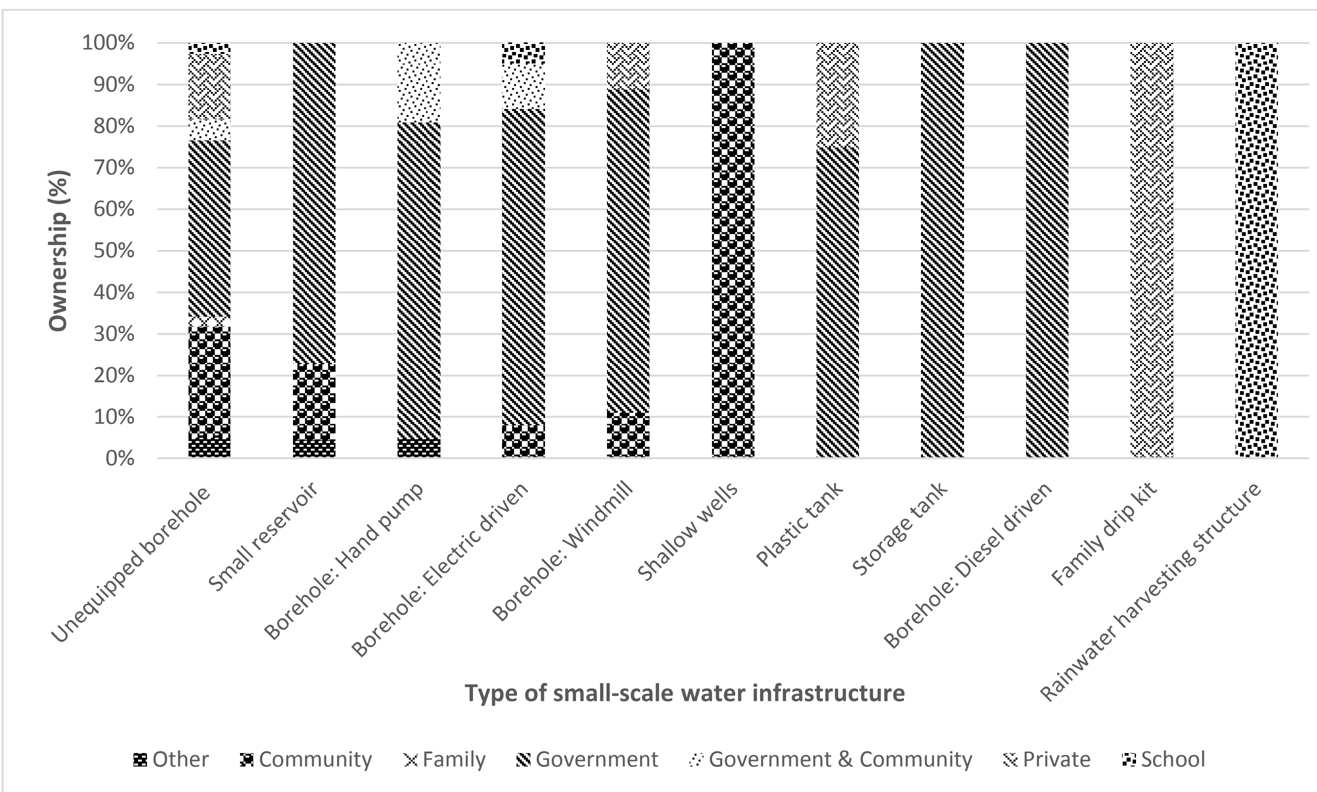

Figure 2.7 Institutional ownership of small-scale water infrastructure (SWI) by type in Nebo Plateau, Limpopo Province

2.3.4 Maintenance of small-scale water infrastructure (SWI)

Figure 2.8 shows the SWI types identified in the study area and responsibility for the maintenance. The results indicate that the maintenance of the highest percentage of SWIs is the responsibility of government. The SWIs maintained by government include unequipped boreholes (38%), hand-pumps (86%), windmills (44%), electric-driven boreholes (77%), diesel-driven boreholes (50%) and small reservoirs (68%). The community is responsible for the maintenance of unequipped boreholes (15%) and small reservoirs (18%).

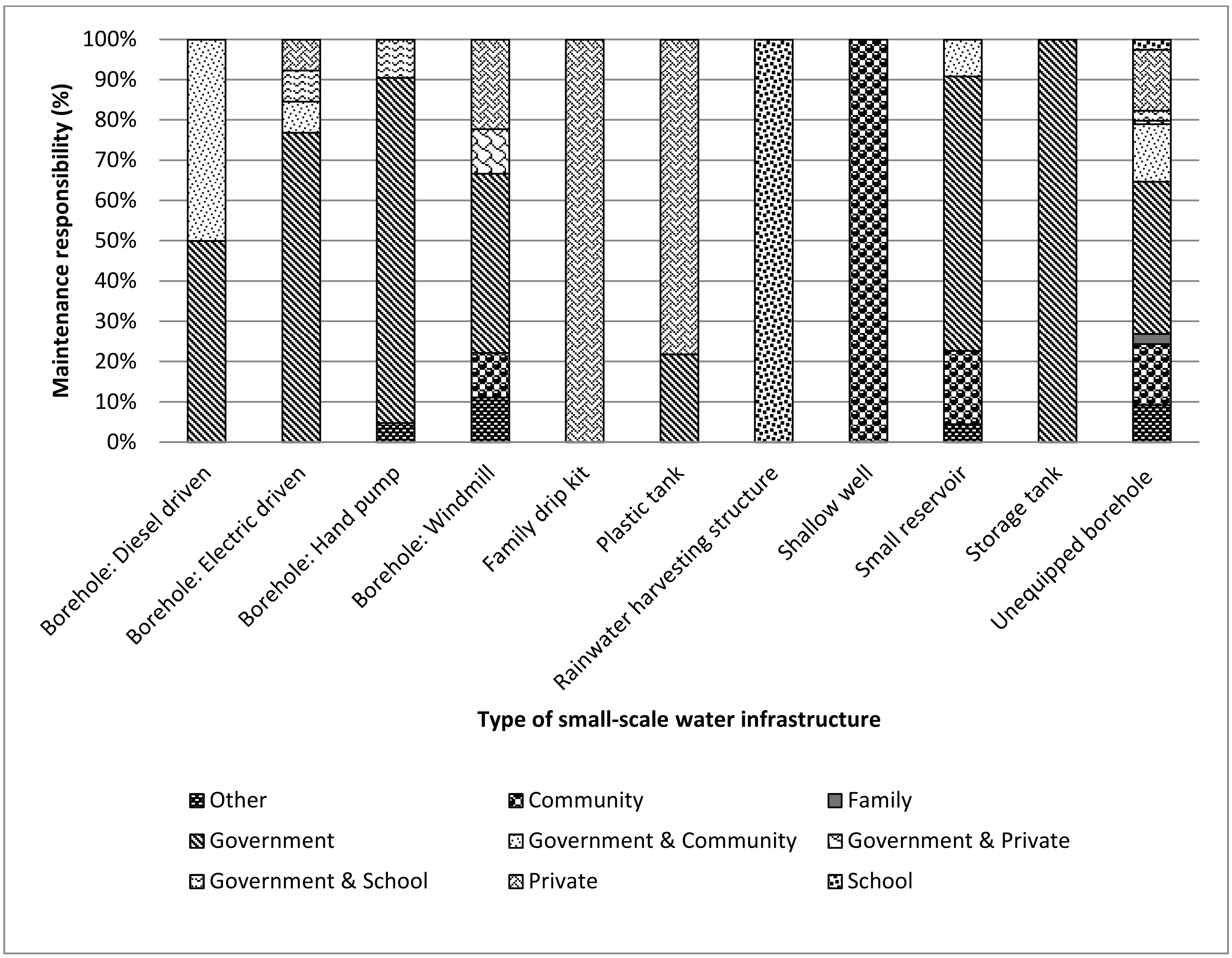

Figure 2.8 Institution responsible for maintenance of each small-scale water infrastructure (SWI) type in Nebo Plateau, Limpopo Province

The results also show that government and community shared responsibility for the maintenance of unequipped boreholes (14%) and small reservoirs (9%). The private sector is responsible for the maintenance of unequipped boreholes (15%), windmills (12%), electric-driven boreholes (8%) and diesel-driven boreholes (50%).

2.3.5 Functional status of small-scale water infrastructure (SWI)

Figure 2.9 shows the overall status of the SWI in the study area. The status is rated according to the functionality of the SWI. The study found that 71% of the SWIs are non-functional (NF), 15% sub-optimally functional (SF) and 14% fully functional (FF). Figure 2.10 shows the SWI types and their functional status. The functional status of the SWIs varied across SWI types. The results show that 87% of unequipped boreholes were NF, 56% of windmills were SF, 67% of storage tanks were FF, 100% of the family drip kits were NF and 33% of the shallow wells were SF.

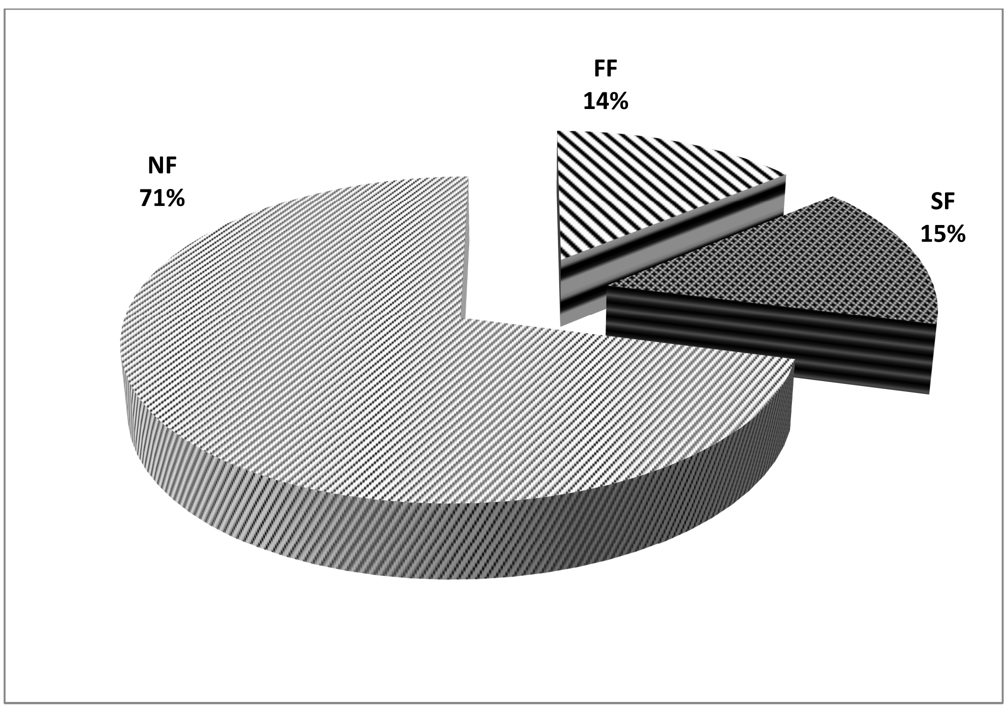

Figure 2.9 Overall functional status of small-scale water infrastructure (SWI) in Nebo Plateau, Limpopo Province

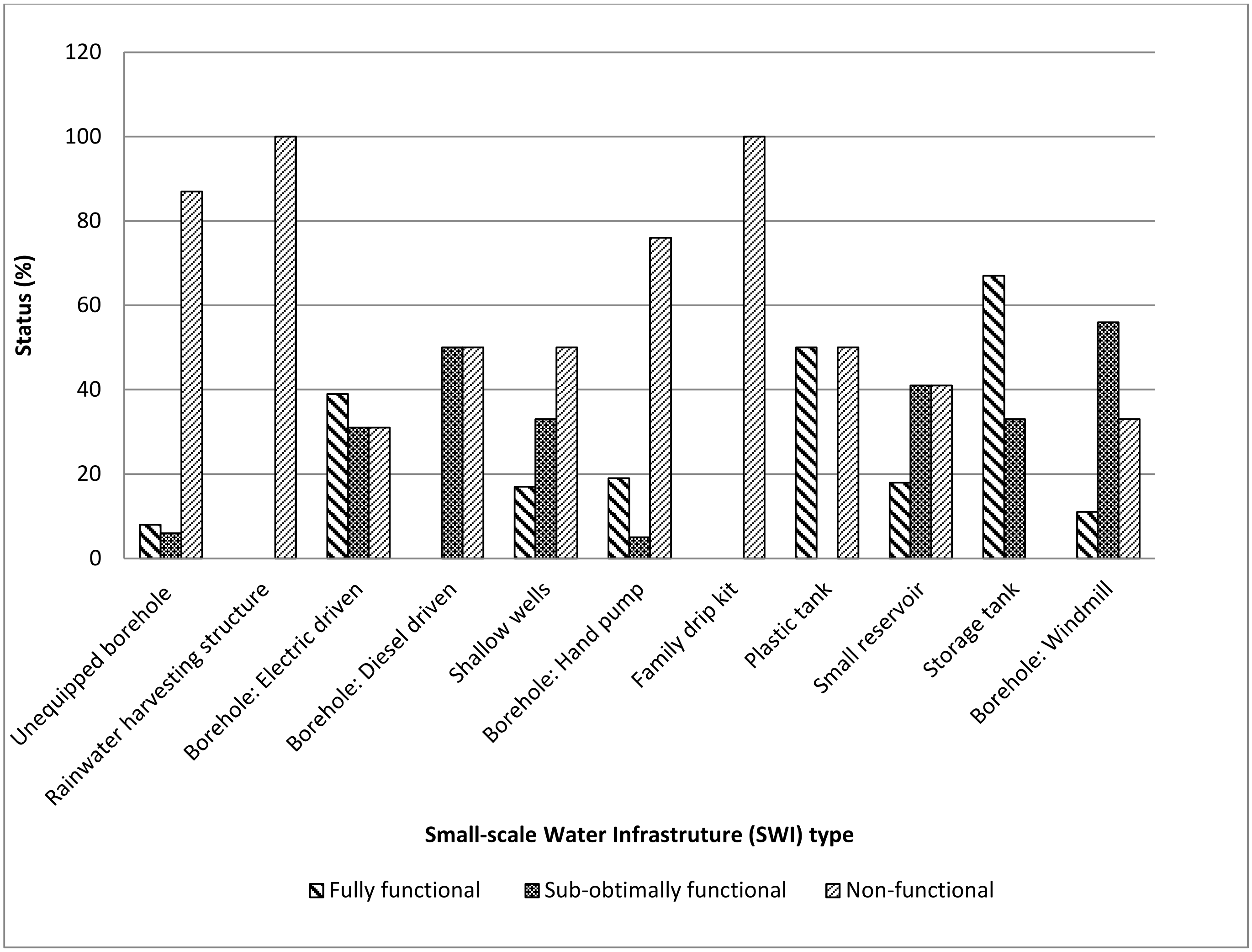

Figure 2.10 The functionality of SWI per SWI type in Nebo Plateau, Limpopo Province

2.4 Discussion

This section focuses on unequipped boreholes, hand-pumps, windmills, engine- and diesel-driven boreholes, and small reservoirs. These made up 91% of the identified SWIs. The other SWIs contributed the least (9%), but it does not necessarily mean they are not valued by the rural communities of Nebo Plateau.

2.4.1 Unequipped boreholes

The findings of the study showed that 59% of the identified SWIs in the study area were unequipped boreholes. According to the WSP and the DWA officials, the existence of the unequipped boreholes in the study area is mainly driven by the fact that they were drilled predominantly by the DWA before they were transferred to the Sekhukhune District municipality between the year 2003 and 2005. The DWA provided funds and contracted the private sector (service provides) to drill the boreholes on their behalf for the rural communities. The Sekhukhune IDP Report (2012) also reports that the rural communities in the study area have been using groundwater from boreholes for many years as their main water source, hence, they are dominant in the area.

Unequipped boreholes that were considered to be functional were mainly used for domestic purposes. This was due to the fact that it was difficult to collect water from the unequipped boreholes, shown in Figure 2.11. However, the unequipped boreholes were only used by the rural communities when the frequently used SWIs were not functional.

Rural community members claimed that the government owns 43% of the unequipped boreholes. However, ownership of these SWIs was not easy to define. The reason behind this was the confusion between government and community members with regards to the ownership of the SWIs. This is due to the fact that the proper handover of the SWIs to the rural communities was not done. This is because the boreholes were unequipped. The government officials claimed that once the boreholes were drilled in the rural communities, they were regarded to be under the ownership of the respective communities. According to the municipal asset management policy, the Water Service Authority (WSA) and WSP own the SWIs. However, the rural community members claimed the ownership of 27% of the SWIs in their communities and also claimed that they shared ownership of 5% of the SWIs with the government. Despite that, it is a possibility that all the SWIs were owned by government, as they were the main funder of the borehole drilling programmes. The fact that the land on which the boreholes were drilled is owned by the rural communities, could have led to some of them feeling a sense of ownership of the borehole.

Figure 2.11 Community member collecting water for drinking from an unequipped borehole

It is claimed by 37% of the respondents that government is responsible for the maintenance of the SWIs. However, there was also confusion with regards to maintenance and ownership. As a result, the rural community members claimed that the maintenance of some of the SWIs owned by the community were the responsibility of the government. They also claimed that they shared maintenance with government. A study conducted by Cousins *et al*. (2008) in Bushbuckridge, South Africa showed that the government was responsible for the major maintenance and that the rural community members were responsible for the minor maintenance of the SWIs in their respective communities.

A larger proportion of the boreholes in the study area were rated to be non-functional, mainly because they were not equipped with an abstraction mechanism, as shown in Figure 2.11. A water quality test was not done in this study, but the rural community members indicated that the reason for not equipping some of the boreholes was that water was contaminated, thus posing health risk for the rural communities. In other instances the water had a salty taste, this is supported by the Sekhukhune IDP Report (2012). Further, the IDP Report (2012) also indicates that mismanagement and the lack of funds also contributed to most boreholes not being equipped, hence most of them were non-functional.

