



Exploration of the Sustainable Use of Groundwater in GaMalebogo, Limpopo

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for the degree

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Abstract

Water scarcity is a global challenge that adversely affects agricultural production, livestock farming, industrial development, and household livelihoods. Although existing research has extensively examined the impacts of water scarcity on rural livelihoods, planning, and welfare, relatively little attention has been given to the sustainable use of groundwater to improve domestic potable water supply in rural communities. Accordingly, this study explores the sustainable use of groundwater to alleviate water scarcity and shortages in the GaMalebogo rural villages of the Blouberg Local Municipality, within the Capricorn District Municipality in Limpopo Province.

A qualitative research approach and an exploratory design were used. Sixteen participants were selected, and a semi-structured guide was employed to collect data. The data analysis was conducted thematically using Atlas.ti's tools and themes to evaluate groundwater's role in addressing water scarcity in the GaMalebogo region. Findings revealed that the villages of GaMalebogo are in an area with a high groundwater table, indicating that groundwater resources are readily available. Despite this favourable hydrogeological condition, water scarcity persists due to leaking pipes and taps, inequitable water distribution, and the mismanagement of municipal resources. As a result, households continue to experience water shortages, which have negatively affected agricultural and livestock production.

Consequently, it is crucial to implement strategies to address this problem and prevent the progression towards water insecurity, characterized by inadequate access to clean and safe drinking water. Furthermore, it was found that villagers who installed private borehole systems maintained a sustainable groundwater supply, even selling water to other villagers when the municipal water system failed. The motivation for privately owned boreholes stems from the unreliability of the municipal borehole water system, which is caused by poor craftsmanship. The municipality's borehole system, established to support the local population, has proven ineffective, mainly due to improper installation of the water piping and lack of maintenance of both the machinery and the piping infrastructure. Given these observations, the municipality should prioritize the maintenance and rehabilitation of existing boreholes, pipelines, and water infrastructure, while strengthening oversight and accountability to ensure equitable and reliable water distribution.

Additionally, constructing water reservoirs at strategically chosen locations near villages should be pursued following a detailed assessment conducted with resident involvement. Moreover, a comprehensive review and upgrade of the current piping network is necessary to ensure more reliable, efficient, and sustainable water delivery across all villages.

Keywords: Groundwater, Borehole, Village water scarcity, Village water security, Village water, insecurity, Sustainable

DECLARATION

This thesis does not include any material that has been accepted for another degree or diploma at any university or similar institution. To the best of my knowledge and belief, it also contains no material that was previously published or written by others, unless properly referenced in the text.

Signed_



Date: March 2026

Thabo Frans Meletse

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To my cherished wife, Dieketseng Meletse, I wish to convey my heartfelt appreciation for being such a supportive partner during this journey.

I am also grateful to God for providing me with the spiritual strength and confidence necessary during this experience. Furthermore, I express my sincere appreciation to my research supervisor, Professor Richard Meissner, for the opportunity to undertake this research and for his invaluable guidance throughout the program.

Additionally, I want to thank Linda Downsborough at the IIE MSA for her steadfast support and encouragement during the coursework and throughout the research project, especially when I faced significant challenges.

DEDICATION

I am dedicating this thesis to my wife, Dieketseng Meletse; our kids, Bohlokwa and Lesedi Meletse; my mother, Nomasondo Meletse; and my late father, Fomele Freddy Meletse.

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ABBREVIATIONS AND ACRONYMS

CSIR:	The Council for Scientific and Industrial Research
GTAC:	Government Technical Advisory Centre
GTAC-MSEP:	Government Technical Advisory Centre -Municipal Socio-Economic Profiles
IPCC:	Intergovernmental Panel on Climate Change
MSEP:	Municipal Socio-Economic Profile
NWA:	National Water Act
NWRS:	National Water Resource Strategy
SDGs:	The Sustainable Development Goals
TDS:	Total Dissolved Solids
WCWDM:	Water Conservation and Water Demand Management
WHO:	World Health Organisation
WRC:	Water Research Commission
WRCS:	The Water Resource Classification System
WSA:	Water Services Act

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Chapter 1: Introduction and Background of the Study

1.1. Introduction

The main goal of this study is to analyse how groundwater can help address the shortage of drinkable water in the GaMalebogo rural villages within the Blouberg Local Municipality, part of the Capricorn District Municipality in Limpopo Province, South Africa. Access to clean, potable water is a vital need that must be supplied to all residents of South Africa, and this responsibility primarily falls on local government, as outlined in the Constitution of the Republic of South Africa (RSA, 1996) (Mbana *et al.*, 2024). The lack of potable water is a major issue for many residents in remote rural areas.

The study includes:

- The background describes the general issue of potable water scarcity in rural areas, highlights the research problem, and explains the need to improve understanding of the sustainable use of groundwater to reduce household water insecurity in GaMalebogo.
- The research aims and objectives are presented to address the identified research problem.
- A literature review examines existing knowledge and identifies gaps in the sustainable use of groundwater to address potable water shortages in rural communities.
- The research design, methodology, conceptual framework, ethical considerations, and chapter outline are presented.

The study concludes with a summary, discusses its limitations, and includes appendices. A literature review was conducted to establish current knowledge and identify gaps in understanding the use of groundwater for addressing potable water shortages in rural areas. The study will be limited in scope, focusing on villages in GaMalebogo from 2023 to 2025. The research design, methodology, and conceptual framework are also outlined, along with ethical considerations and chapter structures. A summary, potential research limitations, and a tentative appendix are also included.

1.2. Background and Rationale for the Study

As the study focuses on GaMalebogo, it is important to understand the characteristics of the rural communities in which the research was conducted. Villages in GaMalebogo are predominantly rural, and the concept of "rurality" lacks a single, universally accepted definition, as it is influenced by both geographical and historical factors. What is considered rural in the Global North can vary greatly from rural interpretations in the Global South, highlighting significant differences in socio-economic

and ethnic perspectives. Additionally, over time, the understanding of rurality changes; areas once labelled as rural may now be on the fringes of urban zones due to urban growth and infrastructure development (Mubangizi, 2023).

In South Africa, the variety of rural landscapes is particularly noticeable. The idea of rural includes large areas of freehold commercial farmland, indicating a traditional Western view of rural areas. However, it also covers scattered settlements within communal lands, which represent a unique rural identity. These communal areas differ significantly from commercial farms in terms of population density, land ownership, and socio-economic factors (Wineman *et al.*, 2020).

Despite South Africa's relatively well-developed water sector, access to safe and reliable drinking water remains a significant challenge in many rural communities. Rural areas are disproportionately affected by rapid urbanization, migration, climate change, and infrastructure limitations. Over 20% of the population, mainly in rural communities, lack reliable access to potable water, highlighting the ongoing insufficiency of safe drinking water in these areas. Limited water access results in greater dependence on contaminated sources, higher rates of waterborne diseases, and persistent public protests demanding that the government fulfil its constitutional obligation to provide clean, safe water (Ishola *et al.*, 2025).

The World Health Organisation (WHO) and Statistics South Africa (Stats SA) report that rural populations still have much lower access to safely managed drinking water than urban areas. This pattern matches regional trends in sub-Saharan Africa, where small, remote rural communities have the least access to drinking water (World Health Organisation and UNICEF, 2025; Statistics South Africa, 2022; Verlicchi *et al.*, 2020). Sustainable water service delivery in these areas is hindered by a common reliance on small, decentralised treatment systems that pull water from surface or groundwater sources. These systems are expensive to set up, operate, and maintain (Verlicchi *et al.*, 2020).

According to Verlicchi *et al.* (2020), countries with limited access to drinking water are primarily in sub-Saharan Africa. In small rural communities, ensuring access to clean water through small, decentralised water treatment plants can be very costly, particularly for capital, operating, and maintenance expenditures. Both natural and anthropogenic factors can pollute source water, including seepage from contaminated sites, industrial effluents, agricultural runoff, acid mine drainage, heavy rainfall and flooding, geochemical processes, and untreated wastewater from rural communities (Verlicchi *et al.*, 2020). These sources of pollution are particularly dangerous in rural areas, where the World Health Organisation (WHO) reports that limited access to safely managed drinking water increases reliance on vulnerable surface and groundwater sources (World Health

Organization and UNICEF, 2025).

Unlike urban areas, which are served by large, centralised water treatment plants with high treatment capacities, rural and semi-urban communities in sub-Saharan Africa often depend on small, decentralised water supply systems. As a result, the quality and quantity of available water sources are frequently poorly defined (Verlicchi *et al.*, 2020). Access to nontoxic drinking water in South Africa remains constrained by a remnant of inadequate service delivery, stemming from spatial and infrastructure gaps during the colonial and apartheid eras (Mishra *et al.*, 2021).

Government policies during the apartheid era were intended to empower the white minority at the expense of the indigenous black majority. "Water apartheid" meant the well-off white minority received clean drinking water, while poor black inhabitants in so-called homelands (Bantustans) were largely left without access to clean drinking water. In 1994, approximately 35% (14 million people) of the South African population had access to a basic drinking water supply service. The 1994 transition to democracy in South Africa also led to the development of a new, comprehensive constitution. The Republic of South Africa's 1996 Constitution recognises access to drinking water as a fundamental human right, stating in Section 27(1)(b) that "everyone has the right to have access to sufficient food and water" (Constitution of the Republic of South Africa, 1996, Section 27(1)(b)) (Mishra *et al.*, 2021).

Subsequently, the new democratic government adopted policies, legislation, and programs that expanded access to potable water services for all South African communities. By 2004, after a decade of democracy, a further 13.4 million South Africans had access to a drinking water supply service, suggesting that only 64% of South African households had access to a reliable one. However, progress in access to basic potable water has been greater in urban areas. To date, South Africa continues to face significant challenges in providing basic drinking water services to some households, predominantly in rural areas. There are issues of water insecurity and a lack of municipal portable water delivery services, predominantly in rural communities in the Limpopo and KwaZulu-Natal Provinces. Although many studies have examined the lack of sustainable drinking water in rural areas, research on household drinking water insecurity remains underexplored (Mbana *et al.*, 2024).

1.3. Research Statement, Purpose, and Questions

South Africa is categorised as a water-stressed republic, expected to face physical scarcity of clean, drinkable water by 2025, with yearly per capita freshwater accessibility below 1000 m³, despite the provisions of the Constitution of the Republic of South Africa, 1996, and the Water Services Act (Mishra *et al.*, 2021). The National Water Act (NWA) 36 of 1998, which must be interpreted alongside

the Water Services Act (WSA) 108 of 1997, was enacted to promote democratic principles and inclusivity within the water sector. It also establishes provisions for managing, conserving, and protecting water resources (Republic of South Africa, 1997). The NWA recognises that past discriminatory practices have hindered justifiable access to water and mandates that water resources be managed in the public interest and fairly (Republic of South Africa, 1998; Qumbu, 2021).

The Water Services Act 108 of 1997 (WSA) implements the constitutional right to sufficient water under Section 27(1)(b) of the Republic of South Africa's Constitution of 1996. Together, these instruments establish the core legal and policy framework for water security in South Africa, requiring the state to take reasonable legislative and other measures, within available resources, to gradually realise this right (Republic of South Africa, 1996; Water Services Act 108 of 1997).

Under the Republic of South Africa's Constitution of 1996, Section 27(1)(b), as well as the Water Services Act No. 108 of 1997 and the Local Government: Municipal Systems Act No. 32 of 2000, local governments are primarily responsible for providing potable drinking water to communities. According to a WSA study, municipalities can provide water services directly or through contractual arrangements with other businesses, in accordance with the Local Government: Municipal Systems Act 32 of 2000. Water service institutions include water service authorities, water service providers, water boards, and water service committees, whereas water service intermediaries may provide water as a secondary obligation associated with another primary contractual function (Republic of South Africa, 1997; Republic of South Africa, 2000).

Despite this comprehensive legislative framework, major implementation challenges persist, particularly in rural towns. According to studies and government publications, many rural areas still experience intermittent or unpredictable water supplies due to ageing infrastructure, limited financial capacity, and weak institutional governance (Department of Water and Sanitation, 2018; Statistics South Africa, 2022). According to the Stats SA Census 2022, approximately 82.4% of South African households had access to piped water inside their homes or yards. However, in provinces such as Limpopo, fewer than one-third of households had piped water inside their homes, and a significant share still relied on alternative or off-site water sources. This pattern reflects broader structural inequities in rural service delivery, as evidenced by the patchy availability of a reliable water supply in municipalities such as Blouberg Local Municipality (Statistics South Africa, 2022). These issues are exacerbated by high unemployment and widespread poverty in rural regions, limiting households' ability to purchase water from alternative sources when the municipal supply fails (Statistics South Africa, 2022; Maleasenya, 2023).

The Blouberg Local Municipality's Integrated Development Plan (IDP) identifies persistent water scarcity and poor water quality in several rural villages in the GaMalebogo area, including Gemarke, Old Longsigne, Driekoppies, Alldays Extension, Raditshaba, Kibi, Sadu, and Swarts, where some water sources are unfit for human consumption due to high salinity. These villages fall within the administrative jurisdiction of the Blouberg Local Municipality, which is part of the Capricorn District Municipality and is responsible for water service planning and bulk water delivery. Despite local governments' constitutional and legislative responsibilities to ensure access to safe drinking water, the efficiency of Water Conservation and Water Demand Management (WCWDM) implementation in optimising available water resources in GaMalebogo remains inadequately documented.

This lack of clarity regarding municipal performance in rural water service delivery forms the basis for this study. Given the persistent shortcomings in water infrastructure, unreliable municipal supply, and the availability of groundwater resources in the area, the study assesses the potential of groundwater as a supplementary source of potable water to alleviate chronic shortages in the GaMalebogo area. It further proposes an appropriate treatment method to ensure the safe and sustainable use of groundwater in rural villages within the Blouberg Local Municipality (Blouberg Local Municipality, 2023/2024).

1.3.1. Problem Statement

Rural villages in the GaMalebogo area of the Blouberg Local Municipality continue to experience chronic shortages of safe and reliable water for domestic use, with serious social, health, and environmental consequences. Residents have unreliable access to potable water for domestic use, and animals are also affected, forcing communities to rely on unsafe surface water sources such as rivers. In other cases, people and animals share the same water supply, increasing the danger of contamination and waterborne infections. Despite the presence of groundwater resources in the area, they remain underutilised because of limited investment, inadequate infrastructure, and weak groundwater management practices (DWS, 2022; Pienaar et al., 2021). This situation reflects a broader issue of water insecurity in the countryside, in which institutional, technical, and management constraints continue to impede effective water service delivery at the local government level.

This study aims to identify sustainable solutions to improve access to safe, reliable water in the GaMalebogo villages by assessing the potential of groundwater as an alternative water source. It seeks to understand the challenges of effectively utilising groundwater to address water shortages and to explore practical methods to ensure a consistent, safe water supply through proper management. Furthermore, the research contributes to the wider discussion of rural water insecurity

in South Africa by examining current access to potable water in GaMalebogo, the challenges in local water management, and the implications for promoting equitable water service delivery in a democratic society.

1.3.2. Research Purpose

This qualitative case study aims to explore how groundwater can be utilised in the rural village of GaMalebogo, located in the Blouberg Local Municipality, Limpopo Province, to supply clean, drinkable water and thus eliminate the community's water shortage.

1.3.3. Research Questions

This study will be guided by the following research questions:

1. What groundwater access methods are available for providing a sustainable supply of potable water in the GaMalebogo villages?
2. What barriers hinder the development and sustainable use of groundwater for potable water supply in the GaMalebogo villages?
3. What operational and management challenges affect the long-term use of groundwater for potable water supply after groundwater systems have been installed?
4. To what extent is groundwater currently used as a source of potable water in the GaMalebogo villages?
5. What strategies can improve the sustainable use of groundwater to enhance access to potable water in the GaMalebogo villages?

1.4. Research Objectives

The following research objective will guide this study:

- 1 To assess different methods for accessing groundwater at GaMalebogo rural villages.
- 2 Identify existing barriers that the GaMalebogo villagers face before the successful installation of any system for accessing groundwater.
- 3 Identify challenges faced by the GaMalebogo rural community after the successful installation of any method to access groundwater?
- 4 Identify the reliance on different methods of accessing groundwater.
- 5 Assess the scale of groundwater usage at GaMalebogo rural villages?

1.5. The Study Area

Figure 1 displays the research area in the Blouberg Local Municipality, located in the northern part of Limpopo Province. GaMalebogo is a rural community situated in the north-western part of the Capricorn District Municipality, one of the five district municipalities in Limpopo Province. The Blouberg Local Municipality covers approximately 9,540 km² and is classified as a Category B municipality, meaning it is a local municipality that shares executive and legislative authority with the Capricorn District Municipality in accordance with the Constitution of the Republic of South Africa (Republic of South Africa, 1996). The municipality also shares international borders with Botswana and Zimbabwe. While the broader municipal region provides the administrative and governance framework for water service delivery, this study concentrates on the villages of GaMalebogo, which face ongoing challenges in accessing safe drinking water. Blouberg is the largest municipality in the Capricorn District, making up more than half of the district's total land area (Mugovhani, 2021). It is marked by low population density, high unemployment, and many rural residents who rely heavily on the district's basic services, including water supply (Mugovhani, 2021; GTAC, 2021).



Figure 1: Illustration of the geographical location of Blouberg municipality, located in the northern part of Limpopo province, bordering Botswana (Mugovhani, 2021)

The village of GaMalebogo is in the Blouberg municipality, part of the Capricorn District. A household is defined as a group of people living together or an individual living alone. As shown in Figure 2, there were 49,166 households in the Blouberg municipality in 2016, and this number is projected to increase to 56,273 by 2026. The household growth rate in Blouberg municipality averages 0.15% annually, which is lower than the 0.34% rate in Capricorn District. All South Africans have the right to access clean drinking water, sanitation, electricity, and wastewater services disposal. Providing

these services to households and businesses is a core responsibility of local municipalities. Good governance is essential for ensuring well-functioning communities with a positive environment for economic growth and job creation (GTAC-MSEP, 2021). The study's target population includes selected community members from four villages, community representatives, and groundwater abstraction service providers in the rural village of GaMalebogo in the western Limpopo province of South Africa.