2.4.2 Equipped borehole: Hand pump

The Afridev hand-pumps and mono-pumps were the most common types of hand-pumps used by the rural communities in the study area. There were also other types of hand-pumps, however, due to the old age of hand-pumps and modification done on them by the rural communities, it was difficult to identify their manufacturer. The existence of different types of hand-pumps in the study area could have been influenced by the different periods in which they were developed or by the popularity of the different makes to the different stakeholders that were involved in their development or installation. Harvey and Reed (2004) stated that is because South Africa does not have a policy that standardizes hand-pumps used in the rural communities. The Afridev hand-pumps are manufactured in India and imported into South Africa on request by agents and the mono-pump is locally manufactured (Harvey and Reed, 2004). This may explain why they are common in the study area.

Hand-pumps are used to abstract groundwater from boreholes to supply water to the rural communities for either domestic, irrigation or livestock use. The MUS component was not included in some of the hand-pumps, as most of them were designed to supply water for domestic use only. The rural communities collected water for livestock watering and irrigation. The water collected for irrigation was used to irrigate backyard gardens. Some of the rural community members would use the water meant for domestic purpose to irrigate. They would irrigate backyard gardens with the waste water from their households. Many studies have also shown that SWIs meant for single purpose are used for multiple uses (Van Kopppen *et al*., 2006; Reautanen *et al*., 2014). This is because the rural communities do not only need water for single-use only (Reautanen *et al*., 2014). Reautanen *et al*. (2014) also indicate that this is mainly because of the compartmentalised and fragmented single mandate of the different WSP's. On the other hand, in some parts of the study area, hand-pumps were designed to supply water for domestic and livestock use. This was done by constructing an animal drinking trough, which was connected to the hand-pump by a pipe, but the trough provided was not large enough to accommodate large livestock. Hence, livestock herders drove their large livestock to the river. The intensive labour involved in pumping water also contributed to driving the livestock to the river for drinking. However, smaller livestock were watered from the drinking troughs.

Hand-pumps (76%) in the study area were claimed to be owned by government and 19% were claimed to be owned by government and community (shared ownership). It was observed that the ownership of hand-pumps was mainly based on the functional status of the SWIs at the time of the survey. The percentage of SWIs owned by government was almost equivalent to the percentage of those that were non-functional. This may also indicate that SWIs for which rural communities feel a sense of ownership, would most likely be managed properly and kept continuously operational by the rural communities. Studies elsewhere have also shown strong evidence or links between the rural community sense of ownership of SWIs and their sustainability (Gomez and Nakat, 2002).

The maintenance of 86% of the hand-pumps was claimed to be the responsibility of government. As mentioned above, it was observed that some rural communities did not want to associate themselves with some of the non-functional SWIs. They could have responded in this way, hoping that the government would recognize its responsibility with regards to maintenance of the SWIs, and they would relieve rural communities without functional SWIs.

Most of the hand-pumps (76%) were non-functional (NF) in the study area. The high percentage of NF hand-pumps was prevalent, despite the fact that mono-pumps were locally manufactured and the spare parts were locally available. This does not agree with literature, as it is expected that the availability of spare parts locally, ensures timely operation of the SWI (Mann, 2003; Graciana and Nkambule, 2012). The underlying issue may be the availability of funds, because other studies show that funds for maintenance are the first to be cut when the budget is tight (Ruiters, 2013). However, capital investment in new SWsI still continues (Ruiters, 2013). The government proposed to move away from hand-pumps and provide the communities with stand-pipe taps. However, in most of the communities where stand-pipe taps were installed, they were not operational. Some rural communities vandalized the hand-pumps to speed up the development of stand-pipe taps in the communities, also supported by a study done by Majuru *et al.* (2012) in the rural communities of Limpopo Province, South Africa.

2.4.3 Equipped borehole: Windmill

Windmills contributed 4% of all the SWIs found in the study area. The percentage of windmills could have been higher, but most of them were installed on boreholes in the animal camps. This made them difficult to reach, as there was no access road in the camps, therefore, the users had to walk to the windmill. All of the windmills observed in the field were manufactured by Climax and were mainly supplied by Steward and Lloyds in Polokwane, Limpopo Province, South Africa.

Water supplied by windmills was mainly used for domestic and livestock (11%), livestock (10.5%), and domestic and irrigation (8%). In most instances, windmills in the rural communities were designed as MUS, taking into account the rural communities multiple water needs. This would in turn contribute to the sustainability of the windmill (van Koppen *et al.*, 2006). Rural communities developed vegetable gardens next to the windmills, to use the water for irrigation. Those that were in the animal camps were strictly designed to cater for livestock drinking according to the rural communities. The reason for this is that they were far from the rural communities' households. They were also not designed to cater for domestic and irrigation purposes.

The rural community members claimed that government owns 78% of the windmills and the remaining SWIs are owned by the private sector (11%) and community (11%). Most of the windmills were developed as part of the drought relief programme in the animal camps, but also spilled over in the communal areas. The rural communities did not seem to want to claim ownership of the windmills. This may be due to the perception by rural community members that the expertise and funds required to maintain the windmills are too high for them to carry. Therefore, they would rather have the government and private sector owning the windmills.

The maintenance of the windmills was the responsibility of government and the private sector. As mentioned above, this was influenced by the need for expertise and funds to maintain the windmills. Some community members claimed that 11% of the windmills were shared maintenance between government and the private sector. This was stated by the respondents that they were not certain as to who should maintain the windmills. The confusion was also provoked by the fact that government contracted the private sector to develop or construct the SWIs, therefore it was thought to be a collaborative effort.

The majority of the windmills were NF (33%) and SF (56%) and the remainder were fully functional (FF). The poor functional status of the windmills was due to the lack of maintenance. They were simply constructed and left there to use without regular maintenance. This is also supported by a study done by Mann (2003) in Southern Africa. According to Hoko and Hertle (2006), because spare parts are available locally, it is expected that the maintenance and repair of the windmills would be done when required. This was not the case in the study area, hence their poor functional status.

2.4.4 Equipped borehole: Electric- and diesel- driven boreholes

The study identified electric-(6%) and diesel-(1%) driven boreholes in the study area. The water was pumped from the borehole to a storage tank. The stored water was supplied to the rural communities though pipes, which used gravity to get to the communal stand-pipe taps. At the time of this study, a programme initiated by the Sekhukhune District municipality Water Services Division to replace the diesel-driven boreholes with electric-driven engines was in the process of being carried-out. This explains the high percentage of the electric-driven boreholes in the study area. The rural community members indicated that this was one of the most preferred systems to supply water, because water is easily accessible and does not require labour to pump the water.

Water was mainly collected for domestic, irrigation and livestock watering, despite the fact that they were designed for domestic water use only. This was done because the rural communities did not only require water for domestic water use. However, it was also convenient for them, because they did not have to carry heavy buckets for long distance to their household and they were able to collect as much water as they needed. They irrigated backyard gardens and watered small livestock (goats, pigs and calves) with the water collected. The larger livestock (cattle and donkeys) were watered from rivers.

The government owned 100% of the electric-driven boreholes and 81% of the diesel-driven boreholes (the remainder was by the communities). The rural communities were hesitant to claim ownership of the diesel-driven boreholes. They did not want to be responsible for the payment of the electricity and diesel bill, which was seen as the responsibility of government at the time of this study.

It was claimed that the maintenance of the majority of the SWIs was the responsibility of government. Most of the SWIs were owned by government and rural communities expected the government to maintain them. The lack of skills to maintain and repair the SWI in the rural communities could also have contributed to communities not claiming responsibility for their maintenance.

The functional status of 50% of the diesel-driven boreholes was NF. The functional status of 39% of the electric-driven boreholes was FF, and the remaining 61% was NF. The NF status was due to the lack of maintenance. Theft of some of the SWI components (engine, transformer and cables) also contributed to the NF status of diesel- and electric-driven boreholes.

2.4.5 Small reservoirs

After boreholes, small reservoirs were the most commonly-used SWI by the rural communities. They were constructed in the vicinity of the rural communities, which made them easily accessible. This made it easy for the community members to collect water from these SWIs. They were mainly used by the rural communities as alternative water sources, when the frequently used facilities were broken-down.

The small reservoirs were mainly developed and used for livestock drinking. Although they were not MUS by design, rural communities also used them for domestic and irrigation purposes. This is also supported by studies done in the rural communities of Zimbabwe on small reservoirs (Sawunyama *et al*., 2006; Mufute, 2007). In the case where the small reservoir was the only water source in the community, they were also used for domestic purposes. Water for drinking was used without boiling, which could cause a serious health risk for the communities. Hoko and Hertle (2006) stated that the use of untreated surface water can increase the risk of getting infected by water-borne diseases, such as diarrhoea or diseases that may eventually lead to mortality. For some of the communities, water from the small reservoirs had become their main water source. The rural communities also developed vegetable gardens around the small reservoir to use the water for irrigation. Water for backyard gardens was sometimes collected from the small reservoirs. However, carrying water from the small reservoirs was not as far as carrying it from the river, which was time-consuming and labour intensive.

It was claimed that most of the small reservoirs (68%) were owned by government and the rest by rural communities. In the interview with officials from the DWA and WSP, they indicated that all the small reservoirs were constructed by government. This contributed to most respondents claiming that most of them were owned by government. Even so, rural community members claimed ownership of 18% of the small reservoirs due to the fact that they were in their communities and it was felt that they are the rightful owners of the land.

The majority of the maintenance of small reservoirs was claimed to be the responsibility of government (68%). The community was responsible for the maintenance of 18% of the small reservoirs. It was claimed that most of the SWIs owned by government and rural community members saw it as fitting for government to take responsibility for their maintenance. Even though government and communities were responsible for maintenance, the small reservoirs were not maintained. This was due to the lack of funds and capacity from the WSP and is supported by a study done by Sithole and Senzanje (2006) in the rural communities of Zimbabwe.

Small reservoirs identified were functional (18%), sub-optimally functional (41%) and non-functional (41%). As mentioned above, maintenance was not done on the small reservoirs, hence their poor functional status. Literature has also indicated that a large number of small reservoirs used by the rural communities are in poor condition due to lack of maintenance (CARE Zimbabwe, 2002; cited by Mufute, 2007). As a result, trees and shrubs were growing on the embankment of the SWI causing cracking and erosion. Some were dried-out and had unwanted plants growing in the small reservoir.

2.5 Conclusions and Recommendations

The findings of the study indicate that boreholes and small reservoirs are the most dominant SWI used by the rural communities in the study area. The boreholes can be categorised according to the different abstraction mechanisms used to pump water. The borehole types found in the study area were as follows: unequipped boreholes, hand-pumps, windmills, electric - and diesel - driven boreholes. Boreholes have been used by the rural communities to supply water for many years in Nebo Plateau. As a result, the technology used to pump water from the boreholes has also been evolving over the years, hence, the different type of technologies used to pump water for the boreholes. The rural community members have expressed their interest in the development of electric-driven boreholes that will supply water to stand-pipe taps in their communities. This is because they are easily accessible, and they are not labour intensive. Therefore, it is recommended that WSP in the study area not only replace diesel-driven boreholes with electric driven boreholes, but also replace other borehole types, as this is definitely the most appropriate investment option.

This study found that water in the study area is used for domestic, irrigation and livestock watering. Most of the SWI identified were designed to supply water for single use, mainly domestic use. The rural communities ultimately used them for irrigation and/or livestock watering, which was common with all the SWI designed for single use. This is a definite indication that there is a need for MUS in the rural communities of Nebo Plateau. It is recommended the stakeholders involved in SWI design and development must upgrade the existing SWIs to MUS and in future design and provide rural communities with SWIs that cater for their multiple water needs.

The study concluded that the government owns most of the SWIs in the study area. This is because government is the main funder and developer of SWIs with the assistance of the private sector, hence some of the SWI were claimed to be owned by the private sector. The rural communities claimed ownership of some of the SWI. The study showed that government owns all the identified electric-driven boreholes in the study area and they are the preferred method of water supply by rural communities.

The responsibility for maintenance interchanged between government and communities. However, since government own most of the SWI, it was expected that the government must maintain them, including those that the rural communities and the private sector own. In some parts of the study area, the rural communities claimed that they shared maintenance with government, as a result, the rural communities were responsible for the minor maintenance and government were responsible for the major maintenance. It was expected that the shared maintenance between government and community would ease the burden on the available limited resources. Despite this, the maintenance of the SWIs was not done. Given the situation in the study area, it is recommended that government take full responsibility for the maintenance of the SWIs until such time that they capacitate the rural communities with the technical skills required to diagnose and maintain the SWIs. Once the rural communities are capacitated, an assessment of their financial resources and their willingness to pay for maintenance of the SWI must be conducted to establish if they can afford the cost of repairs.

Overall, the functional status of most of the SWIs was very poor and unacceptable. The lack of funds and inadequate maintenance of the SWIs was indeed the ultimate cause of their poor functional status. For this reason, it is recommended that stakeholders involved in water management, such as the WSPs and DWA utilize the results presented in this study to attend to the rural communities without water or non-functional SWIs

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3. ASSESSMENT OF THE CONDITION AND CAUSES OF FAILURE FOR SMALL-SCALE WATER INFRASTRUCTURE (SWI) IN NEBO PLATEAU, LIMPOPO, SOUTH AFRICA

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Abstract

It is reported that some parts of Nebo Plateau are receiving water below the legislative standards of the South African government stipulated in the Water Service Act of 1997, due to the poor condition of the small-scale water infrastructure (SWI). Condition is defined as the status of the SWI in terms of its operation and serviceability. The poor condition of the SWI is reported to be caused by a number of factors that include; technical, community, institutional, financial and environmental. The aim of this study was to assess the performance of SWIs and investigate the causes of failure based on the factors that cause the poor condition in Nebo Plateau, Limpopo Province, South Africa. A condition assessment of small reservoirs hand-pumps and windmills was undertaken, using the risk of failure evaluation tool and technical tool kit, respectively. The analytic hierarchy process (AHP) was used to determine the weighting of the top, middle, and underground components of hand-pumps and windmills. Ranking of the SWIs, according to their maintenance requirement and benefits to the rural communities was done. Furthermore, gamma statistics were used to determine the association between condition and different levels of water uses. A qualitative research approach was used to investigate the causes of failure, which were analysed using the theme and domain network analysis. It was found that small reservoirs ($I_c = 0.16$) and Hand-pumps ($I_c = 0.50$) required major maintenance and benefited the rural communities below the minimum level. It was also found that the association of the condition and water-use ranged from weak for windmills (+0.29) to moderate for hand-pumps (+0.35) and small reservoirs (-0.50). There was no statistically significant association between hand-pumps and windmills. The causes of failure were mainly due to lack of proper operation and maintenance (O & M), theft and

vandalisation, the lack of funds and technical skills at municipality and community level. It is, therefore, recommended that a more site-specific O & M plan must be developed to combat the above issues and improve water supply to the rural communities of Nebo Plateau.

Keywords: management, network analysis, performance, risk of failure, small reservoirs

3.1 Introduction

Small-scale water infrastructures (SWI) are used by the rural communities to supply water for domestic, agricultural and rural development (Senzanje *et al*., 2012). These activities are important to enhance rural livelihoods by generating income and ensuring food security (Adank, 2006). However, rural SWI used by the communities in developing countries are failing to supply good quality and sufficient quantities of water, because they are in poor condition (Carter *et al*., 2010).

It is estimated that more than 30% of the SWI in the rural communities of sub-Saharan Africa are in poor condition (Diwi and BIDR 1994; cited by Harvey and Reed, 2004). The poor condition is mainly blamed on the lack of proper operation and maintenance (O & M) and top-down approach, where water service providers (WSPs) focus on supplying quantities of water, while neglecting the condition of the rural SWI in the long-term (Rietveld *et al*., 2008). Many organisations involved in SWI development simply construct the SWI and leave them for the rural communities to operate and maintain. They do not consider important issues such as willingness to pay for O & M, local availability of spare parts, establishing village water committees (VWC), training of WSPs and rural communities, and O & M strategies and policies (Mann, 2003; Rietveld *et al*., 2008 and Boshoff, 2009). Manyena *et al*. (2006) reported that in the rural communities of Zimbabwe, broken down SWI are neglected or not attended to, for a period of up to five years. This indicates that rural communities may sometimes neglect SWI, based on their condition and inability to repair them.

In realizing the high percentage of SWIs in the poor condition, researchers, academics and water practitioners developed methods to evaluate risk of failure, and quantify and classify the condition of SWIs (Kuscu *et al*, 2009; Šadzevičius *et al*., 2013). Most methods focused on risk assessment, which are as follows: (a) Kreuzer and Bury (1984) method is based on a systematic analysis and representation of the probability of failure, using dam safety inspection, (b) Cheng *et al*. (1986) method is popular for its reliability method for any given performance function, (c) Lafitte (1993) method is based on fault-tree analysis and event-tree analysis to calculate the probability of failure, (d) Lafitte (1996) method classify or categorize dams based on global factors that result in their failure, and (f) Šadzevičius *et al*. (2013) method is based on visual observation and field investigations. Most of the tools were aimed at robust urban water supply systems, while neglecting the rural SWIs. This again raised the need to develop tools that can quantify and classify the condition of rural SWIs. Quantifying and classifying the condition of the SWIs aids the WSPs in a specific area to prioritize the maintenance of SWIs based on their serviceability and the benefit to the rural communities. Because of this, Mufute (2007) and Rietveld *et al*. (2008) developed the condition assessment tools that were suitable for SWI in the rural communities of Zimbabwe and South Africa, respectively. Mufute (2007) developed a risk of failure evaluation tool, based on the criteria that affect the physical condition of small reservoirs. The tool systematically classifies the risk of failure, to enable WSP to prioritise small reservoirs requiring attention. The technical tool by Rietveld *et al*. (2008) adapted from the Health, Environment, Social, Economic and Technical toolkit (HESET) also helps WSP to prioritise the maintenance of the SWI. However, assessing the condition of the SWI is not the same as ensuring its sustainability (Carter *et al*., 2010). The condition assessment only provides a snapshot of the current status of the SWI (Rietveld *et al*., 2008; Carter *et al*., 2010). In addition, it does not identify the causes of failure, which are vital to prevent if the good working condition of the SWI is to be maintained.

The aim of this study was to assess the condition of small reservoirs, hand-pumps and windmills, used by the rural communities of Nebo Plateau in the Limpopo Province, and to investigate the causes of failure that contribute to their poor condition. Therefore, the study presents a snapshot of the condition of small reservoirs, hand-pumps and windmills for the WSP to attend to those that require maintenance and do not meet the rural community's water needs. Furthermore, it highlights the cause of failure of the SWIs in the rural communities, to contribute towards their sustainability. The tools used to assess the condition and investigate the causes of the SWI failure in Nebo Plateau are discussed below.

3.1.1 Risk of failure evaluation tool developed for small reservoirs in Zimbabwe

The risk of failure evaluation tool was developed by Mufute (2007) to assess the risk of failure of small reservoirs in the rural communities of Zimbabwe. The tool was developed after realizing that tools, such as the standard base and risk evaluation, were mainly developed for large dams (Bowles *et al.,* 1997; Mufute*,* 2007). These tools also require vast data, which can only be acquired from regular inspection and monitoring equipment installed on the large reservoirs. However, the method used by Šadzevičius *et al*. (2013) on earth dams (reservoirs constructed using soil) in Lithuanian can also be used to assess the condition of small reservoirs, using physical observation and field investigations. STR1.12.03:2006 (2007) construction regulations were incorporated in the Šadzevičius *et al*. (2013) method and used to assess the condition of 260 earth dams in Lithuania and rated according to the computed values (0 - 2.0 = good condition, 2.1 - 4.0 = moderate condition, 4.1 - 6.0 = satisfactory condition, 6.1 - 8.0 = unsatisfactory condition, and 8.1 -10.0 = critical condition). Although the Šadzevičius *et al*. (2013) method is suitable for assessing the condition of small reservoirs, for the purpose of this study, the Mufute *et al* (2007) risk of failure evaluation tool is preferred.

Compared to the Šadzevičius *et al*. (2013) method, the risk of failure evaluation tool requires less technical information and resources to assess the factors that causes the failure of the small reservoirs and was developed for small reservoirs in the rural communities (Mufute, 2007). A qualitative and quantitative assessment of the physical condition of the small reservoirs in the rural communities was conducted to develop the tool. This allowed the identification of factors that affect the physical condition of the small reservoirs. The factors were then compared with design and maintenance guidelines developed for Zimbabwe and other countries (Shaw, 1977; USA Government, 1977; Muyambo, 2000; ASWCC, 2002; WEDC, 2006). The comparison resulted in the development of factors that are suitable and contribute to the failure of small reservoirs in rural communities. After the development of the factors, Mufute (2007) realized that each factor affected the condition of the small reservoirs differently, and as such, a ranking and weighting of the factors was done to determine the weighting of each factor that contributes to failure. The ranking and weighting was not done using a probability method, meaning that, the overall risk of failure score is non-probabilistic, but qualifies as numerical and can be used in data-sparse locations.

The tool was used to evaluate the risk of failure of 44 small reservoirs in the Insiza District, Zimbabwe. The assessment confirmed that the tool can be used to assess the performance of small reservoirs in the rural communities (Mufute, 2007). Therefore, the risk of failure evaluation tool can be used to assess the condition of small reservoirs in the rural communities of Nebo Plateau. However, the tool can be modified, as some components and factors identified for the assessment of small reservoirs in the rural communities of Zimbabwe do not apply to small reservoirs found in Nebo Plateau.

3.1.2 Technical assessment tool

Rietveld *et al*. (2008) developed a technical tool for the rural communities of the Vhembe District, South Africa, to assess the condition of stand-pipe taps. The condition assessment was done by assessing certain components of the stand-pipe taps to estimate their overall condition. The following stand-pipe taps components were segmented and considered for assessment: damage and/or leakage of the tap (I_{tap}), platform under tap (I_{platform}), support for tap (I_{support}), and whether there are informal or secondary connections to the tap, *e.g.* hoses connected for garden irrigation (I_{sec}) (Rietveld *et al*., 2008). Segmenting and physically assessing the different components, reduced the time it takes to assess each part in the field (Rietveld *et al*., 2008). The information gathered from the physical assessment in the field was used to compute the condition index (I_{cond}) (see Equation 3.1). The computed condition index was used to classify the condition of the SWI in a particular area, using a four-tier bench-marking scheme for the components condition, shown in Table 3.1.

$$I_{cond} = \delta_1 I_{outlet} + \delta_2 I_{platform} + \delta_3 I_{support} + \delta_4 I_{sec} \qquad (3.1)$$

Where

I_{cond} = condition index,

$I_{outlet} = \frac{N_{tap,good}}{N_{wp,total}}$ is the condition of the outlet,

$I_{platform} = \frac{N_{platform,good}}{N_{wp,total}}$ is the condition of the platform,

$I_{support} = \frac{N_{support,good}}{N_{wp,total}}$ is the condition of the support,

$I_{sec} = \frac{N_{pump,good}}{N_{wp,total}}$ is the condition of the secondary connection pump,

$N_{wp,total}$ is the total number of water points in the community,

$N_{tap,good}$, $N_{platform,good,}$ $N_{support,good}$, and $N_{sec,\ good}$ these are the numbers of taps, platforms, supports and secondary connections, respectively, in good condition, and

δ_i are the weighting factors for the sub-indices, where $\Sigma\delta_i = 1$.

Table 3.1 Four-tier bench-marking scheme (after Rietveld *et al*., 2008)

Condition index	Description of condition
0.0 – 0.5	Bad
0.51 – 0.75	Fair
0.76 0.9	Sufficient
0.91 1.0	Good

The four-tier bench-marking scheme does not give a clear indication of the maintenance requirements of the SWI and its particular benefits to the rural community. The Stephenson *et al.* (2001) asset condition ranking, as shown in Table 3.2, can be used to determine the maintenance requirements of the SWI. The computed condition index can be used to classify SWI, according to their condition and the maintenance requirements, instead of the four-tier bench-marking scheme. Furthermore, it can be modified to incorporate the benefits derived from a particular ranked SWI. This is suitable, because WSP's can use the results to prioritise the maintenance of SWI in a particular area.

Table 3.2 Ranking of asset condition (after Stephenson *et al.,* 2001)

Rank	Description of condition	Maintenance requirement
1	Perfect/excellent condition	Only normal maintenance required
2	Minor defects only	Minor maintenance required (5%)
3	Backlog maintenance required	Significant maintenance required (10 - 20%)
4	Requires major renewal	Significant renewal/upgrade required (20 - 40%)
5	Asset unserviceable	Over 50% of asset requires replacement

3.1.3 Analytic hierarchy process

The condition assessment by Rietveld *et al*. (2008) seeks to determine the condition of the SWI in the rural communities. However, the use of equal weighting of each component may not fully represent the importance of different components. The importance of these components can be determined through a Multi-Criteria Decision Making process (MCDM) (Hernandez and Uddameri, 2009). The MCDM utilizes a decision making matrix aimed at systematically analysing the importance of one criterion over another. The Analytical Hierarchy Process (AHP) is one of the MCDM methods that have long been used in engineering management decision making processes (Saaty, 1980; Saaty, 1990; Saaty 1994). Other MCDM such as multi-attribute utility theory (MAUT) and multi-attribute value theory (MAVT) can also be used, but the choice of the MCDM is based on the goal. Therefore, the AHP can be used to determine the weighting factor of the different components of the SWI (Saaty, 1994).

To determine the weighting of the different components, using AHP one needs to establish the criteria into which the different components fit. Rietveld *et al*. (2008) divided the stand-pipe taps into the segments (top, middle and support). The top, middle and support can be used as criteria for the AHP. Once the criteria has been established, a pairwise comparative matrix can be constructed, using the criteria and rank the importance of one criteria over the other (example shown in Table 3.3). The importance of one criterion over the other can be determined, using the scale of numbers shown in Table 3.4.

Table 3.3 Example of pairwise comparison matrix

Criteria	**Criteria**			***Weighting (%)***
	Top	Middle	Support	
Top	1	9	1	56
Middle	1/9	1	1/2	10
Support	1	2	1	34

From the example shown in Table 3.3, the number 9 in the ‘top, middle’ position indicates that the top components are more important that the middle components, therefore automatically 1/9 is entered in the ‘middle, top’ position. Note that 2 is entered in the ‘support, middle’ position indicating that the support components are slightly more important than the middle components. At the end, the weightings can be obtained by adding each row and dividing by the total number of all the rows.

Table 3.4 The fundamental scale of absolute numbers (adapted from Saaty, 1994)

Importance of Intensity	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective.
2	Weak or slight importance	
3	Moderate importance	Experience and judgement slightly favours one activity over another.
4	Moderate (+) importance	
5	Strong importance	Experience and judgement strongly favours one activity over another.
6	Strong (+) importance	
7	Very strong or demonstrated importance	An activity favoured very strongly over another; its dominance demonstrated in practice.
8	Very, very strong importance	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation.

3.1.4 Ordinal measure of correlations

Over the years, statistics has been used by researchers to measure the association of dependent or independent ordinal variables. However, it is vital to develop a research question taking into account the different forms of ordinal data (Woods, 2008). The research question is important in specifying the association between ordinal variables and data to be analyzed. For example, “Do these people score higher than those people at post-test, holding pre-test scores constant?” or “Do people who score relatively high on this variable also score relatively high on that variable?” (Cliff, 1996; cited by Woods, 2008). These types of questions are normally answered using Likert-type item responses commonly used in qualitative research (interviews and survey instruments) and are sometimes represented by numbers, for example, good = 1 or average = 2 or bad = 3. However, it cannot be assumed that the distance between the segments are the same, for example, good and average as between average and bad. Therefore, such ordinal data is best analyzed using the relevant statistical method.

Various statistical methods, such as Spearman's rho and Gamma statistic are widely used to estimate the monotonic association between two dependent or independent ordinal variables (Woods, 2008). Ordinal variable is defined as ordinal data in which values are ordered and the absolute distance between the values are unknown (Agresti, 1984; cited by Woods 2008). Ordinal variables exist in two forms, continuous or collapsed ordinal data. Continuous ordinal data is found in a situation, where there is a comparative detailed set ranking of cases in a wide range of comparative categories and the tied rankings are proportionally small. Collapsed ordinal data is found in a situation, where all observations are placed in response categories that are limited to five or six responses per question. It is recommended to use Spearman's rho for continuous ordinal data and Gamma statistic for collapsed ordinal data (Woods, 2008).

Gamma statistic can be used to estimate the monotonic association between the condition of SWI (X variable) and different levels of multiple water-use (Y variable). This is because, it is reported by van Koppen *et al*. (2006) that MUS in the rural communities are sustainable, because they meet the rural communities multiple water needs. As a result, they are less prone to vandalism, because they are valued and maintained by the rural communities (van Koppen *et al*., 2006; Rautanen *et al*., 2014). According to the statement mentioned above, it is expected that most of the SWI in the rural communities catering for multiple water-use are in good condition. However, this may differ from one rural community to another, raising the need to determine the association of different levels of multiple water-use and condition of SWIs in the rural communities. Therefore, Gamma values (G) between +1.0 and -1.0 computed from Equation 3.2 can be used to determine the level of association (Woods, 2008). Table 3.5 shows the levels of association, 0.0 indicating the weakest or no association with a high of either +1.0 or -1.0. A value between +1.0 to 0.0 indicates positive (or direct) association, meaning an increase in X variable will cause an increase of the Y variable. A value between 0.0 to -1.0 indicates negative (or indirect) association, meaning an increase in

X variable will cause a decrease of the Y variable. Once the Gamma value is computed, t-test can be used to determine the significance of the association (Shankar and Singh, 2014). If a p-value is less than the alpha value, it means that the association is significant. The Gamma value (G) is calculated as follows:

$$G = \frac{C-D}{C+D} \tag{3.2}$$

Where:

G= Gamma value,

C = Number of pairs in agreements, and

D = Number of pairs in disagreement.

Table 3.5 Interpretation of level of association

Value	Strength
0.0 - 0.30	Weak
0.31- 0.60	Moderate
≥0.61	Strong

3.1.5 Theme and domain network analysis

The causes of SWI failure can be directly or indirectly linked based on the multitude of factors leading to the failure. A qualitative research approach can be used to establish the linkage of causes of failure. Information can be collected through inquiries with people involved in SWI management and physical field observation. The analysis of the qualitative data from inquiries and observation can be very complex depending on the extent of the problem and research objectives. This can also be worsened by the lack of appropriate tools to analyze the data, resulting in some of the important aspects of the data being overlooked (Bezuidenhout *et al*., 2013).

A cause-effect tool, such as the fish bone or problem tree, can be used to analyze the causes of SWI failure (Watson, 2004). The tool graphically and systematically represents the root causes for a specific effect. The effect can be either positive (an objective) or negative (a problem). The causes (a problem) are those that contribute to the effect, which then allows corrective measures to be taken. Categories are established beforehand and the causes are populated in the categories that contribute to failure. This allows the analysis to specifically focus on a single category. The tools completely overlook the interactions of factors in the different categories that collectively depict behaviour that cannot be explained by simply analyzing the categories separately (Bezuidenhout *et al*., 2013).

The thematic network combined with the Kamada and Kawai (1989) energizing transformation technique can depict complex interactions of causes of failure in the different categories (Bezuidenhout *et al*., 2013). This allows a more detailed analysis of the different causes of failure and their interaction. This can be done by developing a theme network as follows: (a) represent each cause by a vertex (dots), shown in Figure 3.1(a), (b) connect directly related vertices based on the first principle, for example “lack of maintenance” is directly related to “poor condition” and (c) project the network (see Figure 3.1(a)) using the Kamada and Kawai (1989) energizing transformation technique. The technique recognizes the connectivity of the closely related vertices and positions them close to each other, shown in Figure 3.1(b). This can be done using Pajeck version 3.2, a freeware computer software specially designed to analyze complex networks (Huisman and van Duijn, 2003; Xu *et al.*, 2010).

The positioning of the causes allows the researcher to establish the different themes, within the network. The themes represent the interaction of the causes in the different categories. This allows a systemic analysis of the network and identifies critical points that cause failure. The network analysis combined with the Kamada and Kawai (1989) energizing transformation technique can be used to analyze the causes of SWI failure, because of the complexity of the problem and the different factors that cause failure.

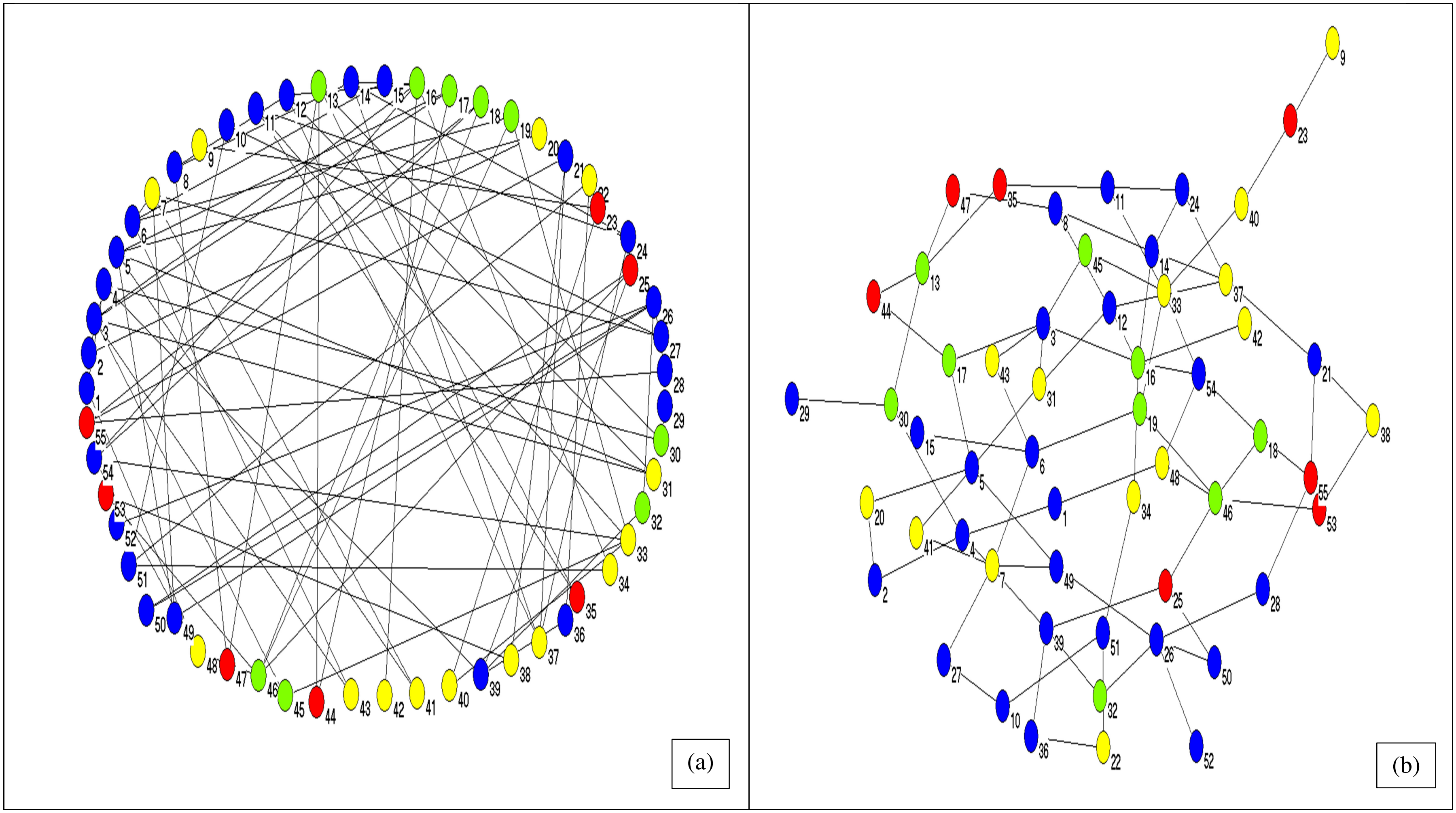

Figure 3.1 The network diagram (a) connected causes according to the first principle (b) after applying the Kamada and Kawai (1989), energizing transformation technique

3.2 Materials and Methods

This section presents a brief overview of the study area. Further, it presents the materials and methods used to determine the weighting factors of hand-pumps and windmills, to assess the condition of small reservoirs, hand-pumps and windmills, and to rank their condition. The theme and domain network approach used to analyze the causes of the SWI failure is also presented in this section.