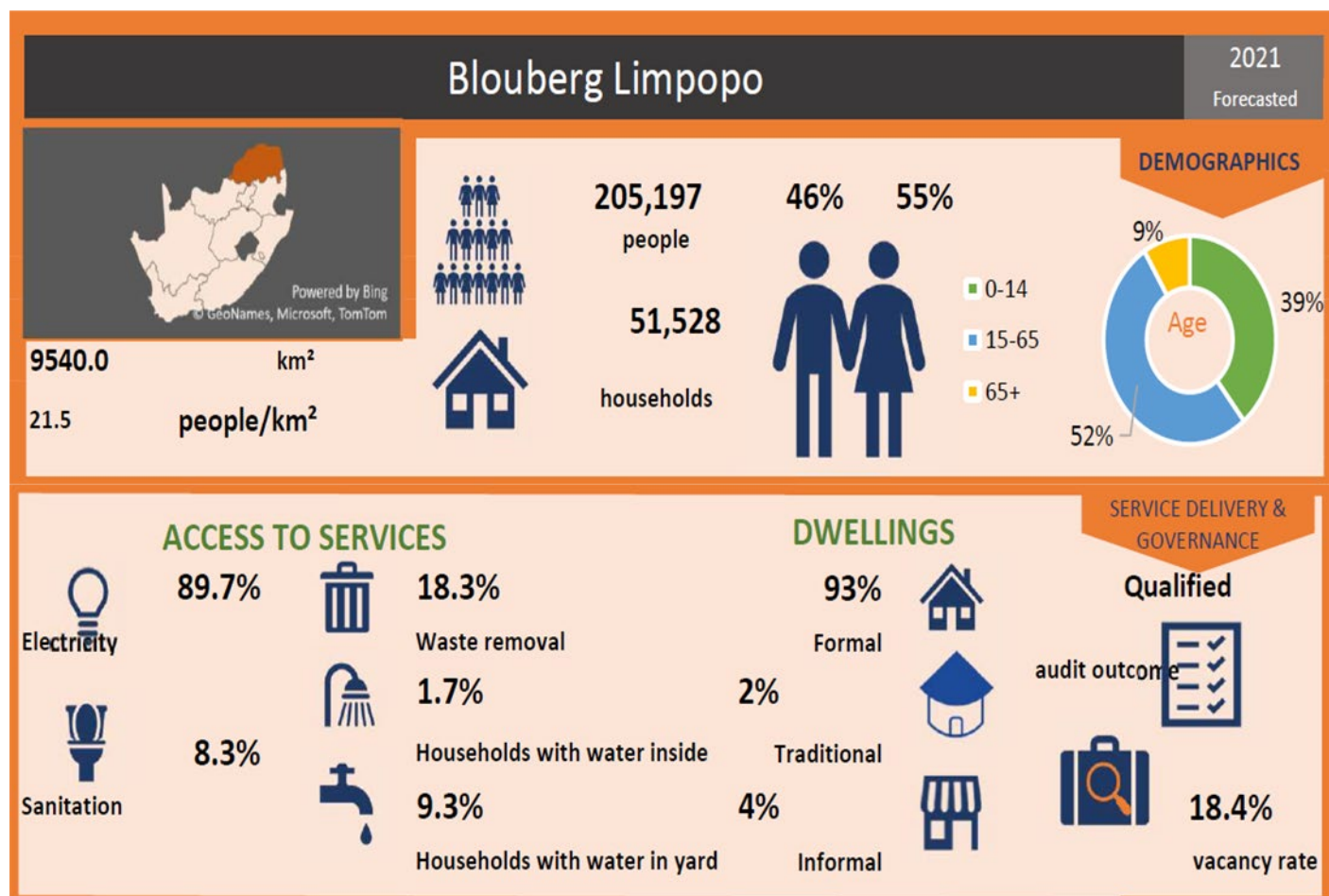


Figure 2: Statistical illustration of the current Blouberg Local Municipality demographics and service delivery status, South African National Treasury (Government Technical Advisory Centre -Municipal Socio-Economic Profiles (GTAC-MSEP, 2021)

The name "Blouberg" derives from the blue mountains of the Maleboho rural community, a mountain range located west of the western terminus of the Soutpansberg Mountain Range, northwest of the town of Vivo. Characterized as a warm region, Blouberg receives annual precipitation of 380-550 mm, with most rainfall occurring in summer. Evapotranspiration rates are notably high during the rainy season (Mugovhani, 2021). The area experiences recurrent drought, which negatively impacts the local economy. The main river in the area is the Mogalakwena River, which supplies water to the Glen Alpine Dam and is the only nearby source of piped water (Mugovhani, 2021).

1.6. Demarcation of the Chosen Research Area

1.6.1. Geographical Dimension

To address water scarcity, this study adopts a geographically focused case study approach. The GaMalebogo villages in the Blouberg Local Municipality were selected as the study area because they experience persistent rural water shortages and were accessible for repeated field visits, participant recruitment, and data collection, thereby enabling an in-depth investigation of groundwater use and local water service challenges.

Long-term disruptions in the municipal water supply, reliance on unsafe alternative sources such as rivers and public boreholes, and the daily strain on households, especially those with women and children who must travel great distances to fetch water, are examples of these experiences. The study's contextual depth and significance are enhanced by this extended experience with water insecurity, which provides insights into local water-use patterns, service delivery issues, and the social effects of limited access to drinkable water.

1.7. Definition of Terms and Concepts

1.7.1 Rural Community

A community consists of a socially linked group of individuals living in a defined geographic area. They share mutual interests, social bonds, and collective responsibilities, especially in managing and using shared resources such as water (Van Koppen et al., 2020). A rural community is characterised by a shared commitment to a common culture, as evidenced by collective values, social norms, and shared understandings of daily life. These are influenced by geographical proximity and functional interdependence, as community members rely on common natural resources, local infrastructure, and communal services. Collective values such as partnership, social support, and respect for traditional authority control social behaviour, while common norms govern acceptable practices regarding resource usage and communal participation. Common interpretations shape how difficulties, such as water scarcity, are understood and addressed collaboratively. These features are evident in GaMalebogo's communal coping strategies and shared expectations regarding water access and municipal service delivery (Maleasenya, 2023).

Rural communities are typically defined as non-urban areas that do not meet the criteria for urban classification, including high population density, significant economic activity, and comprehensive infrastructure. Urban settlements, including official towns and cities with high population densities and advanced infrastructure. Non-urban (rural): Comprising farms, scattered settlements, and

communal lands governed by traditional authorities. (Wineman *et al.*, 2020))

1.7.2 Groundwater

Surface water resources are currently insufficient to meet the growing water demand caused by rapid urbanisation, economic development, and climate variability (Mishra *et al.*, 2021). As a result, groundwater serves as an alternative water source for water supply, agriculture, and economic development. Many uses of groundwater are preferred because of its high quality and low cost. (Addisie M.B., 2022). Among global water resources, groundwater is stored within the Earth's crust. According to UNESCO (2022), groundwater is an essential component of Earth's freshwater system, occurring beneath the surface in geological formations called aquifers. It is replenished through groundwater recharge, which occurs both directly through rainfall infiltration into the soil and indirectly through seepage from rivers, streams, and other surface water bodies. The groundwater then moves through aquifers before naturally discharging into springs, rivers, and wetlands (Gebreslassie *et al.*, 2025; Addisie, 2022). Groundwater systems are often poorly understood outside expert circles because they are maintained below ground and are not visible, despite providing a steady source of freshwater for human and biological uses. Groundwater is commonly accessed through boreholes, and its quality is influenced by interactions between water and the minerals in the rocks and sediments through which it flows (UNESCO, 2022).

For several reasons, particularly the invisibility of this water and the influence of education and established traditions, the characteristics and physical laws that govern groundwater remain largely unknown beyond the community of hydrogeologists, the experts in the study, management, and safeguarding of groundwater resources. This resource offers numerous benefits, especially compared to surface water, and is widely used worldwide for various purposes, including farming, drinking water, manufacturing, bottling, and more (Lachassagne, P., 2021). It is accessible year-round, including during dry seasons and in arid regions, and is effectively protected from surface pollutants. Effective management and safeguards are essential for ensuring both the quantity and quality of groundwater's sustainability. These characteristics make groundwater a potentially sustainable water source for rural communities experiencing unreliable water supplies, highlighting the need to investigate its use to address water scarcity in the GaMalebogo villages.

1.7.3 Water Scarcity, Shortage, Stress, and Security

South Africa ranks among the 40 driest countries in the world, receiving an average annual rainfall of approximately 465–500 mm, which is well below the global average of about 860 mm (DWS, 2022). Challenges such as increased water stress, unreliable water supply, flooding, limited access

to safe drinking water and sanitation, and rising water pollution can impede economic development. Despite the significant value of our water resources, there is no universally accepted definition of water security (Meissner et al., 2018).

Generally, there are two types of water scarcity, namely, physical and economic, according to Higgins (2023). Physical water scarcity occurs when natural factors, such as low rainfall, prolonged droughts, high evaporation rates, and climate variability, limit the availability of water resources to meet demand (Higgins, 2023; Mishra *et al.*, 2021). On the other hand, economic water scarcity occurs when access to water is limited by poor management, insufficient infrastructure, or a lack of institutional and financial resources. Water stress arises when demand for water exceeds supply, or when poor water quality limits its use. It results from both physical and economic water scarcity. Physical water scarcity occurs when natural water resources are insufficient to meet demand due to factors such as low rainfall, drought, and climate variability. Economic water scarcity, on the other hand, occurs when water resources are available but cannot be accessed because of inadequate infrastructure, poor management, limited financial resources, or weak institutional capacity. Consequently, communities may experience water stress even where water resources exist (Higgins, 2023; Mishra et al., 2021). The severity of this stress depends on the share of water withdrawals compared to total renewable resources. An area is deemed water stressed if withdrawals exceed 25% of the renewable water. When the ratio exceeds 40%, it indicates severe water stress, and exceeding 80% signals critical water stress (Higgins, K., 2023).

According to Meissner et al. (2018), water security is a context-dependent condition that reflects people's perceptions of water-related risks, availability, and access, as well as the impacts on their lives and environments. This view presents water security as people's lived experiences of water risks and opportunities, including the quality and dependability of their water supply and their interactions with institutional and natural systems. These perceptions differ across socioeconomic, environmental, and community-government relations, indicating that water security is shaped by both objective and subjective factors (Meissner *et al.*, 2018).

1.7.4 Water supply

Water supply is derived from three primary sources: surface water, groundwater, and precipitation (rainfall and snowfall). Surface water is stored in lakes, rivers, streams, and reservoirs. Groundwater is obtained from underground aquifers that feed wells and springs. Although shallow aquifers can be replenished through both direct precipitation infiltration and indirect recharge from surface water bodies, deeper aquifers containing ancient groundwater are replenished only very slowly under present-day climatic conditions (Gebreslassie *et al.*, 2025; Addisie, 2022). Water supply systems

consist of several essential stages. Initially, water is collected in reservoirs, which can be either artificial or natural storage facilities designed to accumulate water, thereby guaranteeing a dependable source even during dry periods. These reservoirs can temporarily or for extended periods hold water, assisting in regulating availability in response to seasonal changes and variations in demand. After collection, water is conveyed through a network of pipes, canals, and pumping stations, where it undergoes treatment to ensure safety and quality before distribution to end users. This system ensures communities, industries, and agricultural operations have sufficient water for essential activities such as drinking, cooking, sanitation, irrigation, and industrial processes. In essence, the water supply journey covers the entire path from source to user, including collection, storage, treatment, and distribution, with reservoirs serving as key components for storing water and ensuring a steady supply availability. Effective water supply management is essential for maintaining water that is accessible, dependable, and safe for various human and environmental uses (Angelakis *et al*, 2025).025).

1.7.5 Limitations and Delimitations

This study examines groundwater utilisation to address household water shortages in the GaMalebogo communities. It specifically focuses on household water supply, excluding agricultural or industrial water use. Spanning about three years, the research enabled the observation of seasonal changes and assessment of groundwater availability, infrastructure effectiveness, and management approaches that influence sustainable household water access in the region.

The three-year period will include planning and proposal development, designing the study, establishing objectives, and selecting appropriate methods. Literature review and background research, pinpointing existing research on reservoir management, distribution systems, water quality, or demand forecasting to identify gaps and refine research inquiries. Data collection through qualitative methods, including field sampling and surveys of local users. Data analysis and interpretation, data processing, trend assessment, utilization of statistical or hydrological models, and evaluation of implications for water supply systems. Reporting and dissemination, documenting the findings, preparing reports, publishing results, and potentially offering recommendations to municipalities or stakeholders.

This study is limited to a qualitative case study conducted within the GaMalebogo villages, using a purposive sample of key informants and community members. Although the findings cannot be statistically generalised to other communities, the qualitative approach was appropriate because it enabled an in-depth exploration of participants' experiences and perceptions regarding groundwater use for household water supply. The study focuses specifically on groundwater use for domestic

purposes and therefore does not examine agricultural or industrial water demands. Furthermore, some findings are based on participants' experiences and perceptions, which may be subject to response bias. To enhance the trustworthiness of the findings, data were collected from participants with diverse roles within the community and were corroborated with documentary evidence and relevant literature where appropriate. The study also relied on existing hydrogeological information, as long-term groundwater monitoring data for the study area were not readily available. Consequently, the findings should be interpreted within the context of the study area and period.

1.8. Dissertation Structure

The chapter outline structure is as follows:

Chapter 1: Introduction and Background of The Study

Chapter 1 presents a comprehensive overview of the research by providing a contextual background and justification of the study, thereby establishing the problem statement. The research aims, the questions posed, and the study's specific objectives, limitations, and delimitations are then clearly articulated.

Chapter 2: A Literature Review

This chapter is divided into the following three sections: 1) description of groundwater characteristics and evaluation of its availability in the research area and neighbouring regions. 2) exploration of different methods for sustainably using groundwater resources, and 3) highlighting of essential measures needed for sustainable groundwater management and addressing water shortages in rural communities.

Chapter 3: Research Design and Methodology

This chapter outlines the research paradigm, design, and methodology. It provides justification for the research approach adopted (i.e., qualitative approach) to address the study's aim, followed by a presentation of the data collection and analysis methods

Chapter 4: Presentation of Findings

Chapter 4 presents the results of a review of methods for assessing groundwater resources that may affect individual homes and businesses within the GaMalebogo community. The chapter concludes with a list and explanation of the measures the Blouberg Local Municipality has implemented to manage water shortages and scarcity through responsible groundwater use.

Chapter 5/6: Discussion, Conclusions and Recommendations

The main findings are summarized at the beginning of this chapter, followed by the conclusions. The chapter's conclusion, which offers useful suggestions for the municipality, is equally significant. At the same time, areas that require further research are noted.

Chapter 2: Literature Review

2.1 Introduction

This section examines the relevant literature on the sustainable use of groundwater to provide a reliable drinking water supply to the GaMalebogo villages. It also explores empirical research on groundwater management for domestic purposes, including extraction techniques, guiding principles, challenges faced, and sustainability concerns related to groundwater reservoirs. Additionally, it emphasises the significance of conserving this essential resource.

In summary, the review covers key topics, including the sustainability of drinking water resources in South Africa, groundwater as a primary water source in rural areas, and the sustainable management of groundwater for water supply. It also discusses the protection and conservation of groundwater resources, the challenges of using underground water reserves in rural communities, and strategies to address barriers to accessing potable water where groundwater is available. Finally, the review offers a synthesis of these themes and emphasises their importance for enhancing water security in rural regions.

2.2 Sustainability of Water Sources in South Africa

The government of South Africa has introduced several policies and institutional mechanisms to promote sustainable water provision in rural areas, notably through the National Water Act and rural water supply programs (Department of Water and Sanitation, 2018; Van Koppen *et al.*, 2014). Despite these efforts, numerous rural communities still face inconsistent access to safe drinking water, indicating ongoing difficulties in policy enforcement and service provision (Swatuk & Lankford, 2015). While existing studies largely focus on national policy frameworks and infrastructure development, there is limited empirical research assessing the effectiveness of these mechanisms at the local and municipal levels, particularly in rural settings. Furthermore, gaps remain in understanding the sustainability of groundwater-based water supply systems and the capacity of local institutions to manage and maintain them over time (Bazaanah *et al.*, 2023).

Key stakeholders responsible for maintaining the nation's water supply include the government, the private sector, residents, and local communities. They work together to keep water accessible, affordable, and of high quality through initiatives like building and maintaining water infrastructure, encouraging water conservation, and educating about effective water management. Providing access to safe drinking water is one of the most fundamental responsibilities of municipalities, as it is essential for protecting public health, supporting sanitation and hygiene, sustaining livelihoods,

and promoting social and economic development (Water Services Act 108 of 1997; DWS, 2022). South Africa derives approximately 98% of its municipal water supply from surface water sources, including rivers, dams, and lakes, while groundwater supplies the remaining 2% (DWS, 2022). Despite this, more than 1.5 million South Africans still lack access to a reliable supply of safe drinking water (Stats SA, 2023). Water is obtained from sources such as surface water, groundwater (accessed through boreholes and springs), and harvested rainwater, and is distributed to households through infrastructure such as piped networks and communal standpipes (Stats SA, 2023; DWS, 2022). Groundwater is vital, especially in rural areas, serving as a key drinking water resource that supports health, livelihoods, and dignity. Improving water services and their utilisation in developing countries is essential for better sanitation, higher productivity, and easier access to water from remote or unsafe sources, especially in rural areas (Bazaanah *et al.*, 2023).

Groundwater

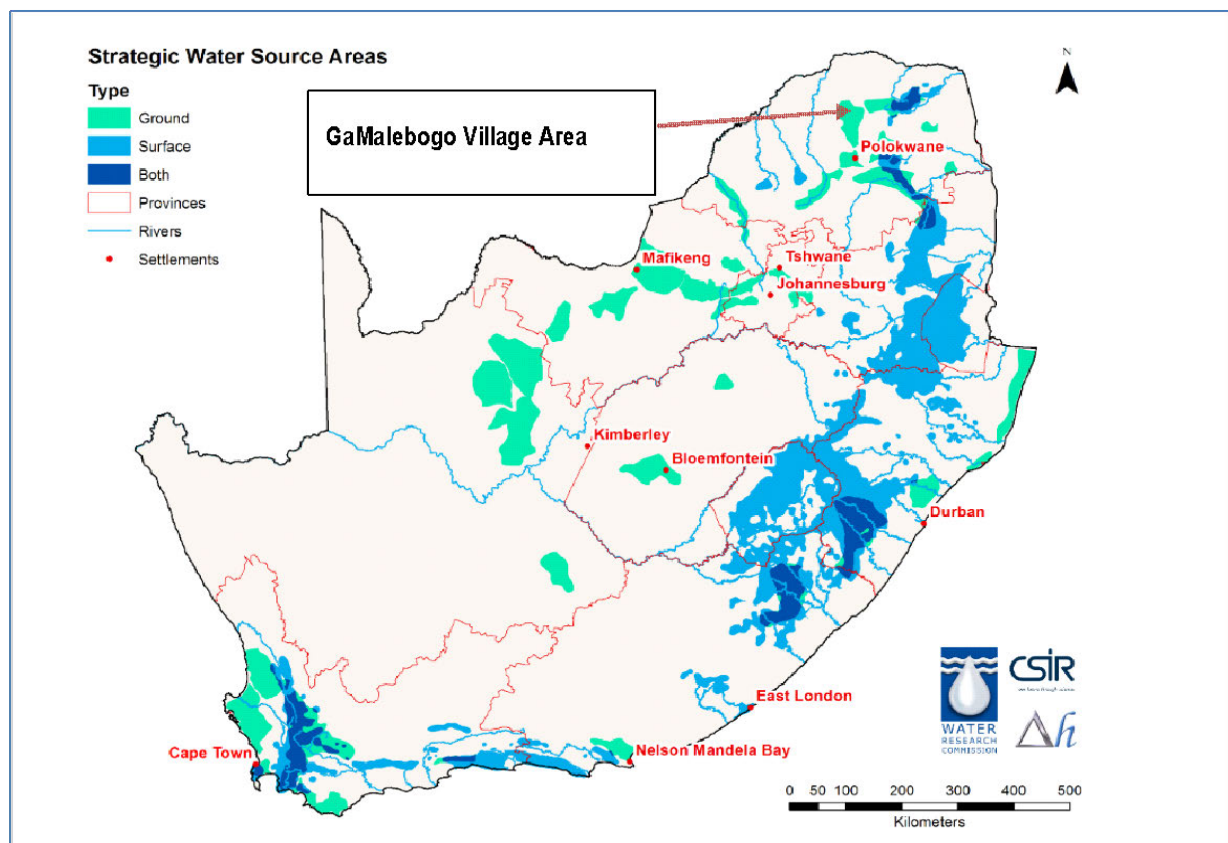


Figure 3: Illustration of a significantly high level of groundwater (Blue Colour) availability in and around Blouberg municipality, Limpopo, including GaMalebogo villages (CSIR, 2024).