3.2.1 Study Site

The study was conducted in Makhudutamaga local municipality (Nebo Plateau), Sekhukhune District, Limpopo, South Africa, shown in Figure 3.2. The Makhudutamaga municipality shares boundaries with Fetakgomo, Greater Marble Hall, Greater Tubatse and Elias Motsoaledi local municipalities, which are all part of the Sekhukhune District municipality.

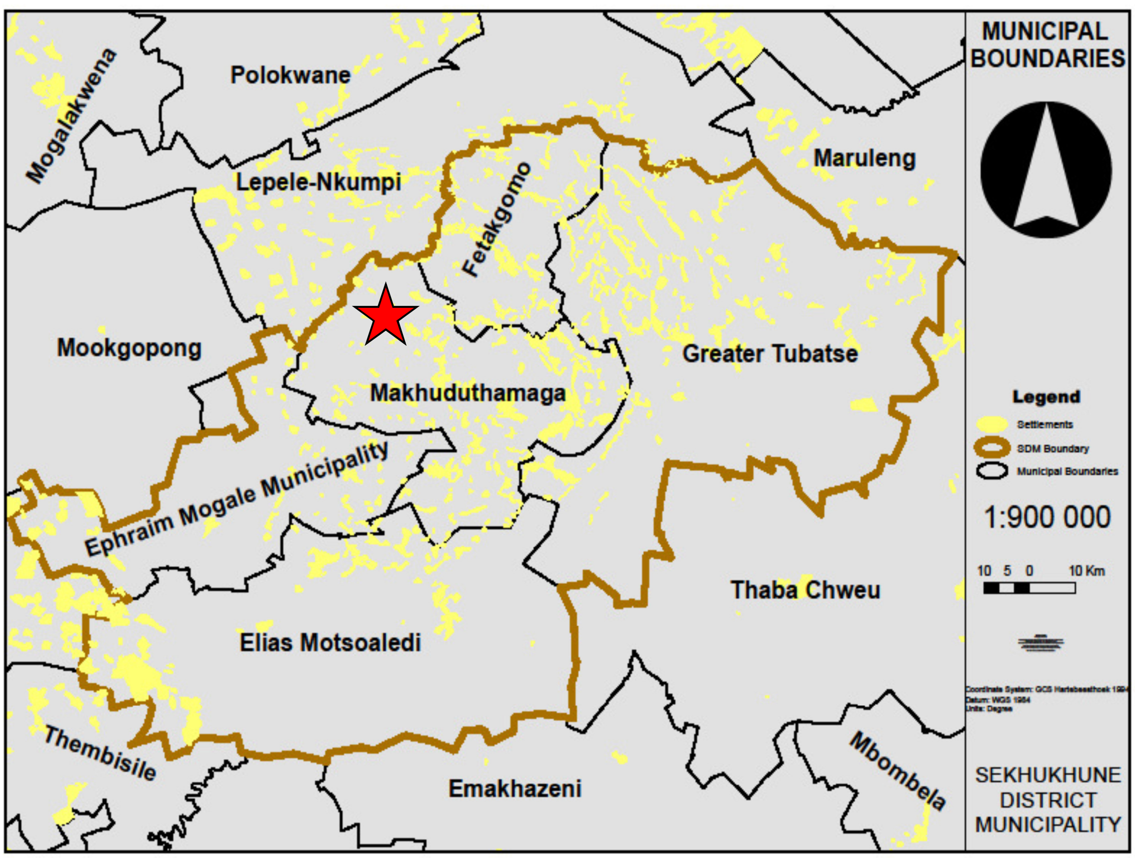

Figure 3.2 Map showing Makhuduthamaga Local Municipality marked by the red star (IDP, 2012)

The municipality consists of 31 wards and 143 villages, with an estimated population of 262,726. The assessment was done in 13 wards. The known dominant SWI used by the communities in these wards are boreholes, small reservoirs and shallow wells (IDP, 2012). Although the SWI mentioned exist in the area, it estimated that 47% of the population in the Makhudutamaga municipality receives water below the standard stipulated in the Water Service Act of 1997 (IDP, 2012). However, there have been speculations that the number may be slightly higher (IDP, 2012). This is because adults are migrating to other areas for better economic opportunities. It is mainly male family members who make the economic migration to other provinces in search of job opportunities. This leaves many of the households being headed by the female family members.

The migration is also caused by the high unemployment rate in the area. Some of the rural community members are employed in agriculture, mining, manufacturing, electricity, government, wholesale, construction and community social structures (IDP, 2012). The most dominating industries are agriculture, mining and tourism sectors. However, these industries are not large enough to employ all of the job seeking population in the municipality. The growth point of the municipality is Jurne Furse, where most of the government services are offered to the community. However, the Mukhudutamaga municipality has not been mandated to provide water supply services to the rural communities. Water provision in the municipality is the responsibility of the Sekhukhune District municipality as the sole Water Service Authority and WSP. The district municipality is also the legal custodian of SWI transferred from the DWA.

3.2.2 Overview of materials and methods

The risks of evaluation tool weightings developed by Mufute (2007) were adopted for the assessment of the whole embankment, spillway and siltation of small reservoirs. For hand-pumps and windmills, the hardware were segmented into top, middle and underground components for physical condition assessment in the field (shown in Appendix C). The weighting of the top, middle and underground components of hand-pumps and windmills were determined using the AHP. The modified Rietveld *et al.* (2008) condition index was used to determine the overall condition of hand -pumps, windmills and small reservoirs. The condition index computed was used to classify the condition of SWI according to their maintenance requirements and the benefit to the rural communities. Additionally, Gamma statistic was used to determine the monotonic association between SWI condition and the different levels of water-use. Furthermore, an investigation of the causes of SWI failure was conducted through inquiries and physical observation and then analyzed using the theme and domain network analysis. The detailed methodology of each method used will be briefly explained later in this section.

3.2.3 Weighting of hand pump and windmill components

Hand-pumps and windmills hardware were segmented into top, middle and underground components for the assessment. In realizing that the components do not have an equal weighting towards affecting the condition of hand-pumps and windmills, the AHP was used to determine their weighting. The top, middle and underground components of both SWI were represented by the top, middle and underground criteria, respectively, to rank the importance of one over the other, as shown in Table 3.6. The description of importance of intensity is shown in Table 3.4. For example, in Table 3.6 the first row, criteria A (top) is moderately more important than criteria B (middle). After ranking of the criteria, a pairwise comparison matrix was developed to determine their weighting factors, shown in Table 3.7. For example, the number 3 in the 'top, middle' position indicates that the top criteria is moderately more important that the middle criteria, therefore, automatically 1/3 is entered in the 'middle, top' position. The weighting were obtained by adding each row and dividing by the total number of all the rows.

Table 3.6 Ranking the importance of hand pumps and windmill components

Row ID	**Criteria**		**More important? *(A or B)***	**Intensity of importance**
	A	**B**		
1	Top	Middle	A	3
2		Underground	B	1
3	Middle	Underground	B	5

Table 3.7 Pairwise comparison matrix for hand pumps and windmills

Criteria	Top	Middle	Underground
Top	1	3	1
Middle	1/3	1	1/5
Underground	1	5	1

3.2.4 Condition assessment of hand pumps and windmills

The condition index developed by Rietveld *et al*. (2008) for stand-pipe taps in the rural communities of South Africa was modified to suit hand-pumps and windmills in the study area. The hand-pumps and windmills hardware was segmented into top, middle and underground components (see example for hand pump in Appendix C). Information on the top, middle, and underground components was collected in the field by physically assessing each component and rating them good or bad with the assistance of the community. The data was recorded on the assessment template (see Appendix D). The overall condition index was calculated using Equation 3.3 (Rietveld *et al*., 2008).

$$I_c = \frac{1}{N_{swi,total}\sum_{i=1}^{i=3}\sigma_i}\left\{\sum_{i=1}^{i=3}\sigma_i\, N_{(t,m,u)}\right\} \tag{3.3}$$

where

I_c = Overall condition assessment index

$N_{(t,m.u)}$ = Total number of top ($_t$), middle ($_m$) and underground ($_u$) components of SWI in good condition

$N_{swi,total}$ = Total number of SWI available in the community

σ_i = weighting factors for the sub-indices, where $\Sigma\sigma_i = 1$.

3.2.5 Condition assessment of small reservoirs

A condition assessment of twenty two small reservoirs found in Nebo Plateau was conducted using Mufute (2007) modified risk of failure evaluation tool. Three out of eight components assessed by Mufute (2007), using the tool in the rural communities of Zimbabwe were selected for the assessment of small reservoirs in this study. The assessment was done by physical observation of the embankment and natural spillway. The degree of siltation was also assessed by visual observation and rated according to the risk of evaluation tool (Mufute, 2007). Different factors that affected the condition of small reservoirs were adopted from the risk of failure evaluation tool, shown in Table 3.8 (and Appendix D). The condition index and overall condition per ward was calculated using Equation 3.4 and 3.5, respectively.

$$CI_{SR} = \frac{\text{Total score}}{\text{Number of factors considered}} \quad (3.4)$$

where

CI_{SR} = Condition index for small reservoir

$$CI_W = \frac{\sum CI_{SR}}{N_{SR}} \quad (3.5)$$

where

CI_w = Overall condition index of small reservoir (s) per ward,

$\sum CI_{SR}$ = Sum of condition indices of small reservoirs in a ward, and

N_{SR} = Number of small reservoirs found in a ward.

Table 3.8 Modified risk of failure evaluation tool (adapted from Mufute, 2007)

Small reservoir components	**Factor/Criteria**	**Description of factor (The number gives the estimated percentage contribution to small reservoir condition)**	**Weight of factor**
Embankment	Termite mounds/animal burrow on embankment	Minor (5)/ Moderate (10)/ Considerable (30)/ Severe (55)	0.5
	Grass cover	Good (0)/ Fair (5)/ Satisfactory (10)/ Sparse (30)/ Poor (55)	0.42
	Foot path	Present (100)/ not Present (0)	0.67
	Tree and shrubs growth	Little (5)/ Moderate (10)/ Dense (30)/ Massive (55)	0.5
	Erosion	Minor (5)/ Moderate (10)/ Extensive (30)/ Severe (55)	0.71
	Cracking	No cracking (0)/ Mild (5)/ Moderate (10)/ Bad (85)	0.58
Natural Spillway	Condition	Good/NA (0)/ Fair (5)/ Satisfactory (10)/ Bad (85)	1.0
Siltation		Low (5)/ Moderate (10)/ High (30)/ Very high (55)	1.0

3.2.6 Ranking of assessed small-scale water infrastructure

The Stephenson *et al*. (2001) condition ranking was modified (see Table 3.9). The initial condition ranking only considered the maintenance requirement, but did not consider whether the SWI was meeting its intended water-use. Therefore, intended water-use was added to the condition ranking. This allowed ranking of the small reservoirs, hand-pumps and windmills, using the condition index computed from Equations 3.3 and 3.5.

Table 3.9 Ranking of small-scale water infrastructure (SWI) condition assessment and community needs (adapted from Stephenson *et al*., 2001)

Rank	Index (small reservoirs)	Index (Hand pumps and windmills)	Assessment result
1	0.0 - 0.05	0.90 - 1.0	SWI in excellent condition and meeting all communities needs
2	0.05 - 0.10	0.80 - 90.0	SWI with minor defects meeting communities needs above satisfactory level
3	0.10 - 0.15	0.70 - 80.0	SWI with backlog maintenance meeting some of the community needs
4	0.15 - 0.20	0.50 - 0.70	SWI that require major renewal meeting minimum community needs
5	Greater than 0.20	0.0 - 0.5	Bad performing SWI that do not meet community needs

3.2.7 Measure of association of condition and water use

Gamma statistic was used to estimate the monotonic association between SWI condition and different level of water-use. Data on the condition and water-use was collected through physical observation in the field and recorded (see Appendix B). Table 3.10 and 3.11 shows the criteria used to rank condition and different levels of water-use, respectively.

Table 3.10 Categories for ranking small-scale water infrastructure (SWI) condition in Makhudutamaga

Condition of SWI	Description of condition
Good	The SWI is functional and supplying water to the community
Sufficient	The SWI is dysfunctional ad supplying some quantity of water to the community
Bad	The SWI is non-functional and not supplying water to the community

Table 3.11 Levels of multiple water-use in Makhudutamaga

Level of multiple water use	Water use
Low	Domestic or irrigation or livestock
Moderate	Domestic and irrigation, domestic and livestock, and irrigation and livestock
High	Domestic, irrigation and livestock

3.2.8 Theme and domain network analysis

A qualitative research approach was used to investigate the causes of SWI failure. The approach allowed exploration of different factors that influenced the SWI to failure, this is also supported by Miller and Glassner (2002). Key informant interviews with relevant stakeholders involved in SWI management were conducted. The stakeholders included, technical staff, extension offices, Limpopo Department of Agriculture (LDA) officials and rural community members. The sample size was not formulated statistically, as the number of stakeholders was determined by their availability. Therefore, a purposive sampling approach was used (Bowen, 2005). The respondents were interviewed on their understanding of the causes of the SWI failure in the study area. A rapid physical field observation was conducted to validate some of the information from the key informant interviews. The qualitative explanatory information gathered from the interviews was categorized into technical, community, environmental and institutional factors to develop a theme and domain network.

3.2.9 Data analysis

The AHP-calculator version 19.02.13 (Goepel, 2013) was was used to perform all the mathematical calculations involved in AHP and determine the weighting of the SWI components. For statistical computations, the Statistical Package for Social Scientist (SPSS) version 21.0 software was used to determine the monatomic association between the condition of SWI and different levels of water-use. A theme and domain network of the causes of failures was developed, using Pajek version 3.2 together with Inkscape version 0.48 software (Bezuidenhout *et al*., 2013).

3.3 Results

This section presents results found in the rural communities of Nebo Plateau.

3.3.1 Weighting factors

Table 3.12 shows the weighting factors of top, middle and underground components of hand-pumps and windmills determined using the AHP. The underground components had the highest weighting factor followed by top and then middle components.

Table 3.12 Weighting factors for hand pumps and windmills in Makhudutamaga

Components	**Weighting factor (σ_i)**
Top	0.41
Middle	0.11
Underground	0.48

3.3.2 Condition assessment

The results presented in Figure 3.3, 3.4 and 3.5 show the overall condition of small reservoirs, hand-pumps and windmills, respectively, in the different wards of Nebo Plateau. The detailed condition of the different components can be found in Appendix E, F and G, respectively.

The condition index of small reservoirs assessed in the study area varied in the different wards, as shown by Figure 3.3. In wards 2, 23, 26, 29 and 30, the condition index was found to be 0.14, 0.18, 0.13, 0.10 and 0.11, respectively. In wards 2, 20, 26 and 30, the small reservoirs had maintenance backlog and met some of the community's water needs. In wards 7 and 23 the small reservoirs required major renewal and met the minimum of the community's water needs. The assessment also found that 45% of the small reservoirs had satisfactory grass cover, with 28% ranging between sparse (14%) to poor (14%) grass cover. Moderate to extensive erosion was found on 77% of the small reservoirs. Mild to moderate cracking was also observed on 73% of the assessed small reservoirs. It was also found that 18% of the small reservoirs had severe erosion and cracking. The presence of foot paths (50% of the assessed small reservoirs) and termites or animal burrowing (100% of the assessed small reservoirs) on the embankment also contributed to erosion and poor condition. The condition of the spillways was found to be excellent (14%), fair (27%), satisfactory (55%) and bad (5%). The assessment found that only one small reservoir had very high siltation. The remaining were found to have low (32%), moderate (45%) and high (18%) siltation.

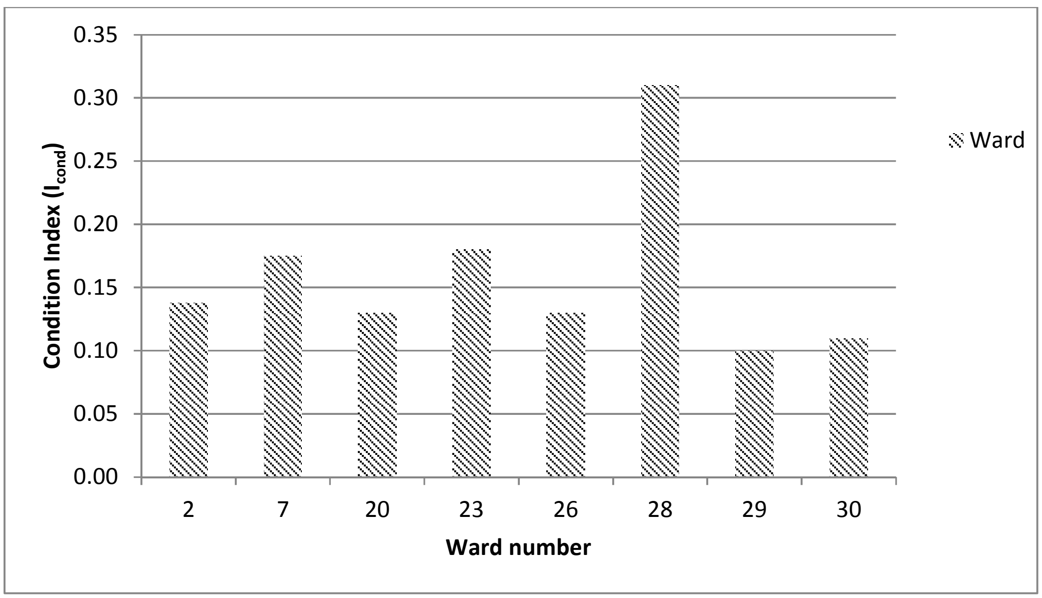

Figure 3.3 Condition assessment of small reservoirs per ward in Makhudutamaga

The condition index of hand-pumps assessed in the study area ranged from 0.20 to 1.00, as shown in Figure 3.4. In wards 2 and 21, the hand-pumps required major renewal and met the minimum of the community's water needs. In ward 30, the hand-pumps were in an excellent condition and met all the community's water needs. About 47% of the hand-pumps required major maintenance, with 53% needing replacement or rehabilitation. The condition of the top

(71%), middle (23%) and underground (48%) components were in poor condition. The condition index of windmills assessed in the study area ranged from 0.59 to 1.00, as shown by Figure 3.5. In wards 2, 26 and 28, it was found that windmills were in excellent condition and meeting all the community's water needs. In wards 29 and 30, they required major renewal/rehabilitation and met the minimum of the community's water needs. However, out of the five wards, only one windmill was found in each of the five wards. The condition assessment found that the top (33%), middle (22%) and underground (22%) components were in poor condition.

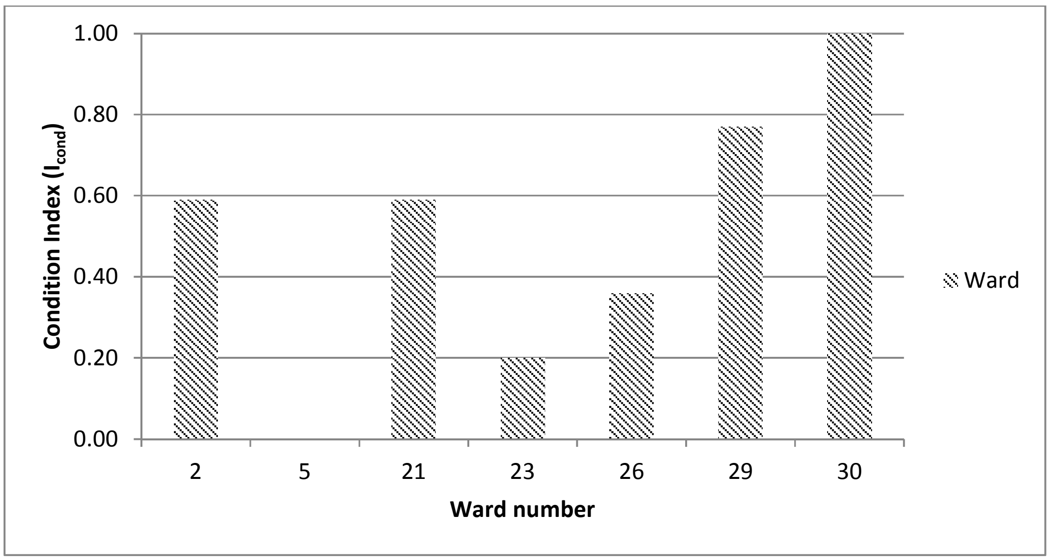

Figure 3.4 Condition assessment of hand-pumps per ward in Makhudutamaga

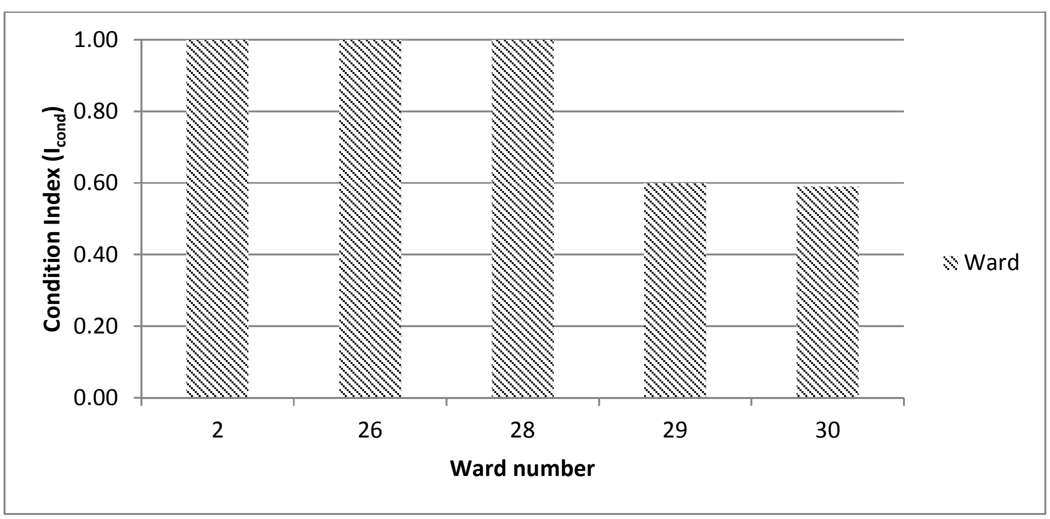

Figure 3.5 Condition assessment of windmills per ward in Makhudutamaga

3.3.3 Measure of association

Results obtained from Gamma statistic (G) and t-test are shown in Table 3.13.

Table 3.13 Measure of association between condition and water uses of SWI in Makhudutamaga

Small-scale water infrastructure type	Gamma value	Description of gamma value (G)	Significance	Description of significance
Small reservoirs	-0.50	Moderate level of association	0.45	Significant
Hand-pumps	+0.35	Moderate level of association	0.69	Not significant
Windmills	+0.29	Weak level association	0.62	Not significant

3.3.4 The causes of failure of small-scale water infrastructure

The theme and domain network (see Figure 3.6) shown below presents the different causes of SWI failure in the rural community of Nebo Plateau. The causes of failure were categorised according to the factors that influence the sustainability of SWI. Different coloured vertices were used to represent the factors, as follow:

(a) Technical (yellow vertex): involves issues that have to do with the technology used to supply water to the rural communities, *e.g.* selection of appropriate technology, O & M and availability of spare parts.

(b) Environmental (red vertex): involves issues that have to do with the effects of the environment on water supply, *e.g.* water quality and protection of water source.

(c) Community (green vertex): involves issues that have to do with rural communities using the SWI, *e.g.* demand for improved services and sense of ownership.

(d) Institutional (blue vertex): involves issues that have to do with the institutions responsible for the management of SWI, *e.g.* decentralization of government responsibilities and implementation of policies.

The Kamada and Kawai (1989) energizing transformation closely placed vertices next to each other to form themes in the network. The technical capacity, institutional capacity, operation and maintenance, and water supply theme were formed; shaded by the colour blue, purple, red and green, respectively.

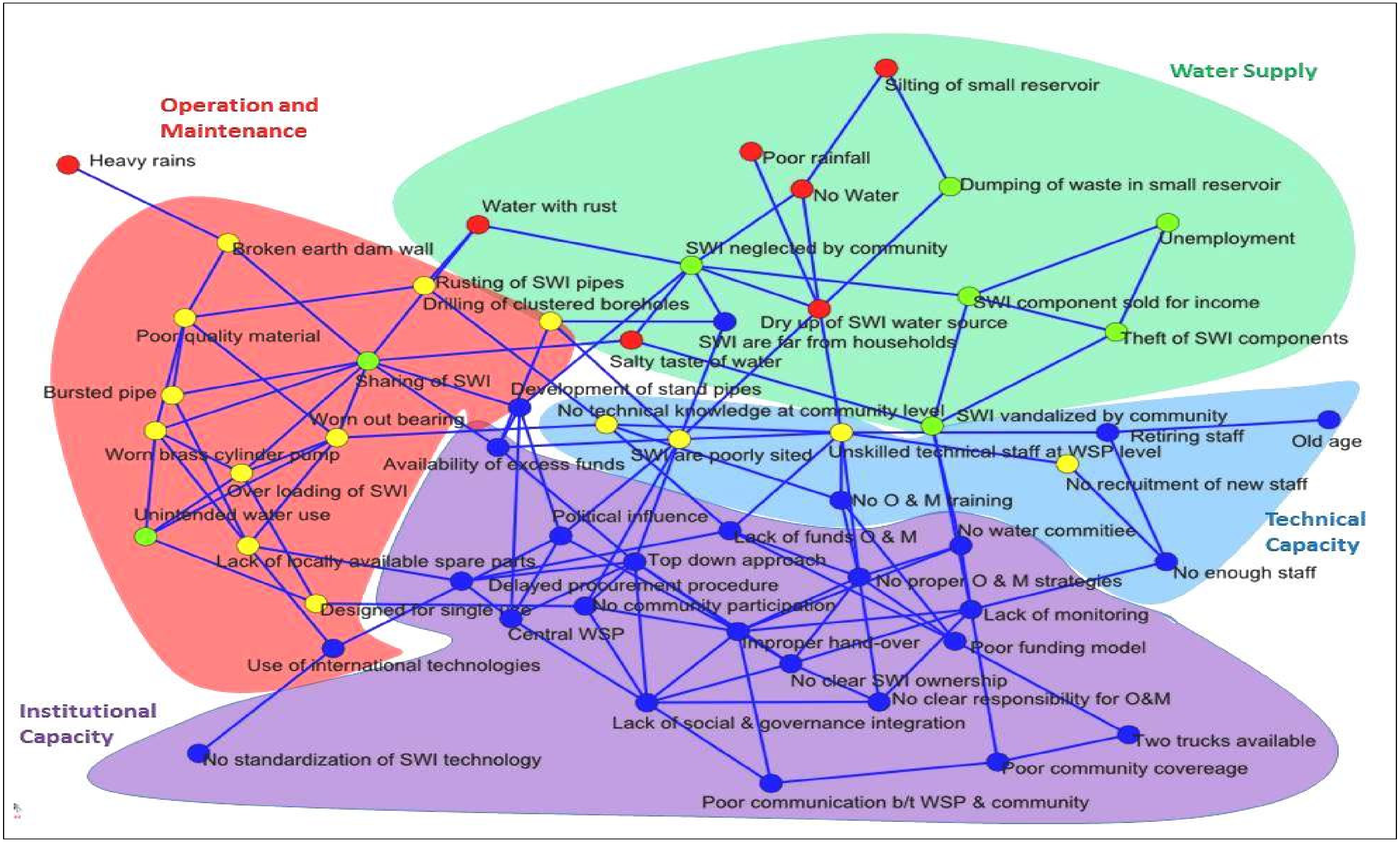

Figure 3.6 Causes of SWI failure theme and domain network for Makhudutamaga

3.4 Discussion

This section discusses the results obtained from the condition assessment of the small reservoirs, hand-pumps and windmills in the Makhudutamanga local municipality. The discussion also includes the association between condition of small reservoirs, hand-pumps and windmills, and the different levels of water-use. The causes of SWI failure derived from SWI manager and rural community members are also discussed.

3.4.1 Condition of small reservoirs

The overall condition assessment of the small reservoirs in the study area indicated that they required major renewal and met the minimum of the community's water needs (I_c = 0.16). This was attributed to the lack of regular inspection and the maintenance of small reservoirs. The lack of clear roles and responsibility contributed to the lack of inspection and maintenance, agreeing with results by Mufute (2007). As a result, poor grass cover, footpath and animals burrowing on the embankment of the small reservoir caused erosion. Furthermore, cracking caused by trees and shrubs growing on the embankment also facilitated erosion (FAO, 2010). Most of the maintenance was mainly required on the embankment. The condition of most of the spillways was satisfactory. However, the condition of some of the spillways was unsatisfactory, because the rural community members were dumping waste material directly on or near the spillways, causing blockage. In some parts of the study area, the rural community members dumped waste materials directly into the small reservoir, resulting in siltation.

3.4.2 Condition of hand pumps

The condition assessment of the hand-pumps in the study area found that they are performing poorly and did not meet the rural communities' water needs (I_c = 0.50). The results are in agreement with trends from data collected in Africa, where more than 50% of the hand-pumps are non-functional due to their poor condition (Harvey and Reed, 2004). In addition, according to a study done by RWSN (2004), it was estimated that there are 250,000 hand-pumps in Africa and more than half are non-functional. Furthermore, Diwi and BIDR (1994) also estimated that 40% to 50% of the hand-pumps found in sub-Saharan Africa were non-functional. This is also backed up by studies conducted in Uganda and South Africa

(Hazelton, 2000 and DWD, 2002). The overall poor condition of the hand-pumps in the study area can be explained by the variation of the condition of the top, middle and underground components. The components were not maintained at all by government and rural community members. As a result, most of the top and middle components were in poor condition, because the parts were worn-out and deteriorating due to old age and the lack of maintenance. In other parts of the study area, the top components were found to be missing. This is because, some of the rural community members stole the top component (pump head) and sold as scrap for cash. In other parts of the study area, rural community members disassembled the hand-pump parts and kept them safe at the nearest household. This was done to facilitate the repair of the hand-pumps at a later stage. In the case of underground components, it was reported by the rural community members that the brass cylinder pump's rubber or leather coupling were worn-out. The underground pipes were also rusting, this was evident from the rust that was discharged with the water.

3.4.3 Condition of windmills

The overall condition assessments of windmills in the study area showed that they are operating with minor defects and met rural community water needs above the satisfactory level (I_{cond} = 0.83). This finding is in agreement with a study conducted in the rural communities of Botswana; it was found that 84% of the rural communities thought that windmills satisfied their day-to-day water needs (Karekezi and Ranja, 1997). Most of the windmills in Nebo Plateau were installed by the government for the rural communities to collect water for their day-to-day activities, but they were not maintained. Furthermore, some of the rural community members had the perception that they require high maintenance cost and they lacked awareness of the technology, consequently the maintenance was not conducted; this is also supported by Karekezi and Ranja (1997). The rural community members in the study area also indicated that the responsibility for inspecting the condition of the windmills was not handed-over to them by the government. Therefore, this was regarded as the responsibility of the government. Further, the rural community members did not have the technical expertise to maintain the windmills, because they were not trained. However, most of the windmills were installed in the animal drinking camps. This made them difficult to access; however, few of the windmills were dysfunctional, stolen and damaged by heavy wind.

3.4.4 Association of condition and water use

This study found that there was a significant moderate association in the negative direction between different levels of water-use and condition of the small reservoirs, as shown in Table 3.13. This means that an increase in the level of water-use (from single to multiple water use) can result in a moderate decrease in the condition of small reservoirs. However, this is not in agreement with van Koppen *et al*. (2008) who state that SWIs used for MUS are less likely to be found in poor condition than SUS. This may be because as the level of water-use increased from the small reservoir, the number of people and livestock moving up and down on the embankment to use water increased. This causes damage to the embankment, however the damage was not repaired.

The association between condition and water-use of hand-pumps and windmills was found to be moderate and weak in the positive direction, respectively, as shown in Table 3.13. Therefore, an increase in the level of water-use results in weak to moderate increase in condition. However, the t-test indicated that the association is not statistically significant. Therefore, the different levels of water-use from hand-pumps and windmills cannot be used to predict the condition of SWI in Nebo Plateau.

3.4.5 The causes of failure of small-scale water infrastructure (SWI)

This study found that there are many different causes of the SWI failure in Nebo Plateau. The causes of failure fall within technical, environmental, community and institutional factors. These factors interact with each other to cause failure of the SWIs. Their interactions show unique thematic problem areas in study area which lead to failure of the SWIs. The thematic problem areas are explained below.

3.4.5.1 Technical capacity

The technical theme consists of technical and institutional factors. The Kamada and Kawai (1989) energizing transformation positioned closely related issues concerning technical staff and skills in the middle of the network. The positioning of the factors in the middle of the network indicates that the institutional capacity, operation and maintenance and water supply themes are dependent on the level of technical capacity available at both the WSP and rural community level.

In Nebo Plateau there is lack of technical skills at both the WSP and community level. Boshoff (2009) and IDP (2012) state that the transfer of technical staff from the DWA to the Sekhukhune District municipality between the year 2003 and 2005 resulted in the loss of experienced staff. This was for the reason that some of the staff members did not want to be deployed to the rural based municipalities. This meant that the newly formed municipalities were without adequate technical expertise. As a result, the ex-staff members decided to open private companies to offer consultancy services to the municipalities. This was beneficial for them as the SWI ownership and O & M was also being transferred to the Sekhukhune District municipality at that time, which was the new Water Service Authority (WSA). This was meant to ease the management of the SWIs, however, it resulted in the transfer of less technical staff with less technical skills and little experience in SWI O & M and without adequate funds to support the transferred responsibilities, as stated by Boshoff (2009). This resulted in the poor planning of SWI O & M.

During the interviews, the technical staff from the WSP indicated that they have not received any formal training since their transfer to the Sekhukhune District municipality. But when they were still in DWA, they received training every six months. They are also getting old and close to retirement, but there is no recruitment of young staff that can take over their responsibility. As a result, the lack of technical knowledge by WSP, rural community members could not be capacitated to properly operate and maintain the SWI.

3.4.5.2 Institutional capacity

The Kamada and Kawai (1989) energizing transformation grouped most of the institutional factors in one common position in network. The positioning of most of the institutional factors on one side of the network indicates that there is a problem with the leadership within the various institutions that are responsible for the management of SWIs. This may be caused by the centralized WSA and WSP at the Sekhukhune District municipality. The WSA and WSP in the District level are responsible for water supply to the five local municipalities that fall under the Sekhukhune District. This promotes the "top-down approach" in the water services provision in Nebo Plateau, as all the roles and functions for water service provision are at District level. The Makhuduthamaga local municipality, where Nebo Plateau is located, does not have the role or function for water service provision in the rural communities. Although the WSP have deployed some of their staff to the local municipality, the decisions concerning O & M are still made at District level.

The rural community members interviewed indicated that most of the water related projects are politically influenced. The community members were not involved in decision making and due to this most of the projects addressing water related issues were not demand-driven. They appeared to be "silent" campaign projects for political parties towards upcoming elections. After the elections, some of the unfinished works remained incomplete. This resulted in the lack of social and governance integration between the WSP and rural communities. This was evident from the lack of platforms for the rural communities to report dysfunctional SWIs to the WSP. The lack of such platforms resulted in the rural communities having to wait for the WSP to come to the villages. However, in the rural communities, there are also no water committees that are responsible for monitoring of the SWIs. During the interviews with the WSP staff, they indicated that they expected the rural communities to do some of the repairs as the SWIs belonged to them. This was not the understanding of the rural communities as they regarded the SWIs to be owned by government. The government is expected to serve the rural communities as per the Water Service Act of 1997 (Water Service Act, 1997). Because of the lack of clear ownership and the WSP not having enough resources (trucks) to cover all the communities, rural communities often waited for long periods and used the dysfunctional SWI to a point where they finally wore out and broke-down.