(CSIR, 2024), as shown in Figure 3. Groundwater is an important component of South Africa's freshwater resources and plays a significant role in sustaining river baseflow throughout the year, particularly during dry periods when surface water availability declines. Groundwater source areas cover approximately 9% of the country's land area and contribute substantially to water security. National estimates indicate that groundwater receives an average recharge of approximately 34,912

million m³ per year through both direct and indirect recharge processes, including rainfall infiltration and interactions with surface water bodies (Mukherjee et al., 2020; DWS, 2022). Although these national assessments offer useful details on groundwater occurrence, recharge, and hydrological importance, they are mainly descriptive and focus on spatial distribution. They provide limited insight into groundwater use at community and household levels, particularly in rural areas where groundwater is often the primary source of drinking water. Consequently, there is a notable lack of empirical research on how communities' access, manage, and sustain groundwater, as well as the social and institutional challenges that impact its use. Addressing this gap is crucial for developing effective, context-specific groundwater management strategies in rural areas (CSIR, 2024).

Under international law, including the principles recognised by the World Health Organization (WHO), access to safe, clean, and potable water is regarded as a fundamental human right. Despite this, approximately 884 million people worldwide continue to rely on unprotected and often contaminated water sources, such as springs, wells, and rivers, for their daily water needs (Malima et al., 2022). In South Africa, the Constitution of the Republic of South Africa, 1996, and the Water Services Act 108 of 1997 recognise access to sufficient water as a basic right. However, water service delivery remains constrained in many rural communities. Furthermore, the public water sector has traditionally been organised into separate sectors, with publicly funded infrastructure generally intended for specific purposes, such as domestic water supply, irrigation, or livestock watering (Malima *et al.*, 2022).

Publicly funded water infrastructure is often used for purposes beyond its intended design. In rural South Africa, Barbara van Koppen *et al.* (2020) found that domestic water supply systems are frequently used for multiple purposes, including household consumption, small-scale gardening, and livestock watering. This multi-use approach enables rural households to derive greater value from existing infrastructure with relatively little additional investment. South African water policies support this principle through the Strategic Framework for Water Services, which promotes the concept of "climbing the water ladder" by encouraging water services that meet a range of household and livelihood needs beyond basic domestic use. Similar recognition of multiple water uses is reflected in the National Water Resource Strategy (NWRS) and the draft norms and standards for household water supply and sanitation (Van Koppen *et al.*, 2020).

To support the sustainable management of South Africa's water resources, the Department of Water and Sanitation introduced the Water Resource Classification System (WRCS) in 2010. The WRCS provides a framework for classifying water resources within each catchment to guide their protection, use, and long-term management in accordance with the National Water Act 36 of 1998 (DWA, 2010). It evaluates social, economic, ecological, and environmental factors within a watershed to compare

the costs and benefits of using versus conserving water resources. Three categories are established to illustrate a continuum from minimally used to heavily used resources. This classification is the initial step in safeguarding water resources and helps determine the necessary quantity and quality of water for ecosystem health and economic support. To identify opportunities for expanding groundwater use, the Water Research Commission (WRC) of South Africa conducted a strategic review. Pienaar *et al.* (2021) evaluated progress in implementing groundwater protection strategies in South Africa over the previous decade and found that, despite policy advances, challenges remain in the effective implementation and enforcement of these measures. These findings highlight the need for improved groundwater management to sustainably use groundwater resources.

In addition to the policy and legislative framework governing water resources, environmental factors, such as climate change, continue to put increasing pressure on water availability. Climate change is increasing the variability of surface water resources in sub-Saharan Africa, reducing the reliability of traditional water sources and highlighting the importance of sustainable groundwater management (Bellwood-Howard *et al.*, 2022). Due to ancient geological formations across the continent, South Africa's groundwater is primarily stored in hard-rock aquifers. Recent scientific assessments indicate that South Africa's groundwater resources are comparable in volume to its surface water resources (Department of Water Affairs, 2013; Xu & Braune, 2010).

Recent scientific assessments indicate that South Africa's groundwater resources are of a similar order of magnitude to its surface water resources (Pienaar *et al.*, 2021; DWS, 2017). Renewable groundwater is estimated at approximately 10,000 million m³ per year (7,500 million m³ during drought conditions), while the assured yield of surface water resources is approximately 12,000 million m³ per year. Current groundwater abstraction remains well below its sustainable potential, indicating opportunities for increased groundwater development. Although large-scale users mainly depend on surface water, many small-scale sources crucial for livelihoods and health rely on groundwater. In Limpopo Province, groundwater levels stayed above historical averages due to good recharge in 2013, though localized deviations exist in some areas from over-extraction or other factors (Pienaar *et al.*, 2021).

Groundwater is particularly advantageous for rural water supply because it is often locally available and can be accessed through boreholes where suitable hydrogeological conditions exist. This reduces reliance on long-distance water distribution systems and provides a more reliable water source during periods of limited surface water availability (Xu & Braune, 2010; DWS, 2010). This makes it an ideal option for small-scale rural water delivery and for small municipalities with limited funds that cannot afford the infrastructure to transport water over long distances from surface sources. Additionally, the role of groundwater in urban water supply is growing, with 22% of towns

relying solely on it and another 34% using both groundwater and surface water (Mochotlhi , 2019).

The area is in the Waterberg District, which comprises five basins, namely, the Lower Crocodile River sub-basin, the Mokolo River basin (including the Tambotie tributary), the Lephalala River basin, the Mogalakwena River basin, and a small section of the Olifants River catchment. The Vaalkop, Roodekopjes, Klipvoor, and Bierspruit dams provide water to the Lower Crocodile River system. Despite this infrastructure, the ecological condition of the Lower Crocodile River has been classified as poor due to pressures such as water abstraction, altered flow regimes, and other human activities. Recent years have seen extensive irrigation and water extraction along these rivers, which have impacted their natural flow and ecological functions (Oosthuizen *et al.*, 2018).

2.3 Groundwater Sustainability

South Africa is experiencing rising water scarcity due to its semi-arid climate, population growth, urbanisation, and the effects of climate change. The reliability and availability of surface water, traditionally the main supply source, are decreasing in many parts of the country. Managing reservoirs and piped surface water to serve 59 million people is becoming more costly. Groundwater is vital for maintaining water security and for diversifying water resources alongside traditional sources (Van der Gun, 2021).

Groundwater systems are constantly adapting to both immediate and long-term shifts in climate, water extraction, and land use (Taonameso *et al.*, 2020). Although groundwater is an important source of water in many rural communities, its quality cannot be assumed to be safe for human consumption without appropriate testing and treatment. Studies conducted in the Tshitale-Hlanganani area of the Vhembe District, Limpopo Province, detected microbial contamination, including *Escherichia coli* (*E. coli*), in drinking water from boreholes, highlighting the potential health risks associated with untreated groundwater (Taonameso *et al.*, 2020). These findings emphasise the importance of routinely assessing groundwater quality against established physical, chemical, and microbiological standards to ensure that it is safe for domestic use and to reduce the risk of waterborne diseases. However, despite annual drinking water risk assessments, many rural municipalities, including those in the Vhembe District, continue to face challenges in providing safe and reliable drinking water to rural communities (Taonameso *et al.*, 2020).

In Limpopo, the 2009 drought in South Africa reduced river flow, leading to the drying up of dams and interlinked water basins. Limpopo Province is predominantly rural, and many communities continue to experience unreliable access to water. This is largely attributed to inadequate water supply infrastructure that cannot meet community demand, as well as challenges in municipal service delivery. Consequently, many households have limited access to a reliable water supply,

highlighting the need for sustainable interventions, including the improved development and management of groundwater resources (Matlakala *et al.*, 2020).

Water quality in many parts of Limpopo Province is considered unsuitable for human consumption because groundwater is vulnerable to contamination from inadequate sanitation systems. In many rural communities, the widespread use of pit latrines increases the risk of contaminants entering groundwater sources, thereby posing potential health and environmental risks. Many rural households require support to ensure water is safe for consumption, as inadequate maintenance of water supply systems can compromise water quality. Improving the maintenance and operation of existing water infrastructure is therefore essential to ensure the reliable delivery of safe drinking water.

Population growth has led some community members to drill their own boreholes for water, as existing pumping systems are inadequate. Insufficient water supply, coupled with illegal connections by community members, strains the already compromised pumping system and risks compromising its structural integrity. Neglected maintenance of the pumps that transport water from boreholes to communities further exacerbates the situation. Ineffective water distribution to communities is attributed to pump failures, elevation differences, and pressure fluctuations within the system. Municipalities have long been criticised for their mismanagement of water resources and sluggish service provision (Matlakala *et al.*, 2020).

In recent decades, there has been growing concern about the scarcity of fresh, potable water, both locally and globally, and the Sustainable Development Goals (SDGs) provide a clear framework for addressing these pressing issues. Globally, an estimated 900 million people lack access to safe drinking water, with 84% of this population residing in rural areas of many developing countries, such as South Africa. Multiple studies highlight a substantial rise in water scarcity expected in the coming years, particularly in developing countries such as South Africa. The contamination of water sources and inadequate sanitation practices contribute to over 10,000 deaths daily, with 5000 of these fatalities occurring in children under five years old. Certain villages in rural areas lack proper sewerage systems, posing significant health risks. Water pollution remains a pressing challenge across many Southeast Asian countries (Bun *et al.*, 2021).

Given the extensive nature of this issue, there has been a growing focus on addressing the scarcity of potable water across regions worldwide. Consequently, it has emerged as a compelling subject of research in the current era. Amid the growing water crisis, alternative water sources have been under scrutiny. Groundwater emerges as a viable alternative owing to its abundance, quality, and local accessibility in areas with pronounced water scarcity. It is a crucial source of potable water.

The annual extraction of groundwater is estimated at approximately 982 km³, making it the most heavily utilised raw material globally. A large portion, over half, of water allocation in many regions goes to domestic use, supplying more than 45% of the world's drinking water, especially in smaller towns and rural areas that rely on local sources. Groundwater acts as an additional source in urban, semi-urban, and rural communities without piped water systems, primarily serving households, farms, and industrial sites with private wells. Known for its cleanliness and strong protection against pollution, it is often linked to surface water, reflecting the increasing reliance on this resource (Bun et al., 2021).

Groundwater has become an important source of freshwater for household use in many rural regions because it provides a more reliable supply where surface water is scarce, seasonal, or vulnerable to climate variability. In addition, limited water supply infrastructure and financial constraints in many rural communities increase reliance on groundwater accessed through boreholes and wells. Groundwater is susceptible to contamination because pollutants can infiltrate the subsurface through natural recharge processes or human activities. Contaminants from pit latrines, agricultural fertilisers and pesticides, industrial effluent, landfill leachate, and poorly managed wastewater can percolate through the soil into aquifers, compromising groundwater quality and rendering it unsuitable for human consumption if left untreated.

Groundwater is susceptible to various pollutants that can render it unsuitable for human use. Groundwater pollution can stem from both natural geological processes and human activities. Numerous global and regional studies have examined groundwater quality data, showing elevated levels of common contaminants such as nitrate. A study conducted by Lalumbe et al. (2022) in the Soutpansberg area of Limpopo Province found that groundwater contained elevated concentrations of nitrate (NO₃⁻), fluoride (F⁻), chloride (Cl⁻), sodium (Na⁺), and total dissolved solids (TDS), making it unsuitable for drinking. The study further reported that elevated nitrate and fluoride concentrations were associated with health risks, including methemoglobinemia and dental fluorosis.

Ensuring access to safe, potable water has become a global priority as population growth, rising agricultural water demands to meet food production needs, and climate change continue to put pressure on available freshwater resources. Groundwater is essential for supporting ecosystems and humans; therefore, sustainable management is vital, as aquifers provide 50% of the world's drinking water and 43% of irrigation supplies. However, because groundwater is a shared resource for people and ecosystems, it is often overused and depleted faster than it can be replenished, especially as food demand rises. Over-extraction can cause problems such as saltwater intrusion and land subsidence, threaten the environment and create geological hazards, especially in certain regions. These issues often impact poor communities the most, particularly in rural areas (Elshall et

al., 2020).

Despite the extensive literature on groundwater availability, recharge, and contamination, a key gap remains in understanding the sustainability of groundwater use at the communal and household levels, particularly in rural contexts. Much of the existing research focuses on hydrogeological characteristics, water quality assessment, and national-scale resource mapping, with limited attention to how rural communities access, manage, maintain, and protect groundwater systems over time. In addition, there is insufficient empirical research on the institutional, socioeconomic, and governance factors that influence sustainable groundwater use in rural municipalities. Addressing these gaps is essential for developing context-specific groundwater management strategies that support long-term potable water security in rural areas.

2.4 Protection and Preservation of Groundwater Resources

Groundwater plays a crucial role in sustainable development when appropriately governed and managed. Individuals involved in groundwater use and management must recognise that its significance extends beyond serving as a water source for human consumption; in many regions, it provides multiple functions and services simultaneously. The delineation of typical groundwater services, categorized into the four distinct groups of ecosystem services, is illustrated in Figure 4: provisioning, regulatory, supporting, and cultural services. It is important to distinguish between groundwater services that depend on groundwater extraction (e.g., drinking, irrigation, and industrial use) and those that are naturally sustained without extraction, such as sustaining wetlands, maintaining river baseflow, and supporting groundwater-dependent ecosystems (Van der Gun, 2021).

Several scholars e.g., Griebler & Avramov, (2015) and Gleeson *et al.*, (2020) have conceptualised groundwater services within the ecosystem services framework, identifying provisioning, regulating, supporting, and cultural services as key functional categories. These studies emphasise that some groundwater services depend on abstraction, while others are delivered in situ through the maintenance of ecological processes and environmental flows. These studies emphasise that some groundwater services depend on abstraction, while others are delivered in situ through the maintenance of ecological processes and environmental flows.

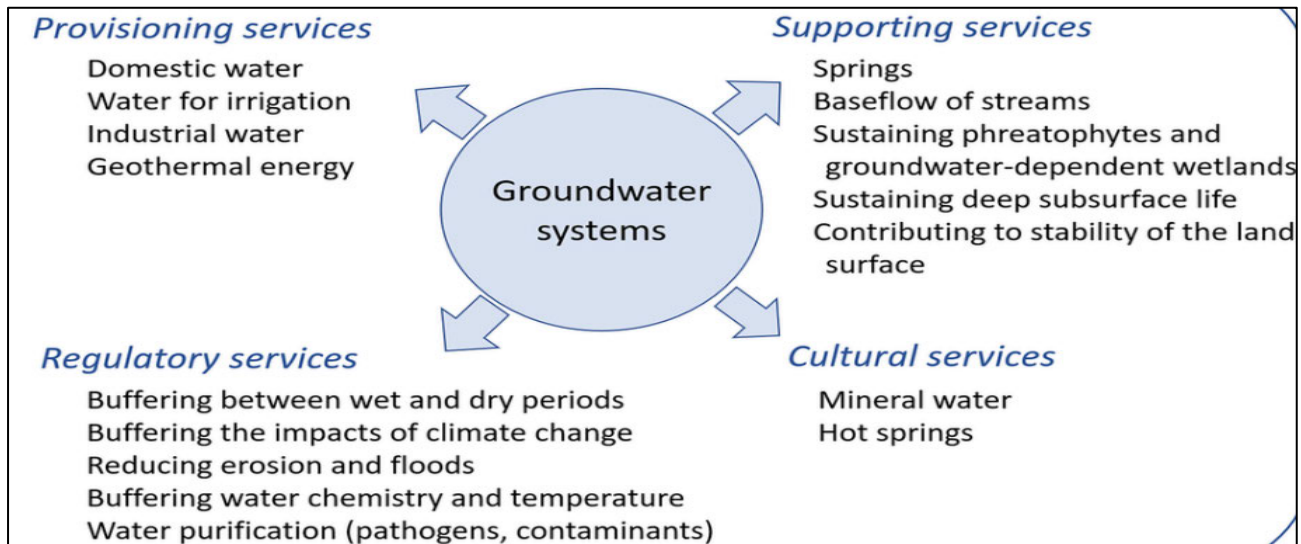


Figure 4: Illustration of typical uses and functions of groundwater systems, Van der Gun J., 2021

While existing research has significantly advanced understanding of the ecological and hydrological functions of groundwater, much of the literature remains focused on conceptual frameworks, hydrogeological processes, and ecosystem-level assessments. There is limited empirical research on how these ecosystem services are perceived, used, and managed at the community or household level, especially in rural areas where groundwater often serves as the main source of domestic water supply. Moreover, studies on groundwater sustainability in South Africa have primarily focused on hydrogeological and water-quality aspects, with comparatively less attention paid to socio-institutional factors such as governance structures, local management practices, and community dependence on groundwater. This gap underscores the need for context-specific research that links groundwater ecosystem services to daily water use and management practices.

One way to prevent or address groundwater overdrafts and improve the sustainability of groundwater resources is to establish and implement demand management. This framework focuses on conserving water by controlling or decreasing water extraction, achieved through better allocation, conveyance, and use. There are many opportunities to implement water demand management measures across the entire water supply system to improve water-use efficiency and promote the sustainable use of available water resources. Implementing restrictions via permit-based allocation and levies on metered abstraction can motivate individuals to lower groundwater extraction.

Households can conserve water by reducing pressure in their water distribution systems, using low-volume flush toilets, adopting waterless sanitation methods, employing other water-saving technologies, and, overall, being conscientious about avoiding water waste. Initiatives such as awareness campaigns, legislative measures, taxation, water pricing mechanisms, energy supply and pricing strategies, subsidies, penalties, and fines play crucial roles in encouraging the desired

behaviours among all stakeholders, including the general populace (Van der Gun, 2021).

Groundwater management is essential for integrating scientific research with water management policies. Monitoring is a key component, tracking changes in groundwater levels to improve understanding of conditions and support effective decision-making. This helps develop suitable policies and promotes the sustainable use of groundwater. It also helps detect contaminants, enabling more accurate assessments of pollution levels. With this data, sustainable groundwater management strategies can be implemented to preserve aquifer water quality and minimize impacts on ecosystems and public health. Additionally, regulating groundwater flow is vital to prevent contaminant or saltwater intrusion from reaching pumping stations, which could disrupt operations (Syafiuddin *et al.*, 2020; Van der Gun, 2021).

2.5 Challenges to Sustainable Groundwater utilisation in Rural Areas

Groundwater makes up 99% of Earth's liquid freshwater and is the most widely used freshwater source worldwide. In many regions, groundwater is the only reliable perennial source of water and becomes the primary water supply where the necessary pumping infrastructure and energy are available. Furthermore, groundwater provides a dependable alternative when surface water availability declines due to climate variability. Currently, groundwater provides nearly half of the world's drinking water, about 40% of agricultural irrigation, and roughly one-third of industrial water needs. Growing withdrawals to satisfy increasing human demand have led to a significant decline in key agricultural and populated areas. Many aquifers are threatened by degradation or are already experiencing seasonal shortages. The expansion of intensive farming and irrigation is a major factor. Residential use of groundwater, both in urban and rural areas, has also increased considerably. Deeper, confined aquifers may be less affected by biological and chemical pollutants, making them preferable for residential use, especially in regions not contaminated with substances such as arsenic (Lallet *et al.*, 2020).

In South Africa, groundwater contamination has been associated with agricultural activities, inadequate sanitation, mining, and naturally occurring geogenic contaminants. Common pollutants include nitrates, fluoride, heavy metals, and microbial pathogens, all of which may render groundwater unsuitable for drinking without appropriate treatment (DWS, 2010; WHO, 2022). Various effective in situ remediation techniques encompassing physical, chemical, and biological approaches have been implemented on a large scale. However, these methods are continually subject to review and assessment to enhance their effectiveness and efficacy. While these approaches show promise in degrading certain groundwater pollutants, there is a current emphasis

on achieving remediation in a more environmentally friendly and cost-effective manner to align with sustainability objectives. Consequently, biological remediation strategies such as bioaugmentation, bioelectroremediation, and biostimulation have gained popularity due to their comparable or superior removal efficiency compared to chemical or physical methods. The prudent management of groundwater reserves is a pressing issue, as a decline in the water table could increase pumping costs and potentially lead to scarcity of surface water sources, thereby raising overall costs (Syafiuddin *et al.*, 2020; Van der Gun J, 2021).

Contamination of both surface and subsurface water sources has become widespread as human activities intersect with water flow pathways. The use of fertilizers, pesticides, and various chemicals, solvents, pharmaceuticals, and pathogens from human waste is causing persistent pollution in shallow and deep groundwater worldwide. Because groundwater has long residence times, it reflects the cumulative impacts of extraction, recharge, and pollution. This leads to water scarcity, pollution, and land subsidence, which could become irreversible due to high remediation costs. The decline in groundwater quality due to natural and human factors, combined with extensive depletion, poses a sustainability challenge for humanity (Lall *et al.*, 2020). Despite the extensive global literature on groundwater supply, depletion, and contamination, numerous gaps remain. First, much of the available research is conducted at the global or national scale, with little empirical attention to specific rural contexts, particularly small villages reliant on communal boreholes. Second, while pollution sources and remediation technologies are well documented, there is insufficient evidence on their practical feasibility, affordability, and long-term viability in rural, resource-constrained contexts. Third, the research concentrates on the biophysical and technical dimensions of groundwater use but pays less attention to institutional, governance, and community-level management challenges that influence reliability and long-term sustainability. Finally, there is a lack of integrated research linking groundwater availability, quality, infrastructure reliability, and household water security outcomes in specific rural areas, creating a gap that this study aims to fill.

2.6 Strategies for Improving Access to Water in Rural Areas

Many approaches have been proposed to expand rural populations' access to potable water, including community-based water management, expanded groundwater development, investment in water infrastructure, and strengthening institutional and governance frameworks. At the global scale, the literature emphasises groundwater as a reliable alternative to surface water, particularly in rural regions where surface water is scarce or seasonal. However, its suitability as a water source depends on local hydrogeological conditions, groundwater quality, and sustainable management practices. Much research emphasises technical solutions but often overlooks long-term sustainability aspects such as infrastructure maintenance, groundwater protection, and community

management capacity. Furthermore, there are few empirical studies assessing the efficacy of municipally adopted policies in rural South Africa. This gap limits our understanding of how socioeconomic circumstances, governance issues, and local participation affect the effectiveness of solutions for potable water access. It underscores the need for further context-specific, longitudinal research.

Pienaar *et al.* (2021) highlight significant changes in groundwater development and governance in South Africa after the 1994 democratic transition and subsequent water-sector reforms. During a major community water supply program, groundwater became the main water source, providing improved access to approximately 27 million people by 2013 (Pienaar *et al.*, 2021). The critical role of groundwater was recognised in government policies and strategies. The National Water Act (NWA), Act 36 of 1998, reclassified groundwater from private to public water and acknowledged it as a 'substantial resource. Under the Act's Integrated Water Resources Management framework, regulations concerning the conservation, protection, management, and regulation of water resources were broadened to encompass groundwater.

The first-time enrolment of all water use under the NWA provides a comprehensive overview of groundwater use by economic sector at the national scale. At the same time, national programs for hydrological mapping and evaluation have provided readily accessible, comprehensible data on the presence and potential of groundwater. This data, together with a significantly improved understanding of groundwater's role, has contributed to integrating groundwater into national planning through improved strategies, blueprints, and feasibility studies. Progress in formulating groundwater-specific regulations within the NWA framework has been limited. This limitation is primarily due to insufficient consideration of groundwater's unique attributes in surface-water management tools intended to safeguard water resources. This inadequacy has been particularly evident during the implementation of the resource-oriented measures procedure, the NWA's principal mechanism for safeguarding water resources (Pienaar *et al.*, 2021).

2.7 Summary

The reviewed literature indicates that groundwater is an essential part of South Africa's water supply system, supporting agricultural activities, industrial processes, and household use, especially in areas facing water scarcity and drought. Its strategic importance is growing as surface water resources become more erratic and limited. Across the literature, interconnected pressures on groundwater sustainability have been highlighted. These include over-abstraction driven by rising water demand, water quality degradation from agricultural and industrial practices, and the escalating effects of population growth and urbanisation. Together, these factors reduce the

resilience of groundwater systems nationwide.

Based on existing research, climate change is expected to affect groundwater recharge, with effects varying significantly across regions. While some areas may see lower recharge potential, others may benefit from limited increases, underscoring the uneven nature of climate-related risks to groundwater resources. This heterogeneity highlights the importance of region-specific assessment and management measures. Overall, the literature emphasises the importance of sustainable groundwater governance through integrated water resource management, supported by ongoing monitoring, scientific research, and stakeholder involvement at the local and municipal levels. Such measures are critical to protecting groundwater resources and increasing their ability to meet current and future water demands.

Chapter 3: Methodology and Data Analysis

3.1 Introduction

This chapter details the data collection methods used in the study and explains the research design, paradigm, methodology, sampling techniques, and data collection tools. The researcher chose a qualitative approach. Data were gathered through document reviews and semi-structured interviews. Additionally, the chapter discusses data analysis procedures and the measures taken to ensure data trustworthiness. Ethical considerations were also considered to reduce potential risks.

This study primarily aims to develop a practical and sustainable method for groundwater use to address water insecurity in the region. A qualitative epistemological research approach is adopted. A qualitative interview questionnaire was administered to community members of the study area and to government officials responsible for supplying water to the GaMalebogo community.

3.2 Research Philosophy

3.2.1 Constructionism

According to a constructionist epistemological theory, human interaction with the social and physical world actively constructs knowledge. Rather than passively absorbing knowledge, people gain understanding through their experiences, interpretations, and interactions with others. Thus, shared interpretations, social processes, and context all influence meaning. This framework challenges the notion of an ultimate truth or objective reality and emphasises that knowledge is subjective and shaped by cultural, historical, and social contexts (Rees *et al.*, 2020).

A constructionist epistemological framework underpins the study at hand. Within constructionist theory, it is posited that the notion of objective truth is absent; instead, individuals generate interpretations of phenomena through active engagement with their lived experiences and circumstances. The present research endeavour aims to employ an interpretive methodology guided by the symbolic interactionist framework. Symbolic interactionists recognise the significance of social interaction in the process by which individuals understand and attribute significance to various phenomena. The utility of symbolic interactionism in comprehending human behaviour lies in its focus on individuals' interpretations of language, symbols, and meanings. The concept of constructionism lacks a universally agreed-upon definition, yet it may be conceptualised as a theoretical framework grounded in a set of assumptions (Rees *et al.*, 2020):

These include critiquing taken-for-granted self-understanding, recognizing that places and moments

shape knowledge, and viewing knowledge as socially constructed through language. In addition, constructionism holds that multiple ways of constructing reality led to diverse interpretations and actions (Rees *et al.*, 2020). The study was designed to address the research objectives while remaining consistent with the overall aim of the research (Mardiana, 2020)

3.3 Research Methodology

The data were systematically analysed using thematic analysis in Atlas.ti, allowing for the identification of recurring patterns and themes. These themes were organised and visualised in Microsoft Excel to aid interpretation and comparison. A total of 16 participants, all residents of the study area, were purposively selected to ensure a diverse range of community experiences and perspectives on water access and groundwater use.

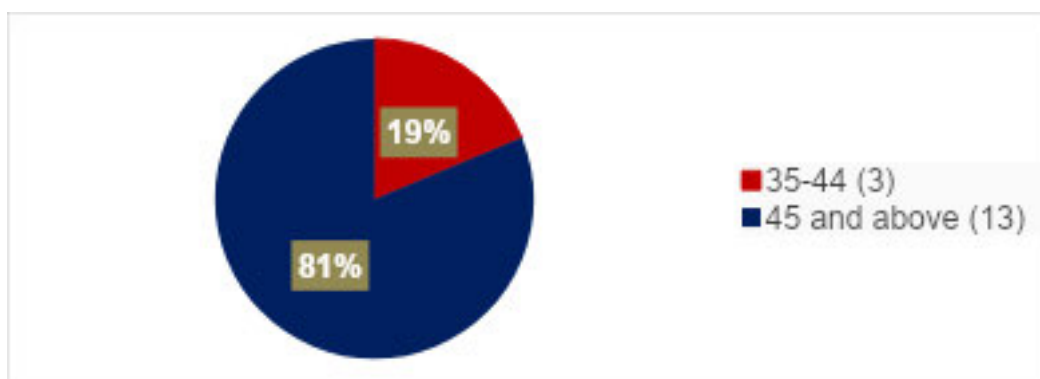


Figure 5: The age grouping of the interview residents at GaMalebogo villages

As shown in Figure 5, of the 16 participants, 13 were 45 years or older, and the remaining 3 were 35–44 years. This age distribution is expected, as many young people from rural areas temporarily relocate to cities for work or further education. Having grown up in the study area and then moving for employment and educational opportunities, the researcher's life path aligns with this broader trend of young people leaving rural areas. The case study approach is well known in qualitative research for providing detailed, contextually grounded, and empirically rich insights into complex social processes. Unlike methods that prioritize abstract generalization, case study research enables researchers to examine multiple sources of evidence, capture the complexity of local contexts, and generate a nuanced understanding of processes, behaviours, and meanings (Yin, 2018; Stake, 1995). The case study approach was selected because it allows for an in-depth examination of the phenomenon within its real-life context. It also facilitates the integration of multiple sources of evidence, thereby providing a comprehensive understanding of the factors influencing the sustainable utilisation of groundwater in the study area.

Exemplar cases can provide insights into a broader population that a survey cannot reveal.

Exemplar cases are intentionally selected to represent a particular category within a larger population. Qualitative analysis typically involves content analysis, a method for analysing collected data. By subjecting qualitative data to detailed content analysis, it can be transformed into quantitative data to validate the results statistically. In a qualitative investigation, a researcher must formulate research questions that explore the meaning of individuals' experiences and elicit their everyday encounters. According to Edward (2020), this process involves interviewing individuals who have experienced the phenomenon. A fundamental premise of qualitative research is that collective experiences have a fundamental essence (Edward, 2020).

Denzin and Lincoln define qualitative research as a situated activity in which the observer is situated in the world, and real-life occurrences are studied through interpretive procedures. This approach emphasizes depth, complexity, and meaning-making over measurement and hypothesis testing (Denzin & Lincoln, 2018).

A phenomenological qualitative research design aims to gain a deep understanding of participants' perceptions, experiences, and meanings regarding the use of borehole groundwater to address water scarcity. Phenomenological inquiry investigates how people experience a phenomenon in their daily lives, with the researcher carefully listening to participants' descriptions to capture both explicit and implicit meanings. This approach emphasises attentive listening, openness to participants lived experiences, and sensitivity to subtle expressions that reveal how the event is interpreted and processed (Van Manen, 2016). In this study, the research task is to enable residents of the selected study region, the GaMalebogo villages, to articulate the obstacles they face and the approaches they use to overcome them, such as the shortage of potable water.

3.4 Data Collection

The qualitative data collection methods included interviews, focus groups, surveys, telephone calls, notes, recorded interactions, and questionnaires (Maleasenya T.S., 2023). The data collection tools included semi-structured interviews and an examination of relevant documents. The researchers' primary data collection method was interviewing. To facilitate a thorough study, the primary method of data collection was face-to-face semi-structured interviews to obtain qualitative data. Interviews with participants are among the most used methods of data collection in qualitative descriptive research (Maleasenya, 2023). An interview guide was developed and used to conduct community-level interviews. It consisted of open-ended questions aligned with the study objectives, focusing on participants' experiences with groundwater use, water supply challenges, and perceptions of sustainable groundwater utilisation. During the field visits, interviews were conducted with 16 purposively selected participants, including community members, ward councillors, and local

business owners. Community participants comprised [briefly describe the demographics, e.g., adult household members responsible for water collection, including both men and women across different age groups], as they were directly affected by local water supply challenges and could provide first-hand accounts of groundwater use and water access. Ward councillors and local business owners were included because of their knowledge of municipal water service delivery and the community's water infrastructure. The researcher developed the interview guide, conducted all interviews, and recorded participants' responses.

To avoid influencing participants with the interviewer's tone, a consistent tone was maintained throughout the questioning. The interview guide was developed using the study objectives and the literature reviewed to ensure that the questions addressed the research problem. It consisted of open-ended questions organised into key themes, including household water sources, groundwater use, water supply challenges, perceptions of groundwater sustainability, and possible measures to improve water access. Face-to-face semi-structured interviews were conducted with purposively selected participants, including community members, ward councillors, and local business owners, to obtain diverse perspectives on water use and service delivery in the study area. Where necessary, follow-up questions were asked to clarify responses and encourage participants to elaborate on their experiences. Throughout the interviews, the researcher maintained a neutral approach to minimise interviewer bias and ensure that participants could express their views freely (Maleasenya, 2023).

Thomas (2022) argues that purposive sampling should be viewed as an information-generating method; it also known as judgment sampling allows for quick and effective participant selection. This non-random technique does not require prior acquaintance or a predetermined number of participants. The first step in the research process is to identify individuals willing to share their expertise and insights.

This study employed maximum variation sampling, a purposive sampling strategy used to capture diverse perspectives and experiences. Participants were selected based on their knowledge and experience of groundwater use and water supply in the study area. Twelve participants were purposively selected from the expressions of interest received. This sample size was considered adequate because qualitative research prioritises the depth and richness of information over statistical representation, enabling the researcher to address the study objectives effectively (Thomas, 2022).

Research instruments play a crucial role in conducting research projects. They help researchers collect data to test hypotheses or answer research questions. Educational research offers a plethora of data collection instruments; each using unique methods to describe and quantify data. Among

the various data collection instruments, the interview is widely used. This research project utilized interviews, a purposeful interaction in which information is gathered from one or more individuals. In interviews, a purposive method for gathering information from one or more individuals. Interviews are often considered the most appropriate, as they enable in-depth exploration of information that cannot be achieved by other methods (Sahoo, R., 2022).

The interview guide comprised four sections. The first introduced the study and obtained informed consent, the second collected demographic information, the third explored participants' experiences of water supply and groundwater use, and the fourth sought participants' views on improving the sustainable utilisation of groundwater. In total, the guide contained approximately eight open-ended questions.

3.5 Data Analysis Procedure

A thematic data analysis approach was used to examine qualitative interview data. All interviews were audio-recorded to accurately capture participants' perspectives. They were transcribed exactly as spoken, and coding was used to identify themes related to water scarcity and shortage. These main themes were subsequently identified and combined. This typically includes consolidating all audio- or video-recorded interview files in a single location, converting observational notes to digital format (e.g., Microsoft Word or Adobe PDF), and digitising paper documents. Essentially, the interview data were merged with information obtained through document analysis. It is advisable to implement a systematic file-naming system in this process and to create a comprehensive data inventory detailing each data source, its storage location, creator, and collection date. This enabled configuring the dataset in a format required by ATLAS. ti.

According to Lester et al. (2020), qualitative fieldwork generally produces large amounts of data, often involving hours of interviews, focus groups, observational notes, and several documents. Consequently, descriptive statistics, such as distribution, central tendency, and variability, were used. Additionally, inferential statistics were employed to estimate population parameters from this sample data.

3.6 Trustworthiness of Collected Data

Trustworthiness, also known as legitimacy and reliability, is crucial in qualitative research. It's essential to understand how researchers demonstrate that their findings are transferable, credible, useful, dependable, and authentic. These five components constitute the foundation of trustworthiness and are examined in detail in the upcoming sections (Haq *et al.*, 2023).

As the qualitative counterpart to legitimacy and reliability in quantitative research, trustworthiness is

a key factor in evaluating the quality and rigour of qualitative investigations. It indicates how well the information gathered and the conclusions drawn from it reflect participants' experiences and meanings. This study employs the concepts of credibility, transferability, dependability, confirmability, and authenticity to establish trustworthiness (Haq *et al.*, 2023). While transferability is strengthened by thorough contextual descriptions that enable readers to evaluate the findings' relevance to comparable contexts, credibility is attained by ensuring that participants' viewpoints are accurately recorded. Dependability is addressed by maintaining a transparent and well-documented research process, and confirmability is strengthened through reflexivity to minimise researcher bias. Authenticity ensures that participants' diverse voices and lived realities are fairly represented. Collectively, these measures enhance the integrity and consistency of the collected data and the study's overall findings (Lincoln & Guba, 1985; Shenton, 2004; Haq *et al.*, 2023).023).

3.6.1 Credibility

To demonstrate sincerity, researchers guarantee that a study accurately measures or tests the intended variables. Consequently, credibility is often linked to internal validity. In quantitative research, establishing truthfulness is crucial. Researchers build affiliation and trust with participants to enhance credibility. Interviews with participants were conducted using interview guides. All interviews were recorded, and notes were taken for certain participants to verify accuracy (Kyngäs *et al.*, 2020).

Maleasenya *et al.* (2023) characterized credibility as the truthfulness of the data or participants' perspectives, along with the researcher's interpretation and representation of these views. One effective method for enhancing credibility is to incorporate member checking into the findings, which involves obtaining direct feedback from participants on the data, interpretations, and conclusions.

3.6.2 Transferability

Transferability refers to how well the results of one study apply to other contexts or groups. It indicates whether qualitative research findings remain relevant across different settings and among various participants. The researcher defines the research context, including data collection and analysis methods, and provides a detailed report of the study and its findings. To help readers assess the significance of the findings and determine their transferability, the researcher must include a rich, detailed description of the study, ensuring that both the data and the context are clear and self-explanatory (Haq *et al.*, 2023).

Transferability refers to how well the results of a qualitative study are applicable across contexts, situations, or populations. Instead of leaving only the researcher to decide, transferability depends

on providing detailed contextual information that enables readers to judge whether the findings apply to their own settings. This involves clearly describing the research environment, participants, data collection methods, and analysis procedures. Thick, detailed descriptions enhance transparency and help others assess the relevance of the findings outside the original study (Lincoln & Guba, 1985; Creswell & Poth, 2018; Haq *et al.*, 2023).

3.6.3 Dependability

When research is repeatedly conducted in the same context using the same methods and participants, the results often remain consistent, helping establish dependability. In this study, dependability was improved by using an interview schedule and audio-recording all session interviews. Dependability is characterised as the reliability of data over time and the specific conditions under which it was gathered. Dependability refers to the consistency of data under similar conditions. The data and detailed descriptions provided in this research necessitated reliability auditing, which was further enhanced by modifying the research design as new insights emerged during data collection (Haq *et al.*, 2023).

3.6.4 Confirmability

Confirmability in qualitative research parallels objectivity, with triangulation reducing researcher biases to support corroboration. It indicates how well findings can be verified by others, reflecting data that genuinely represent participants' responses. During interviews, notes and transcripts were compared to ensure this, allowing the researcher to maintain a methodologically self-critical approach. All data should be archived systematically to protect the findings if challenged (Haq *et al.*, 2023).

3.6.5 Authenticity

Authenticity encompasses the qualities of genuineness, truthfulness, and reality. People tend to form judgments about it, even if assessing someone else's authenticity can be difficult. In research, authenticity refers to how well a researcher captures and conveys participants' feelings and emotions. To ensure valid data interpretations, the researcher used thorough processes and critical evaluation of evidence and interpretations (Haq *et al.*, 2023).

3.7 Ethical Considerations

The researcher followed strict ethical standards throughout the study. Protecting participants' privacy and safety required careful ethical considerations, ensuring respect for those involved and

implementing necessary precautions. The research adhered to the university's ethical guidelines and was approved by the research committee. Special attention was given to participants' rights.