The breaking down of SWIs was not only caused by the poor monitoring and O & M. The lack of spare parts and procurement due to the use of international technologies also contributes to the SWI failure. The use of the international technologies is caused by the lack of policy that standardizes the SWI technologies in South Africa (Harvey and Reed, 2004). This mainly applies to hand-pumps in Nebo Plateau. Different models/brands of hand-pumps were observed in the study area. The use of international technologies is also influenced by the World Bank through their poverty reduction strategies that promotes economic liberation, which makes importing of international technologies cheaper than the locally manufactured technologies (Harvey and Reed, 2004). This makes it difficult for the local manufactures to compete with the subsidized technologies. This also makes it difficult for supply chain to procure spare parts on time from the service providers. However, the delayed procurement of spare parts can also be blamed on the centralized WSP and lack of funds for O & M.

The current funds for O & M are provided by the DWA as part of the agreement for the transferred SWIs. However, the WSP complains that the budget is not enough; this is also supported by most of the literature reviewed (Rietveld *et al*., 2008 and Boshoff, 2009). The Integrated Development Plan (IDP) (2012) report indicates that the lack of funds for O & M is also caused by the lack of the SWI inventory in Nebo Plateau. This makes it difficult to develop funding models that will enable the allocation of an adequate budget for O & M. Although the current available budget is used for the development of stand-pipe taps that do not supply water at the expense of maintenance of existing SWIs.

3.4.5.3 Operation and maintenance theme

Most of the technical factors were connected to the sharing of SWI vertex (community factor) in the operation and maintenance theme. This was because most of the SWIs were not properly operated and maintained by the WSP and rural communities. As a result, the SWIs failed. The failure of the SWIs forced the rural community members to share the next available functional SWI either in their communities or neighbouring communities. This was observed in the case where the frequently used SWI (e.g hand-pump) was discharging water with rust due to rusted pipes or broken down SWI as a result worn-out bearings or brass cylinder pumps. However, overloading of SWI due to sharing also caused them to breakdown. This is mainly due to the overuse of the SWI as it may have been designed to cater for a certain number of households in the rural community but not the neighbouring communities.

3.4.5.4 Water supply theme

The Kamada and Kawai (1989) energizing transformation positioned the community and environmental factors within the water supply theme relatively far apart. The environmental factors are positioned on the left and community factors on the right. This may have been caused by the difference between the two factors but both contribute to the failure of the SWI. The rural communities neglected and vandalised the SWI as a direct response to the environmental factor, which resulted in no water supply.

This is common when water is depleted from the borehole (hand-pump or windmill) probably due to inadequate groundwater recharge and SWI discharging salty water. The rural community members dumped waste material in the dry small reservoirs. The dumping of the waste materials contributed to the reduction of the small reservoirs water holding capacity and siltation.

Rural communities reported that they were unable to use water from some of the reservoirs because of the toxic plants that have grown in the small reservoir. Water from such a small reservoir can led to serious health risk.

3.5 Conclusions and Recommendations

The small reservoirs in the study area required major maintenance and met the minimum of the rural communities' water needs. The maintenance was mainly required on the embankment were erosion was occurring due to poor grass cover, foot path and animals burrowing. Trees and shrubs were also growing on the embankment causing cracking. Hand-pumps were poorly performing and not meeting rural communities' water need. This was because some parts were worn-out and most of the pump heads had been stolen. The condition of windmills was satisfactory, with minor defects. However, some windmills were non-functional, because people had stolen the whole windmill and the tank used to store water. Overall, the condition of the assessed SWI in Nebo Plateau was unsatisfactory and met the minimum of the water needs of the rural communities, mainly due to the lack of maintenance.

The relationship of the level of water-use and condition of small reservoirs was moderate in the negative direction. This was conflicting with literature, because it is expected that as the level of water uses increase from single to multiple water-use, rural communities are more willing to maintain the SWI, hence keeping it in good condition. However, this was not the case in this study because it was found that as the level of water-use increased from the small reservoir, the condition deteriorated. This was due to the fact that as the level of water-use increased the number of people and livestock using the water increased, causing damage to the embankment. For hand-pumps and windmill, the relationship was in agreement with the literature and showed moderate and weak association. However, the relationship was not statistically significant, therefore the level of water-use cannot be used to predict the condition of hand-pumps and windmills in Nebo Plateau.

Overall, the causes of failure constituted of technical, environmental, community and institutional factors. These factors are interdepended and interact to cause failure of the SWI. The lack of technical skills and knowledge at both WSP and community level was the main cause of failure of the SWI in Nebo Plateau. This definitely lead to a cascade of undesirable problems in the area such as ineffective institutional capacity, lack of O & M, lack of funds and poor water supply. Because of the fact that the WSP was centralized; water related projects and programmes were politically influenced and implemented using the top-down approach. The main focus was on increasing the quantities of water by installing stand-pipe taps in the rural communities to compensate for the poor O & M. However, the stand-pipe taps were unreliable, because most of them were not functional. Because of this, the rural communities were forced to use dysfunctional SWI until they broke down. Some of the SWI parts were worn-out due to lack of maintenance. It was also found that poor borehole siting caused SWI to fail. This is because, some boreholes were discharging corrosion in the water; this indicated that the galvanized pipes were reacting with the water. Furthermore, in some areas boreholes were drilled but not equipped because of poor borehole siting, also attributed to the lack of funding.

It is recommended that similar research must be done in the other municipalities, which fall under the Sekhukhune District municipality, in order to compare findings and improve water supply in the District.

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4. PROPOSAL FOR SITUATION BASED BEST SMALL-SCALE WATER INFRASTRUCTURE (SWI) MANAGEMENT PRACTICES IN NEBO PLATEAU, LIMPOPO PROVINCE, SOUTH AFRICA

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Abstract

Worldwide, improved water supply through well maintained and functional small-scale water infrastructure (SWI) has been seen as a strategy to alleviate poverty, enhance agricultural productivity, improve health and ensure food security. The functional status of SWI is dependent on technical, community, environmental, institutional and financial factors that influence or determine improved water supply. The study proposes best SWI management practices for the rural community of Nebo Plateau, Limpopo, South Africa taking into consideration the factors mentioned above. A qualitative research approach was used to conduct the study. The approach used primary and secondary data from the rural communities and interviews with key informants to obtain data and information to derive best management practices (BMP). It was proposed that there is a need to decentralize the current District municipality water service provider (WSP), establish village water committees (VWC), link policy with technology used, consider the effects of environment on technology, ensure availability of spare parts locally, provide technical training for both WSP and rural communities, and allocate funds for operation and maintenance. It was concluded that the technical, community, environmental, institutional and financial factors are interdependent. Therefore, the adoption of the proposed BMP taking into consideration the different factors will contribute to the success of the SWI. It is recommended that the proposed BMPs must be adopted by the relevant stakeholders to reduce the backlog and improve water supply in Nebo Plateau.

Keywords: best management practice, sustainability, water point committee

4.1 Introduction

Worldwide, improved water supply to rural communities has been seen as a strategy to alleviate poverty, increase agricultural productivity, improve health and ensure food security (Sun *et al*., 2010). Improved water supply also contributes towards the Millennium Development Goals (MDGs) aimed at halving the number of people with unsafe drinking water by 2015 (Sachs, 2005). It was reported in the 2012 MDGs update that the goal for safe drinking water was met in 2010 in the world (UNICEF, 2012). However, it was also reported by the Joint Monitoring Programme (JMP) that the rate of water source improvement has been low in the rural sub-Saharan Africa with approximately 283 million people without safe drinking water (UNICEF, 2012). Poor water access has been caused by the lack of properly designed small-scale water infrastructure (SWI), lack of proper operation and maintenance (O & M) and the lack of institutional capacity (Weiskel *et al*., 2007).

In an attempt to improve rural water supply, government, non-governmental organisations (NGOs), private sector and other stakeholders (local and international) engaged with rural communities in the decision making process to introduce a community based approach to rural water supply development (Manikutty, 1997; Marks and Davis, 2012). This was done through involving rural communities in the development and management of SWI (Davis *et al*., 2008), the motive behind this was to ensure a sense of SWI ownership by the communities, with the aim of ensuring sustainable water supply (Kleemeier, 2000; Marks and Davis, 2012). Therefore, to ensure sustainability the water sources must not be over-exploited, but naturally replenished, facilities must be maintained in a condition which ensures a reliable and adequate water supply, the benefits of the supply should continue to be realised by all users over a prolonged period of time, and the service delivery process must demonstrate a cost-effective use of resources that can be replicated (Harvey and Reed, 2003). The sustainability of SWI is influenced by technical, community, environmental, institutional and financial factors (Graciana and Nkambule, 2012). Graciana and Nkambule (2012) found that (based on the study done in Swaziland) technical and community factors are the most critical factors while environmental, institutional and financial factors contributed less to the sustainability of the SWI. They also found that the functional status, shorter distance, adequate water availability, involving community in O & M, involving community in the initial stage of SWI development, availability of funds, willingness to contribute funds for O & M, training of Water Service Provider (WSP) and community, and formation of water committees contributed to the sustainability of the SWI, which is also supported by Lane (2004). This was also evident from the rehabilitation of rural water points and participatory health and hygiene education (RRWPPHHE) project initiated in the rural communities of Zimbabwe, because of the declining support by government to improve water supply, due to budgetary constraints (Lovell, 2000; Practical Action Southern Africa, undated). As a result, there were not enough resources to fund O & M of SWI. In addition, most of their projects did not involve the rural communities, implying that the rural community members did not have the necessary skills to maintain the SWI. The RRWPPHHE project introduced a community based management (CBM) approach where the rural communities played a significant role in O & M of the SWI. This was achieved by (1) involving community throughout the life cycle of the project, (2) training of village pump mechanics (VPM), (3) training community member to form their own SWI management structures and (4) proper hand-over of the SWIs to the rural communities.

This study sought to propose best management practice (BMP) in Nebo Plateau based on the SWI causes of failures identified in Chapter 3. The proposed BMPs are meant to improve the already existing O & M practices and improve service delivery in the rural communities using the available resources at all levels of SWI management.

4.2 Materials and Methods

The study was conducted during September 2012 and comprised of two methods. Firstly, interviews were conducted with the relevant stakeholders that were involved in SWI O & M. Secondly, a review of documents and physical field observation of the O & M practices was done to validate information from the interviews.

The objective of the interviews was to identify the current O & M practices by the relevant stakeholders involved in SWI O & M. The stakeholders included WSP technical staff (5), extension officers (4), Limpopo Department of Agriculture (LDA) officials (2) and rural community members (16). The information gathered in the interviews was qualitative. It was stated by Miller and Glassner, (2002) that researchers are more able to explore and elaborate different aspects of the issue in question, using qualitative methods such as interviews, despite the fact that different respondents can have different views. The sample size depended on the availability and accessibility of the stakeholders, meaning a purposive sampling method was used for the study (Bowen, 2005).

The interviews were informal and the questions posed to the respondents were mainly focused on the solutions that can be applied to benefit users and promote sustainability of the SWI. The respondents were asked to state stakeholders that would take part in implementing the solutions and the type of benefits derived from properly functional SWI. The local language (Sepedi) was used for those respondents that could not understand English.

Furthermore, to validate the information from the interviews, a review of documents (secondary data) and physical field observation were done. This was done in conjunction with the interviews. The researcher travelled with community members and extension officers within the different villages to observe management practices. The qualitative explanatory data collected was categorized into technical, community, environmental, institutional and financial factors. It allowed the proposal of key BMPs in line with the factors. After that, BMPs were proposed from the qualitative data in line with the key BMPs.

Despite the study having limitations due to constrains posed by time, budget and availability of individual stakeholders, it is still believed that the information obtained is adequate and valid enough to give a true picture on the relevance of the BMPs. BMPs are defined in this context as situation specific management practices, which are inclusive of technical, community, environmental, institutional and financial factors that positively influence the performance or functional status of SWI and can be applied at different levels of SWI management to improve water supply in Nebo Plateau.

4.3 Results

This section presents situation based BMPs derived from the interviews, field observation and reviewed documents specific to Nebo Plateau.

4.3.1 Proposed best management practices (BMPs)

The BMPs (see Table 4.1) are aimed at improving the current management practices, taking into consideration the available resources already in place in Nebo Plateau. The implementation of the proposed BMPs requires the collaboration of the different actors at different levels of SWI management. Therefore, the proposed BMPs are applicable at national, intermediate and community level. Although the study was not focused at the national level, it was seen important to involve the DWA, because they are responsible for policy development and regulation, and funding of the development and O & M of the SWI. The intermediate level involves the Sekhukhune District municipality (Water Service Authority and WSP), NGOs and private companies providing water services in the study area. The community level involves the traditional authority, rural community members and VWC.

In Table 4.1, the "key BMPs [Challenge]" column represents the overall BMPs and the challenges they address. This is then followed by the "factor" column, which represents the factors that influence water supply in the rural communities (Graciana and Nkambule, 2012). The factors are briefly explained as follows;

(a) Technical: involves issues that have to do with the technology used to supply water to the rural communities, *e.g.* selection of appropriate technology, O & M and availability of spare parts.
(b) Community: involves issues that have to do with rural communities using the SWI, *e.g.* demand for improved services and sense of ownership.
(c) Environmental: involves issues that have to do with the effects of the environment on water supply, *e.g.* water quality and protection of water source.
(d) Institutional: involves issues that have to do with the institutions responsible for the management of SWI, *e.g.* decentralization of government responsibilities and implementation of policies.
(e) Financial: involves issues that have to do with funding, *e.g.* availability of funds for O & M.

The "BMPs" column represents the BMPs in line with the key BMPs and factors that influence them. This is followed by the "action" column, which represents the different institutions at various levels of SWI management (mentioned above) responsible for implementation of the proposed BMPs. Lastly, the benefits column presents the potential benefits from applying the BMPs in Nebo Plateau.

Table 4.1 Proposed best management practices and the [challenges] they address

Key BMPs [*Challenge*]	**Factors**	**BMPs**	**Action**	**Benefit**
Decentralise district municipality WSP [*Centralized WSP at district level*]	• Institutional	• Decentralize some of the roles and responsibilities in district municipality WSP to local municipality WSP depots *e.g* procurement, financial, planning, etc. and • recruit young technical staff.	• Water service provider • Department of local government	• Improved institutional capabilities, • improved decision making to the local municipality WSP depots, • reduce burden on district WSP, and • improved response time.
Commission capacitated village water committee (VWC) or water point committee (WPC) [*The lack of VWC/WPC and technical knowledge at village level*]	• Institutional • Community • Financial	• Establish VWC or WPC, • VWC should have an equitable representation of men, women, youth and elders, • VWC must be recognized as a legal entity, • develop constitution for VWC, clearly defining roles and responsibilities, • WSP must enter to a service level agreement contract with VWC, and • establish appropriate voluntary remuneration incentive for VWC members.	• Water Service Authority • Water service provider • Village water committee • Non-governmental organizations • Private sector	• Better monitoring of SWI, • regular maintenance of SWI, • reduce of breakdown duration, • improved communication between WSP and VWC, and • stakeholders have clearly defined roles and responsibilities.
Link policy and technology [*Poor selection of appropriate technology*]	• Institutional • Community • Technical	• Develop policies that promote uniformity in technology selection and O & M strategies, and • consult rural communities in technology selection.	• Department of Water Affairs • Water Service Authority • Water service provider • Village water committee	• Provide communities with technologies that are appropriate for their unique needs, and • ensure availability of spare parts.
Ensure that the technology is suitable for the environment [Rusting of galvanized pipes]	• Environmental • Technical	• Select technologies that are suitable for the environment, and • consider borehole siting, chemical composition and screening obstacles in technology selection.	• Water service provider • Non-governmental organizations • Private sector	• Ensure that SWI technologies are appropriate for a specific environment and • reduced health risk to users *e.g* from the corroding galvanized pipes or poor quality water
Ensure availability of spare parts [*Lack locally manufactured technology*]	• Institutional • Financial • Technical	• Make provision for locally accessible spare parts, • parties to enter in to an agreement to ensure supply of spare parts at favourable conditions for both parties and • provide subsidies for VWC to purchase spare parts.	• Water service provider • Private sector	• Ensure sustainability of SWI, and • continuous supply of spare parts locally.
Improve technical knowledge and skills [*Lack of technical skills*]	• Technical • Community • Institutional factor	• Provide training for technical personnel at the WSP, • promote training every six months for WSP technical staff, and • ensure stakeholder involved in SWI planning construction and offer training to VWC.	• Water service provider • Non-governmental organizations • Private sector	• Increased technical knowledge and skills at WSP and community level ,and • ensure proper O & M of SWI.
Allocate funds for operation and maintenance [*Lack of funds for O & M*]	• Financial • Institutional	• Link SWI development plans, policy, strategy and O & M plans/schedules to available funds, and • develop O & M cost guidelines for different SWI.	• Department of Water Affairs • Water Service Authority • Water service provider • Village water committee	• Adequate funding is available for O & M, and • ensure sustainability of SWI.

4.4 Discussion

This section discusses the proposed BMPs based on the situation in Nebo Plateau. The BMPs are not new to the area, but with effective implementation and enforcement the causes of failure can be reduced. The proposed BMPs are driven by technical, community, environmental, institutional and financial factors, that contribute to the sustainability of SWI. However, there factors are interdependent, making it difficult to separate one factor from the other. Key BMPs were derived and are discussed below.