The IIE MSA committee oversees the ethical conduct of research. In line with the IIE MSA policies and regulations concerning human subjects research, the following ethical considerations were to be maintained throughout the study. These apply specifically to the quantitative research parts of the project. For consent, written informed consent will be secured from contacted participants and included in the questionnaire. All consent forms were securely stored on a password-protected hard drive.

In connection with the confidentiality of the research and privacy, secrecy or confidentiality in this research study, the research results and the frame were stored on a password-protected hard disc for a period of 4 years. The data could later be destroyed by formatting the hard disc. The researcher (Thabo Meletse) will be the only person with access to the data, which will be shared with participants on request. Participants are assured that their names and the names of their respective communities or water management departments will be kept strictly confidential. This encompasses the principle of trust, ensuring that participants' confidence is not exploited for personal benefit and that they are not misled or deceived about the research process or its published outcomes. Since South Africa's rural communities are small, there's a risk that the survey may not yield reliable data if some water sector participants decline to participate.

3.7.1 Informed Consent

The researcher is familiar with the Institutions ethical policies, which require obtaining an approval letter before starting the research. This approval was supported by a consent letter granting the researcher permission to access all study-related facilities. The researcher must ensure that potential participants are fully informed about the procedures and risks involved before they give their consent. Participants should also be informed of their right to withdraw from the study at any time. They were notified that notes would be taken and an audio recorder would be used during interviews.

3.7.2 Right to Privacy

Participants did not face any victimisation, and the researcher took steps to ensure their privacy. Their identities remained confidential, and access to their data was restricted from law enforcement to prevent any legal issues arising from the participants. They were not asked to share personal details, including medical history or sexually transmitted diseases. Confidential information was kept strictly private, not shared with anyone, including family or friends, and discussed only in secure

environments. Participants were assured of their right to privacy and told their identities would be kept anonymous.

3.7.3 Confidentiality

The researcher assured participants that their confidentiality would be protected by ensuring that identifying information remains inaccessible to anyone not directly involved in the study. Participants were reassured by the researcher that all information collected from them would be kept strictly confidential and that their names would not appear in the research report. Private data identifying subjects should remain undisclosed. The participants' right to privacy and their right to decline to answer specific questions or to refuse to participate in the interview altogether were duly respected.

3.7.4 Anonymity

The researcher upheld participants' right to anonymity by ensuring that their identities, names, or contact details were not disclosed to any third party, thereby preventing certain participants from being traced. In this context, the researcher affirmed that the identities of the informants would not be disclosed. The measures taken to safeguard identifying information were thoroughly detailed, and participants were assured that any information they disclosed would not be shared with unauthorized individuals.

3.8 Limitations to the Research Methodology

This research explored how groundwater is used to address the shortage of safe, drinkable water in the rural GaMalebogo villages within the Blouberg Local Municipality, using a qualitative approach. This scope limited the ability to generalize the results to the entire Limpopo province or other rural areas nationwide. A key reason for this was the small, unrepresentative sample from the target population. Despite these methodological constraints, the researcher conducted extensive interviews with participants, continuing until no new information appeared—achieving data saturation. While acknowledging these limitations, the researcher took measures to enhance data credibility, suggesting that the findings may be relevant to similar settings.

3.9 Summary

This chapter outlines the research layout used in this analysis. A qualitative approach was chosen to gather data from informants, resulting in qualitative findings. The methodology section details the study area, population, sample size, and selection process. It also explains the data collection methods, analysis procedures, and measures taken to ensure data trustworthiness. Data were

collected through document analysis and interviews. The chapter also discusses the study's limitations, which could have influenced the results, and emphasizes efforts to address ethical considerations to minimize risks. The next chapter will present and analyse the data collected using these methods.

Chapter 4: Results and Interpretation

4.1 Introduction

The previous chapter focused on the research design and methodology used to conduct the study. It provided a framework for the research design and paradigm, followed by a discussion of the data collection and analysis techniques employed. First, the research examined the causes of the potable water shortage in the GaMalebogo rural village community. Second, the chapter investigates the impact of water shortage on private households and small enterprises in the local municipality. This chapter further presents the study's findings, focusing especially on groundwater use to reduce water scarcity. It concludes by outlining strategies the municipality can adopt to tackle the potable water shortage.

4.2 Data Analysis

The data were analysed systematically through thematic analysis in Atlas.ti, allowing for the identification of recurring patterns and themes. These themes were organized and visualized in Microsoft Excel to aid interpretation and comparison. A total of 16 participants, all residents of the study area, were purposively selected to ensure a diverse range of community experiences and perspectives on water access and groundwater use.

As shown in Figure 6, most participants were male (11), while 5 were female. During the interviews, it was also observed that women are not responsible for ensuring water availability in their households, whereas men are responsible through their donkey carts. Once water is available at the homestead, women take over their daily chores. Men also attend local community meetings organised by the local chief, where issues such as water shortages are discussed. One of the interviewed participants said:

“It is the responsibility of men and boys in the family to ensure the well-being of the donkeys and to make sure they are healthy enough to pull the donkey carts for water collection, which is rather far from our house. Carrying water containers is quite heavy for the women and girls.”

The other participant elaborated on this point further when he said:

“According to the Bahananwa tradition, women and girls are responsible for managing the household and ensuring everything is in order, while men and boys must support them in meeting their needs. Women don’t have a place in the traditional council discussions on issues facing the community, such as water. Men must ensure that water is available.”

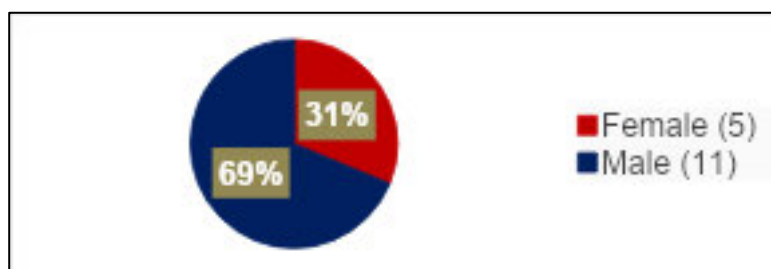


Figure 6: Gender distribution of the interview participants

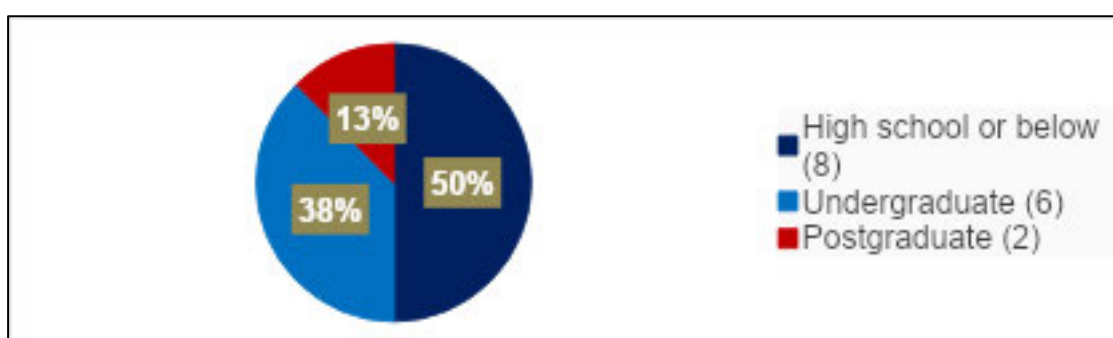


Figure 7: Educational level of participants

As shown in Figure 7, most participants (8) had completed matric or held lower-level qualifications; six had earned undergraduate qualifications (such as diplomas or bachelor's degrees); and two had earned postgraduate qualifications.

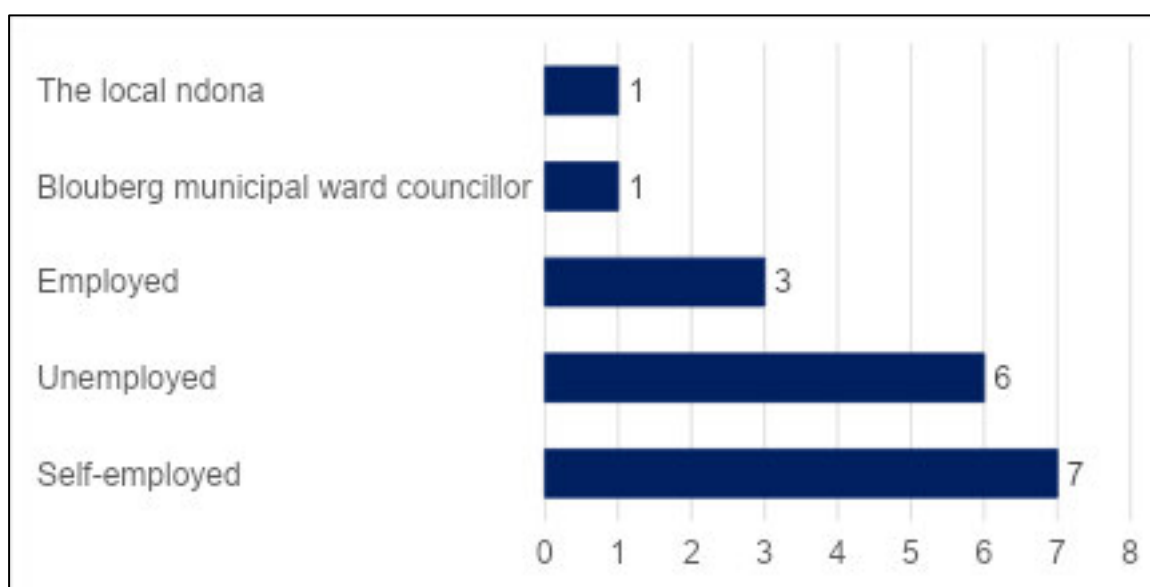


Figure 8: Employment status of the participants

Most participants (44%) were self-employed, primarily engaged in informal economic activities such as small-scale trading, subsistence farming, and casual labour. Six participants (38%) were unemployed, and only three (19%) reported formal employment. In addition, one participant served as a municipal ward councillor, and another held the traditional leadership role of nduna (headman),

as shown in Figure 8.

“The Bahananwa people are very proud and not lazy at all. For example, our forefathers were self-sustaining, working the land and keeping livestock, including goats, cows, and donkeys. We also hunted, but there is no longer enough game around our villages. We know our way around this beautiful land. We currently need assistance from the government to maintain our way of life, which is crop farming and keeping domestic animals, by ensuring the availability of water, because nowadays the rains are not as predictable as in the old days, and at times they don’t come at all,” said the local Ndona.

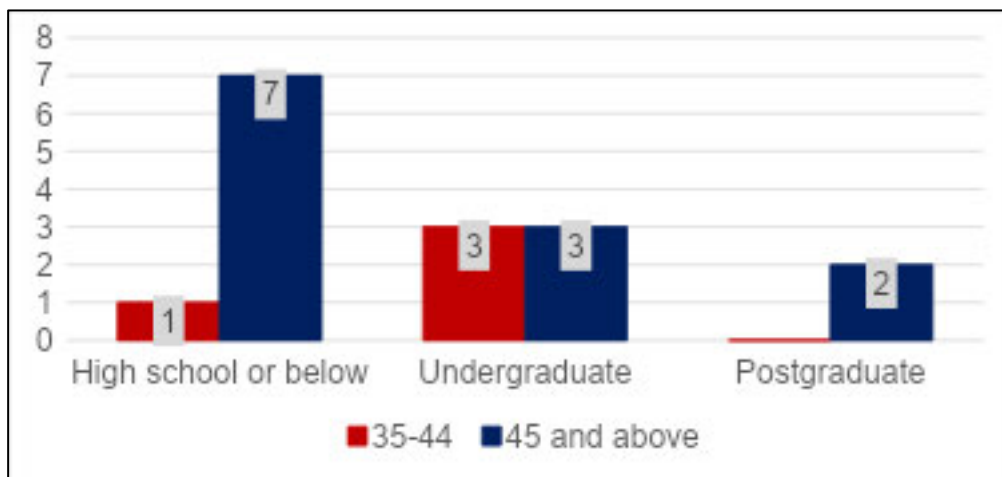


Figure 9: Participants' age group by gender

Figure 9 shows a clear relationship between age and educational attainment: younger participants have higher qualifications, while older participants have a high school education or less. This pattern reflects long-standing inequities in rural school access that adversely affect older generations.

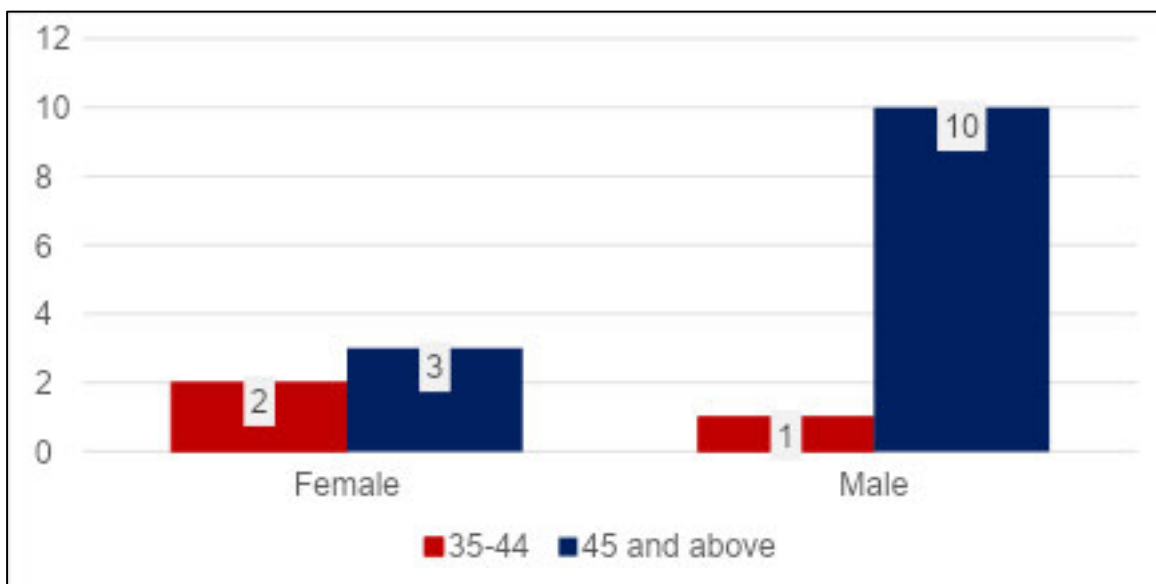


Figure 10: Participants age group by gender

Figure 10 indicates that the study sample is predominantly composed of older adults across both genders, with a particularly strong representation among male participants.

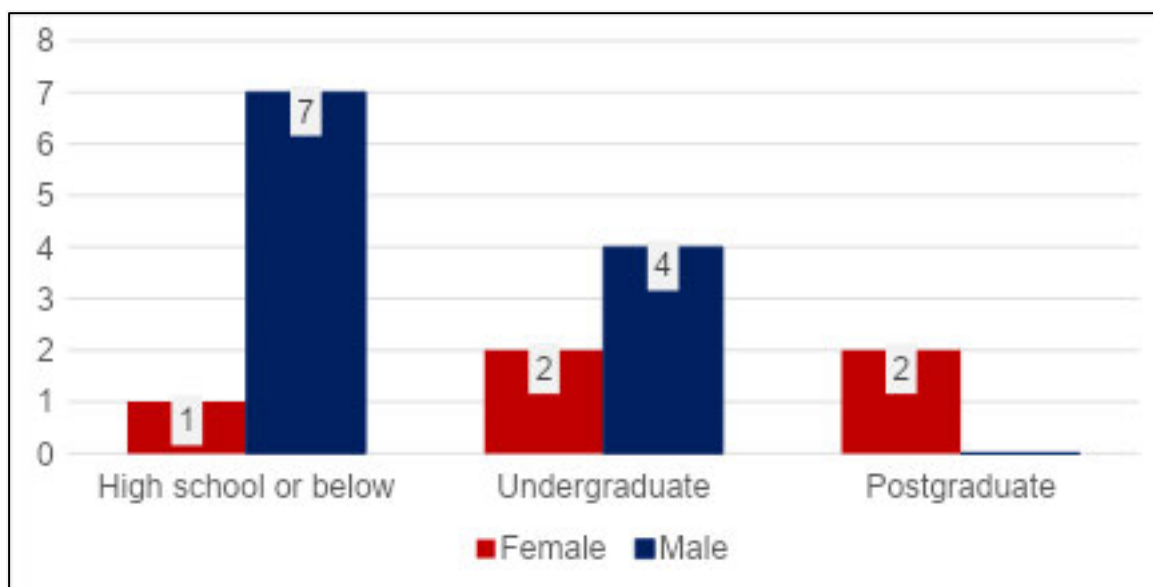


Figure 11: Participants' education level by gender

Figure 11 highlights a gender-based difference in educational attainment, with female participants generally exhibiting higher levels of formal education than their male counterparts.

4.2.1. Access to Potable Water Supply

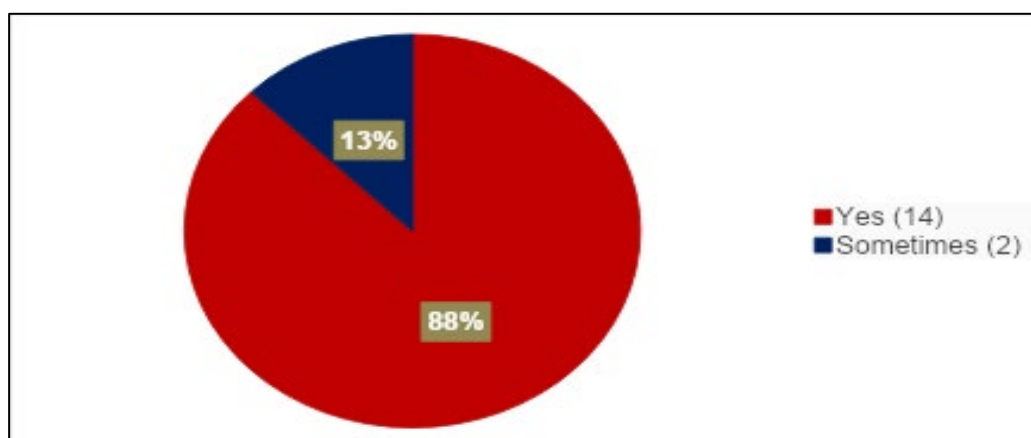


Figure 12: Access to clean drinkable water at GaMalebogo villages

Practically all participants reported having access to clean, potable water for their daily needs, primarily through groundwater sources such as municipality-installed boreholes and privately installed wells; however, two participants reported that, although they have access to these sources, the supply is limited and not consistently available (Figure 12). Some participants reported having JoJo overhead water tanks for water storage, while others indicated they are trying to acquire them.

These efforts reflect household-level coping strategies to manage an intermittent water supply, which is typically available only once a week.