4.4.1 Improved institutional capabilities

As stipulated within the framework of Section 78 of the Municipality Systems Act of 2000 (Municipality Systems Act, 2000), the Sekhukhune District municipality is the Water Service Authority and WSP responsible for water provision in Nebo Plateau. Therefore, the role for development and O & M of SWI is the responsibility of the District municipality, consequently local municipality is not mandated to provide water services to its respective rural communities. In Nebo Plateau, a decentralizing process of the decision making powers which concerns O & M from District level to local municipality can improve water supply. It is stipulated in the Municipality Structure Act of 1998 (Municipality Structure Act, 1998) that the Department of Local Government and Housing has the powers to transfer roles and responsibilities from district to local municipality (Boshoff, 2009). Therefore, transferring the roles for O & M will result in efficient decision making at the local municipality, as they are acquainted with the water related issues in their respective communities, and this point is also supported by Agrawal and Gupta (2005). For example, personnel in charge at the local municipality will be able to make instant decisions concerning O & M without having to consult with the District municipality and they will establish their own procurement office to procure goods and services. However, because the decentralization will result in roles of the institutions changing, this will require strengthening their capacity to assume their new roles effectively. Brikke and Bredero (2003) state that decentralization without building capacity can worsen the problem. Furthermore, effective communication between the District and local municipality is vital to coordinating and implementing activities, because an efficient information and monitoring systems relies on it, to insure acceptability.

Decentralizing will also result in the separation of the budget allocated for SWI development and O & M between district and local municipality, respectively. This will improve water supply, because currently the budget for O & M is compromised by the increasing development of new SWI. Despite this, rural communities still do not have access to improved water supply, because the newly developed SWI fail due to the lack of maintenance (Rietveld *et al*., 2008).

The private sectors contracted by the WSP also played an important role in the implementation of water related projects, such as the development of new SWI and O & M. The District and local municipality need to define the roles of private sector, when it comes to engaging with the rural communities, while performing their contractual obligation. Proper introduction and closure of SWI development projects or programmes initiated by WSP and implemented by private sector in the rural communities must be facilitated by the WSP. This will allow a platform for the WSP to clarify the roles of the rural communities with regards to the O & M of the newly developed SWI.

NGOs also played a vital role in the planning and implementation of SWIs. However, there is a need to improve the communication between the NGOs and WSP to register their water related projects in Nebo Plateau. This is because most of their interventions are project based. Consequently after the project, they leave the rural communities with a functional SWI hoping that either the rural communities or the WSP will maintain them. Therefore, registering of these projects will provide a platform between NGOs, WSP and rural communities, as to who will maintain the SWI.

4.4.2 Village water committee

To complement the devolution of power to local municipality, SWI development agencies must promote the establishment of Village Water Committees (VWC) or Water Point Committees (WPCs). The VWC must be selected by the village members and must have adequate representation of men, women, youth and elders. This ensures accountability at community level and acceptance of the VWC by rural community members (Harvey and Reed, 2003; Harvey and Reed, 2004). After the establishment of VWC, they must be recognized by the WSP as a legal entity. This means they must draft a constitution that outlines their roles, responsibilities and legal framework. Their roles and responsibilities should include monitoring, operation, maintenance, collection and handling of funds (to conduct minor repairs and maintenance), conflict resolution and accountability regarding water related issues in their respective villages. (Lovell, 2000; Harvey and Reed, 2004).

The WSP must therefore contract the VWC with the knowledge of the WSA to perform the roles outlined in the constitution. A service level agreement should be entered into by both parties, also indicating the remuneration, if any, of the VWC members for their voluntary services. However, the remuneration of the VWC members may contradict with the labour laws in South Africa. Therefore, proper consultation with the Department of Labour must be done to avoid legal disputes. By promoting such practices, it will motivate integration between rural communities and WSP, as the VWC will communicate directly with the technical personnel responsible for their water services (Ribot, 2002). This will result in the WSP providing services that are relevant to the rural communities, rather than just providing more water by developing more SWIs.

4.4.3 Policy

Policy development and implementation is a vital component to the sustainability of the SWI. This is because it is the basis in which WSA, WSP, the private sector, public sector, NGOs and VWC provide water services to the rural communities. Therefore, it important for DWA together with the WSA to develop policies that will prevent sectors and actors involved in water supply to the rural communities from using different strategies in the development and O & M of the SWIs, which may cause disintegration, as highlighted by Harvey and Reed (2004). This is mainly influenced by the level of politics in South Africa, which can differ from province, District and local municipality, and even at village level, where improved water supply is witnessed during the election period ("masked campaigning"). Therefore, to achieve sustainable SWI, improved water services should not only be seen during the elections period, but should be a continuous process that provides rural communities with reliable SWIs beyond elections.

Government, NGOs and the private sector are responsible for the implementation of water projects in the rural communities of Nebo Plateau. However, they use different water supply technologies which are not locally manufactured, therefore making it difficult to procure spare parts. This can be corrected by the DWA introducing policies that promote technologies that are locally manufactured or standardizing technologies imported into South Africa. The choice of the technologies should not only be the responsibility of the DWA. But the DWA must adopt a consultative approach for policy change and implementation to create a favorable environment for all the stakeholders involved in water management. Therefore, all stakeholders must agree to change the current policy, to facilitate local manufacturing of SWI technology or standardization of the imported technology, supported by Harvey and Reed (2004). After agreeing, the next step is to develop a strategy document that outlines the following (adapted from Harvey and Reed, 2004);

(a) goals and objectives,
(b) expected outputs,
(c) action that need to be taken to achieve policy output,
(d) indicators and milestones of policy impact, and
(e) funding.

An assessment of the policy concerning the affected stakeholders must be done. This should be followed by a consultation process with the stakeholders to agree on the policy. If there are any amendments the policy document must be revised accordingly and implement by the DWA through the WSA and WSP. As a result, the introduction of appropriate policies and technologies will promote the availability of spare parts locally. However, despite consulting with the rural communities in the selection of the technology, Whittington *et al*. (2009) state that rural communities should also commit to maintaining of the SWIs.

4.4.4 Environment and technology

Technology used to develop SWI is also dependent on the environment. In the context of the environment, the sustainability of the boreholes depends on groundwater resources. Ihuah and Kakulu (2014) conducted a study in the Niger Delta region in Nigeria, and found that that siting, chemical composition and screening of obstacles is vital to ensuring success of the SWI in the rural communities. Therefore, it is important that government officials responsible for siting of boreholes in Nebo Plateau adopt proven methods for siting boreholes. This can be realized by organizing training, which specifically addresses the issues of environment and technology used for the equipping of boreholes. Furthermore, the trained government officials together with the VWC must supervise the construction of the SWIs, which is normally done by the private sector and NGOs. This will ensure the use of technology that adheres to the chemical composition of the groundwater. Many of the SWIs were equipped with galvanized pipes that were susceptible to rusting, however, simply changing the galvanized pipes to plastic pipes can eliminate the problem.

In addition to environmental aspects, some of the small reservoirs and boreholes established in the rural communities have dried-out. Government, private sector and NGOs must consider the change in environment overtime, when siting and designing small reservoirs and boreholes, as this will reduce the risk of the SWI drying-out. Reduced drying out of boreholes and small reservoir will help to curb the occurrence of vandalism of the SWI and the dumping of waste in the small reservoirs.

4.4.5 Procurement and availability of spare parts

After selecting the appropriate technologies for the rural communities of Nebo Plateau, it is important to make provision for the availability of spare parts that are easily accessible. This can be done through private sector or public sector or private-public partnership. Literature has shown that private-public partnership works out to be a better solution to ensure the availability of spare parts (Water and Sanitation Program, 2006). In the case of Nebo Plateau, the WSP acts as a client to the private sector (service provider). The two parties must enter into a mutual agreement, which ensures that the WSP purchase a certain number of parts, according to their short-term (1 year) or long-term (5+ years) O & M plan (including SWI to be developed within the term). This will insure accountability of the WSP and sustainability of the business through the purchase of the spare parts. As a result, this will promote the sustainability of the SWI and the private sector to continue with the supply of the required spare parts.

However, provision should also be made by the private sector for the VWC to be able to purchase spare parts. Many rural communities in Nebo Plateau are poor (IDP, 2012), subsidies should be provided by the government (mainly the DWA or WSP) to encourage the purchase of spare parts by rural communities (50% government and 50% rural communities). This will aid in reducing the maintenance cost on the WSP budget as currently they are responsible for paying 100% of the spare parts cost. It will also ensure that the SWI are maintained by the rural communities as they can afford to purchase spare parts.

4.4.6 Technical training

Simply introducing appropriate technologies and ensuring availability of spare parts does not necessarily translate into the sustainability of the SWI. It is necessary to ensure that the people that are responsible for the maintenance of the SWI have the technical skills to perform their duties. The technical personnel at WSP, which are responsible for the maintenance of the SWI in Nebo Plateau, will need training on the operating and maintaining of the selected technologies. This does not necessarily mean training all the personnel at once, but the training of trainers approach can be adopted. Those that are trained will train those that remained and then the next time a similar training is presented, the other group that did not attend must enroll. After their training, they will refresh the previous groups that attend the training (if necessary). This will ensure that the technical personnel have the appropriate and up to date technical knowledge of the technologies used in training the technical personnel, they will be able to commission training of VWC.

Training of VWC was one of the key successes of the RRWPPHHE to ensure that the O & M of the SWI was done in the rural communities of Zimbabwe (Lovell, 2000; Practical Action Southern Africa, undated). Therefore, adopting this approach will ensure timely maintenance which will result in improved water supply. Training of the VWC should also be the responsibility of NGOs and private sector involved in planning and implementation of SWI project. They must be held accountable by WSP.

4.4.7 Funding of operation and maintenance

It is important to raise and maintain funds for operating and maintaining SWI. Currently, the DWA uses the National Revenue Fund (NRF) which is available on budget to fund SWI development and O & M through the WSA (Moseki *et al*., 2011). The funds are then transferred by the WSA to the WSP. However, the funds are not usually enough, because they are not based on the infrastructure requirement and O & M required in Nebo Plateau and any other rural community served by the Sekhukhune District municipality, but based on the availability of funds. This forces the WSP to prioritize SWI development and O & M in Nebo Plateau. Literature indicates that in most cases development of new SWI is prioritized over O

& M (Rietveld *et al*., 2008; Ruiters, 2013). This can be corrected by DWA, WSA and WSP ensuring that there is a link between SWI development plans, policy, strategy and O & M plans/schedules. This will require a standard guideline of the cost of O & M of the different SWI in Nebo Plateau. The guideline can be used to estimate the annual cost of maintenance of existing and future SWIs. Therefore, the cost of O & M must be presented to the DWA as the current funder of O & M and development of new SWI to allocate the required budget. The VWC should also collect funds from the rural community members that will allow them to attend to minor repairs and conduct maintenance of the SWIs.

4.5 Conclusions and Recommendations

This study can conclude that technical, community, environmental, institutional and financial factors contribute to the sustainability of SWI in Nebo Plateau. However, these factors do not stand alone, they are interdependent. Most of the activities required to achieve sustainability are reliant on the availability of funds. Furthermore, it can be concluded that the BMPs for the community of Nebo Plateau based on the causes of failure are, but not limited to the following:

(a) devolution of decision making powers from district WSP to local municipality WSP depots,
(b) establish VWC to assist WSP on a service level agreement contract,
(c) select appropriate technology,
(d) ensure availability of spare parts,
(e) train water services providers and VWC on O & M, and
(f) ensure availability of funds for O & M.

It is recommended that the different stakeholders within the different the SWI management levels involved adopt the proposed BMPs to ensure sustainability of SWI in Nebo Plateau.

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5. GENERAL DISCUSSION

5.1 Summary

It is reported that 47% of the population living in the rural communities of Nebo Plateau are receiving water below the legislative standards as stipulated in the Water Services Act of 1997. This is because, small-scale water infrastructure (SWI) used by the rural communities of Nebo Plateau for domestic, irrigation and livestock watering are functioning sub-optimally or are non-functional at all. This has been blamed on the lack of SWI inventory, unavailability of funds, unskilled technical personnel, ineffective institutional capabilities and lack of accountability, consequently leading to lack of operation and maintenance (O & M). Despite this, the water service providers (WSPs) continue to develop new SWI to increase water supply as a solution to combat the problem, neglecting maintenance of the existing and newly developed SWI.

Against this background, this study carried out an identification of SWI type, distribution, water use, ownership, maintenance, and functional status. Furthermore, this study conducted an assessment of the condition of small reservoirs, hand-pumps and windmills. In addition to the condition assessment, an investigation of the causes of failure was conducted. Based on the causes of the SWI failure, this study was able to propose best management practices (BMPs) suitable for Nebo Plateau.

Rapid Rural Appraisal (RRA) techniques were used to identify the types, distribution, ownership, responsibility for maintenance and status of the SWIs in Nebo Plateau. The condition of small reservoirs, hand-pumps and windmills was assessed, using the modified technical tool (Rietveld *et al*., 2008) and risk of failure toolkit (Mufute, 2007). The association between the condition of SWI and different level of water-use was determined using Gamma statistic. The causes of SWI failure were investigated using qualitative research approach and analysed using the theme and domain network. Further, a qualitative research approach was used to develop BMPs suitable for the rural communities of Nebo Plateau.

5.2 Conclusion

This study concludes that boreholes were definitely the dominant SWI used by the rural communities of Nebo Plateau and can be categorised according to the technology used to abstract groundwater from the borehole. Small reservoirs, hand-pumps, windmills, unequipped boreholes, family drip kits, and electric- and diesel- driven boreholes were some of the SWIs found in the study area. Most of the SWIs were designed to supply water for domestic purposes only, mainly because the government is focused on supplying water for basic use (domestic) in line with the constitution of South Africa. However, rural communities do not value single use systems (SUS), it was evident from this study that they also require water for irrigation and livestock watering. As a result, the rural communities used SUS as multiple use systems (MUS) to cater for all their water needs. This clearly indicated that there is a desperate need for MUS in the rural communities of Nebo Plateau. Government is responsible for water provision in the rural communities and is the custodian of SWI, according to the constitution of South Africa. As a result, most of the SWIs were owned by government who were also responsible for the correct O & M. However, it was evident that the government was failing to perform their constitutional duties, because 71% of the SWIs in Nebo Plateau were non-functional (NF).This was mainly blamed on the lack of maintenance.

The overall condition of small reservoirs and hand-pumps was unsatisfactory and did not meet the rural communities' water needs. This was because most of the small reservoirs and hand pumps were not maintained by either the rural communities or the WSP. The condition of windmills was satisfactory and met the rural communities water needs above satisfactory level. It was found in this study that the relationship between the level of water-use and condition of small reservoir was moderate but in the negative direction, meaning that, as the level of water-use increase, the condition of small reservoirs deteriorates. This is because the number of people and livestock using the small reservoir increases as water-use increase, causing damage of the embankment as they walk up and down for water. For hand-pumps and windmills, the relationship was moderate and weak, respectively, in the positive direction, meaning that, as the level of water-use increased from single to multiple water-use, rural communities were most likely to value the SWIs and as a result keep them in good condition. However, this was not statistically significant, hence this cannot be used as a basis to predict rural community's willingness to maintain the SWI based on the level of water-use from the SWI in Nebo Plateau.

An investigation into the causes of the SWI failure in Nebo Plateau was carried out and found that various factors cause their failure. The theme and domain network analysis showed that the factors are interdependent, as a result, they create unique themes. The technical skills theme, mainly inclusive of institution and technical factors, was positioned at the middle of the theme and domain network. This definitely means that the rest of the themes are anchored or reliant on the level of technical skills to function effectively. The lack of technical skills resulted in the use of technology that is not appropriate for the rural community and environment, and lack of O & M plan or strategy, resulting in SWI failure. This was because of the lack of technical training and ageing staff personnel. The fact that some of the rural communities were very remote, with poor access roads, and only three trucks allocated to them, made it difficult for the WSP to repair dysfunctional or broken down SWI. The rural communities were forced to share or continue to use dysfunctional SWI until they broke down. This can also be blamed on the inefficient institutional capacity, coupled with political influence, top-down approach, lack of water committees and poor funding models.

Based on the situation in Nebo Plateau, this study proposed BMPs for different levels of SWI management. Decentralization of the central WSP (District level) to local municipality is definitely the key to strengthening institutional capacity. This is achievable through providing training and establishing an effective communication platform. After decentralizing the central WSP, the local WSP must facilitate the establishment of village water committees (VWC's) in the rural communities and enter into a service level agreement to operate and maintain the SWI, including monitoring. This should be complemented by an incentive for the VWC member. The VWC will then act as the rural community's representative in water related projects or programmes. The WSP, Department of Water Affairs, VWC and other affected stakeholders must ultimately engage to select the appropriate SWI technology for the rural communities, which is compatible with the level of technical skills and environmental conditions. The selected technology must be standardized to promote local manufacturing or importation of standard technology. The WSP must then enter into an agreement with the private sector to supply spare parts according to its O & M plan. The agreement should also include SWI's to be developed, in order to ensure availability of spare parts for maintenance. Provision must also be made for rural communities to purchase spare parts at a discounted price, which is subsidised by the government. The above mentioned BMPs success is anchored on the level of technical skills of the WSP and VWC, and availability of funds. Therefore, it is imperative to train the WSP and VWC on a regular basis and develop a funding model that is linked to the O & M of SWI.

5.3 Recommendations

Based on the findings from this study, the following recommendations were made to improve water supply to the rural communities of Nebo Plateau;

a) WSP in Nebo Plateau should use the SWI identification data presented by this research to address the water supply backlogs. The information highlights the current condition of SWI and the problem areas. The data can also be used to develop a database which can be used to allocate resources for maintenance,
b) the single use systems must be upgraded to multiple use systems as rural communities do not require water only for basic use, but for many other complimentary uses,
c) based on the condition of the SWI and the causes of failure, which are unique to the study site it is important to propose BMPs that are site specific to the area to improve water supply, and
d) to adopt the proposed BMPs for the community of Nebo Plateau to derive the optimal service from the SWI in the area.

5.4 Future Research Needs

Future research needs for the Sekhukhune District municipality are as follows:

(a) A similar study in the other municipalities of Sekhukhune District can assist to derive overall district BMPs. This is important as currently the WSP is not aware of the current condition of SWI as evident in Nebo Plateau.
(b) Analysis of processes as followed in planning and development of SWI, with a view to streamline the process.
(c) Analytical assessment of the roles and responsibilities of WSP, NGOs, government and rural communities in the management of SWI.