One participant said, *“We do have clean, drinkable water from the municipality-installed taps connected to the borehole they drilled, but the water is not available all the time. I have no money to buy these big JoJo tanks because I am not working. Besides, when they pump the water, it goes to this neighbour’s JoJo tank first before it reaches other villagers. The water runs out when they stop pumping. I think they need to install one big tank for all of us. The one available is too small because the water runs out before reaching all of us. After all, it fills all the JoJo tanks first.”*

4.2.2. Source of portable water

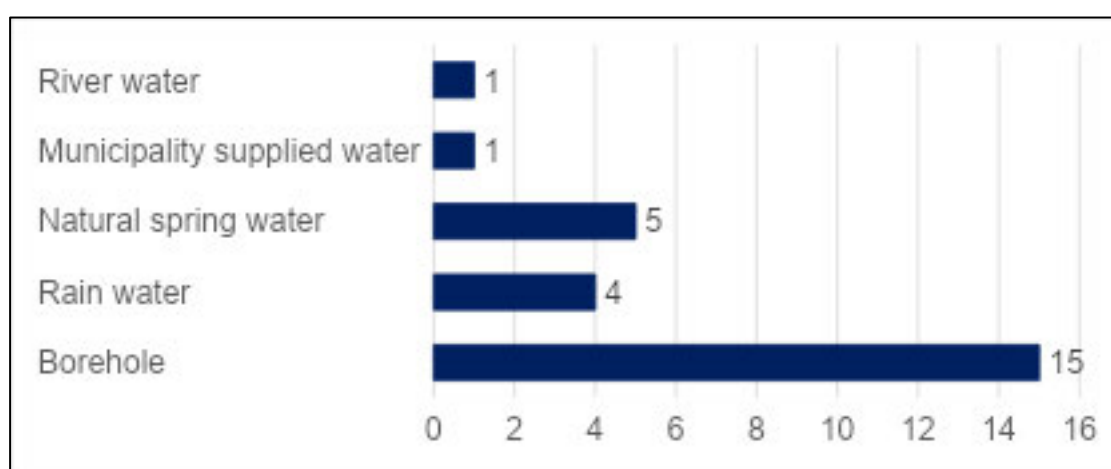


Figure 13: The source of clean, drinkable water for the villagers at GaMalebogo

As illustrated in Figure 13, the primary source of clean, drinkable water is boreholes, followed by rainwater, natural spring water, and other sources. This distribution depends predominantly on the village's location; some are much farther from sources such as spring water. When water is scarce, they rely on sources such as rivers. All participants (100%) reported knowing about groundwater.

One of the participants said, *“The closer one is to the Blouberg-GaMalebogo mountains, the better, because one will be closer to the natural spring that provides drinking water when there is a problem with municipal water. The main dam storing water is at the top of the hill, and the water runs out before it reaches us here at the foot of the mountains. If you don’t have a JoJo tank, it is even worse because you cannot store water. People with boreholes in their yards never struggle with water; it shows there is enough water underground. The rivers have water only during the rainy season, and the water doesn’t stay long enough.”*

4.2.3. Methods for accessing groundwater?

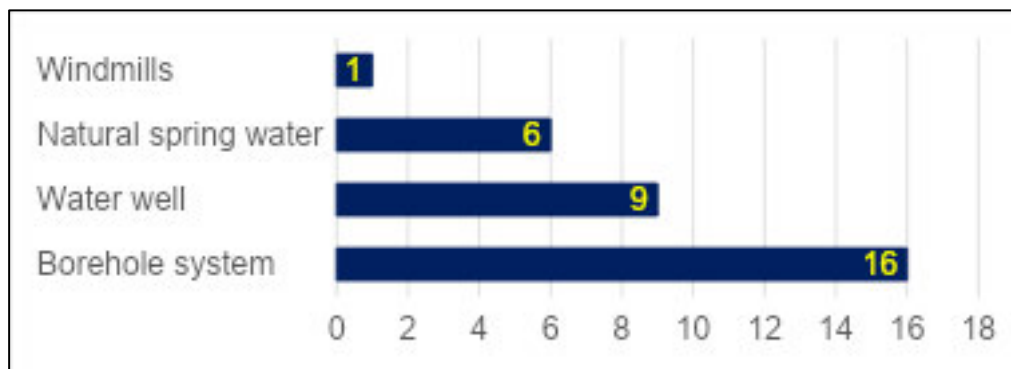


Figure 14: Methods of accessing groundwater known by villagers

Methods of groundwater access were primarily through borehole systems, followed by water wells, natural springs, and windmills (Figure 14). All participants (100%) identified boreholes as the easiest to install and the most reliable method of accessing groundwater. As illustrated in Figure 15, almost all reliable water sources are through installed borehole systems. Other methods are less reliable or require extensive labour for collection, such as natural spring water. Although natural spring water never dries out, even in winter, there is no way to access it efficiently except by carrying small containers. In addition, there is no road leading to it.

“Traditionally, no one should tamper with the natural spring water because it is sacred to the Bahananwa people of GaMalebogo; no one is allowed to install any foreign system for harvesting water around the natural spring. The only thing allowed is to collect the water traditionally, carrying it in small, manageable containers,” as the local Ndonga said.

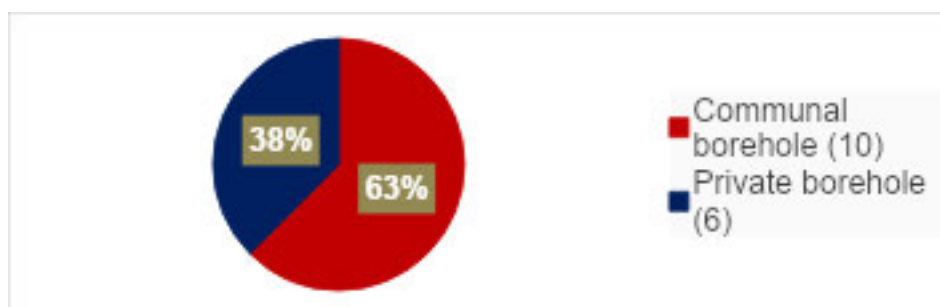


Figure 15: Distribution of access to drinkable water through a privately owned borehole or a communal one

4.2.4. Borehole water use

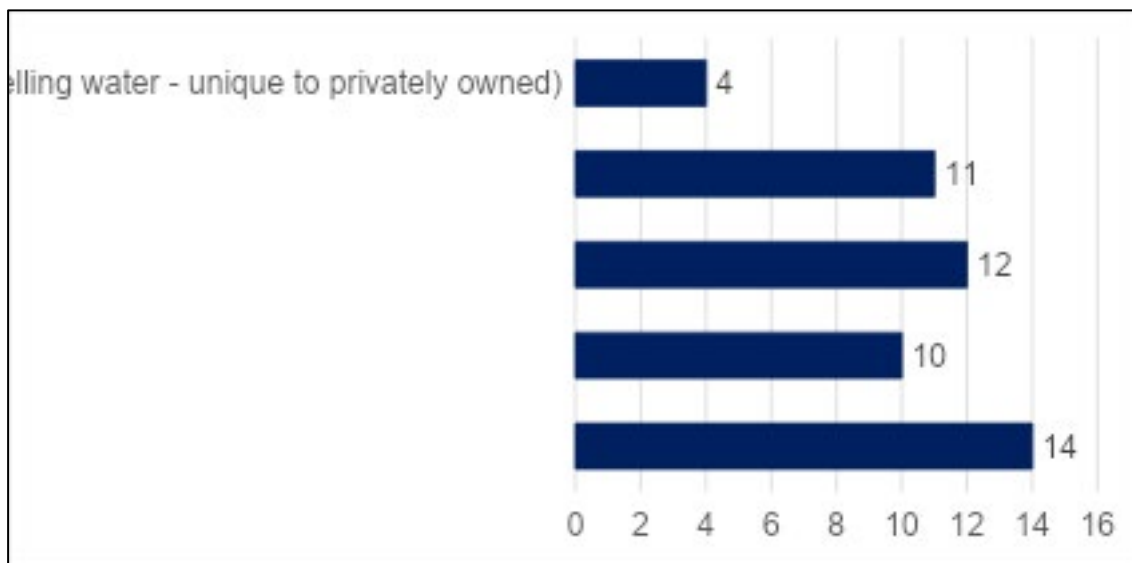


Figure 16: The summary of the need for water in general (The community needs this water for which activities?, What do you use the borehole water for?)

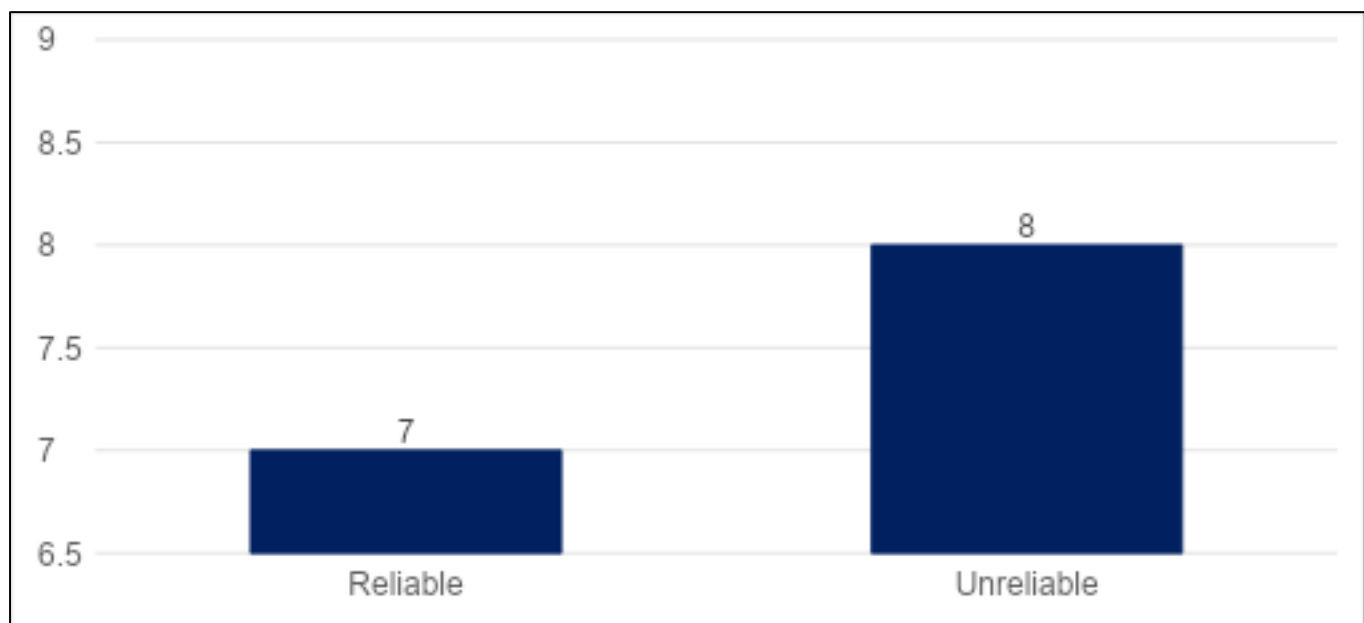


Figure 17: Borehole reliability on sustainable water supply

Figure 17 shows that borehole water was used for multiple purposes. Although the frequency of use differed among drinking, small-scale agriculture, household activities, and livestock watering, participants reported using borehole water across all four categories. Household and livestock use accounted for the largest share of borehole water consumption, followed by drinking and small-scale farming. This pattern indicates that borehole water serves a range of purposes, from sustaining livelihood activities to meeting everyday needs. Additionally, as shown in Figure 17, participants who owned their own boreholes reported that commercial uses of borehole water included water sales.

According to responses from thirteen participants, seven (54%) considered boreholes a dependable source of water for both public and private use. This category comprised the ward councillor and all participants with privately owned boreholes. These findings suggest that privately held boreholes are especially trustworthy, supporting both domestic use and revenue-generating operations. This supports the idea that groundwater is an essential and dependable resource. In contrast, most participants using communal boreholes reported that their boreholes were unreliable due to limited water-supply schedules, interrupted water supply, and power outages, among other factors.

Among the 17 participants who provided feedback on borehole reliability, seven (54%) viewed boreholes as a reliable source of water, a sentiment shared by all participants with privately owned boreholes and the ward councillor. Participants who used communal boreholes, however, reported consistent unreliability, citing limited water supply schedules, periodic service interruptions, and power outages as major contributors (Figure 18).

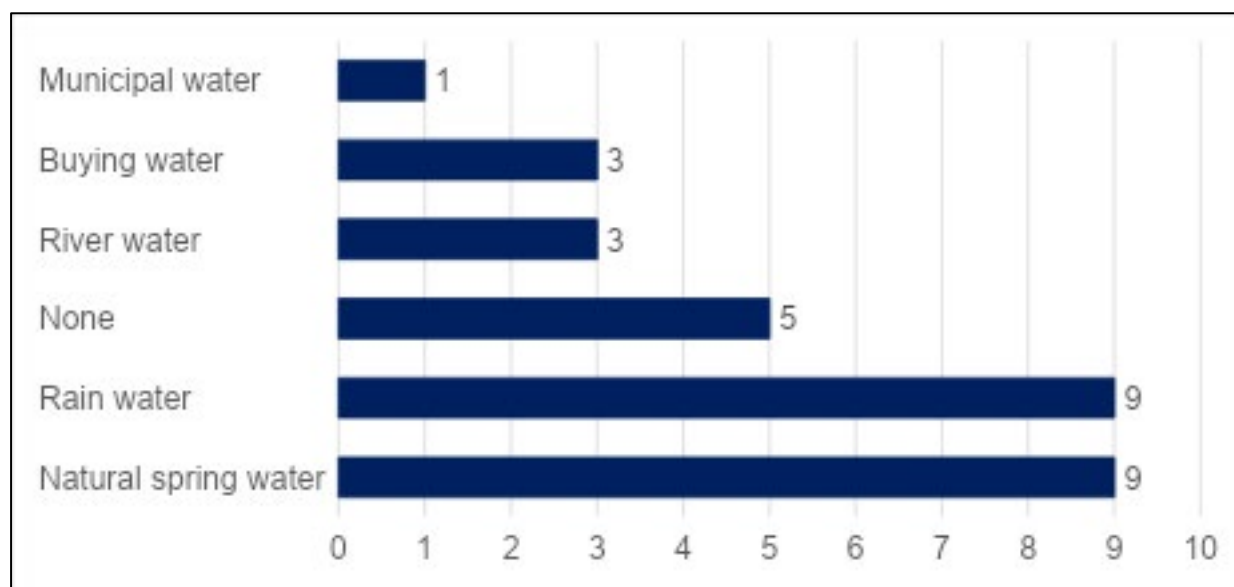


Figure 18: Different sources of accessing clean drinkable water for the villagers at GaMalebogo

Natural spring water (56%), rainwater (56%), river water (31%), water purchased from privately owned boreholes (31%), and municipal water (6%) were other sources of clean drinking water for everyday use. This distribution indicates a heavy reliance on non-municipal and informal water sources, due to the limited availability and unreliability of official water-delivery systems. The use of various alternative sources, especially surface water, also raises concerns about water quality, supply reliability, and long-term sustainability. This shows that households adopt adaptive coping methods to meet their daily water needs (Figure 18 illustrates).

4.3 Privately owned borehole only

Participants who owned private boreholes reported that the primary motivation for installing them was the unreliability of the municipal water supply, cited by most respondents. This was driven by the need for a more dependable and sustainable water source, along with a desire for self-sufficiency. These findings indicate that borehole installation is largely a response to inadequate municipal water services rather than a preference for alternative water sources.

All participants with privately owned boreholes reported occasional challenges with their borehole or pump systems; however, these were generally manageable through routine maintenance. This suggests that, despite technical difficulties, users consider boreholes a dependable water source. Maintenance practices were relatively consistent among participants, with all indicating that borehole pumps and plumbing systems are serviced through annual inspections conducted by professional service providers, reflecting an awareness of the importance of proper upkeep for system longevity.

Most participants expressed a willingness to recommend borehole drilling to others, primarily due to continued dissatisfaction with the reliability of the municipal water supply. However, one participant indicated reluctance to recommend borehole installation, citing concerns about its potential negative impact on their water-selling livelihood. This highlights the socio-economic dynamics associated with groundwater access, where improved self-sufficiency may unintentionally affect informal water-based income-generating activities.

Additionally, all participants stated they depend solely on borehole water for their daily household needs. This heavy reliance highlights the vital role of groundwater in domestic water supply and emphasises the need for sustainable groundwater management and regulations to secure long-term water access.

4.4 Communal borehole only

All participants who use municipal borehole water reported that the municipality installed it. Of the 10 participants who use municipal borehole water, (90%) reported that the municipality is responsible for maintenance, while one was uncertain. All participants using municipal borehole water reported that it does not fully meet the community's water needs because of its limited weekly supply, often necessitating reliance on alternative sources, such as natural springs or privately owned boreholes. All participants who use municipal borehole water reported that the municipality's borehole is convenient, as the taps are installed in each household.

The community borehole water users reported that the only rules are that water is supplied once a

week, that there are rotation schedules, and that they must always close the taps in case water comes when no one is near the tap. All participants who use municipal borehole water said they would consider drilling their own borehole only if they could afford it. Some said they are actively saving toward this, citing the unreliability of the municipal boreholes.

4.5 General Stakeholders Interview responses

The following extra comments were recorded during the interview with the participants. A participant provided the following perspective on this issue, relating to the reasons for the shortage of drinkable water:

“Available clean water at GaMalebogo village is being rotated among different villages. The water is pumped from the 2 municipality-installed boreholes to a reservoir tank located at the top of the hill. Once the tank is full, they open the water to the system. People in the lower-lying areas receive water first, and as the pipes fill, water will be available in villages near the hills. At times, water gets finished first before it can get to the hill areas, as people have installed Jojo tanks in their yards (responded 3).”

Furthermore, the other villager (respondent 5), conveyed his opinions around the issues of buying water because of inefficient rotational water supply in the following manner:

“Some people rely on water continuously throughout the week when the pumps are working, but in the higher-lying areas, we will receive at least one day of water, if we are lucky. This system of rotation will perform better if it is installed properly to control water flow. We are now forced to buy water from our neighbours at R16 per 20-litre drum and pay R10 for transport. Or we are forced to go to the natural spring, which is a bit far, our animals are suffering in winter when there is no water in the natural dams around the village.”

Lack of proper communication between the villagers and the municipality was also highlighted as follows:

“The water supply is insufficient for the villagers. Without a water schedule, they will not have water for the whole week, and they must have capacity tanks to store water. Improved infrastructure, including communal Dams for better distribution, would be beneficial. The community of the villages needs to be consulted first when planning a water project, to understand their needs, and that will result in reliable and efficient water infrastructure.”

4.6 Summary

In their additional comments, participants highlighted several water-related needs in the community.

Suggestions included installing communal dams and additional boreholes, and installing solar- or generator-powered borehole pumps to ensure sustainability. The importance of adequate storage capacity, such as tanks, was also noted, as was the need to reconnect taps directly to houses. The councillor further indicated that the current water supply is insufficient for villagers, underscoring the need to engage the community through consultations to assess needs and guide interventions accurately. Participants expressed concerns about the existing piping system, stressing the need for upgrades and more proactive maintenance. They also noted difficulties in managing livestock during periods of water shortages. Additionally, participants noted that some hillside areas do not receive water, which they perceived as an unfair distribution of the supply.

Chapter 5: Discussion of Findings

5.1. Introduction

The previous chapter summarized the findings, focusing on groundwater use to address water shortages. It examined the causes and impacts of water scarcity in the GaMalebogo villages and discussed participants' recommendations for improving groundwater utilisation and the sustainability of the municipal water supply. This chapter begins with a summary of the main findings followed by conclusions. It also offers practical recommendations for the municipality where applicable, highlights the study's contributions, and suggests areas for future research.

5.2. Summary Of Findings

This study aimed to explore the sustainable utilisation of groundwater in the GaMalebogo villages by examining the factors influencing its use, the challenges affecting its sustainability, and opportunities for improving groundwater management. This will also lead to the identification of challenges faced by the GaMalebogo rural community following the successful installation of any groundwater access method. Thirdly, identify the existing barriers the GaMalebogo villagers face to the successful installation of a groundwater access system. Furthermore, identify reliance on different groundwater access methods and the scale of groundwater use in GaMalebogo rural villages.

5.2.1. The Sources of Portable Water

GaMalebogo comprises several villages, including Gemarke, Old Longsigne, Driekoppies, Alldays Extension, Raditshaba, Kibi, Sadu, and Swarts. Most of these villages rely primarily on the municipality for their water supply. The Blouberg Local Municipality is the sole provider of clean, potable water, supplied by two municipal boreholes drilled in the area. There are no formal water purification systems; groundwater is pumped directly from the boreholes into a reservoir and then distributed to households via a pipe network. Due to the unreliability of the municipal supply, households with sufficient financial means have invested in privately drilled boreholes. Overall, the main sources of potable water in the area are boreholes, followed by rainwater harvesting, natural springs, and, in some cases, river water.

5.2.2. The Reasons for the Shortage of Drinkable Water

The results of this research indicate that a significant factor in the scarcity of potable water is the rotational

water supply system implemented in the regions surrounding the GaMalebogo villages. . However, this rotational distribution system does not provide an equitable water supply. Participants reported that villages located at lower elevations receive water more consistently because the existing distribution network relies on gravity, whereas villages at higher elevations experience more frequent supply interruptions. As a result, the current system contributes to unequal access to municipal water rather than addressing the underlying challenges of infrastructure maintenance and water distribution. This suggests that lower-lying areas are prioritized over higher-elevation areas. Some villagers have sought assistance from external vendors to secure access to water.

Several villagers expressed concern that the rotational water supply system has significantly disadvantaged them. It was also revealed that certain regions within the municipality received water continuously, while others received it only once a week. In hillside locations experiencing severe water shortages, residents are forced to purchase water from villagers who have installed private boreholes. The initially installed or newly installed water distribution system was found to be inadequate to serve the village's growing population. This negligence also led to water scarcity and deficits within the municipality. Water demand has risen, indicating that if demand exceeds supply, water shortages will occur, despite the continued use of two originally drilled boreholes.

5.2.3. Lack of Communication Between the Villagers and the Municipality

This study found a notable lack of consultation and communication between the Blouberg Local Municipality and residents of the GaMalebogo villages. The municipality failed to engage the community in addressing the water shortage. Instead, it would simply arrive and implement an efficient system to alleviate water scarcity. Desperate for access to potable water, the community permitted the municipality and contractors to carry out their installations, seeking relief from the difficulties of obtaining clean water.

The study also revealed that communication failures and the inattentiveness of local councillors significantly contributed to the water scarcity in the rural village of GaMalebogo. Communication emerged as the primary issue, as all interviewees recognised a water shortage in their respective areas. This was attributed to a breakdown in communication between the municipality, via its counsellors, and the villagers, stemming from the councillor's persistent failure to engage with community members. The participants expressed a strong belief that the councillor lacked vigilance and attentiveness to residents' challenges, particularly regarding water shortages. Nonetheless, communication was consistently identified as a critical concern, as there is no engagement during water system installations or breakdowns.

5.2.4. Lack of Scheduled and Planned Maintenance

The research results indicate that the municipality is ineffective and inefficient in managing the repair and maintenance of its borehole pumps, associated infrastructure, and the water reticulation system. Two functional borehole pumps have failed due to a lack of scheduled maintenance, as they are only attended to when they have completely stopped working. Repairs by the municipality can take weeks, if not months. Although some villages within GaMalebogo have a relatively adequate water supply, the primary issue remains the municipality's inability to repair and maintain the machinery. There is a prevailing belief that municipal employees are complacent and lack urgency in fulfilling their responsibilities. This perception stems from residents' ongoing reports of malfunctioning borehole machinery that requires immediate attention, yet the municipality takes no action.

5.2.5. Boreholes

The results suggested that providing boreholes could significantly mitigate water scarcity and deficits in the GaMalebogo Villages within the Blouberg Local Municipality. Many believe boreholes could be a practical solution to villagers' water shortages. Most interviewees see increasing the number of boreholes as the most effective way for the municipality to tackle the issue. A well-planned water pipeline will also help ensure a continuous, sustainable water supply. This is further supported by installing water reservoirs to ensure the system operates effectively, rather than the current arrangement where the borehole pumps run continuously. As one resident suggested, installing a solar-powered system will also help reduce overall operational costs and prevent water supply interruptions during power outages.

Due to interruptions in the water supply, numerous villages were affected because water did not reach all households. In certain locations, leaking pipes restricted water from reaching the reservoirs and some villagers. Despite reports of these leaks and bursts, the Blouberg municipality maintenance team fails to take prompt action. As a result, many villages were affected because water did not reach all households.

Maintenance engineers employed by the Blouberg Municipality are rarely seen in villages addressing pipe leaks and bursts, compelling the community to take matters into their own hands and attempt repairs. Occasionally, untrained residents attempt to repair damaged pipelines independently. Unfortunately, this often leads to additional leaks and bursts due to inadequate repairs. Additionally, the above-ground pipes are vulnerable to harsh weather conditions, posing a risk of falls for children. The findings show that pipe leaks and bursts greatly affect water flow, as the supply is rotational and doesn't reach all areas properly. Consequently, residents may face long

waits to access clean water.

5.2.6. Buying Water from Donkey Carts and Borehole Owners

Because of water scarcity, both villagers and local business owners have resorted to buying water from donkey-cart operators and borehole owners. This measure is taken to ensure the continued operation of businesses and to meet the water requirements for household use, domestic animals, and private gardens. Community members are compelled to use their limited social grant funds to purchase water, thereby adversely affecting their living conditions, as these grants were originally intended to cover essential needs such as clothing and food for vulnerable individuals. The owners of donkey carts have identified this situation as a business opportunity, allowing them to earn substantial income from water sales. They collect water at no cost and subsequently sell it at inflated prices.

Residents with boreholes on their properties sometimes sell borehole water to the surrounding local community and local businesses to support their livelihoods. Many businesses face difficulties because owners often must share the water they purchase with customers. Some households have established specific arrangements with borehole owners, paying a fixed monthly fee for continuous water access. Others purchase water on credit, agreeing to pay later. Since the community heavily depends on social grants, some members struggle to repay borehole owners, causing conflicts within families or among neighbours.

5.2.7. Installation of Borehole System

This research indicates that community members, counsellors, and local leaders believe that, if the municipality provides boreholes, they will have access to an adequate water supply. Historical context was provided regarding the 1990s, when communities relied on boreholes for water, a system that the current democratic government has failed to maintain, despite the municipality facing severe water shortages. In rural regions, the primary means of accessing groundwater is through boreholes fitted with hand pumps; however, this is no longer relevant because they are often located far from many households (Lapworth *et al.*, 2020).

The research findings suggest that the provision of boreholes could significantly help mitigate the water scarcity and deficit experienced. Residents believe that boreholes may provide a viable solution to their water shortages. Certain regions within the village exhibit high borehole yields; if the municipality engages with the community before installing new borehole systems, this could help alleviate water deficiency. Most participants interviewed agree that the municipality's plan to address the water shortage should include the drilling of more boreholes in carefully selected locations. This

should be accompanied by a properly designed and maintained water distribution system to ensure a reliable and equitable water supply to the community. Adequate consultation is essential before implementing any new system. The municipality must understand the community's genuine needs and design a piping system that is both functional and appropriate for the villages.

5.2.8. Conclusions

The chapter outlined the potential use of the Borehole system for groundwater extraction in the GaMalebogo villages to address potable water shortages. The findings indicate that the lack of reliable access to clean drinking water remains a significant challenge in the GaMalebogo villages, primarily because the limited water supply from reservoirs is distributed on a rotational schedule across different areas. This critical shortage is further exacerbated by inadequately installed water-piping infrastructure for the villages' water supply. Ineffective communication, councillors' complacency, and the neglect of leaking pipes all heighten water scarcity across the Blouberg Local Municipality, especially in the GaMalebogo Villages. Furthermore, poor service delivery has unfortunately caused residents to undertake unauthorised repairs of water infrastructure. The lack of effective communication and insufficient stakeholder engagement have also led the municipality to drill boreholes in areas with low groundwater potential. Furthermore, the chapter provided a comprehensive evaluation of the effects of water shortages and deficits on individual households within the community. Some villages equipped with boreholes have established profitable businesses due to the water scarcity. The research found that community members are significantly affected by water shortages, as they are compelled to purchase water from borehole owners and donkey-cart operators, using their social grant funds.

The chapter outlined the municipality's strategies to address water scarcity and deficit. Inefficiencies and ineffectiveness in the repair and maintenance of borehole pumping equipment remain significant challenges for the municipality regarding water supply. Additionally, the municipality was observed to be slow to respond to reports of water leaks within its jurisdiction. Since many residents understand water-harvesting and storage techniques well, the municipality should continue promoting these practices, educate the community on their importance, and offer subsidies for water storage tanks. It is essential to clearly communicate the importance of safe, responsible water use to the public. Additionally, using and refurbishing boreholes can be an effective strategy to address water shortages in the area.

Chapter 6: Conclusions and Recommendations

6.1. Introduction

This chapter commences with a summary of the key findings, followed by the conclusions drawn. Furthermore, the chapter offers practical suggestions for the municipality's implementation, where applicable, includes contributions from the research study, and suggests avenues for future research.

6.2. Summary of Findings

This study was guided by a set of research questions and objectives to examine groundwater access and use in a rural context. The research sought to explore the different methods for accessing groundwater, the challenges encountered after installing groundwater access systems, and the barriers encountered before their installation. In addition, the study investigated the extent to which different groundwater access methods are used and the overall scale of groundwater use. Correspondingly, the research objectives were to assess the available methods for accessing groundwater, identify post-installation challenges and pre-installation barriers, determine the level of reliance on various groundwater access methods, and evaluate the scale of groundwater use within the study area.

6.2.1. Different available methods

During the study, five main water sources used by residents of the GaMalebogo villages were identified:

- Ephemeral rivers flow only after rainfall and are dry for most of the year
- Rainwater harvesting
- Boreholes (privately owned and municipal)
- Perennial springs

Those who can afford have installed boreholes and rainwater collection systems. What is clear is that all reliable, clean, potable water comes from a single source: a borehole, whether in a privately owned or a municipal-operated system. The local river and rainwater are available only during the rainy season and are not sufficiently clean for consumption. Perennial springs are available year-round; however, they are located some distance from certain households. What is clear is that some

residents opted to drill a borehole because the municipality's operated borehole water supply system is highly unreliable. Some owners run a profitable water-selling business in the community due to a lack of water supply.

6.2.2. Post-Installation Challenges

Groundwater is primarily extracted using boreholes and pumps. These borehole pumps may be operated manually, powered by solar energy, or driven by diesel or electric engines. Like other systems, a borehole necessitates maintenance. The fundamental maintenance includes chlorinating the borehole to control iron bacteria and routine monitoring of water levels and quality. None of this is happening with the municipality-operated borehole water systems. As a result, municipality-operated borehole water systems are characterised by leaking pipes, pump failures, and frequent breakdowns due to inadequate maintenance. There is no preventative maintenance at all on the borehole water system; however, those that are privately owned have no problem, as preventative maintenance is in place, and there is a short turnaround time for fixing any breakages on the system.

6.2.3. Pre-Installation Barriers

It was found that the main technical obstacles were inadequate water infrastructure, including poorly maintained boreholes, leaking pipelines, unreliable electricity supply to borehole pumps, and ineffective management of the water distribution system. Additionally, selecting unsuitable borehole locations, such as areas with low groundwater yields or poor water quality, and using drilling and pumping technologies incompatible with local geological conditions can reduce borehole productivity and compromise the reliability of groundwater supply (Gebreslassie *et al.*, 2025).

Furthermore, maintenance issues are exacerbated by a lack of the skills and spare parts necessary for the system's upkeep and repair. In some areas, groundwater occurs at considerable depths, requiring specialised drilling techniques and high-capacity pumping systems, which increase the cost of groundwater development.

Most villagers' emphasised the challenges posed by economic and financial obstacles stemming from the substantial initial costs of borehole drilling pumps, and installation. Inadequate investment by municipalities responsible for water service delivery hinders the provision of appropriate and sustainable water infrastructure in rural communities.

The absence of funding or investment from municipalities that oversee rural communities results in the installation of insufficient systems. Additionally, the operational and maintenance costs associated with borehole systems, including electricity or diesel for pumping and routine repairs,

may pose financial challenges for municipalities and rural communities with limited budgets (Gebreslassie *et al.*, 2025). Social and community obstacles stemming from insufficient community engagement were apparent in the villagers' responses. . When local communities are not consulted or trained, they are less likely to take ownership of water infrastructure or participate in its maintenance, increasing the likelihood of poor management and project failure. The municipality often implements borehole drilling and water supply infrastructure without adequate prior consultation with the community, which may contribute to the poor performance and long-term failure of water supply systems in the GaMalebogo villages. Additionally, some villagers were dissatisfied with the municipality's actions of drilling on their private land without their consent, which may lead to conflicts and disputes over the ownership, control, and use of the installed water infrastructure.

6.2.4. Methods of Accessing Groundwater in GaMalebogo Villages

Gebreslassie *et al.* (2025) describe groundwater abstraction as the extraction of water from aquifers for beneficial use. Groundwater is commonly accessed through boreholes, wells, or springs and forms an important component of water resource management in regions with limited surface water. This is particularly relevant to rural communities such as the GaMalebogo villages, where water shortages are common.

Groundwater can be accessed using a range of methods, depending on local hydrogeological conditions. In South Africa, boreholes are the most common method of abstracting groundwater for domestic water supply, particularly in rural communities where surface water is limited (Gebreslassie *et al.*, 2025).

Groundwater harvesting supports sustainable water management by reducing water loss through evaporation and improving water storage efficiency. However, it encounters challenges such as overextraction, contamination, and the maintenance of harvesting structures. Implementing sustainable practices such as monitoring water levels, regulating extraction, and encouraging aquifer recharge is essential for the long-term sustainability of groundwater resources (Gebreslassie *et al.*, 2025).

In rural villages, communities often rely on a range of methods to access groundwater, shaped by factors such as local geology, the depth of the water table, available technologies, and financial resources. However, in GaMalebogo village, the use of a borehole system for groundwater extraction is the most favoured approach. Survey participants even identified it as one of the most effective and dependable methods.

6.2.5. The scale of Groundwater Use

The findings indicate that households in the GaMalebogo villages rely substantially on groundwater to meet their domestic water needs. In the rural villages of GaMalebogo, groundwater is the primary water source, as surface water sources such as rivers and lakes are limited and only available seasonally. Groundwater is frequently the sole dependable source throughout the year, particularly during dry periods, and is primarily utilised for drinking, domestic tasks (including washing, cooking, and cleaning), watering livestock, small-scale irrigation, and supporting micro-enterprises (such as small gardens).

6.2.6. Impacts of Water Scarcity on Women and Girls in GaMalebogo Villages

Bazaanah P et al., (2023) emphasised that women are the main providers, users, and managers of water in households, often facing direct impacts from poor sanitation facilities. One participant in their study reinforced this point, noting, "Women are the ones who bear the burden of transporting water for as long as four hours each day when the water system (borehole/pipes) fails". Because water is essential for drinking, cooking, personal hygiene, washing, cleaning, and caring for domestic animals, unreliable water supplies disproportionately affect women and girls, particularly during puberty when adequate hygiene is critical.

The unequal distribution of water and hygiene responsibilities can significantly impact young girls, especially during puberty when they need reliable access to water and proper sanitation for personal hygiene. Research shows that in rural areas, most of the water collection and sanitation maintenance duties fall disproportionately on women and girls compared to men and boys. It is also common to see children spending substantial time fetching water and disposing of waste in rural communities. These activities can affect their physical, emotional, and mental health, as well as hinder their educational progress (Bazaanah *et al.*, 2023). Data indicates that women outnumber men in these communities, highlighting the daily burden and stress they face related to water collection. This is unsurprising given that traditional societies often assign specific gender roles to men and women; girls and women are often tasked with domestic chores such as fetching water, cooking, laundry, and household cleaning (Bazaanah *et al.*, 2023).

However, the situation in the GaMalebogo villages revealed a different pattern. During participant interviews, it was observed that women were often positioned at the back, whereas men and boys primarily bear responsibility for ensuring water availability at the homestead. It is only after this that women and girls are permitted to collect water, as cultural norms dictate that they handle most

household chores. Donkey carts are the main mode of transport for fetching water from sources to the homestead. Furthermore, it was clear that a homestead typically comprises all members of the same family, which negates the norm of widows living alone. Additionally, there are no homesteads run by children because parents are absent; uncles, aunts, and other family members assume this role. However, because natural spring water is preferred for drinking, the task of collecting it falls predominantly on women and girls, although the quantities are not substantial. The responsibility for all other water needs, including those for small vegetable gardens, domestic animals, and general homestead use, rests primarily on men and boys.

6.3. Conclusions

The research was conducted to evaluate the potential use of groundwater to mitigate the shortage of portable drinking water in the GaMalebogo villages in the Blouberg Local Municipality, in the Limpopo Province. The findings indicated that the local municipality faces challenges related to both water shortages and deficits, and an evaluation of the underlying causes of these issues was conducted. The following strategies were implemented:

- Most of the villages of GaMalebogo understand the concept of groundwater, and they totally favour the use of borehole systems in relation to other systems in accessing the available groundwater, because it is relatively easy to install.
- The major barrier to installing their own boreholes is due to a lack of funding.
- Lack of residence consultation by the Blouberg municipality before any water installation system projects further feeds into the problem of the water supply system, which does not address or resolve the problem of the shortage of clean water in GaMalebogo villages.
- Currently, at GaMalebogo villages, the main source of clean drinkable water is groundwater through a borehole system, both privately owned and owned by the Blouberg Local municipality
- Water rotational systems were implemented, trying to guarantee equitable sharing of the limited water supply available to the villagers.
- Communication failures and insufficient oversight by councillors and municipality personnel arose due to inadequate interaction between councillors and their constituencies with the villages.
- Neglect in addressing leaking and ruptured pipes exacerbated the issue of water scarcity.

- Despite the rising demand for access to clean water from the villagers, the municipality failed to enhance the capacity of the water supply reservoirs.
- Inadequate service delivery forced residents to resort to illegal repairs of leaking pipes and broken water pumps, causing more problems related to the shortage of clean water in supplies.

The study also showed that households were affected differently by water shortages and deficits. Some residents with privately owned boreholes are capitalizing on the inefficiencies of the existing system and thriving, as their water-selling business is profitable. Residents in lower-lying villages have more consistent access to municipal water due to the current water distribution system. Those living in higher-elevation areas are compelled to purchase water for survival, thereby exacerbating their poverty. Prolonged water interruptions have necessitated that individuals acquire water from donkey carts and borehole proprietors, as survival without water for extended periods is unfeasible.

Finally, the municipality must implement measures to address water scarcity and water deficits, as outlined below.

- It is essential to conduct a thorough consultation before initiating any work aimed at addressing the ineffective water piping system in GaMallebogo Villages. Additionally, a survey should be carried out to determine the water requirements of these villages. This information will guide decision-making regarding the construction of water reservoirs in strategically selected locations within GaMallebogo. Engaging with the local community is crucial when identifying optimal borehole-drilling sites.
- Repairs and maintenance of existing water pumps. Piping systems and electrical equipment must be installed to restore any malfunctioning units to full functionality, thereby supporting smoother water flow.
- It has been found that residents are willing to pay or contribute towards the maintenance of water services to guarantee equitable access to water across the villages.
- Implementing solar-powered borehole pumps is essential for reducing operational costs and providing communities with reliable water access. Additionally, establishing new borehole supplies across all areas will improve overall water availability
- Where frequent power outages interrupt water supply, the municipality should consider installing solar-powered borehole pumps to improve the reliability of groundwater abstraction. In addition, existing boreholes should be properly maintained, and new boreholes should only be developed

in areas where hydrogeological assessments confirm sufficient groundwater availability.

- The municipality should strengthen community education on rainwater harvesting, household water storage, and responsible water use. Improved public awareness can promote water conservation, encourage the use of alternative water sources where appropriate, and help communities better understand municipal water service costs and the importance of protecting water infrastructure.