(d) Research ways that enhance significantly the sense of ownership of rural SWI used by the rural communities.

6. APPENDIX A: MILLENNIUM DEVELOPMENT GOALS (MDGS) AND THE CONTRIBUTION OF IMPROVED WATER AND SANITATION THROUGH SMALL-SCALE WATER INFRASTRUCTURE (ADAPTED FROM FAAL ET AL., 2009)

Millennium Development Goals	**Improved water and sanitation contributions to the MDGs**	**Potential contribution level of SWI improved performance.**	**Role of SWI in achieving MDGs**	**Examples of SWI that play a role in achieving MDGs.**
Eradicate extreme poverty and hunger	Access to water can improve food security and lead to water-based income-generation.	Significant	SWI supply water for agricultural activities, where harvest can be consumed or sold for household income.	Small reservoirs, treadle pumps, family drip kits and rainwater water harvesting
Achieve universal primary education	Better systems means children can attend school with time saved and are healthier.	Moderate	Well maintained SWI will provide sufficient quantity of water reducing water collection time for children to have time to go school in the morning.	Hand-pumps, tube wells and windmills
Promote gender equality & empowerment of women	Better designed systems leads to time saving for productive activities and improved health and security.	Significant	SWI properly maintained are not prone to frequent breakdowns leading to better food production ensuring food security for rural communities and empower women.	All small-scale water infrastructures (to be mentioned in Chapter 2)
Reduced child mortality	Better access to safe water leads to health and nutrition for children and mothers.	Significant	Well-functioning SWI ensure that rural communities do not resort to unsafe drinking water.	Hand-pumps, tube wells and windmills
Improved maternal health	Reduced stress on expectant mother by providing better and safer access to water for a range of uses.	Moderate	By ensuring good performance of nearby SWI it will reduce walking distance to look for alternative sources of water.	Windmill and boreholes
Combat disease	By providing adequate quantity and quality of water for drinking, hygiene and food production.	Significant	Improved SWI performance will provide rural communities with good quality (safe) and quantity of water.	Small reservoirs, treadle pumps, family drip kits, rainwater water harvesting, hand-pumps, tube wells and windmills
Ensure environmental sustainability	By improving the management of natural resources and matching systems design to demand.	Significant	Better designed and performing SWI proved community with sufficient water which will protect other natural recourses such as wet lands from been abused by communities.	All small-scale water infrastructures
Develop a global partnership for development	Though making links between sector and sharing experiences.	Low	Through various water activities performed by rural communities.	All small-scale water infrastructures

7. APPENDIX B: DATA COLLECTION TEMPLATE

Output A4

Template for Small-scale Water Infrastructure (SWI) Data Collection

March 2011

Section 1: Details of Respondent								
Respondent Sex (√)	Male			Female				
Marital status	Single		Married		Divorced		Widowed	
Age of respondent				Years				
Respondent Position in the village	Chief	Kraal Head		Councillor	Committee Chair		Other (specify)	
No of people in the household								
Date of interview								

Section 2: SWI Identification Data			
Type of SWI			
Village		Ward	
Contact person			
Contact details			
GPS Coordinates	Easting		
	Northing		
Surrounding Activities			
Brief description of condition of SWI			

Section 3: SWI Water Infrastructure Data						
3.1 Physical Characteristics						
		Comments				
State of SWI (good/average/poor)						
Approximate capacity or yield (units)						
Required capacity or yield (units)						
Average water point distance (units)						
3.2 Characteristics of use						
		Comment				
No. of people or families with access to SWI						
Minimum water demand (units)						
No. of hours of use of SWI per day						
No. of months per year SWI supplies water						
3.3 Water Quality Characteristics						
Water quality I	**pH**		**EC**		**T^0C**	

Water quality II	TC		NTU		TDS	

Section 4: SWI Water Use Data

When was the SWI constructed?					
Who constructed the SWI? (√).	Government	Community	NGO (Name)	Private	Other (Specify)
What was the intended purpose of construction? (√).	Domestic	Irrigation	Livestock watering		Other (specify)
What are the actual water uses? (√)	Domestic	Irrigation	Livestock watering		Other (specify)

Section 5: Governance and Institutional Matters

Who owns the SWI? (√). Specify.	Government	Community	NGO (Name)	Private	Other (Specify)
Who is responsible for maintenance (√)	Government	Community	NGO (Name)	Private	Other (Specify)
Who is responsible for setting the rules for water use (√)	Government	Community	NGO (Name)	Private	Other (Specify)
Who is responsible for enforcing the rules for water use? (√)	Government	Community	NGO (Name)	Private	Other (Specify)
How much are you paying for water?					

How much water is used per day?	Domestic	Irrigation	Livestock watering	Brick making	Beer making	Other (specify)

What are the basic rules (in terms of allowed water uses)?..
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Do the users comply with the rules? Explain...……………………………………………………….. ………………………………………………………………………………………………… ………………………………………………………………………………………………… …………………………………………………………………………………………………
How are the rules enforced?... ………………………………………………………………………………………………… ………………………………………………………………………………………………… …………………………………………………………………………………………………
What problems are faced in terms of water access and use from the SWI? ………………………………………………………………………………………………… ………………………………………………………………………………………………… …………………………………………………………………………………………………

Is there an alternative water source?	Yes		No	

What is the distance to the alternative water source(s)?	
Type(s) of alternative water source(s)	

What are the water uses from the alternative source? (specify)	Domestic	Irrigation	Livestock watering	Other (Specify)

What are the problems associated with water use from the alternative source(s)?	***Source***	Domestic	Irrigation	Livestock watering	Other uses	Other problems
	Problem					

Section 6: Other Water Uses Data						
How much water is used for domestic purposes per day?						
What are the specific domestic water uses?	Drinking	Washing	Cleaning	Cooking	Bathing	Other (Specify)
When there’s water shortage, what are the prioritized uses?						

What is the alternative source for domestic use?	
How far is the alternative water source?	
What are the problems with the alternative water source(s) for domestic water use?.............................. …… …… ……	
What are the problems in terms of water access and use for domestic?.. …… …… ……	

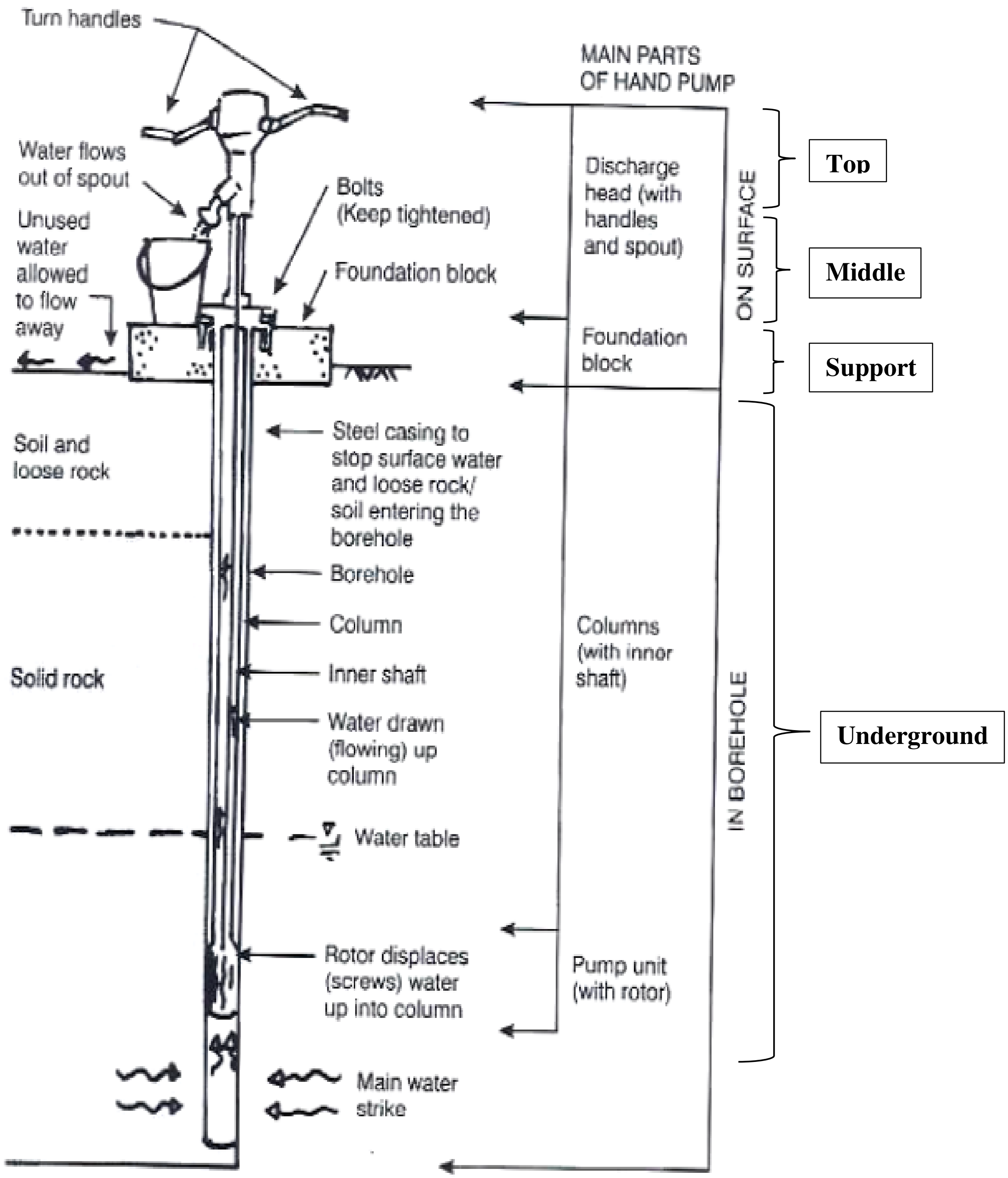
6.1 Productive Water Uses Data	
Brick making	
How many bricks are made per day / month?	
How much water is used per oven?	
For how much is a brick sold?	
Which months are bricks made	
What are the problems encountered regarding access and use of water for brickmaking?…………….. …… ……	
Beer making	
How much water is used for beer making (per day/week/month)?	
How often is the beer made	
For how much is beer sold?	
What is the money used for?	
Problems encountered regarding access and use of water for beermaking……………………………... …… …… ……	

Irrigation (garden/small-scale)						
Types of crops irrigated and size for each	*Type*	Maize	Vegetables	Sugar cane	Fruit trees	Others (Specify)
	Size					
Income derived from the crop(s) per month	*Type*	Maize	Vegetables	Sugar cane	Fruit trees	Others (Specify)
	Amount					

How many times do you irrigate per week?	
Total amount of water used for crop(s) irrigation?	
Irrigation method(s) used for watering the crops	

<table>
<tr><td colspan="9">What are the problems faced concerning irrigation water from the SWI?
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………</td></tr>
<tr><td colspan="9">Livestock watering</td></tr>
<tr><td rowspan="2">What are the types and number of livestock kept in homestead?</td><td>Type</td><td>Goats</td><td>Cattle</td><td>Sheep</td><td>Donkeys</td><td>Pigs</td><td>Chickens</td><td>Other (Specify)</td></tr>
<tr><td>Number</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Amount of water used by livestock per day</td><td colspan="4"></td></tr>
<tr><td colspan="5">What is the distance from homestead to the water source?</td><td colspan="4"></td></tr>
<tr><td rowspan="3">How is the livestock watered:
direct/indirect from source?
(specify if indirect)</td><td>Livestock</td><td>Goats</td><td>Cattle</td><td>Sheep</td><td>Donkeys</td><td>Pigs</td><td>Chickens</td><td>Other</td></tr>
<tr><td>Direct</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Indirect</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Type of services or benefits derived from livestock and the amount of money they are rendered for</td><td>Livestock</td><td>Goats</td><td>Cattle</td><td>Sheep</td><td>Donkeys</td><td>Pigs</td><td>Chickens</td><td>Other</td></tr>
<tr><td>Service</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Amount</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Problems encountered regarding access and use of water for livestock
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………………...</td></tr>
</table>

8. APPENDIX C: GRAPHIC REPRESENTATION OF HAND PUMP COMPONENTS



9. APPENDIX D: CONDITION ASSESSMENT TOOL

General information

Date :…………………………………………………………………

Village :…………………………………………………………………

Ward :…………………………………………………………………

Small reservoirs

Small reservoir components	Factor/Criteria	**Description of factor (The number gives the estimated percentage contribution of small reservoir condition)**	**Estimated percentage**
Embankment	Termite mounds/animal burrow on embankment	Minor(5)/Moderate(10)/Considerable(30)/Severe(55)	
	Grass cover	Good(0)/Fair(5)/Satisfactory(10)/Sparse(30)/Poor(55)	
	Foot path	Present (0)/not Present(100)	
	Tree and shrubs growth	Little(5)/Moderate(10)/Dense(30)/Massive(55)	
	Erosion	Minor(5)/Moderate(10)/Extensive(30)/Severe(55)	
	Cracking	No cracking(0)/Mild(5)/Moderate(10)/Bad(85)	
Natural Spillway	Condition	Good/NA(0)/Fair(5)/Satisfactory(10)/Bad (85)	
Siltation		Low(5)/Moderate(10)/High(30)/Very high(55)	

Hand pump and windmill

Location on SW	**Condition (good or bad)**	**Comment**
Top component		
Middle component		
Underground component		

10. APPENDIX E: ASSESSMENT OF SMALL RESERVOIRS SUMMARY

Location on the small reservoir	Factor/Criteria	Description of factor				
Whole embankment	Termite mounds/animal burrow on embankment	**Minor**	**Moderate**	**Considerable**	**Severe**	
		0.23	0.36	0.18	0.23	
		5	8	4	5	
	Grass cover	**Good**	**Fair**	**Satisfactory**	**Sparse**	**Poor**
		0.09	0.18	0.45	0.14	0.14
		2	4	10	3	3
	Foot path	**Present**	**Not present**			
		0.5	0.5			
		11	11			
	Tree and shrubs growth	**Little**	**Moderate**	**Dense**	**Massive**	
		0.18	0.41	0.18	0.32	
		4	9	4	7	
	Erosion	**Minor** 0.05	**Moderate** 0.32	**Extensive** 0.45	**Severe** 0.18	
		1	7	10	4	
	Cracking	**No cracking**	**Mild**	**Moderate**	**Bad**	
		0.09	0.32	0.41	0.18	
		2	7	9	4	
Natural spillway	condition	**Good**	**Fair**	**Satisfactory**	**Bad**	
		0.14	0.27	0.55	0.05	
		3	6	12	1	
Siltation	Degree of siltation (observation)	**Low**	**Moderate**	**high**	**Very high**	
		0.32	0.45	0.18	0.05	
		7	10	4	1	

11. APPENDIX F: ASSESSMENT OF HAND PUMPS SUMMARY

Hand pump components	Ward 2		Ward 5		Ward 21								Ward 23					Ward 26						Ward 29			Ward 30		
	H_1	***pw***	H_1	***pw***	H_1	H_2	H_3	H_4	H_5	H_6	H_7	***pw***	H_1	H_2	H_3	H_4	***pw***	H_1	H_2	H_3	H_4	H_5	***pw***	H_1	H_2	***pw***	H_1	***pw***	**Pow**
Top components	-	**-**	-	**-**	0.06	-	-	-	0.06	-	-	***0.12***	-	-	-	-	**-**	0.08	-	-	-	-	***0.08***	0.21	0.21	***0.42***	0.41	***0.41***	**0.15**
Middle components	0.11	***0.11***	-	**-**	0.02	0.02	0.02	0.02	0.02	0.02	-	***0.12***	0.03	-	-	0.03	***0.06***	0.02	0.02	0.02	-	0.02	***0.08***	0.06	0.06	***0.12***	0.11	***0.11***	**0.08**
Underground components	0.48	***0.48***	-	**-**	0.07	0.07	0.07	0.07	0.07	-	-	***0.35***	-	-	-	0.14	***0.14***	-	0.10	0.10	-	-	***0.20***	0.24	-	***0.24***	0.48	***0.48***	**0.27**
Overall Performance Index:	**0.59**	***0.59***	**-**	**-**	**0.15**	**0.09**	**0.09**	**0.09**	**0.15**	**0.02**	**-**	***0.59***	**0.03**	**-**	**-**	**0.17**	***0.20***	**0.10**	**0.12**	**0.12**	**-**	**0.02**	***0.36***	**0.5**	**0.27**	***0.77***	**1.00**	***1.00***	**0.50**
Performance ranking		**4**		**5**								**4**					**5**						**5**			**3**		**1**	**4**

p_w: performance of hand-pumps per ward

P_o: overall performance of hand-pumps

12. APPENDIX G: ASSESSMENT OF WINDMILLS SUMMARY

Windmill components	**Ward 2**		**Ward 26**		**Ward 28**		**Ward 29**						**Ward 30**		
	WM_1	***pw***	WM_1	***pw***	WM_1	***pw***	WM_1	WM_2	WM_3	WM_4	WM_5	***pw***	WM_1	***pw***	**Pow**
Top components	0.41	***0.41***	0.41	***0.41***	0.41	***0.41***	0.08	-	0.08	-	0.08	***0.24***	-	**-**	**0.29**
Underground components	0.11	***0.11***	0.11	***0.11***	0.11	***0.11***	0.02	0.02	-	-	0.02	***0.06***	0.11	***0.11***	**0.1**
Underground components	0.48	***0.48***	0.48	***0.48***	0.48	***0.48***	0.1	-	0.1	-	0.1	***0.3***	0.48	***0.48***	**0.44**
Overall Performance Index:		***1.00***		***1.00***		***1.00***	**0.11**	**0.02**	**0.9**	**-**	**0.11**	***0.6***	**0.59**	***0.59***	**0.83**
Performance ranking		**1**		**1**		**1**						**4**		**4**	**2**

p_w: performance of hand-pumps per ward

P_o: overall performance of hand-pumps