Gebreslassie *et al.*, (2025) emphasised that groundwater is a vital resource for domestic, agricultural, industrial, and ecological needs worldwide, supplying drinking water to approximately half of the global population. These findings underscore the importance of assessing groundwater as a sustainable water source for rural communities such as GaMalebogo that experience persistent water shortages.

The findings indicate that groundwater has the potential to supplement existing municipal water supplies in the GaMalebogo villages of the Blouberg Local Municipality, thereby improving household water security. Currently, the existing water systems are not sufficient to provide a reliable, sustainable source of clean water for residents. Installing borehole systems could be a more effective approach and can be implemented in GaMalebogo to solve the water problems.

6.4. Recommendations for Further Research

The study found that groundwater extraction via boreholes is a more effective and sustainable approach to combatting water scarcity in rural areas. Therefore, further research on groundwater use through boreholes is essential to ease water shortages in the Capricorn District Municipality, which manages the Blouberg Local Municipality in Limpopo. Similar studies could be carried out in other municipalities within the district to determine whether they yield similar results. The researcher was able to conduct this study only in the GaMalebogo villages, a rural area of the Blouberg municipality, due to limited time and funding. More research is needed on groundwater use through boreholes to understand its effects on South African farmers, particularly on food production and livestock in agricultural regions.

Historically, in South Africa, the groundwater situation was markedly different. As a concealed resource, it was often treated as a private asset, accessible only to landowners and largely exempt from public oversight. Water rights were a secondary aspect of land tenure, with the landowner above it granted entitlement to use groundwater, allowing extraction with minimal or no regulation. This riparian framework was grounded in Roman-Dutch law, applied during the colonial era under British rule and later under the apartheid regime led by Afrikaner nationalists, from approximately

1810 until the 1990s Nevertheless, the political changes in 1994 catalysed significant water sector reforms in South Africa. These reforms recognised groundwater as an important resource for expanding access to water services, particularly in rural areas, and supported initiatives to increase basic water infrastructure coverage to more than 95% of the population (DWS, 2022). Today, groundwater is a vital component of water resource management and is incorporated into the national water policy and legal structure (DWS, 2022). The impact of this new policy on rural water, which is predominantly supplied by groundwater through a borehole system, needs to be studied.

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Annexure B: Ethical Clearance



Our Ref: M. 711224

Enquiries: [REDACTED]

06 December 2024



Outcome of Ethical Clearance Application for Master of Philosophy in Integrated Water Management.



Student name: Thabo Frans Meletse

Student number: [REDACTED]

Brand and campus: IIEMSA



Dear Thabo,

Thank you for submitting the ethics clearance application for the study: *Evaluating the Sustainable Use of Groundwater in GaMalebogo, Limpopo*:



We are pleased to inform you that your ethical clearance application has been approved with minor revisions to the satisfaction of your supervisor and the Programme Coordinator. This means that you may proceed with data collection once you have addressed the comments shared by the HDC.

You are reminded to inform the IIE's Higher Degrees Committee of any changes made to the research methodology or title of the research prior to examination. Kindly ensure that all ethical considerations are duly applied whilst collecting, analysing and interpreting the data for the completion of your research.

If you have any questions, please feel free to contact your programme team or supervisor directly.

Dr Reza Hosseini

Chair: Higher Degrees Committee



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Annexure B: Stakeholder Research Interview Questionnaire

Stakeholder Research Interview Questionnaire Sample

Research Questionnaire Template

Exploration of the Sustainable Use of Groundwater in GaMalebogo, Limpopo

Introduction

Hello!

Thank you for taking the time to participate in this research study. This questionnaire is designed to collect data for the exploration of the Sustainable Use of Groundwater in GaMalebogo, Limpopo. Your responses will be kept confidential and used solely for academic/research purposes. Estimated time to complete: 10 minutes

SECTION A: DEMOGRAPHIC INFORMATION

1. Age:

- ☐ Under 18
- ☐ 18–24
- ☐ 25–34
- ☐ 35–44
- ☐ 45 and above: ●

2. Gender:

- ☐ Male: ●
- ☐ Female
- ☐ Non-binary / Third gender
- ☐ Prefer not to say

3. Education Level:

- ☐ High school or below: ●
- ☐ Undergraduate
- ☐ Graduate/Postgraduate
- ☐ Other: _____

4. Occupation:

- ☐ Student
- ☐ Employed
- ☐ Self-employed: ●

- Unemployed: ●
- Other: _____

SECTION B: Core Research Questions

How many residences currently use groundwater?

What different methods of accessing groundwater are available? Boreholes, Natural springs, water from the rivers, and a collection of rainwater

What challenges does the GaMalebogo rural community face after successfully installing a method for accessing groundwater? Loadshedding

What barriers does the GaMalebogo community face before successfully installing any system to access groundwater? Financial challenges

Questions:

Do you have access to clean drinkable water for your daily needs?

Answer:

What is the source of your clean, drinkable water?

Answer:

Do you know what groundwater is?

Answer:

What are the different methods you know of for accessing groundwater?

Answer:

Which one of the methods of accessing groundwater is the easiest to install?

Answer:

Which one is reliable?

Answer:

Do you have direct access to borehole water?

Answer:

If yes:

Is it a communal borehole or is it privately owned?

If the borehole is privately owned:

Why did you sink or install a borehole?

Answer:

What do you use the borehole water for?

Answer:

Is the borehole supplying you with a reliable water source?

Answer:

Are you experiencing any difficulties with the borehole or the pump?

Answer:

How do you maintain your pump and plumbing system from the borehole?

Answer:

Will you advise other people to drill boreholes?

Answer:

How do you access clean water for your daily use?

Answer:

What other means are available to access clean, drinkable water for your daily needs?

Answer: None

Communal borehole

(i) The community needs this water for which activities?

Answer:

(ii) Who installed the borehole?

Answer:

(iii) Who is responsible for its maintenance?

Answer:

(iv) Is it reliable?

Answer:

(v) Does it meet the water needs of the community?

Answer

(vi) Is the borehole convenient for the villagers to reach and use its water?

Answer:

(vii) What rules are in place to access the groundwater from the borehole?

Answer:

- (viii) Will you consider drilling a borehole or using other methods to access groundwater?
If no/yes, why?

Answer:

- (ix) What are other means available for accessing clean drinkable water for your daily needs?

Answer:

SECTION C: CLOSING

9. Do you have any additional comments or suggestions?

Answer:

Consent Statement

By submitting this form, you confirm that you understand the purpose of this study and agree to participate voluntarily.

- I agree: •
- I do not agree

Name: **Freddy Waleng**

Signature: **Original Signed**

Themes related to the questions

1. Groundwater Usage and Accessibility

- **Groundwater Access in Rural Communities:** This theme explores how many households use groundwater and their dependence on it for daily needs.
- **Methods of Groundwater Access:** This focuses on the different techniques, such as boreholes, wells, and pumps, used to access groundwater in rural areas.

2. Challenges Post-Installation of Groundwater Systems

- **Post-Installation Maintenance and Sustainability:** This examines the difficulties faced by the GaMalebogo community after successfully installing groundwater systems, such as ongoing maintenance, technical failures, or inconsistent water supply.
- **Community Capacity and Knowledge:** This could cover the ability of the community to manage, repair, and sustain the system once it is set up.

3. Barriers to Installation of Groundwater Systems

- **Financial and Logistical Barriers:** This theme looks at the barriers that prevent the community from installing groundwater systems, such as cost, availability of technology, or access to skilled labour.

- **Regulatory and Environmental Barriers:** This could explore challenges related to permits, environmental regulations, or land ownership that may hinder the installation of groundwater systems.

4. Groundwater Sustainability and Reliability

- **Sustainability of Groundwater as a Resource:** This theme explores the long-term viability of relying on groundwater, considering over-extraction, pollution, and climate variability.
- **Reliability of Groundwater Supply:** Discusses how reliable groundwater is as a consistent source of clean water, including issues like seasonal fluctuations in water levels or contamination.

5. Individual Experiences and Perspectives

- **Personal Experience with Boreholes:** Focuses on individual experiences with boreholes, including satisfaction, reasons for choosing to drill a borehole, and any ongoing issues.
- **Maintenance and Longevity of Boreholes:** This could address how individuals maintain their boreholes and the challenges they face in keeping the system functional.
- **Recommendations and Advice:** A theme that investigates whether individuals would recommend drilling boreholes to others and the reasons behind their advice.

6. Alternative Water Access Methods

- **Alternative Water Sources:** For individuals who do not have boreholes, this theme would explore other methods of obtaining clean water, such as water trucking, rainwater harvesting, or reliance on local water sources.
- **Future for Groundwater Access:** Examines whether individuals would consider drilling a borehole in the future and what factors (cost, sustainability, reliability) would influence their decision.

Annexure C: Example of Stakeholder Research Interview Questionnaire with Answers

With a Private Borehole

Research Questionnaire Template

Exploration of the Sustainable Use of Groundwater in GaMalebogo, Limpopo

Introduction

Hello!

Thank you for taking the time to participate in this research study. This questionnaire is designed to collect data for the exploration of the Sustainable Use of Groundwater in GaMalebogo, Limpopo. Your responses will be kept confidential and used solely for academic/research purposes. Estimated time to complete: 10 minutes

SECTION A: DEMOGRAPHIC INFORMATION

5. Age:

- ☐ Under 18
- ☐ 18–24
- ☐ 25–34
- ☐ 35–44
- ☐ 45 and above: ●

6. Gender:

- ☐ Male: ●
- ☐ Female
- ☐ Non-binary / Third gender
- ☐ Prefer not to say

7. Education Level:

- ☐ High school or below
- ☐ Undergraduate: ●
- ☐ Graduate/Postgraduate
- ☐ Other: _____

8. Occupation:

- ☐ Student

- Employed
- Self-employed: ●
- Unemployed
- Other: _____

SECTION B: Core Research Questions

How many residences currently use ground water? 2000

What different methods of accessing groundwater are available? Boreholes, Natural springs, water from the rivers, collection of rainwater

What challenges does the GaMalebogo rural community face after successfully installing groundwater? Loadshedding

What barriers does the GaMalebogo community face before successfully installing any system to access groundwater?
Financial challenges

Questions:

Do you have access to clean drinkable water for your daily needs?

Answer: Yes, through the Borehole water

What is the source of your clean drinkable water?

Answer: Borehole system

Do you know what groundwater is?

Answer: Yes

What are the different methods you know of for accessing groundwater?

Answer: Only Borehole

Which one of the methods of accessing groundwater is the easiest to install?

Answer: Borehole pump

Which one is reliable?

Answer: Borehole

Do you have direct access to your own borehole water?

Answer: Yes

If yes:

Is it a communal borehole or is it privately owned?

Answer: Privately owned Borehole

If the borehole is privately owned:

Why did you sink or install a borehole?

Answer: The municipality-operated borehole system is highly unreliable

What do you use the borehole water for?

Answer: For household drinking, business needs, Cows and Goats, and small-scale farming

Is the borehole supplying you with a reliable water source?

Answer: Yes

Are you experiencing any difficulties with the borehole or the pump?

Answer: Yes, occasionally, but manageable through maintenance

How do you maintain your pump and plumbing system from the borehole?

Answer: Yearly inspection with the service provider

Will you advise other people to drill boreholes?

Answer: Yes, because the the municipality-operated borehole system unreliable

How do you access clean water for your daily use?

Answer: only through the privately owned borehole

What are other means available for accessing clean drinkable water for your daily needs?

Answer: None

Communal borehole

(x) The community needs this water for which activities?

Answer:

(xi) Who installed the borehole?

Answer:

(xii) Who is responsible for its maintenance?

Answer:

(xiii) Is it reliable?

Answer:

(xiv) Does it meet the water needs of the community?

Answer:

(xv) Is the borehole convenient for the villagers to reach and use its water?

Answer:

(xvi) What rules are in place to access the groundwater from the borehole?

Answer:

(xvii) Will you consider drilling a borehole or using other methods to access groundwater? If no/yes, why?

Answer:

(xviii) What are other means available for accessing clean drinkable water for your daily needs?

Answer:

SECTION C: CLOSING

Do you have any additional comments or suggestions?

Answer: The community needs a solar-powered borehole pump in order to have a continuous water supply

Consent Statement

By submitting this form, you confirm that you understand the purpose of this study and agree to participate voluntarily.

- I agree: •
- I do not agree

Name:

Signature: Original Signed

Themes related to the questions

1. Groundwater Usage and Accessibility

- **Groundwater Access in Rural Communities:** This theme explores how many households use groundwater and their dependence on it for daily needs.
- **Methods of Groundwater Access:** This focuses on the different techniques, such as boreholes, wells, and pumps, used to access groundwater in rural areas.

2. Challenges Post-Installation of Groundwater Systems

- **Post-Installation Maintenance and Sustainability:** This examines the difficulties faced by the GaMalebogo community after successfully installing groundwater systems, such as ongoing maintenance, technical failures, or inconsistent water supply.
- **Community Capacity and Knowledge:** This could cover the ability of the community to manage, repair, and sustain the system once it is set up.

3. Barriers to Installation of Groundwater Systems

- **Financial and Logistical Barriers:** This theme looks at the barriers that prevent the community from installing groundwater systems, such as cost, availability of technology, or access to skilled labour.

- **Regulatory and Environmental Barriers:** This could explore challenges related to permits, environmental regulations, or land ownership that may hinder the installation of groundwater systems.

4. Groundwater Sustainability and Reliability

- **Sustainability of Groundwater as a Resource:** This theme explores the long-term viability of relying on groundwater, considering over-extraction, pollution, and climate variability.
- **Reliability of Groundwater Supply:** Discusses how reliable groundwater is as a consistent source of clean water, including issues like seasonal fluctuations in water levels or contamination.

5. Individual Experiences and Perspectives

- **Personal Experience with Boreholes:** Focuses on individual experiences with boreholes, including satisfaction, reasons for choosing to drill a borehole, and any ongoing issues.
- **Maintenance and Longevity of Boreholes:** This could address how individuals maintain their boreholes and the challenges they face in keeping the system functional.
- **Recommendations and Advice:** A theme that looks into whether individuals would recommend drilling boreholes to others and the reasons behind their advice.

6. Alternative Water Access Methods

- **Alternative Water Sources:** For individuals who do not have boreholes, this theme would explore other methods of obtaining clean water, such as water trucking, rainwater harvesting, or reliance on local water sources.
- **Future Plans for Groundwater Access:** Examines if individuals would consider drilling a borehole in the future, and what factors (cost, sustainability, reliability) would influence their decision.

Using a Communal Borehole

Research Questionnaire Template

Exploration of the Sustainable Use of Groundwater in GaMalebogo, Limpopo

Introduction

Hello!

Thank you for taking the time to participate in this research study. This questionnaire is designed to collect data for the exploration of the Sustainable Use of Groundwater in GaMalebogo, Limpopo. Your responses will be kept confidential and used solely for academic/research purposes. Estimated time to complete: 10 minutes

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10. Gender:

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- ☐ Female
- ☐ Non-binary / Third gender
- ☐ Prefer not to say

11. Education Level:

- ☐ High school or below: ●
- ☐ Undergraduate
- ☐ Graduate/Postgraduate
- ☐ Other: _____

12. Occupation:

- ☐ Student
- ☐ Employed
- ☐ Self-employed: ●
- ☐ Unemployed

- Other: _____

SECTION B: Core Research Questions

How many residences currently use groundwater? 2000

What different methods of accessing groundwater are available? Boreholes

What challenges does the GaMalebogo rural community face after successfully installing any method to access groundwater? Loadshedding

What barriers does the GaMalebogo community face before successfully installing any system to access groundwater? Financial challenges

Questions:

Do you have access to clean drinkable water for your daily needs?

Answer: No, only getting water from the municipality once a week

What is the source of your clean, drinkable water?

Answer: Communal borehole system

Do you know what groundwater is?

Answer: Yes

What are the different methods you know of for accessing groundwater?

Answer: Only Borehole

Which one of the methods of accessing groundwater is the easiest to install?

Answer: Borehole pump system

Which one is reliable?

Answer: Borehole

Do you have direct access to borehole water?

Answer: Yes

If yes:

Is it a communal borehole or is it privately owned?

Answer: Communal-owned Borehole

Privately owned borehole:

Why did you sink or install a borehole?

Answer:

What do you use the borehole water for?

Answer:

Is the borehole supplying you with a reliable water source?

Answer:

Are you experiencing any difficulties with the borehole or the pump?

Answer:

How do you maintain your pump and plumbing system from the borehole?

Answer:

Will you advise other people to drill boreholes?

Answer:

Communal borehole

(xix) The community needs this water for which activities?

Answer: Daily household needs, for their livestock, small scale gardens

(xx) Who installed the borehole?

Answer: Blouberg Municipality

(xxi) Who is responsible for its maintenance?

Answer: Blouberg Municipality

(xxii) Is it a reliable?

Answer: No

(xxiii) Does it meet the water needs of the community?

Answer: No

(xxiv) Is the borehole convenient for villages people reach and use its water?

Answer: Yes, all the household have a tap in their yard

(xxv) What rules are in place to access the groundwater from the borehole?

Answer: Getting water once a week

(xxvi) Will you consider drilling a borehole or use other methods to access groundwater?

If no, why?

Answer: Yes, because the municipality operated borehole is not reliable

(xxvii) What are other means available for accessing clean drinkable water for your daily needs?

Answer: Natural spring water (During winter) and water from the rivers (when it rains)

SECTION C: CLOSING

Do you have any additional comments or suggestions?

Answer: Municipality need to drill more boreholes at different location to boost the current system

Consent Statement

By submitting this form, you confirm that you understand the purpose of this study and agree to participate voluntarily.

- I agree: •
- I do not agree

Name: [REDACTED]

Signature: Original Signed

Themes related to the questions

1. Groundwater Usage and Accessibility

- **Groundwater Access in Rural Communities:** This theme explores how many households use groundwater and their dependence on it for daily needs.
- **Methods of Groundwater Access:** This focuses on the different techniques, such as boreholes, wells, and pumps, used to access groundwater in rural areas.

2. Challenges Post-Installation of Groundwater Systems

- **Post-Installation Maintenance and Sustainability:** This examines the difficulties faced by the GaMalebogo community after successfully installing groundwater systems, such as ongoing maintenance, technical failures, or inconsistent water supply.
- **Community Capacity and Knowledge:** This could cover the ability of the community to manage, repair, and sustain the system once it's set up.

3. Barriers to Installation of Groundwater Systems

- **Financial and Logistical Barriers:** This theme looks at the barriers that prevent the community from installing groundwater systems, such as cost, availability of technology, or access to skilled labour.
- **Regulatory and Environmental Barriers:** This could explore challenges related to permits, environmental regulations, or land ownership that may hinder the installation of groundwater systems.

4. Groundwater Sustainability and Reliability

- **Sustainability of Groundwater as a Resource:** This theme explores the long-term viability of relying on groundwater, considering over-extraction, pollution, and climate variability.
- **Reliability of Groundwater Supply:** Discusses how reliable groundwater is as a consistent source of clean water, including issues like seasonal fluctuations in water levels or contamination.

5. Individual Experiences and Perspectives

- **Personal Experience with Boreholes:** Focuses on individual experiences with boreholes, including satisfaction, reasons for choosing to drill a borehole, and any ongoing issues.
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- **Recommendations and Advice:** A theme that looks into whether individuals would recommend drilling boreholes to others and the reasons behind their advice.

6. Alternative Water Access Methods

- **Alternative Water Sources:** For individuals who do not have boreholes, this theme would explore other methods of obtaining clean water, such as water trucking, rainwater harvesting, or reliance on local water sources.
- **Future Plans for Groundwater Access:** Examines if individuals would consider drilling a borehole in the future, and what factors (cost, sustainability, reliability) would influence their decision.